AI and Data for Decarbonising the Built Environment

Final Report

16/03/2023

Report commissioned by the University of Cambridge, Decarbonisation Network

Contents

Background

The University of Cambridge has established a Decarbonisation Network, providing a forum for academic, industry and the public sector representatives to identify accelerated routes to decarbonisation through Special interest Groups (SIGs). The Network was set up collaboratively by the Strategic Partnerships Office, Cambridge Zero, the Energy IRC and the School of Technology. The Network currently comprises three SIGs:

1. Hard to Decarbonise Technologies
2. The Built Environment
3. Light Harvesting

Professor Ruchi Choudhary leads the Built Environment SIG (in following “the BE SIG”). She and her group are particularly interested in exploring the role and potential of data and AI in decarbonising physical infrastructure. Benefits of utilising data and AI are various and are linked to improvements in operations, connectivity and performance of the buildings. Further, they can help to link technology required for operation of the buildings with the consumers, and particularly their behaviours. However, different challenges need to be addressed in order to capture these benefits.

The SIG has agreed to develop a flagship project that will see cyber-physical infrastructure developed and implemented in the University's properties and associated organisations and their partners, such as colleges and NHS Cambridge, which will serve as testbeds. The project will provide insights into:

- Fact-based, transferable, reproducible routes to support the electrification of the built environment,
- Governance and management structures required for electrification of the Built Environment,
- Innovative technologies that enable effective two-way grids.

A Decarbonisation Network Symposium was held on 30 September 2022 at the University of Cambridge in Cambridge, UK. A roadmapping workshop with about 40 participants took place within the symposium. It aimed to bring together academic and industry communities to identify key challenges in the application of data and AI in the built infrastructure and how to address them through industry-academia collaboration.

Objectives

The following are the key objectives of the roadmapping workshop within the symposium conducted for the BE SIG:

- Identify a list of challenges related to evaluation, analysis and use of data and AI in the decarbonisation of the built environment.
- Prioritise the challenges that are considered as key from both academia and industry.

- Explore key challenges in further depth, e.g. what are the critical questions to be answered in order to address them and what are the resources, enablers and capabilities required.
- Get alignment of future network activities across involved stakeholders.

Methodology

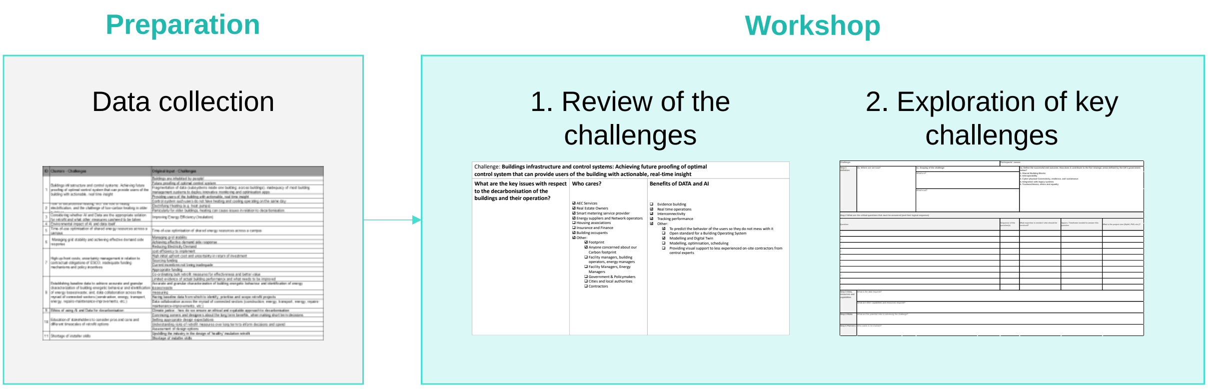
Roadmaps provide a structured visualisation of information for specific strategic aspects. They are used to support strategic planning across a broad spectrum of applications. To structure the workshop programme, the roadmapping methodology based on the IfM's fast-start approach was used.[1] The IfM has developed and deployed roadmapping in several contexts via its fast-start approach. It is appropriate for industry-academia level strategy, examining strategic challenges and exploring innovation opportunities. Generally, it is particularly suitable for understanding and addressing such issues at the 'front-end' of innovation, where decisions have considerable strategic implications.

Workshops are a core element of the roadmapping process, bringing together key stakeholders to identify and explore exploitation routes for new/different ideas or research, support strategy formation, enable communication and formation of new networks, and build consensus for decision-making and action.

Figure 1 shows the overall process. It started with gathering the existing data and collection of further information from the workshop participants through a survey. The delegates shared their ideas on the key challenges, the benefits of addressing this challenge through data and AI and identified stakeholder groups to whom this challenge is most relevant. Participants' inputs were consolidated to provide a baseline and ensure an efficient launch point for the roadmapping workshop.
The workshop itself consisted of two stages:

1. Review of the clustered challenges in small groups in two rotations ("world café"), and
2. Exploration of the key challenges in small groups of participants, who were interested in the challenge, and presentation of the summaries to the plenary.

Figure 1: Overall process



[1] University of Cambridge, Institute for Manufacturing, Phaal, R. (2020), Roadmapping for strategy and innovation, https://www.ifm.eng.cam.ac.uk/uploads/Resources/roadmapping_overview.pdf

Workshop participants are listed in Annex III, while the workshop agenda is in Annex IV.

Key challenges

Based on the data collected, the challenges were clustered into 11 'thematic' challenges and ranked based on their importance and impact before the workshop. See the full list of challenges in Annex I. The eight key priority challenges identified are:

- Challenge A: Buildings infrastructure and control systems
- Challenge B: Decarbonisation of heating and cooling
- Challenge C: AI and data for retrofit
- Challenge D: Time-of-use optimisation of shared energy resources across a campus
- Challenge E: Managing grid stability and achieving effective demand side response
- Challenge F: High up-front costs
- Challenge G: Establishing baseline data
- Challenge H: Ethics of using AI and data for decarbonisation

The review of these challenges during the workshop comprised three main questions:

- What are the key issues with respect to the decarbonisation of the buildings and their operation?
- To what stakeholder groups is this challenge most relevant?
- What are the benefits of data and AI?

In following, the participants worked in small groups and described the challenges in further detail by:

- Defining the successful outcome/ideal future, current situation and the scope;
- Identifying critical questions that need to be answered to address the challenge, including the required expertise and the potential timeframe and project size as well as other resources and capabilities needed, and
- Specifying any risks.

In this second step, the "Challenge F: High up-front costs" was not explored separately as it was considered to be part of the discussion of all other challenges.

Challenges involve multiple stakeholders, including AEC services, real estate owners, service providers, energy suppliers/network operators, housing associations, insurance and financial organisations and occupants. In addition, the interest and influence of stakeholders concerned about environmental impacts, such as building managers, local governments and contractors, the national grid, and research groups, must also be considered in addressing the challenges.

A key outcome of the discussion was a list of overarching research themes that will help address several challenges. These are:

- **The ways in which buildings are used and the impact of heritage designations**: The implications from the use purpose of a building i.e. as a lab or domestic and commercial purposes as well as how legislation affects what data and AI technology can be implemented in the particular building.

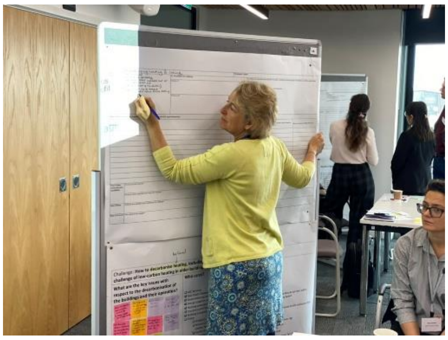
- **Future-proofing data and AI technologies**: The impact of climate change on the use of technology in the buildings and how data will adhere to future standards and regulations.
- **Costs and value for investment in data and AI**: The cost-effectiveness of different strategies and price modelling including supply and demand sides, and cross-over effects with other investment incentives.
- **Engagement models with various decision-makers and stakeholders**: Getting understanding of who makes decisions about what change happens based on data and AI and what the incentives to gather data including building users are required at different stages of the building life cycle (e.g. pre- and post-occupancy) and how to achieve a buy-in.
- **Privacy, security, ethics, and accountability**: Considerations of how the data is shared, who is accountable within different business models and what security systems need to be in place.
- **Geographical scale of data collection**: Scale of data technology can range from the national level, district and building level; thus, considerations how the data is mapped and how to account for different geographies need to be investigated.
- **Translating data into action to inform decisions on which technology to implement**: Translating collected data into actionable insights, targeting 'low-hanging' fruit first for proof-of-concept and developing decision trees to establish a hierarchy of which technologies are best-placed in what application case.
- **Quality and amount of data**: Granularity of the collected data, its accuracy and reliability; how to address missing data; and, what is an appropriate sample size for research to be undertaken.
- **Sustainability of data collection**: Assessment of the environmental impact of the data collection itself.

Following are the impressions from the workshop and the brief summaries of the discussion on each challenge. Further details on the challenges captured during the workshop can be found in Annex II.

"World café" discussions




Exploration of the key challenges

4.1 Challenge A: Buildings infrastructure and control systems

Buildings infrastructure and control systems: Achieving future proofing of optimal control system that can provide users of the building with actionable real-time insights

This challenge is related to building infrastructure and control systems, particularly **achieving futureproofing of optimal control systems that can provide building users with actionable real-time insights**. The critical issues highlighted for the decarbonisation of buildings and operations in this challenge relate to the **knowledge gap, training, data informativeness, and implications for commercial deployment of innovative solutions**.

Data and AI can be employed in **evidence-building, real-time operations, interconnectivity**. Other benefits of data and AI are reported as reducing the workforce, environmental improvement, and accurate predictions,

The main vision is related to user feedback loops, connected buildings, and coordinated systems informing operation of buildings. Currently, there is a range of smart systems with reactive and predictable control systems. There is however a lack of granular data from sensors and actuators.

The scope is limited to the building occupants and operators with access to appropriate sensing and flexibility of systems. Physical modification is out of the scope of this challenge.

The critical questions are related to the time dimension, complexity of building operations, and transparent controls. Furthermore, the value of investment in handling responsibility of data and its protection are also identified as key areas to be addressed.

Data and required resources are linked to consent, open and aggregated data, thought leaders and financial grants. Risks involved are identified as data ownership and physical models of AI models infrastructure.

The critical questions that need to be answered to address this challenge are:

1. How much complexity can the end user understand?
2. Who has the control over building systems – occupiers' managers or users?
3. How to balance occupants' choice? Baseline system and informed choices
4. Where is the best value for investment?
5. Who is responsible for the handling (collection, storage access) of data?
6. How can we use data/what data is protected?
7. What kind or incentives to encourage participation in data gathering uptake?
8. When can decision be outsourced to energy suppliers versus occupiers?

4.2 Challenge B: Decarbonisation of heating and cooling

How to decarbonise heating and cooling, including the role of heating electrification, and the challenge of low-carbon heating in older buildings?

This challenge addresses the question of decarbonising heating and cooling. This also includes the role of heating electrification and the challenge of low-carbon heating in older buildings. The critical issues highlighted in this challenge relate to replacing natural gas, equity of access to new technology, creating awareness, data fragmentation, and industrial heating solutions.

Benefits of data and AI are reported as open standards for building operation systems, user feedback loop, interactive suggestions to occupants to improve efficiency, enabling flexibility to balance the grid, informing an appropriate technology to adopt, prognostic health management for equipment, particularly during post installation.

The key elements of the vision include building heating to be de-gasified by 2040, cross-sector collaboration, and heating technology selection that can address grid demand. Currently, there is a cost aspect of retrofit and a wide variety of building types for which to decarbonise gas heating is needed.

The scope of the solution is limited to domestic and commercial buildings and managed residential buildings. Industrial heating and processes (industrial homes) is specified as out of the scope of this challenge.

The critical questions are related to heating demand, the balance of embodied carbon, technology, and ROI. Furthermore, the balance of different technologies, cost-effective routes and future climate change are also identified as key areas to be addressed. This requires social housing providers, data analytics, skill cost expertise and estate management. The size of the project is limited to 1-5 years.

Data and required resources are linked to building types, current thermal performance and heating, energy consumption, size, occupancy profile, drawing/models and the role of policymakers, regulators, and local government.

The critical questions that need to be answered to address this challenge are:

1. Where is heating demand highest? (Opportunity greatest)
2. What is the balance of embodied carbon vs. carbon saved over life cycle of the system? For a given technology in each location?
3. What is the cost of each given technology? And does it reduce if we aggregate demand?
4. And what is the ROI and energy costs (to prioritise)?
5. What is the right/best balance of different technologies (in different building types) across the building estate?
6. Are there any technology gaps (e.g., for listed buildings)? What is the role of e.g., electric heating of water or direct electric heating instead of gas boilers? What is the decision tree?
7. What is the most cost-effective route to decarbonise these buildings?

8. Are the proposed solutions resilient to future climate change?
9. Can we create a decision tree for selecting appropriate technology for building?
10. Post Occupancy Learning – Separate Project

4.3 Challenge C: AI and data for retrofit

Considering whether AI and data are the appropriate solutions for retrofit and what other measures can/need to be taken

This challenge is related to considering whether AI and data are the appropriate solutions for retrofitting and exploring whether other options or measures can be useful. The critical issues relate to data availability, the impact of electrification on the grid, smart meter customisation, data security and lack of information about building operations.

Data and AI can be employed in engaging building owners, and risk quantification. Other benefits of data and AI are reported as using AI to identify patterns of building/material styles to help design a " healthy" approach.

Currently, data is in silos). Organisations are not collaborating due to the sensitivity around data ownership. Furthermore, data and AI systems are unaffordable for several companies. There is a large percentage of buildings that need to be retrofitted. Technical solutions, such as those identified in MCS, EPC, IoT infrastructure and smart metering, can be used.

The scope is limited to a system-level view (benefits beyond energy-environment/economy well-being) of retrofits, the connection between the system is the individual, prioritisation of benefits, using data for justice and equality and levelling up. Policy and regulations are identified as out of the scope of this challenge.

The critical questions are related to the use of data-rich buildings, privacy and security of data and generating data sustainability. Furthermore, workforce and capital, national data and ecosystem and data reliability are also identified as key areas to be addressed. This required academic, industry, BELS, CDBB, ONS, and the third sector to be involved.

The critical questions that need to be answered to address this challenge are:

1. Low hanging fruit first – Use data-rich buildings to demonstrate value, develop standardized approaches – how to make this possible?
2. Privacy and security of data – Generating synthetic data possible solution?
3. Generate knowledge repository specific to listed buildings
4. What do we need to measure? How to generate data sustainably?
5. Quantifying how much data is enough
6. Workforce and capital – data modelling to quantify needs versus benefits
7. What does the national data ecosystem look like and who does it? How to access data?

8. Keeping it simple – communication and reliability of data

4.4 Challenge D: Time-of-use optimisation of shared energy resources across a campus

This challenge describes the time-of-use optimisation of shared energy resources across campuses. Data and AI can be employed in real-time operations, such as enabling decentralisation of storage and use of energy sources for exploiting commercial opportunities and community benefits.

The key dimensions to the vision are related to the mapping/characterisation of the estate, shared resources, long-term planning, grid flexibility, and combined heat strategy. There are currently emerging technology applications such as compressed heat. Regulation is a limitation on the energy supply.

The scope is limited to the functional campus, but this requires a definition of a campus and its resources capabilities. River source and the same connector to the network are out of the scope of this challenge.

The critical questions are related to the systems approach, mapping, and characterising estate and energy use across the city. Furthermore, campus interaction, emerging technologies, 'legislation and restrictions' are also identified as key areas to be addressed. This requires system thinking, involving building users, university council'/management (decision-makers),

Data and required resources are linked to projections from modelling and reality, social and behavioural decision-making, high-resolution energy data, and system thinking approach by decision-makers. Risks involved are identified as policy uncertainty (political cycles), energy security aspects, climate risks and uncertainties in energy cost modelling.

The critical questions that need to be answered to address this challenge are:

1. How to start assessing who gets what and when? / Get university to take a systems approach?
2. How to unpack and map what is a campus and to include (systems)? How do we map and characterise estate?
3. How to characterise a functional zone?
4. What is the energy use across city i.e., gas?
5. How does campus interact with adjacent opportunities? What is the functional opportunity?
6. What is low hanging fruit to start off?
7. Has tension as soon as choices lock-in i.e., DGS society charges EV – is that best way to use energy?
8. How to build a pathway for technology to come in and be piloted? Can the University set a precedent?
9. What role does emerging technology play?
10. What about legislation and restrictions? Including historic building and committees – What is the balance between conservation and energy?

4.5 Challenge E: Managing grid stability and achieving effective demand-side response

This challenge is focused on managing grid stability and achieving effective demand-side response. The critical are tolerance bands for cooling, thermal storage for demand side response,

Data and AI can be employed in adaptive comfort,

The main vision is related to a fully flexible grid, functioning market, and DSR rights and responsibilities governance.

The current scope is identified as signal and control, financial incentives, policy, granular price signals, dynamic traffic, and increasing numbers of smart devices. Cleaning up data, data gaps, and scaling up are identified as out of the scope of this challenge.

The critical questions are related to smart meter data, energy contracts, energy systems and market structure. Furthermore, better randomised controlled trials, granular domestic usage, DER bill of rights and responsibilities, data privacy and security are also identified as key areas to be addressed. Skills and requirements are statistics, economics, functioning government, and a normal grid as well as skills from other sectors and law/ business to be involved.

Data and required resources are linked to basic usage data, and perception/survey data. Risks involved are identified as black/brown out events, financial costs, and demand for building more grids.

The critical questions that need to be answered to address this challenge are:

1. How to unlock domestic usage? Smart meter data
2. How to make energy contracts more attractive?
3. Change energy system – priced correctly, market structure, OFGEM, business, ESO
4. License to run ESO, sign up customers, pricing model, consumer protection
5. Cost of curtailment during peak generation/turn off/turn down
6. Better randomised control trials, more data, scale-up to value flexible market
7. Better granular domestic usage
8. DER bill of rights & responsibility, sharing car model
9. Data privacy/security

4.6 Challenge F: High up-front costs

High up-front costs; uncertainty management in relation to contractual obligations of ESCO, inadequate funding mechanisms and policy incentives

This challenge is about the high upfront costs, uncertainty management about the contractual obligations of ESCO, inadequate funding mechanisms and policy incentives. It was identified that payback periods are long, and there are supply chain linked issues. Contracts of energy services and contracts between ESCO and building users are hard to manage. Streamlining decarbonisation is challenging due to the lack of coordination between the government, local authorities, builders, and homeowners.

New AI technologies can track performance, reduce cost and predict optimums for required grids. It can better inform investment decisions and realise new opportunities.

4.7 Challenge G: Establishing baseline data

Establishing baseline data to achieve accurate and granular characterisation of buildings' energetic behaviour and identification of energy losses/waste; and data collaboration across the myriad of connected sectors

This challenge is related to establishing baseline data to achieve accurate and granular characterisation of buildings' energetic behaviour and identification of energy losses/waste; and data collaboration across the myriad of connected sectors (construction, energy, transport, repairs-maintenance-improvement, etc.). The critical issues relate to the changing physical environment, knowledge of surrounding buildings, achieving engagement, establishing patterns, ethics and privacy of data, data infrastructure, data sharing and lack of trust from building stakeholders.

Data and AI can find patterns in behaviour, and synthetic datasets.

The main vision relates to predictive power, and an open/trusted system for data sharing and implementation. Currently, there is fragmented data owned by different people who do not necessarily interact with each other. much data is manually collected, resulting in missing information, gaps, and no common language. There is a lack of regulation and the right specialist skills.

The scope is limited to carbon dioxide as a proxy for other GHGs, emissions, and the time limit for baseline data, machine readability, building ownership/usage and within Cambridge city (commercial and residential). Emissions, other GHHs data for >5 years back, and rural areas are out of this challenge's scope.

The critical questions are related to the samples of buildings, baseline models, ontological data structure and ethics. Furthermore, addressing the missing data, data translation and collaboration for different geography are also identified as key areas to be addressed. This requires experts on local buildings and statistics, data science, GDPR/data ethics and RSE. The size of the project is limited to 3 months to 1 year.

Data and required resources are linked to facilitation (industry), the ODIs guidebooks on 'trustworthy data institution' and data ethics and open data standards.

The critical questions that need to be answered to address this challenge are:

1. What is the smallest representative sample of buildings?
2. How accurate/granular a baseline model do we need?

3. How do we create ontological structure for data sharing? Future-proof data standards
4. What data can/can't be shared? Ethics?
5. How do we ensure automated continuous data collection?
6. How much data is required for each building? How far back in time?
7. What is the best model/digital twin to construct for baseline and collaboration?
8. What do we do about missing data?
9. How do we get buy-in? How do we get people to provide and use data?
10. How do we translate data and collaboration to actionable insights and different geographies?

4.8 Challenge H: Ethics of using data and AI for decarbonisation

This challenge focuses on the ethics of using AI and data for decarbonization. The critical issues relate to equity, governance, security, privacy and data-related aspects such as ownership, commercialisation, and sharing.

Data and AI can be employed to remove human bias. Other benefits of data and AI are reported as an open standard for a building operating system and provision of the visual support from central experts to less experienced on-site contractors.

The main vision is linked to industry bodies/associations, certification legislation and Cambridge University estate management. Currently, there is a pre-programmed design involving data gathering of new and old buildings. There is a lack of ethical data governance.

The scope is limited to the type of data, sharing, fairness of outcomes, confidentiality. Detailed data on specifics is out of the scope of this challenge.

The critical questions are related to, accessibility/sharing data and data accountability (security and privacy). Furthermore, data consent and making AI models work for everyone without discrimination are also identified as key areas to be addressed. This required facilities management, software developers, building owners, communities, facilities management, city council, lawyers, ethics department or ethics specialist in AI/data to be involved. The size of the project is limited to the short-term to one year and is continuously evolving. Data and required resources are ensured to have a seamless flow to people.

The critical questions that need to be answered to address this challenge are:

1. How to distinguish different types of data (multidisciplinary project)?
2. Who is the data for – accessibility/sharing of data?
3. Consideration of different building types e.g., labs, retail, residential
4. Accountability of data security and privacy (ensure anonymity)
5. Who is accountable for AI model?
6. What type of data requires consent (if anonymity not available)?
7. How to make an AI model to work for everyone without discrimination?

Annex I List of Challenges

In following, Table 1 shows the clustered challenges including the ideas submitted through the pre-work survey that were allocated to the cluster.

Table 1: Clustered challenges

ID	Clusters of Challenges	Ideas on challenges collected from pre-work
1	Buildings infrastructure and control systems: Achieving future proofing of optimal control system that can provide users of the building with actionable, real-time insight	Buildings are inhabited by people!
		Future proofing of optimal control system
		Fragmentation of data (subsystems inside one building; across buildings), inadequacy of most building management systems to deploy innovative monitoring and optimisation apps
		Providing users of the building with actionable, real-time insight
		Control system users do not have heating and cooling operating on the same day
2	How to decarbonise heating, including the role of heating electrification, and the challenge of low-carbon heating in older buildings	Electrifying heating (e.g. heat pumps)
		Particularly for older buildings, heating can cause issues in relation to decarbonisation.

ID	Clusters of Challenges	Ideas on challenges collected from pre-work
3	Considering whether AI and data are the appropriate solution for retrofit and what other measures can/need to be taken	Improving energy efficiency (Insulation)
4	Environmental impact of AI and data itself.	
5	Time-of-use optimisation of shared energy resources across a campus	Time-of-use optimisation of shared energy resources across a campus
6	Managing grid stability and achieving effective demand side response	Managing grid stability
		Achieving effective demand side response
		Reducing Electricity Demand
7	High up-front costs; uncertainty management in relation to contractual obligations of ESCO, inadequate funding mechanisms and policy incentives	Cost efficiency to implement
		High initial upfront cost and uncertainty in return of investment
		Sourcing funding
		Current incentives not being adequate

ID	Clusters of Challenges	Ideas on challenges collected from pre-work
		Appropriate funding
		Co-ordinating bulk retrofit measures for effectiveness and better value
8	Establishing baseline data to achieve accurate and granular characterisation of buildings' energetic behaviour and identification of energy losses/waste; and data collaboration across the myriad of connected sectors (construction, energy, transport, repairs-maintenance-improvements, etc.)	Limited evidence of actual building performance and what needs to be improved
		Accurate and granular characterisation of buildings' energetic behaviour and identification of energy losses/waste
		Measuring
		Having baseline data from which to identify, prioritise and scope retrofit projects
		Data collaboration across the myriad of connected sectors (construction, energy, transport, repairs-maintenance-improvements, etc.)
9	Ethics of using AI and data for decarbonisation	Climate justice - how do we ensure an ethical and equitable approach to decarbonisation

ID	Clusters of Challenges	Ideas on challenges collected from pre-work
10	Education of stakeholders to consider pros and cons and different timescales of retrofit options	Convincing owners and designers about the long-term benefits, when making short-term decisions
		Setting appropriate design expectations
		Understanding the risks of retrofit measures over the long term to inform decisions and spending
		Assessment of design options
11	Shortage of installer skills	Upskilling the industry in the design of 'healthy' insulation retrofit
		Shortage of installer skills

Annex II Challenges - Workshop outputs

Challenge A

Buildings infrastructure and control systems: Achieving future proofing of optimal control systems that can provide users of the building with actionable real-time insights

Questions	Expertise needed	Timeframe	Project size
2. How much complexity can the end user understand?	UX expertise	communication	
3. Who has the control over building systems – occupiers' managers or users?	Standard Bodies	Agency	
4. How to balance occupants' choice? Baseline system and informed choices		communication	
5. Where is the best value for investment?		Optimization/cost	
6. Who is responsible for the handling (collection, storage access) of data?		Data management	
7. How can we use data/what data is protected?		Data management	
8. What kind or incentives to encourage participation in data gathering uptake?		communication	
9. When can decision be outsourced to energy suppliers versus occupiers?		Agency	

Key issues in the scope of this challenge

- Effective training
- Data collection is not always easy due to lack of "trust" or unwillingness
- Residential?
- Commercial?
- Optimal use of HVAC that balances comfort and emissions
- Control decisions by AI (predictions)
- Policy?
- What does good look like?
- Optimal use of ventilation
- Maintainability
- Hybrid working
- Knowledge gap and misalignment with decision makers
- Future attractive users, flexibility of spaces
- Comfort as a service

- Granular insights that drive behaviour change
- Appropriate comfort when and where needed
- Accessibility of SILO'D data
- Data caretakers not just building caretakers
- How to share RT insights (data) with local authority and policy makers
- Other authorities closing doors

Impacted stakeholders
- AEC services
- Real estate owners
- Smart metering service provider
- Energy suppliers and network operators
- Housing associations
- Insurance and financial services
- Building occupants
- Other:
    - Anyone concerned about our carbon footprint
    - Facility managers, building operators, energy managers
    - Facility managers, energy managers
    - Government and policy makers
    - City and local authorities
    - Contractors
- National Grid/DNO
- Building users/community
- Research groups

Benefits of Data and AI
- Evidence building
- Real time operations
- Interconnectivity
- Tracking performance
- Other:
    - To predict the behaviour of users so they do not interfere with it
    - Modelling, optimisation, scheduling
- Reduced workforce
- Improved environment
- Using building performance to inform future building designs
- Predictions of future demand (and changing factors)
- Reduced footprint
- Balanced load electrical
- Policy interventions for people/commodities in vulnerable circumstances
- Public health implications of these insights (too hot/cold)

Vision and successful outcome
- User feedback loops
- Connected buildings and coordinated systems → informing occupiers

Current situation

- A range - Dumb Systems → Smart Systems
- Reactive Control → Predictive control
- Blunt control today → Not necessarily relevant to what is really going on now
- Single parameter control
- SILOED control system
- Lack of granular data collection
- Lack of sensor actuators

Scope

- The building occupants and operators
- Spaces, time and carbon utilisation (cost -what is the cost?)
- Appropriate sensing
- Flexibility of systems

<u>Out of scope:</u>

- Physical modifications

Data and resources

- Consent
- Open data (Example: Weather) and “unit” data (example: MTG energy demand)
- Aggregated data
- Exemplars, thought leaders, start-ups, massive energy projects
- Finance/grants

Risks

- Data ownership and scope
- Physical AI models of infrastructure

Challenge B

How to decarbonise heating and cooling, including the role of heating electrification, and the challenge of low-carbon heating in older buildings?

Questions	Expertise needed	Timeframe	Project size
1. Where is heating demand highest? (Opportunity greatest)	Other 'users' e.g. social housing providers	1-5 Years	A set of masters' projects e.g. IfM, Civil Engineering, Judge Business School, DivF (Info)
2. What is the balance of embodied carbon vs. carbon saved over life cycle of the system? For a given technology in a given location?	Data analytics skills costing expertise Carbon Trade-offs	1-5 Years	
3. What is the cost of each given technology? And does it reduce if we aggregate demand?	Other 'users' e.g. social housing providers Economies of scale	1-5 Years	
4. And what is the ROI and energy costs (to prioritise)?	Retrofit /heating expertise for consultancies etc. Cost effectiveness	1-5 Years	
5. What is the right/best balance of different technologies (in different building types) across the building estate?	Estates management Technology trade-offs	1-5 Years	
6. Are there any technology gaps (e.g., for listed buildings)? What is the role of e.g., electric heating of water → or direct electric heating instead of gas boilers? What is the decision tree??	Technology expertise & info for industry	1-5 Years	
7. What is the most cost-effective route to decarbonise these buildings?	Heritage building expertise	1-5 Years	
8. Are the proposed solutions resilient to future climate change?			
9. Can we create a decision tree for selecting appropriate technology for building?	IfM, Girls, Judge Business School	1-5 Years	A set of masters' projects e.g. IfM, Civil Engineering, Judge Business School, DivF (Info)
10. Post Occupancy Learning – Separate Project	Plus, social science (human geography)		Ongoing project – Master &PWDs?

Key issues in the scope of this challenge

- How to replace natural gas – boiler gas etc and steam boilers (for scientific uses etc)
- Equity of access to new technology – cost to those who may need it most
- How to educate the user – awareness
- Predictability of demand? (Is there historic data?)
- NB requires fabric improvement for many solutions e.g., heat pumps
- Skills/experience of operators – optimal performance and experience with new system after disparate use
- Managing temperature – “locally” within building especially HMOs etc
- Data fragmentation and maturity across input data sources
- Magnitude of demand in the grid
- If have ‘passivhaus’ or equivalent – risk of overheating in summer
- Post installation support → opportunity for heating and cooling service
- F-gas phase out high GWP of refrigerants used in heat pumps
- British standards based on outdated scientific knowledge
- Options of direct electrical heating e.g., radiant panels
- Advice & info for homeowners to decide what to invest in
- Listed buildings and conservation zones
- Industrial heating solutions e.g., greenhouse

Impacted stakeholders

- Real estate owners
- Smart metering service provider
- Energy suppliers and network operators
- Housing association
- Insurance and financial services e.g., mortgage decrease for increase in e-efficiency, financial incentives for cost of retrofit
- Building occupants
- Others:
  - Facility managers, building operators, energy managers
  - Facility managers, energy managers
  - Cities and local authorities
  - Investment companies
  - Social housing providers

Benefits of Data and AI

- Evidence building
- Real time operations
- Interconnectivity
- Tracking performance
- Others:
  - Open standard for building operation system
  - Required? - Modelling and digital twin
  - Required? - Modelling, optimising, scheduling
  - User feedback loop – Building. M.L. → patterns and
  - Interactive nudging/suggestions to occupants to improve efficiency

    - Enabling flexibility to balance the grid → shifting demand in time
    - Informing of an appropriate technology to adopt
    - Prognostic health management for equipment (post installation)

Vision and successful outcomes

- All building heating degasified by 2040
  → Comfort standards also improved by retrofit
  → Energy security
- Cross sector collaborating e.g., in university sectors, commercial sector etc.
- Heating technology selection addresses grid demand
  → Move GS then AS heating
  → Underfloor heating
  → Radiant electric heating
  (Less investment required in grid, distribution etc)

Current situation

- How to decarbonise gas heating
  → GSHP, ASHP available but not widely rolled out (NB H_2 is not part of the solution)
    1. Cost, especially of retrofit
       → Need to replace entire existing heating system (radiators)
       → Need major thermal retrofit
    2. Wide variety of building types
       → Need prioritisation of buildings
       → Advice on what works where
    3. Market capacity not available for speed
    4. Disruption – decanting disturbance e.g., 6 weeks
    5. User and operators' awareness/confidence
    6. Common knowledge – opportunity for collaboration

Scope

- Domestic, office etc buildings → Commercial buildings & managed buildings

<u>Out of scope:</u>

- Industrial heating and processes (industrial homes)

Data and resources

- Building info → Types, current thermal performance and heating, energy consumption, size, occupancy profile and etc.
- Drawing/models (where available)
- Role of policymakers, regulators, local government. etc.

Challenge C

Considering whether AI and data are the appropriate solutions for retrofit and what other measures can/need to be taken

Questions	Expertise needed	Timeframe	Project size
1. Low hanging fruit first – Use data-rich buildings to demonstrate value, develop standardized approaches – how to make this possible?	Academic		
2. Privacy and security of data – Generating synthetic data possible solution?	Industry and Academic/ (BELS, CDBB, ONS)		
3. Generate knowledge repository specific to listed buildings	Third sector (National Trust)		
4. What do we need to measure? How to generate data sustainably?	Industry		
5. Quantifying how much data is enough	Academic		
6. Workforce and capital – data modelling to quantify needs versus benefits	Industry		
7. What does the national data ecosystem look like and who does it? How to access data?	Industry and Academic/ (BELS, CDBB, ONS)		
8. Keeping it simple – communication and reliability of data	Industry		

Key issues in the scope of this challenge

- How do you deal with charging operation based on data?
- Occupants' actions not known

a) Data availability, no baseline_to quantify benefits of retrofit (deep version shallow)
b) Impact of electrification on grid using data analytics

- Keeping it simple, having reliable data, communication of data
- Lack of information about building's operation
- Smart meter_customisation of retrofit recommendation
- Use of smart meter data to recommend retrofit not done yet
- Ease studies from technology providers of how it's going to improve
- Expertise and people who can make use of data
- Data security makes it difficult to scale knowledge
- Incentives of data/AI not clear
- Maybe right now, we just need to train plasterers, installers and designers and develop maintenance skills
- Changing culture/somebody has to use a digital twin

Impacted stakeholders

- AEC services
- Real estate owners
- Housing associations
- Building occupants
- Others:
    - Facility managers, building operators, energy managers
    - Government and policymakers

Benefits of Data and AI

- Evidence building
- Real time operations
- Tracking performance
- Inform operation and maintenance activities
- Engage building owner
- AI to quantify risks e.g. interstitial condensation fears
- Using AI to identify patterns of building/material styles to help design of 'healthy" approach

Current situation

- Lack of knowledge on data (data is in silos)
- Organisations are not talking
- Data ownership is a highly sensitive issue
- Affordability of data/AI
- Large percentage of buildings that need to be retrofitted
- We have technical solutions
- We some bright spots where database can be used – MCS, EPC, NEED
- IoT infrastructure, smart metering

Scope

- System level view (benefits beyond energy – environment/economy well-being) of retrofits
- Connection between the system is the individual
- Prioritisation of benefits
- Using data for justice & equality and levelling up

<u>Out of scope:</u>

- Policy and regulations

Challenge D

Time-of-use optimisation of shared energy resources across a campus

Questions	Expertise needed	Timeframe	Project size
1. How to start assessing who gets what and when? / Get university to take a systems approach?	-System thinking -Building users -University 'council'/management (decision-makers)	Plan now but also future	Develop use cases-archetypes (finding precedents) → topics in mask -Several projects collect data
2. How to unpack and map what is a campus and to include (systems) →geographical → how do we map and characterise estate?	-Utility camp – biogas better utilised -Land use, GIS, digital modelling -BaS – have maps on aquifers	→ now characterise	Multifaceted research project i.e., energy efficient cities initiatives
3. How to characterise a functional zone? →geographical → how do we map and characterise estate?	-Natural grid, DNO, building users – knowledge (energy use) and grid connections -Business school – commercial up	Could we have master /workshop	PHD/Post-docs – some functional – some geographical
4. What is the energy use across city i.e., gas? → (then review macro) → functional → how do we map and characterise estate?	-Local authority – trailing -Hospitals – lots of use case -Creative phase:-architecture -Community engagement – planners	Case-study examples: -Around statistics/CUP Addenbrookes/ Trumpington meadows →Marshall site/old airfield CUHP	Geographical size: Area that transact campus and city
5. How does campus interact with adjacent opportunities? What is the functional opportunity?			
6. What is low hanging fruit to start off? ← Low regrets Has tension as soon as choices lock-in i.e., DGS society charges	-BGS – innovation vouchers -Judge (decision making analysis)	Mix stuff can get on with but no regrets	

Questions	Expertise needed	Timeframe	Project size
EV – is that best way to use energy?			
7. How to build a pathway for technology to come in and be piloted? Can the University set a precedent?	-Conservation committees -Industry (professional bodies) -JBS – open innovation (not all answers will come from Cambridge University -new process open to that)		Vice Chancellor level (beyond research project)
8. What role does emerging technology play?	-Behavioural scientist		→Could we have short course at the University for sectors e.g., conservation (proactive rather reactive →CBD courses for professionals as well
9. What about legislation and restrictions? Including historic building and committees – What is the balance between conservation and energy?	-Cambridge County Council /government policy. -Conservation committee	-Difficult as gas changes	

Key issues in the scope of this challenge

- Could you sell heat back?
- Shared energy
  → Limited supply heat network renewable source
  → Regulate new direct share
- Maintenance of the issue
- Sdar = dependent on time of day sufficient for building shift – night-time
- Less technological – new administration of such an idea
- Who is the energy supplier?
- Not very democratic (who decides how to work?)
- What is balance – this is a grey area
- Who decides it is fair? (who, when)
  →Ethical issue – who to compare to?
- Mapping energy sources is the transport sector
- What are the shared energy sources → Identify what they are
- Heterogeneity use and ownership (colleges and universities) responsibility, collectively and
- Uses patterns lab – day, students – night

- Where does info sit
- Master plan
  → System
  → Build next to each other
  →Winning (challenge that already exist)
- Is there a centralised system?
- Gates - building computes heat (overheating not stored)
- University Hospital
  →There are building/functions that have priority
- Hybrid functions
- →Do have flexibility and preferential per use of space
- Reject heat from a lab – can that be used
- Shared resources - it's a bigger system than the university
- City – is that included using energy - - river - who owns it

Impacted stakeholders

- Both would care – would get involved to facilitate process
- Real estate owners
- Energy suppliers and network operators
- Optimising plans on campus
- Housing associations
- Building occupants
- Others:
  - Anyone concerned about our carbon footprint
  - Facility managers, building operators, energy managers
  - Cities and local authorities
  - Energy users

- Insurance and finance companies → Energy suppliers
- College – as had to raise money (philanthropist)

Benefits of Data and AI

- Real time operations
- Others:
  - Sam. Harwell Campus - are the commercial opportunities, community benefits
- Setting price to drive demand, excess supply
- Less peaks and troughs (steady stream)
- Incentivises people and neighbours by having system
- Cold campus smooth demand peaks – by having storage – put into local grid
- Philanthropist could de-risk? – backing bonds
- Hydro-plants Mid Wales supplement grid
- Flow of people AI might decide where most people go
- Enabling decentralisation of storage – fill at certain time – power sun midday
- When is the use of energy source most efficient?
- Could be democratic if evidence/info to support it – cars net used at night – enforced democracy!
- If public cannot self-manage, then could benefit (but is that democratic)

- Benefits = method to make it democratic
- Creates need for more active collaboration among energy users and community

Vision and successful outcome

- Mapping/characterisation of the estate
- Potential shared resources
- Co-ordinated efforts identify
- Opportunities – deciding on land
- Long-term planning
- Templates identify what is a functional zone, typology e.g., hospital, as well as geography
- Principles established (language that can be used)
- Add grid flexibility
- Combined heat strategy and grid storage
- More that is economical cleaner, open-door opportunities
- Set precedents to show it is possible with historical buildings
- Top-down catalyst bottom up, macro framework– each do could bottom up - what happens?

Current situation

- Wolfson College has a plan
- We need knowledge of what we need
- Where are we now with individual buildings/colleges?
- Unpack what is a campus → Mapping
  →Some colleges better than others
- Project – rip at boilers put in heat pumps
  → Can't just do
  → What systematically can do
- Project lacking from using the river as a heat source – needs to be co-ordinated with the city
- Modelling to look at demand leads – functions of different buildings
- What is gas use?
- Lots of emerging technology
- Compressed heat that can be used
- Regulations place a limitation on the energy supply
  → Places like Trinity College can afford
  → Historic building restrictions (hugely problematic)
- There is new paradigm, because of the energy crisis

Scope

- What is a functional campus?
- Definition of 'campus'
- Resources capability – land(heat) - and grand source – own control
- Low – hanging fruit
- Old (problematic if historic) and new

<u>Out of scope</u>

- River source (for those acting fast)
- Too political and long process to be met by 2030
- Time and funding dependent on emergent technologies → Can this be implemented on time?
- Example: Oxford saying won't decarbonise energy – grid already decarbonised
- Same connector to network
- → Should the wider city benefit to be involved e.g., neighbour (not university) has excess heat and vice versa?
- → City would complicate further, campus complicated enough
- → If works well for campus than take further to apply locally

Data and resources

- Important (data and target social and behavioural)
- Projections from modelling and reality e.g., stable → shock → stable
- Social and behavioural decision making, this is after information missed – lots of technology solutions
- High-resolution energy data
- High lead data – map scale of the problem
- → Individual actions that need high resolution data
- →There are opportunities to deal in
- → How many MWatt Unit?
- System thinking/wired problems
- Bring in decision makers (shocks) and do scenarios – how unfold ← fun workshop

Risks

- Policy uncertainty (political cycles)
- Huge project ready pyramid professionals and education (perhaps short course) – see G.
- Energy security aspect (don't put 'all eggs one basket', grid will decarbonise)
- Climate risks e.g., continue to get very hot days
- Some places need to be self-sufficient
- Uncertainty energy cost modelling – i.e., change prices
- How to factor in new paradigm shifts (can go beyond natural)

Challenge E

Managing grid stability and achieving effective demand side response

Questions	Expertise needed	Timeframe	Project size
1. How to unlock domestic usage? Smart meter data	Statistics		Data classification
2. How to make energy contracts more attractive?			
3. Change energy system – priced correctly, market structure, OFGEM, business, ESO	Government/OFGEM/economist normal grid		
4. License to run ESO, sign up customers, pricing model, consumer protection			
5. Cost of curtailment during peak generation/turn off/turn down			
6. Better randomised control trials, more data, scale-up to value flexible market	Skills form other sectors broader dataset/customer data		
7. Better granular domestic usage			
8. DER bill of rights & responsibility, sharing car model	Law/business		
9. Data privacy/security			

Key issues in the scope of this challenge

- Sacrifice certain users on how to decide?
- Critical infrastructure - tolerance bands for cooling
- Thermal storage for demand side response
- Octopus Energy ‘google’ of energy shift demand
- Servers temperature sensitivity for how long
- Batteries and electrical storage
- Signal and control through AI
- User incentives needed
- Different renewables, different stability issues
- Retrofit for flexible user behaviour
- User rates between peak/off peak small
- Policy on insulation why heating needed?

- Better understanding of usage psychology
- Inertia in user behaviour change
- Grid capacity

Impacted stakeholders
- Smart metering service provider
- Energy suppliers and network operators
- Building occupants
- Government meetings DCMS
- Distribution networks
- AEC servers
- Insurance and finance companies
- Building managers
- Cities and local authorities (housing association)

Benefits of Data and AI
- Real time operations
- Interconnectivity
- Tracking performance
- Predict and influence behaviour
- Adaptive comfort
- Open climate fix
  → Solar and short-term weather predictions
  → Depressing: Date variability increases demand in some cases
- UK high thermal mass of building
- Planning future infrastructure
- Shifting behaviour
- Forecasting due to weather conditions less/more cooling needed
- From micro gent flexi services e.g., DSR
- Massive benefit where you can shift demand
- Greater visuality (smart meters)
- View grid usage real time 'gamifying'
- Feed into barret formula government spending
- More equitable profit sharing
- Financial incentives

Vision and successful outcome
- Fully flexible grid/market
- Functioning market
- Governance DSR rights and responsibilities

Current situation
- In UK or local, EU/global domestic level, vehicle → grid → battery

Scope
- Signal and control
- Financial incentives
- Policy

- Granular price signals
- More dynamic traffics
- Support more smart devices

Out of scope:
- Cleaning up data gaps
- Do we need to consider homes in clusters by types or are individually for scale?

Data and resources
- Basic usage data
- Perception/survey data

Risks
- Black/brown out events
- Financial cost – need to build more grids

Challenge F

High up-front costs; uncertainty management in relation to contractual obligations of ESCO, inadequate funding mechanisms and policy incentives

Questions	Expertise needed	Timeframe	Project size
1. How to distinguish different types of data (multidisciplinary project)?	Facilities management, software developer, building owner		
2. Who is the data for – accessibility/sharing of data?	Community, facilities management, future planning, city council	Short	
3. Consideration of different building types e.g., labs, retail, residential	Estate, legal advice	Year	
4. Accountability of data security and privacy (ensure anonymity)	Same as #5	Short	
5. Who is accountable for AI model?	Facilities management, software developer, building owner	Short	
6. What type of data requires consent (if anonymity not available)?	Lawyers, ethics department/ ethics specialist in AI/data	Short	
7. How to make an AI model to work for everyone without discrimination?	Same as # 6	Continuously evolving	

Key issues in the scope of this challenge

- New build vs. retrofit for existing buildings
- Payback periods are long
- Each building is different → before solutions
- Architectural protection legislation and listings
- Split incentives who own the building vs who uses it and pays the bills?
- Supply chain issues
- Energy services contracts between ESCO and building user hard to manage
- Streamlining decarbonisation and which technology is best and how do we know?
- Need for mechanisms to dilute high upfront cost over time
- Considering homes as individuals is insufficient and more expensive
- Carrot and stick policy and funding drives from Government.
- Incentives for home owners are framed as cost/benefits as R.O.I. rather than investment
- Reframing investment similar to new bathroom or kitchen
- Significant central grants are short term or lacking
- Government or 'capital holders' for public good are not acting
- Lack of coordination between government local authorities' builders and home owners

- Builders are not operators: New mechanism needed

Impacted stakeholders

- AEC services
- Real estate owners
- Smart metering service provider
- Energy suppliers and network operator
- Housing association
- Insurance and financial organisations
- Building occupants
- Other:
    - Facility managers, building operators, energy managers
    - Government and policymakers
    - Cities and local authorities

Benefits of Data and AI

- Evidence building
- Real time operations
- Interconnectivity
- Tracking performance
- Reduce costs
- Inform investment decisions
- Realise new opportunities
- Data engages and empowers building occupies – to work with ESCO to positive ends
- Regulatory compliance metrics/audible
- Benchmarking, monitoring etc
- Predict optimums for required grids

Challenge G

Establishing baseline data to achieve accurate and granular characterisation of building energetic behaviour and identification of energy losses/waste; and data collaboration across the myriad of connected sectors (construction, energy, transport, repairs-maintenance-improvement, etc.)

Questions	Expertise needed	Timeframe	Project size
1. What is the smallest representative sample of buildings?	Expert on local buildings and expertise on stats	3 months	M.Phil group challenge, part of PhD
2. How accurate/granular a baseline model do we need?	Data science and building energy expert	1 year	Part of PhD/PDRA
3. How do we create ontological structure for data sharing? Future-proof data standards	Industry comms. Data science	Iterative process throughout project	PDRA and Consultants on
4. What data can/can't be shared? Ethics?	GDPR/Data Ethics	Iterative process throughout project	PDRA and Consultants on
5. How do we ensure automated continuous data collection?	RSE	Continuous	RSE
6. How much data is required for each building? How far back in time?	RSE and data science	1 Year	
7. What is the best model/digital twin to construct for baseline and collaboration?			
8. What do we do about missing data?			
9. How do we get buy-in? How do we get people to provide and use data?			
10. How do we translate data and collaboration to actionable insights and different geographies?			

Key issues in the scope of this challenge

- Shadow or smaller buildings from skyscrapers
- Fluids/changing physical environments change baseline
- Knowledge of surrounding buildings to match demand profile e.g., district heating
- How to get engagement from homeowners and commercial occupiers
- Establishing 'patterns' of architecture/materials, in clusters, to scale
- Age of building, lack of blueprints, what material?
- Ethics and privacy on data. What data are you collecting?

- Data ownership and consent e.g., smart meter data
- Eco design regulation LOT 20
- <Non- perfect> data standards will be crucial to an "acceptable level of disharmony"
- Types of usage affects data collection e.g., domestic vs commercial
- Data infrastructure e.g., like open banking
- Shared language "ontology" for data sharing
- Value of data, can companies share it? Pay for it?
- Lack of trust from building stakeholders
- Metrics need to be agreed for data sharing
- How to identify crucial data points – for good enough not necessarily perfect?
- Impact of neighbouring buildings
- Regulations and controls on sharing of data?

Impacted stakeholders

- AEC services
- Real estate owners
- Smart metering service provider
- Energy suppliers and network operators
- Housing associations
- Insurance and finance
- Building occupants
- Other:
    - Anyone concerned about our carbon footprint
    - Facility managers, building operators, energy managers
    - Government policymakers
    - Cities and local authorities
    - Contractors

Benefits of Data and AI

- Evidence building
- Real time operations
- Interconnectivity
- Tracking performance
- Other:
    - To predict the behaviour of the users
    - Modelling and digital twin
- Using AI to find patterns in behaviour
- Synthetic datasets for example data based on zeal data
- Moderate behaviour e.g., dashboards
- Automate systems to moderate usage
- Vehicle charging vs building demands, optimisations
- Aggregate solutions/transfer learning from similar buildings
- Scalability
- Helena. ARVP., Rebecca, Rohilla, Shafique

Vision and successful outcome

- Energy demand/usage for every building in Cambridgeshire for an entire year (temporally) and predictive power →energy cost →building fabric → behaviour and open and trusted system for data sharing and implementation

Current situation

- Fragmented public conversation
- Fragmented data, owned by different people who do not necessarily talk to one other
- Not automated, a lot of data still manually collected
- Lack of the right specialist skills
- Missing data, gaps in data
- No common language
- Lack of regulation

Scope

- CO_2 as a proxy for other GHGs
- Scope 1 and 2 emissions
- Time limit for baseline data: Minimum 1 year, ideally 3-5
- Focus on machine readability of data
- Building ownership/usage
- Cambridge city (commercial and residential)

Out of scope:

- Scope 3 emission, other GHHs
- Data for >5 years back
- Rural

Data and resources

- Facilitation (industry)
- The ODIs guidebooks on 'trustworthy data institution' and data ethics
- Open data standards (see ODI)
- Data ethics

Challenge H

Ethics of using AI and Data for decarbonisation

Key issues in the scope of this challenge

- Occupants of building - Companies and individuals
- Homes vs workplace different attitudes/priorities
- Who is maintaining the data?
- What are you measuring – around the house?
- Access to benefits equity
- Governance
- Data – could be tied together to be able to identify user – no longer anonymous
- Security, privacy, handling

- Data ownership
- Trust
  → Consumers
  → Data sharing
- Ethics – secondary use of wealth of data
- Accountability
  →Diagnosing bias output
- Building user → Agency vs smart building
- Commercialisation of data processing and outputs
- Building ownership
- At what point is the data shared and processed
- Carbon footprint of storage
- What data do you collect and measure?

Impacted stakeholders

- Who is developing it?
- Developers of the AI
- AEC Services
- Real estate owners
- Smart metering service provider
- Housing associations
- Energy suppliers and network operators
  - Demand management
- Insurance and finance
  - Asset assessment – whole life cost and carbon
  - Validation of investment
- Others:
  - Government and policymaker
  - Contractors
- New policy required
  - Single GDPR
  - Who is accountable?
- Who ensures no bias?

Benefits of Data and AI

- AI can be more scalable increased access
- AI setting – who benefits?
- Comfort – or else reduced interest in decarbonising
- Human bias can be removed
- Evidence building
- Real time operations
- Tracking performance
- Other:
  - Open standard for a building operating system
  - Providing visual support to less experienced on-site contractors from central experts (to anyone who doesn't know about decarbonising)
- Saving cost

- AI models can continue to evolve
- End users may not know how to efficiently use the asset
- Building community trust

Vision and successful outcome

- Recognised by other industry bodies/associations
- Recognised certification -> legislation – short-term goals – to – long-term goals
- Create an exemplar – which may lead to project level → University of Cambridge estate management

Current situation

- Pre-programme design – data gathering
- Uneven availability of data – some old, some new buildings
- Lacking ethical data governance

Scope

- Use of data
- Type of data – sharing to 2nd data use
- Fairness of outcomes
- Flow of people/occupancy
- Use function of room
- Confidentiality
- Data going into the model
- What do we already have → Map out – uneven distribution of data (old vs new buildings)

<u>Out of scope:</u>

- Detail data on specific

Annex III Workshop participants

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Lucy Yu, Centre for Net Zero

Please note: only participants that agreed to be named are shown

Annex IV Workshop agenda

Arrival and welcome	09.30 - 10.00
Introduction and workshops aims and process	10.00 - 10.15
Activity: World café	10.15 - 11.00
Break	11.00 - 11.10
Activity: Exploration of the key challenges	11.10 - 12.20
Wrap up	12.20 - 12.30
Gallery review of the topic roadmaps	from 12.30

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Institute for Manufacturing: IfM

The IfM is part of the University of Cambridge's Department of Engineering. With a focus on manufacturing industries, the IfM creates, develops and deploys new insights into management, technology and policy. We strive to be the partner of choice for businesses and policy-makers, as they enhance manufacturing processes, systems and supply chains to deliver sustainable economic growth through productivity and innovation.

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