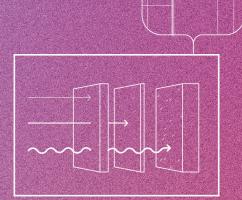
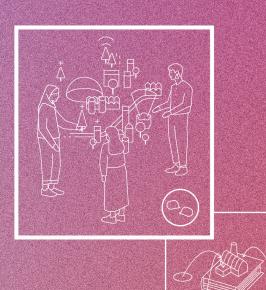
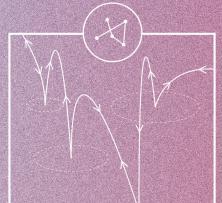
Building Performance Reimagined





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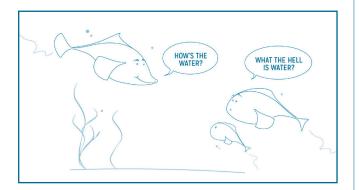
Foreword

Fiona Cousins

It feels strange to start by talking about what this document is not, but it is different to CIBSE's normal publications — and intentionally so. It is not a piece of technical guidance nor is it a reference set of engineering solutions for existing or emerging problems. It is instead intended to animate a range of speculative futures, from the pragmatic to the playful. We hope that it will prompt you to think differently — and more broadly — about the impact of your work and your part in creating the future you want to see.

As building services engineers, we concern ourselves, every day, with building performance. But what is building performance? Do we agree on what we are aiming for? What do we value? Our understanding has changed rapidly in the last few years, as we have been buffeted by pandemics, building disasters, extreme weather events whilst seeing an increased focus on 'wellness'.

We are so embedded in the built environment, with most of us spending 90% of our time indoors and much of the rest of it in constructed outdoor space, that, like a fish in water, we struggle to explain our relationship with our surroundings. The purpose of this report is to help us find a way to see the water.



What we value, and how much we value it, depends on our personal circumstances — when things are tough, we seek protection from the weather, and then start to enjoy the benefits of running water, sanitation, and power. As we relax into the easy availability of those services, we seek security, comfort and control, and then have time to think about the broader impacts of buildings on climate, our physical health, our human interactions, and the natural environment.

What we value also depends on the world around us, especially once our basic needs are met. Buildings and the built environment are expensive, long-lasting, carbon intensive in both construction and operation, and they form the backdrops to our lives. And so, we have historically focused our ideas about building performance on cost and comfort, and more recently, on carbon and individual wellbeing. As we have done so, we've found sophisticated ways to measure and manage these things and sharpened our focus on achieving those metrics.

But our context is always changing, and right now it is changing faster than ever, with technological advances, societal change, and the increasing tangibility of environmental constraints and challenges. It's time to raise our eyes to the horizon and challenge our assumptions about what 'good' looks like.

This report draws on futures methodologies and research to help us imagine what might come next. While it's impossible to predict exactly how the building services of 2050 will look, in our landscape of complexity and uncertainty we can be reasonably certain that we will continue to expect buildings to do more for us, probably using fewer resources.

Planning for unknown futures is hard to do. But all of us have the power to shape those futures and do so, every day, through the work that we do and the decisions we make. We hope that whatever your role in the industry — as an engineer, employer, professional body or as part of a wider network of building stakeholders — you will use this report to find a way to imagine, anticipate and actively shape the best future we can.

Welcome to Building Performance Reimagined.



Fiona Cousins CEng, FCIBSE, PE, LEED Fellow -CIBSE President

"Planning for unknown futures is hard to do. But all of us have the power to shape futures every day, through the work that we do and the decisions we make."

Introduction

Global Context and Major Shifts

To imagine the buildings of 2050 and the services within them first requires a holistic, honest and long-term assessment of how our wider world is changing. There are **high level, global forces that will shape and define our operating context** to 2050 and beyond — changes which present us with new conditions and challenges — and ultimately determine what we will 'value':

"As an industry we need to shift from a compliance mindset to a performance mindset. The former will only set a baseline, whereas the latter helps us advance and meet 'stretch' targets. [...] Performance is increasingly the market expectation, which is starting, tentatively, to drive the policy agenda."

Stephen Hill, Sustainability Consultant at Arup & CIBSE Engineer of the Year 2023

1	Social change		
	Slowing, unevenly distributed population growth.	The global urban population is expected to grow by 2.5bn people by 2050. 80%	
	Increasing urbanisation and migration.	of this population growth will happen in	
	Changing nature of work and building utilisation.	Africa and Asia. ¹	
2	Technological change		
	Accelerating data, artificial intelligence, advanced computing, and digital innovation.	The market for AI technologies is expected to grow to over 1.8 trillion U.S dollars by 2030. ²	
	Energy system transformation and decarbonisation.		
2		Battery energy storage system capacity is likely to quintuple between now and 2030. ³	
3	Economic change		
	Challenges to GDP and 'growth' as core economic success metrics.	Two planet Earths would be needed to meet human demands in 2030 if trends	
	Resource scarcity, material innovation, and supply chain vulnerability.	continue. ⁴	
	Supply chains shifting closer to home and to more reliable sources ('nearshoring' and 'friendshoring').	The richest 1% own half of the world's wealth. The poorest 50% of the world own 0.75% ^{.5}	
4	Environmental change		
	Increasing need for climate adaptation in changing environments (temperatures, sea levels, extreme weather etc.).	6 out of 9 planetary boundaries within which humanity can continue to develop and thrive have been crossed. ⁶	
	Biodiversity loss and ecosystem disruption.		
		Non-irrigated crop yields are at risk of a 50% reduction in Southern Europe by 2050 due to climate change impacts. ⁷	
5	Politico-legal & regulatory change		
	Intensifying geopolitical volatility and new alliances.	The 50% of the global adult population electing new leaders in 2024 will be	
	Fragmenting regulatory landscape.	shaping power dynamics in the longer	
	Net-zero targets and regulatory push for retrofit in many markets.	term. ⁸	
		Supply chains are becoming increasingly consolidated around regional blocs; China is no longer the biggest supplier of goods to the US – Mexico and Canada have surpassed their rates ⁹ .	

Introduction

Global Context and Major Shifts

"The building of the future which delivers 'performance' is one which sees itself as delivering for everyone, rather than the individual users." Our 2050 speculations must be bounded by the above social, technological, economic, environmental, and political realities. But the range of possible futures for the built environment is still wide. **We can, and should, imagine radically different building services in response to rapidly changing contexts.**

Experts ranging from technical building services specialists to thought leaders in film, architecture, technology and public sectors inspired and informed the visions of a longer-term future (see page 14 for full list of expert contributors). Beyond specific ideas related to performance measurement and management across different building types, they described a series of **major shifts**: fundamental changes and challenges to the way that we define buildings' 'value', from the last 30 years to the next 30:

The focus is shifting:

From	to	
Individual benefit	Collective social usefulness	
Human users (user-centric design)	Multi-species stakeholders (human and nature-centric design)	
Consumption, extraction, and emission	Contribution, restoration, and regeneration	
Preventing sickness and protecting health	Improving wellbeing and enabling safety	
Siloed developments and segregated spaces	Whole system approach	
Focus on CapEx (pre-handover design)	Focus on whole building life cycle	
Productivity and output	Resilience and balance	
Value in 'newness'	Value in age and reuse	
Compliance-based design	Performance-led design	

The following chapters explore visions of possible building performance futures, through the lens of four key themes. Each theme is brought to life by a '2050 blueprint' illustrating several speculative features and future building functions. However, shifts in focus as described above are not solely engineering challenges; this report shines a light on other enablers of change too, be they policy, skills or technologies.

"In these themes lies a challenge to the whole engineering mindset; that complicated problems can just be broken down into smaller problems which experts can work on independently - then you put it together, and everything is solved. [...] In fact, Complex Systems have changing behaviours that emerge from the interactions between independent components. To effectively service the complex built environment and its inhabitants requires sensing, monitoring and dynamic response [...] if taken seriously, that would amount to a paradigm shift from an engineering mindset to a complex systems mindset."

Wolfgang Wopperer-Beholz, Systems Analyst & Conceptual Engineer

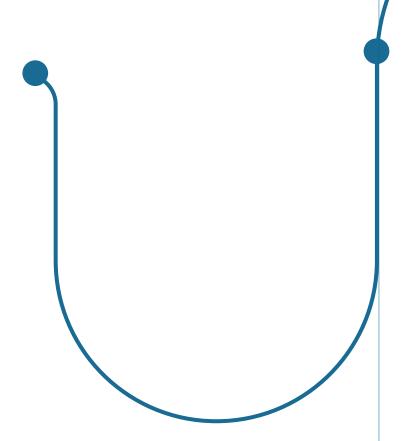
Introduction

Methodology

A three-phase Foresight process

Foresight, often called 'futures thinking', enables structured conversations about change and the implications of this change on a specific issue, in this case the performance of buildings. The research has applied futures thinking techniques to conversations and exercises with a wide range of expert contributors, bringing structure and stretch to 2050 exploration and speculation.

The foresight process had three phases:





represented the most critical uncertainties for future building performance needs/ expectations — and why. How do these drivers interrelate and impact one another?

Each thematic chapter illustrates the relationships at play between impactful

drivers of change.

In a series of **16 in-depth interviews**, and using an adapted **'7 Questions Framework'**,¹², the Foresight team explored, interrogated, and stretched hypotheses on future building 'performance'. Experts were consulted in fields as diverse as neuroscience, technology policy, public health, and economics as well as industry thought leaders from developers to public planners. Interviews were complemented by **Design Futures**¹³ **Workshops** with the technical experts of the future: CIBSE's Young Engineers Network.

The evidence of both long-term and early signs of change gathered in Phase 1 provided stimulus for foresight exercises with expert participants. These surfaced a wide range of possible future needs and expectations – and speculative, yet specific, ideas for measuring and managing performance in 2050. Each thematic chapter brings those ideas to life via illustrations, or '**future blueprints**'.

02

What possible futures emerge?

Interviews: '7 Questions Framework' Design Futures Workshops Gathering early signs of change

Backcasting

03

What are the implications across the building value chain and for building services engineers specifically?

Whilst design futures exercises produce playful, speculative visions of tomorrow, they highlight profound learnings for today. Having parachuted our experts into radically different futures, we asked them: 'what weak signals of change are you already seeing?' Gathering **early signs of change** from the built environment and beyond lends credibility to those radical aspirations. This way, we can more easily imagine how policy, innovation, or societal shifts may take us there.

Finally, a structured **Backcasting**¹⁴ exercise with a cross-section of CIBSE's senior membership connected aspirational ideas to short-term actions and considerations for building services engineers today. The closing section summarises those **technological**, **policy, behavioural, and economic enablers** identified as essential for longer-term change.

Expert Contributors

From a wide range of fields and sectors



Andrew Nolan

Director of Property, Space and Development at the University of Nottingham. Responsible for strategy, further developing and embedding sustainability to improve the University's campus, curriculum and community. Andy has operational responsibilities that include energy procurement, building management system, carbon management, waste and recycling, travel, travel planning.



Carlo Ratti

An architect and engineer by training, Professor Carlo Ratti teaches at the Politecnico di Milano and the Massachusetts Institute of Technology, where he directs the SENSEable City Lab and is a founding partner of the international design office Carlo Ratti Associati. In 2023, he was appointed curator of the Venice Biennale Architettura 2025.



Dani Hill-Hansen

Dani is an Architect and Sustainable Design Engineer at EFFEKT Architects. Her experience spanning design spans the creation of bio-based materials to the integration of passive architectural principles, to co-creation and collaboration tools for circular innovation settings.



Dr Hugo Spiers

Hugo Spiers is Professor of Cognitive Neuroscience in the Department of Experimental Psychology. He is an elected member of the Memory Disorders Research Society and an Associate Fellow of the Royal Institute of Navigation.



Dr Liu Thai Ker

Dr Liu Thai Ker is an architect and urban planner. He previously served as Singapore's chief planner and CEO of the Urban Redevelopment Authority of Singapore, where he oversaw the development of Singapore's 1991 concept master plan. Prior to that, Dr Liu served as the Chief Architect and CEO of Singapore's Housing Development Board, where oversaw the planning of over 20 new towns and 500,000 dwelling units in Singapore. Liu is currently the Chairman of MORROW Architects and Planners.



Gavin Scott

Head of Sustainability at the University of Nottingham. He oversees various areas of the university property portfolio such as waste management, travel and transport, energy management, engagement and legal compliance.



Gina Bocra

Chief Sustainability Officer at New York City Department of Buildings. Gina has over 20 years of experience in sustainable design and has assisted with the technical development of multiple LEED rating systems.



Indy Johar

Indy is the Founder and Executive Director of Dark Matter Labs. He has designed and founded multiple social ventures from HubWestminster.net to HubLaunchpad.net.



Jan Golembiewski

Dr Jan Golembiewski is the director of Psychological Design and is their nominated architect. He is one of the world's leading architects driving innovation in evidence-based architectural and urban design.



Jane Wakiwaka

Jane Wakiwaka is a Sustainability Director at The Crown Estate, and joined the business in 2014. She is responsible for setting out and embedding The Crown Estate's sustainability agenda and Net Zero Carbon Commitment across the business including the development, management and investment of its real estate portfolio.



Jess Bland

Deputy Director at the Centre for the Study of Existential Risk, University of Cambridge Jess has a background in science and technology policy, including working at the Dubai Future Foundation, the Royal Society and Nesta.



Joshua Ashish Dawson

Joshua Ashish Dawson is an Indian-born, Los Angeles-based, film director known for incorporating the built environment as an essential character in his films titled 'Speculative Climate Futures'.



Meg Spriggs

Meg is the Managing Director of Development for the Americas – at Australian-based contractor and developer Lendlease. She has 23 years of development experience to her new role, having overseen the acquisition and development of over 4,000 apartment units.



Prof. Laura Forlano

Laura Forlano, a Fulbright award-winning and National Science Foundation funded scholar, is a writer, social scientist and design researcher. Currently, Forlano is Professor in the department of Art + Design at the College of Arts, Media, and Design (CAMD) at Northeastern University.



Prof. Richard J Jackson

Richard J. Jackson MD, MPH '79 is an emeritus professor at the UCLA Fielding School of Public Health and volunteer faculty at the UC Berkeley School of Public Health. A pediatrician, he served in many leadership positions in environmental health and infectious disease with the California Health Department.



Sharon Prince

Sharon Prince is the CEO and Founder of Grace Farms Foundation, a new kind of boundarydefying public space that advances good locally and globally.



Wolfgang Wopperer-Beholz

Wolfgang Wopperer-Beholz is a trained philosopher and practicing facilitator. He was cofounder of the Hamburg-based product studio mindmatters and betahaus Hamburg and is now coordinator at the Basic Income Earth Network (BIEN) in London.

Building Performance Reimagined

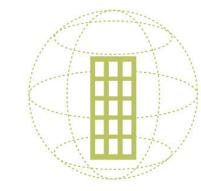
'Health' and 'resilience' as the ultimate aspiration

Two fundamental and universal measures of a future building's 'value' (e.g., its importance, worth or usefulness) surfaced consistently in research and expert engagements. Firstly, the **health** of the living species using, interacting with, and impacted by a building and its operations – both human and non-human. Secondly, the **resilience** of the systems in and around buildings, whether this be on-site services, local economies and supply chains, or broader urban and regional zones. In fact, the words 'health' and 'resilience' were often used interchangeably by contributors when describing important value drivers and needs to 2050 and beyond.

In terms of how we measure 'performance', then, we can be inspired by nature. Which natural ecosystems do we know to be both 'healthy' and 'resilient'? How might we learn from examples in the biosphere which have evolved and improved their own performance over 3.2 billion years?

Just as those systems promote health and resilience, so can our buildings, when we shift our perception of them — the services, and the species within and around buildings as parts of a complex living system — and apply the same metrics. Using four core performance metrics from the natural world, we can explore a fundamentally different approach to service design and delivery.





Variety

...of spaces, uses, and influences; flexibility, adaptability, and multiplicity of use. Healthy and resilient ecosystems reject 'sameness' and use difference to their advantage.

Readiness

...for changing conditions, tangible and intangible threats, risks, and uncertainties. Healthy and resilient ecosystems prevent harm from harsh environments or extreme events, and mitigate disruption.

How might building services optimise space, promote adaptability and diversity of use and user? How might building services reduce risk and harm, and build anticipatory capacity to respond to unseen threats? "It's not good enough anymore to be less bad. In taking cues from nature, we could define building services that heal planetary systems rather than degrade them"

Dani Hill-Hansen, Architect and Sustainable Design Engineer at EFFEKT Architects

In each of these four thematic chapters is a snapshot of the contextual change shaping our needs and expectations of buildings today and in the coming decades. Then, illustrations co-created with technical experts bring to life **possible concepts, features, and facets of future high-performing buildings** — including speculative performance metrics and ways in which future needs may be met. Each chapter includes **implications for building services engineers** and other actors in the built environment value chain.

[Select icons to navigate chapters.]





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Connectedness

...to local infrastructure, context and community – to living and non-living entities within and around. Healthy and resilient ecosystems are connected to other complex systems whilst nurturing internal networks and relationships.

How might building services better respond to the building context and its contents, and integrate with local and wider systems?

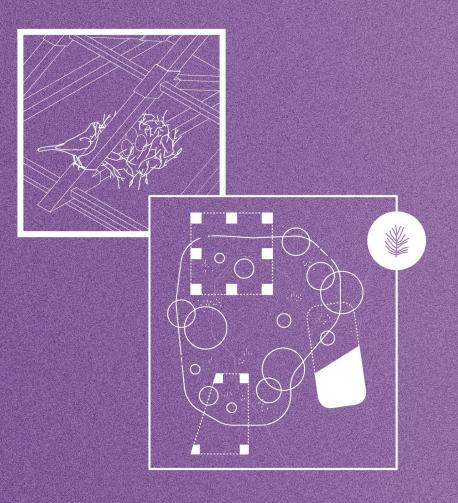
Emergence

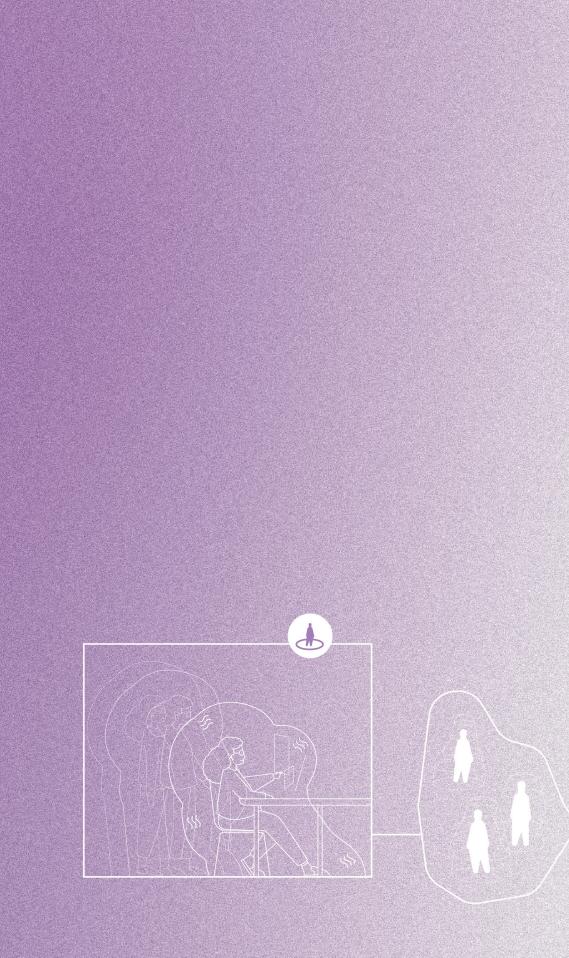
...of new materials, uses, and ideas from what already exists. Learning and adapting throughout life cycles. Healthy and resilient ecosystems generate, restore, and regenerate, unlocking local abundance and balancing supply and demand.

How might building services contribute more than they consume, and learn as structures age?

"We've relied too much on best practices to shape our policies when it comes to citymaking. But best practices lock the future into the past, and they slow down innovation. Now is the time for drastic, moonshot solutions."

Carlo Ratti, Professor at the Politecnico di Milano and the Massachusetts Institute of Technology 





Variety

...of spaces, uses, and influences; flexibility, adaptability, and multiplicity of use. Healthy and resilient ecosystems reject 'sameness' and use difference to their advantage.

How might building services optimise space, promote adaptability and diversity of use and user?

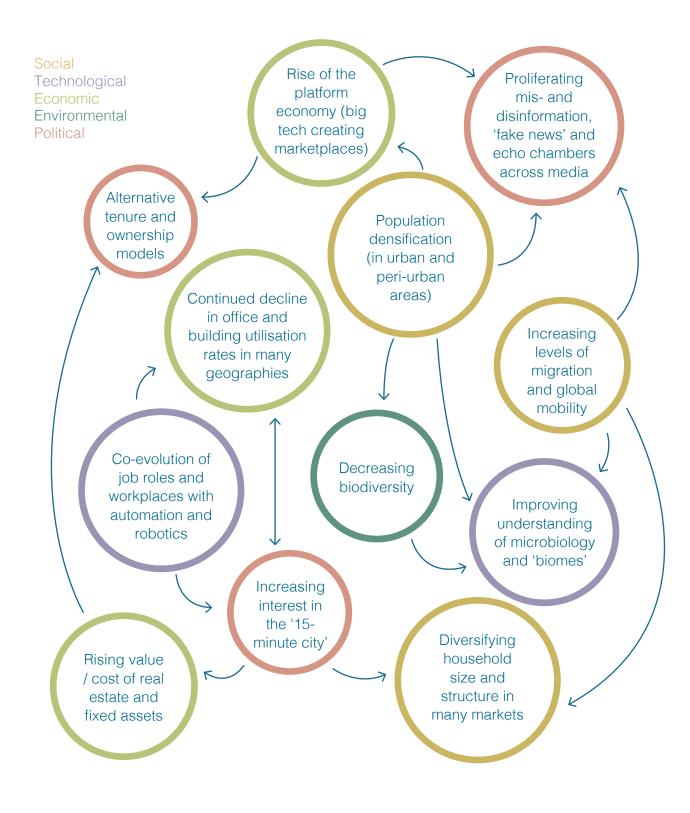
What is shaping our needs and expectations for **Variety?**

In recent decades we have seen declining biodiversity and ecosystem health, whilst our urban areas become more densely populated. Despite increasing migration and global mobility making our cities and countries more diverse and multicultural than ever, buildings are often homogenous. They can be limited in their offer, serving a singular functionality, for select groups of people, and for one select species. This also means many of us physically encounter and engage with an ever more limited spectrum of people, species and environments, which has a psychological and biological impact on us over time. Even at a microscopic level, the health impacts of the diversity of our 'biomes' (the variety of bacteria we harbour inside us and are exposed to around us) are becoming better understood.¹⁸

"One thing that's globally consistent is extreme gentrification, and the extreme push towards more homogeneous, 'luxury' kinds of spaces. There's been a belief, by economic development organisations, cities, and governments that they need to create these kinds of spaces to drive what they see as value, which is dollars coming to their city. Which I don't think is the same as what attracts people to want to be in places."

Prof. Laura Forlano, CAMD Northeastern University

Against a backdrop of economic change and pressure to optimise space, computed by increasingly fluid living and working patterns, multi-purpose, 24/7 spaces serving many more users could flourish. The notion of a '15-minute city' in which all amenities are accessible within 15 minutes' walking or cycling gains traction in many places, meaning new and multiple purposes for local buildings. Services for these spaces would ensure hygiene without being sterile, and offer safe adaptability by managers and occupants.



Only **4%** of non-human mammals on Earth can be described as 'wild', that is, non-domesticated, non-farmed.¹⁵

Over **50%** of the world's total GDP is at risk from disruption caused by loss of biodiversity, equivalent to **\$44 trillion**.¹⁶

39% of global knowledge workers are expected to work hybrid this year – in the US this is **71%**, up from **37%** in 2022.¹⁷

Variety

What does 'Variety' mean for performance in 2050?

In 2050 buildings could be...



Biophilic buildings Spaces that serve a multitude of species, from the microscopic to migrating species — encouraging a variety of life, leveraging nature services, nature-based solutions and biomaterials. These spaces may even promote indoor microbe populations that don't harbour harmful pathogens.¹⁹ "A different comfort thesis emerges in a future where we can be far more specific about measures like microbial density, hyperoxygenation and 'deep work' conditions." Indy Johar "One of the defining characteristics of thriving cities is diversity." Dr Liu Thai Ker



Completely personalised and adaptable spaces to suit the requirements of users at different times, featuring accessible performance data and intuitive user guidance that you do not need technical expertise to 'read'.

"Some elements of future optimisation might be subconscious: do building systems scan your brainwaves or understand your physiology to remember your responses and adapt in subtle ways?"

Dr Hugo Spiers

"On neurodiversity, we still have so much to learn. We live in an extremely ableist society and conform to certain ways of communicating, certain ways of moving your body. Services could and should make space more legible to the whole spectrum of users."

Laura Forlano

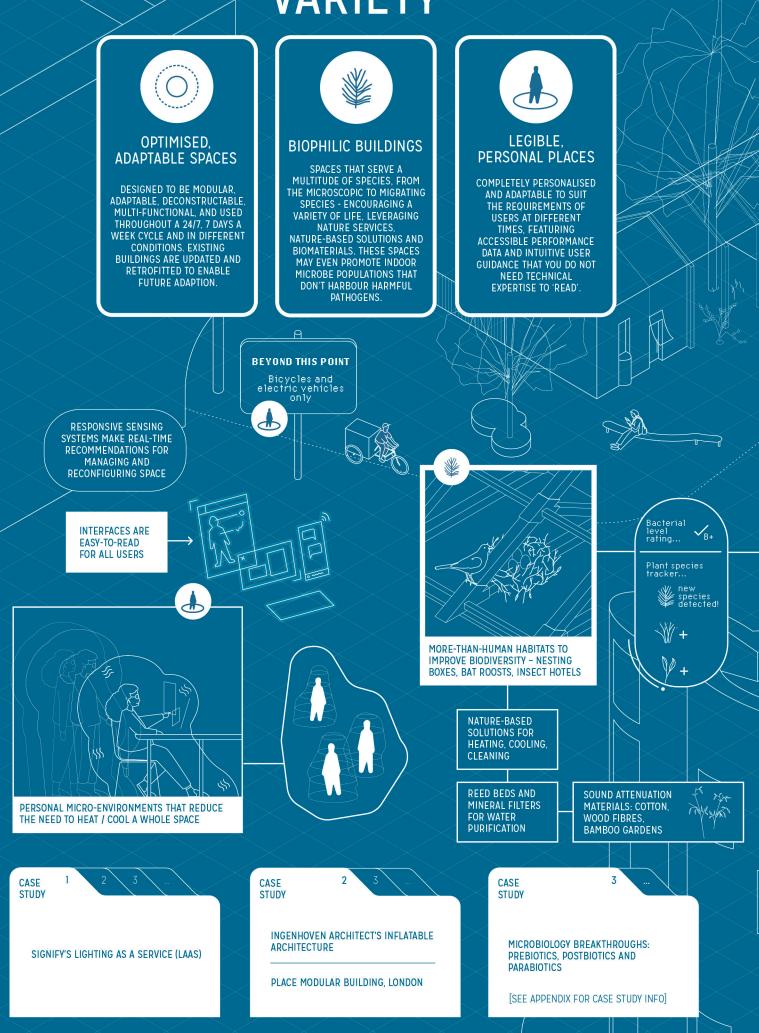
"Currently, a lack of user interface with building systems means a lower tolerance of environmental changes - all down to a lack of perceived control in people's environment."

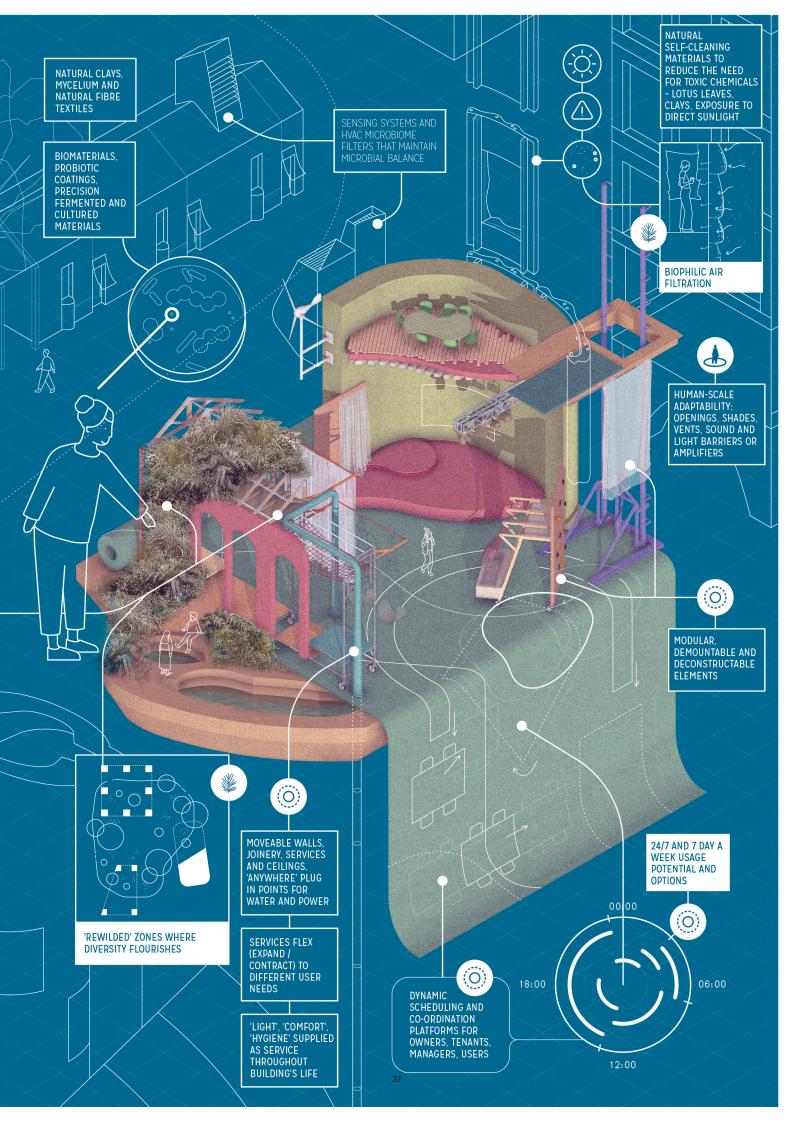
Andy Nolan

"We now have evidence that singleuse buildings with limited functionality do not appreciate in value."

Gina Bocra, Chief Sustainability Officer at New York City Department of Buildings

VARIETY





Variety

Implications for Building Services Design and Engineering

How might building services optimise space, promote adaptability and diversity of use and user?

1

Increased innovation and expertise in modular, deconstructable, and adaptable services.

2

Interdisciplinary collaboration between traditional engineering disciplines and nature services or ecological expertise to better understand the potential of using passive elements and natural elements to provide building services — and the implications for safety.

3

Improved understanding of how to a) integrate and b) maintain new technologies that offer more functionality in one space (e.g. specific technologies related to data centres and 'stacks', reciprocal heat exchange, district air handling units and in-built healthcare equipment). New forms of integrated ownership of these on-site technologies may be required.

4

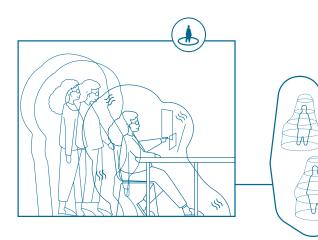
Growing, advanced community of UX (user-centric) design specialists to increase building legibility for occupants to adapt spaces to suit needs, whilst maintaining a safe baseline.

5

Equip occupants to adapt their own microenvironments - via both manual and digital means. As we have shifted from blanket lighting to task lighting, what would the next generation of small-scale personalisation be?

"As opposed to largescale, centralised and inefficient systems, we should consider equipping occupants to adapt their microenvironments. This doesn't look like super high-tech interventions (in fact, it can't for cost reasons) - we may be reverting to or reimagining traditional techniques and moments in the built environment."

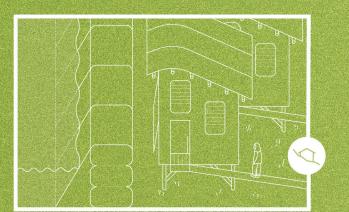
Indy Johar, Dark Matter Labs

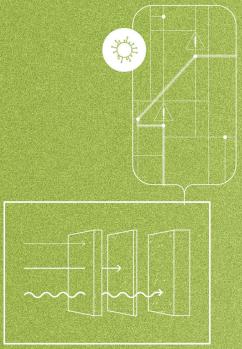


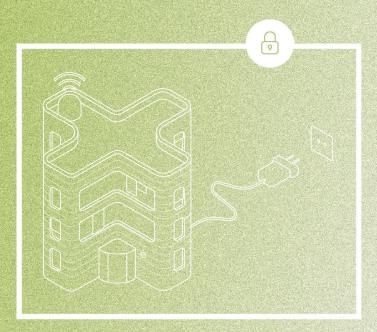
Building Performance Reimagined

02

Readiness







Readiness

...for changing conditions, tangible and intangible threats, risks, and uncertainties. Healthy and resilient ecosystems prevent harm from harsh environments or extreme events, and mitigate disruption.

How might building services reduce risk and harm, and build anticipatory capacity to respond to unseen threats?

What is shaping our needs and expectations for **Readiness?**

We are entering an era of mass vulnerabilities in which physical, digital, geopolitical, and public health risks compound and cascade from one another. Where public funding is thinly spread, citizens turn to private providers and community initiatives to build resilience and ensure business and service continuity in the face of uncertainty. Innovative solutions are informing and informed by increasingly sophisticated modelling of risk in complex systems.

A building takes on new value as a space of 'hard' and 'soft' refuge (i.e. meeting needs for physical protection as well as comfort) in a landscape of perceived and proliferating risk; proving that it can withstand a range of external threats including being 'cut off' entirely. How successfully a neighbourhood can provide safety and security for the communities within it will determine its insurability and viability. "In disasters, people need safe places. Robust buildings like schools and other public buildings are places of refuge that everyone needs, especially those with health challenges. It is not only humane, it is financially foolish to fail to build for disasters, especially now in the era of climate heating."

Prof. Richard J Jackson, Public Health at UCLA

"It's important to remember that these aren't just trends: whether bringing nature into our buildings or the use of digital technologies, they are critical interventions that will be necessary to address the pressures of urban life today."

Carlo Ratti, Professor of Architecture at Politecnico di Milano and the Massachusetts Institute of Technology



About 35.6 million

properties — a quarter of all U.S. real estate — face increasing insurance prices and reduced coverage due to high climate risks.²⁰ **45%** of data centres in the US have already experienced an extreme weather event that threatened continuous operation.²² The urban heat island effect caused by built-up areas can cause parts of cities to be **5–6°C** warmer than the surrounding countryside. This poses challenges to human health and city systems.²¹ Over **800mn** people living in **570** cities could be at risk of sea level rise by 2050.²³

Readiness

What does 'Readiness' mean for performance in 2050?

In 2050 buildings could be...



Digitally secure

Places with the ability to securely collect, process, and store masses of data on users, infrastructure and the wider urban system without compromising on data quality, security or sense of privacy – whether the physical data storage is on-site or via ever more sophisticated cloud solutions.

"Could I customise the building system as a user; turn its recognition or bio-authentication features on and off in the same way I can toggle privacy settings of apps today? Making clear where and how I have rights over my data to promote a feeling of security could be a critical aspect of building services in future."

— Jess Bland



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Invisible risk managers

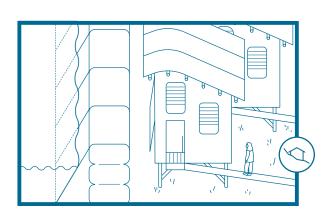
Buildings working as 'live' immune systems, able to monitor, anticipate, detect, and effectively combat unseen threats to users and communities, ensuring they do not impact physical and mental health.

"Purposeful or even accidental release of toxins in the environment is happening now and in a widespread way. More and more people have access to very sophisticated chemicals and biological agents [...] Some of the 'green' chemicals we use because they are biodegradable (take cleaning products) are poorly understood. They actually come with more complex risks that we haven't really explored."

Jess Bland

"Smaller interventions like upgrades to water systems in commercial kitchens that consider food prep spaces and contaminated water can be positively impactful for health."

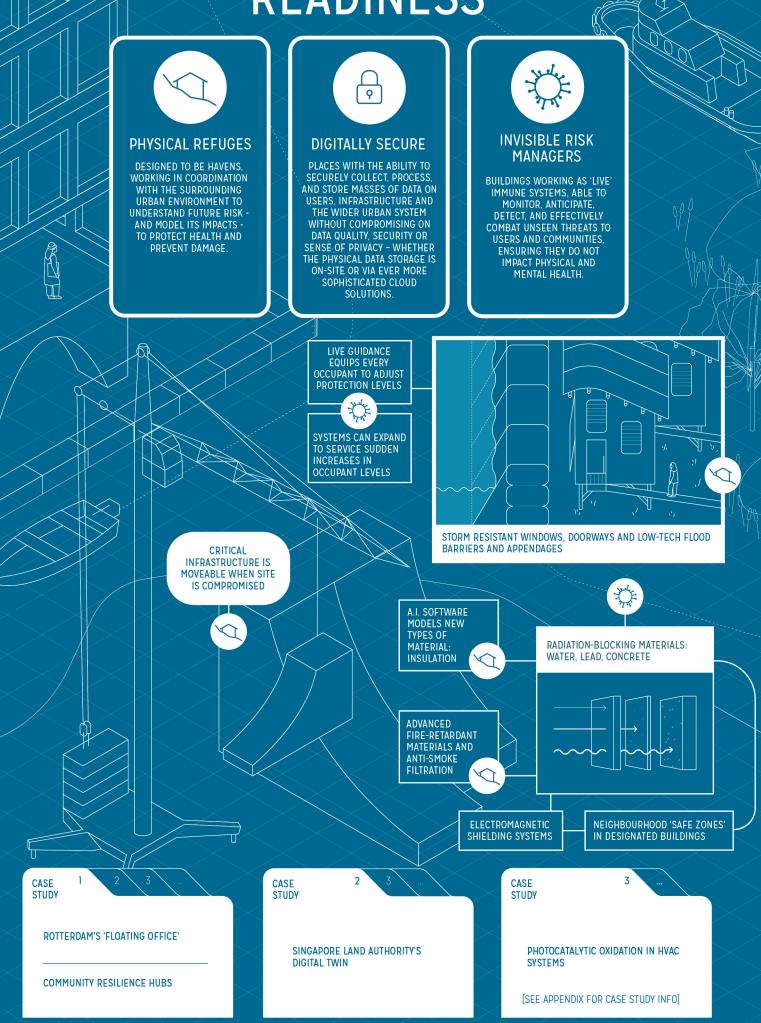
— Richard J Jackson

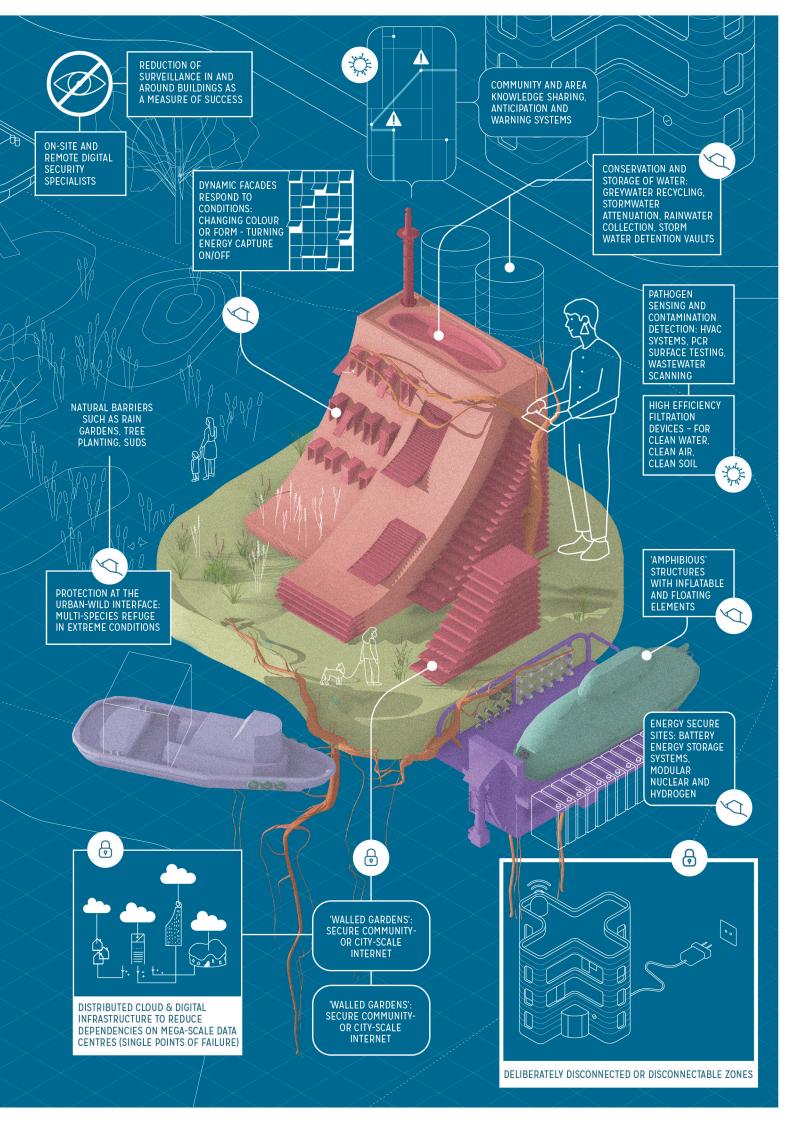


"Things that we've taken for granted, like the connection to utilities, to the grid and to critical infrastructure, are becoming 'wobbly'. When it comes to climate, the frequency of flooding, potential blackouts, even the supply of food to the café in a building: all these things are wobbling. Have you seen the rolling blackouts in Texas? There are places where we thought this would never happen and it's happening."

Jess Bland, Director at the Centre for the study of Existential Risk, University of Cambridge

READINESS





Readiness

Implications for Building Services Design and Engineering

How might building services reduce risk and harm, and build anticipatory capacity?

6

Building services engineers can both **inform and benefit from weather, climate risk and disaster scenario modelling** — to support buildings' responding, mitigating and adapting to increasingly extreme conditions.

7

8

Interdisciplinary design for essential service delivery in 'emergency' refuge spaces: for example, how do water, food and energy temporarily reach inhabitants? What potential for additional capacity can we design in when buildings see a sudden influx of inhabitants?

Partnerships with the next generation of scientists and engineers — those who design digital environments and work with quantum computing — to better understand the implications of encryption, 'smart' services and their vulnerabilities.

9

Deepening expertise of public health (beyond drainage systems): the application, and combination, of building data with nature-based solutions to tackle health concerns and emergencies, for instance learning from wastewater data and air quality data.

10

'Passive survivability' — that is, a building's ability to function for some time when fully **disconnected** — as a hygiene factor for designing and upgrading services and systems.

11

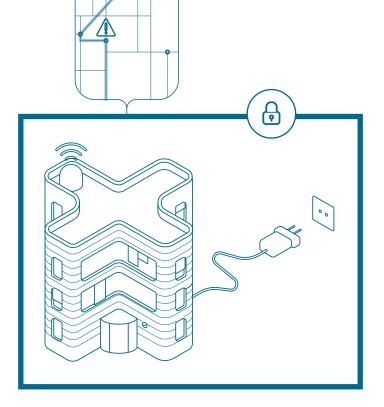
Designing for **buildings which need to 'know' who their most vulnerable inhabitants are** under different conditions (including more extreme yet plausible risks like chemical, biological or radiological events).

12

A new, **GDPR-aware type of engineer** may emerge, able to secure increasingly complex Building Management Systems and converging networks which capture and share multiple individuals' data.

"Do we revert to gated communities, or can building services unlock a new model for community resilience?"



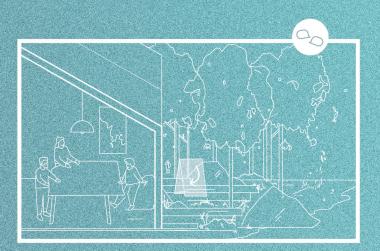


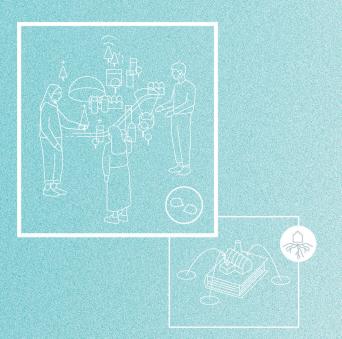
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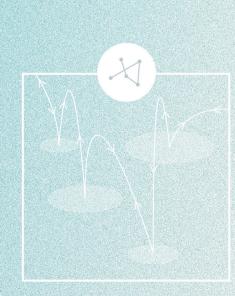
Readiness

03

Connectedness







Connectedness

...to local infrastructure, context and community — to living and nonliving entities within and around. Healthy and resilient ecosystems are connected to other complex systems whilst nurturing internal networks and relationships.

How might building services better respond to the building context and its contents, and integrate with local and wider systems?

What is shaping our needs and expectations for **Connectedness?**

'Connectedness' continues to advance within the built environment as digital infrastructure integrates with the physical. Buildings and their component parts are increasingly internally networked and digitally twinned. In future, we might expect more open-source data and systems, and computing 'at the edge' (i.e. through the Internet of Things, or IoT, that will sense and interact with building occupants). Combined with new utilities models and system-led approaches to planning, more efficient connections can be made externally — between neighbouring buildings and at a city scale.

In addition, connection to context may become more measurable — that is, the extent to which a building is deeply informed by the topography, climate, ecology, and culture of its location. The final measure of connectedness is the knowledge of who and what is in a space, and how social relationships can be nurtured, not superseded, by services. "It all comes down to people! Where people want to be, attracts other people."

Laura Forlano, CAMD Northeastern University

"You need to treat buildings as complex systems, because they also contain the people who are living in them, and the regulatory frameworks around them and the associated financial interests and the whole supply chain connected to it... so large, you can't really comprehend it, so you can't approach them with a deconstructivist engineering mindset, but with an experimental anthropological mindset."

Wolfgang Wopperer-Beholz, Systems Analyst & Conceptual Engineer

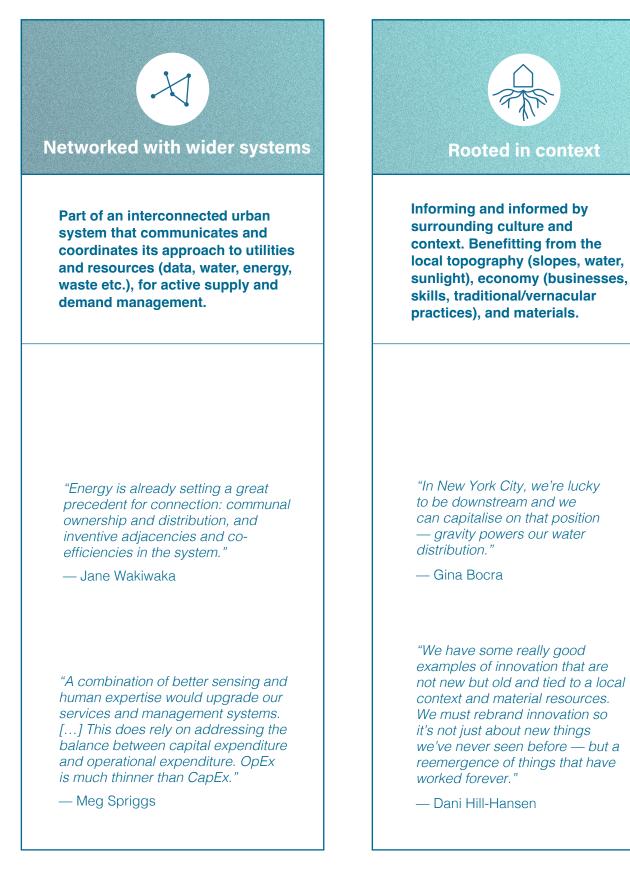


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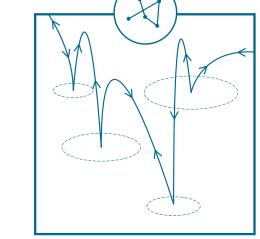
Connectedness

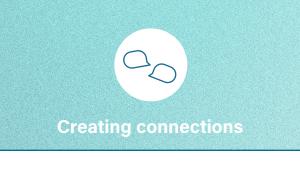
What does 'Connection' mean for performance in 2050?

In 2050 buildings could be...









Actively improving social relationships and enhancing social value for users, the local community, and the broader society — as well as enhancing interspecies connections.

"If we used friendships, marriages, graduations, even patent applications as performance metrics, we might design services for social interaction more seriously."

— Jan Golembiewski

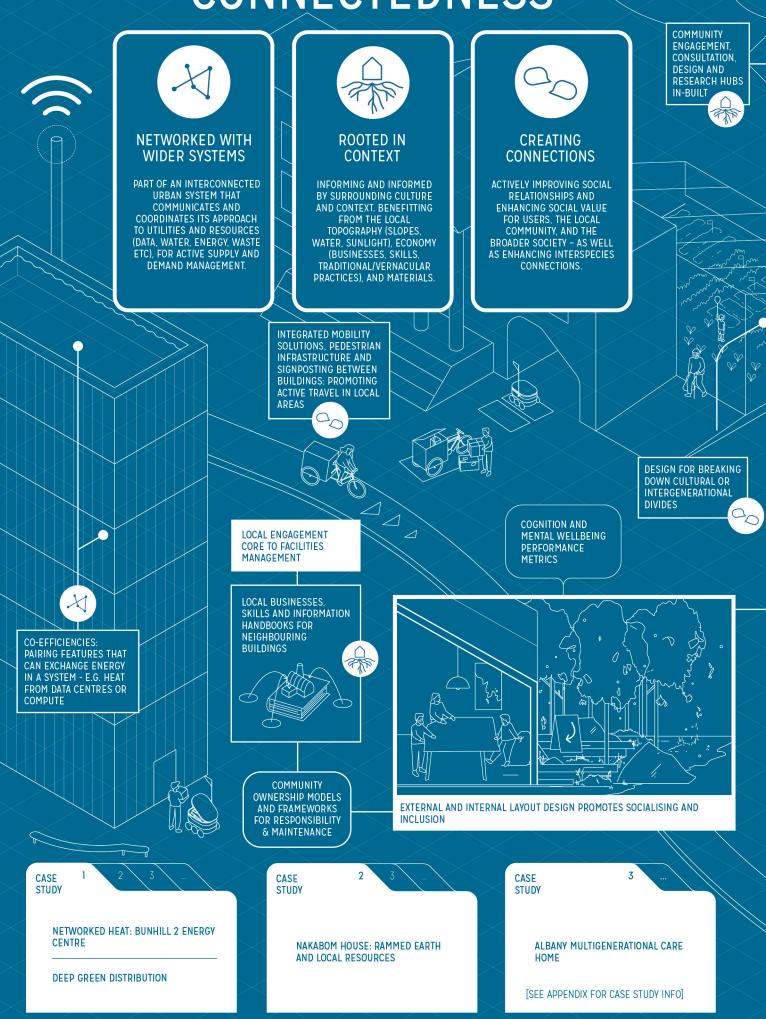
"80 to 90% of our impact on biodiversity happens along the global supply chain. We're also just beginning to quantify the impact of global supply chains on faraway people. So if we're only looking at what happens on-site, we are ignoring most of the true impact of the building."

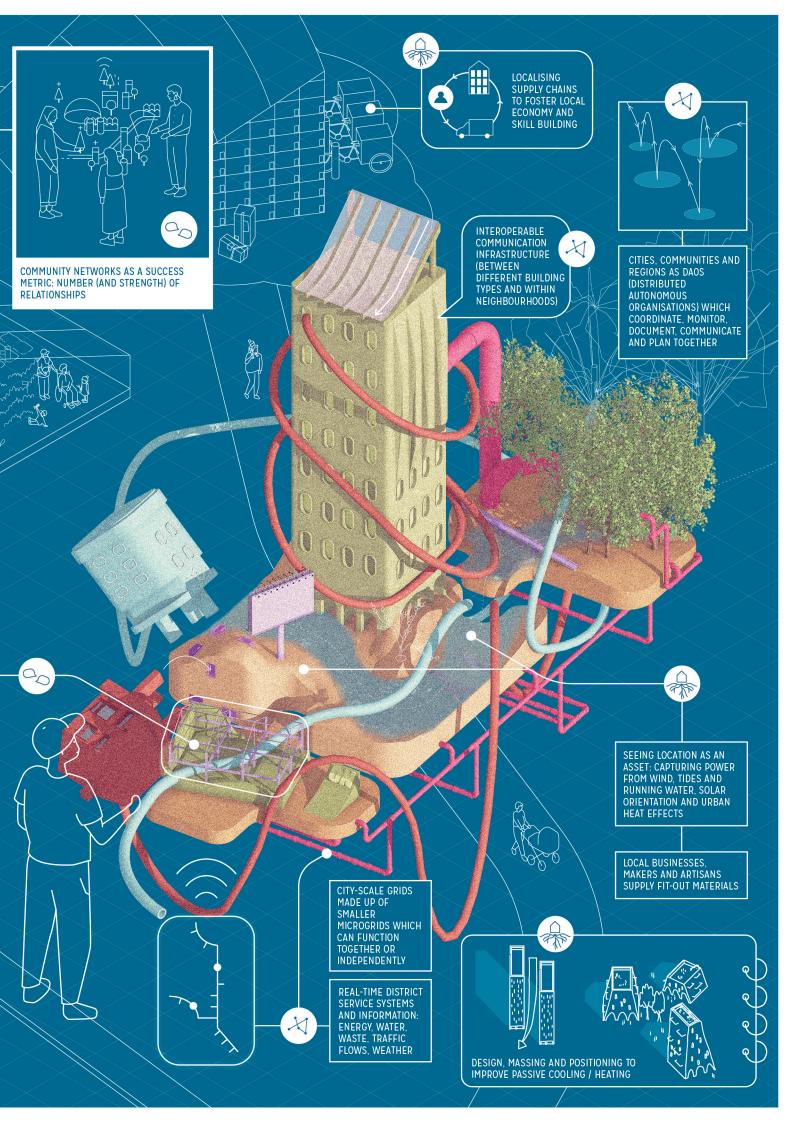
— Dani Hill-Hansen

"We can't just export values and transpose decisions made in another geography to a completely different space and place [...] how many engineers and designers are really asking what occupants and locals need?""

Joshua Dawson, Climate Futures Artist

CONNECTEDNESS





Connectedness

Implications for Building Services Design and Engineering

How might building services better respond to the building context and its contents, and integrate with local and wider systems?

13

A hyper-local, consultative approach to design, delivery and on-going maintenance — proof of understanding local context via **engagement with local people.** This is also about building and benefitting from local memory — why were design decisions made in the past?

14

Articulating and quantifying social value in the provision of services: what are the direct (on-site), indirect (suppliers, community beneficiaries, nature/other species) and systemic advantages?

15

Networks of engineers whose **combined knowledge on neighbourhoods** improves coefficiencies, in wider, complex urban systems. Creating spaces or systems for faster knowledge sharing and problem-solving.

16

Engineers with anthropologist minds who study behaviour and reduce frictions and barriers to social interaction, embracing ambient technologies that, for instance, reduce the amount and complexity of user interfaces. This is also about **telling compelling stories to non-technical stakeholders** who are reluctant to embrace new infrastructure essential to service delivery.

17

Co-location of engineers, architects and urban planners to co-design and manage cityscale utility flows, and to create value from e.g. urban heat island effects, wind corridors, even to redistribute energy excess at building down-times.

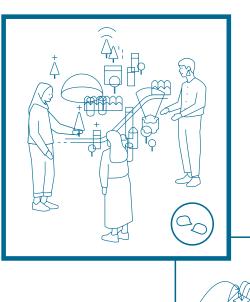
18

An overall shift to a 'systems thinking' mindset for engineers across disciplines.

Connectedness

"People ask me how to plan a city. I say, you need a humanist's heart and scientist's head. You are designing a machine for living that is connected to context and component parts work together, speak to each other — and you fine-tune the services, systems and flows around topography, historical buildings and people."

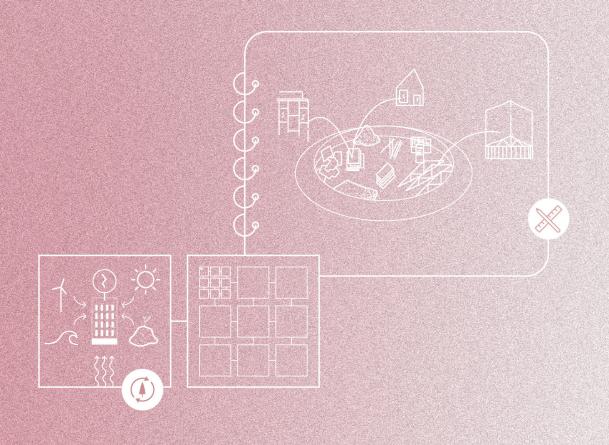
Dr Liu Thai Ker, former Chief Planner of Singapore and CEO of the Urban Redevelopment Authority



04

Emergence





Emergence

...of new materials, uses, and ideas from what already exists. Learning and adapting throughout life cycles. Healthy and resilient ecosystems generate, restore, and regenerate, unlocking local abundance and balancing supply and demand.

How might building services contribute more than they consume, and learn as structures age?

What is shaping our needs and expectations for **Emergence?**

Resources and materials are the key factors pushing and pulling us towards circular economies and regenerative design practices.³⁰ Buildings of all types have the potential to support a radical shift towards a culture of making and remaking — whether facilitating simple behaviour changes through to the integration of advanced, distributed manufacturing and urban agriculture.

Against a backdrop of ageing and outdated infrastructure in many markets, hotly contested resources (especially critical minerals) and skills shortages in most industries, performance may be based on a building's contribution — its users' ability to generate — rather than its consumption or emission. "How about no more new construction for the next 10 years? No more new construction for the next 20 years? Take what you have right now and adapt it to suit your needs... we may surprise ourselves."

Joshua Dawson, Climate Futures Artist



90% of the world's cities rely on forested watersheds for their water supply. Deforestation and biodiversity loss poses an immediate threat to this.²⁷

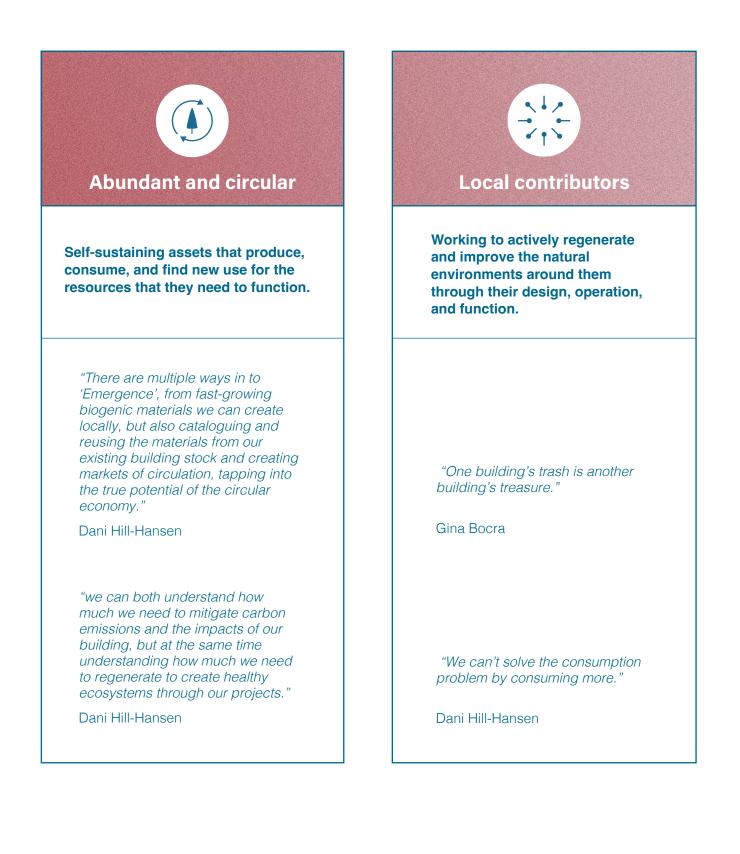
2.01bn tonnes of municipal solid waste is produced globally per year. Open dumps absorb a third of all waste generated, and landfills account for **37%** of all waste.²⁸

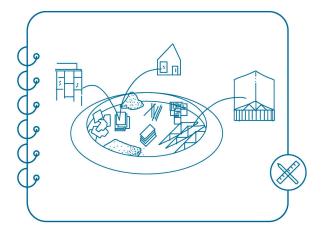
Production and processing of critical resources has become highly concentrated. China is responsible for **70%** and **68%** of graphite and rare earth production respectively, with the Democratic Republic of Congo accounting for **74%** of cobalt production.²⁹

Emergence

What does 'Emergence' mean for performance in 2050?

In 2050 buildings could be...





Spaces that are designed to support and grow a new culture of making and re-making.

Hubs for making

"What about sites that generate labour opportunities for individuals and communities? You'd need a different set of building services to facilitate multiple forms of entrepreneurship."

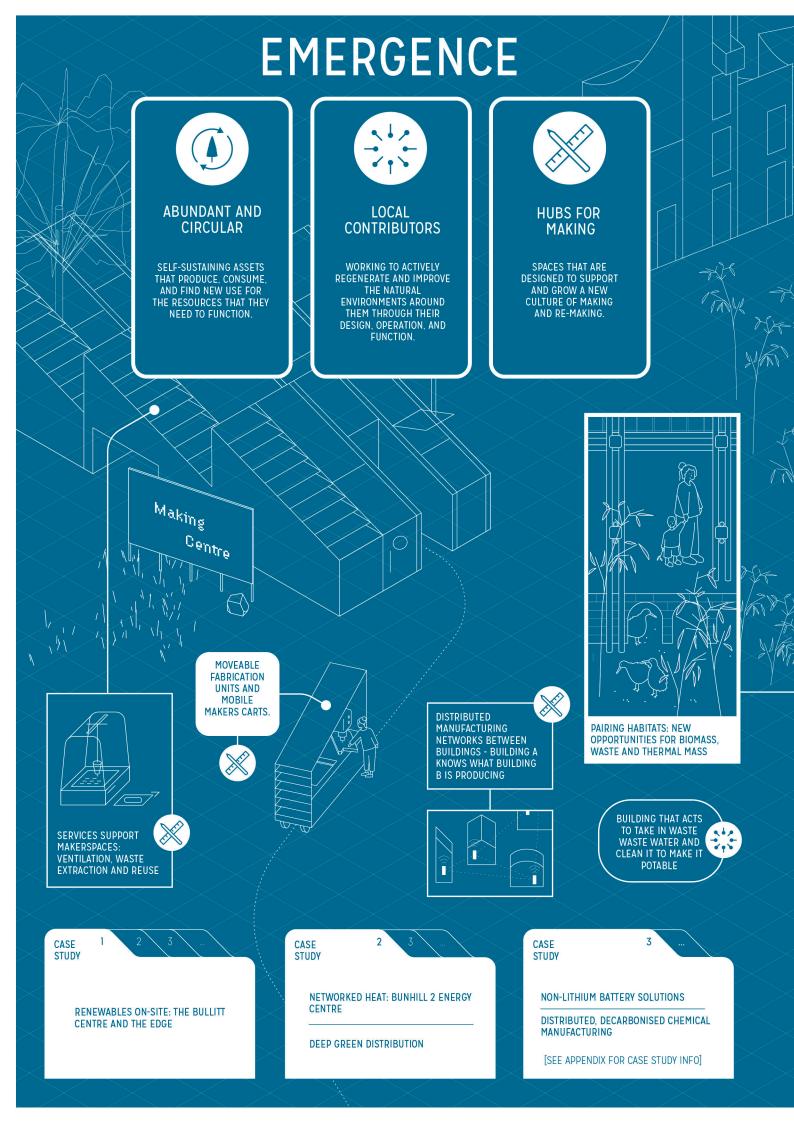
Sharon Prince, Grace Farms

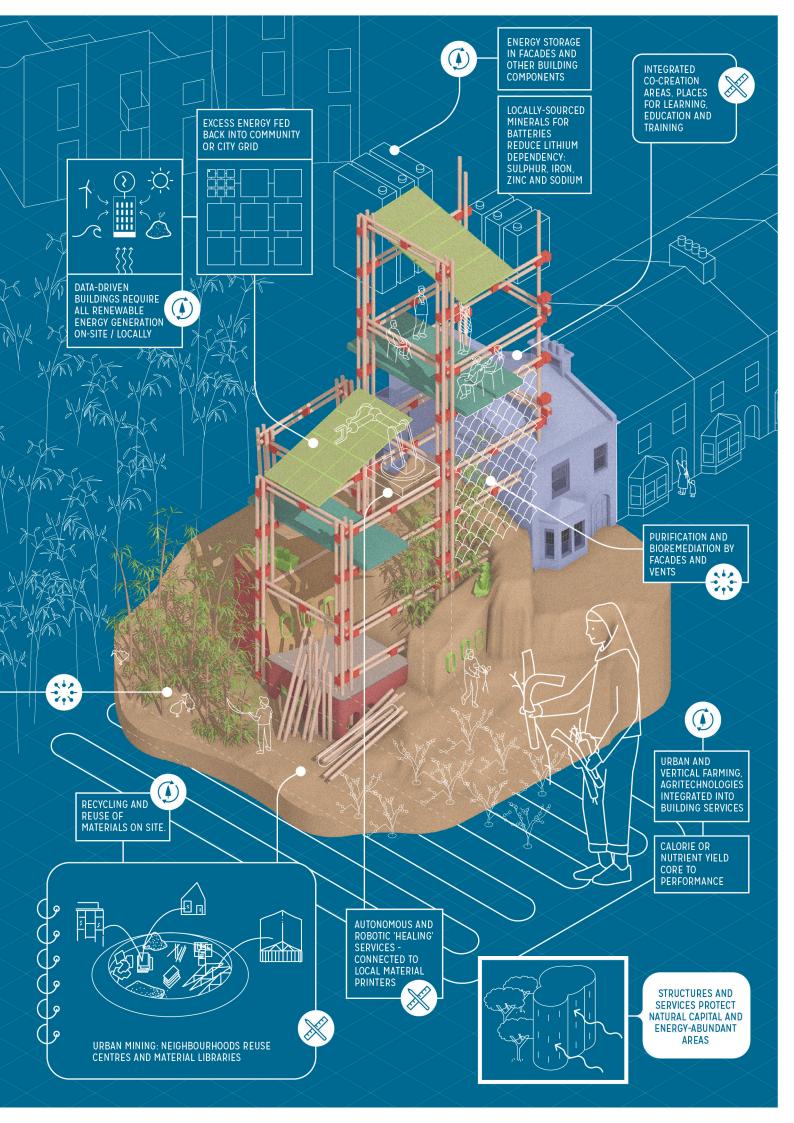
"In Tokyo, for example, buildings interact more seamlessly with their local economy. Boundaries between public and private buildings feel less clear, and more spaces represent opportunities to sell and showcase. What does that culture look like in future?"

Jane Wakiwaka

"In many markets like the UK, there's very little landscape left for new buildings, yet lots of standards are focused on new buildings. We simply don't have the carbon budget to build, so how do we regenerate?"

Indy Johar, Dark Matter Labs





Emergence

Implications for Building Services Design and Engineering

How might building services contribute more than they consume, and learn as structures age?

19

Energy generation and storage specialists are key to innovating / delivering more productive and efficient services, especially in the identification of naturally occurring energy sources e.g. human heat, nearby water.

20

Bioscientists and material specialists teamed with AI softwares to model and remodel component parts of buildings in service of regeneration and local, circular economies.

21

Build on existing activity around **organic and inorganic materials** — joining forces with academic and industry partners to find non-toxic solutions for the mainstream (for example, in phase-changing or responsive characteristics).

22

Service provision may mean the **delivery of a functional 'framework' or shell** which allows communities, public services and businesses to arrive, 'learn' the space and grow into it. Communicating the benefits of this 'emergent' approach to new occupants may dissuade them from ripping out and wasting 'Category A' fit outs. We may do away with this wasteful approach all together.

23

Mechanical and electrical services may expand and advance with more distributed manufacturing, but this comes with safety challenges. Who would provide the warranty for distributed manufacturing 'kits'?

24

iOS for buildings: as smartphone or automotive manufacturers use their software to understand and manage performance over time, building services engineers can consistently optimise performance — provided the information is available to them over time.

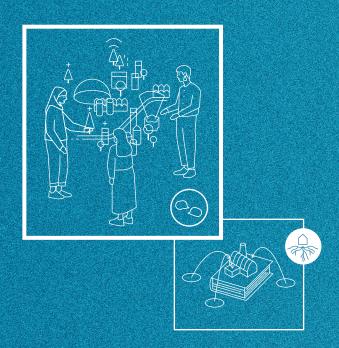
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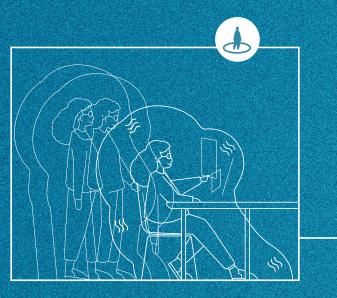
Collaborating to establish more accessible **catalogues or libraries of local materials and component parts**. Whole new markets and sites for testing, authentication, leasing and selling may emerge.

"We have some really good examples of innovations that are not new, but old, and tied to a local context and material resources. We must rebrand innovation so it's not just about new things we've never seen before, but a reemergence of things that have worked forever."

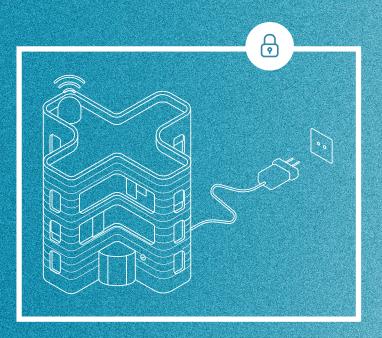
Dani Hill-Hansen, Architect and Sustainable Design Engineer at EFFEKT Architects

Summary and Change Enablers











Summary

The critical importance of building services

This CIBSE report is a conversation starter — a foresight aid to imagining what might happen at the edges of possibility for building 'performance' measurement and management. Ideas here shine a light on the potential evolution of a building services engineer in the coming decades.

In the coming decades, building services engineers may find themselves experimenting and their roles expanding in two directions, depending on location. Firstly, improving the performance of existing structures, spaces and places through retrofit and reimagination; and secondly, setting performance standards in places where there is no precedent, but a growing population to serve. To accommodate the largest wave of building and infrastructure growth in human history, from 2020 to 2060, the world is expected to add about 2.6 trillion ft² (241 billion m²) of new floor area to the global building stock, the equivalent of adding an entire New York City to the world, every month, for 40 years.³¹ There is enormous potential for building services engineers to define new performance metrics and create new forms of value.

However, it is important to acknowledge the complex reality of any effort to shape industry practice and norms. Engineers alone cannot realise these 'healthy' and 'resilient' futures. Joined-up engagement with stakeholders across all sectors and society is essential for driving change, especially when resources are limited and risk is rife.

> Our four performance themes all rely on other **'enablers of change'**. What conversations should take place? What relationships and partnerships should be built? What else needs to happen alongside and beyond our dayto-day design work? Based on 'Backcasting' exercises conducted with CIBSE members and other practicing building services engineers (see Methodology on page 12), the following considerations begin to bridge the gap between visionary futures and activities today.

"Today, within the existing institutional system, and within the existing incentive systems — look for gaps and spaces to experiment, expand and try subversive stuff. That's probably something that everybody across the built environment could or should do within their roles."

Wolfgang Wopperer-Beholz

Change Enablers

Economic considerations

For wider industry, regulators and policymakers

Introduce financial incentives for

developments and designs that support a sustainable and resilient future — and model the future cost benefits of early intervention.

Equally, **disincentivise poor or low usage.** This could include penalising inactivity and vacant spaces, or penalising the planned and premature obsolescence of building elements.

For CIBSE and institutional bodies

Convene economists, policymakers, systems innovators and relevant experts to explore how we might **quantify the 'hidden costs' of building service design** — beyond financial cost. For example, true social 'cost' or natural capital 'cost'.

Seek out and showcase examples of **new ownership and liability models** in the built environment: neighbourhood ownership and maintenance, service 'subscriptions', collective and community insurance.

For engineering organisations and employers

Explore the potential for **smart contracts and smart warranties** alongside product or material passports.

Support experimentation with the **balance between CapEx and OpEx.** What would a project look like that spent 10% of budget pre-handover, and 90% in post-handover 'learning', management and improvement?

For individual engineers and practitioners

Be curious about what you are replacing and where it is going. Consider what can be preserved, amended, appended or usefully deconstructed to reduce many forms of 'cost'.

Imagine that **each component part of a system or services being designed and fitted will 'learn' over time**, and increase in value with age. How does this change your approach?

External experts say:

"Our entire

macroeconomic system is designed, and dependent, on unsustainable growth. You realise that unless we actually change that system, it's hard to make meaningful change in other spaces. [...]

What would a business model look like that incentivises taking care of what we have and teaching people how to maintain and adapt buildings? So that we don't need these deep, costly transformations of buildings for them to be useful."

Dani Hill-Hansen

"Greater diversity of uses brings diversity of revenue streams – this can only be an attractive thing."

Jane Wakiwaka

"The 'Slavery Discount' is a term [Grace Farms has] created to bring to light the hidden costs of construction — and improve our accountancy around social value and social capital."

Sharon Prince

"Parts of Nova Scotia and California are already uninsurable due to climate change... we're on the cusp of a whole new system of assurance and protection."

"Investors and shareholders increasingly drive the sustainability conversation — they demand better outcomes on a number of fronts."

Meg Spriggs

Change Enablers

Education and skills considerations

For wider industry, regulators and policymakers

Offer better **support, skill-building, training and apprenticeships** to people who want to enter the industry from outside of the typical primary/secondary/tertiary education system and traditional engineering degrees.

'Hero' the technical brilliance of building service interventions that are creating positive change — attracting new interest and talent into industry.

For CIBSE and institutional bodies

Issue guidance with different levels of accessibility, **for differing levels of technical expertise** with the aim to improve building service adaptability and legibility for those moving in and around buildings as well as those who maintain, manage and design them.

Offer training and professional development opportunities in the '*spaces between***'** BSE and emerging or adjacent disciplines, such as:

- Risk modelling
- Ecology & nature services
- Anthropology
- Epidemiology
- Psychology
- Systems thinking
- Software development & computing

Actively take on the **role of convenor**, encouraging knowledge exchange and creating connections across disciplines — both traditional and emerging.

Consider the role organisations such as CIBSE have to play in creating **a shared language for service design**, including stories or imagination tools for engaging wider, non-technical groups of stakeholders.

For engineering organisations and employers

Seek training from facilities managers who face a range of daily, operational challenges. Consider them a critical stakeholder in design processes.

Identify the next generation of disciplines and skills required to design for Variety, Readiness, Connectedness and Emergence, and adapt your recruitment strategy accordingly.

For individual engineers and practitioners

Cultivate your UX (user-centric) design skills. Consider the kind of accessible guidance that would make building services intuitive and legible by anyone and everyone.

Hone your systems thinking skills: see yourself as 'connective tissue' between different parts of the urban system. For example, designing an electrical system that is in a dynamic relationship with the local power network.

Design with nature: build an awareness of ecosystem services that can fulfil inhabitant needs and reduce costs and over-engineering.

Lean in to advanced ideas around public health and mental health — such as the wellbeing impacts of interactions with nature, or thriving microbiomes — in order to create environments that support diversity whilst maintaining high standards of hygiene and safety.

External experts say:

"We're missing as a state and as an industry effective ways of thinking about complex systems."

Jess Bland

"Facilitators and translators of knowledge are what we need [...]

What we [Doughnut Economics for Urban Design] do is communicate complexity in a simple way so that anyone can relate to it. It's traditional architecture and communication skills meeting a deep understanding of life cycle assessment. building legislation, systems transition. So it's a whole field and diverse set of skills that have contributed to one project [Doughnut Economics] being successful."

"My role is synthesising information from very different disciplines, and on different levels of abstraction – this is required to understand and drive social change."

Wolfgang Wopperer-Beholz

"Technologies are being integrated at speed, but don't forget, the more advanced the system, the more skilled your users and facilities managers need to be."

Meg Spriggs

Dani Hill-Hansen

Building Performance Reimagined

Change Enablers

Policy and regulatory considerations

For wider industry, regulators and policymakers

Explore the privacy implications of a 'smarter' built environment and work with BSEs on safe and ethical information collection and use.

Promote, or even mandate, multi-functionality and diverse usage across building types (especially commercial property).

Set goals and targets (for embodied carbon, for instance) at a city or neighbourhood-scale, rather than an individual building level — encouraging more holistic engineering solutions.

For CIBSE and institutional bodies

Leverage the convening power of organisations

such as CIBSE to bring together technical experts, regulators and policymakers — for example, to move beyond national or generic regulation and standards towards more local rules, and guidance based on a building's context.

For engineering organisations and employers

Collaborate with landowners and strategic planners to **integrate individual schemes with neighbourhood-scale utilities networks.**

Set braver company policy related to circularity and material reuse, and the true 'cost' of a commission.

Explore new contractual terms, management structures and financial agreements which **enable flexible space sharing, short-term uses and increased public use of spaces.**

For individual engineers and practitioners

Imagine meeting the needs and **protecting the rights of species other than humans**, in and around buildings.

Consider the **opportunities to 'join up' or influence fragmented approval and consent processes** for planning and development schemes.

External experts say:

"What if we deconstruct the adversarial legal framework around building planning, creation, use and recycling?"

Jane Wakiwaka

"As we work more from home, who takes responsibility for ensuring residences are healthy environments? We might expect to see boundaries blurring between residential and commercial rules."

Indy Johar

"Could building services engineers encourage setting limits that are aligned with planetary wellbeing, and therefore a future where we can actually sustain life on this Earth?"

Dani Hill-Hansen

Change Enablers

Governance and cultural considerations

For wider industry, regulators and policymakers

Advocate (and legislate?) for nature as a

stakeholder in tendering and design processes — pushing for buildings and their surroundings to be net-nature positive.

For CIBSE and institutional bodies

Provide tailored guidance for the design of services that will be operated partly onsite (human) and partly off-site (remote, automated). Is there an optimal balance? Where are the risks?

Consider the role of professional bodies such as CIBSE in setting 'missions' and 'goals', alongside 'codes' and 'standards'.

For engineering organisations and employers

Identify networks of local 'knowers' — people who are deeply embedded in the context of a site — to inform design processes and consult on the potential use of space.

Introduce 'whole value chain' and 'whole life cycle' conversations in tendering and design processes: mapping elements such as supply chains, labour, deconstruction, demolition and future use.

For individual engineers and practitioners

Approach comfort in terms of **designing microenvironments**, within which individuals have more control.

Start conversations and build relationships with building owners, operators and occupants — reducing knowledge gaps and making service provision a collaborative act.

Become a storyteller for the built environment, not just a technical expert. Bring to life the value building services provide to humans, communities and nature — and the role every citizen can play in making them 'work' better.

See compliance as a baseline, but performance as the goal.

Building Performance Reimagined

External experts say:

"More consideration of operational implications of decisions made in design and construction stage is required. Sometimes decisions made in design and engineering and construction favour cost implications at the expense of long-term operational drawbacks. [...]

Do building services engineers consider consultation and engagement with younger generations? How much are we telling, versus how much are we listening?"

Jane Wakiwaka

"We'll find ourselves in tension between automated remote and human on-site building management. The former is cheaper, the latter cultivates knowledge which is invaluable. Is there an optimal balance?"

Meg Spriggs

Change Enablers

Technological considerations

For wider industry, regulators and policymakers

Make connections between innovation and the built environment at every level of technology readiness (TRL) — from experimentation to incubation and application at scale.

Nominate and incentivise local areas and communities to trial new systems of services — for instance, connected utilities across and between building types.

Make data open source where possible and safe, to encourage analysis which can improve service design, delivery and performance management of whole areas.

For CIBSE and institutional bodies

Nurture and grow membership expertise in digital twins and modelling. Support

industry to understand how to leverage all of the performance benefits of new sensors and softwares.

Provide guidance and standards on interoperability — of digital twins, and of material/product passports across supplier and building types.

Connect members and industry with academic institutions to spot early signs of technological and materials innovation. Conduct your own analysis and identification of 'early signs of change' with potential impact for building

services.

Advise on the types of data most useful for measuring future 'performance'. What are the data sources? Who or what collects and analyses them?

For engineering organisations and employers

Incubate and encourage in-house innovation via 'hackathons' or dedicated makerspaces.

Partner with technological experts or academics under a shared charter or 'mission' to improve Variety, Readiness, Connectedness or Emergence.

Participate in markets of material circulation and reuse.

For individual engineers and practitioners

Consider your role in **embedding more advanced technologies in places and spaces where they are not understood** or embraced. What accessible language, stories and rationale can build confidence in tenants and homeowners?

Improve the readiness of your designs: deliver innovation in **modular adaptation, and 'plug-ins' or 'add-ons'** that rapidly and drastically increase capacity.

Be curious about, and get comfortable with, software and tools that can be incorporated into service design. **Future building services** engineers will lead 'human-machine teams'.

External experts say:

"The availability of data is already having a huge impact at a city scale in NYC. We now track the consumption of buildings responsible for 60% of emissions here, and we know when their systems are due for maintenance or replacement. This is powerful information as we can nudge them towards better options."

Gina Bocra

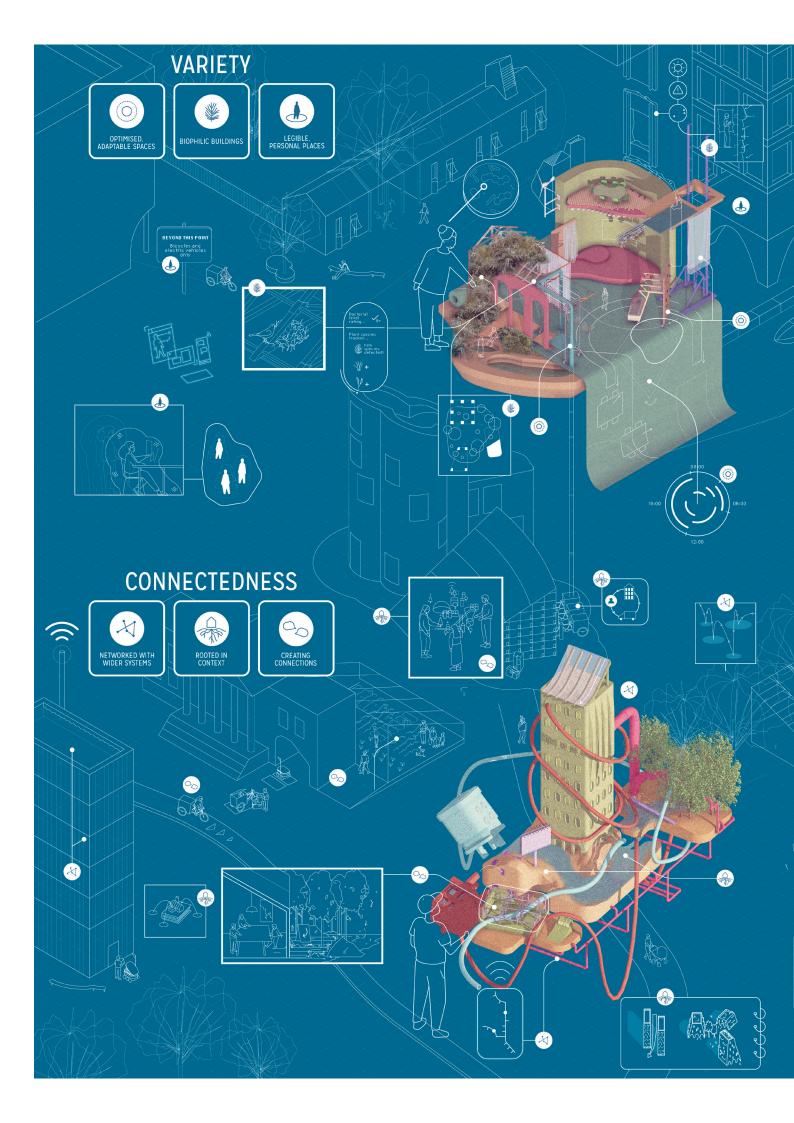
"All of the technologies we need to realise these futures exist in some shape or form. We just need to look outside of our typical points of reference, take a multi-disciplinary approach and reconsider our success metrics [...]

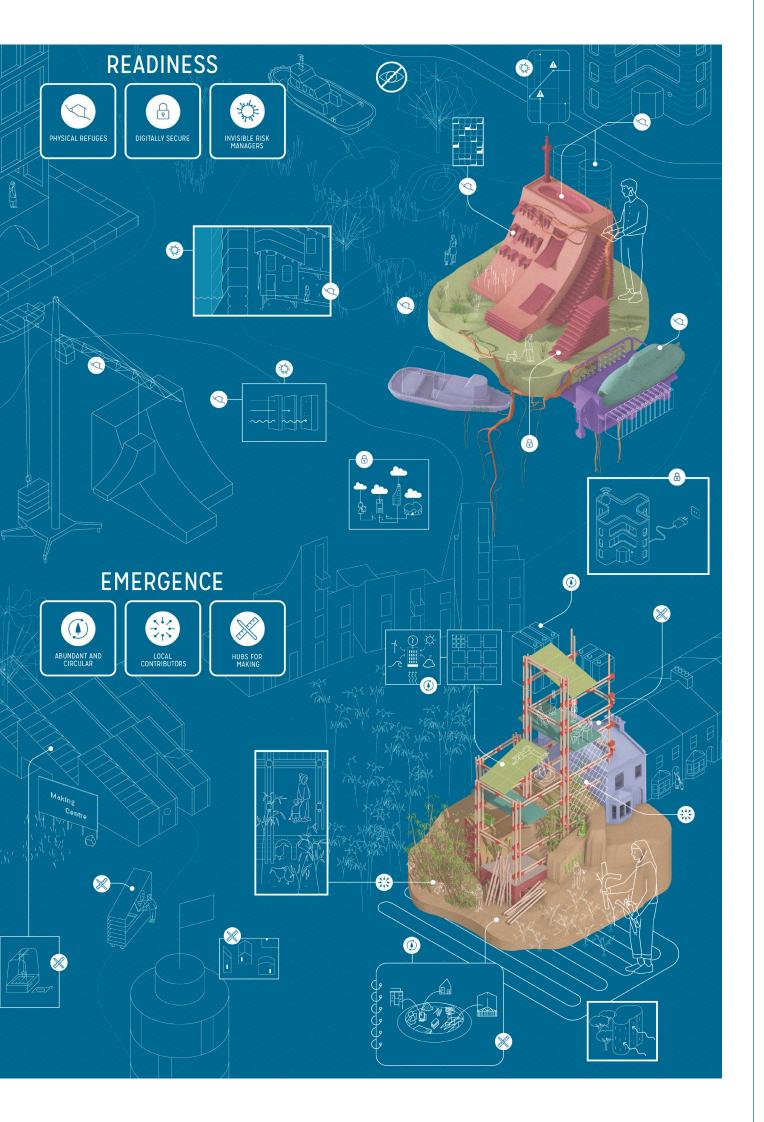
I think technology should always be seen as a tool to help us in a transition, but it is not the solution for changing our world. It should be something that helps us get there. But if we don't set the right boundaries or limits, then technology is just going to be used to perpetuate growth and keep the existing systems and power structures in place."

Dani Hill-Hansen

"Today, we need to think about how we can leverage digital technologies to blend the natural and the artificial world."

Carlo Ratti





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ARUP

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Appendix I - Case Studies

VARIETY

How might building services optimise space, promote adaptability and diversity of use and user? What early signs of 'Variety' can we see?

1. Signify is an example of BSaaS (Building Services-as-a-Service). Signify's product is simply 'Light'; a flexible and ongoing subscription service that responds to the building's changing needs over time, rather than supplying a one-off lighting package. www.signify.com

2. New architectural concepts allow for greater diversity of use

a. Commercial example: Ingenhoven Architects' inflatable architecture has been used for temporary event spaces, like the officials' zone at the Alpine Ski World Cup. <u>www.dezeen.</u> <u>com/2023/12/01/inflatable-ski-start-house-matterhorn-ingenhoven-architects</u>

b. Residential example: modular, deployable and fully demountable developments such as PLACE in Ladywell, London, which uses volumetric technologies for pop-up living quarters. <u>www.</u> <u>rhsp.com/projects/residential/place-ladywell/</u>

3. The line between 'natural' and 'unnatural', 'indoors' and 'outdoors' begins to blur:

a. The field of microbiology is attracting investment and interest from several industries. Early trials of prebiotics, postbiotics and parabiotics in diets and in our external environments are showing promising health benefits. <u>www.mdpi.com/1422-0067/25/10/5561</u>

b. The Vertical Forest is a prototype building for a new format of building biodiversity – blurring the red line between indoors and outdoors. The first example, built in Milan in the Porta Nuova area, consists of two towers that are respectively 80 and 112 metres high, housing a total of 800 trees, providing an amount of vegetation equivalent to 30,000 square metres of woodland and undergrowth, concentrated on 3,000 square metres of urban surface.<u>www.</u> stefanoboeriarchitetti.net/en/project/verticalforest/

READINESS

How might building services reduce risk and harm, and build anticipatory capacity? What early signs of 'Readiness' do we see?

4. Experimental concepts explore solutions for climate change and extreme weather:

a. Rotterdam's first floating office is a functioning, off-grid and moveable headquarters of the Global Centre on Adaptation and Powerhouse Studios. <u>www.</u> <u>dezeen.com/2022/10/24/floating-office-rotterdam-</u> <u>powerhouse-company/</u>

b. Grist media imagines 'Weather Resilience Hubs' in its recent speculative Futures publications – based on real world initiatives like the Kwai Quo (qwi?qwu?) centre in Lake City neighbourhood of Seattle.<u>www.</u> grist.org/looking-forward/from-fiction-to-reality-howresilience-hubs-could-help-people-weather-disastersand-build-community/_

5. Singapore's Digital Twin development is well underway, enabling Singapore Land Authority, multiple stakeholders and developers to model the impact of change and disruption on the city infrastructure and buildings. Mapping at the national scale means community-scale twinning may be closer than we think. www.infra.global/singaporesdigital-twin-from-science-fiction-to-hi-tech-reality/

6. Nature-based solutions can be used to build resilience and mitigate multiple kinds of threat. For example, recent breakthroughs in photocatalytic oxidation mimics the self-cleaning processes of our atmosphere. <u>www.nature.com/articles/s41467-021-22839-0</u>

CONNECTEDNESS

How might building services better respond to the building context and its contents, and integrate with local and wider systems? What early signs of 'Connectedness' can we see?

7. Co-efficiencies and mutual benefits are being explored within existing urban infrastructure a) Bunhill 2 Energy Centre captures excess heat from London's Underground system to heat homes. <u>www.dezeen.com/2020/03/11/</u> <u>bunhill-2-energy-centre-london-undergrounduk-architecture/</u>

b) Deep Green is a decarbonised data centre company that recaptures the heat generated by computing and repurposes it for social good, for free. For example, they are heating leisure centre swimming pools from local data centre excess heat. <u>www.deepgreen.energy</u>

8. Nakabom House is a concept deeply rooted in context: from the rammed earth from the site which makes its walls (a traditional method), to the plastic roofing which was once packaging created by a local water supplier. The building is part of the Abetenim Arts Village, a learning and social centre for locals. <u>www.dezeen.</u> <u>com/2015/06/28/nkabom-house-prototypicalghana-home-mud-waste-plastic-anna-websterabetenim-arts-village/</u>

9. Designing multi-generational spaces is a way to promote lifelong learning and tackle a range of socioeconomic challenges – these spaces require new kinds of building service design. Sites like Belong Chester cater for the oldest and youngest ends of the population. www.theguardian.com/lifeandstyle/2024/feb/06/ young-old-and-marvellous-how-a-care-homebuilt-a-nursery-and-everyone-thrived

EMERGENCE

How might building services contribute more than they consume, and learn as structures age? What early signs of 'Emergence' can we see?

10. Commercial, residential and institutional / public sites are exploring renewable energy creation on-site

a. The Bullitt Centre optimising PV positioning and solar energy storage in Seattle. <u>www.</u> <u>bullittcenter.org/2013/04/03/solar-at-the-bullitt-</u> <u>center/</u>

b. The Edge in Amsterdam (98.36% BREEAM sustainability score) generates more energy for the local area than it consumes. <u>www.edge.</u> <u>tech/developments/the-edge</u>

11. Urban Farming is attracting investment and presents new needs and opportunities for building services to supply utilities and create optimal farming conditions. Examples of vertical farms integrating with existing and new builds include Futurae (US), CubicFarm (Canada), AeroFarm (UAE), InFarm (Germany), Spread (Japan), Farm66 (Hong Kong), iFarm (Finland). www.earth.org/vertical-farming-companies

12. Advancing material technologies and distributing manufacturing capabilities create new needs and opportunities for building services to enable new processes.

a. MycoComposite is a mycelium (fungus) material for constructing e.g. acoustic panels. There is potential for building components to be grown, harvested and printed hyper-locally. www.evocative.com/mycocomposite

b. Innovation hotspots around the world are developing alternatives to lithium ion batteries (for example solid-state, zinc-based, sodiumbased) which present new opportunities for safer energy capture, storage and distribution in and around buildings. <u>www.arstechnica.</u> <u>com/science/2024/03/next-gen-battery-techreimagining-every-aspect-of-batteries/</u>

c. 'DCheM' - distributed, decarbonised chemical manufacturing is being trialled in 20 candidate locations in Western Texas, involving modular process plants, which take advantage of distributed resources and address distributed environmental problems. <u>www.</u> <u>aiche.onlinelibrary.wiley.com/doi/full/10.1002/</u> <u>aic.18265</u>

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