

CIB Research Roadmap

Sustainable Construction

Draft May 2016



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Notes on this draft

This document is a conceptual draft for discussion. Readers are welcome to send comments, suggestions and contributions to chrisnaduplessis@live.co.za

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Introduction

The need for a roadmap

The founding objective of the CIB was to stimulate and facilitate international cooperation and exchange of information between organizations and institutions doing research in building and construction. One of the roles of the CIB is to provide guidance and direction to the research planning of its member organizations through the production of State-of the Art Reports or Research Roadmaps.



*Sustainability
a priority from
1995 to 2016*

CIB Priority Theme: Sustainable Construction

The members of the CIB recognized the importance of sustainable development, and specifically environmental concerns such as the need for resource efficiency, already in the 1980s, with many of its working groups engaging with aspects of sustainability. Recognizing that the built environment has a significant role to play in sustainable development, the CIB established the Priority Theme of Sustainable Construction in 1995. Under the leadership of W82: *Future Studies in Construction*, a project was launched to better understand and define the implications of sustainable development for the built environment.

Developing an Agenda

Following on *Agenda 21: A Blueprint for Action*, presented at the Earth Summit in Rio de Janeiro in 1992, and the *Habitat Agenda*, produced at the World Habitat Forum in Istanbul in 1996, the CIB **Agenda 21 on Sustainable Construction** was published in 1999. This document, a product of extensive international consultation and collaboration, was intended to provide a conceptual framework that is an intermediary between international sustainable development Agendas such as *Agenda 21* and the *Habitat Agenda* and local and regional agendas for the built environment and construction sector.



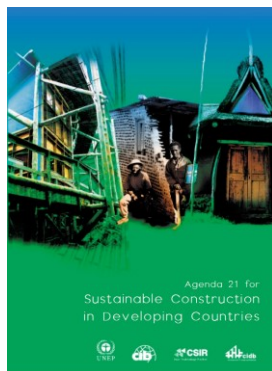
This Agenda had three objectives:

- a) to create a global framework and terminology;
- b) to create a coordinated agenda for the CIB and its partners;
- and
- c) to provide a source document defining R&D activities.

The **Agenda 21 on Sustainable Construction** presented a number of challenges, actions and suggested R&D directions for a sustainable built environment. It advocated the development of decision-making tools, more integrated design, and the inclusion of sustainability issues in education and training. However, its main focus was on reducing the environmental impact of the built environment.

In 2002, at the World Summit on Sustainable Development in Johannesburg, the CIB and its partners launched the **Agenda 21 for Sustainable Construction in Developing Countries** that introduced not only a developing country perspective, but also the social component missing from the previous Agenda. It introduced a research agenda aimed at the development of short- to long-term technological, institutional and value-system enablers, as well as a Strategy for Action aimed at stakeholders that included capacity building, monitoring & evaluation, and the establishment of partnerships and cooperative mechanisms.

A hallmark of both Agendas is the recognition that while there is a common objective and many shared concerns and approaches, the challenges and opportunities varies from country to country, requiring contextually appropriate solutions to the common issues of sustainable development



Sustainable construction means that the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and built environments, while creating settlements that affirm human dignity and encourage economic equity – A21SCDC

SBE Conference series a global partnership between



Impact of the Priority Theme

Over the twenty years of its existence, a number of ongoing activities were established under this theme. The most significant of these are two conference series and the Emerald journal *Smart and Sustainable Built Environment*.

The **World Sustainable Building Conference** (now *Built Environment*) series originated with the First International Conference on Sustainable Construction held in Tampa, Florida in 1994. It became an official biennial conference series in 2000, shifting later to a triennial series from 2005, with regional conferences in the off years. Since 2000, there have been six main World SBE conferences and numerous Regional conferences, publishing thousands of papers on the topic of sustainable building, urban sustainability and other related topics.

The SBE Conference Series is now considered to be the pre-eminent international conference series on sustainable building and construction and maintains a core emphasis on peer-reviewed papers, presentations of regional policy papers and displays of assessed projects.

The **Smart and Sustainable Built Environments Conference** (SASBE) series is the official meeting of Working Group 116 on Smart and Sustainable Built Environments. These conferences take place on a triennial basis. So far there have been conferences in Brisbane, Shanghai, Delft, Sao Paulo and Pretoria.

Working Group 116 is also responsible for the Emerald journal **Smart and Sustainable Built Environment**. Launched in 2012, the journal has published 15 issues and is indexed in SCOPUS, EBSCO and a number of other databases. It is the only journal that focus on holistic solutions and integrated approaches to developing innovative systems, methods and practices for sustainable products and outcomes of all aspects of the built environment.

The theme has further been supported by a number of commissions that focus on aspects of sustainability in the Built Environment.

Active Commissions aligned with the Priority Theme: Sustainable Construction

- W116: Smart and Sustainable Built Environments
 - W115: Construction Materials Stewardship
 - W110: Informal Settlements and Affordable Housing
 - W104: Open Building Implementation
 - W101: Spatial Planning and Infrastructure Development
 - W69: Residential Studies
 - W120: Disasters and the Built Environment
 - TG79: Building Regulations and Control in the Face of Climate Change
 - TG86: Building Healthy Cities
-

“The SB Conference series embodies everything that the CIB aims to achieve in promoting research and innovation that is to the benefit of society”.

CIB Board

The evolution of the sustainability debate and its interaction with other developments have also led to a new Priority Theme on Resilient Urbanization, and a growing number of commissions that investigate aspects of smart buildings and cities.

The big question this report aims to answer is whether the CIB should continue with Sustainable Construction as a Priority Theme. The theme has very successfully achieved its purposes to define the concept and stimulate research and knowledge exchange, with many of the CIB commissions viewing their own investigations through the lens of sustainability and the achievement of goals such as reduced environmental impact, increased social equity and efficient resource use.

It can be argued that there is no longer a need for a dedicated theme to stimulate research in this field. This raises the next question: what should be the next Priority Theme that would take this work further?

What has changed since 1995?

Since 1995, a number of things have changed. There has been some progress in certain areas, new technologies are coming into play, and the concerns underpinning sustainable development has increased.

The low-hanging fruits are in the basket

In the 20 years since this Priority Theme was established, much progress has been made in the areas of education, policy and regulations, technology, and rating and assessment.

Sustainability is part of conventional built environment education

A Google search for “sustainability education” + “construction” returns over 103 000 results; there are over 500 MSc courses available that deals with some aspect of sustainability in the built environment; and most universities include aspects of especially environmental sustainability in their undergraduate courses in architecture, engineering and construction. This is largely driven by industry demand for graduates with some understanding of sustainable construction¹. Finding appropriate pedagogical methods, determining the skills that need to be developed in these courses, and structuring curricula that can accommodate systemic thinking and inter- and transdisciplinary approaches within university structures that continue to be based on disciplinary silos, have become rich areas of research.

Green Building has become big business

The World Green Building Council reported in 2014² that there are a 100 Green Building Councils worldwide, representing over 27 000 member companies and organizations, and 1.2 billion square meters of green building area registered by the WGBC affiliated rating systems.

There is no doubt that these rating systems proved to be one of the big levers in changing market attitudes to sustainable building and construction and driving the phenomenal growth in market share of green building. The latest *World Green Building Trend Report*³ by McGraw-Hill Construction found that globally 94% of architects, engineers, contractors and other consultants polled were involved in some level of green building, defined as a project that has been built to qualify for one

Source: McGraw-Hill Construction, 2013

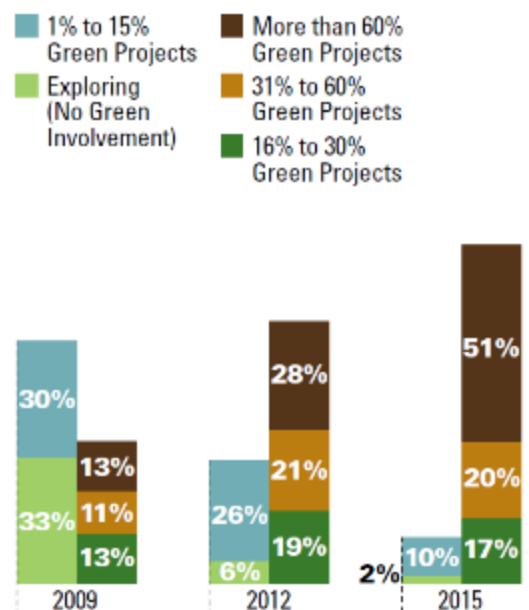


Figure 1: Level of Green Building activity by firms around the world (2012-2015 expected)³

of the rating systems. More than half of the firms polled predicted that by 2015 more than 60% of their work will be green. In Singapore green building projects constituted 66% of construction activity and was expected to rise to 89% of activity by 2015.

The McGraw-Hill Report further found that there has been a definite shift in the drivers for green building, with client and market demand, followed by reduced operating costs and branding, as the main reason companies gave for going green. In their 2008 survey, the main drivers were moral (it's the right thing to do), global competitiveness and environmental regulations. However, these drivers remain strong in Singapore, the United Arab Emirates and South Africa.

Improved health and well-being and increased worker productivity have become the most important social drivers, while reducing energy consumption, greenhouse gas emissions and water use have become significantly more important environmental drivers.

Government has come on board

Governments in both developed and developing countries have established a range of policies and other measures to encourage and enable sustainable building and construction. These range from building codes and standards to incentives such as subsidy, grant and rebate programmes, and in countries with voluntary rating programmes, codes and standards are often based on these rating tools⁴. However, in most countries policy instruments remain isolated from each other, with different policies for energy efficiency, water management, waste management, and other aspects of sustainability.

At an international level, at the 2015 COP 21 meeting in Paris, 195 countries adopted the first legally binding global climate deal which includes recognition of the need to address loss and damage associated with the adverse effects of climate change.

Renewables are rapidly growing their market share

The adoption of renewable energy and building materials has shown phenomenal growth.

The barriers against renewable energy are falling

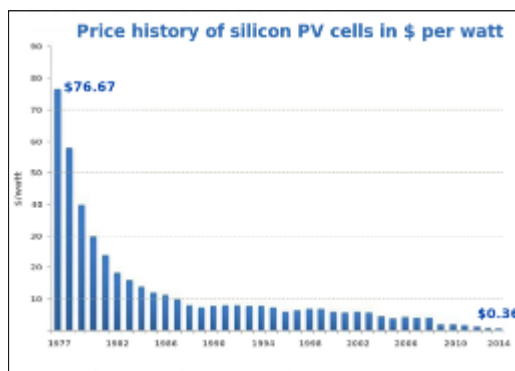


Figure 2: Falling price of polysilicon PV panels⁶

The International Energy Agency reported that energy production from renewable sources are now becoming the largest source of new generation capacity and the per kilowatt costs of solar and wind power has reduced dramatically⁵.

For example, the cost of polysilicon solar panels has dropped from US\$ 76.67/watt in 1977 to US\$ 0.36/watt in 2014⁶.

Coupled with the downward trend in costs, is an increase in installed renewable energy capacity. By the end of 2014, renewables [including large hydro] comprised an estimated 27.7% of the world's power generating capacity, enough to supply an estimated 22.8% of global electricity⁷.

Table 1 Global renewable energy installed capacity⁷

Renewable energy	Global installed capacity by 2014
Solar PV	177 GW
Solar hot water	406 GW _{th}
Concentrating solar	4.4 GW
Wind	370 GW
Geothermal	370 GW
Total renewable power (excluding large hydro)	657 GW

The growth in renewable energy is largely driven by policy, with building codes an important mechanism. By 2015 at least 164 countries had renewable energy targets, and municipalities led the way with a number of metropolitan areas pushing for 100% renewable energy or electricity targets⁶. This is looking increasingly possible. The Orkney Islands are meeting all of their energy demands from renewable sources, as is Lower Austria, while Denmark and Germany have on several occasions produced in excess of their domestic electricity requirements from renewable sources⁸. In February 2016, the first concentrating solar power plant to provide electricity for 24 hours a day was connected to the US energy grid⁹, removing the criticisms that solar energy is intermittent and cannot be used as base load power.

Natural building materials are modernising their image

Renewable building materials such as timber, hemp, straw and bamboo have moved out of the ecovillage and into the mainstream construction market as finishes, insulation or structural elements.



Figure 3: University of East Anglia Enterprise Centre¹⁰ Figure 4: High-rise timber, Tamedia building, Zurich¹⁰

Advances include timber high-rise buildings such as the seven storey Tamedia office building in Zurich designed by Shigeru Ban (Figure 3); and prefabrication of natural fibre

panels as wall cladding, such as the University of East Anglia Enterprise Centre¹⁰ which is clad in prefabricated thatch panels (Figure 4).

Sustainable construction is no longer a hot topic

A Google trend analysis¹¹ shows that the terms 'sustainable construction' and 'sustainable building' has been showing a gradual decline as search term over the past decade (Figure 5). While the term 'green building' has shown comparatively more interest, it has itself declined in popularity (Figure 6). Trending terms, while still of comparatively less interest than 'green building', are 'smart building' and 'living building' (Figure 7). When the analysis is expanded to cities, a similar pattern emerges, with 'sustainable cities' showing a decreasing trend in popularity, and 'smart cities' showing as a growing trend (Figure 8).

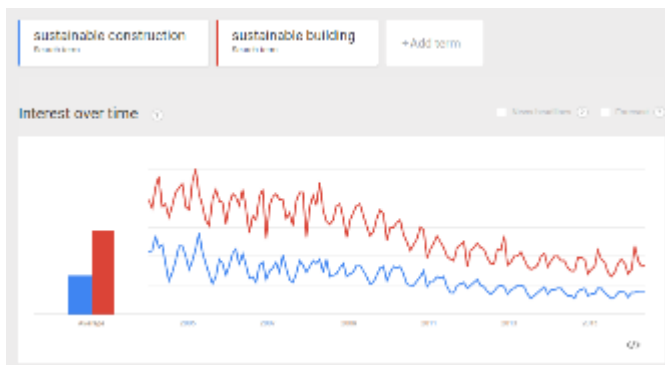


Figure 5: Declining trend-sustainable building and construction

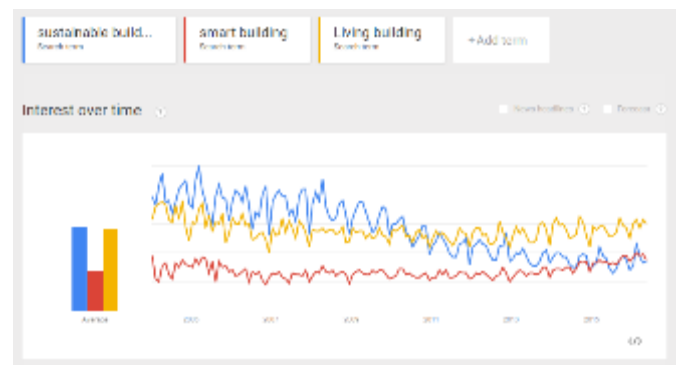


Figure 7: Growing trend - smart building and living building

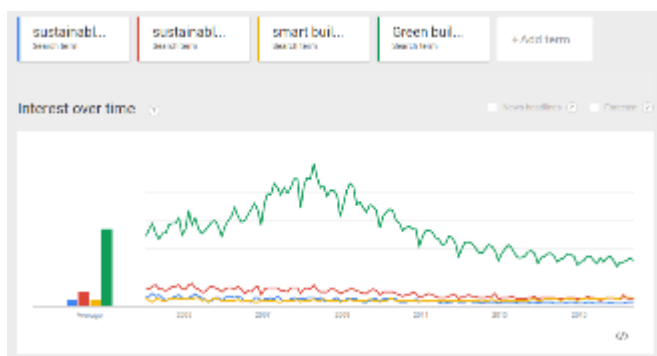


Figure 6: Declining trend – green building

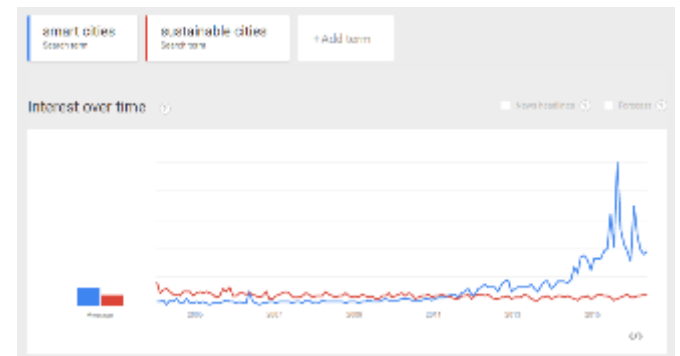


Figure 8: Growing trend - smart cities

From Green Building to Living Building

From the plethora of rating systems that characterized the late 1990's, three main players have emerged: BREEAM, LEED and Green Star. These are constantly improved and adapted to local conditions, which allows greater market penetration. There are also some more localized systems such as CASBEE in Japan, Green Mark in Singapore, DGNB in Germany and the Estidama Pearl rating system in the United Arab Emirates.

*By February 2016,
5 384 projects have
been certified as
LEED Platinum*

**USGBC Project
Database**

*“A smart city
enables energy
efficient and carbon
neutral living,
working and
travelling without
compromising
wellbeing and good
quality of life.”*

**CIB Draft Research
Roadmap Report
Smart City Vision
May 2016**

As these systems mature, the competition to be best in class, combined with national standards and regulations that match or exceed lower certification levels, has resulted in more and more projects being certified in the higher ends of certification (e.g. LEED Platinum or Green Star Six Star), prompting the question of what comes after Platinum.

At the same time, the checklist approach followed by most rating tools, and the tendency to manipulate these tools by cherry-picking categories and targets to get a higher rating, has come under increasing criticism, even though they have provided a useful common language and encouraged the adoption of more sustainable building practices by mainstream construction¹².

The **Living Building Challenge**¹³ is both a philosophical evolution of the concept of green building and a certification programme that provides a next level of sustainable building and addresses some of the criticisms of existing rating tools. It provides a certification alternative that is based on actual performance over a 12 month period instead of modelled or anticipated performance. It also requires that *all* the mandatory Imperatives be met, and instead of setting narrowly defined performance parameters, goals such as Net Zero energy and water mean that the design team can use synergistic and innovative, ‘out-of-the-box’ solutions. .

Becoming smart to be sustainable

The development of intelligent building management systems, building information modelling software and wireless communication technology allows the adaptive management of the built environment to improve its efficiency and rapidly respond to changes in the operating environment such as increased heat loads or traffic

“Smart Buildings are buildings which integrate and account for intelligence, enterprise, control and materials and construction as an entire building system, with adaptability, not reactivity, at its core, in order to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction.”¹⁴

congestion. Advanced technologies such as smart sensors, smart materials and smart meters supports the development of high-performing buildings and cities that can function more effectively in current and future scenarios of constrained resources¹⁴. The ability to collect and analyse data using these tools further enables evidence-based planning, development, design and operations. As can be seen from the Google trends analysis, smart buildings and cities are trending search topics.

Within the CIB, *Working Group 116: Smart and Sustainable Built Environments*, and *Task Group 88: Smart Cities*, are exploring the relationship between smart infrastructure and the built environment and the sustainability of our cities. A separate Research Roadmap on Smart Cities are being prepared as part of the CIB Research Roadmap series.

It is the end of the world as we knew it

The original drivers for sustainable construction centred on urbanization, environmental and occupant health, and resource limitations. In 1995 climate change was a distant and controversial threat, and in 1999 the *Agenda 21 on Sustainable Construction* responded to it mainly in terms of reducing energy use (as part of a strategy built around the idea of limited resources) and the main issue was seen as being able to respond to the possible requirements of the Kyoto Protocol. Today these original drivers remain relevant, but their pressure on human development has increased considerably, expanding the conditions and definitions of risk.

Climate change is here to stay

There is no longer any doubt that climate change is real, that it is caused by human activities, and that it is already happening faster than the models predicted. The IPCC Fifth Assessment Report predict that at the end of the century temperatures may be more than 11°C warmer than the average for the period 1986 to 2005 in some regions of the world (Figure 9). By comparison, in the Fourth Assessment Report published in 2007, their highest predicted change was 7.5°C.

“Climate change would leave the living envying the dead”.

Kofi Annan

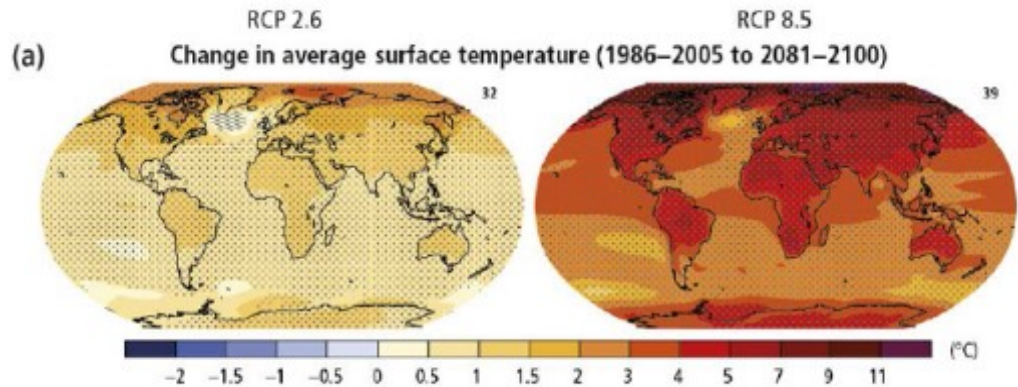


Figure 9: IPCC AR5 best and worst case scenarios

*“During March 2016 average global temperature across land surfaces was 2.33°C (4.19°F) above the 20th century average of 3.2°C...Overall, the nine highest monthly temperature departures in the record have all occurred in the past nine months. March 2016 also marks the 11th consecutive month a monthly global temperature record has been broken, the longest such streak in NOAA’s 137 years of record keeping”.*¹⁵

Atmospheric CO₂ concentrations measured at the Mauna Loa Observatory in Hawaii consistently measured above 400 parts per million since August 2014 and exceeded 409 parts per million for the first time in recorded history in April 2016¹⁶. The Observatory further reported that the annual growth of atmospheric carbon dioxide (CO₂) during 2015 was the largest ever recorded at the Mauna Loa Observatory (more than 3 ppm), and that the annual increase was larger than two ppm for each of the last four years, meaning that the CO₂

“In an extinction event of our own making, what happens to us?”

Elizabeth Colbert²⁰



levels are increasing 200 times faster than during the previous period of sustained CO₂ increase between 11 000 and 17 000 years ago¹⁷.

The normally conservative World Bank warns that as warming of 1.5 °C above pre-industrial levels is already locked in to the earth’s climate system and the end of the century will likely see the world at least 4 °C warmer on average, we need to prepare for a world in which unusual and unprecedented climate extremes becomes the new climate normal¹⁸. This level of warning will make the achievement of human development goals challenging, if not impossible, and the window of opportunity to limit average global warming to below 2°C, as agreed on in Paris in 2015, is rapidly closing. Climate change is gearing up to become a game changer at an epic scale and as its inevitability becomes clear, the discourse is shifting to how we can adapt to the coming changes.

The 6th great extinction is underway

Climate change is, however, not the only environmental crisis we are facing. The recent vertebrate extinction rates and loss of biodiversity experienced is unprecedented in human history and it is suggested that the sixth major extinction event in Earth’s history is already underway, mainly as a result of human actions.^{19,20} This has major implications for the ecosystem services provided by these species, not least of which is food production. For example, unless there are dramatic reversals in fishing practices, ocean acidification and global warming, global commercial fish stocks are predicted to collapse in 2048²¹, taking with it the main source of protein and income for millions of people. Urbanisation and farming practices are contributing to the loss also of vital insect species such as bees, which in turn presents a real danger to continued food security. As a major contributor to biodiversity loss through land use change, destruction of habitats and climate change, the built environment can play a significant role in protecting and restoring biodiversity.

The new urbanisation challenge - preparing for mass migration

The environmental crisis, and especially what is increasingly being referred to as the ‘climate emergency’ or even stronger, ‘the climate catastrophe’, calls for a profound rethink about how and where we build, and how the existing built environment will have to adapt to the challenges of this crisis. One of the biggest challenges will be the relocation of a billion climate refugees. During the past year sea level rise has swallowed five of the Solomon Islands and in the USA, Russia and Canada entire communities are being relocated as a result of sea level rise and melting of permafrost. With more than a billion people at risk from sea-level rise by 2050¹⁸, we will need to relocate people at a scale and speed unprecedented in human history. Judging by how the world responded to the Syrian refugee crisis, the first mass migration with its roots in climate change, the challenge will not only lie in the construction of new cities and infrastructure to accommodate these refugees, but in developing the social structures and values that will avoid major conflict. And as people of different cultures find themselves occupying the same spaces and competing for the same

resources, we will need to think even more carefully about how the built environment can support peaceful co-existence and the creation of new communities.

Welcome to the Anthropocene

Earlier in 2016, a team of scientists published findings that suggest that “humans [have] changed the Earth system to such an extent that recent and currently forming geological deposits include a signature that is distinct from those of the Holocene and earlier epochs, which will remain in the geological record”.²² These changes include atmospheric concentrations of CO₂ higher than they have been in the past 800 million years; the large-scale modification of carbon, nitrogen, and phosphorus cycles; worldwide species invasions and accelerating rates of extinction; changes in geomorphology as result of activities such as quarrying, landscaping and agriculture; and the appearance of fallout radionuclides and manufactured materials such as aluminium, plastics, and concrete in sediments. Microplastic particles are now found in most of our waterways and in there is an estimated 5.25 trillion plastic particles weighing 268,940 tons currently floating in the world’s oceans²³.

The world has become a smaller, more connected place

The rise of globalisation, supported and fuelled by information and communications technology presents both challenges and opportunities for creating a more sustainable world.

In 1995, only a few people had [very clunky] mobile phones and the internet was slow and mainly for nerds. Today, life without wireless communication technology and the internet is unimaginable. Not only does it allow us the convenience of shopping and banking online, accessing information on anything we can think of, paying for goods and services from lunch to using the toilet with our phones, and connecting with friends and family no matter where in the world we are; it also changes the way we think and perceive the world. Social media allows memes of disinformation, counter-information and protest to spread globally in an instant. Personalised algorithms based on individual search histories and profiles means that our intellectual and social worlds became smaller as Google and Facebook determine the information, newsfeeds and advertising we see, kindly assisting us to find in the haystack of information overload only that which it thinks we would like to see.

This level of connection is also making us think differently about how we design, build and manage the built environment. For quite some time now international architectural and engineering firms have been riding the time zones to speed up design and documentation,

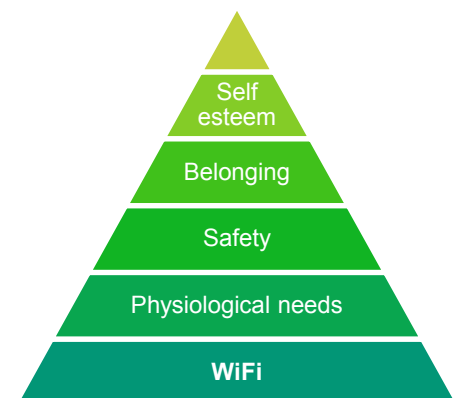


Figure 10: A 2011 UNHRC Special Report declared internet access a basic human right (A/HRC/17/27)

bouncing the work between offices in Australia, the UK and the Americas to provide a seamless 24-hour workday, or outsourcing technical drawings or rendering of models to cheaper labour in India, China or South Africa. The marriage between Building Information Modelling (BIM), Building Management Systems (BMS) and the Internet of Things promise to take the way we think about buildings, cities and infrastructure to another level, and with it, the ability of the built environment to achieve goals of resource efficiency.

This globalisation of architectural and engineering solutions has led to both a closing and a widening of gaps between different regions and economic classes within regions and countries. It frequently comes at the expense of contextually appropriate solutions or the inclusion of other voices around the table in the determination of both the project brief; and the interaction of the project with the social, cultural, regulatory and natural environments within which it is situated is often minimal. International built environment firms with access to the latest technologies and the skills to use them, outperform local companies, which can have a major negative effect in developing countries. On the other hand, the presence and skills of these companies and their international reputational requirements for green building solutions, help to introduce an awareness of green building into developing world countries that in turn drives the development of local regulations and skills.

“In order for us to adapt to this strange new world, we’re going to need more than scientific reports and military policy. We’re going to need new ideas. We’re going to need new myths and new stories...”²⁴

Roy Scranton

The need to find hope in a dying world

Finally, the most profound change since 1995 is the realisation that, as Roy Scranton so inelegantly puts it: “We’re fucked. The only questions are how soon and how badly”²⁴. His basic premise is that the global capitalist civilization we have known is already dead, but that humans can adapt and survive if we “learn how to die” by letting go of our fears, our preconceptions and the way of life that has resulted in the Anthropocene, so that we can rework our stories and create a new form of civilisation.

Coming to grips with the loss of the world we knew and loved is already extracting a heavy psychological toll. The psychological impact of climate change is manifesting as increases in the incidence of stress, anxiety, depression, post-traumatic stress disorder, and feelings of loss, despair and resignation²⁵. Psychologists are also identifying conditions such as ‘eco-anxiety’ and ‘solastalgia’²⁶ related to the sense of helplessness and desolation associated with what Per Espen Stoknes calls “the great grief”²⁷. Stoknes suggests that we need to embrace this grief, if we are to find a collective way forward; that the very act of embracing the pain of the world holds the potential “to break open the psychic numbing” and to “open the heart to reach out to all things still living”²⁷. Accepting that the world as we knew it is dying, allows us to embrace these changes as an opportunity to fix those things that were not working, that were harming the whole; an opportunity to regenerate dying and dysfunctional systems; an opportunity to take action, to hold on to hope²⁸.

“The future belongs to those who give the next generation hope.”

Teilhard de Chardin

A new conceptual framework

It has become abundantly clear that if humans are to survive in the Anthropocene, we need to think differently about how we engage with the fundamental question of the sustainability discourse: how do we create a world in which the functional integrity of the global social-ecological system can be maintained and humans can not only survive, but thrive?

As we are losing biodiversity at all scales of existence, from megafauna to gut bacteria, we are finally becoming aware of how tightly our welfare as a species are tied to the welfare of other species. And we are coming to realise that we have been designing our buildings and our cities as if they are mechanical systems we can control and we can use to control nature, when they are actually complex adaptive living systems – processes, not objects. These insights are driving the ongoing evolution of sustainability thinking based on a shift in worldview, and a profound change in key development narratives that are providing a new conceptual framework for sustainability in the built environment.

Sustainability thinking is evolving

Much has been written about the evolution of sustainability as a concept and how this affects the solutions put forward to the problems of environmental degradation, social injustice and economic inequality in all spheres of life, including the built environment^{29,30}. As the conceptual understanding and corresponding approaches evolve, they include and transcend previous expressions of sustainability. This evolutionary trajectory also reflects a shift from a mechanistic to an ecological or living systems worldview. The trajectory is summarised in Figure 11.

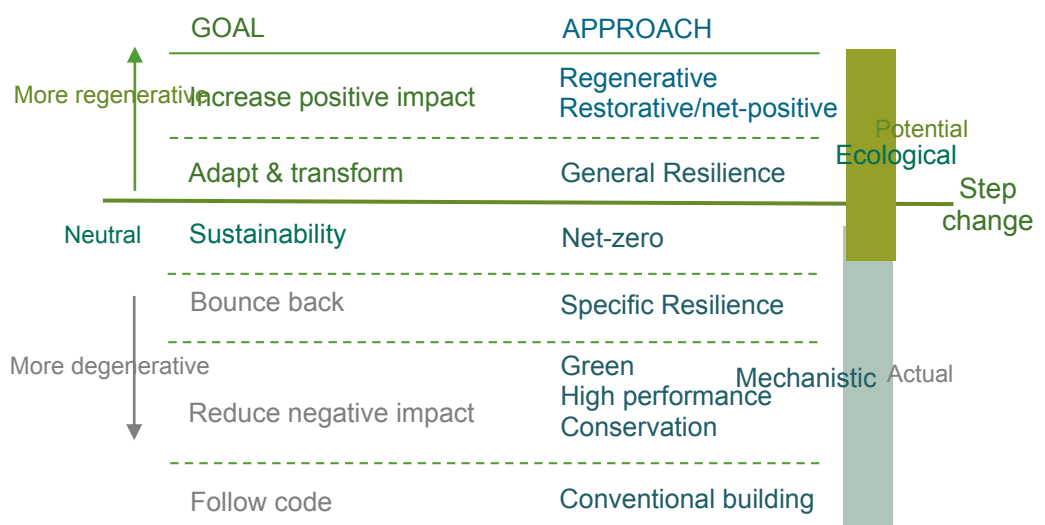


Figure 11: The evolutionary trajectory of sustainability thinking (Adapted from Reed³⁰)

“We talk about living systems, rather than natural systems and human systems, because they are all living systems.”

Pamela Mang



The trajectory begins with conventional practice the main goal of which is to follow code, there is little concern for the environmental or social impact of the project and design problems are solved on an individual basis. The next step in this trajectory is concerned with reducing the negative impact of the project through initial strategies of conservation and high-performance building which eventually evolved into green building strategies. While these strategies become progressively less damaging, they are still dealing with problems in a mechanistic, piecemeal way and are essentially, as Bill McDonough puts it, doing a bad thing less bad. Global change (which includes climate change) prompted the next level in the trajectory, which attempts to build systems resilience to a specific threat such as flooding, sea level rise, fire, or infrastructure collapse as result of disasters. The goal is return the built environment and the social systems it hosts as soon as possible to the state they were in before the disaster struck. However this approach maintains the dysfunctional status quo, it continues to deal with the problems of sustainability in a fragmented way, and draws its understanding of resilience from engineered systems, not living systems.

The next level is that of sustainability as expressed through having a net-zero impact in which negative impacts are offset against positive contributions, leading, in theory, to a system that is in a steady state/ dynamic equilibrium. Seen as the ultimate goal by those approaches at earlier levels of the trajectory, it is seen as the bare-minimum baseline for emerging approaches such as regenerative design. Up to this point, approaches were very much rooted in the actual world, navigating existing system structures and behaviours.

Going beyond sustainability, the approaches shift fully into the ecological worldview and the realm of potential, i.e. that which has not yet manifested or are in the process of manifesting. Frijtof Capra³¹ suggests that while the ecological worldview draws on an understanding of nature and its processes and relationships, it is a much broader concept than that encapsulated in classical ecology or even ecological economics. Implied in ‘ecological’ is an understanding that we are dealing with living systems and all that comes with such systems, including connections, flows, relationships, interdependence, evolution and consciousness. The ecological worldview sees the phenomenal world as constantly regenerated through interactions within systems at all scales and levels of existence (physical, intellectual, emotional, social and spiritual). These interactions result in and from flows of matter, energy, information and influence, as well as processes of adaptation and self-organisation, which in turn allow these systems to evolve. In this world, phenomena do not exist independently, but come into being through different types of relationship and the processes they provoke.³²

The shift line also expresses a shift in the sustainability discourse away from questions about preventing and reducing environmental impact, to the questions of how to survive what has been called the Great Disruption³³ and rebuild a world in which humans and other life can flourish. This requires not only building the adaptive capacity that would allow systems such as cities to ride out the by now inevitable changes brought about by climate

change to the biophysical environment, as well as the global economic system and social systems, but also to “restore a lost plenitude”³⁴ and regenerate currently degraded and dysfunctional social-ecological systems.

Regenerative development is founded on the following philosophical departure points: a) humans, their artefacts and cultural constructs are an inherent part of ecosystems; b) their actions should contribute positively to the functioning and evolution of ecosystems and biological cycles, enabling the self-healing processes of nature; c) their endeavours should be rooted in the aspirations of the context; and d) development and design is an ongoing participatory and reflective process.^{30, 35}

It is important to realise that the understanding of how best to achieve the main objective of sustainability will continue to evolve and new terms may emerge to replace sustainability, resilience and regenerative development. The trajectory is also not as neatly structured as presented above and there is still a lot of overlap and differencing interpretations and normative positions associated with it.

Changing the narratives

The step change in thinking described above is also changing the main narratives of development. The main shifts in narrative brought about by this shift in worldview can be summarised as follows:

- While doing less bad remains important, the focus is expanding to also include questions of how to do more good.
- The language and arguments for a more sustainable approach is avoiding the negative messages of global change, focusing instead on positives and potential.
- There is a growing focus on understanding and increasing the value added by a project to the social-ecological system within which it is situated, and not just the financial return on investment for the developer.
- Resource management is shifting from a utilitarian view of seeing resources in terms of use and exploitation to thinking in terms of exchanges between different resource streams in the system. It realizes that no development can be fully zero-impact, so how can resources best be used so as to grow abundance and potential in the whole system (i.e. not just an exchange of capitals).
- System health (including the health of people and other organisms in the system) is not just something to protect, but to be actively pursued.



Towards the Future

The main purpose of a Research Roadmap is to suggest the destination and the possible routes to such a destination. In this last section we will look at the vision (where we want to be in ten years), what we have to build on and what we need to do to realize this vision.

Where do we want to be in ten years?

Given the severity of the environmental crisis facing us, the bare minimum we should aim for is to see sustainable building adopted as minimum good practice and business as usual; all buildings are energy positive; and we have a transformed construction industry with the knowledge, skills and willingness to pursue alternatives and make a positive contribution.

Challenges that can inform future research

There are still many challenges that need to be explored through research, the following are just some suggestions:

- Changing climate maps will mean that the accepted design norms in a specific area will no longer be suitable to the altered climatic conditions. Building a library of design solutions organised according to climatic zone will help practitioners to find solutions appropriate to the new climate normal.
- While green building assessment tools are fairly well-developed, there are as yet no tools that can be used to determine whether a project will be regenerative, have a positive impact or contribute to the adaptive capacity of an area.
- Coupled with the increasing emphasis on integration between systems within buildings, it is necessary to also look at integration across scales and developing cross-scale thinking as a key decision-making tool.
- Sustainable design and construction requires multi-directional knowledge transfer between the project team and disciplines that are not traditionally seen as part of the built environment, such as ethno-botanists, behaviour psychologists and ethnographers. How these need to be integrated into the project team, budgeted for and participate in development and design processes is still an unknown area.
- The emphasis of research in sustainable building has been on technology, assessment or costing, yet there is little research that looks at softer issues vital to the success of sustainable construction such as behaviour change or values.

Building on current knowledge bases

There are a number of existing areas of research that can be consolidated and/or expanded. These include the development and verification of assessment tools, life cycle analysis of building materials and systems, new solutions to improve building performance and

retrofitting of existing building stock. There is also now enough data available that the analysis and use of this data becomes research opportunities.

Making sense of the data

BIM and BMS provides big data that can tell us if buildings are performing according to expectations or not, that can provide information on user behaviour, can improve sensing ability and calibrate performance models. The challenge is to find ways of sensitively accessing and sharing this data and improving the interoperability of these systems.

Integration made easy

The systemic nature of sustainability solutions requires much better integration between the various systems and components of the building. Seeing the building, its materials and supporting infrastructure as one system calls for integrated systems of information, including the incorporation of sustainability information on products and systems into BIM platforms.

Life Cycle Analysis of new building materials

While the life cycles of conventional building materials such as concrete, steel, brick and timber are fairly well understood and documented, there are a large number of new building materials and systems coming on the market claiming to be 'green' that needs to be more fully investigated.

Creating a knowledge sharing platform

The past twenty years have seen an explosion in research publications and case studies that all contain useful knowledge. However, while these publications are available on databases such as ICONDA, or published in scientific journals, this knowledge is not readily accessible to practitioners or organised in a meaningful way. What is becoming necessary is meta-analysis of these publications.

Similarly there are by now thousands of case studies of buildings that used one or more sustainable building strategies. Collecting and sharing these on a publicly accessible, collaboratively developed and populated platform will increase the impact of research, and assist in further theory and tool development

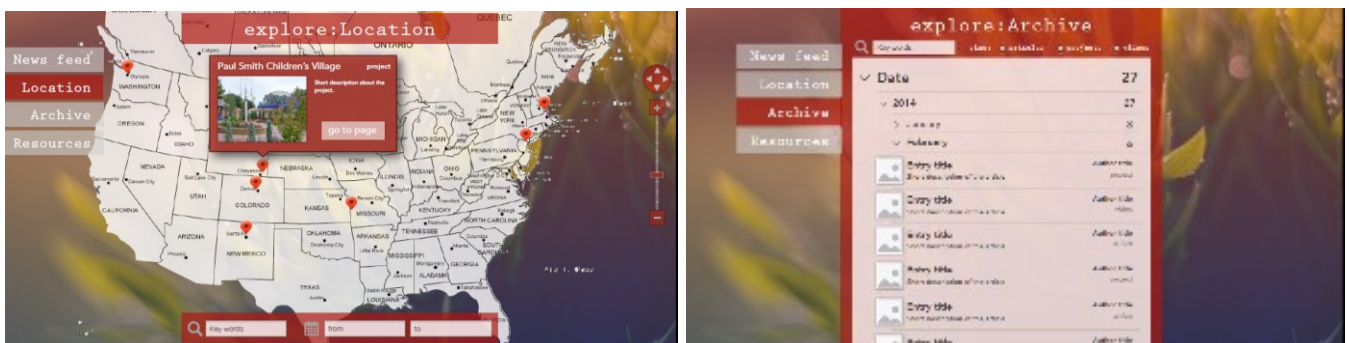
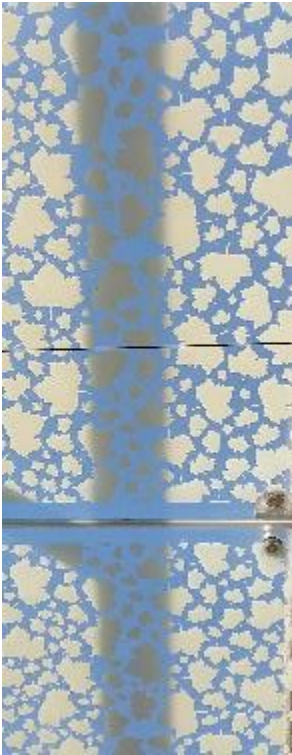


Figure 12: Mock-up of a project-based knowledge hub



New areas of research

Next generation bio-based materials

Bio-based materials such as timber, thatch, reeds and bamboo, as well as glues and finishes derived from animals, shape the earliest traditions of building. As discussed earlier, these materials have been redesigned to suit the more industrialised ways of building that have become prevalent in recent years, with laminated timber and bamboo, bio-composites and pre-fabricated compressed panels of straw or hemp as increasingly popular construction materials. The next generation of bio-based materials takes this thinking a step further to more unconventional materials such as fruit leather made from food waste, hemp plastics and materials which are grown from, for example, slime mould or mycelium³⁶.

Designing for sustainable behaviour

Design for behaviour change has grown significantly as a field in response to the realisation that design for building performance is only one aspect of the success of sustainable building and that conversely, people's behaviour is inevitably influenced by the design of the buildings and systems which they use.

Regenerative development and design processes

The development of the concept of regenerative development and design has been largely practitioner-driven to date. It offers a rich field of research in terms of process, education and assessment tool development.

Concluding a Theme

While there is clearly no end to the research that still needs to be done in the field of sustainable building, the theme has been well-developed and successful. However, the purpose of the Priority Themes is to develop strategic new areas of research. Themes such as Urban Resilience and Smart Cities flowed from the Sustainable Construction theme and respond to the changes in problems, theoretical informants and technology that has come to the fore since 1995. It is suggested that Sustainable Construction be retired as a Priority Theme and a new Priority Theme be identified from the sustainability problematique of the 21st century.

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