Technology Innovation Needs Assessment (TINA)

Non-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 Non-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 non-domestic buildings sector represents a significant opportunity to help meet the UK's GHG emissions targets, as well as providing value through avoided energy costs, amounting to savings of 86MtCO_2 and c. £13bn by 2050. Innovation could 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 failures across the sector to overcome.

Potential role in meeting UK's GHG emissions targets	• The energy used by non-domestic buildings accounts for approximately 18% of UK carbon emissions, while the buildings themselves are diverse in design and use. • By 2050, total UK non-domestic floor area is expected to increase by 35%, while 60% of existing buildings will still be in use. There is significant potential for energy savings across existing buildings, new builds and major refurbishments. • Innovative energy saving measures in non-domestic buildings could save 18MtCO_2 by 2020 and 86 MtCO_2 by 2050, depending upon the rate at which the measures can be deployed. • Across the technology areas of integrated design, build process, management and operation, and materials and components, innovations in management and operation would yield savings quickest, while innovations in build process would save the most carbon to 2050.
Value of abatement potential	• The potential net value from energy savings is c. £13bn to 2050. • Across the technology areas, innovations in integrated design and build process could deliver the most value, while innovations in materials in components will not provide significant value unless costs come down more rapidly than expected.
Green growth opportunity	• Additional global market value of innovative products in this sector could reach c. £488bn over 2010-2050, of which c. £200bn would be accessible to the UK. Of this, innovative products could provide an additional £1.7bn in value to the UK.
The case for UK public sector intervention	• Market failures exist across the buildings value chain, which are currently stifling innovation and progress in improving the energy efficiency of non-domestic buildings. • 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. • The buildings industry is generally domestic, so the UK will need to build capacity to implement energy efficiency measures. • Gathering data on actual building performance is vital to understand the value of energy savings, to implement measures effectively and to overcome split responsibility between different actors in the value chain.
Potential priorities to deliver the greatest benefit to the UK	• Public sector support could provide most value in integrated design, where there are significant potential carbon savings and value from energy costs. There are also significant market failures impeding integrated design innovations, and the UK has a medium-high competitive advantage in the area. • Investment in elements of build process and management and operation measures would also provide significant value, also featuring a number of market failures and lack of opportunity to rely on others. • Investment in materials and components innovations would provide some benefit, however the potential value and carbon savings would be significantly smaller than would result from investment in other areas. • Although each area could be treated in isolation, all areas are interconnected, and realising the full benefit of investment will require an integrated approach supporting innovation in each area.

Chart 1 - Non-Domestic Buildings TINA summary

Technology area	Value of energy savings (£bn)[1]	Value in business creation (£bn)[2]	UK competitive advantage	Potential public sector activity/investment
Integrated design	4.2 (1.4 – 6.8)	1.2 (0.4 – 2.0)	Medium - high	• Prize funding challenge to develop tools for enhancing energy modelling techniques • Collaborative R&D on design tools (DT) • Early pre-commercial demonstration programme for modelling tools and techniques • Convened consortia for demonstration of DTs
Build process	4.7 (1.8 – 9.1)	0.2 (0.1 – 0.4)	Low - medium	• Collaboration for evaluation and demonstration of off-site construction and industrial retrofit • Research and development of standard and community scale retrofit models. • Collaboration to develop online tools • Development of contractual frameworks • Demonstration of improved commissioning
Management and operation	3.1 (0.5 – 6.4)	0.2 (0.0 – 0.5)	Medium	• Collaborative research and development for smart controls • Incubation programme for methods to encourage behavioural change • Development of new carbon management systems and low-cost diagnosis via convened consortia and directed research, with pre-commercial demonstration and trials
Materials and components	0.6 (0.2 – 1.5)	0.1 (0.0 – 0.2)	Medium	• Applied research and development and incubation for low carbon cooling • Challenge-based collaborative research and development for advanced façade materials • Test centres for demonstration of advanced façade materials • Prize-funding for integration into real buildings across area with pre-commercial field trials (a non-domestic Retrofit for the Future)
Total	**£12.6 (3.9 –23.8)**	**£1.7 (0.5 – 3.0)**		

Benefit of UK public sector activity/investment [3]	
	High
	Medium
	Low

Source: BRE, Carbon Trust analysis

[1] 2010-2050 Low-Medium-High deployment with marginal cost of technology included to calculate value

[2] 2010 – 2050 with displacement

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

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

The energy used by non-domestic buildings accounts for approximately 18% of UK carbon emissions[4]. The buildings themselves are diverse in design and use, and are operated by a range of sectors. Overall, the UK's non-domestic building floor area is expected to increase by a third by 2050.

Carbon Trust research has revealed a significant opportunity from existing commercial measures – a 35% carbon saving is possible with a net benefit of at least £4bn by 2020. A carbon saving of 75% by 2050 is achievable at no net cost, however these savings, and additional savings from new technologies, will be difficult to realise without innovation.[5]

Experience from Carbon Trust buildings programmes demonstrates that design, construction and operation processes have equal or greater influence on carbon outcomes than technology in non-domestic buildings.[6]

The actual energy performance of a building will only reflect the design intent if the building is built and operated as designed, and currently there are a number of barriers preventing this. As a result, there is often a significant gap between design expectations and actual performance of a building.

An integrated approach is necessary to take into account the way buildings operate, as a system whose value is greater than the sum of each technology or component used, and in which interaction with users is critical.

Innovative measures could benefit the entire building lifecycle. Ensuring that buildings are constructed and operated as designed will require process innovations, and innovative tools and systems to enable new processes, while improving the physical performance of 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 those focusing on heat and electricity networks and storage.[7]

We have considered three deployment levels of innovations in non-domestic buildings. The amount of energy saved will depend upon the extent to which innovative measures can be applied to the non-domestic building stock[8] 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 user cooperation

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

The medium scenario is used as the central scenario for the following analyses.

[4] Digest of UK Energy Statistics; BRE

[5] *Building the future, today* (Carbon Trust, 2010)

[6] Carbon Trust Low Carbon Buildings Accelerator (LCBA) and Low Carbon Buildings Programme (LCBP) as well as previous *Energy Efficiency Best Practice (EEBP) projects*

[7] Other existing work in this area includes DECC's Pioneering Cities programme, and TSB and EPSRC Future Cities

[8] The building types considered in the TINA analysis include:

- Industrial
- Retail
- Hotels, restaurants and inns
- Commercial offices
- Schools
- Further and higher education
- Government estate
- Public offices
- Healthcare
- Sports
- Heritage and entertainment
- Transport/communications

Description of innovative measures

The innovative measures in this TINA are additional to existing commercial measures, as summarised in Chart 2. Innovations for non-domestic buildings can be split into four major technology areas: integrated design; build process; management and operation, and materials and components.

Integrated design innovations include:

- **modelling and software tools,** which could become faster and more accurate in using passive design to minimise the need for building services;
- **design tools and services,** knowledge tools that could be used to close the gap between design intent and actual performance by addressing the wide variety of buildings and incorporating feedback from operational buildings.

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, including products such as. tunnel-form concrete and tighter supply chain integration;
- **industrialised retrofit techniques**, new construction methods to reduce the cost of refurbishing existing buildings and improve the performance of refurbished buildings;
- **commissioning building services**, ensuring that services (heating, cooling, lighting, and ventilation) are put to use efficiently.

Management and operation innovations include:

- **smart controls and systems diagnostics,** predictive, intelligent user-oriented building management systems and diagnostic applications that optimise performance of building services;
- **carbon management services,** integrating landlord-tenant building management through new investment and leasing models to overcome split responsibility and identified lack of action. While these are not technology innovations, they are necessary process innovations;
- assisting **behavioural change** by providing users with clear information and incentives.

Materials and components innovations include:

- **advanced façade materials and integration**, improving the functional performance of façades to provide light, insulation, shading and ventilation whilst reducing the need for cooling;
- **advanced daylight technologies,** harvesting daylight from roofs and façades through skylights, fibre optics or other means;
- **advanced natural ventilation systems,** using ventilation stacks, atria and automatic openings combined with automatic control systems, passive cooling such as breathable walls, and the effective thermal mass of buildings to reduce cooling and ventilation energy;
- **low carbon cooling,** a range of technologies combined with building thermal mass and phase change materials to moderate temperature fluctuations.

Chart 2 - Comparison of examples of existing commercial and illustrative innovative TINA measures

	Existing commercial measures	Illustrative innovative TINA measures
Integrated design	• Simplified energy modelling used for new build • Dynamic modelling applied to selection of new build and refurbishment projects	• More advanced modelling • Measures to improve accuracy • Incorporating building performance data into design tools.
Build process	• Predominantly traditional construction • Sample details • Manual inspection	• Moves to off-site construction • Automated surveying and inspection tools • Improved process for commissioning and handover • Tools allowing correct sizing of building services
Management and operation	• Programmable thermostats • Reduce room temperature • Optimise start times • Thermostatic radiator values (TRVs) • Lighting – basic timers, turn off for 1 hour, presence detectors • Energy management monitors	• Targeted real time energy usage information • Greater use of hand-held devices for energy efficiency applets • New investment and leasing models that overcome split responsibility between designers, contractors and building occupants • Predictive controls
Materials and components	• Traditional insulation materials • Ventilation shafts and stacks • Light-pipes & sun-pipes • Triple glazing with coatings and insulating gases	• Optic fibre daylighting • 'Switchable' glazing • Dynamic insulation and thin insulation products • Free cooling systems (e.g. groundwater)

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[9]:

- the **uptake** of the innovation, i.e. the maximum proportion of existing floor area 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, integrated 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.

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

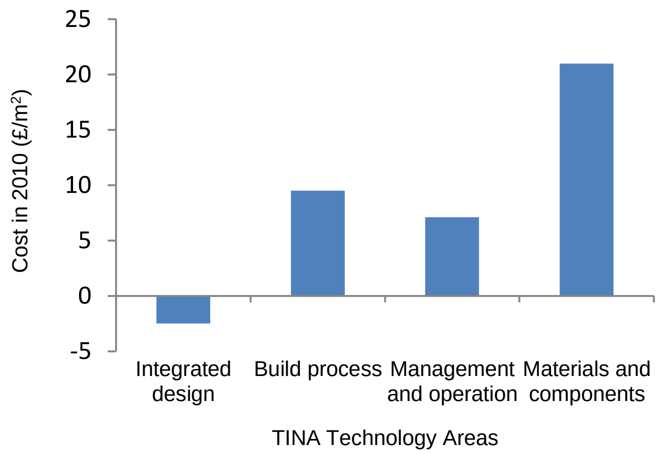
Costs

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 these additional costs. Costs reduce over time with increased levels of uptake and technical advances that reduce the cost of implementation. Starting costs (in 2010) are shown in Chart 3.

- **Integrated design** – costs are negative because cost savings achieved by avoiding the need for additional building services are expected to outweigh the additional costs associated with innovative integrated design solutions
- **Build process** – costs of new materials and specialist skills anticipated to be marginally more than conventional products
- **Management and 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 and commissioning)

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

Chart 3 - Initial costs of innovative measures



Source: BRE, Carbon Trust analysis

9 Values and rationale for these assumptions are provided in the TINA

10 DECC IAG data

Innovative measures could save an additional c. £13bn and 86MtCO_2 by 2050

These savings would result from energy savings of 460 TWh, or 4% over counterfactual energy demand. Chart 4 shows the annual carbon savings resulting from these energy savings. Note that while carbon savings generally decrease with time due to grid decarbonisation, energy savings are still significant out to 2050.

Innovations in integrated design could save £4.2bn and 22MtCO_2 by 2050

Measures in integrated design apply only to new builds and major refurbishments, and so initial savings are small. As more buildings are built or refurbished, carbon savings grow significantly as accessible floor area ceases to be a limiting factor.

Large cost savings are due to a combination of factors: savings continue to 2050, as energy prices are projected to rise; and the costs of integrated design measures are negative, as they reduce the need for costs elsewhere. Note that the ability of integrated design innovations to deliver this value will be influenced by the quality of building performance data.

Innovations in build process could save £4.7bn and 38MtCO_2 by 2050

As with savings from integrated design, build process innovations are initially limited to the new build and refurbishment rates of buildings, however build process innovations ultimately provide the most significant carbon savings of all technology areas. Cost savings are large due to significant uptake in new build and refurbished stock.

Innovations in management and operation could save £3.1bn and 20MtCO_2 by 2050

Savings from management and operation measures are realised very quickly as they are applicable to the existing building stock. However, savings decrease rapidly with grid decarbonisation and as more existing buildings are demolished or refurbished. Measures also have shorter lifetimes as they are associated with the lifetimes of building services rather than of the buildings themselves, and tend to be less effective over time as they are subject to user engagement.

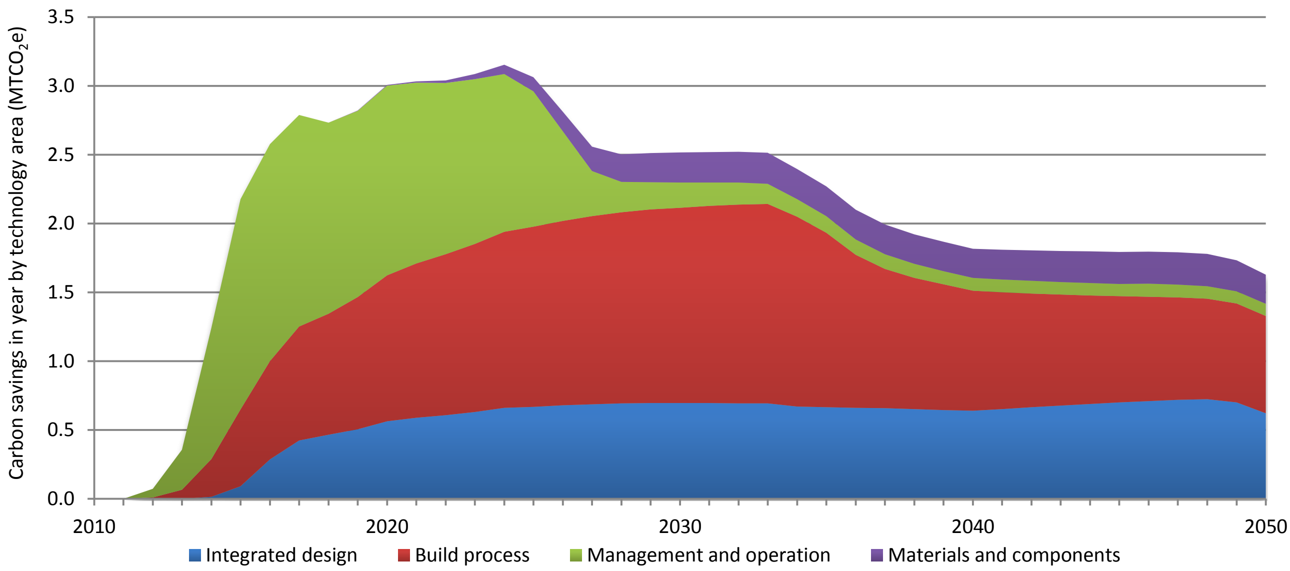
The value of energy savings is smaller in comparison with integrated design and build process due to the timing of the savings – most energy savings are made before energy prices are expected to rise significantly. However, the carbon abatement potential is still significant and can be achieved rapidly.

Innovations in materials and components could save £0.6bn and 6MtCO2 by 2050

Savings from innovative materials and components 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.

Chart 4 - Annual carbon savings



Source: BRE, Carbon Trust analysis

Chart 5 - 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[1] (£bn)			NPV per tonne CO_2 saved (£/tCO_2)	NPV per MWh saved (£/MWh)
			Low	Medium	High		
Integrated design	2	22	1.4	4.2	6.8	185	31
Build process	5	38	1.8	4.7	9.1	125	23
Management and operation	10	20	0.5	3.1	6.4	157	37
Materials and components	0	6	0.2	0.6	1.5	105	17
TOTAL	**18**	**86**	**3.9**	**12.6**	**23.8**		

Source: BRE, Carbon Trust analysis

Green growth opportunity

The global market for innovative products is estimated to be c. £488bn

The global market size for innovations in the non-domestic buildings sector is estimated using the available value from energy and carbon 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[11] have markets that are similar to the UK, with similar future requirements. 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. 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 **integrated 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.

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 intellectual property rights (IPR), skills and specialist tools, specialist components, services and construction approaches.

The tradable portion for **management and 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

[11] Based on the UN Human Development definition

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 **integrated 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 **management and 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.

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 value of the energy and carbon savings that would be redistributed within the UK economy.

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:

- **The landlord-tenant divide -** where one party has no incentive to invest in carbon reducing measures as the other party receives the benefit of the investment. This also prevents data sharing from buildings' energy use.
- **Energy costs are not seen as material** – occupiers place a greater premium on the look, comfort and productivity of a building rather than its energy use, so companies are not prepared to pay a premium in rent for a low carbon building.
- **Lack of knowledge** – companies do not have tools or knowledge to identify low carbon buildings, in part as there is no labelling for high performance buildings outside the public sector.
- **Existing building regulations are not tight enough**, sufficiently enforced, or integrated well with planning tools.

These barriers lead to a 'circle of inertia[12]', where each party believes they cannot act because of the behaviour of another party.

Contractors might say

I could build but developers won't specify

Developers might say

I would specify but funders won't provide finance and tenants are not asking for them

Funders might say

I would provide finance but there is no occupier demand

Tenants might say

I might choose a low carbon building but there aren't any and energy is not a material cost of occupancy

[12] *Building the future, today, Carbon Trust (2010)*

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

- **The building sector has a fragmented supply chain**, with multiple sources of impact on carbon performance and hence multiple opportunities for carbon potential to be lost.
- **The building sector is conservative**, and reluctant to adopt new approaches without clear prior demonstration.
- **Lack of necessary skills** to implement novel technologies and solutions throughout the supply chain
- **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 market failures, which vary within each technology area, summarised in Chart 6.

The critical failure in modelling and software is due to a lack of incentives to share data - neither building owners nor operators provide (or even have access to) the necessary data on building performance. Similarly, developers do not conduct modelling incorporating unregulated demand (demand arising from appliances rather than integrated building services).

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 expect others to develop needed innovations. 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 integrated design innovations where the UK is already a world leader.

Integrated 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 commissioning building services (part of the build process) and developing advanced natural ventilation systems – 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 6 - Market failures in non-domestic buildings innovation areas

	Sub area	What market failures exist?	Extent of market failure
Integrated design	Modelling and software	• Split incentives between tenants and landlords • Lack of materiality of energy costs • Diffuse nature of sector	Critical failure
	Design tools and services	• Split incentives between tenants and landlords • Lack of materiality of energy costs • Diffuse nature of sector	Moderate failure
Build process	Smart manufacturing processes	• Off-site production is fragmented and dominated by relatively small companies with little effective coordination or partnering with major contractors • Imperfect information about benefits combined with high "proving cost" and risk to individual firms	Minor failure
	Industrial retrofit techniques	• Split incentives between tenants and landlords • Lack of materiality of energy costs • Coordination failure is also a problem – facilitating cooperation between landlords is very challenging as no single landlord has an incentive to initiate it	Significant failure
	Commissioning building services	• Existing contractual frameworks do not allow for it • Lack of awareness of need and value • Lack of professional skills needed within trades • No regulatory drivers as it sits beyond building codes • Omission of the need in most building energy strategies	Significant failure
Management and operation	Smart controls and systems diagnostics	• Split incentives between tenants and landlords • Disconnect between the people who procure/design control systems and those who operate them • A lack of information driven by coordination issues in fragmented industry	Significant failure
	Carbon management systems	• Split incentives between tenants and landlords • Lack of materiality of energy costs • Absence of regulatory certainty • Lack of standardised contractual frameworks • Lack of awareness of the need and value	Moderate failure
	Behaviour change	• Lack of materiality of energy costs • Lack of strong regulatory certainty • The "valley of death" represents a problem for many technologies in the sector that are in an early stage of development and may lack appropriate capabilities	Moderate failure
Materials and components	Advanced facades materials and integration	• Inadequate incentives, given the high costs involved • Diverse nature of building stock makes standardisation difficult, constraining potential market size and dis-incentivising investment in production • Lack of knowledge about the systems available and their importance to performance	Critical failure
	Advanced daylight technologies	• Inadequate incentives to secure investment needed to address technology failure and reduce costs • Supply chain failure (with suppliers of lighting systems failing to incorporate daylight systems in their service offers) • Lack of knowledge about the systems available and their importance to performance	Significant failure
	Advanced natural ventilation systems	• Inadequate incentives to secure investment needed to address technology failure and reduce costs • Investors and stakeholders perceive high technology risk • Imperfect information about benefits	Significant failure
	Low carbon cooling technologies	• Significant regulatory barriers: feasibility assessments are expensive and can involve high risk • Inadequate incentives to secure investment needed to fund early stage research, development and demonstration, aimed in particular at finding ways of overcoming significant practical obstacles and to reduce costs • There is a knowledge gap about what is possible and imperfect information based on failure of past systems	Significant failure

Source: Expert interviews, Carbon Trust analysis

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).

Innovation areas with the biggest relative benefit from UK public sector activity/investment

While all technology areas in the non-domestic buildings sector would benefit from public sector intervention, integrated design represents a significant opportunity given the high potential value from energy and carbon savings, medium-high competitive advantage, extensive market failures and no opportunities to rely on others to develop needed innovations.

Investment in elements of build process would also provide significant value, as it suffers from a number of market failures and lack of opportunity to rely on others, particularly in smart manufacturing processes where the industry is already well developed in Germany, Sweden and Austria.

Investment in management and operation innovations would provide value quickly, as measures here can be applied to existing buildings. These are mostly innovations in processes that would allow buildings to be operated as designed.

Investment in materials and components innovations would provide some benefit, however the potential value and carbon savings would be significantly smaller than would result from investment in other areas. **Error! Reference source not found.** summarises the areas that would receive the greatest potential benefit from UK public sector activity across all technology areas.

Chart 7 - Summary of greatest potential impact from UK public sector activity

	Sub area	Value from energy savings (£bn)	Value from business creation (£bn)	UK competitive advantage	Extent market failure	Opportunity to rely on someone else	Benefit of UK public sector activity
Integrated design	Modelling and software	4.2 (1.4 – 6.8)	1.2 (0.4 – 2.0)	Medium - high	Critical	No	**High**
	Design tools and services				Moderate	No	**High**
Build process	Smart manufacturing processes	4.7 (1.8 – 9.1)	0.2 (0.1 – 0.4)	Low - medium	Minor	In part	**Low**
	Industrialised retrofit techniques				Significant	In part	**Medium**
	Commissioning building services				Significant	No	**High**
Management and operation	Smart controls and system diagnostics	3.1 (0.5 – 6.4)	0.2 (0.0 – 0.5)	Medium	Significant	In part	**Medium**
	Carbon management services				Moderate	In part	**Medium**
	Behaviour change				Moderate	In part	**Medium**
Materials and components	Advanced façade materials and integration	0.6 (0.2 – 1.5)	0.1 (0.0 – 0.2)	Medium	Critical	In part	**Low**
	Advanced daylight technologies				Significant	In part	**Low**
	Advanced natural ventilation systems				Significant	No	**Medium**
	Low carbon cooling technologies				Significant	In part	**Low**

Source: BRE, Carbon Trust analysis

Potential priorities for public sector innovation support

In the sections above, we identified the key innovation needs and the market failures hindering these innovations. 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, illustrated in Chart 8. 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.

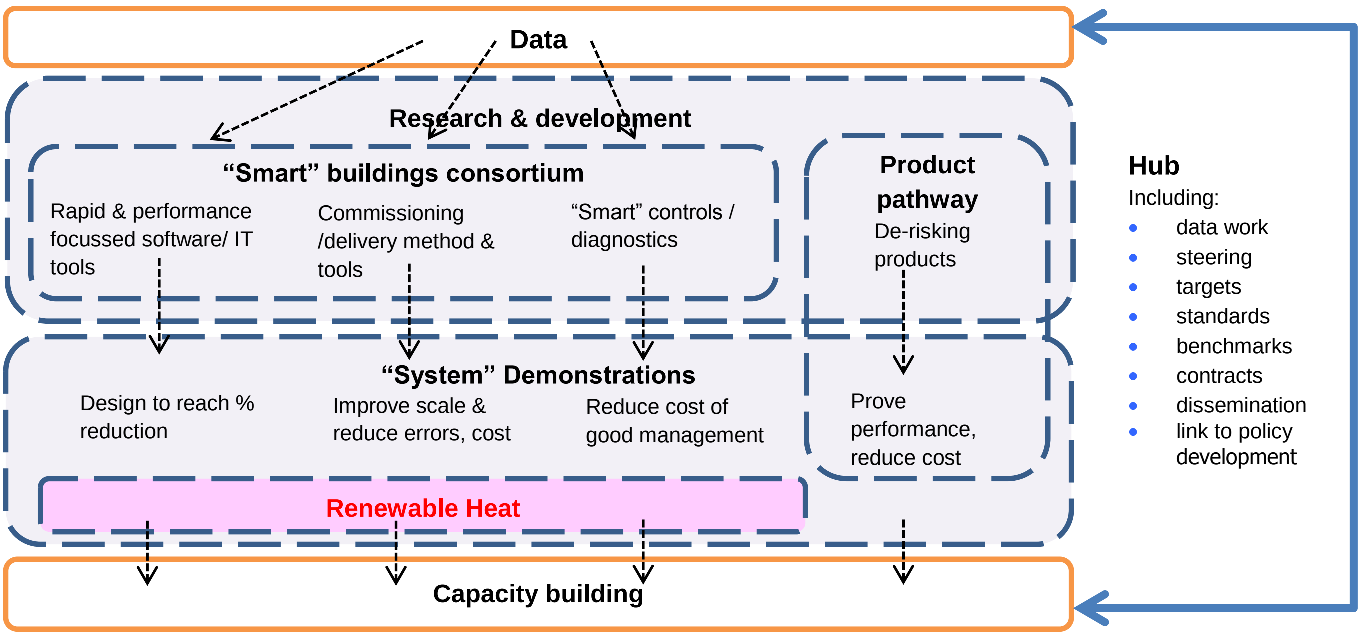
Underpinning all innovations is a need for more data regarding building performance. There is currently a lack of knowledge surrounding the performance of buildings, hindering improvement. Gathering data on actual building performance is vital, and will support efficiency savings in all areas.

Investment is required in research and development across all technology areas, to develop new software and commissioning tools, smart building management 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.

To establish the integrated approach required, a low-carbon non-domestic buildings hub would provide policy direction, set targets, define standards, provide benchmarks, develop contracts and disseminate the latest knowledge across the sector. This hub might be a non-domestic counterpart to Zero-Carbon Hub, featuring:

- A national non-domestic buildings energy performance database
- Systematic gathering of best practice internationally
- Technology and process innovation road-mapping involving industry and government
- Developing fact-based parameters to support the definition of low/zero carbon requirements, and the creation of aspirational standards for different building types
- Independent, non-partisan research into specific innovation areas
- Broader research into what has worked

Chart 8 - Summary schemata of public sector support programme



There are also a number of overarching needs that require non-innovative but necessary interventions. These include:

- **Exemplar buildings**, e.g. a target for percentage of new and major refurbishments of public sector buildings to be zero carbon
- **Development of new contractual models** for procurement of low carbon buildings
- **Knowledge Forum** to disseminate benefits of different buildings technologies to architects and engineers and others in the value chain
- **Convened fora**, including major landlords and occupiers, 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
- **Tighter building regulations** for refurbishments
- **A transparent market:** DECs for all non-domestic buildings
- **Greater incentives** for landlords and tenants to improve energy efficiency
- **Finance for low carbon refurbishment** and capitalisation of energy efficient new buildings

Chart 9 - Potential non-domestic buildings innovation priorities and support

Technology area	Key needs	Indicative scale of public funding	Current activities/investments	Future potential activities
Integrated design	• Improve the accuracy and speed of **modelling and software** by better incorporating operational performance data • Lower cost **design tools and services** that better incorporate feedback from operational buildings and the performance of their energy efficiency-related elements	Millions of pounds	• TSB "Design & Decision Tools" programme • TSB Building Performance Evaluation programme	• Prize funding challenge to develop tools for enhancing energy modelling techniques • Collaborative R&D on design tools (DT) • Early pre-commercial demonstration programme for modelling tools and techniques • Convened consortia for demonstration of DTs.
Build process	• Development of more flexible and cost effective **smart manufacturing** processes/technologies • Demonstration and adaptation of ***low carbon*** **off-site and modern on-site construction** processes • Development of rapid, cost-effective and feasible **industrialised retrofit techniques**. • Research and development of online digital tools enabling carbon **performance-based commissioning** • Scaling up demonstration of improved **commissioning processes**	Tens of millions of pounds	• Buildoffsite • Social housing retrofit (e.g. TSB Retrofit for the Future) • DECC programmes • BSRIA "Soft Landings" • RICS Ska Rating tool • CIBSE technical manuals for commissioning • TSB 'Rethinking the Build Process'	• Collaboration for evaluation and demonstration of off-site construction and industrial retrofit • Research and development of standard and community scale retrofit models. • Collaboration to develop online tools for commissioning • Development of contractual frameworks for commissioning • Demonstration of improved commissioning
Management and operation	• Research, development and demonstration of **smarter control systems** • Research and development of tools and techniques for low-cost diagnosis of energy efficiency measures for **carbon management**. • Early pre-commercial demonstration to test effectiveness of algorithms of diagnostic systems for **carbon management**. • Late stage demonstrations to test/prove **'re-commissioning' services** and methods over a range of non-domestic buildings. • Late stage demonstrations to rest/prove **behavioural change** technologies at scale.	Millions of pounds	• EPSRC/TSB funding for "user-centred buildings" • DECC programmes • EU FP7 Energy Efficient Buildings (E2B) • DECC pilot for non-domestic version of National Energy Efficiency Database (NEED) • LDA support for Better Buildings Partnership • Investment in Low Carbon Workplace Ltd and Standard • BREEAM In-Use	• Collaborative research and development for smart controls • Incubation programme for behaviour modifiers • Development of new CMSs and low-cost diagnosis via convened consortia and directed research, with pre-commercial demonstration and trials
Materials and components	• Research, development and demonstration of advanced façade materials, advanced natural ventilation systems, daylighting and low carbon cooling technologies • Late stage demonstrations that integrate technically proven advanced materials and components into commercial developments to assess and improve commercial viability to meet Green Deal criteria	Tens of millions of pounds	• DECC programmes • BRE innovation park • Tata Centre, Wales • Sustainable Building Envelope Centre • University research • TSB 'Invest in Innovative Refurbishment'	• Applied research and development and incubation for low carbon cooling • Challenge-based collaborative research and development for advanced façade materials • Test centres for demonstration of advanced façade materials • Prize-funding for integration into real buildings across area with pre-commercial field trials to scale up (a non-domestic Retrofit for the Future)

Source: Expert interviews, Carbon Trust analysis

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