Communities and Local Government

Insulation and thermal storage materials: Expert Panel Meeting 13 February 2012

Pre-Publication Draft

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EXECUTIVE SUMMARY

The Expert Panel Meeting

This report documents an Expert Panel Meeting held for the Department of Communities and Local Government in February 2012. The aim of the meeting was to assemble participants from a wide range of backgrounds with experience and expertise, see Appendix 1, on physical and market limitations of thermal management materials and systems. The purpose of the meeting was to provide the Department with information to support its policy- and decision-making in this area.

Participants were asked which of the following types of thermal storage and insulation materials they thought would make the most substantive contribution to reducing energy consumption and CO_2 emissions over the next 5 to 10 years:

Thermal storage materials/systems:

1. phase-change materials
2. long-term heat storage
3. short- term applications

Insulation materials:

1. natural insulation materials
2. new insulation materials
3. vacuum-insulated panels
4. multi-foils

Participants were asked to assess these against two sets of factors

- their technical and performance aspects
- barriers and incentives to their take-up

Their responses at the Expert Panel Meeting were collected in two stages: first, from individual participants captured on their response forms, and second, via group discussions. Both individually and jointly, participants were asked a) to identify which materials/systems would make the most substantive contributions over the next 5 to 10 years, and b) what they saw as the most significant issues likely to impact on these contributions.

Summary of results

Thermal storage materials/systems:

In aggregate, participants see phase-change materials as likely to make the most substantive contribution to reducing energy consumption and CO_2 emissions over the next 5 to 10 years. But they see phase-change materials as facing manifold barriers which may prevent them from doing so, especially since they see few incentives currently working in their favour, see summary Table 30, page 33. And phase-change materials, while selected as the highest priority, are also identified as problematic because they are seen as having the most disadvantages and as raising the most concerns.

Insulation materials:

In aggregate, participants see new insulation materials as likely to make the most contribution over the next 5 to 10 years. But they see these materials as also facing manifold barriers that may prevent them from doing so, especially since they only see a few incentives currently working in their favour, see Table 30, page 34. New insulation materials, while selected as the highest priority, are also identified as having disadvantages and raising concerns.

Participants used two different types of criteria when making their assessments:

1. those relating to ***intrinsic*** characteristics of the materials/systems themselves
2. those ***extrinsic*** to the materials/systems and related to the circumstances in which they have to be deployed

Table 32, reproduced below from page 35, shows some of the most commonly recurring of these intrinsic and extrinsic characteristics drawn from comments made by participants on their individual response forms, see Tables 2-29.

Table 32. Examples of the intrinsic and extrinsic characteristics used to assess the materials/systems under scrutiny

Intrinsic characteristics	Extrinsic characteristics
(Life cycle) energy performance	**Installation issues**, including: Design skills Site operative skills Availability of 'good practice' technical detailing
(Life cycle) carbon impact	
(Lifecycle) costs, including payback periods	
Moisture penetration	
Fire risk	**Operational issues**, including: Occupant awareness and understanding of materials/system and associated controls Reliability and maintenance requirements
Acoustic properties	
Handleability	
Robustness/durability/delicacy	**Operational environment conditions**, including: Modelling/certification requirements arising from legislation such as Building Regulations Rules associated with Government and non-governmental schemes such as the Green Deal or NHBC Investors' perceptions of benefits, incentives and disadvantages
Longevity/decremental decay	
Toxicity	

This table indicates the highly complex nature of the judgements that participants made when they sought to prioritise and comment on the thermal storage and insulation materials under discussion. Doing so required them not just to consider such materials/systems against a wide range of divergent characteristics, but to seek to weigh these against each other in order to estimate which would be likely to make the largest contributions. These assessments often have the quality of personal judgement calls since, as participants themselves conceded, the empirical evidence on which to base them – for instance, about longevity or about the performance of materials in situ, about the savings arising from their effective installation or about their operation in practice – are frequently absent or unknown to them. What is remarkable is that participants still felt able, by drawing on their own diverse experiences and expertise, to prioritise the materials under consideration despite the lack of the empirical evidence that they see as necessary for attempting to do so. However, these personal judgement calls by participants do not constitute a robust basis for government policy- and decision-making.

Recommendations

An underlying purpose of the Expert Panel Meeting was to provide the DCLG with access to experience and expertise that could inform its decision-making on thermal storage and insulation. The meeting sends a clear message here to the Department on this front. If such decision-making is to be evidence-based, then as Table 32 indicates, that evidence has to cover a wide range of both intrinsic and extrinsic factors. It has to include not just a variety of performance characteristics of the materials/systems in question but also a whole range of characteristics of the situations in which they will have to be deployed. To use the words employed by some of the participants, the Department's approach to decision-making here should be both 'holistic' and 'systems'-based. The evidence collected cannot be constrained to modelling or lab tests of the performance of the materials themselves. It should instead be extended to monitoring and evaluating their performance in built and occupied examples, across both new build and retrofitting situations.

1.0 INTRODUCTION

In February 2012, Cambridge Architectural Research and Eclipse Research Consultants convened an Expert Panel Meeting on insulation and thermal storage materials for the Department of Communities and Local Government. The aim of this meeting was to assemble experience and expertise on physical and market limitations of thermal management materials and systems in the UK. Participants in the meeting were asked to discuss what insulation and thermal storage materials/systems they thought would make the most substantive contribution to reducing energy consumption and CO_2 emissions over the next 5 to 10 years. The purpose of the meeting was to provide information to support the Department's policy making in this area.

A wide range of stakeholders with different backgrounds, experience and expertise were assembled at the meeting:

- academics researching the development of novel and innovative materials and systems
- product manufacturers bringing new materials and applications to market
- designers (architects and engineers) specifying such materials and systems
- contractors and housebuilders implementing these on site
- academics involved in researching the market transformations (e.g. skill sets) required for the take-up, and the buildability in practice, of such materials and systems

A list of the twenty-one participants who agreed to take part in the meeting is shown in Appendix 1.

1.1 The format of the meeting

At the meeting, all of the participants were asked the same set of questions about innovative and novel thermal storage and insulation materials.

Thermal storage materials/systems were presented as dividing into three categories:

1. **phase-change materials** – which absorb heat when they melt from solid to liquid and can add thermal capacity without affecting the heat response time
2. **long-term heat storage** – including inter-seasonal storage
3. **short- term applications**, including cooling.

Insulation materials were presented as falling into four categories:

1. **natural insulation materials** – e.g. cork and cellulose
2. **new insulation materials** – e.g. expanded polystrene, polyeurethane, or aerogel
3. **vacuum-insulated panels**
4. **multi-foils**

Participants were asked to identify which of these materials were likely to make the most substantive contribution to reducing energy consumption and CO_2 emissions over the next 5 to 10 year period by considering them each against three themes:

a) technical and performance aspects

b) barriers and incentives to take-up

c) available sources of information about them

The agenda for the Expert Panel Meeting is shown in Appendix 2. Each participant was provided with a response form for capturing their own individual responses, see Appendix 3. Participants were divided into mixed groups for discussions. Working as a group, they were asked to try and reach agreement - first by prioritising the storage materials and then the insulations materials - in terms of which they as group thought would make the most substantive contribution over the next 5 to 10 years. Then, starting with their group's highest priority, they were asked to identify what they jointly saw as these materials' most significant:

- technical and performance aspects
- barriers and incentives to take up.

Finally, the groups were asked to capture highlights of their discussions on flip-charts for reporting back in the following feedback session.

The expert opinion was thus collected in two stages:

1. from individual participants about their own priorities and responses captured on their response forms (handed in for collation at the end of the panel meeting)
2. from groups about their shared priorities and what they jointly saw as the most significant issues captured on their flip-chart sheets (collected at then end of the meeting)

The information captured at the meeting is reported below in these two stages: first individual and then group responses. This information is then drawn upon to generate a set of conclusions and recommendations to the Department.

2.0 PARTICIPANTS' INDIVIDUAL RESPONSES

2.1 Participants' views of the substantive contributions to be made by thermal storage materials

Each of the participants in the Expert Panel Meeting was asked to vote individually on the three categories of thermal storage materials/systems in terms of their ability to make a substantive contribution to reducing energy consumption and CO_2 emissions over the next 5 to 10 years.

Participants were asked to do so by assigning a score of 3 to the material they thought would make the most substantive contribution, 2 to the one next most likely to, and 1 to the material they thought least likely to do so.

Table 1 shows their individual responses.

Table 1: The priority order that individual participants assigned to thermal storage materials

	Participants (n=20)																	
Thermal storage material	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Total	Rank order
Phase-change	3	3	3	3	1	2	1	3	3	3	2	2	3	3	3	3	41	1st
Short-term	2	1	2	2	2	2	2	2	2	3	3	1	1	2	1		26	2nd
Long-term	1	2	1	1	3	1	3	1	1	1	1	2	2	1	2		23	3rd

The sum of their individual votes, in the penultimate column, shows that, in aggregate, the participants thought that phase-change materials are likely to make the most substantive contribution - by a very wide margin approaching 2:1. Short-term storage materials are seen as the next most likely to do so, but only slightly more so than long-term ones.

However, there is not complete unanimity here. Two of the participants thought that phase-change materials are the least likely to do so. And two of them thought that long-term storage materials are most likely to.

2.2 Participants' individual views of thermal storage materials

A. Phase-change materials

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of phase-change materials. 15 of the 20 participants filled in and returned their forms. Tables 2 show their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish) or a concern (misgiving).

Table 2. Phase-change materials: technical and performance aspects

Benefits
This is enabling technology.
The integration of phase change into heating and cooling systems – a couple of examples at this year's CIBSE Building Performance Awards.
Can store heat at set temperature.
Control of temperature is possible.
Higher energy density is possible.
Energy density.
Potential in hot water tanks – more energy storage in a tank of phase change than water, so allowing solar thermal systems to be over-sized.
Aspirations/wishes
Want reversible chemical reactions*.
PCM $\triangle$T operating points should be near transition temperature.
Fire retardant PCMs.
Disadvantages
Near physical limits for PCM basic materials ➔ 250J.g^{-1}.
Likely to be limited in practice.
May be a considerable cost in embodied energy.
Actual performance is unknown.
This is not promoted in Building Regs so would not be taken up.
There are not commercial materials worth using so more materials research is required.
Germany in lead.
Concerns/misgivings
Thermal mass to prevent overheating.
24 hours overheating v. underheating.
How do the embodied carbon levels compare to the embodied carbon savings over the useful lifetime of the materials.
Number of cycles of PCMs.
Mainly adopted in Germany (BASF). UK lacking in resource and knowledge.
End use must be considered.
Product manufacturer and developer and building owner – how product works with other 'system'.
Software integrated with SAP.
Interesting but issues are complex – fire, cost, energy payback, etc. Hot water?? Overheating.
Green Deal Golden Rule – cost.
Neutral comments
Performance.
Management (BMS).

*Some notes may suggest limited understanding of PCMs by participants, which is itself a barrier to wider uptake.

Overall, the participants were evenly balanced in their descriptions of what they saw as the benefits and disadvantages of phase change materials. The most frequently mentioned benefits were to do with the materials' performance, e.g. their energy density or their ability to store heat at a set temperature. But some performance aspects were also cited amongst their disadvantages too, e.g. where these were seen as unknown or as nearing their physical limits.

Participants were more skewed in their descriptions of their aspirations for and concerns about phase-change materials. Concerns were mentioned three times as often as aspirations. And whereas aspirations focused primarily on performance characteristics that participants want to see, their concerns were more broadly based, covering, for instance, both performance and non-performance issues. Amongst the former, participants drew attention to overheating, the number of cycles that phase-change materials can make during their effective lifetime, and the embodied carbon involved in their manufacture in comparison to the embodied carbon saved by them over their useful lifetime. And among the non-performance issues cited were: their effective integration with other systems, the UK's lack of an adequate knowledge and resource-base, and the materials' exclusion from the Green Deal.

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up for phase-change materials. Table 3 shows their responses. Each of these responses has been classified as a barrier, an incentive, or a neutral comment.

Table 3. Phase-change materials: barriers and incentives to take-up

Barriers
Cost/payback.
Cost.
Cost, complexity.
Cost of adaptation.
Cost may be an issue.
Cost of providing within building.
Ability to model in SAP.
SAP/SBEM – C-SAP (?) not favoured, too esoteric.
SBEM/SAP → save on heating → doesn't consider overheating.
Building Regs compliance requires SBEM/SAP for new build so market is stifled by SBEM/SAP products.
Building Regs (for good reason).
Lack of effective modelling.
Fire safety – does it burn/melt and change of behaviour of structure?
Fear of fire.
Fire risk.
Uncertainty about long-term performance, life.
What is overall life carbon impact?
High carbon manufacture.
What is the need? What are the maths comparing 15mm of Fermacell or clay board compared to a phase change board.
Lack of understanding (experience) of how PCM interact with other building materials and systems.
Is it too technical for general application – lack of knowledge amongst non-specialists.
Basic good practice, e.g. lagged H/W cylinders.

Collaboration down supply chain needed.
Energy conversion may be a problem.
Low recycling potential.
Poor fabric moisture performance.
No current market.
Oil price rise – UK can seem to see in future – investment strategy.
UK is lagging behind on R&D with PCMs.
Management: perception of storage heaters
Housing stock characteristics.
Incentives
(None cited)
Neutral comments
As 'short term applications'.
Dynamic Simulation Modelling.
Systems approach required for specific applications.

Overall, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of phase-change materials. While they made 31 comments identifying barriers to take-up, not a single one of them listed any incentives for doing so.

The most frequently cited barriers were cost-related, closely followed by the SAP/SBEM modelling requirements for compliance with the Building Regulations, and then fire risks and the lifetime performance of the materials. But beyond these shared perceptions, participants also identified a very long list of other barriers that were mentioned by only one or two of them.

Participants were also asked if they could signpost useful sources of information on phase-change materials. These are shown in Table 4.

Table 4. Phase-change materials: sources of information

Sources of information
PLEA paper by Colclough and Griffiths. (A)
In situ performance for products will/could differ from theoretical product performance – look at CIBSE Guide 'A' U-values. (B)
CEREB @ LSBU. (C)
Brighton University. (C)
Concern about number of cycles data. Academics say 3,000: manufacturers say 10,000!! (D)
IAQ (E)
AMC4 – fabric solution (F)
IEA Task 24142: Energy conservation through energy storage. Journal/conference publications. (G)
UK ERC Review. (G)
What is the need? Thermal mass in a very low energy building is relatively unimportant compared to an ordinary building*. Ref EcoTech Passivhaus issue; pieces I commissioned from Rob McLeod and Bill Watts on building physics. Also see Jurgan Scneider ref Passivhaus Institute. (H)

*Some notes may suggest limited understanding of PCMs by participants, which is itself a barrier to wider uptake. Letters identify participants, anonymised here.

As Table 4 shows, approaching half of the participants (8 out of 20) in the Expert Panel Meeting identified relevant sources of further information. But they tended to do so cryptically. Where possible, the sources identified by participants have been followed up in writing the literature review.

B. Long-term heat storage

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of long-term heat storage materials. Tables 5 show their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish) or a concern (misgiving).

Table 5. Long-term heat storage: technical and performance aspects

Benefits
Seasonal heat storage.
Seasonal – existing fabric.
Seasonality.
Coolth/solar heat.
High density storage/small volume.
Integration with multi use buildings.
ICAX Ltd utilises a combination of storage and air source heat pumps to deliver very efficient seasonal performance, e.g. COP 8 @ Tesco Greenwood.
PCMs – not only as heat storage materials but also for transport of heat.
Aspirations/wishes
Need for thermo-chemical storage.
Solar thermal X ground source charging.
CHP coupling to thermal storage is an area of interest.
Disadvantages
Does not provide enough flexibility for the homeowner.
Concerns/misgivings
Difficult to see how this would work in practice.
Will heating be the issue of the future for new housing? Perhaps hot water storage should focus on this!
If it can be made effective, i.e. cycle ?? is high, parasitic (/) 1020 lrw.
A lot of unnatural, high carbon, material needed to crate long-term storage – proliferation of unnecessary, toxic materials.

The participants were highly skewed in their descriptions of what they saw as the benefits and disadvantages of long-term heat storage. They listed eight times as many benefits as they did disadvantages. However, their only area of agreement about benefits centred on the materials capacity for inter-seasonal storage. The single disadvantage mentioned was the systems' inability to provide sufficient flexibility, in use, for homeowners.

Participants were more balanced in their descriptions of their aspirations for and concerns about long-term heat storage. But, whereas aspirations focused only on performance characteristics that participants want to see, their concerns were more broadly based, covering, for instance, both performance and non-performance issues. Among the former, participants questioned not only whether long-term storage could work or be made to do so effectively but whether it was needed at all, given a perceived decrease for the need for heating in new housing. And, as with phase-change materials, one participant questioned the desirability of long-term storage because of their perception that toxic materials and high carbon manufacture were needed for long-term storage (which others may dispute).

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up for long-term heat storage. Table 6 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 6. Long-term heat storage: barriers and incentives to take-up

Barriers
Cost of retrofit/new installation.
Investment cost.
Requires large areas and volumes – impractical costs.
Running cost if district system (annual charge) – think of customer running costs and not just CO2 or we won't sell these units.
Size and management reservoirs/concrete.
Large volumes required – water, gravel.
Seems implausible on almost every level – (inter-seasonal).
Heat delivery at wrong time, in client's eyes.
A pity that CHP does not get more in terms of incentives (e.g. excluded from RHI). This could have the most impact together with long-term/short-term storage, but this hinges on CHP being widely deployed.
High density storage is essential for building application.
Combined challenges of storage and transport with high efficiencies.
Lack of need in a truly low energy building.
Incentives
It is essential to think of combinations of buildings which need heating and cooling in groups so that each benefits the other, therefore 'digging up the streets'. In the Netherlands the energy and water utilities do this.
Better for community/district heating.
This will overcome seasonal heating/cooling demand. High potential and also change in diurnal.
Large heat storage systems open up a new industrial sector (so goes beyond the current building industry).

Overall, the participants were skewed in their descriptions of what they saw as the barriers and incentives to the take-up of long-term heat storage. They made three times as many comments about barriers to take-up than they did about incentives for doing so.

The most frequently cited barriers against take-up of long-term heat storage were cost-related, covering both the high capital cost and potentially, in district heating systems, householders' running costs too. This latter disadvantage could be compounded by long-term storage delivering heat at the wrong time, at least from the householders' perspective. In addition to these barriers is the sheer scale of long-term storage systems, seen as requiring large areas and volumes of material. And, as with phase-change materials, one participant questioned whether long-term storage was really needed in a 'truly' low energy building. (This could be disputed as low energy buildings still need hot water.)

Some of these barriers were, however, capable of being seen as incentives. The large-scale nature of long-term storage was presented as being advantageous for community and district heating, where heating and cooling needs could be combined and implemented through integrated working by energy and water utilities. Indeed, long-term heat storage was identified as having a wider potential than just buildings by opening up a new industrial sector.

Table 7. Long-term heat storage: sources of information

Sources of information
Papers by Colclough and Griffiths. (A)
Minority voice on support for long-term storage. (A)
ICAX Ltd, www.icax.co.uk, Mark Hewitt (B)
IFTECH ltd, www.iftech.co.uk, Aart Snijders, IF Technology, Arnhem, NL, a.snijders@ifinternational.com. (B)
Mott Macdonald, 1851 Commission Kensington (Imperial College) (B)
Plenty (C)

As Table 7 shows, fewer participants (3 out of 20) in the Expert Panel Meeting identified relevant sources of further information. Again, when they did so, they too tended to do so cryptically or in an uninformative manner. Where possible, the sources identified by participants have been followed up in writing the literature review.

C. Short-term storage applications

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of short-term storage applications. Tables 5 show their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish), a concern (misgiving), or neutral comment.

Table 8. Short-term storage applications: technical and performance aspects

Benefits
Heat storage – solar storage (added internal gains heating up house – Swiss sorted).
To make simple buildings we need to limit the heat loss to 10 W/m2 approx. At this point, you can eliminate heating system and use heat sources around ambient temperature which stabilises temperature. Termodeck heats @ 22^{o}C. If the air temperature exceeds this, it effectively cools.
The technologies exist – I don't think that it is a barrier.
Hours – can be linked to long-term heat storage.
Load shifting :- temperature of application
Aspirations/wishes
PCM wall-board potential.
Promising materials systems are under development.
Potential to store energy in DHW tank over a winter period or 1 week or maybe 2 weeks.
Disadvantages
(None cited)
Concerns/misgivings
Have we done enough research to know the long-term impact of using these materials in buildings with occupants?
Overheating of new houses as they become better insulated and are specifically designed to take benefits of solar gain.
Design skills.
Neutral comment
Likely to be aforementioned phase change materials.
Cycle bands (?)
Directionality.

The participants were completely skewed in their descriptions of what they saw as the benefits and disadvantages of short-term storage applications. While they listed five benefits, not a single one of them pointed to any disadvantages. The main type of benefit cited related to the performance of short-term storage applications, which some participants reported as being an effective technology.

Participants were more balanced in their descriptions of their aspirations for and concerns about short-term storage applications. As with other thermal storage materials, participants' aspirations focused only on performance characteristics that they want to see. But their concerns were more broadly based, covering, for instance, both performance and non-performance issues. As examples of the former, one participant questioned whether such applications would lead to overheating in new homes if they are specifically designed to benefit from solar gain, while another queried whether enough research has been done on the long-term impact of such materials in buildings with occupants. As an example of a non-performance issue, one participant drew attention to (presumably missing) design skills.

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up for short-term storage applications. Table 9 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 9. Short-term storage applications: barriers and incentives to take-up

Barriers
Cost of materials.
Cost, value.
Reducing the cost of raw materials and control systems.
Cost for regulatory benefit???
Payback is prohibitive.
Is it too technical for general application – over-complicated?
SAP for Building Regs compliance.
Fire performance*.
Incentives lacking. Heat storage for later re-use RHI?. And domestic small scale not included in RHI at the moment.
Effectiveness of products – evaluation and accreditation.
UK conservative.
Incentives
Highly insulated with fabric thermal storage such as Termodeck make the maintenance simple as these buildings do not make change in temperature when shut off – University of East Anglia has many examples. Maintenance can be programmed in conveniently. See Elizabeth Fry Building.
Neutral comment
A.O.L. concerned more with thermal than overheating.

*Some notes may suggest confusion between short-term storage and PCMs. This too may be a barrier to uptake.

Overall, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of short-term storage applications. They made eleven comments about barriers to take-up as against one incentive for doing so.

The most frequently cited barriers against take-up of short-term storage applications were cost-related, covering both the high capital cost and a prohibitively long payback periods, especially given UK conservatism about innovation in buildings. This latter disadvantage would be compounded, a participant suggested, by the current lack of evaluation and accreditation of such materials, which another regarded as over-complicated for general application in buildings.

By contrast, the sole participant who cited an incentive for using short-term storage pointed to the Elizabeth Fry Building at the University of East Anglia where Termodeck has been in use since 1995 – see its 1998 Probe Report, http://www.uea.ac.uk/estates/environmentalpolicy/Probe+report .

Table 10. Short-term storage applications: sources of information

Sources of information
IEA Task 32 data and that published by the TU-Grer (?) team. (A)
Earth tubes – plastic (B)
Termodeck, cast in coils (B)
UEA, BSRIA, CIBSE (B)
Too broad a topic to mention (C)

As Table 10 shows, even fewer participants (3 out of 20) in the Expert Panel Meeting identified relevant sources of further information. Again, when they did so, they too tended to do so cryptically or in an uninformative manner. Where possible, the sources identified by participants have been followed up in writing the literature review.

2.3 Additional comments about thermal storage materials

At the end of the individual response form, participants in the Expert Panel Meeting were provided with space to make additional comments about it. Participants were encouraged to use this opportunity to raise any issues that they thought should have been discussed but which hadn't. These comments have been classified as positive, negative, or neutral. Table 11 shows the additional comments that were made.

Table 11. Additional comments about Thermal Storage Materials

Positive
This should be best chance of making an impact in the medium term (5-10 years). There is a mismatch between supply and demand of heat and power, and this could be managed/regulated quite readily, given the right incentives.
Group 3 didn't really get into discussion of this area. PCM can help with diurnal. Insulating ??? tank materials are important in this area. Sensible possibly best with PCM assisting. Long-term is possibly thermo-chemical storage. We have proved sensible solar seasonal storage but need to capture 4X what is required.
PCMs can ??? solar fraction of storage but by 10-20% but size of stores stays the same.
User-friendly (passive) things will probably work best. Keeping things as simple as possible is also desirable.
Superinsulate thermal storage – especially heat pump-fed thermal storage.
Negative
If we over-complicate our buildings, are we making a complicated problem for future generations?
Controls matter and are a major barrier.
Electric heating or systems is causing fuel poverty.
Consumer behaviour changes are required.
CRP is not cost-effective to the end user.
Systems need extensive performance evaluation post-occupancy.

Instead of debating these products in expert panel meetings, I would advocate trialling them all in real-life projects with a co-ordinated programme of monitoring and evaluation through the process of design-construction-commissioning-operation. An initial budget of £100m should get it started.
SAP needs to change to enable these changes to take place.
Lack of investment is a barrier.
UK is very conservative.
Neutral
There isn't anything ??? not known.
Need to comply with all parts of Building Regs, especially Part B, fire safety – not just Part L.

Participants offered twice as many negative additional comments here as positive ones. Positive comments mainly referred to (often previously mentioned) performance characteristics of thermal storage materials. Negative ones were more broadly framed, covering a very wide range of issues not directly related to the performance of thermal storage materials themselves. These include: providing over-complicated solutions that disadvantage future generations, specifying electrical heating exacerbating fuel poverty amongst current households, the need to conduct post-occupancy evaluations of building containing these technologies, and changes in occupant behaviour that such technologies are seen as requiring.

These additional comments re-iterate a theme common to many of those previously reported in relation to specific thermal storage materials. Whilst participants did focus attention on specific aspects of the performance of these materials and systems, especially those relating to their costs and lifecycle performance, many of their concerns about them are not related to the performance or technical aspects of the materials themselves. Rather these concerns relate to a series of much wider issues to do with:

- whether there are any substantive incentives to, or benefits from, using these materials at present
- where, when and how such materials can be effectively implemented in practice, in both new-build and retrofits, raising issues, for instance, about design skills, supply chain management, and the integration of utilities operations
- whether the solutions on offer are actually necessary given other routes to low energy buildings, especially when judged from a carbon lifecycle perspective, and
- whether they are too complicated, especially for effective operation by building occupants seeking to meet their own perceptions of their needs.

As one of the participants observed, providing answers to these wider questions requires more than modelling or lab-tests. It requires trialling real-life projects through a co-ordinated programme of monitoring and evaluation throughout their design, construction, commissioning and operation.

2.4 Substantive contributions to be made by insulation materials

Each of the participants in the Expert Panel Meeting was asked to vote individually on the four categories of insulation in terms of their ability to make a substantive contribution to r to reducing energy consumption and CO_2 emissions over the next 5 to 10 years.

Participants were asked to assign a score of 4 to the material they thought would make the most substantive contribution, 3 to the one next most likely to, and so on.

Table 12 shows their individual responses.

Table 12: The priority order that individual participants assigned to insulation materials

	Participants (n=20)																Total	Rank order
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P		
Thermal insulation material																		
New	4	4	3	4	4	3	3	4	3	4	4	3	4	4			51	1st
Natural	2	4	2	2	4	4	4	2	3	4	2						33	2nd
Vacuum-panel	3	2	3	3	2	1	3	2	2	3	1						25	3rd
Multi-foil	1	1	1	1	1	2	1	1	1	3							13	4th

The sum of their individual votes, in the penultimate column, shows that, in aggregate, the participants thought that new insulation materials (including aerogel and petrol-derived materials) are likely to make the most substantive contribution - by a relatively small margin of 1.5:1 against natural insulation materials. The latter are seen as slightly more likely to make a substantive contribution than vacuum-panels. And multi-foils are seen as least likely to do so (by the wider margin of 1:4 in comparison with new insulation materials).

There is more unanimity here than participants showed in relation to thermal storage materials. None of the participants thought that vacuum-panels or multi-foils are likely to make the most substantive contribution. Likewise, none of them thought new or natural insulation materials are likely to make the least.

2.5 Participants' individual views of insulation materials

A. Natural insulation materials

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of natural insulation materials. Table 2 shows their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish) or a concern (misgiving).

Table 13. Natural insulation materials: technical and performance aspects

Benefits
K is higher, embodied energy is low.
Low embodied energy and carbon.
Useful for breathable – existing, heritage.
Excellent vapour permeability.
Good materials, have a 'good' public image. Have a good recycling image and providing agricultural industry with a route for by-products.
Good fire retardant.
Low carbon impact.
Natural are multi-functional. Not only thermal but acoustic, hygrothermal, etc.
Potential multi benefit systems.
Max IWI (?)
Aspirations/wishes
(None cited)
Disadvantages
Limited lambda values.
Greater thickness of material is required compared to new materials to achieve performance – not a problem so much with EWI.
Limited thermal conductivity.
Suited to internal uses, not external.
Decrement decay.
Concerns/misgivings
Ease of installation without gaps is critical.
Look at existing materials as first choice. But must be installed correctly.
Need to consider holistic effect of internal insulation. Moisture performance.
Consistency in final structure for injectable materials.
Could these products meet demand?
Are they needed?
Embodied carbon?
Performance to their limit.
Neutral comments
Different types for roof, walls, ground floor.

The participants were skewed in their descriptions of what they saw as the benefits and disadvantages of natural materials. They listed twice as many benefits as they did disadvantages. Participants saw natural insulation materials as performing well, as having a good public image, and as delivering multiple benefits: low energy and carbon impacts, and good fire and acoustic performance and moisture permeability. But natural insulation materials are also seen as having disadvantages: they have low lambda (thermal resistance) than new insulation materials and so require greater thicknesses, they are restricted to internal use, and their performance is perceived to decay over time.

Participants are highly skewed in their descriptions of their aspirations for and concerns about natural insulation materials. Not a single participant listed any aspiration or wish for these (established) materials. But they did offer multiple misgivings. For instance, these materials are seen as being at their performance limits and there are concerns about how well they are being installed in practice and their moisture performance.

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up natural insulation materials. Table 14 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 14. Natural insulation materials: barriers and incentives to take-up

Barriers
Magnitude of supply of materials.
Supply scale.
Availability.
Manufacturers and suppliers much smaller and find it difficult to compete with big brands such as Kingspan and Rockwool.
Supply chain/cost.
Availability and thickness required.
High costs (money not carbon).
Potential cost with increasing demand.
Increased thickness to achieve codes.
Thickness.
Supply chains.
Compatibility with trades (retraining).
Wrong modelling. BS 5650 wrong EN 15026 certificate is ignorant and ‘a tax on innovation’.
Retrofit market is limited.
Research in this area: one wonders what is needed other than market perception/acceptability.
Not a premium board.
Incentive
Good potential – can help agriculture widen market but can the supply be met?

Overall, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of natural insulation materials. They offered sixteen comments about barriers to take-up as against just one incentive for doing so (and even this contained a caveat about supply).

The most frequently cited barriers against take-up of natural insulation materials relate to their limited availability and supply, the impact of increased demand on their cost, and the thickness required. In addition, like storage materials, natural insulation materials are seen as raising issues about training and supply chain management.

Table 15. Natural insulation materials: sources of information

Sources of information
Ty-Mawr Lime, supplier based in Brecon. (H)
WUFI (I)
FIW Munich (I)
Fraunhofer. (I)
www.natural-building.co.uk (J)
www.asbp.org.uk (J)
Poor installation or certification: Jez Wingfield, ex Leeds Met, 2mm bypass between external insulation and wall = almost 100% useless. (K)
I've seen an NHBC approved project with all insulation 50mm to almost 1 metre from concrete façade. This large multi-storey housing block in East London is virtually un-insulated! (K)

As Table 15 shows, only a minority of participants (4 out of 20) in the Expert Panel Meeting identified relevant sources of further information. Again, when they did so, they too tended to do so cryptically or in an uninformative manner. Where possible, the sources identified by participants have been followed up in writing the literature review.

B. New insulation materials

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of new insulation materials. Tables 15 show their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish) or a concern (misgiving).

Table 15. New insulation materials: technical and performance aspects

Benefits
Well-known characteristics.
Volume for volume increase in performance.
Off site construction – benefit (new build).
Possibility for multi-functionality – two birds, one stone, particularly of glazing systems.
Excellent thermal conductivities leading to increased comfort, space saving.
Long term performance – air-based, gas-based.
Potential of materials like aerogels/zerogels can isolate without allowing light. (?)
Heat storage function, hydroscopic properties.
Damage tolerance.
Aspirations/wishes
Accelerate take up/development of new products.
Improvement of performance.
Need thin materials for new and existing.
Deep retrofit is essential.
Must be easily used – systems approach.
Disadvantages
Installation will affect performance to a very large extent.
Installation is key.
Technical detailing
Building Regs – Part L not aligned with Green Deal.
Limiting performance of thermal conductivity of air.

Concerns/misgivings
As-built detailing.
Must show care – don't build in problems – not all homes are the same!
Must be a holistic approach – process as important as product.
Systems approach needed and necessary skills for installation.
Steady vs. fluctuating performance – mismatch between 'ideal manufacturers' "U-values" and real performance, often too large.
High embodied energy and carbon.
Not practicable.
Neutral comment
Must use existing products.
(High priority) new but commercially available (i.e. not aerogels).

The participants were skewed in their descriptions of what they saw as the benefits and disadvantages of new insulation materials. They listed twice as many benefits as they did disadvantages. Participants presented new insulation materials as having well-known characteristics, with lower conductivities leading to increased comfort and space saving, along with good long-term performance and tolerance to damage. But new insulation materials are also seen as having disadvantages: for instance, they are seen as being highly vulnerable to poor technical detailing and inadequate installation.

Participants were more balanced in their descriptions of their aspirations for and concerns about new insulation materials. Some of these aspirations related to the materials themselves, e.g. improved performance or accelerated development and take-up. But others related to their installation, e.g. the call for 'deep retrofitting' using a systems approach. Concerns were also typically focussed on installation issues, such as careful handling of as-built detailing, the need for a holistic, systems approach deploying the necessary skills. But others covered performance issues, e.g. the discrepancies between manufacturers' and real in-situ U-values, and the high embodied energy and carbon of these materials.

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up new insulation materials. Table 17 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 17. New insulation materials: barriers and incentives to take-up

Barriers
Cost.
New: cost, industry will choose cheapest appropriate?
Cost makes it not effective.
Initial cost is barrier.
Cost/performance.
Getting people to pay for retrofit.
Installation probably the greatest barrier.
Installation effectiveness is an issue.
Houses not factory-built, non-standard.
Buildability more important than small differences in quoted U-values or R-values.
Aerogels and VIPs too delicate.

Process issues.
Performance affected by moisture.
IWI- moisture probems?
Prevents breathability*
Existing are tested, accredited.
Certification.
Software modelling – real life not necessarily same as lab trial.
Site performance v. lab results.
Again SAP/SBEM.
Route to market.
Incentives
Regulations are required to support/force take up of best practice.
Legislation will probably be a driver.
Off-site construction.
Green deal, will people see the savings?
Mass-market solutions vs. 'fit for purpose'.
Thickness more important in UK, more so than rest of Europe (due to lack of space and higher prices).
Most have good fire safety.
Post-occupancy evaluation.

*Again, some notes may suggest limited understanding of new insulation materials by participants, which is itself a barrier to wider uptake.

Overall, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of new insulation materials. They offered two and a half times as many barriers to take-up as incentives for doing so.

The most frequently cited barriers against take-up of new insulation materials relate to their (initial) costs, installation and buildability issues, their moisture performance, and the lack of accredited modelling and hence of certification. Conversely, legislation and the Building Regulations are seen as necessary drivers of best practice here, along with off-site construction. Other incentives include the potential savings identified by the Green Deal, which is also seen as driving towards mass-market solutions that are 'fit for purpose'.

Table 18. New insulation materials: sources of information

Sources of information
Breathability by Neil May (H).
David Olivier, d.olivier@energyadvisoryassociates.co.uk (I)
Bob Lowe, UCL. (I)
Too many to mention! (J)

As Table 17 shows, only a minority of participants (3 out of 20) in the Expert Panel Meeting identified relevant sources of further information. Again, when they did so, they too tended to do so cryptically. Where possible and relevant, the sources identified by participants have been followed up in the writing of the literature review.

C. Vacuum-panels

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of vacuum-panels. Table 19 shows their responses. Each of these responses has been classified as being a benefit, disadvantage, an aspiration (wish) or a concern (misgiving).

Table 19. Vacuum-panels: technical and performance aspects

Benefits
U-value (?) = 0.011 possible.
Very good lambda (?)
Aerogel filled is less likely to suffer from degradation due to damage.
Good on balconies and roof terraces where higher performance protected by concrete slabs etc.
Good in retrofit of solid floor homes over screed and under tongued and grooved boarding.
Thinness leaves staircase bottom tread roughly same as existing – modification can easily be carried out over bottom few steps.
Aspirations/wishes
7-10 years ahead.
Systems approach.
Disadvantages
Not easy to install without damage.
Concerns/misgivings
Great potential. Sealing systems that survive and avoid damage are imperative.
Penetration is an issue.
Robust?
Durability.
Reaching limits of performance.

The participants were skewed in their descriptions of what they saw as the benefits and disadvantages of vacuum insulation materials. They listed six benefits and only one disadvantage. Participants presented vacuum-panels as having very good U-values and as being particularly beneficial in specific situations such as balconies and roof terraces, solid floors and at the bottom of staircases. But vacuum-panels are also seen as having disadvantages: for instance, they are seen as being difficult to install without damage.

Participants were no more balanced in their descriptions of their aspirations for and concerns about vacuum insulation materials. Here concerns outnumbered aspirations 2.5:1. One participant suggested that vacuum panels could make a substantive contribution to reducing energy consumption and CO_2 reduction in 7 to 10 years time. Concerns centred around buildability issues, about how robust and durable vacuum-panels are and whether their sealed systems could be installed without damage.

Participants were also asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up of vacuum panels. Table 20 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 20. Vacuum panels: barriers and incentives to take-up

Barriers
Cost.
Cost!
Not cost-effective and difficult to install.
Seals are a problem.
What about product lifetime in the real world.
Longevity.
Adapted from white goods industry – fridges have 15 year life: dissipation and penetration.
7-10 years for effective implementation and market confidence.
Market confidence.
Too delicate.
Incentives
Very low U-values, space saving, super-thin compared to traditional air-based systems.
There will be a market, but niche application/strategic use.

Overall, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of vacuum insulation materials. They offered five times as many barriers to take-up as incentives for doing so.

The most frequently cited barriers against take-up of vacuum panels relate to their costs, installation and longevity. While some participants think that there will be a market for them, because of their very low U-values and super-thinness, this is presented as being niche applications for strategic uses.

Table 21. Vacuum panels: sources of information

Sources of information
EMPA, Switzerland. (B)

As Table 20 shows, only one participant in the Expert Panel Meeting identified a relevant source of further information. And he did so so cryptically. Where possible, sources identified by participants have been followed up in writing the literature review.

D. Multi-foils

Participants were asked to use their individual response forms to identify what they saw as the most significant technical and performance aspects of Multi-foils. Table 22 shows their responses. Each of these responses has been classified as being a benefit, disadvantage, aspiration (wish) or a concern (misgiving).

Table 22. Multi-foils: technical and performance aspects

Benefits
Promising but probably not going to be good enough in the stated timescale.
Aspirations/wishes
(None cited)
Disadvantages
Limited performance.
Better than mineral wool but not as good as manufacturers claim.

In itself not good – hybrid to balance infra-red/(?)
Questionable performance, help with airtightness.
Do not perform as claimed.
Our group felt that the technical performance is unproven except in situations hard to replicate on site.
Concerns/wishes
(None cited)

The participants were highly skewed in their descriptions of what they saw as the benefits and disadvantages of multi-foil insulation materials. They listed five times as many disadvantages as they did benefits. Participants presented multi-foils as having questionnable performance, generally not as good as manufacturers' claims – except for specific situations that are hard to replicate on site. Even the one participant who thought that multi-foils show promise conceded that this would be unlikely to materialise in the 5 to 10 year timescale under consideration.

Participants did not cite any particular aspirations or concerns about multi-foils – possibly because they saw limited potential from multi-foils over the next 5-10 years.

Participants were asked to use their individual response forms to identify what they saw as the most significant barriers and incentives to take-up of multi-foils. Table 23 shows their responses. Each of these responses has been classified as a barrier or an incentive.

Table 23. Multi-foils: barriers and incentives to take-up

Barriers
No recognised accreditation.
Some building controls accept, others not!
New test required.
Lack of agreed standard test method.
Physics is questionable.
Arguments over performance in practice.
Handleability.
Damage on site.
Incentives
Priority is to improve insulation over internal thermal storage. But large-scale seasonal storage can deal with entire cities and very quickly. ATES works in many cities, say 70% of them.

Once again, the participants were highly skewed in their descriptions of what they saw as the barriers and incentives to the take-up of mutli-foil insulation materials. They offered eight times as many barriers to take-up as incentives for doing so.

The most frequently cited barriers against take-up of multi-foils relate to their accreditation – which has yet to be achieved – to their performance in practice, and to their vulnerability to damage on site. One participant thought that multi-foils may have potential for improving insulation over large scale seasonal storage but that this application related to city-scale, not individual buildings.

Table 24. Multi-foils: sources of information

Sources of information
Eames DCLG paper. (B)

Research at Ulster. (B)
Ask John Willoughby!! (H)

As Table 24 shows, only two participant in the Expert Panel Meeting identified a relevant source of further information. And they did so cryptically. Where possible, the sources identified by participants have been followed up in the writing of the literature review.

2.6 Additional comments about insulation materials

At the end of the individual response form, participants in the Expert Panel Meeting were provided with space to make additional comments about it. Participants were encouraged to use this opportunity to raise any issues that they thought should have been discussed but which hadn't. These comments have been classified as positive, negative, or neutral. Table 25 shows the additional comments that were made.

Table 25. Additional comments about Insulation Materials

Positive
Insulation likely to give greater benefit sooner than thermal storage.
Balance insulation v. storage, especially heritage properties. May be best way of achieving improved kwh/m2.
Selling point: thermal insulation and noise insulation combined to gain public acceptance, particularly in urban environment.
Modern buildings have more glass (large windows/walls). Insulation of glass sometimes, e.g. coatings, will become more important.
Negative
Predicted performance – models do not give accurate values.
Predicted vs. actual performance.
How do the embodied carbon levels compare to the carbon savings over the lifetime of the material?
In new build, it is the robustic (?) design and (?) space for storage.
Does NHBC need to change their requirements on full-fill cavities?
Technical details for overcoming non-standard junctions in older buildings to prevent avoidable thermal bridging?
Don't forget to include MVHR when insulating and airtightness.
Retrofit insulation and how do we improve (?) storage and avoid insulating leading to overheating.
Neutral
Add consideration of hybrids.
Storage more than insulation in research.
Holistic approach is important. What about multi-functional materials?

Participants offered twice as many negative as positive comments about insulation materials. One participant suggested that insulation is likely to make a more substantive contribution to reducing energy consumption and CO_2 emissions sooner than thermal storage materials will. But another framed the issue differently, as being about achieving a balance of insulation v. storage, especially as the best way of improving performance in heritage properties. A third participant suggested that a selling point could be materials that combine thermal and noise insulation, especially in urban settings. Participants' negative comments focused on discrepancies between the predicted as opposed to actual performance of insulation materials, the robustness of (NHBC-accepted) detailing for insulation – especially NHBC's exclusion of full-fill cavities, around MVHR, at non-standard junctions in older buildings to avoid thermal bridging, and the need to avoid overheating.

These additional comments re-iterate a theme common to many of those previously reported in relation to specific insulation materials. While participants did focus attention on specific aspects of the performance of these materials, especially those relating to predicted as opposed to actual performance, many of their concerns about them are not related to the performance or technical aspects of the materials themselves. Rather these concerns relate to installation issues such where, when and how such materials can be effectively installed on site without damage while using robust and effective detailing.

3.0 GROUP RESPONSES

3.1 Group views of the substantive contributions to be made by thermal storage materials

Working in their discussion groups, participants were asked to:

- agree which thermal storage materials they jointly thought would make the most substantive contribution to reducing energy consumption and CO_2 emissions in the next 5 to 10 years, and
- identify what they saw as the most significant issues impacting on these contributions.

The purpose of these discussions was primarily to enable participants to share their views, experience and expertise within a mixed group drawn from highly diverse backgrounds. The intention here was to enable participants to leave the meeting having been exposed to what others thought were the most pertinent issues under discussion, rather than to generate additional material for analysis. Table 26 shows what the groups reported in the feedback session as their shared priorities for thermal storage materials.

Table 26. Group priorities for which thermal storage materials will make the most substantive contribution.

	Ist priority	2nd priority	3rd priority
Group 1	Phase-change	Short-term	Long-term
Group 2	Phase-change	Short-term	Long-term
Group 3	?	?	Long-term

As Table 26 shows, not all groups reported which they saw as the storage materials likely to make the most substantive contribution. Where they did, however, these group responses mirror the aggregated scores that individual respondents recorded on their response forms, see Table 1 – but without giving any indication of the diversity of views on this issue actually present in the room.

3.2 Group views of the most significant issues raised in discussion about the thermal storage materials

Working in their discussion groups, participants were also asked to agree what they jointly saw as the most significant issues raised in their discussions about:

- the technical and performance aspects, and
- the barriers and incentives to take-up

of thermal storage materials. Table 27 shows the issues highlighted by the groups during the feedback session.

Table 27. Group feedback on most significant issues for storage materials

	Group 1	Group 2	Group 3
Issues highlighted	Need to accelarate to market 24h, seasonal, quick hit, combined Cost + payback main barriers e.g. Green Deal Golden Rule AIMC4 – achieved Code 4 without renewables Look at SAP – especially thermal mass Industry won't tool up till there's benefit in leg. Fire safety concerns? Occupants don't understant controls Long-term storage needs size – city scale?	Key concern: have to be able to store heat at set temp 200J/g – no more than 250 (tech max.) Fraunhofer Institute has done work Cost – wallboard is wallboard, isn't it? Software can't model latent heat – so leads elsewhere Must be installable in existing buildings Chemical reactions	How to creat demand for these products? Retrofit harder than new build Design is important too – material can't solve all probs Not just materials that need to be smart Passive measures more reliable/durable Many technologies have no payback Lifecycle carbon issues Condensation+air quality concerns Danger of over-optimisation Prob of overall robustness, if technologies are combined Diurnal cycle is most important – long-term storage not important.

As Table 27 shows, the significant issues reported back by the groups do reflect, at least in part, those raised by individual participants on their response forms. Each group did, for instance, identify the importance of both performance issues (e.g. cost, payback, fire, moisture, durability/robustness) and non-performance issues (e.g. impact of the Green Deal's Golden Rule, installability in both newbuild and retrofit, demand creation). But, in comparison to the aggregated individual responses, the group feedback provides only an impoverished subset of:

- the wide range of views held
- the weight of opinion (as expressed through frequency of mention)

by those who took part in the Expert Panel Meeting.

3.3 Group views of the substantive contributions to be made by insulation materials

Working in their discussion groups, participants were also asked to agree which insulation materials they jointly thought would make the most substantive contribution to reducing energy consumption and CO2 emissions in the next 5 to 10 years. Table 28 shows the groups' responses as reported in the feedback session after the group discussions.

Table 28. Group priorities for which insulation materials will make the most substantive contribution*

	1st priority	2nd priority	3rd priority	4th priority
Group 1	New insulation	Natural insulation	Vacuum-panels	Multi-foils
Group 2	New/existing insulation	Vacuum panels	Natural insulation	Multi-foils
Group 3	Natural insulation	New insulation	Vacuum panels	Multi-foils

* Since these priorities were not very clearly expressed on the pinned up flip charts, these recorded results may include misinterpretations.

As Table 28 shows, these group responses (if correctly interpreted) do, for the most part, reflect the aggregated responses recorded on the individual response forms, see Table 12. But there is one significant departure here. Members of Group 2 jointly gave higher priority to vacuum panels than the aggregated individual responses did.

This higher priority is not necessarily inconsistent with the aggregated individual responses recorded in Table 12. It is possible, for instance, that the five individuals who gave vacuum panels a score of '3' as recorded in Table 12 were all members of Group 2. Conversely, this higher priority could also be the result of the dynamics operating within Group 2 - with some members disproportionately influencing the priorities given and/or recorded for the insulation materials. This illustrates how group feedback can be problematic and/or impoverished in comparison with what individual participants recorded about their own views.

3.4 Group views of the most significant issues raised in discussion about the insulation materials

Working in their discussion groups, participants were also asked to agree what they jointly saw as the most significant issues raised in their discussions about:

- the technical and performance aspects
- the barriers and incentives to take-up

of insulation materials. Table 29 shows the issues highlighted by the groups during the feedback session.

Table 29. Group feedback on most significant issues for insulation materials

	Group 1	Group 2	Group 3
Issues highlighted	Rejected natural (performance), VIP (except doors+dormers), multi-foils (do they deliver?), aerogels (too delicate, too expensive) Buildability – blocks+u-value calcs don't match tolerances – need to be 2mm tolerances Thickness is more important than material Lab-based measurements often not achieved in practice. Steady-state experiments don't reflect reality of heating in homes NHBC – prevents full-fill cavities in many regions, but forces cavities everywhere – NHBC v risk-averse	Installation is key – more important than choice of material – both retrofit + new build Good detailing is critical for existing bldgs We need deep retrofit approach – only one chance per bldg New Part L doesn't help – or current software VIPs have great performance, but lose 50% performance when punctured Mkt confidence for VIPs – we're conservative in UK Even if technical side is proven, builders are sceptical Large-scale availability of natural materials	Need holistic approach – acoustic performance – good for nat products Nat (esp. wood fibre) offers some thermal buffering Can be better for interstitial condensation Capillary action – moisture can now be modelled using software In carbon cost, nat materials are better (even if not financially) Poor modelling is barrier in UK Passive House Institute says UK is 10% worse than modelled because of quality on site We shd use ext. insulation in UK – allows better standard of insulation UCL work showed upgrades to 80,000 homes didn't achieve expected savings Cold bridges – thick insulation often doesn't achieve expected savings VIPs are good for green roofs – specialist applications

As Table 29 shows, the significant issues reported back by the groups do reflect, at least in part, those raised by individual participants on their response forms. Each group did, for instance, identify the importance of both performance issues (e.g. expense, delicacy, acoustics, moisture penetration) and non-performance issues (e.g. installation and supply chains). But, across the three groups there is more emphasis on non-performance issues here. As Group 2 highlighted:

> “Installation is key – more important than choice of material – both [for] retrofit and newbuild.”

And this emphasis is also present in the significant issues highlighted by Groups 1 and 3, e.g. the impact of the NHBC, lab-based measurements not achieved in practice, the weakness of steady state modelling, insulation not achieving savings because of cold bridges, upgrades not achieving expected savings. But again, in comparison to the aggregated individual responses, the group feedback provides only an impoverished subset of:

- the wide range of views held, and
- the weight of opinion (as expressed through frequency of mention)

by those who took part in the Expert Panel Meeting.

4.00 SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of results

As Tables 1-28 show, participants in the Expert Panel Meeting did feel capable of prioritising what contribution thermal storage and insulation materials are likely to make to reducing energy consumption and CO_2 emissions over the next 5 to 10 years. Table 30 summarises their priorities for thermal storage materials and the judgements they made about factors affecting their likely contributions.

Table 30. Summarised benefits and barriers etc for thermal storage materials

Material/system	Phase-change	Short-term storage	Long-term storage
Priority	1st	2nd	3rd
Benefits	Some	Some	Some
Aspirations	Few	Few	Few
Disadvantages	Some	Few	None
Concerns	Many	Few	Few
Barriers	Manifold	Many	Many
Incentives	None	Some	Few

Key	Few = 1 - 4	Some = 5 - 9	Many = 10-19	Manifold = >20

Participants jointly see phase-change materials as likely to make the most contribution. But participants view these materials as facing manifold barriers that may prevent them from doing so, especially since they see no incentives currently working in their favour. Their second and third priorities - short- and long-term storage – are also reported as facing many barriers but they are seen as having at least a few incentives supporting their deployment. All three options are viewed as having some benefits. Phase-change materials, while selected as the highest priority, are also identified as highly problematic because they have the most disadvantages and raise the most concerns.

Table 31. Summarised benefits and barriers etc for insulation materials

Material/system	New	Natural	Vacuum-panel	Multi-foil
Priority	1st	2nd	3rd	4th
Benefits	Some	Many	Some	Few
Aspirations	Some	None	Few	None
Disadvantages	Some	Some	Few	Some
Concerns	Some	Some	Few	None
Barriers	Manifold	Many	Many	Some
Incentives	Some	Few	Few	Few

Key	Few = 1 - 4	Some = 5 - 9	Many = 10-19	Manifold = >20

Jointly participants see new insulation materials as likely to make the most contribution to saving energy and CO_2. But participants also view these materials as facing manifold barriers that may prevent them from doing so, especially since they discern only a few incentives currently working in their favour. Their second and third priorities – natural insulation materials and vacuum-panels – are reported as facing many barriers and having few incentives supporting their deployment. All four options are viewed as having at least a few benefits. New insulation materials, while selected as the highest priority, are also identified as having some disadvantages and raising some concerns.

Accordingly, both the thermal storage and the insulation materials seen as the priorities which are most likely to make substantive contributions to reducing energy consumption and CO_2 emissions over the next 5 to 10 years are seen as problematic. They both occupy disadvantaged positions because they are confronted by manifold barriers with little in the way of incentives to support their effective deployment.

4.2 Conclusions

From the statements recorded on their individual response forms, it is possible to build a detailed picture of the assessment criteria that participants in the Expert Panel Meeting used when prioritising materials and selecting what they saw as significant issues impacting on their contributions to reducing energy consumption and CO_2 emissions over the next 5 to 10 years. Between them, participants employed a diverse range of assessment criteria. But these criteria fall into two main categories:

1. those that relate to ***intrinsic*** characteristics of the materials themselves
2. those ***extrinsic*** to the material and related to the circumstances in which those materials have to be deployed

Table 32 lists some of the most commonly recurring of these intrinsic and extrinsic characteristics drawn from participants' comments as reported in Tables 2-28.

Table 32. Examples of the intrinsic and extrinsic characteristics used to assess the materials/systems under scrutiny

Intrinsic characteristics	Extrinsic characteristics
(Life cycle) energy performance **(Life cycle) carbon impact** **(Lifecycle) costs**, including payback periods **Moisture penetration**	**Installation issues**, including: Design skills Site operative skills Availability of 'good practice' technical detailing
Fire risk **Acoustic properties** **Handleability**	**Operational issues**, including: Occupant awareness and understanding of materials/system and associated controls Reliability and maintenance requirements
Robustness/durability/delicacy **Decremental decay** **Toxicity**	**Operational environment conditions**, including: Modelling/certification requirements arising from legislation such as Building Regulations Rules associated with Government and non-governmental schemes such as the Green Deal or NHBC Investors' perceptions of benefits, incentives and disadvantages

Table 32 makes clear the highly complex nature of the judgements that participants were making when they sought to prioritise and comment on the thermal storage and insulation materials under discussion. Doing so required participants to consider materials against a wide range of competing characteristics and to seek to weigh these against each other, especially when estimating which are likely to make the largest contributions. But these assessments must often have the quality of personal judgement calls since, as participants themselves conceded, the empirical evidence on which to base them - about the performance of materials in situ, about the savings arising from their effective installation and operation in practice – are frequently absent or unknown to them. What is remarkable is that participants still felt able, by drawing on their own diverse experiences and expertise, to prioritise the materials they consider despite the lack of the empirical evidence that they see as necessary when attempting to do so. However, these personal judgement calls by participants do not constitute a robust basis for government policy- and decision-making.

4.3 Recommendations

An underlying purpose of the Expert Panel Meeting was to provide the Department with access to experience and expertise that could inform its decision-making on thermal storage and insulation. The meeting sends a clear message here to the Department on this front. If such decision-making is to be evidence-based, then as Table 32 indicates, that evidence has to cover a wide range of both intrinsic (to do with the materials) and extrinsic factors (to do with how they are employed). It has to include not just a variety of performance characteristics of the materials/systems in question but also a whole range of characteristics of the situations in which they will have to be deployed. To use the words employed by some of the participants, the Department's approach to decision-making here should be both 'holistic' and 'systems'-based. The evidence collected cannot be constrained to modelling or lab tests of the performance of the materials themselves. It should instead be extended to monitoring and evaluating their performance in built and occupied examples, across both new build and retrofitting situations.

Appendix 1.
The participants in the Expert Panel Meeting

Workshop Participants	Group
1. Andy Ford, Mott MacDonald	1
2. Bill Gibson, Kingspan	2
3. Brian Cahill, Aspen Aerogels	3
4. Christos Markides, Imperial College	1
5. Darren Dancey, Group Technical Director, Crest Nicholson	1
6. Dr Andrew Peacock, EnergyFlo*	3
7. Dr Russell Binions, UCL	3
8. Gavin Killip, University of Oxford	3
9. Ian Biggin, Phase Energy (BASF)	2
10. Jacquelyn Fox, CIBSE	2
11. Jeremy Watson, DCLG	2
12. Joanne Hopper, Cardiff Metropolitan University	2
13. John O'Brien, BRE	1
14. Julian R G Evans, UCL	2
15. Justin Bere, Bere Architects	3
16. Ken Bromley, DCLG Building Sustainability	1
17. Neil May, Good Homes Alliance	3
18. Paul Voden, Kier	1
19. Phil Eames, Loughborough University	2
20. Philip Griffiths, Ulster University	3
21. Professor Zhen Xiao, Guo, UCL	1

* Unable to attend because of delayed train

Appendix 2.
Programme of Expert Panel Meeting

14.00	Welcome and round table introductions
14.10	Briefing on the Insulation and Thermal Storage Materials project
14.25	Q &A
14.35	Insulation materials: issues and sources of information
	- technical and performance aspects
	- market research
	- barriers and incentives to take up
15.10	Tea break
15.25	Storage materials: issues and sources of information
	- technical and performance aspects
	- market research
	- barriers and incentives to take up
16.00	Building types
	- new build
	- retrofit
16.15	Plenary discussion
16.25	AOB: other over-looked issues
16.30	Close

Appendix 3: Example of uncompleted Individual Response Forms

Thermal storage	Priority
1. Phase-change materials	
Technical and performance aspects	
Barriers and incentives to take-up	
Sources of information	
2. Long-term heat storage	
Technical and performance aspects	
Barriers and incentives to take-up	
Sources of information	

3. Short-term applications, including cooling	
Technical and performance aspects	
Barriers and incentives to take-up	
Sources of information	
Additional comments	

Initials	