EMERGING SMART GREEN BUILDING TECHNOLOGIES

A wide array of smart building technology has transformed the way buildings are built and operated. Such technology advancements will continue to shape future building management by further driving operational efficiencies and sustainability outcomes. Table 3 presents examples of emerging smart green building technology and trends that are anticipated to be available in the market in the future.

Advanced Building Materials	
Aerogel insultation materials	Aerogel insulation material makes use of a hydrophobic nanoporous aerogel structure to produce an ultra-thin wall insulation. It can also be applied to produce silica-based products – a core material for super-insulating windows installed in buildings.
Graphene	Graphene is a sheet of single carbon atoms bonded together in a honeycomb shape. It has been referred to as a miracle material as it is 200 times the strength of steel and 6 times lighter, as well as being biodegradable. Graphene can be incorporated in concrete production to create a composite material 2 times stronger and 4 times more water-resistant than traditional concrete.
Self-healing materials	Self-healing materials are synthetically created substances that can repair damage to themselves without any external diagnosis of the problem or human intervention. Using self-healing materials reduce repair costs and enhance building safety. There is growing potential to incorporate self-healing capabilities into concrete, steel, and glass.
Sensor embedded composite materials	A composite material is made when 2 or more existing materials are combined to create a unique material with new characteristics distinct from the original components. When bringing materials together, it is also possible to add a sensing element to monitor and report on any changes in the materials, such as stresses and strains, or the environment around it. Increasing demand for structural health monitoring in buildings has recently stimulated research into composite materials that have embedded sensing capabilities.
Smart bricks	Smart bricks have the capacity for thermal energy control. With their modular design, smart bricks are easy to connect and create space to accommodate electricity and plumbing networks in buildings.
Building Management and Operations	
Blockchain	Blockchain is a growing list of records, referred to as blocks, which are linked and secured using cryptography. A blockchain has no central owner but is a distributed ledger that is replicated, shared, and synchronised across systems and geographies. Blockchain can connect data-generating machines inside buildings to enhance building operations.
Horizontal elevators	Horizontal elevators offer many advantages compared to vertical elevators. Vertical elevators can occupy a substantial amount of floor space of the building. Since horizontal elevators can transport more people in a single shaft, the buildings can afford to have fewer and smaller shafts. Hence, horizontal elevators can increase the usable floor area of a building, therefore increasing the building's commercial value.
Recirculating shower	A recirculating shower system filters used water and allows the water to be reused immediately. Together with advanced water treatment facilities, this system can be used to facilitate grey water reuse and smart water management in buildings.
Smart dust	Smart dust refers to tiny wireless Micro Electromechanical Systems (MEMS), which can detect everything from light, temperature and pressure to vibrations, magnetism, and chemical composition. Smart dust can serve as sensors within buildings to facilitate the operations of smart building functions. Smart dust can detect structural stresses of buildings and initiate warnings if necessary.

Energy Performance	
Advanced battery technologies	Recent breakthroughs in battery technologies, such as gold nanowire batteries. These batteries can be recharged 200,000 times in 3 months with no performance degradation – remarkable capacity relative to today's batteries. Advanced battery technologies can be coupled with the building's energy storage system to improve energy efficiency and reliability.
Perovskites solar cells	Perovskites present great prospects at becoming the core material of solar panels. It is cheap and has greater sunlight absorbing capabilities compared to silicon. This material reduces the cost of solar panels and allows for a wide variety of affordable solar solutions in buildings, from rooftop panels to vertical panels.
Piezoelectric technology	Piezoelectric materials can generate electricity from vibrations and mechanical stress. For example, if a road is embedded with Piezoelectric material, it can generate electricity from cars moving on top of it. In buildings, floors equipped with piezoelectric technology can generate electricity from people walking on it.
Thermal elastic metal	Thermal elastic metal serves as a solid coolant, which replaces conventional liquid refrigerants in air conditioners. This results in greater energy efficiency and carbon emission reduction.
Wireless charging	Wireless charging utilises simple inductive mechanisms to transfer energy between a power source and a battery situated in a device. Electricity is transmitted by changes in magnetic field intensity between two coils. This enables greater flexibility for building management and operations whilst enhancing user convenience. For example, it can be applied to electric vehicle (EV) vehicle charging.

Table 3 – Emerging trends in smart green building technology

LINKAGE TO BUILDING TYPES

The table below shows the linkage between the 32 recommended smart green strategies and the applicable building types for implementation. For further details on the strategies, please refer to Appendices A to F.

	Building Types	Building Types								
			Industrial		Functional			Commercial		
	Building Types	Residential	Factories / Warehouses	Data Centres	Educational Facilities	Hospitals	Other Community Facilities	Retail	Office	Large district developments
	Building Design & Operations									
A1	Building Information Modelling	•	•	•	•	•	•	•	•	•
A2	Digital Twin	•	•	•	•	•	•	•	•	•
A3	Near Field Communications	•	•	•	•	•	•	•	•	
A4	Robotics for Building Operations	•	•	•	•	•	•	•	•	
A5	Integrated Facility Management System	•	•	•	•	•	•	•	•	
A6	Washroom of the Future		•	•	•	•	•	•	•	
A7	Smart Space Utilisation			•				•	•	
A8	Smart Surveillance	•	•	•	•	•	•	•	•	•
	Health & Wellbeing									
B1	Advanced Solar Technologies for Natural Lighting	•		•	•	•	•	•	•	
B2	Smart Artificial Lighting	•	•	•	•		•	•	•	
B3	Smart Thermal Control	•	•	•	•		•	•	•	
B4	Biophilic Design	•	•	•	•	•	•	•	•	
B5	Smart Air Filtration	•	•	•	•	•	•	•	•	
B6	Smart Light Poles									•
B7	Occupant Automation System	•	•	•					•	
	Energy Performance									
C1	Automated Fault Detection and Diagnostics	•	•	•	•	•	•	•	•	•
C2	Smart Grid Compatibility and Technology	•	•	•	•	•	•	•	•	•
C3	Energy Storage System	•	•	•	•	•	•	•	•	•
C4	High Performance Chillers and Refrigerants	•	•	•	•	•	•	•	•	•
C5	High Efficiency Motors and Drives	•	•	•	•	•	•	•	•	•
C6	Solar Technology for Energy Generation	•	•	•	•	•	•	•	•	•
C7	Micro-wind Turbines	•	•	•	•	•	•	•	•	•
	Material & Waste Management									
D1	Smart Dynamic Glass	•	•	•	•	•	•	•	•	
D2	Nanotechnologies	•	•	•	•	•	•	•	•	•
D3	Automatic Waste Collection Systems	•					•	•	•	
	Water Performance									
E1	Smart Water Metering and Monitoring	•	•	•	•	•	•	•	•	•
E2	Water Efficiency Fixtures and System Controls	•	•	•	•	•	•	•	•	•
E3	Grey Water Reuse and Harvesting Rainwater	•	•	•	•	•	•	•	•	•
E4	Smart Irrigation	•	•	•	•	•	•	•	•	•
	Mobility & Transportation									
F1	Smart Green Parking	•	•	•	•	•	•	•	•	
F2	Intelligent People Flow	•	•	•		•			•	•
F3	Autonomous Vehicles									

Table 6 – Linkage between 32 recommended smart green strategies and applicable building types for implementation

Building Design & Operations

The infographic below illustrates how the various strategies related to building design & operations could be implemented in a building:

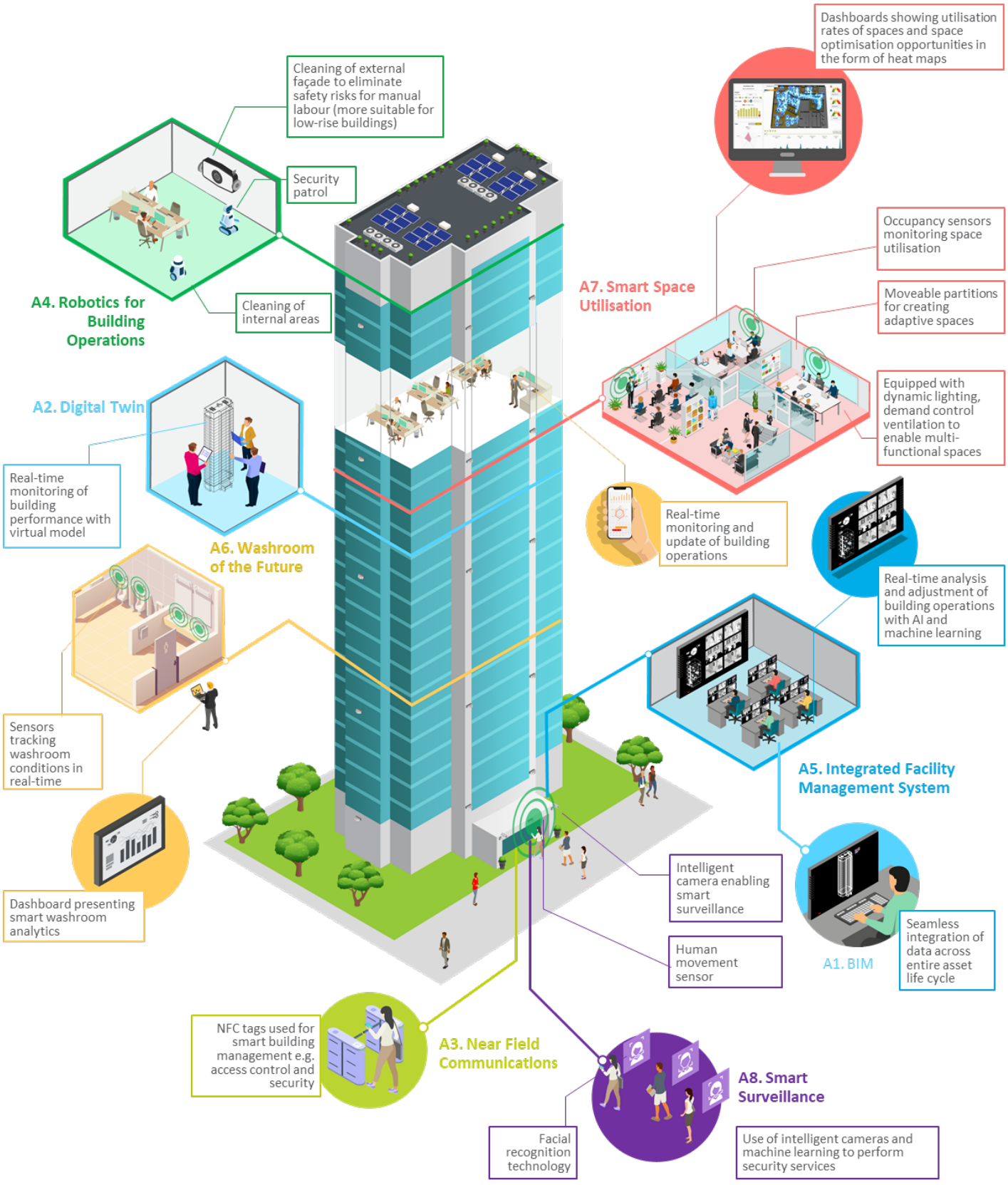

Figure 4 – Building strategies on building design & operations

Health & Wellbeing

The infographic below illustrates how the various strategies related to health & wellbeing could be implemented in a building and its surrounding built environment:

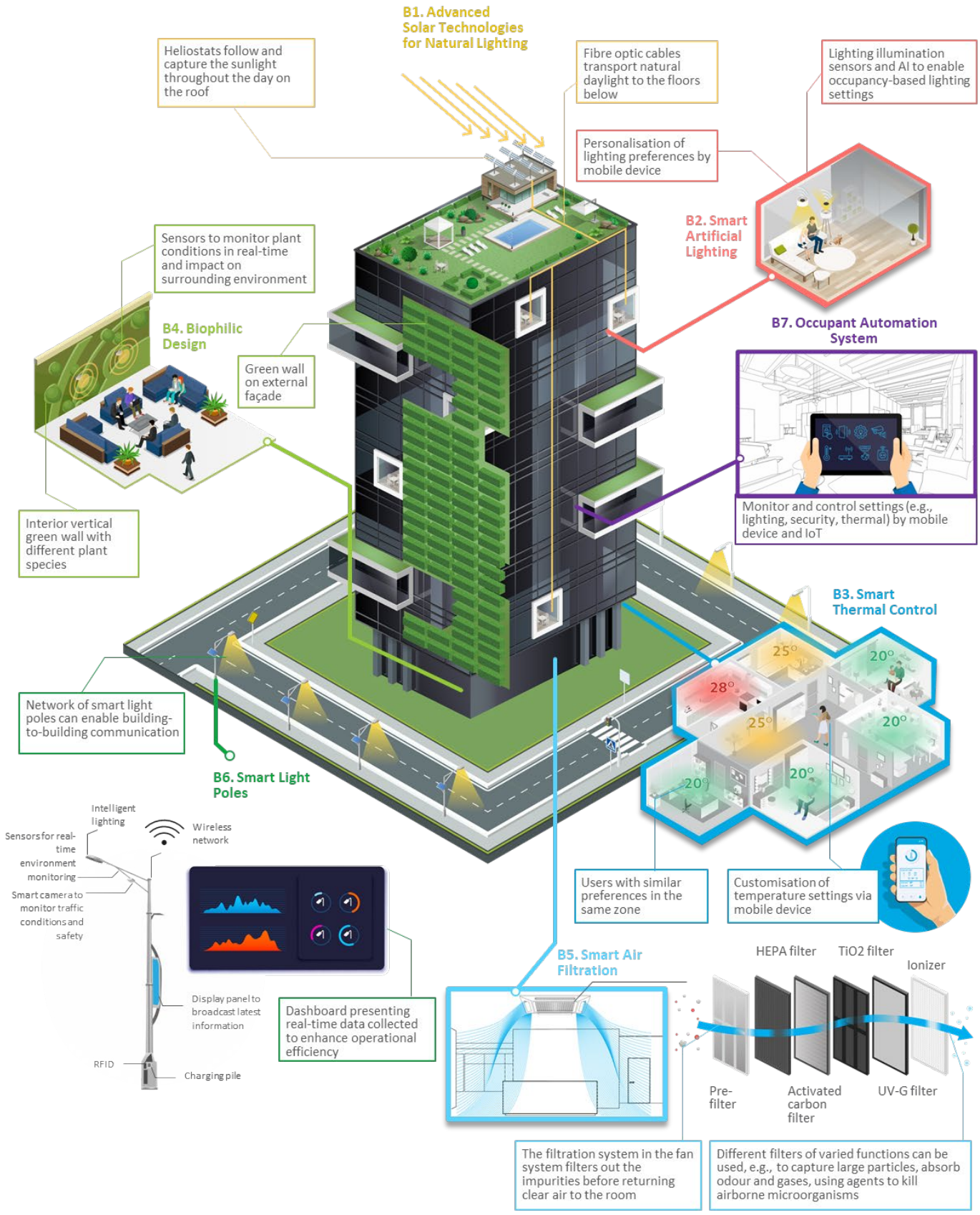

Figure 5 – Building strategies on health & wellbeing

Health & Wellbeing

The infographic below illustrates how the various strategies related to health & wellbeing could be implemented in a building and its surrounding built environment:

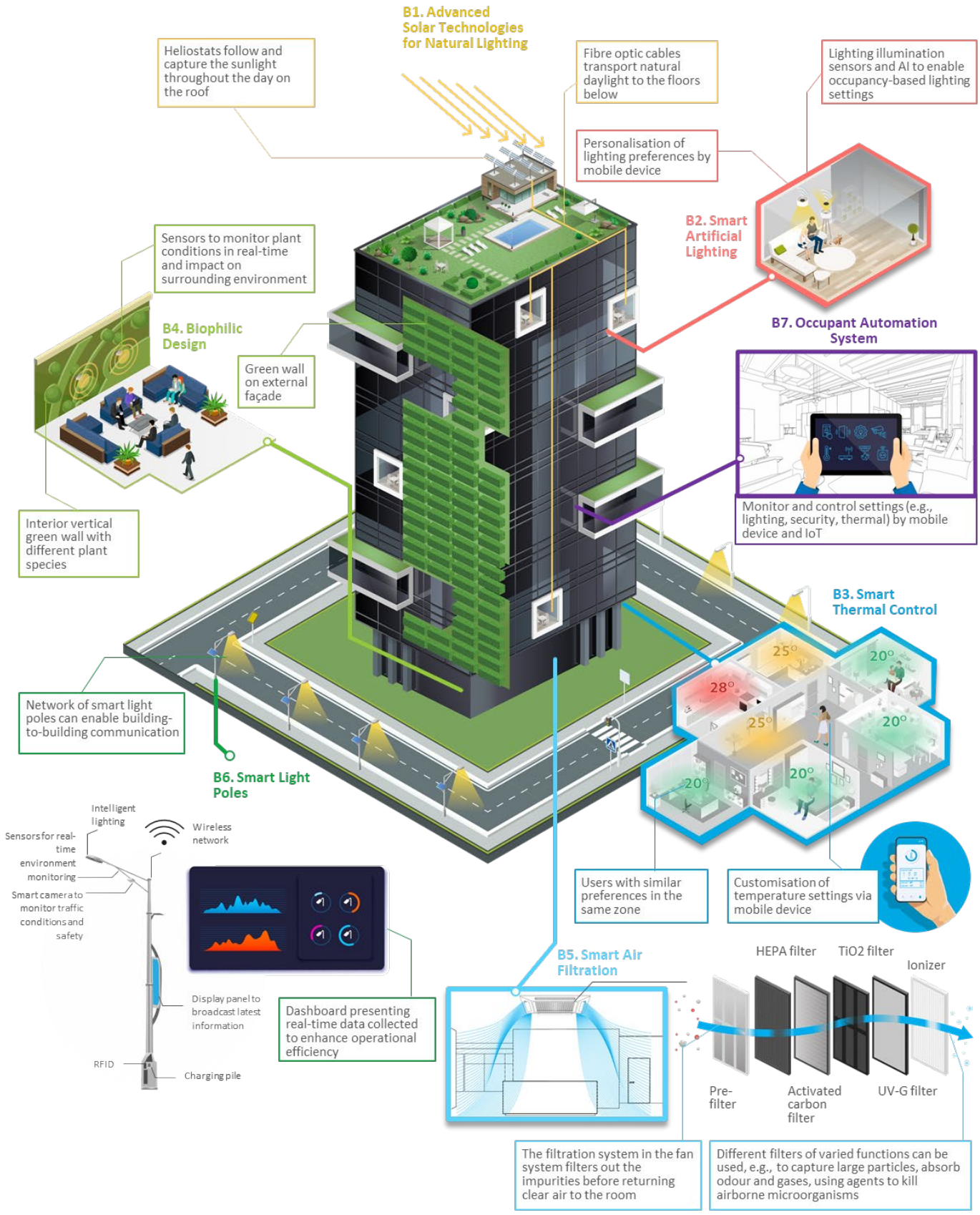

Figure 5 – Building strategies on health & wellbeing

Energy Performance

The infographic below illustrates how the various strategies related to energy performance could be implemented in a building and its surrounding built environment:

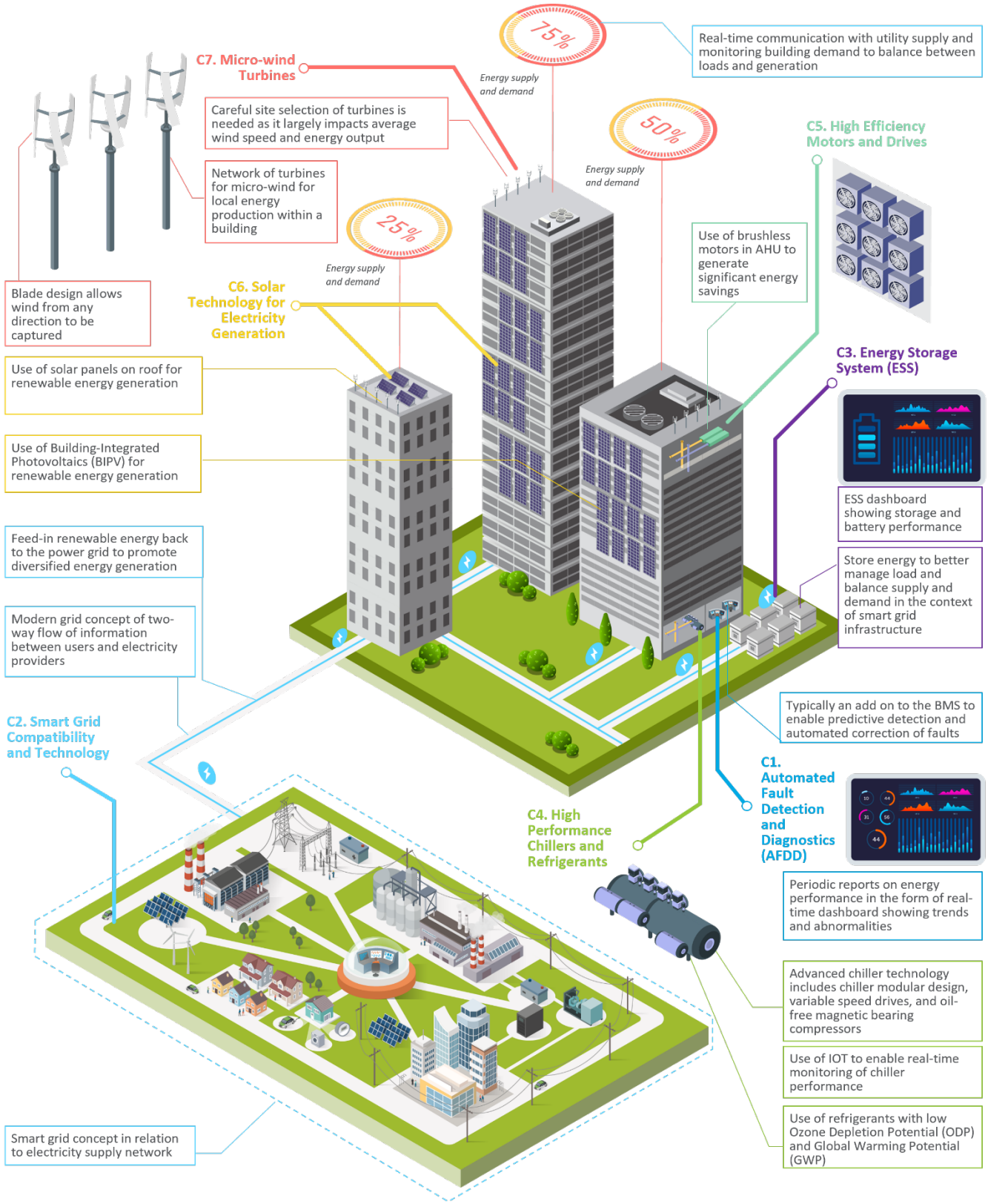

Figure 6 – Building strategies on energy performance

Material & Waste Management

The infographic below illustrates how the various strategies related to material & waste management could be implemented in a building and its surrounding built environment:

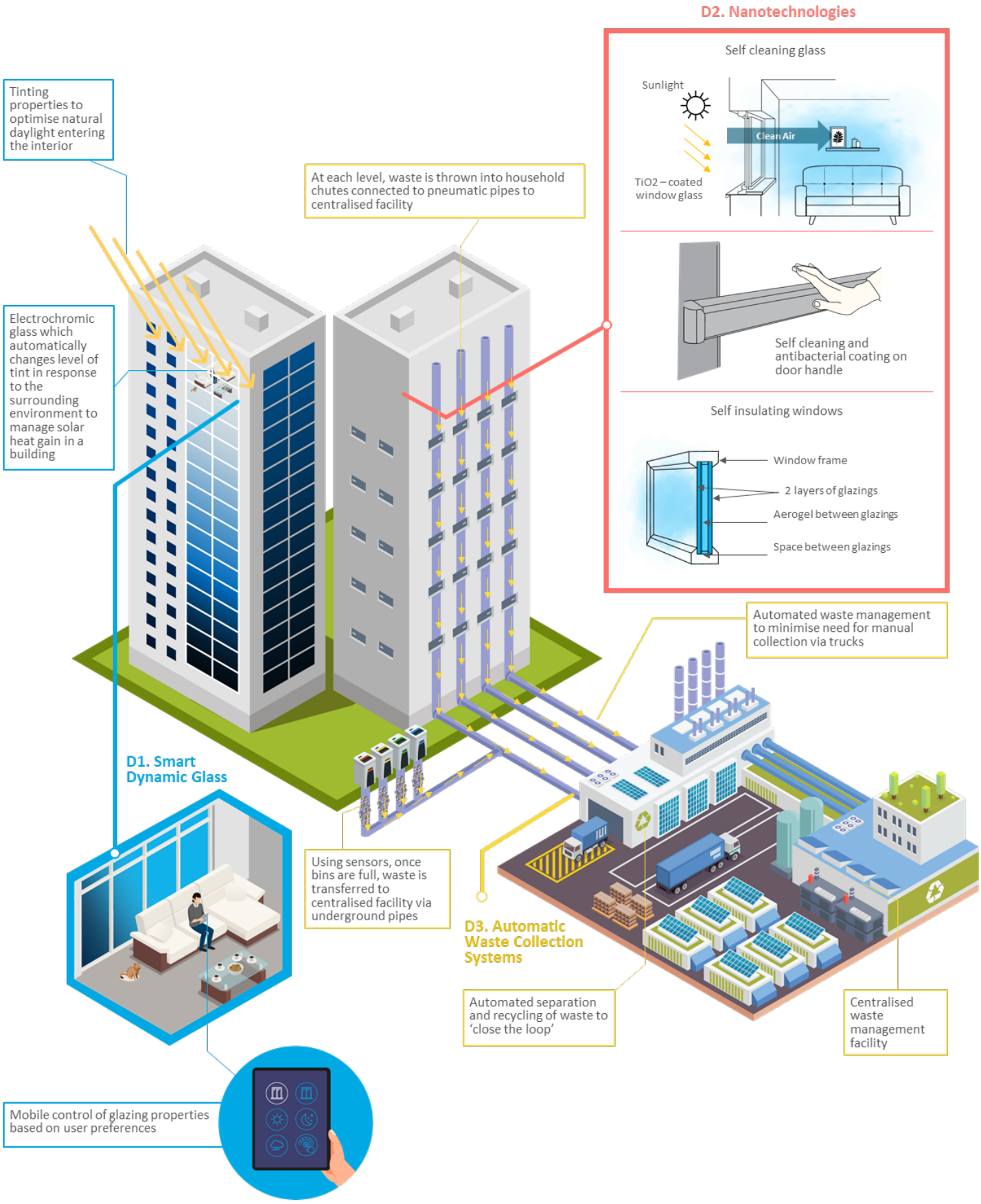

Figure 7 – Building strategies on material & waste management

Water Performance

The infographic below illustrates how the various strategies related to water performance could be implemented in a building and its surrounding built environment:

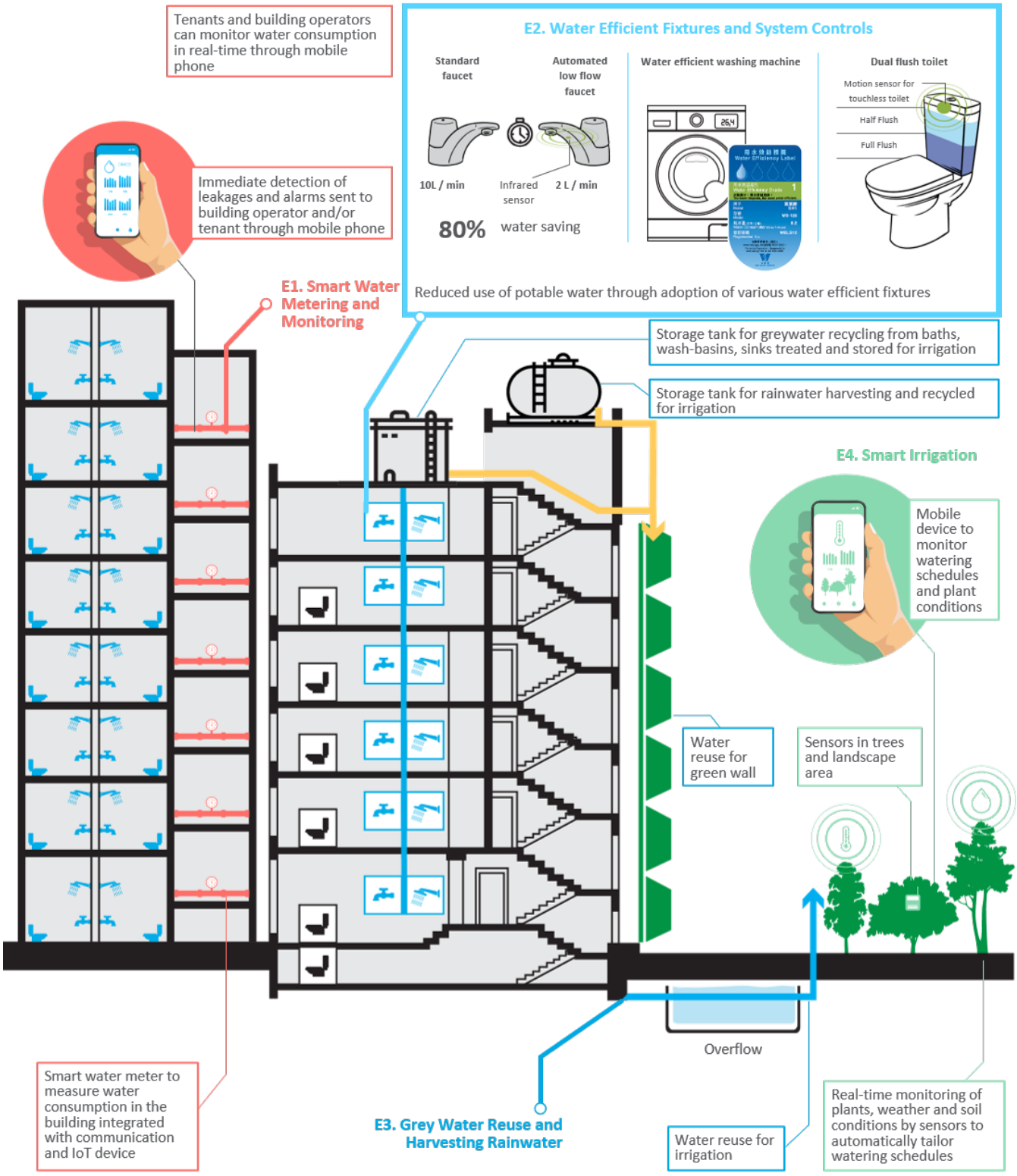

Figure 8 – Building strategies on water performance

Mobility & Transportation

The infographic below illustrates how the various strategies related to mobility & transportation could be implemented in a building and its surrounding built environment:

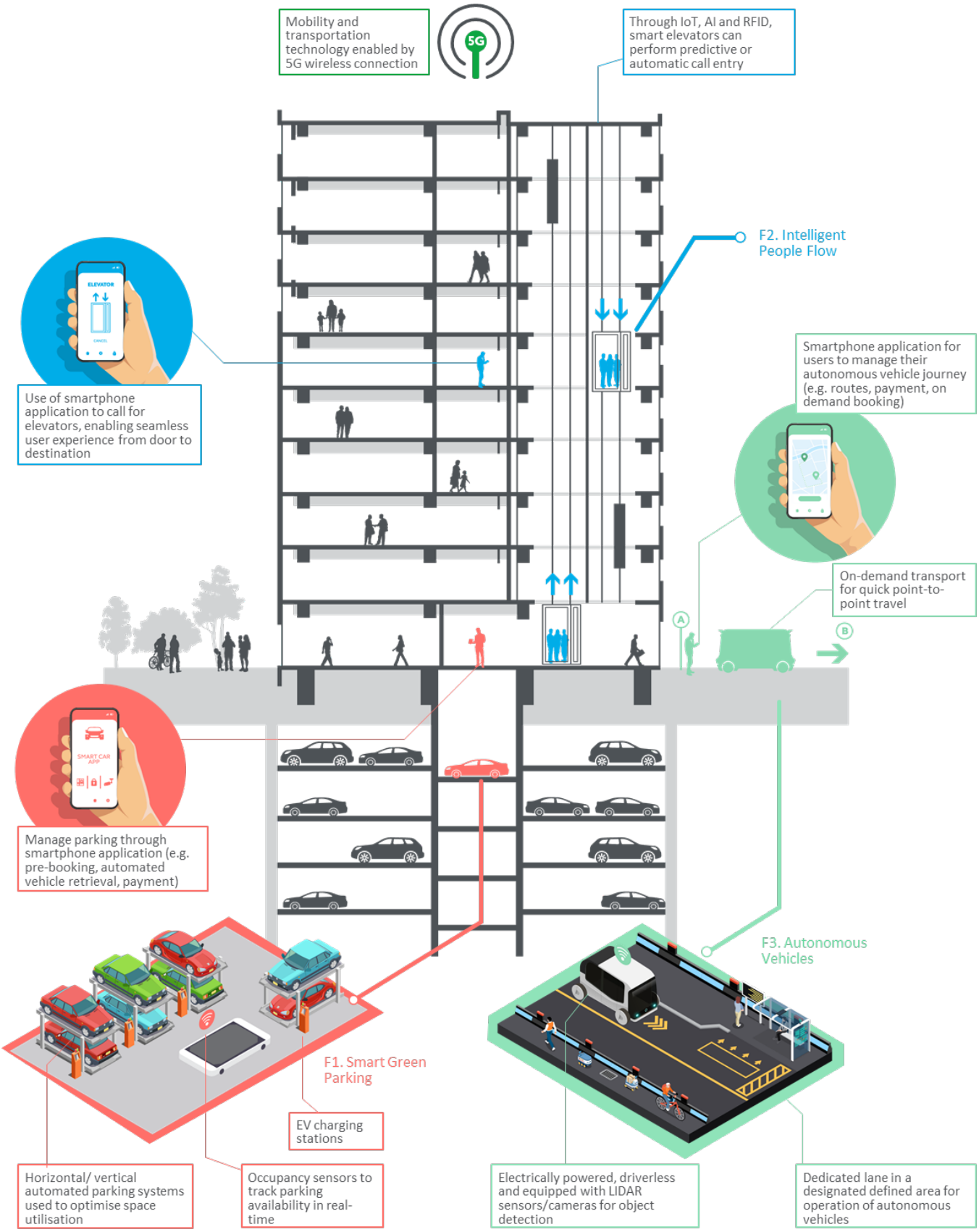

Figure 9 – Building strategies on mobility & transportation