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Predicting the future is an impossible task. One will never get it absolutely right. However, that does not make it a pointless exercise. Instead, such a discussion is a tool to enable conversations about the possible, and to inspire people to think beyond today and look at some of the trends that will shape our future.

The below text and corresponding illustration (see Figure 1) do not aim to depict what all buildings, or even all tall buildings, will look like in the future. Instead, we want to create a vehicle for conversation. We present a tool to highlight some of the functions and characteristics we may expect from cities and buildings in the future, and to explore what that may entail for the sector as a whole.

Can you imagine?

By 2050, the human population will have reached nine billion; of this, 75% will be living in cities. Until then, climate change, resource scarcities, rising energy costs, and a preoccupation with preventing and minimizing the effects of the next natural or man-made disaster will undoubtedly shape our vision of the built environment. As major cities reach their boundary limits, extending transit networks and patterns of urban sprawl will no longer provide an effective solution. Instead, demographic and lifestyle changes will serve as major catalysts in the shift toward increasingly dense and vertical urban environments.

As the future of cities takes center stage, what will we come to expect from the design and functions of the buildings within them?

The year 2050 will mark a generation of internet-native adults who will have lived all their lives engaging with smart devices and materials. They will have experienced technological breakthroughs that will redefine how human beings interact – not only with each other, but with their surrounding environment. We will live in cities where everything can be manipulated in real-time and where all components of the urban fabric are part of a single smart system and an "internet of things." These expectations set the tone for an environment that invites adaptation with ease; a place where hard infrastructure, communication, and social systems are seamlessly intertwined with a conscious necessity to integrate and engage in sustainable design practices.

Future technology will be far more focused on producing unique solutions for individual

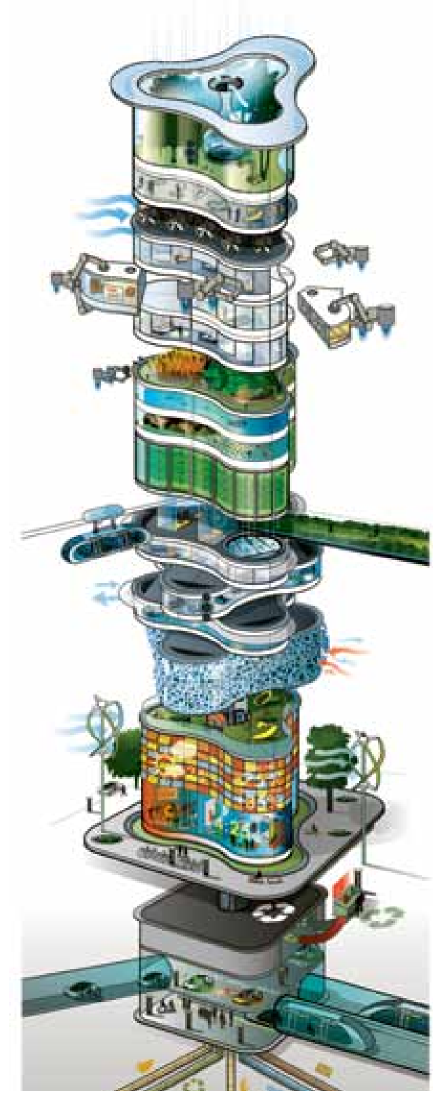

Figure 1. Arup Foresight: future urban building. © Rob House / Arup

Figure 2. Flight Assembled Tower. © Francois Lauginie

people. The necessity for our surrounding environment to inherently understand an individual's preferences and personal needs means all facets of the building network could respond to the specifics of each unique user, down to an individual's genetic composition.

In 2050, the urban dweller and the city are in a state of constant flux – changing and evolving in reaction to emerging contexts and conditions. The urban tall building of the future fosters this innate quality, essentially functioning as a living organism in its own right – reacting to the local environment and engaging the users within. A dynamic network of feedback loops, characterized by smart materials, sensors, data exchange, and automated systems merge together, virtually functioning as a synthetic and highly sensitive nervous system. In this sense, the building's structure is highly adaptive and characterized by indeterminate functions – a scheme in which space and form are manipulated depending on the time of day or the user group currently activating the structure. The system presents a spatial and formal condition that changes constantly. The structure's components are designed to be dynamic, intelligent, and reactive – it is a living structure activated by interaction with the users and its surrounding environment. Structural systems merge with energy, lighting, and façade systems to extend beyond the confines of physical limits, and to shape a new type of urban experience.

Can you imagine a building that has flexible components designed for continuous adaptability?

In this emerging age, significant developments in construction will advance current practices – prefabricated and modular structural systems will be moved and assembled by robots that work seamlessly together to install, detect, repair, and upgrade components of the building system. Technology, spaces, and façades will be rapidly modifiable, dictated by factors such as the addition or subtraction of program, density of dwellers, or other context-based and environmental cues.

There are already clues to this emergent future, albeit at a smaller scale. The installation *"Flight Assembled Architecture"* (see Figure 2) for example – a collaboration between architects Gramazio & Kohler and roboticists at ETH Zurich's Institute for Dynamic Systems and Control – features flying "quadcopters" that construct a six-meter-high twisting tower out of foam bricks. The tower itself is a 1,500-brick, 1:100 model of a "vertical village" conceived by the architectural team. Four flying robots work collaboratively to build it at a rate of 100 bricks per hour, with their movements dictated by digital design data that is translated into mathematical algorithms.

In the high-rise of 2050, materials will feature intelligent design and will be formulated as high-performance composites made from recycled and renewable elements, providing functions such as self-repair or purification of the surrounding air. Already in Mexico City, this idea is becoming a reality. At the Hospital Manuel Gea Gonzalez, the design firm Elegant Embellishments has installed a tiled façade over-cladding on the hospital's Torre de Especialidades (see Figure 3) that utilizes a

Figure 3. Torre de Especialidades, Mexico City. © Alejandro Cartegena

Figure 4. The BIQ House, Hamburg. © Josef Hargrave

superfine titanium dioxide coating to break down air-borne pollution. Activated by ambient light, the coating can neutralize harmful pollutants such as NOx (nitrogen oxides) and VOCs (volatile organic compounds), reducing them into CO_2 and water.

In the field of self-repair, a team of researchers at the University of Illinois (Rincon 2012) are in the process of commercializing paints and adhesives, imbued with microscopic capsules containing a liquid healing agent that can be used to combat corrosion. Likewise at Purdue University, a team is in the early stages of developing solar panels that can "regenerate" when damaged (Webster 2011). At Delft University of Technology, there have been advancements in self-healing concrete (Jonkers 2011). Harmless calcite-producing bacteria, along with nutrients, are embedded in the concrete mixture, and when activated by water, the microbes feed on the nutrients to produce limestone, patching up cracks and small holes.

Continuous adaptability of the building will be established through a multi-layered approach with varying design lifespan for each phase. The first layer is the permanent structure, such as floor slabs. These are deliberately designed to have a degree of permanence, but also to be capable of adaptation for an array of uses and a variety of functions at different times during the life cycle of the building. The second layer of adaptability addresses occupancy-specific components. These elements have 10–20 year lifespans, and may include the façade and primary fit-out walls, finishes, or on-floor mechanical plant. The third layer utilizes the rapidly changing loose fit-out elements – including IT infrastructure – as systems need to accommodate the rapid rate of technological developments of future devices.

Figure 5. Verticrop Local Garden, Vancouver. © Alterrus

Can you imagine a building that produces more resources than it consumes?

Integrated with the smart infrastructure grid, the urban dwelling of 2050 will gather information and react to contextual cues. Components such as photo-voltaic surfaces will enable on-site production and storage of energy, captured and transmitted through alternate means, including on-site fuel cells, the use of vertical transportation systems to harness energy, and algae producing bio-fuel pods. Modified wind turbines will manufacture drinking water from humid air, and water systems will be optimized for recycling and reuse, while filters and surfaces clean air and eliminate pollutants.

Currently, researchers at the engineering consultancy Arup are developing bio-reactive façades that cultivate micro algae as an energy source, or as a source of raw materials for the pharmaceutical and cosmetics industries. The system makes use of waste carbon, generating solar thermal energy in the process (Wurm 2012). Micro-algae circulate through the panels with water and nutrients, absorbing light and carbon, and producing biomass. The part of the solar spectrum that isn't absorbed by the algae heats the water, and this solar thermal heat can be removed to be used in the building, or stored for when it's needed. It is even proposed that the system can be used as a shading device: in the sunny part of the day, the algae can be left to reproduce and reduce solar gain, before harvesting the algae in the cooler part of the day and allowing more light through.

This bio-reactive façade system has already been installed on a residential building in Hamburg – the BIQ House (see Figure 4). In parallel developments, nano-materials chemists at the University of Texas are formulating "solar paint" – tiny, solar energy-harvesting nano-crystals that can potentially be dispersed in a solvent or paint, creating something more user-friendly, durable, and flexible than today's photovoltaic panels.

Green and open spaces will become integral elements of the high-rise building system, dispersed throughout the structure to invite increasing levels of biodiversity and encourage interaction with the other inhabitants of the urban landscape – plants, birds, and insects.

Wind-downdraft protection will be seamlessly integrated, minimizing undesired wind micro-climates around the base of the building. By 2050, exterior devices will seek to harness wind downdrafts to create electrical power.

The future building will help to optimize citywide production, storage and consumption of everything from food and energy to water. Brought about by a concern for depleting natural resources, lack of physical space, and drastic climate change; food production systems, like green spaces, will become integral elements of the sustainable and smart city. Vertical farming techniques and urban agricultural systems, such as hydroponics, will be utilized to address the impending crisis in world food production and follow the same fundamental methodology that urban planners have used for years – building up, as opposed to out.

> "In the high-rise of 2050, materials will be formulated as high-performance composites made from recycled and renewable elements, providing functions such as self-repair or purification of the surrounding air."

Vertical farming is a concept that has been gaining significant credibility and is envisaged in Despommier's 2010 book ***The Vertical Farm*** with hydroponic and aeroponic systems, rather than soil, and complex sensing technology to monitor and regulate growing conditions (Excell 2012). Prototypes have begun to spring up in Sweden, Holland, the United States, and Japan. The South Korean government recently unveiled a three-story system in Seoul, which uses LED lighting to grow leafy green vegetables. Furthermore, in Vancouver, Canada, the first fully-commercial farm – a rooftop carpark-based facility (see Figure 5) – supplies vegetables to a number of nearby restaurants through an online local grocery delivery service (Harrison 2012).

Can you imagine a building that has a sensitive and multifunctional skin?

The façade of the future will be highly multifunctional, plugging in to the city infrastructure, on a macro scale, and as part of the building system. This exterior membrane will provide opportunities for everything from integrated communication networks to food and energy production. Algae systems will enable the on-site production of bio-fuels that are used by the city's wider transportation systems, while heat recovery windows with natural ventilation will allow for air to be brought in and up, intercepting heat that is normally lost. Nano-particle treatments applied to intelligent façade systems will have the capacity to neutralize airborne pollutants, capture CO_2, and clean the air around each structure. The building's highly-sensitive membrane will react to environmental factors such as changes in temperature, wind patterns, atmospheric moisture levels, and sunlight, to provide optimal thermal comfort for the inhabitants and make maximum use of renewable energy production opportunities.

Already these technologies are evolving rapidly in the field of building façade design, a discipline which itself has evolved hugely over the last 10 years. The intricate, feather-like façade of the new Q1 Building in Essen, Germany (see Figures 6 and 7) is comprised of

Figure 6. Q1 Building, Essen. © Günter Wett / Frener + Reifer

Figure 7. Q1 Building overview. © Michael Wolff

> “Vertical farming techniques and urban agricultural systems will be utilized to address the impending crisis in world food production, and follow the same fundamental methodology that urban planners have used for years – building up, as opposed to out.”

approximately 400,000 metal "feathers" that use sensors to respond to external conditions, optimizing the light penetration and internal heat gains. Likewise, Chicago's Willis Tower is undergoing a make-over (Michler 2011), with its south-facing glazing being replaced with high power-density photovoltaic glass – monocrystalline silicon solar cells sandwiched between two glass layers, with an internal prism that directs the sunlight onto the solar cells, while letting diffused light through.

Can you imagine a city where buildings are fully integrated with the surrounding urban infrastructure?

Future building systems will link and integrate transport networks, providing green spaces and fostering and encouraging sustainable behavior. Buildings will become an integral part of the community and redefine what it means to be both "urban" and "natural" at the same time.

The urban dwelling of 2050 will be fully integrated within the landscape of the future city – a dense, and at times cacophonous urban condition. These structures will play a vital role within the context of the public realm, providing an ever-changing backdrop against which people will live, explore, and interact. On-site digital fabrication facilities will allow users to produce individually customized elements. The base materials will be recyclable, to be reconstituted for future product manufacturing. Necessary building components will be manufactured *in situ,* avoiding transportation from off-site factories.

Already a shift can be sensed, from designing buildings as closed systems to integrating them into the wider social fabric of a city. The Leadenhall Building in London (see Figure 8) will incorporate a huge, cathedral-like public space at its base, and more ambitiously, the Amager Bakke waste-to-energy plant by BIG Architects (see Figure 9) aims to offer interaction for the residents of Copenhagen through socially-charged design. The facility, currently under construction, will house a ski-slope on its roof, and rather than continuously emitting by-products from its chimney, will expel rings of smoke whenever a ton of fossil CO_2 is released, delivering a physical manifestation of ecological issues to raise awareness of energy consumption among the city inhabitants.

Figure 8. The Leadenhall, London – the galleria. © British Land/Oxford Properties

Can you imagine a building that has a brain?

The city of 2050 will exist as a framework of highly sensitive and virtually intuitive feedback networks. The system will be self-regulating within the context of each individual building, yet simultaneously function to integrate itself within the surrounding urban infrastructure.

Utilizing data collected from factors such as energy consumption, transportation, weather, and even occupancy requirements; the future building will be able to execute informed and calculated decisions about the optimal use of resources and composition of structures. As a result, the building will have the capacity to create an environment expressly curated in response to the current conditions of the people, environment, and city. The building systems will monitor reflectivity, heat absorption, and heat balance, minimizing the effects of phenomena such as the urban heat island effect. Interior spaces will be fully customizable, and modifiable to fit specific needs from climate conditions and lighting to acoustic preferences. Elements such as sensors and Organic Light Emitting Diode (OLED) technology will allow a whole building surface to illuminate, creating a more even light source. Coupled with daylight-absorbing abilities, the technology will realize the possibility of net-zero energy electric lighting. The user will experience realities that are perfectly tailored to accommodate the program or functions desired.

"Green screens" that display real-time consumption data and trends are already becoming commonplace in corporate buildings. Yahoo was a well-publicized early adopter, with interactive energy-monitoring screens installed in 2008 at its Sunnyvale, CA headquarters. One project aiming to realize this wider vision in a more complex manner is New Songdo City (see Figure 10), a US$31 billion development 60 kilometers south of Seoul, purported to be a "self-aware city that runs on information;" controllers will know exactly where people and vehicles are, and based on previous travel behavior, where they are likely to be going; public recycling bins will credit residents every time they toss in a bottle; buildings will dial up and down the heat, lighting, and electrical current – they will even make sure the lifts are in the right place at the right time – to provide just enough service. Data will expose patterns of waste. It is suggested that overall, New Songdo could emit one-third of the greenhouse gases of a typical metropolis its size, and use 30% less freshwater (Arlidge 2010).

Figure 9. Amager Bakke, Copenhagen. © ARC (Amager Resource Center)

Figure 10. New Songdo City. © Gale International

Conclusion

In the ecological age, buildings do not simply create spaces, they craft environments. They function as part of an urban ecosystem, promote more environmentally conscious and efficient resource management, and actively contribute to the unique needs of the individual user, as well as the wider requirements of the city. By producing food and energy, and providing clean air and water, buildings evolve from passive shells into adaptive and responsive organisms – living and breathing structures supporting the cities of tomorrow. ■

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