



# Buildings of the future

How to take the cognitive leap?



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Connected and well-functioning buildings are at the heart of any leading cognitive city's goals and aspirations.

Traditionally, innovation in buildings was limited to achieving operational efficiency or meeting the environmental goals, however, today the concept of cognitive buildings has crossed the barrier of ideation and is moving towards nascent implementation of cognitive building infrastructure.

Cognitive buildings are essentially conscious buildings that are sensitive to the needs, emotions and requirements of the occupants and the environment. These are focused on delivering personalised and seamless experience to its occupants by using emerging technology led use cases across comfort, safety, and productivity.

PwC is excited to collaborate as digital consulting partners with LEAP, and to share our insights and point of view on the key drivers for Cognitive buildings, framework to assess the existing maturity of the building and a roadmap to achieve the target cognitive state.

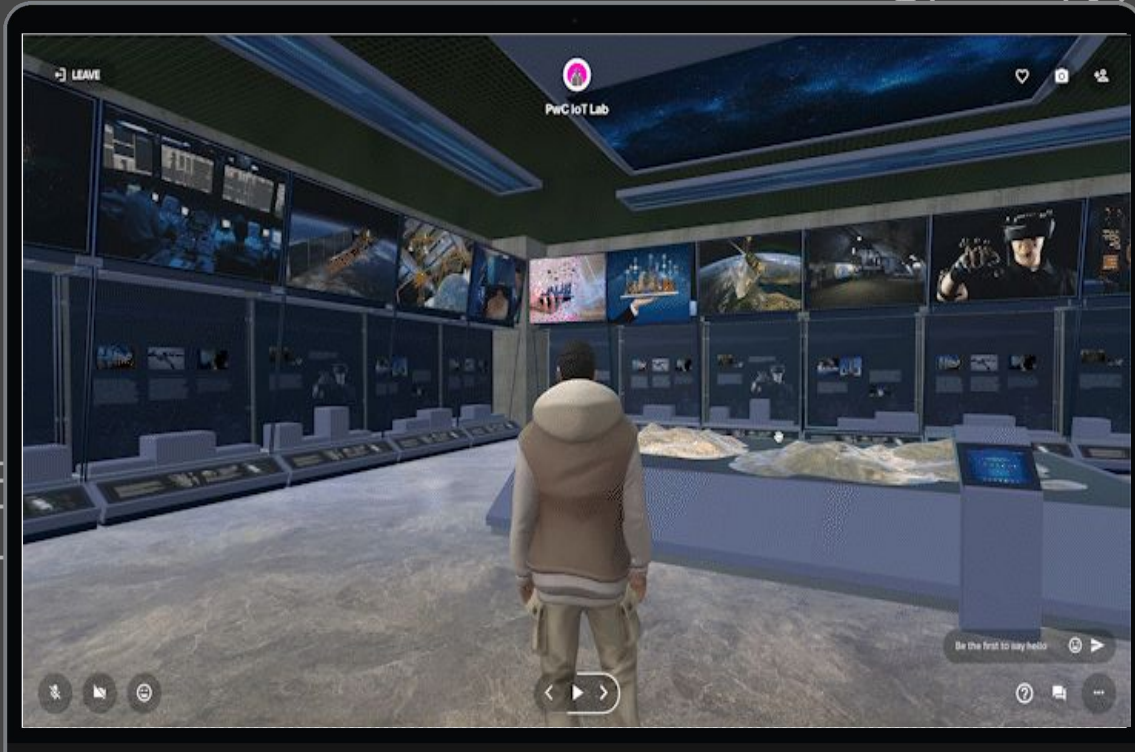
We hope you find this report insightful and look forward to having discussion around this.



Scan to view  
**the introduction**  
to the paper



# Welcome to PwC's IoT Lab



Enter the metaverse and witness a virtual IoT Lab



Click on the **PLAY** button or the **METaverse LINK**

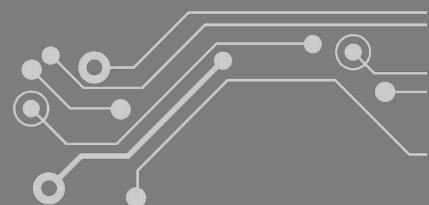
Click on play button above to enter PwC's IoT (Internet of Things) Lab in the metaverse.

Testing concepts, and products and fostering innovation are just some of the key benefits of setting up this lab.

This lab shall help identify and select future-proof technologies

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# Introduction

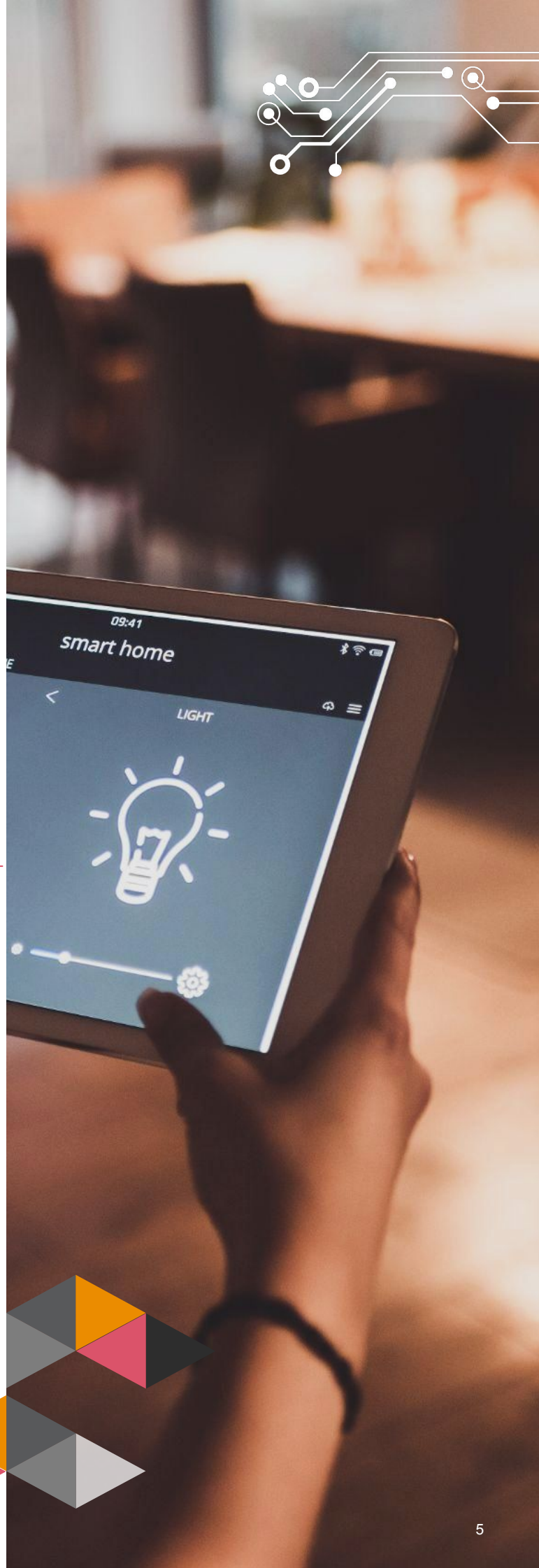
Over the past decade, buildings' management technology has developed exponentially. These developments include interplay of sensors and applications to enable buildings control use cases such as smart heating, ventilation and air-conditioning (HVAC) systems, smart lighting, geopositioning-enabled navigation, space utilisation, energy management and occupant safety, and more. Yet such applications demand a human dimension as well as a technological one, if the full potential of Cognitive Buildings is to be realised. Cognitive Buildings should measure, monitor and improve human experience in the built environment rather than merely improve efficiency and reduce costs.

Cognitive Buildings are now becoming personalised entities that create positive user experiences through a combination of applications with a unified backbone. Cognitive Buildings technology as an industry has already evolved, yet in terms of achieving its full potential the surface has barely been scratched. That potential can only be unlocked if the industry focus moves beyond technology to the user's experience and 'journey' within a building.

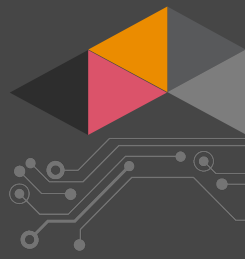
Personalised and unified operations are currently seen as a value-added option in Cognitive Buildings technology: soon, however, they will become a necessary component of any industry-leading Cognitive Buildings offering.



A sensor can tell you the accurate temperature, but only a cognitive building can tell you the optimum temperature

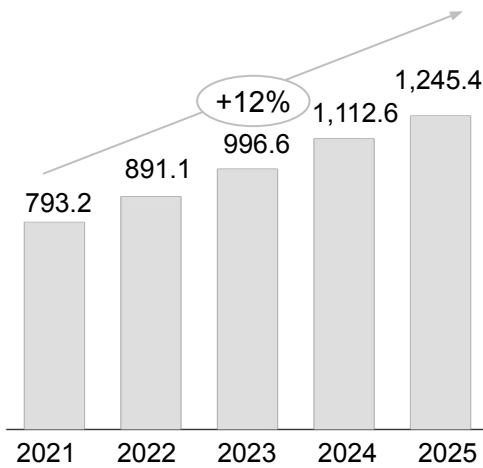


# Cognitive Buildings Overview

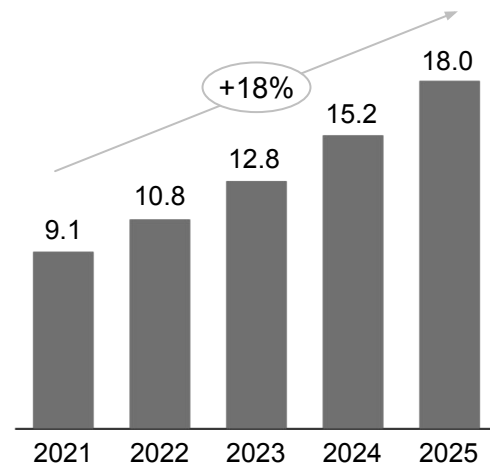


The global IoT market has grown in recent years and is projected to continue that trend at a CAGR of 12% to USD1.2trn by 2025. Similar applies to the regional market, which is projected to grow at 18% CAGR to USD18bn by 2025. The growth of smart cities, as well as IoT adoption on a global scale, is driving the development of Cognitive Buildings including smart homes, smart offices, smart industrial facilities and many other sub-domains. Growth in KSA and the rest of MENA is expected to be even greater, mainly driven by access to reliable low-cost connectivity, favourable government regulations, and the launch of mega-projects.

## Global market (USD Bn)



## MENA market (USD Bn)



The IoT value chain remains fragmented with low margins. Revenue from the overall technology stack attributed to applications is around 66% of the total, with hardware approximated at 28% and connectivity contributing around 6%. The rapid and recent as well as the projected growth in the IoT sensor market is largely driven by the factors depicted below.

The **average price** of an IoT sensor has been falling while use in industries has seen consistent growth

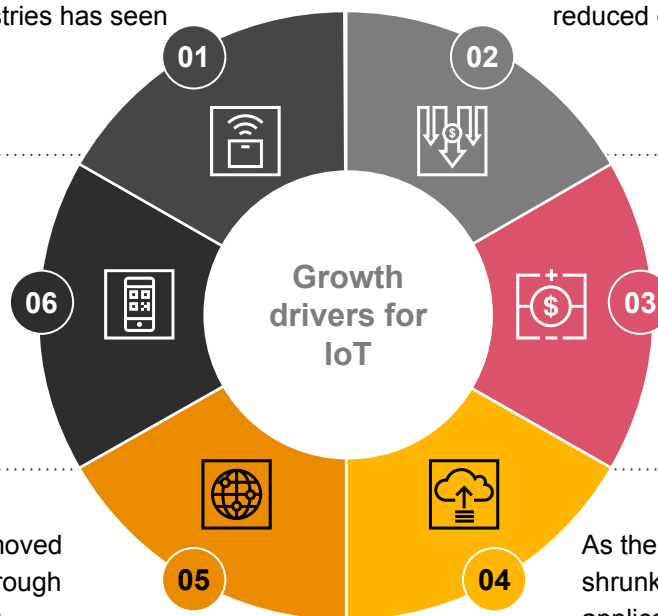
Decreased **component costs** have reduced overall product prices

**Growth in user demand** has been supported by ubiquitous devices such as smartphones and wearables, and pandemic-related demand

The increase in global internet usage through the proliferation of 4G and 5G mobile phones has cut the **cost of connectivity**

Globally, governments have moved towards digital enablement through **supportive policies, funding and IoT projects**

As the **average size** of an IoT device has shrunk many additional use cases and applications have emerged



The growth of the IoT market has directly impacted the evolution of smart cities. The blueprint of smart cities is changing drastically and exponentially, tilting the development model towards human-centred design, energy efficiency and sustainable living.

## Kingdom of Saudi Arabia



The NEOM, AMAALA and AI Ula developments are just a few of the multiple projects built around concepts of improved quality of life, economic growth and social responsibility. All are supported by a **cohesive system of Cognitive Buildings** and safety and communication systems.

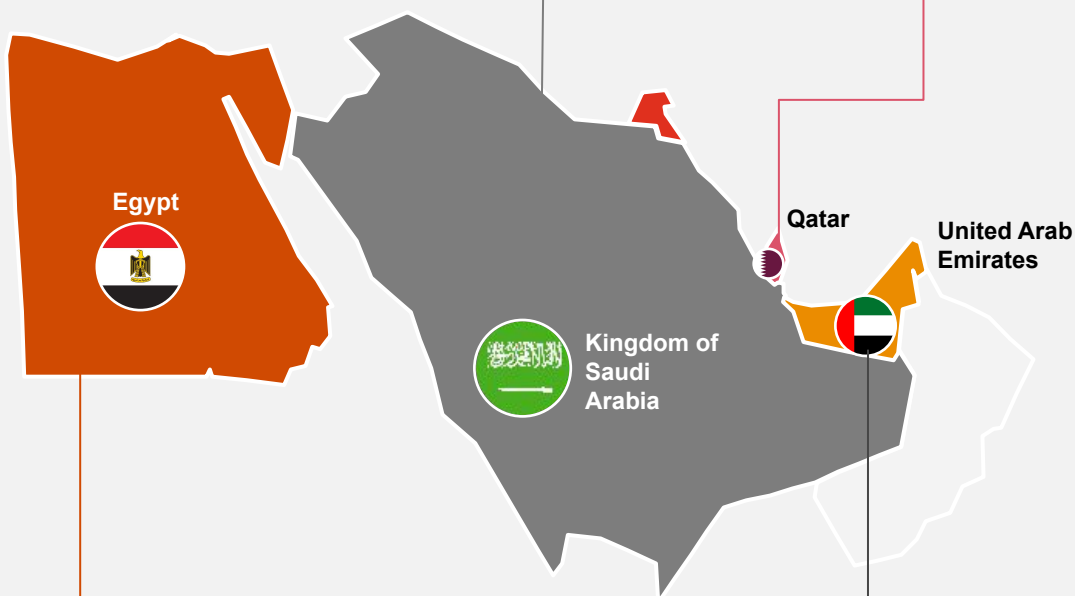
KSA has signed a memorandum of understanding with SenseTime, a leading global AI software company, to run a pilot project that will support the development of a smart city platform for these developments.

## Qatar



Qatar has used **cutting-edge technology solutions** such as digital twins, 'cognitive' lighting control, smart crowd management, safety and surveillance systems and advanced building management solutions to manage events and **enhance the experience** of visitors during the FIFA World Cup 2022.

The World Cup stadiums utilised over **40,000 IoT sensors** to feed the stadiums' digital twin with live data while relying on more than 15,000 cameras to track visitor movements.



## Egypt



Egypt's New Administrative Capital (NAC) outside Cairo is based on the vision of a sustainability capital of the Middle East, augmented **state-of-the-art buildings** and infrastructure.

The NAC is being developed as a smart city with **integrated Cognitive Buildings** and infrastructure to provide many **seamless services** to citizens such as unified access control for facilities throughout the metropolis.

## United Arab Emirates



Dubai's Expo 2020 functioned as a snapshot of Cognitive Buildings creating a **template for global smart cities** on a sustainable, human-centric basis with optimised operations and reduced carbon emissions, conserving resources while also enhancing visitor and resident comfort and security. The subsequent Expo 2022 deployed 15,000 cameras and 3,500 access control readers installed in over 130 buildings.

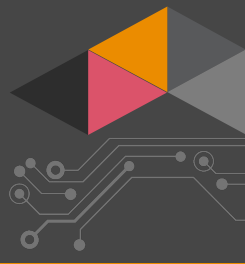
The emirate of Sharjah is the home of the Zaha Hadid-designed HQ of the public-private BEEAH future technology group, a model for the **office of the future**, the most AI-integrated workplace in the region and recognised as one of the smartest, most sustainable buildings in the world.

Proliferation of smart city programmes in the region has driven development of both Cognitive Buildings and smart infrastructure, which are the key building blocks of smart city mega-projects. These building blocks are emerging as the KPIs around which the growth and quality of a city will be measured in the future.

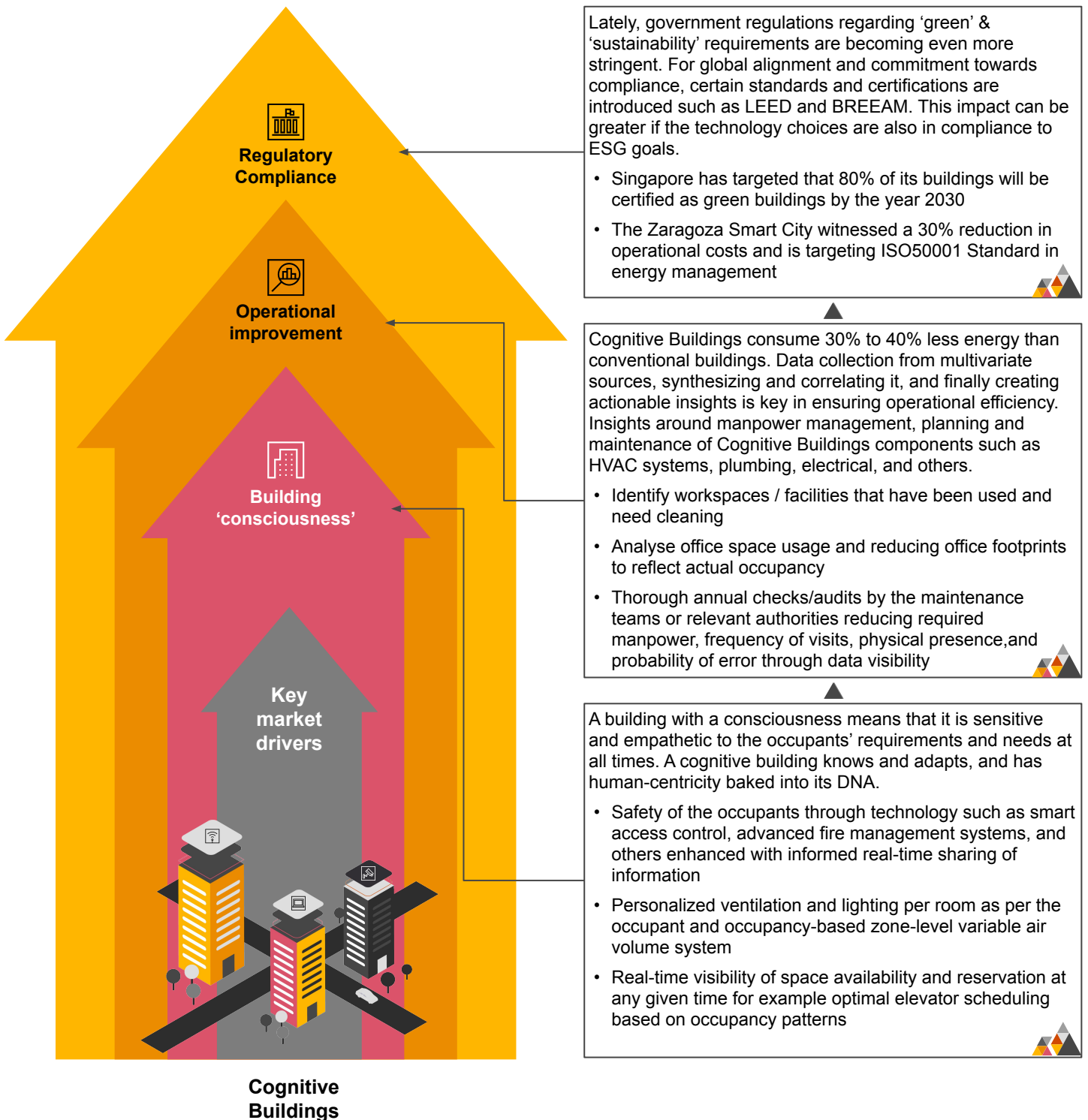


**Cognitive Buildings are the key to a smart cities collaborative ecosystem**

# Key market drivers for Cognitive Buildings

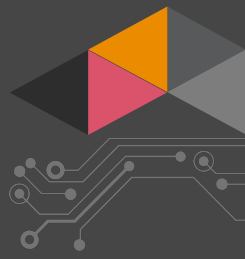


The size of the global Cognitive Buildings market was valued at USD69.8bn in 2021 and is projected to reach USD 201.2bn by 2031, growing at a CAGR of 11.3% from 2022 to 2031. Greenfield as well as brownfield implementation of Cognitive Buildings is driven by the growing need for utility, performance and optimised management building resources. In addition, the need for occupant safety is also a key contributor of Cognitive Buildings market growth. Emerging building management and control technologies including IoT applications will drive the expansion of this segment.



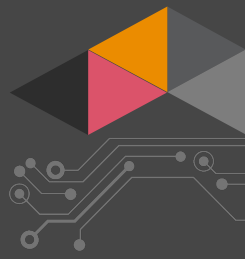


# Cognitive Buildings use cases




The Cognitive Buildings market opportunity is for IoT technologies to find an increasing number of use cases in multiple Cognitive Buildings domains, based around benefits in operational efficiency, security and surveillance, energy efficiency and user experience. The use case domains include:

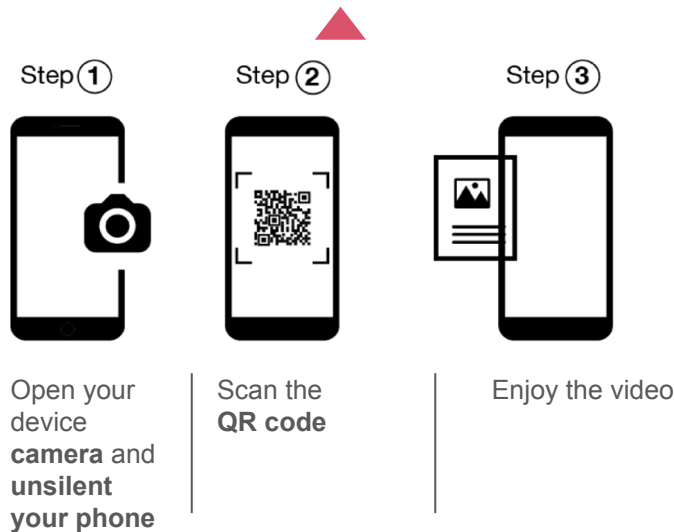
Domain	Use Cases	Examples
<b>Home / Office Automation</b>	<ol style="list-style-type: none"> <li>1. Configure metrics and set up a comfortable environment and healthy conditions for habitability</li> <li>2. Space management e.g. parking, desk occupancy, room booking</li> <li>3. Predictive access controls depending on authorization of personnel</li> </ol>	<ul style="list-style-type: none"> <li>• Smart thermostat</li> <li>• Robot vacuum cleaner</li> <li>• Window / door sensor</li> <li>• Daylight sensor</li> <li>• Video-based parking management system</li> <li>• Desk occupancy sensor</li> <li>• Room booking system</li> </ul>
<b>Environmental</b>	<ol style="list-style-type: none"> <li>1. Measure pollution of gases or contaminants</li> <li>2. Notification of water leakage</li> <li>3. Optimise resource utilisation / consumption, increase sustainability</li> <li>4. Cut maintenance and energy costs by optimising heating, water and lighting expenses</li> </ol>	<ul style="list-style-type: none"> <li>• Air-quality sensor</li> <li>• Ammonia sensor</li> <li>• Chemical sensor</li> <li>• Noise sensor</li> <li>• Soil moisture sensor</li> <li>• Water-quality sensor</li> <li>• Temperature &amp; humidity sensor</li> </ul>
<b>Energy Management</b>	<ol style="list-style-type: none"> <li>1. Optimise the energy system and increase building efficiency</li> <li>2. Prevent ineffective use of resources</li> <li>3. Optimise lighting, heating and water supply in crowded / empty areas</li> </ol>	<ul style="list-style-type: none"> <li>• Smart metering (electricity, water &amp; gas)</li> <li>• Connected lighting depending on data from daylight sensors, occupancy sensors, smart glass</li> </ul>
<b>Waste Management</b>	<ol style="list-style-type: none"> <li>1. Provide hygienic, efficient and economic solid waste storage, collection, transportation and treatment or disposal of waste without atmospheric, soil or water pollution</li> </ol>	<ul style="list-style-type: none"> <li>• Smart waste bin</li> <li>• Odor detection device</li> </ul>
<b>Personal IoT</b>	<ol style="list-style-type: none"> <li>1. Gather biometric data on body movement, heart rate, breathing, temperature and sleep patterns for informed decision-making</li> <li>2. Issue simple commands for voice-activated digital assistants to execute tasks</li> </ol>	<ul style="list-style-type: none"> <li>• Smart watch</li> <li>• Smart bed</li> <li>• Voice activated digital assistant</li> <li>• Smart shipment / mail tracking &amp; delivery</li> <li>• Care robots</li> <li>• Drone delivery</li> </ul>



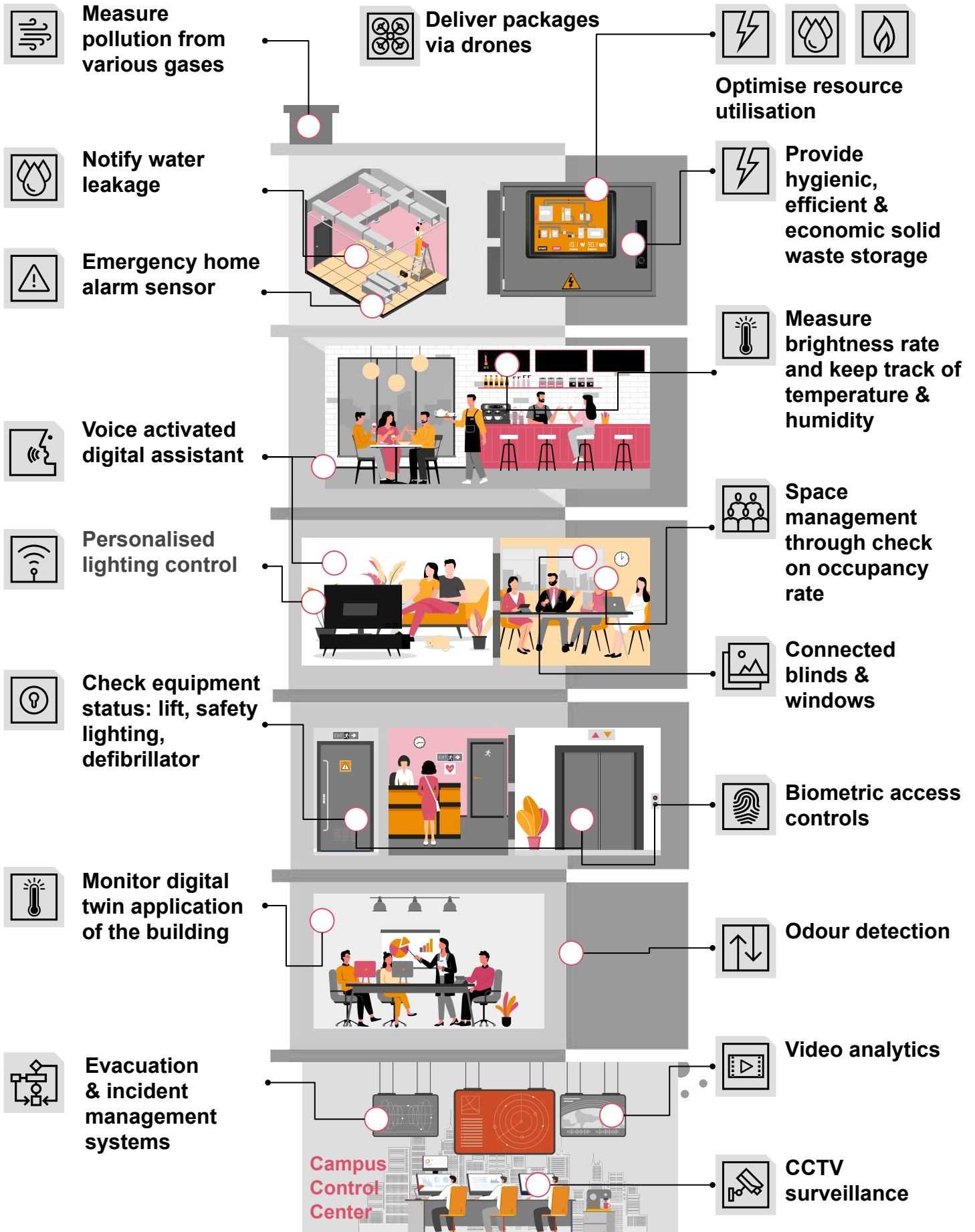
Domain	Use Cases	Examples
<b>Safety &amp; Surveillance</b>	<ol style="list-style-type: none"> <li>1. Employee authorisation management</li> <li>2. Video surveillance in public spaces</li> <li>3. Informed real-time sharing of information with relevant authorities in case of emergency</li> </ol>	<ul style="list-style-type: none"> <li>• Video analytics</li> <li>• Proximity sensor (card reader / card switch)</li> <li>• Biometric access control</li> <li>• Home alarm sensor</li> <li>• Video surveillance systems</li> <li>• Access control system</li> <li>• Smart evacuation &amp; incident management systems</li> </ul>
<b>Operations &amp; Maintenance</b>	<ol style="list-style-type: none"> <li>1. Cut operating costs while improving living standards and fostering sustainability</li> <li>2. Measure the current and future performance of the building</li> <li>3. Improve corporate sustainability</li> <li>4. Increase the efficiency of audit checks performed by operational and maintenance teams</li> </ol>	<ul style="list-style-type: none"> <li>• Digital twin of the building</li> <li>• External use of building data</li> <li>• Building structure monitoring through vibration sensors</li> </ul>



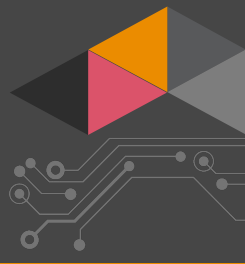
Hi, I am Rua.  
Take a tour with me as I move into my new smart apartment.



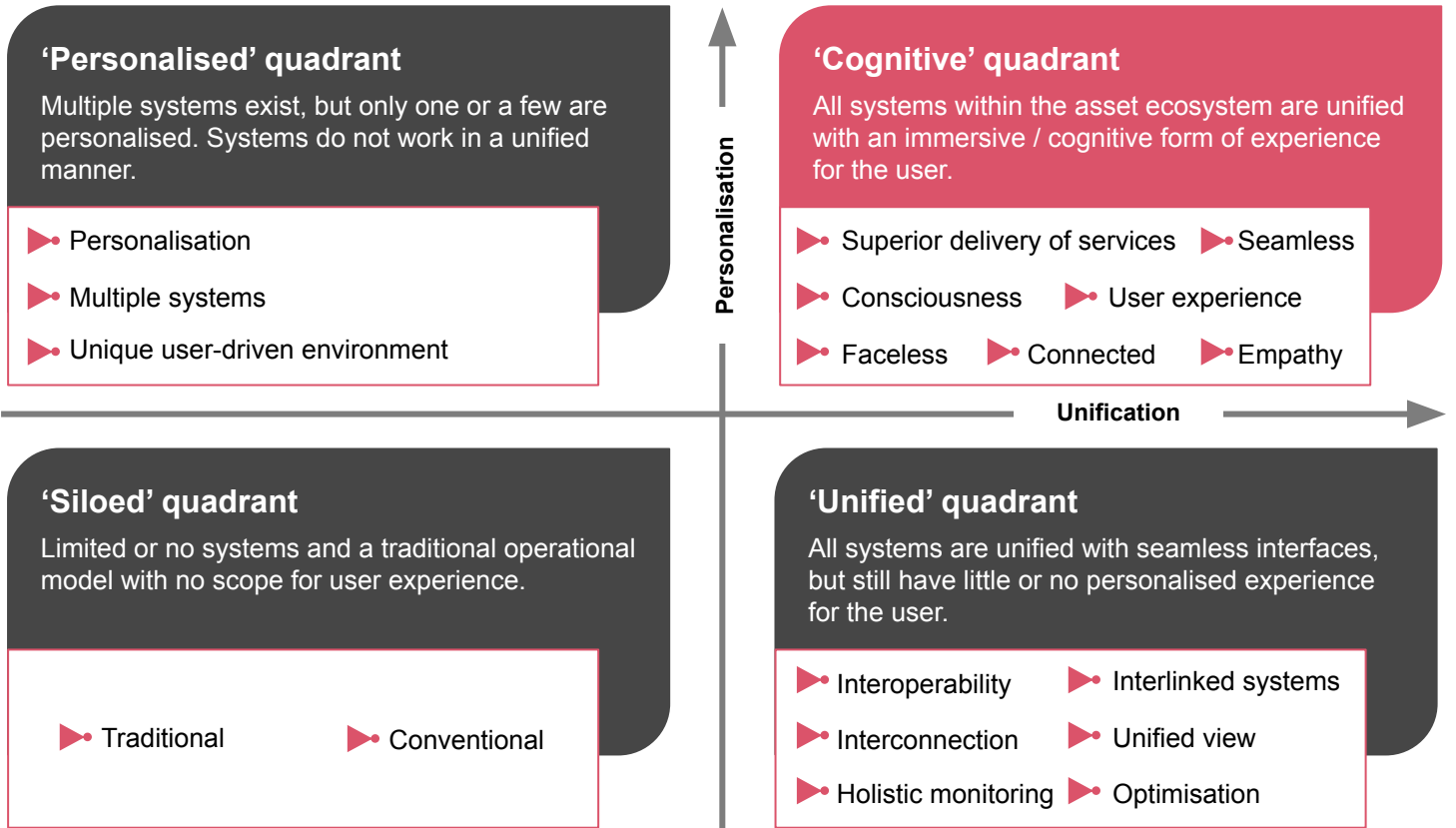
# Cognitive Buildings snapshot



# The Cognitive Buildings quadrant



In addition to providing smart and efficient buildings operations through technological enhancement, Cognitive Buildings are also putting technology at the service of their occupants to create more comfortable, user-centric, safe and productive environments. The degree to which a building achieves personalisation and unification of technologies and functions determines where it stands in the 'Cognitive Buildings quadrant'. This positioning is a function of the maturity of use cases expected by customers, the extent of unification of the building's operations and the experience of its occupants.

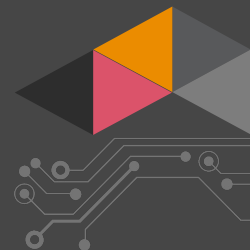


**Graph: Operations unification vs. user experience**

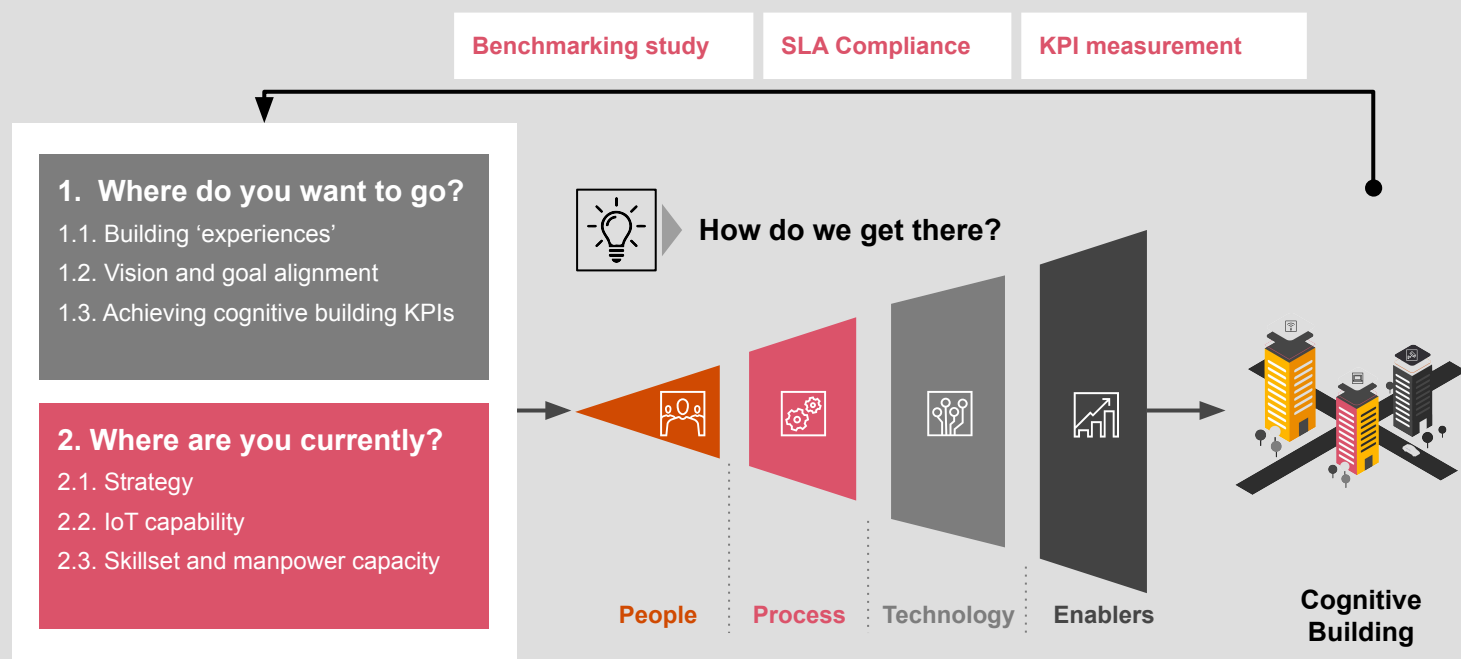
The quadrant shows a building's position based on the level of personalisation and experience provided to its occupants and the extent of unification of systems and applications for enabling building operations. These parameters complement each other to provide a 'cognitive' experience to its users and occupants.



# A Cognitive Buildings framework



To make the journey to the 'cognitive' location in the Cognitive Buildings quadrant, it is imperative that the customer understands the levers that will enable a shift in the people, process and technology domains. This means understanding the current state of buildings design and use, the aspirations of key stakeholders and finally developing the map of a customised approach to achieving 'cognitive' qualities in Cognitive Buildings.

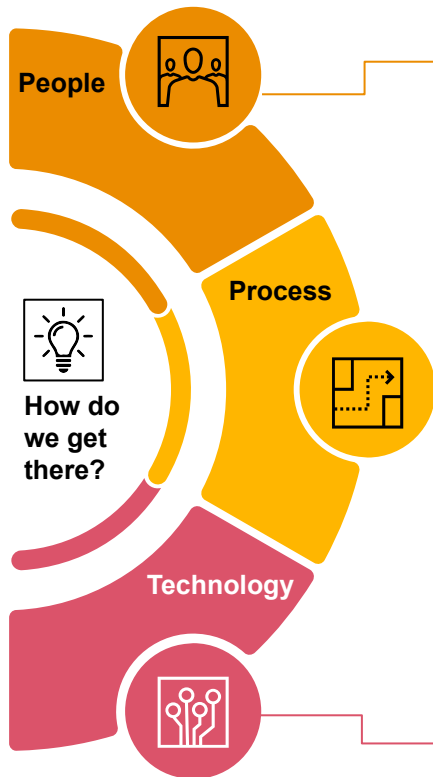
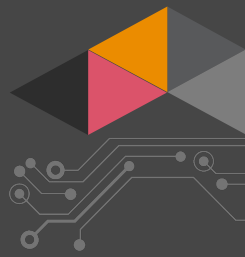


- 1.1 The next wave of buildings will be focused on the experience of the occupant to drive performance and wellness.
- 1.2 Cognitive Buildings will evolve and become the most efficient, safest, greenest, personalised or unified, depending on the developers' vision and strategic goals.
- 1.3 Cognitive Buildings' KPIs may revolve around utility metrics, operational metrics, financial metrics, occupant comfort, productivity measures and safety metrics
- 2.1 Understanding the IoT needs, aspirations and objectives, challenges and planned initiatives, and how they are aligned with organisation strategy.
- 2.2 Assessment of the extent of IoT key protocols, technical capabilities and the key enablers being leveraged.
- 2.3 Analysing manpower optimisation and upskilling to implement IoT solutions.

- People**
  - Training
  - Partner management
  - Manpower capacity
- Process**
  - User journeys
  - Market collaboration frameworks
  - Cognitive Buildings KPIs & compliance
- Technology**
  - Technology roadmap
  - IoT layered architecture
  - IoT labs
- Enablers**
  - Regulatory policies & frameworks
  - Interoperability & standards
  - Cost estimation & quantification tools
  - Business case development
  - Global leading practices

It is important to stress that once the customer's vision for a Cognitive Building has been achieved, it should be 'refreshed' periodically through KPI measurement, checking SLA compliances and aligning with benchmarking studies.

# Journey to the 'Cognitive' quadrant



- **Training** - Practical and theoretical training to upskill the current employees ensuring capability on new Cognitive Buildings platforms, applications and devices
- **Partner Management** - Implementation of various Cognitive Buildings technologies involves a robust enabling ecosystem consisting of OEMs, system integrators, and services providers
- **Manpower Capacity** - The number of personnel required for implementation and maintenance may need to be customised basis their capabilities and organisational requirements

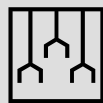
- **User Journeys** - Occupants expectations include personalized features throughout all the touchpoints in accessing various services
- **Market Collaboration frameworks** - Technical feasibility and economic viability, along with value creation are key aspects in sourcing. Appropriate ROI for partners with respect to the invested time, effort and cost is also an accelerator
- **Cognitive Buildings KPIs & Compliance** - Data collaboration utilises data to adapt to the occupants requirements. This also tracks the performance metrics which can lead to operational efficiency, achieving nZEBs (Near Zero Energy Building) targets, energy flexibility among many others

- **Technology roadmap** - Develop a customised IoT technology roadmap for the building requirements based on the fitment and capabilities of solution providers
- **IoT layered architecture** - IoT architecture ensures that the sensors and devices, applications, processes and value chain deployed in the building 'speak to each other'
- **IoT Labs** - Labs or sandboxes allow a controlled environment to integrate, test and monitor innovative applications, devices and sensors and assess if they provide any value-add to the organisation and building's IoT roadmap before commissioning them

## Enablers



**Regulatory policies & frameworks** – staying up-to-date on specific regulatory policies or frameworks may serve as a guide to IoT technology implementations and help deal with complex issues related to the environment. Policies may be related to data protection, privacy, sensor functionality requirements and cybersecurity.



**Interoperability & standards** – IoT systems and components that can communicate and share data can unlock the potential of the IoT paradigm.



**Cost estimation & quantification tools** – a cost-estimation and quantification tool to evaluate the number of sensors and associated licenses may be required to assist in informed decision-making on budget requirements and designing market collaboration frameworks.



**Business case development** – defining a business case framework is critical: this means demonstrating IoT-related business cases via development and launch of lighthouse use cases for both hardware and software.



**Global best practices** – conducting a global leading practices study will help uncover opportunities by comparing aspirations, vision and goals to other companies that have undergone a similar transformation in the Cognitive Buildings domain.

# Towards a 'cognitive' ecosystem

Great progress has been made over the past decades in the Cognitive Buildings segment of IoT to meet both industry and client needs. Yet this is a domain where companies are faced with constant disruption and constant change. All partners in the Cognitive Buildings ecosystem must now move faster to ensure full adoption of next-generation user-centric technology and unlock its value. This will require a collective effort of the whole ecosystem working together.

The journey continues. We at PwC will be there every step of the way to help you reach the promised land of 'cognitive' operations that will enable a smarter, self-optimised, adaptive and user-focused version of our built world.

## References

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- <https://www.idc.com/getdoc.jsp?containerId=AP47762122&pageType=PRINTFRIENDLY>
- <https://www.alliedmarketresearch.com/smart-cities-market>
- <https://strategyofthings.io/wp-content/uploads/2020/08/2020-SBSC-blueprint.pdf>
- [http://www.khatibalami.com/Whitepapers/Amended%20Smart%20City%20Roadmap%20White%20Paper\\_final.pdf](http://www.khatibalami.com/Whitepapers/Amended%20Smart%20City%20Roadmap%20White%20Paper_final.pdf)

# How can we help ?



At PwC we are strongly committed to providing public- and private-sector clients with the tools required to progress in their 'cognitive' journey. We can deliver tailored services across the development stages of integrated building management, from initial IoT ecosystem assessment, to designing user journeys, to assisting in the development of operating models, to designing IoT ecosystem architecture, RFP and supplier evaluation, to the final step of ensuring a smooth launch of integrated building management systems.





Assessment



IoT ecosystem assessment

- IoT readiness assessment (assessment of the existing IoT and tech strategy)
- Leading practice study for alignment and best practice
- Strategic context including business case and return on investment
- IoT hardware and software market assessment

Design & Develop



Operating model

- Define department vision and mandate
- Design user journeys
- Organisational structure and people requirements
- Define governance structure (including KPIs, decision rights, RACI matrices)
- Develop business continuity plan for IoT department
- Perform technology impact analysis and identify recovery objectives for IT applications / services



IoT strategy

- Define IoT objectives
- Develop and prioritise IoT use cases / capabilities
- Simulation of use cases on digital twins / emerging technology
- Develop IoT strategy
- Create strategic roadmap
- Identify list of key OEMs for specific systems, applications or devices



Technology

- IT infrastructure and network design
- Design IoT ecosystem architecture including integration requirements

Implement



RFP and supplier evaluation

- RFP preparation including pre-qualification, technical evaluation, scope of work, technical / functional specifications
- Define service-level agreement parameters for different components
- Support on pre-bid meeting and clarification response
- Vendor response analysis (technical and commercial)

Go Live



Project Management

- Project management activities including risk mitigation and daily project coordination to meet project milestones
- Supply installation testing (use case testing) and go live monitoring
- SLA monitoring for the edge devices, applications and IT infrastructure
- Evaluation of change requests across project life cycle

# Contact us



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