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Use of wood in green building: a study of expert perspectives from the UK

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ABSTRACT

Green building (GB) is an emerging topic in research. However, few studies have directly linked wood materials with the concept of GB. Here, we attempt to increase our understanding of GB and the potential for using wood to enhance this concept from the market point of view, with emphasis on experts in the UK construction sector, using qualitative analysis of interview data. The main results support Abidin's broader concept of GB (2005) and suggest that there is potential for integrating GB and corporate social responsibility in the construction sector; thus we add affordable housing as an additional element in the economic dimensions. Our results further verify the crucial role that the UK government has played in GB formation, promotion and development and showed a positive increase in using wood in the UK construction sector, supporting the notion that the environmental performance of wood is the major driver in embracing wood in the GB concept. In addition, we showed that experts who have sound knowledge of wood as a building material agree on its superior environmental credentials; however, end users who may lack information and knowledge of wood products often show strong prejudice against its use. Finally, we demonstrated that the major drivers promoting wood as a sustainable solution for GB in the UK construction sector include legislation, environmental awareness, attitudes and traditions, market and competition, promotion and communication, and technology and know-how.

1. Introduction

The last decade has witnessed a dramatic global increase in environmental consciousness and in concerns about the effects of business activities on climate and natural resources. Environmental concern has caused companies to consider the merits of new concepts, such as environmental or green marketing, lean thinking, ecojustice and corporate social responsibility (CSR).

From an environmental perspective, the construction sector is particularly concerned with and extensively criticized over issues such as the excessive use of natural resources, high energy consumption, excessive waste and CO_2 emissions (Qi et al., 2010; Varnäs et al., 2009). The UK construction industry, for example, uses around 400 Mt of materials and 6500 ha of land every year and produces around 90 Mt of construction, demolition and excavation (CD&E) waste (19% of total UK waste) (HM Government, 2008). The construction sector accounts for approximately 50% of UK CO_2 emissions (across life cycle processes of the construction work, including the use phase of the building), and is responsible for nearly a third of all industry-related pollution incidents (BIS, 2010). Since the energy consumed in construction is about 40% of the total UK energy consumption (European Commission, 2005), it is time to embrace the concept of green building (GB) for the construction sector.

GB (also referred to as green construction, sustainable building or sustainable construction) is the main construction sector concept used in this context. The US Environmental Protection Agency (2011) defined GB as the "practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation and deconstruction." Bauer et al. (2007) showed that GBs are any buildings subscribing to the principle of a conscientious handling of natural resources. Hwang and Tan (2010) stated "Green building addresses the ecological, social and economic issues of a building in the context of its community."

Wood has been a primary building material used by humankind throughout history and is a sustainable and renewable building material (Herbert, 1993; Sathre and Gustavsson, 2009). Using wood

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in construction can affect carbon balance through the following mechanisms: 1) lowering fossil-fuel consumption in manufacturing compared with alternative materials, 2) avoiding emissions from cement processing, 3) accumulating carbon storage in wood products and forests, 4) avoiding fossil-fuel emission due to biomass substitution and 5) playing a part in carbon dynamics in landfills (Sathre and O'Connor, 2008). Increasing the use of wood in construction and for other long-lived uses would thus aid in achieving the goals of sustainable development.

There are a growing number of technical and case studies focussing on the environmental performance of using wood in construction. For example, Koch (1992) found that structural wood products had consistently lower carbon balances than other non-wood substitutes, such as steel, aluminium, concrete and brick. Schlamadinger and Marland (1996) studied the role of wood products in the global carbon cycle through several mechanisms: storage of carbon in the biosphere, storage of carbon in forest products and use of wood products to replace substitutes requiring more fossil energy in their production. A study from the Canadian Wood Council (CWC, 2004) showed that wood-based construction systems displayed lower environmental impact on the measures of energy consumption, greenhouse gas emission, air pollution, water pollution and solid wastes than steel and concrete systems. Upton et al. (2008) found significant savings of greenhouse gas emissions and energy consumption associated with the use of wood-based building materials in residential construction in the US. Sathre and Gustavsson (2009) examined the use of wood products as a means of mitigating climate change and found that the production of wood products uses less energy and emits less carbon than production of concrete materials, and the inclusion of climate-related external costs improved the profitability of wood construction. Gustavsson et al. (2010) conducted a life cycle assessment of primary energy and the climatic impacts of an eight-storey wood-framed apartment building and found that a negative life cycle net CO_2 emission could be achieved, due to the wood-based construction materials and biomass-based energy supply system.

There are also an increasing number of market studies related to wood construction and its impact on the environment; e.g. Kozak and Cohen (1999) specified the role of wood products in the non-residential construction sector from the point of view of architects and structural engineers and indicated that wood had a fairly healthy share of the structural non-residential market in Western North America, such as in religious buildings, restaurants and commercial/residential combinations. Robichaud et al. (2009) studied the perceived identity of wood among architects in non-residential construction, finding that wood was deemed to be one of the most environmentally friendly materials. In Norway, Bysheim and Nyrud (2009) concluded that experience, perceived behavioural control and attitudes towards the use of wood as a construction material were significant factors influencing architects' intentions to use wood in urban construction and indicated an increased use of wood in the urban construction sector. Knowles et al. (2011) found in the US a positive view of wood and a strong desire to use more wood from design professionals, who regarded wood as the most sustainable structural material available. Hemström et al. (2011) found highly perceived environmental benefits, attitudes and interest in using wood frames in multi-storey buildings, but there were also negative opinions towards wood engineering properties.

However, practically no studies have linked wood materials directly with the concept of GB. Only one recent thesis in this field was done by Noël (2012), who studied architects' opinions of wood as a suitable material for the North American construction industry, finding that wood products could be used to reduce the environmental footprint of GB, improve energy efficiency, reflect a positive image of GB and enhance the green values embedded in GB. Here, we attempt to increase our understanding of the GB concept and the potential for use of wood in enhancing this concept from the market point of view, with emphasis on experts in the UK construction sector.

In 1994, the UK became one of the first countries to publish its national sustainable development strategy, which focused on the construction sector (DTI, 2004). In accordance with the principles of this strategy, the government produced its strategy for sustainable construction, entitled A Better Quality of Life in 2000 (DTI, 2004). The UK also introduced a GB assessment system, the Building Research Establishment Environmental Assessment Method (BREEAM), in 1990, which is the first and most widely applied in the world (Larsson, 1998). With the guidance of the strategy, a set of regulations, standards, assessments, financial incentives, modern methods of construction (MMC) technologies, monitoring and management systems, etc. have been developed to ensure industry commitment to GB. In 2006, the UK government determined that all new residential houses should conform to GB by 2016 and all new buildings should be built in compliance with GB by 2019 (FAITC, 2012). The global GB trend study done by McGraw Hill_Construction (2013) showed that currently about half of the UK construction firms are engaged in GB. The UK has been one of the world's most advanced nations employing GB, which is why we have chosen it as a focus of this study.

The aim of this study is to examine the perceptions and insights of construction experts in the UK regarding the use of wood in contributing to GB. This study aims to explore the following research questions:

- What is the current situation of GB in the UK?
- What are the key drivers and main challenges affecting the use of wood in the UK GB sector?

2. Theoretical background

2.1. Concept of GB

The history of GB can be traced back to the late 19th and early 20th centuries, when buildings such as London's Crystal Palace (built in 1851) and Milan's Galleria Vittorio Emanuele II (built in 1877) used passive heating systems, such as roof ventilators and underground air-cooling chambers, to moderate indoor air temperature (Hansen, 1971; Cassidy, 2003). The GB movement resulted from the demand for more energy efficiency, environmental friendliness and construction practices conducive to human health, which can be traced back to the 1970s and 1980s (Cassidy, 2003; Atlee, 2011). The concept of GB has flourished since the philosophy of SD was introduced in 1987 in the Brundtland Report, because it contributed significantly to the implementation of SD principles (Wu and Low, 2010; Zhang et al., 2011). SD is defined as a "development that meets the needs of the present without compromising the ability of the future generation to meet their own needs" (World Commission on Environment and Development, 1987). Thus, the goal of SD is to secure economic development, social equity and justice, and environmental protection.

While Chong et al. (2009) claimed that there was yet no standard definition of GB, the broad consensus was that all existing definitions followed the fundamental concepts and objectives of SD. In this study, we attempt to categorize these under two domains: the narrow and the broad definitions of GB. Under the narrow GB concepts, definitions were often limited to environmental issues and construction practices, such as material use, technologies and processes, while the broader GB concepts governed the three pillars of SD: environmental, social and economic

responsibilities in a more balanced way (Addis and Talbot, 2001; Brownhill and Rao, 2002; Tan et al., 2011).

The narrow GB concept was typically concerned with the use of locally available natural materials and their environmental performance (Chau et al., 2007, 2010), sustainable design and green architecture that emphasized the design process of the construction, a technical concept called MMC that introduced new building products and solutions (e.g. moving from on-site construction to off-site) (NAO, 2005) or high-performance building, which referred to the practice of increasing building efficiency, such as utilizing a grey and storm-water reuse system and a green roof (Dator, 2010; Chang et al., 2011).

Johnston and Gibson (2008) stated "Green building is ultimately about the relationship of a house and its occupants to the world around them. It's a process of design and construction that fosters the conservation of energy and other natural resources and promotes a healthy environment." The World Architecture Community (2011) defined it as "a structure that is designed, built, renovated, operated or reused in an ecological and resource efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health, improving employee productivity, using energy, water, and other resources more efficiently, and reducing the overall impact on the environment." Dombi et al. (2008) suggested that GB was the practice of increasing the efficiency of using resources in construction, which reduced environmental impact during the building's life cycle through better siting, design, construction, operation, maintenance and removal. Kibert (1994) suggested six principles for creating a sustainable built environment: 1) minimizing resource consumption, 2) maximizing resource reuse, 3) using renewable or recyclable resources, 4) protecting the natural environment, 5) creating a healthy, non-toxic environment and 6) pursuing quality in creating the built environment. In summary, the main objective of narrow GB concepts is to reduce the environmental impact of buildings.

The core of the broader GB concept is the integration and application of SD principles to the comprehensive construction life cycle, from extraction of raw materials to the final process of deconstruction and management of the resultant waste (Tan et al., 2011). Hill and Bowen (1997) developed the comprehensive fundamentals and principles of GB and suggested that GB include social, economic, biophysical and technical considerations with a set of process-oriented principles. According to Adler et al. (2006), GB was a way of enhancing the environment, which benefits human wellbeing, community, culture, environmental health and life cycle costs. Abidin and Pasquire (2005) defined the principles of GB as including: 1) ensuring that people live in a healthy, safe and productive built environment and in harmony with nature, 2) meeting the needs of the present without compromising the potential of future generations, 3) considering the benefits and costs of society and the environment, 4) applying technology towards improving building efficiency and effectiveness and 5) minimizing damage to the environment. We perceive that the broader concept of GB can be most efficiently described by Abidin's diagram (Fig. 1), which consists of three main tasks: environmental protection, ensuring social wellbeing and bringing economic prosperity.

As defined by Qi et al. (2010), the major drivers for construction companies to adopt GB were environmental regulation, managerial concern and stakeholder involvement. In practice, the development of GB is often accomplished through the GB rating system, which provides guidance on the measurements of the sustainability level and enhances the commitment to the best-practice experience (Adler et al., 2006). The GB rating system carries the principles of sustainability into construction practices, its primary role being to provide "a comprehensive assessment of the environmental characteristics of a building, using a common and verifiable set of criteria and targets for building owners and designers to achieve higher environmental standards" (Ding, 2008). The following Table 1 lists the best-known GB rating systems and standards, indicating that the GB concepts have mainly emerged in the developed countries, with the exception of China.

2.2. Environmental soundness of wood in comparison to other building materials

The building and living with wood concept is formed by a multi-layered combination of wood and wood-based materials to serve as a system for working in the construction process of interior design, on-site and off-site construction, decoration, renovation, maintenance and associating with the nearby environment. The structural use of wood and wood-based materials is one of the primary

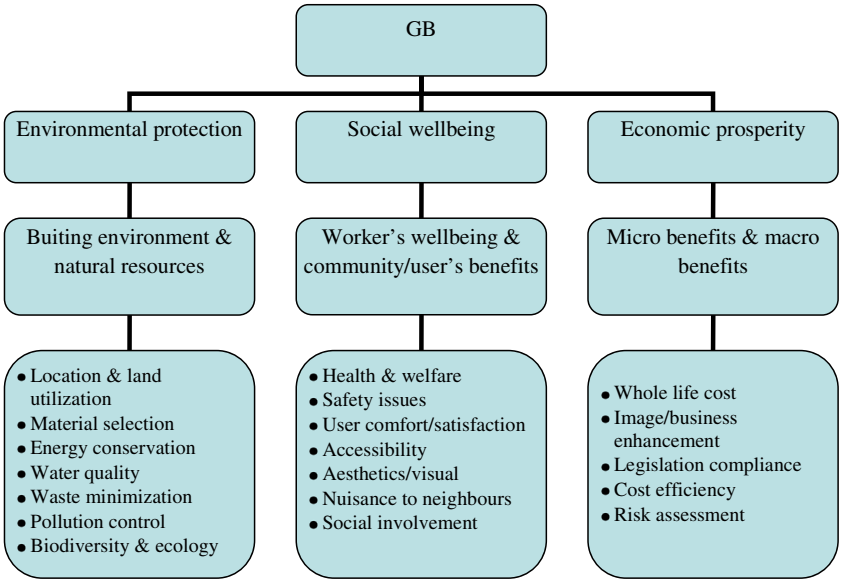

Fig. 1. The diagram of the broader concept of GB. Source: Abidin, 2005.

Table 1
Overview of key international GB rating systems and standards.

GB rating systems		Origin	Year
BREEAM	Building Research Establishment Environmental Assessment Method	UK	1990
BEPAC	Building Environmental Performance Assessment Criteria	Canada	1993
GBTool	Green Building Challenge	International	1995
LEED	Leadership in Energy and Environmental Design	US	2000
NABERS	National Australian Building Environmental Rating System	Australia	2001
GHEM	Green Home Evaluation Manual	China	2001
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency	Japan	2001
GreenStar	Green Star Environmental Rating System	Australia	2003
Protocollo ITACA	Istituto per l'Innovazione e Transparenza degli Appalti e la Compatibilita Ambientale	Italy	2004
HQE	High Environmental Quality	France	2005
GBP	Green Building Programme	EU	2005
DGNB Certification System	German Sustainable Building Council Certification System	Germany	2009

(Sources: Sangster, 2006; Ding, 2008; Espinoza et al., 2012; Geng et al., 2012)

choices in residential building and its popularity has increased steadily. The primary driving forces include the ever-increasing need for affordable housing and environmental consciousness (Fridley, 2002). The market share for timber frame (TF) construction has continued to increase and has become a mainstream method for delivering quality and GB construction. Taking the UK construction market as an example, in 2011 TF construction covered 25.6% of all new housing in the UK (UKTFA, 2011). In addition, the volume of softwood consumed by the UK construction markets in 2008 was 5.2 million m^3, the main use being repair, maintenance and improvement applications in the construction sector (UNECE, 2010).

The strength of wood thus lies not only in its beauty and functionality, but that it is also a genuinely renewable building material (CWC, 2002). The top-rated desirable environmental attributes for wood are renewability, local availability and natural material (Noël, 2012). In today's environmentally conscious world, the benefit of building and living with wood is becoming ever more apparent. There are numerous studies showing that wood and wood-based building materials typically result in lower energy and greenhouse gas emissions, are recyclable and have positive environmental impacts (e.g. Buchanan and Levine, 1999; Gustavsson et al., 2006; FPAC, 2009; Sathre and Gustavsson, 2009). The CWC (2002) showed that wood is the best solution for satisfying the four principles of GB: 1) reducing energy use during building service life, 2) minimizing external pollution and environmental damage, 3) reducing embodied energy and resource depletion and 4) minimizing internal pollution and damage to health.

Building and living with wood can reduce energy use, in particular fossil fuel energy. Its low conductivity and good insulating properties make it 400 times better than steel and 10 times better than concrete in resisting the flow of heat, thus creating significant savings in energy consumption (FPAC, 2009). Wood construction requires not only much less energy to manufacture, but also has the lowest energy consumption across the product life cycle than any other building material. For example, steel and concrete buildings embody and consume 12% and 20% more energy than wood buildings (CWC, 2007).

Using wood can reduce CO_2 emissions through the carbon sink effect of the forests, the carbon storage effect of wood products and the replacement of carbon-intensive materials (BCFCCWG, 2009). Building and living with wood also results in reducing resource use. For example, steel and concrete buildings use 7% and 50% more resources and produce 6% and 16% more solid wastes than wood in both manufacturing and on-site construction (CWC, 2007). There is even possibly zero waste from using high-value-added products such as engineered wood products (EWPs) and system products. Wood is also biodegradable, reusable and recyclable, and its by-products, e.g. sawdust, can be used to make products, such as composite wood or some wood-based panels. Thus, wood is a suitable material for MMC in reducing waste, improving efficiency and speeding construction time.

Furthermore, using wood can result in minimizing pollution. For example, steel and concrete buildings release 10% and 12% more air pollution and discharge 3 and 2.25 times more water pollution than wood buildings (CWC, 2007). Wood is predictable in fire and is also bio-degradable, thus bringing less pollution to landfill and the nearby environment. Even though wood is an environmentally sound construction material, there are still some factors limiting wood use in GB: 1) complex supply of certified wood products, 2) difficulty in rating assessment documentation, 3) contrasting objectives in rating systems and 4) non-green wood (issues such as negative environmental impacts of logging and illegally logged wood) (Noël, 2012).

3. Data and research methodology

3.1. Method

Since the purpose of the study is to increase our understanding of the development of wood use in GB from the point of view of UK experts, we used a longitudinal, qualitative interview study methodology to obtain experts' perceptions and beliefs. The qualitative interview study "seeks to describe and understand the meanings of central themes in the life world of the subjects" (Kvale, 1996), with the main task of understanding the meaning of what interviewees say.

3.2. Sampling

The unit of analysis is the individual informant and a theoretical sample consists of experts from the UK construction and timber sector, associated with 18 organizations originally selected from the Inter-build 2006 Construction Fair (one of the biggest construction fairs in the UK). The study employed theoretical sampling, a purposive sampling technique that allows flexibility and directs all data collection efforts towards the best development of the emerging theory (Glaser and Strauss, 1967; Glaser, 2001).

3.3. Participants

The participants in the study comprised 36 experts. The initial survey was conducted during the Inter-build 2006 Construction Fair between April 22 and 28 2006. Twenty-three experts from 18 different organizations were interviewed, and the follow-up survey was conducted from February 2012 to January 2013. The same group of participants was contacted first. As expected, many were no longer available for the second survey, due to retirement or changing jobs. We thus contacted the people who currently hold the same positions at these organizations. There were 13 experts who responded to the second-stage survey (Table 2). Since the objective of the qualitative interview study was to achieve the representativeness of emerging themes and concepts rather than that of samplings (Al-Busaidi, 2008; Hancock, 1998), the smaller

Table 2
Number of participants and organizations of the two-stage survey.

Organization	Number of organizations		Number of participants	
Year	2006	2012	2006	2012
Industry interest group	3	1	4	2
Timber manufacturer	5	2	5	2
Timber supplier	3	1	3	1
Construction material merchant	1	2	1	3
Timber expert organization	3	2	6	2
Promotional organization	2	1	3	2
Government	1	1	1	1
Total	16	10	23	13

number of participants in the follow-up survey could still provide both accumulative and comparative results.

3.4. Data collection

The data collection method of the first research stage in 2006 comprised face-to-face in-depth interviews. A semi-structured interview guide was given to each respondent several days before the interview, which ensured that a similar set of issues was explored with each respondent. Semi-structured interview is an ideal and flexible tool that gives the interviewees the liberty to interpret their opinions freely while interviewers can interact (Luo and Yang, 2012). The progress of the interview is dependent on the emerging of key themes. The duration of the interviews ranged between 30 min and 90 min, with an average of 1 h. All interviews were recorded.

The second-stage data collection in 2012 was conducted by telephone and email. McNamara (1999) showed that initial interviews may be useful as a follow-up strategy for further investigations; thus, the ongoing analysis may influence the subsequent interview questions, and the direction of the subsequent interviews will be driven by the emerging themes. Since the purpose of this follow-up stage was to provide a more longitudinal perspective on the contemporary views of experts, the interview guide was slightly adjusted, based on results from the first stage, by adding some retrospective information and by a sharper focus on the emerging theory.

3.5. Data analysis

The thematic analysis method was chosen, since it is the most common form of analysis in qualitative research (Braun and Clarke, 2006). It is a method for identifying, examining, analysing and recording themes within data, in which the themes are patterns across data sets that are crucial to describing a phenomenon and associated with a specific research question, and these themes become categories for further analysis (Braun and Clarke, 2006; Kellehear and Gliksman, 1997). Analysis includes writing field notes, reviewing transcripts and coding interviews. The five stages of thematic analysis include 1) familiarizing oneself with the data and discovering recurrent themes, 2) coding of the transcripts based on the objectives of the study and emergent themes, 3) comparing codes between interviews and re-coding, 4) grouping themes together into broader categories through constructing a conceptual framework and 5) summarizing and synthesizing data into charts to demonstrate themes through representative quotes (Watson et al., 2008). All the concepts, properties and dimensions, themes, and categories, are assembled and analysed through a framework, based on thematic matrices. This matrix format allows easier pattern matching and comparisons across interviewees. Finally, a total of 10 themes within two major categories emerged from the data (Table 3).

3.6. Validity and reliability

Internal validity was achieved through pattern matching in the interpretation and explanation of the findings. The use of multiple stages was to establish chains of evidence and thus to construct the reliability of this evolving topic. Despite the fact that the number of interviews in each stage was not high, the data and findings drawn from it became saturated during the research process and, therefore, the present sample is likely to be sufficient regarding the aims of the study. In the reporting of results, careful documentation was also used to ensure the reliability of the results. Moreover, selected authentic extracts of primary data of the interviewees are presented to enable the reader to determine the consistency of the findings and the accuracy of the interpretation.

4. Results

4.1. Development of GB

4.1.1. Views of experts in 2006

4.1.1.1. General public awareness. Many respondents commented that the general public had become more aware of the impact of construction activities, and they believed that the concern for GB would increase, as illustrated by the following quotes:

> *"People are becoming more environmentally conscious, and are using more environmentally friendly materials: less concrete and steel, more gluelam and I-beams"* (a timber manufacturer).

> "*People want to have eco-friendly house.*" (an officer of a promotion organization).

4.1.1.2. The government's role. The answers of the experts suggested that sustainability had an important place in the UK government agenda and that government had been pushing the development of GB through policy development such as standards, legislation, guidelines and assessment systems. For example, they pointed out that the sustainable communities plan Building for the Future was one of the key GB development strategies in 2006. Other quotes include:

> *"The government tries to boost sustainable housing through legislation, and standardization will happen in this sector"* (a timber supplier).

Table 3
The thematic framework of data analysis.

Major categories	Themes	Properties or dimensions
Development of GB	General public awareness	Knowledge and consciousness of general public
	Government role	Government sustainability agenda
	Affordability	Cost-sensitiveness
	Sustainability	Environmental, economic and social responsibilities
Drivers for using wood in GB	Legislation	Supportive standards, legislation, guidelines and assessment systems
	Environmental concerns	Environmental performance of wood
	Stakeholders' attitudes and traditions	Wood reputation and tradition
	Market growth and competition	Market position and competition with substitutes
	Promotion and communication	Marketing and information flow
	Technology and know-how	Research and development and innovation

"Sustainability is on the agenda of the UK government. The UK politics is getting greener and government is the driver" (a timber manufacturer).

Regarding GB building regulations, there was an interesting comment made by a construction material merchant: *"There are too many certifications at the moment, thus causing conflicts, inconvenience and extra cost in the practice."* The interviewee suggested more collaboration and integration of different assessments, systems and standards to build a clearer and unified code of GB.

The interview results showed that building legislation had changed dramatically in the past, and there were higher standards for sustainability issues, especially those related to thermal insulation and conservation (such as the U-value and part L: conservation of heat and power mentioned in the interviews), to improve energy efficiency and reduce CO_2. The interview results showed that specific GB assessment tools have been developed to help achieve government GB plans and sustainable strategy, e.g. ECO-HOME, and BREEAM. Legislation was the direct way to improve construction, but there were also indirect ways, such as through social housing projects, promotion of MMC technology and governmental procurements. The UK government was the sole model in GB for the private sector.

4.1.1.3. Affordability. Many respondents mentioned GB being a cost-sensitive issue, with affordability as one important criterion. In their opinion, affordability and sustainability had to be bonded together and affordable housing was a part of GB, as mentioned by the following example: *"Cost is an important issue; eco-housing has to be price competitive—affordable eco-housing"* (a construction material merchant).

4.1.1.4. Sustainability. The interviewee comments showed that environmental responsibility was a crucial part of GB, mainly dealing with issues of energy efficiency, material efficiency and the environmental impact of on-site construction work. Affordable housing was applied as a major indicator of economic responsibility in GB. In their opinion, social responsibility issues were involved in dealing with work safety and worker wellbeing. For example, moving from on-site manufacturing to off-site manufacturing (MMC) could provide easy and safe solutions and products for both on-site and off-site workers. For example: "Affordable and environmental housing will increase in the following areas: sustainability, eco-friendliness, recyclability, transportation efficiency, energy consumption, off-site manufacturing" (a timber manufacturer). In summary, the development of GB in UK meant affordable, environmentally and socially responsible housing.

4.1.2. Views of experts in 2012

In the past 5 years, the global economic crisis, which started in 2007, has resulted in significant negative effects on the construction business. The UK construction market has shrunk. Interviewees found it difficult to draw a unanimous view about the current state of the UK construction business, since their answers diverged. However, although they have different opinions of the general construction market, there is a consensus that GB is continuing to increase. In their opinion, GB has become the pre-eminent point of growth in the current uncertain market, because of its sustainability commitment; i.e. it has gained additional added values, as shown in quotes such as:

"Value added was becoming a prime concern to ensure you gained what business was left – therefore environmental issues were regarded as value added and helped secure some big contracts" (an officer of a timber expert organization).

"Despite the downturn in the market, green building is the only initiative to show some resilience within the construction sector" (an officer of a promotion organization).

4.1.2.1. General public awareness. In general, interviewees described an increasing concern for GB among the general public compared with 5 years ago. For example: *"There is increased interest and acceptance in green building"* (an officer of a timber expert organization). However, increasing awareness of the pressing cost issue has restricted the development of GB, as mentioned by the following quotes:

"The emphasis on green building has shifted to a greater emphasis on cost and customers are prepared to accept a reduction in sustainable credentials for their buildings as long as they are delivered more cost effectively" (a timber manufacturer).

"The willingness of many buyers to pay premiums has become more restricted during the economic downturn. People are looking for more available and economic GB solutions" (a government official).

4.1.2.2. The government's role. Based on the answers of respondents, we can see that sustainability has been a major issue in UK government thinking. The development of GB is a part of SD, government policies being its domain drivers, as illustrated by the following quotes:

"The main drivers for green building are the UK government's commitments to reduce carbon in construction both from the point of view of carbon storage in buildings and the energy efficiency of buildings" (an officer of a timber expert organization).

"*The UK Governments appear to be more committed to the green building agenda"* (a construction material merchant).

4.1.2.3. Affordability. The interviewees emphasized that cost concern continues to be significant, and it has become the only key issue left for GB to resolve before coming to dominate the construction market. Consumers may be trying to save costs and sacrifice sustainability aspects, particularly during the period of market stagnation.

"Sustainable construction is an opportunity waiting to be seized and for some price is a key issue" (an officer of a promotion organization).

"Interest in potentially more sustainable construction is increasing and the emphasis on its price has now become so pronounced" (an officer of a timber expert organization).

4.1.2.4. Sustainability. Our respondents expressed increasing commitment to CSR issues in the construction sector. They also suggested that the concepts of GB and CSR can be comfortably integrated into the construction sector because they are under the same umbrella principle—sustainability, which balances three dimensions: economic development, social equity and justice and environmental protection. The only difference is that the GB places more emphasis on the end products, while CSR highlights the business and corporation. An expert from a promotional organization suggested that *"GB and CSR are similar versions of sustainability. Using certified wood products is the best demonstration that you and your supply chain are committed to GB and CSR."*

4.2. Drivers for using wood in GB

4.2.1. Views of experts in 2006

In general, experts described a continuous increase in using wood in the construction sector, and in particular, the interviewees

uniformly concluded that wood was a favourable material for achieving the goals of GB. The comments showed that the drivers that enhance wood as the optimal solution for GB in UK construction could be summarized under the following areas: legislation, environmental issues, stakeholders' attitudes and traditions, market growth and competition, promotion and communication, and technology and know-how.

4.2.1.1. Legislation. We found that government emphasis on sustainability favoured timber in the UK construction market, just as one timber supplier put it: "*the use of wood fits perfectly into the government's sustainability agenda.*" The ongoing changes in building legislation and sustainability codes, such as Part L: Conservation of heat and power and code for sustainable homes, made wood an ever-stronger building material, because of its natural thermal and insulation characteristics. Comparing with other substitutes, *"timber frame can easily meet new sustainable housing standards"* (an expert from a timber interest group). Clearly, better sustainability legislation accelerated the use of wood.

However, the difficulty and complexity of wood legislation could also restrict its use. As pointed out by a timber manufacturer, "there are too high requirements (legislations) from the government side regarding the use of wood, thus made more difficult for buyers, users, specifiers and designers to specify/procure the timber which meets the policy, and they attempt to use substitutes".

4.2.1.2. Environmental concerns. Interviews showed that the environmental performance of wood was the major driver for embracing wood as part of the concept of GB in 2006. Respondents focused highly on the environmental performance of wood, agreeing that it had superior environmental credentials, such as improving energy efficiency, reducing resource usage and waste, and mitigating climate change and CO_2 emissions. They believed that wood could easily fit into the broad environmental concerns and balance the conflicts between an increase in life quality with a safe and healthy internal environment and a decrease in the impact on wildlife and protection of the external natural environment. The following are some illustrative quotes:

> "*Timber is a five star sustainable building material*" (an officer from a timber promotion organization).
>
> *"Environmental aspects will promote wood"* (a timber supplier).

As technology develops, the environmental performance of other competitive products has been improving rapidly. Thus, some experts argued that sound environmental performance was no longer the exclusive core competence of wood, which should extend its pure environmental friendliness to broader sustainability issues to win the material selection competition. The following quote illustrates this:

> *"The wood industry has believed that wood is the only sustainable building material. But we have become increasingly aware of the claims of competing materials' sustainability; for example, you can recycle steel as well. We need to stress for homes the sustainability of wood and imply that other materials are not as sustainable"* (an officer from a promotion organization).

4.2.1.3. Stakeholders' attitudes and traditions. There was a clear change in attitude towards favouring wood and GB in the UK during the study period. The reputation of TF manufacturing was ruined during the 1970s and 1980s due to bad design (commented on by many interviewees). However, the reputation and perception of TF manufacturing has improved greatly since those days, as illustrated by the following quote: "*There is a major perception change in timber; five years ago timber was considered as a low value and low tech commodity product. Now it becomes a value added product. Timber has become fashionable, especially timber-frame housing*" (an officer from a promotion organization).

However, there were substantial challenges. Interviewee comments showed that 1) timber is not a traditional building material in the UK, and TF manufacture had a problematic past, 2) people still have prejudices against timber, since it rotted and burnt easily, 3) timber is a difficult living material due to its biotic nature, e.g. twisting and shrinkage and 4) timber is a traditional low-value commodity product with a short life cycle compared with brick and block. The experts found that the lack of available knowledge of timber products caused the prejudice.

4.2.1.4. Market growth and competition. The respondents concluded that the current market demand and competition favoured wood products, and wood products were well positioned because of their sustainable credentials and scope for versatility. Their views led us to conclude that competition between timber products and substitutes has been fierce in the UK market. Facing the current competition, many experts suggested that since all materials had their optimal end-uses, there would be more room for composites and cooperation. Timber is a relatively easy material to combine with other materials in such things as hybrid buildings with a combination of timber and steel. An interesting result was that most respondents agreed that competition between timber and substitutes could be turned into cooperation and in turn increase the use of timber, as stated by one timber manufacturer, "competition is good because it will improve standards and cooperation, and reduce the cost; it is going to increase the use of wood for sure."

However, the main competitive challenge was the fragmented structure of the UK timber product supply chain. Respondents considered that the UK timber products industry lacked a unified voice and suppliers were keener to compete with each other than with rival industries, which, like steel and concrete, were more consolidated and bigger in size, and had more capital for R&D and lobbying as well. One timber supplier suggested: *"Wood is a competitive material, but it also needs more effort in R&D and marketing promotion."*

4.2.1.5. Promotion and communication. Many respondents praised the generic marketing, such as Wood for Good, while TV programmes, such as Ideal Home, have significantly affected the market. Wood for Good, a generic wood campaign initiated in 2000, was one of the largest timber promotional campaigns in the UK. For example, the organizer argued that Wood for Good changed some levels of the public attitude and prejudice against wood and increased wood consumption, as well as making it one of the leading and accessible solutions through the information provided. In general, our respondents agreed on the benefits of generic promotion in the wood sector and suggested that the industry should work together and invest more in such efforts.

The challenge in the wood construction market was the lack of information and knowledge of such topics as the uses of timber products, whole life cost (WLC) information, and technology support. Such information helped not only to launch the products and win a market share, but also to educate partners in the supply chain and end-users. Unfortunately, too much knowledge remained only on the supplier side and was not passed on to the market.

4.2.1.6. Technology and know-how. Recently, emerging construction technology and know-how have been in favour of wood. One that accelerated changes in UK construction was the development of building technology such as MMC, whose objective was to minimize the work on-site and move off-site, and to improve

efficiency, quality, sustainability and predictability, as illustrated: *"MMC is like made for timber products, and the potentiality is huge"* (an officer from an industry promotion organization). To follow the development of MMC, the use of new and innovative timber products increased in the UK construction sector, e.g. LVL (Laminated Veneer Lumber), gluelam and other related products.

The major challenge in 2006 was that considerable amount of technology had already been developed and was waiting for full utilization; however, producers were not willing to invest if they did not have sound evidence of better profitability:

> *"Because of the low overheads and unwillingness to invest, the construction industry tries to develop traditional on-site building. Off-site needs a lot of investment, capital and overhead costs. Lack of investment will hinder value added timber products"* (a government official).

The great majority of respondents also considered lack of education as one of the most distinctive challenges in the current construction industry that prevented the potential applications of wood products from expanding. The importance of education particularly concerned higher value added timber products, due to more demanding end-uses.

4.2.2. Views of experts in 2012

A quote *"There has never been a better time to choose timber as a building material"* (an officer from a timber expert organization) aptly describes the perceptions of respondents concerning the use of wood. The positive feeling between wood products and GB grants wood a crucial role in the construction sector. Even the general construction market has experienced a hard time, compared with 5 years ago; our respondents agreed that the total consumption of wood in the construction sector has increased. The drivers that deliver wood as a favourable solution for GB are essentially the same as 5 years ago.

4.2.2.1. Legislation. The experts added some new information to specify the changes over previous years; for example, emerging governmental regulations such as the UK government's zero carbon target for new housing by 2016, Green Public Procurement criteria and standards and comprehensive green timber procurement policies, such as the EU Timber Regulation (EUTR). As an expert from a promotion organization remarked, the most notable regulation is the new Construction Products Regulation (CPR) introduced in CE-marking: *"The CPR has been adopted by the UK government and CE-marking will soon become mandatory in the UK by 2013. All the construction products have to ensure that they meet the requirements of CPR."*

The question on how to coordinate emerging regulations from different levels is a challenge, as argued by one timber manufacturer, *"Legislation on sourcing with EU regulations, UK national and local regulations should not deter people from using timber."*

4.2.2.2. Environmental concerns. As was the case 5 years ago, our respondents praised the superior environmental credentials of timber, and pointed out that environmental concern is the key driver for promoting the use of wood in construction, as illustrated by the following:

> *"Reflecting on climate changes and reduction of embodied carbon are the key drivers that lead to the selection of timber over other methodologies in building"* (a timber manufacturer).

> *"The main drivers are the UK government's commitments to reducing carbon in construction both from the point of view of carbon storage in buildings and the energy efficiency of buildings. There is a greater willingness to look at timber as a solution to this"* (an officer of a timber expert organization).

BREEAM and *Programme for the Endorsement of Forest Certification* (PEFC) certified wood were the major topics discussed by our respondents, who suggested that these two environmental assessments together ensure the principle of GB and building with sustainable wood:

> "*BREEAM and environmental assessment of buildings is a key driver. In the last few years changes to the building regulations, particularly from a thermal and air tightness point of view, have led to greater emphasis on sustainability and the need to introduce renewable energy sources into buildings as well as the need to reduce waste on all fronts"* (an officer of a promotion organization).

> "*Using PEFC-certified timber benefits in achieving excellent BREEAM ratings, e.g., Levels 3 to 6 of the Code for Sustainable Homes, acoustic and thermal requirements of Part L and Part E of the building regulations"* (an officer of a timber expert organization).

Compared with 5 years ago, our respondents now stressed the term "sustainability credentials" instead of "environmental concerns". For example, one expert from an industry interest group stated that "*The main driver is undoubtedly the sustainability agenda, with the main obstacle in England being culture."*

4.2.2.3. Stakeholders' attitudes and traditions. With regard to people's attitudes to GB and wood housing, our respondents specified an increasing preference for GB, in particular with wood housing. Clearly, the market demand for greener solutions is potentially huge. However, since the economic downturn prevents people from paying more for it, our respondents advocated promoting the potential benefits of building and living with wood, as well as WLC cost information:

> *"Timber systems may be more expensive than competitor/traditional systems but their project cost is not taken into account, i.e., the fact that they are lighter and will save on foundation costs or they may be quicker to install – neither of these factors are taken into consideration during selection as there is generally little or no whole project cost perspective"* (a timber manufacturer).

4.2.2.4. Market growth and competition. Compared with other construction materials, the competitiveness of wood is clearly focused on its environmental credentials. However, price is not currently a strength. A timber manufacturer stated *"timber is perceived as being an expensive method of building. The competitiveness of timber can be overridden when economic considerations prove that while another building method is not as sustainable it is considerably cheaper."* So how to lower the cost of building with wood and improve added value will be the critical future tasks.

Expert opinions showed that there have been two major growth areas in promoting wood in GB in the last 5 years: the 2012 London Olympic constructions and green public procurement, as in quotes such as:

> *"There has been a substantial growth in the use of greener materials in construction, particularly timber, over the last 5 years, especially in the public sector where sustainability of product is a key feature in procurement"* (a construction material merchant).

> *"The Olympic Delivery Authority (ODA) settled their timber procurement policy based on the government's Central Point of Expertise on Timber (CPET) guidelines, and promised that London*

2012 will be the greenest games in modern times" (an officer of a timber expert organization).

4.2.2.5. Promotion and communication. TV programmes, GB awards, and education and training programmes are still the major promotion and communication tools used in the wood construction sector. In addition, signing of timber accords has emerged in recent years. "A *TV programme such as Grand Designs has shown the public a number of different timber solutions. There are education programmes through Wood For Good (CPD to specifiers) and the TRADA University Engagement Programme hoping to influence the next generation of designers in the UK"*(An officer of a timber expert organization).

Compared with 5 years ago, the situation with the availability of timber products has not improved much. The major challenge in the wood construction market is being shackled with limited information. Thus, providing readily available and easy-to-understand information is an important suggestion made by our experts.

"The biggest obstacle to using timber in construction is the lack of information. With timber not only do you have to pay for this information you also have to wade through various pages to glean exactly what you require" (a construction material merchant).

"There is a lack of quality information linking timber's sustainable credentials, engineering data and methods of application, sometimes making timber a complicated choice for designers" (an officer of a timber expert organization).

As specified by our respondents, another crucial challenge in wood promotion is the lack of collective funding, especially with new solutions. For example, "*There is a lack of budget (collectively) to promote wood products (when compared to sectors such as steel) particularly as engineering solutions"* (An officer of a timber expert organization).

4.2.2.6. Technology and know-how. Compared with 5 years ago, our respondents showed an increased acceptance of new technologies for using wood in GB, in particular, modified products that improve timber's debatable properties such as fire resistance, hygroscopic properties, density etc. In addition, value adding has been emphasized by many respondents with reference to products, such as thermal wood, timber solutions and system products.

"The reduction of embodied carbon, structural weight reduction and prefabrication are key drivers that lead to the selection of timber over other methodologies in buildings. Certainly modified products are gaining ground" (a construction material merchant).

"The attitudes to using timber are improving and in particular there is a greater acceptance of new timber technologies with both developers and specifiers; e.g., CLT has been very successful. There is therefore an increasing number of practitioners who have experience in these 'new' solutions" (an officer of a timber expert organization).

Table 4
Summary of two-stage survey results: comparison between 2006 and 2012.

Major categories	Sub-categories	Changes between 2006 and 2012	Important current issues
Development of GB	In general	Continuous increase of GB	• Shrunken UK construction market • GB as the pre-eminent point of growth
	General public awareness	Increasing concern for GB	• Awareness of cost issue restricting the development of GB • Call for available and economic GB solutions
	Government role	Government role as important as before	• GB as a part of SD • Policy frame including standards, incentives, legislation, guidelines and assessment systems • Collaboration and integration with a GB union code
	Affordability	Increasing concern for affordability	• Affordability as one important criterion for GB
	Sustainability	Increasing commitment to sustainability	• Integration of GB and CSR (affordable, environmental and socially responsible) • Certification
Drivers for using wood in GB	In general	Same drivers as 5 years ago	• Focus on environmental and political drivers • Positive correlation between wood and GB
	Legislation	Continuously developing GB-related regulations	• Coordinate different levels of regulations
	Environmental concerns	Changing from environmental concerns to sustainability concerns	• Superior environmental credentials of timber • Environmental concern is the key driver • GB-related assessment and certifications • Broader sustainability concerns
	Stakeholders' attitudes and traditions	Increasing preference for wood and GB	• Lack of available knowledge of timber products • Cost concern • WLC cost information
	Market growth and competition	Continuously growing market for wood construction but tougher competition	• Competition between timber and substitutes can be turned into cooperation • Fragmented structure of UK timber product supply • Price competition • 2012 London Olympic constructions and public procurement
	Promotion and communication	No significant improvement in wood promotion and communication	• TV programmes, GB awards, and education and training programmes are the major promotion and communication tools • Availability of timber products • Limited information • Lack of collective funding
	Technology and know-how	Increasing acceptance of new technologies for using wood in GB	• Value adding • Modern methods of construction • Importance of education and training

4.3. Summary of results

In summary, the core category emerging from the data is that UK experts perceive the importance of increasing the use of wood to promote GB. More specifically, as summarized in Table 4, our respondents perceived 1) an increasing development of GB in UK, 2) the increasing use of wood in the UK construction sector and 3) essential drivers that promote wood in GB, including: sustainability legislation, environmental concerns, the wood market situation and stakeholders' behaviour, improved efforts in marketing promotion and communication, and technological development and know-how.

5. Discussion and conclusions

This paper contributes to the existing studies of GB and wood construction in several ways. First, our findings support Abidin's broad concept of GB (2005) and suggest that there is potential for integrating GB and CSR thinking into the business practices of the construction sector. These two concepts together can tie the principles of sustainability into the construction business and products, and can satisfy the various construction sector stakeholders. Based on the interview results, we found that the UK construction sector not only focuses on issues with narrow scope, such as natural materials, MMC and environmental protection, but also carries out much broader tasks covering environmental, social and economic considerations, which are the major elements of CSR. Clearly, there are many ways for construction companies to integrate GB and CSR, e.g. using wood to mitigate climate change and improving energy efficiency through the life cycle of wood construction; providing affordable houses through value added wood products; using wood construction to enhance working and living conditions and to promote the idea of sustainable communities, e.g. sustainable wood constructions in houses of worship, schools and housing for elderly people; and integrating forest certifications, GB standards and CSR reporting into a unified system to enhance sustainability performance and management.

This study implies that supplying and developing GB to the society will be the most effective way to perform CSR, in other words, committing to CSR based on the principle of sustainability through supply of affordable, environmentally friendly and socially responsible houses. In particular, our respondents suggested that GB is cost-sensitive, and affordability is thus one important criterion for promoting GB. Our results warrant caution in that improvement in the environmental functions of housing should not be offered at an overly high cost, thus avoiding the risk of becoming a more theoretical concept or an expensive experimental product for the wealthier customer segment. Based on our analysis, we argue that affordable housing is an important additional element of economic dimensions, building on the work by Abidin and Pasquire (2005).

Our results imply that providing affordable forms of GB will be the main task for the construction sector. From the product and technological standpoint, lowering the cost can be achieved, by e.g. increasing the use of value added products, favouring massive offsite production and integrating housing supply chains. From the policy standpoint, the government should support affordable housing by such means as increasing social and intermediate housing and subsidizing those who cannot afford to buy or rent property on the private housing market. Thus, the public sector could take a lead in this affordable GB concept in their social housing projects and make it a demonstration model for the private sector.

Second, this study identified the crucial role that the UK government has already played in the formation, promotion and development of GB. Furthermore, there is potential for the government to be responsible not only for creating an overall facilitating environment for SD, but also for collaboration and integration of variations of SD emerging from different sectors, and promoting a clear and unified GB code based on public–private partnerships.

Third, in accordance with discussion on wood providing the optimal solution for GB (e.g. Upton et al., 2008; Sathre and Gustavsson, 2009; Gustavsson et al., 2010), our study identified an overall positive attitude towards using wood in the UK construction sector and found support for the view that environmental performance is the major driver for embracing wood in the GB concept. Another interesting finding is that experts who have experience and knowledge of using wood as a building material agree that it has superior environmental credentials; however, end-users who lack of information and knowledge of wood products may have strong prejudice against using it, e.g. due to fire and safety issues. Therefore, educating end-users about the utilization and basic functional properties of wood seems crucial. Examples of key information required in the market include product information (e.g. technical and physical properties of wood products), conformity information (e.g. building standards and certification), supportive information (e.g. user's guides, installation and maintenance) and cost information (e.g. cost structure and LWC).

In addition, this study identified the trend in wood construction that is changing from low-value and low-tech wood products to high-tech and high-value added products, including the use of hybrid structures (combinations of wood and steel) and composites (such as wood and plastic). As the technology has developed, the environmental performance of alternative products has improved rapidly and is no longer the exclusive core competence of wood materials. Two solutions are emerging in the competition for wood products, i.e. extending the purely environmental performance of wood material to a broader sustainability paradigm, and turning competition in the construction value chain into a mode favouring cooperation.

With the absence of existing studies linking wood to the GB concept directly, the fourth contribution of this study is that we have identified some major drivers promoting wood as a sustainable solution for GB in the UK construction sector. These six drivers are legislation, environmental issues, attitudes and traditions among stakeholders, the market and competition, promotion and communication, and technology and know-how.

A limitation of this study is our sampling procedure. The participants were mainly from the wood product sector, leaving out a wider range of experts from the construction and design sector. In addition, there were many participants from organizations with possibly pro-wood bias. Since this study applied a purposive sampling technique, the interviewees were mainly selected from the Inter-build 2006 Construction Fair, of which the exhibiters were mainly suppliers of construction products, while construction builders and designers were the visitors of the fair and their potential customers. However, since the objective of the qualitative interview study was not to focus on the representativeness and generalizability but to explore an evolving topic, this study succeeded in identifying key themes and concepts with an evenly limited group of respondents. Moreover, inclusion of participants with some possible pro-wood biases also represented the true market situation. In practice, the wood product sector's voice was always derived from the real market demand from the construction sector, while the pro-wood attitude from the organizations represented the current policies from the UK government. To enhance the generalizability of the study, further research should involve broader sets of experts, such as construction developers, builders, architects and designers.

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