University of Cambridge Decarbonisation Network

Symposium

Innovations in UK Building Retrofits

30 September 2022

Emerging Technologies in Retrofit

image credit: iStock.com/marchello74

Contents

University of Cambridge Decarbonisation Network **3**

Symposium Summary: Innovations in UK Building Retrofits **4**

Emerging Technologies in Retrofit 6

How to unleash the full potential of roof-integrated PV? 7

Advanced glass technology for retrofits 8

Low-carbon heating and cooling: inclined wellbores for reduced footprint; digital solutions to model, construct and operate 9

Energy-harvesting IoT tech to easily retrofit smart thermostatic radiator valves to radiators 10

Producing a continuous web of ultra-long carbon nanotubes with various applications. 11

Retrofitting at scale, a materials problem: aerogels and their application in buildings 12

Next Steps **14**

Delegate List **15**

Acknowledgements **16**

Contact Us **17**

Image credit: iStock.com/Ozturk

Image credit: iStock.com/xijian

University of Cambridge Decarbonisation Network

The University of Cambridge is at the forefront of global efforts to achieve net zero, with many of our academics already working with industry and the public sector to accelerate progress. To support these efforts, the University runs a Decarbonisation Network of Special Interest Groups (SIGs) in the following three areas:

- The **Hard to Decarbonise Technologies** SIG (H2D) led by Professor Adam Boies covers work in technologies including transport fuels, power generation, material flows, building materials and industrial processes.

- The **Light Harvesting** SIG (LH) led by Professor Sam Stranks covers work in technologies including photovoltaics, photocatalysis, photo-electrochemical devices, solar-driven fuel generation — including their development, characterisation, deployment and end of life.

- The **Built Environment** SIG (BE) led by Professor Ruchi Choudhary covers decarbonisation of buildings and focuses on collaborations that equally engage industry and the public sector.

The SIGs provide a focus for key technologies in which Cambridge has particular strengths, linking University-wide expertise with a broad industry network. This provides an invaluable opportunity for academics, industry and public sector stakeholders to identify routes to decarbonisation in a non-competitive setting.

The Network works across the collegiate University, and is supported by the Strategic Partnerships Office, Cambridge Zero and the Energy Interdisciplinary Research Centre.

> “There is a lot of overlap between the interests of people with very different backgrounds and expertise – when these people are brought together real insights can be achieved.”

Rebecca Ward, Alan Turing Institute

Symposium Summary
Innovations in UK Building Retrofits

Emerging Technologies in Retrofit: Industry Speakers

Viridian Solar, KT Tan
How to unleash the full potential of roof-integrated PV?

NSG Pilkington, Su Varma
Advanced glass technology for retrofits

Celsius Energy, Inês Cecílio
Low-carbon heating and cooling – Inclined wellbores for reduced footprint; digital solutions to model, construct and operate.

EcoSync, Zsuzsa Mayer & Matt Bailey
Energy-harvesting IoT tech to easily retrofit smart TRVs to radiators.

Q-Flo, Martin Pick
Producing a continuous web of ultra-long carbon nanotubes with various applications.

Thermulon, Rozalie Ryclova
Retrofitting at scale, a materials problem: aerogels and their application in buildings.

Retrofitting and renovation of buildings will be key to reaching zero carbon targets. Much of the UK building stock is aging, with a range of 'hard to treat' and historic buildings that are difficult to upgrade. At the first University of Cambridge Decarbonisation Network Symposium, the Network's SIGs came together under the banner of 'Innovations in UK Building Retrofits'. They explored and identified the most promising technologies with the potential to disrupt the pace of energy retrofitting and thus accelerate the UK's path to net-zero.

Morning Session
Workshop - AI/Data Science for decarbonisation of the Built Environment

Roadmapping workshop on the use of cyber-physical infrastructure to decarbonise the Cambridge University estate as a demonstrator project.

Separate report will be available on the Decarbonisation Networks' website.

Afternoon Session
Emerging technologies in Retrofit

Industry presentations followed by focus group discussions on the application, challenges and opportunities of emerging technologies in retrofit. Summary presented on the following pages.

> "For me, retrofit at scale is a complex systems challenge and I think we all recognise that complex challenges require deep collaboration to overcome them."

Helene Gosden, Arup

Emerging Technologies in Retrofit

"The decarbonisation process, in my view, is a holistic approach so you need different technologies to solve the same problems and I am pleased to see there is a diversification of technologies in an event like today. Everyone is just aiming for the same thing."

KT Tan, Viridian Solar

Focus group questions:

1: How can this technology be applied to decarbonise buildings through retrofit?

2: What are the benefits of the application of this technology?

3: What are the limitations of the application of this technology?

4: What are the open questions related to the deployment of this technology that can be addressed by research?

5: Please give us your ideas on potential academia-industry collaborations/projects. Please indicate any research groups or organisations working on this topic.

A detailed breakdown of the emerging technologies is presented on the following pages. Although their designs and functions differed considerably from one another, several cross-cutting themes relevant to their benefits, applications, challenges and potential research opportunities were identified:

Stakeholder perceptions

An array of stakeholders affect both the implementation and adoption of emerging technologies. This includes, but is not limited to, user acceptance, responsibility of architects in buildings' design and the willingness of investors to invest. Future work includes the education of stakeholders through worked examples, but also understanding what people really care about.

Regulations and policy

Several of the technologies were deemed ready for implementation. However, this was thought to be hindered by regulatory barriers and policy uncertainty. This in turn may affect investment opportunities. In some cases, the technology's appeal was that it overcame some of these barriers, for example, being implemented in historic buildings with limited impact on the building's fabric.

Scaling-up manufacture and implementation

Scaling-up the manufacture and implementation of the current technologies was considered key for mass retrofit. An identified barrier being supply-chain issues and skills-shortage. In the context of Cambridge, economies of scale included: the individual building level, the University estate and the city level.

Data and digitalisation

Data can be used to learn about buildings and understand people's behaviours. This is essential pre-technology application as it is hard to decarbonise something that you do not know anything about. Operational data and digital twins can also enable monitoring of buildings and infrastructure to evaluate a technology's effectiveness.

Life-cycle analysis

Life-cycle analysis takes into account the energy consumption throughout a product's life-cycle. It was recognised that there is a need to consider the embodied carbon associated with a technology's production, as well as considering what happens at the product's end of life i.e. ease of re-use and/or recycling. These assessments also need to be considered at an industrial scale of adoptability.

Systems-thinking

Each emerging technology is part of a system with wider considerations at the building level and beyond. One example being the transportation of technologies to site. There is no 'silver bullet' to enable retrofit. Energy efficiency technologies need to work together whilst considering other impacts associated with their application and constraints of the existing building fabric.

How to unleash the full potential of roof-integrated PV?

Viridian Solar, KT Tan

As a source of renewable energy, solar photovoltaics (PV) is a well-established technology to tackle the decarbonisation process. In addition to the utility-scale power generation, roof-top PV actually plays an important role in microgeneration and decentralisation. Within this sector, the combination of new-builds and roof-integrated PV seems like a match made in heaven – but how do we unleash the full potential of this technology and what problems do we need to overcome?

Benefits and Application

- Acts as a building material and power generator.
- CO_2 intensity of manufacture of roof tiles vs panel – material and embodied carbon offset.
- Lower operational energy running costs and better Energy Performance Certificate (EPC) ratings.
- Potential for guided financial incentives i.e. mortgage lender requirements to meet EPC ratings.

Challenges

- Risks from the elements including fire, water and wind. For example, preventing infiltration of water and spread of fire.
- Supply chain issues and reliance on single country source for materials.
- Cost barriers to recycling at end-of-life.
- Currently little incentive for non-domestic markets and public awareness needs to increase.

Research Opportunities

- Using social science to better understand public acceptance and engage with society more effectively.
- Develop a holistic view of PVs by considering grid stability and using urban planning to actively control generation and demand. Currently there are fragmented data about PV and energy storage ownership.
- Field trials to help discover market potential.
- Better understanding of PV risks i.e. fire, and impact on regulation adherence.
- Alternatives to polymer adhesives as these currently limit the efficiency of cells.
- Life-cycle assessments including researching and reducing cost of end-of-life recycling.

Advanced glass technology for retrofits

NSG Pilkington, Su Varma

NSG Pilkington presented a new glazing concept that removes some of the pain points around renovation while improving building energy efficiency. These technologies included an over glaze retrofit system that acts as a secondary glazing unit. For example, a thin pane of glass can be fitted next to the existing window/curtain-wall system using a special hanging procedure. These connected glazing concepts should be combined with other technologies to maximise impact. Examples given include: building integrated PVs, PV powered sensors to enhance building control, dynamic glazing and heated glazing.

Benefits and Application

Easy to install, lightweight secondary glazing system.

Reduces heat loss and improves energy efficiency and therefore reduces running costs.

Reduces solar gain.

Can be applied to a number of listed buildings. Installation is less intrusive than standard double glazing replacement and also lower in cost.

Challenges

Technology is ready but the investment has been low. This differs from country to country and is impacted by policy and regulations.

Limited by age and condition of the existing glazing, the nature of the mounting location and the surrounding material. This can also impact aesthetics and people's acceptance of the technology.

Specialised skills required for transportation of the glass to site.

Life-cycle energy including embodied carbon of glass production. Difficulty recycling glass materials, especially if they contain aluminium.

Impact on natural ventilation strategies and wider building system.

Research Opportunities

Useful to have worked examples, including numerical validation to show the benefits of technology in reducing operational cost.

Understand how people respond to the technology and the influence of market incentives and policy on adoption.

Improve recycling capabilities including eliminating aluminium in glass. Further investigations into the recycling of peripherals used in the window panes and the reuse of glass.

Investigations into mounting materials including 'warm edge' spacers and new adhesives/tapes.

Reduce the embodied carbon produced during glass production and explore the possibility of using hydrogen as a fuel on site.

Low-carbon heating and cooling: inclined wellbores for reduced footprint; digital solutions to model, construct and operate

Celsius Energy, Inês Cecílio

Celsius Energy is a technology company with a mission to decarbonise the building heating ventilation and air-conditioning industry. A Celsius Energy system comprises a borehole heat exchanger, a heat pump for both heating and cooling, and a digital energy management system. One of the distinguishing features of Celsius Energy systems is the geometry of the borehole heat exchanger, including both vertical and inclined wellbores. Inclined wells, and in particular a star-shaped layout, drastically reduces the surface footprint required for an installation, making it viable for retrofit solutions in urban areas.

Benefits and Application

Delivers heating and cooling needs to a building creating less reliance on external sources.

Inclined wells result in smaller footprint on the surface. Technology can be used in densely populated urban areas.

Use of digital technologies and Energy Management Systems (EMSs) can help maximise heat recovery, and aide data monitoring.

Challenges

Having a regulatory framework available on time, including addressing land and building ownership issues.

Specialist drilling required but a shortage of driving rigs and expertise/ skills-set.

Longer-term maintenance and replacement parts needed for the heat exchangers.

Geological considerations associated with drilling up to 200m depth.

Output heating temperature lower than 55ºc.

Transportation and the distance from the shaft to the end-use.

Research Opportunities

Scaling up the use of the technology to campus or city level.

Learn lessons from other countries including Scandinavian district heating systems, and develop understanding on distribution networks and needs.

Monitoring of regulations and development of a geopolitical database to assist with land ownership issues.

Develop multiple boreholes combining those that can either heat or store.

Systems design and data optimisation including predicting environmental response in different weather conditions.

Energy-harvesting IoT tech to easily retrofit smart thermostatic radiator valves to radiators

Zsuzsa Mayer & Matt Bailey

EcoSync are currently working with colleges in Oxford and Cambridge delivering a possible 30-50% reduction in heating-related carbon emissions and costs. They utilise energy-harvesting Internet of Things (IoT) technology to easily retrofit smart thermostatic radiator valves to radiators, allowing colleges to only heat rooms according to occupancy and need. Once fitted, EcoSync's AI-enabled software allows remote and individualised control of heating using a cloud-based dashboard and QR code app. The solution can be easily installed within hours with no major disruption to students, and no need for wires or additional sensors.

Benefits and Application

Stops people heating empty rooms resulting in energy savings.

Intelligent hardware: no building management system integration needed.

Data from devices powers a machine-learning digital twin of each room which provides an accurate baseline to calculate energy savings and meaningful feedback. People personally motivated to watch "the number" go down. End-users do not necessarily care about IoT – they care about comfort and cost.

Does not use/rely on batteries.

Long-range communication.

Challenges

Constraints of the existing building including modularity of the heating system (single versus dual pipe) or heat pumps.

Interoperability across different sensor data and different aspects i.e. ventilation.

Predictability of return on investment owing to dynamic nature of solution relying on building manager and user settings.

Recognition of full impact of carbon benefit, given constraints of SAP model underlying Energy Performance Certificates (EPCs).

Research Opportunities

Develop understanding of end-user experiences.

Data-driven user engagement including easy user access and visualisation of real-time carbon footprint. Gamification or competitions to educate people about energy use motivate reductions.

Realisable occupancy sensing for radiator control, for example, the use of motion sensors.

Integration across heating/cooling and electricity.

Equitable sharing of data.

Producing a continuous web of ultra-long carbon nanotubes with various applications

Q-Flo, Martin Pick

Q-Flo's technology produces a continuous web of ultra-long carbon nanotube that can be collected as Torstran mat, fibre or web. The web, in turn, can be converted into a dispersion. Front-runner applications include EMI Shielding in composites, air and water filtration and inclusion in energy storage systems. The technology also has the ability to convert methane, including from landfill and other sources, into solid carbon and hydrogen without harmful Green House Gas emissions. At scale, this offers an economic and viable 'green bridge' to support the transition from fossil fuel dependency to renewables.

Benefits and Application

Characteristics of the material include: strength, electrical and thermal conductivity, filtration properties and inherent low manufacturing cost.x

Today's markets: Li-ion battery electrodes, Electromagnetic Interference (EMI) shielding, and area heating air filtration. Potential applications include: water filtration, sensing element in composites, solar thermal panels, underfloor heating mats, sub-pavement heating (roads and airports) and exchange media for heat pumps.

Conversion of methane (from range of sources including natural gas and landfill) to turquoise hydrogen and sequestrated carbon.

Challenges

Establishing industry and manufacturing standards. People need to know how to work with the material in the built environment.

New materials need a market. First market being additive anodes in batteries and then drive along volume curve. Increasing H_2 production and lowering CO_2 intensity.

Developing scale applications while at low production volumes.

Matching performance to products.

Research Opportunities

Development of prototypes for different use cases, including applied research into how to install product and end-use orientated development projects.

Q-Flo is ready to expand and is looking for opportunities to demonstrate its technology at a meaningful industrial scale.

Potential market opportunity in high growth areas.

Cross-sector partnerships in industrial focused grant applications.

Research into post-processing i.e. dispersion and stretching.

Retrofitting at scale, a materials problem: aerogels and their application in buildings

Thermulon, Rozalie Ryclova

With 80% of the building stock that will exist in 2050 already built, approximately 30% of the UK's existing buildings are hard-to-treat due to moisture problems and space restrictions. Current products have not delivered on these demands. Thermulon is developing a novel insulation material: aerogels. Aerogels are super-insulating materials that minimise transfer of heat through building fabric, thanks to their material structure. In addition to being suitable for hard-to-treat buildings, aerogels can be integrated into insulation panels, batts and blankets for new-builds.

Benefits and Application

Advanced insulation material: improves energy efficiency of hard to treat buildings i.e. solid-walls.

Fire-safe, moisture-permeable and made from materials otherwise destined for landfill.

Limited reduction of liveable floor space.

Room-by-room retrofit minimises disruption to tenants.

Thermal bridging in configuration with other materials.

Challenges

Aerogels are not the only answer to retrofit – systems solutions are required. Different materials applicable in different scenarios.

Stakeholder perceptions: agency of architects and designers and acceptance by end-users. Need for vertical integration between manufacturers and installers.

Lack of regulations and policy uncertainty.

Skilled labour shortage limits scaling-up implementation.

Quantifying the embodied carbon associated with scaling-up manufacture.

Research Opportunities

Pilot studies, case studies and open days to raise awareness and educate about technology.

Multi-stakeholder understanding and conversations. Work with specific groups in the sector, including the insurance sector, local authorities and those specialising in historic buildings (National Trust, Landmark Trust, Historic England, Royal Palaces, and Church of England).

Life-cycle assessment studies, including embodied carbon of process at industrial scale.

Opportunities for scaling-up production at speed, including an assessment of feedstocks.

Alternative binding agents that can be combined with aerogels.

Effectiveness and impact of aerogels in different building architypes.

Survey of scientific knowledge in British Standards to try and address regulatory barriers.

Next Steps

As a Network, we believe that so much more can be achieved by working together. Strengthening academic, industry and public sector links can accelerate technologies' development and help with the complex challenge of meeting net-zero. Each technology area has research opportunities identified. If you are interested in taking any of the opportunities outlined in this report forwards, or believe further discussions on a particular issues are required, please do get in touch. Please also contact us requesting relevant connections.

Delegate List

University of Cambridge

Shafiq Ahmed, Energy | Interdisciplinary Research Centre

Manar Alsaif, Strategic Partnerships Office

Hannah Baker, Strategic Partnerships Office

Adam Boies, Department of Engineering

Ana Boskovic, Department of Engineering

Elodie Cameron, Cambridge Institute for Sustainability Leadership

Xiang Cheng, Estates Division

Ruchi Choudhary, Department of Engineering

Isobel Cohen, Cambridge Zero

Rachel Evans, Department of Materials Science & Metallurgy

Shaun Fitzgerald, Centre for Climate Repair

Simone Hochgreb, Department of Engineering

Konstantinos Korakakis, Cambridge Institute for Sustainability Leadership

Erik Mackie, Cambridge Zero

Sabina Maslova, Cambridge Centre for Housing & Planning Research

Simon Pattinson, Department of Engineering

Raheela Rehman, Energy | Interdisciplinary Research Centre

Cristina Rodriguez-Rivero, Department of Applied Mathematics and Theoretical Physics

Jennifer Schooling, Centre for Smart Infrastructure and Construction

External

Matt Bailey, EcoSync

Hui Ben, Newcastle University

Inês Cecílio, Celsius Energy

Auriane Cirasuolo, Cambridge Cleantech

Ben Clarke, British Antartic Survey

Douglas Crawford-Brown, Cambridge Science and Policy Consulting

Josh D'Addario, The Open Data Institute

Len Don, EcoSync

Parthena (Nopi) Exizidou, British Antarctic Survey

Tristan Gerrish, Buro Happold

Matt Goodridge, Thermap

Helene Gosden, Arup

Malcolm Hanna, Legal and General Investment Management

Jason Humphries, Sense Labs

Ashley Johnson, Schlumberger

Zsuzsa Mayer, EcoSync

Samuel Pattuzzi, Carbon 13

Martin Pick, Q Flo

Keyan Rahimzadeh, Front Inc.

Rozalie Ryclova, Thermulon

KT Tan, Viridian Solar

Su Varma, Pilkington - NSG

Rebecca Ward, Alan Turing Institute

Lucy Yu, Centre for Net Zero

Please note: only delegates that agreed to be named are shown.

Acknowledgements

Thank you to our delegates, industry speakers and the SIG's academic lead and their teams. Without your input, the in-depth discussions would not have been possible.

We would also like to thank:

The organising and logistics team including:

- Manar Alsaif and Katherine Ross, Strategic Partnerships Office,
- Ann Thompson, School of Technology,
- Auriane Cirasuolo, Cambridge Cleantech,
- Robert Foster, Mónica Lucena and Agnieszka (Aga) Iwasiewicz-Wabnig, Maxwell Centre.

The symposium's workshop facilitators:

- Diana Khripko, Arsalan Ghani and Theresa McKeon, Institute for Manufacturing | Engage.

Additional break-out group facilitators:

- Raheela Rehman, Erik Mackie, Shafiq Ahmed, Jennifer Schooling, Ruchi Choudhary, Adam Boies and Rachel Evans.

Photographs of the event by Mike Thornton, StillVision Photography and Manar Alsaif.

The symposium was funded by the University of Cambridge Pump Prime Fund, set up to enable knowledge exchange between academics and external practitioners. Thank you to the committee for this opportunity.

Rapporteur: Hannah Baker, Decarbonisation Network Coordinator.

image credit: iStock.com/alphaspirit

Contact us

Hannah Baker, Decarbonisation Network Coordinator, Strategic Partnerships Office, University of Cambridge: **decarbnetwork@admin.cam.ac.uk**

More information about the University of Cambridge Decarbonisation Network can be found at: **www.decarbnetwork.hub.cam.ac.uk**

UNIVERSITY OF CAMBRIDGE