A Frost & Sullivan White Paper

Digital Sustainability: The Path to Net Zero for Design & Manufacturing and Architecture, Engineering, & Construction (AEC) Industries.

Analysis of the Market in UK & Ireland, Nordics and Benelux

By Fredrick Royan, Vice President, Sustainability and Circular Economy, Frost & Sullivan

In Partnership With

AUTODESK.

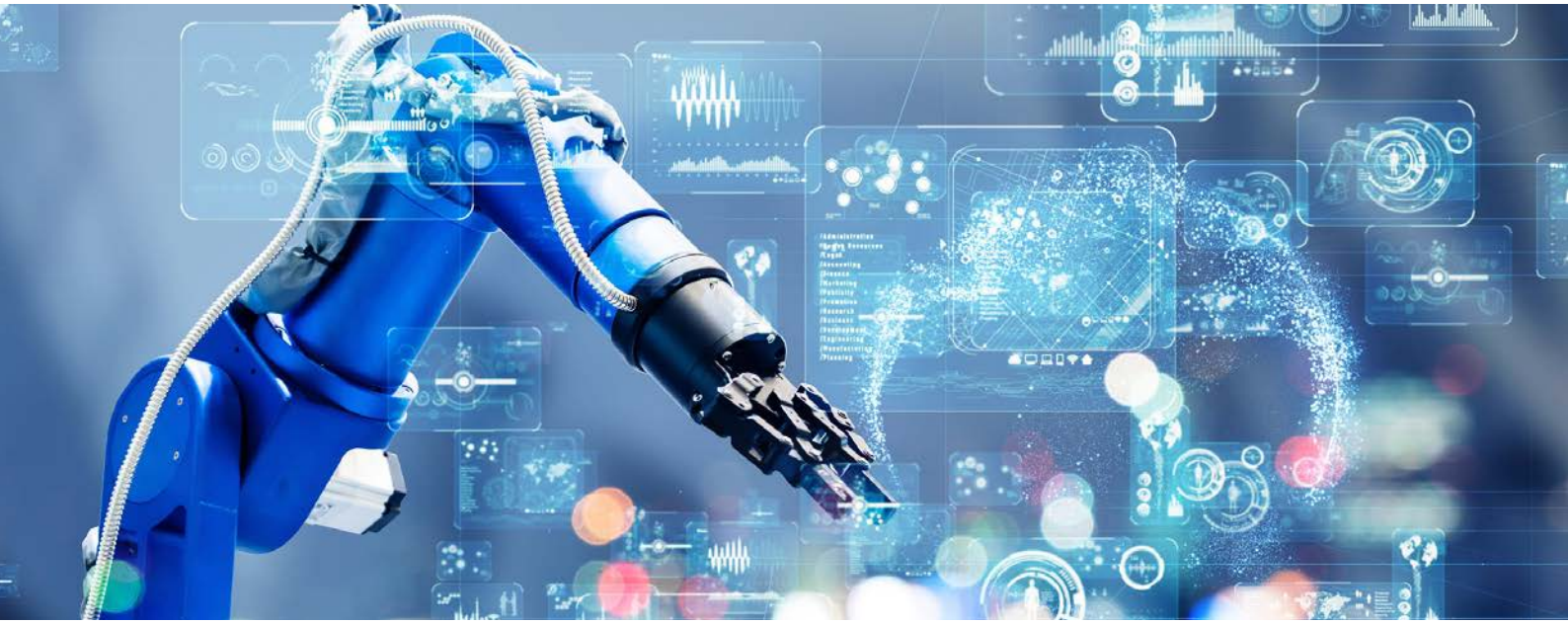
Table of Contents

Preface

Urbanisation and the rapid pace of industrialisation—exacerbated by the intensity and frequency of extreme weather events and their devastating consequences—demonstrate the fragility of an interconnected global economy. In 2020, the Covid-19 pandemic exposed how structural inequalities violate social fabrics, creating a digital underclass populated by disconnected communities. In particular, the disruption of normal work patterns and the need for social distancing has brought productivity in many industries and facilities to a near standstill, though essential work has been able to continue. The key to avoiding similar disruptions in the future and ensuring a more sustainable economy is resilience, achieved through much greater levels of digitalisation. Remote operations, automation, data analytics, and artificial intelligence (AI) help keep business operations moving without the need for close-proximity human interaction. In addition, the growing importance of sustainability across the key stakeholders of government, industry and the public, compounded by the impending climate emergency, creates a need to act now.

Today's reality positions digitalisation as a centrepiece of a resilient future. Autodesk has partnered with Frost & Sullivan to conduct research on sustainability and related digital technologies focused on the architecture, engineering and construction (AEC) and manufacturing (both discrete and process) industries in three key European regions: UK & Ireland, Nordics (Norway, Sweden, Finland and Denmark) and Benelux.

On the other side of the Covid-19 pandemic, the transformation from physical to digital operation will continue in the AEC and manufacturing industries. The results of this research illustrate the trajectory toward sustainability and digital deployments on which firms are at various stages of maturity. Conclusions disclose how both local and regional policies and new areas of digital sustainability influence industries and companies on the path toward a net zero global economy.



Abstract

This research analyses the extent to which sustainability is a driver in advancing strategy, reporting measures and initiatives, optimising resources, reducing carbon emissions, improving supply chain management, decreasing costs, supporting customer retention, and providing stakeholders with a competitive edge. It also analyses the role of digital solutions deployed to bolster sustainability and any related challenges, new initiatives, and innovative digital offerings designed to support future sustainability goals.

Research results are based on a quantitative survey of 600 organisations across the two segments of design and manufacturing and architecture, engineering, and construction (AEC) covering the three regional segments of the UK & Ireland, Nordics and Benelux. The goal is to measure and compare the level of sustainability demonstrated by AEC and manufacturing companies in these selected regions of Europe and present the steps they are taking to improve their standing.

The analysis highlights organisations' efforts to develop or enhance their sustainability strategies, including tangible targets and the development and/or utilisation of digital tools and services to monitor, measure, integrate, and manage their processes and systems on the path to net zero.

Rapid urbanisation and the continual depletion of limited resources are driving the need for a new systems-thinking approach to how resources are consumed and retained in a closed-loop circular economy. The deployment of data-driven solutions such as sensors, building information modelling (BIM), digital twin, track-and-trace, material passport, 3D printing, and robotics is set to unleash an era of value-driven data analytics. This in turn takes a step beyond delivering insights toward achieving optimised decision-making based on artificial intelligence (AI) and machine learning (ML).

1. Top 10 Key Takeaways

The research covered an exhaustive process, combining the detailed findings of the substantial number of quantitative survey findings, with the in-depth qualitative interviews of leading executives.

This provided a comprehensive insight into the issues facing executives and decisions makers, and supports the analysis on how the sustainability agenda across organisations in design, manufacturing and AEC is emerging. There are 10 key takeaways from the research:

1. The UN Sustainability Development Goals (SDGs) and the accompanying circular economy business model have become more strategically important given the demand from customers, investors, and employees in the new normal with digital tools central to enhancing resilience.
    - Customers, investors, and employees in the AEC and manufacturing industries are now driving the urgency and momentum of sustainability across the UK & Ireland, Nordics and Benelux.
    - Covid-19 has highlighted the fragility of supply chains and processes.
2. Value-driven data and analytics inform better decision-making in strategic priority areas such as net zero.
    - Net zero has emerged as a common goal of most, if not all, customers across the three regions in the manufacturing and AEC industries; data gathered from tracking carbon emissions (embodied and operational) informs strategy planning and the implementation of associated initiatives.
    - Methods to more effectively streamline data collection and enable effective data-driven decision-making is an area of growing need. For instance, greater transparency between and integration of supply partners is needed in the manufacturing industry. Better integration between architecture, engineering, and construction should extend to the operation and maintenance of the buildings throughout their lifecycle.
3. Interest has increased in embodied carbon tracking, life cycle analysis (LCA), and other digital tools for hybrid working patterns and reduced travel.
    - Embodied carbon in materials, in both manufacturing and construction, is a priority as companies look to reduce carbon intensity with use of alternative materials on the journey toward net zero.
    - The majority of the AEC industry has witnessed a transformational shift in terms of working patterns, with hybrid work models set to become the norm going forward. There is an increasing need for both simple digital tools to support employee well-being and digital solutions, such as the Internet of Things (IoT), virtual reality (VR), and drones, to support remote work, operations, and safety.

4 The step up in addressing emissions across the entire value chain from scope 1 to 4.

- Organisations are looking to advance focus from direct emissions (scope 1 and 2) to indirect emissions (scope 3) in measuring and reporting their carbon emissions.
- In AEC particularly, plans are being made for scope 4 to cover the carbon emissions of projects owned by a third party.

5 Sensors and related business models built on artificial intelligence (AI) and machine learning (ML) are changing the dynamics from static building information modelling (BIM) to dynamic digital twins to accelerate the sustainability benefits derived from the integrated approach.

- Forward integration in the construction industry is needed to tap into buildings' sensors and thus design efficient, cognitive buildings and pipe networks.
- Sensors are also driving productivity and efficiency in the manufacturing industry.

6 Supplying customers with better information and skills empowers them to make informed choices about sustainable materials and metrics.

- Customers are driving the sustainability agenda in the AEC and manufacturing industries when provided a platform that delivers the information necessary to drive their sustainability design efforts.
- Real-time visualisation of sustainability metrics in the planning processes or at customer sites is crucial to drive the much-needed change in behaviour.

7 Supply chain sustainability is growing in importance and increasingly supported by product passports, track-and-trace solutions, and cutting-edge sustainability rating, labelling or certification.

- Digital solutions such as product passports and track-and-trace solutions for critical materials are set to shape the closed-loop of resources in the circular economy.
- A new sustainability rating similar to the energy efficiency rating of products is set to strongly influence change among manufacturing, design and construction companies and customers.

8 Net positive gain in terms of biodiversity and nature-based solutions is gaining traction in the AEC sector.

- Biodiversity is driving focus in the AEC sector with measures (such as the 10% net gain requirement in the UK), which requires new construction projects to have a 10% net gain in biodiversity in any projects that impacts the environment.
- An opportunity exists for digital tools to assist with the monitoring, measuring, and reporting of biodiversity, in addition to other sustainability metrics.

9 Robotics and 3D printing will play a key role in resource-intensive sectors such as concrete and steel.

- Steel and concrete are highly carbon-intensive, and robotics can reduce concrete consumption by more than two-thirds, thus greatly contributing to reduced carbon emissions.
- Robots offer a considerable socio-economic benefit in enhancing safety levels, reducing exposure to hazardous substances, and addressing the labour shortage in the European Union (EU) construction market.

10 Digital concentration and inequality has emerged as a key concern across large-to-small industries and within organisations.

- Deployment of digital solutions in construction and manufacturing is relatively concentrated. A definite need to push for more penetration and utilisation of digital solutions is apparent, especially among small and medium-sized enterprises (SMEs) and across large organisations.
- Organisations are looking to invest in improving their employees' awareness of and skills in utilising digital tools to realise the untapped benefits and to improve their sustainability posture.

4. Digital Sustainability in The New Normal of AEC and Manufacturing

The majority of organisations surveyed maintain that the Sustainability Development Goals (SDGs) are a strong influencer, or even a model framework, for developing and defining their sustainability strategies. Among the 17 SDGs, several are environment-related: SDG6, water and sanitation; SDG7, affordable and clean energy; SDG11, sustainable cities and communities; SDG12, responsible consumption and production; and SDG13, climate action. However, more are gaining traction within the broader strategic framework of the AEC and manufacturing industries, namely SDG3, good health and well-being; SDG5, gender equality; and SDG15, life on land.

The Covid-19 pandemic can serve as a reset button for a green recovery, but it should also be taken as an opportunity to accelerate focus on the SDGs, supported by the circular economy business model as a key lever of digital transformation. **Figure 1** illustrates how digital solutions can drive the B2B growth opportunities of sustainability in a circular economy business model to drive opportunities for a closed loop of resources across industries.

Figure 1: Growth Opportunities for Digital Sustainability, Global, 2021

Sustainability and Circular Economy is Driving Growth Opportunities of Water, Energy, and Resource Regeneration/Recovery Across Cities and Industry Value Chains with an Interdependence on Critical Resources in an Increasingly Connected World.

3 Good Health and Well-being	5 Gender Equality	6 Clean Water and Sanitation	7 Affordable and Clean Energy	10 Industry, Innovation and Infrastructure	11 Sustainable Cities and Communities	12 Responsible Consumption and Production	13 Climate Action

Sustainability	Sustainability as a Service	Smart Environment in Cities & Buildings	Net Zero Cities, Nations, and Industries	Industrial Water & Waste Management Services	Circular Economy of Waste to Value	Green Feedstocks and Fuels
Digital Solutions	BIM & Digital Twin	3D Printing and Robotics	Cloud, Data Centres, Networks, and IT	Customer Experience and Contact	Digital Media and Cyber-security	Digital Media and Cyber-security

Aerospace & Defence	Agriculture & Nutrition	Energy	Chemicals & Materials	Mobility
• Aerospace Systems • Airlines and Airports • Defence & Security • Space • Unmanned Systems	• Nutritional & Functional Ingredients • Preservation, Sensory, & Textural Ingredients • Agriculture and Nutrition Technologies • Agrochemicals & Animal Feed Ingredients	• Power Generation • Grids • Energy Storage • Critical Power • Distributed Energy	• Chemicals in Infrastructure & Mobility • Personal Protection Equipment • Packaging • Metals & Minerals	• Vehicle Systems and Technologies • Autonomous Driving & Connected Mobility • Logistics and Supply Chains • Commercial Vehicles
Industrial Automation	**Homes & Buildings**	**Healthcare**	**Oil & Gas**	**FMCG – Fast Moving Consumer Goods**
• Process Equipment & Machines • Automation • Electronics & Measurement	• Smart Buildings & Automation • Lighting & Facility Management • Digital & Cognitive Buildings • Building Energy Management	• Digital Health • Advanced Medical Technologies • Pharma & Clinical Diagnostics	• Exploration & Drilling • Production & Completion • Supply Chain • Renewable Feedstocks	• Retail • Food & Beverages • Personal Care & Home Care

Design, Engineering, & Consulting	Architecture	Construction	Programme/Project Management	Design
Research, Banking, & Finance	Fintech	Academia	Investment Advisory	Insurance

Source: Frost & Sullivan

Together with the SDGs, the European Green Deal is another key driver of sustainability across the AEC and manufacturing industries in Europe. Additional support stems from strong customer and investor demand as well as local, national, and regional procurement needs, combined with other environmental, social, and governance (ESG) policies and legislation. The European Green Deal is a differentiator that will catalyse the low-carbon transition and drive sustainability on the global stage. These initiatives will help transform industry sectors that are particularly challenged by environmental impact and transition to more sustainable methods. Green finance will drive funding for development and adoption of innovative technologies at proven industrial scale. The European Green Deal is a framework within which a strong foundation can be set for a sustainable economy.

The European Commission's energy efficiency and energy performance directives for buildings were updated in 2018. The directives mention installing automation and control systems and energy management systems in certain buildings, with an objective to improve energy efficiency. The directives reference long-term renovation strategies for decarbonising national building stocks by 2050 and have mandated that all new buildings must be Net Zero Energy Buildings (nZEB) from 31 December 2020.

To boost buildings' energy performance, the EU has established a legislative framework that includes the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) and the Energy Efficiency Directive (EED) (2012/27/EU). The amended EPBD (2018/844/EU) includes stronger renovation strategies aimed at decarbonising the national building stocks by 2050, with indicative milestones for 2030, 2040, and 2050. Moreover, smart technologies will be promoted more intensely, for instance, by requiring the installation of building automation and control systems as well as devices that regulate temperature at the room level.

Along with the EU's EED and EPBD policies, the UK's initiative of Energy Savings Opportunities Scheme (ESOS) as per Article 8 of the EED, requires large sector companies to perform comprehensive energy audits and identify opportunities for energy savings every four years. Under the National Energy Efficiency Action Plan (NEEAP), the UK has national and regional level energy-efficiency measures and implementation guidelines for buildings.

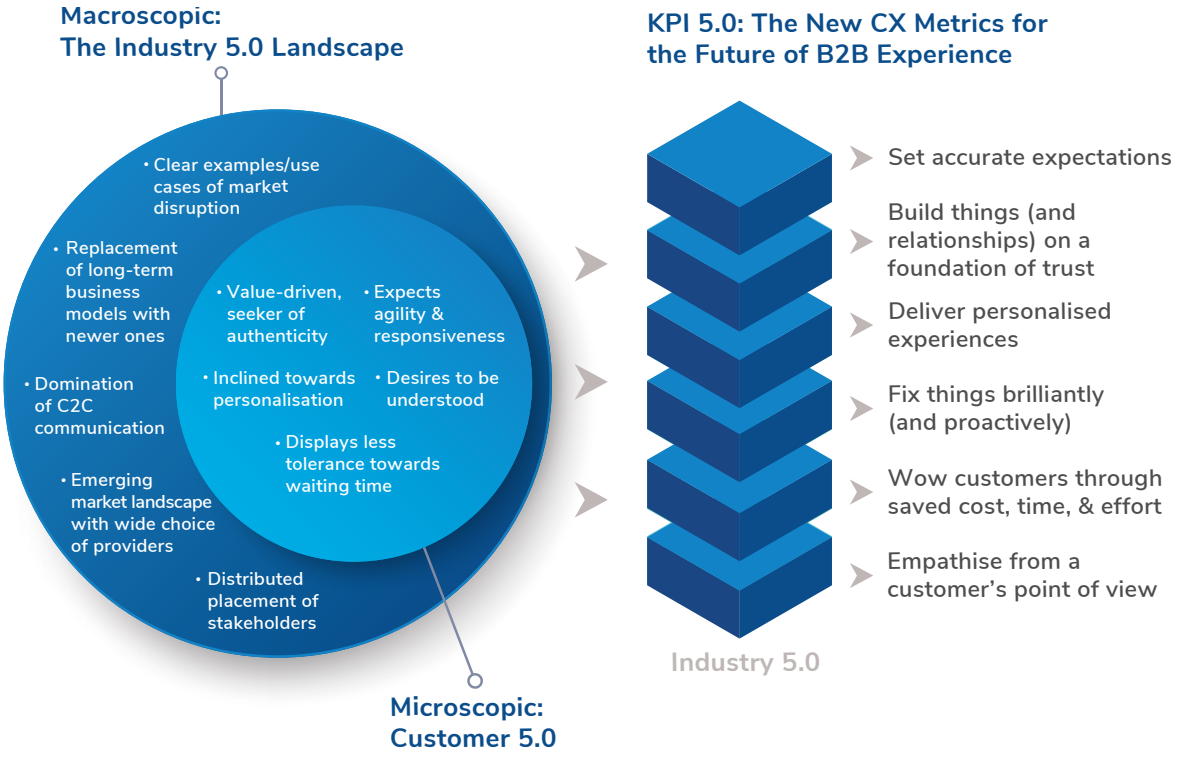
The EU has also passed directives to make processes smooth for peer-to-peer energy trading. The UK, Germany, and the Netherlands are frontrunners in implementing large-scale blockchain-based energy trading. **Figure 2** highlights some of the key digital enabled trends in the building sector.

Figure 2: Key Trends In the Building Sector, Europe, 2021

Source: Frost & Sullivan

The manufacturing industry is witnessing a transformational shift with key factors such as personalisation of customer products, agility of delivery, and responsiveness for proactive support that will guide Industry 5.0. This shift is set to contribute to long-term sustainability and profitable interactions among stakeholders in the business-to-business (B2B) and business-to-consumer (B2C) environments.

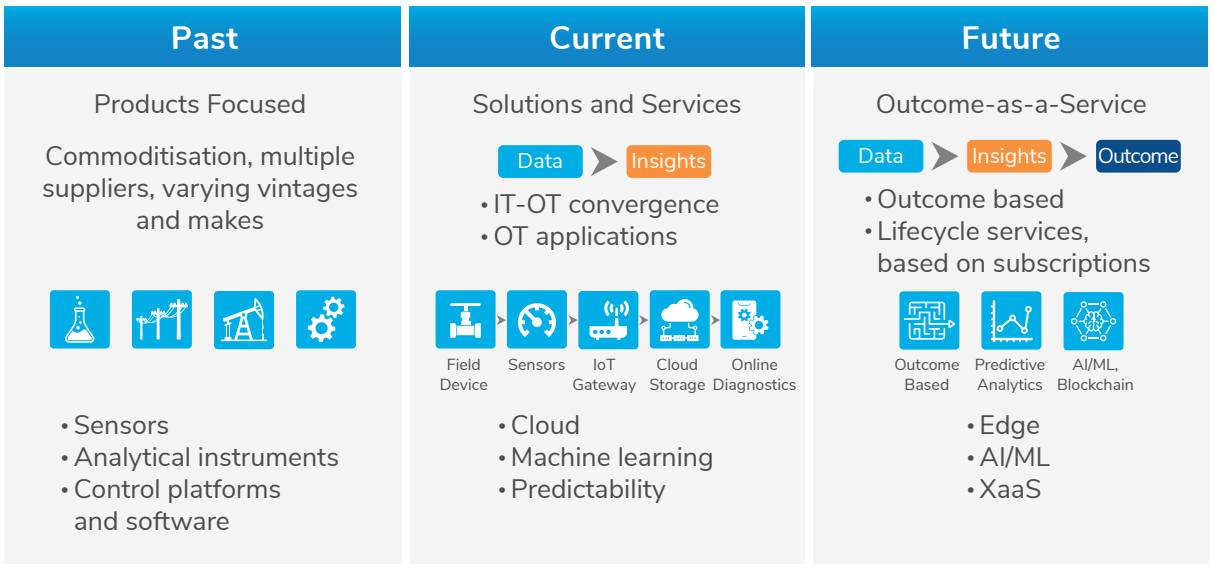
Figure 3: Industry 5.0 and Customer Experience Metrics in The Future of Manufacturing, Europe, 2021



Source: https://info.microsoft.com/rs/157-GQE-382/images/FoF_Infographic_Final_V2.pdf

Digital tools will support manufacturing companies significantly when transforming their business models and delivering enhanced value to customers. The evolution from product centric to solutions and services offered through an outcome-as-a-service model will map into customers' sustainability needs, such as life-cycle services.

Figure 4: Roadmap for Customers Going Digital, Europe, 2021



Source: Frost & Sullivan

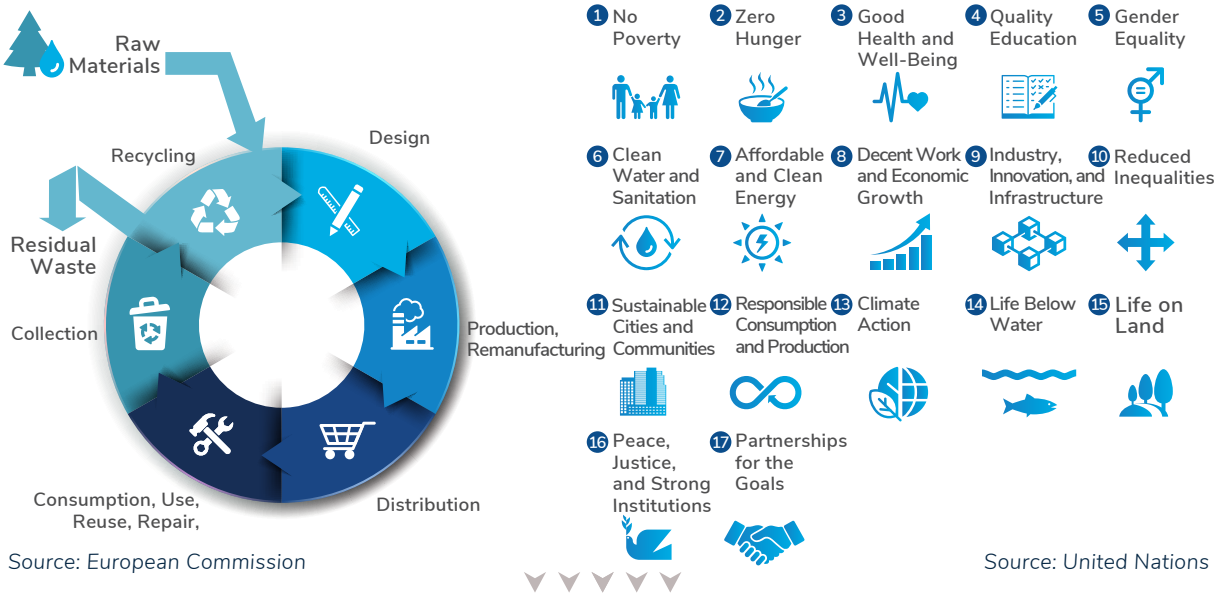
5. Key Influencers of the Future of AEC and Manufacturing

SDGs and The Circular Economy

The goals adopted at the 2015 United Nations Sustainable Development Summit provide the principles, framework, and targets for all stakeholders across the value chain to identify key development areas and seek continual improvement with regards to sustainability and climate action.

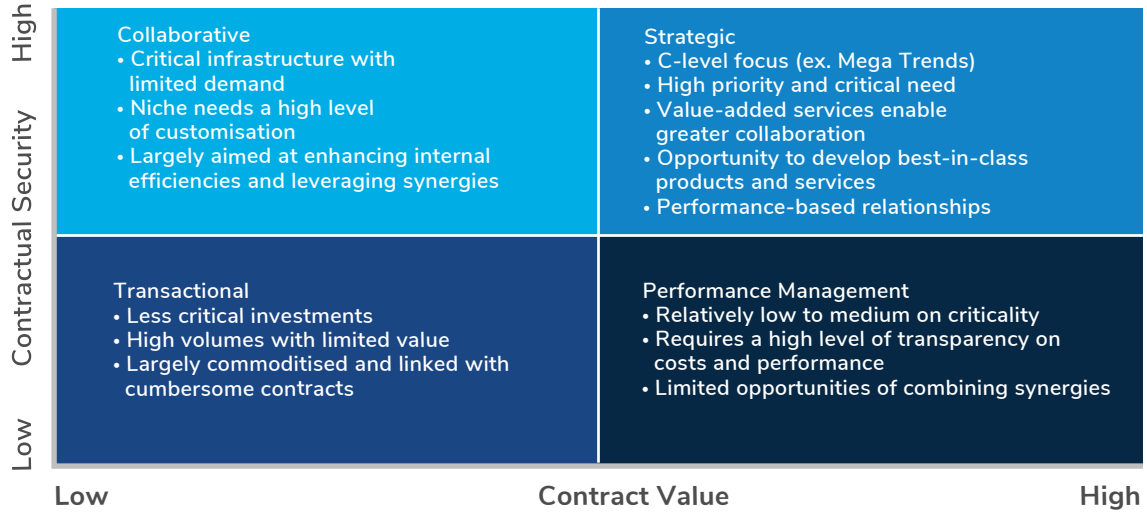
Being at the forefront of environmental best practices, the EU initiated the important journey towards a circular economy by adopting the Circular Economy Action Plan in 2015. This initiative forms the foundation for the EU Green Deal and is set to experience renewed attention as the region begins its recovery from Covid-19. Some of the key areas of focus are resource-intensive sectors such as construction and buildings, power, packaging, plastics, electronics and ICT, batteries and vehicles, textiles, food, water, and nutrients.

Figure 5: Sustainability and Circular Economy Influencing Purchasing and Investment Criteria, Europe, 2021



Source: European Commission

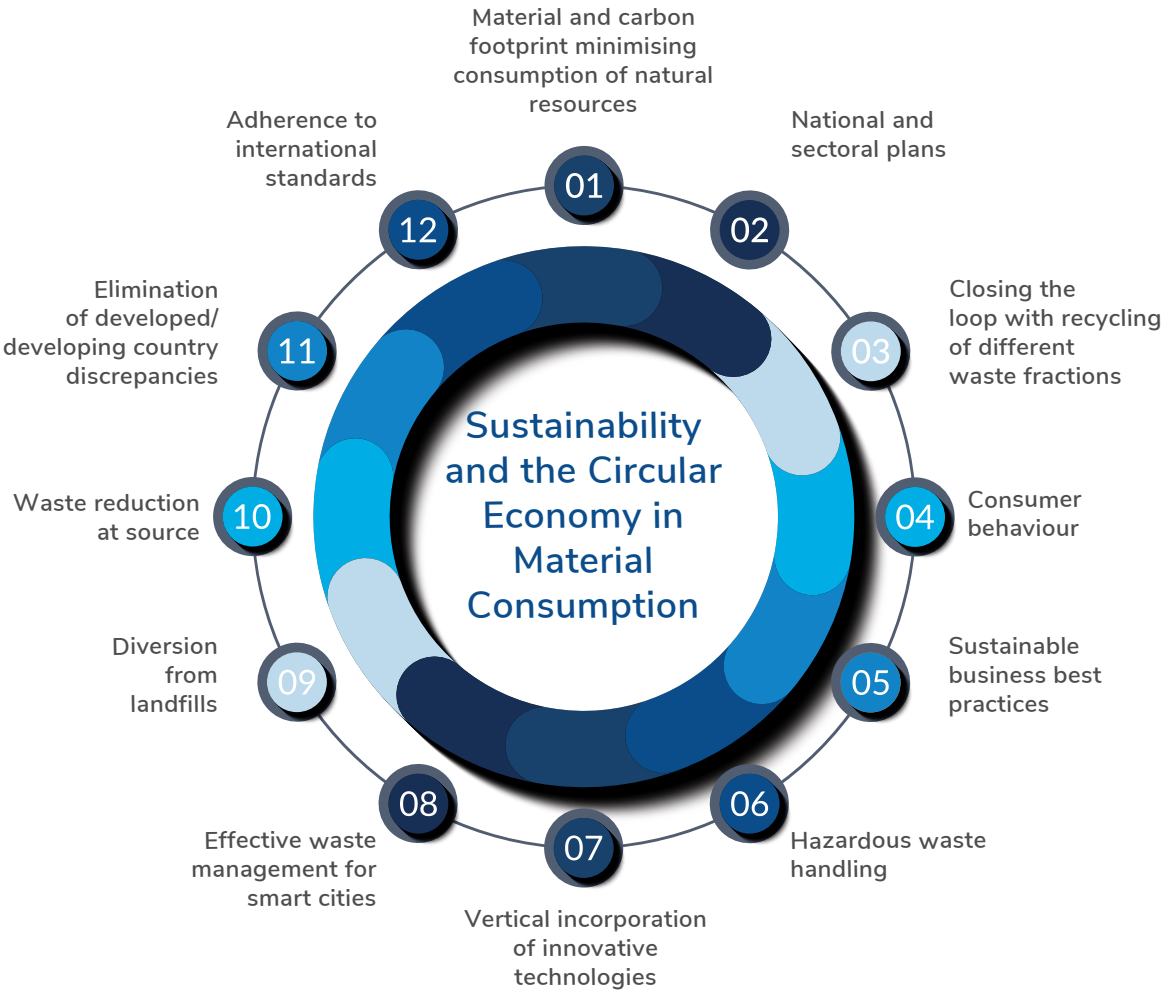
Source: United Nations



Source: Frost & Sullivan

One of the key SDGs in the context of achieving net zero in carbon is SDG 12: Responsible Consumption and Production. Fulfilment of Goal 12 hinges on addressing the rapid expansion of material consumption globally and the growing material footprint per capita. It calls for the urgent action necessary to tackle over-extraction of natural resources and to enforce policies and actions aimed at resource efficiency, waste reduction, and incorporation of sustainable practices across all economic sectors.

Figure 6: Sustainability and Circular Economy in Material Consumption, Global, 2021



Source: United Nations; Frost & Sullivan

Risk, Resilience, and the Role of Digital Transformation

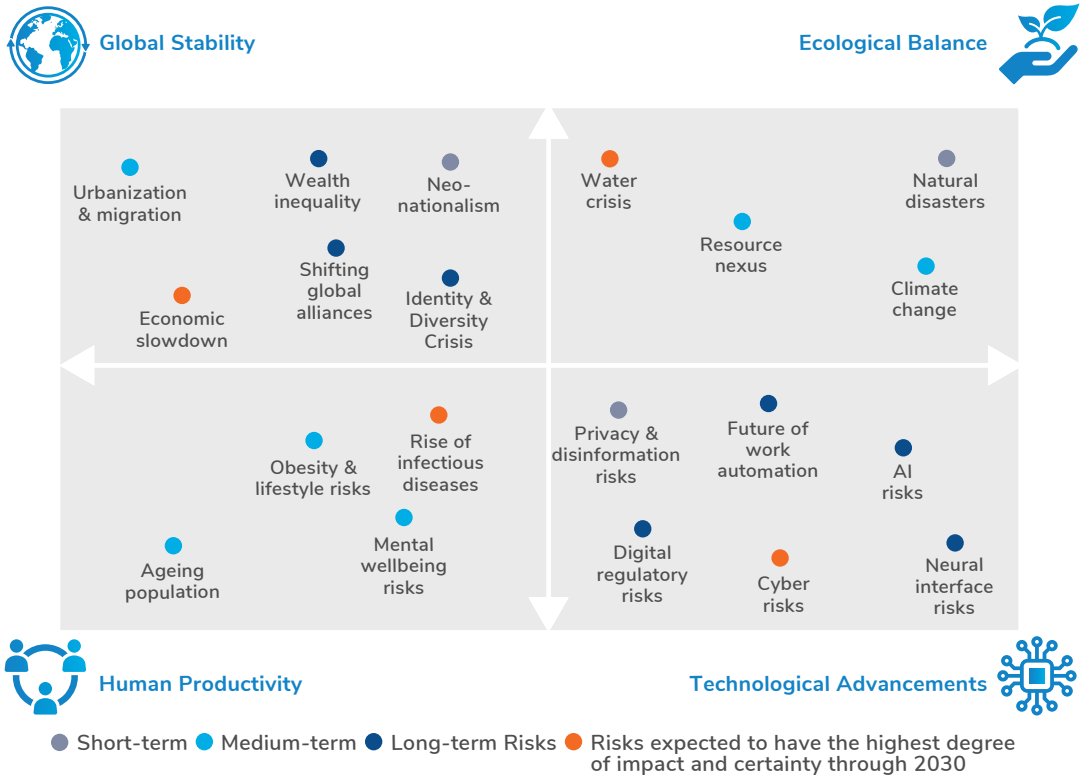
For the first time since its initial publication in 2005 - the World Economic Forum's Global Risks Report 2020 states that the top five threats (in terms of likelihood) are all environmental: extreme weather, climate action failure, natural disasters, bio-diversity loss, and human-made environmental disasters. In the latest edition of the Global Risks Report 2021, four of the top five previous risks are retained, with Covid-19 placing infectious diseases as a societal risk replacing natural disasters.

Moreover, two notable additions in the latest report are digital power concentration and digital inequality, which ranked 6th and 7th, respectively. Investments made in digital transformation are being realised by many organisations, however, a large portion had not foreseen the need for or did not have the capacity or resources to deploy digital solutions and benefit from the associated services. This particular challenge must be addressed with the provision of flexible and affordable packages and also by customising solutions to serve the specific needs of SME customers.

Top 20 Major Risks

Frost & Sullivan has identified 20 major risks, presented in **Figure 7**, that have the potential to severely disrupt the global economy, equal to the disruptive potential of Covid-19.

Figure 7: Key Future Risks with Greatest Potential to Impact Economy, Global, 2019 - 2030



Source: Frost & Sullivan

Risk and resilience have become paramount in light of the Covid-19 pandemic, highlighting the increasing interdependence among leading economies and related supply chains. This understanding intensifies focus on their impact on built infrastructure and assets in cities and industries, particularly risks such as extreme weather events and insecure supply of key resources such as water and energy. Consequently, infrastructure, services, and solutions are needed that can capture and utilise data that is flexible, adaptable, intelligent, and responsive—the key elements of digital transformation that underpin the shift to an era of digital sustainability and circular economy. The digital evolution will cover aspects such as smart manufacturing, digital twins, asset condition monitoring and optimisation, smart sensors, smart meter/grid, demand response, and automated trading. These elements will be particularly important in the design and manufacturing segments.

6. Results from the survey on Sustainability in AEC and Manufacturing in the UK & Ireland, Nordics and Benelux

A key part of this research is the quantitative survey on sustainability and the role of digital technology in the two sectors of AEC and manufacturing across the 3 regions of the UK & Ireland, Nordics and Benelux.

Table 1: Sample Structure of Quantitative Survey

Country	Total	Manufacturing	A&E	Construction
Denmark	50	20	21	9
Finland	50	17	20	13
Norway	49	16	16	17
Sweden	50	20	16	14
Nordics	199	73	73	53
Belgium	90	28	22	40
Luxemburg	20	7	9	4
Netherlands	90	26	33	31
Benelux	200	61	64	75
Ireland	50	17	16	17
UK	151	49	49	53
UK / IRL	201	66	65	70
Total	600	200	202	198

Source: Frost & Sullivan

Table 2: List of Companies that Participated in the Qualitative Discussions
The below table indicates the focus areas of these firms, however, some span multiple sectors.

Sl. No.	Name of Company	Region	Sector
1	TRILUX	Benelux	Manufacturing
2	ArcelorMittal	Benelux	Manufacturing
3	Alliander	Benelux	Manufacturing
4	BAM	Benelux	Construction
5	Stamhuis	Benelux	Construction
6	VK Group	Benelux	AE
7	ODICO	Nordics	Construction
8	Tyrens	Nordics	Construction
9	Bonava	Nordics	Construction
10	Robot at Work	Nordics	Construction
11	Sweco	Nordics	AE
12	Norconsult	Nordics	AE
13	Assemblin	Nordics	AE
14	EFLA	Nordics	AE
15	A-insinöörit	Nordics	AE

Sl. No.	Name of Company	Region	Sector
16	Landsec	UK/Ireland	Construction
17	Wills Bros	UK/Ireland	Construction
18	AECOM	UK/Ireland	Construction
19	PM Group	UK/Ireland	AE
20	Mace	UK/Ireland	AE
21	Bryden Wood	UK/Ireland	AE
22	Polypipe	UK/Ireland	Manufacturing
23	Playdale	UK/Ireland	Manufacturing
24	IMI Group Ltd	UK/Ireland	Manufacturing

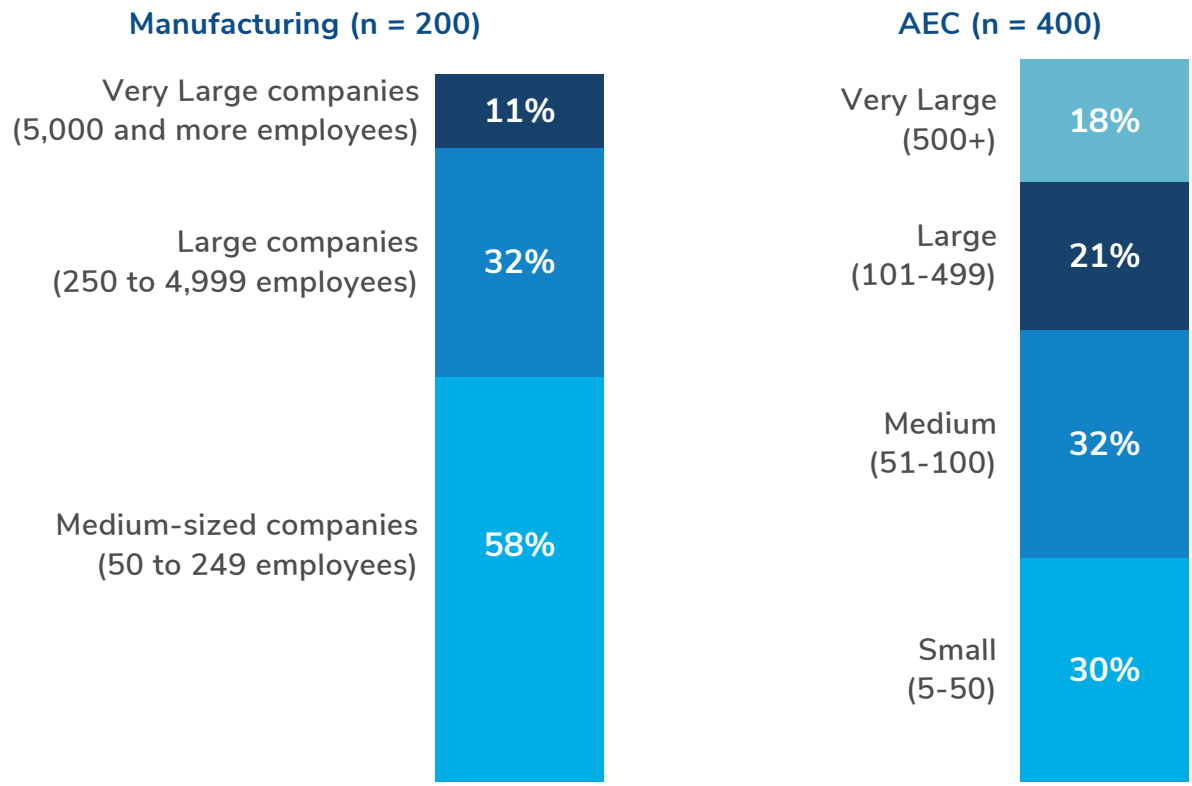
Segments	No. of Interviews by Region			
	Benelux	Nordics	UK & Ireland	TOTAL
Manufacturing	3	0	3	6
Construction	2	4	3	9
AE	1	5	3	9
TOTAL	6	9	9	24

Source: Frost & Sullivan

Distribution of Sample Structure by Company Size

To ensure the sample is representative of the sectors, the manufacturing sector is split based on number of employees into 3 categories: very large (5,000+ employees), large (250 to 4,999 employees), and medium (50 to 249 employees). Given the diverse size of organisations in the AEC segment, it is divided into 4 categories: very large (500+ employees); large (101-499 employees); medium (51-100 employees); and small (5 to 50 employees), which holds a significant share of the segment.

Chart 1: Distribution of Sample Structure by Company Size

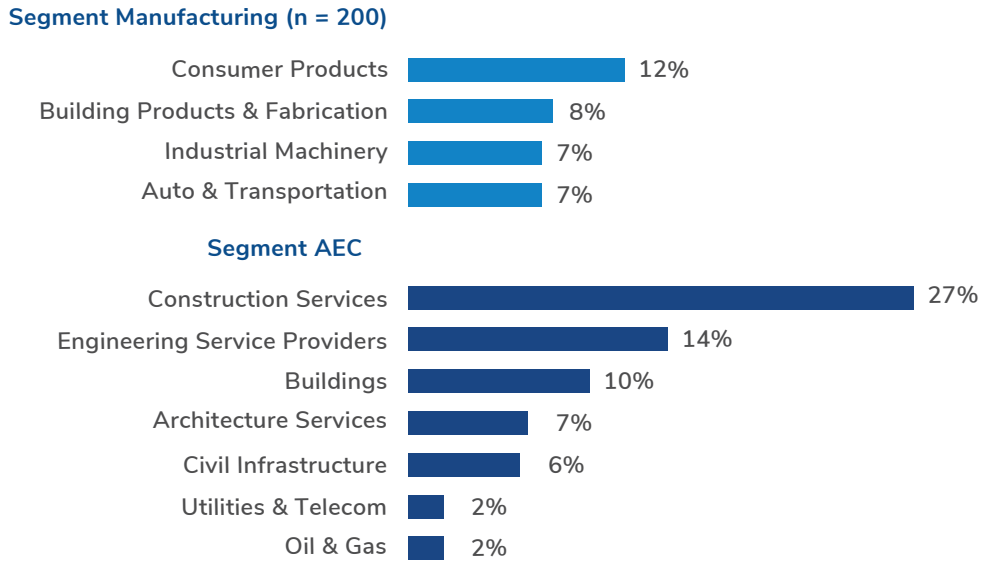


Source: Frost & Sullivan

Distribution of Sample Structure by Segment in Manufacturing and AEC

The sample structure within the manufacturing segment has a slightly higher proportion for consumer products and a relatively even split between the other 3 segments of building products & fabrication, industrial machinery, and auto & transportation. In the AEC segment, the majority of the sample coverage is in construction services, engineering service providers, buildings, and architecture services.

Chart 2: Distribution of Sample Structure by Segment in Manufacturing and AEC

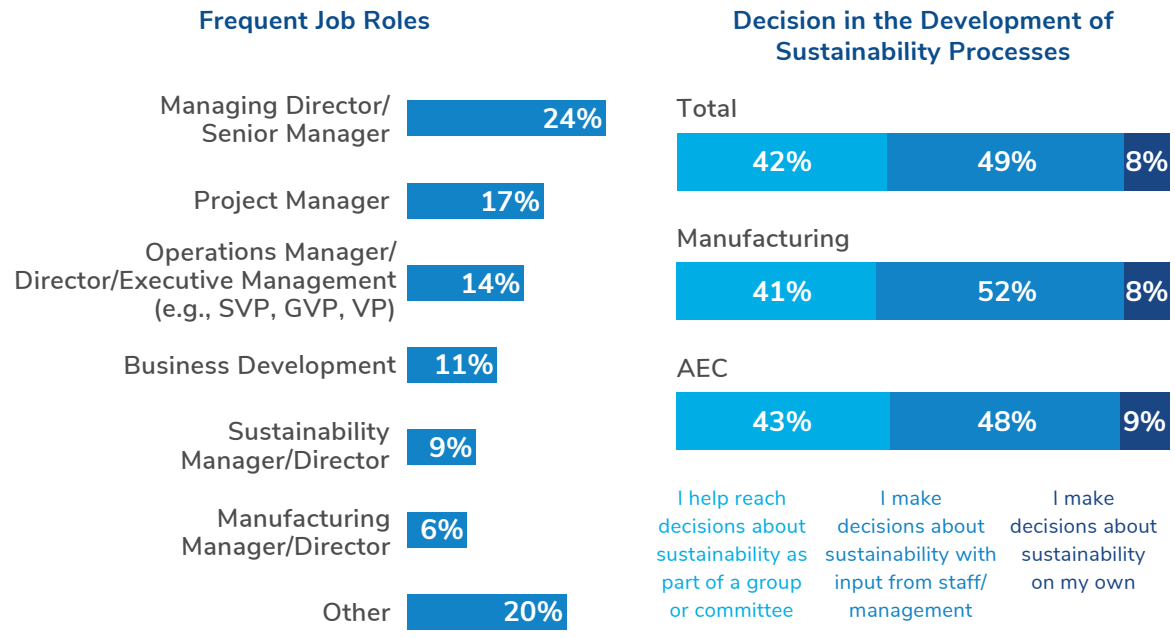


Source: Frost & Sullivan

Role of Respondents and Influence on Decision-making Regarding Sustainability

Roughly 1 out of 4 respondents are in a senior management position, which reflects the increasingly strategic importance of sustainability in organisations; however, it is worth noting that company decisions are mainly conducted by a decision-making team, which demonstrates that sustainability has a cross-functional role in an organisation.

Chart 3: Role of Respondents and influence on decision-making regarding sustainability



Please note: Category job role "other" includes roles such as Architect 3%, Product/Design Manager 3%, Innovation Manager 3%, Corporate Partnerships 2%, R&D Manager 2%, General Contractor 2%, BIM Manager 1%, explicit other 5%.

Source: Frost & Sullivan

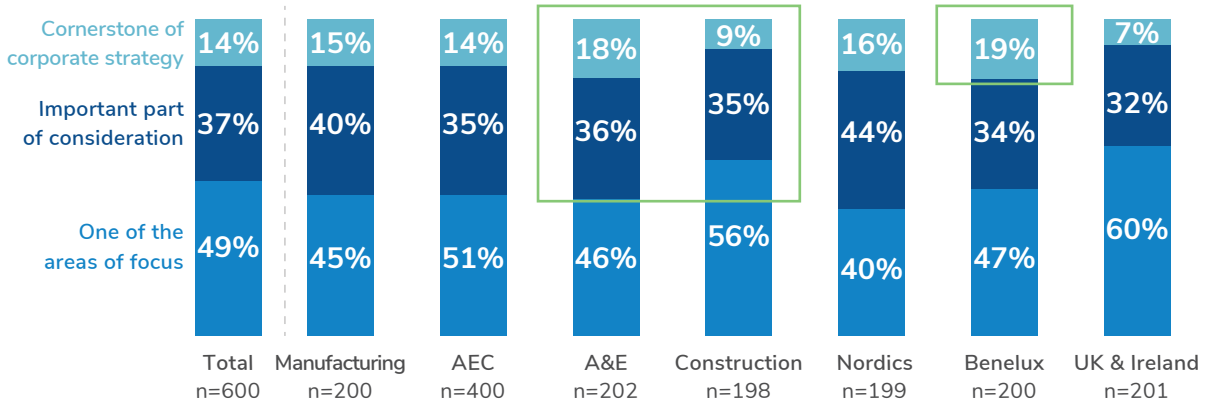
> We have recently developed a sustainability department that plans and is involved in sustainability management. The group working on these initiatives engages with other departments to secure their buy in. With this approach, we aim to pull all our people together so that they are on board to achieve our sustainability goals. We reflect on the environment of our people and our projects in the world. The group of people implementing these new initiatives in the organisation come from multiple departments, from engineering, concept design, and others. Concept design creates the sustainable concepts, and we engineer solutions for this. From that perspective, we are getting more people in the organisation to speak to us about the sustainable solutions.
>
> - Ko Bontje, Manager of the Innovation Department at Stamhuis

Sustainability As an Established Element in Company Strategy

Almost half of the companies surveyed report sustainability is an important part of the strategy, or even a cornerstone of their business. For many of them sustainability has become a key part of their strategy, especially with the launch of the UN SDGs in 2015. Since then, companies have looked at assessing some of their sustainability priorities to either map, align, or relate them to one of the 17 SDGs.

Environmental legislation plays a pivotal role in driving sustainability in the manufacturing sector; however, the resource intensity, and especially the significant impact of carbon emissions generated mainly by the construction industry, is sharpening focus on sustainability in the sector. Interestingly, in Benelux, 1 in 5 companies see sustainability as a cornerstone of corporate strategy compared to less than 10% of companies in the UK and Ireland. The Nordics is by far the most mature region in terms of sustainability.

Chart 4: Importance of sustainability by Industry and Region



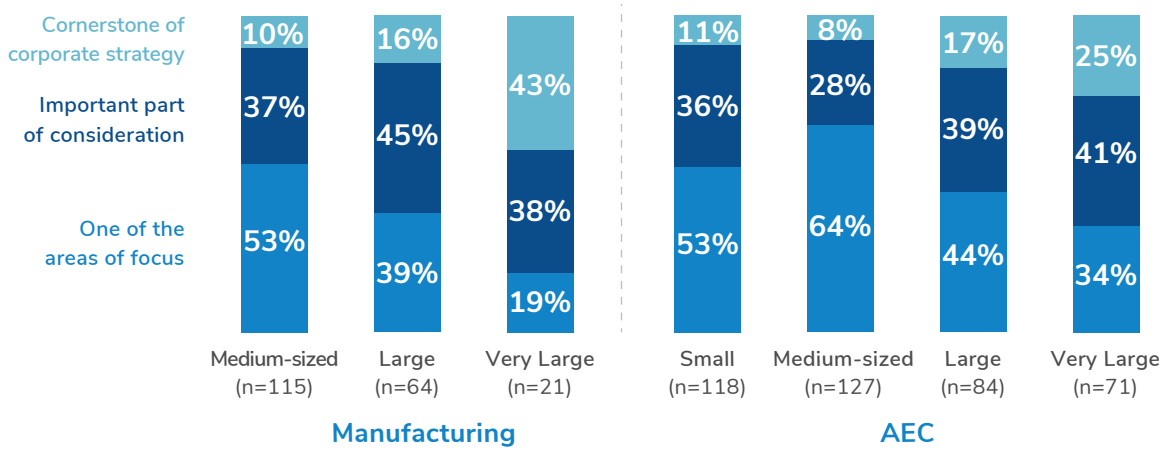
Base: All respondents (n=600).
S8. How important is sustainability/environmental impact in your company strategy?

Source: Frost & Sullivan

Importance of Sustainability Increases with Company Size

Large, resource-intensive companies in manufacturing, in particular, consider sustainability as a core part of their strategic vision; 43% cite it is a cornerstone of their corporate strategy. In the very large segment of the AEC industry, close to two-thirds of organisations cite sustainability as an important consideration, and 1 in 4 regard it as a cornerstone of their corporate strategy. This outlook of large AEC companies is certainly influenced by their customers, in particular those in the public sector. These companies are also pushing their sustainability agendas to drive focus on the supply side. However, smaller organisations face challenges such as acquiring dedicated resources or skills needed to invest in sustainability initiatives.

Chart 5: Importance of sustainability by Company Size



Base: All respondents (n=600).
S8. How important is sustainability/environmental impact in your company strategy?

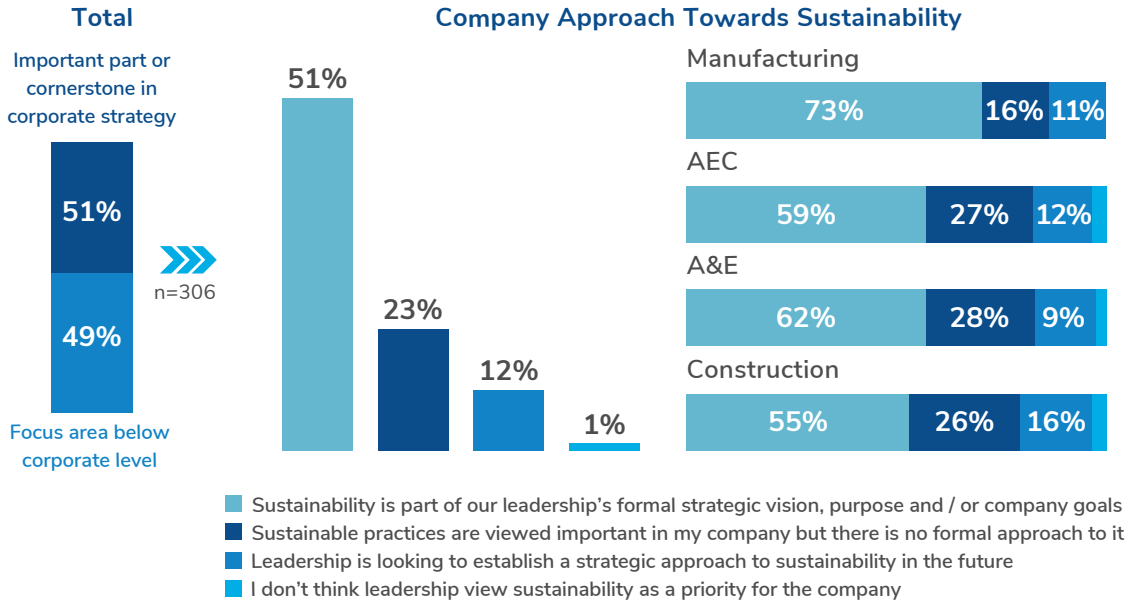
Please note: Sample for large companies shows trends only.

Source: Frost & Sullivan

Close to Two Out of Three Respondents Regard Sustainability as a Core Part of Strategic Vision

Nearly two-thirds of the respondents understand sustainability as a component of formal strategic vision from a leadership approach. In addition, 12% of the companies plan to take a more strategic approach in the future. Approximately three-quarters of manufacturing companies consider sustainability part of leadership's strategic vision. The Architecture and Engineering (A&E) segment is a bit more advanced; however, the construction segment is not far behind.

Chart 6: Company Approach Towards Sustainability in Manufacturing and AEC (A&E and Construction)



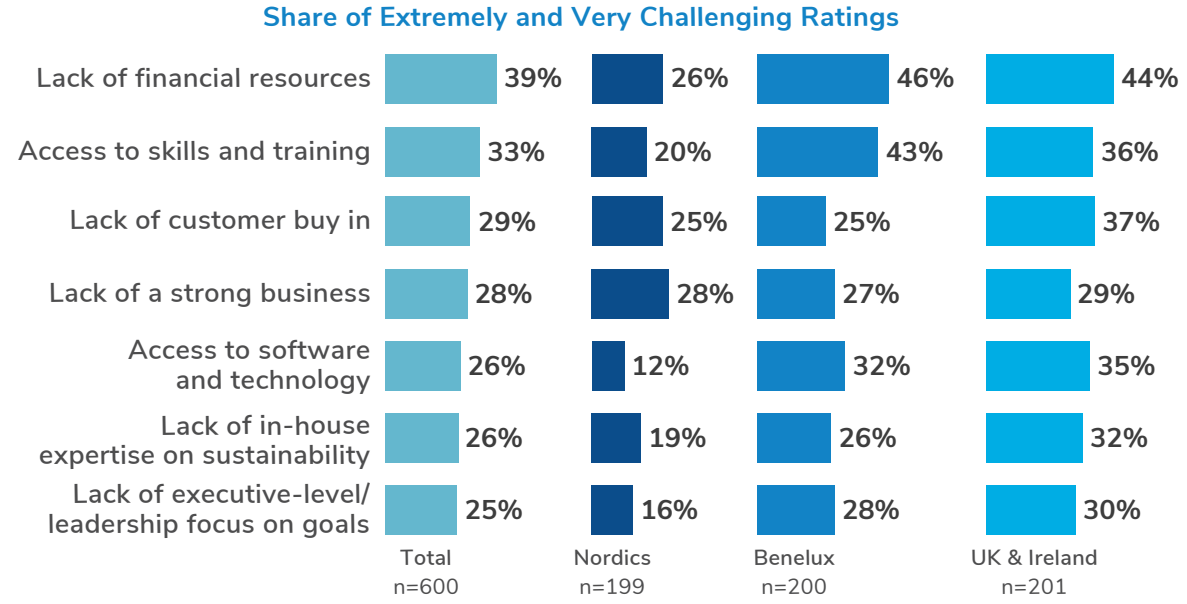
Base: Companies with corporate focus on sustainability (n=306).
Q1. Let's start with a general question, which of the following statements best reflects your company's approach to sustainability/environmental impact?

Source: Frost & Sullivan

Nordics by Far the Most Mature Region in Terms of Sustainability

The Nordics emerged as the most mature regional segment ahead of Benelux, the UK and Ireland. It has the lowest level of perceived challenges, especially in financial resources and access to skills and training. These achievements reflect a long legacy of companies focusing on the environmental, social, and governance (ESG) aspects of corporate strategy and building strong capabilities and expertise in sustainability when servicing their projects and clients. Simultaneously, they have invested the much-needed upskilling and training of their employees. The maturity of digital sustainability in the Nordics is highlighted further by the region's view of access to software and technology as less of a challenge when compared to views from the other regions. Companies in the Nordics leverage software and technology to drive sustainability across the region.

Chart 7: Main Challenges for Achieving Sustainability by Region



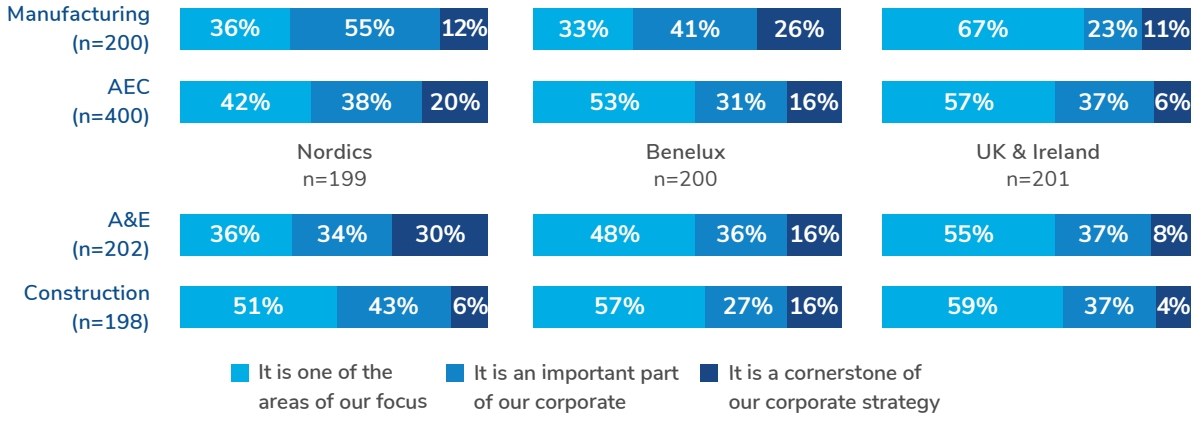
Base: All respondents (n=600).
Q6. How challenging are the following aspects for achieving your sustainability/environmental impact goals?

Source: Frost & Sullivan

Sustainability Maturity Differs by Region in Manufacturing and AEC

Manufacturing firms in Benelux (67%) have established sustainability processes at the corporate level and build on the strong push of climate action, whereas firms in the Netherlands have focused on advancing their circular economy policy. Interestingly, A&E companies in the Nordics have a very strong corporate sustainability focus, which is rooted by a robust legacy of focus on both the environmental and social aspects of business and industry in the region. However, as a whole, AEC is stationed in the middle of its sustainability journey, with the A&E segment having progressed farther than the construction segment. This difference highlights a disconnect that needs to be addressed to effectively drive sustainability in the overall AEC industry. The A&E segment of the AEC industry does play the role of a specifier in construction projects, but lacks the controls in the final selection of materials and products in the project.

Chart 8: Importance of Sustainability Split by Industry within Region



Base: All respondents (n=600).
S8. How important is sustainability/environmental impact in your company strategy?

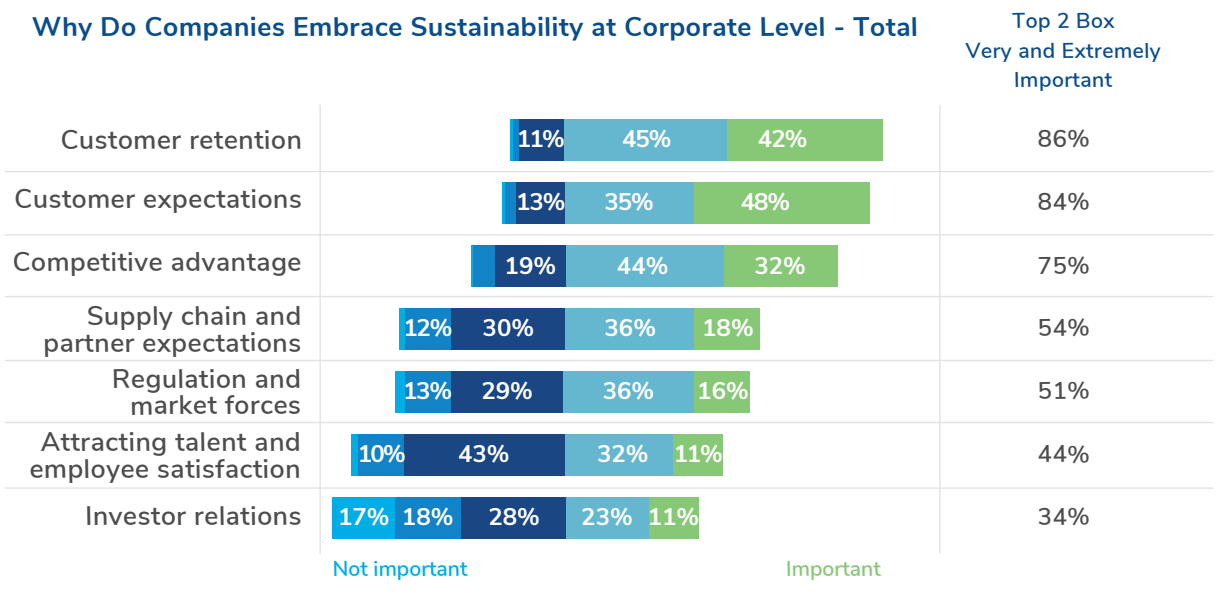
Please note: Sample size varies between n=53 and n=75 for manufacturing, A&E, and construction per region and can be seen as a trend only.

Source: Frost & Sullivan

Customer Expectation and Retention Emerges as a Key Driver for Focus on Sustainability

Customers retention and expectations emerge as the most important drivers for sustainability at a corporate level, followed by competitive advantage. Interestingly, more than 76% of companies say they have a competitive advantage when sustainability is embraced at the corporate level. However, investor relations are only relevant for about a third of companies, which could indicate that the sector is dominated by private or family owned companies. It is also possible that investor relations is still in its growth phase of driving sustainability.

Chart 9: Key Factors for Companies to Embrace Sustainability at a Corporate Level



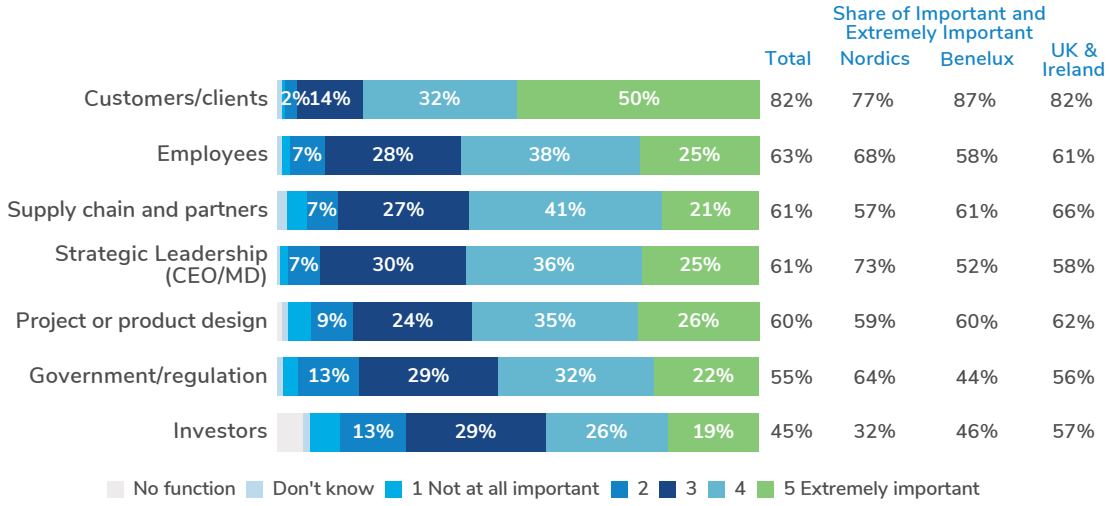
Base: AEC Companies with corporate focus on sustainability (n=306).
Q2. Why is your company embracing sustainability at a corporate level?

Source: Frost & Sullivan

Customers and Employees Are the Main Influencers for Sustainability across Regions as well as across Manufacturing and AEC

Employees are key internal stakeholders and are strongly driving sustainability strategies. Strategic leadership is also driving sustainability, particularly in the Nordics (73%). In the UK and Ireland, investors are a bigger influencer (57%) of sustainability initiatives.

Chart 10: Impact of Departments and Groups on Sustainability by Region



Base: All respondents (n=600).
Q12. How important are the following groups/departments in driving sustainability/environmental impact strategies in your company?

Source: Frost & Sullivan

> The number one sustainability driver for Sweco is its current and future employees. When asked why, current employees say, 'it is because what I do has relevance in a wider sense and the company focus on climate action.' When we look for new employees and interns, they often say that the main differentiator between us and our competitors is in terms of project work in relation to climate.
>
> - Mattias Goldmann, Head of Sustainability at Sweco

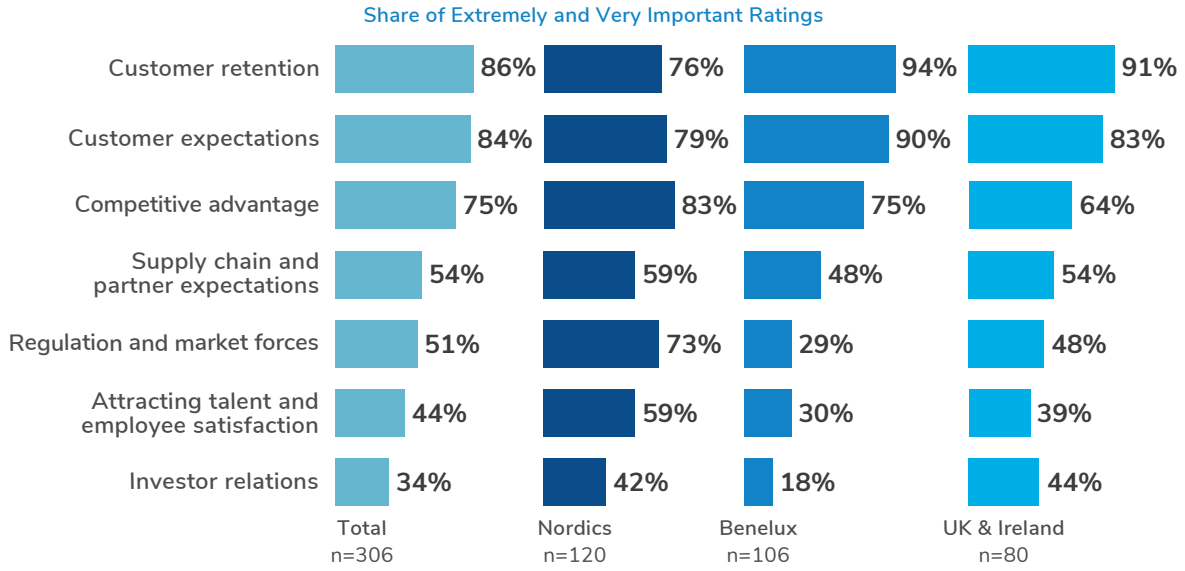
> Customers validated our view that they are the main sustainability driver at EFLA. This is an important discussion, as is the use of instruments such as green bonds.
>
> - Gudrun Jonsdottir, Team Lead at EFLA Consulting Engineers

> Our 800+ employees are highly educated and aspirational, so many require meaningful work. The better we can address sustainability in our work, the better employer we are, and more people want to work for us. Attracting talent is crucial.
>
> - Liisa Jäätvuori, Chief Sustainability Officer (CSO) at A-insinöörit

Customer Retention and Competitive Advantage Emerge as the Most Important Driver in the Nordics

The Nordics are strongly driven by regulations and market forces, which could indicate sustainability maturity. This is not necessarily driven by governmental rules, as building certifications are often much more established in the Nordics. There is a similar trend of strong employee attraction in the Nordics.

Chart 11: Key Factors for Companies to Embrace Sustainability at Corporate Level by Region



Base: Companies with corporate focus on sustainability (n=306).
Q2. Why is your company embracing sustainability at a corporate level?

Source: Frost & Sullivan

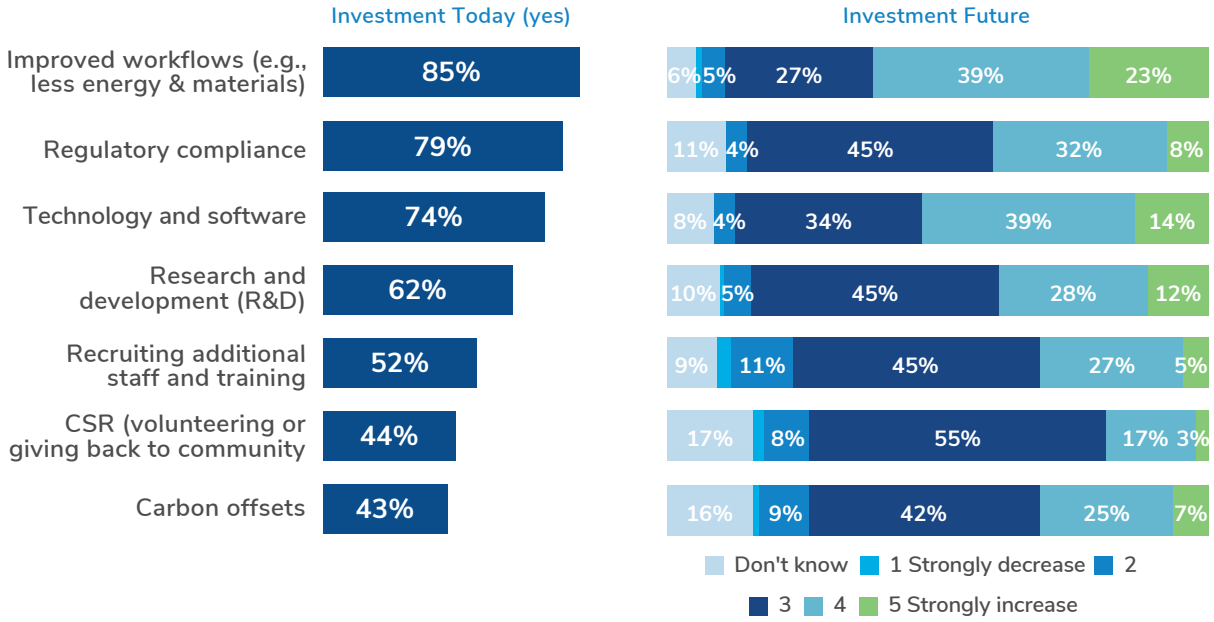
> Customers are a strong driver for our sustainability strategy. One of our biggest customers is the Swedish Transport Agency and they give us a premium when we perform better in terms of climate.
>
> - Mattias Goldmann, Head of Sustainability at Sweco

> The sustainability goals and the Green Deal are key drivers, together with different procurement demands and different user expectations and legislation.
>
> - Katrin Discher, Director of Sustainability at TRILUX

Value-driven Data and Analytics for Better Decision-making: Strong Investment in Workflows, Compliance, and Technology/Software

Companies are already investing in improved workflows, regulatory compliance, and technology/software. Most plan to increase this investment, especially regarding improved workflows and technology/software. There is a growing emphasis on better streamlining and integration of software tools because it will drive efficiency and productivity. This is a value-add that will also address unmet needs through its analytics and will support decision-making regarding complex sustainability challenges. The operational and behavioural awareness of digital twins is helping people achieve better outcomes throughout the life cycles of products, buildings, and infrastructure.

Chart 12: Areas of Investment in Sustainability - Today and In the Future



Base: All respondents (n=600).
Q10. Today, where is your company investing to become more sustainable? How will that change in the next two years?

Source: Frost & Sullivan

> 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. Once the building is operational, we can also monitor it remotely and real time. There's a huge potential role for technology because it can help us stop working at an individual building level, the way that we're finally starting to see BREEAM, and LEED function. We've traditionally operated building by building, but we want to construct societies and we feel that the very minimal level of emphasis should be blocks or quarters or areas of a city. This is where technology offers the most benefits.

- Mattias Goldmann, Head of Sustainability at Sweco

> We need to be able to digitise our design methodologies to have a much cleaner transition from computational design to the delivery of a manufacturable product.

- Nils Rage, Sustainable Design and Innovation Manager at Landsec

> The real challenge of our project is to develop the goals with respect to life cycle analysis (LCA) or life cost cycle (LCC) and then use these tools to make decisions quite early in the process. We have a group of people; environmental specialists and BIM specialists, focused on addressing this issue by making the calculations and analysis together.

- Gudrun Jonsdottir, Team Lead at EFLA Consulting Engineers

> We have decided to measure our handprint, that is, the positive environmental impact we have on our clients' projects. While designing the way to measure handprint, we are already doing everything we can to increase it with regards to process. We are implementing guidelines and task lists for everyone who works in projects so they have easy instructions on how to make projects greener.
>
> - Liisa Jäätvuori, Chief Sustainability Officer (CSO) at A-insinöörit

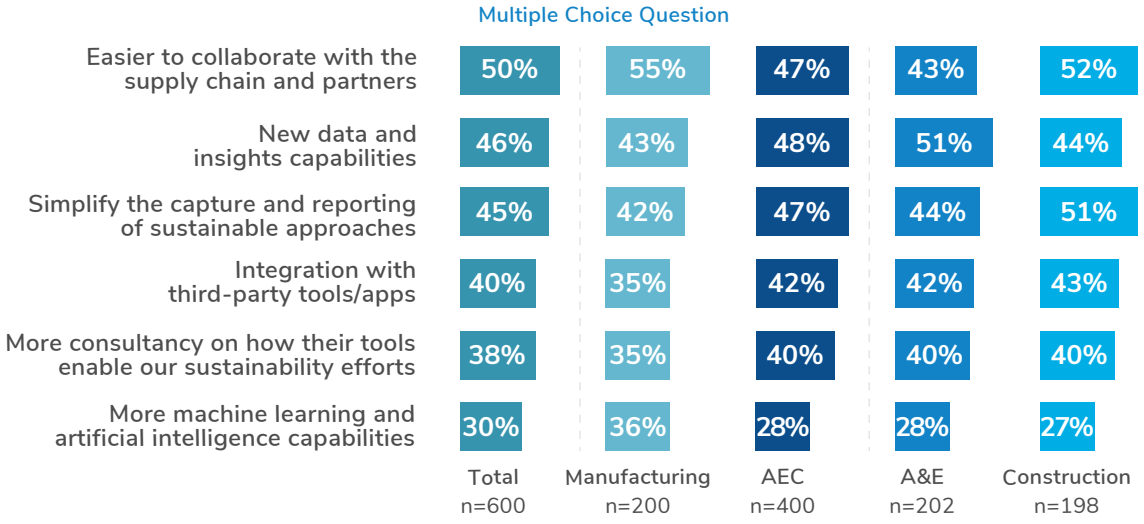
> We already have a CO2 footprint for our products, but there are different countries with different needs. So we as a manufacturer have to look at how can we develop and utilise this data, providing in different levels. We also have to look at what this means for the end user, because we provide enormous amounts of data, and we have to determine what data is really relevant.
>
> - Katrin Discher, Director of Sustainability at TRILUX

Supply Chain Support is the Number One Theme

Supply chain sustainability is particularly high in manufacturing (55%) and construction (52%) due to the relatively large number of suppliers and vendors. This is in contrast to A&E's 43%, which has far fewer suppliers.

However, support via new data insights and capabilities are stronger in A&E given the need to influence the downstream construction segment in terms of material specifications and performance linked to sustainability. Companies in the Nordics have far more advanced internal data intelligence teams. They will not need the same support technology partners and benefits provided by the more established supply chain, logistics and infrastructure service providers.

Chart 13: Areas of Support from Software Providers to Support Sustainability Efforts



Base: All respondents (n=600).
Q11. What would you like to see your software providers do more of in support of your company's sustainability efforts?

Source: Frost & Sullivan

> When you talk about digital sustainability, it's about planning, the supply chain and how you get the material you choose. How you choose the best materials out of millions of products and get them delivered efficiently. We have the tools and they're getting better. It is innovation driven by digital.

- Jarl Cornell, Strategy and Group Development at Assemblin

> If we want to achieve a low carbon building - we need to set the goals quite early on, and have everyone involved. At the moment, setting specific carbon footprint thresholds or limits takes an effort and has to be considered case by case. We need to study the supply chain, and search for the correct level of ambition in the current market situation. We are expecting to be able to lift the threshold for every new project, as low carbon solutions become mainstream.

- Liisa Jäätvuori, Director of Sustainability and New Services at A-insinöörit

> 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

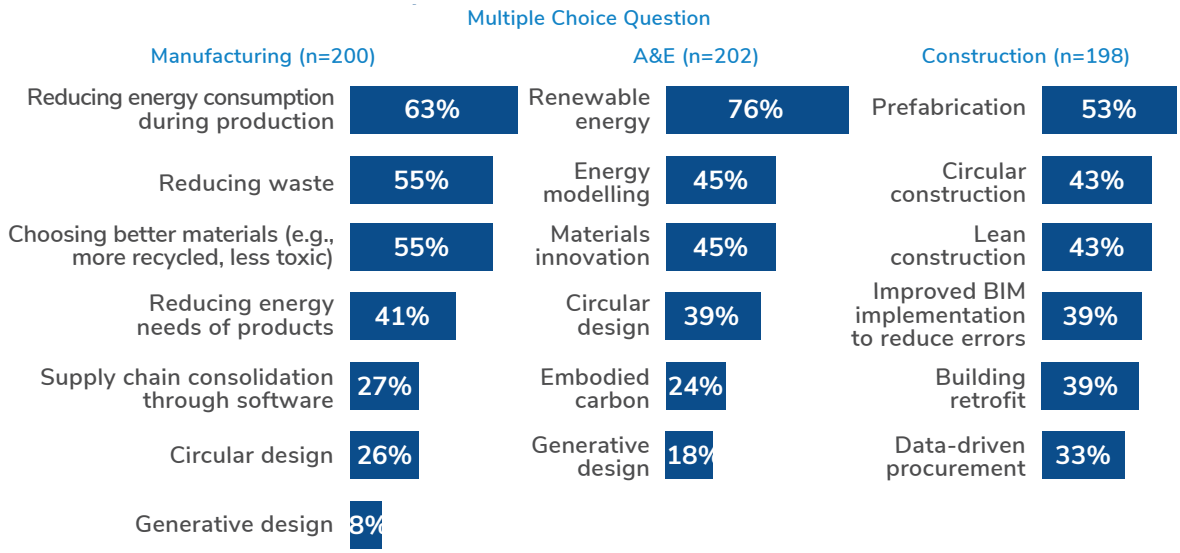
> We use a digital twin for a demolition project and are able to map what we have inside the building. We can identify and track all the reuse and recyclable materials. For digital twin and inventory models, we can bring much more value to the client than its direct value. We can use it in a demolition project for the client to visualise how the building is, take the contractor on a virtual tour, or get some citizens to tour virtually and buy items inside the building. We can make a buy and sell circular economy platform that will have multiple benefits.

- Elli Kinnunen, Technology Manager of Sustainable Building Design at A-Insinöörit

Life Cycle Analysis: Increased Interest in Embodied Carbon Tracking

With an increasing focus on carbon emission reduction and a focus shift from Scope 1 and 2 to Scope 3, there is a strong interest in LCA and LCC products. These products will need to address specific areas of focus in manufacturing; energy efficiency, waste minimisation, alternative materials. In the AEC industries, the focus is on energy modelling, renewable energy and innovative constructions materials. There is a need for LCA methodology standardisation because there are currently many different LCA methods in many countries across Europe with differing impact categories. High costs associated with the LCA development are hindering its deployment in sustainability initiatives.

Chart 14: Industry Trends to Reduce Carbon Emission in Manufacturing, A&E and Construction



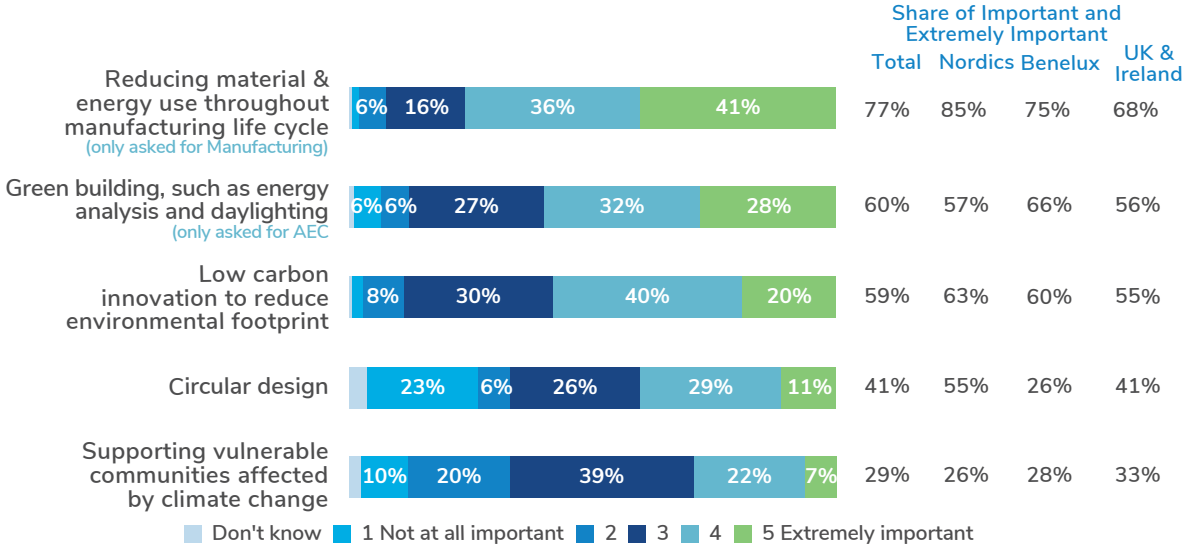
Base: All respondents (n=600).
Q15. / Q16./ Q17. For your industry, which of the following do you think will have the biggest potential to lower carbon emissions?

Source: Frost & Sullivan

Embodied carbon is an important sustainability initiative across regions as highlighted by the need for low carbon solutions and materials to reduce environment footprint. There are many software tools looking to cover embodied carbon; however, the databases that support this software are not fully reliable and require many manual overrides. There is a definite role for BIM to help in supporting the reliable calculations of embodied carbon.

Buildings performance management is an increasing focus of sustainability initiatives linked to energy intensive lighting and HVAC operations, both in AEC and manufacturing. There is a growing role for building energy management systems that are expanding on the sensors and data that monitor, measure, and manage energy efficiency.

Chart 14: Importance of Sustainability Initiatives by Region



Base: All respondents (n=600).
Q13. How important are the following initiatives for your company's main strategic sustainability/environmental impact goals?

Source: Frost & Sullivan

> In terms of software—we are currently developing our own tool for evaluating the environmental LCA of buildings and building elements. It is called VKaLCA and has been approved by BRE for use in the BREEAM evaluation.
>
> - Valerie Vergaert, Principal Sustainable Design at VK Architects & Engineers

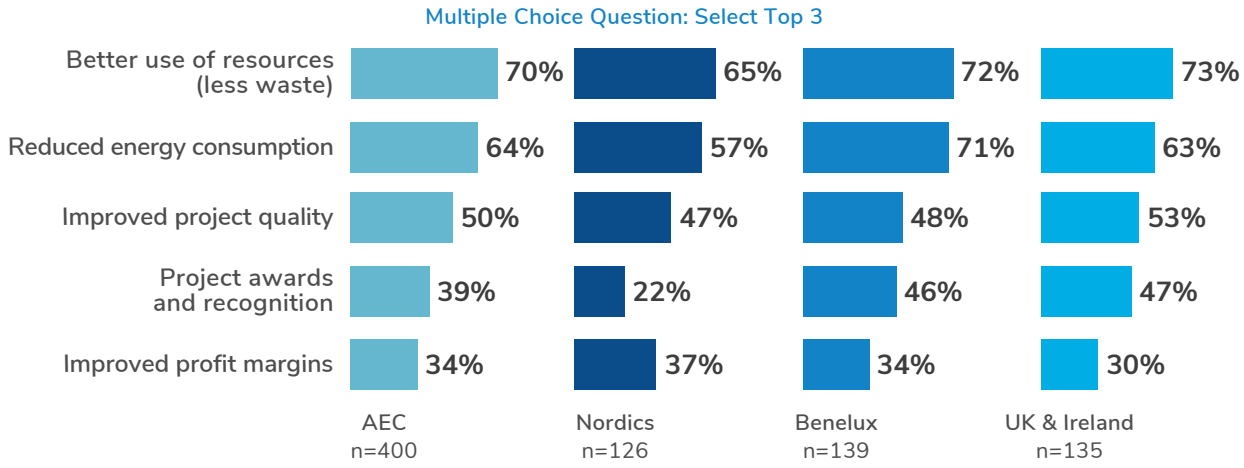
> The real challenge of our project is to develop the goals with respect to life cycle analysis (LCA) or life cost cycle (LCC) and then use these tools to make decisions quite early in the process. We have a group of people, environmental and BIM specialists, focused on addressing this issue by jointly making the calculations and analysis.
>
> - Gudrun Jonsdottir, Team Lead at EFLA Consulting Engineers

> One of our key materials is called HPL (high pressure laminate), which is made from recycled paper—paper pulp in a silicon resin bath. It forms a very hard material. This has a high percentage of already recycled material in it.
>
> - Barry Leahey MBE, CEO and Managing Director at Playdale

Sustainable Use of Materials Emerges as the Strongest Driver in the AEC Industry

In the Nordics, companies are the least likely to engage in sustainability initiatives for awards and recognition. This is a much stronger driver in Benelux and the UK and Ireland. Energy efficiency is a bigger driver in Benelux compared to the Nordics and UK and Ireland. The maturity of the sustainability in the AEC Industry is evident with the improved profit margins compared to the Benelux, and the UK & Ireland.

Chart 15: Biggest Benefits of Sustainability Initiatives in AEC - by Region



Base: AEC companies (n=400).
Q3. What are the biggest benefits to your company as a result of adopting sustainability initiatives for project delivery?

Source: Frost & Sullivan

> We're committed to helping our customers improve their sustainability credentials through the projects we deliver. Circular design is critical to this 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 trust from data in 3D models that the amount of concrete we need is just right – so can limit waste. We hope to continue investing in technologies such as BIM and digital twins to support our customers to meet and raise their own sustainability goals.

- Marius Jablonskis, Technology Manager at Norconsult

> We are looking to offer a more energy-efficient solution and a more water-efficient solution to help our customers be more sustainable. We are working to find new ways of taking care of them and extending our value. Cooling and heating are the key areas of focus.

- Asvor Brynnel, Head of Communications and Sustainability at Assemblin

> Decarbonisation is driving demand for a new generation of advanced materials. Business-led collaborations of scientists, next-generation engineers and universities, combined with research into material engineering and technology automation to develop and promote sustainable materials. There is a great focus on components that respond to environmental changes and undergo material property changes. The drive towards Net Zero Energy Buildings presents opportunities for materials to increase modern building energy efficiency, such as low emissivity glass increasing heating and cooling systems effectiveness. Also, phase change materials capable of storing or releasing energy in the walls, floor, and roof increase the effectiveness of the thermal profile. Engineered timber is one of the most exciting opportunities in the industry right now, as it provides a carbon-negative construction material alternative to traditional steel and concrete. The latter will remain necessary to our industry but must go through radical innovation to decarbonise their processes. Applying engineering technology to timber could help us design light, efficient alternatives for manufacturing structures that sequester carbon and a route to rethinking construction emissions.

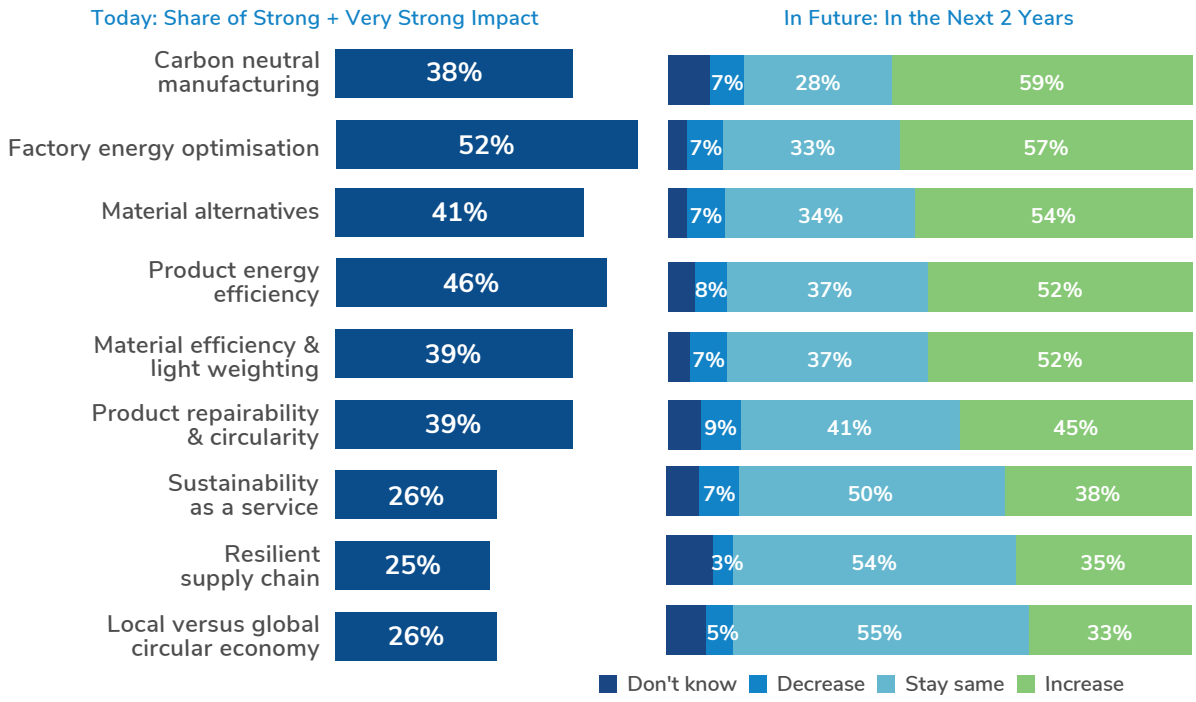
- Nils Rage, Sustainable Design and Innovation Manager at Landsec

Carbon Neutral Will Be a Strong Focus in Manufacturing over the Next Few Decades

The carbon neutral agenda is a key priority for the European manufacturing industry as it builds on the net zero goal of the EU Green Deal and the related national and regional policies. The manufacturing industry's current focus is largely on energy optimisation within factories, product energy efficiency, and material alternatives that deliver added value to customers. Moving forward, there will be an even greater focus on achieving carbon neutral manufacturing. In the automotive industry, Jaguar Land Rover already has a carbon-neutral status for its UK manufacturing plants. Other European automakers have the goal of achieving a similar status in the next 10 years.

Factory design and the growing collaboration between design, build, and manufacturing teams is driving the opportunity for convergence, as they all have the goal of optimising the factory floor in relation to the entire building. Digital twins are set to play a crucial role in optimising and improving energy use and efficiency. Alliander, a leading power network operator in the Netherlands, is well on track to achieving carbon-neutral status by 2023 through a combination of measures, such as improving energy efficiency, leveraging renewable energy, and employing offsetting measures such as purchasing renewable energy certificates from wind farms in the Netherlands.

Chart 16: Sustainability Trends in Manufacturing - Today and Future



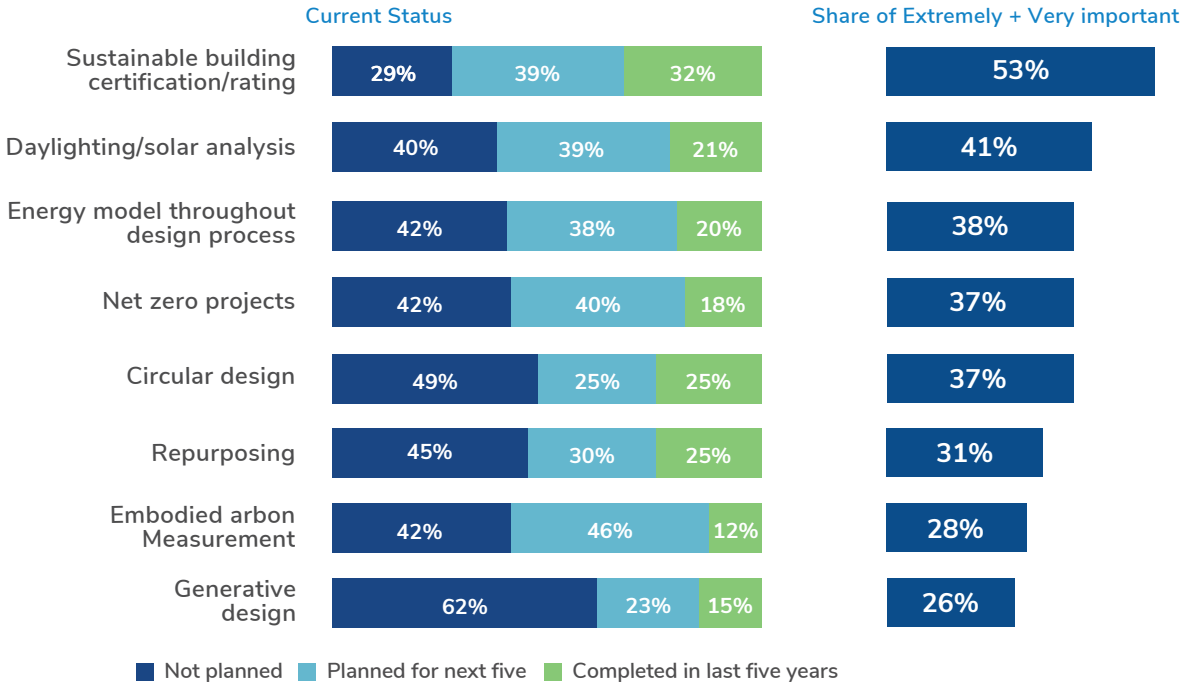
Base: Manufacturing (n=200).
Q22. Looking at current trends in sustainability, how would you rate the impact of the following aspects for your business today and in the next two years.

Source: Frost & Sullivan

Building Certifications are the Strongest Driver for Sustainability in the AEC

Sustainability building certification or rating has emerged as the key driver across the UK & Ireland, Nordics and Benelux. Since early 2010 to 2011, the UK-BREEAM and the US-LEED building rating systems have been popular across the European continent; however, the latter is becoming more popular with US-based companies with European operations and they are driving a strong sustainability agenda. Even in relatively mature regional markets for sustainability such as the Nordics, UK-BREEAM and US-LEED are preferred over some of the national building certifications. There is also interest in building certifications related to health and well-being inside buildings, such as the WELL Building Standard certification.

Chart 17: Sustainability Drivers for Customer Projects in AEC



Base: AEC (n=400).
Q20A. How important are the following aspects for driving your products or customer projects?
Q20B. Have you completed or planned one of the aspects.

Source: Frost & Sullivan

> A lot of our customers want to certify their buildings and as part of that we obviously help them install systems that play an instrumental role for them to get certified.
>
> - Jarl Cornell, Strategy and Group Development at Assemblin

> More increasingly in recent times, we are seeing the social aspect of sustainability- parts of social behaviour have come in - from ergonomics of the building to the WELL standard - day lighting standards, green buildings and bio-philic design.
>
> - Barry McDermott, Group Head for Sustainability at PM Group

> Our industry needs the right frameworks to organise itself around. I'm genuinely excited by the introduction of the NABERS UK scheme that rewards operational energy performance of assets instead of theoretical design. Lessons learnt from overseas (Australia) prove that this can lead to genuine market transformation around energy usage in commercial buildings.
>
> - Nils Rage, Sustainable Design and Innovation Manager at Landsec

> We are ourselves a BREEAM Accredited Professional (AP) and Assessor, and also WELL Accredited Professional. In some projects we apply HQE - which is more current in the French part of Belgium, or LEED – which is requested by international clients. Almost all our office projects in Brussels are BREEAM certified.

- Valerie Vergaert, Principal Sustainable Design at VK Architects & Engineers

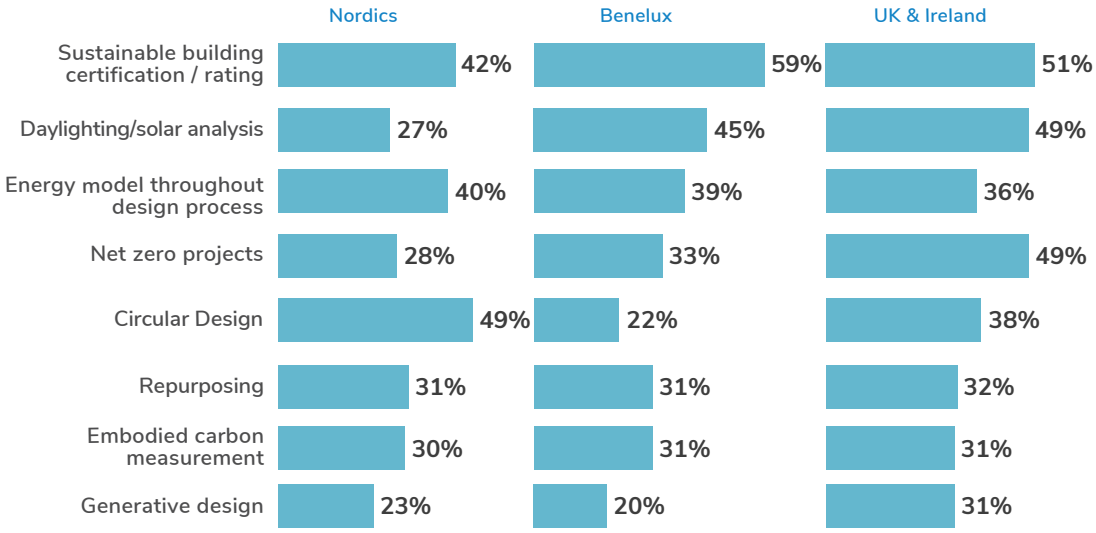
> Large part of our client representation comes from North America- so LEED accreditation is a large area of interest with respect to sustainable building design, particularly among the clients that had a very strong focus on environmental sustainability.

- Barry McDermott, Group Head for Sustainability at PM Group

Certifications and Net Zero Is Strongest in UK with Circular Design Being the Strongest Driver for Customer Projects in the Nordics

In terms of sustainability drivers for customer projects in AEC across the three regions, building certification or rating is much stronger in the Benelux and the UK & Ireland. It is worth noting that net zero projects benefit from sustainability drivers much more in the UK & Ireland. This could be related to the BIM mandate launched in 2012 to 2013, which had an aim to drive carbon reduction in buildings. It could also benefit from the increasing focus on embodied carbon in the UK Green Building Council (UKGBC) net zero carbon guidance.

Chart 18: Sustainability Drivers for Customer Projects by Region



Base: AEC (n=400).
Q20A. How important are the following aspects for driving your products or customer projects?
Q20B. Have you completed or planned one of the aspects?

Source: Frost & Sullivan

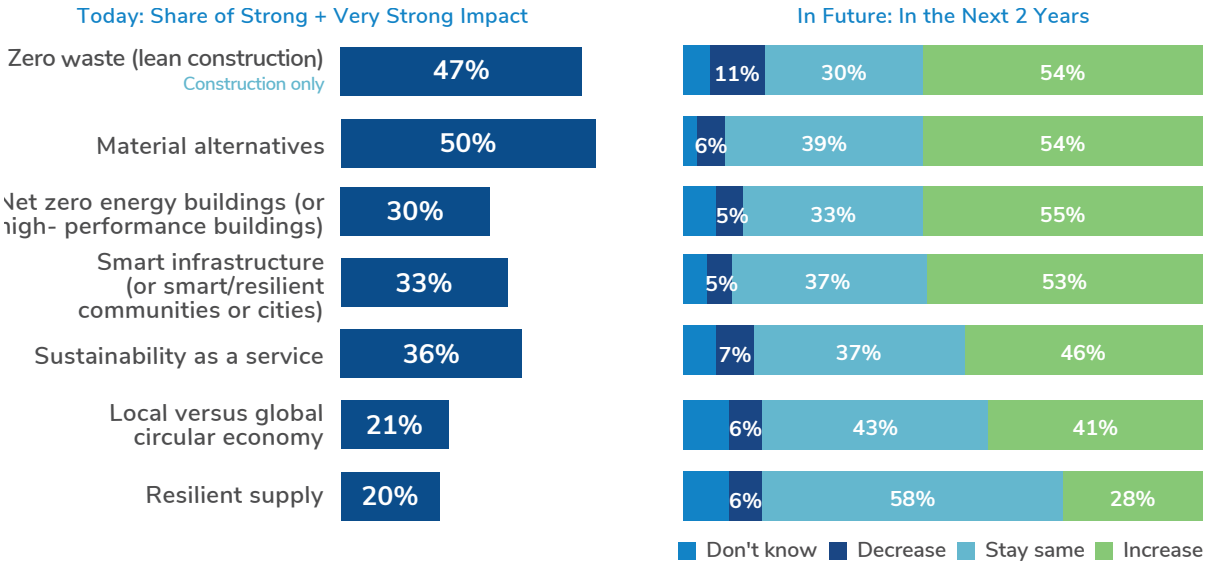
> The UK Green Building Council (UKGBC) net zero carbon guidance encompasses both net zero carbon in operation, and embodied carbon. It's clearly important to be striving for net zero carbon by 2050 or 2030—but we really need to make sure that there is net zero carbon in operation as well.
>
> - Helen Hough, Sustainability Lead at Bryden Wood

> Circularity is emerging as a new way of thinking. Success requires a shift in a 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 at Norconsult

Material Alternatives and Zero Waste (Lean Construction) Is a Key Trend Set to Accelerate in the AEC Sector

The high rating of zero waste (lean construction) is a strong indication of the promising prospects of key technologies, such as robotics, 3D printing, and pre-fab and modular construction. Material intensity of the construction sector presents an important role for technology solutions and services aimed at evaluation and selection of material alternatives. There is a growing importance of a common data environment (CDE) so that teams have access to real-time data for design coordination and review, which streamlines the process and helps drive project efficiency.

Chart 19: Sustainability Trends in AEC - Today and Future



Base: AEC Companies (n=400)
Q22. Looking at current trends in sustainability, how would you rate the impact of the following aspects for your business today and in the next two years?

Source: Frost & Sullivan

> Reducing your embodied carbon, more than operational carbon, is all about lean design. Obviously, the less material we use, the cheaper it becomes for clients, and we have the opportunity to specify more high quality products that get your embodied carbon down. Unless you optimise design and lean design strategy, you're not going to get there.
>
> - Helen Hough, Sustainability Lead at Bryden Wood.

> Material would be the area of focus. We will start seeing governments pushing forward tender guidelines in terms of the sustainability metrics of materials used in the playground industry. There will be greater scrutiny on the constituent materials in a product and the end of life and recyclability.
>
> - Barry Leahey MBE, CEO and Managing Director at Playdale

7. Impact of Covid-19 on Sustainability in AEC and Manufacturing

Covid-19 has laid bare the fragility of an increasingly interconnected global economy. This reality positions digitalisation as a centrepiece of a resilient future. The growth and maturation of digitalisation, driven by the need for economic resilience, will open up latent demand and opportunities in the circular economy. It furthers the ability to identify, track, accelerate, and scale efficiency improvements. These capabilities advance circular economy initiatives by bringing together stakeholders in the value chain and uncovering valuable relationships. It positions digitalisation as a core component for a green recovery and the deployment of innovative solutions to increase productivity and efficiency within the framework of sustainable principles.

> It's very difficult to imagine going back to last February, when I would travel for 45 minutes each way to a meeting. I think we will change permanently the consideration of in-person meetings, which will reduce traveling in the long term. It's quite an investment to actually meet face-to-face, and sometimes – but not always - it serves its purpose.
>
> - Liisa Jäätvuori, Chief Sustainability Officer at A-insinöörit

> When the pandemic struck, I wondered whether sustainability would drop to the bottom of the agenda of decision-makers. Looking back, I can declare that this has not been the case: not only for Landsec but across the industry. The net-zero challenge has settled in and hasn't slowed down this year. If anything, the Covid-19 crisis revealed what happens when we fail to price systemic risk correctly.
>
> - Nils Rage, Sustainable Design and Innovation Manager at Landsec

> The pandemic highlights the role that buildings play on our health and well-being. We can respond to these challenges through design and technology, for example, by introducing contact-less access, monitoring the occupancy density, or controlling the filtration levels in our environment. Technology can help us monitor and manage our buildings and respond to future challenges more accurately.
>
> - Nils Rage, Sustainable Design and Innovation Manager at Landsec

> Our carbon footprint as a business has substantially reduced because so few people are travelling. In 2019, 40% of our carbon footprint was business travel. And in 2020 business travel is 30% of what it was before. So that's really positive because obviously Covid isn't positive and lockdown isn't positive, but the fact that people have learned to adapt and be productive remotely and accept the change very quickly, is a great thing.
>
> - Isabel McAllister, Responsible Business Director at Mace

> Carbon neutral for professional services companies, there's only so much that one can actually reduce; ultimately some offsetting is needed. The vast majority of emissions are associated with scope 3 particularly - business travel. Scope 3 emissions and reducing it is going to mean a significant change in the business model and the culture.
>
> - Barry McDermott, Group Head for Sustainability at PM Group

> What's really interesting is how clients are now changing briefs. They are more interested in looking at how we can adapt buildings for future uses. How do we change offices into residential, or adapt living space to vary working at home and being with families? There's been a lot of change that way and Covid has sped up the whole process. Having adaptable buildings is really important; the idea being that a building will last longer if it's got multiple uses.
>
> - Helen Hough, Sustainability Lead at Bryden Wood

> Covid has impacted in a big way. I think especially the digitisation of the company is getting a real boost and that's something our innovation team has been trying to create in the last few years. This is positive for our company and its sustainability goals.
>
> - Ko Bontje, Manager of the Innovation Department at Stamhuis

8. Technology for Digital Sustainability and The Circular Economy

a. Design for Manufacture and Assembly and Associated Benefits of Embodied Carbon Reduction and The Circular Economy

Design for manufacture and assembly (DfMA) is set to become even more important as companies in the AEC and manufacturing sectors begin to assess their carbon emissions impact from supply chains on the projects and products. There is a growing realisation of design's importance to facilitating carbon reduction and a circular economy of resources. New ways of designing products for manufacture and assembly provides a framework and principles for products to be manufactured in a simpler and cost-effective manner. The manufacturing sector has witnessed tremendous progress with the use of DfMA, especially in industries such as automotive, which has benefited from an increasing role of advanced automation as well as innovative materials. The automotive industry has also realised the cascading impact and benefits from establishing a remanufacturing industry.

In the lighting industry, TRILUX has recently concluded a research project called Repro-light that examined energy efficiency and material efficiency. TRILUX conducted this research about modular luminous solutions and reviewed their material efficiency partly due to legislation and partly due to requests concerning service of a few luminaires. The findings revealed that it is not always the most sustainable solution that is the most sustainable approach. Beginning in 2021, TRILUX is embarking on another research project that looks at sustainable material use in future luminaire design. The focus will begin with the recycling process and the end of life of a product in order to ascertain the value of critical material. Key objectives of the research project are aimed at how to make sure that luminaire are given back into recycling process, which materials can be reused either in lighting industry, and which can be re-purposed in other industries. The research will also look at the product specification given that product design plays a critical role to extending sustainability value to all users.

Construction of infrastructure and buildings is an extremely carbon-intensive process that encompasses the entire supply chain, from the extraction of natural resources to its transportation and manufacturing. In the construction sector, digital tools like BIM are being implemented by companies such as Sweco (especially in large construction projects). DfMA principles are providing promising results in projects such as The Forge, an office building of Landsec, which has been designed by Bryden Wood. The Forge was endorsed by the UKGBC as being the UK's first net zero carbon office building, and a key part of the project was the on-site prototyping and use DfMA processes. This prototyping benefited from Innovate UK funding, and its successful use onsite means that new construction techniques can be tested prior to installation.

> When we do large scale construction projects we place a big emphasis on BIM to ensure we minimise the impact in the process. We also do this to digitise what is in the building, such that years later, it becomes a resource bank so that we might not need to go to Congo for cobalt or to China for earth metals.
>
> - Mattias Goldmann, Head of Sustainability at Sweco

> We are focused on data driven design, where we optimise almost everything in our building. We start with a structural phase and build up the building to compare how much concrete or steel or other material is needed. Then we add information such as CO2 emissions. We can measure things early on, and help the customer make decisions that suit them best. We don't need to optimise only carbon, structures or cost. We can optimise all parameters together. That's very powerful for us and enables a circular economy.
>
> - Elli Kinnunen, Technology Manager of Sustainable building design at A-Insinöörit

> The industry needs investment in more efficient building manufacturing, construction and assembly methods. In 2020, we pioneered a project called The Forge in Southwark, London. This is our approach to platform design to manufacture and assembly – essentially a more standardised, componentised approach to construction. Rethinking construction means moving away from a manual approach to an automated process that leads to higher quality, faster delivery speed and reduced wastage. This modernised construction and design method resulted in a reduction of 20% in embodied carbon when compared to conventional construction methods.
>
> - Nils Rage, Sustainable Design and Innovation Manager at Landsec

> The construction industry is continually innovating to become more sustainable and reach aspirational Net Zero Carbon goals. One such way is introducing sustainability and digitisation themes early on in the design and construction process. Early and effective collaboration here can come in many forms. For us; that's the use of BIM and modelling. The utilisation of BIM allows us to track both the project performance and environmental impacts. Combining technology and sustainability here provides us with the opportunity to present the client with a robust model from which they can appreciate the asset's full life cycle impact and its intricacies. It gives our clients the certainty and ability to fully comprehend the requirements to maintain, deconstruct, and recycle their assets and, therefore, deliver more sustainable results.
>
> - Chris Landsburgh, Environmental and Sustainability Manager at Wills Bros

> Embodied carbon is a good factoring technique and it covers pretty much every discipline. This is why it's so important to the company. We have been looking at concrete – both traditional techniques to reduce embodied carbon and innovative technologies. The materials that go into it are one thing, but you also need to look at where they're sourced and how they get to site. Following the UKGBC net zero carbon guidance, which is net zero carbon in operation and embodied carbon, and as the delivery partner for the Design for Performance initiative, we've already made a commitment to train and support the industry in working to close the performance gap.
>
> - Helen Hough, Sustainability Lead at Bryden Wood

One of the key design challenges related to data centres is that the rapid growth of digitalisation is resulting in an enormous quantity of power and is putting pressure on renewable energy to offset emissions. Amsterdam is the regional hub for data centres in Europe with the Dutch Data Center Association (DDA) reporting annual growth of around 18% to 20% over the last few years. The data centres are getting increasingly larger and one of the latest ones in the Netherlands uses as much as power as the city of Amsterdam (with the country having seven more pending licenses to build). This poses a significant challenge and an interesting opportunity for network grid operators such as Alliander, who have now formed a partner consortium looking to address this as a design challenge. The work packages of this research project include changing architecture, technology roadmap and circular procurement.

> The research project on data centres involves partnering with government, suppliers, software developers, and data centre users to find out whether there is a long-term type of data factory user that uses a small amount of energy. This involves looking at different types of hardware architecture, software architecture, and service designs to significantly reduce the energy needed.
>
> - Pallas Agterberg, Director of Strategy and Innovation at Alliander

> We developed a smart meter that is based on the similar principles of a Fairphone, which is that every device can be taken out for repair, or to be changed, separately. If there's something wrong with the smart meter you don't have to throw away the entire product, and step by step, we're doing this in our entire supply chain. For the building materials we use software to ensure supply chain sustainability.
>
> - Pallas Agterberg, Director of Strategy and Innovation at Alliander

Another interesting use case of design for manufacture and assembly is the Amsterdam Airport Schiphol, which BAM is involved in. Although the aviation sector was severely affected by Covid-19, the airport authority is keen to push ahead with the sustainability agenda and temporarily delayed the project.

> At Amsterdam Airport Schiphol we are building a circular project by reverse designing with reused materials. First, in a circular demolition project we're going to dismantle and really take components apart. Secondly, we are requested to come up with a new design for a building and this will be created in the same geographical area. We're going to make this building from components that become available from the dismantled or demolished project.
>
> - Tom Blankendaal, Project Manager – Circular Economy at Royal BAM Group

Another interesting use case regarding the manufacture and assembly and reduction of embodied carbon is an EU-funded research project that ODICO is working on alongside a German university. This uses machining wax instead of expanded polystyrene (EPS) because it is 100% circular and can be recast, rebuilt, and reused. This is an extremely compelling benefit for ODICO, which is a pioneer in robotics for concrete structures. The use of the machining wax instead of EPS will result in basically zero waste and add to the vision of developing a 100% waste-free concrete production workflow.

> In addition to removing emissions from concrete structures by enabling cost-effective realisation of more efficient designs, we are also removing the emissions that are associated with what we have with formwork manufacturing.
>
> - Asbjørn Søndergaard, Co-founder and CTO at ODICO

c. Robotics and 3D Printing

Cement production and calcination account for 8% of global anthropogenic CO2 emissions, which is about four times that of the aviation industry. Due to the massive consumption of carbon-intensive materials (such as concrete and steel) and its associated high-emission factor, robotics and 3D printing can significantly reduce the construction sector's environmental impact.

> **ODICO is a small company, and that means that the actual footprint of our operations is negligible. Rather, our focus is on how the technologies we develop can have a potentially enormous positive impact in reducing construction's environmental footprint. To achieve this, we are making robots accessible. Factory on the Fly is a robot module in a container and can go to the construction site and the factory. Basically, that means that you can avoid a lot of emissions that are related to logistics because you can bring the factory to the construction site.**
>
> - Asbjørn Søndergaard, Co-founder and CTO at ODICO

Software applications now allow access to design optimisation formulations that predict structural system layouts and present design alternatives to minimise the weight of components in construction structures. As such, robotics and 3D printing, together with the increased use of recyclable materials (e.g. expanded polystyrene and machining wax) offer promising prospects to improve on-site efficiency. They also address health and safety concerns and mitigate environmental issues. Apart from their socio-economic benefits—such as enhancing safety levels by reducing exposure to hazardous substances and addressing the labour shortage in the EU construction market—robotics and drones support the workforce by improving workflows and cutting costs.

> **Robots are developed by engineers and presented to a craftsperson. The education level needed to get the craftsperson to embrace this new technology presents a big gap. We take our Robot At Work platform and we make it work alongside the craftsperson to develop the solution. Every time we make a new solution or discuss a new solution for a task in the building sector, we focus on them. Should the craftsperson be doing less work, or should we increase their paycheck? If we don't succeed in one of those two instances, we have failed. Helping them enables them to stay longer in their job. They can earn more money, and can go home without being tired and steer clear of hazardous work.**
>
> - Finn Kirkegaard Christensen, Founder at Robot at Work

Construction is a labour-driven industry and most employees are trained in manual tasks without robotic programming exposure. However, mobile on-site interventions offer reliable and easy-to-apply construction solutions accessible to all staff members through a tablet or iPad. Concrete often accounts for 80% of construction project costs, and the use of robotics and 3D printing reduces formwork, which can save up to 70% of the concrete used. By integrating robotics, automatic computational techniques, and manufacturing design, advanced technologies and applications remove the risk of moving large objects over unprotected spaces, reduce the excessive consumption of timber and carbon-intensive materials, and address the high-risk and labour-intensive dimensions of on-site construction.

ODICO is a pioneer in the field of robotics for concrete and several successful projects worldwide in seven countries, including the UK, the United Arab Emirates, Norway, and Australia.

> We introduced drones on the safety side some time ago to do checks that would be unsafe for a human being to do. One of our 12 fatality prevention standards is about working in confined spaces – so now we can fly a drone into a confined space to see what is going on rather than risking the safety of a colleague.
>
> - Annie Heaton, Head of Sustainability Engagement and Disclosure at ArcelorMittal

> We optimise and make the craftsperson hands more productive on-site or in the prefab factory. When we look 5 to 10 years into the future, Robot at Work will offer many different solutions and help reduce the 40% lack of labour in Europe to 20%.
>
> - Finn Kirkegaard Christensen, Founder at Robot at Work

> By replacing manually produced timber formwork with robotically manufactured EPS formwork, we are achieving significant reductions of the production C02 footprint. Unlike timber formwork, which is dense and typically incinerated after use, EPS requires much less energy to produce and can be recycled directly.

- Asbjørn Søndergaard, Co-Founder and CTO at ODICO

> In some cases, a building's quality is low because it was built by unskilled artisans. Our robot solution will be able to assist companies in producing high-quality concrete structures.

- Finn Kirkegaard Christensen, Founder at Robot at Work

> Digital technology will massively improve industrial processes. You can see this happening already in safety, where you've got drones being used to do dangerous monitoring tasks. And AI technology could be applied to air emissions. For example, in Spain, we have air quality detectors around a plant to monitor ambient emissions, and we have cameras. You can use camera intelligence to capture, analyse, and even predict what is going to happen in terms of air emissions.

- Annie Heaton, Head of Sustainability Engagement and Disclosure at ArcelorMittal

d. Track & Trace and Material Passport

Focus is increasing on supply chain sustainability as companies are stepping up from measuring and off-setting their Scope 1 and Scope 2 carbon emissions to Scope 3, which covers the emissions from the upstream and downstream of the supply chain. This presents complex challenges in terms of number of suppliers and materials, as well as the key challenge associated with data and transparency to verify and validate critical aspects of the supply chain. Going forward, there will be an increasing role for digital solutions, such as track-and-trace and material passport, as cities, nations, and the European regions push the agenda of a circular economy.

In Sweden, research and development projects involving various stakeholders in the construction sector are aimed at tracking the information from the source to the building, and then developing standards, frameworks, and protocols. This will have a significant impact and help drive sustainability and circular economy agendas with respect to construction projects.

> **Track-and-trace solutions will be key to solving the sort of material banks of the future and to get to the circular economy. We suggest product owners demand it and make sure there is such a process. For instance, one of our customers that we are proud of mentioning is Northvolt, which wants want to be the world's first battery manufacturer using exclusively existing batteries. The way it embrace sustainability really helps us understand the track-and-trace components here. I believe this is going to be a key component to increased competitiveness in the future—having your track-and-trace better than your competitors.**
>
> - Mattias Goldmann, Head of Sustainability at Sweco

The Dutch government aims to be 100% circular by 2050 and has an interim 2030 target to be 50% circular. From 2023 onwards, based on a framework being developed, construction companies and industries from other sectors will need to align with solutions to fulfil circular economy objectives. Within this initiative, material passports are being defined regarding what they should look like and minimum requirements. Material passports help with mapping of materials in the building—quantity and material types—which will assist during building demolition because information will be known about what materials can be retrieved. The concept of material passports was conceived in 2016-2017 and introduced by Madaster, leading to the digital material database passport.

Alliander, a grid operator in the Netherlands, trialled a track-and-trace project of the copper it consumes and disposes of to ensure the same is being kept in a circular loop. When the project was up and running, high quality track-and-trace data was obtained; however, the signal disappeared. Consequently, Alliander worked with other grid operators in the region that also used copper and created a procurement framework, leading to strengthened demand for a circular approach.

> We started several circular-related purchasing initiatives—like our own workwear and copper.
>
> - Pallas Agterberg, Director of Strategy and Innovation at Alliander

> We are also working on material passports for BAM's construction projects. And that's a strong collaboration with the digital team, the BIM modellers and engineers looking to convert BIM models into material passports.
>
> - Tom Blankendaal, Project Manager – Circular Economy at Royal BAM Group

> We recently completed a pilot project with environmental management platform Q-Flow. The objective was to move away from laborious, time-consuming on-site manual data gathering to digitise the record-keeping of any material entering or leaving the site, speeding up the process and removing the risk of human error. Their technology applies artificial intelligence capabilities to picture processing, thereby automating the data acquisition procedure.
>
> - Nils Rage, Sustainable Design and Innovation Manager at Landsec

e. Safety, Good Health, and Wellbeing

SDG3 on good health and well-being has emerged as an important part of the sustainability strategies of companies in AEC and manufacturing across the UK & Ireland, Nordics and Benelux. This applies to safety in the workplace, a key priority, especially in critical sectors such as construction and manufacturing, and also the health and well-being of office employees and remote workers. Some surveys have indicated that working from home has reduced time taken off for short-term illnesses, but there has been an increase in leave for long-term illness. It could be a bit early to directly link this to the pandemic, but it could be an important aspect to look at in the new normal of remote working. Companies are also looking to drive good health and well-being in construction, with a focus on air quality and lighting. The role of digital solutions is increasing, ranging from sensors to drones. A shift in design and manufacturing from mitigation to adaptation is needed as the world deals with systemic change from increased natural disasters and Covid-19.

> We launched our new strategic plan for the next five years—Route 25. In Route 25, the focus is clearly on well-being. This includes a focus on well-being in our projects, but also well-being of the employees.
>
> - Valerie Vergaert, Principal for Sustainable Design at VK Architects & Engineers

> Together with our financial objectives, we also have the business-supporting objectives, which include science-based target and zero harm. Zero harm is to ensure that everybody that works for Bonava, either as an employee or a subcontractor, actually can come home in the evening to the family without getting hurt.
>
> - Patrik Lindvall, Head of Innovation and Digitalisation at Bonava

> Digital technology can give us more information than we had before. For example, for a long time we've been using thermal imaging to look for signs of wear and tear in the lining of a blast furnace, so we can predict the maintenance that will be needed. Together with big data, AI and robotics, the benefits to industry will be huge in terms of time, energy and material efficiency.
>
> - Annie Heaton, Head of Sustainability Engagement and Disclosure at ArcelorMittal

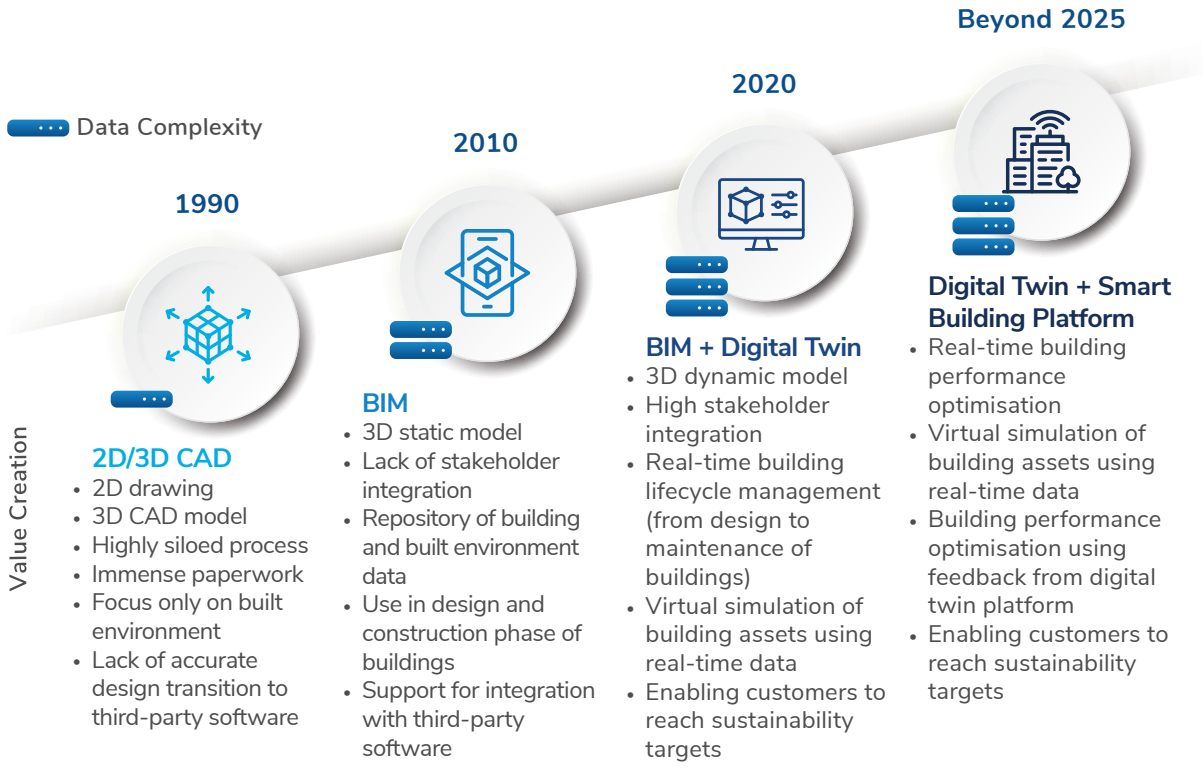
> We do a lot on stakeholder engagement through digital in the different parts of the world where we operate. Mobile phones are becoming an increasingly important tool in this. For example, in Brazil our stakeholders can use an app to see what is going on at the steel plant today, and communicate with its managers quickly and effectively if they have an idea, or want to raise a concern. Some of our sites conduct pulse surveys – where you take the pulse of your local stakeholders every month. It's a very simple three minute survey to check how people are feeling – very valuable to track the changing sentiments within local communities, so that we can respond effectively.
>
> - Annie Heaton, Head of Sustainability Engagement and Disclosure at ArcelorMittal

f. BIM and Digital Twin

The adoption and implementation of BIM and digital twin in the construction and manufacturing industry is advancing rapidly; however, the pace of adoption varies significantly across Europe. Twelve European countries have some kind of BIM mandate or active BIM programmes in place to support BIM implementation in public sector projects. The European Commission-funded EU BIM Task Group brings together national BIM standards and efforts into a common approach to enable digitilisation in the construction industry. Twenty one countries were part of the task group to support BIM adoption in European public sector projects.

Net zero building construction is gaining importance due to the critical contribution in tackling climate change. The evolution of BIM extending to the digital twin solutions enables sustainable construction by incorporating economic efficiency, energy and resource efficiency, and environmental performance in different stages of construction. The key role of the solutions is monitoring, measuring, and managing the processes and operations, in terms of architectural and energy performance, with the ultimate goal of optimising energy consumption.

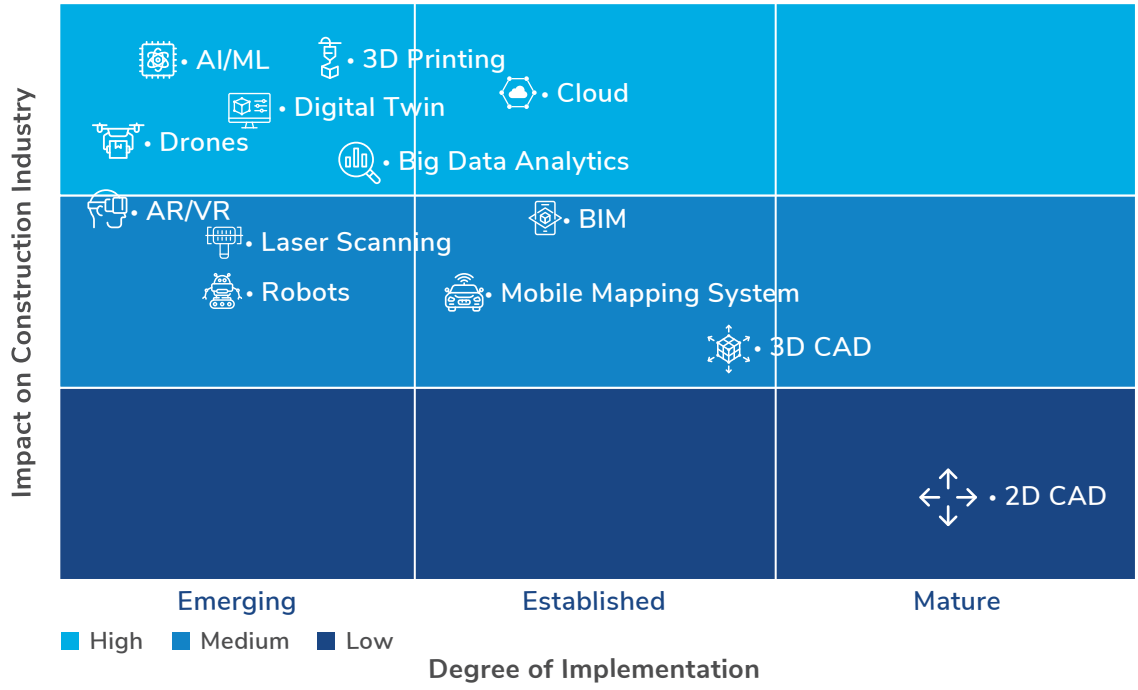
Figure 7: Evolution of BIM and Digital Market in the Construction Industry, Global, 1990-2025



Source: Frost & Sullivan

Local BIM standards are deeply rooted in individual countries, but the need for development of data interoperability is critical for data sharing for customers working with different BIM vendors. This development will happen in the near future and will allow open BIM software at both regional and global scales. In the manufacturing industry—from the construction of the entire building/factory that the equipment operates in to the design of products—if the whole process is connected, digital twins can drive resource optimisation to reduce waste and improve efficiency and energy usage. Furthermore, it could adapt to future requirements including the installation of new machinery and support for the selection of alternate and sustainable materials and feedstocks to manufacture goods.

Figure 8: Impact of Technologies in the BIM and Digital Twin



Source: Frost & Sullivan

> We invest in different tools to implement the sustainable perspective in all our projects. We have different kinds of BIM technologies, digital twins, and other technologies. Digital twins enable the use of AI in the building process. We try to see what kind of technology can be used to make the process more efficient, and, at the same time, more sustainable.
>
> - Per Lofgren, Head of Sustainability at Tyrens

> I'm a firm believer that BIM is the key enabler for us to be successful when it comes to reaching our targets, similar to the UK BIM mandate that came out in 2012-2013 that the UK saw as a way to reach some of the carbon reduction. If we don't achieve our vision with the digital twin, I am afraid that we will not achieve any of the other goals that we have later on. For our Lighthouse projects, we've had a good digital twin for the last couple of years—in those, all see the benefits—with BIM, seeing is believing for a lot of people. It simplifies reporting, and it will greatly simplify or even automate the production of the EPD moving forward.

- Patrik Lindvall, Head of Innovation and Digitalisation at Bonava

> We are using a BIM because we build so many projects for the same customers - we have all the elements standardised, coded and built in 3D. With those 3D elements we create our BIM. The coded elements connect to our workflows outside the BIM.

- Ko Bontje, Manager of the Innovation Department at Stamhuis

> Moving from BIM towards Digital Twin has a significant impact even in simple but important aspects such as awareness. For example, we have incorporated costs into our digital models making our engineers aware of financial consequences that design changes have. Whenever a part is modified, costs are being updated on the fly, and results of such changes can be explored in a granular manner or in totality. This has allowed us to increase the awareness and mitigate the potential risks. The same is applicable when focusing on design optimization and material choice influences on key metrics of CO2 emissions. This information will increase awareness internally, as well as at the customer end, enabling more informed and sustainable decision making.

- Marius Jablonskis, Technology Manager at Norconsult

9. Conclusion

This research has provided an opportunity to complement some of the quantitative results of a survey with 600 respondents, alongside 24 discussions with leaders for sustainability, digital, and innovation across a spectrum of industries. The coverage has spanned discussions with start-ups, SME's and larger companies working in the two segments of AEC and manufacturing. The overwhelming consensus is that there has been a reset and calibration of risks and resilience, as well as an even greater realisation and urgency for action on climate and broader aspects of sustainability by leveraging the framework of the SDGs. Given the interconnected nature of industries and society on finite resources of water, energy, and material resources, the increasingly connected world does provide the digital infrastructure to map, monitor, measure, understand, and better manage assets, facilities, and resources in a closed loop of a circular economy business model.

Evolving from the dynamic BIM process to digital twins—digital reflections of physical entities—will help designers, manufacturers and builders to predict, and support with informed decisions based on real-world conditions through sensor data and intelligent models. The operational and behavioural awareness of digital twins will help businesses achieve better outcomes for people throughout the lifecycles of products, buildings, and infrastructure. In the era of convergence, supply chains will be shorter and more resilient through collaboration between AEC and manufacturing companies and their suppliers.

Some of the key trends we are set to witness in digital sustainability in the coming years are:

a. CO2 and climate change will certainly continue to be important—with the focus shifting to mitigation and adaptation.

b. Circularity—reduced use of scarce resources and an increased focus on design for reuse instead of single use (digitalisation has a key role). Design thinking from the start, with a shift in focus on material use from what needs to be built to the most efficient use of resources in a circular economy.

c. Machine learning and AI that are more accessible and available will help in extracting and delivering value on sustainability.

d. Systems thinking of connecting the different dots and looking at it from a different perspective in totality, which will help in reaching new levels of sustainability.

e. Pre-fabrication will also become mainstream. In the past, it was used for standardised institutional use or spaces with limited footprint, but this can go mainstream, delivering the numerous benefits of off-site construction and reducing the requirement of on-site team members.

f. Building automation and control systems - understanding the interaction of the different systems operating in a building and having the right knowledge to make informed decisions. This links to elements such as pressure, heating, air quality, both inside and outside a building or manufacturing plant.

g. Supply chain sustainability and associated focus on embodied carbon is also set to witness a digital sustainability push to address key bottlenecks of measurements associated with Scope 3 emissions. The need to access data will drive open protocols and greater transparency from the producers.

h. Big Data management could also be an important area given the volume of information. Associated sustainability challenges will increase a focus on deriving value from the data available.

i. Digital technology will drive tangible efficiency improvements in manufacturing and AEC with greater integration of design, process and operational workflows.

About Autodesk

Autodesk makes software for people who make things. If you've ever driven a high-performance car, admired a towering skyscraper, used a smartphone, or watched a great film, chances are you've experienced what millions of Autodesk customers are doing with our software. Autodesk gives you the power to make anything. For more information visit autodesk.com.

FROST & SULLIVAN

Frost & Sullivan, the Growth Partnership Company, works in collaboration with clients to leverage visionary innovation that addresses the global challenges and related growth opportunities that will make or break today's market participants. For more than 50 years, we have been developing growth strategies for the Global 1000, emerging businesses, the public sector and the investment community. Is your organisation prepared for the next profound wave of industry convergence, disruptive technologies, increasing competitive intensity, Mega Trends, breakthrough best practices, changing customer dynamics and emerging economies?