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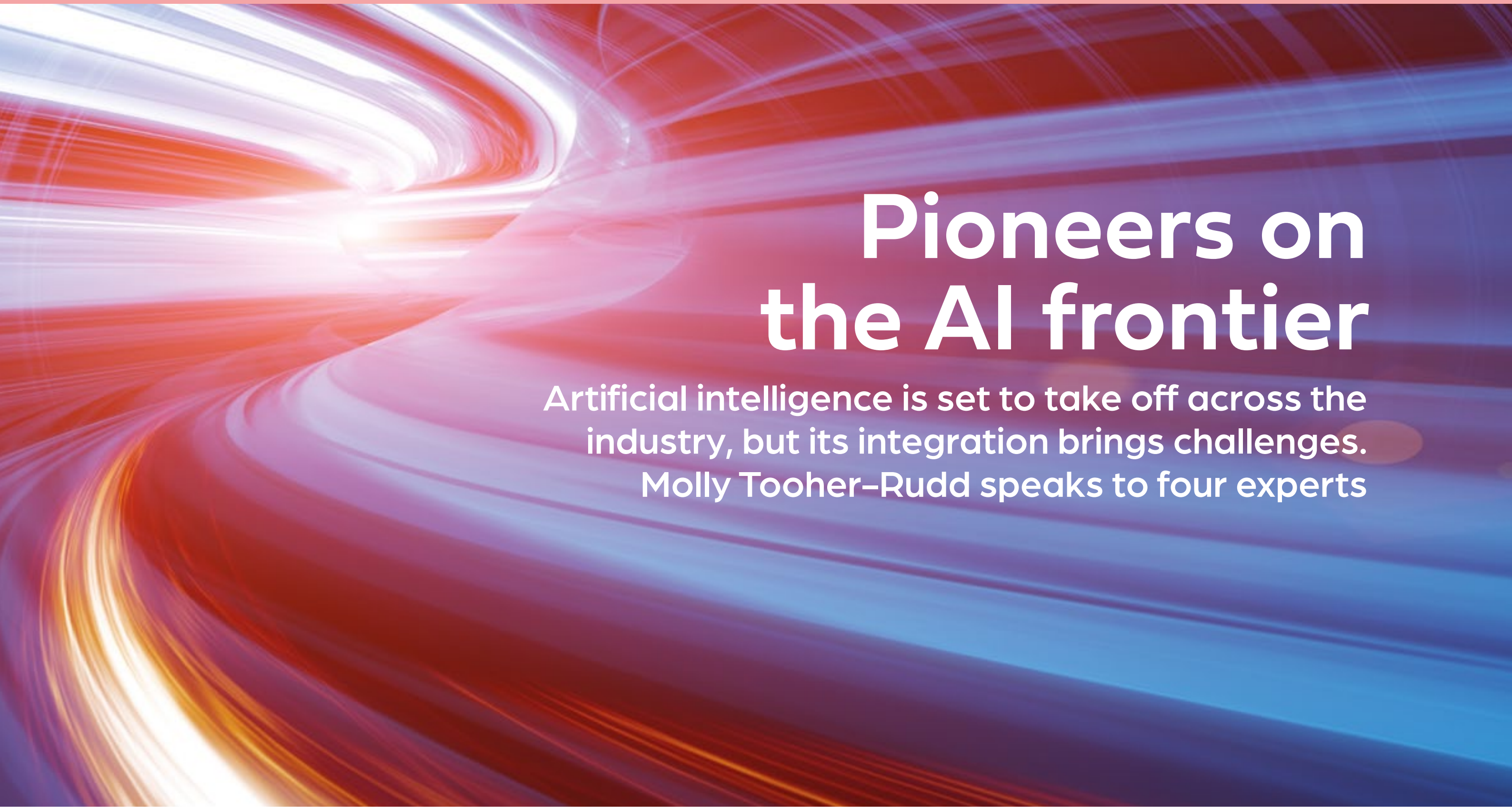
Smart buildings special

Visualising carbon in office design

Collaboration and smart ventilation

How AI is reshaping future design

Top experts at four leading consultancies dissect AI's emerging opportunities and underlying risks



Pioneers on the AI frontier

Artificial intelligence is set to take off across the industry, but its integration brings challenges. Molly Tooher-Rudd speaks to four experts

The use of artificial intelligence (AI) has been catapulted into the mainstream, and its application in the building services industry is on the rise.

There is a vision of the future where AI is seamlessly integrated into every aspect of a building's function, and consultants are already exploring how it can be used to enhance the design, management and operation of building systems.

However, the rise of AI brings its own set of challenges and complexities, particularly around data security, system integration, regulatory compliance, and reliability and accuracy. In response, regulatory frameworks are being developed to ensure integration is safe and ethical.

While some countries, such as the US and UK, are taking a sector-specific approach to regulation, the EU introduced the Artificial Intelligence Act in June 2023, which addresses critical issues such as data protection, data usage and transparency.

Cementing AI into building services

AI is already applied in many areas relating to building services such as: energy management and optimisation; predictive maintenance; building automation; occupant comfort; design and planning; security and surveillance; and emergency response and safety.

> **"While AI provides many great opportunities, there is the potential for unknown risk."**

Arup global automation leader, director and Fellow Michael Beaven, says Arup has been using AI and machine learning (ML) for many years, including developing a tool telling engineers how significant cracks are in tunnel walls.

Beaven says the use of AI has now become endemic, because the interface with the technology is now easier for everyone to understand. 'Previously, the barrier to entry was high, but now people can use ChatGPT to write code,' he says. Arup is leveraging ML to expedite problem solving, says Beaven. In a major commercial project in London, he says replacing traditional energy analysis models with regression-based AI slashed computation time. 'What would have taken 18 months on a laptop, or four weeks in the cloud, takes just seven seconds,' he says.

Foster + Partners began exploring ML in 2018 to understand how the integration of neural networks can help predictive models generate solutions easily. Martha Tsigkari, senior partner, and head of applied research and development, says it was able to predict deformation of passive materials under thermal conditions.

By analysing laminate layering, Foster + Partners reverse-engineered a process to train models to predict deformation patterns. This generative design approach, using distributed computing to run thousands of calculations, allows scalable applications such as designing a façade that deforms to create shading when its heated.

May Winfield, global director of commercial, legal and digital risk at Buro Happold, says AI allows the analysis of huge amounts of data generated by smart buildings. 'We can feed data into an AI model and ask it questions. Some of the options could be ridiculous, but it will spark new ideas.'

A key benefit of AI, she says, is automating boring and repetitive tasks, allowing designers to add value elsewhere: 'It allows our engineers to do the amazing creative work they do best.'

Several companies have launched

their own in-house large language models (AI-based programs such as ChatGPT). Tsigkari says such a program called 'Ask Foster and Partners', allows engineers to access the company's large archive using simple text questions.

'One of the challenges of AI is that lots of good, organised data is required to train a system to predict things well,' says Gavin Bonner, head of data and digital at Cundall. 'AI is more specific than automation. It needs a data source that it reads and learns from, and then applies new context or new content based on that material,' he explains.

Bonner says Cundall has built a cloud Lakehouse environment, which combines the benefits of large repositories of raw data with organised sets of structured data. The aim is to set the company up for effective ML across several disciplines.

While the computational power of AI promises to revolutionise the way buildings are designed, it comes at an environmental cost. The power needed to sustain AI is vast and growing; the International Energy Agency has estimated that electricity consumption associated with data centres, AI and cryptocurrency will grow from 2% of global energy use in 2022 to 4% by 2026.

Winfield says data centres need to become more efficient to handle the surge in demand that AI brings.

Cost is another barrier to adoption, says Bonner, pointing out that the deployment of AI systems requires substantial expenditure in data collection, storage, and analysis.

Winfield is concerned by the trajectory of AI if it is left unchecked. 'With anything new and shiny, people tend to run at it head-first. But while AI provides many opportunities, there is the potential for unknown risk,' she says.

Winfield believes large language models such as ChatGPT have scraped huge amounts of data from the internet, so there is the potential inadvertently to plagiarise designs or ideas. 'There is a huge issue around copyright that companies must navigate,' she says.

Confidentiality is another issue. Many building services firms work on unique, confidential projects. Feeding sensitive data into public AI systems could lead to breaches of confidentiality, with proprietary designs or models inadvertently exposed to competitors.

There are also safety elements to consider, says Bonner. 'If you're using an AI system to optimise an MEP design that's related to safety, fire, structural design, it opens you up for a lot of scrutiny and you must be very transparent in the way that you are developing AI applications,' he says.

'If you ask the AI chatbot a question about your building, are you going to trust the answer? What if something goes wrong and there's a massive leak in the building; whose fault is that? It's an issue people are currently wrestling with.'

Beaven stresses that engineers are responsible for the AI output. 'No matter where it comes from, it must always be checked,' he says.

Bonner says the EU AI act will help minimise risks. 'There's a lot you must comply with to ensure systems meet the requirements of the law,' he says.

The Act requires that AI systems deemed high risk, such as critical infrastructure, meet multiple requirements and undergo a conformity assessment. Bonner says Cundall is ensuring AI processes comply with the act, which could be adopted elsewhere.

The rise of AI necessitates a new skill set, which firms must address. However, Bonner says the accessibility of AI through 'low-code and no-code platforms' like ChatGPT will enable a broader range of professionals to use AI.

The future

The industry experts don't expect AI to replace building services engineers; the human element remains indispensable. Winfield says that AI's strength lies in its ability to repeat patterns, but it cannot understand concepts or capture the nuances of human creativity.

'Our AI strategy board analyses where the technology can benefit our business. At the moment ,we're looking at quick wins that can allow our engineers to do what they do best – which is the thinking and creating amazing work,' she says.

Tsigkari says AI tools should become facilitators rather than replacements of creative processes. 'As with all disruptive technologies, AI can help us rethink everything that we have been taking for granted and effectively innovate in a new way.'

Beaven says engineers have to learn to drive the machine. 'We need to be clear on what measures we give AI and who says it's of real benefit for people. We need to interpret that ourselves. It can't be the machine,' he says. ●

Artificial intelligence glossary

Artificial intelligence: the simulation of human intelligence in machines that are programmed to think, learn, and make decisions

Machine learning (ML): a subset of AI that involves algorithms learning from, and making predictions or decisions based on data

Neural networks: a series of algorithms that mimic the operations of a human brain to recognise patterns and solve problems

Deep learning: a subset of ML involving neural networks with many layers, enabling the analysis of complex patterns in data

Generative design: an iterative design process that uses algorithms to generate a wide range of design solutions based on set parameters.

Visualising whole life carbon

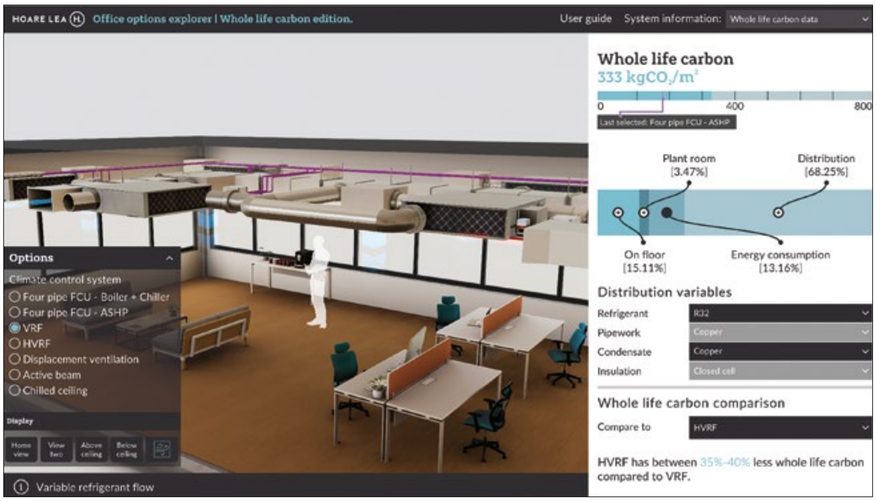
Hoare Lea's early-stage selection tool calculates whole life carbon for HVAC systems, while providing 3D visualisations for each specification. **Esam Elsarrag** demonstrates the software by assessing the performance of seven different systems

Heating, ventilation and air conditioning (HVAC) systems are crucial for indoor comfort, but are also significant contributors to a building's carbon footprint. The growing emphasis on sustainability in building design has highlighted the need for comprehensive whole life carbon (WLC) analysis in HVAC systems.

The drive towards net zero carbon buildings necessitates innovative tools that can assess and visualise the WLC impact of various HVAC systems. This article presents a 3D visualisation tool based on a framework for early-stage selection of HVAC systems, focusing on minimising embodied and operational carbon emissions. The tool aims to support decision-making in the early stages of building design, aligning with net zero carbon goals.

The concept of whole life carbon includes all greenhouse gas (GHG) emissions throughout the entire life-cycle of a building, covering operational and embodied carbon emissions. Embodied carbon emissions pertain to GHG emissions resulting from the manufacture, transportation, maintenance, and disposal of buildings, while operational carbon emissions indicate GHG emissions associated with the day-to-day operation of a building. CIBSE TM65 documents embodied carbon emissions for MEP systems and has a standardised methodology for assessing embodied carbon for products that are lacking Environmental Product Declarations.

The relationship between embodied carbon and operational carbon will evolve significantly as demand-side electrification progresses. This change is expected because of anticipated improvements in power generation efficiency, driven by a greater reliance on renewable sources, which should reduce the carbon emissions associated with electricity generation. Additionally, European Union regulations and standards intend to phase out the use of refrigerants with high global warming potential (GWP).



Visualisation of VRF option for an office

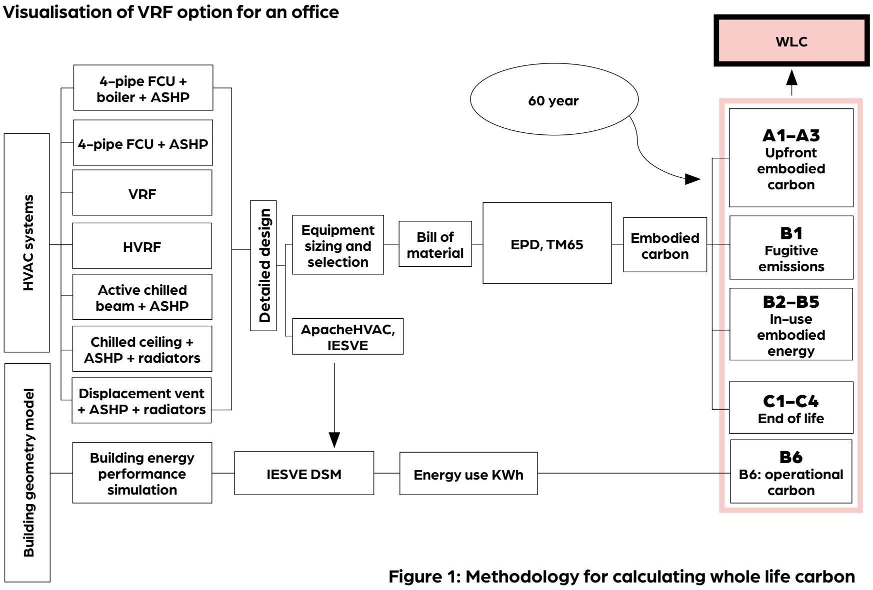


Figure 1: Methodology for calculating whole life carbon

In the early design stages, HVAC engineers face the challenge of limited data, particularly regarding the carbon footprint of HVAC equipment and materials. Making informed decisions at this stage can influence a building's long-term environmental impact significantly.

The rapid pace of technological advancements further complicates the selection process, making it essential to integrate innovative benchmarking solutions and interdisciplinary collaboration. Figure 1 shows the framework used to incorporate data for the visualisation tool.

Comparative analysis of HVAC systems via visualisation

The digital visualisation tool incorporates several essential features to address the challenges of whole life carbon analysis in HVAC systems. First,

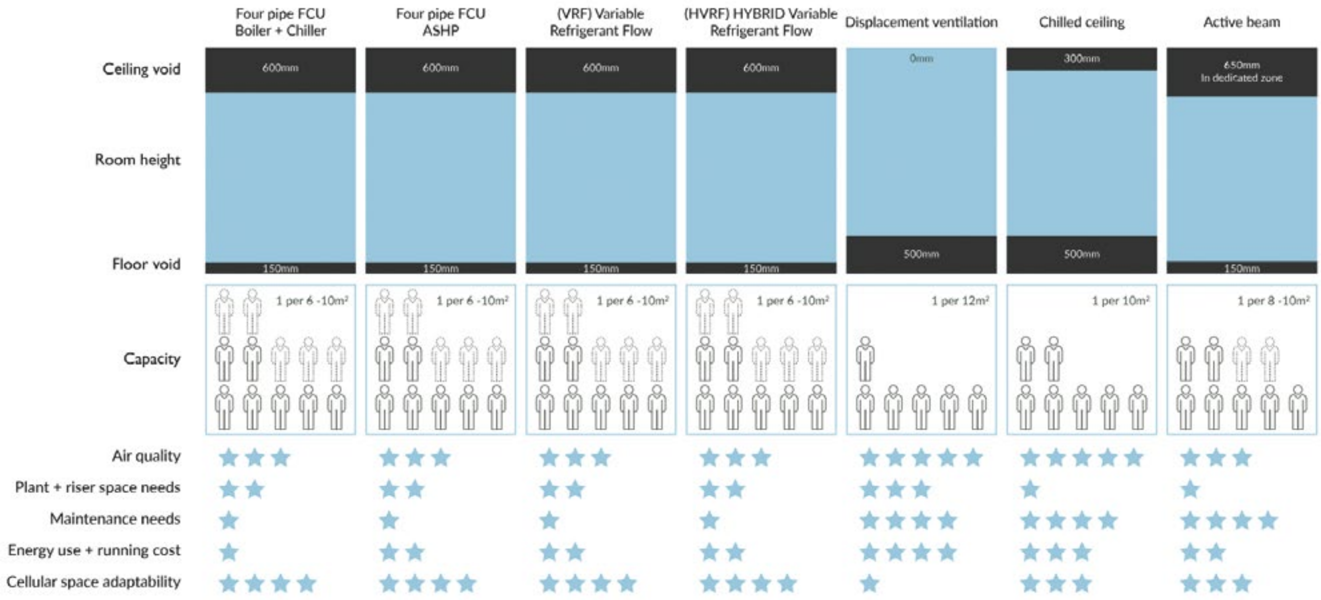


Figure 2: Sample showing whole life carbon calculated for seven systems

it integrates normalised data on embodied and operational carbon emissions, offering a comprehensive view of each HVAC system's whole life carbon impact. This data is sourced from standardised databases and industry benchmarks, to ensure its accuracy and reliability.

Second, the tool includes interactive HVAC systems' performance, energy consumption and WLC comparison, and visualisation of the system in 3D, using different material selections.

These schematics allow users to engage with visual representations of system components and their associated carbon impacts, aiding in understanding the consequences of various design choices.

Third, the tool's comparative analysis capability enables users to evaluate multiple HVAC systems across various criteria, taking into account different material selections for major components that may provide variations in embodied carbon for the selected system. This feature is particularly valuable for making informed decisions aimed at achieving net zero carbon goals.

Finally, the tool is designed with a user-friendly interface. It guides users through complex datasets and offers clear visualisations, making the information accessible to both technical and non-technical users.

The visualisation tool in Figure 2 show seven climate-control systems offering different material options and configurations. See panel 'Summary of system options' for an outline of each.

Each system's design flexibility allows for tailored solutions that can be adapted to specific building needs and material preferences. The digital tool provides a breakdown of comparisons between these systems.

It is worth noting that, while the visualisation tool provides comparisons on operational energy and whole life carbon breakdown, it also offers hints and guidance on associated parameters, such as air quality and thermal comfort potential.

Results

According to the tool, the gas boiler baseline scenario has the highest energy consumption, at approximately 60kWh·m^{-2}.

When comparing electrical-based systems using vapour compression, the air source heat pump-fan coil unit (ASHP-FCU) exhibits the highest energy consumption, at 44kWh·m^{-2}, while the ASHP radiator system coupled with displacement ventilation has the lowest, at around 18kWh·m^{-2}. This represents a reduction of about 60% in energy consumption compared with the ASHP-FCU system.

The active chilled beam system and passive ceiling systems also demonstrate significant advantages over variable refrigerant flow (VRF) and hybrid VRF (HVRF) systems.

In the context of embodied carbon, systems that incorporate ASHPs, such as the ASHP radiator system with displacement ventilation, demonstrate the lowest operational and embodied carbon emissions.

These findings underscore the importance of selecting HVAC systems that balance efficiency with low carbon emissions, especially in the context of refrigerant GWP and associated leakage percentages.

Although most VRF systems use R410a, it is intended in this sample to compare the potential of VRF with low-GWP refrigerants, such as R32. However, a few smaller VRF systems

"Users can evaluate multiple systems across various criteria, taking into account different material selections"

are introduced with R32, which has a lower GWP of 675kgCO_2e/kg but comes with limited capacities.

When using R32 refrigerant, additional precautions must be considered during the planning and installation of VRF systems because of its classification as 'mildly flammable'.

Figure 3 depicts the embodied carbon associated with all system components and materials, inclusive of operational energy emissions and refrigerant leakage emissions throughout their lifespan.

The baseline gas-boiler scenario has the highest WLC, at 353kg$CO_2 \cdot m^{-2}$; however, the VRF system is nearly comparable, at 335kg$CO_2 \cdot m^{-2}$. This is noteworthy given the use of a lower-GWP refrigerant.

If R410a is used in line with major market installations and commercially available systems, the VRF WLC will surpass the baseline scenario. The ASHP radiator system coupled with displacement ventilation exhibits the lowest WLC, at 112kg$CO_{2e} \cdot m^{-2}$, representing a reduction of approximately 45% in WLC compared with the ASHP-FCU, at 204kg$CO_2 \cdot m^{-2}$.

The active chilled beam system and

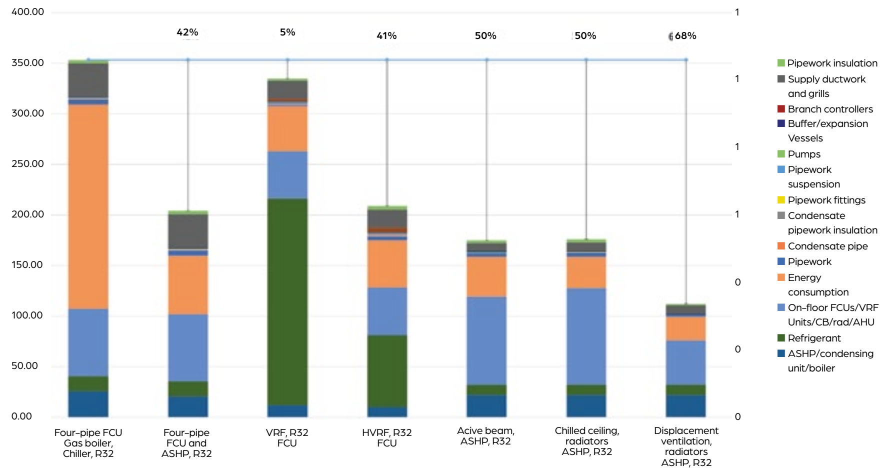


Figure 3: Whole life carbon breakdown per HVAC system, kg$CO_{2e} \cdot m^{-2}$

passive ceiling systems demonstrate comparable WLC values at 175kg$CO_2 \cdot m^{-2}$, showcasing a 15% reduction compared with ASHP-FCU and HVRF systems, and a 47% reduction compared with the VRF system.

Selecting the appropriate HVAC system within the context of WLC requires a comprehensive approach that considers embodied and operational carbon.

The rise of artificial intelligence has led to the development of advanced HVAC digital visualisation tools that are now crucial for HVAC engineers and building designers. These tools enable more sustainable decisions on climate-control systems during the early stages of building design.

By incorporating low-GWP refrigerants, efficient design strategies and advanced materials, the carbon footprint of buildings can be reduced significantly. As the industry moves towards stricter carbon-reduction targets, such holistic approaches will be essential for achieving net zero goals. ●

● **Dr Esam Elsarrag MCIBSE is a consultant at Hoare Lea**

Summary of system options

- **4-pipe FCU systems: Available with boiler and chiller, or ASHP, these systems use low-temperature hot water (LTHW) and chilled water pipes, along with fan coil units and fresh air handling systems, to manage ventilation and maintain comfort**
- **Variable refrigerant flow (VRF) systems: These employ refrigerant pipes and branch controllers for precise temperature regulation. Some VRF setups also integrate a hybrid of water and refrigerant components, known as hybrid VRF systems (HVRF).**
- **Active chilled beam system with ASHP: This system uses chilled beams and fresh air handling units to provide comfort throughout the building. All zones receive either cold water or hot water via 4-pipe units, allowing some zones to receive cold water for space cooling while others simultaneously receive hot water for space heating. The units contain an integral air supply that passes through nozzles, inducing air from the space, up through the recessed ceiling units.**
- **Chilled ceiling and radiator system with ASHP: This system provides heating and cooling for the entire building. LTHW and chilled water (CHW) pipework are distributed from the plantroom to each floor and then further conveyed at a high level on each floor plate. The LTHW pipes connect to low-temperature heating radiators, while the CHW pipes are linked to passive-chilled ceilings. The system relies on natural convection within the conditioned space.**
- **Displacement ventilation and ASHPs: These systems provide heating for the entire building. LTHW pipework is distributed from the plantroom to each floor and then further distributed within each floor. The LTHW pipes are connected to low-temperature heating radiators, and the system relies on displacement ventilation.**

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Building a sustainable future while ensuring business continuity

One of the hidden challenges for businesses aiming for sustainability is the very buildings in which they operate. Currently, buildings consume about 30% of the world's energy and account for nearly 40% of its annual CO_2 emissions. This makes the built environment a significant area to target for climate action.

However, many businesses neglect to include buildings in their sustainability goals, often fearing the disruption and potential loss of productivity that a retrofitting transformation might bring.

Retrofits or new builds?

Considering that 80% of today's buildings will still be in use in 2050, simply constructing new eco-friendly buildings isn't the solution. Many older buildings are not up to par with current environmental standards – 85% of rented non-domestic properties will not meet legal minimum energy performance levels by 2030.

Research indicates that retrofitting office buildings can cut carbon emissions by up to 70%, so this is where businesses should focus to really impact their net zero journey.

Additionally, retrofitting can improve employee comfort, health and wellbeing, improve energy efficiency and reduce bills, and meet growing demand for better green credentials.

Retrofitting will soon be legally required, with the Minimum Energy Efficiency Standard mandating better energy performance ratings. The current minimum Energy Performance Certificate rating for non-domestic properties is E, but this must improve to C by 2027 and B by 2030.

Is the fear of retrofitting unfounded?

Retrofitting doesn't need to be a disruptive rip-and-replace project. A digital-first approach can ensure business continuity while advancing sustainability goals.

Deploying digital technologies can be less disruptive and more effective from a life-cycle carbon perspective. Additionally, failing to decarbonise buildings swiftly could result in stranded assets that lose value and become unattractive to investors, making the risk of not retrofitting greater than the perceived disruption.

Developing a digital-first retrofit strategy

Digital tools are available to transform the carbon footprint of existing buildings and minimise the impact of new builds. By following three key steps – strategise, digitise and decarbonise – business leaders can ensure their buildings are future-proofed and compliant with incoming regulations.

1. Strategise: Develop a clear, achievable roadmap to reduce emissions. Define the level of implementation needed and the potential impact on emissions reduction, and account for any operational disruption. This helps assess the timescale for return on investment and gain board buy-in.
2. Digitise: Measure and monitor energy consumption and carbon emissions. Leaders need to track energy use to identify waste and gather trusted data through digitisation.
3. Decarbonise: Use smart energy management solutions, such as automation, internet of things devices, renewable energy sources, and upgraded building systems. These technologies enable businesses to reduce energy waste and costs effectively without compromising building operations.

By targeting areas with the biggest climate impact – reducing reliance on fossil fuels and minimising energy demand – leaders can create a digitally driven strategy that delivers maximum rewards with minimal disruption.

● **Download Schneider Electric's net zero buildings guide to find out more about digital-driven transformation: https://bit.ly/4fu48Dz**

Life Is On | Schneider Electric

A golden age for smarter living

As the UK's population ages and climate warming intensifies, smart technology will be essential to ensure resilient and comfortable homes, says ABB Smart Buildings' **Kevin Lenton**

The demographic makeup of the UK is rapidly changing. The United Nations forecasts that by 2043, those aged 65 years and above will account for 24% of the population.

However, another study by English Housing Survey (2020-21) found that 1.1 million older adults live in homes that do not meet the government's Decent Homes Standard, which includes efficient heating guidelines.

Indoor environments that are too cold or too hot for sustained periods present potentially serious health risks and financial implications for residents, and further strain on the NHS.

These figures highlight the urgency of providing more homes that meet the needs of an ageing population.

Smart technology has an important role to play in making housing resilient. Systems can automatically optimise comfort and energy use, and alert carers if residents need help.

The appetite for smarter homes is growing. Samsung's Smart Home Buyers Index 2024 found that 88% of respondents aged over 65 wanted a smarter home – larger than any other age category.

With ABB as one of its technology partners, Cartwright Pickard and The Helen Hamlyn Centre for Design's study, *Age-inclusive design principles: Shaping a sense of belonging in later life*, aims to develop principles for age-inclusive buildings.

It looks at the microclimate from the outside in: from orientation and design, to the technologies that can enhance the living experience.

The study outlines the importance of the local climate, such as the wind and solar conditions that can affect energy consumption, and air quality.

In city centres, it says attention should be given to mitigating the urban heat island; the Met Office says anthropogenic climate change could produce UK summers up to 6.8°C hotter in the coming decades.

In the UK, recent heatwaves such as the 40°C+ temperatures of 2022 exposed homes' lack of resilience. CIBSE now defines residential overheating as when the internal temperature threshold of 26°C is surpassed for more than 3% of the time.

Exceeding this limit can negatively affect residents' health and comfort.

Smart technologies can help manage the internal climate in a warming climate by combining automation with greater independence and control.

Technologies currently in play include PIR Sensors that can detect when a room is unoccupied and automatically switch off heating. They can also enhance safety by alerting the care team if a room that should be occupied appears empty, or is occupied and potentially overheating.

Energy Efficiency Control systems prevent the simultaneous operation of heating and cooling systems and adjust accordingly when they detect windows are open, ensuring systems are not working against each other.

Wall-mounted controllers allow older residents to operate smart home systems from convenient locations. Ease of use is provided by a connected system of sensors, smart switches, sockets, and actuators for motorised curtains, blinds, and window openers.

Compatible with Apple, Amazon, and Google assistants, voice control also simplifies the operation of home systems to programme heating times. ABB's i-bus KNX system allows easy addition of voice control through a software update.

This smart technology is already being embedded in age-inclusive designs for new developments including at Brobyholm in Sweden, which will eventually see 2,500 smart homes fitted with smart energy systems that will optimise comfort and energy use (see panel below). ●

● **Kevin Lenton is product marketing director for ABB Smart Buildings UK**

Smart-living Swedes

The Brobyholm estate by S. Property Group is a pioneering age-adaptive living development in Stockholm, with 500 homes to be completed by 2025 and a total of 2,500 planned.

Residents have access to an integrated smart home solution combining ABB-free@home and Samsung SmartThings, managed via an app or device. Each home features an energy management system that optimises energy use across appliances, lighting, cooling, heating, and blinds.

The system prioritises renewable energy for heating and cooling, reducing emissions and energy bills and optimising thermal comfort. Surplus solar energy heats water tanks, while low solar energy triggers energy-saving modes. The system adapts to residents' habits, using geo-fencing data to pre-heat or pre-cool homes.

Optimising performance with smarter ventilation

Partnerships between FMs, digital consultants and ventilation suppliers have the potential to achieve smarter systems that increase energy efficiency, while ensuring a safe and healthy indoor environment, says Breathing Buildings' **Louise McHugh**

As part of the drive towards net zero carbon, suppliers are accelerating the development of new smart products that reduce energy consumption.

Ventilation installations, for example, are now intelligently connected and controlled by sensors throughout buildings. Compatible with the building management system (BMS), the system is continually being optimised through algorithms, to ensure a healthy environment while minimising energy waste.

According to Jupiter Research, the number of smart buildings globally is expected to increase from 45 million in 2022 to 115 million in 2026. This is welcome news for facilities managers (FMs), who acknowledge the benefits of smart buildings, including improved safety and time savings.

Recognising the merits of collaboration, building services manufacturers are partnering with internet of things (IoT), FM, and health and safety (H&S) experts, and tendering for projects as one entity. The partnership between Breathing Buildings, IoT Horizon and facilities management company Thomson FM, for example, is pitching for smart modular-accommodation projects.

IoT Horizon is a smart buildings company, working with clients on everything from technology selection and installation to monitoring and data-driven decision-making, with a focus on sustainability, cost reduction and improving indoor environments.

Pooling expertise allows for greater efficiencies, with IoT experts integrating all services into one digital software platform, and multi-sensors feeding back to a dashboard. This simplifies data viewing for FMs and building owners, enabling informed business decisions. Manufacturers can provide solutions tailored to building demands, avoiding over-specification, while FM and health and safety experts ensure compliance with regulations and achieve maximum efficiencies.

"Clients generate numerous datasets, but this information is often underused"

'This collaborative approach is a real benefit as an FM,' says Mark Whittaker, general manager at Thomson FM and chair of the Institute of Workplace and Facilities Management. 'Having one digital platform, rather than multiple separate portals that are disconnected from the BMS system, streamlines the process and enhances efficiency.'

The partnership, led by IoT Horizon, is tendering for new-builds as well as energy-efficiency retrofits; analysing buildings' existing data can yield significant benefits. For instance, considering access-control data alongside temperature and CO_2 data can optimise heating and ventilation, ensuring energy is not wasted when occupancy is low.

Clients generate numerous datasets – such as BMS data and existing meter readings – but this information is often underused. 'Many smart building companies fail to adopt a holistic approach that could benefit their projects,' says Niamh Allen, managing director at IoT Horizon. 'Our approach involves collaborating with industry professionals to maximise the effective use of this data.'

A recent project for a theatre company aimed to improve energy efficiency without compromising indoor air quality (IAQ). On a single digital platform, IAQ data was linked to the ventilation system to ensure safe CO_2 levels were achieved without over-ventilation, and temperature sensors triggered higher ventilation rates during performances.

As buildings become more airtight and thermally efficient, IAQ becomes increasingly important. Efficient buildings must also provide a healthy workplace environment. Remote monitoring of indoor conditions allows tasks to be performed without an onsite engineer, which helps address the shortage of skilled FM engineers.

Smart buildings and sophisticated remote-monitoring technology can also help streamline health and safety demands. The Building Safety Act has increased the value of data and the need to evidence compliance. 'The ability to evidence tasks is critical,' says Whittaker. 'A common platform to access data easily and demonstrate compliance is essential.' ●

● **Louise McHugh is a product manager at Breathing Buildings**