Retrofit at scale

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SPECIAL COLLECTION: RETROFITTING AT SCALE: ACCELERATING CAPABILITIES FOR DOMESTIC BUILDING STOCKS

EDITORIAL

Retrofit at scale: accelerating capabilities for domestic building stocks

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HIGHLIGHTS

Retrofitting domestic buildings is essential for meeting targets to mitigate the catastrophic impacts of our changing climate. Current rates of retrofitting are far lower than necessary for achieving global net zero climate targets. To date in privately owned homes, policymakers have largely relied on piecemeal activity and often short-lived retrofitting programmes and financial incentives. Consequently, this special issue explores what capabilities and capacities are needed to deliver retrofit at scale. Looking across different scales—national, municipal, neighbourhood and individual sites—this special issue provides insights to shape policies, organisational structures and delivery strategies for different scales, building types and supply chain actors. These papers highlight the need for a clearer definition of what retrofit incorporates, alongside the collection of high-quality data and rigorous building metrics. In addition, diverse business models are needed to ensure that a variety of actors across the public and private sectors are well positioned to engage in coordinating building retrofit at scale. Finally, it is essential that any acceleration of retrofitting activity is coupled with consumer protection mechanisms and support for developing supply chains which incorporates both existing workers and encouragement for new entrants. It is only through this multifaceted approach that domestic building retrofit can be delivered at the speed and scale necessary.

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1. BACKGROUND

The United Nations Framework Convention on Climate Change (UNFCCC)[1] Paris Agreement in 2015 agreed a target of limiting global temperature increase to well below 2°C—with a target of 1.5°C—above pre-industrial levels by 2050. Buildings play a crucial role in achieving this: a fast transition to fossil-free energy supply and reductions in the energy needed to heat and power them are required. The buildings sector (residential and commercial) accounts for approximately 28% of total energy-related global CO_2 emissions (IEA 2019). Recognising the scale of the challenge, the European Commission (EC) has proposed targets for a 60% reduction in buildings' greenhouse gas (GHG) emissions by 2030, with an 18% reduction in energy consumption for heating and cooling (EC 2020).

The domestic sector is especially important, accounting for 24% of global anthropogenic emissions in 2010 (Lucon *et al.* 2014). Major GHG contributions in this sector come from the energy used for heating and cooling. Globally, 32% of residential energy consumption comes through space heating; energy use for heating and cooling in residential buildings is set to grow by 79% between 2010 and 2050 if business-as-usual continues (Lucon *et al.* 2014). Further increases in residential consumption are connected with global trends for a growing number of households, and increased building floor area per household. In the UK, this challenge has led the Climate Change Committee (CCC) to emphasise that the country 'will not meet [its] targets for emissions reduction without near complete decarbonization of the housing stock' (CCC 2019: 11).

The vast majority of existing buildings are likely to still be in use in 2050. For example, in the European Union (EU), the building stock is old and changes slowly: more than 220 million building units (85% of the stock) were built before 2001, and roughly 90% of these will still be standing in 2050 (EC 2020: 1). Approximately one-third of today's EU building stock was built before the introduction of regulations on thermal insulation in the 1970s, and so have poor energy efficiency performance. Although the rate of new build and building replacement is higher in emerging market and developing economies, there are still numerous existing buildings to consider here (IEA 2021b).

Therefore, a major contribution to achieving emissions reductions must come from the deep energy retrofit (hereafter 'retrofit') of the existing building stock. Such retrofitting includes a combination of improving the building fabric to reduce the need for heating and cooling, and changing the building services (heating, cooling, ventilation, hot water, electricity) to carbon free systems. To ensure successful outcomes, retrofitting must also embrace social, cultural, and material values and practices. For example, retrofitting work can include a consideration of how users interact with technologies (*i.e.* when implementing smart controls). Retrofitting is likely to yield distinct comfort practices, such as using lower temperature heating systems for longer periods, and replacing air-conditioning with natural ventilation and cooling. (A forthcoming *Buildings & Cities* special issue will focus on alternatives to air-conditioning.) Occupant expectations of comfort will need to be managed to accommodate this. It will also involve interdependent activities in the retrofitting process (planning, operation, maintenance, occupant engagement) to prevent unintended consequences, including loss of cultural value and performance gaps (Kohler & Hassler 2012; Shrubsole *et al.* 2014). The International Energy Agency (IEA) has indicated that one in five buildings worldwide needs to be retrofitted to be zero carbon ready by 2030 (IEA 2021a).

Such retrofitting at scale can generate far-reaching social, environmental and economic benefits. With retrofitting interventions, buildings can be made healthier, more comfortable, more accessible, greener and more resilient to extreme natural events. Buildings with greater energy efficiency can be cheaper to run, help to alleviate energy poverty (CCC 2019) and prevent marginalisation of vulnerable people (Klinsky & Mavrogianni 2020). Deep energy retrofit can reduce pressure for greenfield construction, helping preserve nature, biodiversity and fertile agricultural land. Investing in buildings can also inject a much-needed stimulus in the construction ecosystem and the broader economy. Energy retrofitting works are labour intensive and can create jobs and investments rooted in local supply chains (*e.g.* Maby & Owen 2015). Retrofitting at scale can also generate demand for energy and resource-efficient equipment, stimulating broader manufacturing supply chains. For example, it is anticipated that by 2030 an additional 160,000 green jobs could be created in the EU construction sector through retrofitting at scale (EC 2019).

Despite these benefits, the rate of retrofitting remains low. To date, efforts have focused on social housing, where standardisation and public sector and housing association ownership makes activity at scale more achievable. In private homes and mixed-use buildings, policymakers have relied on an ad hoc approach requiring interaction among different occupational groups, and taking place over a long timescale (Topouzi *et al.* 2019). Only 11% of the EU existing building stock undergoes some form of renovation each year. This renovation very rarely addresses energy performance, with the weighted annual energy retrofit as low as 1% in some places. Across the EU, deep retrofits that reduce energy consumption by at least 60% are carried out in only 0.2% of the building stock per year, and in some regions energy retrofitting is virtually absent (EC 2020). More broadly, for a net zero energy scenario, the IEA anticipates retrofitting rates of 2.5% and 2.0% per year to 2050 in advanced and developing economies, respectively (IEA 2021b).

Thus, there is a large gulf between current slow retrofitting rates and the portion of domestic buildings that rapidly need intervention to meet climate targets. This special issue begins to address this gap by bringing together a collection of papers that focus on increasing the rate of retrofit. A broad gamut of interventions is needed (*e.g.* Kerr & Winskel 2020 on household investment in retrofit; and Gillich *et al.* 2018 on the design of optimal retrofit programmes), and not all are addressed herein. The special issue has a particular focus on the knowledge gaps outlined in the following section.

2. SOME IMPORTANT KNOWLEDGE GAPS

Successful retrofitting will only be achieved through aligning political, economic, social and technical systems. *Policy and governance*, in particular, can provide appropriate conditions for mass retrofit. For example, central governments have the capacity to create and enforce long-term retrofitting targets; implement tools and collate data to support retrofitting (such as Energy Performance Certificates—EPCs); and develop financial support to stimulate retrofitting activities (*e.g.* grant funding and favourable tax conditions). However, the cost of retrofit still remains too high. There are ongoing efforts to simplify design interventions, improve construction management and create economies of scale. Much of this may be supported by working across the level of the whole building stock. Solutions for reducing construction costs and increasing productivity by scaling are being sought. These include more standardisation, prefabrication, digitisation, automation and increasing the size of retrofitting schemes (Wiebes 2019). However, national schemes can also overlook the diversity of localities and restrict flexibility in how different groups might respond.

There is recognition that retrofitting schemes customised to local circumstances can be more successful than nationwide strategies (Gillich *et al.* 2018), and ample evidence that local actors play a crucial role in the delivery of wide-scale retrofitting activities (Bartiaux *et al.* 2014; Dowling *et al.* 2014; Hoicka *et al.* 2014; Caputo & Pasetti 2017). In addition, working at the region or city levels allows for a planned, strategic approach that can move beyond individual buildings (Dixon & Eames 2013). However, different localities may be inconsistent in their application of retrofitting strategies, and serious consideration is needed on how retrofits will be delivered in different contexts. Further, there is uncertainty around the capacity of local schemes to be scaled up. Thus, there is a need for detailed exploration of how such localised approaches can deliver retrofit at the speed and scale necessary.

Additionally, successful energy retrofitting will require a 'house as a system' approach (Stanislas *et al.* 2011), which recognises the building envelope as a single thermal unit (Clarke *et al.* 2017). Practitioners working on building retrofit require knowledge, communication, problem-solving, coordination and project management skills (Clarke *et al.* 2020a). This integrated approach also incorporates socio-technical interventions that traverse distinct professional domains, *e.g.* wall insulation, low carbon heating installation and the potential addition of renewable energy technologies (Lowe & Chiu 2020). The repair, maintenance and improvement (RMI) sector currently undertakes the majority of domestic renovation work (*e.g.* extensions, kitchen and bathroom refurbishments), and would be well positioned to contribute to scaling energy retrofitting. However, the sector is currently characterised by fragmentation and skill sets restricted according to discipline or technology. There are still unanswered questions around how such actors can be supported to develop *supply chains* for retrofitting at scale.

Although policy approaches and technological solutions have been identified (but not yet effectively applied at scale) for most of the residential sector, *heritage buildings* still present a challenge. Heritage buildings make up a significant portion of the building stock: one-quarter of all EU buildings were constructed before 1950 (BPIE 2011), whilst up to 40% of UK buildings could be classed as traditional (Pickles *et al.* 2017). These buildings have specific characteristics that may need to be accounted for in retrofitting processes. In addition, building tradespeople may have limited knowledge of these specificities, and few tools exist to support them in this work. In addition, actual energy use in many old buildings can be less than modelled energy performance (van den Brom *et al.* 2018, 2019a, 2019b). This gap, wherein measured consumption is lower than modelled consumption, has been termed the *prebound effect* (Sunikka-Blank & Galvin 2012), and work is needed to understand how occupant practices contribute to this lower than expected consumption. Crucially, such prebound may make the economic feasibility of retrofitting heritage buildings more problematic.

3. CONTRIBUTIONS IN THIS SPECIAL ISSUE

What are the capabilities and capacities for delivering retrofit at scale? This special issue addresses this question by focusing on the underlying conditions needed to deliver mass retrofit of the domestic building stock. It considers policy, governance, and organisational capabilities and structures. In particular, what opportunities exist for the supply chain to deliver robust solutions and what roles can the public and private sectors have?

The vision and concept for this special issue was created by guest editor Faye Wade, along with the framing of topics and research questions. Both Faye Wade and Henk Visscher commented on double-blind reviews of papers (except those in which they were specifically involved). The full list of papers in this issue is shown in ***Table 1***.

Table 1: Articles in this special issue 'Retrofitting at Scale: Accelerating Capabilities for Domestic Building Stocks', *Buildings & Cities* (2021), 2(1); guest editors Faye Wade & Henk Visscher.

AUTHORS	TITLE	DOI
F. Wade & H. Visscher	Retrofit at scale: accelerating capabilities for domestic building stocks	*10.5334/bc.158*
F. Brocklehurst, E. Morgan, K. Greer, J. Wade & G. Killip	Domestic retrofit supply chain initiatives and business innovations: an international review	*10.5334/bc.95*
K. Simpson, N. Murtagh & A. Owen	Domestic retrofit: understanding capabilities of micro-enterprise building practitioners	*10.5334/bc.106*
M. Tingey, J. Webb & D. van der Horst	Housing retrofit: six types of local authority energy service models	*10.5334/bc.104*
P. Hofman, F. Wade, J. Webb & M. Groenleer	Retrofitting at scale: comparing transition experiments in Scotland and the Netherlands	*10.5334/bc.98*
J. McCarty, A. Scott & A. Rysanek	Determining the retrofit viability of Vancouver's single-detached homes: an expert elicitation	*10.5334/bc.85*
F. Wise, A. Moncaster & D. Jones	Rethinking retrofit of residential heritage buildings	*10.5334/bc.94*
H. S. van der Bent, H. J. Visscher, A. Meijer & N. Mouter	Monitoring energy performance improvement: insights from Dutch housing association dwellings	*10.5334/bc.139*
V. Gori, V. Marincioni & H. Altamirano-Medina	Retrofitting traditional buildings: a risk-management framework integrating energy and moisture	*10.5334/bc.107*

Hofman *et al.* and Tingey *et al.* both contribute to understanding the *policy and governance* needed for successful energy retrofitting at scale. Hofman *et al.* include detail on two case studies: Local Heat and Energy Efficiency Strategies (LHEES) in Scotland and Social Innovation Labs for a Zero Energy Housing Stock (SMILE) in the Netherlands. Meanwhile, Tingey *et al.* consider 31 cases from across British local authority-led projects for energy efficiency and low carbon heat.

Hofman *et al.* compare transition experiments for local area-based retrofitting in Scotland and the Netherlands. Transition experiments are activities that explore how societal problems can be overcome through 'learning by doing'. The authors contrast Scotland's top-down (central government-led) approach with the Netherlands' bottom-up (led by civil society, citizen groups and local non-governmental organisations) experiments. This makes a valuable contribution to understanding why such transition experiments often fail to result in systemic change. Specifically, they find that elements of both approaches will be needed for experiments to result in wider scale, systemic shifts in approaches to retrofitting. Through this, it is likely that coordination from a variety of local actors, including citizen groups, private and third-sector organisations, and local authorities will be needed for delivering successful retrofitting at scale.

This reiterates the findings of Tingey *et al.* who explore local authority business models for energy efficient retrofit. The authors develop a typology of six types of energy service models: municipal in-house (directly managed by local authorities); energy performance contractors (a contractor obliged to deliver a preset level of energy efficiency); municipal district energy companies (local authority owned, but with separate legal structure); local third-sector businesses; district energy concession contracts (a contract between the local authority, public sector organisations and a commercial energy utility); and municipal energy utilities (licenced retail companies). The findings suggest that engagement from actors across different sectors is beneficial, with in-house, energy performance and third-sector energy service models allowing flexibility that could support faster residential retrofit. For this, they argue, local authorities need resources to develop and coordinate programmes.

Both papers show that public sector actors could play a crucial role in encouraging the uptake of retrofitting, and engaging homeowners. Indeed, the incentivisation and education of homeowners is likely to be crucial for enhancing demand for retrofit, and encouraging supply chain development. This is a common thread for both Brocklehurst *et al.* and Simpson *et al.* who focus on the role of *supply chains* for delivering retrofit at scale.

Brocklehurst *et al.* coupled a rapid evidence assessment of international supply chain initiatives for domestic retrofitting with expert interviews. They identify fragmented supply chains in studies from the Netherlands, Denmark, Finland, Norway, Sweden, France, the US and Australia. In turn, vocational education and training (VET) in these regions is fragmented and lacks coordination. This international perspective highlights the scale of the problem, and also suggests that there will be opportunities for shared learning and problem-solving going forward.

This particular piece of research was borne out of a request from the UK's Department of Business, Energy and Industrial Strategy (BEIS). The authors note that the initial questions posed by policymakers were 'unanswerable' and based on 'erroneous assumptions', indicating an ongoing need for collaboration between industry, research and policymakers, and an exploration of how this translates into optimal policy design. One suggestion from Brocklehurst *et al.* is to address these challenges with slow change, thinking about the longer term reform of the RMI market to deliver retrofit, and avoiding the 'boom and bust' of previous short-lived policy efforts.

Noting that practitioners are often overlooked in retrofit policy design (and building on, *e.g.*, Owen *et al.* 2014; and Wade *et al.* 2016a), Simpson *et al.* use interviews with small and micro-enterprises working in the RMI sector. Using a psychological model of behaviour change, COM-B (Capabilities, Opportunities, Motivations, Behaviours), the authors focus on practitioner capabilities and opportunities or constraints in applying them. Simpson *et al.* also find that training is often within trade boundaries, and highlight that this is likely to limit future capability. Supporting Brocklehurst *et al.*'s 'slow change', the authors identify that practitioner capabilities are developed over decades, often drawing on multi-generational learning. Using this evidence, they suggest a key role for experienced tradespeople in finding retrofit solutions and sharing them with newer colleagues. Further, the authors emphasise the value of practitioner's networks of trust, especially with other practitioners. The authors echo earlier calls (*e.g.* Wade *et al.* 2016b) to harness these strong networks in order to develop effective supply chain capabilities.

The significance of retrofitting *heritage buildings* is apparent in two papers in this special issue. Wise *et al*. argue for more comprehensive understandings of heritage buildings in order to identify appropriate retrofitting interventions. Through 12 case studies in the UK, incorporating site visits, interviews, energy modelling and energy diaries, Wise *et al*. gather detailed insights about the interconnections between heritage buildings and their occupants. In particular, study participants reported positive energy behaviours, including only heating parts of the house in use and using additional clothing for warmth. The authors also find that standard energy models (in this case the Reduced Data Standard Assessment Procedure—RdSAP)[2] considerably overestimate the energy use of heritage buildings (by an average of 66% across the cases studied). Against these findings, the authors recommend a more holistic approach to retrofitting heritage buildings, incorporating 'softer' retrofit measures (*e.g.* thick curtains) and user behaviour. This includes a recommendation to revise RdSAP to incorporate options for behavioural tailoring.

Continuing a focus on building models and design tools, Gori *et al*. present a new framework for moisture risk management in heritage buildings. They develop a systematic approach that considers the management of risk within six main stages: the identification and assessment of risks; the identification of measures for mitigating risks; the reassessment of risk after mitigation; a decision about whether to apply mitigation; and monitoring following the intervention. The authors also echo Wise *et al*. in calling for a more holistic approach to interventions in heritage buildings, this time incorporating both moisture and energy efficiency together. Returning to a focus on retrofitting supply chains, Gori *et al*. highlight that their tool could be incorporated into existing PAS 2035[3] frameworks to help overcome the challenge of a fragmented construction industry.

McCarty *et al*. also include heritage buildings in their analysis. With a focus on the City of Vancouver, Canada, the authors use expert elicitation to assess the feasibility and likelihood of future retrofitting. These experts include policymakers and practitioners with experience undertaking building retrofit assessments in the region. The authors develop a series of archetypal households, covering different building typologies and occupant demographics, and ask experts to make an assessment of their retrofit viability. This presents a sobering, but realistic, view of the viability of future retrofit. In particular, the authors find broad alignment amongst experts that pre-2010 non-heritage homes will likely be demolished and rebuilt by 2050 as a result of the economics of Vancouver's real-estate market and high land values. Although this could result in more energy efficient homes, the experts doubted whether these would be built to the standards needed. The clear implication of this research is that the governance of standards and enforcement is insufficient to achieve the desired goals and therefore requires radical change. In addition, there are significant embodied energy and carbon implications for the processes of destruction and subsequent construction from scratch. The experts were more positive about heritage buildings, the retention of which would likely be valued above land redevelopment and lead to retrofitting in this sector.

In contrast to McCarty *et al*., van der Bent *et al*. find that demolition plays a more minor role, this time in updating the Dutch social housing stock. The authors monitor progress towards the energy performance target (Dutch Energy Label B) agreed by non-profit social housing associations. Using information available through the social rented sector audit and evaluation of energy saving results (SHAERE) scheme, the authors analyse data on over 2 million Dutch housing association properties each year between 2017 and 2020. Monitoring progress in this way is useful to get an insight into the reality and effectiveness of policies and programmes seeking energy efficiency improvements. Through this, the authors identify a steady improvement in the energy performance of the Dutch social housing stock (representing one-third of the entire housing stock). The majority of improvements came through traditional measures, *e.g.* high efficiency gas boilers and improved insulation (approximately 86%), but innovative systems (*e.g.* solar photovoltaic systems and heat pumps) were installed in relatively few properties. This is despite the importance of such systems for reducing GHG emissions. Finally, and echoing one of Tingey *et al*.'s recognised business models, van der Bent *et al*. highlight the role of large urban housing associations in driving improvements of energy performance in the domestic sector more broadly.

4. RECOMMENDATIONS FOR ACTION

This special issue provides valuable illumination of several facets of retrofitting at scale, including: policy and governance, supply chains, heritage buildings, and stock-level analyses. Through this, it has presented new insights ranging from how the capabilities of building practitioners develop, through detail on how heritage building occupants manage energy, to how local authorities can help to coordinate retrofitting at scale. Papers in this issue have also provided new tools and techniques of value to researchers and practitioners alike. In particular, the issue includes: a typology of public sector energy service models; useful recommendations for developing RdSAP; and a new framework for moisture risk management in heritage buildings.

The recommendations and tools presented here provide guidance that can be implemented by policymakers and practitioners. However, there is still some way to go to deliver retrofitting at the speed and scale necessary to meet climate targets. These papers have revealed the need for future research to consider: how retrofit is defined; quality data and metrics; business models, financing and consumer protection; and supply chain development. Each of these is now elaborated, and through this a series of actions for policy and governance is identified.

4.1 DEFINING ENERGY RETROFIT

Several of the papers here highlight that definitions of retrofit may need to be modified. In particular, Wise *et al.* highlight the role of softer interventions in delivering energy retrofit, whilst Gori *et al.* emphasise that moisture and energy efficiency need to be considered together in retrofitting heritage buildings. In addition, van der Bent *et al.* query whether retrofit is framed too narrowly by not incorporating climate adaptation measures alongside those for mitigation. Further research needs to critically reflect on the implications of shifting definitions. Would such broadening help to accelerate or slow down retrofit activity? How might the training of supply chain actors need to change to incorporate additional interventions?

4.2 ESTABLISHING QUALITY DATA AND METRICS

Regardless of global context, successful retrofitting can only be monitored through high-quality data collection and rigorous, ongoing evaluation (Fawcett & Topouzi 2020). Good data are particularly crucial for planning domestic energy retrofitting at scale, *e.g.* through area-based schemes that rely on an accurate picture of the existing building stock. However, existing data collection falls far short of what is needed (this rapidly became apparent with Scotland's pilot Local Heat and Energy Efficiency Strategies; Wade *et al.* 2019; Wade & Webb 2020; Hofman *et al.*), and work is required to ensure that rigorous, detailed data are made available. The existing building stock shows a huge variety of typologies, building age, qualities, building owners and occupants, and detailed stock-level models can help to navigate this complexity for planning retrofit (*e.g.* see the London Building Stock Model; UCL 2020; Steadman *et al.* 2020). To successfully deliver retrofitting at scale, work is needed to ensure that these models are applicable for all buildings, including informal settlements in international contexts (Janda *et al.* 2019).

The embodied emissions of improvements to the building stock also need consideration to ensure a holistic approach to GHG reductions by balancing embodied and operational emissions. The EU now includes the full life cycle of buildings in its definitions of how to make the buildings more energy efficient (EC 2020). Applying circularity principles to building retrofitting could reduce materials-related GHG emissions for buildings. It will be useful to explore how these new definitions shape the understandings and metrics of retrofitting interventions. Such life cycle analyses could be particularly important in countries with a large proportion of unfit housing.

Furthermore, two-thirds of countries lack building energy codes. Nations are beginning to respond to the IEA's recommendation to adopt mandatory performance requirements which include the existing building stock (IEA 2021b). Exactly how these standards are being developed with a sensitivity to the local context and building stock will require interrogation, and their suitability will need to be assessed over time. In addition, such codes, standards and regulations need rethinking to be based on actual measured building performance. A range of metrics is needed, with specific ones being used as necessary to measure the actual outcomes of any retrofit programme (Bordass 2020; van der Bent in this issue).

4.3 DEVELOPING BUSINESS MODELS, FINANCING AND CONSUMER CONFIDENCE

Although some of the contributions here mark a significant shift away from earlier thinking around how to retrofit individual homes, knowledge gaps remain. In particular, retrofitting at scale will only be achieved if the unit cost of delivery and the risks to clients and building occupants are reduced. New financing models for domestic retrofit could be particularly beneficial here. Building on Tingey *et al.* and earlier work (*e.g.* Brown 2018), further exploration of business models and contractual frameworks for retrofitting at scale is needed. This includes: performance-related outcomes; service-related pricing (*e.g.* heat-as-a-service; Britton *et al.* 2021), performance guarantees, and models using a 'one-stop shop' whereby one organisation takes responsibility for the entire retrofitting project. Such business models could present new ways to engage occupants in domestic energy retrofitting. Further research is needed to understand public acceptability of these models alongside developing appropriate policy mechanisms to support them. In addition, appropriate forms of consumer engagement and empowerment need to be developed alongside suitable legislation for reducing the risk to consumers and enhancing consumer protection.

4.4 SUPPORTING SUPPLY CHAINS

Several papers in this special issue have indicated avenues for further enquiry to understand, and shape, supply chains for domestic retrofit. In particular, Simpson *et al.* and Brocklehurst *et al.* both advocate for long-term curriculum development and looking to multi-generational interactions between practitioners in the UK. Much could be learnt from detailed studies of vocational education and training (VET) processes in different countries, particularly building on the work of Clarke *et al.* (2020b, 2021). A next step is to look at how educational reform can be incorporated where necessary (building on Killip 2020), particularly how researchers can work together with policymakers and practitioners to incorporate change amidst these deeply embedded and complex educational systems. An additional question, raised by van der Bent *et al.*, is: what happens if the construction industry (and associated sectors such as finance, real estate and regulation) cannot deliver mass retrofit targets in the short (20-year) time period available? Developing understandings of new actors and approaches for delivering retrofit could contribute here. In particular, new technologies for delivering mass retrofit, such as off-site modular construction, are increasing in prominence (Schwehr *et al.* 2011). However, their success is not a given. There is a need to critically evaluate the potential of these approaches, and their implications for existing construction supply chains and workforce skills.

4.5 POLICY AND GOVERNANCE ACTIONS

The delivery of domestic retrofitting at scale is essential for meeting emissions reduction targets. There is a crucial role for supportive governance and long-term, consistent policy to deliver on all the aspects outlined above. Policymakers need:

- To develop existing tools for data collection and monitoring building quality (*e.g.* RdSAP and EPCs) such that they can support the generation of accurate environment data sets.
- To empower central government departments and local governments to assess data, set targets and monitor building performance.
- To develop tools and techniques to support area-based retrofit planning. These tools might include: accessible data repositories; maps of the existing building stock and opportunities for, for example, heat networks; and support and accreditation for trusted trader lists in local communities.
- To use building energy models (underpinned by good data) to plan energy retrofitting at scale.
- To support public sector and non-profit actors to deliver retrofitting at scale, this will include:

    - local authorities who may be involved in area-based planning for retrofit
    - social landlords who can lead by example and begin to engage homeowners in area-based retrofitting
    - local citizen groups who may have a crucial role in supporting homeowner retrofitting.
- To develop national-scale, long-term campaigns to inform and incentivise homeowners to explore retrofitting options.
- To provide higher levels of consumer protection for retrofits, and to provide clarity and reduce consumer risk.
- To work with industry to ensure that vocational education and training is fit for purpose in delivering energy retrofitting, including high-quality programmes and financial support to encourage existing workers to retrain.
- To elevate the importance of RMI trades for tackling the climate emergency. To use this grounding to encourage new entrants into the sector, and reform training for existing workers.

Retrofit continues to be an ongoing challenge worldwide. *Buildings & Cities* encourages further research and commentaries on the development of mass retrofit solutions of the building stock.

NOTES

1 See *https://unfccc.int/*.

2 RdSAP was developed by the Building Research Establishment (BRE) and forms part of the methodology used by the UK government to assess and compare the energy and environmental performance of dwellings. RdSAP can be used for existing dwellings. For more information, see *https://www.gov.uk/guidance/standard-assessment-procedure/*.

3 PAS 2035 is a Code of Practice developed by the UK BEIS and the British Standards Institute (BSI) for introducing energy efficiency measures into buildings. PAS 2035 includes two core principles: fabric first and whole-house retrofit, and outlines a series of roles for those involved in building retrofit.

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COMPETING INTERESTS

The guest editors have no competing interests to declare.

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