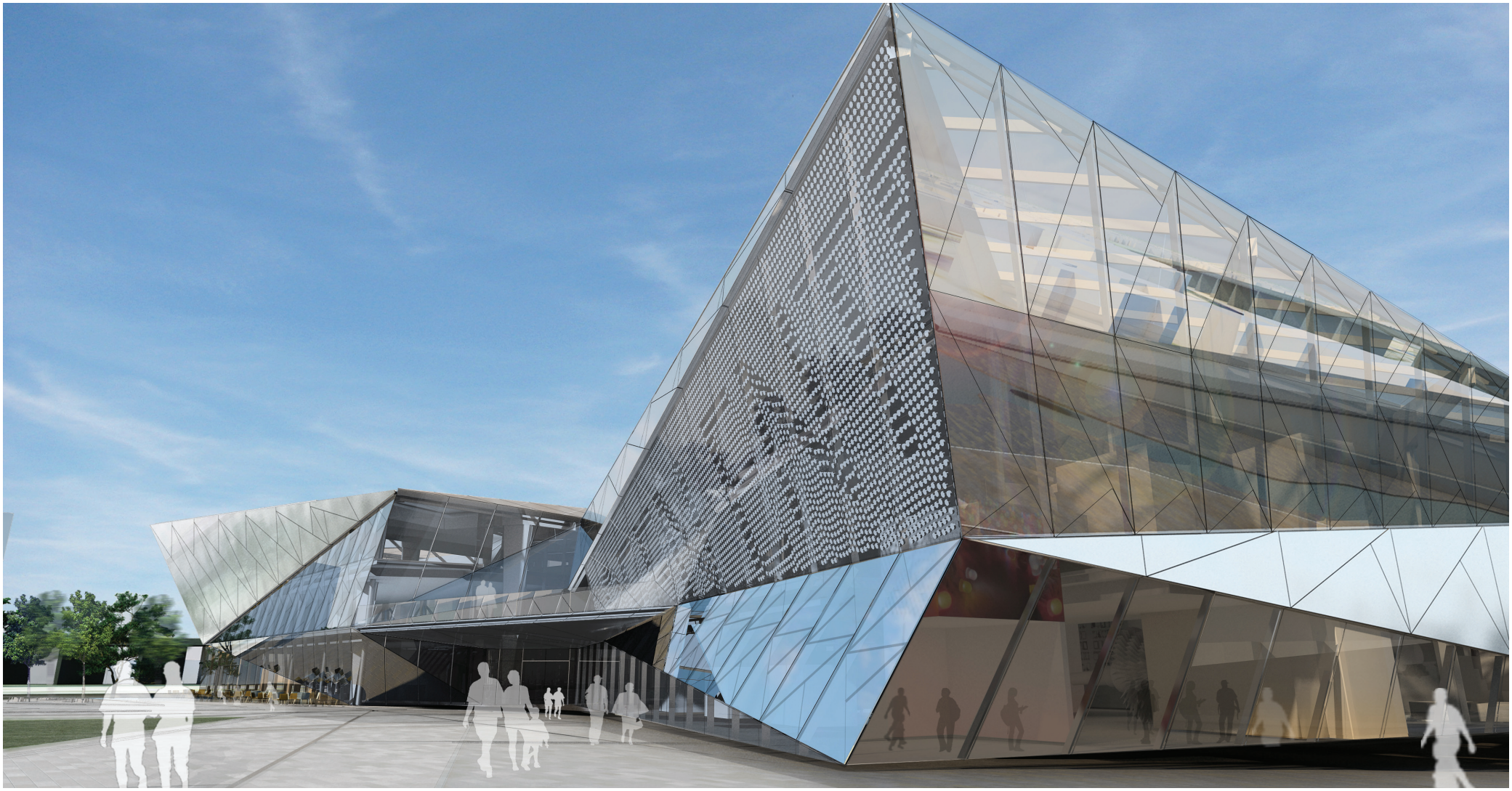
UK Roadmap for Energy Efficient Buildings



National Platform for Construction

Knowledge Transfer Network

Modern Built Environment

Executive Summary

The Modern Built Environment KTN, EPSRC and the Technology Strategy Board supported a workshop in March 2012 to seek opinions on the shape of innovation and research in energy efficient buildings in the UK. The workshop explored what the innovation gaps are, what are the key barriers and where resources should be targeted in order to maximize the impact of public funding for UK businesses. Attendees included a selection of high level executives from industry, government and funding agencies. There were also representatives from a number of research centers and senior academics from universities across the country. The list of registered participants is included in the Appendix.

The meeting outcomes contribute to build a roadmap for research and innovation in Energy Efficiency. It can be used to inform conversations with the Green Construction Board, Research Councils, Catapult Centers, BIS, DECC, European Commission, etc. This first step towards a UK roadmap on Energy Efficiency has been endorsed by the National Platform for the Built Environment which is an industry-led group focused on increasing the level of business-led research applicable to the built environment and to create a powerful voice to enable the industry to establish a strategic research agenda and influence the regulatory environment.

Methodology

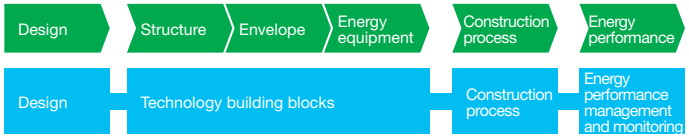
The workshop initially explored relevant challenges and drivers for innovation in construction based on the National Platform report on Challenges and Research Priorities of the Construction Industry (November 2011). This report reviews recent construction sector reports and existing research roadmaps to identify key challenges faced by the UK construction industry.

The challenges more relevant to Energy Efficiency were selected by the groups. Challenges in this context are defined as a "practical need specific to the construction industry that arises as an implication of general trends and visions, whose realisation may be hindered due to constraints, and which requires specific responses or enablers"

This exercise resulted in the selection of 12 out of 67 key challenges, or 'drivers', across five main categories:

- Demographics
- Global Economy
- Climate Change Adaptation
- Climate Change Mitigation, including: Energy generation and supply; Carbon in project design; Low carbon economy
- Industry factors, including: Capability, Procurement, Performance

The next step involved exploring targets and barriers for innovation in the building sector to develop and validate, the tools, technology and process components to support the transition towards an energy neutral European built environment. The targets were extracted from the E2BA Energy Efficient Buildings Association Vision to 2020. The suitability and completeness of those targets for the UK was explored by participants grouped following the different elements of the construction supply chain as per the diagram below.



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At the *design* stage that more than 80% of the building performance is set both in terms of energy savings and cost of ownership over the life cycle before refurbishment.

Structural parts of a building can be mechanically and thermally optimized with sophisticated tools: the focus must now be put on the embedded CO2 which comes from the materials.

The *building envelope* becomes the most critical part when it comes to energy efficient buildings. For new buildings, materials and energy equipment integration already allow low energy demand but investment costs must be reduced. For refurbishment, a whole value chain innovation process is required where design, technology and construction are even more intertwined than for new buildings.

Energy equipment must adapt to the lower unit energy demand from more energy efficient buildings, which requires sizing down to-day portfolio while keeping energy efficiency at the highest level possible as well as unit investment cost down.

Construction processes are now part of the critical path to reach the final energy performance. Any defect can lead to disorders and even pathologies which hamper the durability of the building performance. Several complementary routes can be envisaged i.e. prefabrication of standard units which facilitate field integration, new field integration process with more detailed internal performance control, new sensors to check intermediate performance steps, continuous improvement processes as part of a quality process, training of workers on the impacts of a wrong installation on the final energy performances, etc.

Performance monitoring enables users to oversee and control their own consumption, allows detecting potential misuses of buildings due to a lack of awareness of the users, potential disorders and/or pathologies of the monitored building. Moreover, conditional maintenance approaches can bring added value in guaranteed performance contracts.

The workshop finally explored the R&D trajectories for each of the above value chain elements of the building sector. Progressive market availability of technologies and processes came from large scale demonstration priorities. For technologies that have been already demonstrated, large scale deployment raised technical and non-technical issues that need to be resolved to ensure industrial uptake of research results.

The resulting R&D, Demonstration and Deployment elements were summarized and prioritized by each group. Prioritization was based on what are the key activities that will better contribute to an innovative Energy Efficient Built Environment in the UK. The next step to take the resulting actions and aspirations forward would involve the validation and development of an action plan to specify what needs to be addressed and who might do it. R&D and demonstration actions that were not selected would also need to be reviewed.

The results presented in this report have already been used to feed into the European agenda on energy efficient buildings for Horizon 2020 through the Energy Efficient Buildings Association.

The following pages present for each element of the supply chain key drivers, targets, barriers, industry responses (R&D, demonstration and deployment) and selected actions. Color coded lines and boxes are shown to illustrate the link of each item to the resulting selected actions.

Prepared by Marta Fernandez, Arup

Selected Actions

Design

Improve rigour in energy performance modelling

Establish minimum standards for Energy Performance Certificate in existing buildings

Build a fine grained BIM database of buildings/ cities with real time feedback

Structure

Develop workable retrofit solutions

Explore Deriving Benefit from Materials – knowledge based approach to material selection and therefore benefits derived; re-use of materials

Research Novel Materials – Bridging gaps in current materials performance; solutions for problems with no current solution

Envelope

Improve theoretical understanding of practical measures to improve current stock, requiring detailed analysis of optimal solutions and analysis of current stock

Demonstrate planning friendly solutions and reduce industry fragmentation of communication to reduce planning resistance and improve compliance with regulations.

Provide performance warranties and innovative financing models to overcome resistance to investments due to high capital costs

Energy Equipment

Agree a long term fully defined strategic goal to achieve optimum energy performance

Explore business model innovations

Research heat optimisation

Construction Process

Promote inter-operability – European platform/ network of facilities to test and validate innovative construction processes

Study kit of parts process – R&D for cost effective innovative robotised/automated construction tools to optimise the installation and fitting of prefabricated solutions

Explore flexible structure – warranties, contracts, risk, liability, rapid prototyping

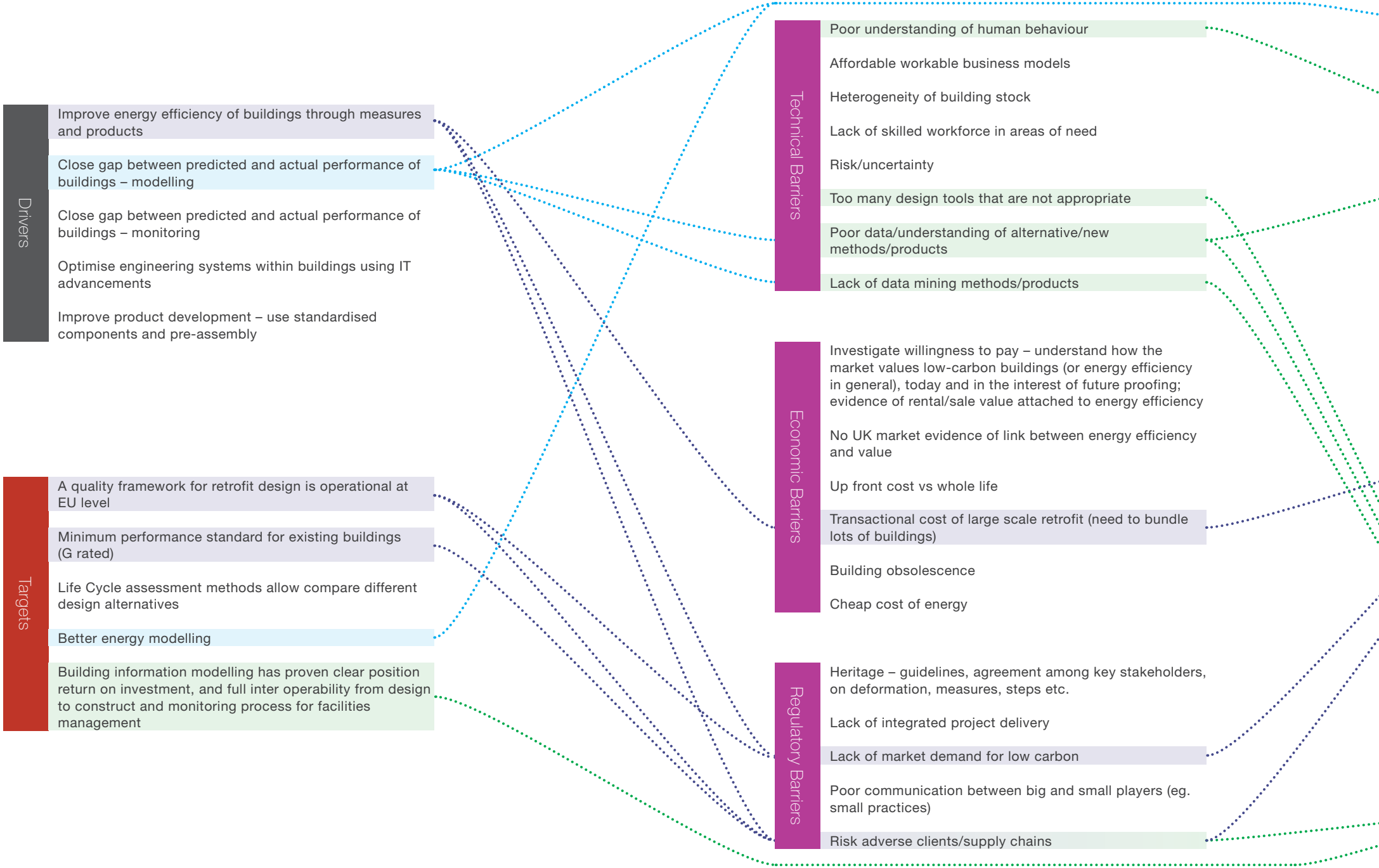
Energy Performace

Maintain EU investment in a pan-European PPP network to provide a consistent basis for energy performance R&D funding support

Develop a long term strategy for R&D investment to improve maintenance approaches and practices in energy performance

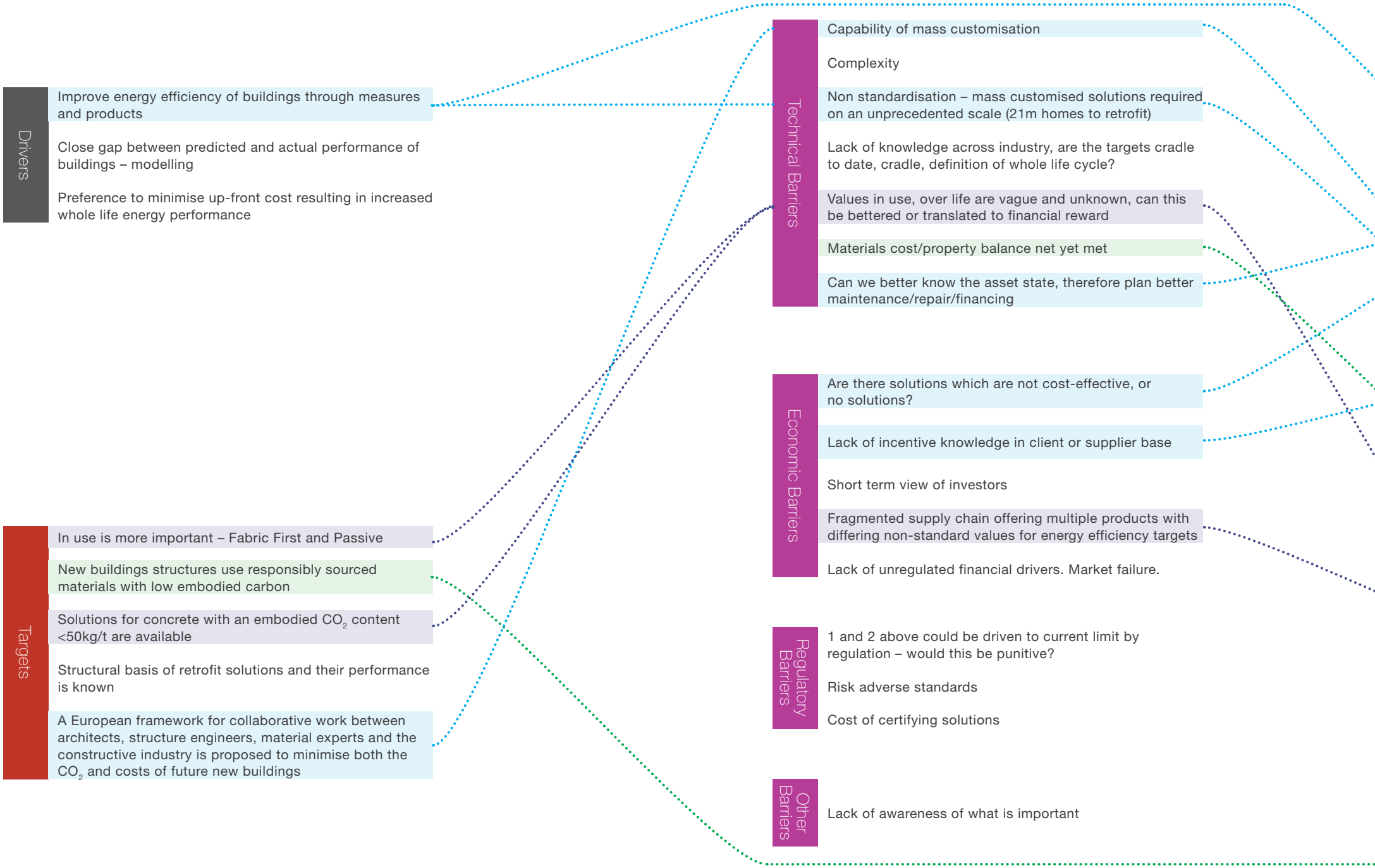
Disseminate and roll-out of solutions

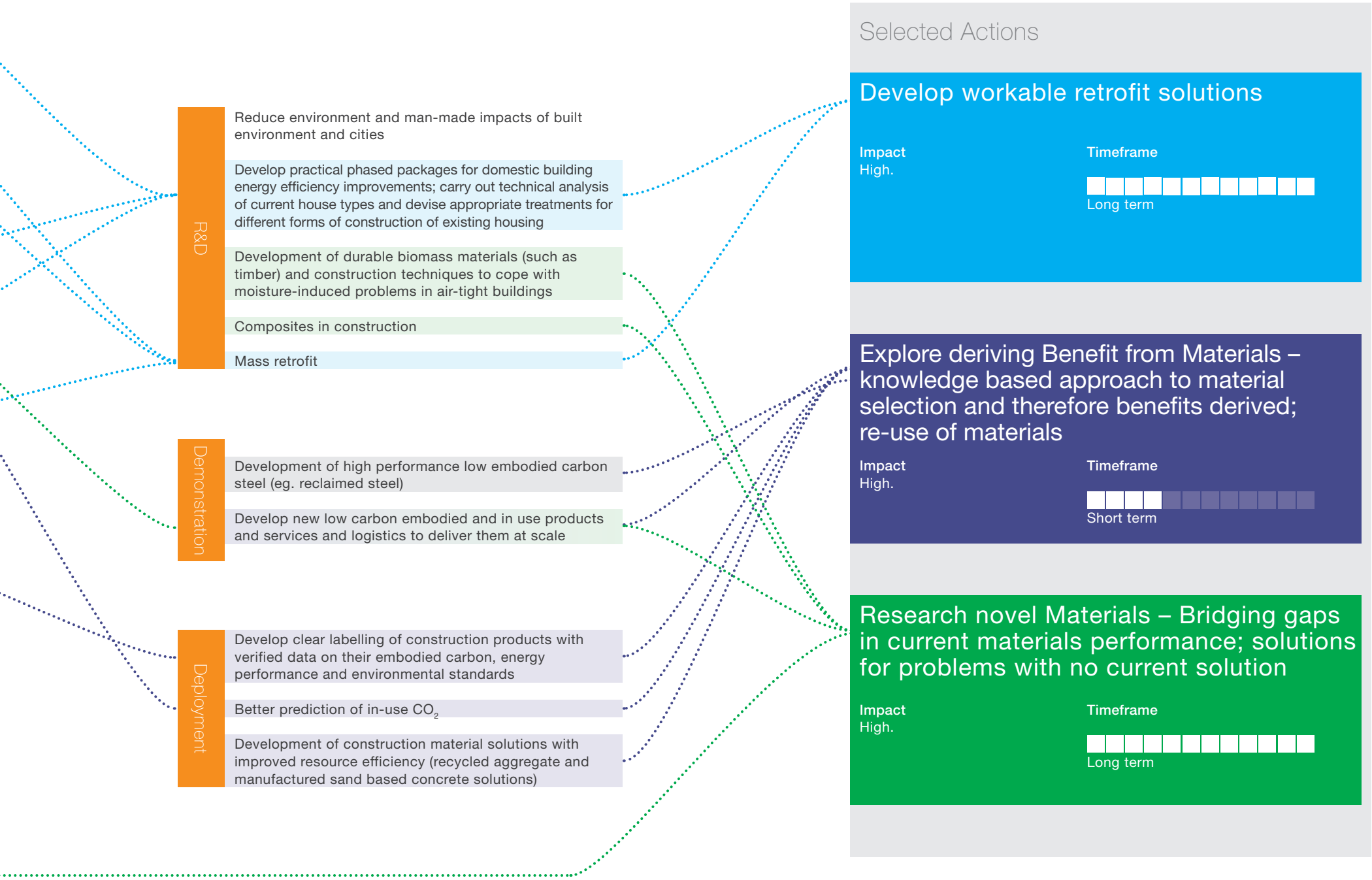
Design


Drivers
Improve energy efficiency of buildings through measures and products
Close gap between predicted and actual performance of buildings – modelling
Close gap between predicted and actual performance of buildings – monitoring
Optimise engineering systems within buildings using IT advancements
Improve product development – use standardised components and pre-assembly
Targets
A quality framework for retrofit design is operational at EU level
Minimum performance standard for existing buildings (G rated)
Life Cycle assessment methods allow compare different design alternatives
Better energy modelling
Building information modelling has proven clear position return on investment, and full inter operability from design to construct and monitoring process for facilities management
Technical Barriers
Poor understanding of human behaviour
Affordable workable business models
Heterogeneity of building stock
Lack of skilled workforce in areas of need
Risk/uncertainty
Too many design tools that are not appropriate
Poor data/understanding of alternative/new methods/products
Lack of data mining methods/products
Economic Barriers
Investigate willingness to pay – understand how the market values low-carbon buildings (or energy efficiency in general), today and in the interest of future proofing; evidence of rental/sale value attached to energy efficiency
No UK market evidence of link between energy efficiency and value
Up front cost vs whole life
Transactional cost of large scale retrofit (need to bundle lots of buildings)
Building obsolescence
Cheap cost of energy
Regulatory Barriers
Heritage – guidelines, agreement among key stakeholders, on deformation, measures, steps etc.
Lack of integrated project delivery
Lack of market demand for low carbon
Poor communication between big and small players (eg. small practices)
Risk adverse clients/supply chains

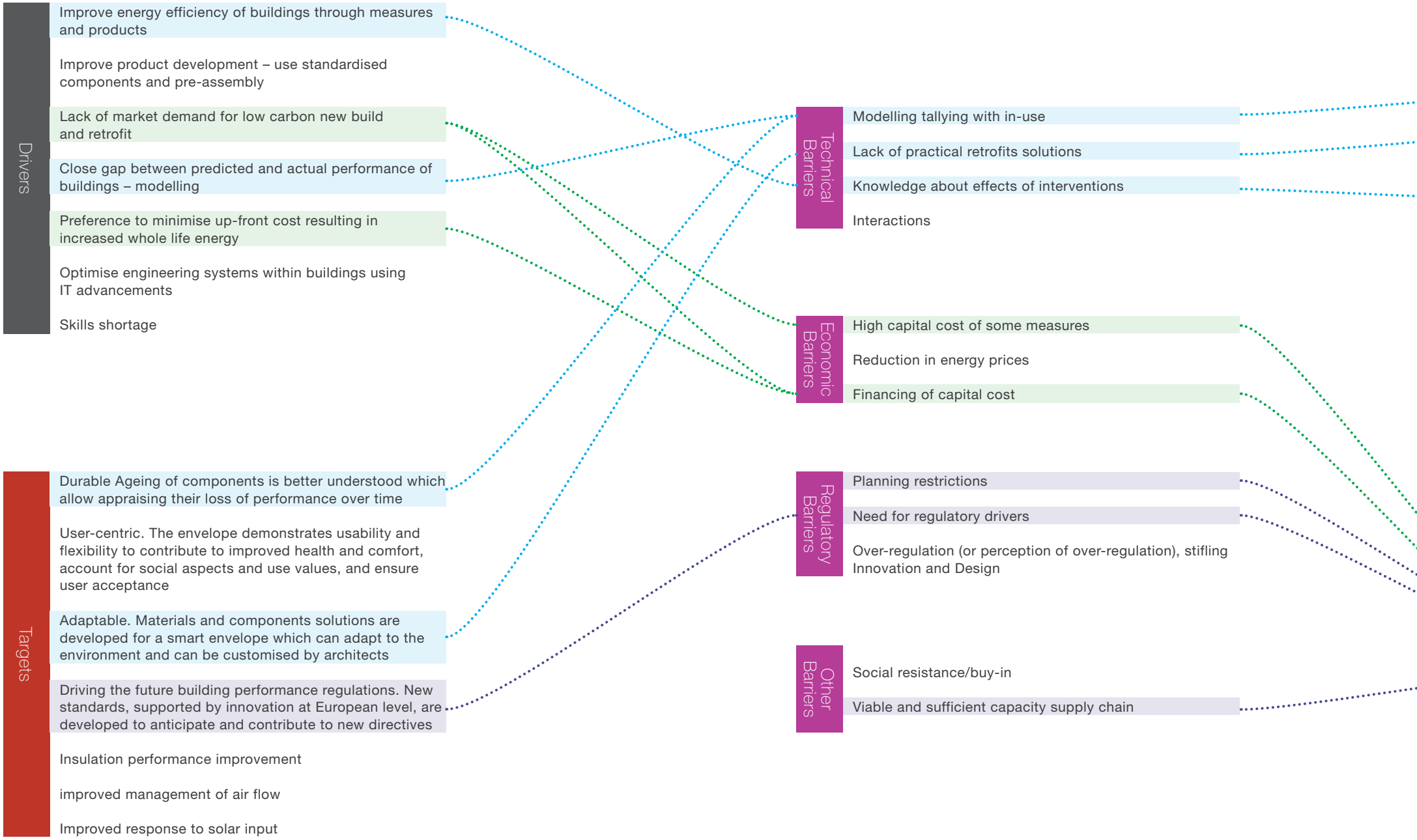

R&D
Develop more rigorous estimates of energy performance based on real situations and incorporate this into models
Evaluation/comparison of design tools using real world case studies
Real-time performance of energy-efficient building design: Enhance building – grid – user interaction flexibility to enable sound strategies for peak-load abatement while ensuring high comfort to the users, eg. predictive/adaptive controls, load shifting and energy storage
Demonstration
Develop innovative training techniques to speed up the adoption of BIM and related data exchange standards
Ongoing monitoring of new-build and retrofitted properties to assess the actual performance of measures against modelled predictions
Introduce minimum standards for existing buildings by mandating Energy Performance Certificate ratings for all non-domestic buildings
Set up BIM demonstrations to validate return on investment for a wide scope of end users (case studies)
Develop building stock dynamics models and tools
Deployment
Deployment of Display Energy Certificate/Energy Performance Certificate administered by suppliers
Need for policy requirement for landlords and tenants to agree an Energy Management Plan for their buildings to accompany Display Energy Certificate
Set up a European observatory of buildings for a feedback from the field (including monitoring techniques and data processing)
Create a database of BIM information filled by manufacturers and used by designers
Selected Actions
Improve rigour in energy performance modelling
Timeframe
Short term
Establish minimum standards for Energy Performance Certificate in existing buildings
Timeframe
Short term
Build a fine grained BIM database of buildings/cities with real time feedback
Timeframe
Mid term

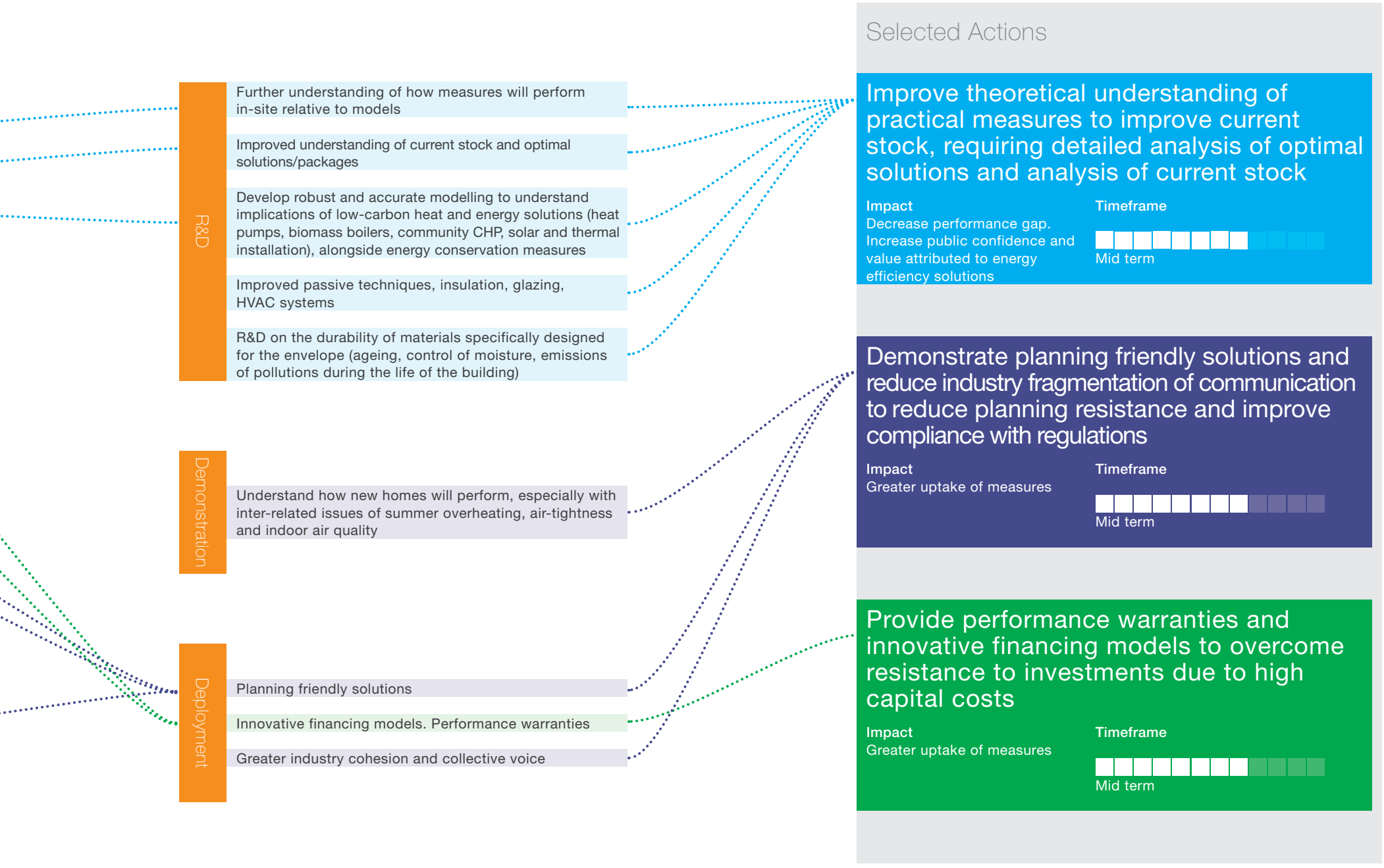
Structure


Drivers
Improve energy efficiency of buildings through measures and products
Close gap between predicted and actual performance of buildings – modelling
Preference to minimise up-front cost resulting in increased whole life energy performance
Targets
In use is more important – Fabric First and Passive
New buildings structures use responsibly sourced materials with low embodied carbon
Solutions for concrete with an embodied CO_2 content <50kg/t are available
Structural basis of retrofit solutions and their performance is known
A European framework for collaborative work between architects, structure engineers, material experts and the constructive industry is proposed to minimise both the CO_2 and costs of future new buildings
Technical Barriers
Capability of mass customisation
Complexity
Non standardisation – mass customised solutions required on an unprecedented scale (21m homes to retrofit)
Lack of knowledge across industry, are the targets cradle to date, cradle, definition of whole life cycle?
Values in use, over life are vague and unknown, can this be bettered or translated to financial reward
Materials cost/property balance net yet met
Can we better know the asset state, therefore plan better maintenance/repair/financing
Economic Barriers
Are there solutions which are not cost-effective, or no solutions?
Lack of incentive knowledge in client or supplier base
Short term view of investors
Fragmented supply chain offering multiple products with differing non-standard values for energy efficiency targets
Lack of unregulated financial drivers. Market failure.
Regulatory Barriers
1 and 2 above could be driven to current limit by regulation – would this be punitive?
Risk adverse standards
Cost of certifying solutions
Other Barriers
Lack of awareness of what is important

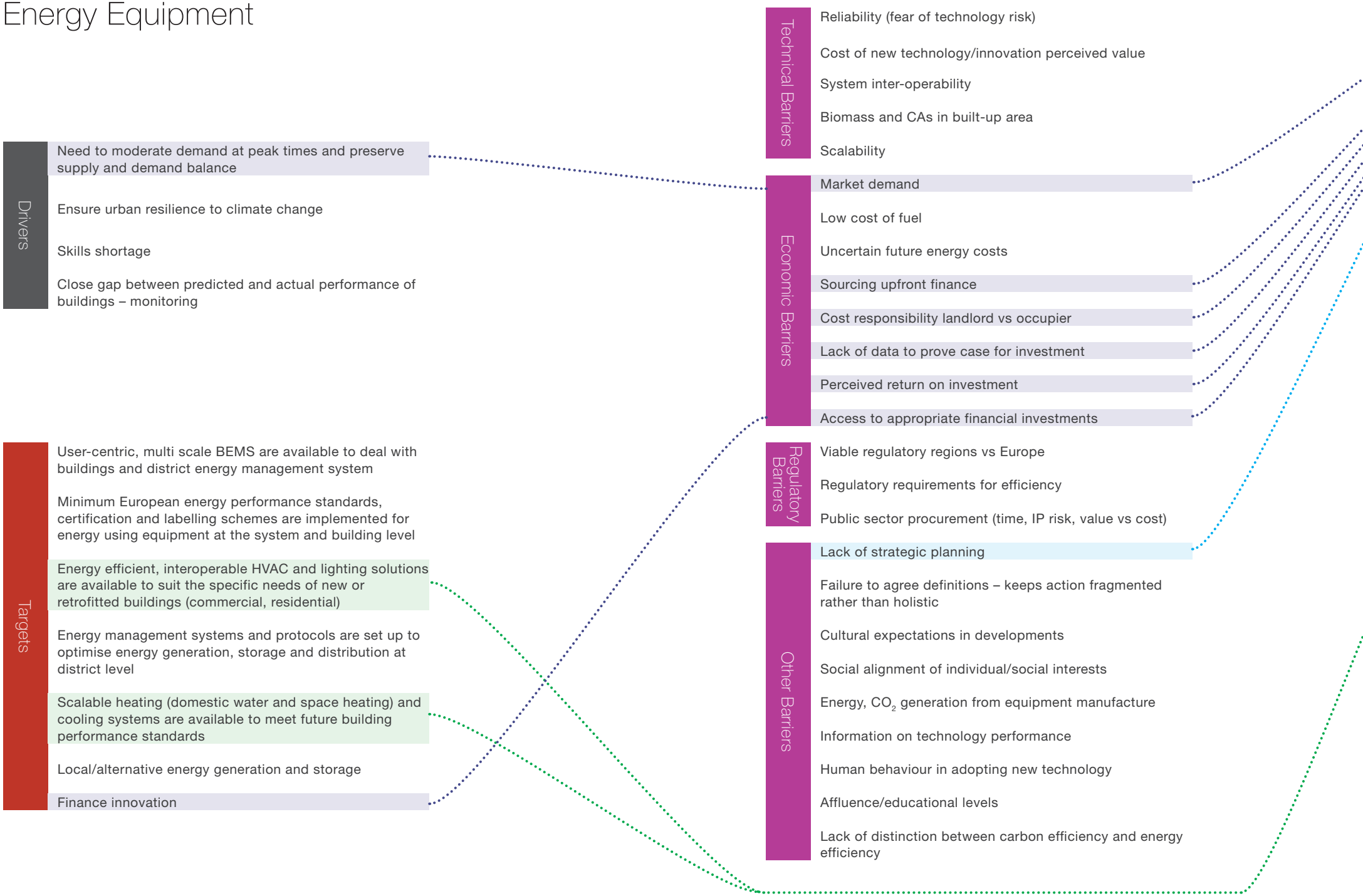

R&D
Reduce environment and man-made impacts of built environment and cities
Develop practical phased packages for domestic building energy efficiency improvements; carry out technical analysis of current house types and devise appropriate treatments for different forms of construction of existing housing
Development of durable biomass materials (such as timber) and construction techniques to cope with moisture-induced problems in air-tight buildings
Composites in construction
Mass retrofit
Demonstration
Development of high performance low embodied carbon steel (eg. reclaimed steel)
Develop new low carbon embodied and in use products and services and logistics to deliver them at scale
Deployment
Develop clear labelling of construction products with verified data on their embodied carbon, energy performance and environmental standards
Better prediction of in-use CO_2
Development of construction material solutions with improved resource efficiency (recycled aggregate and manufactured sand based concrete solutions)
Selected Actions
Develop workable retrofit solutions
Impact
High.
Timeframe
Long term
Explore deriving Benefit from Materials – knowledge based approach to material selection and therefore benefits derived; re-use of materials
Impact
High.
Timeframe
Short term
Research novel Materials – Bridging gaps in current materials performance; solutions for problems with no current solution
Impact
High.
Timeframe
Long term

Envelope


Drivers
Improve energy efficiency of buildings through measures and products
Improve product development – use standardised components and pre-assembly
Lack of market demand for low carbon new build and retrofit
Close gap between predicted and actual performance of buildings – modelling
Preference to minimise up-front cost resulting in increased whole life energy
Optimise engineering systems within buildings using IT advancements
Skills shortage
Targets
Durable Ageing of components is better understood which allow appraising their loss of performance over time
User-centric. The envelope demonstrates usability and flexibility to contribute to improved health and comfort, account for social aspects and use values, and ensure user acceptance
Adaptable. Materials and components solutions are developed for a smart envelope which can adapt to the environment and can be customised by architects
Driving the future building performance regulations. New standards, supported by innovation at European level, are developed to anticipate and contribute to new directives
Insulation performance improvement
improved management of air flow
Improved response to solar input
Technical Barriers
Modelling tallying with in-use
Lack of practical retrofits solutions
Knowledge about effects of interventions
Interactions
Economic Barriers
High capital cost of some measures
Reduction in energy prices
Financing of capital cost
Regulatory Barriers
Planning restrictions
Need for regulatory drivers
Over-regulation (or perception of over-regulation), stifling Innovation and Design
Other Barriers
Social resistance/buy-in
Viable and sufficient capacity supply chain

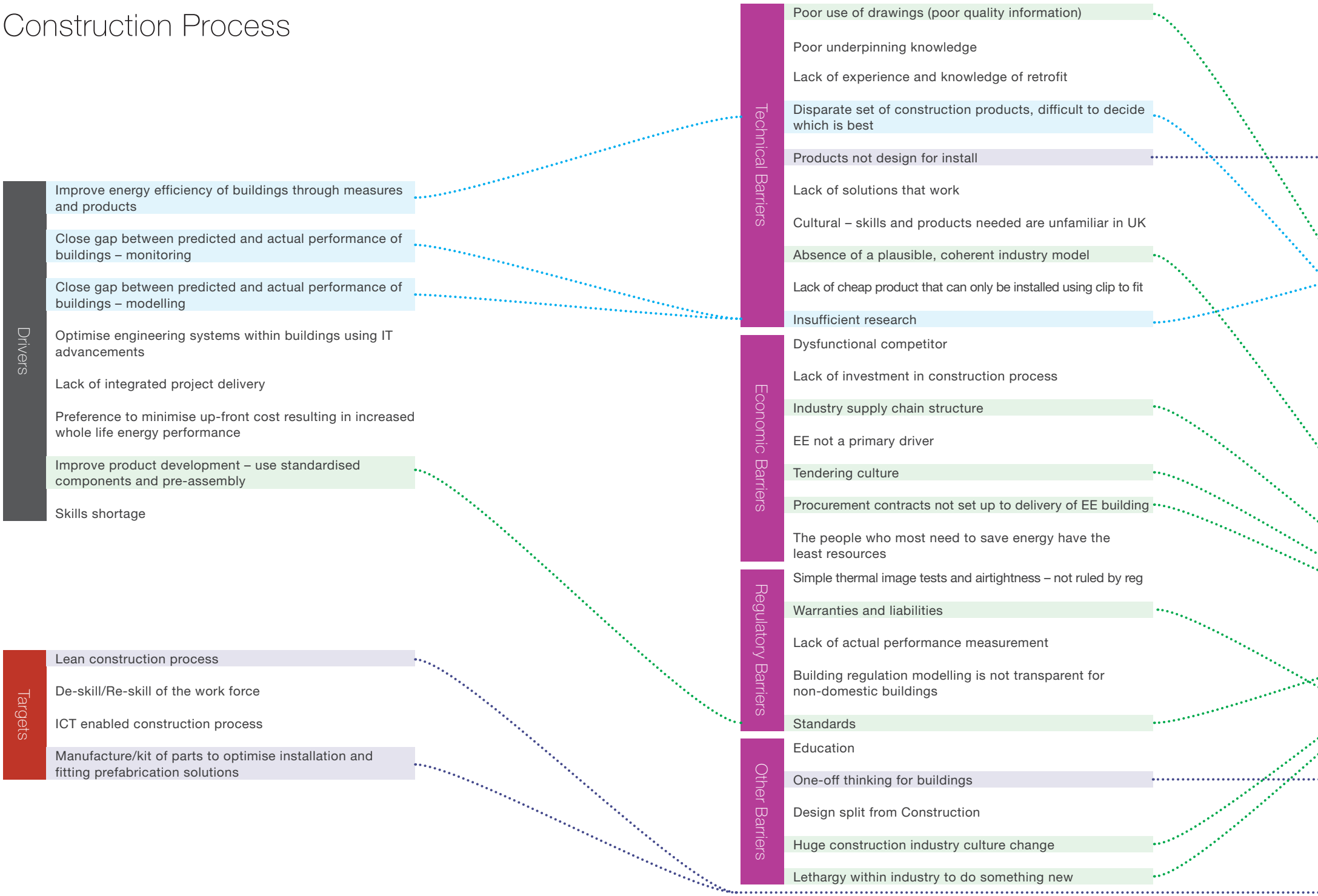

R&D
Further understanding of how measures will perform in-site relative to models
Improved understanding of current stock and optimal solutions/packages
Develop robust and accurate modelling to understand implications of low-carbon heat and energy solutions (heat pumps, biomass boilers, community CHP, solar and thermal installation), alongside energy conservation measures
Improved passive techniques, insulation, glazing, HVAC systems
R&D on the durability of materials specifically designed for the envelope (ageing, control of moisture, emissions of pollutions during the life of the building)
Demonstration
Understand how new homes will perform, especially with inter-related issues of summer overheating, air-tightness and indoor air quality
Deployment
Planning friendly solutions
Innovative financing models. Performance warranties
Greater industry cohesion and collective voice
Selected Actions
Improve theoretical understanding of practical measures to improve current stock, requiring detailed analysis of optimal solutions and analysis of current stock
Impact
Decrease performance gap. Increase public confidence and value attributed to energy efficiency solutions
Timeframe
Mid term
Demonstrate planning friendly solutions and reduce industry fragmentation of communication to reduce planning resistance and improve compliance with regulations
Impact
Greater uptake of measures
Timeframe
Mid term
Provide performance warranties and innovative financing models to overcome resistance to investments due to high capital costs
Impact
Greater uptake of measures
Timeframe
Mid term

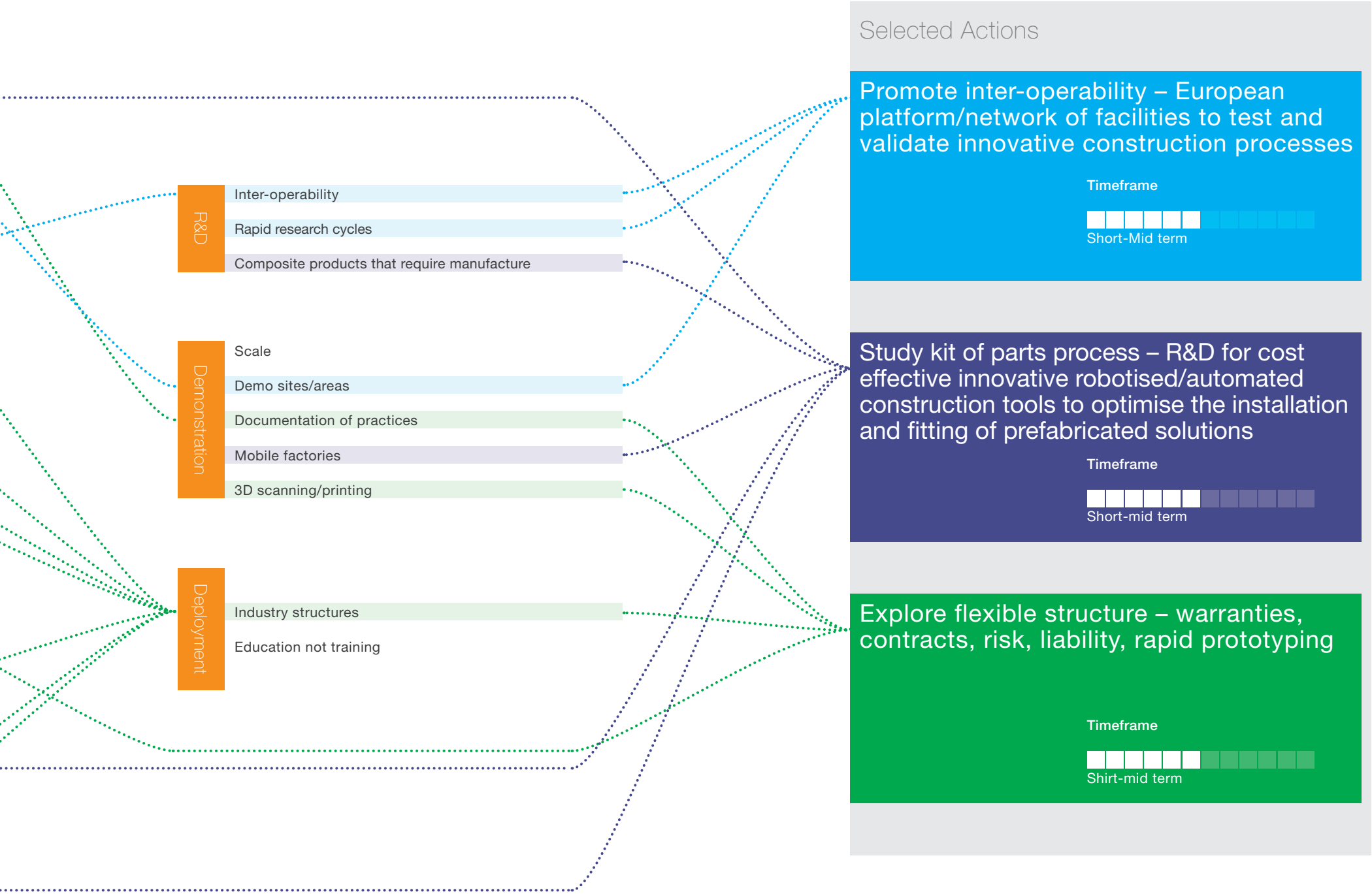
Energy Equipment




R&D
Develop products for lighting (more sophisticated lighting controls; DC lighting; raised lighting levels without additional energy consumption)
Establish how exactly zero-carbon performance is to be defined and how far the use of renewable energy is to be taken into account in the assessment of performance
Gather data on the carbon performance of buildings and the energy equipment itself (esp if innovative), and understand level of non-compliance and its impact on carbon emissions; review compliance mechanisms
Understanding extent of behavioural change
Expectations of comfort
Development of heating optimisation systems (hot water vs. space heating)
Harmonise test procedures and introduce efficiency labelling schemes to facilitate trade and transparency on performance for energy using products
Heat and cooling technologies
Demonstration
Understand how best to utilise combination of energy solutions eg. combination of centralised and distributed energy solutions for housing developments; optimise energy supply solutions for buildings and districts
All levels – alternative energy/heat technologies in buildings such as photo-voltaic, heat pumps, fuel cells
Development of low-cost compact, building and grid-integrated thermal energy storage having potential for energy storage pooling
Demonstration of DC only building with only one inverter to connect to the outside grid
Development and demonstration of reliable scalable and cost-effective integrated solutions for building-grid interaction and for local energy production, eg. combining solar hot water and electricity production from building integrated PV
Domestic and community based decentralised electricity generation; distributed energy and heat (both demonstration and deployment)
Deployment
Standards Equipment and whole building
Messaging
Standardised benchmarking and calculation tools to deliver information to decision-makers (architects, engineers, professional builders) on energy performance of different technologies
Training and info for small business, construction and suppliers
Develop education and training methodologies and certification standards for building sector professionals involved in the selection and installation of energy equipment, to increase understanding, build-up skills and accelerate technology take-up
Selected Actions
Agree a long term fully defined strategic goal to achieve optimum energy performance
Impact
Implementation plan with room for expected innovation
Timeframe
Long term
Explore business model innovations
Impact
Need to know who is going to make money and how, is it construction/utilities/landlords; need to understand why action should be taken
Timeframe
Mid term
Research heat optimisation
Impact
Critical not just for increasing energy efficiency but critical to resolving the energy dynamic of a building – relationship of heating/cooling is critical
Timeframe
Long term

Construction Process





Selected Actions

Promote inter-operability – European platform/network of facilities to test and validate innovative construction processes

Timeframe

Short-Mid term

Study kit of parts process – R&D for cost effective innovative robotised/automated construction tools to optimise the installation and fitting of prefabricated solutions

Timeframe

Short-mid term

Explore flexible structure – warranties, contracts, risk, liability, rapid prototyping

Timeframe

Shirt-mid term

Energy Performance

Drivers

- Improve energy efficiency of buildings through measures and products
- Close gap between predicted and actual performance of buildings – monitoring
- Close gap between predicted and actual performance of buildings – modelling
- Optimise engineering systems within buildings using IT advancements
- Need to moderate demand at peak times and preserve supply and demand balance

Targets

- Several in vitro testing labs are networked over Europe to quantify the use value of energy solutions to reduce building consumption
- Models (continuously re-calibrated with field data) are able to split performance contribution between the various critical building components for retrofit application
- A European observatory on energy performance monitoring is set up with a European wide database
- Approaches for conditional maintenance, based on continuous monitoring of the equipment and building performance, are implemented
- A European standard for building energy performance metering technologies and data analysis methods is set up to ensure the compliance with performance guarantee contracts. Multi-criteria metering (acoustics, indoor air quality) is integrated as an option
- Systems and protocols are set up to measure energy performance at the district level, taking into account energy storage, production and distribution
- Ensure targets cover retrofit not just new build
- Need testing labs from in vitro through to in vivo
- Need target for positive energy homes and districts (and measures)

Technical Barriers

- Lack of standardised ways and methods to measure Energy Efficiency (quantify)
- No knowledge on medium/long term impacts of metering/ monitoring devices
- Design for performance – ill-informed about effective solutions
- Lack of evidence on demand controllers
- Lack of community wide energy systems
- HVAC complexity and system inefficiency
- Building controls not working
- No coordinated approach across EU to retrofit performance evaluation (shared learning)
- Real system – little understanding of how real buildings perform with real tenants – need low cost widely usable evaluation, real-time methods

Economic Barriers

- Barriers to dynamic pricing (tariffs)
- Poor understanding of performance gap inhibits investment
- Lack of funding to implement changes
- No investment performance monitoring – public or private. Needs regulatory driver
- Focus on initial cost not life cost

Regulatory Barriers

- Lack of standardised metering/monitoring systems
- Lack of standards and inter operability (eg. BEMS and smart grids)
- Lack of Government incentives to improve Energy Consumption
- Lack of EU wide standards on energy

Other Barriers

- Skills – lack of joint learning by professionals and skilled workers leads to sub-optimal performance
- Skills – lack of local skills to deliver performance specification


R&D
R&D on mass manufacturing of plug and play modular solutions and pre-assembly of building parts in factories
Champion public-private testing strategy and partnership across EU
European platform/network of facilities to test and validate innovative construction processes
Consistent, comparable protocols and formats of building performance data
Demonstration
Smart Buildings – R&D on ICT tools to improve interfacing (communication and data sharing) between the workers involved in the construction process
R&D for cost effective innovation ICT-assisted (eg. based on robust smartphones and tablets) construction tools
Smart building energy use metering and control
Buildings operating interactively with people, learning user behaviour and preferences, optimise the use of power and heating
Research into systems-level approaches to managing and operating buildings to reduce CO2 emissions and optimise energy use
Deployment
People in Buildings – Develop products for wiring and controls (whole house systems and the interplay between technology and consumer behaviour, switching appliances on and off, control speed of fans and motors, plug-in display wiring)
Development of training and education platforms (using ICT-enabled tools) to provide certified training sanctioned by an evaluation process
Monitor post-occupancy performance as a formal structured part of procurement process as a verification of predicted value/design criteria
Stimulate consumer demand through a framework of incentives, interventions, via carbon price, taxes, subsidies, and regulation
Management of energy use in buildings (currently in residential and commercial sectors energy costs are small proportion of total costs)
Understanding appropriateness/feasibility of different fiscal incentives to overcome inertia and low customer awareness of energy efficiency in domestic buildings
Selected Actions
Maintain EU investment in a pan-European PPP network to provide a consistent basis for energy performance R&D funding support
Timeframe
Short term
Develop a long term strategy for R&D investment to improve maintenance approaches and practices in energy performance
Timeframe
Mid term
Disseminate and roll-out of solutions
Timeframe
Long term

References

Challenges and Research Priorities of the Construction Industry (November 2011), National Platform

Energy efficient Buildings 2020, Research & Innovation Roadmap, Working document for discussion within the EeB PPP AIAG (June 2012), Technofi

Energy Efficient Buildings PPP Multi-annual Roadmap and Longer Term Strategy (2010)
Ad-hoc Industrial Advisory Group, European Commission

Research Priorities for the Definition of a Multi-Annual Roadmap and Longer Term Strategy (2009),
Ad-hoc Industrial Advisory Group, European Commission

Energy Efficient Buildings Association Vision to 2020 (2012), E2BA

Appendix

List of attendees

Organisation	Name	Job Title
Aedas	Judit Kimpian	Director of Sustainable Architecture and Research
Arup	Chris Jofeh	Director Buildings
Arup	Jennifer Schooling	Research Business Manager
Arup	Marta Fernandez	Associate Director Global Research
Arup	Sue Wolf	Project Leader
Arup	Thomas Briault	Associate
Asite and CICE, Loughborough University	George Charalambous	Research Engineer
Beyond BIM	Ray Crotty	
BIS	Chris North	Deputy Head International Knowledge and Innovation Unit
BIS	Peter Whittington	Assistant Director Research & Innovation
BRE	David Richardson	Group Director Building Technology
Brisbane Creative Industries	Hannah Suarez	
Brunel University	Mizi Fan	Head of Research
Building Research Establishment Limited	Christopher Yapp	BRE Graduate
Buro Happold	Philip Pointer	
CIRIA	Bill Healy	Chief Executive
Cleantech Investor	Felicia Jackson	Editor
ConstructionSkills	Patrick Bowen	Future skills manager
DCLG	Jeremy Watson	Chief Scientific Advisor
DECC	Emma Owen	Programme Manager, Innovation Delivery
Dept for Business, Innovation and Skills	John Green	Secondee to Green Construction Board
Enviros	Helen Fairclough	National Contact Point
EPSRC	Caroline Batchelor	Senior Manager for Infrastructure & the Environmen
EPSRC	Chris White	Portfolio Manager
ERP	Richard Heap	Executive Analyst
GE, UK & Ireland	Mikele Brack	Director, Cities
Green Structures	Thomas Lipinski	CTO

Organisation	Name	Job Title
HMG	Paul Morrell	Chief Construction Advisor
IAE	Arsim Shala	Managing Director
IES Ltd	David McEwan	Director
Institute for Sustainability	Ed Metcalfe	Director
Institute for Sustainability	Terry Mcgivern	Head Resource Efficient Buildings
Institute of Energy and Sustainable Development	Peter Mallaburn	Director of Policy
Johnson Controls	mark reynolds	Business Development Mgr
Johnson Controls	Peter Ferguson	Dir Energy & Sustainability Advisory Services
kcmc	john conti-ramsden	director
Living PlanIT SA	Robin Daniels	Executive Vice President
Loughborough University	Keyur Vadodaria	Research Associate
Loughborough University	Tarek Hassan	Professor of Construction Informatics
Manchester City Council	Dave Carter	Head, Manchester Digital Development Agency (MDDA)
MBE KTN	Deborah Pullen	Director
Moixa Energy	Chris Wright	Design Director
Narec Capital	Michael Hitchcock	COO
National Housing Federation	Corine Meier	International Affairs & Funding Officer
OISD, Oxford Brookes University	Tim Dixon	Director/Professor
Oxford Data Management	Amatsia Kashti	
Rachel Capon Consultant Scientist	Rachel Capon	Consultant Scientist
Sheffield Hallam University	David Johnson	Knowledge Transfer Champion - Sustainability
Skanska	Sam Stacey	Head of Innovation
Sustainable Construction iNet	John Liddle	Director

Appendix continued

Organisation	Name	Job Title
Technology Strategy Board	Ian Meikle	Head of Low Impact Buildings Programme
The unIversity of Sheffield	Hasim Altan	Lecturer & Director
Torr Vale Mills .ltd.,	Pete Cunningham	Chairman
TWI	Alec Gunner	Project Coordinator
University of Cambridge	Aidan Parkinson	PhD Candidate
University of Cambridge	Tatiana Vakhitova	
University of Nottingham	Brian Ford	Professor of Architecture
University of Reading	Jacopo Torriti	Lecturer in Sustainable Technologies
University of Salford	Will Swan	Senior Lecturer
University of Sheffield	Jie Zhang	Professor of Wireless Systems
University of Sheffield	Lenny Koh	Professor
University of Westminster	Ana Serra	RDO
Wates Group	Chris Woods	R&D Director