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THE FUTURE OF WORK

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CONTENTS

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Dear Valued **watt**now Reader

This issue of **watt**now features Smart Buildings. If you, like me, have been keeping your ear to the ground, then you will know that an extensive study carried out by Juniper Research has listed Shanghai, Seoul, Barcelona, Beijing and New York as the top 5 Smart Cities in the world.

The ranking of 50 world cities is based on an evaluation of many different aspects of smart cities, covering transportation and infrastructure, energy and lighting, city management and technology, and urban connectivity.

In our first feature article, on page 20, we discuss sustainable smart buildings for the planet, people, and profit. Fueled by an increased focus on carbon emissions, market demand, potential savings, and evolving laws and regulations, the commercial construction industry is now embracing the concept of sustainable smart buildings.

Companies aiming to improve their workplaces are juggling a large set of competing demands for investment to support both on-site and remote work. We flip the coin and work on what we can develop right now, especially living with the 'new normal.' Read the article on page 32.

Systems Integrators have a challenging role in today's rapidly evolving building automation market. Long established design and installation practices have been disrupted by migration from serial to IP networking, new wireless IoT technologies, and increasing expectations from specifiers and end-users for easier-to-use solutions. Read more on page 50.

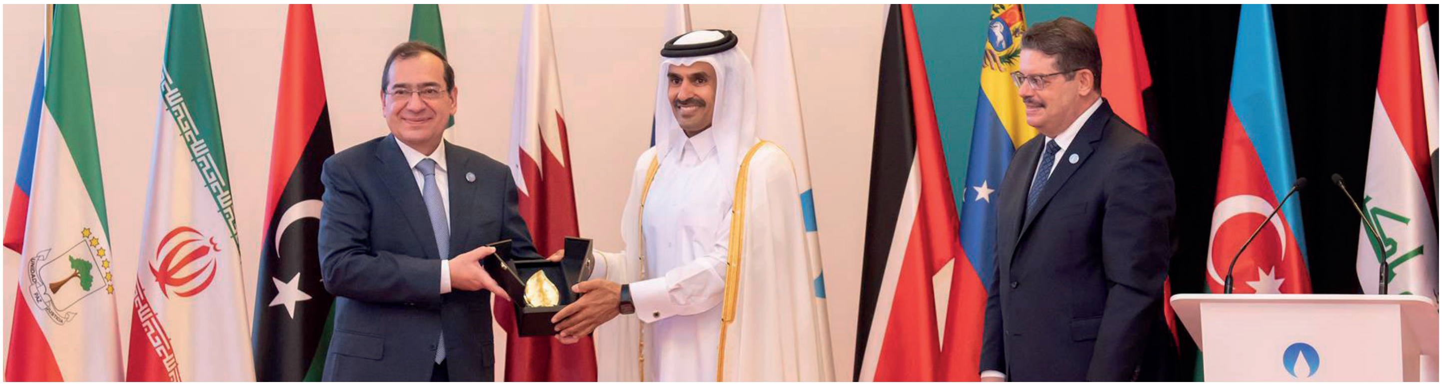
The SAIEE is gearing up for its Annual General Meeting on the 24th of March 2022 at SAIEE House. If you would like to attend in person, please email Gerda Geyer for catering purposes. The event will be a Hybrid event, and we encourage you to join online if we cannot see you in person. More details will be made available closer to the time.

The April issue features Rotating Machines, and the deadline for this issue is the 14th of March. I encourage you to send me articles - you do not have to be a writer - to minx@saiee.org.za.

Herewith the March issue; enjoy the read!

Minx

GECF recognises leading personalities with first-ever awards



HE Saad Sherida Al-Kaabi flanked by HE Tarek El-Molla (left) of Egypt and HE Eng. Mohamed Hamel of the GECF

The Gas Exporting Countries Forum recently announced the recipients of the inaugural GECF Awards.

The 'Long-Term Commitment to Natural Gas Award' was conferred on HE Saad Sherida Al-Kaabi, the Minister of State for Energy Affairs of Qatar and President and CEO of QatarEnergy.

This recognition has been designed to celebrate individuals whose sustained leadership in developing the natural gas industry resulted in an outstanding global record of achievement across the length of their careers.

The 'GECF Foundation Award' was presented to HE Viktor Zubkov, the Chairman of the Board of Directors of PJSC Gazprom and the Special Representative of the President of the Russian Federation for Cooperation with the GECF. HE Zubkov received the honour for his exceptional services to the establishment and advancement of the GECF.

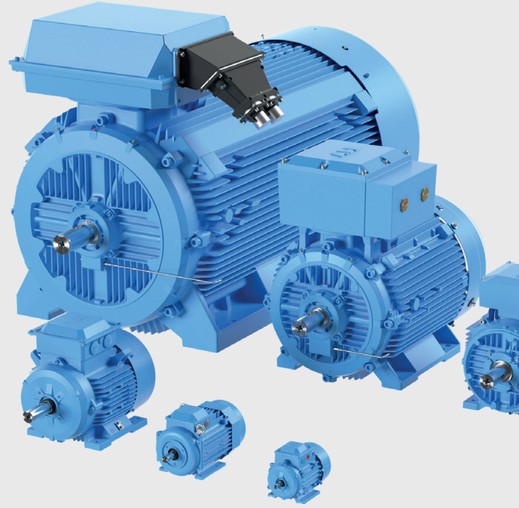
The 'Friend of GECF Award' was granted to Engineer Emad Abdel Latif Mohamed of Egypt for his over four-decade-long contribution to the gas industry in the Middle East.

The GECF Awards have been conceptualised to become the gas industry's most sought after recognition. They are open to individuals and institutions from both the GECF and non-GECF Member Countries, such as international gas and energy companies, national gas companies, academic and research institutions, media and international public figures. wn

HE Nikolai Shulginov of Russia receiving the award on behalf of HE Zubkov from HE Tarek El-Molla (left) of Egypt. HE Eng. Mohamed Hamel of the GECF is on the right

Eng. Abdel Latif Mohamed flanked by HE Tarek El-Molla (left) of Egypt and HE Eng. Mohamed Hamel of the GECF

Rising electricity price drives demand for higher-efficiency motors



With electricity prices increasing rapidly, the justification for adopting more efficient motors is that much greater. To achieve this improved efficiency, such motors are designed to run cooler, which prolongs the insulation lifespan for added reliability. Although most First World and many local end users specify higher-efficiency motors, the South African market still largely opts for cheaper IE1 motors, which are cheaper to buy but more expensive to run.

"The bulk of South African low-voltage (LV) motor purchases are driven by price," notes Bearings International (BI) Business Unit Leader: Motors and Drives Stephen Bekker. On average, the initial capital outlay constitutes less than 5% of the cost of a motor over its lifespan.

A small percentage is maintenance, while most of the running cost is the electricity consumption. The payback is generally under two years, with the average motor lifespan of ten to 15 years or more translating into an eightfold saving on the initial capital outlay.

Leading supplier BI is an ABB Channel Partner for low-voltage LV motors. "ABB is regarded as one of the largest motor manufacturers in the world, if not the largest. It is a premium product known worldwide for its reliability and design," highlights Bekker. BI provides comprehensive support for ABB LV motors from sales to stock, technical support, application support and spares. BI stocks the ABB IE1 and IE3 motor ranges, with IE4 and IE5 motors available ex-factory. The complete offering ranges from 0.55 kW to 355 kW and higher if requested. However, BI concentrates on the 15 kW to 250 kW four-pole motor range, believed to make up 75% of total IE3 motor sales.

"We have found that ABB motors are installed in many countries across Africa, so our aim is to make the LV units more accessible in terms of end-user sales. We are seeing more of a demand in South Africa from an OEM and project specification perspective," adds Bekker. Locally, mining has always proven a lucrative sector for BI. With high commodity prices and projects coming back online after delays due to Covid-19, this industry is a key focus for BI going forward. Other growth sectors include sugar, pulp and paper, food and beverage, and water and wastewater.

"ABB's extensive range allows us to offer high-quality solutions to all industries," stresses Bekker. BI has grown the Motors & Drives team from two resources to a team of five with a sixth position still open. The Team includes a Product Development Leader, two Business Development Leaders and an electric motor technical expert. "Our plan is to train up technical support within BI, as well offer customer training," he concludes. wn

Rugged tools give reliable results on construction sites

Construction sites are harsh environments for instruments that need to give accurate results time after time, even if they have been dropped, kicked or stepped on. COMTEST is offering Fluke construction instruments, including laser levels that are engineered to stay within specification, even after a one-meter drop. Whatever electricians, HVAC engineers, surveyors, inspectors, bricklayers, carpenters, roofers and plumbers need reliably measured, like distance, temperature, cable location, electrical values to indoor air quality across building sites, Fluke has a range of durable tools to meet the needs and deliver guaranteed results. For more info, click here. wn

Tecnam P2010 H3PS Hybrid Aircraft Takes to the Skies for the First Time – A Milestone in Green Aviation

Tecnam P2010 H3PS is the first General Aviation aircraft with a parallel hybrid configuration to take flight, representing a significant milestone on the aviation industry's journey towards de-carbonisation and R&D on alternative powertrains.

In collaboration with Rolls-Royce and Rotax specialised teams, Tecnam Aircraft successfully flew the new P2010 H3PS hybrid aircraft for the first time on December 21st, 2021, at precisely 3:54 pm CET. The Permit to Fly was issued by ENAC, the Italian Civil Aviation Authority.

The flight was performed by Tecnam's Chief Experimental Test Pilot Lorenzo De Stefano, with Tecnam, Rolls-Royce and Rotax Teams on the ground assisting in this historic moment. Tecnam P2010 H3PS is powered by a 104kW Rotax 915 IS engine coupled with a 30kW Rolls-Royce electric motor, totalling 134kW (180hp) powertrain in a fully integrated parallel hybrid configuration. As such, this four-seat aircraft is the first of its kind.

According to Tecnam Aircraft's R&D Director Fabio Russo, the H3PS successful flight test demonstration marks a significant milestone on the aviation industry's journey towards de-carbonisation and R&D on alternative powertrains.

"Though H3PS is not intended for market purposes, our successful flight tests demonstrate that hybrid powertrain, with combustion engine coupled with an electric motor, can bear the same useful load of the traditional 180hp combustion engine," said Russo.
H3PS, which stands for "High Power High Scalability Aircraft Hybrid Powertrain," is funded under the European Union Horizon 2020 research and innovation program. Launched in 2018, the project has reached its objectives. With H3PS' success, Tecnam Aircraft and project partners have validated the aircraft's scalability potential, lower emissions, state of the art power management technology, building a viable launchpad for future green aircraft models.

Commenting on the future developments, Tecnam's Managing Director Giovanni Pascale Langer stated that the company will continue to drive the green transition in aviation. "Tecnam's approach to innovation is truly sustainable," said Pascale Langer. "Our development focuses on three key pillars: environmentally friendly, technologically viable and marketable solutions. We do this by leveraging our multi-generational expertise, research and development, next-generation technology, and strategic partnerships."
"I look forward to seeing H3PS inspire more innovation and drive our industry forward with cleaner, more efficient technologies," Pascale Langer concluded.

Rob Watson, President of Rolls-Royce Electrical, added: "The successful first flight of the P2010 H3PS demonstrator is a pioneering achievement by the team to advance hybrid-electric flight. Working with Tecnam and Rotax has been hugely beneficial. This project has continued to build our capabilities in delivering all-electric and hybrid-electric power and propulsion systems for the advanced air mobility market. Rolls-Royce is committed to investing in the technology solutions to enable and deliver sustainable aviation."

"In December 2021, ENAC issued the permit to fly, for research and development purposes" - commented the Director-General of ENAC, Alessio Quaranta – "to the first Made in Italy General Aviation aircraft powered by hybrid propulsion system (electric - unleaded fuel): the Tecnam P2010 H3PS. ENAC actively participated in this challenge in developing the new propulsion system and its integration within the Tecnam P2010 airframe, in line with Authority's commitment towards a Sustainable Aviation future." wn

Electrolux & PowerOptimal announce Pioneering African-Born Solar PV Smart Geyser Solution

This unique smart geyser system transforms the installation, maintenance, energy efficiency, and overall cost of geysers for property developers, insurers, and households.

Electrolux South Africa and PowerOptimal announced the Elon Smart Water Solution, the world's first smart geyser with integrated solar PV capability. The locally designed solution reduces cost and risk across the entire hot water and services value chain with improved efficiency.

"We are excited about this new smart and environmentally sensitive water heating solution as we believe it will revolutionise the installation, customer experience, maintenance and cost of geysers for property developers, insurers and households alike.

Once the Elon Smart Water Solution is widely implemented in the region, the demand will only grow because businesses and consumers will quickly reap the environmental, maintenance and financial benefits," said Murray Crow, Managing Director at Electrolux South Africa.

He added, "We aim to become a global sustainability leader in our product lines; our company constantly seeks solutions that help shape living for the better. The smart hot water solution exemplifies the Electrolux Group's ambition to reduce the carbon footprint of our products and our operations overall."

Through its sustainability framework, For the Better 2030, Electrolux is committed to becoming climate neutral across the value chain and globally works at reaching its climate targets. The brand aims to develop products and services that enable people to save energy, water, and resources every day while helping to foster a more circular economy. Since 2015, the company has reported a 70% reduction in absolute CO2 emissions from operations.

NEW HIGH-TECH SOLAR SOLUTION A GAME-CHANGER

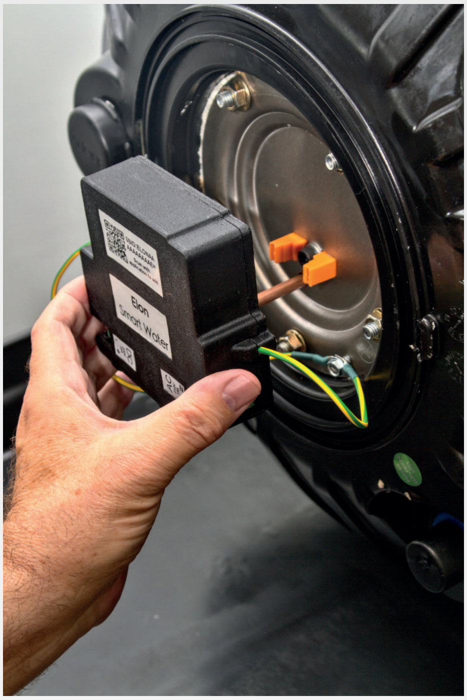
Electrolux South Africa, the local market leader in hot water solutions through its Kwikot brand, and PowerOptimal, local manufacturer and developer of the Elon Smart Water Solution, have partnered exclusively to grow the smart hot water market.

Together they believe that the environmentally sustainable new system will enable reduced electricity bills, access to tax incentives and reduced carbon emissions. The Elon Smart Water Solution will monitor and closely manage geyser performance and energy consumption and provide early alerts to homeowners and insurers in case of water leaks, element failures, or other problems.

PowerOptimal's Chief Executive Officer, Richard Fearon, said the solution would transform traditional, old electric geysers into smart, plug-and-play connected geysers that can be monitored and managed from a mobile phone.

"The Elon Smart Water Solution will change the water heating playing field on the continent and solve several problems that we are facing in terms of high 'dirty energy' consumption and the soaring cost of electricity."

Dr Sean Moolman, Chief Operating Officer at PowerOptimal, commented that 87% of electricity consumed in South Africa is generated using coal, the most environmentally damaging fossil fuel on the planet. "The country



is one of the biggest polluters globally in terms of pollution per unit of energy generated. As 40% of household energy consumption is used for water heating, there is a major opportunity for managed carbon footprint reduction."

The Elon Smart Water Solution will be launched in 2022.

For more detailed information on the environmental, financial and risk mitigation benefits of the Elon Smart Water Solution, please visit elonsmartwater.com. wn

SAIEE UJ STUDENT CHAPTER MAKES US PROUD:

The Gwakwani Project

The Gwakwani Project, based in Limpopo, is headed by Research Connect from the School of Electrical and Electronic Engineering at the University of Johannesburg (UJ). The project has been in operation since 2014 and aims to provide the rural village of Gwakwani with off-grid solutions such that facilities be accessible. The mission of UJ Research Connect is to enable students to participate in real-life engineering projects which form part of the broader community. The most recent trip, in late November 2021, allowed the University of Johannesburg's South African Institute of Electrical Engineers Student Chapter (UJ SAIEE SC) to engage in the Gwakwani Project.

By Manjilika Suknandan and Mitch Thurston

BACKGROUND

In 2013, the School of Electrical and Electronic Engineering at UJ identified the rural village of Gwakwani needing assistance with its infrastructure. It began exploring the creation of a Smart Rural Village. Gwakwani is situated approximately 670 km from Johannesburg and is home to just under 100 residents. Due to its remote location, electrification provided by the national grid is inaccessible to the village. Access to treated water from water treatment plants is also infeasible, and the community's water supply was consequently reliant on the nearby Mutale River via a diesel-powered pump.

With village leaders and local counsellors' backing, an eleven-member team from the UJ School of Electrical and Electronic Engineering partnered with Grundfos, Vision Automation, and Clever Devices and Designs. We installed a solar-powered pump system and two solar panels that are used to supply the village with four essential outside floodlights, one inside pump house light, and one power outlet to charge cell phones and battery-powered lanterns. This established the commencement of the Gwakwani Project in 2014. Since then, with the support of Schneider Electric, solar lights have been installed in every household; a solar-powered bakery has been constructed, a crèche housing has been constructed, a television and DSTV service has been built.

During the June 2019 trip, a Sigfox communication base station and cold storage facility (sponsored by the Industrial Development Corporation (IDC)) was built and commissioned. The most recent trip focused on providing a more reliable and stable power source to the Sigfox station and other maintenance work.

INFORMATION AND COMMUNICATION TECHNOLOGIES

Preventive maintenance focuses on maintaining the condition of equipment to prevent breakdowns through monitoring deterioration and undertaking regular minor repairs, which reduces the probability of equipment breakdown and extends equipment lifespan. Preventive maintenance needs to be performed on the already existing infrastructure in Gwakwani. More efforts can be focused on developing other facilities rather than perpetually conducting maintenance on the current establishments, which contributes to the project's sustainability. However, maintaining infrastructure in this way requires appropriate instrumentation for condition monitoring, thus leading to the communication phase of the Gwakwani Project.

Due to the village's remote location and limited to no cellular signal, the UJ Research Connect team utilised radio technology to monitor all the

From left: Mitch Thurston, Christopher (Gwakwani resident), Brandon Ormond, Prof Suné von Solms, Manjilika Suknandan.

installed equipment remotely. This enabled the team to ensure that all the equipment is in working order, remotely from Johannesburg. The communication phase of the project included: the installation of a Sigfox communication tower in collaboration with Sqwidnet and Schneider Electric; and the development and installation of sensors to monitor and evaluate the infrastructure in Gwakwani to assist in preventive maintenance. These sensors formed part of the IoT monitoring systems implemented in the solar-powered bakery electrical supply, cold storage and borehole. IoT monitoring systems were also put in place to monitor the work environment inside the bakery, the activity in the village centre, and all the battery banks and photovoltaic systems installed throughout the village.

SIGFOX NETWORK

The Gwakwani village has no mobile signal coverage; however, across the Mutale river (which runs along the edge of the village), there are two small hills with voice and data signal exposure at its top. Therefore, to implement preventive maintenance technologies in this environment, the Sigfox network was established in the village.

Sigfox technology uses Ultra Narrow Band (UNB) radio technology and operates in the unlicensed, publicly available band to exchange radio messages over the air. Each sensor collects information, where this information is packaged and

Fixing antenna at the Sigfox communication base station

Celebrating a job well done

sent via RF link to the Sigfox base station on the hill, where a secure IP connection to the Sigfox communication network is established using 3G/4G technologies. The data messages are stored in the Sigfox cloud, where the project team can utilise the data for operation and performance monitoring.

The successful deployment of the Sigfox monitoring sensors led to the project's expansion. The UJ Research Connect team has now deployed environmental monitoring sensors to assist in malaria research for sustainable malaria control.

THE TRIP

The most recent trip to Gwakwani took place from the 23rd of November 2021 to the 26th of November 2021. Three members of the UJ SAIEE SC; Manjilika Suknandan (Chairperson), Mitch Thurston (Treasurer) and Brandon Ormond (Former Chairperson), were a part of the team that participated in the project, along with two members of UJ Research Connect; Prof Johan Meyer (Head of School: Electrical Engineering) and Prof Suné von Solms (Associate Professor). The purpose of this trip was to carry out maintenance on equipment in the area and conduct surveillance on the village and the surrounding areas for upcoming trips and other potential projects.

A new Sigfox radio system (sponsored by Sqwidnet) was installed to replace some of the older equipment installed during the trip in 2019. This was done to increase the signal's range and reliability in the area. Since the Sigfox radio system relies on electricity provided by the solar panels, which were previously installed in 2019, the team fixed a supercapacitor battery, MPPT and GSM modem to allow for a reliable signal during periods when the solar panels are not providing enough power. A supercapacitor battery was chosen as the energy storage device for this system due to its superior lifespan compared to electrochemical batteries. Lithium-ion batteries tend to have a lifespan of 500 to 10,000 cycles, while supercapacitors have a lifespan of 100,000 to a million cycles. The village of Gwakwani is subject to relatively high temperatures throughout the year (frequently above 40°C), which would degrade the lifespan of a battery even further. In contrast, supercapacitor batteries are capable of withstanding much higher temperatures.

During this trip, the team also retrieved, repaired, and upgraded several environmental monitoring sensors. One of the reasons it is essential to the team to maintain the Sigfox radio system is to ensure that these sensors can gather data uninterruptedly. A large area was mapped by the team of where Sigfox signal could be detected – this included Gwakwani, the village of Mutele, the area of Feskraal and Crook's Corner in Kruger National Park, which is at the edge of Zimbabwe and Mozambique. Drone footage along the Mutale River, near Gwakwani, was obtained, providing visual aids in determining the breeding environment to which mosquitoes may be drawn.

The Student Experience

The students, a part of the team, enjoyed the experience wholeheartedly. Not only is this project an excellent opportunity to visit different places and learn about different cultures, but it is also an excellent opportunity for students to apply the theory learnt during their studies. The practical use and implementation of 4IR technologies were also recognised, and it was enlightening how they can be applied in a rural setting. Having an opportunity to work with one's hands and see the community one hopes to help through these projects was undoubtedly an unforgettable experience.

One aspect of the trip that the students noted as the most eye-opening was the opportunity to interact with their lecturers in a different environment. The students asked questions on many topics and were more than satisfied with the inciteful feedback received.

The UJ SAIEE SC would like to express the utmost gratitude to everyone who endeavoured to make this trip possible. We want to extend our gratitude to Tshipise Forever Resort for their hospitality and care during our stay. wn

Supercapacitor battery

Cleaning out the old electrical box

From left: Mitch Thurston, Manjilika Suknandan, Prof Suné von Solms, Brandon Ormond and Prof Johan Meyer

New Smart facilities for FUCHS Lubricants

The new head office and warehouse for FUCHS LUBRICANTS SOUTH AFRICA is on track to be completed this month."It will be completed on time and within budget, which is a significant achievement not only for such a complex industrial project but also because Covid-19 regulations and protocols had to be taken into account at all stages," comments MD Paul Deppe.

The company is investing over R250 million in the expansion at its current location in Isando, Johannesburg, in the wake of rapid growth in Sub-Saharan Africa. The feasibility study for the initial scope of work was embarked upon in 2019, with DRA Global appointed as the Engineering, Procurement and Construction Management (EPCM) consultant. The Phase 1 expansion, which consists of the office complex and new warehouse, commenced in June 2020. While Phase 2 is still in concept development, it is planned to comprise a new lubricants plant to bolster its strong growth and expansion plans for the continent.

ILS was appointed as the warehouse consultant. The warehouse system will be based on a fully integrated barcoding system using SAP. The warehouse itself will incorporate the latest technology, including all wrapped products, with 100% selectivity and batch control introduced. The latest materials-handling equipment will also be implemented, such as narrow-aisle lift trucks stacking to 17 m high.

The warehouse features 13-m-high cast concrete tilt-up panels that provide a firewall between the warehouse and the production facilities close by. These panels of this size are believed to be a first in South Africa. In addition, the fire protection system is being designed to the latest international best practice.

The new head office building involves the refurbishment of an existing building on-site. "We took the existing structure back to its bare bones and created a new concept entirely from scratch that was based on the context of it being an industrial building within an industrial precinct," highlights Graeme Palmer, Owner and Director of GPD Studio, the architectural firm contracted to the project. The main design elements were off-shutter concrete work, face brick, two-tone plaster finishes, steel, and glass.
Sustainability elements incorporated in the final building include low-flow sanitary fittings, movement sensors on all lights, which have low-wattage LED fittings, and double glazing to enhance thermal performance, with one skin comprising low-emissivity high-performance glass. Natural shading elements have been included on the façade in concrete 'eyebrows' to provide shade in summer and allow light in for warmth in winter.

In addition, cavity walls reduce heat transmission, while PV panels reduce the overall power demand. Another feature is a rainwater harvesting system due to the large roof area provided by the warehouse, with one tank to irrigate the new landscaping and a second tank to supply the urinals and cisterns.

Looking to the future, Deppe is confident that the new head office with its visibility will be a testament to FUCHS' strong

A render of the new FUCHS' head office by GPD Studio

An aerial view of the new FUCHS' head office and warehouse

growth prospects on the continent. "We have a lot of confidence and are growing market share. This makes our Phase 1 expansion such an important step forward that will consolidate our South African operation as the regional hub for Sub Saharan Africa," concludes Deppe. wn

My Smart City empowers residents in eThekwini

Service delivery in the City of eThekwini has been on an upward trajectory during the last year. The metropolitan municipality marginally beating Cape Town in the News24's Out of Order Index findings, published in October last year.

This is welcome news for the residents of Durban and its surrounding towns, as eThekwini residents can now become involved in ensuring their metro improves its status as a clean, desirable residential, leisure and business location.

Residents in eThekwini can help speed up the resolution of service delivery issues - such as potholes, water and power outages - by logging infrastructure and service delivery problems on My Smart City. The free and independent platform places citizens in the driving seat to logging, monitor and track issues and is available on the Apple App Store, Google Play Store or via the My Smart City Website.

The My Smart City platform was built by Acumen Software, global experts in software solutions, and it has been successfully launched in Johannesburg, Cape Town, Tshwane and Ekurhuleni.

"We are delighted to roll out the MySmartCity platform in eThekwini.

Despite the social unrest in July 2021, the metro has exciting and positive developments. We are thrilled to be part of providing residents with a platform where they can share their service delivery issues, track and monitor progress and see issues resolved expeditiously," says CEO of Acumen Software, Joao Zoio.

Johannesburg and Cape Town residents who have logged service delivery issues on My Smart City have seen a three to fourfold improvement in turnaround times. The improved resolution times are due to My Smart City's dedicated dispatch centre that ensures issues are directed to the correct municipal channel.

The dispatch centre also follows up on behalf of residents and with City officials responding to focused calls being logged by My Smart City.

The My Smart City team has also added a new social feed to the app, bringing razor-sharp focus to what is happening within an area. Citizens can engage and share current affairs within their communities and extract information around power outages, load shedding schedules, water outages, road closures, and stay updated with community alerts specific to where they reside.

"For the first time, South African citizens have open visibility of service delivery issues that have been reported. As registration numbers on the platform grow, the citizens' voices will become more powerful. The unity of citizens through one channel has a direct impact on the upliftment and repair of their City's infrastructure and public spaces," says Kennedy Mogotsi, COO of Acumen Software.

eThekwini residents can now log issues such as:

- Interrupted water supply;
- Electricity outages or problems with electricity supply;
- Street light repairs and outages
- Waste and garbage removal;
- Maintenance of roads and repairs of potholes;
- Requests to clean streets and public spaces; and more...
- With the new social feed, residents can now:
- View, engage with and share neighbourhood announcements
- Gain insights into scheduled and unplanned community outages and alerts
- Connect and follow neighbours, influential people and municipal leaders

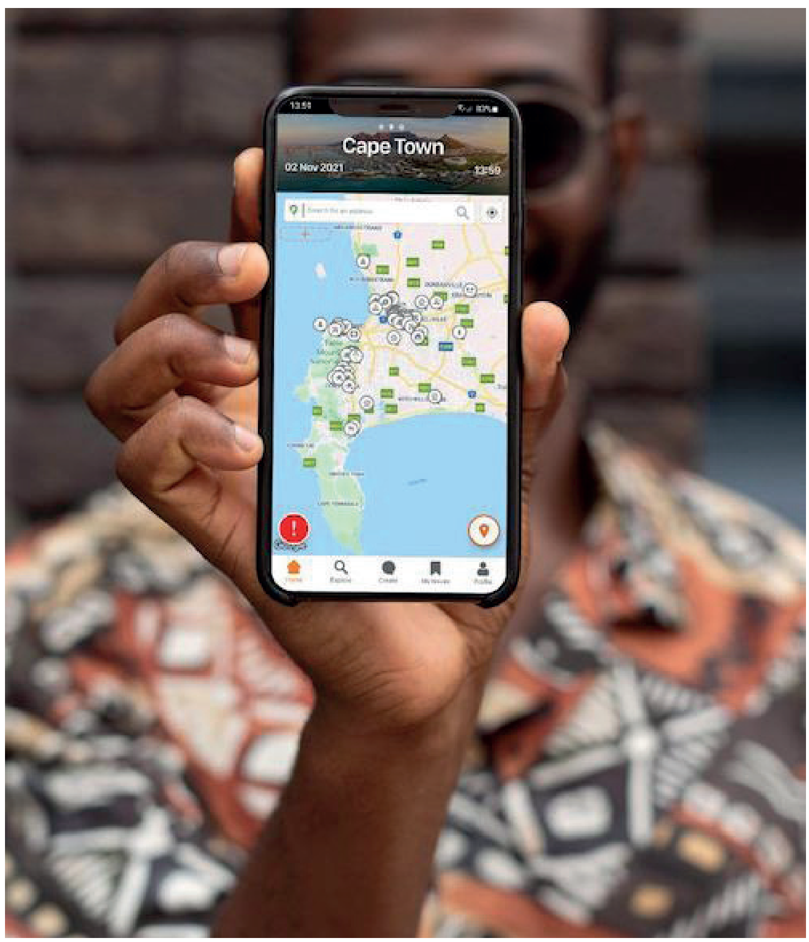
While the My Smart City teams are not responsible for resolving service delivery issues directly, their dedicated dispatch and support teams escalate issues to

the City's service providers for resolution. My Smart City lifts the burden from citizens having to call into call centres and follow up on their reported matters. The easy-to-use and transparent platform gives citizens a voice and promotes accountability through technology.

"Many historical systems used by municipalities are seen as voids and pacifiers where complaints get lost, buried and forgotten. My Smart City escalates and pushes for resolution of issues through our Dispatch Centre, and leverages media pressure with the publication of statistics on the City's service performance," concludes Zoio.

My Smart City calls on eThekwini residents to download, register, and efficiently log issues in their areas. Join the other thousands of citizens who now have a voice through a platform owned by them that generates real action and meaningful change.

In time, residents will be able to source private services, manage crowd-funding initiatives and gain access to community social and sporting events. wn



New Solar Training Centre for Takoradi Technical University, Ghana

Representatives of the Ghana Solar Industry and international partners of the University inaugurated the new Solar Training Centre and launched the 3-week Solar Planner Course for Students.

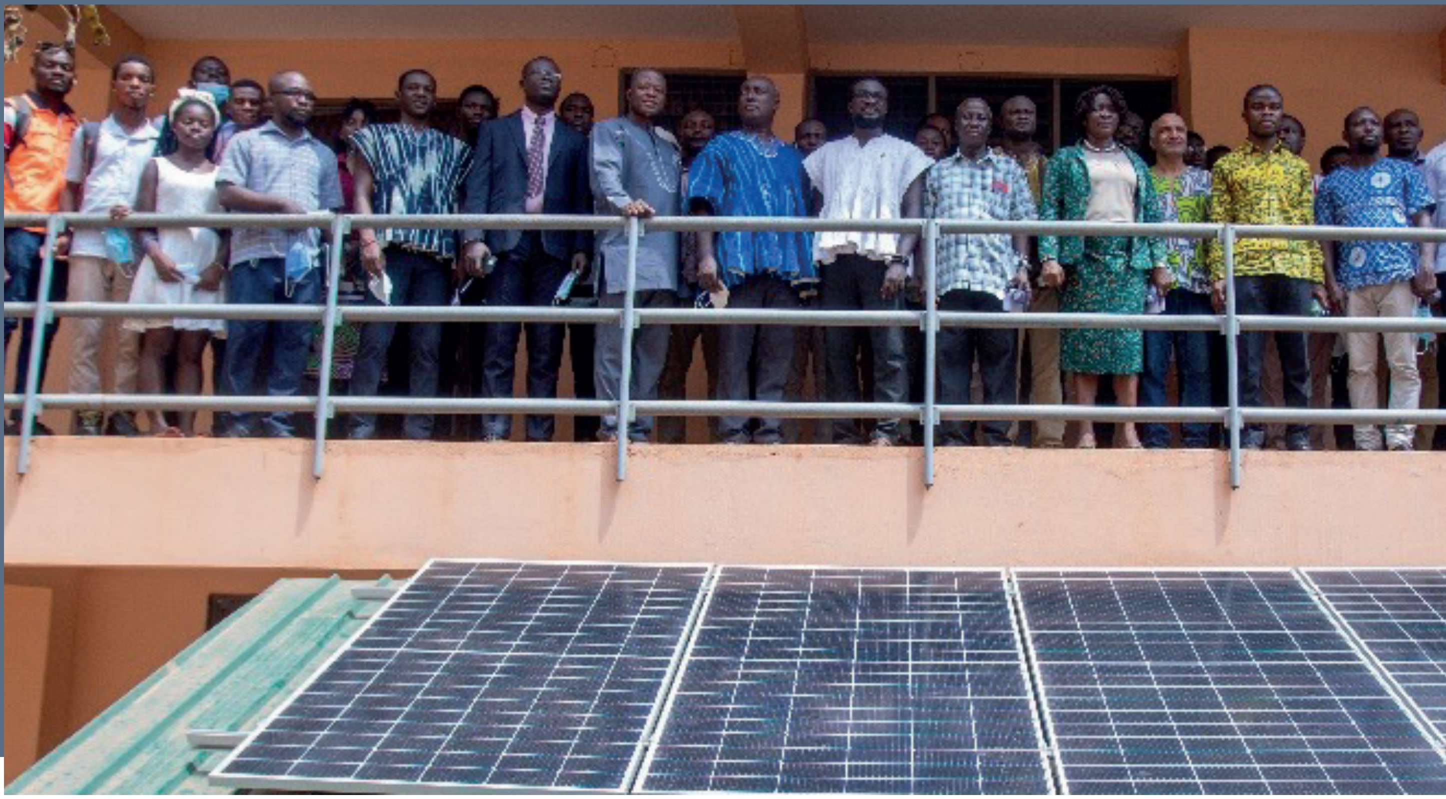
Takoradi Technical University (TTU) in Takoradi, Ghana, held the international inauguration of its new Solar Power Training Centre, a permanent facility dedicated to solar photovoltaic training and improving the employment prospects of its graduates. The inauguration was followed by a stakeholder workshop attended by leading lights in the country's solar energy industry and representatives from many of the international partners involved in creating the centre. TTU and her international partners, GREEN Solar Academy and Valentin Software GmbH, also launched the 3-week Photovoltaic Planner training programme for TTU graduates and final year students.

The Solar Training Centre at TTU will offer practical solar training tailored to the applicants' experience and the demands of the local PV industry in Ghana. To this end, it has been equipped with the latest equipment and course material available worldwide. GREEN Solar Academy and Valentin Software GmbH supported TTU with the training development. The students can now benefit from the two companies' international experience in training and PV system simulation.

The handover and commissioning of the centre already took place in December, the inauguration now officially presents the centre to the Ghanaian solar industry and the international project partners. Vivian Bluemel, Technical Director of GREEN Solar Academy, who, together with the German Valentin Software, is one of the project's initiators, appreciates the University's engagement during her speech: "Universities can contribute significantly to a prosperous industry by adapting trends early. By supporting young students to establish themselves in the solar industry, TTU is definitely on the right track because solar energy is a trend that is going to stay."

Speaking at the opening ceremony of the inauguration, Dr Enoch Yeboah Agyepong, Director of the Renewable Energy Association of Ghana (REAG), had this to say:
I desire to see learners who are unafraid to go to the lab and play around with the equipment. Some students do not know how to handle equipment, so let's use this programme and the internship to give more depth to their learning.

After the official opening, the guests were invited on tour through the new facilities where B-Tech graduates and final year engineering students exploring a career in solar energy will be able to enrol for a 3-week training course in all facets of solar system design and installation. The centre comprises of classrooms, a computer laboratory and purpose-built training roofs where students get a real feel for installing an actual solar system on a roof. Students will be schooled in PV basics, planning (manually and with PV*SOL premium), installation, operation, maintenance and costing, as well as payback periods, all with a strong focus on practical application. On completion, they will



Excited guests gather to view the Solar Training Centre Workshop and Training Facilities, such as the mock roof for practical installation.

have the opportunity to intern with a local installation company, many of whom have already signed pledges and Letters of Intent demonstrating their support for the initiative.

Prof. (Mrs.) Maame Afua Nkrumah, Dean of International Programmes and External Linkages Office (IPELO) at TTU, explains the importance of this facility for the youth at the University: "Ghana is a country with a high number of graduates, high unemployment among the youth and high levels of solar irradiation. The Solar Training Centre at TTU and the internship programme that follows becomes a sustainable channel to turn challenges into opportunities that will benefit both the individual and the industry at large."

The inauguration was followed by a stakeholder workshop, which brought together solar industry bodies and key role players in a discussion on how to shape the partnership with TTU to promote PV training and internship opportunities for the youth in the long term and make it a beneficial experience for students and companies. Many of the workshop participants are already members of Solar Hub West Africa, a loose network of African and European solar companies cooperating to promote renewable energy in West Africa.

The training centre and internship programme that follows was made possible due to the joint efforts of TTU and two leading players in the solar energy industry, GREEN Solar Academy and Valentin Software. Thanks to the German Federal Ministry for Economic Cooperation and Development (BMZ), financial support has been realised.

Local support in the form of state-of-the-art equipment and commitment to offering the first internships to graduates of the training centre is provided by Tino Solutions, a successful Ghanaian installer and distributor of solar equipment.

Equipping the centre was made possible through collaboration with global solar brands such as Phocos, Victron, Jinko Solar and Fronius. The partnership with Tino Solutions has supported the centre with Victron Energy inverters and batteries and Jinko Solar modules.

ARE YOU A STUDENT OR A SOLAR COMPANY AND WANT TO KNOW MORE?

Students who want to get a head-start in their career in solar energy are welcome to inquire about the first 3-week pilot to be held early this year and are invited to contact TTU Senior lecturer Dr Stephen Afonaa Mensah.

Solar companies interested in participating in the internship programme and contributing to upskilling youth in the PV industry, or seeking professional solar training for their staff and distributors, can get in touch with Dennis Wiredu Asare, the head of GREEN Solar Academy Ghana, at ghana@solar-training.org. wn

Sustainable smart buildings for the planet, people, and profit

Fueled by an increased focus on carbon emissions, market demand, potential savings, and evolving laws and regulations, the commercial construction industry is now embracing the concept of sustainable smart buildings.

According to recent reports, the smart building market will grow from $43.6 billion in 2018 to $160 billion by 2026. What constitutes a sustainable smart building has also evolved significantly over the past two decades to consider a building's environmental impact and its safety, security, overall social performance, and cost reduction over its lifecycle. As the commercial real estate market becomes increasingly competitive, building owners need to answer the call to make their buildings smarter and more sustainable in a way that considers the impact on the planet, the people, and the profit of the business itself or run the risk of lower occupancy rates and property values.

To make informed decisions that ensure sustainable smart buildings, stakeholders need insights and benchmarks that can only come from measurable assessment criteria and actual data. To effectively collect that data, building owners and operators need to consider emerging technologies and infrastructures that enable cost-effectively connecting a wide range of smart devices and systems within a building and across campus environments, smart communities, and smart cities.

In 2020, the Telecommunications Industry Association (TIA) and UL teamed to launch SPIRE, the industry's first comprehensive smart building assessment and rating program that holistically measures building technology and performance, taking into account the entirety of a smart building.

Built-in conjunction with UL, the leading global safety science company, and with criteria developed by the TIA

industry working group of more than 60 leading commercial real estate, asset management, technology and telecommunications industry leaders, SPIRE is built around six distinctive categories - connectivity, health and well-being, life and property safety, power and energy, cybersecurity, and sustainability.

A vital part of these criteria is assessing advanced, interoperable technology that enables the collection and analysis of data to improve building performance, occupant experiences, and operational efficiency that support sustainability.

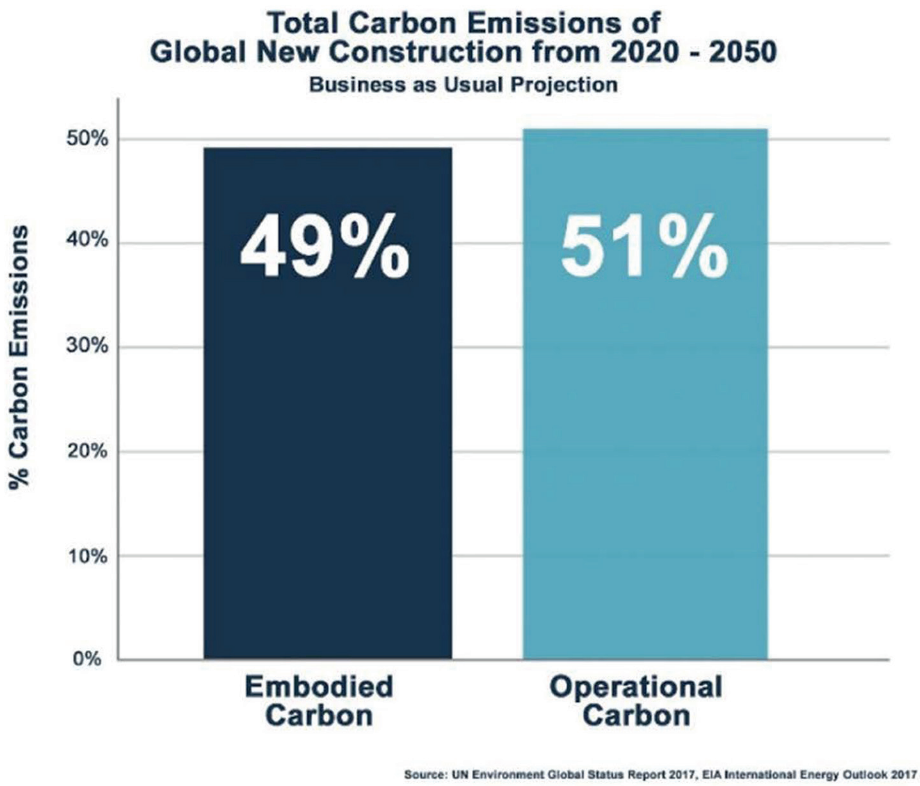
Thanks to the synergy of smart technologies in enabling sustainability to drive innovation and technology deployments that will ultimately enable vital data collection and analysis needed to assess, monitor, and maintain sustainability in a smart building.

To that end, organisations should work with their members to understand how the industry and companies are achieving smart building sustainability goals in a complex, challenging marketplace undergoing increasing and evolving environmental concerns, regulations, and expectations.

Based on detailed research, recent statistics, and interviews with leading global companies, this paper presents expert viewpoints on smart building sustainability, including:

- The evolution of sustainability concepts
- Primary industry and global driving forces to sustainability
- The foundational role of data in achieving sustainability
- Technologies, solutions, and strategies for achieving sustainability goals
- Key challenges to sustainable smart building implementation
- The need for sustainability assessment and certification programs
- The future outlook for sustainable smart buildings

The concept of a sustainable building, or "green" building, has evolved significantly over the past two decades.



What traditionally constituted a building's sustainability was focused primarily on energy consumption, conservation of natural resources, and material reuse and recycling. Today, industry experts believe that sustainability has become a much broader concept that relates to a building's overall ability to provide a comfortable, healthy, and productive environment over the lifecycle of the building without negatively impacting the natural environment.

The "blue" building is a newer concept that expands sustainability beyond its conventional "green" metaphor, adopting the position that sustainable buildings can no longer be just about the impact on the natural environment but instead should focus on three key pillars— planet, people, and profit. When it comes to designing, constructing, and operating a building that embraces the planet's future, the prosperity of its people and surrounding community, and the success of the business itself, there are also far more factors to consider.

MORE THAN JUST ENERGY CONSUMPTION

The impact a building has on the planet should now factor in more than just energy consumption and operational carbon (greenhouse gas emissions from operating a building). Industry experts believe that embodied carbon, which represents the emissions of greenhouse gases during building construction, should also factor into a building's impact. While operational carbon currently accounts for 28% of total greenhouse gas emissions and embodied carbon accounts for only about 11%, estimated increases in building construction have industry experts predicting that by 2050, the levels will be nearly equal.

Determining embodied carbon also requires in-depth information such as environmental product declarations (EPDs) from manufacturers and certification companies like UL that indicate components' composition and impact on the environment. Sustainability from an environmental perspective should also now consider modern concepts such as net-positivity, where buildings create more energy or resources in their lifetime than they consume.

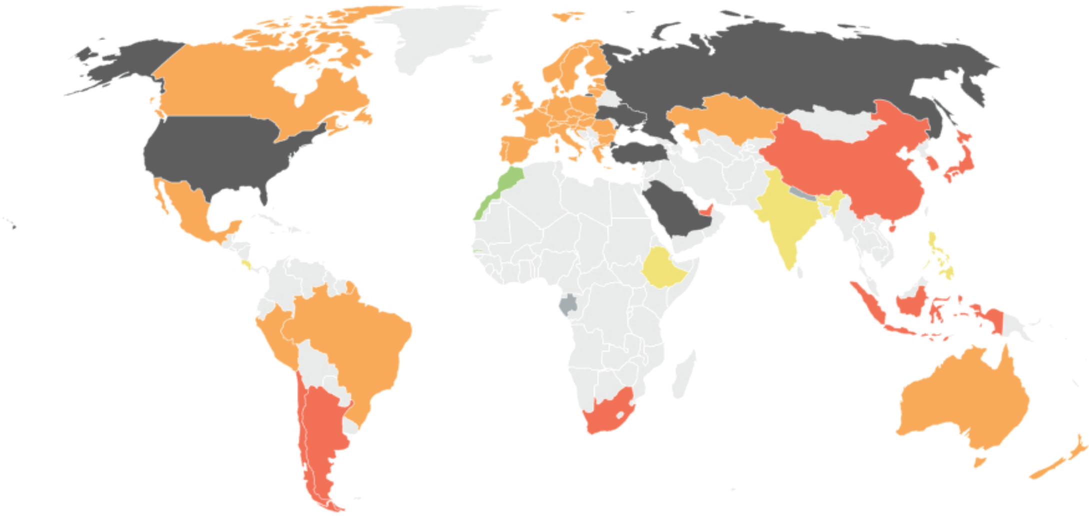
IT'S ALL ABOUT THE PEOPLE

The health and well-being of people in a building has a lot to do with air quality and temperature but is expanding to consider the physical, psychological, and social impacts on the human experience of building occupants. This encompasses everything from the layout and lighting of spaces that enable an interactive and productive environment to the ability to prevent disease and eliminate volatile organic compounds (VOCs) and odours in the air. It also means providing a sense of individual engagement and purpose for occupants and ensuring diversity, equality, and other factors that provide occupants with a sense of acceptance and inclusion.

CONSIDERS ALL OPERATIONAL EXPENSES

Business profit considerations that rely on a sustainability approach now include much more than energy cost. Today's sustainable smart building must consider all costs associated with operations and maintenance by implementing circular economy principles that aim to reduce waste, increase reuse and recycling efforts, and keep products and materials in use as long as possible.

Operational costs reduction should also consider practices like demand response capabilities and net-positivity that can further reduce expense over the lifecycle of the building. Practices like predictive maintenance to prevent problems before they arise and even the ability to efficiently handle building emergencies and prevent cybersecurity attacks impact a building's operational expense and sustainability. Industry



The maps displayed are for reference only.

LAST UPDATE: *June 2019*

CRITICALLY INSUFFICIENT	HIGHLY INSUFFICIENT	INSUFFICIENT	2°C COMPATIBLE	1.5°C PARIS AGREEMENT COMPATIBLE	ROLE MODEL
4°C+ WORLD	*< 4°C WORLD*	*< 3°C WORLD*	*< 2°C WORLD*	*< 1.5°C WORLD*	*<< 1.5°C WORLD*
RUSSIAN FEDERATION	ARGENTINA	AUSTRALIA	BHUTAN	MOROCCO	
SAUDI ARABIA	CHILE	BRAZIL	COSTA RICA	THE GAMBIA	
TURKEY	CHINA	CANADA	ETHIOPIA		
USA	INDONESIA	EU	INDIA		
UKRAINE	JAPAN	KAZAKHSTAN	PHILIPPINES		
	SINGAPORE	MEXICO			
	SOUTH AFRICA	NEW ZEALAND			
	SOUTH KOREA	NORWAY			
	UAE	PERU			
		SWITZERLAND			

experts also agree that how a building impacts occupants' productivity, safety, and satisfaction directly impacts the operational expense, including tangible costs associated with healthcare and employee turnover.

KEY DRIVING FORCES

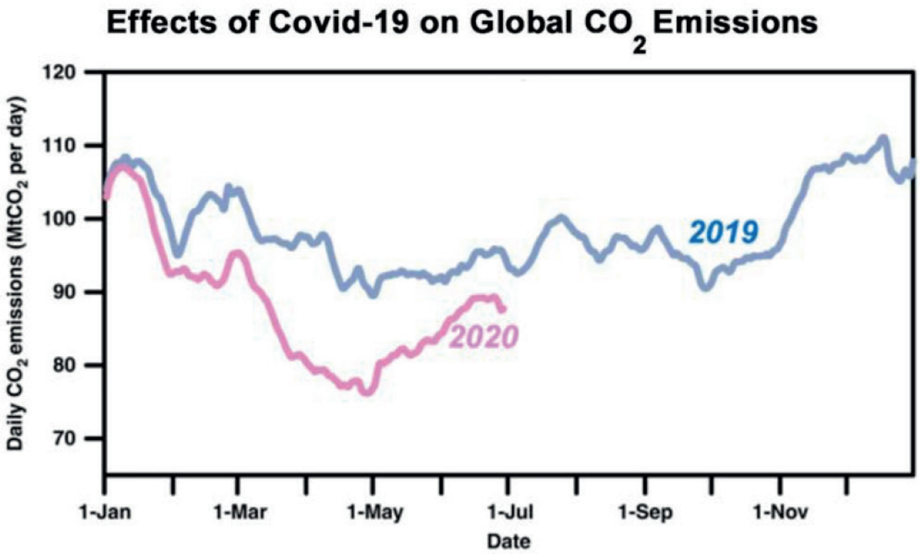
What now constitutes a sustainable smart building is determined by various drivers from marketability, consumer expectations, and evolving regulations towards an increased focus on climate change and an overall shift in the way people live, work and play in today's society.

CLIMATE CHANGE

The world today is not meeting previously set climate goals. In 2016, nearly 200 countries signed the landmark Paris climate agreement with its goal of limiting global warming to well below 2°C and commitment to curtailing greenhouse gas emissions by 2030. By 2020, most countries were not on track to meet their targets. Buildings are a significant contributing factor, with an estimated 40% of global carbon emissions attributed to the built environment, including 28% attributed to operational emissions alone. In addition, building construction, in general, is on the rise. Two-thirds of new building construction is expected to occur in countries that do not have mandatory energy codes in place. On top of it all, rising temperatures worsen extreme environmental events. Increasing wildfires, rising sea levels, and other environmental problems have increased societal focus on limiting climate change, leading to new regulations, incentives, and market demand that further drive the need for sustainability.

THE HUMAN FACTOR

The human factor and changes in building occupant behaviour also



significantly impact carbon emissions. The vast increase in population and human consumption over the past century are contributing factors. The expanding globalised economy also means the delivery of more goods and services in the global supply chain and a more significant movement of people around the globe that produces more emissions and waste, creating a society that, unfortunately, sustains unsustainability. This became very clear during the current COVID-19 pandemic, where stay-at-home orders worldwide resulted in a sharp 8.8% decrease in global CO2 emissions in the first half of 2020 compared to the same period in 2019.

We also spend more time in commercial and public buildings today than we did a century ago, with studies indicating that humans spend an average of 90% of their time indoors. While real estate decisions used to be about location, it's now equally important to tenants to have an optimal space with the latest technology and capabilities. This places more emphasis on thermal comfort and indoor air quality. At the same time, there is an increased demand among occupants for buildings that meet physical, psychological, and social expectations, such as diversity, equality, and other factors that provide a sense of acceptance. Engaging occupants in sustainability efforts through awareness campaigns, feedback, and empowerment drives a culture of sustainability.

Employees want the ability to set their own temperature and lighting levels in their workspace, have ample Wi-Fi coverage and encourage collaborative environments.

Younger generations today are also more concerned about sustainability and the planet. As these individuals move into management roles, sustainability will be a significant factor in their decision-making.

THE COVID-19 IMPACT

The recent COVID-19 pandemic increased the focus on health and well-being within buildings. Smart building technologies that improve safety and prevent sickness were once considered "nice to have" but are now considered "need to have." For example, smart solutions like UVC disinfection lighting have experienced growth in the market and touchless technologies that allow users to operate doors, vending machines, and elevators with their smartphones.

At the same time, surveys indicate that many workers will maintain some level of work-from-home practice, with one New York City survey indicating that employers expect 56% of workers to continue working from home at least part of the time. The pandemic is also driving changes in how office spaces are organised. Building operators and facility managers are striving to optimise the efficiency of unused spaces and distribute work areas in a way that maintains social distancing and enables desk sharing while ensuring safety, comfort, and productivity. Industry experts believe that the pandemic will ultimately create competition in the commercial real estate market and favour buildings that offer an overall healthier and safer user experience.

Despite an estimated 80% drop in occupancy in 2020, the pandemic did not reduce building energy use as much as expected. Studies show that 25% of building energy use did not change, and another 60% only showed a reduction by 23%. Most industry experts attribute this to building loads that cannot be turned off regardless of occupancy, lease agreements, and simply maintaining proper air temperature and humidity for building operation systems and critical IT equipment. However, the lack of energy savings recognised in 2020 also motivates many building owners and operators to look at why energy consumption did not decrease and how they can improve.

REGIONAL DRIVERS

Sustainability is also a regional phenomenon that depends on regulations, government initiatives, urbanisation, culture, and other market variances. Due to growing concerns over climate change, some governments worldwide are developing and imposing various laws and regulations that encourage the development of sustainable smart buildings. For example, the European Union (EU) has established several directives to reduce energy consumption and meet the goal of zero-energy buildings. Many European governments are also implementing financial incentives and subsidies that further drive the development of sustainable smart buildings in the market.

Overall, sustainable smart buildings are developing faster in high urbanisation areas. The Seattle region is a hot spot for sustainable development and San Francisco, San Diego, Portland, the greater Washington D.C. area, Boston, and Austin. The vast urbanisation happening in the Asia-Pacific region, especially China, is pushing rapid digital transformation and sustainability in this region. Sustainable smart building development also varies globally depending on the culture. For example, while regulations unquestionably come into play, Europeans, in general, are more focused on sustainability from an individual, building, and community standpoint. As cities across Europe undergo urban renewal and revitalisation, they are being revamped as smart, sustainable cities. In particular, sustainability is becoming a key criterion for investors in Sweden, where commercial real estate holding companies demand a certain percentage of certified sustainable buildings.

Smart buildings can also play an active role in regional smart grid use and resiliency via grid-connected renewable energy generation. Solar, wind or geothermal reduces peak demand, feeds excess electricity back into the grid, and uses intelligent management systems that manage energy production and enable load balancing. Implementing peak load management protocols, demand response capabilities, and integrated building-to-grid power management allows smart building owners and operators to reduce energy costs and tariffs. By automatically responding to real-time price and smart grid requests and taking advantage of local utilities' financial incentives, all of which ultimately helps lower regional electricity rates and reduce grid instability.

DATA AS THE FOUNDATION

Effectively maximising and assessing sustainability in a smart building requires actionable insights that can only come from data. This requires technologies and solutions that collect and analyse real-time data about the building performance and the environment in which buildings operate to continually make adjustments that improve sustainable operations throughout the building lifecycle. Most smart building experts agree that data is the number one enabler— data about everything from energy and natural resource consumption to air and water quality, system status and required maintenance, occupancy, parking availability, and more.

While data is considered "gold" in a sustainable smart building, it is essential to ensure that captured data is "clean." Clean data is considered relevant, reliable, and actionable, meaning it can be acted upon. In contrast, "dark data" is typically dormant, often incorrectly formatted for use, and cannot be acted upon, meaning that it holds little or no significant value or insight. Digital transformation such as implementing smart sensors, data analytics, dashboarding, and business intelligence platforms can help ensure that captured data is clean and actionable.

For efficient operations and reduced cost, the data should also not be standalone but instead transferable across various interoperable, integrated systems, including both Information Technology (IT) and Operational Technology (OT) networks. For example, information about the number of people or amount of CO_2 in a room collected via sensors should be shareable with HVAC systems and modelled with social data, energy costs, weather predictions, and other building information in a way that enables automatic response to increase ventilation or lower the temperature and sets optimal steering parameters for the HVAC system. The key to success is data democratisation that enables always-accessible, easy-to-understand information for all systems and stakeholders to leverage for effective decision-making.

INFRASTRUCTURE AND PROTOCOL MATTERS

While data is the foundation behind sustainable smart buildings, the physical layer infrastructure that enables wired and wireless data transmission needs to be appropriately designed and implemented to support real-time communication. Careful consideration must therefore be given to the cabling media and wireless communications. Ample coverage - both wired and wireless - throughout the building and its surrounding property must also be in place, with plenty of capacity for expansion to support future building needs. Additionally, networks can connect over various communication protocols and for various systems to "talk" to one another and leverage cloud-based solutions. The data must be shared via open standards and protocols like Internet Protocol (IP), which has become ubiquitous for communicating information across premises and service provider networks. Standardisation will therefore be crucial as more smart building technologies enter the market.

At the same time, wired and wireless infrastructures need to be physically secure with proper encryption and cybersecurity practices in place to prevent increasing cyberattacks and back-door mechanisms that threaten to disrupt smart building operations. Management and use of personal data (i.e., name, email, geolocation, etc.) is also a consideration given evolving privacy data regulations around the globe that prevent sharing personal data about building occupants.

The infrastructure should also be designed to support efficient, safe powering of devices via remote powering technologies to improve sustainability. Power over Ethernet (PoE) delivers up to 90 Watts of safety extra low-voltage (SELV) power over the same network infrastructure that transmits data to and from devices such as cameras, Wi-Fi access points, cameras, LED lights, sensors, access control panels, and building automation controllers. The use of PoE eliminates the need to deploy traditional AC power circuits to devices, saving material, labour, and pathway space for a greener, more sustainable approach. To support sustainability, it's essential to consider Environmental Product Declarations EPDs, health product declarations (HPDs), Declare Labels and other green product certifications when selecting the components that comprise the infrastructure, such as cables manufactured in a zero-waste landfill facility.

LONG RANGE WIRELESS EXPANDS CAPABILITY

It is essential to acknowledge that sustainable smart buildings are often part of a larger smart campus, smart community, or smart city with multiple and often remote smart devices transmitting the information. Beyond the internal operations and short-range wired and wireless (i.e., Wi-Fi) communication over a local area network in a single building, data from remote and mobile smart devices enables smart community/city applications like smart traffic and parking, smart lighting, wayfinding, asset tracking, smart waste management, damage detection, air quality monitoring, weather detection, and even pet and animal tracking.

While 5G/6G cellular is ideal for remote smart devices that need high data throughput (e.g., video, autonomous vehicles), coverage is not yet widespread. The fact remains that most smart building solutions do not require high throughput. Many remote smart IoT devices only need low-speed (< 1 Mb/s) communications to transmit tiny amounts of sensor data, which is where low-power, wide-area wireless networks (LPWAN) come in. Cellular communications also place significant battery strain on devices and can only support most battery-powered devices for a limited number of hours.

WAN open protocols are ideal for connecting battery-operated remote smart devices that do not require high-speed data rates. It is also well suited for large-scale smart technology roll-outs. These deployments are achieved via WAN gateways that wirelessly receive data and forward that data via IP over service provider or local area networks to systems that interpret the data. Unlike cellular, where devices consistently synchronise with the network and drain batteries, communication via WAN only happens when devices are ready to send data in response to events, schedules, or other actions. Batteries on remote devices can therefore last much longer; in some cases, up to ten years.

With low susceptibility to interference and the ability to penetrate dense building materials, WAN is ideal for supporting smart device communications throughout all areas of a building, including basements and underground locations like parking garages. Depending on the environment and obstructions, certain WAN technologies offer long-range coverage for large campus and community deployments, typically up to 3 km wide in an urban environment and reaching 7 km in rural areas on a single gateway. Using multiple gateways, a WAN infrastructure can also cover entire communities, cities, and regions, ideal for companies needing to collect data from multiple remote locations.

TECHNOLOGIES, SOLUTIONS, AND STRATEGIES

Leveraging actionable data to achieve smart building sustainability that focuses on the planet, people, and profit is achieved via a broad range of technologies, solutions, and strategies. Growing demand, digital transformation, and emerging technologies are currently driving the development of new smart building solutions.

Several emerging technologies can leverage actionable smart building data to improve sustainability, including artificial intelligence (AI), machine learning (ML), and virtual and extended reality (VR/XR). For example, while still in the early phase of adoption, AI can be leveraged to analyse data from smart sensors and devices to monitor anomalies, enabling predictive maintenance. It can also generate data patterns to make improvements over time and share that data with other building systems and devices that can teach themselves to respond accordingly through machine learning.

The digital twin is one of the newest emerging technologies that rely entirely on data and can leverage virtual and extended reality to optimise sustainability. Using building information modelling (BIM), real-time data about the environment, and advanced analytics, a digital twin is essentially a digital replica of a building and its spaces, systems, assets, and occupants. Using virtual reality, a digital twin can provide complete visibility of a building and how it operates to assess performance and gain insight into how it will perform in the future. Digital twins can help uncover opportunities for energy savings and simulate the impact of adding technologies, modifying systems, changing space layout or occupancy, and other changes to the built environment. Digital twins will continue to evolve and become more mainstream. Still, they will also require greater collaboration among solution providers and integration among building systems to provide a complete digital representation of an entire building.

CLOUD-BASED PLATFORMS

Clean, interoperable data is also vital to leveraging cloud-based solutions supporting integration and enabling data analytics and reporting. Bringing data from smart sensors and devices into cloud-based platforms can ease the process of achieving greater building intelligence by providing a comprehensive framework and dashboarding that re- fines and clusters information in a way that supports decision-making and response by both people and systems. Cloud-based platforms will also enable the advancement of digital twins, as cloud environments better facilitate analytics and simulation. They can also leverage stored data to support emerging gamification applications that make data more consumable and support game-based learning for visualising long-term financial and sustainability implications.

SMART BUILDING DEVICES

Advanced sensor technology has given rise to more smart building devices that can collect information about the surrounding environment, share that information with other systems, and analyse the information to make adjustments. Today's smart sensors can detect a wide range of factors for optimising operations efficiencies and sustainability, including:

- Temperature, humidity, CO2, VOC, radon, toxic and combustible gases, and other contaminant sensors to monitor air quality and adjust ventilation as necessary
- Occupancy, daylight harvesting, and optical sensors to detect people and ambient/sunlight levels to adjust lighting, ventilation, temperature, shading, and other actions that save energy, improve health and well-being and increase productivity
- Pressure, level, and water-quality sensors to detect the presence of or changes in gases or liquids for leak detection, equipment condition monitoring, and waste and water characteristics
- Information about local energy production and storage from on-site energy generation like solar, wind, or geothermal
- Proximity sensors, accelerometers, and geolocation sensors that detect objects and movement for crowd control, parking availability, asset/fleet tracking, wayfinding, assembly line optimisation, and even rodent control
- Infrared sensors to detect heat and movement for intrusion detection, body temperature monitoring and a variety of other uses

These smart sensors are perfect examples of devices that do not require high-throughput communications and can be efficiently and cost-effectively deployed.

With advanced sensor technology, the possibilities are virtually endless for maximising sustainability. Some of these sensor technologies are being leveraged by insurance companies to prevent damage and costly claims, while others are more focused on safety and security or energy efficiency. However, when actionable data from a multitude of these sensors can be shared across building systems and come together for analysis via advanced technology and software-based smart building applications, cloud-based platforms, or digital twins, it provides complete visibility to assess, report on, and both simulate and stimulate the sustainability of a building.

CHALLENGES TO IMPLEMENTATION

The reality is that implementing solutions for a sustainable smart building comes with several potential challenges. With advancements in sensor technology and an increased number of IoT solutions to choose from in the marketplace, building owners and operators are challenged with ensuring they select reliable components and devices that support interoperability and provide the actionable data and functionality they need. This holds true for more than just components and devices for greenfield development—everything from building materials and furniture to fixtures should be verified for sustainability. Third-party verification of standards compliance and EPDs can help determine the impact of products on sustainability and ensure that hazardous materials don't end up in a building.

Selecting well-established solutions with a proven track record can also help ensure success. For example, because LoRaWAN has been widely deployed and proven across a wide range of markets, experts around the globe have accumulated considerable experience and an understanding of best practices that can inform successful deployments. Additionally, given the highly diverse marketplace and complex value chain, those embarking on implementation should choose partners wisely and engage in an established ecosystem that allows them to collaborate with industry experts rather than risk going it alone. IoT connectivity providers, in particular, are recommended partners for enabling an effective and successful technology roll-out.

Even when smart building technologies are in place, building owners and operators need to ensure best practices in utilising those technologies and strive to balance sustainability goals across the planet, people, and profit to avoid generating future debt. For example, energy and carbon reduction goals can compete with health and wellness goals. While increased ventilation rates can improve indoor air quality for occupants, building owners and operators need to ensure that they are not over ventilating and adversely impacting energy consumption and the carbon emissions of the building. This will be a significant challenge as employees return to the office and increase ventilation to improve air quality in response to the COVID-19 pandemic.

Integrated smart systems will be integral to tackling these challenges. They can regulate the appropriate levels of outdoor air to be brought into a building, provide an understanding of how that air is processed, and quantify the overall indoor air quality. By collecting clean, actionable data and technologies like ML/ AI, systems can analyse trends to understand how the building has been operating over time and make adjustments as needed.

As weather patterns shift due to climate change, these capabilities will become invaluable to understand the impact and adjust accordingly. Siloed data isn't the only barrier to optimising sustainability. Siloed thought processes across all stakeholders—developers, engineers, owners, and operators—can also limit the implementation of smart building technologies. Therefore, it is vital to ensure collaboration for project delivery goals, implementation, and data usage. Democratising data and demonstrating how it can be leveraged for achieving different goals across an organisation can help break down silos. However, sustainability goals often compete with capital planning. The total performance of the built environment versus the total cost can be a barrier when there is a lack of value consensus and understanding of the return on investment (ROI).

While some goals such as energy consumption, waste reduction, and others with bottom-line impact have a clear ROI, the complexity of systems in a sustainable smart building can make determining ROI more difficult. This is particularly true for solutions that aim to improve occupant health, wellness, and satisfaction.

Expected ROI can also vary based on stakeholder goals, region, and industry maturity. For example, where PoE lighting is readily accepted and doesn't require an electrician, labour costs are easily calculated to demonstrate capital savings, and the energy savings of LED lights is easily calculated for operational savings. In regions where real estate portfolios are boosted via sustainable smart buildings, or smart building technologies are more mature, there may be a greater focus on value versus cost, and ROI may be easier to obtain. Both Capex and Opex can impact ROI, and it's essential to consider cost and ease of implementation, recurring costs, and overall scalability. As a case in point, setting up a WAN network is fast and easy, with roll-outs that can be completed in a matter of days or weeks. The small recurring charge of the gateway is also far less than traditional cellular fees, and once the network is in place, it paves the way for massive scaling and new technologies.

Most smart building experts cite education as vital to ensuring that key stakeholders understand the importance of integration that starts with the design phase. They also need to understand that sustainability can be achieved in a way that ultimately saves money.

Educating these individuals about the type of data that can be analysed and leveraging digital data to simulate outcomes through technologies like digital twins and gamification can broaden their perspective. At the same time, organisations need to educate employees on making better decisions and adopting practices that support sustainability via incentives and a sense of inclusion.

The good news is that as technology continues to evolve and smart building technologies become more predominant, the industry is starting to understand better the importance of sustainability and progress toward more quantifiable measurements that can help determine ROI.

THE NEED FOR ASSESSMENTS AND CERTIFICATION

While data is the foundation of a sustainable smart building, holistic assessments that consider all aspects of a smart building built on a measurable, verifiable, and objective, a repeatable framework of criteria is vital to benchmarking efficiency, operations, and occupant experiences to determine investment strategies. Assessment is also vital for building owners and operators to know where they stand, identify solutions with the most significant impact, and achieve ratings and certification that can be leveraged to promote their commitment to sustainability.

SELF-ASSESSMENT AS THE FIRST STEP

Companies looking to determine areas where they can improve sustainability first need to have a baseline for where they are today. For example, TIA QuEST Forum's Sustainability Assessor is ideal for companies in the information and communications technology (ICT) industry to rapidly self-assess and benchmark their sustainability and corporate social responsibility programs against industry best practices.

By simply answering key questions, the Sustainability Assessor gives an organisation a rating of how they perform in ten different areas of sustainability. These areas include environmental management, resource efficiency optimisation, carbon footprint and ozone depletion, corporate and social responsibility, supply chain management, stakeholder engagement, organisational engagement and capability, eco-design, and end-to-end delivery. The sustainability assessor then maps these different areas to the scale of impact it will have on the top and bottom line of the company and provides customised recommendations for improvement.

While TIA QuEST Forum's Sustainability Assessor is based on the ICT industry's TL 9000 standard and is geared more towards assessing the sustainability of a company's, or their supply chain's, operations, the online self-assessment tool of TIA UL's SPIRE Smart Building Assessment and Rating Program is designed to assess physical buildings in any market or industry. The SPIRE self-assessment tool provides an automated, user-friendly platform for entering building information based on the six specific SPIRE assessment criteria—connectivity, health and well-being, life and property safety, power and energy, cybersecurity, and sustainability. It allows building owners and operators to gain valuable insights into the current state of their smart building and acquire an assessment of building functionality that can be used as a roadmap for future improvements to help increase asset values. Through UL and other testing services, building owners and operators can also assess their indoor air quality and other building factors that can help identify problem areas to address.

All of these assessment tools are important as building owners and operators are coming to realise they need to do their part in protecting the planet while delivering quality occupant experiences and reducing cost.

CERTIFICATION PROGRAMS

Over the past couple of decades, sustainability has focused on several nationally or globally recognised smart building certification programs in the marketplace. Many of the following certifications are considered prestigious and offer organisations the means to promote their commitment to sustainability and the environment:

- LEED – U.S. Green Building Council Leadership in Energy and Environmental Design
- BREEAM – Building Research Establishment Environmental Assessment Method
- Green Globes – Used primarily in Canada and the U.S.
- Living Building Challenge – Created by the International Living Future Institute
- WELL Building Standard – Administered by the International WELL Building Institute (IWBI)
- Fitwel – Operated by the Center for Active Design (CfAD) ▪ Building Owners and Managers Association (BOMA) 360 Performance Program
- Other nationally and globally recognised rating systems, such as Singapore BCA Green Mark, Australian Green Star, German Sustainable Building Council's DGNB, France's Haute Qualité Environnementale (HQE) and China Academy of Building Research (CABR)
- Codes such as ASHRAE 189.1, International Green Construction Code and CALGreen

While these certifications create awareness and fulfil green building criteria, they have not had as strong of an impact as most proponents of sustainable smart buildings would like. These certifications also focus primarily on the conventional concept of "green" buildings rather than taking a more holistic approach. Another challenge with some certifications is that adoption varies from region to region due to the origin of the certification, culture, and government influence. In areas of Europe, for example, a LEED or BREEAM certified building enables real estate companies to apply for bonds and incentives such as reduced interest rates, which provides significant savings. In other regions where government grants or subsidies are available, developers may focus on those incentives rather than opting for non-government-based certifications.

To thoroughly address environmental issues on a global scale, smart building experts see the value in harmonising certifications and cross-pollinating the best practices from different regions, thereby supporting those regions that have not yet reached maturity.

The need for harmonisation and a broader, more holistic approach to sustainability are key driving factors behind the development of TIA UL's SPIRE Smart Building Assessment and Rating Program. Existing certifications like LEED, BREEAM, and others are brought into the fold as part of the sustainability criteria of the assessment. Still, the SPIRE program also takes a broader approach to consider connectivity, health and well-being, life and property safety, power and energy, and cybersecurity. Based on measurable data, these six criteria together consider the planet, the people, and the profit of a sustainable smart building. Organisations have a complete smart building evaluation using an objective, evidence-based assessment framework based on data. They can earn a UL Smart Building Verified Mark, plaque, and building performance rating.

It is not just whole-building certifications that deliver value. Device certifications also play a critical role in ensuring that a building effectively supports and collects data from IoT devices and sensors.

For example, several mobile carriers certify modules, chipsets, or devices for their 5G service, and organisations like the Ethernet Alliance certify devices for PoE to ensure interoperability and compliance with industry PoE standards.

ROLE OF CODES AND REGULATIONS

While certification programs offer significant value, they are optional, unlike codes and regulations. Building codes and regulations are often at the very base level of sustainability with minimum requirements. Still, with an increased focus on climate change, most industry experts believe that will shift as the regulatory requirements catch up with the markets and legislation is introduced.

Codes and regulations vary from region to region based on culture, market status, and other factors. While regulatory bodies in Europe are primarily interested in safety and privacy, others may focus more on energy consumption or the impact of wireless communication frequencies. Codes and regulations can vary from city to city where authorities with the jurisdiction (AHJs) have different requirements and varying concerns about sustainability and the environment.

As regional markets focus more on smart building concepts, some AHJs may begin to focus on carbon emissions and adopt smart building requirements, which can help encourage a sustainable smart building approach in regions where it has been lacking. In markets where sustainable smart buildings are becoming the norm, real estate organisations are working closely with the public sector to push ways to focus sustainability into local laws and regulations.

THE FUTURE IS BRIGHT

Regardless of the driving factors—from growing concern surrounding climate change to market demand and even the impact of the COVID-19 pandemic—industry experts all agree that the increased focus on the sustainability of smart buildings and the shift to a broader "blue" building concept that takes into consideration a building's impact on the planet, the people, and profit over its lifecycle is a step in the right direction.

There's no doubt that sustainability and smart buildings are here to stay. With an estimated 40% of all carbon emissions globally attributed to the built environment, there's also no doubt that the two together can have a significant impact.

Sustainability must be an absolute baseline for smart buildings. As the sustainability concept has evolved, that means deploying and integrating smart building technologies that address all aspects of a building's impact—plant, people, and profit.

Supporting building owners and operators on the path to a sustainable smart building can only come from clean, interoperable, and actionable data via infrastructures combined with certification programs with verifiable assessment criteria like SPIRE that provide a starting point and a benchmark for any organisation. As organisations worldwide come together to address and tackle building sustainability head-on, they will ultimately discover that it's not just about the technology or the ROI. It's also about seizing the opportunity to make changes today for a better tomorrow. wn

The ROI of Smart Workplace Investments

Understanding the Potential Gains from Optimising Space Performance & Employee Experience

Companies aiming to improve their workplaces are juggling a large set of competing demands for investment to support both on-site and remote work. With so many new priorities, a natural question to ask when evaluating any new product is how the returns on that investment (ROI) compare to those of other potential products.

By Nicole Weygandt, Ph.D.

Smart workplace solutions, which encompass hardware and software solutions to optimise the physical workplace, streamline ways of working in the office, and create a positive workplace experience, have become increasingly cost-effective but still represent a significant investment. Discussions of ROI for smart workplace technologies often stumble over the fact that the technologies have a vast range of applications, not all of which will be relevant to every company, because of differences in workplace cultures and existing technologies.

To help companies evaluate smart workplace solutions, this paper outlines the different ways companies can capture return on investment from sensor-based workplace technologies aimed at optimising space and employee experience. It draws heavily on third-party research to explain both the source and size of potential returns and outlines different approaches to calculating returns so that potential investors have all the necessary tools to estimate the potential gains for their own office spaces.

SPACE OPTIMISATION

Perhaps the largest and most visible source of ROI from smart workplace solutions is the return on space optimisation: If a company can eliminate an entire floor or building by cutting down on unnecessary space, the savings on rent, utilities, and services are substantial and easy to quantify

to stakeholders. The same is valid for avoiding future real estate investments: finding ways to make the most out of an existing portfolio (even if it doesn't lead to space reductions) can help delay or reduce the amount of real estate required for expansion.

Space optimisation falls into three approaches: footprint optimisation focuses on managing the amount of space; in aggregate densification aims to optimise the amount of space per person; while optimising the space mix ensures that the types of spaces provided align with the spaces employees need to support their work.

Optimising the footprint of the workplace involves the comparison of the aggregated square footage of a location or portfolio to the actual need based on occupancy and utilisation data. It takes place by aligning the actual use of each type of workspace to best practice benchmarks, subject to adjustments based on industry or company characteristics. Additionally, it is critical to consider peak or maximum occupancy alongside the more commonly cited average when setting optimisation targets. Workplace sensor technologies are crucial to this optimisation approach, delivering the continuous reporting and level of granularity that enables data-driven decision making around when and how much space to add or release.

Densification refers to reducing the average amount of space per person by fitting more people into the same space. When done well, densification occurs without detracting from employee experience or productivity and may even result in a more varied workplace ecosystem as specialised spaces are added. The most well-known path to densification is shifting from private offices to cubicles, bench seating or other open-office desk arrangements. Another common path is eliminating assigned seating and reducing the desk-to-person ratio. In these densified environments, smart workplace solutions like sensors can help employees quickly find and access the spaces they need by identifying which spaces are available in real-time. The benefits of densification can take the form of space savings, but research has also linked densified environments to higher productivity and collaboration.

Space mix optimisation refers to the reconfiguration of collaboration spaces like conference rooms or huddle rooms to align the size of the space with actual usage patterns. More generally, it captures the attempt to align demand and supply of space to be primarily used at or near capacity. Space mix optimisation occurs by measuring how often a space is used over time, typically through headcount sensors, although other sensor and monitoring options exist. Actual measures are then compared to both occupancy and utilisation benchmarks to evaluate the combined performance of each space, which can help identify which spaces are underperforming and, ideally, also to understand why.

OPTIMISING THE EMPLOYEE EXPERIENCE

Employee experience reflects efforts to enhance employee engagement, with benefits in retention and productivity. Although a wide range of factors shapes the employee or workplace experience, some estimates suggest that the physical and technological environment contributes up to 30 per cent of the overall employee experience.

Workplace research on flexible and agile spaces provides one approach to understanding how technologies can enhance the employee experience. These flexible work concepts rely heavily on technology to function smoothly. The productivity enhancements associated with workplace experience and enabled by smart workplace technology fall into several categories: purpose, autonomy, communication, and reputation.

Purpose describes how technology helps employees find and access the spaces and tools they need to complete different types of tasks in the office. Additionally, purpose can also include matching employees with spaces that fit their personalities or needs (such as difficulty concentrating in noisy environments or environmental preferences), separate from the actual tasks they are performing. Aligning space with purpose is one of the central tenets of activity-based working and the governing logic of other types of flexible work, including hybrid work.

Autonomy refers to the sense of efficacy that arises from employees' ability to choose their workspace in the office. In this view, productivity (along with benefits like talent retention) is not just enhanced by having well-designed spaces that support certain types of activities but is also the result of the feeling of empowerment and satisfaction that comes with choice. This positive feeling, in turn, results in greater performance.

The concept of communication captures both serendipitous encounters that can spark creativity along with day-to-day teamwork and a sense of community. One of the key ways technology can enhance workplace connections is by making it easier to find colleagues and facilitating densification.

Reputation encompasses both the ability of the corporate image to provide gains in terms of talent attraction and retention and broader benefits in terms of morale. Having a high-performing workplace, which includes both space and technology, has been associated with several positive outcomes, including being perceived as more innovative and more likely to be recommended to others by current employees.

Finally, in addition to the four categories above that are associated with a high-performing flexible workplace, technology also serves as a powerful tool in optimising the work environment for performance on an ongoing basis. Expressly, monitoring and analysing data about how employees interact with space is not limited to understanding what size conference rooms employees prefer. Still, it can also gather systematic data on how employees respond to changes in the fit-out. Thus, a final benefit of technology is its ability to enable active experimentation in the workplace.

Each broad class of workplace optimisation can be illustrated through simplified use cases, but the reality is that calculations are likely to be far more complex in practice. A single company might be deploying solutions across multiple locations with different average rent, salaries, or employee numbers. Even within two sites owned by the same company in the same city, the outcomes could look quite different. We offer a three-step process that allows potential investors to estimate their potential gains:

1. Determine the optimisation scenarios that apply to each part of your portfolio.
2. Gather relevant organisational inputs, both from internal sources and publicly available resources such as benchmarking data.
3. Use those inputs to calculate either ROI or technology break-even estimates to guide decision-making, keeping in mind that the returns from different scenarios may not be perfectly additive.

WHAT IS A SMART WORKPLACE?

Smart workplace technologies encompass a range of solutions to optimise the physical workplace, streamline ways of working in the office, and create a positive workplace experience. They range from IoT-enabled hardware like space and indoor air quality (IAQ) monitoring devices that can be used to generate management insights and automate workplace processes to mobile apps and digital signage for a better workplace experience. This solution space is even beginning to extend beyond the traditional office to reflect an interest in coworking and hybrid working.

While this diversification can be a boon to companies seeking tailored solutions to their emerging needs, it complicates the technology selection and evaluation process. Are companies better off buying a single integrated solution, even if it means potentially locking themselves into that ecosystem? Should they choose special-purpose apps for each workplace need and develop custom integrations that may require updating as new product releases are pushed out? Which use cases are business-critical and nice to have, and does any one solution support everything?

This paper is designed as a guide to understanding the potential returns around one subset of smart workplace technologies: software platforms that capture, process, analyse, and visualise space monitoring data. These technologies are designed to optimise two essential attributes of the workplace: space performance and employee experience, each of which can be further subdivided to reflect different optimisation functions. While treated as discrete categories for the sake of clarity, in practice, they are overlapping and changing one can affect the others.

In addition, not every attribute is equally significant in terms of potential returns depending on where a company is located on its workplace optimisation journey. As such, companies need to adjust their expectations and calculations of return on investment (ROI) to their unique circumstances. The paper aims to give readers the information and tools to make those internal adjustments and evaluate how and to what extent these technologies might suit them.

TWO PATHS TO ROI: SPACE & EXPERIENCE

Companies aiming to improve their workplaces are juggling a large set of competing demands: more investment into health and wellness, more investment into reservations systems to support flexible or hybrid work, more investment into building analytics to help guide real estate strategy, and more investment into remote working tools like video conferencing equipment, all while responding to growing cybersecurity risk. With so many new priorities to add to existing needs, a natural question to ask when evaluating any new product is how the returns on that investment (ROI) compare to those of other potential products.

Smart workplace solutions have become more cost-effective over time as technology has improved, and the price of sensors has fallen. The growth of Software as a Service (SaaS) business models in this space has also improved the value proposition of these products as clients get access to new features and improvements over time. Even so, these solutions can represent a significant investment that requires extensive internal approvals – not to mention substantial time commitments by real estate and IT teams that are evaluating different options.

This evaluation, however, is not easy. Discussions of ROI for smart workplace technologies often stumble over the fact that the technologies have an extensive range of applications, not all of which will be relevant to every company. For example, a sensor-based reservation system for workstations is essential in a workplace where teams are frequently changed. Employees regularly switch

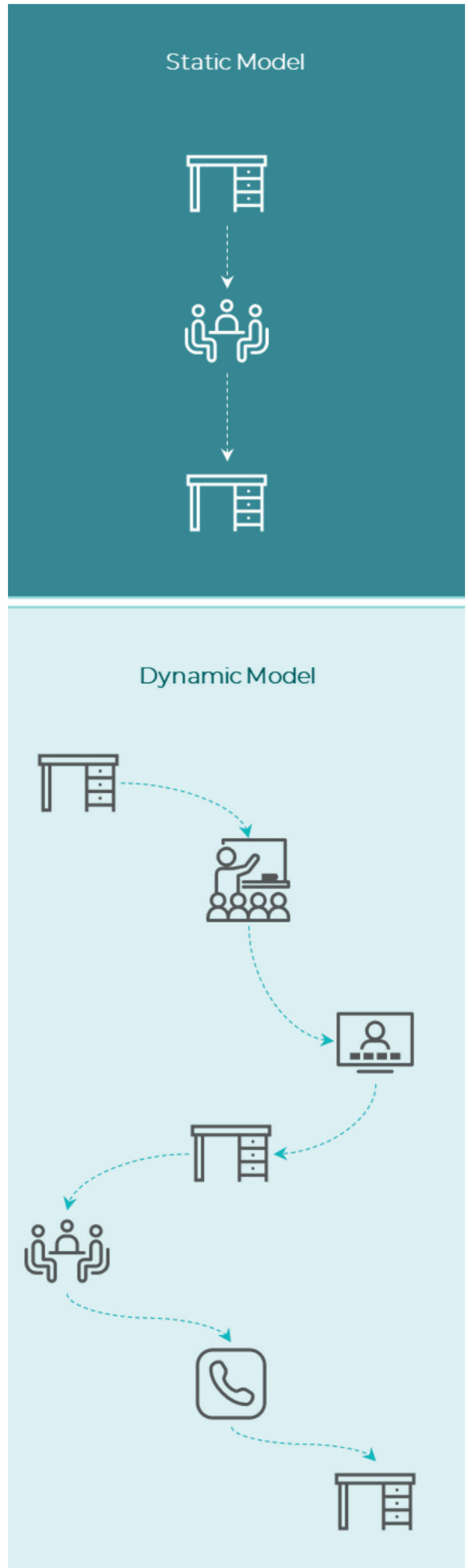


Figure 1: Smark workplace solutions

between different work areas and the low seat-to-employee ratio. However, suppose a company has stable teams that spend most of their day at individual workstations and an office culture where most people gravitate to the same desk every day. In that case, a simple reservation system without sensors might suffice.

Likewise, the ROI of a smart workplace investment will also vary based on what solutions a company already has in place. An integrated workplace management system (IWMS), for example, will represent a much more significant value gain to a company switching from a mess of spreadsheets than one that is simply migrating from one IWMS to another. Likewise, a company switching from a wide range of different reservation apps across different locations to a single, global solution fulfils a different need than a company adopting a reservation system for the first time.

With these limitations in mind, this paper aims to spell out different categories of returns on smart workplace solutions, focusing on the insights gained from workplace sensors. It draws heavily on third-party research to estimate a range of outcomes returns so that potential investors can assess which scenarios fit their situation most closely. It should be noted that, beyond variations in use cases, outcomes will also be affected by a range of other factors, including location, employee salary and activities, and workplace concept. The cost of solutions, one of the components of ROI, will also vary substantially by the scope of the project and the choice of technology. Therefore, companies should use this guide as a starting point to guide conversations as they develop tailored estimates.

We focus on two broad categories of returns on smart workplace solutions: space and employee experience. Each of these, in turn, is subdivided further to reflect different ways in which technology can prove beneficial. For space, we consider footprint, densification, and right-sizing. For employee experience, we focus on productivity and talent management. Most workplaces can expect to see benefits across multiple categories and sub-categories. Still, the precise combination can vary across time and location, making it challenging to calculate ROI. Rather than offer a simple formula for calculating returns on investment, we present the research and business case along with general approaches to calculating returns that can be adapted on a case-by-case basis.

OPTIMISING SPACE PERFORMANCE

Perhaps the largest and most visible source of ROI from smart workplace solutions is the return on space optimisation: If a company can eliminate an entire floor or building by cutting down on unnecessary space, the savings on rent, utilities, and services are substantial and easy to quantify to stakeholders. The same is valid for avoiding future real estate investments: finding ways to make the most out of an existing portfolio (even if it doesn't lead to space reductions) can help delay or reduce the amount of real estate required for expansion.

That said, space optimisation can go well beyond managing the size of the footprint. Whereas footprint optimisation focuses on managing the amount of

Footprint

Densification

Space Mix

Optimize the aggregate square footage by eliminating excess space
Objective: Reduce overall square footage (current of future)

Increase the number of people in a given space
Objective: Reduce square footage per person

Adjust the size and use of different spaces to align supply and demand
Objective: Increase usage of each space type

Figure 2

space in aggregate, densification aims to optimise the amount of space per person. Finally, optimising the space mix or stacking can also ensure that the spaces provided align with the spaces employees need to support their work. All three approaches (optimisation of footprint, density, and space mix) can result in significant returns, but they do not all result in the reduction in physical space.

Potential investors in smart workplace technologies need to carefully consider how each of these strategies aligns with their respective real estate portfolio and their optimisation objectives as they assess the potential benefits of the investment. The potential for gains from optimisation can depend on the state of the existing portfolio, ranging from factors like location, size, and primeness, which influence the size of savings, to factors like lease term or the ability to sublet which determine when savings can actually be realised.

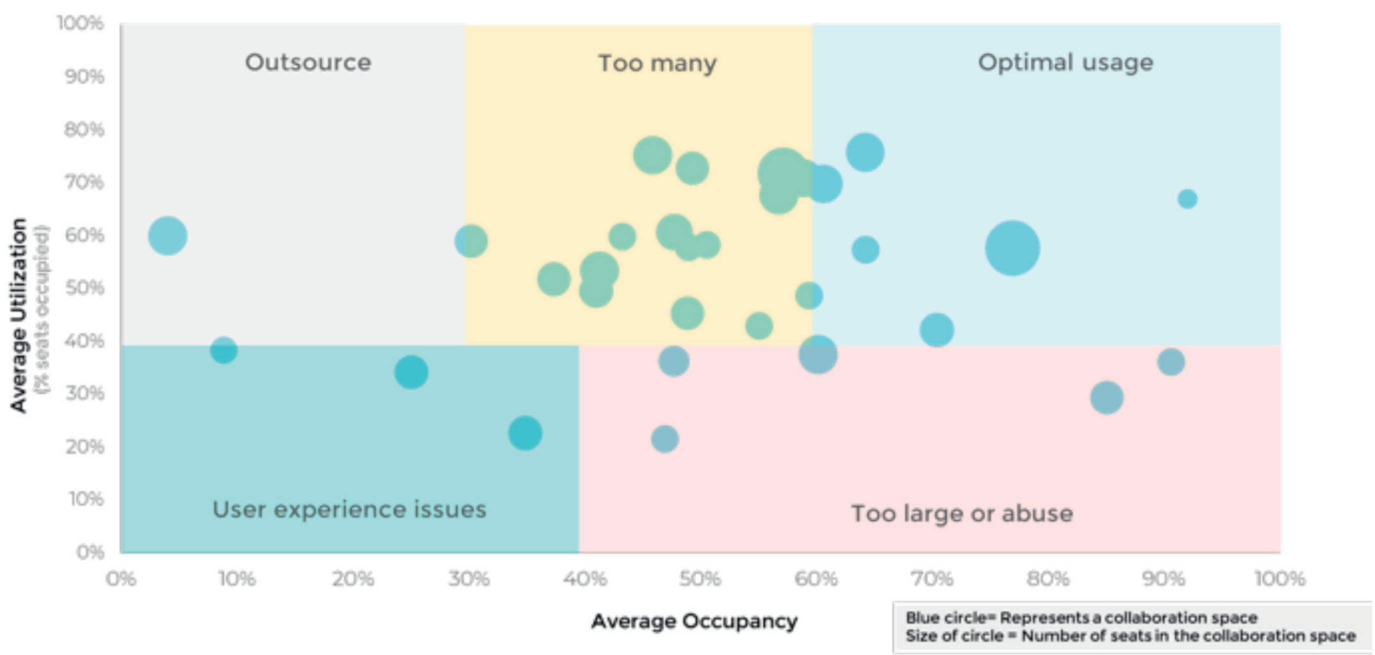
FOOTPRINT OPTIMISATION

Optimising the footprint of the workplace involves the comparison of the aggregated square footage of a location or portfolio to the actual need based on occupancy and utilisation data. In most cases, it involves identifying and eliminating wasted space, meaning conference rooms that sit empty most of the time and workstations that are only used half of the time and could be consolidated through desk-sharing. This assessment often occurs in anticipation of a change in workplace concepts, such as a shift from assigned desks to flexible seating or the implementation of expanded remote or hybrid work policies that could reduce the number of people in the office. It might also coincide with a change in office location or lease renegotiation, which would allow a company to capitalise on any potential savings immediately.

Broadly speaking, footprint optimisation takes place by aligning the actual use of each type of workspace to best practice benchmarks, subject to adjustments based on industry or company characteristics. A standard benchmark for individual workstations or desks is 70% average occupancy. This means that, on average, workstations should be occupied or in use approximately 70% of the working day within a given time frame. One corporate survey found that actual levels of occupancy across all spaces (not just workstations) in most industries fall between 49% and 68%, suggesting substantial room for optimisation.

Here we should note that the best practice benchmark for collaboration spaces like conference rooms may differ from workstations. While benchmarks might change due to hybrid work practices, traditionally, occupancy in collaboration spaces has been set at a somewhat lower target of 60%, partly reflecting the diversity of size and characteristics of collaboration spaces.

Space Occupancy vs. Utilization



Source: Rudy Clonen, Global Strategic Advisor, Spacewell

Figure 3

Additionally, it is critical to consider peak or maximum occupancy alongside the more commonly cited averages when setting optimisation targets. In addition to average occupancy, organisations should also target maximum occupancy rates above 95% for workstations to ensure that they are not over-supplying space. In the case of collaboration spaces, a similar calculation should take into account utilisation numbers, meaning the share of people in space relative to its capacity (in other words, for group spaces, it is essential to consider both how often they are used and how many people are in each space). Focusing on utilisation helps space planners differentiate between conference rooms used for group meetings rather than being misused as personal offices.

The balancing act involved in optimisation is illustrated in the figure below: considering both occupancy and utilisation, we can see optimising for just one dimension could lead to sub-optimal outcomes overall. A space might always be occupied while only being used by one or two people using a conference room as a personal office (which would place the room in the red zone in the following chart). Where spaces are rarely used but near capacity when in use (grey zone), such as training rooms or board rooms, it might be more efficient to rent off-site space for those gatherings. We can identify both the problems and potential solutions by examining both dimensions simultaneously.

Workplace sensor technologies are crucial to this dual optimisation approach. While a growing number of companies are now monitoring space usage, surveys suggest that over 80% of organisations rely on badge swipe data, with visual observation being the second-most used source of information.

FOOTPRINT OPTIMISATION ROI CALCULATION

Although estimating the gains from footprint optimisation is challenging, a natural point of departure for such a calculation would be to start with a comparison of average occupancy rates in one's industry to optimised benchmarks. The difference represents a rough estimate of how many desks or conference rooms can be eliminated.

Here it is important to note that average occupancy is only a starting point – in practice, complete optimisation needs to also take into account maximum and spread of occupancy rates to ensure that there are no performance issues in practice. The following example, which focuses on average occupancy, serves solely as a rough guideline of savings potential.

Let us begin with a life science company located in a prime location in Boston with 300 employees. The typical allocation of space per person in 2019 was 200 square feet in its sector, so we assume a beginning footprint of 60,000 square feet.

The company currently has average occupancy levels typical for its industry, or 60%. Suppose workplace technologies allow the company to raise its average occupancy levels from 60% to the 70% best practice mark. In that case, it can potentially eliminate 10% of its space without impacting workplace performance, assuming that maximum occupancy was also below 90%.

In a prime location in Boston, the rent per square foot is $99, so optimising the footprint can result in overall savings of $594,000 per year in this example. This figure would need to be set against the cost of the technology used to evaluate actual occupancy and utilisation data. Still, even at an exorbitant cost of $9.90 per square foot, such a project would break even in its first year.

While this represents a simplified calculation that would need to be modified for the specific characteristics of each company and location, it serves as a helpful guidepost in evaluating potential returns on footprint optimisation.

These are potentially powerful tools that can often be readily applied, but they have significant limitations. Badge swipes might only capture entry into a building or floor or (if used at the room level) might only measure the first participant in a meeting. If additional attendees fail to check in once the room is occupied, occupancy measures might be accurate, but the actual headcount would be lost. Badge swipes are also unlikely to accurately reflect when users leave a room, missing out on information about whether the length of bookings aligns with actual usage. Visual observation is typically limited to randomised or scheduled spot checks and, therefore, cannot capture actual flows of people across spaces.

Instead, various sensors (and increasingly also technologies like conference room video or WiFi networks) can continuously track usage patterns to provide an accurate picture of both utilisation and occupancy over time. These granular data can then be evaluated using big data analytics to determine whether space can be eliminated or converted to a different use, potentially resulting in a reduction in office footprint, with surplus space being sublet or eliminated in future leases. Sensors can thus be used for the initial optimisation. They should be used on an ongoing basis to ensure that the behavioural changes that result from the changing office space do not require further interventions.

From a change management perspective, having objective, ongoing measures about space utilisation is also essential for responding to complaints about not finding rooms. Actual usage data can be used to verify reports, help direct users to alternative locations, and explain management decisions about what types of spaces are available, all parts of ongoing optimisation activities.

DENSIFICATION

Densification refers to reducing the average amount of space per person by fitting more people into the same space. It is often a complement to footprint optimisation, although it is not a precondition (or necessary consequence) for changing the office footprint. Although densification has been negatively associated with cubicle farms, densification is not inherently a negative development. When done well, densification occurs without detracting from employee experience or productivity and may even result in a more varied workplace ecosystem as specialised spaces are added.

The most well-known path to densification is shifting from individual private offices to cubicles, bench seating or other open-office desk arrangements. Although widely maligned in popular culture and frequently accompanied by complaints about noise and distractions, this shift is often well-intentioned and is commonly accompanied by other design improvements. One key objective of the transition to open seating is to encourage greater communication and teamwork, although some research questions the effectiveness of this strategy. When done well, this type of densified environment also accounts for the need for privacy and focus by allocating some of the freed-up space to concentration spaces and phone booths. In such an activity-based environment, smart workplace solutions like sensors can help employees easily find and access the spaces they need by identifying which spaces are available in real-time. In this way, the workplace provides for various spaces to accommodate different ways of working while also encouraging more interaction.

Another common path to densification is to eliminate assigned seating altogether. In this scenario, companies can reduce the desk-to-person ratio from the traditional 1:1 level to as few as 0.6 desks per person. This can be achieved without causing shortages when employees spend at least part of their time in other parts of the office (such as conference rooms) or away from the office (such as when they are making sales calls or, increasingly, when they work from home). While the potential savings are substantial, for a flexible seating arrangement to be successful – mainly when density levels are high – it is essential to have management buy-in and the right technology in place.

Floorplans showing occupancy of desks can help avoid wasted time and frustration spent searching for available seats. Useful features also include the ability to find colleagues. For workplaces that use reservations for workstations (which can, however, limit the extent of densification), sensor or check-in data can also be used to cancel bookings in the event of a no-show automatically. This feature is likely to become more critical as companies embrace flexible working.

The benefits of these two approaches to densification take several forms. First, densification can lead to space savings (as well as fit-out cost savings) by reducing the number of desks that need to be maintained and equipped, either based on current usage or in anticipation of expansion needs. It must be kept in mind that these cost savings need to be balanced against the need to invest in workplace technology, more collaboration spaces, and design improvements.

Second, when densification involves a shift to more open seating with corresponding investment into noise remediation and modern design, it can be associated with higher employee productivity, communication, innovation, and reputation. One natural experiment that compared employees in traditional cubicles to those moved to a modern, open-plan office found that, in addition to increasing workplace density by 14%, the change was associated with increased employee perception of organisational innovativeness and collaboration along with greater satisfaction with co-workers.

A survey of Australian office workers similarly found that employees in a Flexi-desk environment reported more favourable ratings in terms of overall building satisfaction and perceived productivity than fixed-desk employees despite a significant reduction in the individual workspace. One possible reason was that a substantial increase in collaboration spaces accompanied the densification associated with Flexi-desking. This factor likewise can contribute to increases in employee interaction.

SPACE MIX OPTIMISATION

Space mix optimisation (or right-sizing), as used in this paper, refers to the reconfiguration of collaboration spaces like conference rooms or huddle rooms to align the size of the space with actual usage patterns. More generally, space mix optimisation attempts to align demand and supply of space to be primarily used at or near capacity. Space mix optimisation is often pursued alongside other space-saving approaches but may also be undertaken independently.

Notably, space mix optimisation may result in a smaller office footprint, but it might also simply alter the space mix without affecting the size of the office. As a result, the savings from optimisation can be more difficult to project than other space strategies.

Space mix optimisation takes place by measuring how often a space is used over time, typically using headcount sensors, although other sensor and monitoring options exist. Actual measures are then compared to both occupancy and utilisation benchmarks to evaluate the combined performance of each space, which can help identify which spaces are underperforming and, ideally, also to understand why.

For example, conference rooms that are constantly in use but are occupied far below capacity could indicate one of two problems: that employees are using conference rooms as private offices or that conference room capacity poorly reflects typical team size. In the former case, a solution would be to add more individual focus rooms for employees to use when they need privacy. In contrast, the latter case might best be addressed by resizing or partitioning some conference rooms to accommodate smaller teams.

Conversely, if conference rooms are rarely used but are close to capacity when occupied, a natural next step is to analyse the purpose of those infrequent meetings. Suppose rooms are only being used for quarterly all-hands meetings, for example. In that case, a company might be better off renting space in a nearby hotel for those quarterly events and giving up (through lease changes or subletting) their poorly used space.

While some degree of optimisation is possible using user surveys and manual counting, these methods only capture information at the moment in time rather than on an ongoing basis. Manual optimisation, therefore, is frequently a one-time or intermittent exercise. On the other hand, sensors can capture information about when and how long each space is being used, ensuring a more tailored work environment. As illustrated in the figure below, sensors allow for a better fit-out of the workspace from the beginning, and their added value increases over time.

Space mix optimisation in this smart workplace scenario is approached as an ongoing, iterative process. When rooms are resized, added, or eliminated, those reconfigurations can result in

DENSIFICATION ROI CALCULATION

A rough calculation of the potential savings from densification starts with the current space allocation per person or desk, compared to a target level. Those targets might vary across different offices based on business function or set according to benchmarks in different markets.

Tools like Cushman & Wakefield's Global Occupier Metrics calculator, for example, allows users to view local market best practices for net square feet per desk and is also able to estimate rent and cost per square foot based on primeness of location and quality of fit-out. Such tools allow occupiers to estimate both the potential rent savings from reducing the space per person and any necessary cost adjustments associated with fit-out improvements.

For example, assume a software company in Chicago with 100 employees currently allocates 150 square feet per desk in a location that represents the market average.

The company chooses to densify its offices to reach the 113 square feet per desk average. In this case, the company might expect to save up to 1,369 square feet across all its employees.

It chooses to allocate 500 square feet of that saved space to new collaboration spaces as part of a strategy to encourage innovation and releases the remaining 869 square feet in its upcoming lease renegotiation.

The overall savings on rent in the market represent $19,987 per year, before considering the one-time fit-out costs from the redesign and any additional technological investments. However, those additional costs are partly offset by the redesign's productivity improvements, discussed under "Experience."

unanticipated employee behaviour changes. Employees who previously stayed at their desks for confidential calls instead of occupying conference rooms might gravitate towards newly added phone booths, revealing pent-up demand for different space types.

In this case, the returns from space mix optimisation might be reflected in productivity improvements as employees can match their space to their needs without searching for workarounds.

EMPLOYEE EXPERIENCE

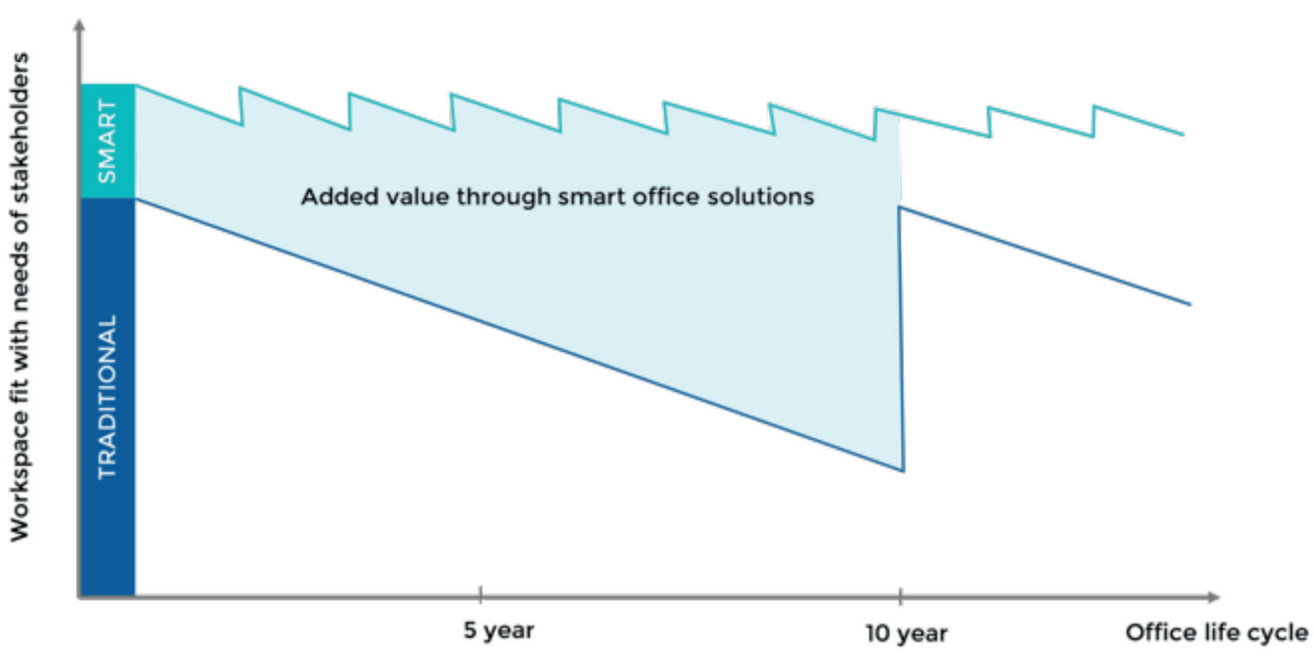
"Workplace Experience" has been a buzzword for some time, reflecting both alarmingly low levels of reported employee engagement, along with the potential benefits of high engagement in improving absenteeism, workplace safety, and work quality. Although the employee or workplace experience is shaped by various factors, from work-life balance to diversity, some estimates suggest that the physical and technological environment contributes up to 30 per cent of the overall employee experience. Investing in office design and the technological tools that help employees navigate features and amenities can yield significant benefits.

Those benefits are particularly pronounced in knowledge industries where creativity, innovation, and intellectual engagement are vast drivers of value, and productivity is not always a direct reflection of the time spent on a task. Leading technology companies like Google, Apple, and Facebook are famous for their corporate campuses and extensive amenities. By providing such rich working environments, these companies seek to offer their employees surroundings that motivate, foster creative "collisions" and collaboration, support different working methods, and make it easy and attractive for employees to spend most of their time at the office.

While not all companies have the resources of a leading tech company, the power of workplace technologies to support employees applies even to those without a sprawling corporate campus. For many such companies, workplace technologies operate in the background to help determine what's working, what could be improved, and to generally make things run more smoothly. To justify such an investment, however, companies need to communicate the potential ROI to internal stakeholders, which can often be a challenge.

This section draws on workplace research, particularly research focusing on flexible and agile spaces, to demonstrate how and – to the extent possible – how much enabling flexible office designs can enhance employee productivity. Smart workplace

Enabling Ongoing Optimization with Technology



Source: Rudy Clonen, Global Strategic Advisor, Spacewell

Figure 4

technologies are virtually essential to making such flexible concepts work smoothly, so at least some of those gains can be attributed to the technological investment. Still, it is essential to note that smart workplace solutions can also yield returns in more traditional offices with assigned seating (although those returns are likely to look different).

The productivity enhancements associated with workplace experience and enabled by smart workplace technology fall into several categories: purpose, autonomy, communication, and reputation.

FIT-FOR-PURPOSE SPACES

Purpose describes how technology helps employees find and access the spaces and tools they need to complete different types of tasks in the office (this is also commonly described as an activity-based work environment, or ABW). Additionally, purpose can also include matching employees with spaces that fit their personalities or needs (such as difficulty concentrating in noisy environments or environmental preferences), separate from the actual tasks they are performing. Aligning space with purpose is one of the central tenets of activity-based working and the governing logic of other types of flexible work, including hybrid work.

The fundamental idea behind purpose as a driver of value is that fit-for-purpose spaces allow each employee to be most productive throughout the day. Thus, taking a confidential call is more accessible in a quiet phone booth than in a crowded bullpen, while also more efficient than sitting alone in a conference room. Additionally, purpose-based technologies also assume that space needs are not constant over time, so assigning an employee to a suitable desk is insufficient. Technologies thus need to be able to accommodate frequent changes and a wide range of space types.

Survey data suggest that giving employees access to suitable spaces can substantially impact productivity. A recent survey of employers, for example, found that over sixty per cent of U.S. respondents estimated that flexible choice of workspaces increased productivity by 20% or more. Self-reporting by employees likewise suggests that as many as 1 in 5 experience productivity impacts from accessing their preferred seating, in part because of the way different spaces affect communication patterns.

Technology supports purposeful office design in two ways. From the end-user perspective, technologies like reservation apps help to match employees with spaces that meet their needs. Search tools can help users understand which spaces are available, what features exist in each space, and how to navigate to those spaces. Booking functionality allows users to make sure that they have access to the space at the moment or to plan for their day.

From the real estate manager's perspective, workplace technologies provide essential information about what spaces employees use to optimise the space mix. Perhaps a building's focus rooms are booked back-to-back all day while large conference rooms sit empty, suggesting a mismatch in the types of provided spaces and what is needed.

SENSE OF AUTONOMY

Autonomy refers to the sense of efficacy that arises from employees' ability to choose their workspace in the office. In this view, productivity (along with benefits like talent retention) is not just enhanced by having well-designed spaces that support certain types of activities but is also the result of the feeling of empowerment and satisfaction that comes with choice. This positive feeling, in turn, results in greater performance.

The effects of autonomy are difficult to disentangle from purpose, but employee surveys suggest that choice matters. One cross-sectional survey of 400 knowledge workers, for example, found statistical evidence suggesting that the effects of workspace operate indirectly through engagement and satisfaction.19 Similarly, a survey of 20 Australian office buildings found that even building characteristics that were similar across flexible seating and fixed seating groups, such as indoor air quality and comfort, were perceived more positively by workers in flexible seating arrangements.

This might have partly been because employees could exercise their autonomy to choose specific spaces that suited their temperature or ergonomic preferences, which might otherwise be difficult if seating were assigned. Even so, experiments testing the effects of disempowerment on the performance of office tasks found that it reduced feelings of psychological and physical comfort and organisational citizenship behaviour, suggesting that at least a portion of the effect is psychological.

The technological contribution to autonomy is much the same as in the case of purpose: it enables autonomy by making it easier for end-users to understand the options and exercise a specific choice. It also supports managers in adapting the environment to reflect patterns of employee choices over time.

CREATIVE COMMUNICATION

The concept of communication captures both serendipitous encounters that can spark creativity along with day-to-day teamwork and a sense of community. In many respects, communication overlaps with purpose, as workspace choices often reflect the need to exchange ideas or work in groups. However, communication can also be fostered separately from room configuration. Specifically, technology can enhance workplace connections by making it easier to find colleagues and facilitating densification.

Densification can be particularly influential in fostering communication, given the importance of physical distance in the workplace. Research suggests that the probability of communication within an organisation is closely tied to physical proximity, reaching an "end of regular communication" at just 50 meters. The adverse effects of physical distance are especially severe for inspirational communication and, surprisingly, are not only limited to face-to-face communication but also extend to other media types. Using technology to reduce the physical distance between team members can positively affect teamwork and creativity across organisations.

Elsewhere, sitting near other people has improved coordination and fostered a general awareness of what others are doing. Field experiments even suggest that sitting in modern open office spaces rather than in more traditional, separated cubicles enhance co-workers' happiness and overall commitment to the organisation, thus contributing to engagement and a sense of community. By facilitating densification without overcrowding (discussed in the previous chapter) and providing easy ways for people to find each other across an office, workplace technologies thus have essential benefits that are particularly pronounced in industries built on innovation and teamwork.

REPUTATIONAL BENEFITS

Reputation encompasses both the ability of the corporate image to provide gains in terms of talent attraction and retention and broader benefits in terms of morale. Having a high-performing workplace, which includes both space and technology, has been associated with several positive outcomes, including being perceived as more innovative and more likely to be recommended to others by current employees. Other surveys have found that over 80% of businesses saw flexible working as part of their talent attraction and retention strategy in 2019, mainly because employees have signalled that it is an essential factor in their choice of employer.27 This number is likely to increase as employers seek to accommodate workers wary of returning to the office.

Such intangible factors are challenging to quantify in terms of ROI. Given the high cost of replacing employees, which studies have placed at 90-200% of an employee's annual salary, improving talent retention can be essential in evaluating workplace technologies.

Finally, in addition to the four categories above that are associated with a high-performing flexible workplace, technology also serves as a powerful tool in optimising the work environment for performance on an ongoing basis. Expressly, monitoring and analysing data about how employees interact with space is not limited to understanding what size conference rooms employees prefer. Still, it can also gather systematic data on how employees respond to changes in the fit-out. Thus, a final benefit of technology is its ability to enable active experimentation in the workplace.

LIMITATIONS TO ESTIMATING WORKPLACE EXPERIENCE EFFECTS

While the preceding section attempted to capture some of the gains from improving employee experience, projecting the return on smart workplace investments from this standpoint is complicated by several factors. First, productivity can be complicated to quantify in the modern office: How does one measure a chance conversation's impact on product development?

How can one capture the impact of avoiding minor annoyances like not finding a seat near the conference room where the big meeting will occur? One common approach to addressing this question is to focus on time savings from interventions like reservations systems. Still, they often underestimate the overall impact of having a well-functioning workplace by ignoring psychological and reputational factors.

An additional challenge is that workplace technologies tend to be rolled out in conjunction with other changes and that the causal impact is difficult to isolate. Additionally, the effects tend to vary, with some positive and occasionally negative effects. Suppose shared desks promote a greater sense of autonomy, enhance collaboration, and feel smaller to employees. What is the overall productivity gain, and how much can the changing workplace concept be attributed to the software that enables that concept?

Finally, employees' workplace preferences are not uniform – others revile well-received interventions by some groups. Surveys, for example, indicate that flexible seating is equally liked and disliked among employees,29 so aggregated effects will depend somewhat on how much each of those groups is affected by the change. Likewise, some studies suggest that receptivity to flexible work concepts is affected by age, with older age cohorts preferring more traditional office configuration.

UNDERSTANDING OVERALL RETURNS FROM SMART WORKPLACE INVESTMENTS

The purpose of this paper has been to provide potential investors with the background to understand how workplace technologies focused on space management operate and what the extent of potential returns is likely to be based on reputable third-party research. While each section above outlines a simplified use case that draws on publicly available benchmarks or averages to illustrate the size of returns in different contexts, the reality is that calculations are likely to be far more complex in practice. A single company might be deploying solutions across multiple locations with different average rent, salaries, or employee numbers. Even within two sites owned by the same company in the same city, the outcomes could look quite different. For example, a pharmaceutical company might see significantly different returns from density and space mix optimisation in an R&D lab staffed by scientists working in teams than a Sales office where reps travel most of the time.

Beyond the challenge of accounting for context, one additional difficulty in generalising ROI is that most potential adopters are likely to use the technology to support multiple use cases, such as a combination of footprint optimisation and employee productivity optimisation. Here, we caution potential adopters against assuming that the returns from both activities are strictly additive. The optimisation is an ongoing process and is highly dependent on effective change management. Actions to improve one aspect of the workplace can occasionally have negative impacts on others, such as how reducing the size of workplaces can save on rent, increase the likelihood of collaboration among team members, and give rise to more noise.

EMPLOYEE EXPERIENCE ROI CALCULATION

While these limitations make it challenging to anticipate the precise impact of the returns of smart workplace technologies on employee experience, existing research does strongly support the idea that there is a positive impact on productivity from deploying office concepts and supporting technologies that favour flexibility.

While the actual size of that effect is difficult to precisely estimate, an alternative approach is to think about a good order of magnitude for the aggregated impact of technology applied to flexible working. Suppose we know that fit-for-purpose spaces alone can result in self-reported performance improvements of as much as 20%. In that case, it is reasonable to assume that at least some of this benefit comes from the technology that supports the optimal use of these spaces. Taking a conservative approach, a reasonable estimate of the contribution of technology in a flexible workplace might be on the order of a 1-3% increase in employee productivity.

With such a range, we can then translate this productivity improvement in financial terms using profit estimates per employee.

In Q4 2020, for example, the average revenue per employee in the property & casualty insurance industry was $1,315,102.

Applying the 1-3% range above, the potential revenue gain would thus be $13,151-$39,453 per employee per year from using smart workplace technologies.

Other sectors might see substantially higher or lower numbers. Still, if we assume the average density of 155.7 square feet per person typical for financial services, this scenario's break-even figures for technology would be $84-253 per square foot.

A GUIDE TO ESTIMATING ROI OF WORKPLACE TECHNOLOGIES

Given this complexity, we have opted to conclude this paper with a series of simplified formulas for assessing the potential gains from deploying technologies for each optimisation scenario rather than with a unified formula that exaggerates the potential for returns by simply adding each scenario. Potential adopters are encouraged to evaluate each of these scenarios if it is likely to apply to their portfolio and to use publicly available benchmarking data referenced in the previous pages as a point of comparison. These estimates can then serve as a point of entry for discussions with expert consultants, vendors, and other industry players to get a more accurate picture of what technologies would be the best fit for reaching those goals.

We follow a three-step process for estimating essential information, outlined below.

1. Determine which optimisation scenarios are likely to apply, both for space (footprint, density, or space mix optimisation) and experience. The formulas opt to focus on aggregated productivity gains from experience rather than on time increments no

longer lost to searching (a standard metric), as the former category more accurately reflects the types of experiential returns highlighted in this paper and a focus on time vastly underestimates the actual value of workplace technologies on a building's end users.

2. Gather relevant inputs for the organisation. Ideally, this would include the following information for each location:

Office Size	Sq Ft
Office Location	City & Primeness
Office Fit-Out	$perSqFt
Occupants	# of Employees
Salary	$ per Employee
Workday	# of Hours per Week per Employee
Space per Occupant	Sq ft per Employee (per Desk or Overall)
Rent	$perSqFt
Productivity	Revenue per Employee
Space Mix	Desk-to-Collaboration Ratio
Density	Desk-to-Person Ratio

Publicly available sources for benchmarks and best practices can easily be found online. We recommend the following sources as a starting point:

- Cushman & Wakefield's Global Occupier Metrics database,
- JLL's Occupancy Benchmarking research reports

In addition to these sources, many proprietary databases and tools are available through real estate service providers, consulting firms, and vendors.

3. Use the inputs from step two for the following calculations. In some cases, we offer multiple formulas for the exact estimation to consider the scenario from different angles. Keep in mind that the outputs of each calculation do affect each other and that the overall estimate might be somewhat lower or higher than the aggregated total.

See calculations on the next page...

FOOTPRINT OPTIMIZATION CALCULATION

This calculation begins with two options for approaching the overall potential for reducing square footage.

Option A focuses on optimizing according to best practice square footage per employee or person to achieve a rough estimate of how much the aggregate square footage can be adjusted:

$$Square\ Footage\ Reduction\ \boldsymbol{Option\ A} = Current\ Sq\ Ft\ - (Best\ Practice\ Sq\ Ft\ per\ person\ \times people)$$

Option B focuses on identifying and eliminating the number of unused spaces, which is likely to lead to a better estimate (particularly for workplaces with a wide range of spaces or less-common arrangements such as lab spaces that might mean that the "best practices" space per person does not reflect the work environment).

$$Square\ Footage\ Reduction\ \boldsymbol{Option\ B}: Current\ Sq\ Ft - (\#\ of\ empty\ workspaces\ \times sq\ ft\ per\ desk)$$

Using the estimated square footage reduction from either Option A or B, it is possible to estimate the square footage savings using actual or estimated costs per square foot.

$$Square\ Footage\ Savings = Cost\ per\ Sq\ Ft\ \times Sq\ Footage\ Reduction$$

The final step in the calculation takes the potential savings to estimate an ROI or alternatively to calculate a breakeven cost of the technology per square foot to evaluate the options on the market.

$$Square\ Footage\ ROI = \frac{Square\ Footage\ Savings}{Technology\ Cost\ per\ Sq\ Ft\ \times Current\ Sq\ Ft}$$

Note: When we refer to the number of empty workspaces/desks in some calculations, this should be linked to the concept of "vacancy". Occupancy/vacancy varies throughout the day and, therefore, defining this value requires continuous monitoring (through technology). One should also take into account the notions of active occupancy (presence detected by a sensor) and passive occupancy (person is momentarily not at the desk but the desk is not available to others) to determine vacancy. For an in-depth analysis of vacancy, multiple variables need to be considered, including standard deviation as an indicator of the potential for improvement. A box and whisker plot is a helpful tool in this context.

DENSITY OPTIMIZATION CALCULATION

This calculation begins by calculating the estimated square foot reduction from increasing density. As with square footage optimization, we offer two different approaches to estimating this value. Option A focuses on desk-to-person ratios as a way of estimating the space savings from densification, whereas Option B looks strictly at space per person metrics, which often consists of an average of all types of spaces per person rather than just workspaces. In both options, we include a line item to account for the possibility that workplaces might want to partially compensate for densification by adding additional collaboration or other common spaces.

$$\begin{aligned} &\mathit{Density\ Sq\ Ft\ Reduction}\ \boldsymbol{Option\ A} \\ &\qquad = (\mathit{Desk\ to\ Person\ Ratio}\ \times \#\ \mathit{of\ Employees}\ \times \mathit{Sq\ Ft\ per\ Employee}) \\ &\qquad - ((\mathit{Benchmark\ Desk\ to\ Person\ Ratio}\ \times \mathit{Employees}\ \times \mathit{Sq\ Ft\ per\ Employee}) \\ &\qquad + \mathit{Additional\ Sq\ Ft\ for\ Collaboration\ Spaces}) \end{aligned}$$

$$\begin{aligned} &\mathit{Density\ Sq\ Ft\ Reduction}\ \boldsymbol{Option\ B} = (\#\ \mathit{of\ Employees}\ \times \mathit{Sq\ Ft\ per\ Employee}) - \\ &\qquad ((\#\ \mathit{of\ Employees}\ \times \mathit{Benchmark\ Sq\ Ft\ per\ Employee})\ + \\ &\qquad \mathit{Additional\ Sq\ Ft\ for\ Collaboration\ Spaces}) \end{aligned}$$

Once the estimated square footage is calculated, potential savings can be calculated based on actual or estimated costs per square foot.

$$\mathit{Density\ Savings} = \mathit{Cost\ per\ Sq\ Ft}\ \times \mathit{Density\ Sq\ Ft\ Reduction}$$

Finally, the ROI takes into account the cost of technology or the calculation can be adapted to estimate the breakeven cost of potential technological investments.

$$\mathit{Density\ ROI} = \frac{\mathit{Density\ Savings}}{\mathit{Technology\ Cost\ per\ Sq\ Ft}\ \times \mathit{Current\ Sq\ Ft}}$$

SPACE MIX & PRODUCTIVITY OPTIMIZATION CALCULATION

This calculation can be used either for estimating productivity optimization returns as well as space mix optimization returns, as the latter operates largely by way of improving the employee experience. To estimate the potential gains from productivity optimization, we present a single option that focuses on revenue per employee and apply a multiplier to this value. Sensitivity analysis can easily be performed by adjusting the multiplier.

$$\begin{aligned} &\mathit{Productivity\ Optimization\ Gains} \\ &\qquad = \#\ \mathit{of\ Employees}\ \times (\mathit{Revenue\ per\ Employee}\ \times \mathit{Est.Productivity\ Gain\ Percentage}) \end{aligned}$$

As with the preceding calculations, the ROI can be estimated with further information on the technology cost (which can be highly variable depending on the nature of the technology, both in terms of software and hardware), or alternatively investors can use this calculation to estimate a breakeven technology cost.

$$\mathit{Productivity\ Optimization\ ROI} = \frac{\mathit{Productivity\ Optimization\ Gains}}{\mathit{Technology\ Cost\ per\ Sq\ Ft}\ \times \mathit{Current\ Sq\ Ft}}$$

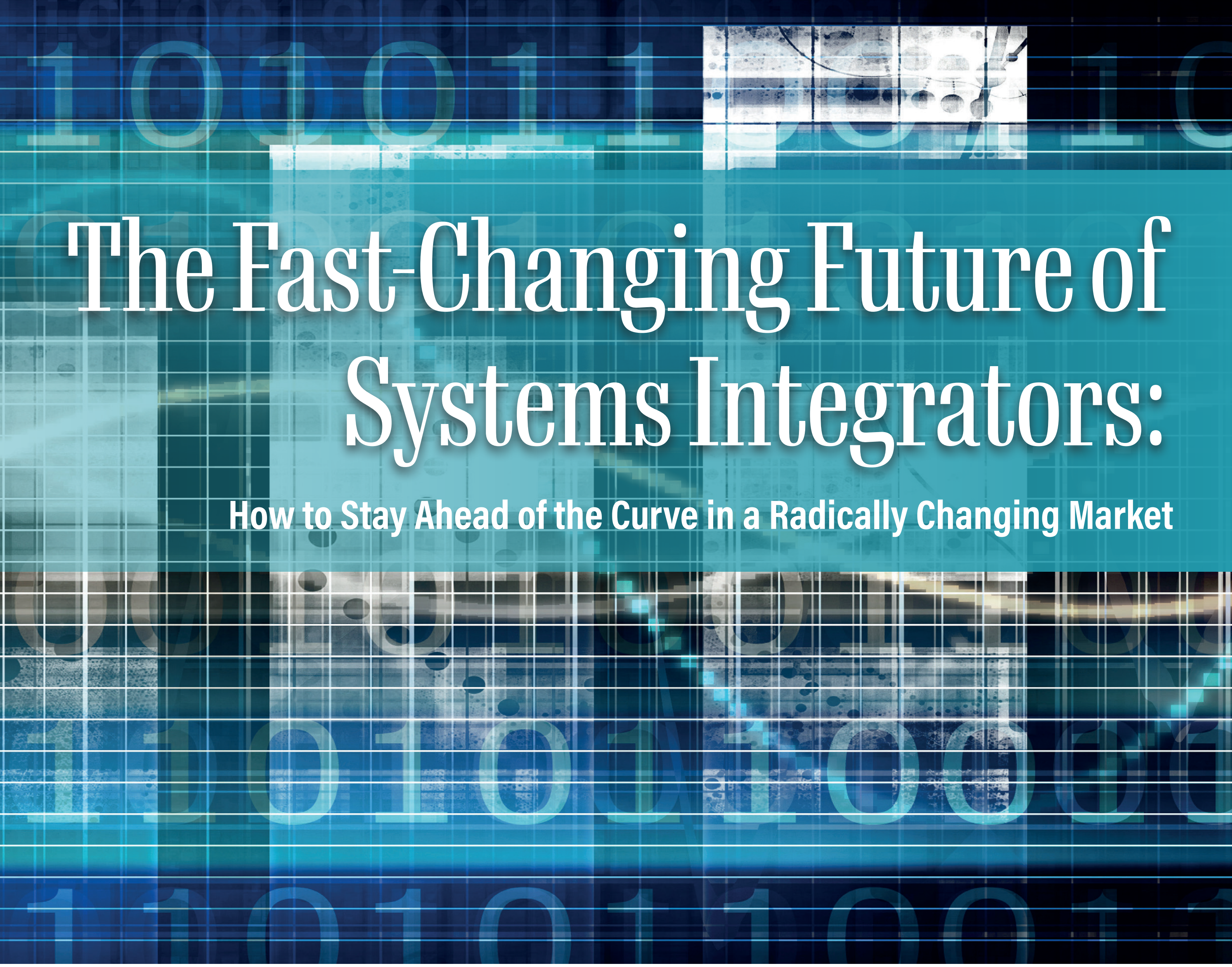
The calculation presented above focuses strictly on potential gains to employee revenue. Another common approach is to focus on time saved from the use of technology and aggregating it across the workforce. We omit this alternative because it fails to address the intangible gains from workplace improvements that are the core benefit highlighted in the research literature. wn

Systems Integrators have a challenging role in today's rapidly evolving building automation market. Long established design and installation practices have been disrupted by migration from serial to IP networking, new wireless IoT technologies, and increasing expectations from specifiers and end-users for easier-to-use solutions.

For larger projects, a much higher degree of integration is expected. Beyond linking lighting and HVAC, integration with business applications such as room booking, wayfinding, and asset management is needed. These systems need to be managed via a "single pane of glass" (SPG) approach to visualisation to reduce end-users ' otherwise complex set of user interfaces. This is a far cry from the days when all we needed was a networked HVAC control system! To keep up, or even get ahead, a new generation of software technology will be required to fulfil current and future requirements.

Most of the software currently available for building automation applications was architected 15-25 years ago, so although suppliers have made many significant iterations to the original versions, the software's core design pre-dates the newer IT, IoT, and mobile-oriented needs of today's market. At best, features to support mobile touchscreen use, semantic tagging and data-modelling have been added-on rather than incorporated into the design.

This white paper discusses the various trends that are changing and driving success in the smart buildings sector, highlighting how your business can utilise new technology offered to deliver easier to use building automation and integrated smart buildings solutions faster, more efficient ways.



The Fast-Changing Future of Systems Integrators:

How to Stay Ahead of the Curve in a Radically Changing Market

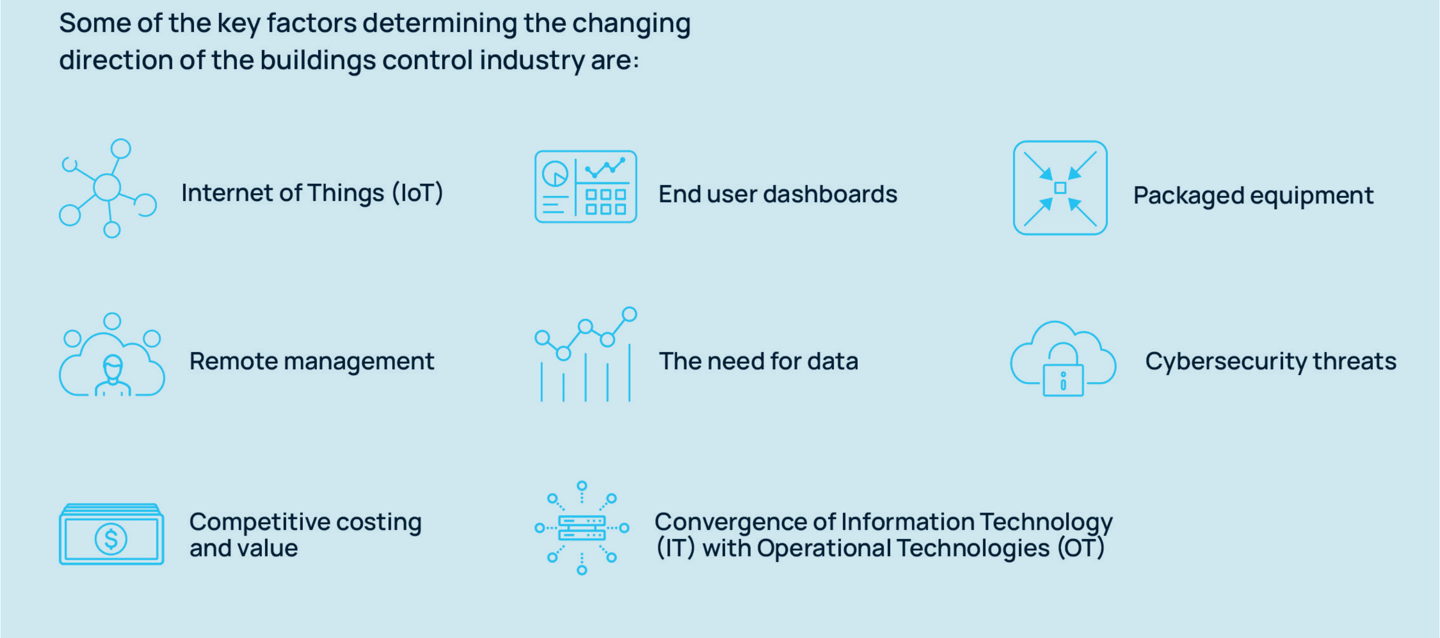


Figure 1: How building controls are changing and where the market is going

Although the building automation market has long used the term "Systems Integrator" (SI) to describe specialist controls sub-contractors who install, configure, and commission the building's controls system, the amount of integration of multiple systems has for most projects been confined to control of the HVAC equipment, sometimes with the addition of metering and lighting management.

As end-user expectations of "smart buildings" have steadily increased, new value propositions have been brought into play by both existing and new entrants involving additional sensors for air quality, presence detection, and geo-location. This has led to a new breed of companies known as "Master Systems Integrators" (MSI). Such companies offer a higher level of systems integration expertise and a greater understanding of Smart Buildings' IT aspects to address the increasingly complex requirements found in the specifications for larger building projects.

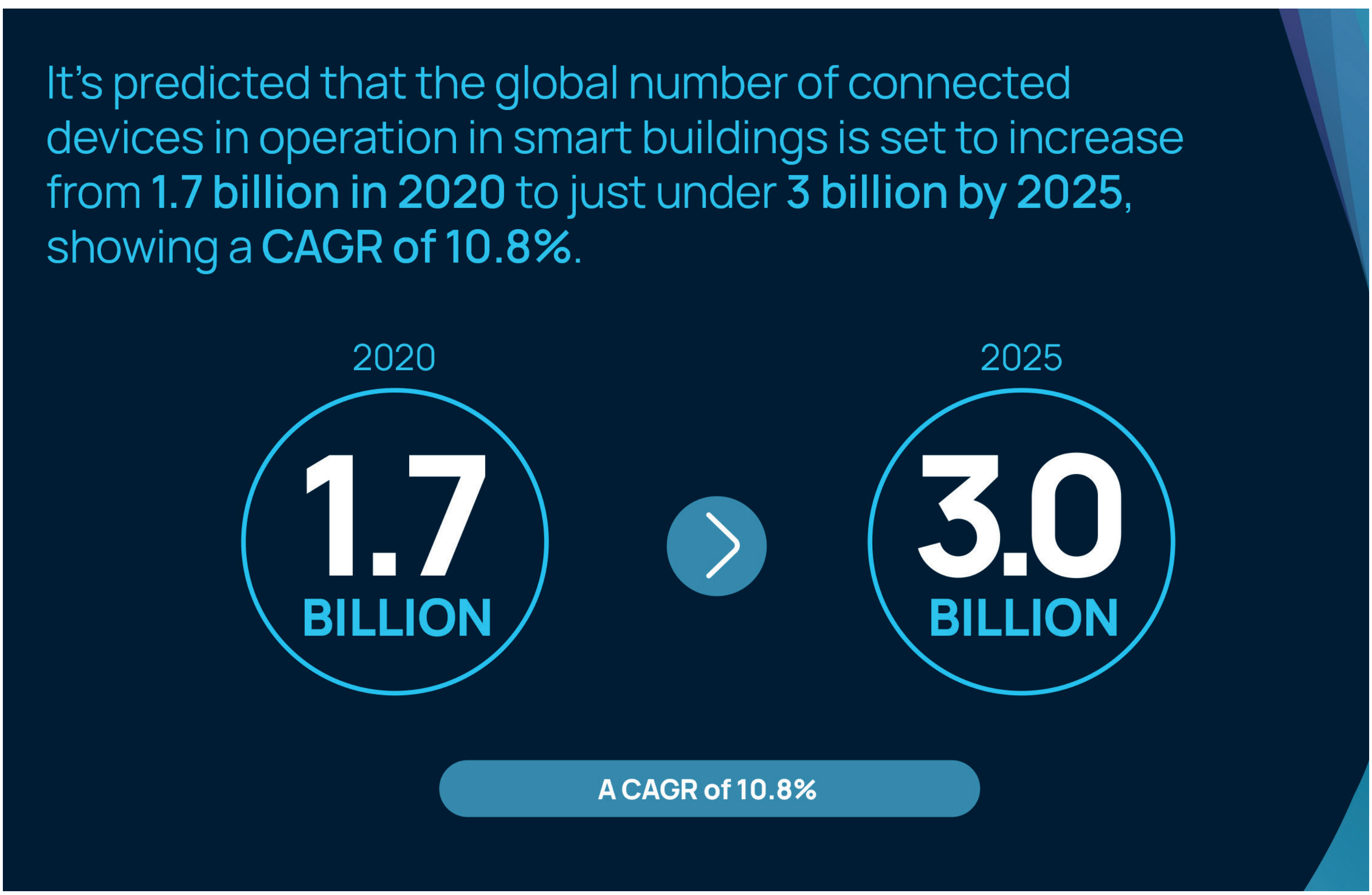
Currently, only a tiny minority of controls specialist contractors can justify calling themselves an MSI. Still, it is becoming more apparent now that all Systems Integrators will soon need to "up their game" to some extent as the innovations pioneered on larger projects filter down to the rest of the market. Fortunately, new software technology is now becoming available that addresses the trends listed above, enabling SIs to more efficiently deliver smart building solutions that are both simpler to use (for the end-user) and faster to engineer (by the SI).

So, let's look at the areas mentioned above in a little more detail to see how SIs can adapt to get ahead of the competition and provide better results for customers.

ADVANCING TECHNOLOGY

INTERNET OF THINGS

The Internet of Things (IoT) is an umbrella term that covers a raft of technologies that have enabled new business propositions. Fundamentally IoT is about connecting devices to a software application (usually hosted at cloud level) that delivers new business value in some way, such as by monitoring desk utilisation to provide hot desk management services or to track people's location within a building to provide wayfinding and space management services. Typically, the new sensors required to deliver such propositions use wireless technology to enable easy retrofit deployments. They are mostly separate from the already installed building automation system(s). Many of these IoT solutions are currently designed to send their sensor data directly to the cloud application, which then web serves dashboard-



type visualisations to users. The additional real-time data these systems collect would also help optimise the environmental controls in the building, so there is a requirement to integrate the IoT data with the data from the BMS. However, for an SI to respond to a customer's request to achieve this, they need software capable of supporting REST or MQTT type integrations since that is how the new breed of IoT software expects to integrate with other systems. Whilst most HVAC integrations can now be achieved using the BACnet protocol and most electrical integrations via Modbus, this is not the case for IoT integrations, and much of the BMS supervisory software currently used is not well suited to this.

This situation leads Systems Integrators and specifiers to think afresh about the software they use on their projects to capitalise on the new opportunities that the IoT brings. What is needed is a Building IoT (BIoT) integration platform that spans the BMS, the IoT system(s) and the business applications.

Suppose outdated technology is used that isn't compatible with IoT. In that case, customers won't benefit from valuable analytics, reporting, control, and data delivered by a modern data management application based on semantic tagging. Unless a well-featured BIoT-oriented software framework is used on a project, the engineering will be a lot more complicated and unlikely to deliver all the customer's functionality and reduce the SI profitability due to the high level of skilled labour required.

It's predicted that the global number of connected devices in operation in smart buildings is set to increase from 1.7 billion in 2020 to just under 3 billion by 2025, showing a CAGR of 10.8%. Therefore, if customers feel they're not getting the most up-to-date, multi-functional and IoT-friendly system, there is a risk they will go elsewhere.

PACKAGED PLANT

Due to the high cost of working on a construction site, there has, for some time, been a trend towards the controls for equipment being installed, and sometimes even commissioned, at the factory, so the HVAC or other equipment arrives on-site as "packaged plant". This reduces the scope of work for the SI. Instead of needing to procure, install and configure controls and associated sensors and actuators for the AHUs, chillers etc., they are only required to make a network connection and provide visualisation graphics for supplied plant items.

However, control of the related pumps and valves or dampers tends to be custom configured per project within the BAS. The advantages of packaged plants for the equipment manufacturer are apparent; not least is that they can ensure the controls fitted are programmed to provide the optimal performance for their specific equipment. To minimise the time required to integrate the packaged plant item, the automation software needs to support a "template" for it, a pre-configured file that fully defines all the data points required.

In some cases, the graphical visualisation and operating manual documentation. Either the manufacturer or the SI can create these templates. In future, as more of the BAS applications support templates, the speed with which equipment can be added to the overall system will dramatically increase. On projects that utilise templating, especially where large numbers of each plant item (such as VAVs or FCUs) are installed, the system engineering time saved can be as much as 80%. There is no doubt that more and more equipment will be packaged in the future since the cost benefits are significant, so SIs need to adapt their approach to embrace this and invest in templating the equipment they are required to integrate. Ideally, the building services consultant on the project will specify that the manufacturer should provide a template, or at the very least, a standardised way of defining the data points that need to be connected since specifying BACnet is not enough to enable the automation of the system integration process. SI engineering time is required to configure the BACnet device integrations. If Project Haystack tagging is used, the SIs' integration task is greatly simplified and much closer to a "plug-'n'-play" approach. As FIN Stack natively supports Haystack, including templated devices is automatic.

CONVERGENCE OF IT WITH OT & CYBER-SECURITY

Even before the rise of IoT applications, and since BAS manufacturers began to deliver IP based controllers, there has been a desire for building specifiers to converge the information technology (IT) systems with operational technology (OT) systems. In the early stages of the migration, from BAS serial networking to IP, there were many concerns on both sides; the IT departments were concerned about the BAS somehow compromising their business-critical IT infrastructure, either due to poor cyber-security or due to bandwidth issues. On the OT side, there were concerns about the reliability of the IT infrastructure since the environmental control and other services like lighting have to be working 24/7.

Now that IP networking has become so ubiquitous, the unification of the infrastructure is happening since installing separate IP networks in parallel is an unnecessary extra cost. Virtual LANs and a better understanding of both sides of the bandwidth management issues has made such convergence easier. A much more significant disruptive factor is the commercial aspect as to who contracts to install and commission the overall integrated systems. There is now a clear trend towards IT-focused companies acquiring more OT skills and domain knowledge to take over the MSI role on larger projects. Fortunately for SIs, IT businesses currently tend not to have sufficiently deep expertise in HVAC control, so there is an opportunity to find new ways of working cooperatively with the IT sub-contractor(s).

Whether the converged IP infrastructure is delivered by the Systems Integrator or by the IT provider, there is a solid need to be working with a platform that fully supports the IT requirements and enables such converged network solutions to be delivered efficiently and securely. Solutions that will ensure your customers are set up for success, not failure, are needed, which involves working with IT. IoT oriented protocols such as REST and MQTT, rather than just the conventional BMS ones.

One of the biggest pre-occupations of IT is how to deliver a cyber-secure solution. Historically, BAS software has offered relatively poor cyber-security, primarily due to the ageing architecture mentioned earlier and the applications only being able to run on Windows rather than the inherently more secure Linux OS. There have been well-publicised examples of poorly configured systems being hacked. This is yet another reason for SIs to select a modern software framework that has been designed to provide a high level of cyber-security.

CUSTOMER REQUIREMENTS, USABILITY, AND PRODUCTIVITY

THE NEED FOR – AND VALUE OF – DATA

Buildings are an expensive asset, both to build and maintain. As building automation technologies have developed and lower cost sensor technologies have become available, more and more building-related data is being generated in real-time. The value of analysing and basing decision-making on this real-time data is becoming more and more apparent. To enable this data to be processed automatically by computer software, it needs to be structured using data-modelling and semantic tagging methodologies such as Haystack or Brick.

In the past, there's never been a focus on data for Systems Integrators; it's not necessarily been deemed as an essential factor of the initial integration. However, the way things are heading, there's going to be more and more pressure to supply this early in the project, rather than see it as an extra that the customer must sort for themselves at a later date, should they require it – which, let's face it, they will.

These days, building managers want to be as productive and efficient as possible, using the state-of-the-art technology and standards with which SIs could be working. Standards like Project Haystack, which is open to all initiative, defines how data is abstracted using a data model and semantic tagging, making data easier to obtain and exchange between systems and applications.

Standardising on the use of Haystack isn't just better for the customer. It's efficient for the Systems Integrator, too. Simplifying integration and configuration tasks means getting the job done quickly and making more profit yet giving the customer a better result and, most importantly, giving them valuable data at their fingertips.

The desire for end-user dashboards and increased productivity all-round

With the need for such detailed data comes the requirement for user-friendly dashboards so that customers can effectively manage all their building systems in one central location. That's the direction the market is heading in, rather than just relying on the use of equipment graphics and floor plan schematics, which is what most Systems Integrators have become so accustomed to in the past.

Interactive dashboards which simplify the representation of the data flowing from the building(s) makes everyone's life easier but require careful thought and well-designed layouts to be effective.

This is a skill SIs will increasingly need to acquire as end-users have heightened expectations due to their experience of dashboards in their business applications and elsewhere.

This trend can positively impact the role of Systems Integrators, as there are options out there, such as FIN Stack, that now make it much easier to create customised dashboards for each project.

THE CHANGING WORKING ENVIRONMENT

THE FUTURE IS REMOTE

As internet capabilities have grown, it has been clear that more work can be achieved remotely for some years, but the COVID crisis throughout 2020 and beyond has accelerated this trend.

This has also impacted the building management market as businesses have needed to remotely manage more building services related issues. While the pandemic led to a short-term decline in the Smart Building markets around the world in 2020, they have bounced back in 2021, with the need for remote work fueling changes as to how buildings are managed. The long-term consequence will be significant for building automation, especially remote connectivity.

Now, more than ever, there's an increasing requirement for remote building management that's efficient and safe – from both a health point of view and a cyber-security perspective. Increasingly, Systems Integrators are expected to provide their users with access to fully manage Building Automation Systems (BAS) from anywhere via mobile devices and desktop browsers.

If up until this point, you haven't been working with a framework that can deliver this sort of functionality for your customers, it won't be long before it is regarded as essential for all projects.

Staying ahead of cyber security threats
The growing threat of cyber security being compromised is something that Systems Integrators should deal with. As building automation is getting smarter, so are those willing to damage the safety and security of the buildings the systems are integrated with.

According to a study carried out by leading cyber-security experts, Kaspersky, in the first half of 2019, almost 4 in 10 smart buildings (37.8%) were targeted by malicious attacks.

What's often the case in these scenarios is that the hacks aren't so much the system's fault in place, but more so to do with how they're being managed and operated. This could be anything from users not acting on alerts quickly enough or, in the high-profile case of the 2013 Google Australia office hack in Sydney, the company was still opting to run an out-of-date version of a legacy system.

Therefore, it should be a priority for both SIs and building operators to ensure they employ the latest most secure connectivity software to avoid becoming another one of those statistics. Mitigating the risk of getting hacked in such a way that damages business and reputation involves reasonable operating procedures and deployment of a secure connectivity solution that provides end-end encryption of the data connection and makes managing user permissions easier and more secure.

If you're not operating with the most up-to-date and protected software, you and your customers are running the risk of falling victim to cybercriminals.

CONCLUSION

ADAPTATION IS KEY

When it comes down to it, all the key points listed above lead to the conclusion that Systems Integrators and systems specifiers can no longer continue to go about their work in the way that has been the norm in the past. Carrying on as if nothing is changing isn't an option anymore.

The rapid technological advancements and unprecedented world events are causing disruptive changes to build automation markets. The opportunity is there for those who can adapt and respond by embracing the latest systems and associated software. Doing so will ensure survival and the potential to flourish in this rapidly evolving business environment.

IT'S POSSIBLE TO KEEP COSTS DOWN

For Systems Integrators, to successfully carry your business forward and stay one step ahead of your competition, there is a need to step outside of your comfort zone and have the confidence and motivation to change. With a future that looks so different, there is a risk you will get left behind.

Outdated software applications that are complicated to configure will lose out to newer "next-generation software" offering end-users and those who install and commission systems a simpler and easier way to interact and manage buildings. Adopting data standardisation will enable the various building systems to become more easily integrated than previously.

With all these new trends and increased labour costs due to the market's skills shortages, it may feel like dealing with the pressure to improve smart buildings' performance while decreasing system costs is too difficult, significantly as the complexity of projects is increasing. This is a solvable challenge.

One way in which you can reduce costs and increase value is to use a software framework that:

- It is faster to engineer, so reducing installed cost and increasing scope for working with more customers
- Utilises a standardised data model and tagging to make multiple system integration much easier
- Provides visualisation tools to enable rapid customisation to meet end-user requirements in a cost-effective way
- Uses Cloud and IoT technology to simplify deployment and remote management

WHAT SOFTWARE IS NEEDED?

If you were to shop around, there are most likely several different solutions that could be used side by side to tackle each of the hurdles and changes we've discussed above.

Doing so is not only complicated and clunky when it comes to integration; it's just not cost-effective. wn

Retrofitting and Repurposing

The global capital investment in coal-fired power stations is immense, and much of this heavy industrial plant is capable of remaining fully serviceable for many years to come. Despite the pressure to decommission coal-fired power stations, there is an alternative way forward.

By Dudley Basson

A coal-fired power station is a complex combination of several heavy industrial systems. The only parts of this that are under pressure to 'go' are the coal handling systems, furnaces and coal supply chain.

All the rest can remain functional, staffed and connected as a vital part of the grid. This will require retrofitting and repurposing of the power station to green status.

The first obvious question to arise is what will replace the coal? The coal-less power station will require energy inputs from several sources and colossal energy storage facilities.

SCALE OF OPERATION

Before proceeding, it is necessary to consider the scale of operation. Modern large power stations will typically have an output of 3 to 4 GW. Colossal wind farms have only recently been commissioned, having outputs exceeding 1 GW.

A 1 GW wind farm using 10 MW turbines would require 100 turbines spread out over a vast area and increased to provide stored energy when the wind is blowing with less gusto.

The land area required by wind turbines depends on factors such as the predominance of wind direction, matrix

or single line arrangement etc. The turbines cannot be placed near each other due to wake turbulence.

WATCH: For an extensive list of wind turbine farms and the land area required per MW.

The land area required for turbines varies greatly, but an averaged rule of thumb can be taken as 30 hectares/MW or 3,3 W/m^2.

The spacing of wind turbines is a highly complex study in fluid dynamics. Good spacing is vital for optimal power output. Horizontal spacing of 7 rotor diameters is commonly used but may be increased to 15 diameters. Trailing spacing is commonly from 5 to 10 diameters.

Wake turbulence can cause harmful fatigue stresses and reduced power output in trailing turbines. The rotor height above ground is also a highly significant parameter. Solar farms will also require vast expanses of land. Most South Africa's solar plants generate less than 100 MW of electric power. South Africa's new PV solar farm at De Aar has an area of 473 hectares and an output of 175 MW giving 370 kW/ha or 37 W/m^2.

Solar power can, in some cases, exceed 1 kW/m^2, but the PV panels are wavelength selective and cannot capture the full spectrum of solar power. PV panel efficiency is commonly from 15% to 20%.

Concentrated solar power (CSP) farms capture all wavelengths of solar power as heat. Still, the collectors require sun tracking and the heat can only be converted to electrical energy at less than 50% efficiency using a steam-driven turbo alternator or a gas turbine. Falling prices of PV panels have given these a cost advantage over CSP. CSP towers are capable of producing extremely high

temperatures for research work. CSP farms can typically have an 8% to 18% solar to electricity efficiency.
Dish-Stirling CSP installations have achieved solar to electricity efficiencies of over 30%.

WATCH: A video for details of Stirling engines (10:37 mins.)

Andrew Forrest's Fortescue Metals Group has unveiled plans to power its Australian Pilbara mining operations – and other green industries – with a massive 5,4 GW renewable energy hub combining wind and solar generation as well as battery storage. This project proposes to generate electricity from up to 340 wind turbines (2 GW) and a solar farm of up to 3,33 GW, alongside battery storage of 9,1 GWh.

With about 25 million, Australia now has nearly 1kW of PV installed per person – quickly retaining its world-leading status. By the end of 2021, there were more than 3,04 million PV installations in Australia, with a combined capacity of over 25,3 GW, the Australian PV Institute noted.

HyDeal Spain will be the first industrial implementation of the HyDeal Ambition platform announced in 2021, supplying renewable hydrogen to produce green steel, green ammonia, and green fertilisers. Recently, IRENA (International Renewable Energy Agency) ranked the project as the largest giga-scale renewable hydrogen project globally. Anchor sponsors include international steel manufacturing corporation ArcelorMittal, Spanish gas transmission system operator Enagás, Spain's chemical group Fertiberia and Madrid-based hydrogen company DH2 Energy. Production is planned to start in 2025; the total installed capacity will reach 9,5 GW of solar power and 7,4 GW of electrolysers by 2030.
WATCH the following video (6 Feb 2022) of the largest power generating installations. (20:22 mins.) You can see that it is challenging for renewables to compete with a 4 GW coal-fired power station.

Supplying the power station with surplus energy from wind, solar and hydro through the grid for heat and battery storage may not be sufficient to maintain uninterrupted output.

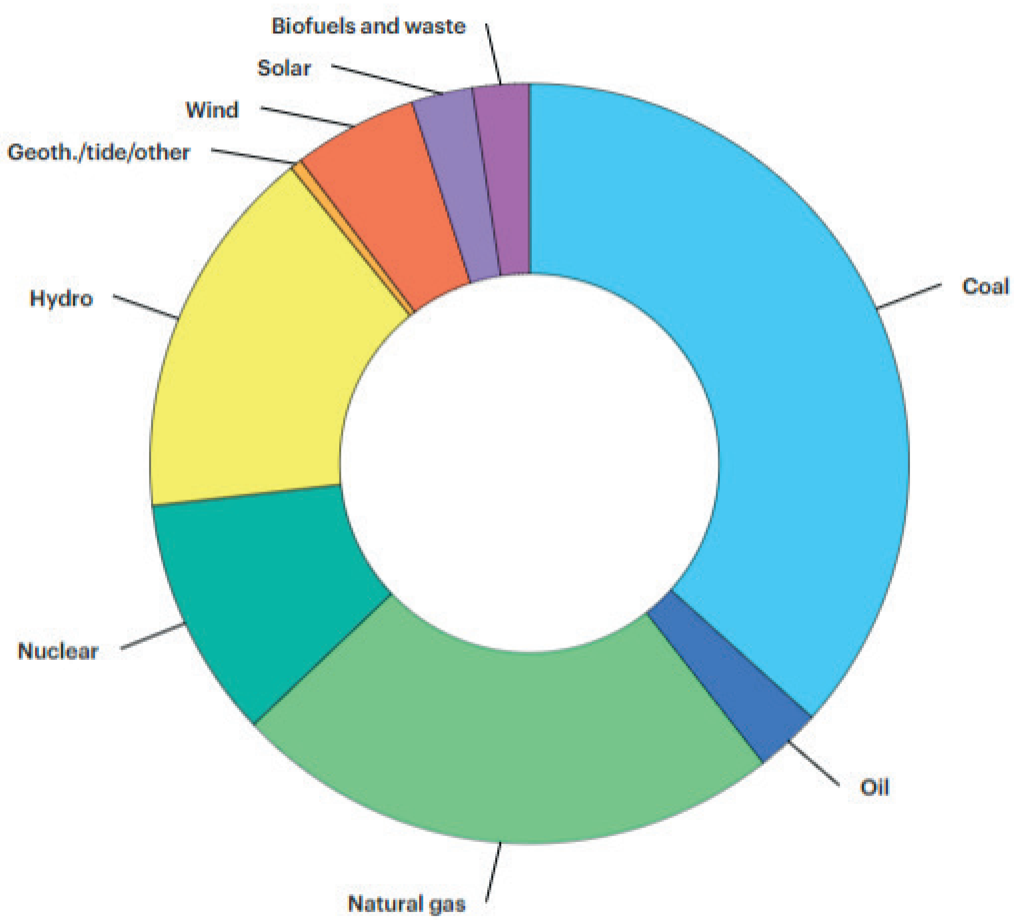


Figure 1: World gross electricity production by source, 2019

It has long been thought that nuclear fusion power would be the ultimate clean and cheap electricity source. Experiments using tokamak machines have been conducted for decades. In Feb 2022, encouraging results were announced by scientists of the Joint European Torus (JET) tokamak near Oxford, UK, but industrialisation is still thought to be decades away.

CLICK HERE For statistics of global power generation and consumption for 2019.

The pie chart (Fig 1) presents that wind and solar power generation will need to be increased by more than fourfold to replace coal. There is little likelihood that this could be accomplished in less than two decades. The combustion of natural gas is also a major CO_2 emitter requiring attention, Electrical energy demand can also be expected to increase due to the proliferation of electric vehicles.

It is here that a newly developing heat source will come into play. This is the Small Modular Reactor (SMR). These are under intense development as small footprint nuclear power stations. For retrofitting coal-fired power stations, these will only be required for their heat output and not with their turbo-alternators and steam cooling systems. Supplying a power station with heat from sources other than coal-fired boilers can potentially extend the working life of the power station by eliminating the need for boiler tube maintenance.

The retrofitted power station will need heat exchangers for heating the feedwater, superheater and reheater. The SMRs will typically have less than 300 MW electrical power or less than 1 GW heat power. The SMRs will usually be factory manufactured and transported to the site. Lead times are expected to be typically less than four years.

The power station will require a rapid response scheduling system to route the power flow to suit changing input, storage and output conditions, functioning as a mini smart-grid.

Including supercapacitor, storage may help deal with spikes and dips in the power output. However, the core of the power station will remain the turbo-alternators and their steam supply. The condensers and cooling systems will remain unchanged.

The dynamically scheduled inputs and outputs should provide continuous load following output and storage of surplus power. The design of the repurposed power station will require detailed computer modelling of all aspects of operation over an extensive period.

The smart power station will provide a hub for an islanding zone in the eventual countrywide smart grid and continue functioning despite stress elsewhere in the countrywide grid. The smart power station should also have sufficient spare capacity to provide a 'spinning reserve' when various components require downtime.

This technical paper proposes a controller design that is robust to parameter variations occurring in a thermal power plant process. This schedules coal and air inputs, feedwater flow and electrical output. This could be adapted to the multiple heat inputs of the retrofitted power station.

The large scale electrical storage and dispatching would be scheduled separately from the turbo alternator output. The data modelling is done using MATLAB.

CLICK HERE for a technical paper on dynamic simulation of thermal power plants.

When burning coal, the mass of CO_2 generated will be more than double the mass of the coal, depending on quality. The atomic mass of carbon is 12 amu, and the atomic mass of oxygen is 16 amu.

The atomic mass of CO_2 will therefore be 44 amu.

INPUTS

Academic papers describing SAPG (Solar aided power generation) have shown that it is economically viable to use CSP (Concentrated solar power) to reduce coal consumption by preheating the boiler feedwater; however, this will not be sufficient to eliminate coal consumption. If a CSP farm is available in the vicinity, this would undoubtedly provide valuable heat input for immediate dispatching or storage. This would also require a trough or tower CSP farm in the vicinity.

Inputs will be primarily determined by the situation of the power station and availability of wind and solar farms, and the availability of space for further capturing of green energy.

PV and wind farms supplying energy through the grid will need to produce more than double their nominal output to provide stored energy due to their low load factors and when green energy input is unavailable for extended periods.

It has occurred in European countries that their offshore wind turbines have produced more power than could be consumed locally, resulting in energy being exported to neighbouring countries, or even the use of negative pricing, paying users to consume extra power. This is not the result of excessive generation capacity – it is the result of insufficient energy storage capacity. It may be necessary to install more turbines to move entirely off coal.

Storing electrical energy as heat may seem counterproductive. However, this can provide practical energy storage of up to a week or more and ensure continuous stream for the turbo-alternators. It is vitally important that the turbo-alternators remain continuously synchronised with the grid. This can be done at 100% efficiency, but heat can only be converted to electrical energy at less than 50% efficiency.

The burgeoning worldwide hydrogen-methane-ammonia-methanol industries may also significantly influence the provision of an uninterrupted heat supply for steam raising.

The retrofitted power station will also be able to use geothermal energy where available. If the power station is not fitted with any fuel supply, all the nuclear coolant and turbine steam circuits will be in closed loops, well insulated from heat loss. The only emission will be water vapour from the cooling towers.

STORAGE

All forms of energy storage are currently undergoing extensive R&D, but several significant milestones have been achieved.

Lithium-ion batteries are in widespread use for both vehicular and bulk storage use. This can only improve as the research progresses.

Designing cobalt-free batteries should significantly reduce the cost.

Redox flow batteries are well suited to bulk industrial storage and are undergoing extensive research to improve their specific energy. The vanadium redox battery seems to hold much promise.

WATCH the following video on lithium sodium batteries (11:35 mins.)

CLICK HERE for more information on the aluminium-air battery that has phenomenal specific energy but is a primary cell that unfortunately cannot be recharged. This can be deployed in specific niche situations.

CLICK HERE to view this excellent video on the remarkable iron-air battery (11:30 mins.)

Three companies in China recently launched graphene-enhanced lead-acid batteries, and they claim that graphene materials boost the performance of the batteries.

Research in the use of graphene in battery development is well underway.

CLICK HERE for a description of the Jan-2022 (expensive) graphene battery market report.

Heat storage of energy is well suited to bulk industrial use – this is available in two broad categories: with or without phase change materials (PCMs).

Without PCMs, the heat storage utilises only the sensible heat of the storage medium without accessing the latent heat of PCMs. Almost any common material can be used, such as rocks in a confined space for building heating or even buildings' concrete or masonry structure. The quantity of energy stored is directly related to the temperature range employed. Molten salt storage uses a eutectic mixture of salts to have a melting point best suited to the energy equipment. Several different mixtures of salts are in use, usually nitrates.

CSP farms commonly use salt heat storage for delivering power after dark. Systems using salt heat storage require the salt to be molten at all cycle stages without using latent heat. Salt storage can conveniently supply heat at the temperatures required by power stations. Due to the high boiling point of salt, it is not necessary to have the salt under pressure.

The working temperatures of the power station will determine the temperature of the heat storage required. Retrofitting the heat supply will require heat at the working temperatures of the superheater for the high-pressure turbines and the reheater for the intermediate pressure turbines.

The reheater performs essential functions. It raises the steam quality for the intermediate turbine by raising the temperature, reducing water droplet damage to the turbine blades, and improving efficiency by raising the enthalpy. The reheater will typically operate at the same temperature as the superheater.

Modern power stations will most likely operate using supercritical water. The critical point of water is at 373,95 ˚C and 22,06 MPa (3200,1 psi or 217,75 atm.). This is the minimum temperature and pressure for supercritical water. At lower pressure, superheated steam can be hotter than supercritical water. Water is neither liquid nor gas in the supercritical state and cannot form bubbles.

High strength steel alloys are used for boiler tube manufacture. The hoop stress in the tubes must allow for an ample safety factor, especially at elevated temperatures. In the quest to raise the thermodynamic efficiency above 50%, steam temperatures of up to 700 ˚C have been proposed. This poses severe materials requirements. Steel has a maximum tensile strength at about 230 ˚C. At about 360 ˚C, it has the same tensile strength as at 21 ˚C, after which it declines further with a rise in temperature.

CLICK HERE for an excellent technical treatment of the use of supercritical water and superheated steam in turbines, see:

The service conditions of a fossil-fired boiler are among the most severe of any large, engineered structure. Flame temperatures may reach more than 1660 ˚C during the combustion of the fuel. Tube metal temperatures within the furnace will be 400 ˚C and up; in superheaters and reheaters, temperatures of 620 ˚C are typical; and in the support materials, temperatures of 760 ˚C to 815 ˚C are possible.

The products of combustion may be corrosive to the materials of construction. Ideally, only pure water and steam would be used, but, in practice, deviations from the ideal are expected. Life expectancies of these steam generators are 25 to 30 years or more.

Metal at 400 ˚C can be seen glowing red in the dark. At 525˚C, it can be seen glowing red in daylight, and at 580˚C, glowing red in direct sunlight. At 1230 ˚C, steel is hot enough for hammer forging and blacksmithing.

The continuous flow of water through hot boiler tubes is vitally important. A sizeable stationary steam bubble against the side of a boiler tube could result in catastrophic tube failure.

PCM (Phase Change Material) heat storage relies primarily on the latent heat of the material, which stores energy as it liquefies or releases energy as it solidifies and can work in a small temperature range. Dispersing thermally conductive nanostructures is an effective method to improve the thermal performance of phase change materials.

A remarkable new development is in aluminium-graphite heat storage. This utilises aluminium's latent heat, which has a melting point of 660,3 ^{0}C. The aluminium rods are encapsulated in a graphite block with a melting point of 3600 ^{0}C. The low melting point and high latent heat make aluminium eminently suited to this purpose—this device stores electrical energy input by heating the graphite and melting the aluminium. The energy is recovered by fluid flowing in tubes passing through the graphite. CLICK HERE to view the video (29 Sep 2021) describing this system: (11:15 mins.)

E2S Power AG was incorporated as a joint venture between SS&A Power Development and WIKA Group, a global leader in measurements technology. The company's purpose is to develop and implement thermal energy storage with a significant focus on retrofitting and repurposing existing coal-fired plants utilising the latent heat of aluminium for heat storage.

The Siemens Gamesa ETES (Electric Thermal Energy Storage) modules provide thermal energy storage in volcanic rock. A global series of pilot plants provides 10-100 MW power, energy storage of 100-200 MWh, and steam temperatures of 300-620 ˚C.

CLICK HERE for more information.

Siemens Gamesa pilot facility in Hamburg-Altenwerder 130 MWh heat storage

Electrically heated air is blown through 1000 tons of volcanic rock, heated to 750 ˚C. Airblown through the heated rock is used to raise steam for driving a turbo alternator. The pilot facility in Hamburg-Altenwerder can store 130 MWh as sensible heat.

The MERUS Energy Storage System (ESS) provides containerised lithium-ion battery storage with extensive control facilities, including peak shaving and microgrid operation.

WATCH: an excellent video of the MERUS Energy Storage System and microgrid control (3:11 mins.)

WATCH: GKN Hydrogen offers metal hydride energy storage (2:35 mins.)

Metal hydride hydrogen storage has a similar specific energy to a vehicle lithium-ion battery. There are several complex processes for metal hydride hydrogen storage.

Supercapacitors are gaining in popularity, as these devices can store and release energy very quickly and are helpful in many applications - including energy generation, grid power support, automotive, consumer devices and more. Further advances in supercapacitors are being made using the new wonder-material graphene.

WATCH the following video for Skeleton curved graphene supercapacitors: (14:02 mins.)

A novel form of energy storage can be found in the CO_2 Energy Dome.

This uses a closed quantity of CO_2, which is compressed to a liquid state for storing energy and then later released for driving a gas turbine for generating electrical power. The heat generated during compression is saved and used later to pressurise the expanded gas.

CLICK HERE for more information on the unpressurised CO_2 is stored in an inflatable dome.

Compressed air energy storage (CAES) utilises compressed air pumped into a large underground cavity or a salt cavern which is later used to drive a gas turbine. Salt caverns are self-sealing. The power can be increased by burning fuel with the air. The efficiency can be improved by storing the compressed heat for later reheating the compressed air. In coastal areas, underground water can provide isobaric compressed air.

A variant using a huge undersea bladder can be found in the January 2022 issue of **watt**now.

WATCH the following excellent video on liquid air energy storage (13:10 mins.)

The gravity-based, long-duration energy storage technology of Swiss company Energy Vault (Fig 2) has gained a foothold in the potentially massive China market through a deal that will kick off with a 100 MWh project in the Jiangsu Province.

Systems are modular and can be built in 10 MWh increments up to multi-GWh storage projects. This will presumably have a faster switching time from storage to supply than would be obtainable from a pumped-storage hydroelectric scheme installed on level terrain.

WATCH it in action at (1:56 mins).

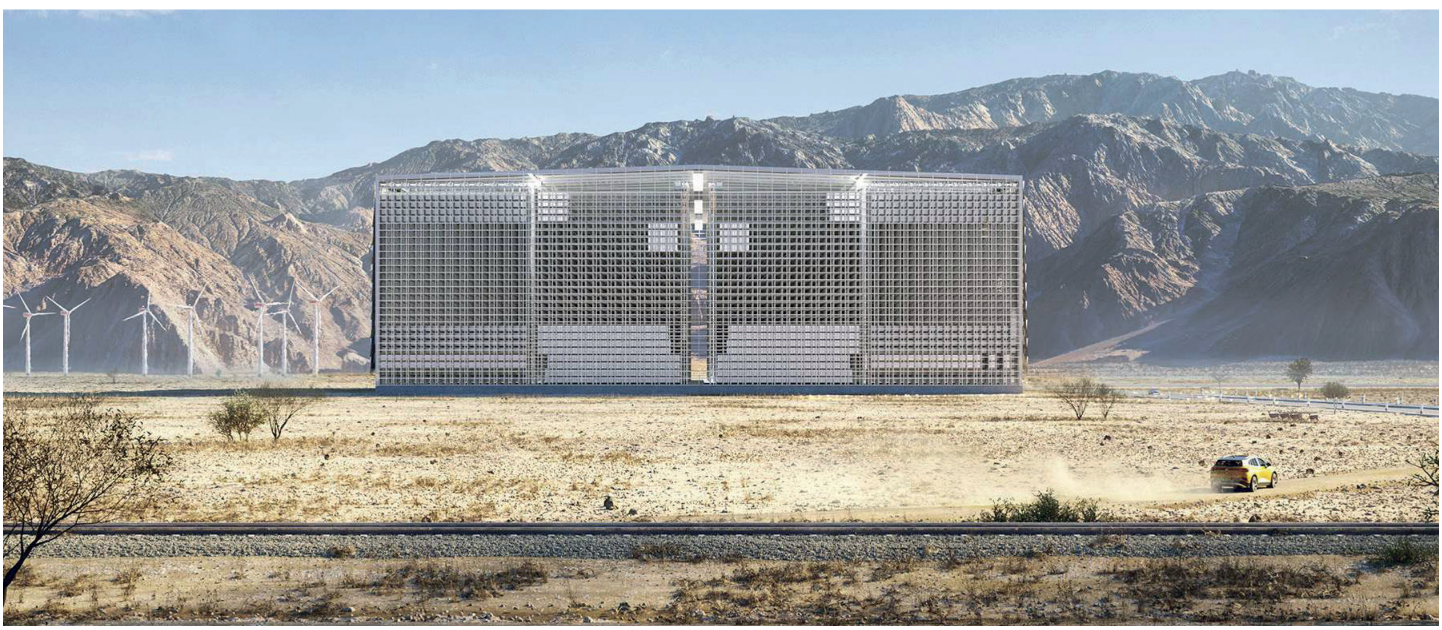


Figure 2: Energy Vault - This energy accumulator device will store energy by raising 30-ton bricks.

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The beauty of this device is that it uses only an interplay between electrical energy and gravitational potential energy. It gives no emissions, requires no air, water, fuel, heating or cooling and no chemical or nuclear reactions.

Limitless energy can be derived from ocean waves and tides. Many projects have been launched to capture this energy, but the technology may have to mature further before this can come into widespread use.

Exciting advances are being made in flywheel energy storage and retrieval, using high speed vertical cylindrical flywheels spinning magnetically levitated in a vacuum. Flywheels usually have relatively short spin-up and spin-down times but high power throughput.

Flywheels have been used to power buses, which allowed them to have spin-ups at bus stops.

In the 1940s, flywheel buses were used for a time in Switzerland. These had 1,5-ton flywheels spinning at 3000 rpm, which had unfortunate gyroscopic effects.

The buses would usually travel 6 km between spin-ups. A recent comeback uses 8,5 kg flywheels spinning at 30 000 rpm and utilises regenerative braking.

The classic steelworks Ilgner sets used huge flywheels for smoothing extremely varying rolling mill power.

CLICK HERE for more information on Beacon Power 20 MW 5 MWh Flywheel Storage.

The flywheel modules have 1135 kg carbon composite cylindrical rotors spinning at 15500 rpm and 15-minute spin-up and spin-down times at maximum power.

SMALL MODULAR REACTORS (SMRS)

WATCH an excellent introduction to the use of SMRs, see (15:20 mins.)

A large number of manufacturers are involved in the burgeoning SMR industry. This video describes the development of reactors by Rolls Royce. This manufacturer has had much involvement in submarine reactors and is presently developing a reactor for use in Moon mining.

The University of Sheffield's Nuclear AMRC (Advanced Manufacturing Research Centre) will work with Rolls-Royce SMR to develop the manufacturing capability for various advanced processes, using modern machining, joining and testing facilities of the Nuclear AMRC's research factory in Rotherham. The centre will also support the design of a new UK factory for significant SMR components.

The Rolls Royce SMR power plants are of aesthetically pleasing design and can be built on three seismic raft foundations: for the reactor, power generating and cooling sections.

Beacon Power 20 MW 5 MWh flywheel energy storage

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SMRs have an advantage in that their small footprints will be built on seismic rafts protecting them from seismic activity. Seismic rafts are not a new idea. The ancient Greek temple complex in Paestum (Ancient name Poseidonia) in southern Italy was built on a natural geological seismic raft, which no doubt attests to the present day good condition of the buildings, despite proximity to a nearby volcano. Extensive geological studies have been made of this area.

Prof. Antonino Giuffrè, the leading Italian expert in seismic analysis of heritage buildings, observed that the sand-filled trenches in the Paestum foundations recall modern anti-seismic systems based on the decoupling of the foundations from the ground.

The ancient buildings at Paestum and Pompeii can be seen in this clip from the 1969 movie "Goodbye Mr Chips" (3:54 mins): Paestum starts at 3:12.

Global public acceptance of nuclear power is crucial for a large-scale increase in nuclear power generation.

Despite statistics showing that nuclear power is the safest form of generation and that air travel is safer than road travel, disasters in these areas are devastating to public opinion.

The ghosts of Chernobyl and Fukushima remain to haunt us and will not go away. The urgency of reducing global warming does appear to be easing resistance to nuclear power in Europe, even in Germany, where there was significant opposition to nuclear power following the Fukushima disaster.

Potentially dangerous industrial installations will typically have multiple fail-safe facilities in place, any one of which would prevent disaster. These, however, count for nothing when faced with negligence, cost-cutting and poor supervision, as evidenced by the tragic Bhopal chemical disaster of 1984. Hydrogen cooling of alternator rotors has been standard practice for many decades and requires simple precautions for displacing the hydrogen or air from the alternator for maintenance. Who could have expected a recent hydrogen explosion to destroy an extremely costly alternator?

Currently, there are globally 441 power-producing nuclear reactors in operation. Unfortunately, the few have met with a disaster that influences public opposition to nuclear power. See table 1.

China is the first country to connect an SMR to the grid and a second reactor is under development. This 200 MW unit is a fifth of China's first design Hualong One and is the world's first pebble-bed helium-cooled reactor.

China is the world's largest investor in nuclear power, with estimations suggesting it will pay up to 440 billion dollars towards building new nuclear power plants over the next 15 years, allowing it to overtake the US as the world's top generator of nuclear electricity.

Unlike coal-fired power stations, which have stabilised in design over the decades, nuclear reactors have several designs for fuel power control and the coolant's material used to transfer the output power.

CLICK HERE to view the following paper on the working and control of nuclear reactors.

The purpose of the reactor coolant is to remove heat from the reactor and transfer it to a plant that can convert it to electrical power. The simplest arrangement for small reactors is to use a single closed

TOP 15 NUCLEAR REACTOR COUNTRIES BY 2021	
United States	93
France	56
China	51
Russia	38
Japan	33
South Korea	24
India	23
Canada	19
Ukraine	15
United Kingdom	13
Spain	7
Belgium	7
Sweden	6
Germany	6
Czech Republic	6

Table 1

water circuit which includes a steam turbine. This requires that the reactor vessel be pressurised and heated to turbine pressure and temperature, and it will transfer radioactivity to the turbine and condenser.

For molten metal or gas coolants, the heat must be transferred through one or more heat exchangers to the turbine water circuit.

Many coolants can be used in reactors that will respond in different ways to neutron bombardment and develop radioactive isotopes. Even water can become radioactive. The proton nucleus of the hydrogen in water can acquire a neutron, becoming deuterium, changing the water to heavy water. If it acquires another neutron, it becomes tritium, resulting in radioactive water. Tritium has a half-life of 12,32 years.

Other coolants are Air, CO_2, heavy water, helium, molten sodium, molten lead, molten salt and others.

Molten sodium is seldom used as it can

pose a serious fire hazard if it comes in contact with water.

CLICK HERE for further information on reactor coolants can be found.

- Thorium is a possible alternative to uranium as an SMR fuel but may need more R&D before widespread use.
- It is more abundant in the earth's crust than uranium and exists naturally as a single isotope Th-232.
- It is fertile rather than fissile and can only be used as a fuel in conjunction with a fissile driver material - (U-233, U-235 or Pu-239).
- It can breed U-233 to be used in nuclear reactors.
- It produces less waste than uranium.
- It is well suited to molten salt reactors.

CLICK HERE for extensive info on thorium.

The multiple isotopes of the heavy metal elements present a complex field of study.

South Africa is fortunate to have uranium production as a by-product of gold production. Uranium production exceeds that of gold by weight but not by value.

Now that global warming is moving into global emergency status, we are left for the short term with a simple but dire choice: coal or uranium. Both of these come with a plethora of pros and cons. Words from the song "Defying gravity" come to mind:

Too late for second-guessing
Too late to go back to sleep
It's time to trust my instincts, close my eyes and leap!

A "Golden Buzzer" performance of this song can be viewed and heard here. This video has been viewed well over 28 million times.

The conversion of a coal-fired power station to green status is presented here as a talking point. The retrofitting of a power station and deployment of an SMR will be a hugely complex and costly undertaking requiring meticulous planning and expert consultation.

The first retrofitted and repurposed power station will provide an invaluable pilot plant for the further conversion of power stations and implementation of mini-grid control.

Academic authorship articles on nuclear power generation and the development of SMRs can be found in the January 2021 issue of **watt**now. wn

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07/03/2022	SAIEE Telecoms Section presents an ST-Talk: IPv6 over 5G via MS Teams
08/03/2022	Writing Good Technical Specifications
09/03/2022	SANS 10142-1 Edition 3
09/03/2022	Fibre Optics
11/03/2022	SAIEE Annual Awards
14/03/2022	Finance Essentials for Engineers
15/03/2022	Technical Report Writing
17/03/2022	Earthing and Lightning Protection
17/03/2022	Fundamentals of Practical Lighting Design for Commercial and Industrial Applications
23/03/2022	Fundamentals of Developing Renewable Energy Plants
23/03/2022	SAIEE Railway Chapter presents: Fuel Cell Rail Motive Power Applications
24/03/2022	Cable Jointing and Selection
24/03/2022	SAIEE Annual General Meeting 2022
29/03/2022	Webinar: Load Research Chapter

APRIL 2022

DATE	TITLE
05/04/2022	Fundamentals of Medium Voltage Protection
05/04/2022	Operating Regulations For HV/MV Systems - ORHVS
06/04/2022	High Voltage Measurement and Testing
07/04/2022	Incident Investigation and Management (Root Cause Analysis)
11/04/2022	Fundamentals of Power Distribution
12/04/2022	Construction Regulations from a Legal Perspective
20/04/2022	Select, Maintain & operate your Rotating Electrical Machines like a Pro
20/04/2022	Technical Report Writing
21/04/2022	LV/MV/HV Switch Gear Operation, Safety, Mainatance and Management

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