



## **Stakeholder Workshop ABI, London Friday 12<sup>th</sup> October 2007**

### **Workshop 1: Previously identified needs/challenges**

**During the first workshop stakeholders considered the previously identified research needs/challenges from the 2001 stakeholder workshops that led to the BKCC programme of research. Stakeholders were asked to vote whether they thought the need/challenge was still valid and asked to provide comments to back-up their vote.**

*Building resilience into existing building stock – vulnerability and risk audits as a means to establishing priorities*

Yes: 100%

Reasons 'yes':

- Commercial and domestic stock will account for 70% of the building stock by 2050.
- There is disconnection between existing/historical design standards and current/future conditions.
- Trees in relation to existing buildings: local authorities don't always understand the level of risk.
- Little evidence of resilience is available generally.
- Knowledge is available, but there is a lack of commitment and funding. Need risk audits and prioritisation as 1 in 10 year rainfall events occurring more frequently.
- Need to look at ways in which buildings we've designed to work originally and how modern impositions stop them working in the best way for building preservation and routine maintenance.
- Likely risks of flooding, energy supply, insulation etc.
- Detailed research on drainage on the road network.
- How to mitigate the effects of flooding e.g. water into under-floor space
- Many areas e.g. London are still surprised by the effects of summer rainfall episodes. Need vulnerability mapped clearly.
- LCCP retrofit work was limited only to 3 types of residential property. Research is still to be done on the commercial sector.
- There is general awareness and acceptance of the problem. Knowledge transfer has been successful, but it needs implementation.

- No current legislative drivers in building/planning regulations. Having more information on impacts on existing building stock will push for this, message not getting through on vulnerability of stock.
- Research into high risk areas and benefits of green infrastructure (more holistic approach required).
- Building climate control systems: are they up to the job? Will they break down in extreme conditions, what are the health risks?
- Enable the best integration of new research of materials to the impacts on existing building stock.
- Effects on large public buildings – especially historic buildings.
- Need to deal with uncertainty.
- Commercial sector needs work that might be done better as climate models improve.
- How often will high frequency, potentially low consequence systems are exceeded e.g. drains and gutters.
- Historic environments – are they a priority? Have greater constraints on ways to adapt than other existing building stock but is it a luxury to be concerned about them?
- Great gap between actual practice and best, recommended practice as regards building resilience into existing stock – there are barriers, obstacles and ignorance that need to be overcome.
- Existing building stock is our biggest vulnerability. It's 99% of annual built turnover, but hardest to assess and improve.
- Need to understand heat gain due to longer sunshine hours: implications on building structure and effects on internal environment.
- Recent events demonstrate that resilience is not great, more research and knowledge of current situation would be good.
- Little available information.
- Understanding rates of rainfall and how guttering and drainage should be designed to cope.
- Impact re listed building legislation, difference between traditional and modern building materials and methods and vulnerability.
- Integrating renewables into environmental control systems
- Building stock is hugely valuable and a long-term prospect. Drainage is also a critical issue.
- Drainage and housing.
- Better dissemination of knowledge.
- Need to implement and research the effects of proposing storm water detection on or around new and old buildings.
- Flood risk continues for buildings on floodplains. Dwellings and business also relevant to water infrastructure, drainage and freshwater supply security.
- Affect of air movement on mould.
- High frequency, low consequence designs – but systems need to change to accommodate high frequency, high volume.
- Impact on collections.
- Interoperability of different solutions e.g. diving a historic building into small compartments and making it more airtight will reduce energy

costs but reduced air movements leads to more mould and the need to clean delicate items.

- Can you relax relative humidity and temperature parameters if air movement is good?
- Flooding, energy infrastructure, road surfaces, drainage systems.
- Resilience is important in the context of uncertainty. Audits – help more towards more quantitative approach.
- Significance of existing stock of relative depth of focus. New build important re adaptation.
- 75% of building stock that will be there in 2050 is already in existence.
- Housing stock has huge variability and will continue into the long-term.
- Need to improve our understanding of the existing housing stock, need to understand how it can be adapted without impacting on their performance.
- Need to make sure that all current infrastructures are adapted to any future climate change.

*Soil mechanics, subsidence risk and foundation construction and design specifications – including drying and frost damage potential*

Yes: 28%; No: 21%; Don't know: 51%

Reasons 'yes':

- Impact of trees.
- Historic buildings were designed to withstand local conditions. Need to understand the relationship between soil and building structure and subsequent changes and alterations as well as buried archaeology.
- Special regard to vegetation should be investigated as it can compound or mitigate against impacts. Vegetation is also impacted.
- Initial work has been done and a little specification updating has occurred but impacts and adaptation responses not looked at in detail. Need experimentation and data.
- Water logging of ground during wetter winters, impact of drier summers.
- The impact on transport systems.
- Subsidence and heave are major issues in London – particularly with residential developments. Need to understand the proportional risk due to climate change, tree induced risks and poor development/land settlement. When/how to and how much to underpin buildings.
- Especially if more tree planting/urban greening in cities to adapt to urban heat island, could enhance subsidence risk of buildings.
- Design of foundations for historic buildings where buried archaeology may be an issue.
- Need our existing housing stock to last for decades to come. Subsidence is a widespread issue that requires further research.
- Recent DfT study identified soil moisture deficit as a climate impact especially for road/rail.
- Critical to our understanding on how to sustain the existing stock without impairing its performance – often the lack of standardisation is ill-understood.

- Issue of below ground archaeology

Reasons 'no':

- It is a manageable problem.
- Knowledge is generally available and the number of failures due to this problem are not high, but may become a problem in the future.
- Surely enough is known about foundation performance in dry areas etc. How about countries with a wide range of temperatures/moisture regimes?
- Should be well researched already.
- In transport industry it is already a known problem and the geotechnical industry must know the impacts of expanding/contracting soils?

Reasons 'don't know':

- Many homes are built on poor foundations.
- Dissemination needed.
- What are the significant changes predicted without climate change.
- Buildings rarely fail because of engineers, building control etc, err on the side of caution and over-provide resilience.
- No detailed modelling work with climate scenarios or analysis of suitability of climate models.
- This may underlay the vulnerability of the existing stock e.g. the foundation construction would presumably affect the building resilience, therefore this should be considered along with other impacts.

*Role of groundwater in flooding – associated risks*

Yes: 58%; No: 21%; Don't know: 21%

Reasons 'yes':

- Socio-economic impacts of groundwater flooding and how this affects different communities based on their wealth.
- Explore flash flooding.
- Drainage and slope stability issues.
- Lack of application of research in context.
- Groundwater recharge; vegetation and 'porous' green spaces should be considered.
- Local Authorities don't seem to have any knowledge on how groundwater will affect them.
- Modelling using UKCIP08 probabilistic scenarios.
- More applied research required.
- Knowledge transfer.
- Need to understand groundwater levels and the impact of rainwater on levels; need a better understanding of space under cities.
- Study of extreme events.
- Flooding in historic environments.
- Need to understand how heavier rainfall/wetter winters affect base flow, aquifer recharge and localised flooding.
- Recent events demonstrate that there are gaps/challenges.

- Research is already being done by DEFRA and specific consultant teams with EA. Knowledge needs to be applied to specific climate change programme.
- Application gap.
- Need to deepen understanding and raise public awareness of how unseen water storage affects flood risk. Research needs to feed into the planning process.
- Need more modelling.
- Challenge in terms of climate scenarios – need more evaluation of sequences of events, how well are they simulated and how do they change?
- Need to know the implication of extreme weather events.
- Implications for major house building in the Thames Gateway.
- Issue with threat from insurance companies not to insure properties.
- Need to know more about the added impact of groundwater on top of extreme coastal flooding.
- Impact on water quality.

Reasons 'no':

- Already good data capture and analysis.
- Not in London. Groundwater and its movements are well investigated as part of managing tube infrastructure.
- Recent floods were surface flooding therefore should concentrate on that.
- Well researched area – data and weather patterns to apply research to real situations is lacking.

Reasons 'don't know':

- Function of landscapes

*Sustainability of existing drainage systems (SUDS) in the face of climate change – implications for design of new drainage systems*

Yes: 65%; No: 16%; Don't know: 19%

Reasons 'yes':

- Knowledge and application of SUDS is limited.
- Seldom recognition of the potential role of SUDS, focus is on the negative consequences.
- Knowledge should inform governance of flooding and drainage management.
- Current applications seem to crisis management not future developments.
- Existing drainage systems were not designed with climate change in mind and flooding is a major issue.
- Research on utilising grey water.
- Role of residential properties in drainage integration and flood control.
- Need more transfer of application experience.
- More research needed especially as many proposed new developments are in areas of high flood risk. This is needed urgently

give the size and timescale of many new developments e.g. Thames Gateway. Need to maintain a high research profile to encourage government to adopt appropriate measures.

- Need to transfer research findings into design methods that can integrate future refinements of the climate models.
- Gap in integrating SUDS in built environments, mainly in how to maintain them long term.
- The major economic impact they may have.
- Using rainwater to supplement mains water (for non-potable water) and reduce flood risk. Need to understand the limits to SUDS to reduce flood risk and rainwater harvesting to supplement supply.
- How to incorporate these approaches in the existing built environment – providing for the whole community and not just as bolt on adaptations to individual projects.
- Don't really need research on SUDS but need work to show costs and other benefits of retrofitting SUDS through large-scale implementation schemes.
- Socio-economics of grey water systems.
- High level of disasters to collections is caused by failure of rainwater goods.
- Implementation not technical issues.
- Extreme weather events on drainage.
- With drier summers and wetter winters need to implement a sustainable system which could make use of grey water e.g. collect rainwater in the winter to help infrastructures and communities adapt to drier summers.

#### Reasons 'no':

- Existing initiatives in place. However, there are cost implications of doing this which would act as a barrier, as well as educating people.
- Research is not required but more design aids for builders.
- Technically understood, need is for organisational responsibilities to be determined.

#### Reasons 'don't know':

- Lot of problems, maybe due to lack of implementation and knowledge transfer: awareness in terms of application.
- Private drainage systems are often installed in historic buildings, these are often limited, and how can they be adapted?
- Archaeological implications of introducing new drainage. What about rural areas and the use of the landscape to soak up water before it gets to the urban environment. Agricultural practices also need updating to manage surfaces better and prevent runoff.

*Continued viability and comparative advantages of building material and construction techniques – implications for maintenance and costs*

Yes: 62%; No: 13%; Don't know: 25%

#### Reasons 'yes':

- Needs to be a viable case on buildings, roads, carbon imprint.
- Loss of traditional skills in building maintenance makes survival of historic structures increasingly not economically viable. Need to understand which structures are most cost-effective long-term and develop skills to maintain them.
- Recent work (e.g. TRL work for DfT) on road maintenance and climate change shows that some materials may not be viable in the future. Techniques will become out-dated and whole life considerations need to be sought (infrastructure and buildings). Also there will be material supply and demand changes and sustainability issues.
- Application and dissemination through the industry as materials for construction is a major contribution to CO2 emissions and climate change.
- Transfer of knowledge between parties is required.
- Lot of knowledge on what works and what doesn't re building materials for climate change but this is not being effectively transferred down to the architect/builder: WHY?
- Maintenance and costs in relation to latest climate change models output needs to be integrated into design methodology. Embedded carbon should be integrated into design method.
- Research information has not penetrated to the average builder: techniques and products have not changed.
- Maintenance costs are frequently imposed on the client without discussion of the alternatives.
- If we question move to light weight construction/MMC are sustainable to owner rather than economic to the developer.
- The whole issue of life cycle costs has not been recognised and accepted by those who commission new developments. Need for easy to understand methodologies.
- Support BRE projects looking at this subject.
- Not only in terms of maintenance and costs but also in relation to the content of the building. Storage of collections and implications.
- TRL have done some work on road construction and maintenance. Possible scope for studies of e.g. Mediterranean countries who have been dealing with high temperatures for many years.
- More studies on ports.
- Needs to be embedded into BRE's Green Guide.
- Construction industry needs hard facts and figures of the advantages (monetary, carbon + social) of using alternative design which feeds into construction techniques. Fear of the unknown so are using traditional techniques and materials.
- Use of offshore substrates needs to be considered with respect to shoreline management and coast defences and sea level rise.
- Quality and quantity of recycled building products.
- Very important in terms of issues around future proofing, the buildings legacy and issues of adaptation and mitigation. This area has been pushed due to inertia and challenge of change.
- Need to develop a robust set of principle, tools and data to underpin the evolution of the built environment.

- Need a methodology to enable comparison of the performance of different techniques – new and traditional.
- Embodied carbon is important – need to understand how we can assess and quantify the impacts from this embedded carbon.

Reasons 'no':

- Needs to be part of a wider study on building performance.
- Knowledge is there but needs to be incorporated into whole life costing of buildings.
- Good scenarios are needed.

*Construction site conditions, techniques for flood risk areas, performance of traditional materials, impacts of air pollution, pests and insects.*

Yes: 44%; No: 33%; Don't know: 23%

Reasons 'yes':

- Vegetation in relation to air pollution.
- Causes much decay. Adds to the cost. Rat population rises.
- Losing knowledge in how to apply 'common sense' solutions to historic sites. Lack of understanding of natural ventilation.
- Should consider impacts of climate change on pollutant linkages of contaminated sites. Pest and insects important to construction materials but also 'tree health'. Air pollution impacts important to human and ecosystem health. Should consider links to EPSRC PURE programme.
- Something for HSE to consider?
- Performance of traditional materials and construction techniques still not understood and not recognised in construction codes.
- Legislation needed.
- Understanding materials in a changing environment.
- Particularly pollution (and emerging pests/insects). From a local perspective there is a knowledge gap on pollution generated by Heathrow airport and perhaps more generally from the air travel activities – existing and future.
- Air quality impacts on collections. Increase in the range of pests and eradication measures.

Reasons 'no':

- Body of knowledge in UK and abroad.
- Too broad, unless looking at lifetime of materials e.g. comparing CO2 emissions of heavy weight materials (e.g. concrete) vs. air con.
- Predominantly a commercial issue.
- Not a priority but impacts of air pollution would be interesting.

Reasons 'don't know':

- Impacts of air pollution – may also have a negative impact on biodiversity and pests, so that there may not be an increase of pests or indigenous pests.
- Good construction management practices are largely known and should mitigate against most of the potential impact.

- Emphasis should be into prevention of pests rather than treatment.
- Is this the role of the construction industry?
- Need to understand the interaction between air pollution and climate change and the impact on all sectors.

*Coping with peak demands, performance under changed climate, viability of wind, wave and hydropower, access to offshore facilities*

Yes: 64%; No: 8%; Don't know: 28%

Reasons 'yes':

- Energy industry don't 'get it' yet!
- Short termism may mean a large gap in energy supplies. In depth analysis of carbon emission/gain is essential.
- Yes for energy. Should be integrated with targets for use of renewables including biomass power generation.
- More investigation on decentralisation of energy generation and storage – feasibility, impacts etc. There is great vulnerability in the energy infrastructure of this country too.
- District and community structure.
- Probabilistic techniques.
- Sensitivity of mechanical equipment to change in operation environment (e.g. humidity, mean temperature, peak temperature) needs to be understood and critical systems identified.
- Need more understanding of renewable options.
- Role of local non-networked micro-generation.
- Energy storage should be a priority for research as it is common to all form of generation.
- Change in peak winter and summer demand may cause problems to existing infrastructure. Need to analyse change in HDD's to CDD's. Sensitivity of electrical control systems to temperature.
- Viability of nuclear.
- Energy storage – issue of local electricity production for small scale.
- Existing distribution systems of electrical energy are extremely inefficient and can not cope with hot summer events.
- Joint research with specific regions and supply companies to actually influence on ground planning and retro-fit improvement.
- Gaps between linking our micro-understanding of end-users and the macro grid-level implications.
- Emergency services in particular are highly vulnerable in times of extreme weather when coupled with power loss, so is a key issue.
- Impact on historic environments.
- Climate change impacts on hydro-power have not been considered – similarly offshore effects.
- Climate change and nuclear waste disposal.
- Viability and potential performance of alternative technologies.

Reasons 'no':

- Telecoms industry should deal with this.
- Should be easy

Reasons 'don't know':

- Currently telecoms infrastructure cannot always cope with peak demands but increasing capacity of mobile phone technology may have a negative effect on human health.
- Need for low-technology, long-lasting solutions, cost-effective in the long-term, easy to maintain and adapt.
- Should be funded by industry rather than research body – commercial driver.

*Overheating of buildings and alternative cooling techniques*

Yes: 59%; No: 23%; Don't know: 18%

Reasons 'yes':

- Not just to cool buildings from over-heating but also that projected long-term increased demands on infrastructure can result in buildings becoming even more over-heated. Cooling systems also require energy and generate heat, but need to do this in a way that creates synergies with mitigation. Heat from buildings needs to be captured and recycled.
- Role of vegetation in shading and evaporation cooling.
- No real understanding of low CO2 strategies for cooling existing and new buildings.
- Need low-tech, low-energy, low-impact cooling systems for historic buildings that make use of traditional architectural features. Needs better application and risk assessment methodology to persuade owners/managers to take appropriate action e.g. sensitive retro-fitting.
- Should include assessment of vegetation shading to mitigate against overheating and include assessment of life-cycle of alternatives including air conditioning systems.
- Still a tendency to build greenhouses and use mechanical air conditioning if they get over-heated.
- Existing techniques are not suitable for large public or commercial buildings (hospitals, offices, schools).
- Is a problem now, don't know the problems associated with some of the quick win solutions.
- Understanding how existing patterns impact on urban heat.
- Drive for energy efficiency may increase risk of over-heating in new development. Support for a cooling hierarchy.
- Retro-fitting cooling systems into existing buildings.
- One of the biggest challenges. Adaptation research should also focus on showing the related carbon reduction benefits. Need to properly quantify the demand reduction in energy for a retro-fitted or better designed new building.
- If aimed at practical solutions.
- Sensitive solutions in historic buildings.
- Big problem area which is being exacerbated by changes in building regulations.
- Should look at transport too.

- Role of ventilation.
- Interaction of adaptation and mitigation. Challenge is partly one of communication and e.g. working with professional bodies.
- Concern that as we encourage building owners to mitigate against climate change by reducing energy use by double glazing etc. the major impact is likely to be overheating and need for cooling.

Reasons 'no':

- Building regulations are moving in the right direction to address this, industry knowledge is good if not always well applied.
- In most areas, opening a window is sufficient, air conditioning is not yet essential.
- Lots of research going on: issue of dissemination of information, best practice and a strong drive towards more stringent specification on better temperature control systems. However, this area is not complete and retro-fitting techniques need investigation – including residential and government buildings.
- Application is the issue.
- Huge potential in the private sector.

Reasons 'don't know':

- Commercial interest will rise as cost of operating increases.
- Significant research in Australia.
- Lots of research already on designing efficient cooling systems into new buildings.

*Humidity and ventilation in buildings – drying and performance of building materials in the face of projected changes in climate*

Yes: 33%; No: 26%; Don't know: 41%

Reasons 'yes':

- Role of air movement in determining mould growth.
- Health risks e.g. mould, damp.
- More knowledge needed about effect of traditional building materials; influence of contents, fittings, finishes.
- Specific interest in higher humidity buildings such as museums (and archives) and galleries. Objects within buildings require humidity control rather than temperature control.
- Do we really understand ventilation?
- It has taken decades to reach our present level of wealth and knowledge to be able to design buildings that do not suffer from mould and damp. Climate change will introduce new elements of complexity upsetting our present minimal efforts.
- Environments suitable for collections.
- Lack of completed modelling wall in EHF to predict behaviour in a changing climate.
- Stringent operating parameters of dehumidifiers and air conditioning are too conservative. Are climate change researchers talking to dehumidifier and air conditioning manufacturers?

- Air movement? Air tightness? Can relative humidity go up if there is air movement?
- Implications for health and human comfort.
- To build on EHF work to understand the performance of traditional building materials.
- Methods for adapting to humidity and ventilation needs may not be viable due to other issues e.g. air quality inside and outside.

Reasons 'no':

- Cultural issues.
- A lot of research into building materials already.
- Other institutes are leading on this.
- More details of heat needed.
- Not a priority.
- Research already undertaken in this area.

Reasons 'don't know':

- Does current research factor in effects of drying and performance, increased flooding and extreme heat affects on buildings.
- Part of wider post occupancy studies.
- Is this not well known by buildings engineers?
- Impact on human health?
- More interested in over-heating and flooding.

*Land-use policy and planning – guidance on flood risk, long-term efficacy of remediation measures for brown field sites, and vulnerability to wind damage*

Yes: 52%; No: 24%; Don't know: 24%

Reasons 'yes':

- In terms of understanding why knowledge about flood risk etc. seldom count highly in relation to other issues (e.g. economic) – influencing decision makers, short termism still rules.
- Building in low-lying areas has become essential – better guidance and governance on site practice, public knowledge.
- Very important to consider sustainability of remediation of contaminated sites in lieu of climate change and build upon work begun under EPSRC SUBRIM consortium. Including risk of flooding. Wind damage to building but also green infrastructure are very important.
- There is a great need for fully backed-up and accepted and adopted guidance and answers for this area. Further work is needed on this and more guidance etc needed. More specific than things like PPS etc.
- Urban flooding is complex and risks are not fully understood. Research is in hand under water industry and other programmes. Effectiveness/application of planning controls is questionable.
- Very strong need for this to be applied in the Thames Gateway area for example.
- The policy is addressing flood risk only and direct impact on affected areas. But the wider long-term socio-economic impacts and dynamics

are not addressed. It focuses on new development but not existing communities.

- Need inroads into planning policy.
- The national planning policy developed so far has not been fed through to the local level of plans.
- New construction on floodplains requires much research as regards the housing itself, infrastructure and related concerns.
- Need more information on implications of Government proposals to build house on floodplains (including wider implications for associated transport and energy infrastructure).
- Very important with climate change planning policy upcoming.
- Crucial in terms of putting research into practice. Need evidence-base for changing current situation e.g. London Plan. Greenspace/bluespace.
- More needs to be done to inform decision makers to make informed decisions and show leadership in terms of sustainable design.

Reasons 'no':

- Lots of work already done – but need to make this data and research more widely available.
- Possible a value in identifying/analysing case study examples.
- Policy and planning should be addressed elsewhere.

Reasons 'don't know':

- Not sure if land-use planning and policy is based just on projections of increased population growth? How humans adapt needs to be taken into account in terms of local sustainability issues i.e. potential increase of using land to grow local crops.

*Changes to legislation, standards and regulations as drivers of change – regionally specific and more flexible legislation to allow for innovation*

Yes: 49%; No: 27%; Don't know: 24%

Reasons 'yes':

- Research strongly needed to build public support for legislation, standards and regulation. Congestion zone for example is meant to address congestion but also improves the environment, yet still resistance from some stakeholders, motorists and businesses.
- A key issue as a focus for research. Critical to involve relevant stakeholders at the outset, especially regulators.
- Broader discussion is needed.
- More emphasis on strategic planning and the legislation etc. which will allow a holistic plan for urban environments. Innovation is required and should be encouraged.
- This is assuming that legislation is keeping up with new issues such as climate change but it is not. E.g. European Sea Directive that made SEA requirement in 2004 and climate change was not specifically dealt with in part of that process. Environmental Impact Assessment is also lacking for climate change.

- Include economic and social changes.
- Need to understand best way to use these tools in coping with climate change and driving lifestyle change.
- Influence of Treasury Rules in public sector investment decisions: dominated by short-term considerations.
- Require evolution/changes in law, policy etc to be evidence based and such evidence needs to come from research.
- Much policy is currently being decided on 'political hoof'. How can legislation be more performance based?
- Mechanisms for ensuring stakeholders are consulted.
- Strategic thinking.
- Local and regional differences are important to consider and adaptability would be an advantage to implementation on the local level.
- Climate change although a global problem is very regionally specific. Therefore flexible legislation is needed to be able to adapt and provide relevant policies for specific areas as different regions may need to adapt in different ways.

#### Reasons 'no':

- Linkages with climate change seem reasonable.
- Not a research priority. Already in hand under DEFRA's 'Making space for water'. Political will to change legislation and regulation may still be lacking.
- Building regulations need to change too.
- Need for new legislation but look at the new knowledge and see what types of legislation guidance, manuals and tools are required.
- Flexibility – need some firmer legislation and then allow for local flexibility within the rulebook to account for local climate impacts.
- Promote scenarios.

#### Reasons 'don't know':

- Flexibility is essential.
- Could be interesting e.g. should we legislate for adaptation? What would the implications of that be? Who should be responsible for driving adaptation?

*Lifestyle changes – implications for future use of buildings, energy demand and the efficacy of adaptation options*

Yes: 67%; No: 15%; Don't know: 18%

#### Reasons 'yes':

- Big knowledge gap is efficacy of adaptation options.
- Part of a wider need for socio-economic inputs/scenarios along with climate change scenarios.
- People's lifestyles and behaviour will inevitably change. This will influence infrastructure use and therefore need. As an example, green space use is likely to be very high in times of high temperature events.

- This is a completely cross-cutting issue and the needed research is unlikely to end.
- Need to create a socio-economic background and an urban/built environment that is flexible and adaptable. Also need to look at social attitudes and not trust technology will solve all problems.
- Home working vs. manufacturing.
- Effects on heritage sector are very important.
- Remember the general public: how to engage, involve, stimulate, inspire and harness their abilities and capacity for change.
- Improvements in lifestyle/behaviour can have a bigger benefit than technology. Need to better quantify and value (£) this benefit. Will help shape policies, communications and pricing of energy/water.
- Are we assessing the right thing? Should it be embedded water?
- Include implications for transport e.g. more domestic tourism? Also demand – more mitigation?
- We are designing and building very inflexible buildings. Locking people into living individually in show boxes.
- How do we extrapolate past advancements in lifestyle changes into the future?
- May be a good way to focus on positive future projections in contrast to crisis management.
- Psychology of materialism.
- Potential to have a big impact on the energy used by people in the built environment.
- Link between the research with life-style changes and informing the general public on adaptation.

#### Reasons 'no':

- Lifestyle changes are too difficult to predict with accuracy to base reliable research findings on, at least in the long-term, unless you do research on how to change behaviour.

#### Reasons 'don't know':

- Concerns about how lifestyles won't all change in the same direction, but that this could further exacerbate inequality.
- Need to bridge generation gap, help young people understand how older existing stock was designed to work, not dismiss as worthless because difficult to impose new technology on it.
- Application of this information is the priority.
- Likely to be difficult to model/assess quantitatively.

#### *Effects on transport – choice, reliability, costs of impacts and safety in light of extremes*

Yes: 45%; No: 8%; Don't know: 47%

#### Reasons 'yes':

- Real concern that unless public transport can cope with increased demands and can adapt to climate change, users will go back to using cars. TFL has done a lot of scenario planning but this does not really

take account of adaptation (more mitigation). More research is needed on heat effects on pavements, roads, tunnels etc.

- Huge investments on public needs will depend on accurate forecasting.
- Currently thoughts on what will happen regarding choice of transport mode in extremes are all based on speculation. In London TFL and its infrastructure companies (Metronet and Tube lines) are carrying out work in assess costs of impacts, but require better London-specific data on temperature and extreme rainfall.
- Awareness of the problem but changes at the moment are pushing existing technologies, rather than looking at new modes and choices.
- Why travel? Re-establishment of local communities.
- DfT not up to speed on how climate change will impact on transport infrastructure and even less up to speed on integrating into policy. Need more support on information finding.
- Sensitivity of mechanical systems to climate change and identification of climate critical systems – change in design/operational methodology. In addition need to understand integration requirement and benefits of centralised vs. localised systems.
- Not on effect of climate change but effect of response to climate change.
- Britain's motoring network has often been built regardless of adverse local micro-climates so what hope is there for the future with more extreme weather events. Recent acquisitions of rolling stock for the underground were designed without regard to increasing temperatures on the underground system in London.
- Our transport networks are fragile.
- Transport will become more important in the future; need particular focus on ports and airports.
- Inter-linkages within networks (urban, national, international).
- Implications of energy infrastructure and fuel supply.
- Not certain how climate change directly affects reliability of each mode.
- Bio fuels and their impacts on other cultures and environments. 'Life cycle costs of bio fuels – global costs of bio fuels' research is needed.
- Freight, canals and trains.
- Behavioural and physical infrastructure issues affect ability to respond immediately to extreme events.

Reasons 'no':

- This will be driven GHG mitigation (with the possible exception of logistics and JIT manufacturing and distribution).
- Should be funded by commercial transport industry.

Reasons 'don't know':

- Need research to convince providers of public transport to provide vehicles that are reliable and comfortable in extreme conditions.
- What affects choice?
- Choice driven by many things not just climate change.
- Need to look at it holistically with its wider impact on climate change through emissions.

*Dissemination from research to professionals and practitioners – accessibility and understanding*

Yes: 92%; No: 5%; Don't know: 3%

Reasons 'yes':

- Important that practitioners but also general public, understand the need for adaptation, lifestyle changes, legislation.
- Particularly local authority politicians and senior management.
- Knowledge transfer is a two-way process.
- Should be an overarching approach to BKCC2.
- Most research projects are not in the public domain.
- It is only professionals who are engaged with research communities that know what research exists. Challenge is to cascade beyond professionals to consumers and businesses.
- Needs to be consolidated in different forms for different audiences.
- Translating work into an understandable written format and knowing the barriers to uptake in industry.
- Research papers need to be translated into information which is attractive to be read by others and therefore have better chance of application.
- Seems to be the whole ethos behind SKCC.
- Involvement of stakeholders is essential to make sure researchers address relevant problems and provide necessary tools.
- And to policy makers, politician and businesses.
- Because otherwise we would not be funding UKCIP! Very difficult task to make complicated climate data understandable and usable.
- Need to make climate change adaptation research easily understood by different sectors, also tailor it to make it relevant to them and give them tangible mechanisms to deal with it.
- Understand best routes to bridging gap, translation into design methodology, appropriate channels (role of professional institutions), establishing vocabulary and communication routes.
- Always requires effort, cross-disciplinary research is always difficult.
- Ways of sharing knowledge between practitioners and professionals from different sectors.
- Clear simple advice with the costs, benefits, risks and opportunities well set out is needed.
- This is usually where we fail.
- Extremely important. Experience is that clients either a) do not know of existing BKCC work or b) do not use it if aware of it.
- Should start from the practitioners not from the researchers. Professional institutes have a role.
- Whose role is it to disseminate information? How can this be achieved most effectively? How to encourage sharing information between practitioners?
- Major problem area. Much knowledge is out there, but many professionals are too busy to absorb complexity.
- How? What is the most effective vehicle?

- Started the process in BKCC/SKCC but it is a slow process.
- Critical to increasing body of knowledge and educating within organisations e.g. Local Authorities and non-technical experts.
- Decision makers don't have easy access to research and how it applies to them – they don't know where to look.
- This is only just starting to happen.
- This is a key area where the stakeholder model needs to be extended through existing frameworks/networks such as the professional institutions who can act as a bridge.
- Need to be able to access the most up to date information and to advertise where information is available. The end-user needs to depict to the researcher what is needed and required by them.

Reasons 'no':

- Information is there just not being taken up.
- Just need more of the things we are doing.

*Need to draw on best practice and experience from other locations*

Yes: 60%; No: 22%; Don't know: 18%

Reasons 'yes':

- Need to understand what others are doing – can't solve everything ourselves. Collation and dissemination is important.
- Drainage Slope stability issues. Have ready proven solutions.
- Always need to review and utilise other countries' research and practices but should be brought back to a UK context. Programme should encourage the formation of international collaboration.
- Best practice and experience needs to be available in up-to-date formats. Not sure how much analogue information can help but lessons can be learnt from what other people are doing and adapting to your own region.
- What we might experience in the future is already being experienced by someone somewhere.
- Yes but solutions can't be transplanted without due regard to local context.
- Emphasis on bringing together what is already known rather than re-inventing new technologies?
- Yes, but should not be exclusively relied on nor replace home-grown research.
- Is there a two-way learning that can take place?
- Sharing our expertise with developing countries.
- Scandinavians design good housing and urban districts.
- Sharing knowledge with practitioners in other countries could reassure us to become more innovative.
- Learn from other people's mistakes.

Reasons 'no':

- Beware of spatial analogues.

- Need to evolve solutions that suit local traditions, materials, conditions and culture, not impose alien solutions on regional identity. Beware of false attraction and quick fixes.
- Only to some extent, because although climate change is a global phenomenon the focus needs to be on local knowledge, life-style, resources and techniques.
- UK is too far ahead on probabilistic modelling.
- Already being done substantially.
- Not a barrier.
- In the heritage sector is not feasible to adopt practices outside the cultural context.

Reasons 'don't know':

- Other cities are already experiencing the types of extremes that we will plan for. How do they design buildings, infrastructures and utilities? Or don't they have a similar scale operation to us? E.g. 'Lessons for London' publication.
- UK advising China's Dongtan.

*Assessment of the capacity of the sector (and components thereof) to respond to change – adaptive capacity and barriers to change*

Yes: 85%; No: 5%; Don't know: 10%

Reasons 'yes':

- Do we fully know the barrier to change and will this be affected by supply and demand.
- Adaptive capacity is neither well known nor understood. Extreme inertia in sectors to change makes this difficult.
- Perception that there isn't sufficient capacity to adapt while other considerations are a higher priority.
- Identify the most effective levers to influence change in the sector.
- Self awareness – long term carbon imprint needs education.
- Need to develop skills base to implement adaptation strategies and techniques.
- It is applicable to both socio-effects and hard material construction environment effects. E.g. capacity of an already existing construction/infrastructure to be able to adapt and where it cannot physically carry on adapting. E.g. people's capacity to adapt – attitude, skills gap etc.
- Impact of regulatory regime on the ability of regulated infrastructure industries to plan and invest for climate change needs to be looked at.
- Sectors themselves should fund this.
- New forms of policy and awareness of changes of lifestyle will be coming from the bottom up and established practice will not be addressing it.
- Very little on how adaptation works top to ground level and what prevents adaptation occurring.

- Very important in terms of understanding skills base required (technical, professional, management) in adapting systems and businesses to climate change.
- Heritage industry has very limited capacity to make changes.
- Academy of Sustainable Communities specifically set up to raise awareness and skills in sustainability in the built environment, but still waiting for the dramatic change that needs to take place to happen in the associated professions.
- Skills deficiency.
- Perception of cost is a barrier to change.
- Policy makers need to be aware of any constraints.
- Need more creative thinking at regulatory level to push challenging new thinking.
- Business/commerce is the most difficult area to make adaptations as it will almost inevitably mean a reduction in sales volume.
- Cuts across all socio-economic issues.
- A way in which stakeholder perspective can provide a 'reality check'.
- Understanding institutional barriers to change and behavioural barriers to change is an important research area.
- Needs to be better cohesion between different sectors to respond and implement change and adaptation in the most effective way.

#### Reasons 'no':

- Already known

#### Reasons 'don't know':

- Not just physical capacity but skills sets, legal frameworks etc.

#### *Other comments*

- Economic benefits of research for practitioners.
- Public database on all available research/costs/risks available to 'public' as well as professionals.
- Gaps appear to be in the integration of knowledge and practice and in liability in maintenance, ownership vs. construction and design.
- Knowledge transfer - use of knowledge in practice – bridging gaps between research community and design/engineering community (Role of Institutions).
- Sensitivity of mechanical systems to climate change (extremes and means), identification of critical systems/components, design and operational methodology (Role of Institutions).
- Embodied energy vs. expending energy.
- Concrete/high thermal mass vs. air con/tri-generation
- Relative CO2 emissions and other environmental impacts.
- Permeable paving vs. cool materials.
- Permeability vs. drainage.
- How to use UKCIP08 – defining thresholds/return periods etc.
- Research is needed into what to do about the threats identified.

## **Workshop 2: Key research/knowledge gaps**

**During the second workshop stakeholders were divided into groups to identify additional research needs and to consider the nature of the response to address them.**

Yellow group

*Green infrastructure – role as a vulnerable adaptation*

- Links with ongoing research on green infrastructure (natural environment, trees in particular)
- Urban heat island – role of green infrastructure as an adaptation option (DEFRA research)
- Ecosystem services – valuing these services through time
- Role of green infrastructure in stabilising embankments
- Research on existing green infrastructure also capacity to add new green infrastructure - planning to support, governance
- Resilience of green infrastructure – health and sociological implications

*Making adaptation decisions in light of climate change*

- Embedded carbon in construction materials and structures – minimising footprint
  - Adaptation perspective – adaptation decisions made in light of this carbon footprint
  - One of many costs
  - Use of local (recycled) materials
- How to understand through adaptation and mitigation – methodology for assigning value to building materials – lifecycle value, priority setting criteria
- Framework – discrepancy with other objectives: health concerns, internal environments.

*Post-occupancy monitoring and maintenance*

- Cost to run and maintain
- Relative to design criteria
- Methodology to discuss
- Experience (case studies)
- Long term issues – systems replacement – relative importance's in decision making
- Implications for different types of air con (museums relative to other types of buildings)
- Commercial buildings
- Behavioural changes of occupants and implications for efficacy – mechanics for prevention – legislation, governance and regulations

### *Influencing decisions and behaviour through incentives*

- Builders etc. (not just owner occupier) – behaviours and social (recycling)
- Influencing decision/policy makers
- Best/most effective approach
- Behaviour of shareholders
- Message to support behavioural change
- Individual levels – practices to procedures

### *Influencing practices and procedures*

- Construction
- Designs
- Operation/maintenance
- Quality/aesthetics
- Role of legislation, regulations, guidelines, training

### *Implications of climate change for energy storage*

- Potential of various methods
- Link to renewables and potential vulnerabilities

### *Potential for multiple adaptive purpose infrastructures*

- Multiple use of existing infrastructure
- Drainage, heating/cooling
- Use of rainwater collected
- Whose funding?
- Alternative objectives – contributions to self maintenance of urban areas

### *Costing adaptation*

- Economic
- Comparing alternatives
- Linked to successful adaptations
- In context of asset management and replacement
- Methodology (process v outcome)

### Green Group

#### *Adaptability of modern housing: what can we learn from existing more flexible stock?*

- Learning from historic buildings – methods and materials in designing new building for adaptation

- Retro-fitting of buildings – how to incorporate adaptation to existing buildings
- Identify thresholds of performance that buildings need to achieve under climate change

*Retro-fitting existing building stock and green space*

*How will adaptation of buildings affect other issues e.g. health, wildlife etc.?*

- Holistic approach to adaptation options in the built environment

*Adaptation options – integrate design to achieve adaptation and energy efficiency*

- Achieving integrated design in respect of adaptation as well as energy efficiency
- Building design as well as extended built environment and landscape
- Need multi-disciplinary personnel
- Higher education system needs to include integrated training

*Public attitude to non-essential energy intensive aesthetics e.g. neon advertising boards, water fountains*

- Socio-economic issue
- Incorporate adaptation actions/solutions to replace non-efficient current practices
- Linking local aesthetics to landscape design

*Risks and advantages of grey water systems – public attitude and technology*

- Change perception of the way grey water is used – public attitude to grey water

*Benefits and disadvantages of green space*

- Benefits of green spaces to tackle the impacts of climate change

*Incorporation of renewable energy sources in historic buildings/sites in a sympathetic manner – retro-fitting link*

- Over-engineering/passive design
- Existing knowledge about sustainable building techniques

*Methodologies e.g. decisions trees for a range of adaptation options for decision makers*

- How do decision makers prioritise between various options e.g. by means of an evaluation tool

*Sensitivity analysis of the impacts of climate change on various aspects of the built environment to focus attention*

- In order to prioritise effort and resources
- For example, what types of buildings respond better to certain impacts of climate change.

*How to adapt buildings to cope with the increase in mould development*

- Higher temperature and higher precipitation cause increase in humidity and growth of mould
- Role of ventilation or lack of concentration in minimising heating by air tightness which has an effect on ventilation
- Examined within the context of physical and mental health and comfort
- Also the effect on physical materials

*What is the most effective response to extreme events vs. adaptation options*

- Respond to effectively to extreme events through developing an adaptation strategy
- Resources and plan in place
- Quantification of responses
- Clear, assigned responsibility

*Strategic approach to adaptation e.g. city level, catchment scale*

- Not just site specific

Blue group

*Dust, mould, pests but relate to all existing buildings*

- Synergistic effects of dust etc
- Energy savings restrict ventilation
- How to respond to increased prosperity to mould growth – damage to health and property
- New pests with climate change

*Heritage: what can we learn from old buildings; which can be transferred to existing stock*

- Effect of mitigation and changes to historic building stock
- New retrofit options for historic building stock
- Education and training in low tech solutions for owners
- Transferring learning from old buildings to new: what can we learn?

*Investments and costs: from macro to micro*

- Development of economy based on mitigation
- Socio-economic scenarios
- Cost-benefit of adaptation – conducted on a variety of scales
- TCPA – CBA at a variety of scales – ASSCUE
- Evidence from best practice case studies e.g. green roofs
- Life-cycle costs and benefits

*Community – e.g. socio-economic scenarios*

- Including global migration to community participation
- Awareness raising and involvement
- Democracy- choice
- People not aware of investment now, will have benefits in the future – not seeing long-term investment now – our pension fund
- Picture of future that can be seen on a variety of scales

*Methodologies for adaptation*

- Rating resilience of buildings to climate change
- Assessing the risk: what? To whom? Likelihood?
- UKCIP08
- Bringing research into practice and practice into research
- Enforcing regulation

*Transport – supply and demand – modal shift*

- Transport network resilience
- Must address both mitigation and adaptation
- Consider inter-dependency between transport and energy
- Supply and demand – the need to travel: changing lifestyle, effects of migration
- How will climate change affect the types of transport people take – modal shift?
- How can the networks cope?
- How do passengers want to travel when the weather changes?

Red group

*Understand the impact of behaviours and lifestyle on the effectiveness of adaptation*

- Research on building consensus e.g. smoking ban – lessons for adaptation, link to legislation
- How do people interact with buildings and space around buildings e.g. open windows in a sealed environment
- Mitigating energy use resulting in more energy use e.g. patio heaters
- Influencing behaviours and understanding why people do what they do e.g. Australian water conservation programmes

- Anticipating what lifestyle changes might be

*Cooling buildings: lifecycle analysis of energy (embodied + expended): also for water and carbon*

- High thermal mass and embodied energy vs. air con and expending energy
- Link to renewables
- What do we know about embedded water – what do we know about this – links to water pricing – links to behaviour change
- Cost of moving water around
- Compare water consumed in present billing period with previous years – leads to behaviour change

*Better understanding of performance of building materials*

- Linked to embodied energy discussion
- Existing housing stock vs. skills to repair and adapt it – dissemination of knowledge
- Heavy vs. light construction

*Creating robust methodologies for measuring the performance of buildings for developing and informing adaptation strategies*

- Creating baselines for measurements for performance of buildings – needed so can understand how currently working to know implications of adaptations
- Readily accepted methods for measuring performance of buildings and inappropriate retrofits e.g. historic buildings
- Which scenario to adapt to
- Sealing buildings vs. wanting more ventilation in the future
- Current stock and traditional buildings (pre 1919) e.g. Victorian terraces and new builds

*Appropriate system (e.g. cooling) for building use and content*

- Actual research of things in use
- Heating/cooling to match space and use of space
- Impact of changing climate on:
  - Archives which need to be kept cool – rely on air conditioning (possibly unreliable) or passive systems
  - People in homes and offices

*Permeability vs. drainage in urban environment*

- Managing permeability of materials
- Reduction of gardens
- Increase in runoff (what to do with this water),
- Implications for biodiversity,

- UHI impacts

*Cool materials e.g. roofs and pavements*

- Cool roofs are currently a wasted opportunity
- Green roofs
- Cooling
- Wasted space
- Prevention better than cure

*Urban health effects*

- Increase in asthma with increase in population density
- UHI
- Human comfort and heat stroke
- Vector diseases

*Nuclear energy in a changing environment*

- Viability of wind
- Cooling needs of power stations
- Availability of energy during extremes e.g. heat wave in France, impacts on nuclear energy supply

## **Workshop 3: data, knowledge and expertise required**

**Following workshop 2, stakeholders were issued seven votes to prioritise which knowledge gaps/research questions they deemed most important. The research issues with the most votes became the focus of workshop 3. Stakeholders were asked to identify 'who' would need to be involved in that research questions; what 'knowledge and skills' were required and what 'data and information' would be needed.**

### **Impacts of behaviours and lifestyles on effectiveness of adaptation**

#### *Who?*

- Access to building and end users:
  - Housing associations
  - Consumer associations
  - Local community groups
  - Different cultures and types of family units
  - Commercial owners/developers
  
- Media (for dissemination)
- Architects, designers etc and their professional bodies (e.g. RIBA, ICE)
- Sociologists, behavioural scientists, psychologists
- BedZed people and transition towns
- Legislators e.g. treasury
- Heritage – have already started looking at behaviour change
- People who provide transport e.g. Transport for London
- Property agents
- Health professionals
- Unions
- Local authorities (transport and parking etc)
- UKCIP and DEFRA
- People in buildings
- People who don't want to see change e.g. consumer led businesses (oil?)
- Technology providers (their products result in behaviour change).

#### *Knowledge and skills?*

- Energy usage of/in building
- Need to know when people are in buildings
- Ability to do surveys
- Use focus groups to increase knowledge
- Communication skills (advocacy, PR people)
- Understanding what incentives and barriers work and how (social anthropologists)
- Models of behaviour change
- Knowledge of building regulations and planning laws

- Tools/skills to measure and define effectiveness of adaptation
- Persuasive skills (engagement, marketing etc)
- International experience

#### *Data and information?*

- Access to a range of buildings in use
- Access to buildings already adapted
- Access to information on energy being expended in building e.g. itemised water and energy bills
- Perception analysis of what people think of adaptation and how to take them on
- Medical research on health effects
- Socio-economic data (historic and future)
- International experience
- Role models, leaders, inspirational people and organisations

### **Potential for multiple purpose adaptive infrastructure**

#### *Who?*

- Everyone
- Central government departments – those responsible for infrastructure
- Statutory bodies – EA, RDA
- Local authorities (health)
- Utilities – need to work together
- Consultancies
- English partnerships – housing corporation, social housing
- Planning bodies
- ICE
- IMECE
- IEEE
- Owners of infrastructure
- Communities willing to give it a whirl!
- Emergency planners
- Facilities managers
- Customers: what do they want?
- Designers
- Communicators

#### *Knowledge and skills?*

- Time from stakeholders
- Monitoring benefits and achievements
- Historic research
- Engineering skills
  - Material science
  - Mechanical
  - Structural
  - Electrical

- Industry know how – both UK and beyond
- Understanding of community behaviour and drivers
- Soft skills – beyond disciplinary, integrating knowledge skills/boundaries
- Tools (analysis software) for designing skills
- Legal and regulatory skills
- Innovations/inventors
- Architects/landscape
- Disseminating skills
- CBA

### *Data and information?*

- Ownership/responsibility
- Asset management data/information
- EIA data
  - Ecology survey
  - Geotechnical survey
  - Strategic/heritage survey information
- Community demographics – impacts on community
- Stability appraisal data
- Previous research (worldwide) – case studies
- Economic survey
- Cumulative affects data – positive/negative – adverse affects, limits and impacts
- UKCIP08
- Best practices
- Economic and social costs and health
- Drivers/limits to get utilities working together

### **Green infrastructure role as a vulnerable/valued adaptation**

### *Who?*

- Agencies
- Forestry commission
- Transport agencies
- Waste companies
- DEFRA
- Transition towns
- RTPi
- TCPA
- RA's
- CABE (Space)
- CIWEM
- CCW
- SNH
- Consider private gardens
- EA
- Network rail

- UKCIP LA
- Health authorities
- Water companies
- SUDS – governance issues
- Housing trust
- English partnerships
- ABI
- Tree wardens
- All utilities
- HLF – urban parks programme
- Botanists (Kew)

*Knowledge and skills?*

- Civil engineering – geo-technical
- Horticultural skills
- Landscape architectural skills
- UKCIP08
- Evapotranspiration modelling
- Spatial analogues (Germany, International, green roofs)
- Potential damage of roots
- Synergies with hydrological and hydrogeological cycles
- Recycling – energy substitution
- Political PR communication skills
- Define ‘green infrastructure’
- Include peri-urban, city, region
- Legislation, policy, planning
- Urban agriculture
- Adaptation techniques
- Thermal performance
- UHI effect
- Social value

*Data and information?*

- Scale of benefit
- Risks associated and opportunities
- Costs of adaptation
- For what benefit
- Maintenance in adverse climate
- Costs
- Rates of surface sealing
- Potential benefits of transport, location (city centre) etc
- Health
- Urban crime
- Water resource availability now and in the future
- UKCIP08
- Land suitability, soil, light

**Incorporation of renewables in historic sites – retro-fitting**

Applicable to traditional buildings (extend applicability) Pre-1919: 4 million houses (25 % of stock), private ownership needs behavioural change

### *Who?*

- Owners of historic buildings
- National Trust
- EH
- HHA
- NTS
- Local authorities
- ICON
- Devolved organisations: CADW, HS, NI
- Engineers
- CIBSE
- RIBA
- Electricity authorities
- General public
- Georgian etc. society
- SPAB
- Conservation Architects
- Social housing landlords
- Contractors
- Suppliers and providers of renewables
- Church of England and other faith organisations
- Curators and archaeologists
- EA
- DCMS
- Civic Trust
- DRAHWL (WAG)
- HRP
- RDAs
- Forestry Commission
- Organisations for historic gardens and landscapes
- Water industry
- Energy saving trust
- DEFRA
- UKCIP
- UCL – sustainable heritage
- National Grid
- Renewable energy companies
- Railways and Canals
- Planners
- Industrial archaeologists
- Association of Independent Museums and Rural Museums

### *Knowledge and skills?*

- Renewable technology

- Historic building structures
- Hydrology
- Structural engineering
- Conservation of buildings/sites/collections
- Environmental design
- Life cycles
- Multi-disciplinary team working
- Integrated design
- Cost consultancy – quantity survey
- Builders
- Innovation
- Stakeholder management
- Project management
- Architecture
- Knowledge of legal issues associated with buildings
- Training of site staff
- Maintenance
- Building regulations
- Economics

*Data or information required?*

- Life cycle costing and analysis
- Existing building performance
- Desired thresholds: performance, constrains, energy efficiencies
- Natural resources available – site specific
- Geotechnical and aquifer information
- Case studies
- State of the art technologies
- Climate data
- Environmental data
- Environmental cost benefit analysis
- Economic cost benefit analysis
- Access to plans
- Previous projects
- Funding (government etc)
- Planning regulations