

IDAT7219 Smart Building Technology

<http://ibse.hk/IDAT7219/>



智能大廈科技

Introduction



Ir Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

Aug 2024

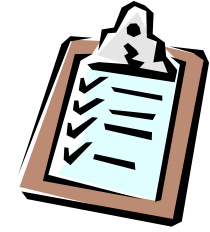


About the Lecturer

- ***Ir Dr. Sam C. M. Hui*** 許俊民 博士 工程師 <http://ibse.hk/cmhui>
 - Adjunct Assistant Professor 客席助理教授, HKU Dept of Mech Engg
 - PhD, BEng(Hons), CEng, CEM, BEMP, HBDP, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA
 - CEng = Chartered Engineer
 - CEM = Certified Energy Manager
 - BEMP = Building Energy Modeling Professional
 - HBDP = High-performance Building Design Professional
 - LifeMAEE = Life Member, Association of Energy Engineers
 - AssocAIA = Associate Member, American Institute of Architects
 - ASHRAE Distinguished Lecturer (2009-2011)
 - President, ASHRAE Hong Kong Chapter (2006-2007)



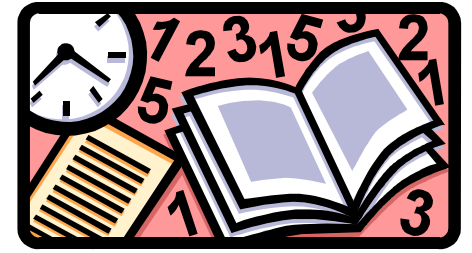
Contents



- Course background
- What is smart building?
- Why smart building?
- Evolution of smart building
- Future development



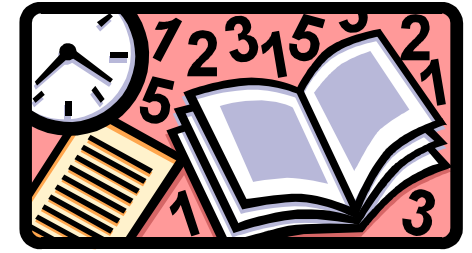
Course background



- IDAT7219 Smart Building Technology
- Educational Objectives:
 - To introduce the basic concepts and principles of smart building technology
 - To develop students with the essential knowledge and skills in its applications
 - To appreciate the key success factors of adopting smart building technology

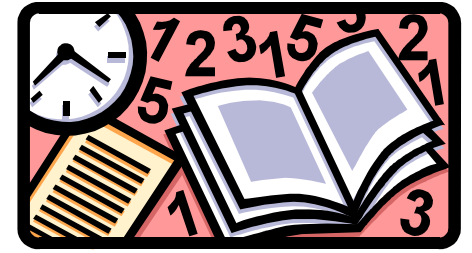


Course background



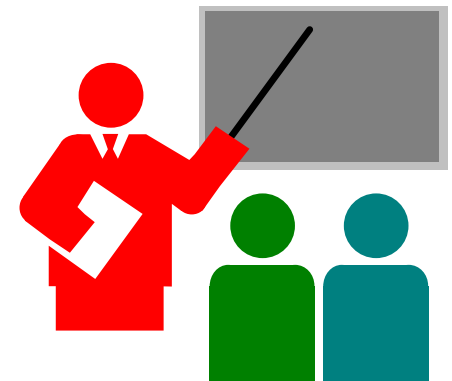
- IDAT7219 Smart Building Technology
- Learning Outcomes:
 - To describe and apply the basic concepts and principles of smart building technology
 - To understand the essential knowledge and skills in its applications
 - To evaluate the key success factors of adopting smart building technology





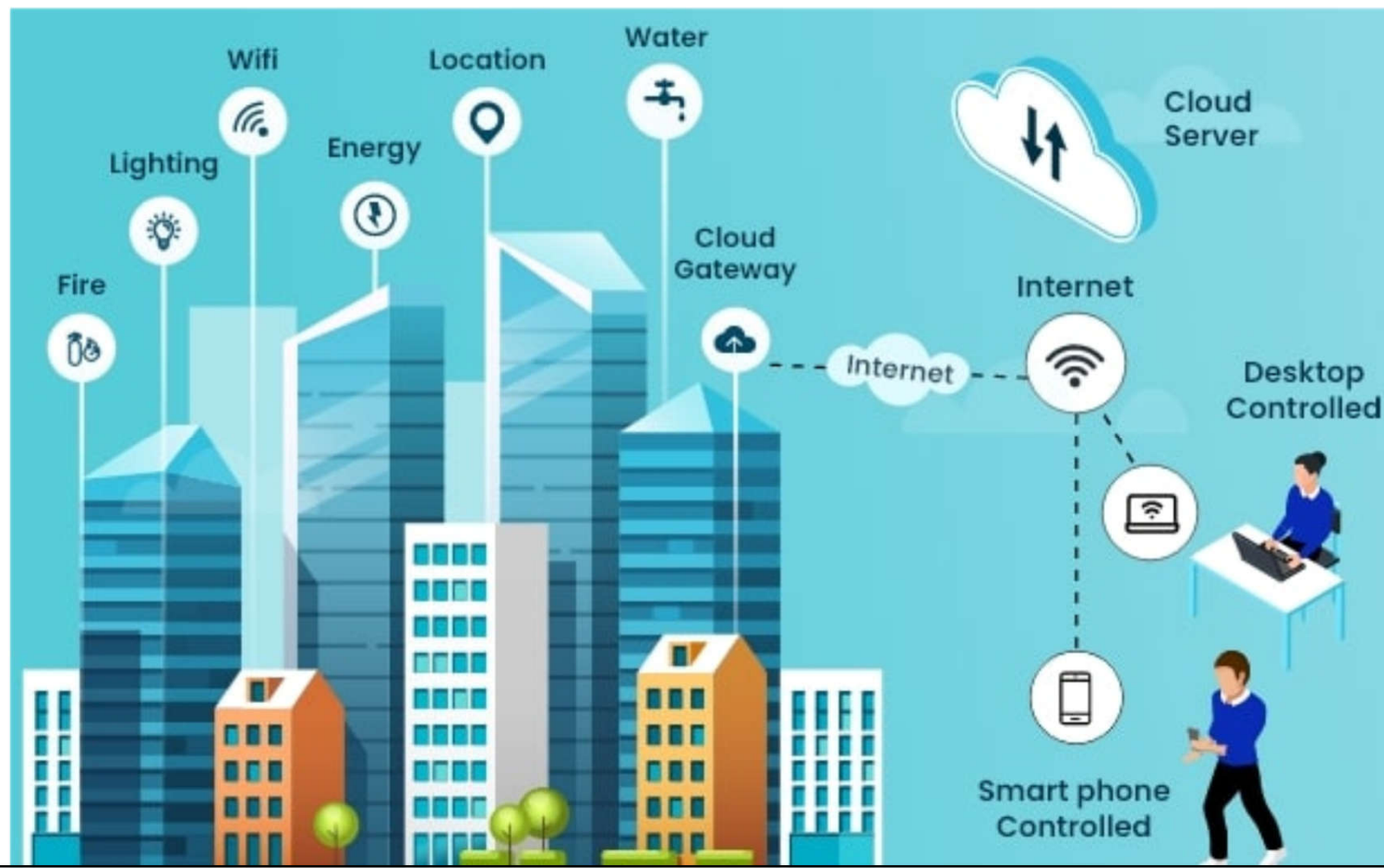
Course background

- Prerequisite:
 - Nil.
- Assessment Methods:
 - Examination (60%) – 2 hours written
 - Continuous Assessment (40%) – 2 assignments
- Course Website:
 - <http://ibse.hk/IDAT7219/>

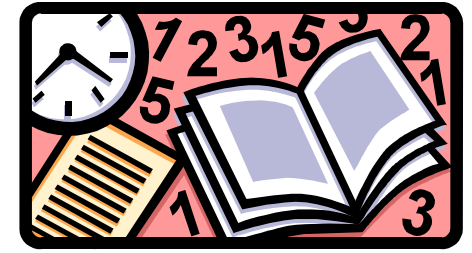


Study topics of IDAT7219 Smart Building Technology

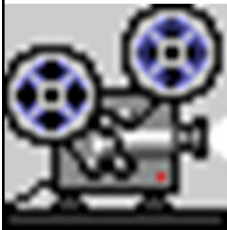
1. Introduction
2. Basic Concepts
3. Key Technologies
4. Building Automation
5. Building Analytics
6. Facilities Management
7. Smart Lighting Solutions
8. Smart HVAC Systems
9. Smart Security & Safety
10. Smart Energy Management
11. Smart Cities
12. Practical Examples



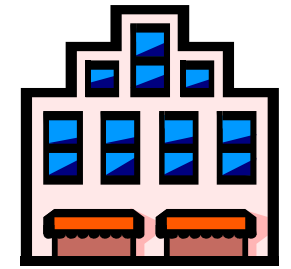
Course background



- Study methods
 - Lectures (core knowledge & discussions)
 - Further Readings (essential study information)
 - Videos (illustration & demonstration)
 - References (useful supporting information)
 - Web Links (related links & resources)
- Assignments
 - Practical skills & applications

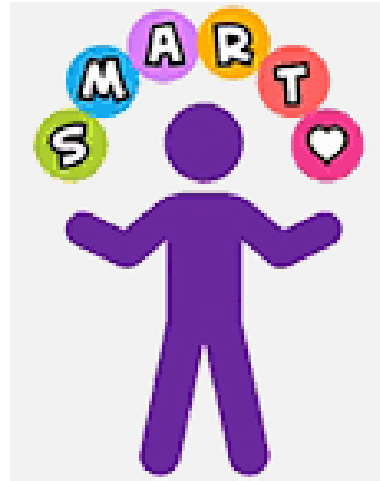


What is smart building?



- Definition of smart:

- Having or showing a high degree of mental ability: intelligent, bright

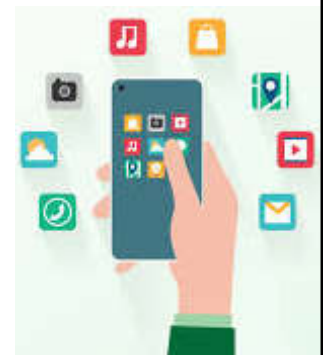


- Smart people:

- Able to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly & learn from experience

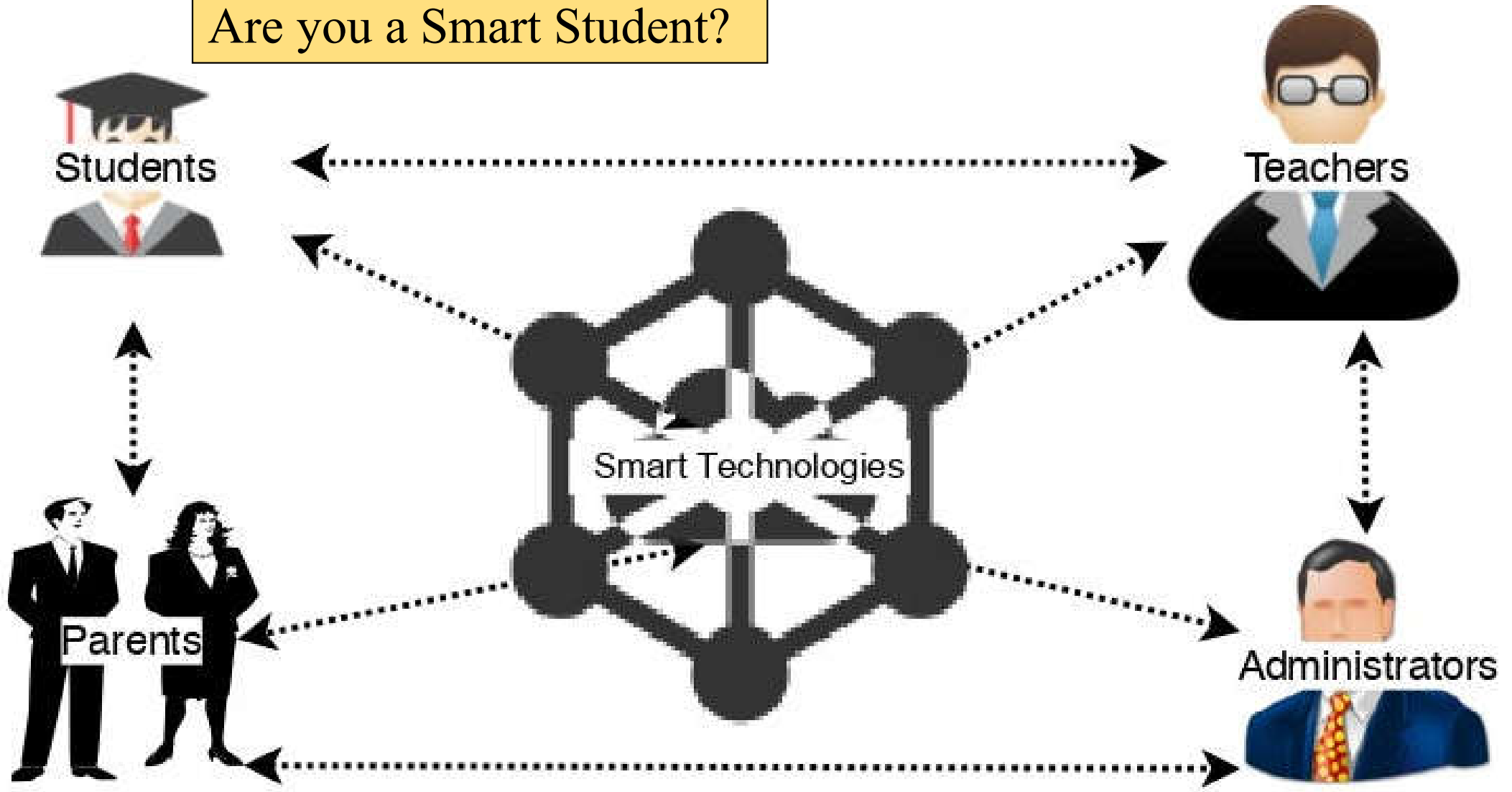
- Smart device: (e.g. a smart phone)

- An electronic device connected to other devices or networks & can do more than its basic functions

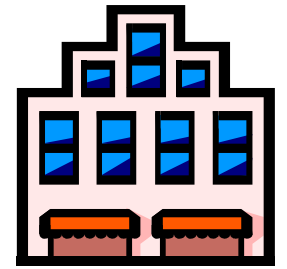


Smart education with smart students & smart teachers supported by smart technologies

Are you a Smart Student?



What is smart building?



- Smart building

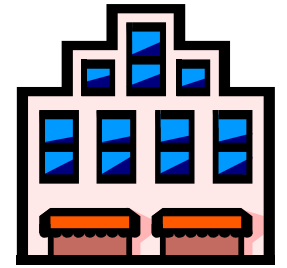
- It is a fairly ambiguous term
- It centres on the use of interconnected technologies to make buildings more intelligent & responsive, so as to improve their performance

- Smart technologies

- Can facilitate better decision making & automation of responses
- Use of computer software, information & communications technology (ICT)

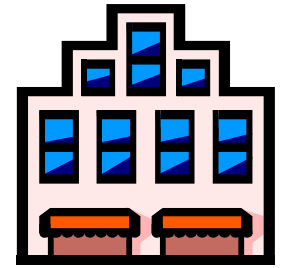


What is smart building?



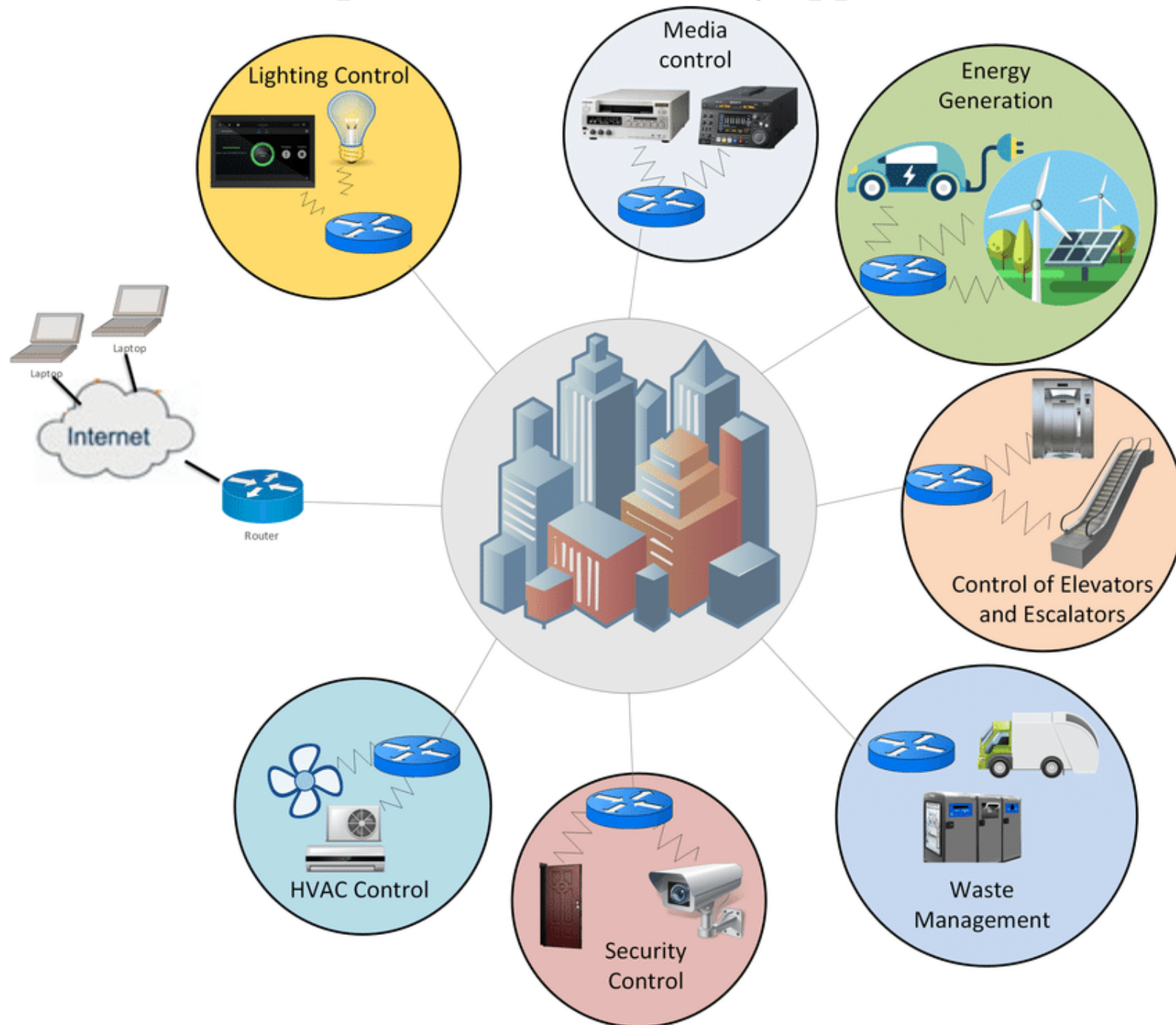
- No one wants to live in a “dumb building” but it’s difficult to define what makes a building smart or intelligent
- A simple definition of smart building:
 - A building that uses technology & processes to become more efficient operationally, protect the health & safety of occupants, improve employee productivity & reduce its impact on the environment

What is smart building?



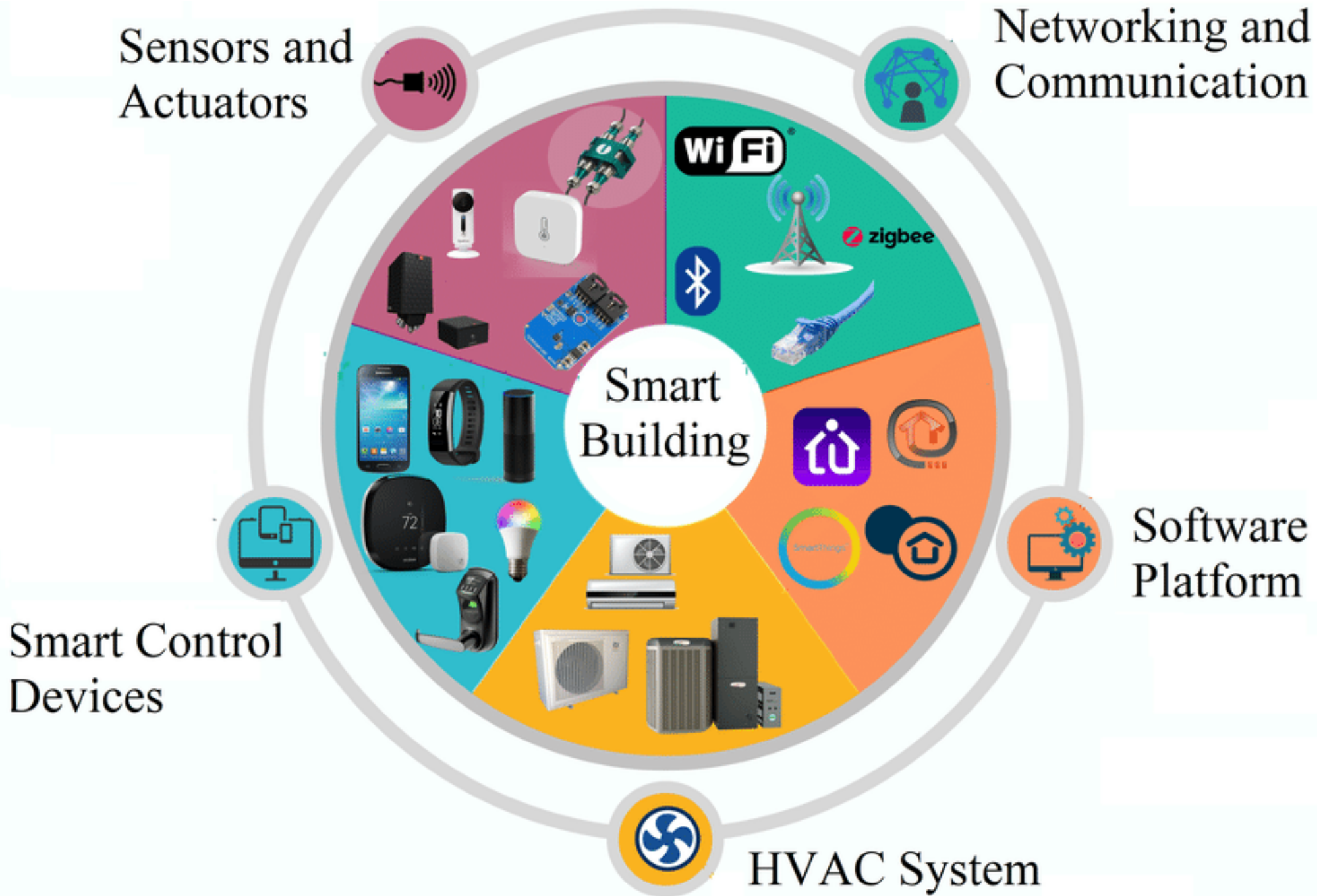
- Smart building
 - Is an integrated system that takes advantage of a range of computational & communications infrastructure & techniques
 - Can improve the user experience, optimize management & reduce costs
 - Can monitor performance, detect inefficiencies, diagnose possible causes, make automatic adjustments, alert staff to critical issues & improve productivity

Example of smart building appliances

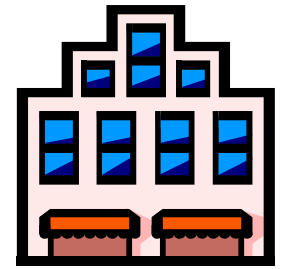


(Source: Qolomany B., Al-Fuqaha A., Gupta A., Benhaddou D., Alwajidi S., Qadir J. & Fong A. C., 2019. Leveraging machine learning and big data for smart buildings: a comprehensive survey, *IEEE Access*, 7: 90316-90356. <https://doi.org/10.1109/ACCESS.2019.2926642>)

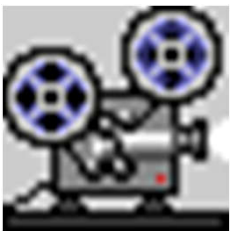
Components of smart buildings



What is smart building?



- Five senses of a smart/intelligent building
 - Environmental monitoring
 - Visual management
 - Communication enablement
 - Security integration
 - Network connectivity



Video: What is a Smart Building? (4:57)

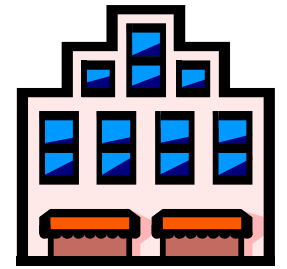
<https://youtu.be/8NzsQw46kDI>



Sensing technologies of a smart building

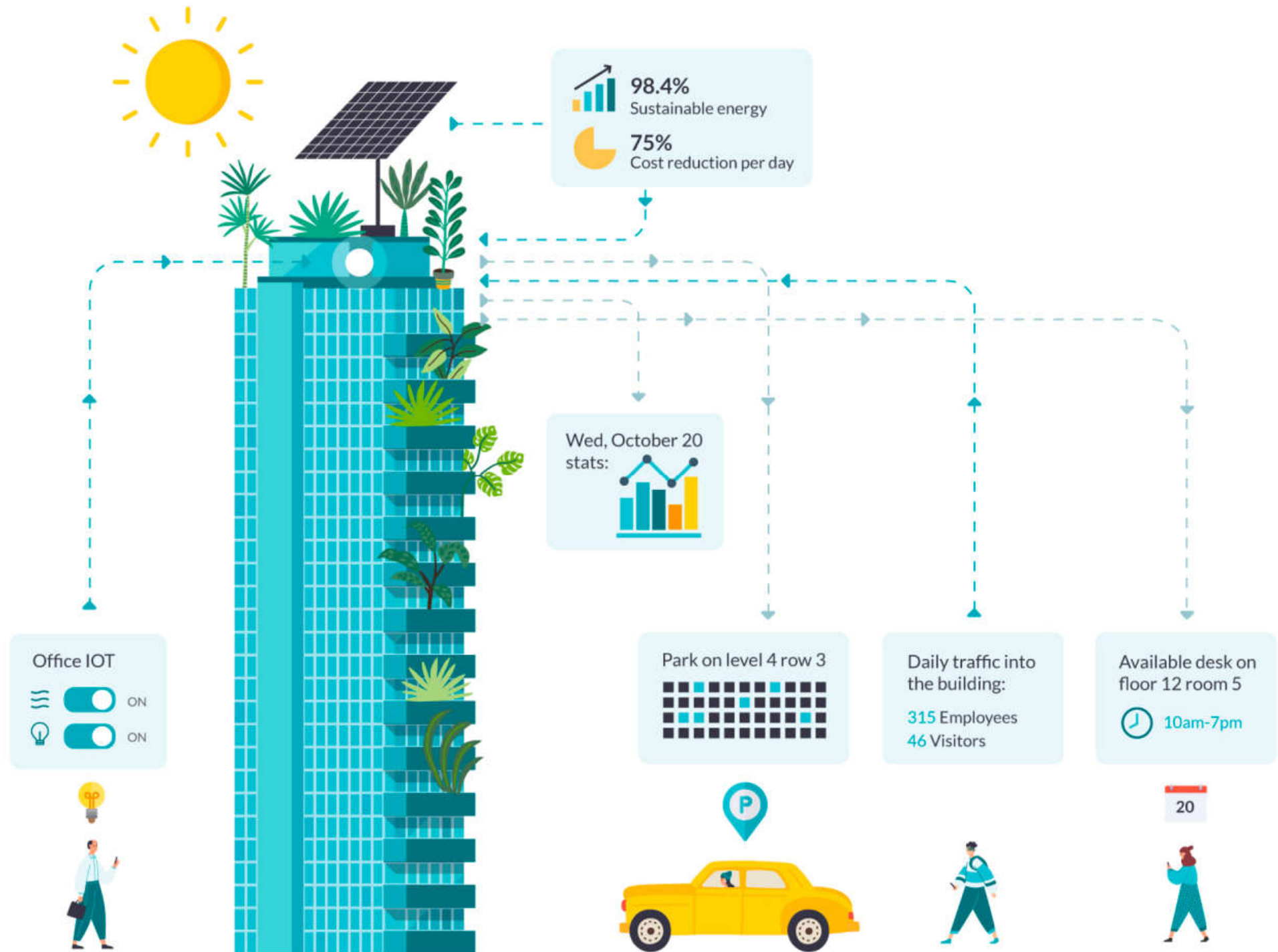


What is smart building?



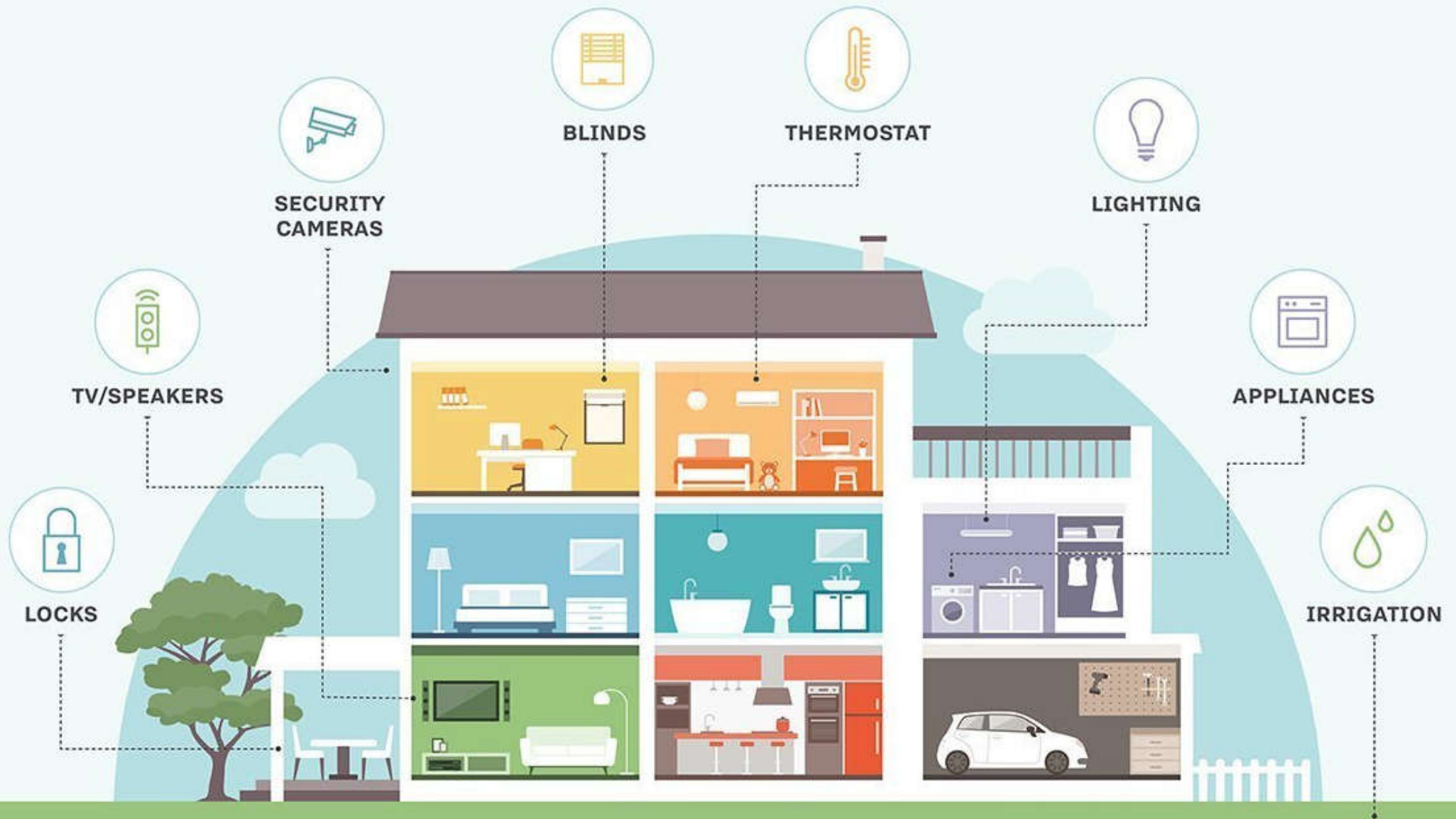
- Smart building technology
 - To make the building more efficient, useful, convenient & profitable
 - To put real intelligence into buildings
 - To use building automation, digital & intelligent infrastructure to optimize business value
- Can be applied to different types of buildings
 - Smart offices & commercial buildings, smart homes, smart hospitals, smart factories

Examples of smart building functions in a commercial building



Smart home technologies

HOME SMART HOME



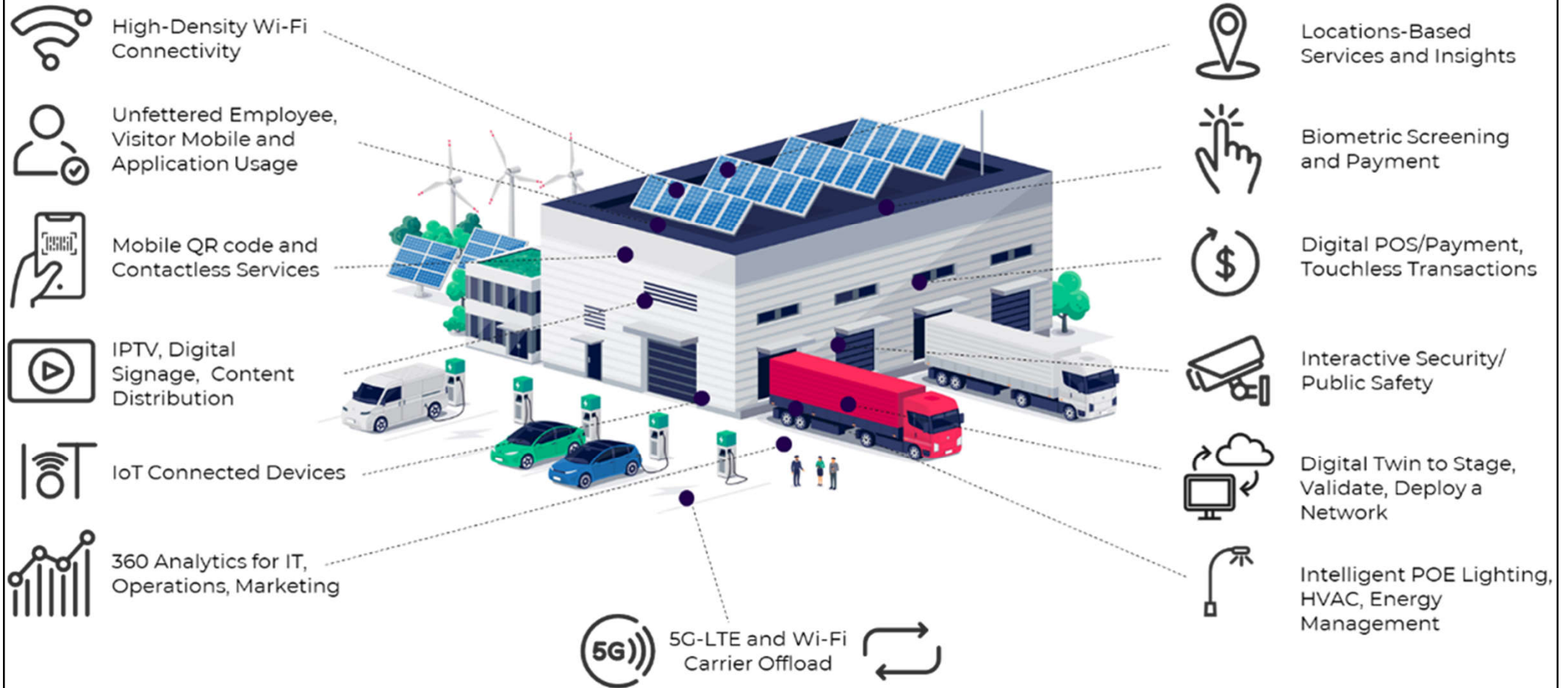
Remote control with smart plugs in smart/intelligent home



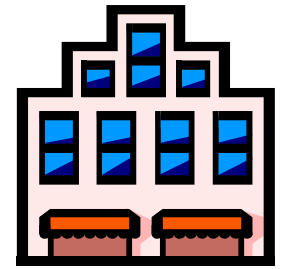
Smart hospital & smart healthcare facilities



Basic concept of smart factory building



What is smart building?



- Four basic components of smart buildings:
 - 1. Internet of Things (IoT) sensors & devices
 - To monitor the building performance, conditions & various parameters
 - 2. Integrations of building systems
 - Systems & components can communicate efficiently
 - 3. Connectivity
 - Connected to the Internet & cloud-based services
 - 4. Building automation/management system (BAS/BMS): control of systems & equipment

Why smart building?

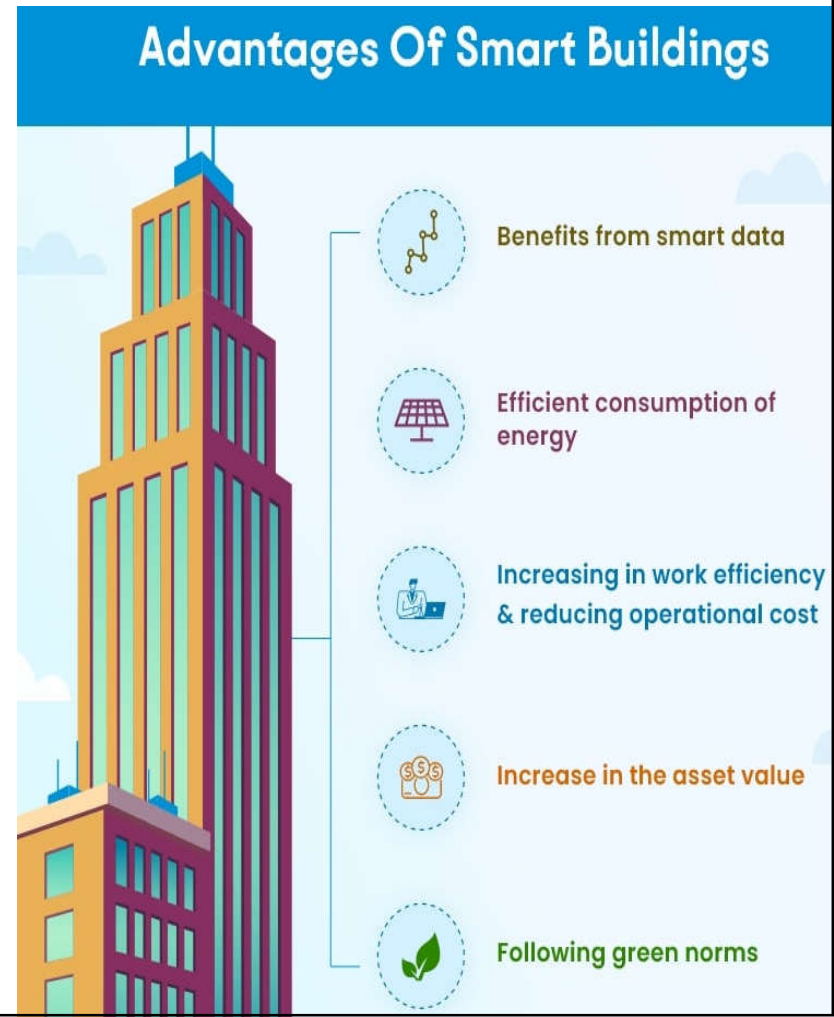


- Why opt for smart building?
 - Comfort for occupants
 - Automated control of building systems
 - Cost optimization
 - Reduced environmental impact
 - Integration capabilities
 - Preventive maintenance by analyzing real-time & historical data
 - Enhanced health & well-being

Why smart building?



- Major benefits of smart buildings:
 - Automation opportunities
 - Quantifiable building insights
 - Predictive maintenance
 - Better resource utilization
 - Reduced energy consumption
 - Real-time building insights
 - Reduced operational costs
 - New workplace opportunities



Smart building drivers/goals

Energy Cost Savings

Facility Management

Tenant Interactions

Operational Efficiency

User Experience

Maintenance

Productivity

Compliance

Revenue Generation

Tenant Attraction

Improved Safety and Security

Increased Business Opportunities

Predictive Analytics

Carbon Reduction

Meeting CSR Goals/Tracking

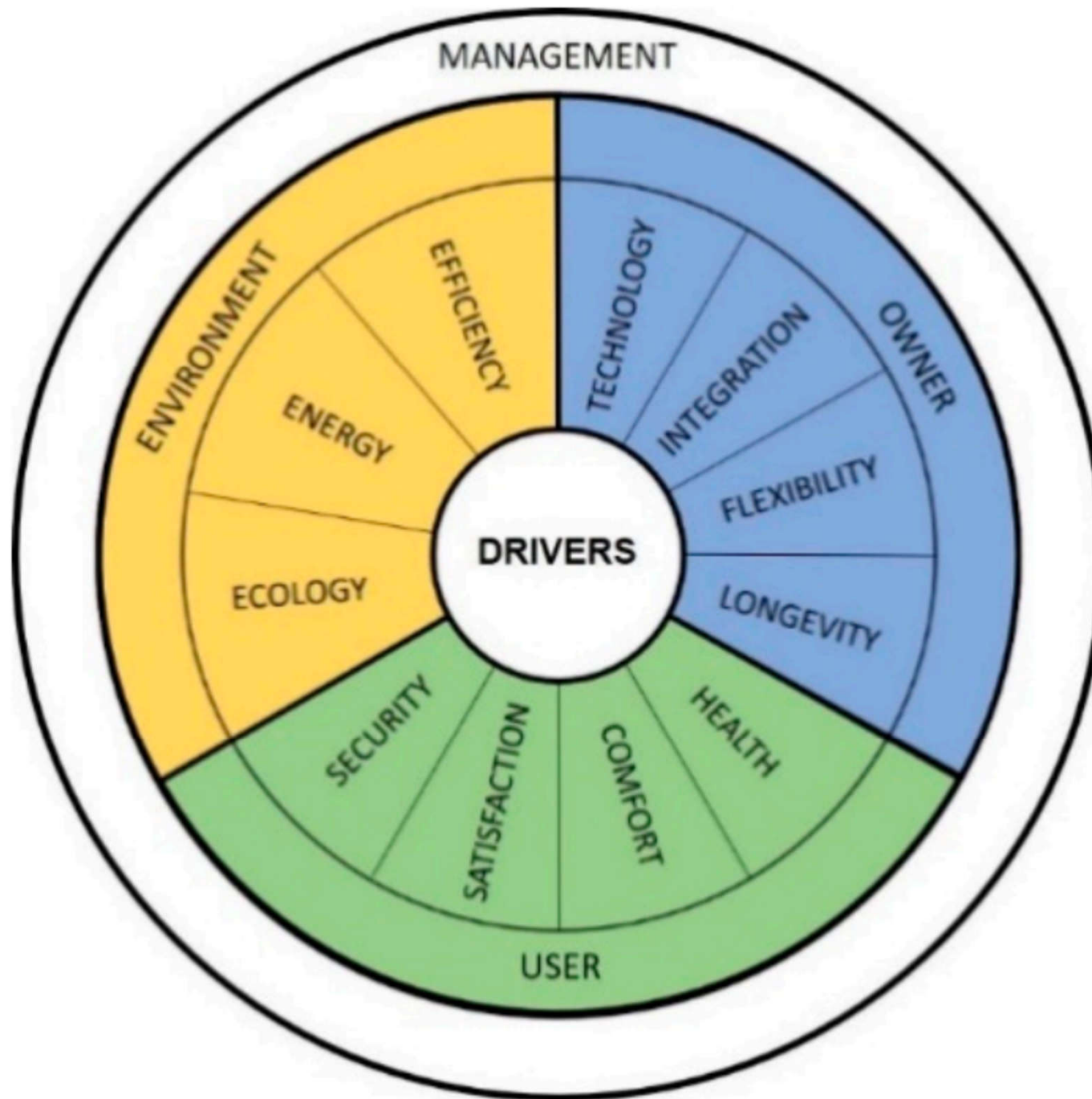
Cybersecurity



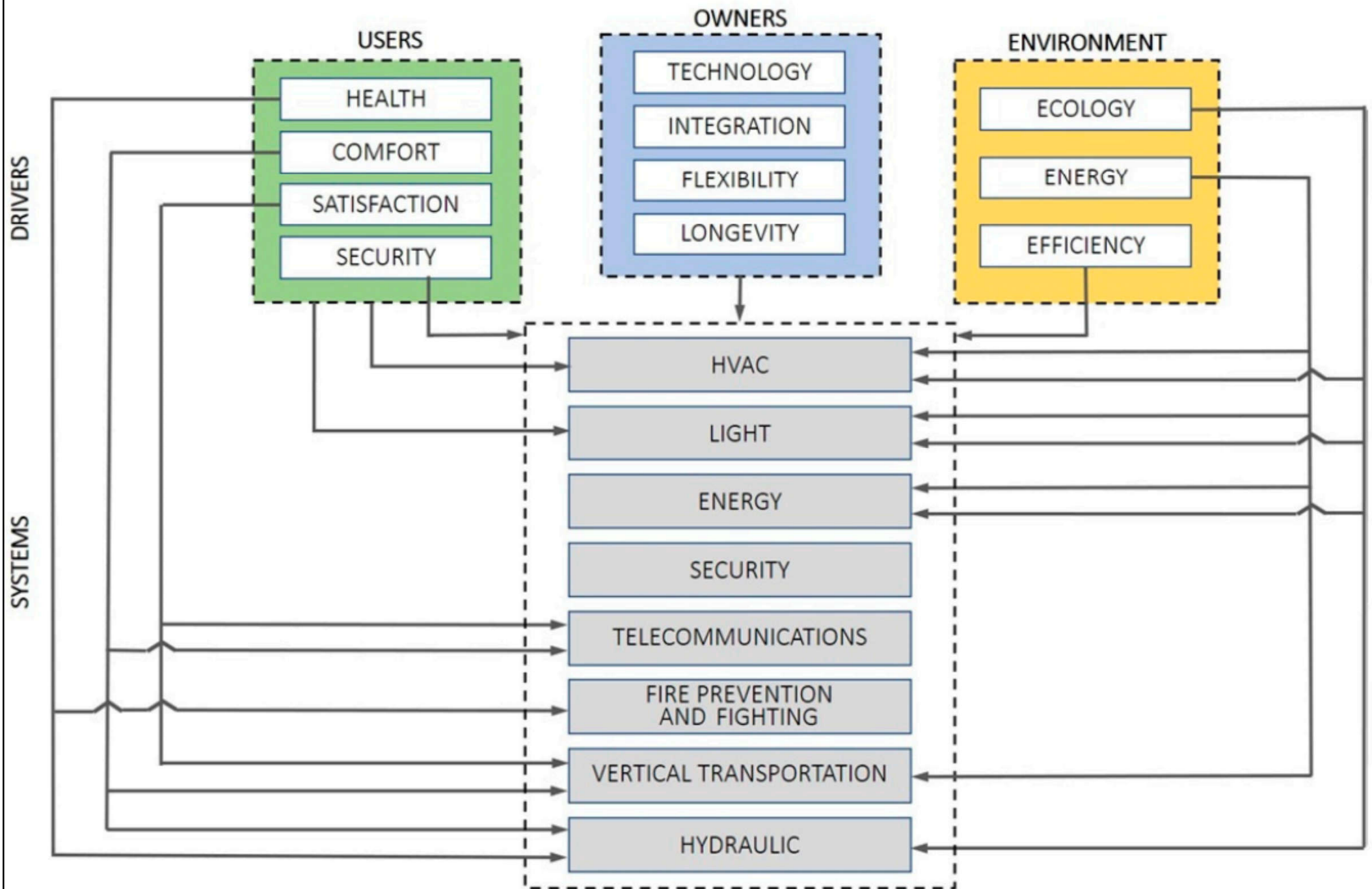
Why smart building?

- Main drivers of smart buildings:
 - For building users (or occupants)
 - Health + Comfort + Satisfaction + Security
 - For building owners (to improve property value)
 - Technology + Integration + Flexibility + Longevity
 - For the environment (or society)
 - Ecology + Energy + Efficiency
- Typical building systems:
 - HVAC, lighting, energy, telecommunication, security, fire safety, lifts & escalators, plumbing

Drivers of smart buildings grouped by category



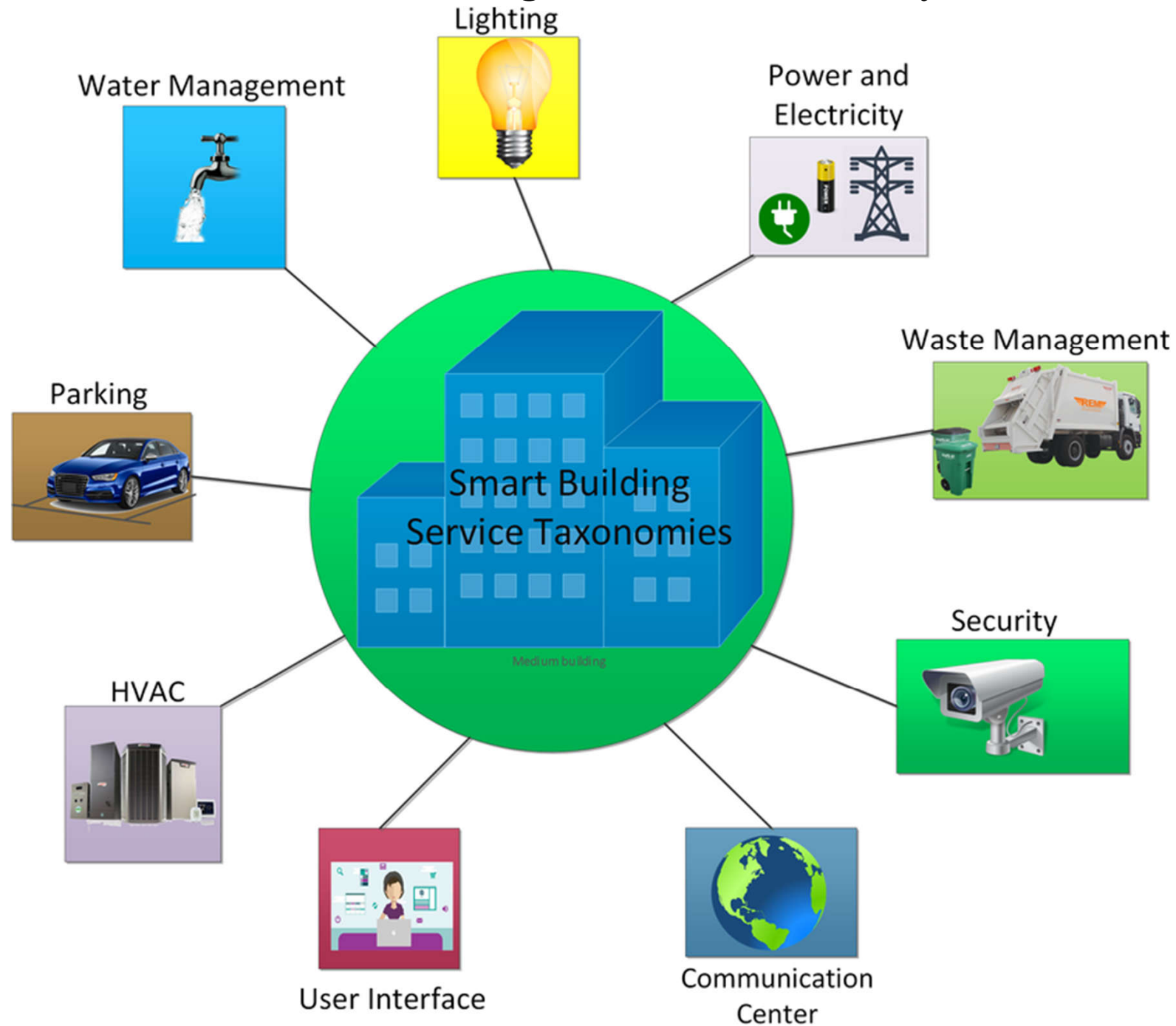
Relationships between drivers & systems for smart buildings



Major building systems & services of a smart building



Smart building services taxonomy



(Source: Qolomany B., Al-Fuqaha A., Gupta A., Benhaddou D., Alwajidi S., Qadir J. & Fong A. C., 2019. Leveraging machine learning and big data for smart buildings: a comprehensive survey, *IEEE Access*, 7: 90316-90356. <https://doi.org/10.1109/ACCESS.2019.2926642>)

Why smart building?



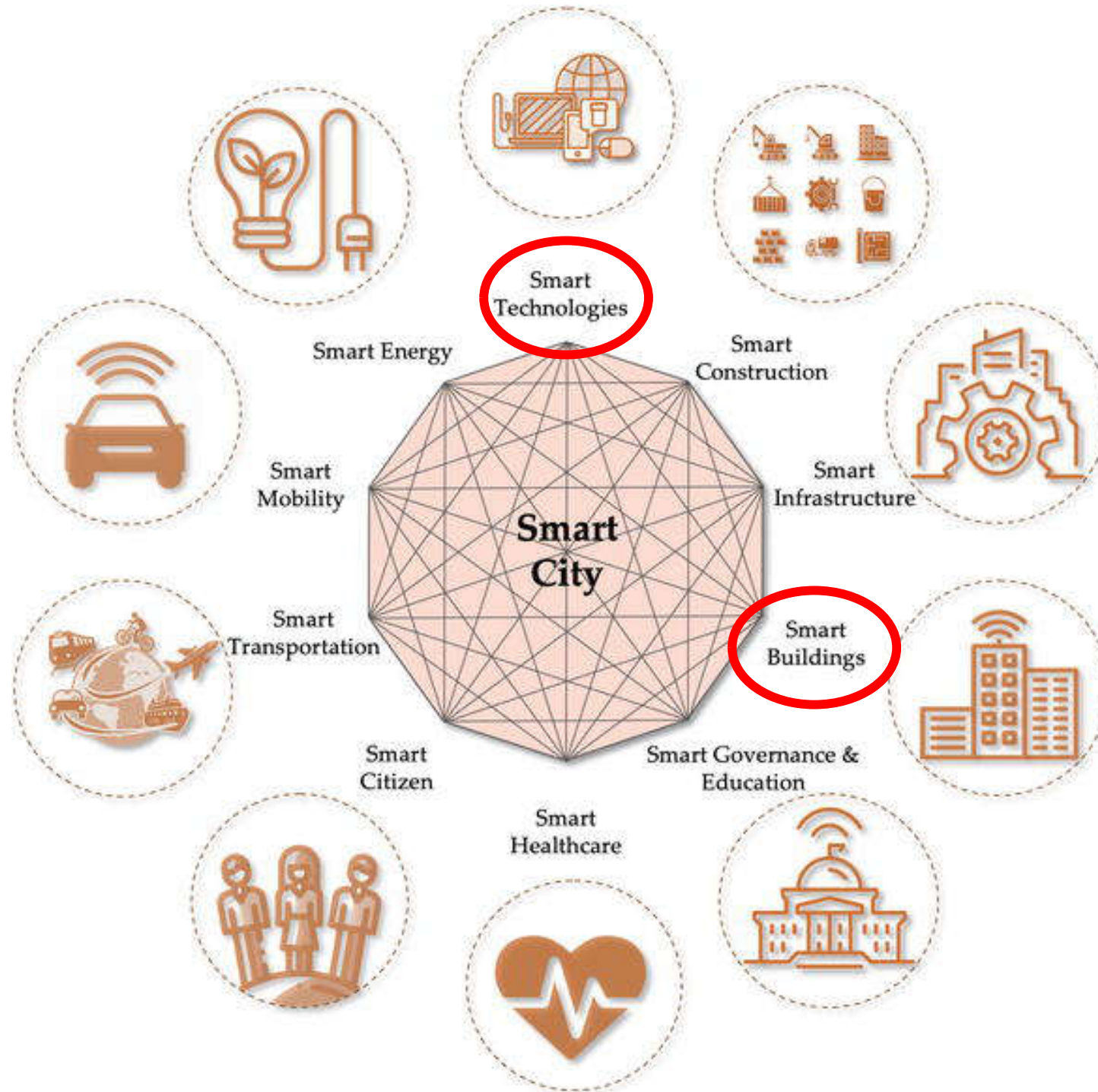
- Smart buildings also tie into smart city & smart power-grid technologies, with building automation playing an important part in sustainable building & resource management
- Better networks, increased connectivity, advanced sensors & more computer power are making smart building projects possible
 - The computing systems capture trends in the data generated by the sensors & do analysis

Why smart building?



- Smart concepts in built environment
 - With the main focus on smart cities, smart buildings, smart offices & smart homes
 - To enhance flexibility & efficiency of built environment
- Smart city components:
 - **Smart technologies**, smart construction, smart infrastructure, **smart buildings**, smart governance & education, smart healthcare, smart citizen, smart transportation, smart mobility, smart energy

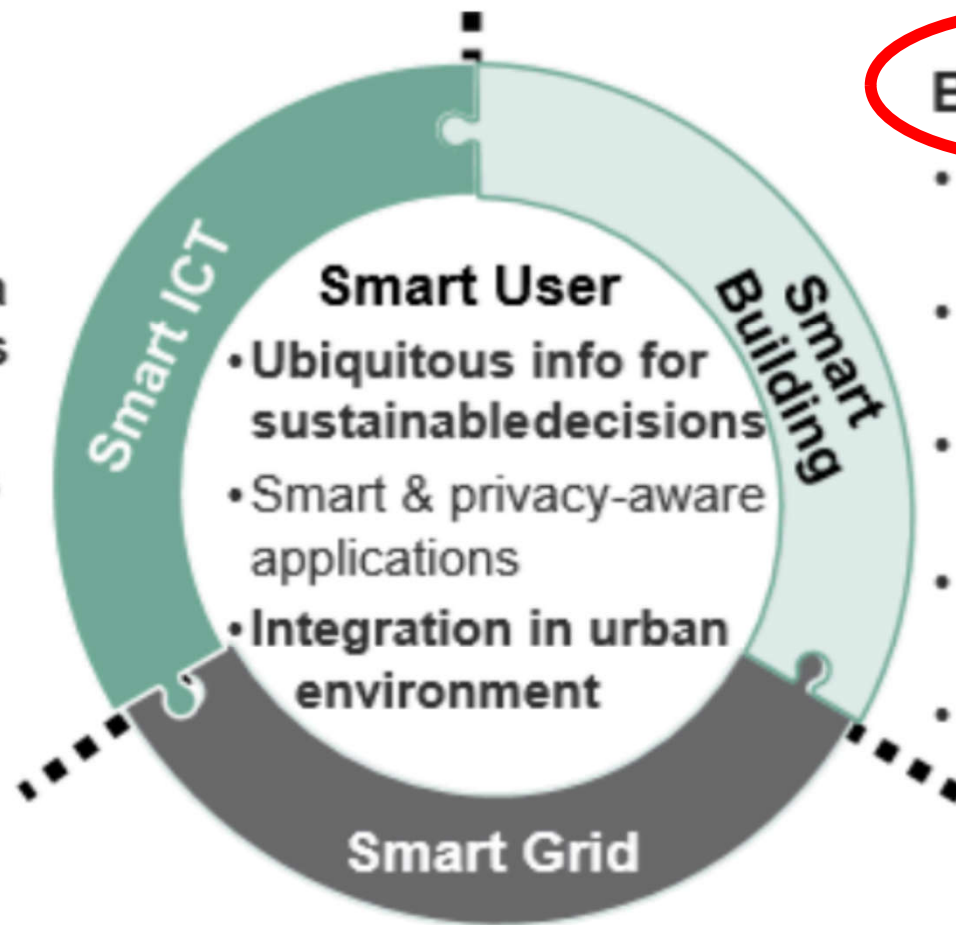
Smart city components & the connections among them



The fundamentals of future smart cities

Information and communication technology

- **Cross-domain data driven applications**
- Modern data integration solutions
- **Big data analytics**
- Multitenant data aggregation and provisioning



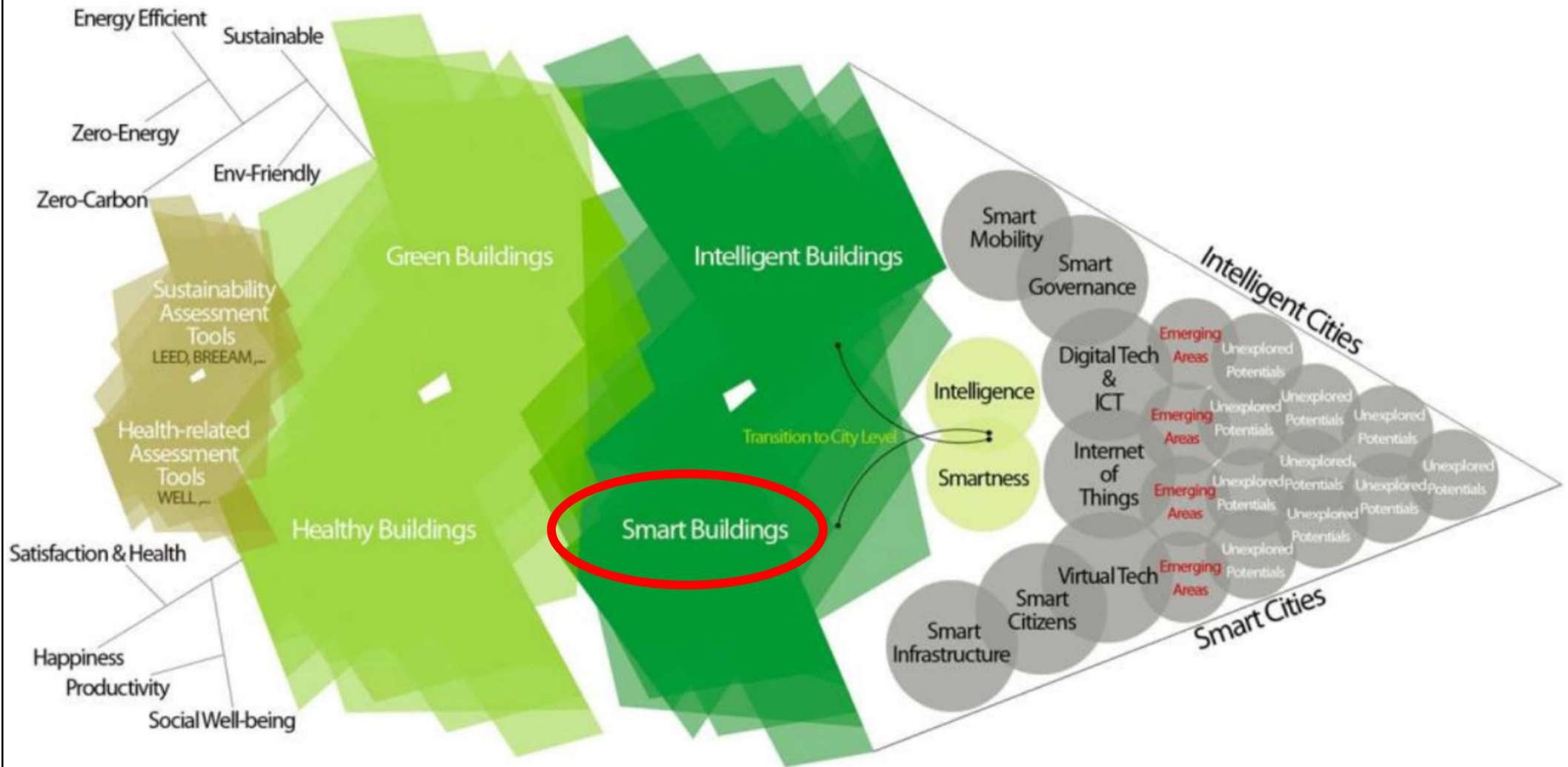
Building

- Decentralized renewable generation of power & heat
- Innovative energy storage technologies
- **Intelligent optimization of self consumption**
- **Participation in energy markets**
- Context / situation specific home automation

Urban Grids

- Effective solutions for grid monitoring and alarm handling
- **Adaptive LV grid management**
- **Operative and strategic grid planning**

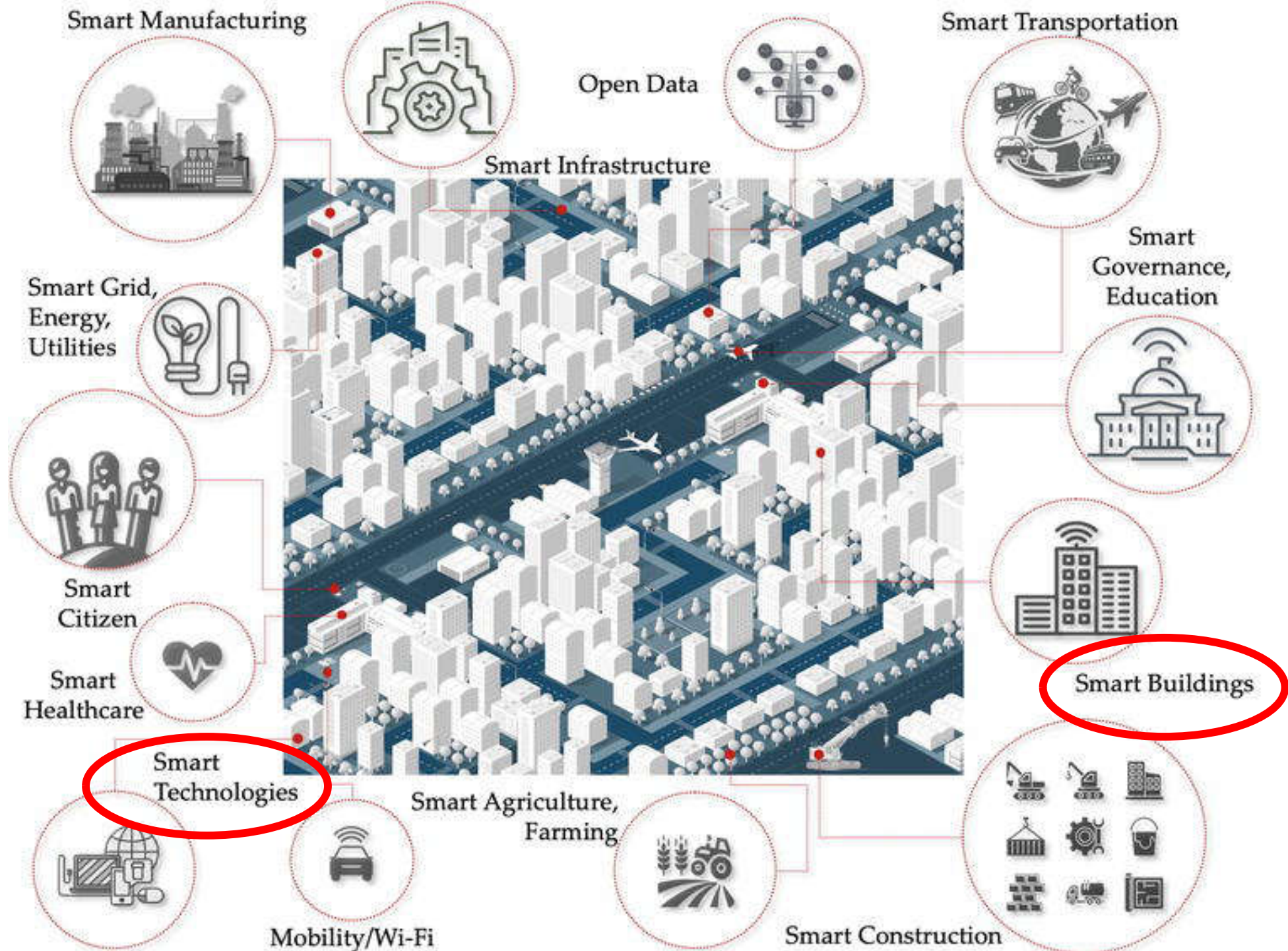
Overview of intelligent & smart buildings and cities concept



(Source: Ghaffarianhoseini A., AlWaer H., Ghaffarianhoseini A., Clements-Croome D., Berardi U., Raahemifar K. & Tookey J., 2018. Intelligent or smart cities and buildings: a critical exposition and a way forward, *Intelligent Buildings International Journal*, 10 (2) 122-129.

<https://doi.org/10.1080/17508975.2017.1394810>)

Smart buildings & smart components in a smart city



Integration of smart buildings to smart city infrastructure

Current “smart cities” are being driven primarily by people’s use of technology.



Evolution of smart building



- Evolution of buildings
 - 1. Conventional (with simple building control)
 - 2. Automated building (with building automation)
 - 3. Intelligent building (with telecom & computers)
 - 4. Smart building (with networks & Internet)
 - 5. Cognitive building (can learn & predict behaviour)
- Aims to offer occupants an efficient, flexible, safe & comfortable condition

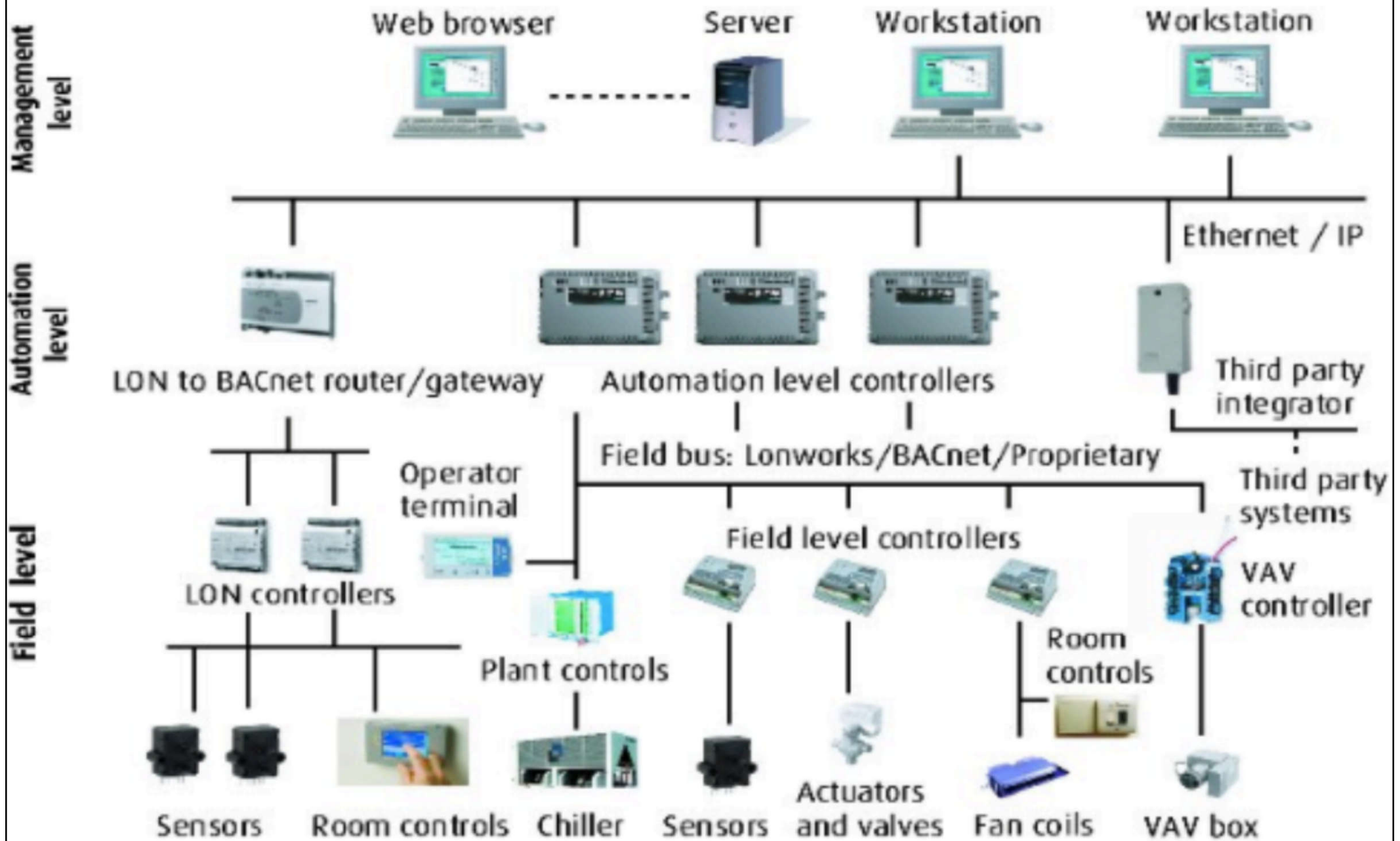
The evolution of smart building (1950s to 2000s)

Time	Evolution	Type of building management
1950s	<ul style="list-style-type: none"> • Using pneumatic control with compressed air in automated buildings • Execution of fire alarm system 	Building Control
1960s	<ul style="list-style-type: none"> • Emergence of analogue & then digital microprocessors • ‘Work saving time’ device implementation 	
1970s	<ul style="list-style-type: none"> • Systems for crime prevention & energy preservation 	
1980s	<ul style="list-style-type: none"> • Construction of the 1st intelligent building • Implementation of single-functional systems • Emergence of telecommunications & personal computers 	Intelligent Building
1990s	<ul style="list-style-type: none"> • Implementation of multi-functional systems • Supporting communication among controlled facilities by open protocols 	Building Automation
2000s	<ul style="list-style-type: none"> • Implementation of systems integrated with computers • Utilizing Internet protocol (IP) network technologies & boosted network capacity • Emergence of Wi-Fi • Achieving remote monitoring & control through the Internet 	Building Performance

The evolution of smart building (2010s to now)

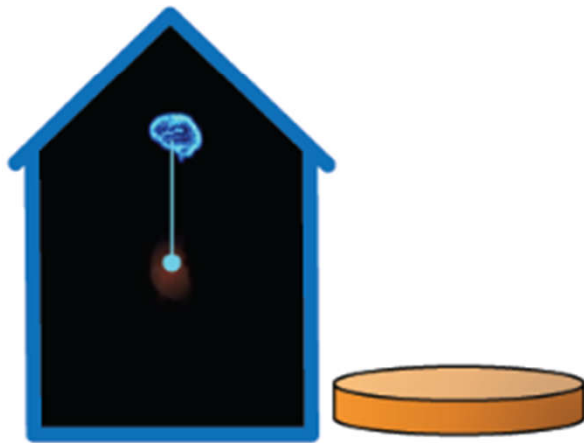
Time	Evolution	Type of building management
2010s	<ul style="list-style-type: none"> • Implementation of enterprise network-integrated systems • Delivering multiple services by combining BAS & IT through <ul style="list-style-type: none"> • Internet Protocol network • Integration & management because of modern IT technologies e.g., Web Services, XML, distance portfolio management & helpdesk management, multimedia communication via cellular phone • Emergence of BIM & embedded intelligence 	Smart Building
2020s	<ul style="list-style-type: none"> • Integration of building & industrial PLC system, cloud computing & IoT, data mining & data-centric energy management, cyber security & protection, hardware & software analytics, the progress of Smart City, and utility meter monitoring & reporting 	

Illustration of three-layer building automation system (BAS) architecture



Evolution of buildings & their integration with management systems

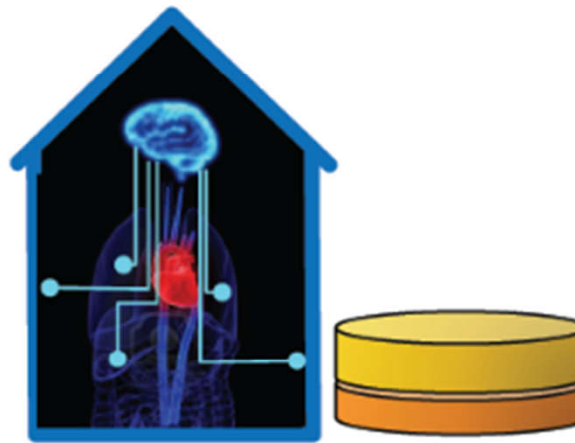
Automated Buildings (1980 – 2000)



Control & Visualise KPIs

- + Good for manual monitoring
- + Allows identifying general issues
- Not enough data to identify energy waste

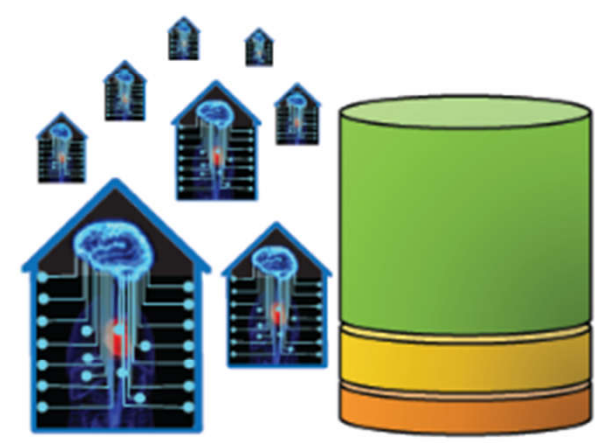
Smart Buildings (2000 – 2015)



Energy Management

- + Monitors consumption of main assets and consumers
- Only primary datapoints are analyzed

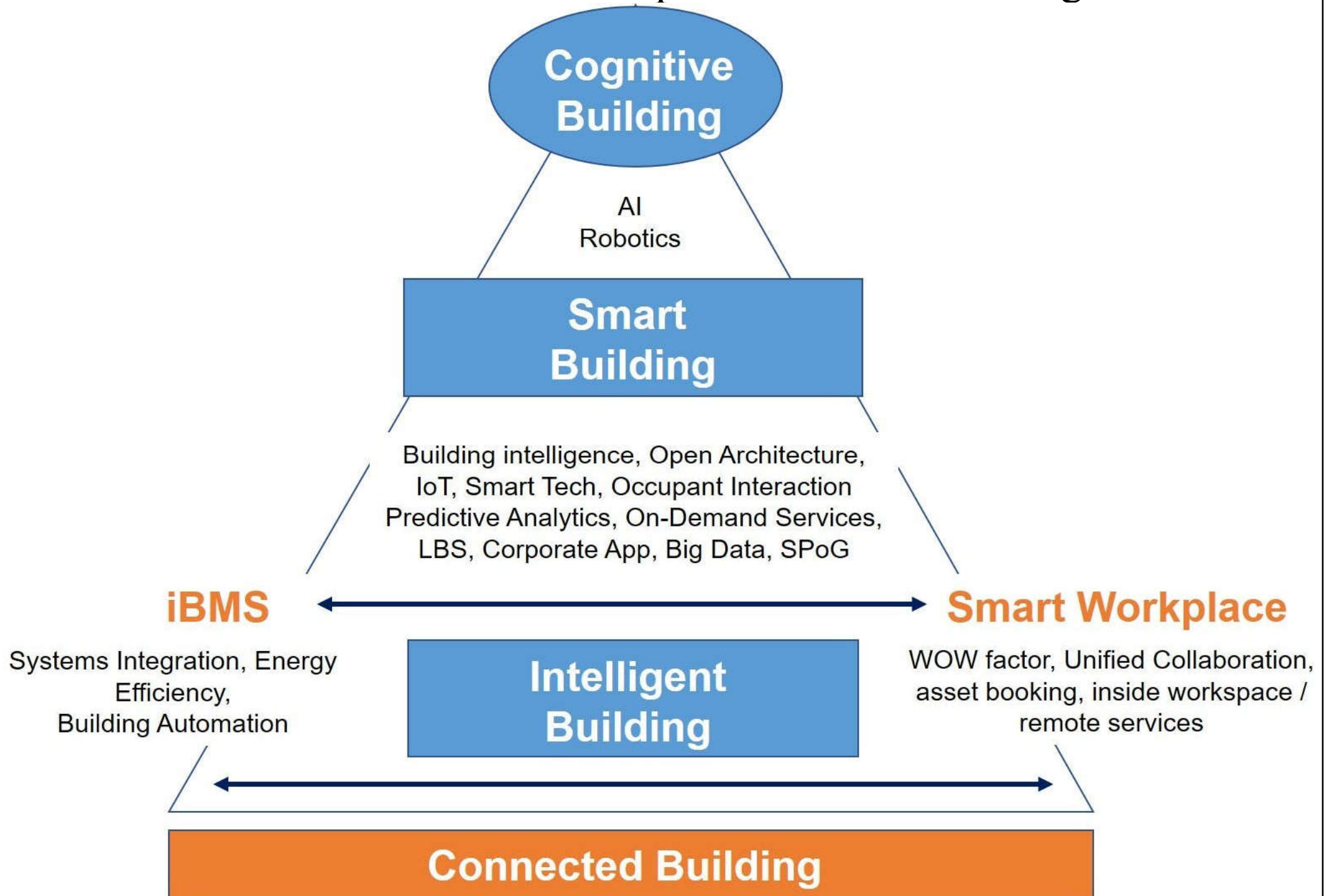
Cognitive Buildings (> 2016)



Learn & Predict Behaviour

- + Predictive control down to desk level
- + Understand energy flow and building occupancy
- + Consider comfort preferences of users and context such as weather
- Requires new analytics to deal with the amount of data

Current & future development of smart building

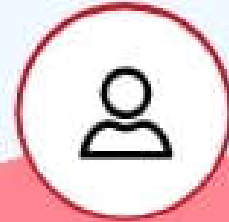


Development of different generations of smart buildings



1st Generation Smart Buildings

Firstly, the focus was on building create infrastructure to gain occupants' attention



2nd Generation Smart Buildings

Extended the flexibility of owners & occupants' by integrating the Internet of things.



3rd Generation Smart Buildings

Transforming buildings into agile, automated, sustainable ecosystems. Propelled by lot platforms.

Evolution of smart building



- Current definition of smart buildings are the concentration on the users & the interaction with the user of a building in high levels
 - Capability to adjust itself to different surrounding parameters & conditions using outward context-led data on the behaviour of the users
- Applicable information is acquired within a smart building to facilitate the management of the environment by the users/occupants

Building operational technology & external information technology for smart buildings



Evolution of smart building



- In most recent research smart buildings are:
 - Defined as those which benefit from the efficient & cutting-edge sensors & electronic devices as per connected together & communicate with each other to generate a large amount of data (Big Data), to control & manage the building smartly to boost reliability & performance of the building & reduce energy consumption & cost; more importantly to provide a desirable, flexible & safe environment for occupants

Evolution of smart building



- Key features of modern smart buildings:
 - 1) Environmental friendliness
 - 2) Flexibility & utilization of space
 - 3) Add value quality to economic life cycle cost
 - 4) Well-being & health of the occupants
 - 5) Efficient working
 - 6) Security & safety actions
 - 7) Culture – address the expectations of the client
 - 8) Innovation & effectiveness of technology
 - 9) Management & construction procedures
 - 10) Sanitation & health (e.g. during COVID-19)

Evolution of smart building



- Smart buildings in the 21st century
 - They are now capable of making connections between people & surrounding environments such that buildings are more responsive to the demands of users & city in a more sustainable fashion which consequently boost human's wellbeing
 - Industry 4.0 with the integration of Internet of Things (IoT) & digital data analytics
 - Artificial intelligence (AI)-based systems, cloud-based platform, blockchain technology

Evolution of smart building

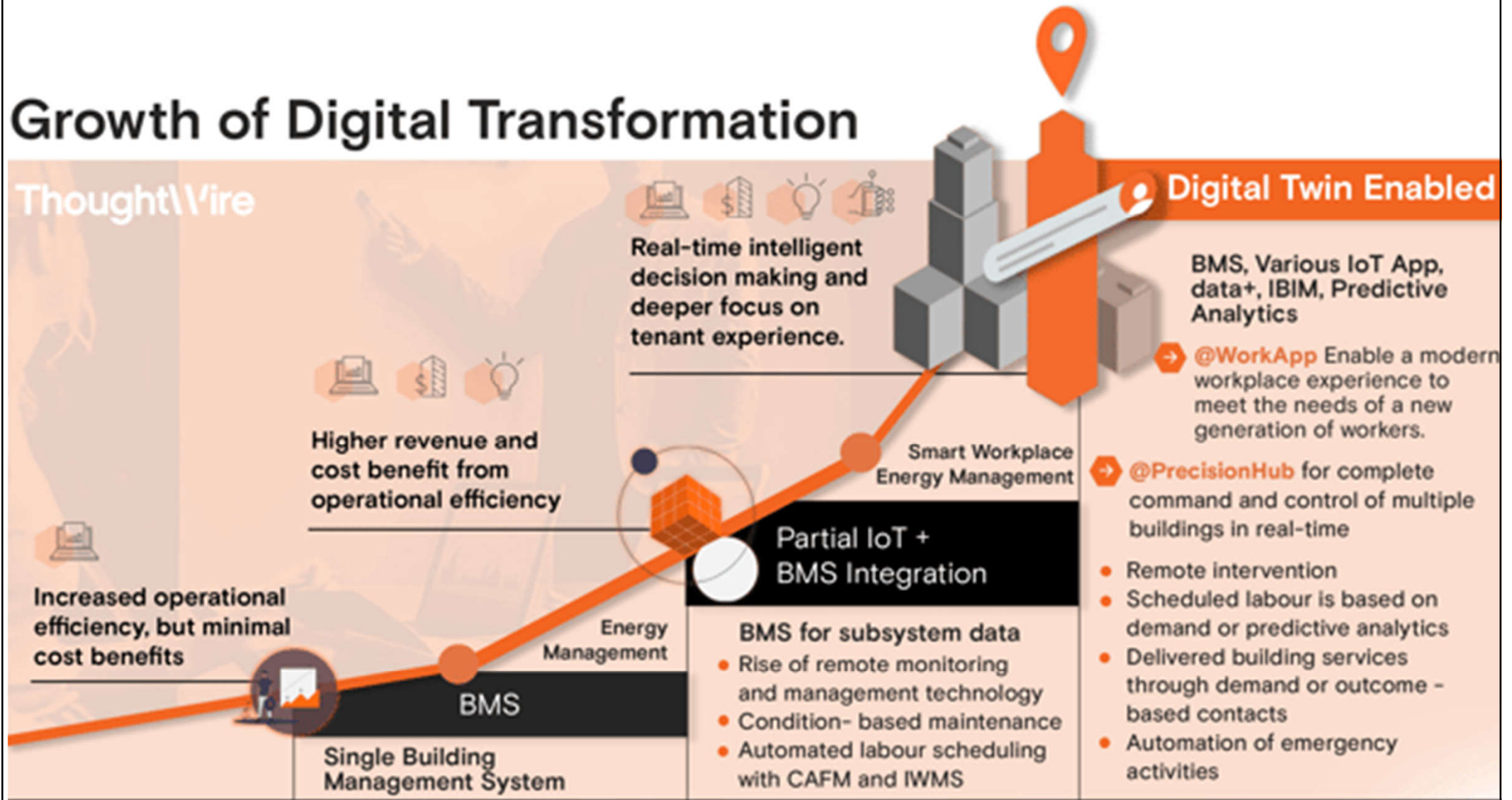


- Technology trends in future smart buildings:
 - 1) Accommodate a cloud-based IoT platform
 - 2) Organize smart building technology via multiple asset-distinct IoT Platforms
 - 3) More adaptable to the fast change of demands and needs & focus more on sustainability aspects
 - 4) Will be highly user-centric, with advanced & innovative analytics, system integration & edge computing (improve remote building management services & maintenance)

Growth of digital transformation & smart building evolution (from limited control to a fully integrated digital twin)

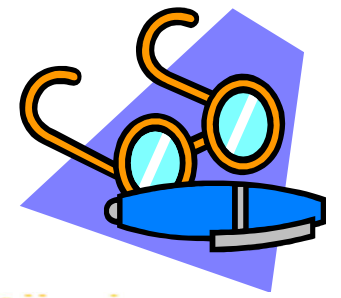
Growth of Digital Transformation

ThoughtWire

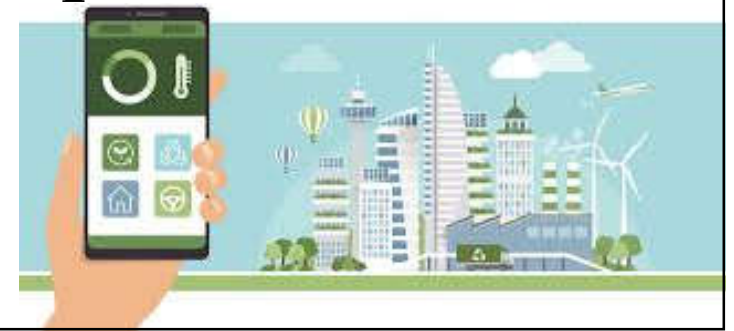


Smart Building Evolution

Future development



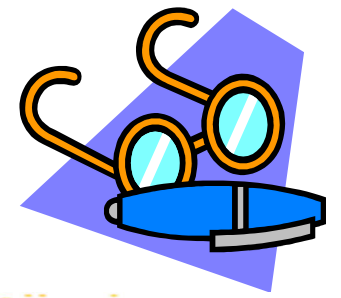
- Smart buildings depict the evolvement of the most up-to-date infrastructure & integration of automated control systems, data computing & artificial intelligence
- They can adapt itself to the surroundings according to both inner & outer parameters and can learn, interact & self-adapt to the needs of the occupants



Current & emerging technologies of smart buildings

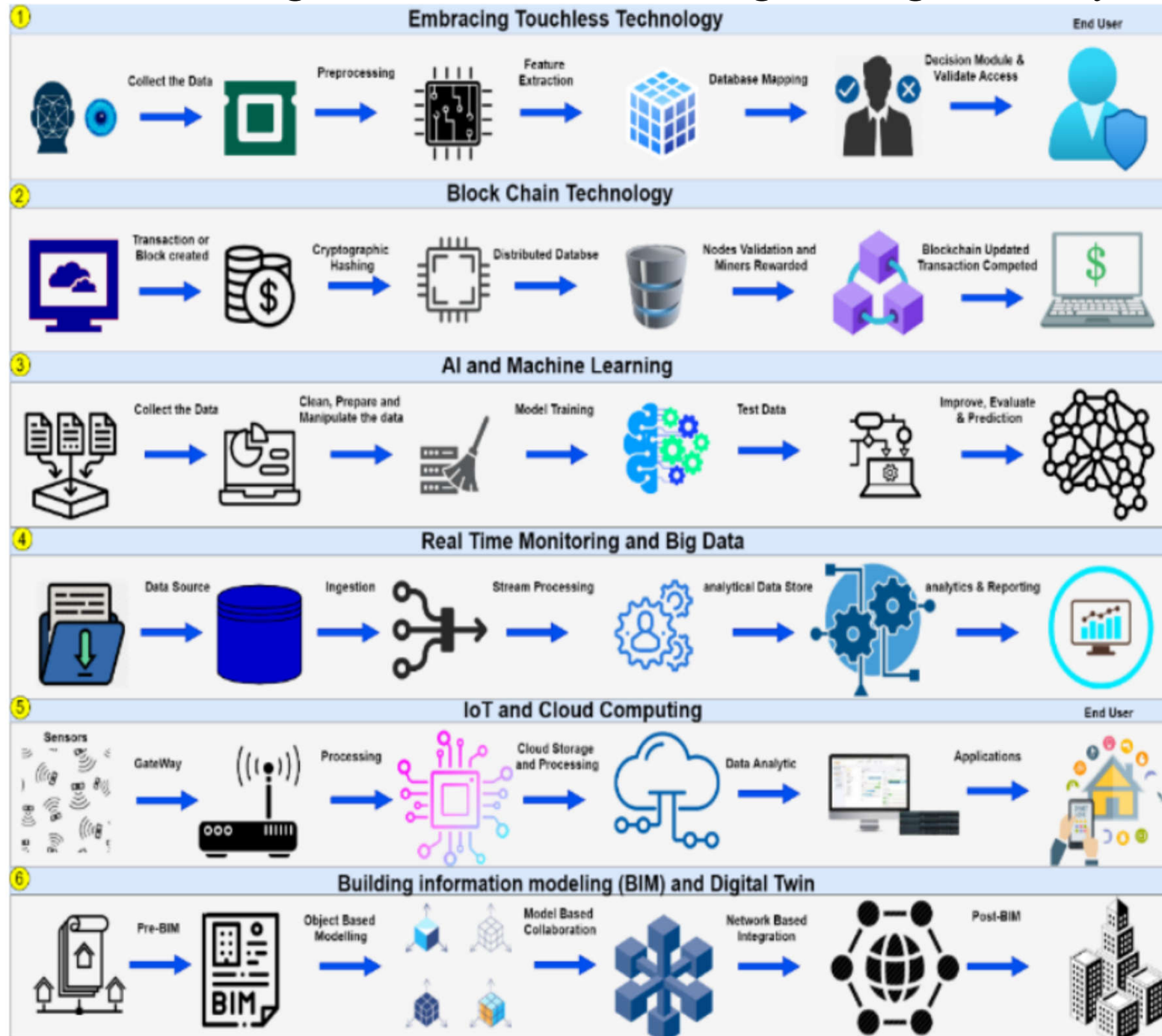


Future development



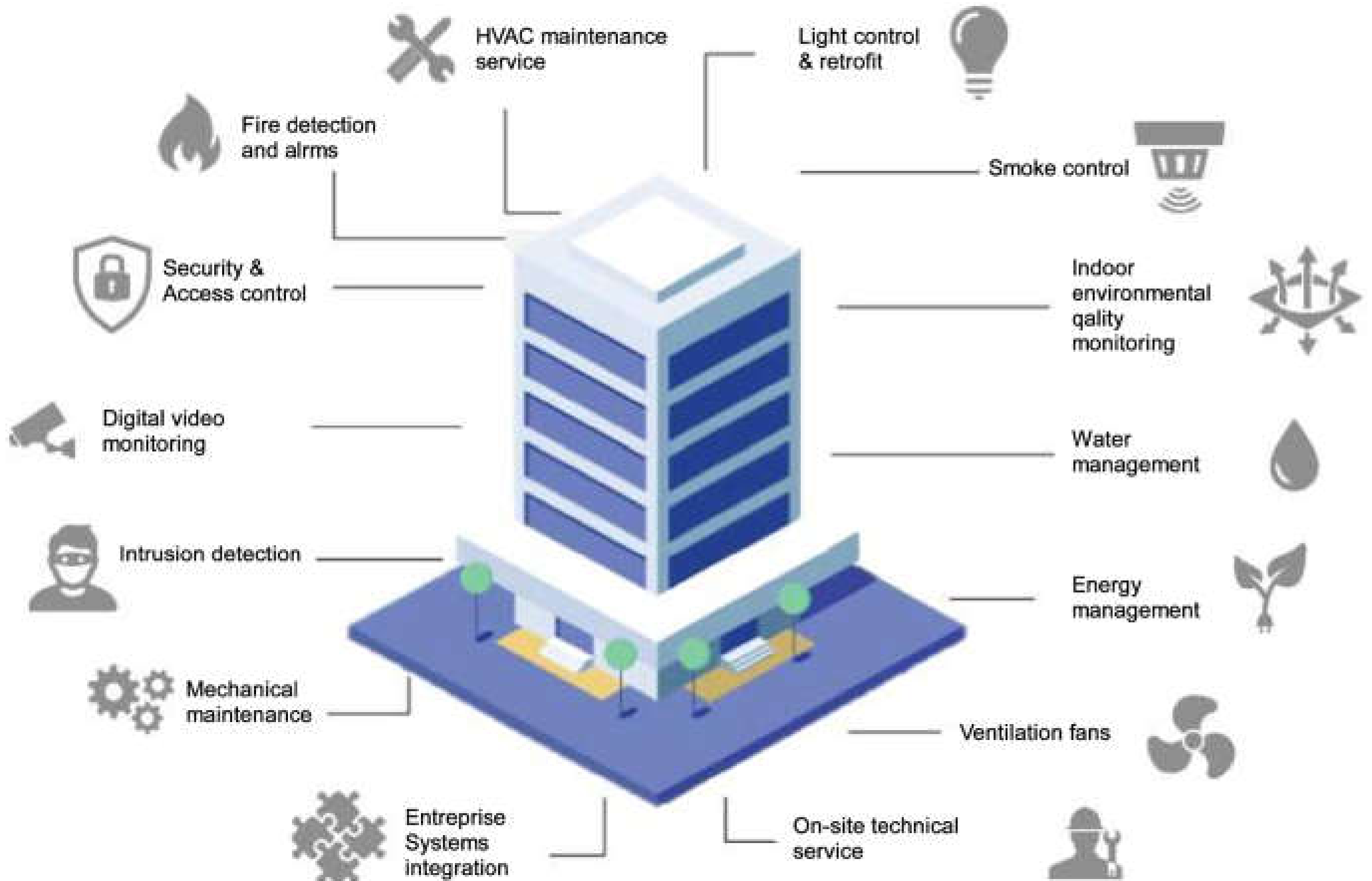
- Latest technology trends:
 - 5G & Wifi 6 with high-speed communication
 - Edge computing to improve response time & save bandwidth
 - Artificial intelligence (AI), machine learning (ML), digital twin (DT), blockchain
 - Smart living, smart healthcare & smart city
 - Wearable technology & devices, smart mirrors
 - Robotics, smart materials, drones
 - Virtual reality (VR), augmented reality (AR)

Smart technologies model for building management system



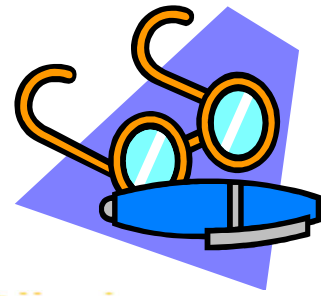
(Source: Singh D. & Singh A., 2023. Role of building automation technology in creating a smart and sustainable built environment, *EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy*, 10 (01) 412-420. <http://dx.doi.org/10.5109/6781101>)

AI-big data analytics for building automation systems



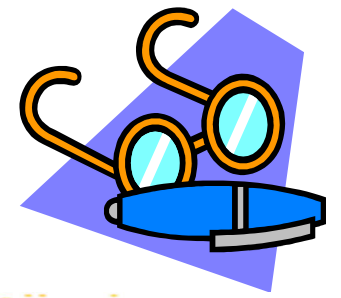
(Source: Himeur Y., Elnour M., Fadli F., Meskin N., Petri I., Rezgui Y., Bensaali F. & Amira A., 2023. AI-big data analytics for building automation and management systems: a survey, actual challenges and future perspectives, *Artificial Intelligence Review*, 56: 4929-5021. <https://doi.org/10.1007/s10462-022-10286-2>)

Future development



- New technologies for smart buildings:
 - 1. Smart sensor utilization
 - 2. Big data analytics & engineering
 - 3. Fault detection & diagnostics (FDD)
 - 4. Fog & cloud computing
 - 5. Development of software engineering & algorithms of human-computer interaction
 - 6. Building dashboards & indoor positioning
 - 7. Smart windows & smart mirrors

Future development



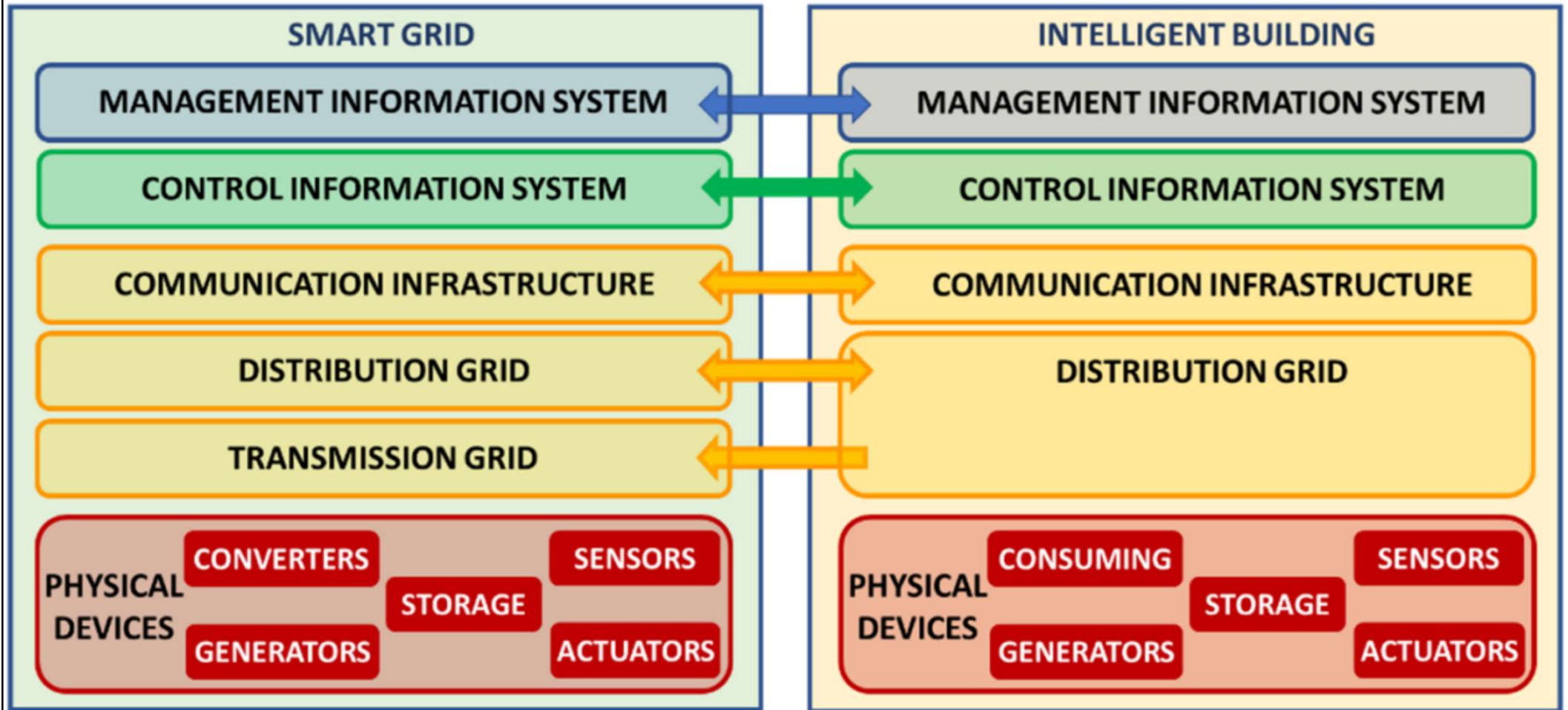
- Smart grid & smart energy integration

- Aims at energy efficiency, emission reduction goals & other climate change-related issues (e.g. decarbonisation)

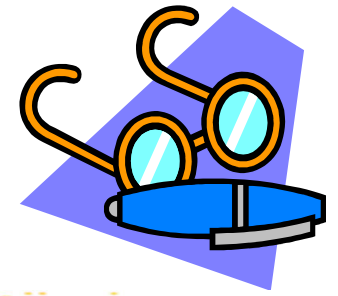


- Integration of renewable sources, storage systems & predictive control algorithms
- Consider the complex energy interactions between buildings (grid flexibility services, demand side management, energy monitoring platforms)

Integration of intelligent building (IB) & smart grid (SG)

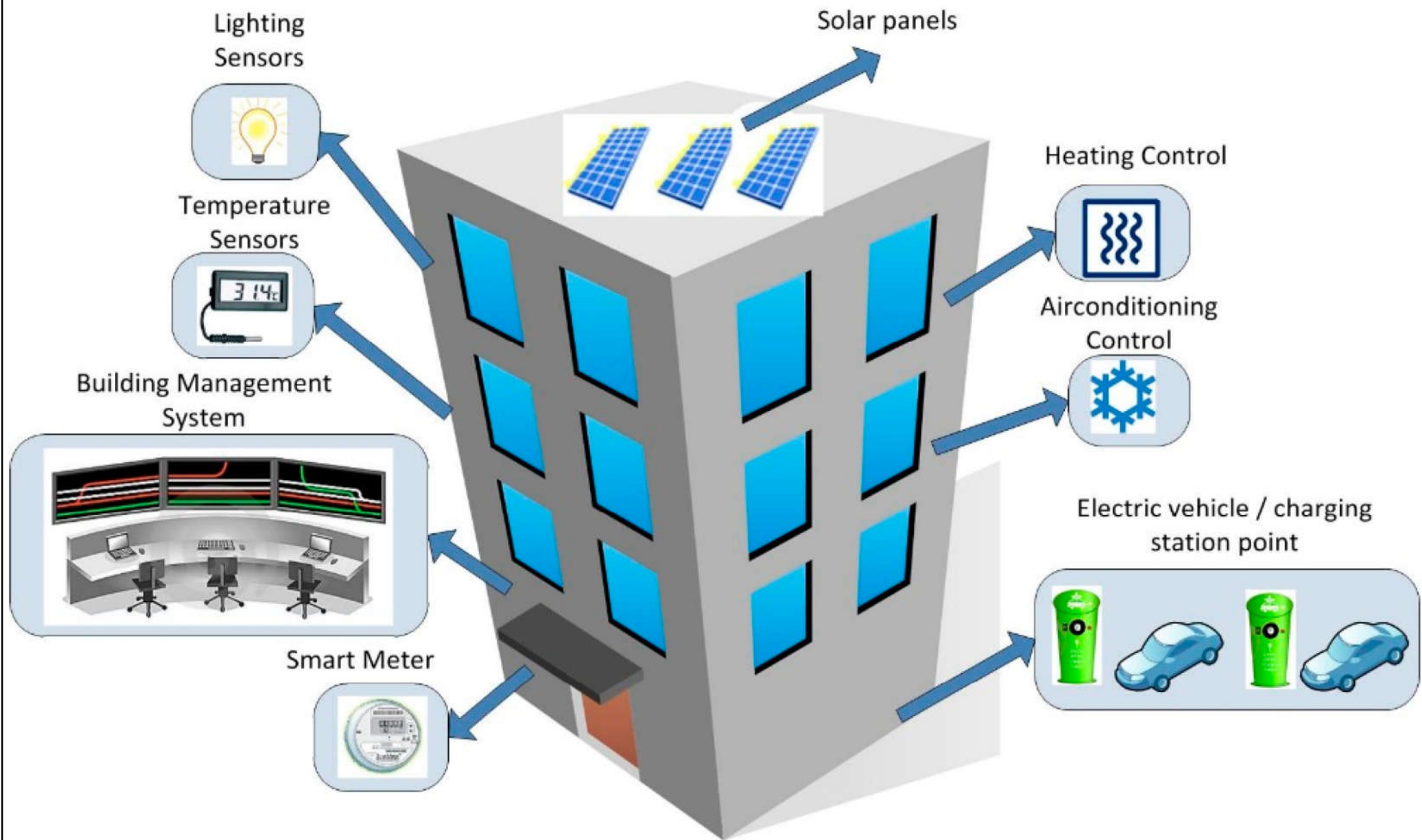


Future development

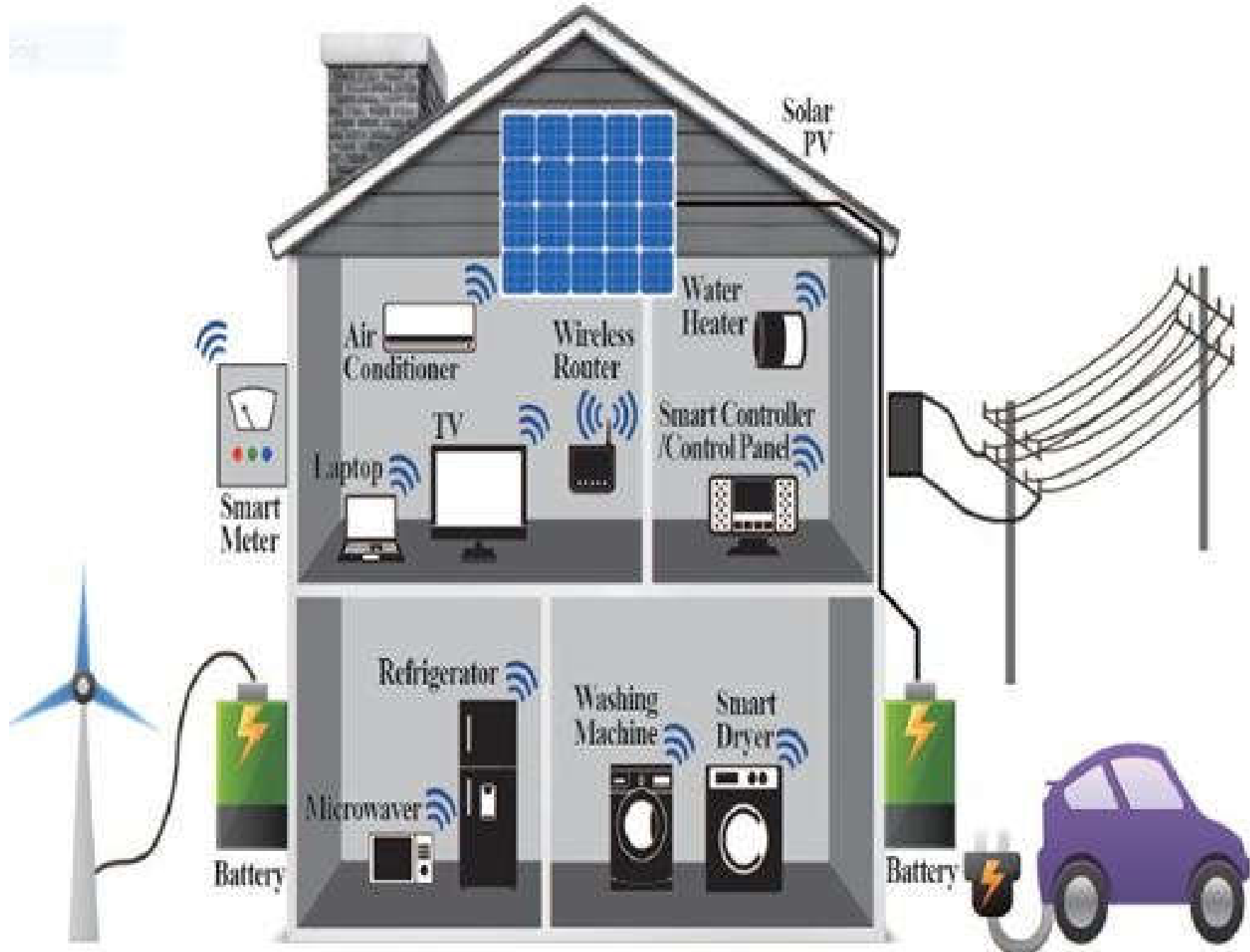


- Features of smart building to work with smart grid:
 - Energy load coordination
 - Advanced control of HVAC, lighting & any other energy systems, including data collection, to increase performance
 - Diagnostics & reporting functions, with integrated automation to measure energy & greenhouse gas emissions
 - Ongoing two-way information exchange between the grid & the building
 - On-demand response to pricing signals received from the grid

A smart building & its various energy management options



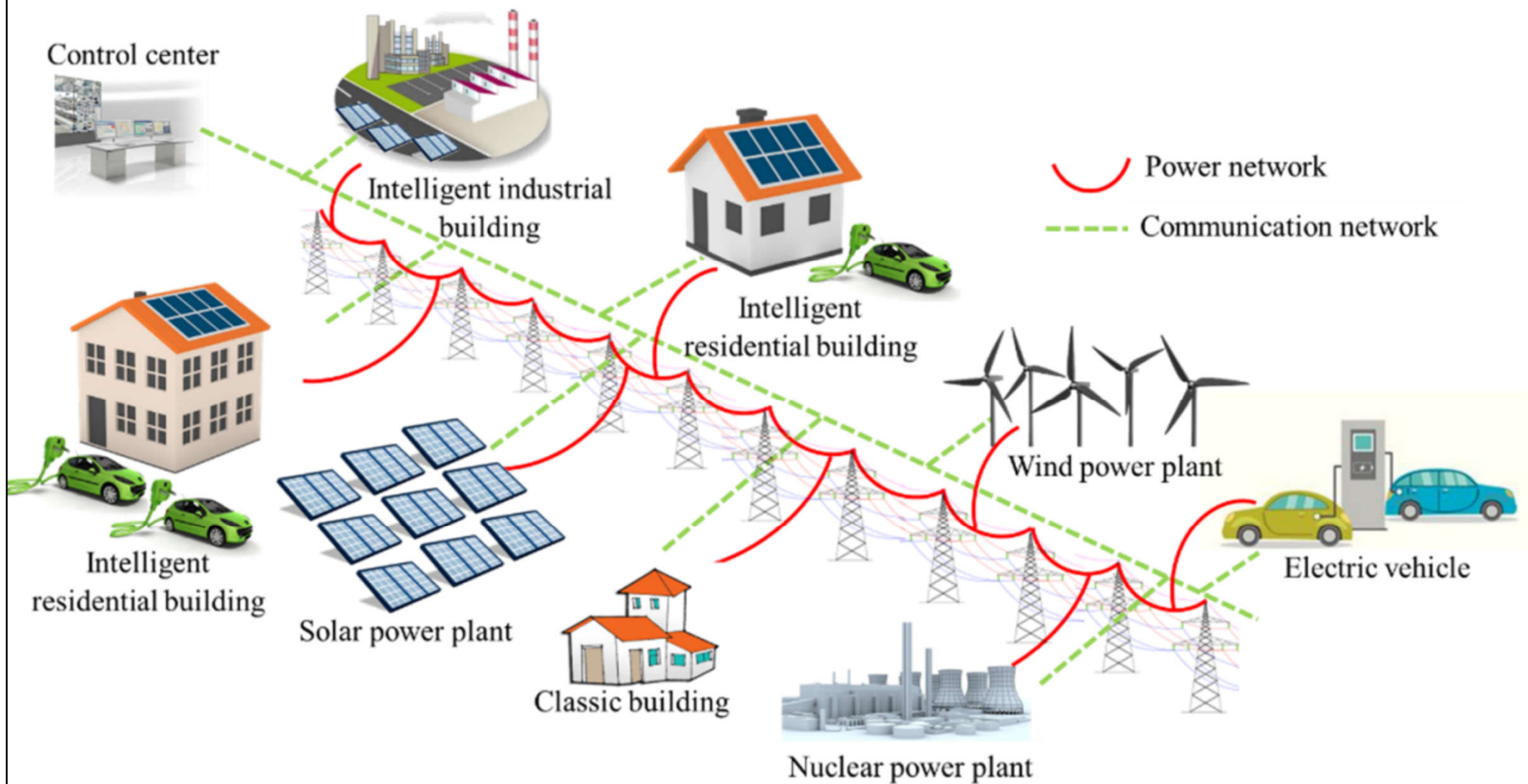
Future smart home integrated with renewable energy for optimization



(Source: Swalehe H., Chombo P. V. & Marungsri B., 2018. Appliance scheduling for optimal load management in smart home integrated with renewable energy by using whale optimization algorithm, *GMSARN International Journal*, 12: 65-75.

<https://www.researchgate.net/publication/325596107>)

Intelligent buildings as systems within the whole smart grid





Further reading

- The ultimate guide to smart buildings
<https://www.mapspeople.com/smart-buildings>
- What is a Smart Building?
<https://www.resonai.com/blog/what-is-a-smart-building>
- Eight Major Benefits of Smart Buildings (and How to Capitalize on Them) <https://spaceiq.com/blog/smart-building-benefits/>
- Smart Built Environment Including Smart Home, Smart Building and Smart City: Definitions and Applied Technologies <https://www.intechopen.com/chapters/74934>