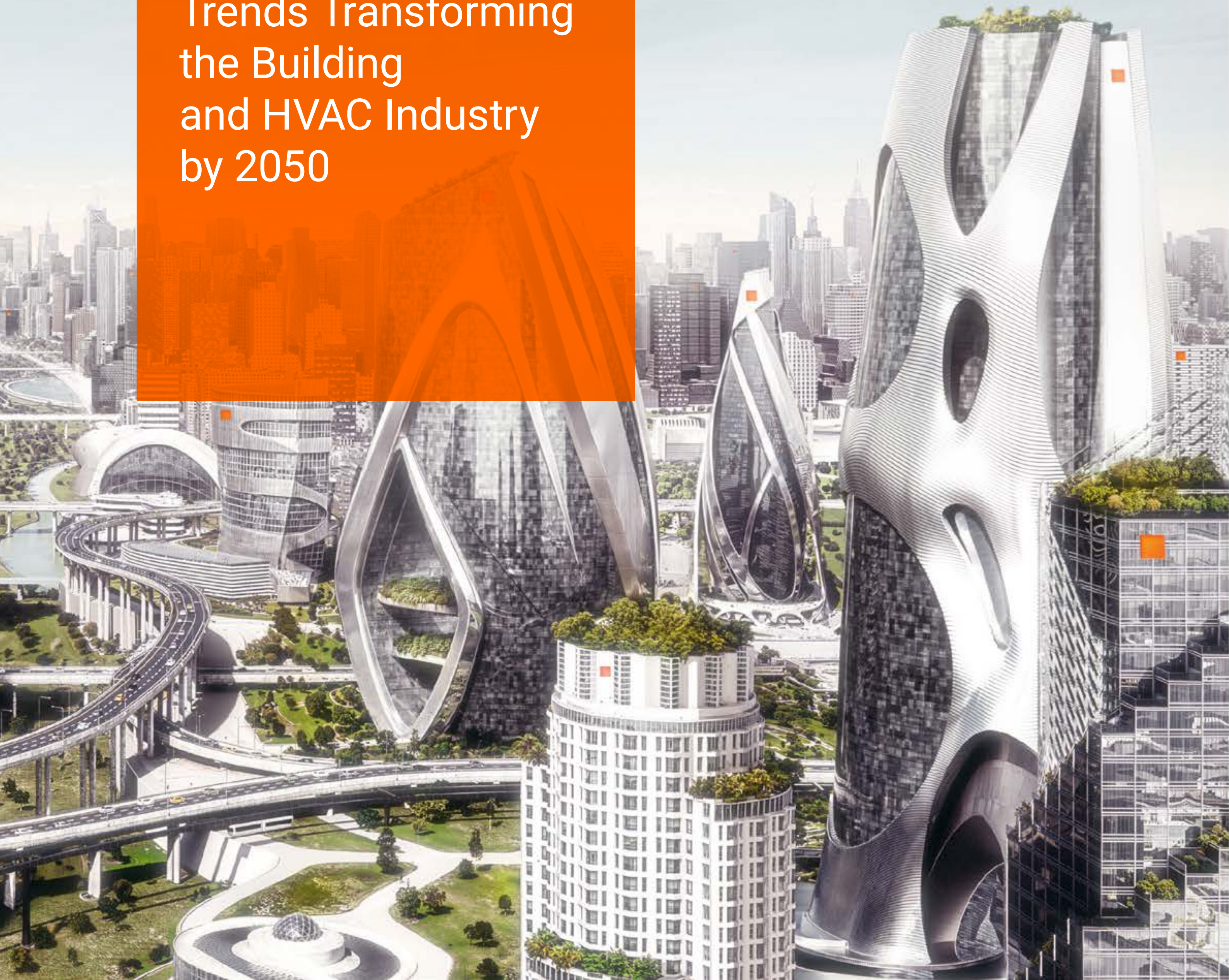
Building Tomorrow

Trends Transforming the Building and HVAC Industry by 2050



Dear Reader,

As we celebrate Belimo's 50th anniversary, we reflect on our journey of innovation while also looking to the future and exploring the opportunities and challenges that lie ahead. With this glimpse into the future, we present a vision highlighting the transformative trends set to redefine the building, heating, ventilations and air conditioning (HVAC), and building automation and control system industry (BACS) industry over the next quarter-century.

This industry vision targets a diverse audience. It provides Belimo employees with a unified perspective — a north star — to guide our innovation journey. For industry stakeholders, it offers insights to drive progress and support the creation of sustainable, resilient, and intelligent buildings. Additionally, it serves as a resource for anyone interested in understanding the evolving landscape of the building and HVAC industry.

It is a combination of secondary research and insights gathered from a global workshop series. We invited industry experts in Germany, the US, China, and India to share their views on what will transform the building, HVAC, and BACS industry going forward. By adopting a broader scope beyond BACS, we aimed to consider the wider context that will drive our business. The result is a unique and comprehensive summary of trends shaping our industry.

At Belimo, we believe in the power of collaboration and the value of shared knowledge. This goes beyond the company boundaries. By openly addressing the challenges and opportunities ahead, we intend to inspire innovation, strengthen partnerships, and contribute to a future where buildings are more comfortable, energy efficient, healthier, and aligned with global sustainability goals. We invite you to delve into this content, reflect on the insights, and join us in building tomorrow.

Sincerely,

Patrick Burkhalter
Chair of the Board of Directors

Lars van der Haegen
Chief Executive Officer

Contents

Overview of the Methodology and Resulting Building and HVAC Trends

Trends are patterns or movements that indicate the direction in which industries, markets, or behaviors are evolving over time. They represent environmental, economic, societal, and technological changes, offering valuable insights into emerging opportunities and challenges. Understanding trends is essential for industries as they shape customer expectations, competitive dynamics, and regulatory landscapes. By identifying and analyzing trends, businesses can anticipate changes, innovate effectively, and stay relevant in a rapidly evolving world.

This document explores the key trends influencing the buildings and HVAC industries and their implications for the HVAC Building Automation and Control Systems (BACS) industry. Our approach began with identifying megatrends — large-scale transformative forces. From these megatrends, we derived specific building and HVAC trends that reflect developments in the built environment. For each building and HVAC trend, we have outlined corresponding implications for the HVAC BACS industry.

The megatrends shaping the building and HVAC industries include global warming, green technology, changing demographics, urbanization, health and well-being, safety, individualization, the rise of China and India, talent scarcity, artificial intelligence, digitalization and connectivity, and cybersecurity. For each trend, we have outlined the corresponding implications for the HVAC BACS industry.

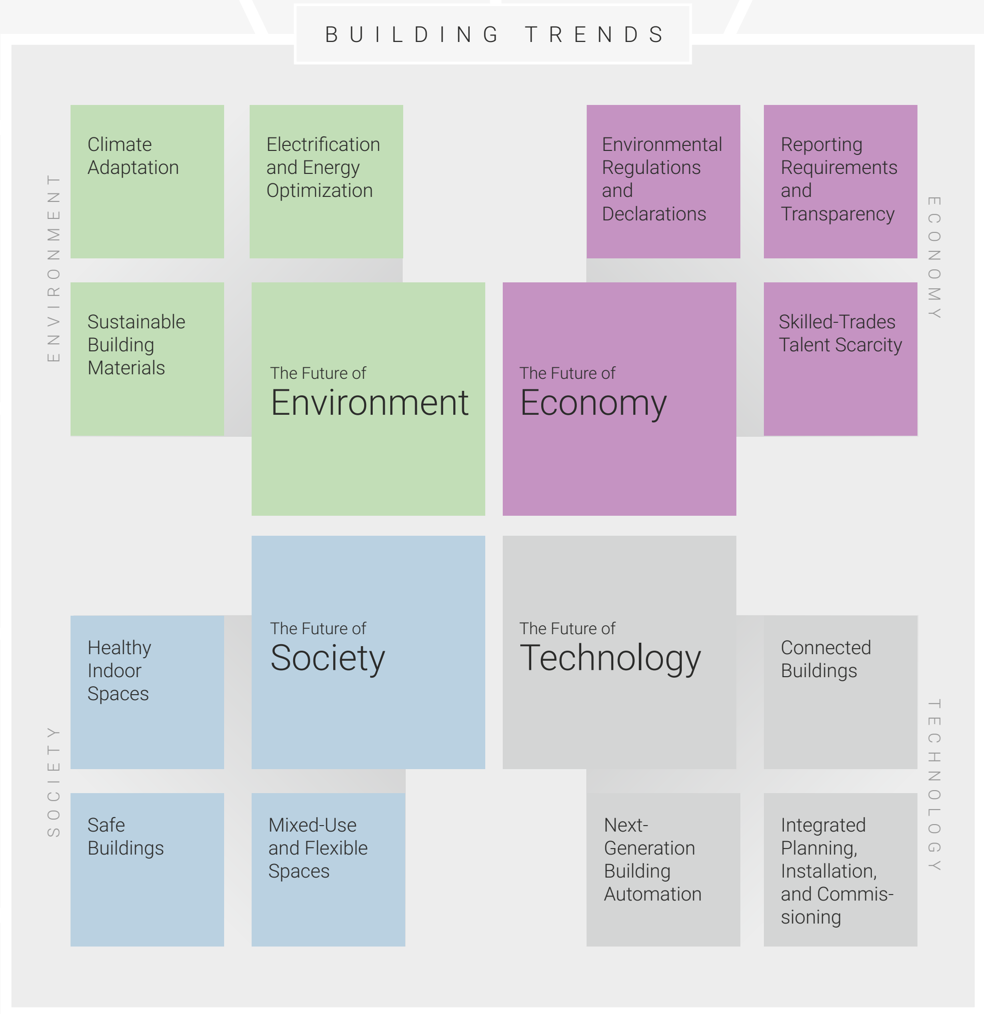
The trends are categorized into four thematic sectors:

The Future of Environment highlights the relationship between buildings and the planet, emphasizing how environmental changes and sustainability shape the future.

The Future of Economy examines how economic shifts, regulations, and resource dynamics impact the building industry and its stakeholders.

The Future of Society addresses evolving human needs and expectations, focusing on building design and functionality.

The Future of Technology summarizes trends that explore the transformative effects of technological advancements on buildings and their operation.


BUILDING TRENDS
ENVIRONMENT
Climate Adaptation
Electrification and Energy Optimization
Sustainable Building Materials
The Future of Environment
ECONOMY
Environmental Regulations and Declarations
Reporting Requirements and Transparency
Skilled-Trades Talent Scarcity
The Future of Economy
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The Future of Society
Healthy Indoor Spaces
Safe Buildings
Mixed-Use and Flexible Spaces
TECHNOLOGY
The Future of Technology
Connected Buildings
Next-Generation Building Automation
Integrated Planning, Installation, and Commis-sioning

The Future of Environment

Climate Adaptation: Rising temperatures will drive the need for buildings to protect occupants better, influencing design, material selection, and cooling systems.

Electrification and Energy Optimization: Achieving net-zero will require reducing building energy intensity by optimizing how thermal energy is generated, recovered, stored, and consumed.

Sustainable Building Materials: To cut embodied emissions, the industry will reduce material use, shift to bio-based materials, and improve conventional building materials.

The Future of Economy

Environmental Regulations and Declarations: Regulations will tighten, demanding a reduction of operating emissions and, increasingly, embodied emissions.

Reporting Requirements and Transparency: The need for more accurate ESG reporting will demand more granular and reliable reporting of energy flows in buildings.

Skilled-Trades Talent Scarcity: To address the widening skilled-trades talent gap, the construction and HVAC industry will invest in attracting talent and enabling unskilled labor.

The Future of Society

Safe Buildings: Enhanced safety measures will become vital to address the risks of extreme weather events, urban densification, cyber threats, and new technologies.

Healthy Indoor Spaces: Growing awareness of the upsides of healthy indoor spaces will shape building designs to focus on thermal comfort, air quality, acoustic comfort, and optimal lighting.

Mixed-Use and Flexible Spaces: The shift to multipurpose, adaptable buildings will accelerate, allowing spaces to evolve more quickly to meet changing needs.

The Future of Technology

Connected Buildings: IP-based communication protocols, semantic domain models, and secure over-the-network updates will help to overcome some of today's challenges of connected buildings.

Integrated Planning, Installation, and Commissioning: Planning, installation, and commissioning of buildings and building automation devices will become more integrated.

Next-Generation Building Automation: Next-generation building automation will combine deeper integration with decentralized intelligence, flatter architectures, and AI-driven capabilities.

The Future of Environment

The Future of Environment highlights the relationship between buildings and the planet, emphasizing how environmental changes and sustainability shape the future.

Climate Adaptation

Rising temperatures will drive the need for buildings to protect occupants better, influencing design, material selection, and cooling systems.

Electrification and Energy Optimization

Achieving net-zero will require reducing building energy intensity by optimizing how thermal energy is generated, recovered, stored, and consumed.

Sustainable Building Materials

To cut embodied emissions, the industry will reduce material use, shift to bio-based materials, and improve conventional building materials.

The Future of Environment

Climate Adaptation

As temperatures rise, buildings will face increasing pressure to fulfill their core purpose: protecting occupants from extreme outdoor conditions. This change will impact the design of buildings and their surroundings, influence material selection for building envelopes, and increase the adoption of cooling systems.

Regional Relevance

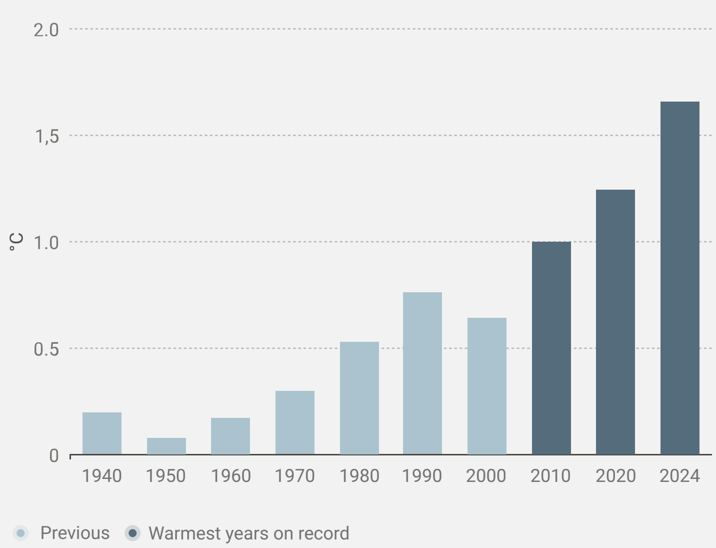
EMEA | Americas | China | India

The Heat Crisis: Action Needed to Protect Lives, Cities, and Economies

In 2024, the global average temperature surpassed 1.5 °C [2.7 °F] above pre-industrial levels for the first time, marking the hottest year on record and continuing a troubling trend in which 24 of the warmest years have all occurred since 2000 (1). This pattern is expected to accelerate, with the global average temperature expected to rise by 2°C [3.6°F] or more until 2050, if all current policies are implemented (2). According to the International Energy Agency (IEA), every 1°C [1.8 °F] rise in global temperatures results in a 25% increase in global cooling degree days (CDDs). CDDs are a measure of how much and for how long the outside temperature exceeds a specific baseline, typically 18°C [64.4 °F], implying a significantly higher need for cooling going forward.

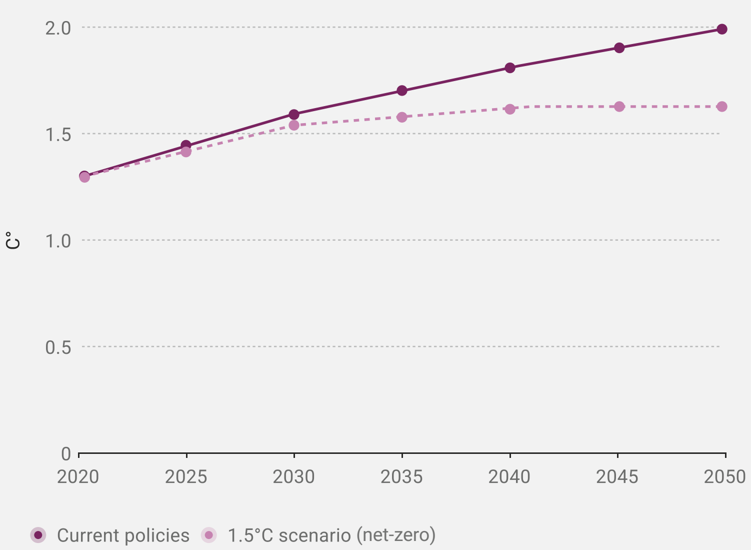
By 2050, nearly 1,000 cities are expected to face average summer highs of 35°C [95 °F] or more, up from 354 cities today, putting 1.6 billion urban residents at risk of extreme heat — an 800% increase (3). This escalating heat will disrupt ecosystems, strain healthcare systems, and impose severe burdens on global economies. Heat stress is projected to reduce global working hours by 2.2% by 2030, equivalent to the loss of 80 million full-time jobs (4). At present, heat-related fatalities account for nearly half a million deaths annually, a figure that is likely to rise further due to aging populations and rapid urbanization (5). For example, cities like Delhi and Karachi are experiencing an increased frequency of deadly heatwaves that claim thousands of lives and disproportionately affect vulnerable populations, including the elderly (6).

Global Temperatures Above Pre-Industrial Levels



2024 marked the hottest year on record in a troubling trend in which 24 of the 25 warmest years have all occurred since 2000

Forecast: Global Temperatures Above Pre-Industrial Levels



Global average temperature is expected to rise by 2°C until 2050 if all current policies are implemented

Buildings and HVAC Design in a Hotter World

In a world that is becoming increasingly hot, buildings will play a pivotal role in protecting public health and sustaining productivity. Architectural designs, material choices for building envelopes, and the adoption of efficient cooling systems will become critical.

To reduce solar heat gain, future designs will integrate features like porticos, trellises, awnings, louvers, and blinds. Strategic building orientation and vegetative solutions, such as green roofs and living walls, will enhance insulation and minimize heat absorption. Landscaping with deciduous trees and urban greening will improve airflow, provide seasonal shading, and lower ambient temperatures by several degrees. However, balancing aesthetic appeal with energy efficiency remains a challenge. Visual considerations should no longer overshadow practical features like shading structures [7].

Building envelope materials will also play an increasingly vital role. High thermal mass materials, such as stone and earth, which are commonly used in traditional buildings in the Mediterranean and North African regions, naturally regulate indoor temperatures and reduce reliance on mechanical cooling [7]. Innovative materials like vacuum insulation panels, silica aerogel, and advanced coatings with reflective properties are pushing the boundaries of efficiency. These technologies enable thinner insulation with up to five times the effectiveness of traditional materials.

Despite the likely adoption of these passive cooling measures, the demand for active cooling systems capable of adapting to extreme weather conditions is yet to surge worldwide, driven by both emerging and developed economies. In emerging economies, rising incomes and improved access to electricity will accelerate the adoption of air conditioning. In developed economies — often located in more temperate regions — rising temperatures and the adoption of heat pumps, which can provide cooling when operated in reverse, will increase electric demand. Consequently, cooling is becoming the fastest-growing energy use in buildings. According to the IEA, global energy demand for space cooling is expected to more than triple by 2050, consuming as much electricity as China and India use today combined [7]. This surge in demand underscores the urgent need for smart cooling strategies, such as building night cooling and energy-efficient cooling solutions.

Implication 1 for HVAC BACS Industry

Integration with Other BACS Verticals

To optimize occupant comfort while minimizing energy consumption, seamless integration of active cooling systems (e.g., chillers), passive cooling systems (e.g., awnings, louvers, and blinds), and other building automation verticals (e.g., lighting) within building automation and control systems will become critical.

Implication 2 for HVAC BACS Industry

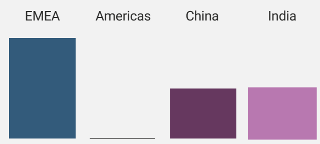
Higher Field Device Uptime Requirements

As climate adaptation transforms HVAC systems from comfort-enhancing features to essential public health infrastructure, maintaining uptime will become paramount. Continuous monitoring, condition-based maintenance, and hot-swap technologies will be vital for reliable performance in critical applications.

Electrification and Energy Optimization

About one-fourth of global CO_2 emissions stem from building operations. Achieving net-zero by 2050 requires further decarbonizing fuels used by buildings and reducing energy intensity through optimization of how thermal energy is generated, recovered, stored, and consumed.

Regional Relevance

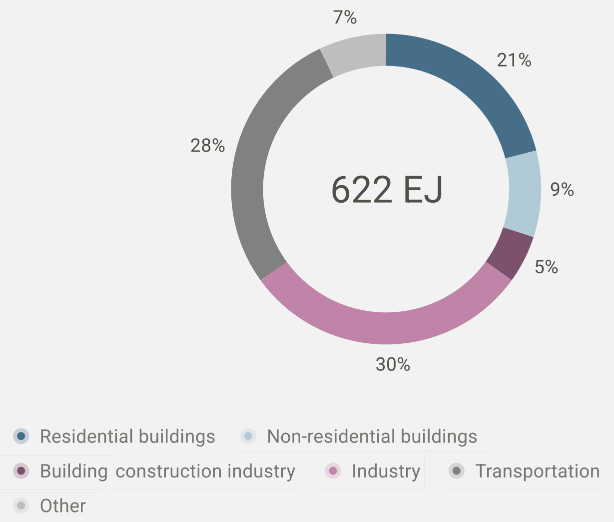


Operational Emissions: A Major Contributor to Global CO_2 Emissions

The building industry is one of the largest global energy consumers, as buildings' operations account for 30% of final energy consumption. About 40% of this energy is used for heating, ventilation, and air conditioning, with the remainder used for lighting, equipment, elevators and escalators, and more. In 2022, buildings' operations comprised 27% of global CO_2 emissions, 9.8 Gt CO_2 (8). To sequester that much CO_2 emissions, we would need a forest roughly the size of China.

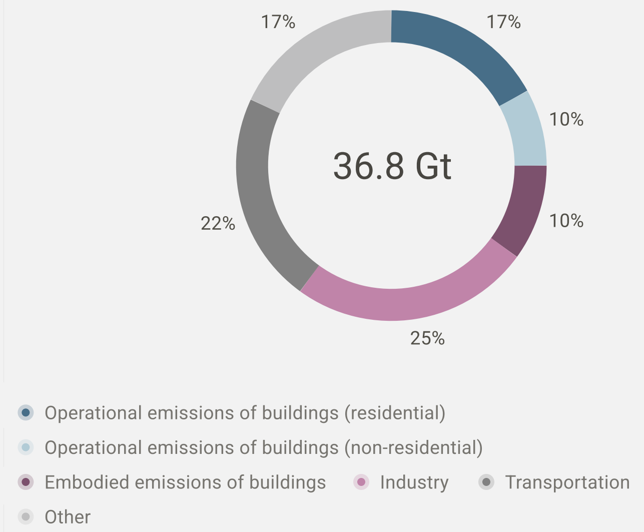
The good news is that buildings are shifting to renewables and electricity as an energy source, enabling long-term carbon elimination if power generation is fully decarbonized. The bad news is that, in absolute terms, the use of fossil fuels in buildings has increased at an average annual growth rate of 0.5% since 2010 (8). The primary driver behind this growth is an increase in global floor area, which has grown faster than the energy intensity (the energy consumed per floor area) has declined. Another driver is the increased use of space cooling. Energy consumption for space cooling has more than tripled since 1990. There is also a multiplier effect as more than half of floor space additions until 2030 will occur in areas with high needs for space cooling. This trend is going to continue. By 2030, global floor area is expected to increase by around 15%, equivalent to the entire built floor area of North America today (9). To align with the net-zero scenario from the International Energy Agency (IEA), fuels used by buildings must be further decarbonized and energy intensity reduced.

Breakdown of Global Final Energy Consumption, 2022



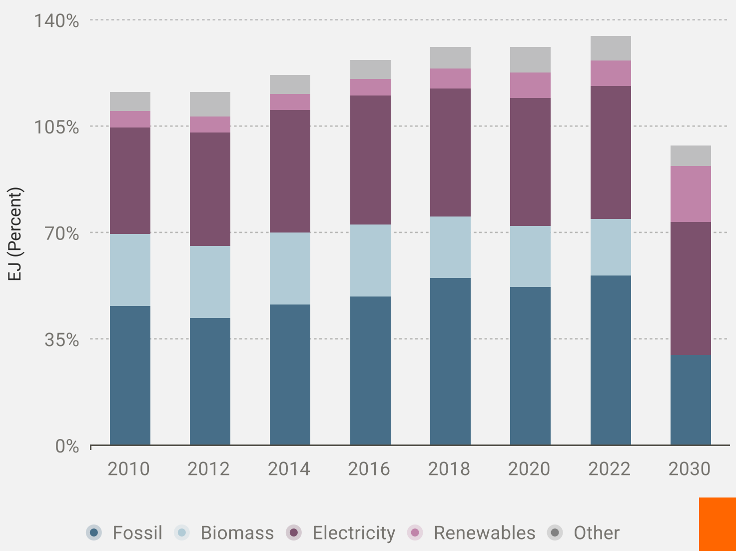
The operation of buildings consumes about 30 % of global final energy consumption

Breakdown of Global CO_2 Emissions, 2022



The operation of buildings causes 27 % of global CO_2 emission, or 9.8 Gt of CO_2

Energy Consumption of Buildings by Fuel Type

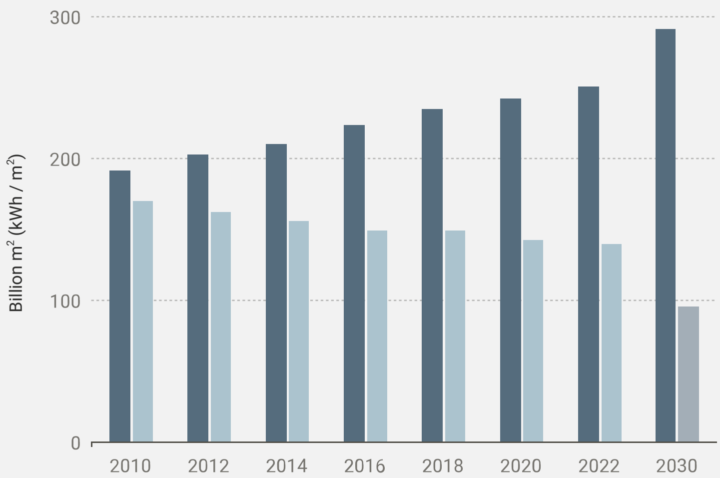


Increased use of fossil fuels since 2010

↗ +0.5%/year

To align with the IEA's net-zero scenario, building fuels must be decarbonized further

Global Floor Area and Energy Intensity



Global floor area / 2022–2030

↗ +15%

Energy intensity / 2022–2030

↘ -31%

To align with the IEA's net-zero scenario, energy intensity — the energy consumed per floor area — must be further reduced to offset floor area growth

Decarbonizing Building Fuels and Reducing Energy Intensity

Decarbonizing building fuels and reducing the energy intensity will require optimizing thermal energy generation in buildings: recovery, storage, and consumption.

Optimizing thermal energy generation for heating means transitioning from fossil-fueled systems to heat pumps powered by renewable electricity. According to the IEA, tripling the global heat pump stock by 2030 could reduce CO_2 emissions by 500 Mt annually (10). However, most heat pumps nowadays use hydrofluorocarbon refrigerants with high global warming potential (GWP). Without intervention, the 2030 heat pump stock could emit 740 Mt of CO_2 equivalent (10). Solutions include transitioning to hydrofluorocarbons with lower GWP, hydrocarbons, or other natural refrigerants. Hydrofluorocarbons, though, require further research in the field of toxicity and atmospheric decomposition, and hydrocarbons need additional safety precautions for flammability. For cooling, demand is projected to more than triple by 2050 due to climate adaptation (7). Mitigating the associated increase in energy intensity will require improving the efficiency of cooling systems and greater adoption of passive cooling solutions. In addition, on-site photovoltaic electricity and storage can help to decarbonize increased energy intensity due to cooling.

Another way to decarbonize buildings' fuel mix is by recovering and redistributing waste heat. Increasingly, excess heat from municipal waste plants, data centers, metro tunnels, industrial sites, electrolyzers, or nuclear power plants will be captured and redistributed through district heating networks. Enabled by the adoption of heat pump technology, anergy networks are also expected to gain momentum. Anergy networks transfer thermal energy between buildings at ambient temperatures (10-25°C [50-77°F]), reducing heat losses.

Heat pumps and waste heat usage will also drive stronger adoption of thermal storage units (or thermal batteries), serving as an efficient way to balance energy supply and demand. Heat pumps can convert surplus electricity from renewable sources like wind or solar photovoltaics into thermal energy when electrical power is abundant, and electricity prices are low (10). And waste heat from industrial processes or data centers can be stored for later consumption, preventing the energy from dissipating unused into the environment. Thermal energy storage is also highly efficient, achieving 90-98% efficiency for multi-day storage and 70-80% for seasonal storage.

However, one of the most efficient and cost-effective ways to reduce the energy intensity of buildings is through the broader application of building automation and control systems (BACS). That especially applies to the building stock, the majority of which needs upgrading. For instance, in the EU, 97% of the buildings are considered energy inefficient (12). ISO 52120-1 highlights that upgrading from standard BACS (class C) to high-energy performance BACS (class A) can achieve energy savings of up to 40%. These retrofits often require minimal changes, such as adding dynamic hydronic balancing valves, variable water-flow systems, demand-controlled airflow, or modulating room controls with occupancy detection. Given its high impact and low cost, the adoption of advanced BACS is expected to accelerate, particularly as the current retrofit rate of 1.0% per year falls short of the 2.5% required to achieve net-zero by 2050 (13).

Implication 1 for HVAC BACS Industry

Design for Retrofit

The global building stock is largely established, with only a small number of new buildings added each year. Upgrading existing buildings with state-of-the-art BACS will require components designed for easy retrofitting, along with tools and solutions that simplify the replacement process, such as factory-built, customized drop-in replacements.

Implication 2 for HVAC BACS Industry

Thermal Storage and Load Control

BACS will play an increasing role in thermal storage and load management, controlling the charging and discharging of thermal storage systems based on real-time demand, demand forecasts, weather forecasts, and energy prices (demand response).

Implication 3 for HVAC BACS Industry

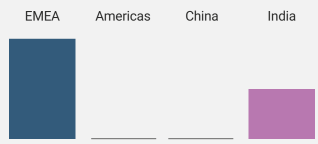
District Energy Control

The scope of BACS will extend beyond managing energy flows within buildings to regulating bidirectional energy flows between district energy networks and buildings, necessitating seamless integration with the district energy network's control system.

Sustainable Building Materials

Almost 10% of CO_2 emitted globally stems from building construction, maintenance, renovation, and deconstruction. Achieving net-zero requires cutting not only operational but also embodied emissions by using less new or reused material, shifting to bio-based materials, and improving conventional building materials.

Regional Relevance



Embodied Emissions: A Growing Challenge for Building Decarbonization

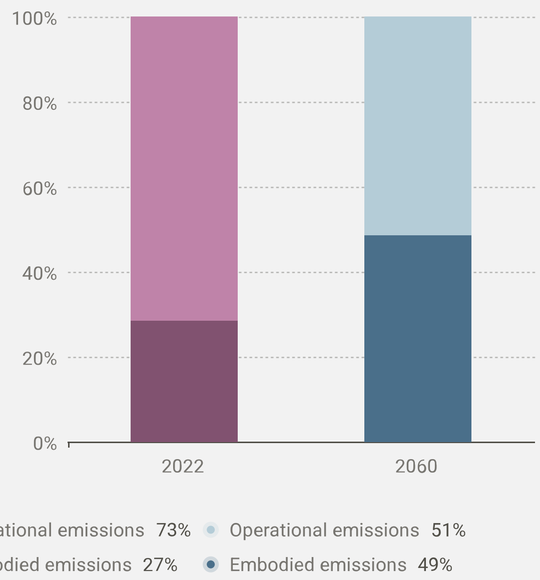
Operational energy use in buildings accounts for approximately 30% of global energy consumption, increasing to 34% when including the energy used for producing cement, concrete, steel, and aluminum for construction (8). The CO_2 emissions associated with the entire lifecycle of these materials — from production to construction to usage to end of use — are called "embodied emissions." In 2022, these embodied emissions represented 6.8% of global CO_2 emissions (8). This figure is raised to 10% when including the emissions from the production of bricks, glass, and copper (14).

The share of embodied emissions is expected to rise significantly going forward. The Global Alliance for Buildings and Construction (GlobalABC) projects that global raw material consumption will nearly double by 2060 under a "business-as-usual" scenario, with one-third of this growth driven by the construction sector (14). In this scenario, the share of embodied CO_2 emissions in total building emissions will almost double between today and 2060 (14). The construction industry thus risks becoming locked into a high-carbon development trajectory.

The Pressure to Reduce Embodied Emissions

Rapid reductions in embodied emissions are essential to limit global warming to below 1.5°C [2.7°F]. GlobalABC suggests three key approaches: avoiding waste and building with less

Share of Embodied Emissions on CO_2 Emissions of Buildings



The share of embodied emissions on buildings' emissions is expected to almost double by 2060

new material, reuse of construction elements, shifting to bio-based building materials, and improving design for disassembly for conventional building materials and processes.

Avoiding waste and building with less new material means transitioning to a circular economy. The most significant opportunity for this lies in the planning and design stage. By integrating circular design strategies early in the construction process, embodied emissions can be reduced by 10–50%. Another lever is to design buildings for flexible use, allowing a building's lifespan to be extended.

Shifting to earth- or bio-based building materials is another approach that offers significant potential for decarbonization. For instance, using bio-based options like timber, bamboo, hemp, and straw can reduce emissions by up to 40% compared to conventional materials, provided these resources are harvested and processed sustainably.

Despite these new approaches, there is also the need to improve conventional building materials and processes. For cement and concrete, reducing clinker content, electrifying production, and using alternative binders can reduce emissions by up to 25%. Recycling steel reduces 60–80% of energy consumption and associated emissions. However, the growing gap between scrap supply and demand ensures that primary steel production will remain necessary. By transitioning to direct reduced iron technology and electric arc furnaces powered by renewables, emissions from primary steel production can be reduced by up to 97%. Decarbonizing aluminum production depends on renewable-powered production and increased recycling, potentially reducing energy use and associated emissions by 70–90%. Glass production can be decarbonized through electrified production and stricter recycling policies. Plastic decarbonization requires improved recycling methods and the development of bio-based and biodegradable plastics [15].

Achieving all of this will require greater coordination between producers and consumers, including manufacturers, architects, developers, communities, and occupants. Strong policy support, regulations, and incentives across all stages of the material lifecycle, from production to end-of-use, are hence essential.

Implication 1 for HVAC BACS Industry

Device Longevity

Extending the lifespan of HVAC BACS devices reduces the need for replacements, minimizing the environmental impact. Longer-lasting devices lower waste and hence contribute to sustainability goals.

Implication 2 for HVAC BACS Industry

Eco-Friendly Materials

Eco-friendly materials will become standard in HVAC BACS devices and packaging. Examples include recycled or bio-based plastics for device housing, lead-free brass for valves, and low-impact manufacturing processes.

The Future of Economy

The Future of Economy examines how economic shifts, regulations, and resource dynamics impact the building industry and its stakeholders.

Environmental Regulations and Declarations

Regulations will tighten, demanding a reduction of operating emissions and, increasingly, embodied emissions.

Reporting Requirements and Transparency

The need for more accurate ESG reporting will demand more granular and reliable reporting of energy flows in buildings.

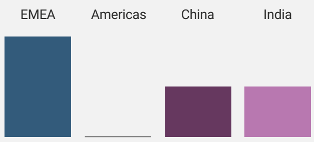
Skilled-Trades Talent Scarcity

To address the widening skilled-trades talent gap, the construction and HVAC industry will invest in attract-ing talent and enabling unskilled labor.

Environmental Regulations and Declarations

Governments are shifting from voluntary commitments under the Paris Agreement to binding energy codes targeting building CO_2 emissions. While building codes to reduce operational emissions will tighten globally, regulations will also expand to address embodied carbon to provide transparent lifecycle data on construction materials.

Regional Relevance



Energy Codes and Building Emissions: From Paris Agreement to Action

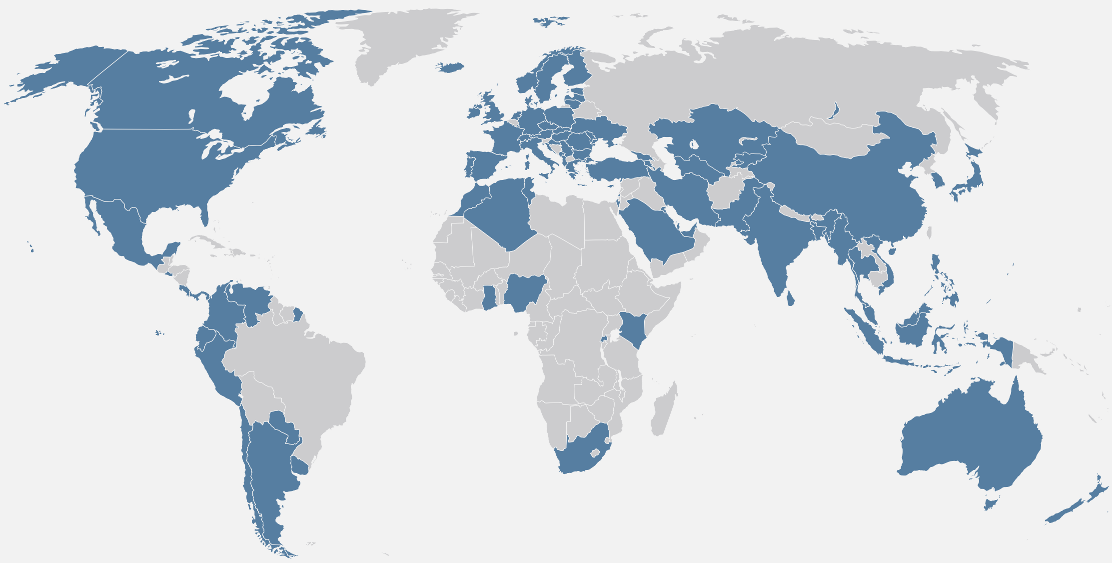
A total of 191 nations, almost all sovereign states, and the European Union have ratified the Paris Agreement, committing to limit global temperature rise to well below 2.0°C [3.6 °F], with efforts to cap it at 1.5°C [2.7 °F] above pre-industrial levels (16). As buildings are major contributors to global CO_2 emissions, governments are moving beyond non-binding framework legislations or recommendations to binding directives, adopted codes, and regulations, making CO_2 reduction in buildings mandatory rather than optional.

The EU's Energy Performance of Buildings Directive (EPBD) sets minimum energy performance standards to achieve a highly efficient, decarbonized building stock by 2050. European countries implement the EPBD by developing and enforcing national regulations. For example, Germany implemented the EPBD through its Gebäudeenergiegesetz (GEG), or Building Energy Act, which encompasses various measures, including a requirement for non-residential buildings with heating and cooling capacities over 290 kW [82.5 tons or 98`9520 BTU/h] to install building automation systems (17). As of 2030, that capacity limited will be loweres to 70 kW. In some US cities like New York, strict energy codes, such as the Local Law 97, set emissions limits, with penalties starting in 2024. For example, the owner of a 9,000 m² [100,000 sq ft] building, who takes minimal action to reduce emissions, could face fines of up to USD 1 million (18). China's "dual carbon" goal of peaking emissions by 2030 and achieving carbon neutrality by 2060 led to the 2022 General Code for Building Energy Conservation and

Renewable Energy Utilization, China's first mandatory regulation for building emissions [19; 20]. India's Energy Conservation Sustainable Building Code (ECSBC) introduced energy performance standards for commercial buildings, with several states making it legally binding [21; 22]. Often, these actions are also supported by financial incentives for building owners.

However, as of 2024, only 88 countries have adopted building energy codes in at least one city. 55% of these codes have remained unchanged since 2015, potentially failing to meet modern high-performance standards [23].

Countries with Binding Energy Codes or Standards



Tightening Regulations for Buildings

With increasing pressure to meet decarbonization goals, more countries are expected to move from non-binding framework legislations or recommendations to binding regulations to reduce CO_2 emissions. While many regulations focus on reducing operational emissions, embodied carbon is also increasingly under legislative scrutiny, creating the need to document products' embodied emissions. Environmental Product Declarations (EPDs) could serve this purpose. EPDs are standardized, independently verified documents that provide transparent, quantifiable data about a product's environmental impact throughout its life cycle, including, but not limited to, carbon emissions.

As of early 2024, over 120,000 EPDs [24] for construction products exist globally, with widespread development across Europe, the Americas, Asia, Latin America, and the Middle East [22]. Although EPDs are currently mostly voluntary, manufacturers use them to demonstrate carbon transparency, support green claims, and market their products as sustainable. Additionally, many green building certifications, such as LEED, BREEAM, DGNB, and the Living Building Challenge, award credits for using materials covered by an EPD [25]. These certifications add significant value, with green buildings in some Asian cities commanding rental premiums of up to 28% [26].

Regulations, however, are tightening. In France and Germany, companies must have an EPD for any construction product with environmental claims. Norway requires at least ten products with EPDs for large public projects, and Italy mandates a minimum percentage of recycled content in public buildings. Similarly, Denmark, Finland, and Sweden require assessments of embodied carbon in buildings, with EPDs serving as evidence for compliance [22].

Starting in 2028, the Energy Performance of Buildings Directive (EPBD) will require all large buildings over 1,000 m² [10,000 sq ft] in EU member states to be assessed for embodied carbon, extending this mandate to all new buildings by 2030. These upcoming requirements are expected to significantly increase demand for EPD data, solidifying their role in sustainable construction practices [27; 28].

Implication 1 for HVAC BACS Industry

Energy-Efficient HVAC BACS Devices

As transparency of the environmental impact of HVAC BACS devices grows, attention shifts to their energy efficiency. Low power consumption during operation and standby in relation to the energy savings unlocked by HVAC BACS devices will become increasingly critical.

Implication 2 for HVAC BACS Industry

Environmental Product Declarations (EPDs)

The rise of EPDs means that HVAC BACS device manufacturers must provide verified data on the environmental impacts of their products' life cycles. This ensures compliance with regulations targeting embodied carbon but also boosts marketability.

Reporting Requirements and Transparency

The complex landscape of sustainability reporting poses harmonization challenges, but ESG reporting drives efficiency, reduces risks, and meets growing investor and customer expectations. Reliable aggregation of granular data will be key for reporting compliance and resource optimization.

Regional Relevance

EMEA Americas China India

Adapting to Accountability

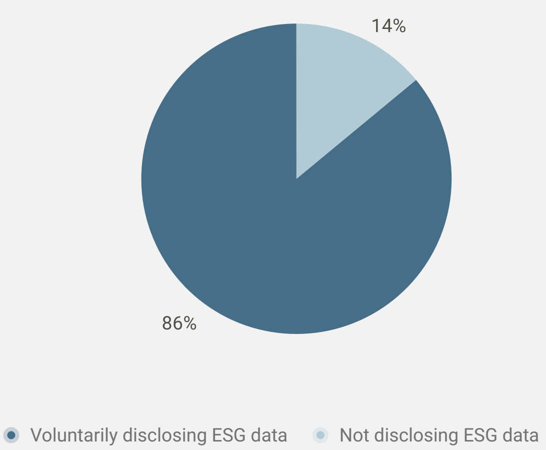
Sustainability reporting means disclosing how a company integrates environmental, social, and governance (ESG) factors and what it does to improve them. Globally, almost 20 organizations pursuing diverse objectives are involved in defining sustainability reporting standards, including non-profits, business consortiums, and the United Nations programs [(29)].

This heterogeneity makes the harmonization of reporting standards a daunting challenge. For instance, companies that fall within the scope of the EU Corporate Sustainability Reporting Directive (CSRD) are required to report according to the European Sustainability Reporting Standards (ESRS), which differ from the most widely used standards issued by the Global Reporting Initiative (GRI). At the same time, companies must also comply with the EU Taxonomy Regulation, which emphasizes environmentally sustainable business activities, and the Corporate Sustainability Due Diligence Directive (CSDDD), which focuses on human rights and environmental due diligence [(30)].

Although complying with diverse ESG requirements can be complex and costly, comprehensive ESG reporting offers benefits that extend beyond regulatory compliance. Enhanced ESG transparency often drives action by enabling companies to identify inefficiencies, reduce costs, and achieve substantial financial gains. A McKinsey & Company study found that executing ESG effectively can impact operating profits by up to 60%, for example, through reduced energy consumption or lower water intake [(31)].

Investors in the US and Europe also increasingly prioritize ESG factors as a strategy to mitigate risk and portfolio volatility [32]. Environmental metrics often receive significant attention, particularly voluntary commitments to the Science Based Target initiative (SBTi), to which many leading companies subscribe. However, social factors like indoor air quality, thermal comfort, lighting, and noise levels are equally important. These elements directly impact occupant health and well-being, reducing long-term risks, preventing disease, and increasing productivity. With 86% of S&P 500 companies now voluntarily disclosing ESG data, transparency has become a standard expectation, reinforcing trust among investors and customers [33].

Share of S&P 500 Companies Voluntarily Disclosing ESG Data

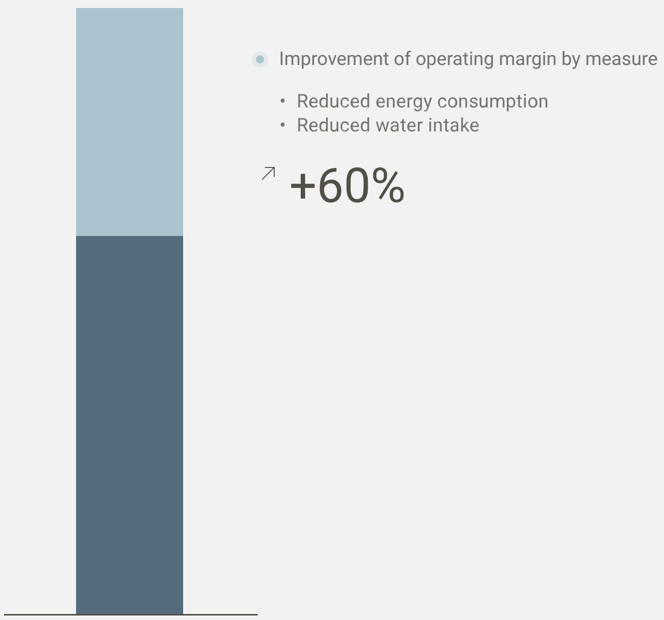


Investors in the US and Europe also increasingly prioritize ESG factors as a strategy to mitigate risks and portfolio volatility

Transparency as a Lever for Sustainability

Reliable, high-quality data is fundamental to meaningful ESG reporting. However, many buildings face challenges in obtaining and integrating this data. Critical metrics are often fragmented across systems, delivered in incompatible formats, or consolidated manually using basic spreadsheets, which impedes a clear understanding of operations. To overcome these hurdles, companies increasingly adopt centralized reporting platforms and real-time monitoring systems, capturing and managing data across real estate portfolios for decision-making and public reporting.

Accurate data collection at granular levels enables better insights into building operations and resource optimization. For example, Germany's "Heizkostenverordnung," or Heating Costs Ordinance, mandates the detailed measurement and allocation of heating and hot water costs, Impact of Executing ESG Strategies Effecitvely on Operating Profits



Despite its complexity and cost, environmental, social, and governance (ESG) reporting also offers financial benefits through transparency

requiring property owners to install devices that track individual energy consumption and provide monthly usage transparency. Such regulations underscore the importance of data in driving sustainability and efficiency. Similarly, monitoring and reporting are integral to some green building certifications, such as RESET, which mandates accredited IEQ monitors connect to the RESET Cloud and report data every 30 minutes [34].

Implication 1 for HVAC BACS Industry

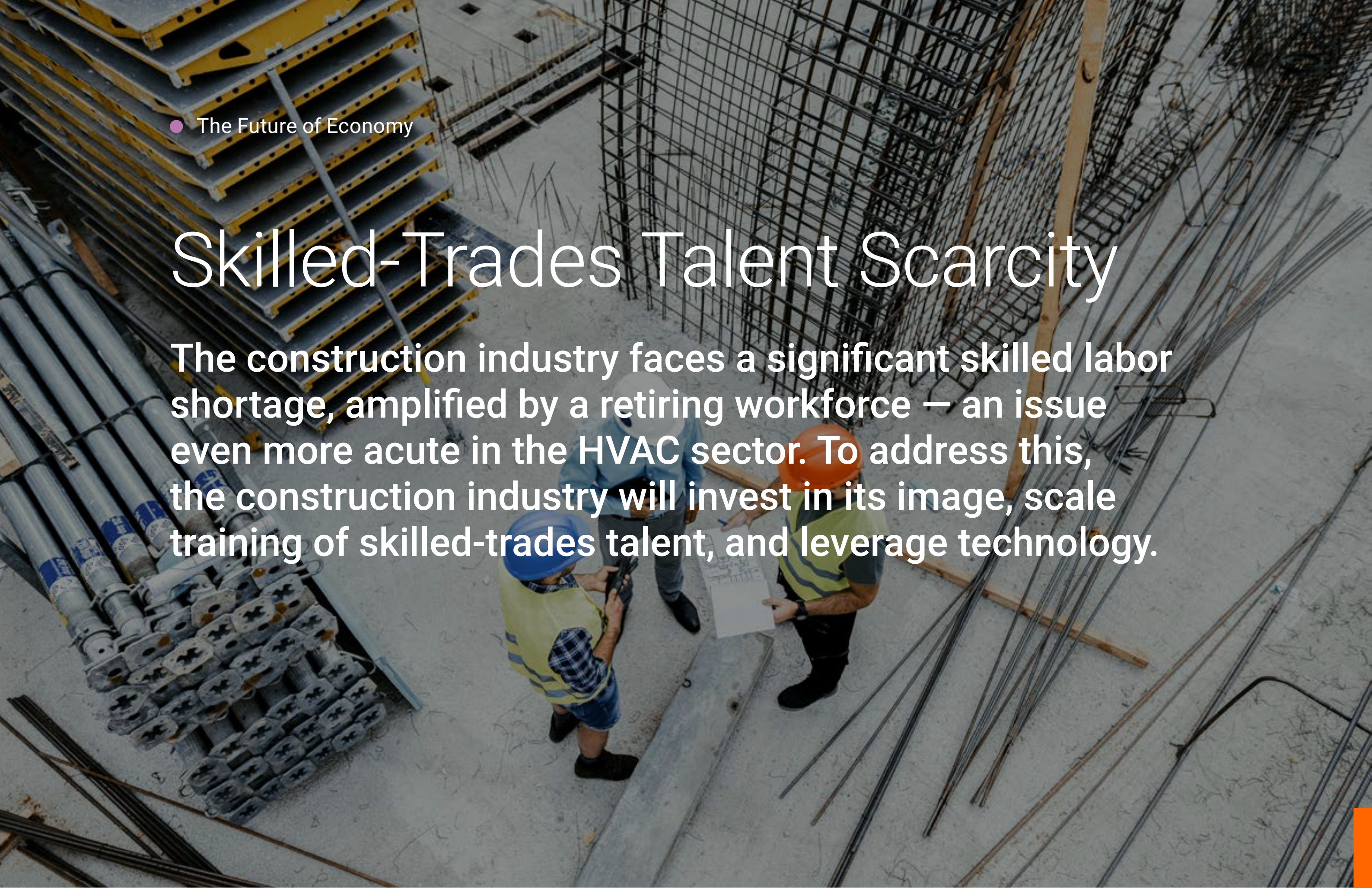
Granular Energy Monitoring

Tightening reporting standards will drive the adoption of granular monitoring systems for electrical and thermal energy flows in commercial buildings. These systems enable usage tracking at the room or zone level, facilitating tenant-specific aggregation enabled by HVAC BACS.

Implication 2 for HVAC BACS Industry

Certified Metering

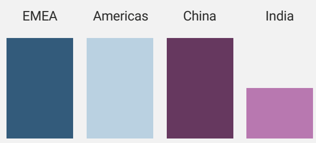
Increasing demand for precise ESG reporting will fuel the adoption of certified metering devices for electricity, thermal water, and air, such as those compliant with MID (Measuring Instruments Directive). These meters will ensure accurate measurement and transparent reporting for regulatory compliance.



Skilled-Trades Talent Scarcity

The construction industry faces a significant skilled labor shortage, amplified by a retiring workforce — an issue even more acute in the HVAC sector. To address this, the construction industry will invest in its image, scale training of skilled-trades talent, and leverage technology.

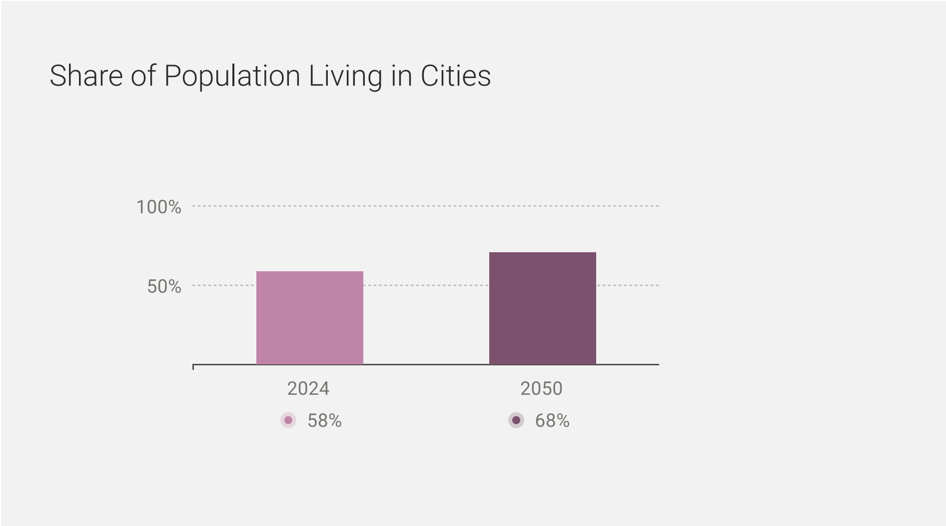
Regional Relevance

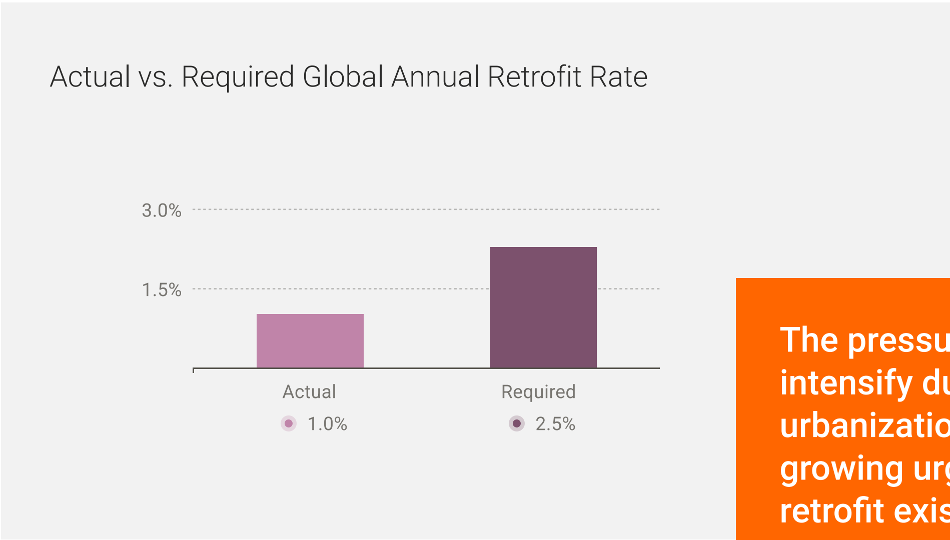


The Widening Skilled-Trades Talent Gap

94% of construction companies report that finding skilled staff is a key challenge [35]. The skilled-trades shortage in the construction industry stems from several key factors. First, the industry suffers from a poor image, as construction work is often perceived as physically demanding, with long hours and challenging conditions, deterring younger generations from entering the field. Second, in many countries, there is a lack of vocational training and apprenticeship programs to address shortages in specialized roles in building technologies, such as electricians, pipe fitters, ventilation technicians, or system integrators. Third, workers with transferable skills are often drawn to other industries offering better pay or working conditions, a trend accelerated by the COVID-19 pandemic, which caused many workers to leave the sector permanently.

The pressure is set to increase as urbanization grows [36], driving demand for new construction. Simultaneously, retrofit rates must globally more than double — in some regions even more — to meet net-zero goals, and the repurposing of commercial real estate in response to hybrid work trends will add to the workload. Compounding this, many workers are nearing retirement. McKinsey & Company estimates that by 2032, 16% of today's construction workers and 29% of HVAC mechanics in the US will have retired. At the same time, high churn rates will persist, with 1,194,000 construction laborers and helpers and 239,000 HVAC&R mechanics leaving the industry. As a result, 1,514,000 construction jobs and 380,000 HVAC jobs will need to be filled by 2032 in the US alone [37]. The 2023 European Employment Services (EURES) report on labor





The pressure will intensify due to rapid urbanization and the growing urgency to retrofit existing buildings

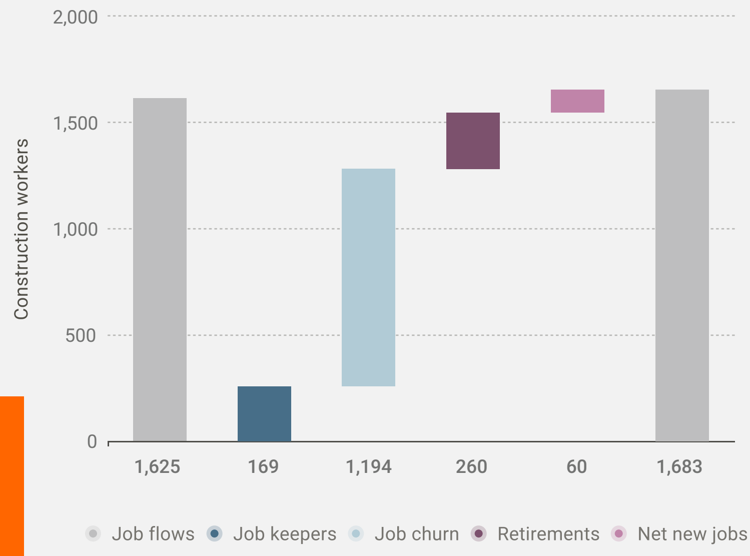
shortages reveals a similar trend in Europe. Twelve countries report a shortage of construction workers, with six identifying it as highly severe. For HVAC mechanics, eleven countries face shortages, six of which are classified as severe [(38)].

Building the Workforce for Net-Zero: Closing the Skilled-Trades Talent Gap

To address the widening skilled-trades talent gap, the construction and HVAC industries must improve their image, invest in education and training, adopt new technologies, and work with governments to implement supportive policies. Bridging this gap is critical to meeting labor demands and achieving net-zero goals.

Attracting younger generations to skilled trades requires improving the industry's image. Surveys show 74% of Generation Z perceive a stigma around vocational training compared to four-year universities, and only 5% of parents encourage trades careers [(39)]. Additionally, underrepresented groups remain untapped; in Europe, women comprise just 2% of construction workers and 0% of HVAC mechanics [(39)]. In the US, the share of female HVAC workers is 2.6%, only slightly higher [(40)].

Job Flows in the US, 2022–2032 — Construction Workers

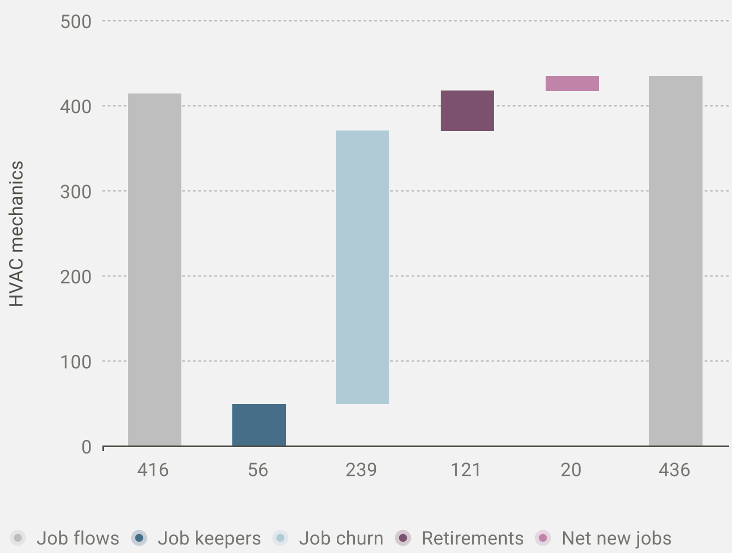


New hires of construction workers

↗ 1,610

A significant share of construction workers and HVAC mechanics is nearing retirement, ...

Job Flows in the US, 2022–2032 — HVAC Mechanics



New hires of HVAC mechanics

↗ 300

... leaving a widening skilled-trades talent gap

Expanding education and training is also critical. Vocational training, certifications, apprenticeships, and on-the-job training must be accessible to untrained workers and career changers. Programs like ROVC in the Netherlands, which trains 15,000 professionals annually, provide a blueprint for success. Upskilling the current workforce is equally important, with 35–45% of Europe's renovation workers needing training in areas like insulation, ventilation, or heat pumps [(41)]. Professional training curricula also need transformation, integrating AI, cybersecurity, and software engineering alongside traditional expertise.

Rising labor costs will spur technological innovation to boost efficiency. Components designed for error-free installation will reduce training needs, while augmented reality can guide workers on-site or connect them with remote experts. Prefabricated and modular construction offer further solutions, with preassembled elements like riser zones and facades requiring less labor, cutting timelines, and improving quality.

Finally, supportive policies are also essential, including open immigration frameworks that enable foreign workers, who have traditionally helped address labor shortages, to join the workforce.

Implication 1 for HVAC BACS Industry

Design for Easy Installation

Amid complex HVAC systems and a skilled labor shortage, HVAC BACS devices will have to become more intuitive and error-free to install. Application-specific mechanical tools, digital tools, and augmented reality will simplify installation — and appeal to the younger generation.

Implication 2 for HVAC BACS Industry

Prefab

Prefabricated components like piping packages with the required field devices, AHUs equipped with HVAC BACS devices, pre-installed fan coil units (FCU), variable air volume (VAV) boxes, prefabricated manifolds, or prefabricated vertical modules will gain prominence to simplify installation, reduce on-site errors, and enhance efficiency in building projects.

Implication 3 for HVAC BACS Industry

Product Training

Every product introduced to the market must be accompanied by comprehensive, accessible, and engaging training. This training can take the form of in-person workshops, on-demand virtual modules, or interactive webinars.

The Future of Society

The Future of Society addresses evolving human needs and expectations, focusing on building design and functionality.

Safe Buildings

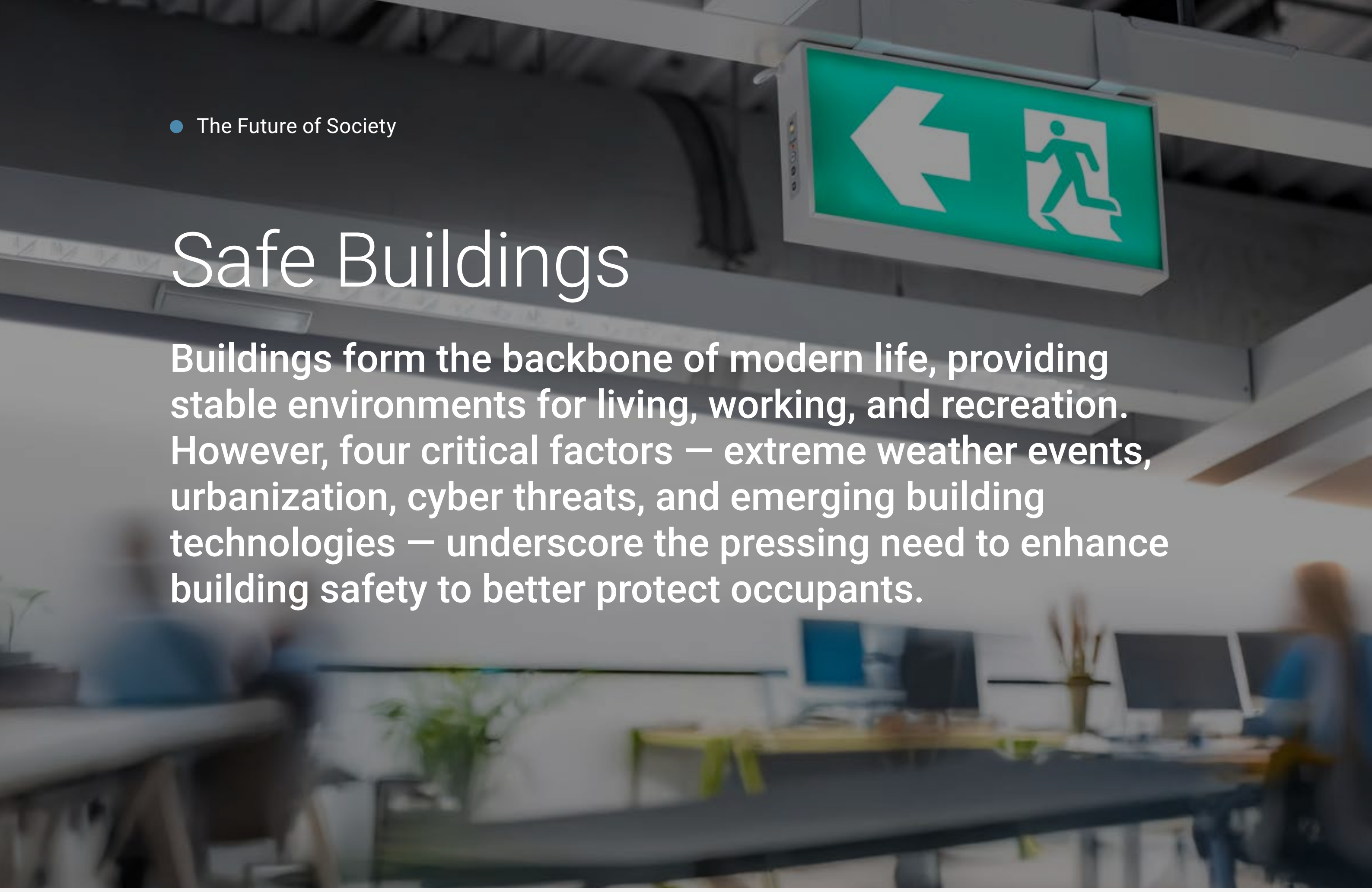
Enhanced safety measures will become vital to address the risks of extreme weather events, urban densification, cyber threats, and new technologies.

Healthy Indoor Spaces

Growing awareness of the upsides of healthy indoor spaces will shape building designs to focus on thermal comfort, air quality, acoustic comfort, and optimal lighting.

Mixed-Use and Flexible Spaces

The shift to multipurpose, adaptable buildings will accelerate, allowing spaces to evolve more quickly to meet changing needs.



Safe Buildings

Buildings form the backbone of modern life, providing stable environments for living, working, and recreation. However, four critical factors — extreme weather events, urbanization, cyber threats, and emerging building technologies — underscore the pressing need to enhance building safety to better protect occupants.

Regional Relevance

EMEA Americas China India

An Increasingly Harsh Environment for Buildings

The need for safety is one of the most basic human needs [(42)], and buildings exist to provide people with a safe shelter from the environment. However, the environment is becoming harsher. Climate change is intensifying extreme weather events, urbanization exacerbates the consequences of building fires, and digitalization amplifies cybersecurity threats. Meanwhile, new technologies making their way into buildings introduce new safety risks.

Extreme weather events are intensifying. For instance, in the US, nine of the top ten years for extreme rainfall in the period from 1910 to 2024 have all occurred since 1995 [(43)]. Globally, 2023 saw 170 flood disasters, double the 1990s average [(44)]. Furthermore, cyclone intensity has also risen significantly, with a notable increase in the US over the past 30 years [(45)].

Urbanization intensifies the impact of building fires. As the number of people living and working in an area increases, the consequences of building fires will become more devasting — a trend already evident in the US, where non-residential building fires over the past decade have risen by 27%, with fire-related deaths increasing by 83% [(46)].

Digitalization of buildings also increases their vulnerability to cyberattacks. Kaspersky reports that nearly 40% of computers used to manage smart building automation systems have faced malicious cyberattacks [(47)]. A striking example of the potential damage from a seemingly insignificant IoT device is a casino hacked through a smart thermometer in its lobby aquarium, which allowed access to its high-roller database [(48)].

Finally, new technologies bring new safety risks. For instance, new refrigerants with low global warming potential used in chillers and heat pumps can be flammable or toxic. Lithium-ion batteries used for energy storage risk "thermal runaway," a process causing overheating of the battery, toxic gas release, and potential ignition. In 2023, the UK recorded a 46% increase in fires linked to lithium-ion batteries [49].

Ensuring Building Safety in Design and Operations

Safety considerations in design and operations will become increasingly critical to ensure that buildings continue to provide safe environments for occupants.

Proactive measures to protect buildings from extreme weather are more cost-effective than post-event repairs. In flood-prone regions, buildings will increasingly use water-resistant materials like concrete or PVC bricks instead of plasterboard and plywood. Buildings in regions with heavy precipitation will feature reinforced roofs and guttering. In high bushfire-risk areas, buildings will incorporate fire-resistant materials, shutters, and sprinkler systems. Buildings in cyclone-prone areas will be designed to withstand stronger wind loads [50].

The increasing likelihood and severity of building fires will drive higher fire safety standards. Advanced fire-resistant materials, such as intumescent coatings and composites, will improve fire containment. Fire detection systems using interconnected sensors and AI will enhance real-time monitoring and response. Fire and smoke spread in ventilation ducts will be increasingly controlled by motorized dampers, as mechanical dampers are no longer adequate. And fire suppression systems will evolve with wider use of water mist technology and environmentally friendly fire suppression agents [51].

Increasing cybersecurity threats, coupled with stricter regulations such as the European Cyber Resilience Act, will accelerate the adoption of secure communication protocols in building automation and control systems. Protocols leveraging technologies like TLS-based encryption and certificate-based authentication will ensure secure, tamper-proof communication between devices and systems.

Finally, risks associated with new building technologies will require targeted mitigation strategies. Mechanical equipment rooms using low-GWP refrigerants, such as R-290 (propane) and R-717 (ammonia), will require special gas sensors. Similarly, rooms housing lithium-ion batteries will be equipped with sensors for detecting hydrogen and other hazardous gases like ethylene, propylene, methane, and carbon monoxide [52].

Implication 1 for HVAC BACS Industry

Automated Fire Safety Systems

Driven by increased safety awareness, fire safety systems will become increasingly automated. For instance, fire dampers will increasingly be motorized, smoke extraction automated, and staircase pressurized. These systems enable precise and automated activation during emergencies, ensuring faster responses and improved protection for occupants and property.

Implication 2 for HVAC BACS Industry

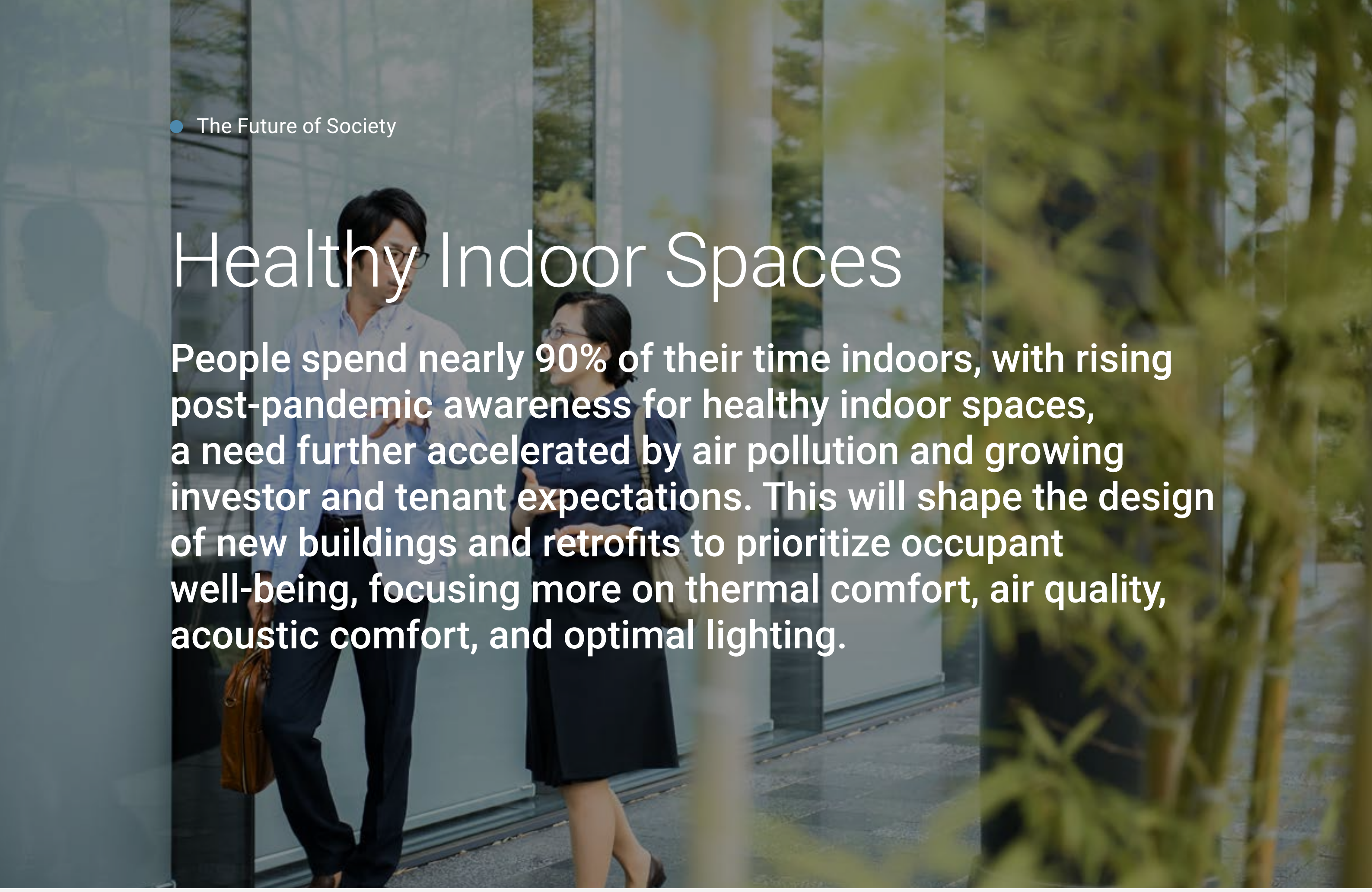
Secure Building Automation Protocols

The rise of secure building automation protocols, such as BACnet/SC and KNX IoT, will become a critical priority as the interconnectivity of building automation and control systems with cloud platforms accelerates.

Implication 3 for HVAC BACS Industry

Specialty Gas Sensors

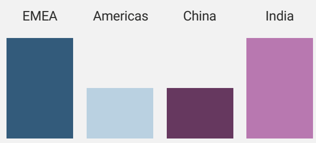
The deployment of new technologies in buildings will necessitate a new generation of indoor air safety sensors. These sensors will extend beyond traditional parameters, such as CO_2, volatile organic compounds (VOCs), and particulate matter (PM), to monitor refrigerants, combustible gases, and toxic emissions, ensuring safer indoor environments.



Healthy Indoor Spaces

People spend nearly 90% of their time indoors, with rising post-pandemic awareness for healthy indoor spaces, a need further accelerated by air pollution and growing investor and tenant expectations. This will shape the design of new buildings and retrofits to prioritize occupant well-being, focusing more on thermal comfort, air quality, acoustic comfort, and optimal lighting.

Regional Relevance



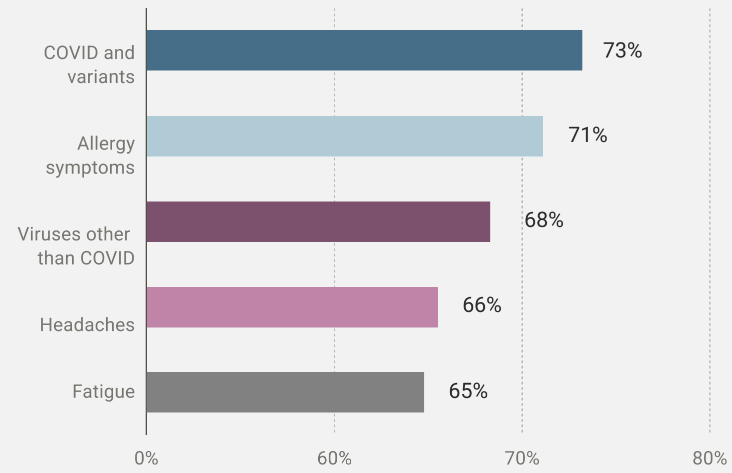
The Case for Healthy Indoor Spaces

Individuals in developed countries spend nearly 90% of their time in enclosed buildings [53]. With urbanization rates increasing, the global population spending more time indoors will increase further. Since the pandemic, awareness of hygiene and indoor air quality (IAQ) has grown, with a survey of 1,120 American workers showing widespread concern about the health impacts of poor IAQ [54]. This trend is further accelerated by post-pandemic health priorities, urban air pollution, and ESG strategies.

The pandemic and the shift to hybrid work models have increased attention on hygiene and IAQ in office and residential spaces. For instance, maintaining proper relative humidity levels between 40–60% is critical, as dry mucous membranes heighten infection risk and viruses survive longer on dry surfaces. Similarly, increased ventilation, reduced recirculation of indoor air, and improved air filtration can reduce sick leave from infectious diseases by 9–20% [55].

As urban populations increase, so do the concentrations of air pollutants in cities. Today, 99% of the world's population lives in places where air pollution exceeds WHO guideline limits [56]. In 2023, Delhi's average particulate matter PM2.5 concentration exceeded the WHO guideline by over 20 times [57]. Both short- and long-term exposure to air pollution exacerbates health issues, increasing respiratory and cardiovascular diseases, healthcare costs, and mortality, with the WHO linking air pollution to 6.7 million premature deaths annually [56].

Share of Respondents at Least Somewhat Concerned with Poor IAQ



The pandemic has heightened awareness for hygiene and indoor air quality

Additionally, investors and tenants are increasingly integrating health metrics into their ESG strategies. While this contributes to broader societal benefits, it also delivers immediate advantages for investors and tenants. Investors see up to a 7.7% increase in rents for certified healthy buildings (58), while tenants benefit from an 8% improvement in employee performance due to better IAQ (59).

The Future Essentials of Healthy Indoor Spaces

As demand for healthy indoor spaces grows, new buildings will increasingly prioritize occupant well-being, while existing structures will be retrofitted to meet these standards. Features such as thermal comfort, healthy indoor air quality, acoustic comfort, and optimal illumination will gain increasing relevance. High-quality sensors measuring and monitoring these parameters will become ubiquitous.

Thermal comfort is a key reason we have buildings. It plays a significant role in the way we experience spaces where we live and work. Six primary variables contribute to an occupant's thermal comfort: dry bulb temperature, radiant temperature, relative humidity, air speed, metabolic rate, and clothing (60). The first four variables can be controlled by the HVAC systems to provide occupants with a healthy and comfortable environment. However, today many buildings do not yet control these four variables properly.

Good IAQ supports health, well-being, and productivity. It is influenced by occupant respiration (CO_2, pathogens), outdoor pollutants (particulate matter, harmful gases), indoor emissions (volatile organic compounds), and foundation emissions (radon). Effective ventilation and advanced filtration are essential, yet many buildings still rely on manual window opening, which is inefficient for air quality and energy use.

Acoustic comfort is a key factor in creating a productive and satisfying built environment, as unwanted internal and external noise can disrupt work and relaxation. External noise has been linked to health risks like hypertension, stroke, and diabetes, while also increasing annoyance [61]. Internally, noise from electronics, HVAC systems, and occupants can reduce concentration and productivity [61]. To address these challenges, mitigating exterior noise, managing internal sound sources, and using sound-absorbing materials can enhance acoustic comfort.

Optimal illumination ensures visual comfort and reduces issues like eyestrain, headaches, and productivity losses. Beyond visual benefits, light significantly affects physiology by regulating the circadian rhythm, which controls alertness, digestion, and sleep. Improper lighting can disrupt this rhythm, leading to sleep disorders and higher risks of conditions like obesity, diabetes, and cardiovascular disease. To address this, buildings will increasingly adopt circadian lighting, glare control, automated shading, dimming, and daylight optimization [61].

Occupant well-being can also encompass more than just these environmental factors, such as drinking water purification, promoting healthy eating habits, encouraging physical activity, and supporting mental and emotional health through building design. Many of these aspects are addressed in today's healthy building certifications, such as WELL.

Regulations also increasingly incorporate healthy indoor environment requirements. For example, the revised European Performance of Buildings Directive (EPBD) mandates that new non-residential zero-emission buildings, as well as those undergoing major renovations, where feasible, include measurement and control systems to monitor and control IAQ [28].

Implication 1 for HVAC BACS Industry

Ubiquitous IAQ Monitoring and Control

IAQ sensors will become ubiquitous, tracking, displaying, and controlling key IAQ parameters such as temperature, relative humidity, CO_2, PM, VOCs, and pathogens. These sensors will increasingly connect to dashboards that show real-time values and IAQ trends for diagnostic purposes.

Implication 2 for HVAC BACS Industry

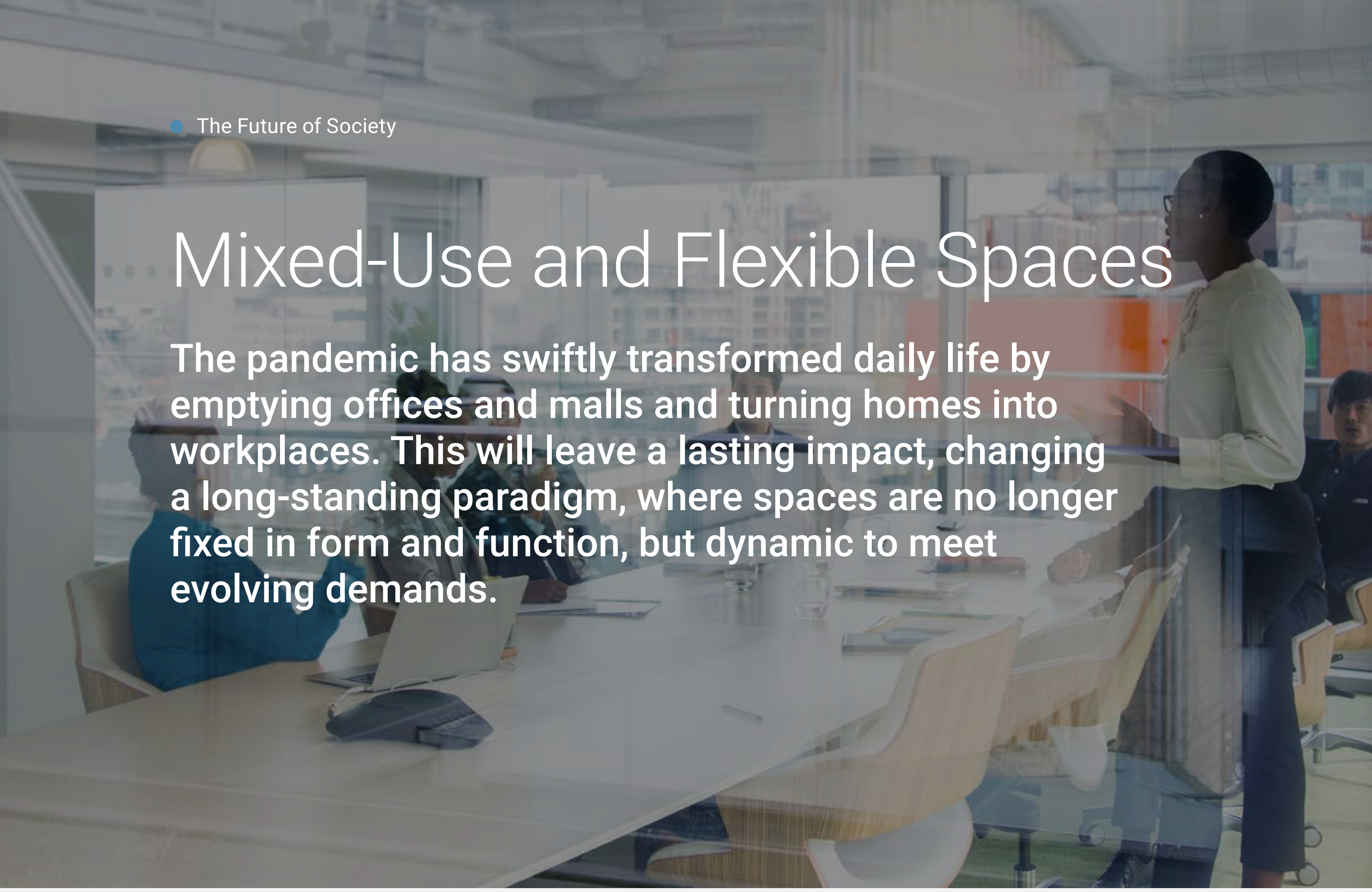
Multi-Parameter Sensors

To gain specific insights, room sensors measure multiple indoor environmental quality parameters as single, multi-functional devices. These devices will track temperature and relative humidity, IAQ parameters such as CO_2, PM, and VOCs, smoke, luminosity and occupancy, and noise levels. Increasingly, integrated room sensors will need to be certified to gain approval for green building projects or retrofits [62].

Implication 3 for HVAC BACS Industry

Acoustic Optimization

Advances in design reduce operational noise from mechanical HVAC BACS devices like actuators and valves. To ensure comfort, noise levels must be kept low, even when multiple components operate simultaneously, such as during coordinated actuator movements or valve adjustments in dense system environments.



Mixed-Use and Flexible Spaces

The pandemic has swiftly transformed daily life by emptying offices and malls and turning homes into workplaces. This will leave a lasting impact, changing a long-standing paradigm, where spaces are no longer fixed in form and function, but dynamic to meet evolving demands.

EMEA Americas China India

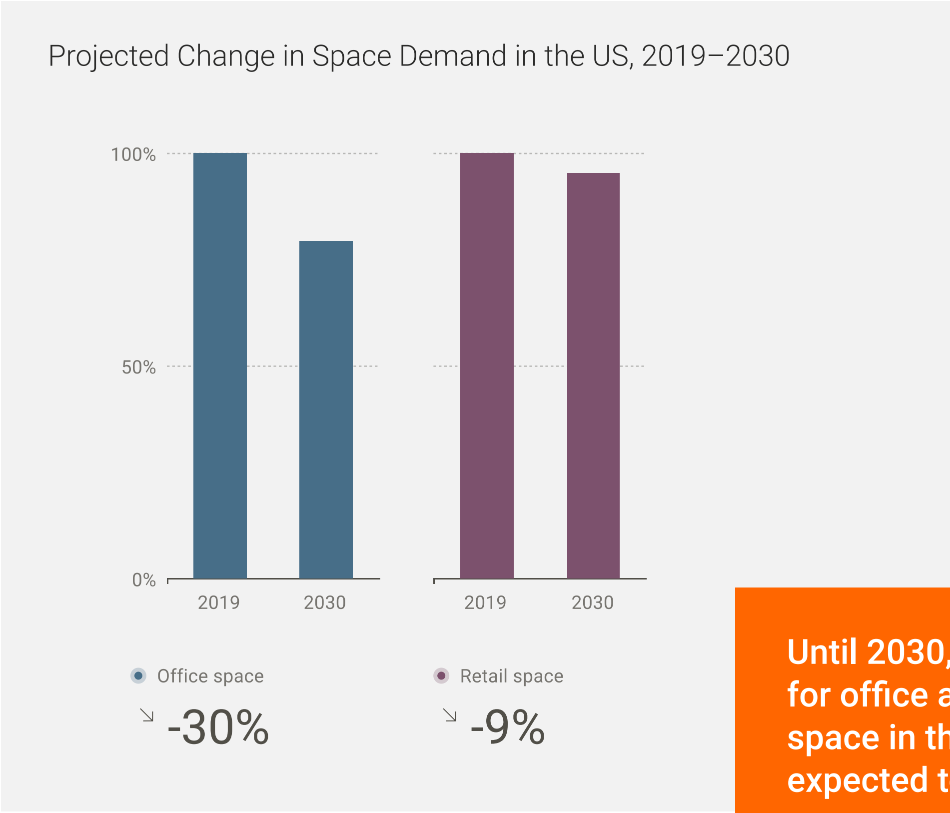
Regional Relevance

Spaces for New Realities

The pandemic rapidly reshaped how we live, work, and interact. Offices emptied, shopping malls became deserted, and homes turned into workplaces as people adapted to new life-styles.

At the end of 2024, the office vacancy rate in the US was 20.1%. That is a 30-year high, with more than 84 million m^2 [900 million sq ft] of office space empty — enough to fill New York City's One World Trade Center 300 times (63). More long-term, McKinsey & Company estimates a 13% decrease in office space demand by 2030 compared to pre-pandemic norms (64). Similarly, retail space faces enduring challenges from the growth of e-commerce, with demand projected to be 9% lower by 2030 than before the pandemic (64). In contrast, demand for residential space is expected to increase, driven not by a return to urban cores but by population growth that matches pre-pandemic trends.

This disparity highlights the need for more adaptability in spaces, where spaces are no longer seen as something fixed and permanent but as something dynamic.



Until 2030, the demand for office and retail space in the US is expected to decline

From Static to Dynamic Spaces

The ability of a building to accommodate change is becoming a key factor in its longevity, economic success, and carbon footprint. As a result, demand for mixed-use and adaptable buildings will continue to grow.

Mixed-use buildings integrate multiple functions, such as residential, commercial, office, and hospitality, within a single structure to maximize space efficiency and adaptability. Combining different use cases in one structure offers unparalleled benefits for its occupants: increased traffic for commercial tenants and improved convenience for residential tenants. Mixed-use buildings also offer benefits to their landlords. This includes higher rents, as office spaces in mixed-use environments are able to command up to 33% higher rental prices and increased flexibility to shift spaces from one use case to another [65]. The shift to mixed-use buildings is already taking place. For instance, in the US, there were nearly 200 malls in January 2022 that had plans to incorporate residential units, repurposing vacant retail into residential space [66].

This concept of adaptability extends to broader architectural solutions and flexible buildings. Flexible buildings include reconfigurable layouts with movable walls, enabling buildings to transition seamlessly between use cases. Reconfigurable layouts also contribute to a reduction of embodied emissions as the lifetime of buildings, or parts thereof, is extended. Supporting this flexibility, though, requires infrastructure such as modular wiring, plumbing, and HVAC systems that can adapt to different configurations or loads without extensive renovations. In Zurich, a case study demonstrated that incorporating movable walls and independent technical systems in an office building could unlock nearly USD 550 million in value by converting vacant spaces into co-working or residential units, reducing vacancy risks by over 70% [67]. Similarly, innovative elevator systems now allow a single elevator group to serve multiple applications, such as residential, office, or hospitality, making it easy to accommodate changing applications or passenger groups [68]. However, these flexible designs also present challenges. More complex wiring, plumbing, and HVAC systems often have higher initial costs and, if not implemented correctly, also higher energy consumption compared to customized designs. Balancing adaptability with cost efficiency and sustainability is critical to maximizing the long-term value of flexible spaces.

Implication 1 for HVAC BACS Industry

Adjustable Zone Control

The growing need for adjustable zone control will elevate the importance of advanced building automation and control systems. As spaces are reconfigured for new uses, systems will require real-time adaptability through software that seamlessly adjusts. This flexibility will enable efficient climate control tailored to dynamic layouts while maintaining occupant comfort and energy efficiency.

Implication 2 for HVAC BACS Industry

Wireless/Power-over-Ethernet (PoE)

To enhance flexibility, the adoption of wireless and Power-over-Ethernet (PoE) systems for HVAC BACS devices will increase. However, most wireless devices will still rely on wired power connections, as energy harvesting technologies remain unreliable, and battery maintenance is impractical at scale.

Implication 3 for HVAC BACS Industry

Automatic Balancing

Automatic (re)balancing of air and water flows will be required to ensure optimal distribution across zones upon adjustments in the zone. This ensures that changes in one area do not negatively impact others or cause undersupply or oversupply.

The Future of
Technology

The Future of Technology summarizes trends that explore the transformative effects of technological advancements on buildings and their operation.

Connected Buildings

IP-based communication protocols, semantic domain models, and secure over-the-network updates will help to overcome some of today's challenges of connected buildings.

Integrated Planning, Installation, and Commissioning

Planning, installation, and commissioning of buildings and building automation devices will become more integrated.

Next-Generation Building Automation

Next-generation building automation will combine deeper integration with decentralized intelligence, flatter architectures, and AI-driven capabilities.

Connected Buildings

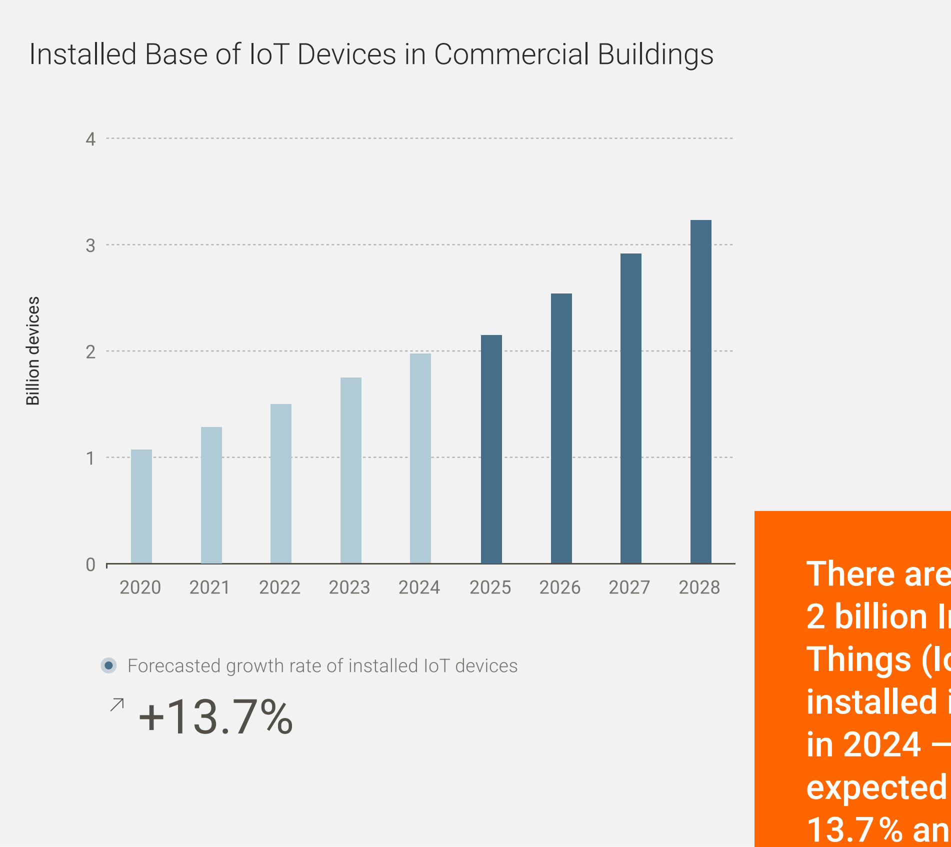
The number of IoT-enabled devices in buildings is rapidly increasing, but several challenges, such as limited interoperability and scalability, lack of upgradability, and data overload, still prevent their full potential from unfolding. IP-based communication protocols, semantic domain models, and secure over-the-network updates will help overcome those hurdles and unlock new use cases.

	EMEA	Americas	China	India
Regional Relevance				

The Growth of IoT Devices in Buildings and Their Hurdles

Today, there are approximately 2 billion Internet of Things (IoT) devices installed in buildings, a number expected to grow by 13.7% annually going forward [69]. IoT devices in buildings are networks of interconnected sensors, systems, and equipment that collect and exchange data to optimize operations, improve energy efficiency, and enhance occupant comfort and security. Examples include connected security and access control systems, HVAC and building energy management systems, workplace management systems, smart lighting systems, escalators and elevators, parking systems, fire and safety systems, and indoor environmental quality monitors. A single building housing tens of thousands of IoT devices is one of the most complex controlled systems in the world — even more complex than autonomous vehicles or industrial robots.

While integrating IoT devices in buildings offers substantial opportunities, several challenges currently limit their full potential. A primary obstacle is interoperability, as many IoT devices rely on proprietary protocols, complicating the integration of systems across different building automation verticals and obstructing seamless operation. Scalability remains another significant hurdle, as managing expanding IoT networks becomes increasingly complex without IoT devices that can automatically recognize and coordinate with other IoT devices. Additionally, upgradability is critical, as IoT device firmware often becomes outdated much more rapidly than the hardware due to advancing technology, requiring frequent updates to ensure efficient and secure operation.



There are about 2 billion Internet of Things (IoT) devices installed in buildings in 2024 — a number expected to grow by 13.7% annually

Unlocking the Full Potential of Connected Buildings

Seamless integration across building automation domains will not only unlock new potential in more efficient energy management and further cost reduction but also introduce new use cases, providing a step change in user experience. For instance, HVAC systems can dynamically adjust temperatures and ventilation in offices and conference rooms based on expected occupancy, forecasted weather, and individual preferences. Smart lighting systems can adapt brightness to sunlight levels, mimicking natural daylight changes to support circadian rhythms. Additionally, intelligent infrastructure can enable location-aware interactions, personalized signage for events and visitors, real-time workspace and meeting room availability, and automatic release of unoccupied reserved spaces [(70)]. To enable these advancements, the current barriers of interoperability, scalability, upgradability, and data overload must be overcome.

Interoperability challenges can be addressed by adopting IP-based communication protocols, enabling seamless interaction between IoT devices from various manufacturers. A unified IP-based infrastructure simplifies network management, reduces costs associated with proprietary solutions, and allows diverse building systems to share data over a single IP backbone [(71)]. However, this shift will require greater involvement from IT management teams in the design, commissioning, and decision-making processes of building automation systems.

Overcoming scalability challenges will necessitate the adoption of semantic domain models, which define relationships between components, systems, and data flows in the building automation domain. These models provide data context, enabling complex systems to self-configure.

Lastly, automated upgradability of IoT devices will also be essential to address security concerns, as manually patching thousands of devices in a building is impractical. Secure, over-the-network updates will depend on resolving interoperability challenges as a prerequisite.

Implication 1 for HVAC BACS Industry

IP-Based Communication Standards

The adoption of IP-based standards like BACnet/IP and KNX IoT is driving seamless interoperability across HVAC systems. These protocols simplify integration efforts, enabling more efficient and reliable data exchange between building devices. Standardized communication ensures compatibility across vendors and reduces costs associated with custom solutions, while also enhancing scalability for future technology advancements.

Implication 2 for HVAC BACS Industry

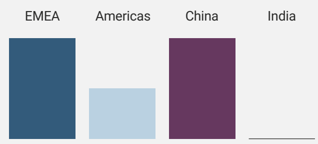
Semantic Domain Models

Semantic domain models are becoming crucial for enabling smarter and context-aware building systems. By allowing HVAC BACS devices to interpret and process data meaningfully, these technologies enable systems to communicate more effectively. This facilitates enhanced interoperability, streamlined operations, and greater adaptability to complex scenarios, such as optimizing energy use in response to real-time conditions.

Integrated Planning, Installation, and Commissioning

Global construction labor productivity lags other industries due to fragmented planning, execution and operation, limited data exchange, and outdated progress monitoring methods. Innovative approaches such as integrated project delivery, advanced digital planning, and digital workflow management will help to streamline project execution, reducing costly rework and project delays.

Regional Relevance



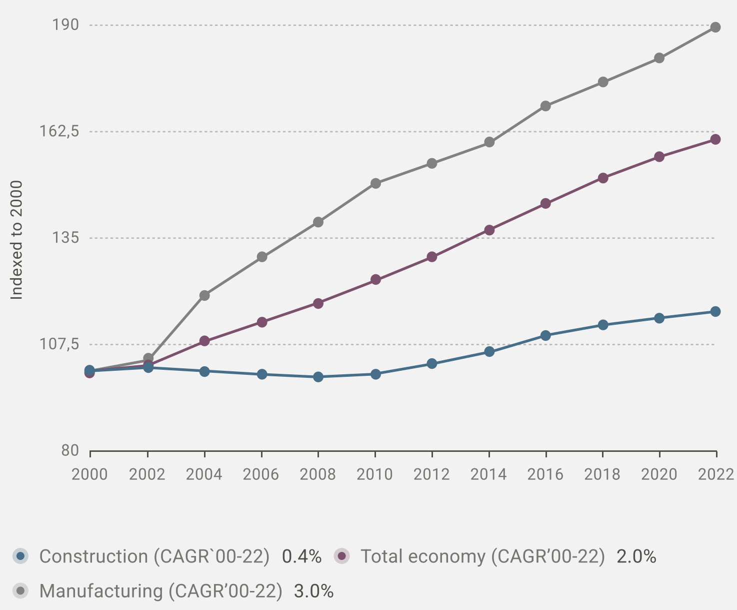
Siloed Processes: Barriers in Modern Construction

Between 2000 and 2022, global construction industry labor productivity grew by less than 0.5% annually, significantly trailing the 2% productivity increase of the broader economy [72]. Among other reasons, persistent inefficiencies in project management methodologies and lack of use of digital tools in planning and progress monitoring hinder progress.

Traditional construction project management methodologies often overlook the complex interdependencies between trades. Each party is expected to focus solely on their specialized tasks and pursue their own contractually defined objectives. This siloed approach leads to significant fragmentation and diverting interests not only between trades but also between the planning, the execution and operational phases of the project.

Current planning processes reflect this fragmentation. They consist of multiple disconnected activities, including architectural design, structural engineering, and mechanical and electrical planning. These activities may run sequentially or in parallel, though still being disconnected with limited data exchange between them. This disconnect in the data exchange extends project timelines and frequently leads to design conflicts, such as the installation of HVAC ducts clashing with plumbing or other building systems. Such issues are often only identified during the execution phase, requiring costly on-site adjustments. Moreover, the commissioning of building automation devices is still mostly done manually, making the process error-prone and

Real Gross Value Added per Hour Worked, 2000–2022



Between 2000 and 2022, construction industry labor productivity grew by less than 0.5% annually, significantly trailing the 2% productivity increase of the broader economy

devices not working optimally. Over the building's 20+ year lifespan, maintenance interventions often further reduce efficiency.

Additionally, outdated progress monitoring and quality control methods impede real-time insights, making it challenging for project managers to identify and resolve bottlenecks proactively.

In sum, these challenges often lead to inconsistencies and errors in project execution, resulting in costly rework and delays. This emphasizes the urgent need for a more integrated, digitalized approach to project planning and execution.

Building More Integrated and More Digital

A more integrated and digital approach to planning, installation, and commissioning can address the previously mentioned challenges. This includes adopting new project management approaches, leveraging digital planning tools, and utilizing digital workflow management platforms.

New, more collaborative project management approaches, such as integrated project delivery (IPD), will help to align the interests of all parties in a construction project. IPD is an approach where all relevant participants are involved from the very beginning of a project, injecting their expertise and sharing both benefits and risks. This approach reduces siloed thinking, minimizes design conflicts, prevents material waste and rework, and ultimately leads to faster project delivery and lower costs [73].

Digital planning tools, such as building information modeling (BIM) or generative design, support collaborative project management approaches and will be increasingly adopted. BIM offers a digital 3D representation of a project's physical and functional characteristics, ensuring accurate, up-to-date information and serving as a reliable decision-making foundation throughout the project lifecycle. Enhanced by AI, BIM tools can also automatically identify potential issues before they arise or increase planning efficiency and variant discussion by means of algorithm-based and automated planning. Studies show that 75% of BIM adopters report a positive return on investment. Beyond design, BIM can also model execution schedules (BIM 4D) and costs (BIM 5D), helping to keep projects on time and within budget [(74)]. The use of BIM also paves the way for digital twins, laying the foundation for operational efficiency improvements during the installation and commissioning phases [(75)]. Data needed for the commissioning of a device can be downloaded from a cloud-based digital twin prior to delivery, allowing devices to arrive pre-configured and ready for installation at the construction site. This reduces on-site installation times, minimizes errors, and ensures seamless integration between systems.

Finally, digital workflow management tools will improve material handling and progress tracking. These tools enable the streamlining of material flows and provide real-time monitoring of construction activities. Enhanced by technologies such as drone-supported inspections, these tools will enable more accurate progress tracking, identify potential delays, and improve transparency and accountability, allowing project teams to adapt quickly to changing circumstances.

Implication 1 for HVAC BACS Industry

Seamless Integration into Design and Operating Tools

HVAC BACS device data will seamlessly integrate with digital design and operating tools, such as BIM and BMS, to allow for easy field device selection and dimensioning. This ensures a unified data flow across the building lifecycle, reducing design conflicts and enhancing system performance.

Implication 2 for HVAC BACS Industry

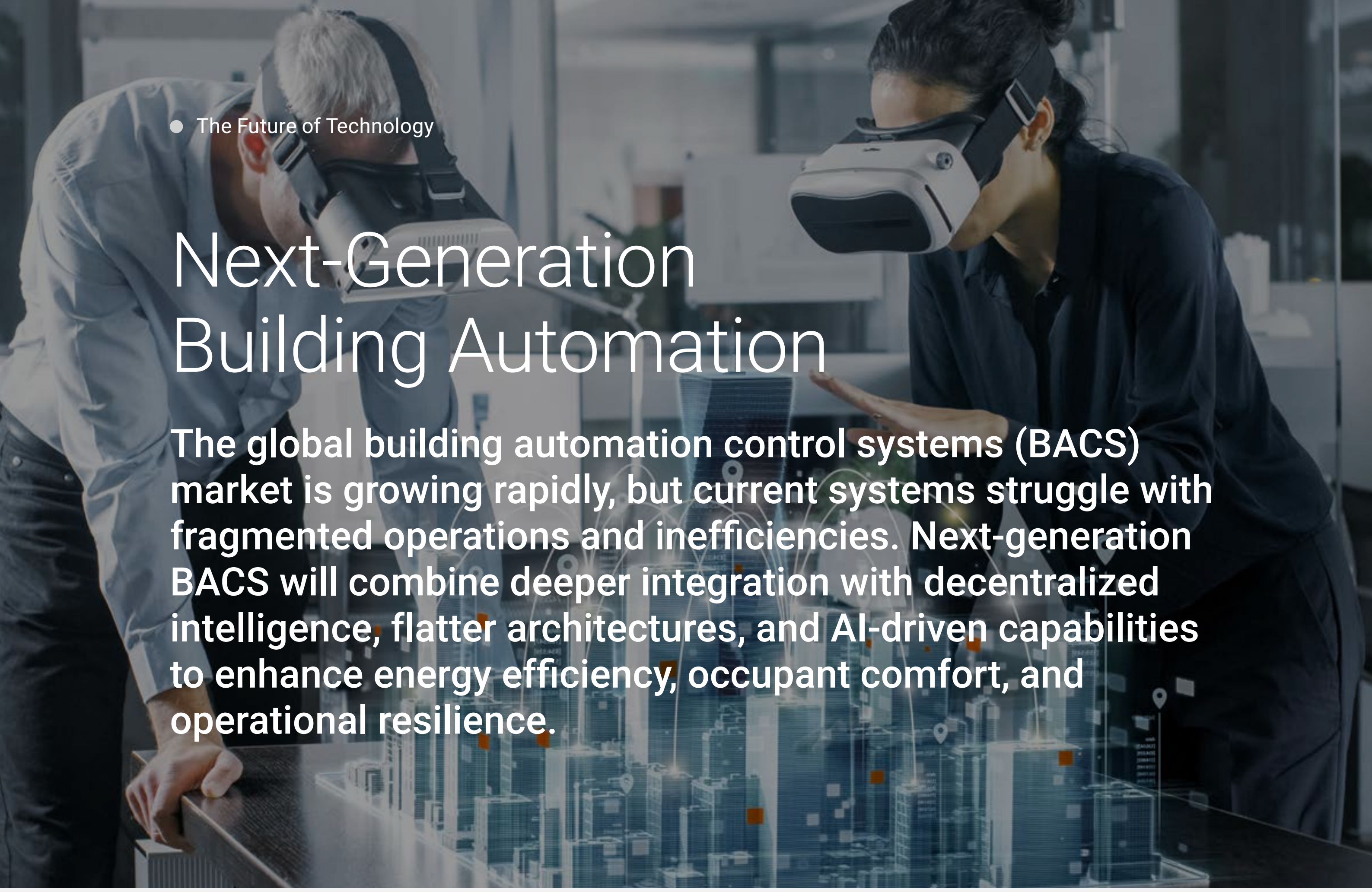
Plug-and-Play/Self-Commissioning

HVAC BACS devices will self-commission through cloud-based configuration data, automatically connecting and integrating into the BMS. This approach allows the contractor to focus on physically connecting the devices, reducing manual configuration, shortening timelines, and minimizing installation errors.

Implication 3 for HVAC BACS Industry

Digital Twin

Every HVAC BACS field device will have a cloud-based digital twin that stores specifications, operational metrics, and maintenance data. Digital twins enable predictive maintenance, improve energy efficiency, and support data-driven decision-making.



Next-Generation Building Automation

The global building automation control systems (BACS) market is growing rapidly, but current systems struggle with fragmented operations and inefficiencies. Next-generation BACS will combine deeper integration with decentralized intelligence, flatter architectures, and AI-driven capabilities to enhance energy efficiency, occupant comfort, and operational resilience.

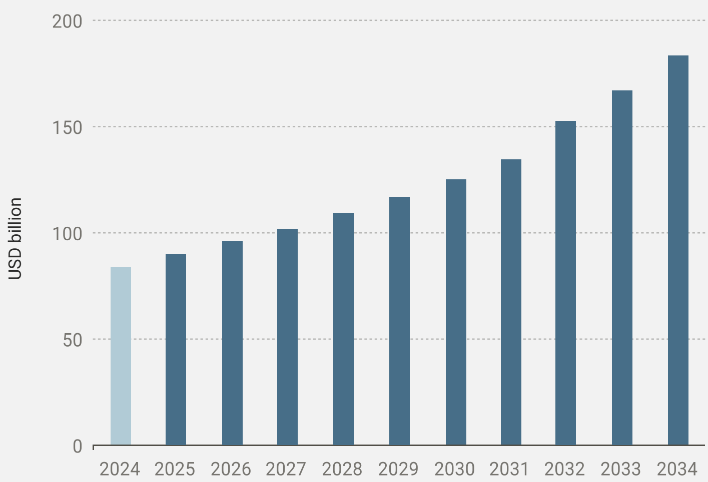
	EMEA	Americas	China	India
Regional Relevance				

The Challenge of Fragmentation and Complexity for BACS

The global building automation control systems (BACS) market is estimated to be around USD 82 billion, forecasted to grow by 7.9% [(76)]. Despite this growth, the current generation of BACS is still not prepared for the challenges and complexities that arise with the need to optimize comfort, safety, and energy efficiency across building automation domains.

The current generation of BACS is typically designed to manage specific functions like HVAC, lighting, or security independently, leading to fragmented operations, discomfort, and inefficiencies. To address those challenges, BACS will need to manage the simultaneous optimization of multiple building domains, a challenge often unmet by the current BACS due to the isolated nature of building domains. Moreover, as buildings incorporate more advanced technologies, the complexity of managing disparate systems centrally increases, often requiring specialized knowledge for each subsystem. Centralized systems, while offering a unified control interface, often struggle to handle this complexity. These constraints highlight the need for next-generation BACS that address the multifaceted demands of modern buildings.

Size of Building Automation Market



Forecasted growth rate of BACS market

↗ +7.9%

The global building automation control systems (BACS) market is estimated at around USD 82 billion in 2024, forecasted to grow by 7.9%

From Centralized Control to the Edge

Next-generation BACS will combine deeper system integration with increasing decentralization and edge intelligence. The trend can be broken into three interconnected themes: the duality of integration and separation, flatter system architectures, and the transformative role of artificial intelligence (AI).

The duality of integration and separation is at the heart of this evolution. On the one hand, there is a push to unify building automation verticals, such as HVAC, lighting, and security, into interconnected platforms. Integrated systems improve energy management, streamline operations, and simplify monitoring through centralized control. On the other hand, independent sub-systems are emerging as a viable alternative to address growing system complexity. These systems operate decentralized and autonomously, offering improved reliability, simplified installation and maintenance, and increased flexibility for upgrades. This dual approach allows buildings to balance integration with autonomy based on their unique requirements.

The development of flatter BACS architectures based on enhanced standardized communication technology is another defining characteristic of this trend. Traditional BACS rely heavily on centralized systems to process data and make decisions. The rise of IP as the standard protocol, together with edge computing, transforms this centralized decision-making towards decentralized decision-making. Edge computing pushes intelligence to the building network's edge, enabling data to be processed and decisions to be made directly at the sub-system level. This topology does not rely anymore on a central BACS which increases overall system resilience and performance by reducing complexities and latencies. It enables real-time optimiza tion and user-centric functions at the sub-system level. For example, IoT-enabled HVAC sub-systems can dynamically adjust performance in response to changes in occupancy or environmental conditions of a room, improving efficiency and resilience without the need for a centralized BACS decision-making.

Finally, artificial intelligence is transforming building automation by enabling real-time, data-driven optimization. AI systems analyze information collected from IoT sensors to predict and adjust energy use, ensuring a balance between occupant comfort and energy efficiency. AI-based optimization adapts to variables like occupancy, weather forecasts, and energy demand patterns. This capability not only enhances comfort but can also reduce energy consumption by around one-fourth depending on the quality of the installed system and its maintenance (often, the quality of systems deteriorates over its lifetime due to careless maintenance activities). Acknowledging its crucial role in improving efficiency and reducing operational costs, it is expected that AI-enabled BACS will be implemented in over 60% of commercial buildings in the next years, ensuring the systems operate smoothly and efficiently, and minimize downtime and lifecycle costs [77].

Implication 1 for HVAC BACS Industry

Decentralized Solutions

The shift toward decentralized solutions will significantly impact HVAC BACS. Functional entities will be grouped with their own decentralized logic, ensuring full operational responsibility under a single vendor. This can apply to air handling units (AHUs), variable air volume (VAV) units, and zones where multiple building systems converge, for example, HVAC, blind control, lighting, and fire safety.

Implication 2 for HVAC BACS Industry

Self-Learning and Optimization

AI-powered HVAC BACS devices will become self-learning and self-optimizing, adapting to dynamic conditions such as occupancy and weather. These devices will continuously improve their performance, making real-time adjustments to energy use and providing a more comfortable and efficient building environment.

Regional Differences

While building and HVAC trends are global phenomena, their impact and momentum vary across regions. Some trends gain more traction in certain areas due to unique local priorities, challenges, and conditions. The following sections explore these regional differences, highlighting the specific focus areas shaping the built environment in EMEA, the Americas, China, and India.

EMEA

In Europe, The Future of Environment emerges as the most critical sector on the trend radar. With one of the world's oldest building stocks, the region prioritizes retrofitting to meet modern energy-efficiency standards. Europe demonstrates its commitment to sustainability through the widespread adoption of energy-efficient designs to reduce both operational and embodied carbon emissions. Policies like the EU Energy Performance of Buildings Directive (EPBD) reinforce the region's focus on decarbonization. Additionally, Europe's fast adoption of advanced HVAC technologies and innovative construction materials highlights its proactive approach to providing high occupant comfort while achieving climate goals. Environmental advancements are a cornerstone of Europe's vision for the built environment.

Americas

In the Americas, The Future of Society emerges as the most prominent sector on the trend radar, driven by an increasing focus on healthy indoor spaces and safe buildings. Urban densification and the intensification of extreme weather events underscore the urgent need for resilient building designs. Advancements in indoor air quality are gaining critical importance as the region continues to transition to hybrid work models and prioritizes occupant well-being. With reduced federal climate action, states like California and cities like New York and Boston will lead energy efficiency efforts. For the other states, rising electricity demand, particularly from data centers, and aging infrastructure will drive investments in building energy efficiency, as they are as they are more cost-effective than upgrades to the power grid.

China

In China, The Future of Technology emerges as the most significant sector, driven by the country's rapid urbanization, increasing demand for modern infrastructure, and advancements in smart building technologies. Ambitious national objectives, such as achieving carbon neutrality by 2060, are serving as powerful catalysts for innovation across the building and HVAC sectors, promoting the development of intelligent, energy-efficient, and sustainable solutions. With an innovation trajectory that mirrors the remarkable progress seen in industries like robotics, automotive, and artificial intelligence [78], China is setting itself up to become a global leader in this space. These advancements are not only addressing current challenges but also shaping a transformative future for the nation's built environment, redefining how cities and buildings function on both regional and global scales.

India

In India, The Future of Environment emerges as a pivotal sector on the trend radar, shaped by the nation's increasing population, rapid urbanization, rising energy demands, and growing vulnerability to climate change. With high urban population density and extreme heat waves becoming more frequent, India is prioritizing climate adaptation strategies, such as the integration of energy-efficient cooling systems and passive design features. The country is also making strides in electrification and energy optimization, with ambitious initiatives to enhance building energy efficiency. These efforts are transforming the built environment and positioning India as a regional leader in sustainable urban development.

List of Abbreviations

AHU	Air Handling Unit
AI	Artificial Intelligence
BACnet/SC	Building Automation and Control Networks — Secure Connect
BACS	Building Automation and Control System
BIM	Building Information Modeling
BREEAM	Building Research Establishment Environmental Assessment Method
CDD	Cooling Degree Days
CO2	Carbon Dioxide
COVID-19	Coronavirus Disease
CSDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Sustainability Reporting Directive
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen / German Sustainable Building Council
ECSBC	Energy Conservation Sustainable Building Code
EPBD	Energy Performance of Buildings Directive
EPD	Environmental Product Declaration
ESG	Environmental, Social, and Governance
ESRS	European Sustainability Reporting Standards
EU	European Union
EURES	European Employment Services
FCU	Fan Coil Units
GEG	Gebäudeenergiegesetz / Building Energy Act
GlobalABC	Global Alliance for Buildings and Construction
GRI	Global Reporting Initiative
GWP	Global Warming Potential
HVAC	Heating, Ventilation, and Air Conditioning
HVAC&R	Heating, Ventilation, Air Conditioning, and Refrigeration
IAQ	Indoor Air Quality
IEA	International Energy Agency
IEQ	Indoor Environment Quality
IoT	Internet of Things
IP	Internet Protocol
IPD	Integrated Project Delivery
ISO	International Organization for Standardization
LEED	Leadership in Energy and Environmental Design
PM	Particulate Matter
PoE	Power over-Ethernet
PVC	Polyvinyl Chloride
RESET	Regenerative, Ecological, Social, and Economic Targets
ROVC	Regionaal Opleidings- en VormingsCentrum / Regional Training and Education Center
S&P 500	Standard and Poor's 500 Index
SBTi	Science Based Target initiative
TLS	Transport Layer Security
UK	United Kingdom
US	United States
VAV	Variable Air Volume
VOCs	Volatile Organic Compounds
WELL	WELL Building Standard
WHO	World Health Organization

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