



EPSRC/ARCC network workshop 2016

The future of built environment research in the light of societal challenges

Report on discussions and next steps

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Engineering and Physical Sciences
Research Council

Executive summary

This workshop was the first stage of an ARCC-led discussion to engage the research community, research councils and other stakeholders – policymakers and practitioners – in the future of built environment research needs and opportunities in light of the challenges facing society.

The discussions highlighted the importance of a research agenda that encourages discovery of the best possible outcomes in building design and refurbishment, rather than a ‘making do’ approach.

Researchers and stakeholders outlined a vision of the future for built environment research and capabilities. Their thoughts included:

- changing the way buildings are designed and constructed
- how they interact with supporting services
- how they function, are maintained, refurbished and perform to ensure they are fit for purpose into the future.

Buildings must be adaptable to changing needs and climates, and function to meet the needs of a healthy, resilient, and low carbon society.

Workshop participants identified critical areas of research that require inter- and multi-disciplinary research supported by cross-council – and broader – investments to further short-term (to 2020) research in robust and healthy buildings and urban form. The research areas include those focused on:

- improving and adapting existing stock
- improving the accuracy of assessment of performance
- improving our understanding of the interconnections of buildings with supporting services and infrastructure above and below ground, including ecosystem services offered by green and blue infrastructure.

Building capability and channels for knowledge exchange and interdisciplinary working, particularly links between engineering sciences, social science and natural sciences, are crucial to ensure the best return for investment in built environment research. This report provides an initial analysis and early synthesis of the discussions.

Next steps for the ARCC network

Our work with the research community continues, and look longer-term towards a resilient and sustainable future, specifically with research needs and capabilities for the medium- (to 2050) and long-term (to 2080) in mind.

We will build on the themes from this workshop, and further explore these and others with the network community through a provocation series. We will also synthesise aspects of existing research on adaptation in the built environment, with the aim of developing accessible outputs based on the knowledge and evidence needs of policy and practice.

Previous ARCC Assemblies have successfully showcased existing research and supported interdisciplinary discussion. The next assembly is scheduled for Autumn 2017. We will design this event specifically to bring together researchers and stakeholders in order to share thinking between the research community, the needs of industry and society in general, and to include the ideas articulated at the workshop.

Motivation and objectives

The Engineering and Physical Sciences Research Council (EPSRC) currently funds around 40 projects worth £16m in their Built Environment research area.

To continue engagement activities that support the research community in developing proposals, and to inform associated investment decisions, the ARCC network and EPSRC sought discussion with and input from the broader research community along with invited policy and practice stakeholders. This allowed us to identify emerging challenges and priorities in built environment research, and included exploring links and integration with related research areas. Discussions at the workshop built on evidence submitted during the recent EPSRC [Balancing Capability](#) exercise and centred on the four interlinked Outcomes included in the EPSRC Delivery plan that underpin UK prosperity: [Productivity](#), [Connectedness](#), [Resilience](#) and [Health](#).

With this in mind, the aim of the workshop was to identify and explore research requirements and potential associated pathways towards a more sustainable and resilient built environment. The objectives were to:

- define a vision and perspectives on the future of built environment research
- identify pathways and timescales for enabling research to enhance the built environment
- identify crosscutting, interdisciplinary and multi-sector research challenges.

The focus of the workshop was on research related to buildings – domestic and non-domestic, urban, suburban and rural – and their interactions with occupants, the surrounding curtilage, form, supporting services and the building environment.

Drawing on the material from the workshop and related activities, a longer-term roadmap for research will be developed to respond to environmental and societal challenges such as climate change, population growth and the ageing population. Our wider provocation series will allow additional input from those not able to attend the event.

Summary of identified research needs

The workshop allowed participants to explore and identify research needs that would contribute to delivery of a productive, connected, resilient and healthy nation to 2080 and beyond (see Appendix 1). The initial focus was on short-term needs. Key aspects of the [74 research needs identified on the day](#) are summarised here:

Tackling existing (ageing) stock

‘Retrofit’ was discussed in terms of the flexibility of buildings, of how a physical environment can be adapted for personal and social needs as well as to a changing climate. Participants noted that the term ‘retrofit’ has connotations of the past, and that we need to move from ‘retrofit’ to adaptability, to encourage thinking about future change. As a result, the need to consider a flexible approach must be more explicit in construction and refurbishment programmes.

From across the identified research needs, it was clear that building adaptability must be considered in a holistic sense, not just with climate change in mind. Highlighted challenges include how to retrofit adaptability to improve the lifetime of current buildings, and how to ensure that those adaptations remain flexible to cope with future change without requiring ongoing retrofitting.

An evaluation of refurbishment and retrofit options in terms of performance and contribution to occupant well-being is needed. To make existing buildings more adaptable over their life and as the climate changes, evidence is needed for:

- the costs / benefits of good maintenance
- options for adapting stock to meet changing urban patterns, for example greater urban density, infrastructure needed, accessibility of technology, diverse life styles and user needs
- the needs of people living in existing buildings / communities

Identifying novel and innovative materials and design interventions that maintain / improve sustainability into the future is essential. Any new materials must also take into account other policy requirements, such as low carbon emissions.

Assessment of performance

A critical point raised was the need for a more integrated approach to collecting, processing and storing data and information from across the built environment field to support further analysis (for example modelling studies) and all aspects of decision-making, including regulatory requirements and business models for industry. This approach would increase efficiency in capture and use of available data and information, and build trust in the evidence being provided, for example:

- improving overall quality of life by identifying new applications and approaches to using sensors, data, and data analytics to drive smarter, low-cost solutions for resilient buildings
- developing standardised methods for assessing the performance and adaptability of buildings over their lifecycle to inform the design and / or retrofit of buildings
- exploring approaches to capturing qualitative issues such as well-being, social perception and community action for enhanced design and improved functionality of buildings.

There is a need for research that supports a more holistic understanding of appropriate building / urban form and fabrics, taking into account the interactions above and below ground between factors such as energy efficiency, indoor and external environmental air quality, overheating and drainage, along with biophysical factors such as the impact of moisture, rain, wind and vegetation. Understanding these interactions will help to identify the most beneficial approach to design and build, be it individual or clusters of buildings, or neighbourhood-level and city places and spaces. Different approaches to eliminating errors in the construction and operation of buildings are needed, along with efforts to reduce the performance gap that still exists between building design and practice.

Green infrastructure

Many of the research needs identified or referenced the benefits of green infrastructure (GI), both indoors and out, in an increasingly urbanised country, including:

- positive health impacts through improved air quality
- water / air / soil benefits
- reduction of detrimental impacts of flood and drought, particularly as extreme weather events are expected to be more frequent as the climate changes.

Research is needed to improve the understanding of interactions between green infrastructure and building services, buildings, occupants and urban form as well as with above ground and subsurface structure, services and infrastructure systems. This will help to optimise the benefits of green infrastructure and lead to a better understanding of how it can reduce the consequences of built environment failures as the climate changes.

Ideas for future innovation in this area included investigation, modelling and testing of dynamic 'green buildings' that are responsive to the needs of the occupants and the spaces within which they exist. In raising these ideas, participants recognised that these buildings (as well as green infrastructure) can benefit the health and wellbeing of occupants, as well as provide an opportunity to improve energy efficiency with the re-use of resources such as waste for energy production.

Health and wellbeing

The 'people' aspect of buildings was a consistent theme; what do we see the role of buildings being in our future? It was strongly suggested that design should be for people, their comfort and wellbeing, and engender a sense of social connectedness and connectedness with the natural environment. With increasing density and urbanisation, more people are living in closer proximity, so attention to what people would like from these communities, and how the built environment can support that, is essential. This could be enabled through the replacement of the energy performance certificate with a building satisfaction certificate.

There was a strong consensus of the need for a research focus that links the built environment to the nation's health and wellbeing. The inflexibility of current regulatory and compliance regimes was highlighted, particularly the lack of incentive for developers to take these things into consideration. This led to the identification of a broader issue related to weak regulatory policing, as well as the market and business models of construction and land use which disconnect land owners and developers from construction quality, and eventual use. Multidisciplinary research could explore how new modelling capabilities, processes of construction and advances in material science could be combined with new market and professional products, for instance finance, insurance and warranty, that would create an incentive for industry to improve quality rather than lower standards to generate maximum return. The point was also made that innovation could be cheaper and made more accessible through focusing research on improving conventional products for the homeowner market.

Improving skills, knowledge exchange & technology transfer

There remains a significant gap between most academic research and industry practice. Essential on-going efforts to close this gap include facilitating engagement between communities, industry and researchers, through the independent communication of the value of research outputs to end users, and enhancing the understanding of what different communities need from each other.

Much new technology doesn't get further than the laboratory, therefore further efforts are needed to promote technical advances and to move new technology towards mainstream market integration, including working through InnovateUK. New and bespoke mechanisms may be needed for funding, and to facilitate the use and application of technical advances with social and public benefit that lack commercial merit, and therefore fall outside existing mechanisms.

Links across the research councils

The difficult nature of truly interdisciplinary work was discussed, in the context of both research proposal development and research council funding, along with the integration of stakeholder and research needs as well as data collection. A representative from a civil and structural engineering design practice commented:

“ I would say we’re starting to see some really interesting research questions and challenges that are emerging from today... on all the things we’ve been talking about today, what really stuck in my mind from the discussions was about how do you build the right team and get the right skills? Whether it’s developing the question and figuring out exactly what problem you’re tackling, whether it’s actually doing the research, whether it’s making sure it’s adopted and on a very simple level, industry needs real help with making sure some of the science and research innovation is finally adopted in the 99% of projects that are not your Olympic Park or your Shard or your Millennium Footbridge. ”

Uncertainty about the state of our environment and other factors in the longer term (to 2080) was raised as a component that needs multidisciplinary consideration. Examples were given of the potential for changing home working patterns and conversion of transport systems to electric, resulting in less noise and pollution at the street level as well as of changes in human behaviour and the interplay of people with their surrounds (environmental psychology). These all have implications for building services, building structure and function, and the design and configuration of urban form.

Out of the [74 research needs](#) (pdf, 6.3 MB) identified at this workshop, 58 (78%) highlighted areas where potential links across the research councils would be particularly beneficial in tackling some of the themes, and really looking to address the bigger societal issues. Areas identified for potential action across research councils included training and support for inter- and multi-disciplinary research, introducing innovative approaches to research on nexus topics, and studies looking at the process of knowledge exchange within the built environment sector. Developing and ensuring continuity of expertise in academia was also highlighted.

Specific collaborations between EPSRC and both ESRC and NERC were particularly emphasised:

EPSRC and the Economic and Social Research Council (ESRC)

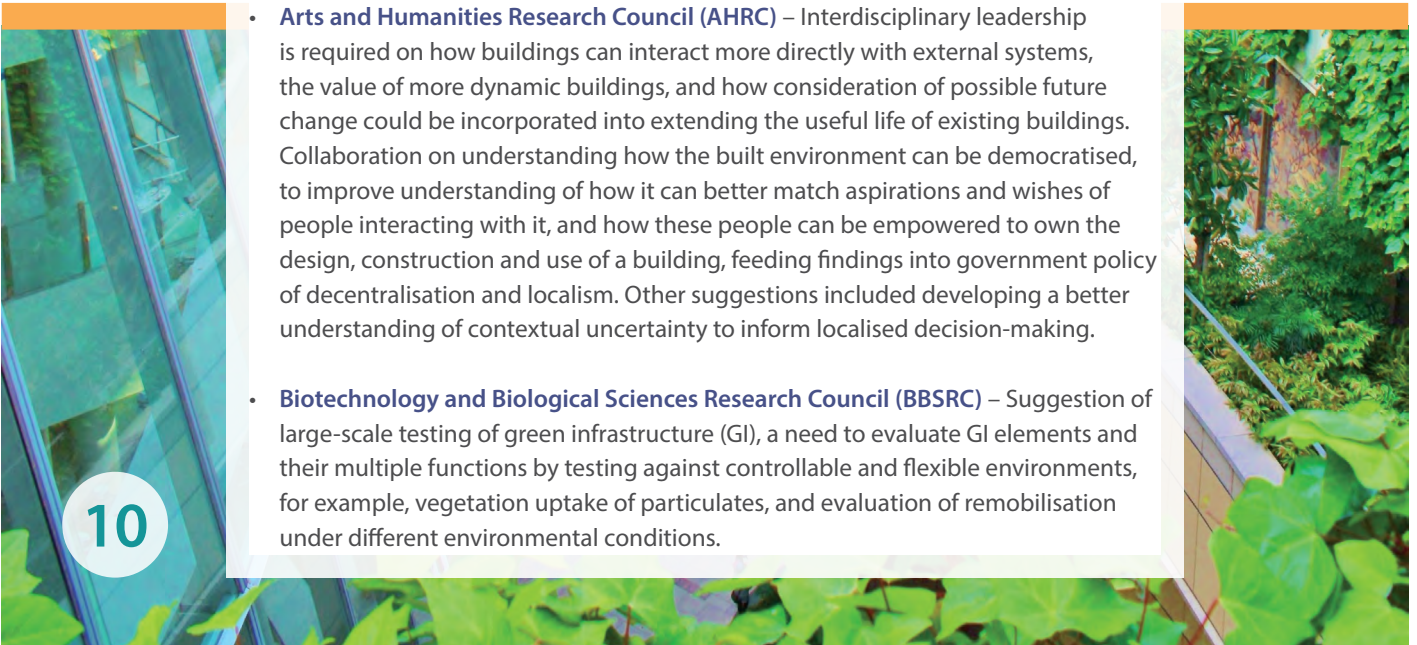
Although EPSRC research funding has been allocated to inter- and multi-disciplinary research, a dedicated EPSRC-ESRC investment focus should be considered to make best use of engineering solutions resulting from EPSRC-funded research. It was also felt that engineering-focused research should not just keep up with societal changes (i.e. population growth) but also consider what sort of buildings society might prefer to live in by 2080 and beyond. There is a need to work collaboratively with social scientists to understand the implications of how buildings are designed, constructed, managed and used. In addition, we need research to explore the role of expertise in the future of our built environment – are buildings designed for expert control and if so what happens when the expert leaves? Furthermore, multi-disciplinary research is needed that explores what a decarbonised / zero carbon and climate-resilient society actually looks like, and what that means for our built environment.

EPSRC and the Natural Environment Research Council (NERC)

A number of suggested research needs identified requirements for improvements in understanding of the interactions between buildings and infrastructure and biophysical-environmental systems. Research related to cascading impacts of system failures and green infrastructure solutions (indoors and outdoors) was highlighted, as well as inter-relationships between the built environment and food systems, and the built environment, microclimates and environmental (particularly air) quality. More methods that are capable of assessing the potential effectiveness of flood propagation solutions are needed. Other ideas included investigating how buildings could be considered more like organisms, as a living system.

Other research councils

- **Arts and Humanities Research Council (AHRC)** – Interdisciplinary leadership is required on how buildings can interact more directly with external systems, the value of more dynamic buildings, and how consideration of possible future change could be incorporated into extending the useful life of existing buildings. Collaboration on understanding how the built environment can be democratised, to improve understanding of how it can better match aspirations and wishes of people interacting with it, and how these people can be empowered to own the design, construction and use of a building, feeding findings into government policy of decentralisation and localism. Other suggestions included developing a better understanding of contextual uncertainty to inform localised decision-making.
- **Biotechnology and Biological Sciences Research Council (BBSRC)** – Suggestion of large-scale testing of green infrastructure (GI), a need to evaluate GI elements and their multiple functions by testing against controllable and flexible environments, for example, vegetation uptake of particulates, and evaluation of remobilisation under different environmental conditions.



Also development of innovative materials for refurbishment of building stock including development of bio-based materials, chemically engineered for strength. We need to develop an understanding of urban soil-built environment interaction, particularly of the effect of construction activities, building forms and type on soil structure, in order to improve resilience of underground infrastructure.

- **Medical Research Council (MRC)** – Interesting research needs identified around valuation of the built environment beyond current system, in terms of population health as well as adaptation, creation of a sense of place and inclusivity. Suggestion of making use of the data collection potential from integrating digital health and buildings, to better understand health parameters and to identify more precisely elements of lifestyle and means of protecting, preventing and quickly intervening to solve health problems in a more efficient manner.
- **Science and Technology Facilities Council (STFC)** – Research on the development of policy and fiscal drivers, trust in information and increased efficiency in management of building performance, of improving understanding of lifecycle carbon and environmental impacts of built environment interventions and for analysis of how urban spaces could be used to reduce impacts of flood and drought hazards and associated risks.

Appendix 1

Agenda

9:30 **Registration**

Towards developing a roadmap: current capability

Identifying key research outputs anticipated within the next 5 years focusing on those outputs expected to help enable future research and capability

10:00 **Introduction**

10:05 **Setting the scene from an EPSRC perspective**

10:20 **Introducing the themes:**

- Property level and scalable solutions
- Built environment as a living system, interdependencies with supporting infrastructure
- What lies beneath (urban soil resilience, groundwater, geo-environmental engineering)
- Ageing built environment and supporting infrastructure
- Preparing society and industry (consumers, markets and industry interactions)
- Data forms, new measurement, modelling and analysis capability and techniques

10:35 **Considering the vision**

What does the built environment of a productive, connected, resilient, healthy nation look like in 2080 and beyond? What are the game-changers?

11:00 **Parallel session #1. Developing the themes**

What are the research needs and drivers and where are the interlinkages? Identifying short-, medium- and longer-term requirements.

11:45 **Refreshments**

12:00	Parallel session #2. Developing the themes
12:45	Lunch
13:30	Feedback from parallel sessions
14:30	<p>Consideration of timeliness / urgency of research needs raised within the themes:</p> <p>Looking towards a roadmap to respond to environmental and societal challenges</p> <p>Hearing from stakeholders: their perspectives</p>
15:45	Next steps
16:00	Close

Vision and game-changers

The workshop participants considered elements of a vision for the built environment in the context of a productive, connected, resilient and healthy nation in 2080 and beyond. Discussions lead to the following stand-out features for the future built environment:

- buildings that enable a healthy, resilient, zero carbon society
- buildings designed to better meet people's needs
- buildings constructed with consideration of material re-use, circular economy, and robotics
- buildings retrofitted to reduce energy use and adaptable to changing needs and climates
- buildings and their supportive infrastructure that mutually evolve to adapt to changing needs, climates and energy use
- improved understanding and exploitation of the interactions between buildings and infrastructure services including the water-energy-food nexus
- functioning of existing stock and new build that is flexible and able to meet occupant needs (multi-functional, flexible, adaptable to changing needs and uses, building services able to learn behaviour, anticipate and maximise energy efficiency)
- purposeful design and creation of social and natural spaces, making best use of green and blue infrastructure and integration with the surrounding natural environment
- creative response to disruptive technologies – for instance, development of emission free vehicles could subvert the current conception of what a transport interchange is in relation to the building's function and incorporation of buildings in confined spaces
- resolution of disconnects between building ownership, design, construction, operations, business models – driven by well-informed occupants.

The workshop participants also identified potential game-changers, those significant changes that would shift the future of the built environment, including:

- human well-being rather than economic growth as the driver for development
- depopulation/population decline
- climate change is mitigated and therefore the agenda moves to other issues
- climate change impacts lead to mass migration
- nuclear fusion/decarbonisation – provision of safe, reliable and potentially unlimited 'zero carbon' energy
- proactive budgets – shifting from short-term return to pump-priming
- self-sustaining built environment that captures and sequesters CO₂
- waste treatment without water, and treatment on site
- completely circular built environment, no new construction materials produced
- next generation sensors for improved management of the built environment
- effective exploitation of data with necessary security
- autonomous systems and vehicles mainstreamed
- improved understanding of the water-energy-food nexus
- effective treatment of current gap between outputs from research at Technology Readiness Levels 1-3 and willingness of industry to pick up for commercialisation at TRLs 8-9
- integrated multidisciplinary funding system – built environment issues are multidimensional, requiring similar funding response.

Delegates

An open call was issued through the ARCC network inviting expressions of interest from researchers to attend the workshop. Applicants were asked to include a brief summary of research frontiers when addressing current and likely future built environment challenges and a summary of their relevant expertise, research and innovation interests. Nearly 60 applications were received and following a selection process by the ARCC network, 50 were chosen to ensure a balanced group across institutions and areas of expertise. A small number of key stakeholders from policy and practice were also invited to share their perspectives on evidence needs and research requirements.

List of participants

Dana Abi Ghanem	University of Manchester
Eleanor Atkins	Staffordshire University
Chris Baker	University of Birmingham
Sarah Bell	UCL
Valeria Branciforti	Knowledge Transfer Network
Rachel Capon	
Lena Ciric	UCL
David Coley	University of Bath
John Dover	Staffordshire University
Sandra Dudley	London South Bank University
Stephen Evans	UCL
Martin Field	University of Northampton
Zoe Fitzgerald	Innovate UK
Guangtao Fu	University of Exeter
Stephen Garvin	BRE
Jacqueline Glass	Loughborough University
Michael Green	Anglia Ruskin University
Rajat Gupta	Oxford Brookes University
Stephen Haben	Oxford University
Abigail Hathway	University of Sheffield
David Holtum	EPSRC
Bingunath ingirige	University of Huddersfield
Lynne Jack	Heriot-Watt University
Nick Jackson	DEFRA
David Jenkins	Heriot-Watt University
John Kamara	University of Newcastle
Zoran Kapelan	University of Exeter
Jessica Lamond	University of the West of England
Ranald Lawrence	University of Sheffield
Graham Leeks	NERC/CEH

Sarah Lindeman	
Robert Lowe	UCL
Zhiwen Luo	University of Reading
Patrick Manu	University of the West of England
Anna Mavrogianni	UCL
Martin Mayfield	University of Sheffield
Jane McCullough	ClimateNI
Francesca Medda	UCL
Alice Moncaster	Cambridge University
Anastasia Mylona	CIBSE
Marialena Nikolopoulou	University of Kent
Christopher Noyce	ESRC
Nazmiye Ozkan	Cranfield University
Sabine Pahl	Plymouth University
Kate Pangbourne	University of Leeds
Paul Reynolds	University of Exeter
Peter Rockett	University of Sheffield
Riccardo Russo	University of Essex
Li Shao	University of Reading
Phil Sivell	UKCIP/ARCC network
Jakob Sprickerhof	EPSRC
Roger Street	UKCIP/ARCC network
Helena Titheridge	UCL
Briony Turner	UKCIP/ARCC network
Udeshika Weerakkody	Staffordshire University
Peter Winslow	

Links

[Supporting future research council investments](#)

[Towards developing a roadmap – current capabilities](#) (pdf, 2.3 MB)

[Themes: background, visions and game changers](#) (pdf, 7.9 MB)

[Themes: Research needs](#) (pdf, 6.3 MB)