UK GREEN BUILDING COUNCIL

REIMAGINING BUILDINGS

A ZERO ENERGY BUILDING IN 2050: WORSHOP SUMMARY

The Edge, Amsterdam © OVG Real Estate

Contents

Introduction

This report puts forward a set of innovative ideas to design and operate **zero energy buildings** for 2050.

The purpose of this report is to inspire and challenge the built environment industry to acknowledge the current 'signals of change'; look forward to 2050 and build capacity for zero energy buildings.

Current **signals of change** estimate the global population exceeding 9 billion, with 75% of people living in cities, by 2050. Future generations will have expectations for a connected, adaptable and efficient built environment where all industry roles are entwined and professionals engage in sustainable design practices[1]. People and businesses will also seek solutions for rising energy prices and efficient methods to cut carbon emissions. Consequently, there will be a need for innovative solutions designed to tackle the increasing energy demand, and deliver zero energy buildings.

Within this report a number of **innovative ideas** will be identified for the built environment industry to deliver zero energy buildings. The ideas have stemmed from industry professionals coming together in a 'futures workshop' facilitated by UK-GBC. They relate to the experience, design and operation of a building, all of which could be enablers to reach zero energy by 2050.

As the sponsor for this 'futures workshop', Heathrow Airport will use its own terminal buildings as case studies, and explore innovations in energy reduction that could be considered in the design of new airport buildings. The ideas will expand on the energy efficiency measures designed into Terminal 2, which is Heathrow's latest and most efficient BREEAM-certified terminal building.

The innovative ideas within this report draw on the knowledge of cross-industry experts to inspire the industry to set challenging long term strategies and strive to design zero energy buildings for 2050.

SIGNALS OF CHANGE

Signals of change are significant trends that suggest challenges to be overcome or new ways of thinking in order to shape a sustainable future. They can range from advances in technology, changing social movements or unique behaviours to move towards a more sustainable world.

WHAT IS A ZERO ENERGY BUILDING?

An energy-efficient building where, on a source energy basis, the annual delivered energy is less than or equal to the on-site renewable exported energy[2].

[2]A Common Definition for Zero Energy Buildings, U.S Department of Energy (September 2015)

Background

Background to reimagining buildings: Heathrow Airport

Heathrow Airport is an international gateway and the UK's only Hub airport (ie. an airport is where passengers transfer between flights to support larger airlines and global networks). Without these transfer passengers, the UK would not be able to support direct long haul connections around the world[3].

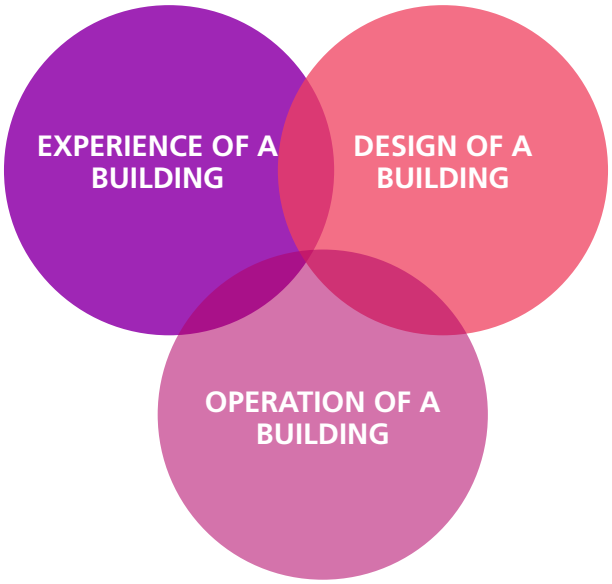
Heathrow has two runways, 80 airlines, four terminals and 75 million people arriving and departing every year. The airport is looking at how radical innovative design could make a zero energy terminal building more of a reality.

Heathrow have committed to reduce carbon emissions from buildings and other fixed infrastructure by 34% by 2020, against 1990 levels[4].This is being delivered by improving energy efficiency and investing in on-site energy generation. Over 70GWh of electricity has already been saved by energy efficiency improvements and Heathrow operates a biomass combined heat and power plant.

Heathrow approached the UK Green Building Council (UK-GBC) to generate new ideas and solutions that could reduce the energy demand of future terminal buildings. A workshop was held with UK-GBC members to use cross-industry knowledge and generate a range of innovative ideas for a 2050 building. The aim of the workshop was to brainstorm the design concepts and features a future terminal could include, and how the building could be used differently to reduce energy. The innovative ideas could also be applied for any large public building. Case studies of airport terminal buildings are used to illustrate inspirational ideas to radically reduce energy and contribute to an overall zero energy building.

Innovation in reimagining buildings

The workshop successfully generated a number of innovative ideas relating to changes in smart buildings, design and function. In order to apply these to all building types, they have been categorised under three themes relating to the overall building performance.



The three themes are inter-connected and influence each other in order to create a zero energy building.

Throughout the report, the signals of change already experienced in buildings will be explored. The ideas generated are in response to the signals of change and the report will describe how they contribute to a zero energy building.

EXPERIENCE OF A BUILDING

Elements of the building that can generate an experience for the user (e.g. people, lighting, temperature)


The Edge, Amsterdam © OVG Real Estate

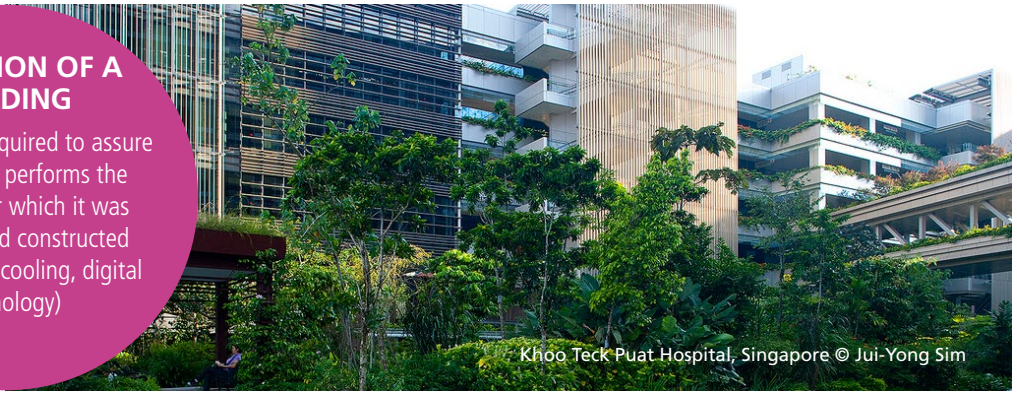
DESIGN OF A BUILDING

The architectural, engineering and technical aspects influencing the design of a building (e.g. shape, layout, technology)


SANAA factory building © Julian Lanoo, Vitra

OPERATION OF A BUILDING

The services required to assure the building performs the functions for which it was designed and constructed (e.g. heating, cooling, digital technology)


Khoo Teck Puat Hospital, Singapore © Jui-Yong Sim

Experience of a building

SIGNALS OF CHANGE

- GROWING DIGITISATION
- INTERNET OF THINGS
- MOBILE WORKING
- SMART INFRASTRUCTURE
- INTELLIGENT BUILDINGS

Signals of change

The relationship between people and buildings is likely to be quite different by 2050. The future generation of building users will adapt to the current signals of change to become more digitised and mobile. The new demands will require an evolution to more intelligent building performance to satisfy the building users. Buildings will therefore need to be both beneficial to the environment and the people within it. The movement towards digitisation and intelligent buildings will drive the experience of a building to become more versatile and efficient for 2050.

Thanks to the 'Internet of Things',a new wave of creativity is radically changing the use of electronics, appliances and retail sectors. The growth in connectivity has the potential to add an estimated one half of the global economy, to global GDP by 2025. The industry is facing better connected buildings, infrastructure and cities that have become more resource and energy efficient, by adapting to the growth in technology and connectivity[5].

For example, the NEST thermostat allows homeowners to create a personalised schedule for heating their homes, using a smartphone or tablet. Smart technology effectively becomes an all-in-one controller and monitoring system for goods and devices[6]. This demonstrates how smart technology will be integrated into future buildings.

CASE STUDY: THE EDGE, AMSTERDAM

The Edge, Amsterdam © OVG Real Estate

The Edge in Amsterdam is one of the most sustainable and smartest buildings in the world. The Edge demonstrates that current buildings are responding to the signals of change in digitisation and intelligent buildings, leading the way for the rest of the built environment.

The rise and integration of digital technology has enabled the building to be connected, via a smartphone app, to the building users and their schedules. This rise in digitisation has driven a new way of working and consequently shaped the environment in which they will work.

The building has achieved the highest BREEAM score ever awarded, 98.4%, and rates as the greenest building in the world. Contributing to the buildings 'green' status are the 28,000 sensors that the Edge can use to track motion, light, temperature and humidity to make the building more comfortable for the users and reduce energy consumption. The southern facing wall and roof of the building is coated with solar PV panels, enabling the Edge to use 70% less electricity than a typical office building6.

Even by 2016, the Edge has radically transformed the user experience by creating a "building that is sensitive to its surroundings and created a technologically productive and happy working environment" (Deloitte Netherlands CEO; Peter Bommel)[7].

Innovative ideas for 2050

EXPERIENCE OF A BUILDING FOR 2050

- DIVERSE BUILDING PURPOSE
- SMART BUILDING PERFORMANCE
- INCREASED SENSOR INTEGRATION

Diverse building purpose

By 2050, the design of buildings and their purpose will need to match the signals of change as the change of building user evolves. The change in use can be described as a building being used for different purposes by a wider range of people.

The standard use of a building, such as an airport terminal or retail centre, will shift to encompass more than one service. For example, in buildings that are hubs where people congregate, virtual meeting environments may be included for users to meet and network. The users may range from any profession and any global location.

The growing variety and increase in users will help contribute to a zero energy building by improving the use of space, therefore resulting in less wasted energy. The education of building users is also important in reducing the energy demand within the building. By improving the knowledge of how to use the building efficiently and how they can contribute to reducing the buildings demand, the overall energy usage will decrease.

An example of this for airports could be to provide greater retail provision in general public access areas, open to all shoppers, including those not boarding a plane. The area would therefore be in greater demand with a wider network of consumers and not solely relying on departing passengers. Furthermore, innovation in renewable energy and kinetic energy could be implemented to generate energy from the movement of people within the building.

Smart building performance

The change in demand can be described as the change of building performance in order to meet the needs and demands of a building user. A signal of change, that is influencing the demand of building users, is the growth of intelligent buildings that are technologically advanced with interconnected systems.

Smart buildings will have the ability to "read" user demands such as temperature variations, available working spaces and more efficient parking. Integrating advanced technology, such as self-sufficient renewable energy, smart technology and advanced heating and cooling methods, to meet these demands will contribute to a zero energy building.

The change in demand is already being met in the Edge building, but for 2050, all building types (such as offices, healthcare, homes) will need to implement these methods and integrate them as standard.

Increased sensor integration

By 2050, the integration of sensor technology will be seen as standard in many buildings, as infrastructure becomes smarter and more efficient. Currently, systems such as CCTV, air quality and fire detection sensors are all on separate energy sources that could be integrated. By integrating the sensors into one larger system, it should use less energy and increasing the buildings' efficiency.

Smart systems that work with sensor integration could enable data sharing to serve the building more efficiently8. Increasingly intelligent buildings can become more resource efficient and a better place to work, whilst reducing energy costs. In the USA, it is estimated that nearly $25bn of energy costs could be saved by the greater use of intelligent technologies in buildings[8].

THE EXPERIENCE OF AN AIRPORT IN 2050

Heathrow Airport could draw on the innovation relating to the experience of an airport, in order to achieve a zero energy terminal building:

- Minimising the distance from the terminal entrance to boarding the plane to use the space more efficiently and shorten the passenger journey, therefore improving their experience.
- Providing services rather than goods (e.g. shifting from retail space to health and wellbeing services).
- Radicalising the future of retail in terminal buildings, that may move to an online experience with items collected at the destination.

Design of a building

SIGNALS OF CHANGE

- ADAPTABLE SPACE
- SUSTAINABLE MATERIALS
- ENERGY EFFICIENCY
- GREEN INFRASTRUCTURE

Signals of change

To become zero energy, the design of buildings for 2050 will have to adapt to the growing need for adaptable space, sustainable materials, improved energy efficiency and green infrastructure. These signals of change are also highlighting the need for the design of buildings to incorporate more efficient daylight and temperature controls, in order to provide a more comfortable environment.

Passivhaus design incorporates standards to address these signals of change. The minimal energy used for space heating and cooling resulting in high levels of thermal comfort are met through this method of design. The planning and design stages of building will be influenced by the signals of change to provide more efficient and sustainable buildings9.This form of design is driven by the shifting demand for more efficient and controlled space from building users.

Future buildings will also incorporate materials made from recycled and renewable elements that could include self-repairing mechanisms or purify the surroundingg air[10]. By incorporating solutions into the design stage to meet the signals of change, a zero energy building can be achieved.

CASE STUDY: VITRA CIRCULAR FACTORY

SANAA factory building © Julian Lanoo, Vitra

In 2013, Vitra, the German furniture manufacturer, revealed a 60,000ft² circular factory that is used as its latest shipping centre. The circular layout of the building allows greater efficiency in the delivery and logistics of goods to various locations. As a result, this reduces the traffic flow and simplifies the processes internally. The shape and layout of the building allows for an adaptable assembly zone in the middle section, which can be shaped to meet future requirements and needs[11].

Creating an adaptable model in the design phase is essential to achieving an efficient layout for all building types. A major benefit is the ability to then integrate the building systems and smart technology into the design of the building, to adapt to future changes of users, purpose and operators of the building. In the case of manufacturers, less space is needed "as robots and automation are reducing the space needed for production lines" (Steven Hawkins, Director of Automation Services, Stellar, 2012)[11]. A greater use of vertical space reduces the footprint and results in lower energy costs per square foot.

Innovative ideas for 2050

DESIGN OF A BUILDING FOR 2050

- USE OF ZONES
- INCREASED GREEN SPACE
- ADAPTABLE SPACE

Use of zones

Current buildings, with little adaptable space, are responsible for around 40% of global energy consumption. In order to reduce energy consumption, the design of buildings could include a series of zones that correlate to a particular use of that area (e.g. warm and cool zones, quiet zones). The idea for the use of 'zoned' spaces is driven by the need to provide adaptable and efficient spaces by future building users.

Architects and designers will have to better identify 'in-use zones' and areas that can be switched off when not in use. By identifying these areas, energy consumption can be dramatically reduced by using space more efficiently. This method of 'reading' zones through innovative technology and sensor integration will contribute to a zero energy building.

Increased green space

The demand for more outdoor space and integrating nature with building design will grow in significance, leading up to 2050. Integrating areas of green space within the building footprint will reduce and even offset emissions. Less heating, lighting and associated infrastructure will be needed, therefore contributing to a zero energy building.

In the future, the signals of change will encourage the integration of green space to improve air quality standards, drive down energy use and improve building user satisfaction[12]. Growing evidence, leading to 2050, will show that wider spaces of biodiversity can mitigate localised urban heat islands. To negate this effect, the building design will have to maximise green space to a minimum of 0.5ha in order to achieve suitable cooling and shading effects for buildings in 2050[13].

Adaptable space

The wider variety of users will demand improvements in building design to include adaptable space, as standard, for a 2050 building. The growing trends relating to improved energy efficiency and green infrastructure, influences the building design to incorporate efficient spaces that may have more than one use.

Global challenges in the industry, such as restricted development, higher building costs and growing inequality, need to be addressed by all future building types. Adaptable space is one method of addressing these global challenges. By reducing the building footprint, the area addresses restricted development, more sustainable materials can be used to negate costs and an increased variety of users to counteract inequality[14]. VITRA's circular factory is an example of how space can be designed to adapt to the future economy and environment.

THE DESIGN OF AN AIRPORT IN 2050

Heathrow Airport could become more energy efficient through radical approaches to terminal design:

- Reducing the height of ceilings within the terminal and finding a way of harnessing the internal thermal gradient to re-use waste heat within the building.
- Flipping the design of a terminal upside down – passengers could use the cooler part of the building, where the baggage is currently processed.
- Conveying planes to the people – planes could be lined up at a limited number of gates, so passengers have a shorter journey from entry to boarding the plane. Therefore, fewer gates will be needed requiring less space overall.

Operation of a building

SIGNALS OF CHANGE

- BIOMIMICRY
- INTELLIGENT TRANSPORT SYSTEMS
- SYSTEM INTEGRATION
- DRIVERLESS VEHICLES

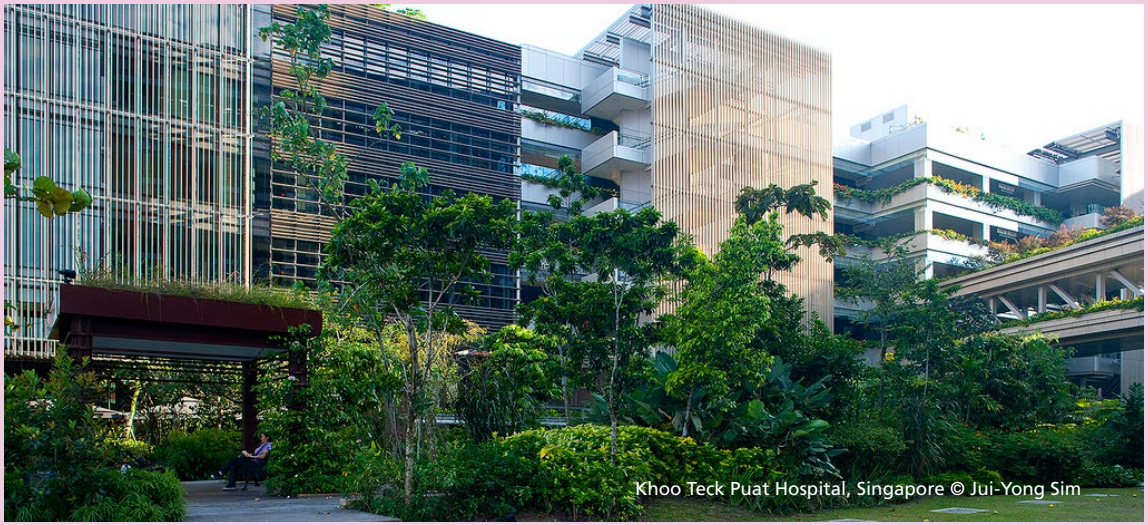
Signals of change

By 2050, people will be expecting a building to perform efficiently and in real-time, which relies on how the building operates. Over the next 30 years, innovative features will need to be included in the building's operation, relating to intelligent systems, system integration and driverless vehicles, to match the demand from future building users.

The signals of change show the growth in people's desire to connect buildings to nature. Buildings are moving beyond implementing sustainable measures to more regenerative design which enables buildings to contribute positively to the environment[15].

Examples of efficient regenerative design includes the future infrastructure needed for driverless vehicles and transport connections. The vehicles reduce the need for associated road infrastructure and energy demands, so that one automated vehicle could potentially replace ten private vehicles[16].In addition, trends towards the harvesting of energy and adiabatic cooling, will drive the movement towards zero energy buildings.

CASE STUDY: KHOO TECH PUAT HOSPITAL, SINGAPORE



Khoo Teck Puat Hospital, Singapore © Jui-Yong Sim

The need to create a tranquil setting in healthcare buildings is a compelling demand to include biomimicry into their design. The Khoo Teck Puat hospital serves more than 700,000 people living and working in north Singapore. The hospital design team recognised the benefit of a biophilic design despite the larger building costs. The hospital has condensed its building footprint by reducing the distance from the drop-off area to the emergency department to 20 metres. Subsequently, the reduction in the building size has driven down the building energy demand by reducing the associated infrastructure and energy users (e.g. heating, lighting)[17].

Some of the design features include fins that are built along the walls to channel prevailing winds into the building, enhancing the airflow by 20-30%. Sunshades over the windows are designed to redirect sunlight to enhance the brightness of the wards and reduce the need for artificial lighting[18]. Renewable energy also contributes to its efficient design by integrating solar PV panels on the roof, to power public areas, and a solar thermal system to produce hot water. The hospital has been able to increase its energy efficiency by 30% compared to present hospitals and is leading the industry by example towards a zero energy building.

Innovative ideas for 2050

OPERATION OF A BUILDING FOR 2050

- BIOMIMICRY
- ENERGY HARVESTING
- ADIABATIC COOLING

Biomimicry

Leading to 2050, the benefits of biomimicry will drive the industry to recognise that integrating nature into building design can lower energy consumption and therefore operational costs. Incorporating on-site renewable energy, such as solar PV panels, fuel cells, energy harvesting and small-scale wind turbines, into the design stage of the building will contribute to zero energy operation.

Integrating nature into a buildings design draws on the human connection to nature and the positive contribution it will make to the wider environment[19]. A 2050 building will challenge the conventional design features and emphasise the reduction of energy consumption. This can be achieved through the characteristics of a biomimicry building such as, resource efficiency, the use of less polluting materials and increased biodiversity.

Energy harvesting

Energy harvesting can re-use wasted energy and filter it back into building systems, enabling a building to reduce its energy consumption. The method of energy harvesting is a process that captures small amounts of energy that would otherwise be lost as heat, light, sound or movement to improve energy efficiency and enable new technology within buildings[20].

All building types in 2050 could harness this method of energy re-use and integrate the engineering and technology needed (e.g. capturing wasted energy from lifts, escalators or heating/cooling systems). Solar panels and wind generators can be considered as energy harvesting systems, that have become alternative energy sources for buildings. But by 2050, smaller devices may become increasingly important as systems that can capture milliwatts of energy from light, vibration, thermal or biological sources[21].

Adiabatic cooling

Services, such as adiabatic cooling, will become increasingly common as an alternative to energy and water intensive cooling towers for the industry in 2050. The use of adiabatic cooling units can save more than 40% in electricity usage, therefore driving down the overall energy consumption of a building[22]. The process is enabled by integrating an adiabatic cooler into an existing system, that pre-cools warm air, to reduce the overall energy needed to cool the surrounding environment.

The adiabatic system increases the overall efficiency in existing cooling systems, by using less energy and water resources, therefore assisting buildings to become zero energy.

THE OPERATION OF AN AIRPORT IN 2050

A terminal building in 2050 will require radical changes to the operation of the building, in order to reduce the overall energy consumption:

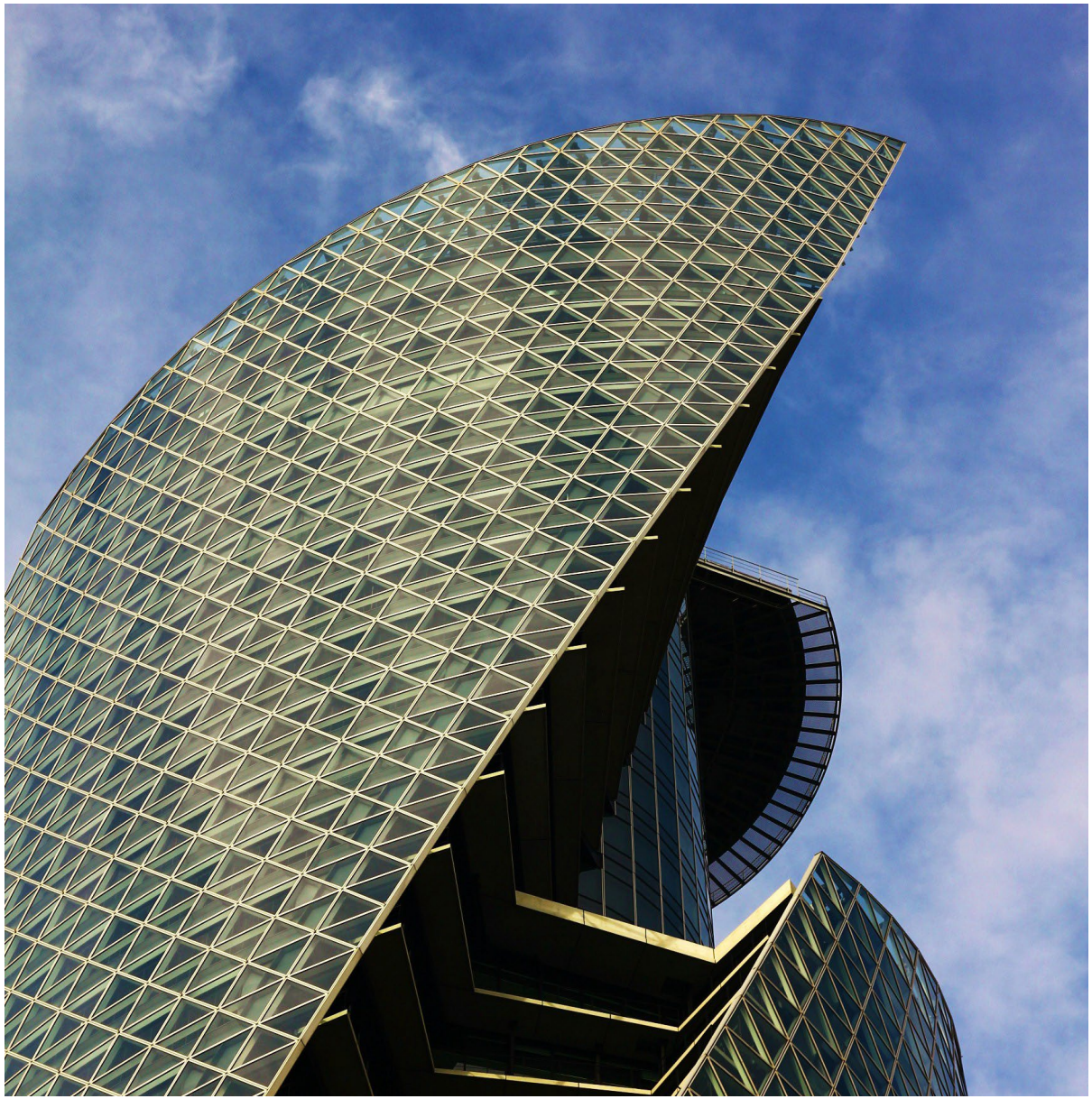
- Increase the exposed thermal masses in the building to reduce energy consumption and demand.
- Harvest the excess energy generated by lifts, escalators and travelators into electricity that can be reused elsewhere in the terminal.
- Harness kinetic energy from movement – (e.g. harvesting the energy from planes landing on runways, movement of baggage and water flows).
- Removing display screens within terminals and increase the use of digital ink that only uses power when the information changes.

Summary

This report details a series of innovative ideas relating to the experience, design and operation of buildings that could enable the building performance to reach a zero energy standard. The built environment industry could integrate these ideas into aspiring long term strategies to achieve a zero energy building in 2050.

If the industry is to achieve a zero energy buildings for 2050, then the signals of change we are experiencing today relating to digitisation, evolving technology, adaptable design and connectedness to nature need to be understood, in order to incorporate the correlating solutions into buildings now, and in the future.

The innovation examples provided within the report are designed to provide inspiration and ambition to strive towards radical changes in changing building operation, design and experience.



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- **Marylis Ramos, PRP Architects**
- **Danny Winch, UTC**
- **Graham Neal, Interserve**

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