BUILDINGS & CITIES

Fabric first: is it still the right approach?

BRIEFING NOTE

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ubiquity press

ABSTRACT

'Fabric first' describes an approach to improving the thermal performance of residential buildings by prioritising the improvement of fabric. It has historically been widely advocated. However, the urgency of complete decarbonisation challenges this approach in existing buildings. Heat decarbonisation is necessary to deliver zero-carbon goals. In many cases, no additional fabric improvement is needed to decarbonise heating; a heat pump, or other zero-carbon heat supply, will be enough. Retrofitting fabric first may not be feasible across the whole housing stock on timescales necessary for rapid decarbonisation and could therefore slow housing decarbonisation. However, fabric improvement will continue to have an important role. Energy use in buildings with a 'heat pump only' retrofit will be higher than if insulation were also improved. Fabric should continue to be prioritised in new buildings and where low-cost insulation measures are available. Fabric improvement can have other benefits: lower running costs, improved comfort, reduced damp risk, better heat pump performance, reduced overheating risk and lower requirements for electricity capacity increases. The suitability of a heat-pump-only approach to building decarbonisation should therefore be decided building by building. For national building stocks, complete decarbonisation of heating systems is required, but stock average fabric improvement may be 30–50%.

POLICY RELEVANCE

Combining rapid decarbonisation with comfortable and healthy homes will require coordinated programmes of heating system change and fabric improvement. To develop supply chain and consumer confidence, minimum energy and carbon standards for existing buildings will be needed. High-efficiency heat pumps will need to be the dominant heating technology. As they currently have higher capital costs than fossil fuel boilers, rapid market deployment will require financial incentives. For equity reasons, in low-income

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KEYWORDS:
building insulation; building stock; buildings; climate policy; fabric first; heat decarbonisation; mitigation; public policy; space heating

TO CITE THIS ARTICLE:
Eyre, N., Fawcett, T., Topouzi, M., Killip, G., Oreszczyn, T., Jenkinson, K., & Rosenow, J. (2023). Fabric first: is it still the right approach? *Buildings and Cities*, 4(1), pp. 965–972. DOI: https://doi.org/10.5334/bc.388

DOI: 10.5334/bc.388

households, public and/or landlord funding will be needed. Innovative finance options and/or supply industry obligations may also be useful. Energy regulation and taxation need to ensure that decarbonised options have lower operating costs. Investments will be needed in workforce education, skills and occupational standards, supported by robust quality assurance programmes. Consistent, good quality advice will be needed from both installers and independent advice services. Deployment programmes should be monitored to ensure existing evidence gaps are addressed.

1. INTRODUCTION

Making residential buildings more energy efficient has been an important objective of energy policy in most countries since the oil crises of the 1970s. The recent gas crisis in Europe has reminded policymakers that energy efficiency remains an important goal to allow affordable energy services and to address energy security concerns (Eyre & Oreszczyn 2022).

Climate change mitigation provides a new context, not just to reduce emissions but to reduce them to zero by mid-century to meet the goals of the Paris Agreement. There is an urgent need to improve building energy performance as part of the shift to net zero. This will include new build meeting net zero standards. However, it also implies the need to retrofit existing buildings to net zero, which is a more substantial challenge.

In cool and temperate climate zones, space heating is the dominant energy use in residential buildings. Domestic hot water is also a significant demand in all climate zones. A shift to net zero emissions' heating practices is therefore needed.

There is broad agreement that significant contributions to this goal can be made from both fabric improvement and heating systems, but less agreement on their relative importance and interaction (Rosenow & Hamels 2023). A 'fabric first' approach has often been advocated, but this is now being challenged. This Briefing Note sets out the basis of the controversy and proposes ways forward for policymakers. It identifies the relevant issues, at the level of both individual buildings and whole housing stocks, and sets out some policy recommendations. The analysis is based primarily on research on, and understanding of, the UK housing stock. However, nothing in the analysis is highly UK specific. In the parts of the world with significant space heating requirements that are currently provided by fossil fuels, similar principles will apply, but there will be differences where cooling is the dominant requirement and/or energy is already decarbonised.

2. WHY 'FABRIC FIRST'?

Consistent with most research and practice, fabric first is defined here to mean an approach to improving the energy efficiency performance of new and retrofitted buildings in which work to reduce heat loss precedes addressing the efficiency of building services. It typically promotes use of high-insulating individual components, low thermal bridging and well-controlled ventilation. The implications for energy use are most significant in the context of space heating.

The fabric-first approach first appeared in the context of new build in the years following the oil crises of the 1970s, leading to the Passivhaus standard (BRE 2023), which requires high energy performance. While there are ongoing arguments about how ambitious these goals should be, there is general agreement that standards for new build should seek to deliver high energy performance, *i.e.* low heat loss, even in the context of decarbonised heating.

Fabric first has also been widely advocated in the context of retrofit, *e.g.* in standards (BSI 2019), by professional bodies and programme specifications (TSB 2014). In this context, the interpretation of fabric first can vary hugely, from installing very basic measures to 'whole house' retrofits.

There is a very large literature on the benefits of fabric improvement demonstrating advantages at both the societal and individual levels (Fawcett & Killip 2019). These include occupant benefits:

- lower energy costs
- warmer homes
- reduced overheating risk as the climate warms
- better physical and mental health (Liddell & Guiney 2015)
- better indoor environment, *e.g.* improved air quality, less damp (Fisk *et al.* 2020)

and broader societal benefits:

- reduced carbon emissions
- creation of skilled jobs (Hanna *et al.* 2023)
- reduced need to supply zero carbon energy (Langevin *et al.* 2023)
- reduction in fuel poverty and health costs
- increased use of heating for demand response (Crawley *et al.* 2022).

3. PROBLEMS OF FABRIC FIRST

Fabric first retrofit remains uncontroversial in cases where it improves thermal performance using relatively cheap, and easy-to-install measures, *e.g.* roof and cavity wall insulation.

Whilst fabric first has an appealing logic of reducing waste, historically the approach has not been rigorously followed in practice. Changes in heating systems away from open fires and individual room heating to central heating, more efficient boilers (Elwell *et al.* 2015) and now heat pumps (Rosenow *et al.* 2022) have all taken place in parallel with fabric change and also made a large contribution to improved energy efficiency.

Many homes have already installed some easier and cheaper fabric measures. Further improvements therefore increasingly involve more expensive and disruptive measures, *e.g.* solid wall insulation, floor insulation and ventilation control (Topouzi *et al.* 2019). These form part of what is often referred to as 'deep retrofit' (or 'deep' renovation), which seeks to achieve ambitious levels of heat demand reduction consistent with the building type and climate zone (BPIE 2021). However, current rates of deep retrofit are low. They are constrained by sector skills, supply chain capacity and negligible consumer demand. Even in the European Union, where it has been most actively promoted, rates average 0.2% of the stock annually (BPIE 2021).

Whilst this rate can, and should, be increased, this will require major changes in construction sector skills and capacity. Roll-out to the whole building stock would take decades. Because of the long timescales, the benefits of fabric improvement may no longer justify fabric first in the original sense of completing fabric improvement before heating system change.

4. THE NET ZERO IMPERATIVE AND FABRIC FIRST

Fabric first was first proposed at a time when all heating fuels were polluting, so reduced fabric heat loss was the priority. However, with the costs of renewable electricity falling quickly, there is now the prospect of zero-carbon electricity replacing fossil fuels at significant scale (Lowe & Drummond 2022). This change, coupled to the net zero goal, fundamentally changes the context for residential energy efficiency (Rosenow & Eyre 2022). Use of decarbonised fuels, in particular electricity, becomes more important and urgent.

Electricity can be used very efficiently in homes through heat pumps. Electric heat pumps are a well-established technology in many countries, with deployment increasing rapidly in Europe due to the gas price increase after the Russian invasion of Ukraine (Rosenow & Gibb 2023). They are typically around three to four times more efficient than fossil fuel boilers.

For heat decarbonisation, heat pumps are therefore the main future option: both air- and ground-source, deployed either in individual buildings or on district energy networks. The choice between air and water as the heat carrier in buildings (in pipes or ducts) is likely to depend on existing heating practices and cultural norms, which vary across countries (*e.g.* between Europe and

North America). Heat pumps can also provide cooling, which may be an additional attraction to consumers as temperatures rise, but clearly also increases energy use.

Whilst fabric improvement can contribute to reducing energy bills and carbon emissions, it can only be additional to heat decarbonisation, not an alternative to it. A shift from boilers to heat pumps now provides both the largest energy efficiency opportunity in the housing stock as well as the biggest carbon mitigation potential. A universal focus on fabric first in retrofit, regardless of cost or speed of delivery, could therefore slow housing decarbonisation.

5. DECISION-MAKING FOR INDIVIDUAL BUILDINGS

For individual buildings, case-by-case decisions have to be made about how to combine investments in low carbon heating systems and fabric improvements. Decisions will take account of both investment costs and operating costs—this is particularly relevant where current gas/electricity price ratios make operating costs of heat pumps higher than those of gas boilers. These are major issues for many households, as well as of concern to landlords. Beyond meeting decarbonisation goals cost-effectively, there are many other issues and values informing building owner decisions (Fawcett & Killip 2014). Especially in owner-occupied stocks, these tend to limit opportunities for retrofit to specific 'trigger points' and therefore slow the rate of change.

Fabric first is still a valid principle where the improvements proposed are cost-effective; these are likely to be low-cost insulation measures (Lowe & Oreszczyn 2020). However, what constitutes a low-cost measure is not fixed, as some costs are context dependent, *e.g.* high- efficiency windows have low marginal costs at the point of renewal and the costs of floor insulation are much lower if related building works are already planned (Fawcett 2014). Optimum levels of investment in fabric may therefore vary over time, and between identical buildings. There is no universal rule for where fabric first should give way to 'fabric second'.

In many cases, residential buildings are already sufficiently well-insulated to need no additional fabric improvement to decarbonise their heating; a heat pump, or other low carbon supply, can be installed and achieve this goal. As the electricity system decarbonises, so will heating delivered via electricity. Heat pumps can be used efficiently in a wide variety of buildings (ESC 2023). They operate more efficiently on lower temperature heating systems, and therefore there are trade-offs between heat pump capacity, radiator area, flow temperatures, fabric insulation and system efficiency. Heat pump system efficiency in practice varies significantly (ESC 2023), probably largely due to these factors and installation quality. Some inappropriate properties were excluded from the installation programme and 'suitability of the wider UK housing stock for heat pumps should therefore not be inferred' (Delta-EE 2022: 4).

A heat-pump-only solution is therefore not always best. It will be necessary to have an 'understanding first' of what is appropriate for each building. The type and suitability of heat pump installation needs to be decided on a case-by-case basis. In some cases, significant fabric improvements may be needed, with a professional assessment to ensure affordable heating in homes that are comfortable and healthy. Decisions for each home can only sensibly be made on the ground using an integrated design approach. In this way, decarbonisation and other goals can be achieved at the pace required, without incurring excessive costs or inappropriate installations, which would lead to loss of consumer confidence in technologies and market actors.

Installation quality will be critical. This has significant workforce implications. In many cases, collaboration across heating system change and fabric improvement will be needed. Historically, there is resistance in the construction sector to new ways of working and new technologies. The retrofit sector is dominated by small, locally based companies, many with limited capacity or experience of zero-carbon practices. Devolution of delivery to this large, fragmented workforce seems unavoidable, which points to a need for stronger policy in support of occupational standards, training, accreditation and compliance (Killip *et al.* 2021). These investments should result in improved labour productivity and better jobs.

6. DECISION-MAKING FOR THE BUILDING STOCK

Complete decarbonisation of the building stock will require huge capital expenditure. National cost-effectiveness will therefore be an important test for heat decarbonisation policy. All heating systems will need to be made zero carbon, and in the medium term these changes will be more important than fabric measures, both to improving overall building energy efficiency and reducing emissions.

The extent of fabric improvement needed will therefore vary across the stock. In some cases, *e.g.* where apartments are dominant, the role of fabric improvement may be limited. A recent detailed evaluation of a stock of 33,300 homes (85% flats) in London suggested that fabric measures alone would only achieve a 13% cut in gas use, at a cost of £31,900 per dwelling (Evans *et al.* 2023). From a societal perspective, to be cost-effective, fabric should be improved up to the point where further improvement has a higher cost than future zero-carbon electricity supply, which will tend to exclude high-cost insulation.

However, an energy-system wide analysis is more complex than comparing costs of fabric improvement and zero-carbon heating systems. For the reasons set out above, there are interactions between fabric quality and heating system performance. Given the importance heating plays in total energy demand, seasonal heat pump performance, which can in practice range from a coefficient of performance of 1 to 5, will play a critical role in determining the scale of electricity supply investment, and therefore the cost of the energy transition. The largest additional upstream costs are likely to be in zero-carbon generation to accommodate the peak demand of a widespread shift to heat pumps (Eyre & Baruah 2015). In addition, electricity networks in some places will need to be strengthened.

Importantly, decarbonisation cost-effectiveness is not the only test for building retrofit. Residential buildings are homes: they need to be healthy, comfortable and affordable. And unless decarbonisation aids with these goals, it is unlikely to be acceptable. Energy use in homes where fabric is unchanged will be higher than if fabric were also improved. Many homes could also benefit in other ways from fabric improvement, *e.g.* health and wellbeing, comfort, climate resilience, and damp reduction. And there are multiple broader societal benefits, as set out above. Particularly at a time of high energy prices, that points to a high short-term focus on fabric improvement for households on low incomes and in poor housing.

Across whole housing stocks, there are significant uncertainties in these benefits. The optimal level of fabric improvement depends on which benefits are taken into account and how the uncertainties are addressed. The existing literature addresses these inconsistently, but a review finds the optimal stock average energy demand reduction from fabric measures is likely to be 30–50% (Rosenow & Hamels 2023). This analysis suggests a balanced and well-integrated approach is necessary, with both heat demand reduction and efficient heat supply decarbonisation.

At the level of whole building stocks, rapid, socially acceptable, decarbonisation of homes will require installation programmes of both heat pumps and fabric improvements. There are already some examples of these (EST 2023). Programmes will need to be sufficiently flexible to meet the requirements of different buildings and their occupants.

7. CONCLUSIONS

The imperative to decarbonise buildings completely implies a shift away from fossil fuels for heating. If this is to be done quickly, it challenges the idea of fabric first, where this involves complex and expensive deep retrofit.

In many individual buildings, decarbonisation can be achieved by changing to a zero-carbon fuel, in most cases a heat pump using decarbonised electricity. In some cases, this will be the least-cost approach to decarbonisation; in others, notably where there are low-cost insulation opportunities, some fabric improvement will still be needed. Fabric improvement can also be justified by other considerations, including addressing cold, damp and overheating, and their implications for comfort and health.

This implies an 'understanding first' approach for individual buildings, taking into account the costs and savings for different building types and conditions, but also the needs of occupants for a comfortable and healthy home. This can only be done by a well-qualified professionals, such as a retrofit coordinator. Workforce competence will be key.

Fabric improvement can reduce the need for upstream electricity investment and brings social and economic co-benefits. These benefits suggest more fabric improvement than if decisions are based on energy cost–benefit analysis alone. For the whole building stock, complete heat decarbonisation will be needed, but addressing all policy goals points to average fabric improvements of 30–50%, and therefore large fabric improvement programmes.

8. IMPLICATIONS FOR POLICY

Combining rapid decarbonisation with comfortable and healthy homes will require well-integrated programmes of heating system change and fabric improvement. This will require policy packages that address the issues identified above without creating overly complex policy mixes that may slow uptake of both decarbonisation and fabric efficiency. Policymakers will need to coordinate initiatives across a range of activities, including understanding the implications for upstream energy systems and broader economic goals.

Some governments have targets for heat pump deployment rates but not targets for the efficiency at which they should operate. Policy should encourage the development and deployment of high-performance heat pumps.

Heat pumps currently have higher capital costs than fossil-fuel boilers, and capital expenditure is further increased if fabric and/or heat-emitter improvements are also installed at the same time. The equity implications of higher capital costs are very important for policy. For low-income households, public and/or landlord funding will be needed. In other cases, innovative finance options and/or obligations on energy or heating supply companies may be useful to provide incentives for early adoption by householders and to grow the market quickly. Where electricity/gas price ratios make the operational costs of heat pumps higher than those of gas boilers, policy needs to address this through fiscal measures and/or altering the incidence of policy costs on the two fuels.

Driving change will require future minimum standards for the energy and carbon performance of existing buildings (Sunderland & Santini 2021). These will need ultimately to mandate both the use of zero-carbon fuels and a high standard for fabric performance at key trigger point such as change of ownership.

In many cases, relative fuel costs currently favour the use of gas over electricity, which is a perverse incentive where electricity is increasingly decarbonised (Rosenow *et al.* 2022). In the short term, this can be addressed by taxation of gas and/or shifting policy costs off electricity and onto gas. In the longer term, falling costs of renewable electricity will achieve this goal (Lowe & Drummond 2022).

Large investments will be needed in enabling programmes in a sector dominated by small companies, notably in workforce education, skills and occupational standards (Killip 2013). Robust quality assurance programmes will be needed for fabric improvement, heating technologies and their installation.

Building consumer trust and knowledge of new technologies will be important both to ensure public support and effective operation of heating systems. Consistent, good-quality advice will be needed from installers and independent advice services.

There are evidence gaps in many areas, including energy performance gaps, heat pump efficiency, grid costs, embodied carbon, training needs and policy effectiveness. These do not justify inaction, but rather suggest a need for collecting better data quality on building fabric and installation quality by ensuring that deployment programmes are monitored and lessons learnt as the transition progresses.

ACKNOWLEDGEMENTS

The authors are grateful to two anonymous referees and the editor for helpful comments, which improved the paper.

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COMPETING INTERESTS

The authors have no competing interests to declare.

FUNDING

This work was supported by UK Research and Innovation through a grant to the Centre for Research on Energy Demand Solutions (grant number EP/R035288/1).

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TO CITE THIS ARTICLE:
Eyre, N., Fawcett, T., Topouzi, M., Killip, G., Oreszczyn, T., Jenkinson, K., & Rosenow, J. (2023). Fabric first: is it still the right approach? *Buildings and Cities*, 4(1), pp. 965–972. DOI: https://doi.org/10.5334/bc.388

Submitted: 29 September 2023
Accepted: 18 November 2023
Published: 15 December 2023