ASITE™

SMART RETROFITTING

The Key to Decarbonizing the Built Environment

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INTRO

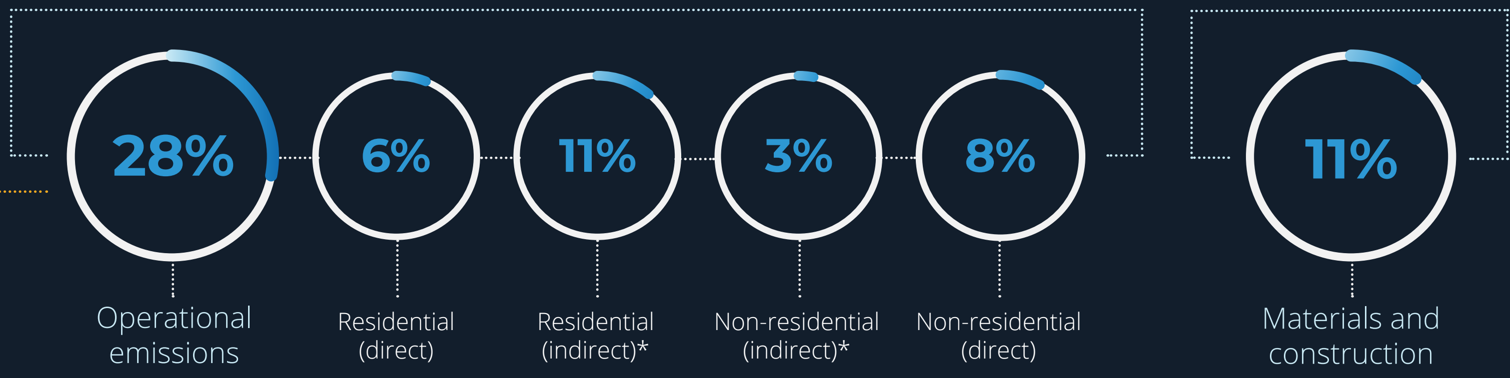
Climate change is the most pressing issue of our lifetime.

The global warming of the planet, caused by carbon pollution, has resulted in an ever-growing need to invoke action for climate change mitigation. The awakening of our society to the need for action for climate change has been the driving force behind a multitude of global initiatives and agreements focused on decarbonization.

*The most prominent of these is the **Paris Agreement**, which has the overall aim of **limiting the global temperature increase this century to within 2 degrees Celsius** above pre-industrial levels while pursuing means to limit the increase to 1.5 degrees.*

The importance of the existing building stock in delivering these goals alongside the UN Sustainable Development Goals, which place focus on sustainable cities and communities as well as climate action, is paramount.

Buildings, both in their operation and construction, currently account for the largest share **(39%)** of global energy-related carbon emissions.



*Indirect emissions are emissions from power generation for electricity and commercial heat[1]

With 80% of the homes that people will inhabit in 2050 already built[2] and up to 75% of today's buildings expected to still be in use by 2050[3], priority must be placed on retrofitting existing buildings, both residential and commercial, at scale to meet energy-saving targets. Simply put, our climate goals cannot be reached without upgrading the existing building stock.

This report examines how the construction industry can mitigate carbon emissions through the smart retrofitting of built assets, with a particular focus on residential and commercial buildings. Through a broad analysis of the deployment of technological solutions in this area, this report provides insight into the burgeoning role of digital twins in the industry's journey to net-zero.

Message from the

CEO

NATHAN DOUGHTY **ASITE CEO**

The time for debate on global warming and climate change is past. Extreme weather conditions have become increasingly commonplace around the world, and those most vulnerable are already the worst affected. What is at stake is our continued cohabitation on this shared planet Earth.

Now is a time for action.

The Paris Agreement was an incredible achievement and a landmark feat for the global community, but it was simply a starting gun and we are short on time. As noted by Lord Deben, Chairman of the UK's independent Committee on Climate Change, our 2050 net zero date is not a date invented by us for our convenience. It is the latest possible date that we must reach that target, and still have some chance of controlling the devastating effects of climate change.

Our common built environment is much more than just bricks, mortar, and feats of engineering. It is also the people, societies, and whole industries which make the structures around us a living part of our biosphere – literally an extension of the Earth. Like any extension, our built environment needs to play well with its host structure or end up being rejected in the long term – along with its occupants! The relationship between our planet and the built environment must be treated as symbiotic.

The industries central to delivering and maintaining our built environment: architecture, engineering & construction, property management, facilities and asset management, and, (yes!) technology, software, and manufacturing have a huge role to play in the advancement of net zero carbon goals and are crucial to our future.

This report examines the challenges before us all and dives into how digital transformation and digital engineering will help us work together to achieve a resilient and sustainable built environment – for everything already built and everything we build next.

"Digital transformation and digital engineering will help us work together to achieve a resilient and sustainable built environment."

RETROFITTING:

A GLOBAL EFFORT

In response to the Paris Agreement, an increasing number of governments are introducing national strategies, setting out their commitments to a carbon neutral future. While these policies point regions in the right direction, there is more to be done.

MEGACITY PARTNERSHIPS

We are also seeing individual cities make commitments beyond those made at a national level.

C40 is a network of 97 megacities, representing over 700 million citizens and one-quarter of the global economy, committed to delivering the goals of the Paris Agreement at a local level.[4] Nineteen members of the coalition, including London, Tokyo, and Johannesburg, have already committed to net zero carbon new buildings by 2030.

The World Green Building Council's 'Build Upon' project is comprised of eight European partner cities working to help cities lead the charge towards net zero carbon by 2050. The project aims to unlock the vast potential of buildings by developing strategies and solutions to scale up energy-efficient building renovation.[5]

UNITED KINGDOM

In June 2019, the UK Government became the first major economy in the world to pass laws to end its contribution to global warming, requiring the UK to bring all greenhouse gas emissions to net zero by 2050.[6]

However, as of March 2020, nearly two-thirds of UK homes are still failing to meet long-term energy efficiency targets. On this, Dr. Tim Forman, a research academic at the University of Cambridge's Centre for Sustainable Development, stated that now only a national project of scale would be enough to help the UK meet its 2050 net zero carbon target.[7]

EUROPEAN UNION

The European Commission is working towards a union-wide net zero emissions target as part of its European Green Deal, which seeks to achieve a climate neutral economy by 2050. Several targets in the deal directly impact the construction industry, with circular economy and building renovation flagship elements.

Specifically, the strategy suggests the current renovation rate of Europe's building stock must almost double to meet energy efficiency and climate targets – likely requiring more stringent legislation.[8]

INDIA

In its commitment to the Paris Agreement, India pledged to reduce the emission intensity of its gross domestic product (GHG emissions per unit GDP) by at least a third, compared to 2005 levels, by 2030.

India is expected to become the most populous country in the world by 2027. However, as 75% of the buildings expected to exist in India in 2030 have not been built, India's focus needs to be placed on avoiding the carbon lock-in associated with new buildings, and build sustainably.[9]

USA

Despite withdrawing from the Paris Agreement, net zero emission targets remain a focal discussion in the United States. To date, 10 US states and 291 cities and counties, as well as hundreds of American businesses and universities, have pledged to uphold the Paris Agreement and commit to a clean energy economy. The "We're Still In" movement represents over 159 million Americans and over $9.46 Trillion in GDP. President-Elect Biden promises to sign the USA back up to the Paris Agreement on his first day in office on 20th January, 2021.

In the US, buildings are responsible for 27% of national emissions.[10] While retrofitting existing building stock is noted as a way to increase the efficiency of existing buildings, a formal nationwide policy is needed to achieve global goals.

UNITED ARAB EMIRATES

Party to the Paris Agreement, the UAE monitors the emission of gases that lead to the greenhouse effect and has reduced its per capita carbon emissions, seeing CO_2 emissions per person per year reduce from 32.6 tons in 1990 to 21.9 tons in 2010.[11] The UAE Clean Energy Strategy 2050, states that new buildings in the UAE should be net zero carbon structures by 2030 and existing buildings should reach that level by 2050.

Retrofitting under-construction, newly-constructed, and existing buildings has already been suggested as a way to reach this target.[12]

AUSTRALIA

Responding to the Paris Agreement, Australia introduced its first Nationally Determined Contribution (NDC), pledging an economy-wide target to reduce greenhouse gas emissions by 26%-28% below 2005 levels by 2030.

Buildings – their construction, operation, and maintenance – in Australia still account for almost one-quarter of the country's carbon emissions. Evidently, the current mandatory minimum requirements for energy efficiency are not enough.[13]

In October 2019, the Green Building Council and Property Council launched a policy toolkit, urging governments to adopt practical plans to reduce emissions in the building sector, noting the need for targeted action to meet Australia's global commitments.

ADDRESSING EXISTING BUILDINGS

While climate change is undoubtedly a global issue, the journey towards decarbonization must take into consideration regional disparities.

In developing countries, more than half of the building stock needed by 2050 has yet to be built, lessening their retrofit needs. For this reason, the onus of addressing energy consumption and greenhouse gas emissions related to the built environment lies with developed nations where much of the future building stock is already in place.

UNDERPERFORMING BUILDINGS

As noted, 80% of today's buildings will still be in use in 2050; however, 75% of this stock is energy inefficient[14], with the majority of buildings predating modern energy standards.

In Europe, many buildings are over 100 years old. 68% of the dwellings were built before the 1980s when most EU countries introduced energy building regulations.

In the United States, of over 135 million dwellings, 59% were constructed before the 1980s and over 76% before 1989. This predates the widespread adoption of model energy codes governing construction. Similar trends are also observed for US commercial buildings, with about 54% constructed pre-1980 and 71% pre-1989.[15]

These older buildings contribute to exceptionally high energy demands and high levels of greenhouse gases, most of which can be attributed to the burning of fossil fuels for space and water heating and the generation of electricity.

Therefore, to reach zero emissions in the most cost-effective and practical way, it's crucial that we also lower energy demand (and thus, power generation).[16]

Correspondingly, we also need to address energy inefficiency – the Electric Power Research Institute reports energy and energy-related expenditures cost US companies $800 billion annually, and roughly 42% of the energy used to heat and cool space is wasted.[17]

Accelerating efficiency retrofits will ensure that our future building stock is suitable for a zero-carbon economy.

CLIMATE RESILIENCE

Much of the existing building stock is not well adapted for present or future climates. While much of the wider conversation is future-looking, we must also address current climate-related challenges such as higher temperatures and flooding.

Indoor air quality, relating to a wide variety of pollutants, is also a key concern. While the industry has the capacity and technology to support high thermal efficiency (warm in winter and cool in summer), safe moisture levels, and excellent indoor air quality, an integrated approach to design, build and retrofit is needed.[18] This pertains to both residential and commercial buildings.

INEFFECTIVE BUILDING CODES

As noted, there are already several mandatory legal acts and a variety of legislative guidelines that support efforts to improve the energy performance of existing buildings.[19]

Historically, the scope of building energy codes in developed economies only focused on new residential buildings. The scope was progressively expanded to include new non-residential buildings and, more recently, to cover existing buildings undergoing renovation or alterations.[20]

However, it is clear that these are either not stringent enough or are just generally ineffective.

Among the world's largest and most advanced countries, not a single one will achieve the mission of the Paris Agreement under their current trajectory.[21]

In the EU, for example, rates of retrofitting are currently very low; the 1% annual rate of reduction of the (domestic and non-domestic) building stock's primary energy consumption sits way below what is needed.[22]

BARRIERS TO OVERCOME

Despite increased awareness surrounding energy inefficiencies, the low uptake of decarbonization and retrofit activities can be attributed to several barriers.

While these obstacles range in complexity from country to country, this report focuses on three dominant barriers which, while some progress has been made to overcome, still require additional and immediate action.

FINANCE

The initial investment required to retrofit a building successfully is high, with the deep retrofit of a home costing, on average, between £30,000 and £50,000.[23]

For commercial buildings, the costs are even higher. Despite long-term savings, the return on investment (ROI) is often not as immediate as desired, with it often being a cumulative process over many years. This is in sharp contrast to owners' expectations to see ROI within three to seven years.[24]

Moreover, financial institutions remain reluctant to invest due to unfamiliarity with the technologies, regulatory risk, short investment horizons, high transaction costs, and a lack of suitable finance mechanisms.[25]

While some regions have implemented financial incentives and funding models to increase uptake, in many cases, these are not enough. Sustainable finance methods are vital to delivering retrofits at scale.

SUPPLY CHAIN CAPACITY

In a survey by the UK National Housing Federation, 34% of respondents named a lack of capacity and capability in supply chains as a principal obstacle to retrofitting.[26]

Due to the erratic and low demand, the supply chain currently does not have the capacity to complete the widescale retrofitting required to meet global targets.[27]

This is widely attributed to the shortage of knowledge and skills required to deliver often bespoke solutions. To successfully reduce the carbon output of a building, a coordinated approach is needed between those involved in retrofitting.

However, the industry is often characterized by its fragmentation. This results in poor use of resources and inefficient building performance.[28] Increased awareness and upskilling across the supply chain are required.

THE DISRUPTION FACTOR

When considering residential and commercial buildings, retrofitting is often undertaken in conjunction with a building's routine operation, which raises a number of logistical and technical obstacles. The "disruption factor" refers to the disturbances linked to refurbishment work, which can impact a resident or building owner's decision to renovate.[29]

For homes, an incremental approach is argued to be most effective. This allows a home to be upgraded over time while inhabited and also helps to incorporate the inhabitants' everyday practices into the planning of the retrofitting.[30]

For commercial buildings, retrofitting is often required to occur during quiet periods and within a quicker timeframe to minimize disturbances.

Speaking at the 'Construction News Decarbonising Construction 2020' conference, Sonal Jain, Sustainability Director at JLL, spoke about her company's recent refurbishment of the Empire State Building in New York, noting how the company had to work around the buildings operational schedule to achieve its goals.

A total of

6,541

windows were retrofitted at night, with the assembly line working within the building to save time.

Sustainability and efficiency were implemented in every part of retrofitting, resulting in a

38%

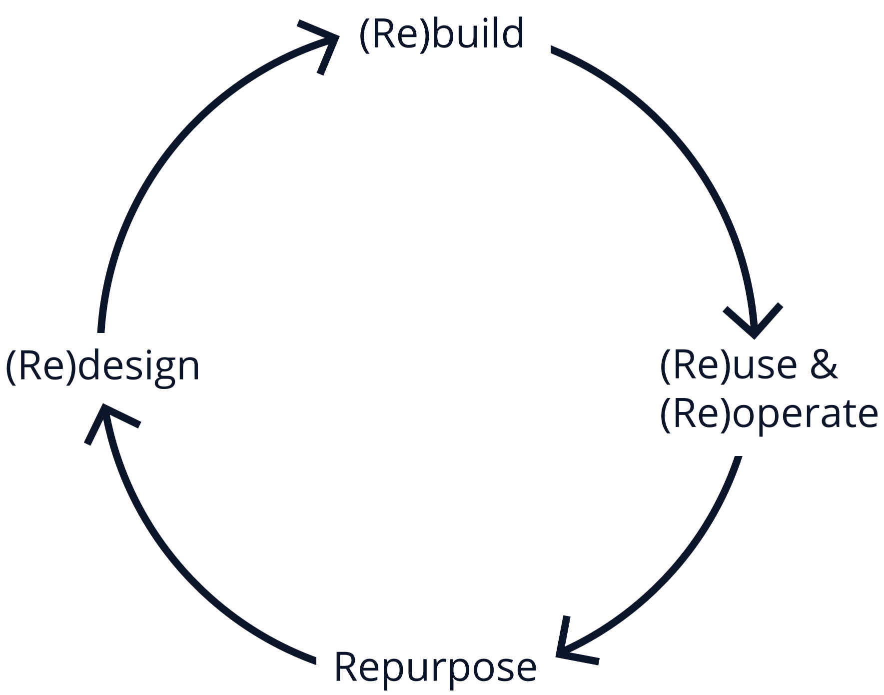
reduction in energy consumption.

TRANSFORMATIVE TECHNOLOGIES

Digital engineering, including the tools and processes that it encompasses, could bolster our efforts to reduce carbon emissions and overcome existing obstacles.

Moreover, these technologies allow for greater network interconnectedness among regions, which is imperative to a global approach.

CIRCULAR ECONOMY



A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems to bring clear environmental, social, and economic benefits.[31] These principles, which enable a restorative and regenerative built environment, also drive retrofitting programs.

The EU-funded BAMB (Buildings as Material Banks) project works to enable the shift to a circular building sector by championing the repair, reuse, and recovery of building materials and components. The BAMB Circular Building Assessment (CBA) is a methodology that compares and assesses product and material resource flow during the lifetime of a built asset and beyond; this also includes extending the life of buildings through increased adaptability and flexibility.[32]

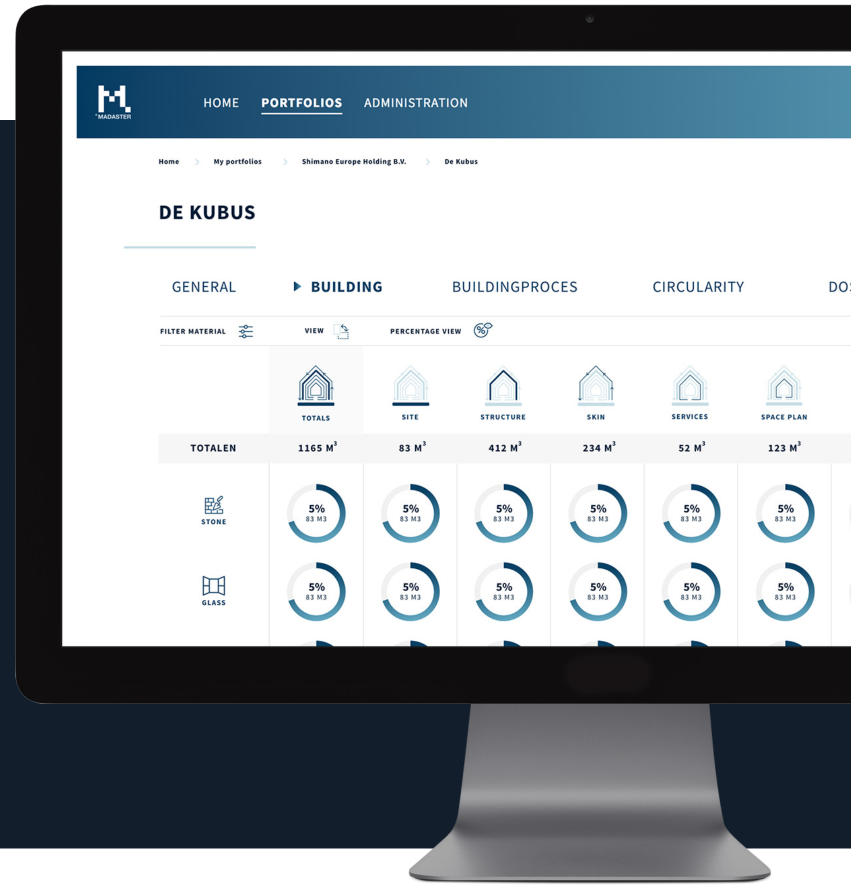
The method is being developed into a prototype BIM-compatible software product that can access data from BIM/CAD models combined with BAMB-generated datasets, and other external or user-supplied data, to provide an assessment of reuse potential[33], transformation capacity, resource productivity, and energy performance.

MATERIAL PASSPORTS

To establish long-term circularity in the built environment, we need quality, open ingredient data on what materials are in a building. Material passports are qualitative and quantitative documentation of the material composition of a building, showing their recycling potential and environmental impact.[34] Creating value through recovery and reuse is a key part of the retrofit process, and this requires that information is easily accessible – material passports offer an effective tracking mechanism.

To support this, computational technologies, such as BIM and Geographical Information Systems (GIS), allow for the modeling and analysis of building stock, in terms of material composition and the creation of a public material register. BIM-based material passports can support the optimization of the retrofitting process. BIM offers a knowledge base for geometry and material properties as well as coupling to further databases for assessment of eco-indicators and recycling potentials.[35]

Dutch non-profit organization, Madaster, is focused on realizing the concept of the material passport in the industry. Their mission is to provide designers and others along the construction chain with the means to upload BIM data on a building to a platform that will automatically generate a material passport describing the materials in each layer of the building and how easy it is to retrieve them.[36] Such an inventory, if deployed on the current building stock, would greatly expedite the retrofit process.

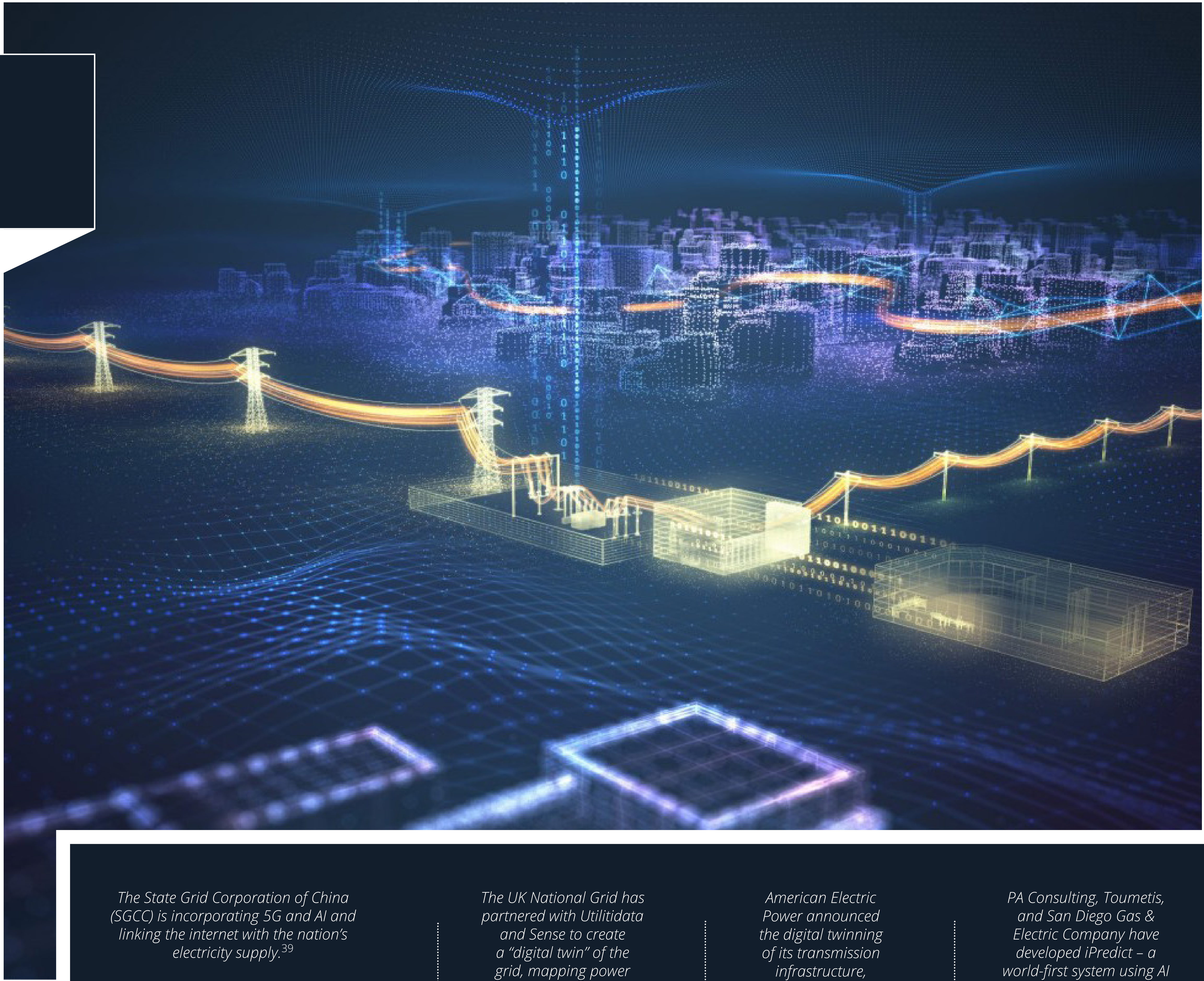


SMART GRID INTEGRATION

As it stands, existing power grids are insufficient when it comes to energy efficiency, reliability, security, or the integration of renewable energy to meet our net zero goals. With little change over the last decade, the deployment of low-carbon technologies will result in less predictable electricity production, changing load patterns, and a need to enable electricity flow in both directions. Therefore, new flexible ways of balancing supply and consumption are required.[37]

They are fitted with information and communications technologies (ICTs), including sensors, in-home smart meters, and automation systems, to the electricity network to enable real-time, two-way communication between suppliers and consumers. This creates a more dynamic interaction on energy flow, which will help deliver electricity more efficiently and sustainably.[38] Here, connected buildings become both receivers and energy distributors, enabling end-user energy management.

Connecting the existing building stock to integrated infrastructure, supported by intelligent technology, has a key role to play in handling rapid urbanization, reducing our environmental impact, and "future-proofing" our societies beyond our 2050 targets.



The State Grid Corporation of China (SGCC) is incorporating 5G and AI and linking the internet with the nation's electricity supply.[39]

This so-called "energy internet" offers a new energy model, ensuring a cleaner and more efficient use of energy.[40]

The UK National Grid has partnered with Utilitidata and Sense to create a "digital twin" of the grid, mapping power flow, voltage, and infrastructure from the substation to the home.

American Electric Power announced the digital twinning of its transmission infrastructure, developed in collaboration with Siemens (pictured).

PA Consulting, Toumetis, and San Diego Gas & Electric Company have developed iPredict – a world-first system using AI to prevent power outages by predicting asset failures weeks in advance.[41]

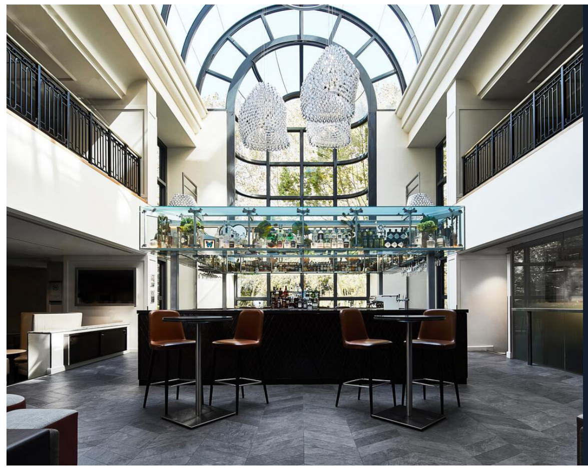
SMART BUILDINGS

Smart buildings use a range of technologies, such as sensors and actuators, to gather activity data on elements within a building that can then be analyzed and measured to produce useable insights[42] to automate various processes, such as HVAC systems.

Critically, these systems and devices are connected and "talk" to each other as well as a central system to make the building more efficient, reducing its environmental impact. The collection of status, automation, and actionable data means that issues are quickly detected and addressed.

Cloud computing alongside affordable Internet of Things (IoT) technology, like real-time data and analytics software, submetering, and wireless sensors[43], have made building-automation systems economically viable for a wider range of organizations.[44] Thus, overcoming many of the financial barriers associated with retrofitting older buildings.

Furthermore, every building type and nearly all historic buildings can benefit from smart systems and management platforms.



Renowned Sydney hotel, Sheraton Grand Sydney Hyde Park upgraded its backend systems to reduce its environmental footprint and energy consumption while improving the hotel's overall energy efficiency. From sensors to services, by connecting everything through one IP backbone, various management systems are integrated to leverage digitization and Big Data.[45]

According to the McGraw Hill Construction SmartMarket Report, intelligent buildings use

20-40%

less energy and result in

8-9%

lower operating expenses with valuations

7.5%

higher than those with older systems.

DIGITAL TWINS

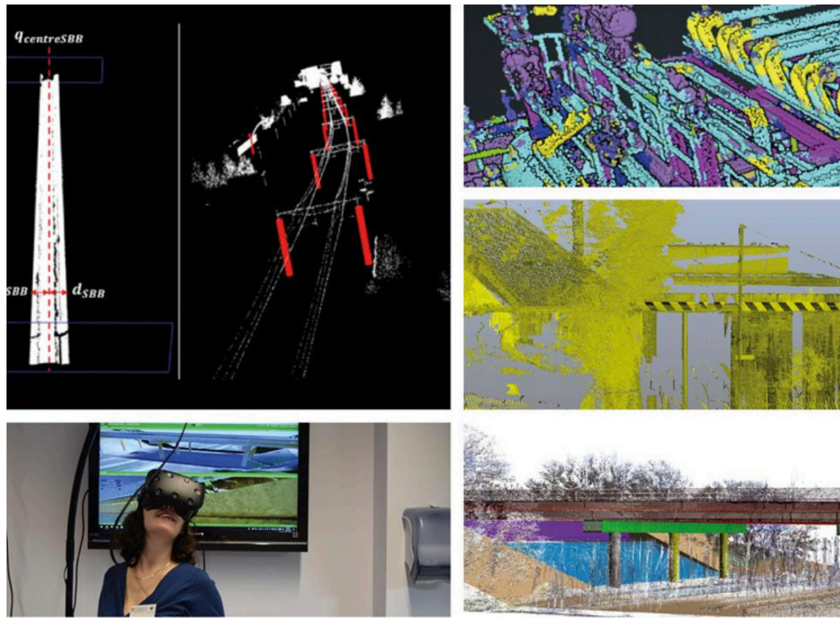
The consolidation of the physical and digital world and move to turn our everyday data into value is most prevalent in digital twins – that is, the digital representation of an asset, process, or system.

IoT technologies provide us access to a constant stream of real-time operational data. This, alongside AI and analytical software supported by cloud infrastructure, has put us in a position to transform this data into actionable insights in the form of perception, prediction, recommendations, and simulation.[46]

A calibrated model can be created through the interrogation of data from the built asset, which is used to determine the appropriate inputs for a simulation model that, in turn, is compared to measured sensor and meter data. This calibrated model then becomes a digital asset. In the case of retrofitting, digital twins enable the retrospective analysis of existing structures to deliver necessary transformation.

Optimization is a key driver of sustainability and resource efficiency, and this is where digital twins excel.[47] By helping to visualize the invisible, digital twins ensure that past projects meet future goals.

The Laing O'Rourke Centre for Construction Engineering and Technology's Construction Information Lab Group, in association with Cambridge University, has received funding to enhance building progress monitoring and quality control through Digital Building Twins. Titled "BIM2TWIN: Optimal Construction Management & Production Control", the project aims to build a Digital Building Twin (DBT) platform for construction management that implements lean principles to reduce operational waste of all kinds, shorten schedules, reduce carbon footprint and costs, and enhance quality and safety.[48]



A selection of research from the Construction Information Technology Laboratory.

THE FUTURE OF RETROFITTING

As a holistic monitoring tool for tracking an asset in real-time, this report concludes that digital twins offer the most comprehensive resource for retrofitting at scale. A sophisticated amalgamation of multiple technologies, they integrate data from a number of sources, providing an understanding of real-world conditions, such as energy flows, environmental conditions, and material attributes.[49]

IDENTIFYING INEFFICIENCIES

In the UK, the Institution of Civil Engineers is touting digital twins as key to achieving net zero emissions by 2050 due to their ability to enhance our understanding of a physical asset and identify inefficiencies within a building to support retrofitting.[50] Through the interrogation of real-time data and information received from sensors, the virtual replica can identify areas where energy is being wasted.

The widespread adoption of digital twins could, therefore, transform global retrofitting programs and actively contribute towards achieving both our decarbonization targets and UN Sustainable Development Goals (SDGs).

TRACKING & PREDICTING

Data regarding the individual components within a building over its lifecycle is tracked, stored, and referenced by the digital twin, allowing for predictions regarding maintenance and how materials will operate under different conditions to support resilience.

According to a US Department of Energy study, maintenance techniques targeting energy efficiency can result in up to 20% savings annually.[51] Predictive maintenance enables building stakeholders to anticipate material failure and pre-emptively arrange for the component to be updated.

In an existing asset, changes can be tracked to datasets within the building as they occur, including refurbishments, new installations, and change of ownership, ensuring data validity when renovating and updating the building.[52]

THE HUMAN ASPECT

To optimize decision making during the retrofitting process, the activity of the occupants need to be considered. Although energy inefficiency and waste can be attributed to the lack of standards during construction, people also play a key role.

A digital twin can monitor human interaction with an asset and derive value from the real-time data fed into the model from an integrated mix of IoT technologies, including sensors and trackers. This information can then be utilized to inform the retrofitting process and determine how the building can operate more sustainably.

LONG-TERM SUSTAINABILITY

A digital twin offers long-term purpose and value to the sustainability of the built environment, even beyond the attainment of our global 2050 goals.

For one, the tracking of materials and their properties enables a more sustainable and circular approach to construction, allowing materials to be re-claimed at demolition and improving certainty regarding their repurpose.[53]

Additionally, connecting the virtual replicas to create an ecosystem of digital twins that can communicate across boundaries, share data, and learn from each other would facilitate meaningful collaborations and solve global challenges.[53]
A global effort to capture and derive valuable insights into the built environment can be harnessed to reduce our climate impact in perpetuity.

FUTURE-PROOFING

As mentioned, alongside enhancing the decision-making, digital twins allow us to "future-proof" buildings and integrate resilience into the retrofits. The virtual replica can simulate conditions quickly, allowing building stakeholders to understand what-if scenarios, predict results more accurately, and prepare their buildings for such events.[55]

Singapore provides a great example of this. The virtual representation of the city is, among its many uses, being utilized as a simulation model, allowing designers and planners to test real scenarios in a digital space. These results are then used to plan and develop an action plan to combat such challenges should they arise.

ARUP: **THE HAGUE**

Unlike others, whose digital twin development has primarily focused on new builds, Arup has identified how digital twins can enhance the retrofitting process.

In the Netherlands, Arup is building a digital twin for its project retrofitting and upgrading the Dutch Government's County Hall building in The Hague.

Arup is operating their digital twin in the planning stage of their retrofitting project, using over 30,000 data points from the existing Building Management System alongside an additional 350 IoT sensors specifically tailored to measure user interaction to extract data and optimize the team's decision making.

As such, the digital twin can create different alternatives for an energy-neutral county hall that can be digitally simulated and tested before being implemented in real life. This allows the team to test different design alternatives in the context of the exact user interaction and building specifics.

The objective of this project is to work with the authorities to determine optimal retrofitting and improvement of the existing structure, in order to achieve an energy-neutral building by 2040.[56]

DRIVING DECARBONIZATION WITH DIGITAL ENGINEERING

While retrofitting buildings, especially those post-occupancy, poses a much larger challenge than starting from scratch, demolishing properties and replacing them with more sustainable ones is not cost-effective and doesn't fit with our aspirations to nurture a circular economy that minimizes the impact of building materials and construction processes on the environment.[57] If we are truly committed to operating in an environmentally responsible manner, we must strengthen the implementation of rapid smart retrofitting strategies globally supported by digital engineering, specifically digital twins.

A digital twin is a combination of resources and information collated on a shared platform, providing a single source of truth for the asset it virtually replicates. This approach utilizes a variety of technologies allowing us to not only achieve our goals but future-proof our buildings beyond 2050 decarbonization targets.

To extract value from the technologies and resources currently available and create a built environment underpinned by resilience and sustainability, the industry needs to operate in a holistic manner with regard to operating and maintaining existing buildings. Expanding our technical infrastructure to enable data connectivity and a bi-directional flow of information will be necessary to connect real-world assets to digital twins via IoT, sensors, and real-time data.

Asite's mission is to ensure that, as an industry, we can send and receive, capture, share, and collaborate on all the data we are collecting to derive actionable insights to solve global issues. However, this should not be based on proprietary tools. The Enterprise Service Bus (ESB), which provides the ability to build connectors and is open to any type of system, needs to be expanded to become the Industry Service Bus for the built environment.

This is precisely what we need to deliver on digital twins and enact a global strategy based on extensive data analytics to support global energy transformation and drive the decarbonization of the built environment.

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ABOUT

Asite's vision is to connect people and help the world build better.

Asite's open construction platform enables organizations working on capital projects to come together, plan, design, and build with seamless information sharing across the entire supply chain.

Asite's comprehensive range of solutions connect dispersed teams across the lifecycle of capital assets, enabling them to build better and build resilience. With Asite, capital project owners stay at the forefront of innovation, maintaining a golden thread of information throughout a project to facilitate the creation of digital twins.

Asite is headquartered in London's Tech City with regional offices in New York, Houston, Dubai, Riyadh, Sydney, Hong Kong, and Ahmedabad.

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