Technology Innovation Needs Assessment (TINA)

Domestic Buildings
Summary Report

November 2012

Background to Technology Innovation Needs Assessments

The TINAs are a collaborative effort of the Low Carbon Innovation Co-ordination Group (LCICG), which is the coordination vehicle for the UK's major public sector backed organisations in the area of 'low carbon innovation'. Its core members are the Department of Energy and Climate Change (DECC), the Department for Business, Innovation and Skills (BIS), the Engineering and Physical Sciences Research Council (EPSRC), the Energy Technologies Institute (ETI), the Technology Strategy Board (TSB), the Scottish Government, Scottish Enterprise, and the Carbon Trust. The LCICG also has a number of associate members, including the Governments of Wales and Northern Ireland, Ofgem, the Crown Estate, UKTI, the Department for Transport, the Department for Communities and Local Government, the Ministry of Defence, and the Department for Environment, Food and Rural Affairs.

The TINAs aim to identify and value the key innovation needs of specific low carbon technology families to inform the prioritisation of public sector investment in low carbon innovation. Beyond innovation there are other barriers and opportunities in planning, the supply chain, related infrastructure and finance. These are not explicitly considered in the TINA's conclusion since they are the focus of other Government initiatives, in particular those from the Office of Renewable Energy Deployment in DECC and from BIS.

This document summarises the Domestic Buildings TINA analysis and draws on a much more detailed TINA analysis pack which will be published separately.

The TINAs apply a consistent methodology across a diverse range of technologies, and a comparison of relative values across the different TINAs is as important as the examination of absolute values within each TINA.

The TINA analytical framework was developed and implemented by the Carbon Trust with contributions from all core LCICG members as well as input from numerous other expert individuals and organisations. Expert input, technical analysis, and modelling support for this TINA were provided by BRE.

Key findings

Innovation in the domestic buildings sector represents a significant opportunity to help meet the UK's greenhouse gas emissions targets as well as providing value through avoided energy costs, amounting to savings of 73MtCO_2 and c. £16bn by 2050. Innovation could also help create export opportunities that could contribute an estimated £1.7bn to GDP to 2050. Public sector support will be required to unlock this value, as there are significant market barriers across the sector to overcome.

Potential role in meeting the UK's GHG emissions targets	• The energy used by domestic buildings in the UK accounts for approximately 25% of the UK's total emissions. • Innovative energy saving measures in domestic buildings could save approximately an additional 11MtCO_2 by 2020 and 73MtCO_2 by 2050[1]. • Across the technology areas considered (pre-construction and design, build process, building operation, and materials and components), innovations in building operation would save the most carbon, most quickly, predomantly from the existing building stock.
Value of abatement potential	• The potential net value from energy savings is c. £16bn (4.5 – 37.5)[2] to 2050. • Across the technology areas, innovations in building operation could yield most value. • Innovations in pre-construction and design, and build process could also yield significant value. • Innovations in materials and components will not provide significant value unless costs come down faster than expected, however improved and cheaper materials (e.g. thin insulation products) may amplify savings from other areas.
Green growth opportunity	• Additional global market value of innovative products in this sector could reach c. £620bn[3] cumulatively over 2010-2050, of which c. £220bn would be accessible to the UK. Of this, innovative products could provide an additional £1.7bn[1] in value to the UK.
The case for UK public sector intervention	• Market barriers exist across the buildings value chain, stifling innovation and progress in improving the energy efficiency of domestic buildings. These include a lack of high-quality data, split incentives between various actors, and regulatory uncertainty. • The UK cannot exclusively rely on other countries to develop the innovation needed. The UK is already a world leader in a number of technologies and has unique requirements including climate, diversity of building stock and building usage patterns. • Construction services are generally delivered by local firms, so the UK will need to build capacity to implement innovative energy efficiency measures. • Gathering data on actual building performance in-use is vital and should be encouraged to understand the value of energy savings, as well as to innovate and implement measures effectively. Split incentives between different actors in the value chain currently prevents this from happening.
Potential priorities to deliver the greatest benefit to the UK	• Public sector support could provide most value in building operation innovations – due to high value from energy savings – and in pre-construction and design innovations – where the UK is a world leader – due to high value and the presence of market barriers. • Support for elements of build process innovations could also provide significant benefit. • Support for materials and components innovations would provide some benefit, however the potential value and carbon saving would be significantly smaller than would result from support in other areas. • Although each technology area could be treated in isolation, they are interconnected, and realising the full benefit of investment will require an integrated approach supporting innovation in each area.

[1] Cumulative to 2050, medium deployment scenario

[2] Medium (low – high) deployment scenarios

[3] Medium deployment scenario

Chart 1 - Domestic buildings TINA summary

Technology area	Value of energy saving (£bn)[4]	Value in business creation (£bn)[5]	UK competitive advantage	Potential public sector activity/investment
Pre-construction and design	2.9 (1.3 – 5.5)	0.85 (0.39 – 1.59)	Medium-high	• Prize funding challenge to develop tools for enhancing energy modelling techniques • Early pre-commercial demonstration programme for modelling tools and techniques • Establish consortia for retrofit tools • In-use data collection programme for highly-rated buildings • Convened consortia including major social landlords and professional bodies to define and demonstrate new practices, combined with knowledge sharing activities
Build process	3.7 (1.6 – 8.6)	0.16 (0.07 – 0.38)	Low-medium	• Collaboration for evaluation and demonstration of off-site construction and industrial retrofit • Research and development of standard and community scale retrofit models. • Support development of standard models that will be appropriate for different building and tenure types • Trial commercial model for community-scale refurbishment
Building operation	8.8 (1.4 – 21.2)	0.64 (0.10 – 1.54)	Medium	• Collaborative research and development for smart controls • Incubation programme for methods to encourage behavioural change • Information dissemination programme • Data collection programme for highly-rated buildings • Research to evaluate the effectiveness of innovative systems on influencing householder behaviour
Materials and components	0.5 (0.2 – 2.3)	0.04 (0.01 – 0.16)	Medium	• Challenge-based collaborative R&D in early stage fabric technologies aimed at improving performance • Prize funding for integration of later-stage technologies into real refurbishments combined with pre-commercial field trials to scale up • Field trials considering most efficient rated buildings, to see why they are performing better than average
Total[6]	**16.0 (4.5 – 37.5)**	**1.69 (0.57 – 3.66)**		

Benefit of UK public sector activity/investment[7]	
	High
	Medium
	Low

Source: BRE, Carbon Trust analysis

[4] 2010-2050 medium (low – high) deployment with marginal cost of technology included to calculate value

[5] 2010 – 2050 with displacement

[6] Note that totals may not provide expected figures due to rounding

[7] Also taking into account extent of market failure, UK competitive advantage and opportunity to rely on other countries

Energy efficiency in domestic buildings has an important role to play in meeting the UK's GHG emissions targets

The energy used in domestic buildings accounts for approximately a quarter of UK carbon emissions. The existing building stock itself is diverse in age, building type, tenure and energy efficiency.

There are strong policy ambitions in the UK affecting domestic buildings. The Climate Change Act 2008 requires an 80% cut in emissions by 2050, and a significant part of this must come from the domestic buildings sector. Moreover, all new domestic buildings will have to produce zero emissions from regulated energy use by 2016.

Given that three-quarters of domestic buildings that will exist in 2050 have already been built[8], strong attention also needs to be given to improving the performance of the existing domestic buildings stock, both by using existing buildings more efficiently, and though refurbishment.

Research has shown that there is often a gap between the design intent of a building and its actual performance.[9] Overcoming this gap will require an integrated approach taking into account the way buildings are used, as a system whose value is greater than the sum of its parts, and where interaction with householders is critical.

Innovative measures could benefit the entire building lifecycle. Ensuring that new buildings are constructed and used as designed will require process innovations, and innovative tools and systems to enable processes, while improving the physical performance of new and refurbished buildings will require innovations in building technology.

Also significant, though beyond the scope of this TINA, is the wider context in which low carbon buildings sit. Other TINAs consider these, in particular Heat, and Electricity Networks and Storage.

We have considered three deployment levels of innovations in domestic buildings. The amount of energy saved will depend upon the extent to which innovative measures can be applied to the domestic building stock (applicable to existing buildings, new builds and major refurbishment) in the UK, so this is the variable that is altered in the scenario analysis.

The extent of deployment will depend significantly on regulatory 'push' and market 'pull', so the scenarios are based on policy and market needs:

- **Low scenario** – depends on effectiveness of policy measures in existing buildings, new build and refurbishment rates that allow improvement in stock, and perception of measures as low risk (from energy and carbon prices and cost of measures)
- **Medium scenario** – as above, plus strong market demand for low carbon buildings, a supportive legislative framework and structured processes for gathering feedback on actual performance
- **High scenario** – as above, plus strong political focus coupled with a highly skilled industry, and householder co-operation

These are compared with a counterfactual scenario, which assumes that the grid is decarbonised and existing cost-effective commercial measures are implemented.

Description of innovative measures

The innovative measures in this TINA are additional to existing commercial measures. Innovations for domestic buildings can be split into four major technology areas: pre-construction and design; build process; building operation, and materials and components.

Pre-construction and design innovations include:

- **modelling and software tools,** which could become faster and more accurate in maximising the use of passive design strategies;
- **tools to identify retrofit opportunities quickly, cheaply and accurately –** measures that minimise intrusion to identify opportunities in existing buildings to improve energy performance e.g. heat cameras linked to vehicles or laser surveying tools allowing insulation panels to be pre-assembled;
- **design tools and services** providing greater expertise and knowledge in domestic buildings and their services to complement micro-generation and district heating, to allow their integration during construction works or simplify their adoption as a future retrofit measure.

Build process innovations include:

- **smart manufacturing processes,** e.g. off-site construction, where individual modules are pre-manufactured and assembled on-site, and modern on-site construction and manufacturing, and tighter supply chain integration;
- **industrialised retrofit techniques**, new construction methods to reduce the cost of refurbishing existing buildings and improving the performance of refurbished buildings.

[8] Low Carbon Construction Innovation and Growth Team, final Report (2010)

[9] Wingfield *et al*, "Lessons from Stamford Brook – Understanding the Gap between Designed and Real Performance" (2008), Leeds Metropolitan University

Building operation innovations include:

- **smart controls and systems diagnostics,** predictive, intelligent householder-oriented building controls and diagnostic applications that optimise performance of building services (e.g. central heating);
- assisting **behavioural change** by providing users with clear information, incentives and innovative tools with which to interact with buildings.

Materials and components innovations include:

- **improved fenestration**, to improve the functional performance of windows to provide appropriate levels of light, insulation, shading and ventilation.
- **advanced insulation products,** lighter-weight, thinner, cheaper insulation to meet the increasing standards of Part L Building Regulations and the Code for Sustainable Homes – these may include solid wall insulation or more advanced phase change and nano materials;
- **low carbon cooling and ventilation,** a variety of technologies to service buildings with lower energy demand: natural ventilation methods, ventilation heat recovery and other techniques to replace conventional technologies and solutions.

Calculating the magnitude and value of energy and carbon savings

Innovative measures can provide energy savings additional to those achievable from the existing commercial measures included in the counterfactual.

Total savings achieved from each innovation are derived from a number of assumptions:

- the **uptake** of the innovation, i.e. the maximum proportion of existing domestic buildings to which the innovation can be applied;
- the **energy saving potential** of the innovation as a proportion of existing energy demand for each end use (e.g. 10% saving from lighting);
- the **lifetime**, and **performance at end of life** as a proportion of original performance (known as 'persistence') of the innovation;
- the **time to reach uptake** – a measure of the market's ability to implement the innovation;
- the **year of introduction** of the innovation, and
- the **roll-out period** for the innovation in existing buildings – a measure of the rate at which the innovation can be implemented in existing buildings based on refurbishment cycles.

Innovative measures are not replaced at the end of their life, as these measures will no longer be considered innovative once they are due to be replaced. Attributing further savings resulting from replacement of these measures may be counting savings that would happen anyway, without public sector support.

Uptake rates are defined according to the building type to which the innovations will be applicable – existing buildings, new builds and major refurbishments. For example, pre-construction and design innovations are not applicable to existing buildings; they are applicable to new buildings and major refurbishments.

Energy saving potential is divided into both building type and energy end use (heating, lighting or cooling). For example, build process innovations in new buildings may reduce energy demand from space heating by 50%, but by only 20% from cooling.

While building types are treated similarly for analytical purposes, each faces different challenges to deployment, which are discussed in more detail later.

Energy savings are calculated by multiplying the number of buildings by uptake rate and energy saving potential. Carbon savings are then calculated from these energy savings using projected carbon emissions factors.[10]

Costs

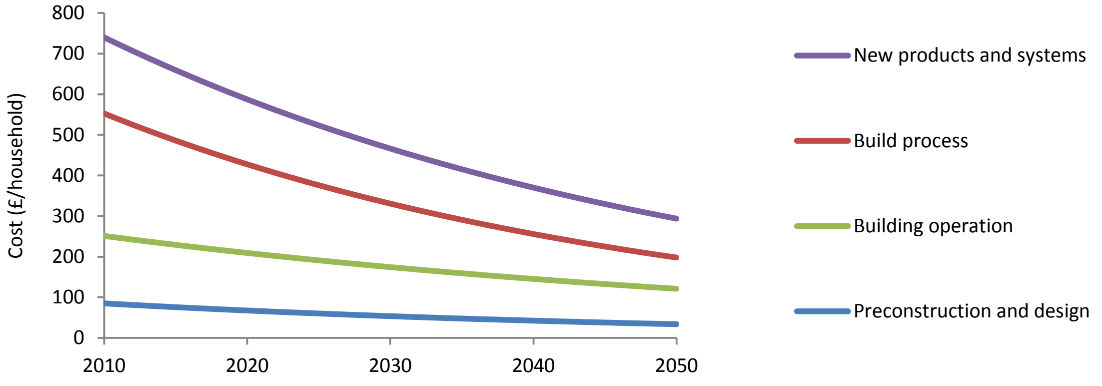
For most innovations, there is an increase in overall costs associated with additional services or higher quality materials. The cost assumptions used in this analysis are this additional cost. Costs reduce over time with increased levels of uptake and technical advances that reduce the cost of implementation.

- **Pre-construction and design** – additional cost is assumed to be largely offset by reduction in services (e.g. smaller boilers)
- **Build process** – costs of new materials and specialist skills anticipated to be marginally more than conventional products
- **Building operation** – additional costs for software, controls and information systems
- **Materials and components** – additional costs for materials (e.g. insulation) and processes (e.g. air-tightness details)

Costs are modelled to reduce proportionally to total deployment of each innovation – each time treated floor area doubles, cost reduces by 10%, as shown in Chart 2.

[10] DECC IAG data

Chart 2 - Net costs of innovative measures in domestic buildings



Source: BRE, CT

Innovative measures could save an additional £16bn and 73MtCO_2 by 2050

These savings would result from energy savings of 393TWh, or 2.4% of counterfactual energy demand. Chart 3 summarises carbon savings and value from energy savings, while Chart 4 shows the annual carbon savings resulting from these energy savings.

Innovations in pre-construction and design could save £2.9bn and 14MtCO_2 by 2050

Innovations in pre-construction and design are slow to realise savings as they are constrained by the new build rate of domestic buildings. For the same reason, savings are initially small, but continue increasing as more domestic buildings are constructed.

As energy prices are modelled to be higher in the latter half of the timeframe considered, value from energy savings is also significant.

Innovations in build process could save £3.7bn and 23MtCO_2 by 2050

Build process innovations are among the most significant of the technology areas considered in terms of carbon savings and value from energy savings. This is due, in part, due to high uptake rates in new build and refurbished stock. However, the opportunity for uptake is limited by the new build and major refurbishment rates. Build process innovations are also slow to realise savings.

Innovations in building operation could save £8.8bn and 32MtCO_2 by 2050

Savings are large compared to the other innovation measures and can be achieved quickly, as shown in Chart 4, with an uptake of around 10% (in the medium scenario) acros the entire building stock achieved over the next decade. This rapid uptake is due to the significant proportion of the domestic building stock that could benefit from building operation innovations. While savings do decrease beyond 2030 due to assumptions regarding grid decarbonisation and the relatively short lifetimes of building operation innovations, savings are so significant in earlier years that building operation innovations provide the largest carbon savings and the greatest value from energy savings overall.

Note that these high savings are due in part to the fact that three quarters of buildings that will exist in 2050 have already been built, and assume that householders have sufficient incentive to implement measures as quickly as the market can deliver them. Deployment, and therefore savings, would be significantly curtailed without such an incentive.

Note also that these savings are reliant on energy performance improvements due to smart systems occurring as well as expected. More research into the effects of such systems is needed, as the interactions between householders and such systems are complex and not yet fully understood.

Innovations in materials and components could save £0.5bn and 4MtCO_2 by 2050.

Savings from innovative products and systems are significantly smaller than other innovations as they are assumed to become effective later and are generally only applicable in specific certain circumstances, and so have very low uptake rates.

Value from energy savings is also low due to the high cost of measures, though would be larger if costs come down faster than modelled.

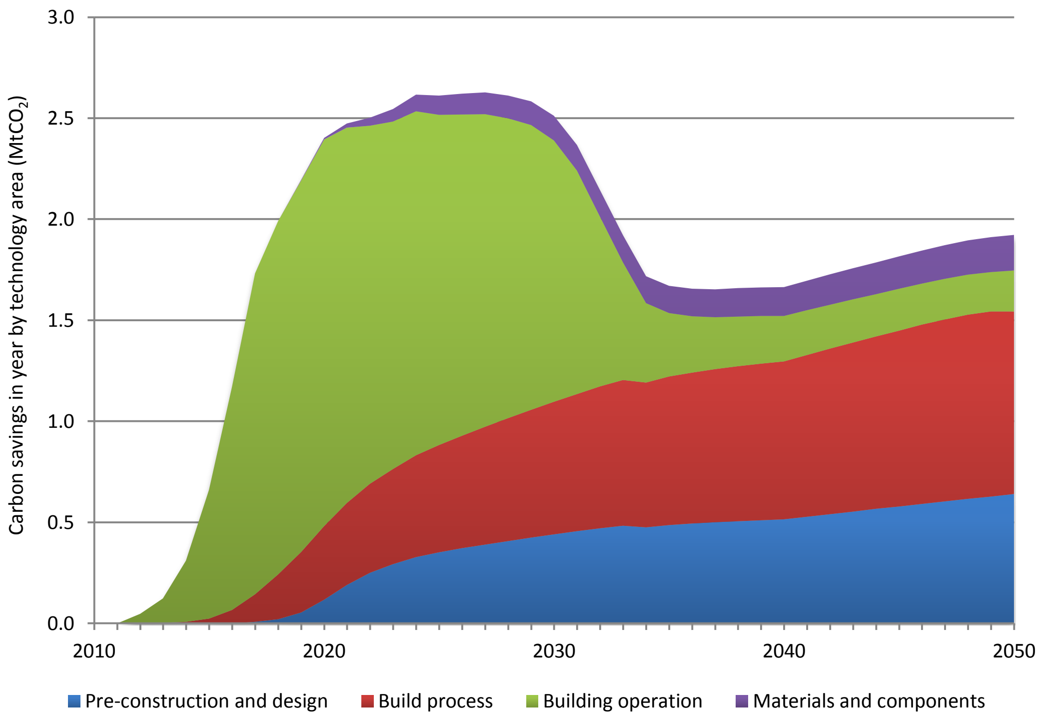
Note: we have not considered the value of avoided carbon emissions to ensure consistency across the TINAs, however the presence of an applicable carbon price would increase the value of innovative energy efficiency measures

Chart 3 - Summary of abatement potential and value of innovative measures

Technology area	Carbon savings to 2020 ($MtCO_2$)	Carbon savings to 2050 ($MtCO_2$)	NPV of energy savings to 2050 (£bn)	NPV per tonne CO_2 saved (£/tCO_2)	NPV per tonne MWh saved (£/MWh)
Pre-construction and design	0 (0 – 0)	14 (7 – 34)	2.9 (1.3 – 5.5)	202	34
Build process	1 (0 – 2)	23 (10 – 48)	3.7 (1.6 – 8.6)	165	29
Building operation	9 (1 – 23)	32 (6 – 80)	8.8 (1.4 – 21.2)	277	57
Materials and components	0 (0 – 0)	4 (1 – 7)	0.5 (0.2 – 2.3)	142	24
TOTAL	**11 (1 – 26)**	**73 (23 – 169)**	**16.0 (4.5 – 37.5)**		

Source: BRE, Carbon Trust analysis

Chart 4 - Annual carbon savings



Source: BRE, Carbon Trust analysis

Green growth opportunity

The global market for innovative products is estimated to be c. £620bn to 2050

The global market size for innovations in the domestic buildings sector is estimated using the available value from energy savings as a proxy for the additional cost the market would be willing to bear for the innovations. The global market value is scaled up using the ratio of estimated global floor area to UK floor area. It is assumed that developed countries have markets that are similar to the UK, with similar future requirements[11]. It is also assumed that the market for innovative measures in BRIC countries will start from 2020 and then evolve at a similar rate as that assumed for developed countries. Other developing countries are assumed to have limited markets for technologies that support very low carbon buildings and are excluded from global market calculations.

It is also assumed that the market would be willing to pay 25% of the potential value through energy savings in order to realise them, though in reality this figure will vary by technology.

Only part of the global market will be accessible to the UK, given the generally domestic nature of the construction industry, the accessibility of each technology area varying based on its tradable portion.

The tradable portion for **pre-construction and design** is estimated to be 60% of the global market. Although building energy modelling software and other tools are tradable globally, design services tend to be delivered by local professionals, and some design services are only appropriate for countries with similar climates and construction techniques. There is significant scope for exportable equipment and intellectual property rights (IPR).

The tradable portion for **build process** is estimated to be 30% of the global market. Building products, components and building services tend to be used in or close to those countries where they are manufactured, though there are global opportunities for exporting (IPR), skills and specialist tools, specialist components, services and construction approaches.

The tradable portion for **building operation** is estimated to be 30% of the global market. The export value of many services or associated software and hardware is likely to be low. The market for specialist products and services is global, and for some of these markets, the English language is an advantage. The provision of some services (e.g. audits) will be largely limited to local providers but there may be some IPR with export value.

The tradable portion for **materials and components** is estimated to be 60% of the global market. Many of the potential innovations, in the form of new products or materials, professional expertise and design tools, have worldwide applications and some technologies are likely to have a large market overseas. There is also significant scope for exportable equipment and IPR.

UK competitive advantage

The UK has various strengths that would allow it to take advantage of the accessible market opportunity in each technology area.

The UK has a **medium-high** competitive advantage in **pre-construction and design**, estimated to be 10% of the accessible market. The UK is a global leader in building information modelling (BIM), there is widespread use of energy modelling amongst UK practices and there is active research and development in energy modelling. Low carbon cities around the world also use UK expertise, standards and best practice tools.

The UK has **low-medium** competitive advantage in **build process**, estimated to be 3% of the accessible market. There is growth in the uptake of off-site construction in the UK together with active government support and research by UK universities, however there is significant competition from other countries in build process innovations.

The UK has **medium** competitive advantage in **building operation**, estimated to be 5% of the accessible market. The smart controls and systems market is mature in the UK and strongly linked with the IT industry, where the English language is an advantage. There is UK capability in many areas, but services could be carried out locally, though there may be some IPR export value.

The UK has **medium** competitive advantage in **materials and components**, estimated to be 4% of the accessible market. The UK is a leader in many innovations that may have global applications, which could provide value in export of products and IPR.

Contribution to the UK economy

The additional value to the UK economy, based upon the methodology outlined above, is c. £1.7bn[12] to 2050.

There is additional value not captured by this figure, including maintaining (or increasing) UK competitiveness in the construction industry to capture future value, and the provision of associated but non-innovative services.

[11] Developing countries based on the UN Human Development definition

[12] Including an additional displacement factor of 50%

The case for UK public sector intervention

To capture the value from these technologies, there is a strong case for targeted public sector intervention, especially where there is evident market failure. The following section analyses the need for intervention based on the extent of the market failures and on opportunities to rely on others.

Market failures impeding innovation

There are many overarching market failures across each technology area, though individual innovations also face specific market failures. Overarching market demand failures include:

- **Energy costs are seen as immaterial** – householders may not be willing to change their behaviour or make improvements to buildings because the energy savings are considered negligible.
- **The landlord-tenant divide** – affects tenanted properties, where one party has no incentive to invest in energy saving measures as the other party receives the benefit, also known as a 'split incentive'.
- **Complex planning requirements surrounding the self-build industry**, which could otherwise provide opportunities for buildings to use innovative materials, designs and building methods – obstacles to self-build include access to land and sourcing architectural and planning services. Self-builders lack a single point of contact that can provide integrated solutions.
- **Fragmented industry –** the burden of gathering information and liaising with various contractors to pursue a retrofit is often on the householder.
- **Lack of regulatory certainty around compliance** - few of those engaged in building new homes – from designers and product manufacturers to developers and contractors – can or will invest to the greatest extent in the development of solutions to achieve carbon compliance to zero carbon standards until they know the metrics by which their work will be measured.
- **Lack of certainty around Government policy,** which may be preventing investment in innovation.

Additionally, there are a number of supply conditions influencing market failures:

- **The building sector is conservative** and reluctant to adopt new approaches without clear prior demonstration or regulatory drivers.
- **There is a lack of necessary skills** and experience required to implement novel technologies.
- **Existing conventions around contracting have a negative impact** on low carbon outcome. There is no requirement for the construction industry to fix mistakes, as actual performance may not be a contractual requirement. Nor is it easy to measure or prove a cause of worse than expected energy performance.

Although these overarching market failures affect all innovation, there are specific failures, which vary within each technology area, summarised in Chart 5.

Critical failures in modelling and software are due to the lack of high quality data and the lack of incentives to share what data there is. Furthermore, developers do not conduct modelling incorporating unregulated demand (demand arising from appliances), and some modelled designs are difficult to build without error.

The UK cannot rely on other countries to drive innovation with the required focus and pace

In some cases, innovation needs may be similar in other countries, such that the UK could rely on these countries to develop innovative measures instead. There are two kinds of innovation activity, which may be needed: research and development, and demonstration and adaptation.

In general, the UK could rely on other countries for research and development activities. However, this is not the case for pre-construction and design innovations where the UK is already a world leader.

Pre-construction and design innovations would also need to be explicitly tailored for UK needs, based on the building stock and climate conditions. This is also true for products and systems (such as developing advanced natural ventilation systems) as the UK has very specific needs, which would require specialist research.

Given that the UK has a unique set of characteristics, and given that buildings are largely constructed by domestic firms, any innovation will need to be demonstrated and adapted specifically for local needs. Therefore, as the UK cannot rely on other countries to adapt innovations to its own needs, and it is difficult to import industry learning, UK activity will be required.

Chart 5 - Market failures in domestic buildings innovation areas

	Sub area	What market failures exist?	Extent of market failure
Pre-construction and design	Modelling and software	• Incomplete information regarding actual building performance (especially refurbishment) • No incentives to share learning (combined with inconsistency in their application and non-compliance) • Fragmentation of the supply chain	Critical failure
	Tools to identify retrofit opportunities	• Lack of information on performance of existing buildings as compared with new build • Identification and retrofit actions will need to make use of existing triggers (e.g. remodelling a bathroom) • Tools would need to be very sophisticated to see widespread uptake, however tools are currently poorly developed	Significant failure
	Design tools and services for district heating	• The UK has very limited district heating infrastructure, resulting in lack of information and experience	Moderate failure
Build process	Smart manufacturing processes	• Off-site production is fragmented and dominated by relatively small companies • Energy efficiency is often not the incentive for off-site and smart construction	Minor failure
	Industrialised retrofit techniques	• Refurbishing domestic buildings incurs a high ‘hassle cost’ meaning that householders are unlikely to carry out significant measures without incentives • Split incentives between landlords and tenants • Lack of materiality of energy costs • Lack of data to identify retrofit opportunities	Significant failure
Building operation	Smart controls and diagnostics	• Lack of materiality of energy costs does not encourage householders to alter their behaviour in order to save energy • Split incentive between landlords and tenants results in a lack of incentives for owners to invest in such controls if they are not householders • Lack of high quality data may prevent optimal design of controls and may prevent householders from becoming aware of where behavioural change may be able to reduce energy consumption	Significant failure
	Behaviour change	• Lack of materiality of energy costs does not encourage householders to alter their behaviour to reduce energy consumption • Lack of high quality data may prevent householders from becoming aware of where behavioural changes may be able to reduce energy consumption • Challenges in communicating energy performance data to householders	Significant failure
Materials and components	Improved fenestration	• Low perceived benefit and high cost • Would involve significant disruption during refurbishment	Moderate failure
	Advanced insulation and thermal materials	• Diverse nature of the building stock makes standardisation difficult • Inadequate incentives given high costs involved • Lack of knowledge about available systems and their importance to performance • Regulatory and insurance hurdles are significant for use of overseas technologies and materials	Critical failure
	Passive low carbon cooling and ventilation technologies	• Inadequate incentives to secure investment needed to address technology failures and reduce cost • The perceived risk of trying new technologies may dis-incentivise their use in favour of existing ‘tried-and-tested’ measures	Significant failure

Potential priorities to deliver the greatest benefit to the UK

The UK needs to focus its resources on the areas with the biggest relative benefit to the UK, and where there are no existing or planned initiatives (both in the UK and abroad).

While all technology areas in the domestic buildings sector would benefit from public sector activity, some would benefit more than others.

Chart 6 summarises the areas that would receive greatest potential benefit from UK public sector activity across all technology areas.

Chart 6 - Summary of greatest potential impact from UK public sector activity

	Sub-area	Value of energy saving (£bn)	Value of business creation (£bn)	UK competitive advantage	Extent of market failure	Opportunity to exclusively rely on others	Benefit of UK public sector activity
Pre-construction and design	Modelling and software	2.9 (1.3 – 5.5)	0.8 (0.4 – 1.6)	Medium-high	Critical	No	**High**
	Tools to identify retrofit opportunities				Significant	No	**High**
	Design tools and services for district heating				Moderate	No	**Medium**
Build process	Smart manufacturing processes	3.7 (1.6 – 8.6)	0.2 (0.1 – 0.4)	Low-medium	Minor	In part	**Low**
	Industrialised retrofit techniques				Significant	In part	**Medium**
Building operation	Smart controls and diagnostics	8.8 (1.4 – 21.2)	0.6 (0.1 – 1.5)	Medium	Significant	In part	**High**
	Behaviour change				Significant	In part	**High**
Materials and components	Improved fenestration	0.5 (0.2 - 2.3)	0.0 (0.0 – 0.2)	Medium	Moderate	In part	**Low**
	Advanced insulation and thermal materials				Critical	In part	**Medium**
	Passive and low carbon cooling and ventilation technologies				Significant	In part	**Low**
		16.0 (4.5 – 37.5)	**1.7 (0.6 – 3.7)**				

Source: BRE, Carbon Trust analysis

Potential priorities for public sector innovation support

In the sections above, key innovation needs and market failures were identified. The analysis points to a number of priorities for public sector investment in innovation. These include both overarching needs and those specific to each innovation.

Overcoming the various market failures will require an integrated approach. Although each area could be treated in isolation, all areas are interconnected and realising the full benefit of investment will require an integrated approach to solve the numerous market failures across the entire value chain.

Underpinning all innovations is a need for more data regarding building performance. There is currently a lack of knowledge surrounding the performance of buildings, hindering improvement. Gathering data on actual building performance is vital, and will support efficiency savings in all areas.

Investment is required in research and development across all technology areas, to develop new software and design tools, smart building operation controls and new products. As the UK is unique in terms of its building stock, usage patterns and climate, investment is also required in adapting innovations to UK conditions and to demonstrate them. A theoretical public sector support schema is shown in Chart 7.

Key overarching needs common across the domestic buildings sector include:

- A sophisticated national domestic buildings energy performance database
- Systematic gathering of best practice internationally
- Technology and process innovation road-mapping involving industry and government
- Independent, non-partisan research into specific innovation areas
- Broader research into what has worked and why
- Knowledge fora to disseminate benefits of different buildings technologies to designers and developers
- Convened fora to define new practices that integrate best available buildings technologies combined with knowledge sharing activities
- Development of essential skills using learning modules developed in partnership with learning from innovation demonstration programmes
- Greater incentives for landlords and tenants to improve energy efficiency

Though organisations such as the Zero Carbon Hub and the National Refurbishment Centre already play a role in facilitation, a high-level integrated hub for domestic buildings could manage data centrally, set targets, standards and benchmarks, and provide a centralised repository for knowledge across the domestic buildings sector.

A detailed assessment of needs, current activities, potential activities and the indicative scale of public sector support is shown in Chart 8.

Chart 7 - Summary schema of public sector support

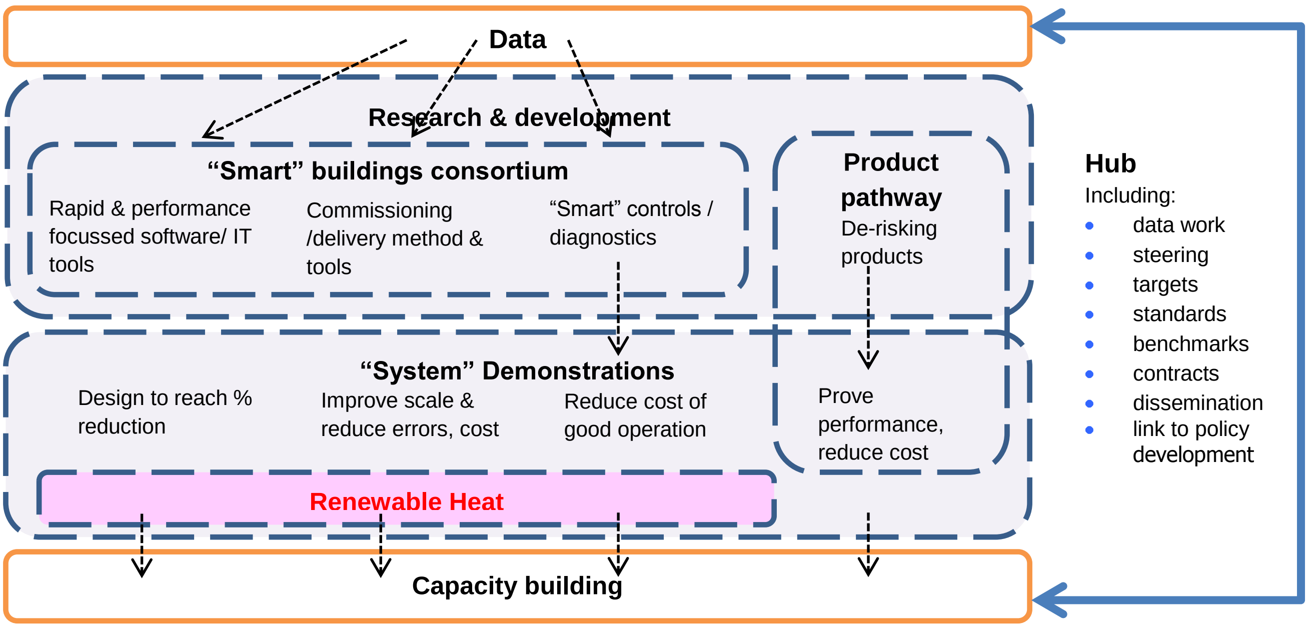


Chart 8 - Potential domestic buildings innovation priorities and support

Technology area	Key needs	Current activities	Future potential activities	Indicative scale of support
Pre-construction and design	• Improve the accuracy and speed of modelling and software by better incorporating operational performance data • Development and demonstration of modelling tools that enable designers to better assess and manage uncertainties in buildings' carbon performance. • Develop innovations that allow rapid assessment through mass surveying tools, of existing buildings to identify failures in performance • To ensure that the design of dwellings can accommodate and integrate with microgeneration and district heating technologies	• National Refurbishment Centre • TSB Retrofit for the Future • TSB Building Performance Evaluation programme • English House Condition Survey	• Prize funding challenge to develop tools for enhancing energy modelling techniques • Early pre-commercial demonstration programme for modelling tools and techniques • Establish consortia for retrofit tools • In-use data collection programme for highly-rated buildings • Convened consortia including major social landlords and professional bodies to define and demonstrate new practices, combined with knowledge sharing activities	Millions of pounds
Build process	• Development & demonstration of proven, cost-effective components and systems for off-site construction and installation of building elements • Development & demonstration of rapid, cost-effective solutions for low carbon retrofit that can be rolled out in a co-ordinated way	• Social housing retrofit (e.g. TSB Retrofit for the Future) • TSB Rethinking the Build Process • TSB Scaling-up Retrofit (2013) • *Insite* conference • DECC Solid Wall Insulation Research Programme	• Collaboration for evaluation and demonstration of off-site construction and industrial retrofit • Research and development of standard and community scale retrofit models • Support development of standard models that will be appropriate for different building and tenure types • Trial commercial model for community-scale refurbishment	Tens of millions of pounds
Building operation	• Timely information from and about household energy consuming systems and services • Research, development and early demonstration of smart metering and intelligent control systems that are appropriate to residents • Demonstration of technologies, promotions and other awareness raising initiatives is needed, which will assist behavioural change among building users by allowing them to automate control • Measures that translate to "unregulated" energy use (appliances and plug-in equipment), which is increasing	• ETI Smart Systems and Heat programme • TSB/BRE *Energy Pet* project • Ofgem Low Carbon Networks Fund • CIBSE Intelligent Buildings Group	• Collaborative research and development for smart controls • Incubation programme for methods to encourage behavioural change • Information dissemination programme • Data collection programme for highly-rated buildings • Research to evaluate the effectiveness of innovative systems on influencing householder behaviour	Millions of pounds
Materials and components	• Demonstration of advanced insulation and thermal materials, with some research for materials appropriate for retrofit • Demonstration of advanced fenestration, with some research for glazing materials appropriate for retrofit • Demonstration of demonstrate alternative technologies such as retrofit mechanical ventilation heat recovery (MVHR) systems	• BRE innovation park • Tata Centre, Wales • Sustainable Building Envelope Centre • AIMC4 • CIBSE Natural Ventilation Group	• Challenge-based collaborative R&D in early stage fabric technologies aimed at improving performance • Prize-funding for integration of later-stage technologies into real refurbishments combined with pre-commercial field trials to scale up • Field trials considering most efficient rated buildings, to see why they are performing better than average	Tens of millions of pounds

Source: AEA, expert interviews, Carbon Trust analysis

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