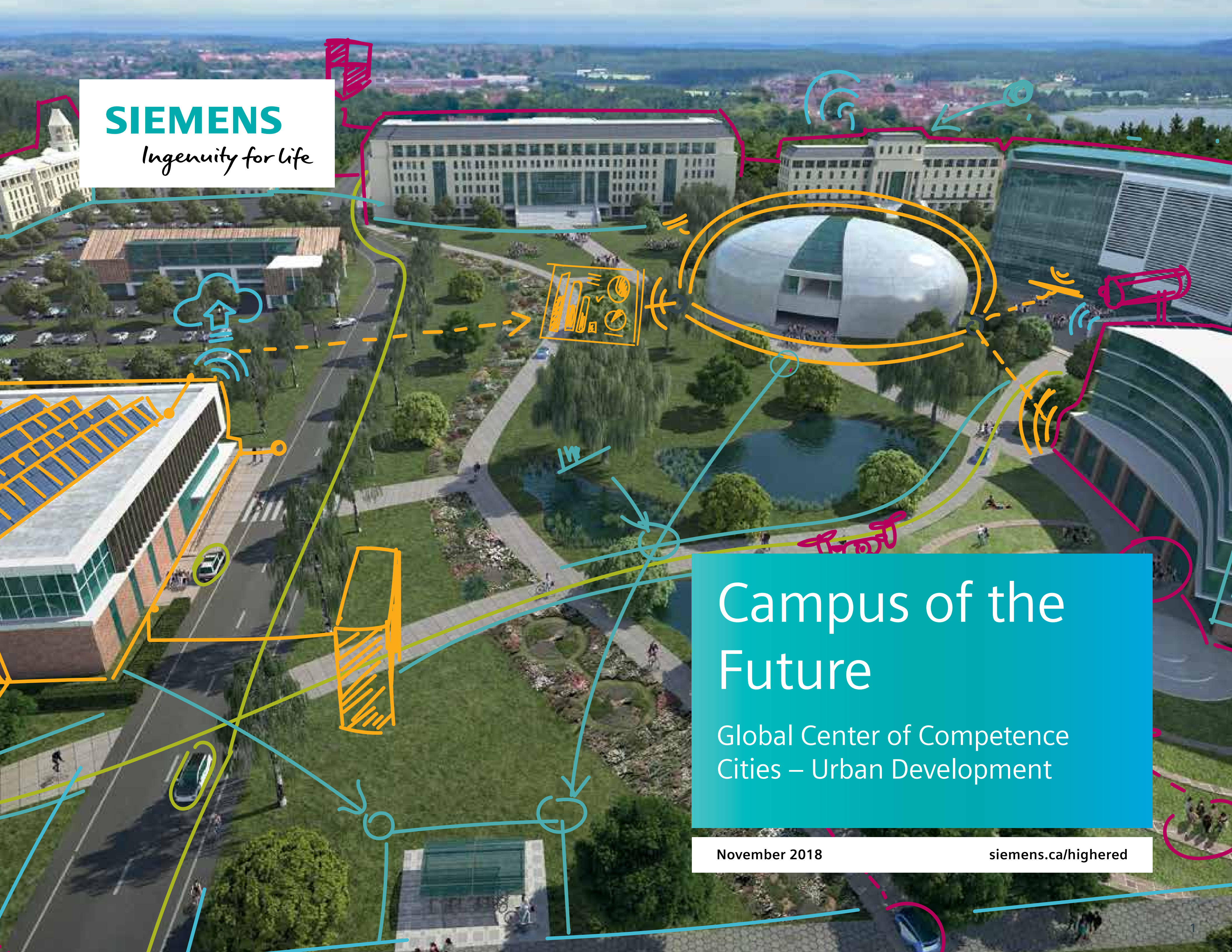
SIEMENS
Ingenuity for life



Campus of the Future

Global Center of Competence Cities – Urban Development

November 2018

siemens.ca/highered

CONTENTS

1 EXECUTIVE SUMMARY

The Campus of the Future will be the one that enhances the learning experience for each and every student. We all learn differently, and when we struggle to understand something, the campus is the perfect place to embrace learning networks, both the physical and the virtual. The physical campus promotes interaction and discussion, which helps in cementing the knowledge gained from classroom and online teaching.

If we can combine the physical and digital worlds within this campus environment we can make this learning experience ever better. We can personalize the learning to every individual and create an experience that improves results and makes it a place that attracts the very best students. To achieve this we need to embrace the right technology choices that will provide the learning environment to produce our future leaders!

The digital aspect of learning is changing fast, programs and outreach to students is changing, but in many ways the physical university or college campus has not yet had the same deep structural change. However, this will be happening as competition for the best faculty, students and research partners is only growing. Campuses will be reflecting these deeper changes as they make ideal living laboratories to test innovations that will shape the campuses and cities of tomorrow. These technologies, including grid-interactive buildings, small-scale renewable electricity, on-demand transportation, and the democratization of the energy system, offer wide-ranging benefits including cost savings, pollution reduction, and on-campus learning opportunities. All these technology trends share the theme of democratization: everyday people can now participate in sectors that used to be highly centralized withe high barriers to entry. Digital technologies are now enabling real-time interactions with those systems, so students and staff can give input and enjoy greater flexibility.

Democratization of energy will be the single biggest change in energy usage over the next 40 years. This means that many more people will come to own, or share in the ownership of production, distribution and storage of energy, in the same way that the car democratized transport, or that the Internet democratized access to and distribution of information. Energy generation and distribution is moving from an infrastructure designed and planned by engineers to people and industries taking a stake of their own in energy production. This applies from the level of the individual who produces renewable electricity, to corporations or cities that purchase or incentivize renewable power generation, micro-grids and energy storage systems.

Buildings are becoming smarter, generating data about their operations, and gaining the ability to interact with the electricity grid, digital management systems, and their occupants. Technologies supporting this transition include Building Management Systems (BMS), which monitor and manage all mechanical and electrical services in building, including electricity, heating, ventilation, air conditioning, access control, fire safety, and lighting. This is complemented by Performance Monitoring software that analyzes long-term consumption of energy, water, and more. Grid-interactive buildings will soon be able to communicate directly with the grid. They will be "prosumers" that consume, generate, and store electricity, and sell it back to the grid, while also reducing their own demand through efficiency measures. Future buildings may even adapt to individual profiles to create personalized climate, lighting, and workspaces, while communicating with occupants through voice commands or gestures.

In the energy sector, the trend is toward renewable, decentralized, and participatory networks. Growing concern about climate change and air pollution is catalyzing a shift away from fossil fuels towards renewable electricity and renewable or more efficient heat sources. While the aging of grid infrastructure offers an opportunity to upgrade and o more decentralized, and digitally-managed electricity infrastructure. At the same time, the decreasing price of technologies like solar PV panels is letting more people participate as "prosumers" in small-scale electricity production, storage and sales. With these technologies, we can decarbonize and democratize energy generation, use digital technology to better manage the peaks and troughs of energy use, produce electricity locally, and minimize the amount of electricity drawn from the grid.

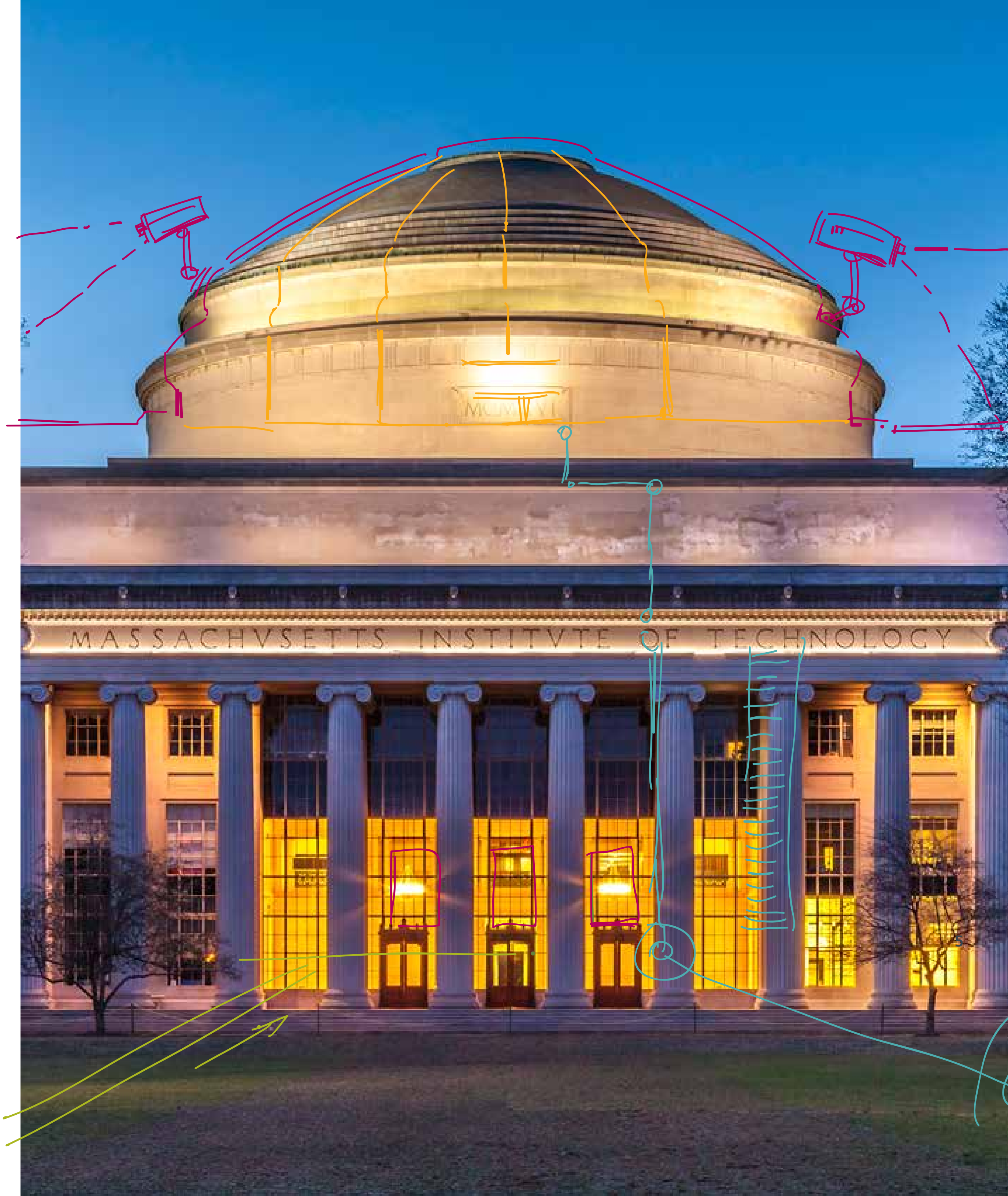
Transportation is becoming multi-modal, electric, shared, digitally connected, and autonomous. Electric vehicles will soon be cost-competitive with conventional cars, while bicycle share schemes and ridesharing are growing ever more popular.

Digitalization is allowing us to demand, track and share rides and this layering is adding both flexibility and predicatability to transport.

However, as these features and autonomous vehicle scale up, we must be aware of the interactions between these trends – for example, it's not inevitable that AVs will be electric or shared. By thoughtfully integrating these transportation technologies, campuses can be even friendlier for walking and cycling, with clean, autonomous, demand-responsive ridesharing servicing longer trips or less mobile students.

These technologies have the potential to dramatically reduce campus emissions, both by reducing consumption of electricity and heat, and by sourcing the electricity more sustainably. However, if heat and transportation become electric without shifting to a cleaner electricity source, electrification could improve local air quality but actually increase total greenhouse gas emissions. Therefore, it is essential that the shift towards electric heat and transportation progresses in tandem with sourcing renewable electricity.

Data Management is becoming ever more important across campuses, universities, colleges and cities. They all need a way to bring their data into a platform where it can be better understood and utilized. To that end, Siemens has leveraged insights from its manufacturing units to create MindSphere, an overarching platform that brings together digital infrastructure in a cloud-based, open IoT operating system. MindSphere retrieves data from multiple sources, including buildings, electricity generation sources, and heat networks, and then analyzes it for patterns and trends. This gives campuses advantages such as predictive maintenance of their equipment before it gives out, improving building energy efficiency, and optimizing the usage of shared, bookable rooms. As campuses incorporate the emerging technologies described in this report, MindSphere will help campuses manage their digitally-connected equipment as one interconnected ecosystem. In the future, technologies such as MindSphere could be even better employed to manage the vast research being produced by professors and students and discover new possible applications for the data.



CAMPUS OF THE FUTURE BENEFITS MATRIX

	MODERN CAMPUSES TODAY	INNOVATION	WHERE IS IT HAPPENING?
Education	• Provide standardized teaching which leads to wasted resources (time, space, attention).	• Artificial intelligence makes one-to-one tutoring increasingly possible at enormous scale.	**US Navy's Education Dominance** The US Navy has introduced an AI-based tutoring system called Education Dominance to get IT specialists to adequate levels of training in months rather than years. **Chapter 5**
Data	• Use data to improve educational experiences, building usage, energy consumption, security, and more. • Collect data across campuses, with an aim to improve learning and space utilization.	• Using data as part of an educational curriculum.	**Keele University and University of Sheffield MindSphere Innovation Network** Keele University creates the largest Smart Energy Network Demonstrator in Europe involving microgrid management software, digitalization of 24 substations, the installation of 1,500 smart meters, 500 home controllers, 20 EV chargers, with a 5MW renewables integration. **Chapter 5.1.7**
Energy	• Are generating a portion of electricity on-site. • Have a focus on resilient energy systems across all services.	• Decarbonization of heat as well as electricity.	**University of New Hampshire** UNH's $28 million combined heat and power facility provides the main source of heat and electricity for the Durham campus. **Chapter 5.1.2**
Buildings	• Are focusing on creating the most productive environment for users – comfortable, responsive and manageable. • Are energy efficient and in many cases produce electricity or were designed to minimize energy use. • Are monitoring energy use remotely and are actively optimized.	• LiFi (Light Fidelity) – high-speed wireless data transmission through light. Increases security because data can only be received within the range of the light. • AI is used to understand how buildings are being used and it can update settings automatically.	**LiFi, light enabled WiFi** Icade the French real estate investment company is piloting this technology in its smart office in La Defense, Paris. **Chapter 5.2.7**
Mobility	• Provide safe walking routes both day and night. • Are integrating electric mobility into campus fleets.	• Digital technology is used to eHail campus transport.	**MIT SafeRide OnDemand Shuttle Pilot** MIT Parking and Transportation Office launched the SafeRide OnDemand Shuttle pilot to improve safety for members of the MIT community. **Chapter 5.3.4** **3D Printed Autonomous Olli Shuttle – University at Buffalo** Olli, a smart shuttle already being deployed to commuters in Washington, D.C. and Berlin, is now launching operations at the University at Buffalo. **Chapter 5.3.2**
Security and Fire Safety	• Are able to avoid false alarms through video verification or a monitoring service. • Use biometrics for the authorization of access to restricted areas.	• Verification of fire or security breaches are connected to building management systems so that responders are alerted and buildings quickly evacuated. • Biometric security.	**Universities using biometric sensors for access control.** Universities are using biometric hand readers to authenticate students by the size and shape of their hands, to control access to their dorms and dorm rooms. **Chapter 5.4.2**
Campus Space and Asset Management	• Are aware of how building and learning spaces are being utilized. • Are able to track and locate high value technologies.	• Booking management systems respond to occupancy in real time.	**Indoor positioning at Agnelli Foundation, Turin.** Agnelli Foundation Headquarters in Turin, Italy is an advanced Internet-of-Things office building that detects and communicates the presence of occupants and positioning data, automatically triggering the appropriate response of the building's facilities. **Chapter 5.2.8**

AMERICAS

- St. Catharine College
- Kentucky Christian University
- University of California, Sutardja Dai Hall
- St. Clair County Community College
- Wayne State University
- Purdue University, West Lafayette
- Virginia Tech, Blacksburg
- Florida Institute of Technology
- West Virginia University
- Virginia Tech
- Texas A&M University
- Barry University
- University of Miami
- University of Minnesota
- Florida State University
- University of Florida, Institute of Food and Agricultural Science
- University of Florida, Mid-Florida Research and Education Center
- Point Loma Nazarene University
- Portland State University
- Michigan State University
- Rush University Medical Center
- George Mason University
- Tahoe Center for Environmental Sciences
- Wheaton College
- Notre Dame College
- Miami University of Ohio
- Georgia Tech's Molecular Science and Engineering
- Animal Health Research Center of the University of Georgia
- Coastline Community College
- Chaffey College, Rancho Cucamonga
- United States Air Force Academy
- Middle Tennessee State University
- Tennessee State University
- Algonquin College, Ottawa
- Université du Québec à Trois-Rivières

EUROPE

- Wels Polytechnic School
- Paracelsus University
- Kufstein University of Applied Sciences
- Vienna University of Economics and Business
- WiFi Technopark Linz
- Mozarteum University
- Czech Technical University
- Photovoltaics in Danish ESCO/EPC Projects
- Le Mans University
- Fraunhofer HHI
- AEG Energy Campus
- Esslingen University of Applied Sciences
- Darmstadt University of Applied Sciences
- Hamburg University of Applied Sciences
- Technical University Bergakademie Freiberg
- Bonn University's Juridicum
- Stuttgart University
- University of the Arts
- Freie Universität Berlin
- Karlsruhe University
- Veterinary Research Institute ‚Gut Ruthe'
- Würzburg University
- Beilngries College of Bavarian Cooperatives
- Freiburg University
- Central European University
- University of Genoa, Savona Campus
- Utrecht University, Faculty of Geosciences
- Vestfold University College
- Theremin Center for Electroacoustic Music
- Zaragoza University, Edificio Paraninfo
- Alcalá de Henares University
- Alicante University
- Umeå University
- Ångström Laboratory, Uppsala
- Hospitality Management School
- Aargau Technical College
- Basel University, Pharmacological Center
- Hochschule Rapperswil
- Istanbul Aydin University
- University of Wolverhampton
- University of Manchester
- Salford University
- Clare College

MIDDLE EAST, ASIA / PACIFIC

- Royal Melbourne Institute of Technology
- Kangan Institute
- China Academy of Building Research
- University of Hong Kong, Centennial Campus
- University of Hong Kong, Chow Yei Ching and Tsui Tsin Tong Buildings
- Hong Kong Polytechnic University
- University of Hong Kong, SPACE Community College
- Hong Kong Polytechnic University
- Biosafety Level 3 Lab, University Malaysia Sabah
- King Khalid University
- Republic Polytechnic
- Daebul University
- Chung Cheng Memorial Library
- Zayed University

Building Management | Energy Management
Access Control | Transportation
Fire Safety | Services
Security | Energy Services
Heating, Ventilation, Air-conditioning

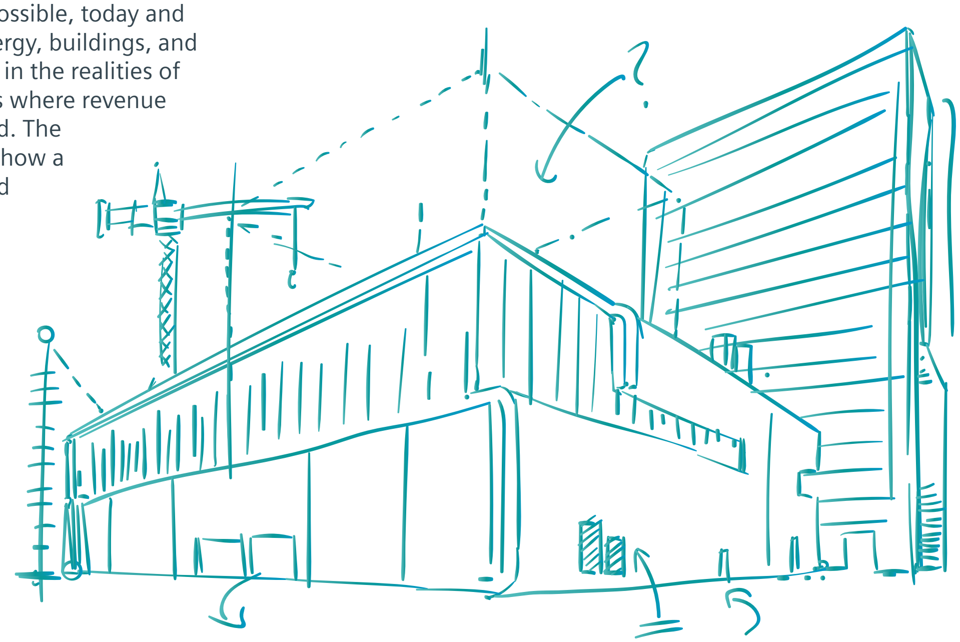
2 INTRODUCTION

Technology leaders are predicting a future where everything is connected, commerce happens digitally, and automation is in all spheres of our lives.

This is a future of autonomous cars and electric airplanes, of self-learning AI buildings in carbon-neutral neighbourhoods. This future will be driven by people demanding cleaner air and carbon-free energy, and enabled by technology that unlocks competitively–priced, renewable electricity and sustainable, on-demand mobility. Universities and colleges will need to reflect these changes, both to attract the best and brightest faculty and students, and to ensure that their campus contributes positively to the community. How can universities and colleges upgrade their current systems to take part in this future? Most campuses reflect larger cities: they contain both historic and modern buildings, have an internet and electricity grid that meets today's needs with little margin, and aspire to increase their usage of renewably-sourced electricity. This means that campuses can benefit from the same smart technologies that are making cities cleaner and more efficient. Digital technology has fundamentally changed how we learn and access information. As we move to the virtual in many parts of our lives, education remains necessary to train systems thinkers for digitally-oriented jobs that don't even exist yet. However, digitalization will not change the fact that employers will want engineers with real-world experience, and future entrepreneurs will deliver a couple of projects before building their own start-up. Universities and colleges can create these opportunities with a smart campus where students actively engage with and manage systems.

This technology future is not that far off, and campuses can start creating a high-functioning digital system today. Users are increasingly demanding that technology be interoperable with new components from any manufacturer, and can be incrementally scaled up over time, which means that universities and colleges face less risk of their investments becoming "stranded assets." Instead, cities and campuses are seeing benefits from being a "first mover" in adopting new technologies.

Siemens is proposing in this document to use technology as an innovative attractor to boost a campus' reputation and to better prepare its graduates. This report examines what is possible, today and into the future, for campus energy, buildings, and transport. It is firmly grounded in the realities of limited budgets, and highlights where revenue could be created, or costs saved. The result is a roadmap illustrating how a university or college dean could lead their campus towards a connected, efficient and sustainable future.



3 TRENDS IN HIGHER EDUCATION

Critical to the success of universities and higher education facilities will be their ability to adapt to the changing trends in where, how and when we all learn.

For example, there is little reason to invest in a campus if learning is expected to be international and digital. That being said, not all learning is going online, and the growth in cities despite the age of the internet has demonstrated that location, more specifically co-location, is still vitally important. It is therefore important that university leaders consider the physical future of their campuses in light of the changing educational trends. The following considers how some of the global educational trends may impact physical campuses.

Data cited by Studyportals[1], highlighted that high-income countries will see the growth in student numbers stagnate unless they start to reach out to non-traditional students, over the age of 24 and living off campus, and in lower to middle income will see growth in more typical students grow relative to the number of institutions. Studyportals identified a couple of archetypes of success, which included specialization into niche research institutes, the creation of scalable digital universities, student experience focused university with high-quality facilities and mentoring, and professional learning institutes focusing on career advancement with strong ties to industry.

DIGITAL LEARNING

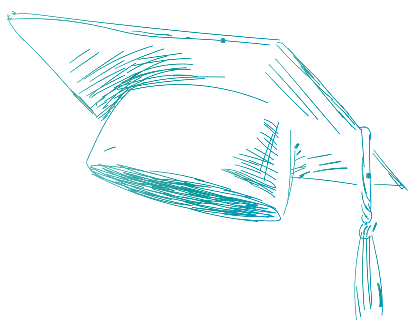
Digital learning is reshaping the role of the campus as universities offer more distance and part-time programs – however, collaborative learning and building social and professional communities remain key to the university experience.

A Traditional, campus based student population will remain a core market for many universities, but it will become a relatively smaller part of the educational business as a whole.

Campuses will need to cater to part-time students who may take the odd class across the week or be there full-time for a limited number of weeks per year. This means managing space to have a flexible supply of housing and study spaces. Campus information and communications infrastructure will need to seamlessly connect students to educational materials, each other and the professor, even when some or all of them are off-site. Campus wayfinding and internal communications apps are likely to become ever more necessary to connect people when they are physically present.

REMOTE LEARNING, VIDEO CONFERENCING

Remote learning is the remote delivery of training using a variety of different methods including e-learning courses over the internet, live webinars, live face-to-face internet training and pre-prepared, tailored podcasts. Remote learning gives students the flexibility to study when and where they want. They don't have to leave family and friends and can just carry on with normal life. Despite these and other positive impacts there are also negative associations which can be found in the area of the level of anonymity and the lack of direct human interaction between learners and their instructors.



[1]Studyportals, Envisioning Pathways to 2030: Megatrends shaping the future of global higher education and international student mobility. January 2018.

3 TRENDS IN HIGHER EDUCATION

IT INFRASTRUCTURE

Remote learning requires best available communication bandwidth to ideally transmit live video streams to a large amount of receivers. To achieve the best results, universities must use the best available communication technology to let the physical distance between teachers and students appear as small as possible. However, there are many regions, not only in developing countries where these bandwidth are not available. Here, the quality of the content can be gradually reduced by, e.g. transmitting only audio streams or making content available only offline.

STUDENT DEMOGRAPHICS

Student demographics are becoming more diverse, including a rising demand for life-long learning.

Changing student demographics may mean less demand for on-campus residential space, but more on-campus meeting and or shared spaces. More shared spaces requires new ways to allocate, monitor and manage space. Digital occupancy and space allocation apps will become all the more important. This will require sensors in each individual room and more sensors in areas where walls can be moved.

Satellite campuses are nothing new to many universities, and this trend is likely to continue and ways to better link these spaces to the main campuses both virtually and physically will be important.

Accessibility to and across the campus will be important and transport will need to cater to a wider range of ages and physical abilities.

STUDENTS EXPECTATIONS

There is an increasingly commercial relationship between universities and students, with students expecting quality experiences and spaces in return for their tuition payment, as well as a return on their investment in the degree.

Studyportals cites a continuing divergence between the skills of recent graduates and the skills actually needed in the local economy. There is growing pressure to ensure higher education can fill both local employment needs as well as more aspirational opportunities. Universities are often now working more with local companies and to train new entrants to the jobs market as well as mid-career training targeted on specific company needs.

BIG DATA

Universities are leveraging data to improve all aspects of the educational experience and physical campus, including recruitment and admissions, facility operations, student experiences, and sustainability.

Benefiting from data-driven decision-making, campuses need to install the required sensor, monitors, or reporting procedures to collect the data, and implement software solutions that can clean and analyze data to extract trends and recommendations. Hands-on experience will become even more sought after and the more contact students have with the data the better their chances for future employment.

DIGITALIZATION

Digitalization and automation is expected to continue to disrupt many employment areas, even those previously thought more immune as they required more highly-skilled employees.

Both Studyportals and Arup have cited the predicted automation of jobs, even those previously thought to be highly-skilled and therefore somehow immune to disruption. Automation will mean that more and more people will seek to re-invent their careers. Many may choose jobs that prove harder to disrupt and require vocational skills. There may be more of a need for campuses to reflect this change and move away from lecture halls to more project space with a wider variety of equipment and technologies, especially as automation is expected to disrupt even more sectors, including those that were previously considered to be immune to disruption, such as law or medicine.

Universities must ensure that programs teaching high-demand skills have adequate resources and room to grow, and give students the opportunity to gain hands-on, on-campus experience with emerging technologies like distributed energy systems and renewable power generation.[1]

3 TRENDS IN HIGHER EDUCATION

FINANCING

Critical energy projects usually require substantial amounts of start-up money. However, schools and institutions of higher education can fund new energy management and microgrid projects in a number of new and innovative ways. Below are several common methods for funding energy related infrastructure projects:

Build-Own-Operate models

This financing solution enlists a qualified third party for the installation, operation, and maintenance of the required equipment. Below are two popular versions of this model:

- Energy Performance Contracts (EPC): Customers partner with energy service companies (ESCOs) to share the risk of implementing energy-efficient power-generation solutions. Upon implementation of a solution, ESCOs guarantee cost savings associated with reduced power consumption and improved operational efficiency. Customers submit payments, which should be less than the savings generated, at set intervals. Over time, these projects pay for themselves. If savings fall short of the guarantees, ESCOs pay the difference to customers.

- Power Purchase Agreements (PPA): External developers design, deliver, and operate the microgrid system. In exchange, users purchase power at an agreed-upon price. In this model, consumers buy power from generators rather than utilities.

Internal and Public Sector Financing

Internal financing is an option and may even include government grants and subsidies. The Office of Students and Research England have stated that Higher Education Institutions should manage their estate in a sustainable way and reduce carbon emissions, in line with a Carbon Management Plan and Estates Strategy. However capital allocations are usually constrained by budgets and other competing projects.

Green Banks and Funding

'Green financing' assists in the development of environmentally friendly projects. The interest-free Revolving Green Fund (RGF) is an investment vehicle where savings are recycled again and again to fund projects now and the future, thus establishing a sustainable funding cycle while cutting operating costs and reducing environmental impact.

Siemens Financial Services

Siemens has its own Bank which can help organizations with the right finance solutions to accompany their energy projects, ranging from advisory services to debt and equity capital. As an expert in energy efficiency and renewable energy funding, we can help find the right package needed to achieve customers' energy goals in an affordable way. With a global network of energy finance professionals, we provide capital and expertise that is backed by more than 160 years of Siemens' innovation, financial strength and diligent risk management.


MindSphere
Lounge
MindSphere
Lounge

CASE STUDY: UNIVERSITY OF SHEFFIELD, MINDSPHERE INNOVATION NETWORK

The University of Sheffield is a Siemens Principal Partner, collaborating in areas including energy, healthcare and manufacturing. Their latest partnership is part of the MindSphere Innovation Network (MINe), where Siemens connects UK universities' estate and research assets to MindSphere, Siemens' open, cloud-based IoT operating system that connects machines and physical infrastructure to the digital world[2]. This allows the university to access real-time and historical data that can inform improvements teaching and in research collaborations between academics and industry partners. This collaboration will build on Sheffield City Region's strengths as a digital hub, helping students develop the skills to succeed in a future of digitalization, and uncovering new business models and commercial opportunities through digitalization[3].

The MindSphere Lounge, the physical home of the University of Sheffield's IoT platform, will be a key part of the university's foray into digital learning and teaching. There, students gain hands-on experience with digital platforms. Meanwhile, teams from Siemens are based on campus to support projects and engage communities[4]. Professor Sir Keith Burnett, President and Vice-Chancellor at the University of Sheffield, said: "Just as business moves towards 'Industry 4.0', we are matching this with 'Education 4.0' in which students, academics and business come together in a shared digital environment to solve problems and boost productivity."[5]

DATA ANALYTICS
Photo voltaic Panels
ENERGY SAVINGS
WIND POWER SITES
CAN ALSO BE USED FOR STUDY
SECURITY DRONES

4 TRENDS IN CAMPUS TECHNOLOGY

ENERGY SYSTEM

Renewable Energy
Universities are significant energy consumers, serving millions of students, spending huge amounts on energy bills, which makes them an excellent candidate to save money with renewable energy. Very often their campuses have buildings and land that make good locations for hosting clean energy projects.

INTELLIGENT BUILDINGS

Today's students are smart, tech savvy and looking for more than just a safe and comfortable experience when they choose a university. Campuses that invest in intelligent buildings demonstrate a commitment to providing the best experience for their students.

High Performance Building Automation System
Building automation and controls are responsible for the control of indoor environmental quality. Building Automation systems are still not being used to their full potential to lower energy consumption. A building with high performing systems will maintain indoor environmental quality parameters appropriately, resulting in excellent energy performance and highly motivated and productive students and staff.

Enlighted, a Siemens company developed an IoT platform for commercial buildings. The platform consists of sensors, its own network, and software applications. The core of Enlighted's platform are smart sensors, streaming data to the cloud. The platform enables reduced energy use, improved space utilization, better environmental management, greater asset utilization and decreased operational costs. The sensors can be installed in every light fixture and can collect data 65 times per second to detect environmental and occupancy changes and react to lighting and HVAC needs. Based on an advanced smart lighting control application, the Enlighted platform can lower lighting costs of a building up to 85 percent when combined with advanced LED fixtures. In addition, the platform can locate people and assets within a building and analyze the occupancy of floors and rooms. Finally, in combination with Siemens solutions, the Enlighted platform can optimize the energy efficiency of HVAC systems.

Centralized and integrated building functions
Desigo CC from Siemens enables all building systems to communicate with each other. It is a centralized, customizable platform that integrates the management of multiple disciplines, from heating, ventilation and air conditioning to lighting and shading, power, fire safety and security. Desigo CC allows intelligent interaction between multiple disciplines to realize new application scenarios tailored to individual requirements.

Building Data Analytics
Building data analytics software Navigator from Siemens enables campus managers to improve their equipment efficiency to reduce energy costs while maintaining user comfort. The key to optimizing energy performance across a campus is using long term IoT, sensor and meter information to take actions to eliminate any possible inefficiencies.

Digital workplace experience
As important as optimizing energy efficiency of buildings, is the interaction of the buildings systems with the users who work in the building or have the task to run it. Smart Apps offer the ability to connect, control, and communicate with the workplace. Their features help users adjust lighting, find and book available rooms and desks, and share immediate feedback with workplace teams.

Comfy, a Siemens company developed a simple to use app that enables people to control their environment. Through the Comfy app, Siemens Building Technologies will create amazing workplace experiences, putting people in the centre of a building. Comfy integrates with existing building automation, IT networks and IoT systems to provide on-demand control and smart automation. Employees can use the app to make immediate changes in temperature and lighting, book rooms and desks, and provide feedback on their space.

4 TRENDS IN CAMPUS TECHNOLOGY

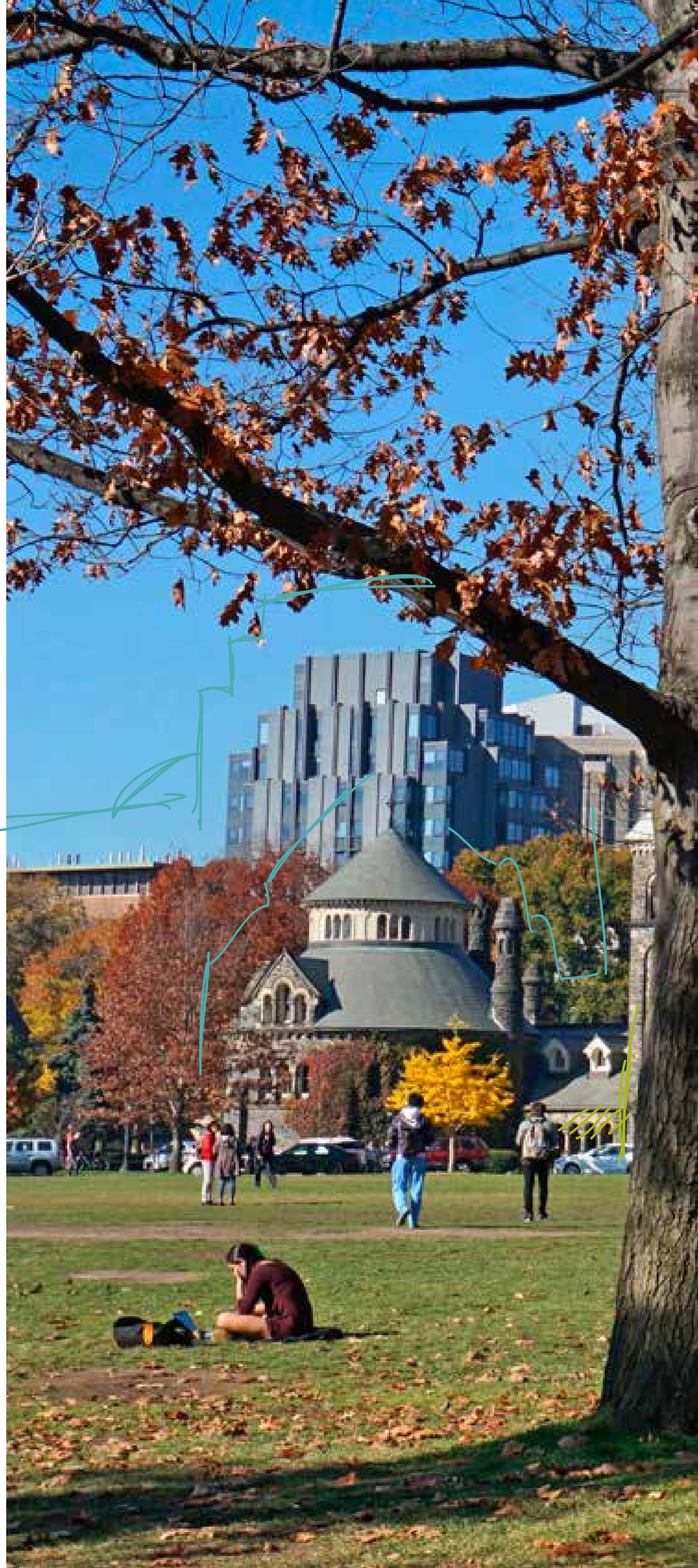
SECURITY

Biometric
Biometric controls are becoming increasingly important as a safety factor. In addition to biometric access control for smartphones and tablets, biometric access control for campuses, buildings and rooms is also increasing. Biometric identification can occur via fingerprint, iris-scan, face recognition, voice recognition or palm vein biometrics. The advantage is that each employee or authorized person has unique characteristics that can not be stolen or hacked by others. In addition it is easier to use biometric access systems as the person does not have to carry keys or cards or remember any codes.

Drones
Drones are already widely used in the security industry and huge growth is expected for this market in the near future. The advantage of drones is that they can do things which are impossible for fixed surveillance cameras like birds-eye views over large areas or dispatching rapidly to areas of interest and that they are hundreds of times cheaper than a helicopter. Drones can be applied for security guard tours as they are capable of patrolling more rapidly and extensively than human guards, as well as being unimpeded by physical barriers on the ground.

TRANSPORTATION

Connected autonomous E-vehicles
Campuses and universities have to transport students from parking lots, from surrounding housing, satellite campuses and more, to their classes which is usually solved by a circulating bus system. Connected autonomous e-vehicles will revolutionize campuses' transport. They communicate with other vehicles, with passengers, with roadside traffic infrastructure, with navigation systems and with the cloud. Instead of driving on the same route, they are flexible enough to help students and staff to reach any destination at any time. The system will be highly efficient by calculating optimized routes for an optimized number of passengers and minimized energy consumption.




MONITORING

5 TODAY

Digital democratization has the ability to transform campuses today. Imagine a campus where renewable electricity feeds into a virtual power plant, which balances energy supply and demand and fuels electric, e-hailed vehicles traveling between automatically climate-optimized and predictively-maintained buildings. These benefits are actually possible today, with campus-oriented technologies currently available across energy, buildings, mobility, safety and security, and space and asset management. These technologies will lay the groundwork for campuses to lead the way as innovators.

This digital democratization is also the future of learning. Higher educations is already trending towards individually customized learning experiences, with a focus on real-world applications and an emphasis on innovation. The future leaders in higher education will offer students coursework and projects that can be tailored to their specific interests, and prepare them for technological advances in their fields. Technology on campus can support this leadership, by connecting students with educators and examples worldwide, and enabling them to study how, when, and where it best suits their personal preferences. Campus technologies can also serve as living laboratories where students in engineering, physics, chemistry, and more will gain their first hands-on experience with the equipment of their future careers.

Blockchain

Blockchain technology maintains a distributed database with a shared list of records. Since there is no single point where that ledger is stored, from which it could be hacked or corrupted, these transparent records are guaranteed to remain reliable. In general, this can build trust among distributed, individual users, and facilitate peer-to-peer transactions and exchanges. As applied to energy systems, blockchain enables local producers and consumers to buy and sell electricity directly among themselves in participatory networks, without a third-party middle-man. This is in action today in the LO3 Brooklyn Microgrid, detailed in the Case Studies section, where a block of neighbours have created their own hyper-local energy marketplace.

Artificial Intelligence

From autonomous vehicles to smart digital assistants, we are seeing rapid progress in artificial intelligence (AI). Technologies are already available today that use AI to find patterns and trends in various aspects of campus activity, such as energy usage or passenger trips. This data can inform predictions that can make operations more efficient or to improve the experience of students and staff. For example, AI-derived predictions about when energy usage is highest can point to ways to reduce consumptions, and data about when the most e-hailed rides will be requested can ensure that sufficient vehicles will be available at that time.

US NAVY'S EDUCATION DOMINANCE

The U.S. Navy has introduced an AI-based tutoring system called Education Dominance. To get IT specialists to adequate levels of training previously required highly experience instructors, a significant amount of classroom time, and then several additional years of on-the-job training. The objective of the program was to demonstrate that experts could be created in months rather than years and to demonstrate economic scalability – that technology could replicate an exceptional educational environment.

The Digital Tutor was installed in the Navy's entry level school for ITs in Pensacola. Graduates using the Digital Tutor dominated over participants of competing programs, often by margins that were described as "huge".

5.1 ENERGY

Reliable energy – for electricity, heat and cooling - is essential for modern daily life. University campuses, where students both study and live, are dependent upon electricity and heat to deliver classes and ensure students' health and well-being. Reliable energy is generally taken for granted, but forward-thinking students and staff are already asking their universities to be leaders in creating and utilizing greener energy. Small, local, and renewable energy can be cost-effectively generated in many communities and universities.

Over the past century, large utilities have been able to scale up production of electricity, and in some cases heat, to provide for a growing population and new consumption points. Utilities were able to achieve scale by using fossil fuels, which generated a reliable supply, but worsened local air quality and are a major factor in climate change. Additionally, in the US and most of Western Europe, the electricity distribution, grid system, and power transformers were constructed or installed between the 1950s and mid-1970s. They are now reaching the end of their projected service life, and starting to cause power outages or "brown-outs." An upgrade of these networks will be required just to satisfy existing electricity demand. However, this turnover gives us a chance to rethink our energy systems, without creating "stranded assets." Meanwhile, the need for climate change adaptation and stable energy prices, and concepts like urban resilience, are shifting the energy conversation towards the small and local. The economies of scale that created large electricity producers are diminishing, although we may still rely on them in the near term. However, our electricity demand will soon outstrip their current generation, as we shift towards electric heat and transportation. This gap can be filled by renewable generation.

Users will likely be the ones funding grid improvements in some way, but the more self-reliant campuses will likely face lower energy costs in the future. This is leading future-oriented thinkers to embrace technologies that enable a radical shift in how energy is generated, distributed, used and stored. Fundamentally, the barriers to entry in the energy market have lowered and new players are gaining access to what had been a closed and highly regulated market. New words like "prosumer" have entered into everyday conversations and there is a market belief that we are witnessing a democratization of electricity today. Public concern about air quality is focusing the debate about future power generation towards electricity because it can be produced cleanly and renewably. Alternative fuels may be efficient in specific cases, but electricity appears set to be the future currency of energy, including heat.

There is a huge amount of variance across energy systems, but at the core is an aim to decarbonize and democratize energy generation, use digital technology to better manage the peaks and troughs of energy use, produce at least a portion of the power locally, and minimize the amount of electricity drawn from the grid. These types of systems would not necessarily make your campus an energy island, because resilience means maintaining options, but it could mean that your campus runs on cleaner electricity, may warm some buildings with heat pumps, and stores electricity in batteries. Decentralized energy makes communities and campuses more independent from the national power grid and thus more resilient against power outages created by flooding, storms or simply an aging system.

5.1 ENERGY TECHNOLOGIES

SOLAR PHOTOVOLTAIC PANELS

The established technology of solar photovoltaic (PV) panels create renewable and carbon free electricity, which can be used where it is generated. PV cells convert solar radiation into electricity by using semiconductors made from silicon.

A photovoltaic system is comprised of multiple panels, and installations can be installed in the ground-based solar farms, on rooftops, or on walls. The installation can be fixed or it can track the sun across the sky. A solar panel with a size of one square metre located on a building near London, UK can produce 170 kWh per year under ideal conditions. This amount of energy equals about 4.25% of the average annual household electricity demand of 4,000 kWh in the UK.

PV installations need a lot of horizontal space, because the technology has an efficiency of only 20%, and the solar panels need to directly face the sun. Solar panels produce direct current which has to be converted to “utility frequency” or alternating current using a solar inverter before it can provide electricity to the attached building or local microgrid. Excess electricity can be fed back into the conventional grid. When feeding electricity into the grid, a two-way energy meter is required, to separately record consumption and in-feed.

DISTRICT HEATING AND COOLING SYSTEMS

District heating or cooling is an efficient method of delivering either heat or cooling for indoor spaces to a number of buildings within its system or “district”. It can also provide domestic hot water from a central energy generation plant to a number of buildings within its system or “district.”

A central energy generation plant generates steam or chilled water and transports it via a pipeline network to buildings, where heat exchangers pass the energy to individual buildings.

It needs a piping network both within a building and across the district. It also requires a generation source, and a central heating or cooling plant capable of providing heating and cooling for up to hundreds of buildings. The pipe network can be buried under ground or routed above ground. The buildings need instrumented and metered heat exchangers to separate district hot water supply and building hot water supply, and circuits to make the energy accessible for end users. Inside the buildings, heat or cold can be distributed via underfloor heating, radiator heating, chilled ceilings or ventilation systems.

UNIVERSITY OF NEW HAMPSHIRE

UNH’s combined heat and power facility (COGEN) went online in 2006. COGEN provides the main source of heat and electricity for the five million square foot Durham campus. The facility retains waste heat lost during the production of electricity and uses it to heat buildings. The facility cost an estimated $28 million with a pay back within 20 years. The installation led to a reduction in greenhouse gas emissions of 21 percent in academic year 2006 compared to 2005. In 2009, UNH began using processed landfill gas from the EcoLine project, a landfill gas-to-energy project that uses methane gas from a nearby landfill as the primary fuel for the COGEN plant.

5.1 ENERGY TECHNOLOGIES

DEMAND RESPONSE

Our energy distribution systems are not adequately prepared for fluctuating generation from solar or wind power plants, nor for the direct feed-in from decentralized energy sources. These challenges can be met with flexibility on both the generation and the demand side. This flexibility makes it possible to compensate for the fluctuating in-feed caused by solar or wind energy. It also allows operators to optimize and stabilize local distribution networks.

Demand Response (DR) programs provide an opportunity for consumers to play a significant role in the operation of the electricity grid, by reducing or shifting their electricity usage during peak periods in response to financial incentives.

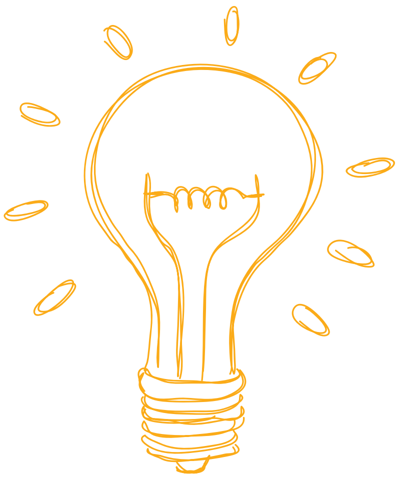
Demand response programs are being used by utilities to balance supply and demand. DR programs can lower the cost of electricity in wholesale markets, and in turn, lead to lower retail rates. Demand Response provides the flexibility needed to enable consumers to respond to price signals or network utilization. If the energy prices are high or there is under-frequency in the grid, big consumers such as large-scale, industrial heat pumps or fans can be switched off, or loads can be switched on in the case of excess supply, such as from PV panels on a sunny day. Load shedding, to avoid consumption peaks, is already a well-established technique to balance energy use. In many countries, load management systems (also called ripple control systems) can, for example, turn on boilers at night when tariffs are lower, then switch them off during the day. Demand response offers bundling of energy loads and energy generation, as well as the possibility to offer this flexibility in reserve energy markets. This allows not only providers of big loads and consumers to participate in these programs, but also small providers, which would be aggregated into a bigger virtual participant.

Demand Response can be carried out by energy suppliers themselves or by third parties called aggregators. In both cases, distributed loads and generating units are connected to a central system. This central system aggregates the individual components into products for marketing in the operating reserve markets. The operating reserve is the generating capacity available to the power grid operator within a short interval of time to meet demand in case a generator goes down or there is another disruption to the supply. The aggregation platform ensures that the offered services are always available to the markets. At the same time, it enables companies to participate in the operating reserve energy market without risks for operational processes.

The roll-out of smart meters means that today private households can participate in DR programs. They would receive an incentive from the utility or the aggregator in return for being flexible in how or when they operate household appliances such as washing machines or dishwashers. This aspect is only suitable for certain household uses, whereas others (like oven use) tend to be less flexible.

DR needs flexible demand loads, which can be switched on or off depending on the grid scenario. Ideal technologies for DR are pumps, fans or compressors and are typically found in industrial plants rather than a campus. However, some universities may have labs or particular buildings where this technology could be applied. Additionally, smaller generating units such as biomass power plants, waste incineration plants or emergency power systems are well suited for demand response.

DR programs are provided by the aggregator or the utility via operating centres with online connection to the energy markets and online communication to participating energy suppliers and users to transmit respective switch-on or shutdown signals.



5.1 ENERGY TECHNOLOGIES

MICROGRID

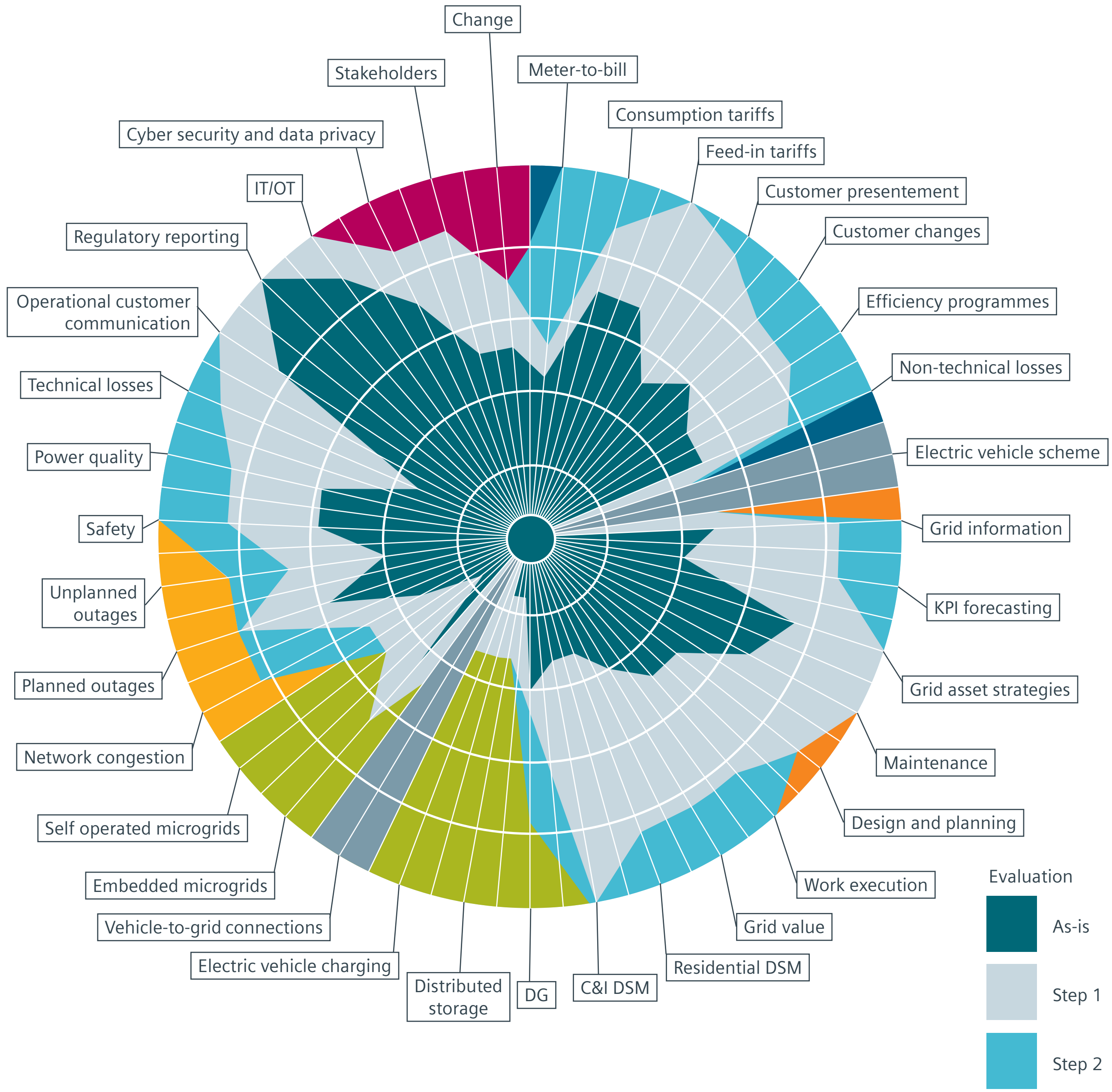
A microgrid is a self-balancing energy system that combines small-scale electricity and heat generation units with battery storage. It directly supplies a designated area and has only one or a few connections to the main grid. The microgrid system monitors and calculates whether any additional electricity was taken from the grid, or whether there was an excess in the system that was either stored or fed into the grid. Microgrids can be a major element of a campus energy strategy or Smart Grid strategy.

Microgrids are small power grids that can supply subscribers with electricity largely independent of the conventional power grid. Microgrids can be divided into: 1) off-grid microgrids, which operate completely independently of the main electricity network, and 2) connected microgrids, which are connected to the power grid, but can decouple from the grid if necessary and go into island operation. There are also hybrid systems, where local electricity is created or shared within a neighbourhood or very local area using the existing grid, and payments are made separate from the utility. The three main components of a microgrid are distributed power sources (e.g., photovoltaic, wind energy), consumers, and an intelligent control system.

Microgrids have several advantages over conventional power grids. Since microgrids can be operated autonomously, it is possible to service loads within the network independently of the higher-level power grid. This so-called island operation is particularly useful in case of grid failures or blackouts. The microgrid can be disconnected from the power grid, thus ensuring the power supply for the participants. As a result, critical places such as hospitals or server farms can be much better protected against failure.

A microgrid requires an intelligent management and control system that balances energy demand and supply by integrating all energy resources and consumers. It automates the control of all microgrid components and the connection to the national grid, to meet energy needs and ensure stable operating conditions with minimal operational staff.

5.1 ENERGY TECHNOLOGIES



SMART GRID COMPASS

A microgrid can play a key role in a campus Smart Grid Strategy. Siemens has developed The Smart Grid Compass®, an extensive framework for the development of Smart Grid related strategies, guides campuses towards initiatives that can improve your progress towards your goals, and estimate the performance level you are likely to achieve in a benchmark comparison. The results of the Smart Grid Compass evaluation are compiled (see below) to form a dependable basis for decisions that are focused on added value.

5.1 ENERGY TECHNOLOGIES

VIRTUAL POWER PLANTS

A virtual power plant is an association of decentralized units in the power grid, which are coordinated via a common control system. The units can be electricity producers, including biogas turbines, wind power, photovoltaic, combined heat and power plants, hydroelectric power plants, electricity consumers, electricity storage and Power-to-X (Power-to-Gas, Power-to-Heat) plants.

The purpose of the Virtual Power Plant is the flexible aggregation of power from the connected assets. Any decentralized, energy-storing or -consuming actor in the electricity market can become part of a virtual power plant. The group of individual units is managed by a central control system, which not only coordinates the individual systems in the virtual power plant by means of a special algorithm, like a single large-scale power station, but also reacts to network conditions and reserve energy call commands by transmission system operators. In connection with the electricity trade, the Virtual Power Station is also able to react quickly and efficiently to price signals from the electricity markets and to adapt its operational style accordingly.

A Virtual Power Plant is operated from a central operation centre, and needs secured and tunneled bi-directional communication to grid operators, energy generators, energy markets and consumers for the transmission of operational commands and online grid conditions. The operation centre analyzes all data and manages the initiation and execution of all trading transactions on the electricity exchange.

ON-SITE ENERGY STORAGE – THERMAL AND BATTERY

On-site electrical or thermal energy storage allows excess electricity or heat within a system to be stored within the same system without requiring any alignment with the electricity grid. Storage is seen as a requirement before renewable wind and solar sources can become main electricity sources. Storage is also seen as a way to close the gap in daytime and night-time electricity prices, as they can be programmed to sell or provide stored energy at a certain price point. Real-time selling of electricity at a specific price point is not yet possible for relatively small users like households, but it is expected to become a new normal in the near future.

Batteries and thermal storage allows for the storage of energy in the form of heating, cooling or electricity. Storage is particularly critical when using renewable or intermittent power sources such as solar PV, and if used to store electricity at cheaper tariff times, can be effective in lower campus operational costs and GHG emissions. They can also be offered to grid providers as load capacities in order to balance demand and supply in return for financial incentives.

It requires a battery pack with connections to the generation sources, microgrid, and/or main electricity grid. Thermal energy storage is possible through a variety of systems, including heat storage in steam tanks, hot stones, concrete, or molten salt.

KEELE UNIVERSITY CREATES THE LARGEST SMART ENERGY NETWORK DEMONSTRATOR IN EUROPE

Funded by the European Regional Development Fund (ERDF) and UK Government, Keele University and Siemens are creating Europe's largest Smart Energy Network Demonstrator (SEND). Owning their own water, gas and electricity network has meant the latest energy innovation can be implemented. The project involves microgrid management software, digitalization of 24 substations, the installation of 1,500 smart meters, 500 home controllers, 20 EV chargers, with a 5MW renewables integration package. The SEND aims to reduce carbon emissions substantially each year and will serve as a living laboratory for researchers, start up communities and government to develop low carbon technologies and sustainable energy systems for the future, acting as a catalyst for economic growth within the city.

CASE STUDIES:

BROOKLYN MICROGRID, NEW YORK CITY: DISTRIBUTED GENERATION, PARTICIPATORY NETWORKS AND MICROGRIDS

Distributed generation of renewable electricity is already a reality in Brooklyn, New York City. LO3 has partnered with Siemens and TransActive Grid to create the Brooklyn Microgrid. By installing rooftop solar panels on their homes, residents produce sustainable electricity to meet their own needs, sell to neighbours, or even return to the main NYC electricity grid. The Brooklyn microgrid can operate in connection to the main grid, to draw extra electricity as needed while increasing the overall proportion of renewables, but can also operate in "island mode," as a self-contained, self-sufficient grid that increases resilience by providing back-up electricity for emergency services during outages or natural disasters. The microgrid's accounting uses blockchain technology, an online, transparent accounting system which is known for powering the Bitcoin virtual currency. The organization is run as a benefit corporation, which is a for-profit business that can positively impact society and the environment as well as pursuing revenue, and it plans to gift shares to local businesses and residents. In this way, the Brooklyn Microgrid serves as an example to cities and university campuses worldwide, demonstrating the potential to increase generation of renewable energy, distribute electricity production, and empower community members to engage with their local grid infrastructure.

ALGONQUIN COLLEGE AND SIEMENS CO-CREATED A PIONEERING SUSTAINABILITY CURRICULUM

As the world faces unprecedented environmental challenges, there's a huge need for special leaders to emerge. Leaders that demonstrate what can and must be done for a sustainable future. Algonquin College is Ontario's fourth largest college with about 20,000 students in Eastern Ontario. Algonquin College is a leader in sustainability across global academic institutions and has a zero net carbon footprint goal for 2042.

With Siemens help, Algonquin College is today serving as a 'living lab' of leading-edge sustainability technologies including on-site cogeneration for energy independence, energy storage and a microgrid. It creates a unique culture of sustainability at the College, including a sustainability graduate certificate program; and the integration of sustainability into the curriculum of all undergraduate disciplines for every student. The Energy Innovation Centre on the campus where infrastructure upgrades for energy efficiency, resulting in a $3.2 million annual savings for the college have been implemented provides students with hands-on access to the newest technologies. And there is a dedicated Siemens sustainability officer onsite to drive and promote Algonquin's sustainability initiatives.

Working with Siemens, Algonquin College can give its students state-of-the-art lab experiences in new technologies that will drive the jobs of the future. Algonquin College has future-ready learners coming out of its programs who are ready to change the world. Throughout the project, Algonquin College and Siemens enjoyed a unique spirit of partnership.

I really believe that the work Siemens and Algonquin have done together is absolutely ripe with ingenuity. We have put our brains together to come up with groundbreaking ideas to drive toward a net zero carbon footprint.

Cheryl Jensen, President, Algonquin College


GRID

5.2 BUILDINGS

The concept of what a building can be is rapidly evolving. Rather than static boxes that house technologies, the buildings themselves can become smart, automated, digitally-integrated technology systems. To improve the comfort, convenience and safety of their occupants, buildings can automatically adjust the indoor environment to suit real-time weather conditions or individual preferences, while optimizing for energy efficiency. Smart, digital management of space and assets means that rooms and equipment can be allocated and reserved efficiently. Above all, smart building security systems can more sensitively detect dangers like a fire or an intruder. As self-learning AI systems progress, buildings can continuously improve these features while requiring less human involvement, which will save valuable time and resources.

Technologies for buildings and energy are starting to merge, becoming more synergistic. Grid-interactive smart buildings can produce electricity with on-site renewables and store it in lithium-ion batteries. They will communicate digitally with the surrounding smart grid to sense when it would be advantageous to withdraw electricity from the city's network, or possibly sell it to the grid for a profit. By combining building technology with energy transmission and distribution, smart grids can significantly improve energy efficiency while reducing greenhouse gas emissions. The technologies that will support smart buildings include: smart meters, thermostats, inverters, building automation systems, wireless sensing networks, distributed energy storage, and digitally-connected appliances.

However, efficient building management encompasses more than just energy. Future-proof building management platforms integrate all aspects of a building – from building automation to fire safety, security and energy. This holistic approach will enable building managers to monitor and control different features in real time, to create synergies and to reduce operational costs.

BUILDING INFORMATION MODELING

Today, construction projects face multiple challenges in the areas of time, costs and quality. Planning errors and inaccurate or incomplete plans have a strong impact as well as environmental aspects, accidents or a lack of cooperation in the interdisciplinary work. These challenges can be met by holistic project planning, and developing an approach that connects all parties involved, which is called Building Information Modeling (BIM). BIM is a digitally supported process for planning, constructing and operating buildings that enables a significant productivity increase in the construction industry. BIM allows for simulation of energy consumption and usage scenarios and helps to make buildings future-proof.

BIM is a construction-based planning and control method supported by digital technologies. It serves to optimize and support the processes of planning, construction and operation of buildings and allows for an integrated, multi-dimensional, life-cycle view. The basic principle behind BIM is the creation and the management of digital virtual representations of the physical and functional properties of a building. These flow into a shared pool of relevant data that can be used as a basis for decision-making throughout the lifecycle, from early planning to demolition.

The core is an initially three-dimensional computer model that, in addition to spatial information such as dimensions or position in the room, also contains further building information on materials, time sequences, costs and usage data, and thus adds further dimensions. The basic principle behind BIM is the creation and the management of digital virtual representations of the physical and functional properties of various components of a building. The resulting data basis can be exchanged in a transparent communication between all parties involved in the planning, construction and operation of the building and handed over for further processing. This allows a comprehensive and efficient consideration of a building throughout its lifecycle.

The benefit of BIM is the simplification of planning, construction and operation. It reduces the risk of errors, makes costs transparent, increases the speed of processes and strengthens the cooperation. Automated collision checks help to reduce planning errors and avoid them as completely as possible. Problems can be detected early and thus costly changes in the later construction process as well as associated delays can be prevented. Data does not need to be entered multiple times, as models can be brought together in a coordination model by everyone involved, including architects, civil engineers, structural engineers, and builders. Immediate and continuous availability of all current and relevant data is given. Visualization using 3D models improves project communication and project marketing. The resulting information can also be used for building operation as the central documentation of the data forms the basis for facility management.

5.2 BUILDINGS

BUILDING MANAGEMENT SYSTEMS

Building Management Systems (BMS) are a critical component to managing energy demand in a building, most commonly implemented in large projects with extensive mechanical, HVAC (heating, ventilation, and air-conditioning), and electrical systems. It includes sensors, actors, controls and management stations, interconnected via dedicated networks and communication protocols.

A BMS monitors and manages all mechanical, electrical and electromechanical services in a commercial or educational building, which includes electricity, heating, ventilation, air-conditioning, access control, fire safety, lights and blinds. It concentrates online information from thousands of data points onto a management station, with a graphical user interface that provides full access to all building processes. It allows for the integration and exchange of information about HVAC, energy management, fire safety, access control, or video surveillance systems, allowing for enhanced functionality, process transparency and security in buildings.

A Monitoring System superordinated to the BMS and based on an IoT platform analyzes building data from sensors and meters, giving visibility into the long-term performance of facilities and infrastructure. It helps to monitor building system performance, energy demand and energy supply. It provides transparency, giving full insight to make critical improvements. Using a central, cloud-based platform, it can maintain total control over a single building, a campus or an entire portfolio.

A BMS consists of software and hardware distributed throughout the building in electrical cabinets, plant rooms and offices, interconnected via an industrial IP network, utilizing specific building automation communication protocols. It is operated by a facility manager who is responsible for overall comfort, operational expenses, and building or campus security.

A monitoring system running on an IoT platform needs access to a building's automation system or its sensor and meter network. Consumption and process data get transferred from the building onto a cloud platform, where it can be accessed by building performance analysis and reporting applications. This means that building operators can look across an entire portfolio of buildings or across a campus, to compare performance and detect outliers or problems within the systems, then take appropriate action.

GRID-INTERACTIVE BUILDINGS

Grid-interactive buildings play a key role in the ongoing transformation of energy systems. They consume, generate, and store energy, while also reducing their own energy demand through lower consumption. They are able to communicate directly with the power grid, making them "prosumers." This means that they are able to feed electricity into the grid, thereby turning the building into a power plant.

Grid-interactive buildings make use of energy storage systems like batteries or thermal storage. They store surplus energy from their energy generation systems, like PV or CHP, to make use of it during the next consumption period. By participating in Demand Response programs, provided by the utility, building operators can be incentivized to volunteer their storage or load capacities to the grid operator, at times when the grid has too much or too little energy (see Demand response). Key features include the complete integration of all systems and energy sources as well as the permanent monitoring of all energy flows.

It needs a Building Management System with all sub-systems fully integrated, as well as energy storage systems and communication to the utility. This could happen via a smart meter that receives charging or discharging requests and pricing forecasts.

HEATING, VENTILATION, AIR CONDITIONING (HVAC)

Heating, Ventilation and Air Conditioning is used in buildings to maintain internal air quality, and regulate internal temperatures and internal humidity. Internal air quality in a building can be maintained by introducing fresh outside air and by extracting used air, by either mechanical systems including fans or by natural ventilation systems.

In commercial developments, HVAC is provided by air handling units connected to ducts, which supply air to and extracts air from internal spaces or by heating systems using gas- or oil-fired boilers to heat up water to be circulated through a system of pipes connected to radiators which deliver heat through convection. Air handling units typically comprise filters, fans, heating, cooling elements, dehumidification equipment, and dampers, heating systems comprise boilers, pipes, pumps and radiators or underfloor heating systems. HVAC can consume large amounts of energy, and where possible, supply should be reduced to the real demand by dedicated demand control strategies and passive systems adopted.

Ventilation, which means extracting internal air and replacing it with outside air, can increase the need for heating and cooling, but this can be reduced by re-circulating a proportion of internal air, or by heat recovery systems that recover heat from air that is being extracted and uses it to pre-heat incoming fresh air.

Because of its interaction with other elements of the building, it is important that HVAC is considered at the outset of the building design process. HVAC is mostly controlled by a building management system to maximize occupant comfort and minimize energy consumption.

5.2 BUILDINGS

GROUND-SOURCE HEAT PUMPS

Heat pumps are devices that can raise or lower ambient temperatures by using air, soil or water as the primary heat source. Heat pumps use compressors to supply homes with heating and hot water. Unlike oil and gas heating, heat pumps do not require fuel for heating. Instead, they use the heat of the environment. Ground source heat pumps (GSHPs) use buried water pipes and an anti-freeze liquid to absorb heat from the ground. In the so-called thermodynamic cyclic process, the heat pump increases this temperature further, so that it is suitable for heating a building. Depending upon the temperature needed, additional heat from solar thermal plants or electrical immersion heaters can be used to raise the water temperature even further to reach the desired room temperature or for the preparation of domestic hot water.

Ground Source Heat pumps use electricity to raise the temperature of the heat taken up from the ground to a level that can be used for space heating via underfloor heating systems or radiators. It can also be used to heat up air in an air handling unit and provide it to the building space via a system of air ducts. A GSHP circulates a mixture of water and antifreeze around a ground loop. The fluid absorbs heat and boils, even at temperatures below 0°C. The resulting gas is then compressed, which further increases its temperature. The gas is passed into heat exchanger coils, where it condenses, releasing its latent heat. The process then repeats.

Ground temperature remains at a fairly constant temperature, so the heat pump can be used throughout the year. GSHP can be three to four times more efficient than conventional electric heaters. Heat pumps generate lower temperature levels than heating boilers and match very well to low temperature underfloor or trench heating systems.

A ground source heat pump should be installed inside the building in a dedicated plant room with good sound insulation. A GSHP runs on electricity so it needs a separate power supply. GSHPs need to be connected to a water pipe network buried in the ground near or under the building. The pipe network can be located in the foundation of a building or in boreholes sometimes reaching more than 100 m deep. Additional pumps and pipe connections are required to pump the anti-freeze liquid through the pipe network in the ground and to connect the heat pump with the heating and cooling distribution systems of the building.

SIEMENS SERVICE PORTAL

THE FUTURE OF PREVENTIVE AND CORRECTIVE MAINTENANCE SERVICES.

Digital technology is changing the dynamics of service as it is fast, convenient and always on. Digitally enhanced maintenance services from Siemens Building Technologies offer responsiveness, insights and transparency by using data analytics, remote action and access to global experts. Digitally services strengthen a campus existing service program by leveraging connectivity, data and the power of a global network of experts. They harness building data and turn it into insight and action that drives building performance. Data is collected from sensors and equipment through secure data transfer.

The web-based Service Portal enables a higher level of service for operators and users. Its intuitive interface allows to manage schedules, track repairs, generate reports and access critical information, quickly and efficiently. Support calls can be placed, and additional requests can be made. Connectivity ensures that experts can begin diagnosing and solving issues sooner, so maintenance issues are resolved faster. It provides transparency on existing service contracts and allows to stay on top of support tickets and their progress. Experts can be accessed at the Advanced Service Centers who monitor and analyze systems and can apply fixes remotely. Technicians arriving on-site are equipped with data and the right tools to address issues immediately. As security is priority data is transferred using a powerful and secure VPN tunnel, employing firewalls and the latest authentication, authorization and encryption technologies.

Digitally enhanced maintenance services provide better monitoring and diagnostics, online scheduling, remote tuning, updates and backups.

5.2 BUILDINGS

AIR-SOURCE HEAT PUMPS

Air-source heat pumps use the external air as a primary heat source to provide heat and hot water for buildings.

Air Source Heat Pumps (ASHPs) use electricity to extract heat extract heat from the outside air. They run on electricity, but extract heat that is constantly replenished naturally. A refrigerant fluid is run in heat exchanger coils through the external air. The fluid absorbs heat and boils, even at temperatures below 0°C. The resulting gas is then compressed, which further increases its temperature. The gas is passed into heat exchanger coils, where it condenses, releasing its latent heat. The process then repeats, it is the same process as in the GSHP. ASHP can be three to four times more efficient than conventional electric heaters, but are slightly less efficient than GSHPs.

Air heat pumps can be installed inside or outside a building. They will need to be installed on a wall or on the ground in an area with good air flow, ideally by a sunny wall. Split air heat pumps for a partially inside and outside installation are also available. Air heat pumps work best when heating a well-insulated space.

PERFORMANCE MONITORING

Performance Monitoring solutions, like the Siemens analytics tool Navigator, provide Digital Services that create full transparency around the operation of campuses. It is a software that analyzes long term building consumption and creates reports that provide transparency on all building processes including energy and water consumption. It is a cloud-hosted service that accesses offline building energy consumption data to optimize a building's performance sustainability. It analyzes the operation data and reports how much energy was used, when, and where, using representations including trend curves and pie charts. This allows operation managers to identify anomalies in consumption, like at times when the building is unoccupied. The campus can then capture savings potential by e.g. adapting timed functions to the building's use patterns.

Other reports can be generated for commercial managers to supervise energy budgets, for sustainability managers to monitor CO_2 emissions and for facility managers to support maintenance of the mechanical systems.

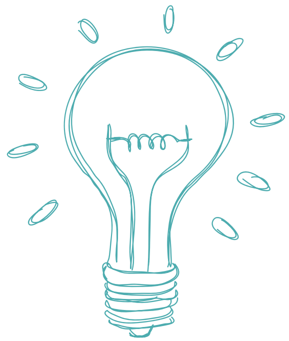
The system needs a communication connection to a buildings sensors and meters, and a function to automatically transmit new sets of data. Data gets stored on an IoT platform from where it can be accessed and analyzed by dedicated apps.

DIGITAL ASSET MANAGEMENT

Whether they are tech assets like SmartBoards and expensive laptops or simply furniture items like desks and chairs, a university needs to track its assets and equipment efficiently as they are never immune to theft and misuse. They have to be digitally tracked and monitored, to check their location, usage patterns and the state of their maintenance. Digital asset management cuts down on theft and loss and allows predictive maintenance to keep everything in working order.

Digital asset management uses active or passive RFID, Bluetooth or Wifi technology to track location of assets. A software is used to monitor and record location of thousands of devices.

Bluetooth Low Energy (BLE) beacons and WiFi antennas will need to be installed and calibrated to the expected use and functioning of different assets. The higher the density of beacons and antennas, the higher the accuracy of the location determination.



LiFi

LiFi, light enabled WiFi, is being piloted in commercial buildings to improve internet security and provide denser coverage – Paris, France.

Icade the French real estate investment company is just only one of the many companies piloting this technology. 20 LiFi Luminaires will be used in its smart office in La Defense, Paris. LiFi stands for Light Fidelity and is a Visible Light Communications (VLC) system which runs wireless communications at very high speeds up to 224 Gb/s. The first LiFi network was launched at ITMO University in June 2017. LiFi is now being used in projects in more than 20 countries. There are a range of industries that use LiFi including: leading engineering services, telecommunications industry and UK's military, intelligence and security. LiFi can be used as a lifesaving technology in disaster operations. LiFi will help maintain business continuity, mitigate risks and when disaster may strike, assist emergency response efforts.

CASE STUDY:

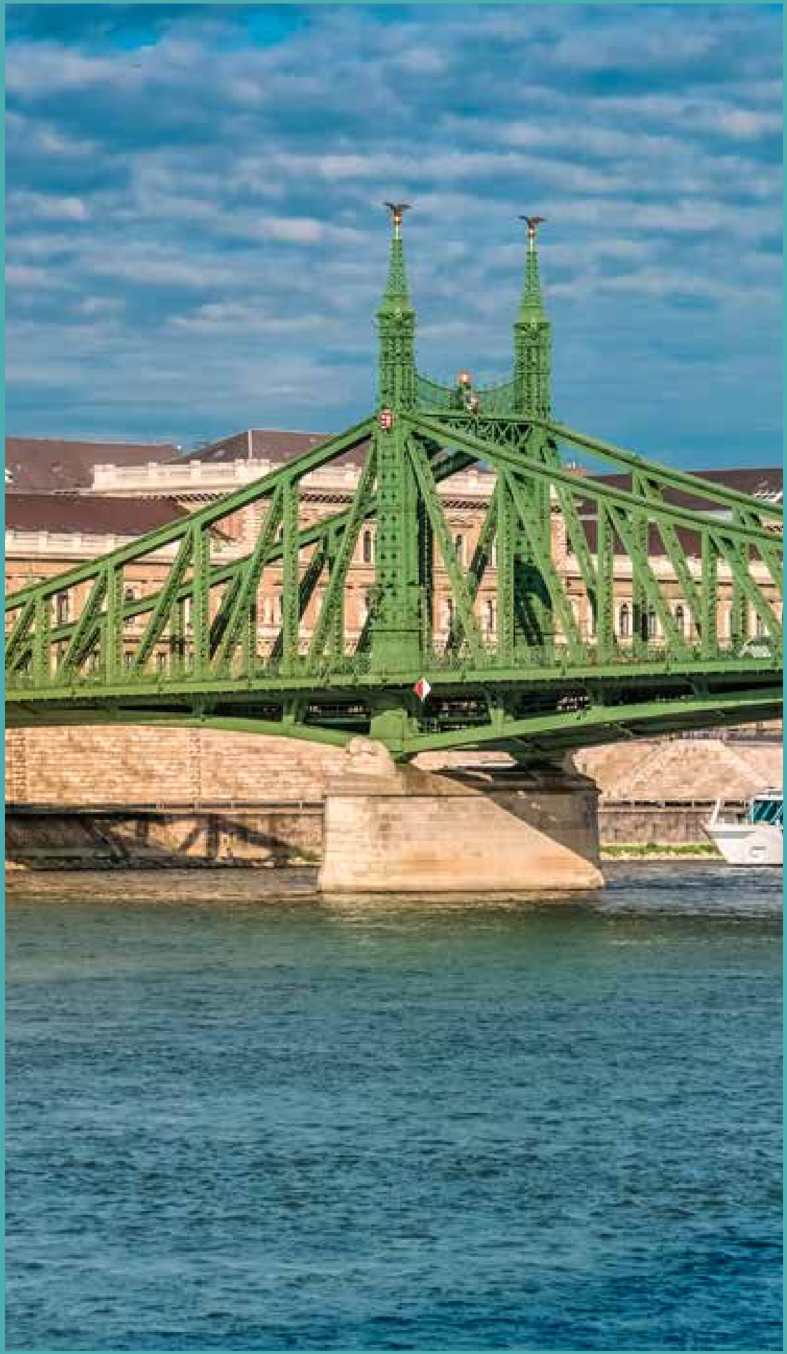
CENTRAL EUROPEAN UNIVERSITY, BUDAPEST, HUNGARY

In September 2016, Central European University in Budapest, Hungary opened two new state-of-the-art buildings, "offering high-tech space for learning, teaching, research, and the exchange of ideas in line with the University's commitment to open debate and community engagement[6]."

"The new and renovated buildings are acoustically treated to dampen sound in corridors and open spaces and enhance sound quality in the auditorium and classrooms. Classrooms and meeting rooms offer the most advanced connectivity options, allowing professors, guest lecturers and students to share notes, presentations and other media via electronic whiteboards and screens using the Barco Clickshare system. Two tiered classrooms offer broadcast technology for recording and webinars. The amount of social spaces and communal gathering spots has increased dramatically for CEU's nearly 1,500 students, who come from over 100 countries.

The new auditorium facing Nador street seats 400, more than double the size of CEU's previous auditorium. The room can be divided into two separate, acoustically sound rooms for conferences or performances and also offers video and broadcasting technology as well as stage lighting and a backstage area for arts productions. All parts of the buildings are wheelchair accessible and power points are situated lower for the convenience of all University guests.

O'Donnell and Tuomey designed the new campus to comply with CEU's commitment to sustainability. In July 2015, the CEU campus design was awarded "Very Good" status by BREEAM officials, making it the second higher education institution in continental Europe and the first in Central and Eastern Europe to receive this distinction. BREEAM is the world's leading sustainability assessment method for master-planning projects, infrastructure and buildings. Every detail was considered to lessen environmental impact and lower utility usage, from the micro-shading technology in glass structures and windows to the natural ventilating system created through the pitched roof design and the communal rooftop garden featuring locally specific bird- and bee-friendly species and rainwater collectors. A smart building management system (BMS) designed by Siemens monitors occupancy and adjusts utilities accordingly to significantly reduce heating and cooling needs and costs[7]."




e-bikes
211 163 060
40
39
38

5.3 MOBILITY

No matter the university's location or the size of the campus, staff and students will have their own ways of moving to, from and across campus, at all hours of the day and night. Digital technology has rapidly altered how we move around in cities, with consequences and applications for campus transport. Regardless of the mode of transportation, safety on university campuses is of critical importance, and digital technology offers ways to enhance safety at a reasonable cost.

Today, most universities provide safe travel options, such as night shuttles and monitored walking routes. Digital technology is now creating even more safe transportation options for universities, including e-hailed night shuttles, shared on-demand daytime shuttles, and cycle and eBike sharing programs.

Affordability is always a concern for students, as well as contracted campus employees. Real-time vehicle tracking and hailing is reducing the costs of shuttle systems, allowing them to travel directly to the passenger instead of following a planned circular route. This means that the university needs fewer shuttles and less fuel. Providing 24-hour monitored walking routes and cycle parking areas means that students feel more comfortable and safe using the cheapest, most sustainable form of transport – their feet. Digital technologies can also improve transport for disabled students and staff, as the university can provide more services and flexible routes.

Electric vehicles are now moving into the mainstream. They are proving to save costs over time, because they need less maintenance and because electricity prices are generally cheaper and more stable than petrol. They also offer environmental and health benefits: their lack of local emissions would improve campus air quality and, especially when combined with renewable electricity, would reduce greenhouse gas emissions.

ELECTRIC VEHICLES

Electric vehicles are vehicles that use electricity as their fuel source. They can be powered by either lithium-ion batteries or hydrogen fuel cells, and different types of vehicles have different charging profiles. For example, some vehicles can be charged rapidly in under 30 minutes whereas others need a longer period of time.

They will improve the campus air quality, decrease greenhouse gas emissions, and reduce street noise. Campuses can switch their fleets to electric, minimizing the impacts of their maintenance vans and departmental vehicles.

Electric fleet and personal vehicles will require a local charging infrastructure and, for full benefits, access to low-carbon electricity. Charging infrastructure does not have to be expensive, particularly if there is flexibility in how the vehicles are used. For example, night-time shuttles can be charged during the day using solar PV.

The take-up of electric vehicles would significantly increase campus demand for electricity, and campus leadership must be prepared for this change by ensuring that their grid connection and their local distribution system has the capacity to provide the required additional electricity.

ON-DEMAND, DIGITAL CAMPUS TRANSIT

Digitalization of mobility is creating changes across the mobility sector. Existing campus shuttles that follow a circular path could be better utilized through the use of digital technology. Shuttles can now be hailed, and shared bikes found and reserved – all via smart phones. This means that fewer shuttles are needed as they can be more precisely deployed. This generates cost savings, particularly during off-peak times when the system is still needed, but often under-utilized. This in turn reduces waiting times and uncertainty for all campus transit modes and generates a dataset about mode usage that can be used to predict needs, routes and maintenance.

Shuttles and bike shares will need digital trackers and a fit-for-purpose app.

5.3 MOBILITY

ELECTRIC BIKE (E-BIKE) SHARING

Students and staff can reserve or walk-up to borrow an eBike from conveniently located hubs. Payment can be made through an eTicketing app. Digital monitoring will track lost or stolen bikes, and alert operators if there is a shortage at any hub.

EBike sharing provides access to a low-carbon, cost-effective way to move around campus, without students have to purchase, maintain and park their own eBikes.

This scheme would require docking stations with chargers in accessible areas, eBikes, loanable helmets, and an app to reserve, pay for, and monitor the eBikes. Staff might also be required to make repairs or move eBikes to more in-demand areas. In general, campuses can promote cycling by providing safe parking racks and cycle-only routes away from car traffic.

MONITORED WALKING ROUTES

Monitored, safe walking routes let students know which routes are well lit, most frequently used, monitored by camera or police patrol, or have frequent emergency signal stations. It can be paired with a mobile app like "I Am In Danger," which allows students to discreetly call for help to their current location.

They give students safer options for walking home, which is especially beneficial for students alone at night.

This scheme needs the campus to designate a central route, and to populate it with their selected tool such as street lights, cameras, or patrols. An app would need to be linked to the campus security department or local police.

DISABLED TRANSPORT TECHNOLOGIES

Mobility for disabled students and staff can be improved with on-demand shuttles, and with wayfinding apps for the visually impaired, such as the way-finding app that helps blind people navigate the London Underground.

A wheelchair-friendly shuttle can move students around campus on demand, and wayfinding apps make it easier for the visually impaired to travel on foot through all areas of campus.

It requires blind-friendly mobile apps linked to a shuttle with sufficiently frequent service, and wayfinding apps that are customized to the specific campus environment.

3D PRINTED AUTONOMOUS OLLI SHUTTLE – UNIVERSITY AT BUFFALO

Olli is a 3D-printed, electric, self-driving, smart shuttle developed by US company LM Industries. Already being deployed to shuttle commuters in Washington, D.C. and Berlin, Olli is now launching operations at the University at Buffalo.

Though at this stage Olli is mainly used for autonomous vehicle education and mapping it will also drive passengers to their destinations on the campus. It provides a safe, efficient and environmentally friendly transportation option and with a maximum speed of 25 mph, it is especially well-suited to environments like college campuses.

This project is supporting Governor Andrew M. Cuomo's goal to reduce greenhouse gas emissions by 40 percent by 2030.

MIT SafeRide OnDemand SHUTTLE PILOT

February 2018, the MIT Parking and Transportation Office launched the SafeRide OnDemand Shuttle pilot. SafeRide is expected to improve safety by providing on-demand, after-hours and late night, shuttle services for members of the MIT community. The service will cover a relatively large area including on-campus housing and off-campus areas where students may live. The system uses 14-passenger vans to provide door-to-door shared rides.

CASE STUDY:

MIT AND FORD, CAMBRIDGE, MA, USA

The Massachusetts Institute of Technology (MIT) in Cambridge, MA, USA partnered with Ford in 2016 to deliver an on-demand, electric shuttle service for students, which was simultaneously a research project helping Ford explore technologies for autonomous, on-demand shuttles. Students hailed one of three new shuttles using a smartphone app, and were quickly shuttled around campus or to nearby areas of the city. This made it easier for students to move between classes and get home safety at night, while avoiding air pollution on campus. Data about travel patterns was gathered and shared with the research team to optimize pick-ups, routes, and drop-offs, which provided a better experience for passengers and reduced the vehicles' energy consumption. This was applied to improve the company's Dynamic Shuttle Project for employees on their Dearborn, MI campus, and generally to explore future transportation technologies as part of the Ford Smart Mobility project. Specifically, Ford was looking at ways to improve detection of pedestrians using LiDAR systems with lower resolution than are currently employed in most of today's LiDAR-equipped vehicles. Most autonomous vehicles (AVs) today use LiDAR, and future AVs are expected to as well. Improving the accuracy of lower-resolution LiDAR systems means that AVs will be less dependent on supplemental information from cameras, which could their production costs and make them more affordable. At MIT, since the driver remained in control and the campus is a more controlled environment than an urban street, the project provided a safe way to evaluate the real-world performance of the hardware[8].

5.4 SECURITY AND FIRE SAFETY

The security of students and staff is the top priority of any university, and a key aspect of quality of life on campus. New technologies offer more ways than ever to detect intrusions, monitor the whereabouts and condition of valuable equipment, expedite the fire alarm and evacuation process, and more. This is made possible through the provision of integrated access control, video surveillance and fire safety solutions. These would be maintained and monitored by staff who react quickly to alarms or events triggered by the systems.

VIDEO SURVEILLANCE

Video surveillance is one of the most widely employed security technologies. It is used primarily by security authorities for visual surveillance and for assessing situations.

Should a security incident occur, the video stream can provide important evidence. In addition, video surveillance can also act as a deterrent, resulting in less vandalism and giving people a greater sense of safety.

A particular difficulty for campuses is how to monitor multiple camera feeds in a cost effective manner. Intelligent video analytics solutions like Siemens Site IQ can help automate video analysis recognizing objects like vehicles or persons entering policy zones or crossing virtual fences allowing surveillance to focus on potentially important events.

Video surveillance systems need cameras connected to a central server or a cloud system, and apps for analysis and tracking of individuals or objects. Video surveillance systems are operated by security personnel, on-site or in a decentralized command and control centre.

ACCESS CONTROL SYSTEMS

Access control systems help to protect campuses from theft and potentially violent intruders. They use various types of technologies to identify individuals, from card readers to facial identification, limiting access to authorized people only.

Access control compares ID information received by a card reader, a keypad or a camera with centrally-stored personal data, and depending on matching results grants access to a room or resource. Latest innovations also allow for the use of digital keys downloaded to a smartphone. IoT technology allows campus security to operate and manage widely distributed buildings, and even different campuses. Globally distributed users and keys can be enabled or disabled from one central location. Access control systems can exchange information with other systems, such a room booking system, and can be used for employee time tracking.

Access control systems need access control points, most typically at a door. To unlock the door, ID information has to be entered into the system, e.g. by a PIN, a card or by biometric information. The reader or sensor has to be connected to a server or a cloud-based system where applications compare ID information and manage access rights.

UNIVERSITIES USING BIOMETRIC SENSORS FOR ACCESS CONTROL

Johnson and Wales in Denver, Colorado, San Diego State University, and, most recently, the University of Central Florida in Orlando are using biometric hand readers for access control to campus buildings.

The hand readers authenticate students by the size and shape of their hands, to control access to their dorms and dorm rooms. Soon, they will also use the biometric readers to enter a 24-hour computer lab, obtain meals, check out library books, access the athletic fields and obtain bookstore charge backs. The faculty is using the system to enter academic facilities.

Biometric readers solve the problem of lost cards, which can grant strangers access to the universities facilities.

5.4 SECURITY AND FIRE SAFETY

INTRUSION DETECTION SYSTEMS

An intrusion detection system supervises doors and windows of a building and raises an alarm in case an intrusion is detected.

If a window or a door is opened, or movement is detected outside of the permitted times, an alarm is raised in the central system and security personnel are informed via alarms, lights, text message, or email.

Intrusion detection systems in buildings typically include sensors on all external doors and accessible windows, together with movement detectors to cover critical areas. In areas with high risk of earthquakes, they can also include seismic detectors to monitor for vibration and shock.

FIRE SAFETY

Fire safety solutions provide reliable fire detection, fast alarms and evacuation processes, and extinguishing solutions tailored to a particular room's requirements. Technology available today can use lights and variable sign postings to guide people to safe exits. Fire systems can be adapted to whatever may be in the building, which is particularly important in the case of libraries and laboratories.

Fire incidents not only endanger students and staff and result in financial losses, they also severely damage campus reputation. It is the goal of fire protection to save people, goods and infrastructure from the dangers and effects of fire. Advanced signal analysis fire detectors from Siemens are the first fire detectors equipped with two optical sensors, two thermal sensors, and an electrochemical carbon monoxide sensor. This means they not only detect fires with utmost reliability, but can also be used to measure hazardous carbon monoxide concentrations. Advanced fire safety systems also protect against false alarms, which are an expensive and frequent nuisance on many campuses today.

A fire safety system requires a comprehensive system of sensors, alarms and extinguishers throughout campus, and a central control to monitor them and report alarms to responders.

SECURITY MANAGEMENT

Today, university campuses usually have more than one security system installed. A powerful security management system offers a management application that combines all of them into one system comprising centralized alarm management, supervision and control to secure the safety of people and facilities.

Security management systems integrate fire safety, access control, intrusion detection and video surveillance. This allows for information exchange between systems in order to, for example, verify a fire or intrusion alarm through video surveillance. They provide step-by-step management for emergency situations, including guidance for intervention forces and reporting of incidents and activities.

Security management systems rely upon a suite of surveillance tools including smoke and fire detectors, access control, cameras, ID card readers, and systems for alarms and mass notification, all united in a central software suite that can monitor problems and alert the appropriate responders.

MASS NOTIFICATION SYSTEMS

Clear communication of e.g. a routine message about avoiding a full parking lot or a stressful emergency situation where people have to be guided out of harm's way is essential for public security. A mass notification system like Desigo Mass Notification sends one-way messages to inform students, employees and the public of an emergency. Such systems improve safety and security of single buildings or a whole campus by providing alerts and real-time instruction during a crisis.

Mass notification systems have a database of names, phone numbers, email addresses and delivery methods. Emergency notification software has a strong communications infrastructure with enough bandwidth to deliver thousands of messages. Students, professors and employees can be contacted via prerecorded phone calls, text messages, emails and social media. Mass notifications systems get activated by human action or sensing devices such as smoke or gas detectors and specialized task-specific security systems.

Mass notification systems also provide integration of building systems and emergency notification procedure protocols recommended under the NFPA 3000 standard in keeping a building and its occupants safe and secure.

Siemens can help to understand the guidelines under the **NFPA 3000™ standard for Active Shooter/Hostile Event Response Program.** We can help to evaluate specific needs around this new standard to protect a buildings or campus' occupants in order to coordinate an effective response in the event of an emergency situation.

CASE STUDY:

VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS (WIRTSCHAFTSUNIVERSITÄT WIEN), VIENNA, AUSTRIA

The Vienna University of Economics and Business (Wirtschaftsuniversität Wien) consists of six building complexes, each the work of a different international architect. The campus design is open, with public access to all the ground floors and open spaces. The centrepiece of the campus is the Library and Learning Center, designed by British architect Zaha Hadid, which features a large forum and library as well as study and reading areas that overlook the Prater. Sustainable building techniques were a major focus in the design of the new WU – as a green building, it uses energy extremely efficiently. After four years of construction, the new WU campus opened in October 2013. It can accommodate 23,000 students and a staff of 1,500, all on a net usable area of 100,000 square metres.

The relocation effort was monumental: 26,000 moving boxes, 22,000 linear metres of books, and 42,000 pieces of furniture.

Safeguarding buildings and areas amidst a daily flood of people is a challenge for any security planner. Ideally, everyone should enjoy freedom of movement in a comfortable environment and still feel safe. To meet these requirements, Siemens designed and installed an extensive video technology system across the entire campus – nearly 300 IP cameras with sophisticated software. The WinGuard SiControl security control station, with links to 14 third-party systems and approximately 27,000 data points, five operator stations and a video wall, guarantees the best possible overview and controllability of the various systems, including fire safety, access control, video technology, measuring and control technology, as well as heating, ventilation and air conditioning.

In addition, an intelligent people-counting solution was implemented using video technology. The SeeTec software adds functionality and flexibility to video surveillance while being cost-efficient. SeeTec uses a modular, network-based approach. A rigorous client/server architecture underlies the entire concept; the client modules are used solely to visualize and administer the surveillance system. Therefore, no separate program is needed to start recording image data. This project significantly increased security for students, staff and assets.

5.5 CAMPUS SPACE AND ASSET MANAGEMENT

Dissecting a university campus into its smallest elements highlights just how many technologies already exist across the site. Technologies could mean everything from building management systems of varying age and capabilities, to microscopes and computers, and to even refrigeration and cooking equipment.

Managing all of these university assets is a huge task and is often split into facilities management, department management or IT management. This means that university decision makers rarely, if ever, are able to see the different technology or equipment usage rates, age, and performance levels across the campus at one time. This makes it difficult to allocate resources and budget properly, which may results in poor allocation of funds, races to spend money before budget is lost, and under-investment in certain areas.

Digital technology is impacting working environments, which have already started to change with the use of "hot-desking" and collaborative spaces. Universities can also benefit from asset tracking and monitoring, digital room booking, and space usage optimization. Each asset in a campus facility, such as furniture, computers, technical devices or vehicles, can be equipped with a small Bluetooth tag and can be located via a web interface at any time. This makes inventory easier and helps prevent theft. Indoor positioning also makes it possible to analyze how people are using, or not using, spaces, which can inform plans to optimize space usage.

DATA PLATFORM: MINDSPHERE

MindSphere is a cloud-based, open IoT operating system that works as a Platform as a Service (PaaS) and enables a relatively new digital opportunity, Infrastructure as a Service (IaaS).

It is a platform that can retrieve data from multiple sources. The data is brought into the platform where specific applications can mine the data to create new information tailored to the initial request. For example, it allows for predictive maintenance on specific items which can directly lower repair costs and improve overall equipment effectiveness, including energy efficiency and productivity. In the university context, this could mean something as simple as highlighting the relative age of technologies across departments, identifying outlier buildings for maintenance and performance and increasing the understanding of how campus space is being used.

The platform needs to be connected to devices for data to be drawn from, an application developer which could be the OEM of specific technologies or students, and a team of campus leaders to advise on the information needs and determine the types of data to source and utilize.

MindSphere

5.5 CAMPUS SPACE AND ASSET MANAGEMENT

INDOOR POSITIONING

Indoor positioning systems allow for wayfinding and online tracking of people and assets inside of buildings. The same functions which are known from outdoor GPS systems are now also available indoors.

Indoor positioning can guide students in universities to the right auditorium or visitors to the right meeting room also over different floors via smartphone based navigation apps. It can also analyze the walking path and location of students and employees and identify which meeting rooms are frequently and seldom used. This gives highly valuable information for campus space management as it can improve the space usage ratio.

The ability to track assets and people increases the situational awareness of campus operation and security teams by having online information on the location of vehicles, devices and security staff members. Operation and maintenance services save time by having continuous overview of their inventory. Security teams can react faster and more effectively to incidents through improved staff coordination.

Indoor positioning technology allows users to use their smartphones to individually control room temperature and lighting in their immediate vicinity, find and reserve available meeting rooms nearby, and helps visitors find their way around a building more quickly. Beyond that, it is easier to protect assets against loss or theft, take inventory and locate equipment at any time which is important, for instance, to quickly find mobile equipment in a research facility.

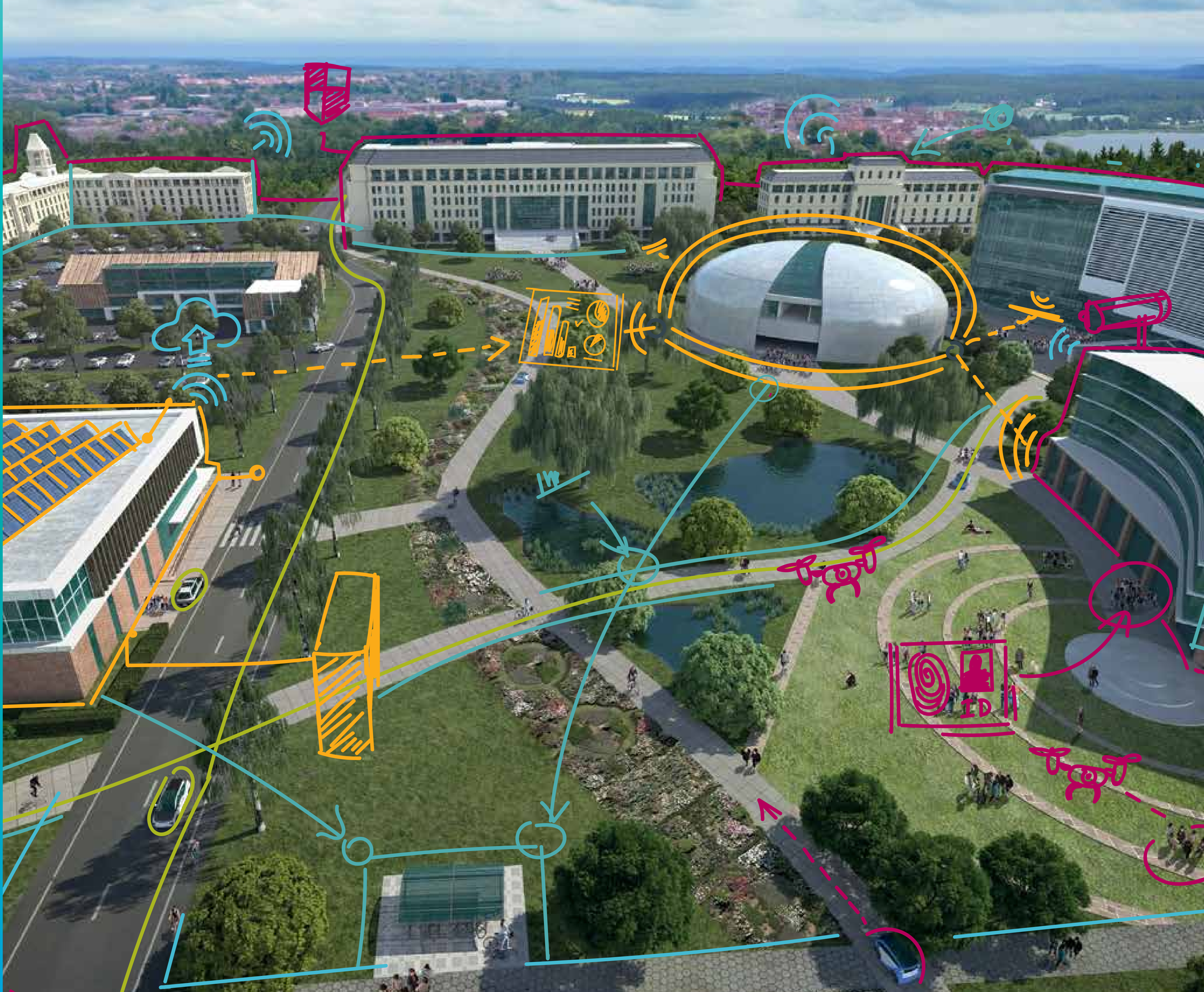
Depending on the selected technology, indoor positioning requires either battery powered Bluetooth beacons or locator nodes capable of sensing WiFi, BLE, Ultra-wideband and RFID. The localization platform can be hosted on a cloud platform, but an on-premise installation is also possible. Movable assets must be fitted with something like an RFID tag so they can be located at any time.

CASE STUDY:

AGNELLI FOUNDATION HEADQUARTERS, TURIN, ITALY

Agnelli Foundation in Italy has had its historic headquarters in Turin transformed into an advanced Internet of Things (IoT) office building, demonstrating how digitalization is transforming conventional workplaces into the smart workplaces of the future. The new office featuring 3,000 m^2 of coworking space was opened in mid-June 2017. Hundreds of sensors monitor all kinds of building data, including the location of the occupants but without identifying them. Sensors constantly check temperatures, CO_2 concentration, and availability of meeting rooms. A three-axis indoor positioning system based on smartphones and custom tags was installed. It detects and communicates the presence of occupants and positioning data, automatically triggering the appropriate response of the building's facilities. The indoor positioning system is integrated with Desigo CC, the building management system from Siemens which monitors climate, lighting, access control, CCTV and alarms and can be used to book meeting rooms. All these features can be adapted in real time depending on the number of people in different environments.

The easy-to-use system has a gaming-style interface and is available through an app for people who are in the building. The app lets occupants access the building, interact with coworkers and book meeting rooms as well as personalize their preferred environmental settings. The renovation of the Agnelli Foundation headquarters shows that the IoT approach works not only in new buildings but can also be successfully implemented in existing ones. In the early 20th century, the historic landmark was the villa of Fiat founder Giovanni Agnelli and later became the venue for design experiments by leading Italian architects, including Amedeo Albertini and Gabetti & Isola. Thanks to BT Italy, it is now a perfect place to work.


ID

6 TOMORROW

On the Campus of the Future, today's digital technologies will have scaled up and become fully integrated. Investments today lay the groundwork for future innovations and benefits, like grid-interactive buildings that synergize with automation software and artificial intelligence to optimize energy efficiency. New technologies for remote digital monitoring will predict campus usage to improve convenience and safety, while reducing costs and maintenance needs. By powering all campus buildings, transport and communications with decarbonized electricity, a Zero-Carbon Campus will become a reality.

New Technology: Blockchain

In the future, Blockchain is predicted to disrupt the business-as-usual in the energy sector. According to the World Energy Council, blockchain "has the potential to change the way we arrange, record and verify transactions, with the underlying model shifting away from a centralized structure (exchanges, trading platforms, energy companies) towards decentralized systems (end customers, energy consumers interacting directly[9])." This means creating more direct relationships between energy producers and consumers, and making it easier for small providers to participate in the energy market, on a scale that can disrupt the whole sector and remove the need for middlemen. These changes are not so far off – 87% of industry experts expect major changes in less than five years[10].

New Technology: Artificial Intelligence

As AI progresses, integrating it into many aspects of buildings, mobility, energy, and more could radically shift how we interact with those systems. A key difference will be the ability to program for priorities and goals rather than for specific actions. For example, instead of automating a building to turn off the lights at 8pm each night, an AI-enhanced building management system could turn off the lights in any empty area as people leave the building at night. It could follow a priority like "Keep people comfortable" rather than "Maintain a temperature of 20°C," or "Keep the building safe" rather than "Only open the door for authorized swipe cards." It could meet those goals based on real-time input from the building's occupants, which also feeds in to improving future operations.


92%
ENERGY PROFILE

6.1 ENERGY

In the future, technology will enable the democratization of energy. Electricity generation, distribution and retail will be delivered at the local level in peer-to-peer transactions. This future will work at a much smaller scales, and automation will be critical in its delivery. Remaining ahead of the curve means getting to know these systems now, and getting ready for better storage devices, widespread take-up of electric vehicles, and full building automation. These technologies will allow for the most efficient and profitable use of existing electricity, making the most of current generation before adding more capacity.

Key features of future energy systems will be mitigating the peaks and troughs in consumption, balancing demand on the traditional grid, storing energy, and selling or using stored energy profitably. Blockchain is building our trust in these technologies, creating new forms of transactions that will disrupt the future utilities market.

ENERGY PROFILING

All staff and students will access real-time statistics about their personal energy usage.

This will raise awareness about resource management and enable personal decisions to reduce consumption, decreasing the campus' overall carbon footprint.

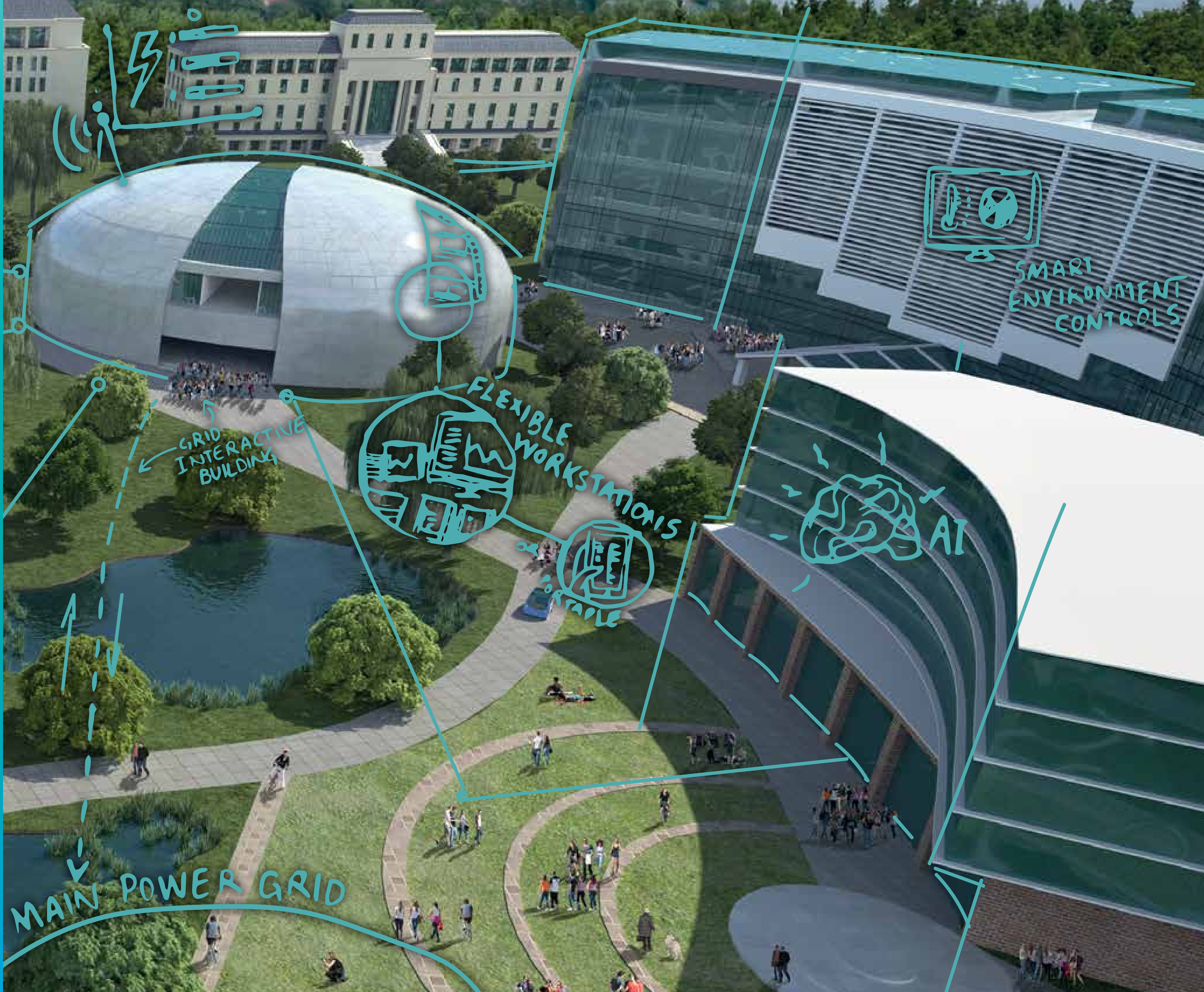
Energy profiling will require monitoring of all points of energy consumption on campus, and a commitment to open-access data.

LOW-CARBON HEAT

Heat will be decarbonized using a mix of renewable electricity, thermal storage, ground-source heat, and efficient management of building climates.

This will minimize the environmental impacts of heating campus buildings, and lower utility bills.

Infrastructure investments may be required to incorporate those technologies into the existing heat system, but can work alongside traditional components.


SMART ENVIRONMENT CONTROLS
FLEXIBLE WORKSTATIONS
GRID INTERACTIVE BUILDING
AI
MAIN POWER GRID

6.2 BUILDINGS

In the future, technology will enable the democratization of energy. Electricity generation, distribution and retail will be delivered at the local level in peer-to-peer transactions. This future will work at a much smaller scales, and automation will be critical in its delivery. Remaining ahead of the curve means getting to know these systems now, and getting ready for better storage devices, widespread take-up of electric vehicles, and full building automation. These technologies will allow for the most efficient and profitable use of existing electricity, making the most of current generation before adding more capacity.

Key features of future energy systems will be mitigating the peaks and troughs in consumption, balancing demand on the traditional grid, storing energy, and selling or using stored energy profitably. Blockchain is building our trust in these technologies, creating new forms of transactions that will disrupt the future utilities market.

FUTURE-PROOF BUILDINGS

Today, new commercial buildings have a planned lifecycle of up to 50 years. However, many buildings have to adapt to frequent changes of use. This means that planning a building does not only have to consider the requirements of the present, but also the technical demands of the future. This means enabling short-term use changes, as well as accommodating technologies which don't yet exist.

Usage of almost all buildings starts changing from the first day they are occupied. Changes of usage are mostly caused by changes in the building user's business model or their organizational structure. Universities have to be flexible to cope with fast changing educational models and student demographics, and buildings can help them support that dynamism.

To facilitate a quick adaptation of mechanical infrastructure to these changes, the building has to be carefully planned and prepared for it. Mechanical infrastructure includes all cabling for power and communication, all piping and ducting for the distribution of fresh air, heating and cooling, and also the building construction itself. Changes to mechanical infrastructure are cost-intensive and, as they are linked to construction works, they can also disrupt normal usage.

Generally, the mechanical infrastructure has to be flexible enough to allow for all kinds of conversion of building sections and rooms and for all kinds of new technologies. Pipes, ducts, cable trays and raisers have to be planned not only for the immediate usage, but must also be sufficient to support future usage scenarios and technical requirements. This will also have an effect on the total life cycle length of a building. Planned for enhanced flexibility of technology and infrastructure, buildings could have a total lifespan of 70-80 years, compared to 50 years today.

GRID-INTERACTIVE BUILDINGS

Grid-interactive buildings will play a key role in future energy systems. They consume, generate, and store energy, reduce their own energy consumption, and communicate with the power grid. They will react to price signals from the utility and include electric vehicles into their energy strategy.

Grid-interactive buildings make use of energy storage systems. In the future, they will not only charge their storage systems with surplus energy from their own generation, they will also react to price signals from the utility and charge their storage systems at cheap tariff times from the grid. This concept will also include battery storage in electric vehicles connected to the on-site charging system. At peak demand or high tariff times, their batteries can be used to cover the electrical demand of the building, and then they will be recharged before a pick-up time agreed with the owner. By using the cheapest energy tariffs, buildings will minimize their operational costs.

Grid-interactive buildings need a Building Management System with all sub-systems fully integrated, energy storage systems, and communication to the utility. This will allow it to receive pricing signals, and create and share its own energy forecast. All electric vehicle charging stations have to be integrated into the energy network, to maximize use of on-site storage capacities.

6.2 BUILDINGS

PERFORMANCE MONITORING AND DATA AS A SERVICE

In the future, Performance Monitoring will analyze offline and online building consumption data as it does today. In addition, it will also analyze performance of building heating, ventilation and air-conditioning processes in real-time. It will have a direct connection to the BMS which in the future can also be a cloud service, enabling it to autonomously adapt process settings to optimize comfort and energy efficiency.

This Performance Monitoring can be part of a Data as a Service package. In this new business model, universities can contract a business to aggregate their data in the cloud, analyze it for trends and areas of potential optimization, and feed back data-driven building management commands that an on-site staff person can review and approve those decisions for consistency and alignment with the campus goals. It is critical that control be split between the cloud and the physical campus, so that building operations can continue if connection to the cloud is lost.

In addition to analyzing data and reporting energy use, it will interpret current and long-term building process conditions using AI. Using direct integration with the BMS, it will autonomously make adaptations to the BMS configuration and settings in order to achieve maximum comfort for the users, as well as the best energy efficiency to minimize operational costs.

In the future, BMS functionality will move into the cloud and on to IoT platforms. BMS logic will at least partly stay in the building, so that it can still control itself in case of network issues or natural disasters.

Performance monitoring needs full integration with the BMS on an IoT platform, and an AI engine to interpret building current and long-term processes. It will require sensors, meters and data collection and transfer mechanisms on all campus infrastructure and spaces, with thoughtful indicators and goals. The higher the number of meters and sensors, the higher process and consumption transparency, so the higher the improvement potential. Web-based analysis applications allow for access of wide or globally spread facilities and sites.

SMART ENVIRONMENTAL CONTROLS

Location-based services will allow building users to define their own individual comfort profiles that travel with them to any location in the building as their personal comfort bubble. Services and environmental controls will also adjust to the current or shortly-anticipated number of occupants, and local weather conditions.

New developments in building management, lighting, air conditioning, monitoring, security, system apps, information screens, WiFi, and automated elevators will mean that services are adjusted before the student or staff even steps out of the elevator.

Location-based services use Bluetooth Low Energy (BLE) beacons or WiFi technology to determine the indoor location of an individual or an asset. BLE beacons or WiFi antennas have to be distributed throughout the building. The higher the density of beacons and antennas, the higher the accuracy of the location determination.

6.2 BUILDINGS

FLEXIBLE, CUSTOMIZED WORKSTATIONS

Building management systems will use digital appointment calendars to arrange users' workstations in line with their preferences before they arrive and save energy when a user is not present. Buildings will increasingly have the ability respond to voice commands, and accommodate the wishes of their occupants, possibly in form of personal digital assistants.

This will allow for workstations that are both flexible and temporary, as well as customized and pre-set, allowing campuses to maximize the use of workspace while providing the optimal conditions for individual productivity.

This solution entails a building management system with interfaces and access to digital appointment calendars. It will also use access control systems to identify when a workstation is booked, and to know when a user has entered the building so that it can adjust climate and lighting to their preferences.

INTERACTIVE BUILDING COMMUNICATIONS

Users will communicate with digital buildings using voice commands, gestures and smart devices.

This will allow buildings to be programmed quickly and by people without technical training, saving time for facilities staff. It will also allow people to adjust lighting and temperature settings and control shading systems.

Building and home automation systems will use cameras and microphones for user communication via voice commands and gestures. This can run through a smartphone app that utilizes cameras and microphones to receive user communications.


NO NEED?
AUTONOMOUS VEHICLE

6.3 MOBILITY

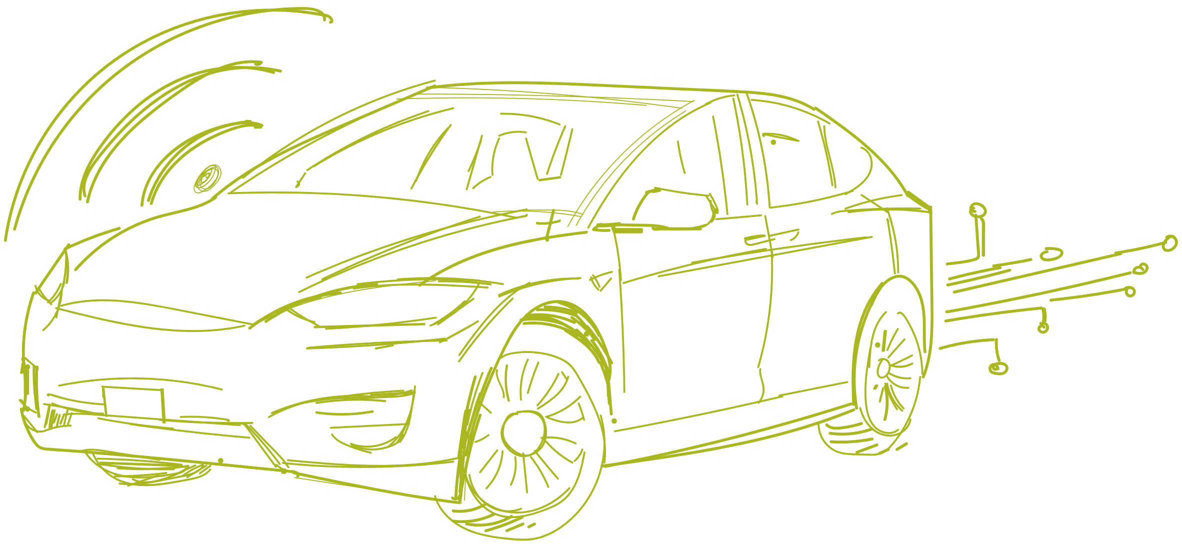
With the mainstreaming of automated, driverless vehicles, students and staff can enjoy safe, efficient rides at any time. This same technology will integrate seamlessly into campus logistics and delivery processes. Electrification of all campus mobility options will improve both local air pollution and global greenhouse gas levels.

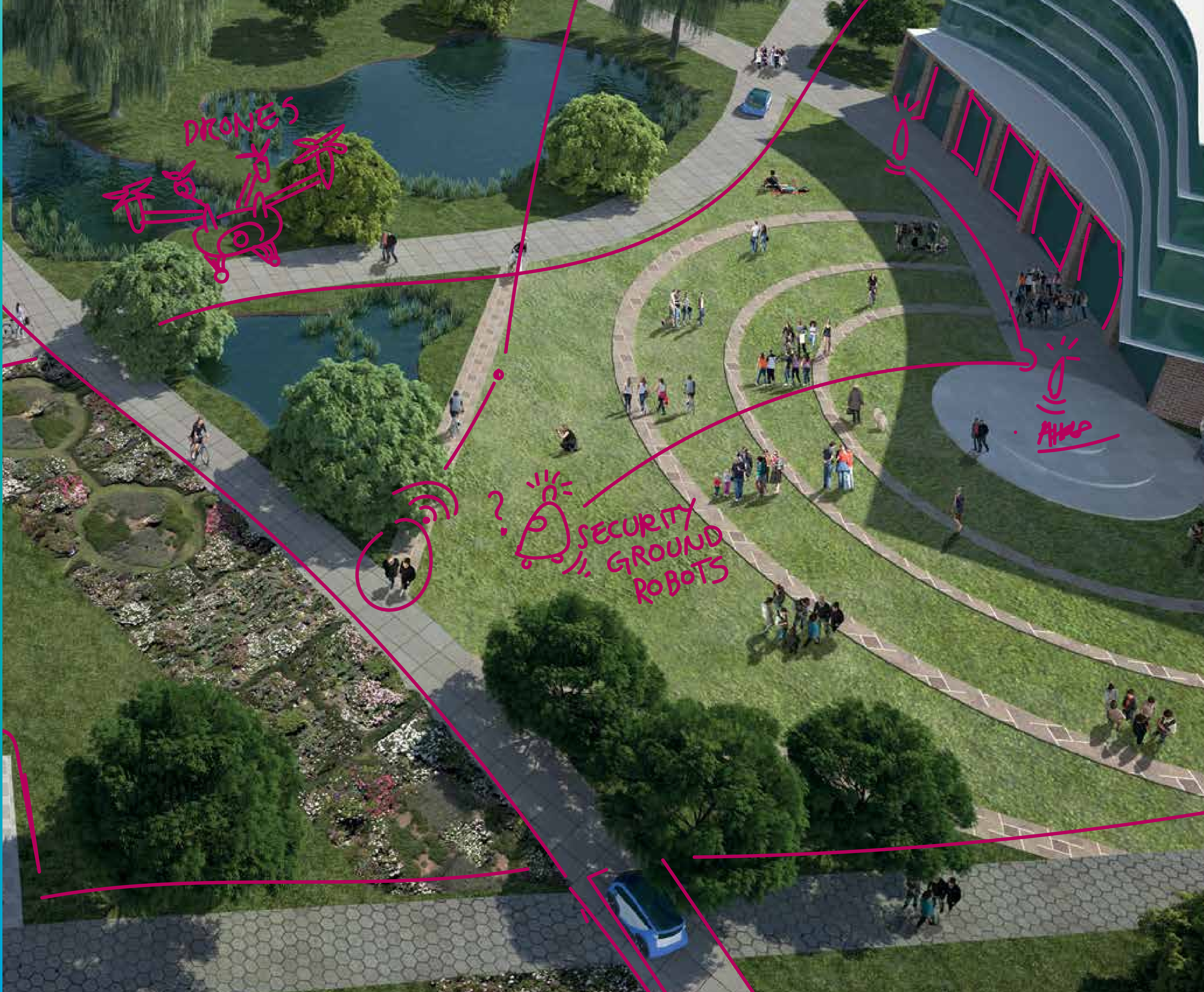
AUTONOMOUS VEHICLES

Autonomous vehicles will drive themselves around campus, saving on labour costs and improving road safety. Today, people generally assume that AVs will be electric, shared and connected. This combination of elements will make them more sustainable and have less of a negative impact in our cities and across campuses, as they may otherwise incentivize more driving. It will be up to campus heads to ensure that AVs do not lead to simply more congestion and that they are indeed electric, shared and connected.

Autonomous vehicles will not require a driver, which will save on labour costs, and could be used for any campus vehicle. The campus decision-makers will have to determine when and how they should be used, and when is it necessary to keep a human driver. They will provide on-demand transport around campus, and simplify logistics and deliveries with precisely-timed, convenient trips.

They may need to interact with sensors on buildings or street equipment, and hubs to recharge or await tasks. AVs will need to interact with other cars around them, traffic signals, people and other possible hazards. Cars will need to be equipped with not only driving software, but also a host of communications points to enable interaction with the roads and other vehicles. If the AVs are indeed electric, then chargers will be required.




DRONES
SECURITY GROUND ROBOTS

6.4 SECURITY AND FIRE SAFETY

Recent high-profile fires and storm disasters have demonstrated that these issues are still very present in our modern lives. In some cases, the slow reactions by officials have also demonstrated just how much we all take fire security and general safety systems for granted. Growing concerns about urban resilience, climate change and terrorism means that these systems are only becoming more important. Digitalization can make these systems more responsive and widespread.

Future campus security and fire systems may include security drones and robots, new facial recognition technologies, biometrics, CCTV cameras, and wearable technologies that can monitor safety and health. Implementing these technologies will require balancing our needs for privacy and security.

These technologies will allow us to make best use of human resources by outsourcing certain tasks to machines. Security robots and drones will be able to identify possible intrusion or persons in need and call emergency services, but a human will still be required. These technologies can be used for time consuming, repetitive tasks that don't require a person, where computers can have higher accuracy than a worn-out security person. This will make the staff available to react and use physical force if needed.

Digitalization will allow us to secure more spaces and specific technologies, and monitor them cheaply. Restricted areas can be more strongly protected with requirements for facial recognition or biometric finger printing.

DRONES

A drone is a flying robot. Drones (or unmanned aerial vehicles, UAVs) are small, unmanned aircrafts that can carry parcels or be equipped with imaging equipment. They can be piloted by human remote control or autonomously.

Drones can be used for a variety of things. Most interesting for campuses are security and logistics purposes. On campuses, drone deliveries could free up road space by transporting goods through the air and enhance campus security with aerial surveillance. Drones are not tied to one place and can thus monitor previously inaccessible or even larger areas than fixed cameras or react to spontaneous events. Drones can also support the campus maintenance team by inspecting roofs or other high places.

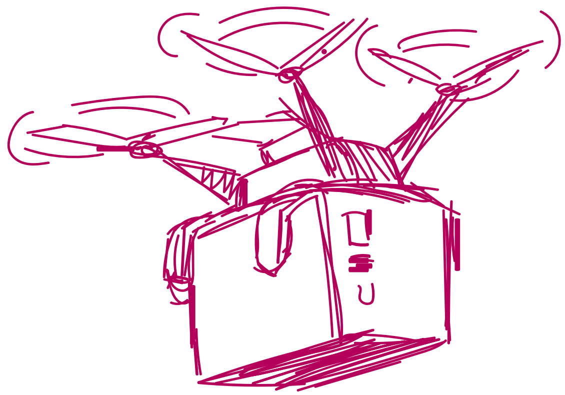
They will need places to recharge their electric batteries and await incoming tasks, and the campus will have to manage their airspace to avoid collisions or nuisances.

SECURITY GROUND ROBOTS

Security ground robots are vehicles that can carry things or people or be equipped with imaging equipment. For example, they could be autonomous driving cars with cameras for surveillance purposes, or robots to deactivate explosive devices.

Security drones, autonomous vehicles, or robots can provide video images from non-supervised areas or from current incidents. They can provide visual evidence of intrusion or fire alarms and increase the safety of security staff.

Security drones or vehicles are part of an integrated site security system including access control, intrusion detection and fire safety systems.



6.4 SECURITY AND FIRE SAFETY

SMART GLASSES

Smart glasses have a display, audio output, camera, microphone, GPS, internet access, Bluetooth connectivity. They can also download and run apps. Smart glasses in combination with facial recognition technologies can be used by security personnel to quickly identify individuals.

Smart glasses work similarly to other smart devices. However, since they are not hand-held, the users' hands stay free for other tasks. As the display is right in front of the eye, the user doesn't have to look down and can stay focused on the current action, traffic, or security incident.

Smart glasses need network connectivity and, if used for security purposes, access to Danger Management systems operated in a Command & Control Center.

WEARABLES

Wearables like cameras and smart watches transmit health conditions and video footage of a security guard to a Command & Control Center to increase personal security and to create video evidence of emergencies and incidents.

Sensors capture health data, e.g. heart rate, blood pressure, steps made, speed, etc, and combine this with video footage from body cameras in a transmission to a Command & Control Center. Video displayed on the front of the camera towards involved persons helps to deescalate the conflict situation as soon as they see themselves on the display.

Wearables need network connectivity and access to Danger Management systems operated in a Command & Control Center.

BIOMETRIC VERIFICATION

Biometrics like fingerprint or facial recognition identify individuals quickly and reliably via personal biological characteristics. Fingerprint sensors identify individuals by a scan of their fingerprint, and facial recognition identifies individuals from a video image. At site perimeters or building entrances, these systems increase security check speed and prevent queues. A main benefit of biometric verification is convenience, as there are no passwords to remember or access passes to carry.

It compares facial characteristics or fingerprints with a face or fingerprint database. Facial recognition combined with location based services improve effectiveness of access control systems by granting site or room access only to authorized persons, or by opening doors only for authorized smartphones.

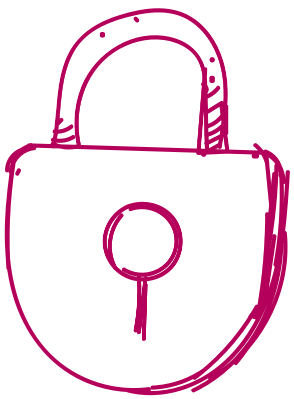
Biometric verification needs fingerprint scanners and cameras to scan human characteristics. IT also requires software to convert the scanned biometric data into a standardized format and to compare match points of the observed data with stored data for identification.

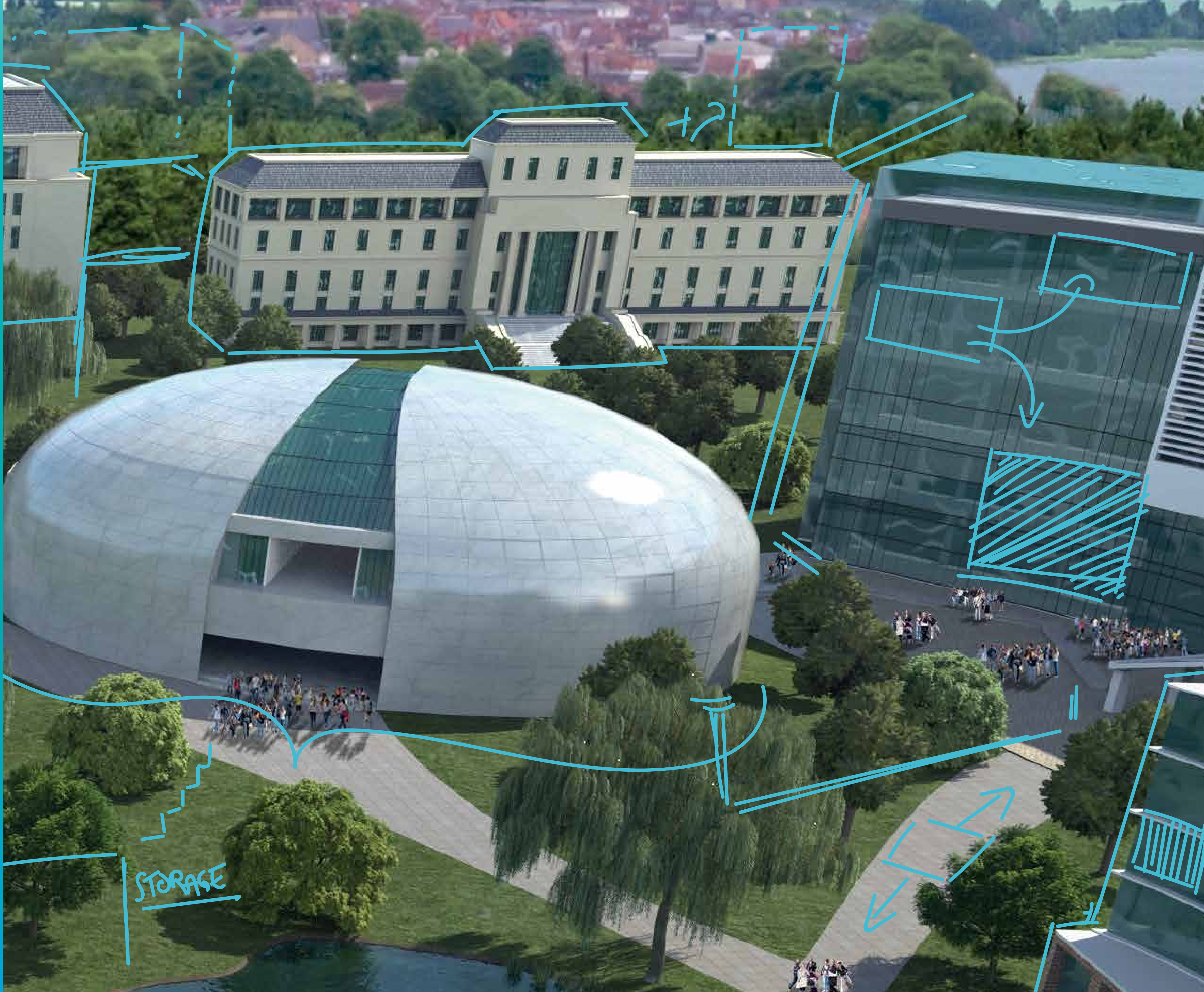
CCTV SYSTEMS

CCTV (closed-circuit television) systems use fixed cameras to transmit a video signal to a specific place, on a limited set of monitors. These are commonly used today to create video evidence. The key issue in the future will be how to use this real-time information to stop crime from actually happening, or to zero in on the perpetrator before they are able to escape. There is a possible role here for AI to identify what a crime looks like, then alert authorities and zoom in on the attacker.

They are most often used for crime deterrence, or to identify perpetrators. In combination with facial recognition, they could allow for tracking of individuals. Semantic video analysis will enable identification of individuals based on verbal criteria describing the sought-after person. There is also significant non-security related benefits that campuses could use, such as making real-time lip-reading possible for deaf students in large lecture halls.

It requires cameras with links to the monitoring room on campus. They can be installed in a variety of different locations or surfaces, such as the outdoor of buildings or the ceilings of high-traffic rooms.



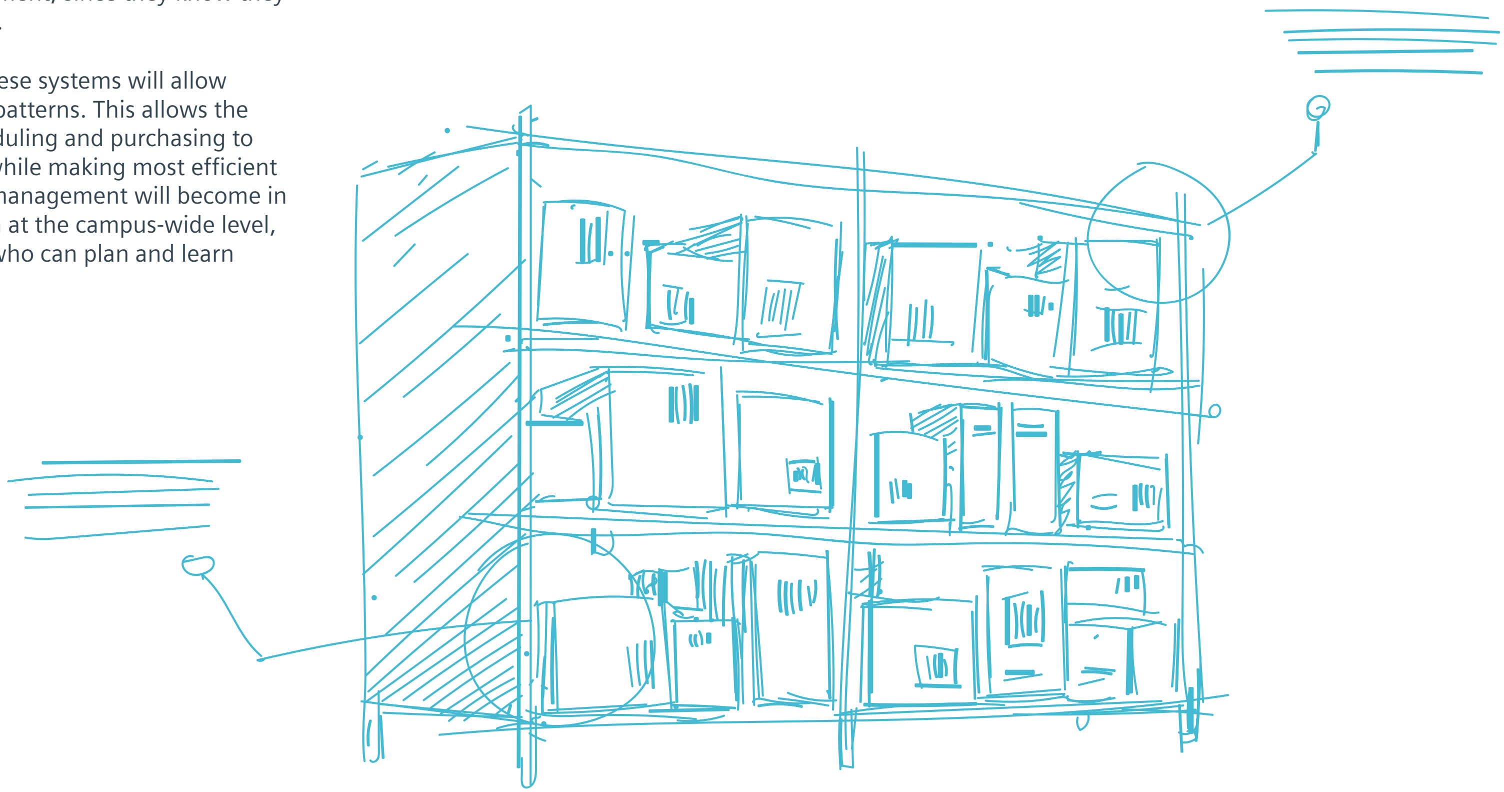

STORAGE

6.5 CAMPUS SPACE AND ASSET MANAGEMENT

In the future, management of campus assets and space will be centred around digital monitoring and management. Rooms can be remotely monitored to ensure safety and avoid conflict or under-use, while all campus assets and equipment can be digitally tracked to prevent loss or theft. This can lower costs of duplicate purchases, by making it easier for labs or departments to share equipment, since they know they can always reserve or find it.

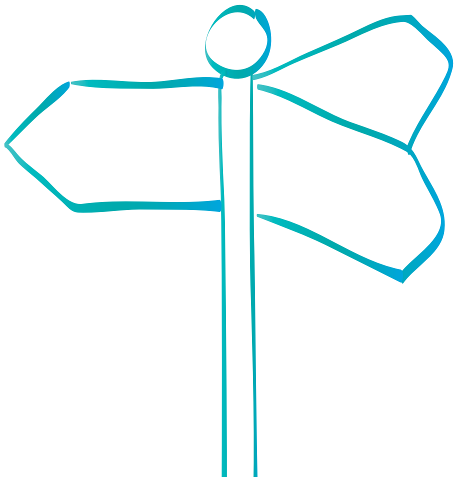
All the data generated by these systems will allow for in-depth analysis of use patterns. This allows the campus to adjust their scheduling and purchasing to best meet students' needs while making most efficient use of current assets. Data management will become in indispensable service – both at the campus-wide level, and to the individual users who can plan and learn about their consumption.

This digitalization of the campus will have an add-on benefit of supporting marketing efforts. It will be possible to give in-depth, highly realistic, interactive virtual tours of the campus to people in all corners of the world, which can boost recruitment of new students and enhance the university's overall reputation.



7 SMART CAMPUS ROADMAP

The smart systems described here unlock new opportunities to grow and leverage the sharing economy on campuses. Universities are already at the forefront of blurring the boundaries between workspace and homes, but a smart campus can take this a step further. Digital room booking allows the same room to be used for classes by day, student society meetings in the afternoon, and entertainment or studying in the evenings. This uses space more efficiently and saves costs, while providing room to meet everyone's needs. Meanwhile, for a campus to truly thrive, these technological solutions must be integrated with liveable design at a human scale, alongside ecological systems and green space that support benefits like clean air and stormwater management. The basis for all this is the digital twin of the building created by building information modeling or BIM. With BIM, a building is built twice – first virtually and then physically. The physical construction process begins only after the virtual building meets all expectations and specifications, saving time and costs while improving quality. BIM allows optimization of the design based on a simulation of the future use, identifies planning errors by collision detection methods and allows the calculation of the expected energy consumption. The digital twin can be used beyond the planning and construction phase and therefore also has a measurable positive effect on the long-term and cost-intensive operation phase.



TOP 10 LONG-TERM GOALS TO BENEFIT CAMPUS USERS

The top 10 long-term goals for the built environment provide huge benefits to campus users. Among the possibilities are:

1. Digital twins for all new buildings
2. Net zero energy for all new buildings
3. Comprehensive smart building technology
4. Highest performance automated control systems, from HVAC to door security
5. Multi-functional and future-proof design to ease flexibility
6. Technical cooperation and interaction between entire building blocks
7. Intensified integration of private buildings with public utilities and transportation
8. Improved relationships between buildings and their environment
9. Healthier work-live-learn spaces
10. Optimized work productivity

THE FUTURE OF LEARNING

Above all, however, is the university's core mission to educate future leaders. By integrating technology into students' educational experiences, universities will create the highest quality learning environment and prepare their graduates for the rapidly changing job market and world. Digital technologies on campus don't only benefit the behind-the-scenes operations and efficiency. They also have direct benefits for the educational experience of students on campus. Campuses with distributed energy systems and digitalization bring cutting-edge technologies directly to the students. By directly, consistently interacting with and learning from these advanced systems, students will gain hands-on experience in the generation, distribution and use of energy that will bring their coursework to life and boost their employability. For maximum training benefits, systems should be incorporated into relevant curricula, set up to allow tours and study projects, and come with informative signage around campus. Technology will be a major part of our future world, so having students engage with it in a real way, at the earliest points possible, will be critically important in developing cutting-edge skills.

Digital integration also means that advanced remote communications will expand the university's global reach and number of potential students and lecturers. With these technologies, remote students can participate fully in learning opportunities, and that the pool of lecturers is no longer limited to nearby academics. Advanced technology in file-sharing, communications and conferencing will allow students and staff to engage fully from anywhere in the world. Smart screens will have flexible, touch-sensitive displays and customizable tiled sizing, and will be ubiquitous throughout campus, filling entire walls.

REFERENCES

[1] Arup Foresight, 2018. "Campus of the Future" http://www.driversofchange.com/projects/campus-of-the-future-2018/

[2] "The MindSphere Innovation Network." Siemens, www.siemens.com/uk/en/home/company/topic-areas/digitalization/the-mindsphere-innovation-network.html.

[3] "The University of Sheffield Is a Siemens Principal Partner." SCR, sheffieldcityregion.org.uk/investors/university-sheffield-siemens-principal-partner/.

[4, 5] University of Sheffield. "Digital Innovation: MindSphere Lounge." Research into the Safe Disposal of Nuclear Waste Receives £1.5 Million Boost - News - Engineering at Sheffield - Faculties - The University of Sheffield, 12 Jan. 2018, www.sheffield.ac.uk/news/nr/mindsphere-lounge-siemens-university-sheffield-1.731694.

[6, 7] https://www.ceu.edu/article/2016-09-15/central-european-university-opens-two-state-art-buildings-downtown-budapest

[8] https://techcrunch.com/2016/07/27/ford-and-mit-project-provides-on-demand-electric-shuttles-for-students/

[9, 10] https://www.worldenergy.org/wp-content/uploads/2017/11/Blockchain_full-paper_FINAL.pdf

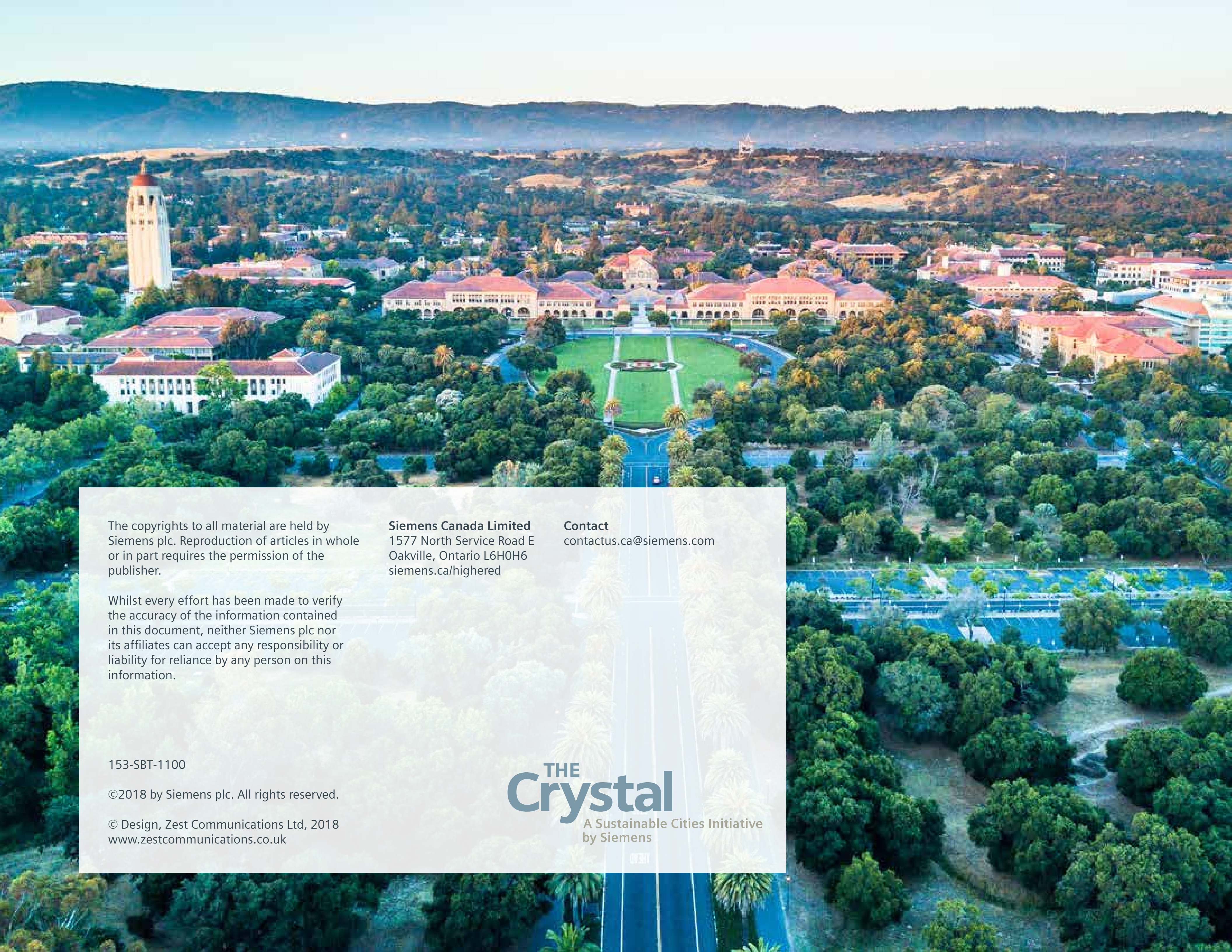
Siemens Global Cities Centre of Competence

Siemens Global Cities Centre of Competence brings together city experts from across the world with specialist knowledge in city governance, city management and infrastructure planning. These experts work with cities to help demonstrate the role of infrastructure and technology in dealing with many of the most challenging impacts facing cities as a result of urbanization, climate change and demographic change. Digitalization will be a major factor in overcoming many of these urban stresses and this book aims to illustrate the capability of Siemens infrastructure solutions in tackling these challenges. Digital urban infrastructure is the foundation in the development of Smart Cities.

The Crystal

The Crystal, located in London's Royal Docks, is home to Siemens Global Cities Centre of Competence and is the world's largest exhibition on urban sustainability. The Crystal is also one of the world's most sustainable buildings having achieved both BREEAM Outstanding and LEED Platinum, the two highest certifications in sustainable building design.

THE Crystal
A Sustainable Cities Initiative
by Siemens



Siemens Canada Limited
1577 North Service Road E
Oakville, Ontario L6H0H6
siemens.ca/highered

Contact
contactus.ca@siemens.com

153-SBT-1100

THE Crystal
A Sustainable Cities Initiative by Siemens