

28th April: Looking into the future



Aims

This month, we looked into a specific resource - wood - and the panel of witnesses explored how shifts in the way we use wood may change and by focusing on timber in buildings, we generated questions related to both forestry production and the kinds of materials that architects, designers and engineers will be looking for.

Witnesses

Peter Freer-Smith, the Chief Scientist for Forest Research and Forestry Commission, joined **Jon Kirkpatrick**, the Head of Sustainability, Europe, for Lend Lease and **Michael Ramage**, a Senior Lecturer in who is leading a new Centre for Natural Materials Innovation in the Department of Architecture.

Research gaps

Peter argued that **the UK has moved from a past focus on woodland creation to an agenda driven by climate change adaptation and protection from pests and pathogens, both couched in terms of resilience.** Climate adaptation work focuses on the silviculture of different species - the practice of controlling the establishment, growth, composition, health, and quality of forests to meet diverse needs and values – as well as the properties of the wood itself. He finished by stressing the need to value woodlands not only in terms of the resource they provide, but also in terms of their conservation, their landscape, recreational value, their forest protection, their soil protection, their water management qualities, even flood defence. If all of these are considered, the price may be a loss of production – is this one we are willing to pay?

Jon said that it is clear there are considerable sustainability and construction benefits to using timber. Although he agreed with Michael that **some of the barriers to using more natural building materials are technical, he stressed that there are also considerable challenges associated with people's perceptions** of whether they are a viable and competitive alternative to steel and concrete. In his experience, some of these are practical such as fire risk, strength or durability which in turn impact mortgages and insurance. Others relate to economics, changes to the design and construction of the building and the environmental impact of the materials. This catalysed a discussion related to how the 'true' costs and benefits of natural material could be explored throughout the supply chain from where it is grown to where it is used.

Michael's new Centre aims to develop new sustainable applications for plant-based natural building materials such as bamboo and cross-laminated timber. Ultimately, he wants to use these materials like this to create skyscrapers more than 10 storeys high. When thinking about what these buildings will look like, he argued that **a paradigm shift is needed in the way buildings are designed rather than simply applying steel and concrete-based design expertise.** The properties, strengths and weaknesses of these new plant-based materials will allow architects to experiment and create new structural forms.

Wicked problems and questions generated by the open discussion included:

- **How can we measure the 'true' costs and benefits of using timber in construction**, including the impacts of material processing (such as glue), methane and carbon emissions during shipping and transportation? Even though the carbon emissions from shipping are low, would it be more sustainable to source it from as close as possible to the construction site rather than producing it in another country?
- According to FRA 2015, planted forests make up 7% of the total global forest area but provide 45% of industrial round wood consumption. Peter argued that **planted forests could supply the bulk of our wood requirements and protect remaining natural forests.** Given changing uses, is this feasible?
- **What tree species are needed to supply the timber for future buildings and where in the world will it come from?** The most productive trees are fast growing eg eucalyptus, but how many and which aspects of construction are they suitable for? We tend to think about supply chains like this in global terms but would reducing the use of timber for paper really increase the supply of suitable grade wood for construction? As these forests already exist, can we – or should we - increase the use of such timber by material innovations?
- **What are the barriers to using natural material in buildings and how can they be overcome?**
- **Could the land sparing/land sharing debate be extended to forests and forest ecosystems?**

Witnesses

This month, the three witnesses are:

Professor Peter Freer-Smith	Chief Scientist, Forest Research and Forestry Commission
Jon Kirkpatrick	Head of Sustainability, Europe, Lend Lease
Michael Ramage	Senior University Lecturer, Department of Architecture, University of Cambridge

Biographies

Professor Peter Freer-Smith

As Chief Scientist for Forest Research and Forestry Commission, Peter ensures that Forest Research provides the scientific knowledge and expertise required to achieve sustainable forest management. He ensures that advice to policy makers and practitioners is based on good scientific understanding and sound research and contributes to the formulation and implementation of the Forestry Commission's policies and objectives. Additional responsibilities include Head of Station at Alice Holt Forest near Farnham in Surrey (where he is based) and representing Forest Research on the Forestry Commission Research Management Board.



Peter studied for his first degree at Stirling University gaining a first class degree in Biological Sciences. His PhD was on the Impacts of Air Pollutants on Trees. Both his PhD and DSc are awarded by the University of Lancaster. Peter did two periods of post-doctoral research at Lancaster before moving to a lecturer's post at the University of Ulster. He joined the Forestry Commission in 1987. In June 2005 Peter was appointed Honorary Visiting Professor in the School of Biological Sciences, University of Southampton. He was appointed Forestry Commission Chief Scientist in 2009.

Jon Kirkpatrick

Jon Kirkpatrick heads up sustainability for Lend Lease across the EMEA region, and acts as the central liaison for all sustainability issues across all of its business units. His role covers two essential areas, environmental operations plus associated performance and development innovation and strategy (both environmental and community investment).



In addition to embedding sustainability across the business, he is also ultimately responsible for sustainability on major projects at Lend Lease, and works primarily on significant urban regeneration projects across Europe (such as Elephant and Castle & The International Quarter). Jon works closely with the development teams to focus on comprehensive urban and infrastructure problems, including finding solutions for renewable energy, water, waste, transport, biodiversity, green infrastructure and public realm issues through integration of sustainability into design. Before joining Lend Lease, Jon has experience across a wide number of major projects globally including the London 2012 Olympic Park and Education City in Qatar as an associate director of EDAW/AECOM.

Michael Ramage

Michael Ramage is an architectural engineer and Senior Lecturer in the Cambridge University Department of Architecture, a fellow of Sidney Sussex College, and a founding partner of Light Earth Designs. He studied architecture at the Massachusetts Institute of Technology, and worked for Conzett Bronzini Gartmann in Switzerland prior to teaching at Cambridge.



His current research is focused on developing low-energy structural materials and systems in masonry, better housing in the developing world and improved engineered timber and bamboo through natural material innovation. He teaches, researches and designs buildings, and receives research funding from the Leverhulme Trust, the Engineering and Physical Sciences Research Council, the Royal Society, the British Academy, Cambridge University and industry.

Setting the scene

Professor Peter Freer-Smith, the Chief Scientist for Forest Research and Forestry Commission, will bring a 'supply side' perspective to this discussion. He will explore trends in planted forests and the implications for the future of forest products supply in the context of a changing population and climate.

Jon Kirkpatrick is the Head of Sustainability, Europe, for Lend Lease and acts as the central liaison for all sustainability issues across all of its business units. In addition to embedding sustainability across the business, he works primarily on significant urban projects across Europe including regenerating over 28 acres across three sites at the heart of Elephant & Castle in the heart of London.

Michael Ramage from the Centre for Natural Materials Innovation will begin by talking about why architects and engineers need to move beyond thinking about tall buildings in terms of steel and concrete. He will also discuss some of the work that he and his group are doing to develop new sustainable applications for renewable, energy-efficient and plant-based natural building materials, such as bamboo and cross-laminated timber.

Full references

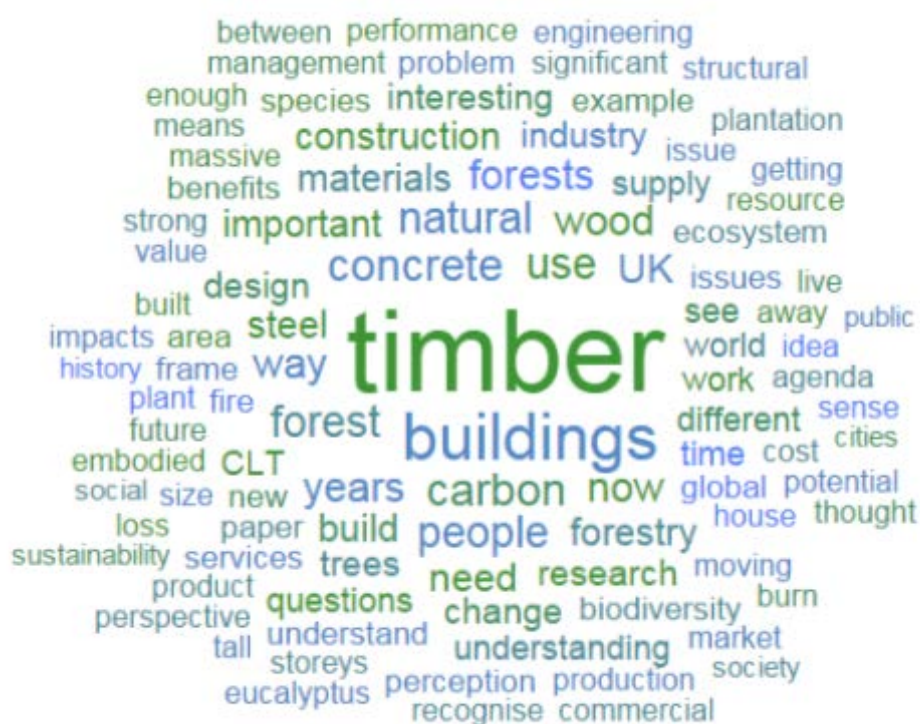
Tim Payn, Jean-Michel Carnus, **Peter Freer-Smith**, Walter Kollert, Shirong Liu, Christophe Orazio, Luiz Rodriguez, Luis Neves Silva, Mike Wingfield (in prep) Changes in planted forest and future global implications

Patrick Fleming, Simon Smith and **Michael Ramage** (2014). Measuring-up in timber: a critical perspective on mid- and high rise timber building design . Architectural Research Quarterly, 18, pp 20-30
doi:10.1017/S1359135514000268

One of the projects that Jon will use as an example is the regeneration of Elephant and Castle and you can read more about it here: <http://www.lendlease.com/emea/united-kingdom/projects/elephant-and-castle-regeneration>

Word Cloud

Created by using Word It Out - www.worditout.com – based on the transcript of the meeting (edited to exclude non subject-specific words).



A summary of the main points

"I'd say that within the UK we have moved from a past focus on woodland creation and to some extent biodiversity which has been a major focus in recent years to an agenda driven by climate change adaptation and protection from pests and pathogens, (both crouched in terms of resilience)." Peter Freer-Smith

- The future of plantations and sustainably managed forests- is there a significant role for mono-culture 'crop' forests to play in the future supply of timber?
- Currently planted forests make up 7% of the total global forest area but provide 45% of industrial roundwood consumption – in the future, is it feasible for planted forests will supply the bulk of our wood requirements and protect remaining natural forests?
- What tree species are needed to supply the timber for future buildings and where in the world will it come from? Does reduced use of timber for paper really increase the supply of suitable grade wood for construction? Can we increase the use of such timber by material innovations?
- Exploring the social and ecosystem services value of forests and forest landscapes
- Developing new ways of processing and using wood in buildings
- A paradigm shift is needed in the way we design buildings rather than simply applying concrete-based design expertise
- The future impacts of climate change on forestry – risks and opportunities
- Quantifying and modelling the value of competing land uses, including forests - the competing uses/functions of forests (timber, paper, biofuel, biodiversity, recreation) paralleling similar pressures on agricultural land. Has the land sparing/land sharing debate been extended to forests?

Costs and benefits of using timber in construction, including the impacts of material processing (such as glue), methane and carbon emissions during shipping

Introductions by the witnesses

Peter Freer-Smith: Forest resources and management (he sent us his notes)

I'd like to explain that my professional responsibilities are for UK forestry that is the full range of stakeholders/beneficiaries – to a) see that the sector delivers what it has the potential to deliver and b) to see that the forestry sector gets a fair deal in the light of its potential to deliver and when confronted with the pressures that there are on land and other resources.

Secondly as a forest scientist my interests are at the supply end of the discussion today and I'm particularly concerned with the science/policy /practice linkages.

In this introductory 10 mins I want to say a brief work on three areas:

- 1) Global resource supply and some of the associated issues, pressure points and governance.
- 2) A quick word about the UK specifically – we are an interesting case
- 3) And Rosamunde asked me specifically to consider next generation research questions – by far the hardest bit.

Global resources are covered in the paper which was e mailed round – this is a quick preview of the FAE Global Forest resource assessment which will be released in September this year at the World Forestry Congress in South Africa.

Forest cover globally has been declining since the iron age at a rate which accelerated during the industrial revolution and – in terms of the loss of primary forest – is still increasing. This loss of forest cover has had a number of effects including making a contribution to atmospheric CO2 content and some equally dramatic effects on the environment and biodiversity locally. We are very fortunate to have the FAO GFRA and all the numbers I'm about to quote are from it. The Assessment was started in 1980 and so we have good quantitative data since then.

The net loss of forest area globally is the combined outcome from deforestation and woodland creation. It shows that the area of forest cover globally has decreased for 4.13 Billion ha in 1980 to 3.99 Billion ha in 2015.

Rates of overall loss have been:

- 1990 – 2000 8 Million ha/year
- 2000 – 2005 5 M ha/year

- 2005 – 2010 6 M ha /year
- 2010 – 2015 8 M ha /year (UK is c 24 Million ha)

Since the world land area is c.11.623 Billion ha globally forest cover has now decreased to 34.28%.

There is not an International Convention on Forestry or a European Legally binding agreement on Forests although over the years there has been much talk of it. The FCCC and Biodiversity Convention all impose forestry instruments.

The UN has run a Forestry Forum and important UN initiative has been the REDD and REDD + . That is funding to schemes to Reduce the Emissions of Green House gases from Deforestation and Forest Degradation. Essentially a UN funding scheme to protect forests in developing countries.

Other key international instruments have been on Illegal logging, EU Timber Trade Regulation and Forest Law Enforcement Governance and Trade (and VPAs) and Forest Certification to achieve sustainable forest management although this still covers on 4 % of global forest area. CITES – global; agreement on endangered spp.

Since the area of planted forests has been increasing the net forest area data hide a continuing decline in primary and natural forest area.

Of course it's bad that primary/natural forests with all their biodiversity, conservation and environmental benefits are declining.

However it is good news that plantation forestry is increasing – it becomes possible that planted forests will supply a bulk of wood requirements and act to protect the remaining natural forests. Currently planted forests make up 7 % of the total global forest area but provide 45 % of industrial roundwood consumption.

There is considerable scope for planted forests to contribute to biodiversity, landscape and other ecosystem services as well as to meet the bulk of global wood needs. Tree breeding can substantially increase production – In Eucalyptus tree breeders have more than doubled productivity and even the UK SS breeding programme has increased yield by 23% without loss of wood quality.

Planted forests may be very acceptable as a land use on degraded land and thus as long as we continue to create planted forests and to manage them sustainably we are likely to be able to meet global timber needs.

Just want to mention two more points on the international side. Firstly IUFRO have just established a Task force on Planted forests for which I am the UK contact point. This is an important initiative which aims to move forward the potential of planted forests

Secondly illegal logging, governance, international trade and controls. Remain very important.

A very brief word about the UK then as on industrialization – we led the world on deforestation and by the end of the second war had decreased our forest cover to c. 4% - its now 12 % so we feel that we are experts on reforestation – woodland creation.

One reason it's worth mentioning the UK is to illustrate how national policies operate – it was a national programme to re- establish forest cover and it was achieved by a combination of a Government programme which included land acquisition and grant aid to private forestry. Not more than 20 years ago the domestic market only provided c. 10% of softwood roundwood needs and the processing industry was on its knees. Today its 40% as a result of the new forests coming to production. This is influenced strongly by the price of roundwood on the world market and the use of wood as a biomass fuel has helped to hold up prices.

Softwood production in the UK is about 8 – 10 Million m³ per year, and does support a processing industry. Including my multinational like UPM Tillhill.

Hardwood production is much lower at 0.5 to 1.0 Million m³ per year and is potentially much greater. There is talk of a potential as high as 5 million m³ per year. Only about 58% England's woodlands are managed and there is a target to raise this to 66 % by 2018. Recently policy has moved away from woodland creation to woodland management and protection. Grown in Britain – new initiative.

On **future research needs** I'm going to keep my initial comments quite general and perhaps we'll get into more detail during the evening.

I'd say that within the UK we have moved from a past focus on woodland creation and to some extent biodiversity which has been a major focus in recent years to an agenda driven by climate change adaptation and protection from pests and pathogens, (both crouched in terms of resilience). Climate adaptation work focuses on different species their silviculture and wood properties. And in upland forestry in particular this

means a serious look at species mixtures to achieve resilience. These policies have implications for wood processing and utilization.

Carbon management and other ecosystem services are important. We still have a National Capital committee I think!

In Europe there is a stronger interest in novel uses for wood – the bioeconomy as it's often called. And internationally – as I've already indicated conservation, social and governance issues will remain important. Forest pests and pathogens will remain important since the threat they pose will continue to be present as long as we have timber, plants and wood packaging moving internationally.

Jon Kirkpatrick, Head of Sustainability, Europe, Lend Lease (by Bhavna Sharma)

Need to understand pressures and drivers of market globally for developers and clients

- 50% of populations in urban cities
- Represents 2% of landmass of the world
- Expected growth by 2050 is 5%
- Increased footprint

Accountability

- 100 year old building
 - Design of structures not optimised for long term use and focus on long term planning will allow buildings to be reused in the future
- Health and safety
 - Instant injury free
 - Extends to supply chain
- FSC UK
 - Resource focus and supply chain

Timber construction

- Perception issues
- Sustainability benefits
 - Example CLT structure in Melbourne: Carbon footprint lower than concrete building equivalent, even though timber shipped from Austria
- Drawbacks
 - Contractor and developer perception
 - lower grade
 - low class
 - Fire risk
 - Mortgage/insurance issues

Social

- Design
 - Low VOCs
 - Natural material interiors
 - Feature wall in Melbourne to display timber construction
- Accountability
 - Material choices decision making for process (lack of research)
- Schools
 - Effects of materials of experience of space, behaviour, health (lack of research)
- Cost/benefit analysis
 - Value of natural materials
 - Requires full construction scope rather than solely a material comparison

Additional comments:

Process

- Upfront process in CLT design, which is set early on in manufacturing, compared to concrete or steel where adjustments can be made on site
- Lean design - speed of construction an argument for CLT to be used
- Hybrid technologies for design appropriate

Summary of points

- 1) Perception from an economic and social standpoint needs to be explored if timber will be a competitive alternative to conventional materials
- 2) Market drivers are demand and cost, but need to be explored through full scope of construction
- 3) Social aspects not only focus on the design and construction, but extend to responsibility and impact on the overall supply chain

Key points people took away from the witnesses in the Original Forum

After the meeting, everyone was asked to outline the three things that they took away from the discussion and what aspects of they found most interesting. These included ideas or questions that they would like to explore more or those we didn't talk enough about.

The future of plantations and sustainably managed forests

Is there a significant role for mono-culture 'crop' forests to play in the future supply of timber? It wasn't said explicitly last night but I got the feeling that the consensus was that there is, I just wonder how significant they should be.

Through well managed forests, we can withdraw a lot more wood - sustainably - than is currently the case globally. But this requires a view to forests as to some extent being a resource base rather than only a conservation zone. Research is needed to quantify this potential increase in sustainable withdrawal and how this compares with potential demand for wood products in construction.

I thought the FAO figures presented by Prof Freer-Smith were revealing: such a large proportion of industrial roundwood still coming from natural forests at present, but production from plantations on the ascendancy. I came away with a changed perspective on tropical plantations - perhaps they could be good for biodiversity conservation if they help relieve pressure on primary tropical forests. If.

What tree species do we need?

The potential of plantation forestry to take the pressure off global deforestation. In particular, the ethical and practical implications of increasing wood production in certain countries through the intensive cultivation of genetically modified species such as the Eucalyptus in Brazil.

The most productive trees are fast growing eg eucalyptus, but how many and which aspects of construction are they suitable for? Does reduced use of timber for paper really increase the supply of suitable grade wood for construction? Can we increase the use of such timber by material innovations?

Exploring the social and ecosystem services value of forests and forest landscapes

We didn't discuss the social/ritual significance of woodland, something which emerged viscerally from the national psyche at the great forest Sell Off debacle, when people became aware of a routine operation that had been running for years.

Britain is still a deforested country, even if forest growth has been spectacular recently - its from a very low base. But much of the space in which trees used to grow now forms treasured romantic landscapes, bare and denuded - moors, fells, hill tops etc. Contrast e.g. the Black forest, the lower Alps.

Innovation and design

Developing new ways of processing and using wood in buildings and improving its performance

There is a lot of research still to be done on the properties of natural materials and how well these properties match the performance required in construction. Especially pressing is the need to better understand WHY we have such performance requirements, and whether a shift to natural materials would cause these performance requirements to change because the entire design of buildings would change.

There are many unknowns still about the performance of timber in fire and genuine concerns over some aspects due to the lack of familiarity with the material in the UK (real contribution to the fire load, glue

delamination, self-extinguishment etc) and this is an important area for study. It reinforces and supports your (and Arup's) multidisciplinary approach to timber and development of holistic solutions. I came away genuinely buoyed by it.

The value of hybrid technologies - it doesn't have to be all timber

CLT is routinely being overdesigned for structural elements; not enough attention paid to timber floor cassettes which can be installed efficiently.

The potential for research regarding hybrid technologies for modified wood and the economic/social/health benefits of wood if entering the UK construction market. The role of vested interests and building codes into shaping the existing construction industry (concrete, steel, cement).

A paradigm shift in the way we design buildings

We need to re-think the design of timber buildings from scratch, rather than applying concrete-based design expertise

Recycling and re-using timber from buildings

It was clear from Jon that Lend Lease don't focus on embodied impacts as the primary driver, but it is an important part of the story and better end of life information is needed I think; will we be putting large engineering timber in landfill (I think not) or do we, as Peter Guthrie was suggesting, need to think more clearly about future scenarios for timber recycling now including avoiding treatments?

The future impacts of climate change on forestry

I was really interested in how you are working at so many scales on timber: cellular to city.

The future impacts of climate change on forestry seems a major risk, but also an opportunity. Is there a strategic case for scaling up forestry cover in the UK back to the sort of averages in other European countries Peter was talking about?

Quantifying and modelling the value of competing land uses, including forests

The low carbon credentials of the use of wood in construction are still not well quantified with respect to lifecycle carbon. This is in large part because the counterfactuals on the use of the land - if not for timber production - are not well quantified or even specified. Research is needed to allow development of better models for competing land uses, with both economic and non-economic drivers included.

Something that interested me from the discussion was the competing uses/functions of forests (timber, paper, biofuel, biodiversity, recreation) paralleling similar pressures on agricultural land. Has the land sparing/land sharing debate been extended to forests?

The prospects for supply increases seem good - better use of current forest, and improved productivity of trees. Decrease in use of wood for paper.

The supply of timber needs more exposure - there is an OVER supply of softwood timber in Europe, Canada does not replant its softwood harvesting, and there is more potential in European hardwoods such as Beech and Ash.

Costs and benefits

Interesting to hear that wood could be a cost-effective alternative to steel and concrete. Not so if the raw material costs were the only consideration, but the speed of construction at the building site makes it attractive.

Material processing: We didn't discuss the use of glues in laminated woods. These are obviously important contributors to structural strength but what is their environmental impact, esp at deconstruction.

Methane: Is it really correct to assert that since methane is a far more harmful greenhouse gas (~20 times the impact) than CO₂ that we should really just burn wood rather than let it rot? This suggestion seems nonsensical to me, if we consider that at periods during its history the Earth had huge forest cover, all of which was left to rot and release methane, then this would imply that green house levels would have been far higher previously.

Peter Guthrie's reply: As for methane versus carbon dioxide, the rule of thumb is 25x greater in its greenhouse effect (global warming potential =25, GWP of CO₂ is 1), despite being shorter lived in the atmosphere (12 years), see <http://epa.gov/climatechange/ghgemissions/gases/ch4.html> , so it would always be better to intercept CH₄ and burn it to produce CO₂. All rotting vegetation produces methane (eg landfill)

Carbon emissions and shipping: I was interested to learn that shipping timber all over the globe contributed less to the carbon budget than the last 50-100 miles (or so) of timber movement by road.

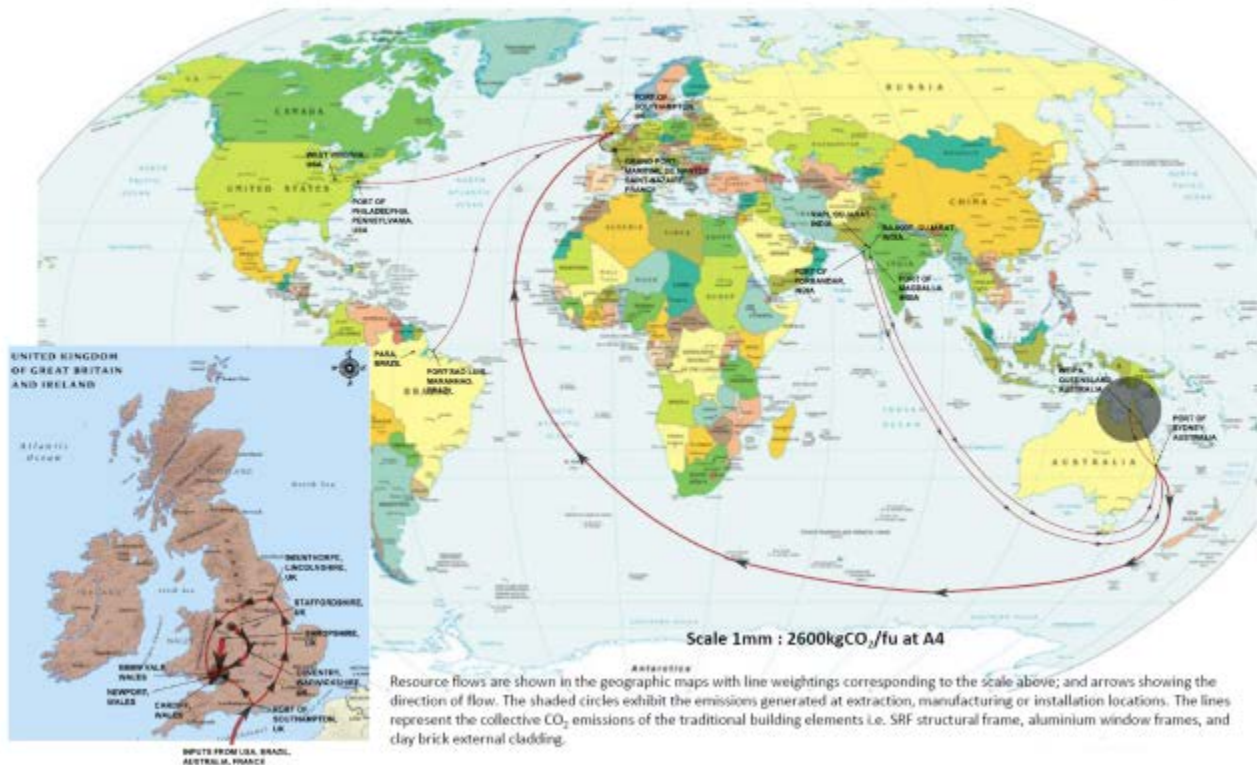
Also, regarding the 'embodied carbon' sustainability arguments of timber constructions - how they can be overstated, and the need for whole-life cycle assessment and deconstruction issues. I still find it surprising that shipping large volumes of timber round the world has a negligible carbon footprint.

Reply from Peter Guthrie: The CO₂ emissions from shipping by sea compared to over land

I was surprised there was not more widespread understanding that the carbon associated with shipping is small comparatively with transport on land and in particular the "last 20 miles". I attach a report done by Sita Shah, a fourth year student studying civil, structural and environmental engineering (not peer reviewed or published) which makes the point well – see figures below:

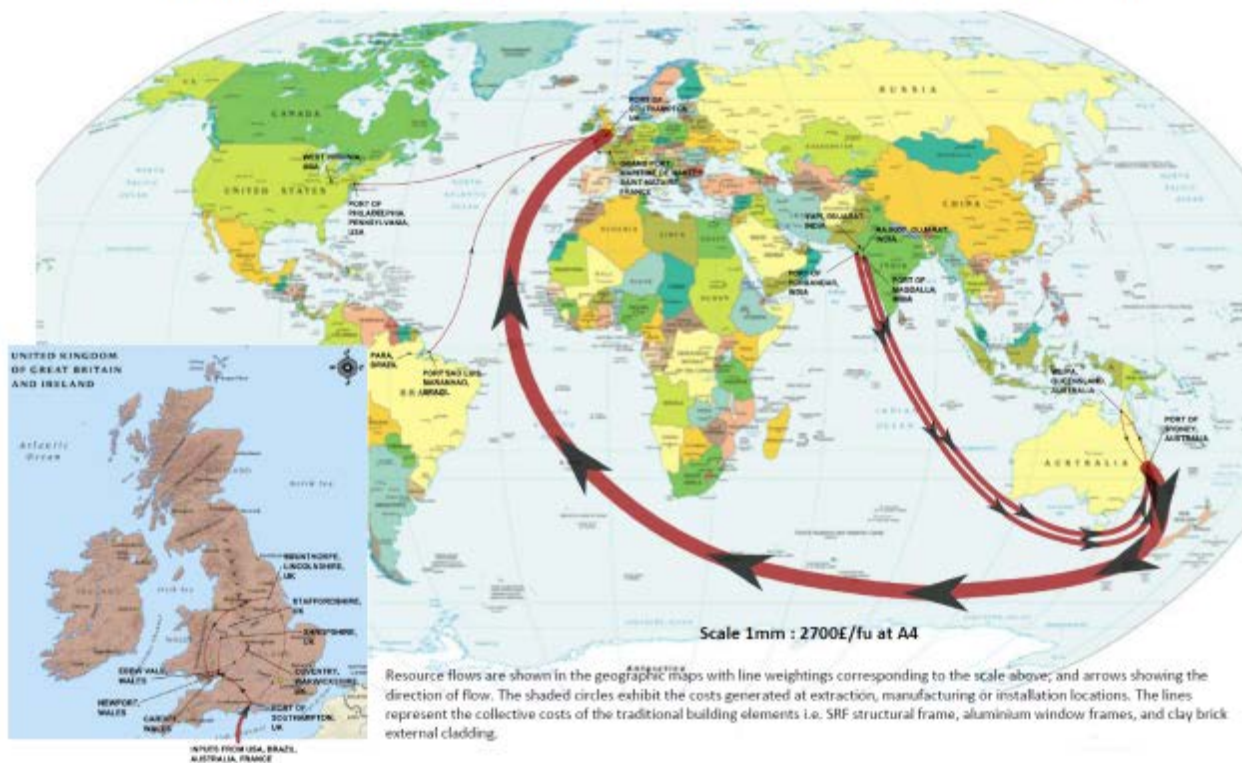
Co2 emissions – the thicker the line, the higher the emissions

5.1.6.1 Insertion III – Geographical distribution of supply chain metrics for Traditional building elements – CO₂ emissions kg/fu



The cost of shipping the timber in GBP – again, the thicker the line, the higher the cost

5.1.6.2 Insertion III – Geographical distribution of supply chain metrics for Traditional building elements – Cost £/fu



Changing people's perceptions of using wood as a building material

Much of the focus was on the structural and architectural properties of wood as an alternative to concrete. I was surprised that the only refs to aesthetic properties were essentially negative; there are significant advantages here, which contribute to well being. Wood enables much more organic forms - cf. the use of wood in art nouveau decoration, window frames etc. Wood panelling has traditionally been associated with warmth and cosiness - watch any period movie!

I was surprised to hear about the resistance to use of wood in construction. I had thought building regs and conservatism in construction would mean changes are slow, but I also thought pressure for change would be high. We need to work at multiple levels to improve this- architect research and education, construction industry education, and material innovation.

The importance of perception, and hence of engaging social sciences

Timber faces many barriers as a mainline construction material, from codes to prejudice in designers to lack of skills on site to fear of fire (made worse by the recent destructive fire at Nottingham University).

As a great fan of wooden building I was fascinated to hear that influential people in the construction industry don't want to see exposed wood in their buildings!

The existing public scepticism on timber-framed and clad buildings and how awareness could be raised on the issue. There is a need for exemplar housing and public building projects.

Attendees

<u>Name</u>	<u>Where they are from</u>
Adrian Campbell	Arup
Bea Schlarb-Ridley	British Antarctic Survey
Bhavna Sharma	Department of Architecture
David Coomes	Department of Plant Sciences
Dimitra Dantsiou	Department of Architecture
Doug Crawford-Brown	Department of Land Economy
Gemma Cranston	Cambridge Institute for Sustainability Leadership (CISL)
Henry Burrige	DAMTP
Ian Hodge	Department of Land Economy
Jon Kirkpatrick	Lend Lease
Michael Ramage	Department of Architecture
Miles Parker	Cambridge Centre for Science and Policy (CSaP)
Paul Dupree	Department of Biochemistry
Paul Linden	DAMTP
Peter Freer-Smith	Forestry Commission
Peter Guthrie	Department of Engineering
Richard Brooke	Forestry Commission England
Rosamunde Almond	DAMTP
Simon Smith	Smith and Wallwork
Will Simonson	Department of Plant Sciences