

Challenges and Opportunities of Low or Zero Carbon Building: Prospects of Business Models

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Abstract

There is an emerging consensus amongst governments, business sectors and civil societies regarding the urgent need to address the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. The building and construction sector has been identified with the most opportunities for cost-effectively reducing carbon emissions. However, although business opportunities have been identified for low or zero carbon building (L/ZCB), L/ZCBs are generally perceived as more expensive and challenging than conventional buildings. Also, L/ZCBs are often addressed solely from their technological and environmental perspectives, while important economic and socio-cultural aspects have been overlooked or examined implicitly. This paper aims to contribute to the knowledge of the challenges and opportunities of L/ZCB in a systems manner, and to explore how business models can help construction organisations address the former and maximise the latter. The research was carried out through the combination of a comprehensive literature review and case study with a large construction organisation which played a significant role in the UK and internationally. The examination of the challenges and opportunities employed the PESTEL analysis framework (Political, Economic, Socio-cultural, Technological, Environmental and Legal). The case study included a desk study, observations, meetings and personal interviews with senior business and sustainability managers of the company. The results suggest the imperative role of business models for L/ZCB developments. Establishing and innovating business models were considered to present an opportunity for the company to sharpen their competitive edge in the market. A wide take-up of business models of L/ZCBs among construction firms was perceived to fit well the building industry's socio-technical system in addressing the multiple challenges.

Keywords: Low or Zero Carbon Building, Business Models, Socio-technical, PESTEL Analysis, Systems Approach.

1. Introduction

Rapidly growing energy use worldwide has raised concerns over the problems of energy supply and security, which contribute to the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. Practically all major greenhouse gas emitters now have climate change legislation (Townsend *et al.*, 2011), which will form the basis of a global agreement to be reached by 2015 (Fankenhauser,

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2012). Buildings, as a whole, contribute the biggest single proportion to total energy consumption in many countries, accounting for up to half of primary energy resources (Butler, 2008; Pérez-Lombard *et al.*, 2008). The building and construction sector has been identified with the most opportunities for cost-effectively reducing carbon emissions and helping to address the multiple challenges (IPCC, 2007). In the UK, the built environment accounts for an estimated 40% of total energy consumption and produces 50% of all UK carbon emissions (CLG, 2007a). The UK government has committed to reduce carbon emissions by at least 80% over the 1990 baseline by 2050 and set 'zero carbon' targets for all new dwellings from 2016 (CLG, 2007a) and non-residential buildings from 2019 (CLG, 2008a). The UK government has described achieving these targets as a 'transformation in its [the construction industry's] own structure and practice' (HM Government, 2010: 2), which requires 'a revolution in the way we build, design and power our homes' (CLG, 2007b: 9).

The UK government's Business Link (2011) elaborated a range of business opportunities introduced by the transition to the low carbon economy in a variety of business sectors, of which a significant one is low or zero carbon building (L/ZCB). It has been suggested that 'Over the next 40 years, the transition to low carbon can almost be read as a business plan for construction, bringing opportunities for growth' (HM Government 2010: 4). However, L/ZCBs are being addressed in many cases solely from their technological and environmental perspectives, while other important aspects, e.g. economic and socio-cultural, have been overlooked or examined implicitly. This approach is problematic, as the construction industry faces multiple challenges in delivering buildings of quality, quantity, affordability and environmental sustainability (Goodier and Pan, 2010). The concept of business models only became widely prevalent with the advent of the Internet in the mid-1990s. Teece (2010) pinpointed that the concept of a business model lacks theoretical grounding in economics or in business studies, and quite simply there is no established place in economic theory for business models. These features inevitably introduce a source of confusion and obstruction to research in business models. While L/ZCBs are generally perceived to be more expensive and challenging, the opportunities and benefits of establishing and innovating their associated business models remain largely unknown. Therefore, this paper aims to contribute to the knowledge of the challenges and opportunities of L/ZCB in a systems manner, and to explore how business models can help construction organisations address the challenges and maximise the opportunities. The exploration is conducted within the UK context, while the discussion draws on the wider knowledge base where possible.

2. Research method

This research was carried out through a combination of a comprehensive survey of the literature and case study with a large construction organisation which played a significant role in L/ZCB developments in the UK and internationally.

The examination of the challenges and opportunities of L/ZCB drew on a systems approach. Research highlights the importance of resisting the temptation to focus on the physical aspects of construction but adopting a holistic approach to sustainable construction development (Pearce, 2003; Butler, 2008). Such a holistic approach is crucial to L/ZCB,

where there may be a tendency to focus rather narrowly on buildings' technical details, yet the far reaching nature of L/ZCBs' 'transformation' (HM Government, 2010: 2) requires a systems approach to address the broader context of L/ZCBs. The systems approach has been noted by several studies within the context of new buildings (Glass *et al.*, 2008; Osmani and O'Reilly, 2009; Goodier and Pan, 2010), and more generally in climate change policy (Fankenhauser, 2012). This present paper therefore uses a PESTEL analysis to examine the political, economic, socio-cultural, environmental, technological and legal factors associated with L/ZCB, so that 'a systems approach could shed new light on the problem' (Glass *et al.*, 2008: 4535). This PESTEL framework also guided the exploration of ways, in which business models can support L/ZCB developments.

The case study company was an international property and infrastructure group operating in forty countries, with a typical turnover of £900 million for its UK operation. The integrated approach to business of this company spanned activities from identifying and developing land, through construction to property management. The company's long-standing commitment to sustainability has evolved into an aspiration to be a global leader in sustainability. The case study comprised: (1) a desk study of the organisation's websites, brochures, reports and publications on the business' mission, objectives and strategies regarding L/ZCB; (2) meetings with key members of its senior sustainability and business managers, including the Head of Sustainability (HoS) for Europe, the Middle East and Africa (EMEA) who reported directly to the CEO, and the Senior Manager of Sustainability (SMoS); (3) observation of the presentations made by the CEO, and the HoS and the SMoS at two distinguished national conferences, which covered the topic of L/ZCB and the company's practice and business strategies; and (4) personal interviews with the HoS and the Head of Strategy and Business (HoSB) on an individual basis. All these participants had a strategic company-wide remit. For the interviews a list of questions was provided to the interviewees beforehand, which helped to improve the efficiency of data collection and quality of data collected. Each interview took around an hour. All the interviews were audio recorded. Transcripts verified by the interviewees, together with the notes obtained of the meetings and the presentations were used for qualitative analysis. The analysis followed the logic of identifying and verifying codes, themes and patterns.

3. Challenges and opportunities of L/ZCB: PESTEL analysis

The challenges and opportunities of L/ZCB are examined below in each PESTEL aspect. However, these challenges and opportunities are interrelated and should therefore be interpreted together. Therefore, cross-aspect discussion is made where possible.

3.1 Political aspects

Politics presents pivotal opportunities for L/ZCB. The opportunities exist at a number of levels: 1) internationally, e.g. as introduced by EU energy efficiency legislation, the international climate change framework being developed by 2015 (Fankenhauser, 2012), improving cross governmental communication and cooperation, integrating of demand and supply side policies (Glass *et al.*, 2008) and government-led 'golden carrot competitions' to stimulate supply chain reform (Lowe and Oreszczyn, 2008: 4480) as up to 86% of a

company's total emissions are via their supply chain (indirect emissions) (Matthews *et al.*, 2008); 2) nationally, in the case of UK, for all new domestic buildings to be zero carbon from 2016 and all non-domestic buildings from 2019 (CLG, 2008b); and 3) regionally, e.g. by the London Borough of Merton's game-changing promotion of on-site new build renewable energy generation (Lowe and Oreszczyn, 2010; Osmani and O'Reilly, 2009; CLG 2011).

However, there exist severe challenges to L/ZCB as well. A critical one is the uncertainty of the definition of L/ZCB (i.e. what exactly a L/ZCB constitutes), which remains within the above-mentioned multi-level policy landscape (HM Government, 2010; Lowe and Oreszczyn, 2010; Osmani and O'Reilly, 2009). This definition-related uncertainty, albeit containing technical, economic and socio-cultural dimensions, is fundamentally a political challenge as governments define L/ZCB inconsistently. This inconsistency is illustrated by the inclusion of off-site renewable energy generation for L/ZCB, in the case of the UK, from 2012 (CLG, 2011). The uncertainty of the L/ZCB definition is also directly or indirectly attributed to many other policies, e.g. the UK's loss of stamp duty exemption, unstable feed-in-tariff regime, the way new policies such as the Green Deal and National Planning Policy Framework emerge (see Osmani and O'Reilly 2009), a lack of joined up thinking between different policy areas such as energy and housing and poor communication between government departments (Lowe and Oreszczyn, 2008). This challenge is also global, illustrated by the lack of clear consistent policies addressing climate change internationally (Fankenhauser, 2012). Nevertheless, despite the uncertainty of the definition being a critical challenge, the ability to change the definitions of L/ZCBs presents opportunities for L/ZCBs to be responsive to the changing PESTEL factors, e.g. market demand, emerging technologies, scientific evidence and social trends, which introduces business opportunities to those who pro-actively engage with L/ZCBs.

3.2 Economic aspects

The 'recent sharp economic downturn' is a key economic challenge to L/ZCB (Goodier and Pan, 2010: 4). In addition to the economic instability, climate change and peaking fossil resources are likely to result in significant economic contraction, particularly in the Minority World (Glass *et al.*, 2008). The scale of the challenges and responses required renders current incremental approaches to building provision reform based on ecological modernisation insufficient (Lowe and Oreszczyn, 2008; Jackson, 2009). There is a growing New Economics literature on degrowth (Sekulova *et al.*, 2013), circular (Jackson, 2009), steady state (Daly and Cobb, 1990) and free (Boyle, 2012) economy models and strong sustainable consumption (Røpke, 2009). These perspectives highlight further limitations in current L/ZCB initiatives, including their focus on the metrics of carbon rather than more holistic approaches to sustainability which embrace social justice and socio-culturally inscribed patterns of consumption of, through and within buildings. An underlying commitment to economic growth may predispose policy makers and developers to missed important opportunities or glaring paradoxes. New Economics' implications for L/ZCB building provision remains a significant research gap. Seyfang (2010) suggested small scale, grassroots models of L/ZCB construction have the potential to both upscale and inform mainstream L/ZCB provision. While some commentators identified that small operators remain at the forefront of L/ZCB development (Lowe and Oreszczyn, 2008; Seyfang, 2010;

Peterman *et al.*, 2012), these approaches remain on the margins of current policy and practice. Isiadinso *et al.* (2011: 444) considered 'achieving economies of scale as a crucial aspect of the uptake of low carbon buildings.' Furthermore, efficiencies of scale may enable L/ZCB compliance (Pan and Garmston, 2012) and interest in and experience of L/ZCB amongst volume builders is burgeoning (Osmani and O'Reilly, 2009; Bell *et al.*, 2012). Second to the challenge presented by the economic growth paradigm is the perception of L/ZCBs as more expensive. Although as Lowe and Oreszczyn (2008: 4479) noted, 'the most cost effective measures in existing and new UK housing have already been undertaken' and L/ZCB is often currently more expensive (CLG, 2011), industry perceptions of L/ZCB's costs exceed reality (NNFCC, 2010; Dunster, 2012). The industry uncertainties regarding both costs and demand for L/ZCB are significant challenges (Lowe and Oreszczyn, 2008), particularly due to the conservative nature of the industry.

However, despite the many challenges, economic opportunities abound. Research suggests there is already significant demand for L/ZCBs (Osmani and O'Reilly, 2009; Bell *et al.*, 2010) and there are considerable opportunities for this to grow and support L/ZCB as energy prices escalate, fund resource supplies become less stable and external costs are internalised more effectively (Jackson, 2009; Sekulova *et al.*, 2013). There are many opportunities to help internalise external costs within energy and construction which would make L/ZCB the most economically attractive option, these include Tradeable Energy Quotas tax and other pricing mechanisms (Jackson, 2009). While cost challenges render L/ZCB sales premiums neutral, L/ZCB becomes a net boon through the marketing, market differentiation, reputation and early intervention cost saving it represents (Osmani and O'Reilly, 2009). Pro-active L/ZCB engagement can lead to enhanced brand recognition and reputation as well as being more cost effective in meeting L/ZCB standards as they become more stringent (Carter, 2006). L/ZCB also protects against the business risks of future legislation, widespread adoption of carbon accounting methods and increasing costs of current construction methods (Glass *et al.*, 2008). Government can enhance these opportunities through fiscal based legislation (Glass *et al.*, 2008) such as the UK's Green Deal, providing grants and facilitating the trend towards socially responsible investment funds accessible to L/ZCB.

3.3 Socio-cultural aspects

The key socio-cultural challenges to L/ZCB include the construction industry's conservative nature and the limited public awareness of and demand for L/ZCBs. Industry challenges include widespread risk-averse attitudes and reluctance to innovation (Lowe and Oreszczyn, 2008), skills shortages (Glass *et al.*, 2008), slow take-up of sustainability (Pearce, 2003) and a fragmented structure with few large and many small players (Glass *et al.*, 2008; Pan and Goodier, 2012). Many in the industry are unwilling to adopt what they view as untested technologies (Osmani and O'Reilly, 2009). Given the new knowledge, new skills, innovation and holistic/integrated approaches required for L/ZCB (Peterman *et al.*, 2012) and L/ZCB's necessary 'revolution' (CLG, 2007b: 9), the lack of 'collaborative integration of the supply chain and silo-based habits of the industry's institutions' (HM Government, 2010: 7) presents a significant challenge to developing, communicating, implementing and monitoring new L/ZCB products and approaches. Glass *et al.* (2008: 4534-5) note the industry's traditional, conservative disposition 'under-performing legacy' and 'begrudging response' which mean

that 'In the short term at least, change needs to be imposed top-down, and supported bottom-up with encouragement and reward.' The industry's perception of fluctuating (Peterman *et al.*, 2012) or low demand for L/ZCBs amongst clients (Osmani and O'Reilly, 2009) and the general public (Lowe and Oreszczyn, 2008) is another challenge, compounded by concerns such as 'sick building syndrome' due to high levels of air tightness (Lowe and Oreszczyn, 2008) and the aesthetics and space of on-site renewable (Isiadinso *et al.*, 2011). This is exacerbated by the industry's poor reputation and criticisms of greenwash and 'spin' (Glass *et al.*, 2008).

Nevertheless, there exist important socio-cultural opportunities for L/ZCB. Osmani and O'Reilly (2009) rank them second only to mandatory legislation in their potential to drive L/ZCB. The industry's highly concentrated nature (Pan and Goodier, 2012) affords opportunities, as well as challenges, for L/ZCB, as once volume builders commit they can rapidly roll out L/ZCB and put greater resources to the challenge, whereas educating, training and committing numerous SMEs may be slower and more difficult. The tension here is that L/ZCB innovation has been driven by small firms and particularly grass roots initiatives (Seyfang, 2010; Peterman *et al.*, 2012). L/ZCBs offer reputational benefits spanning from the wide industry to specific projects, which lead to further opportunities. L/ZCBs can help build, rather than 'consume' human capital (Lowe and Oreszczyn, 2008), encourage staff to be more IT-literate and informed on specification/design (Harty *et al.*, 2007), attract high calibre employees and draw upon a 'growing carbon culture' which government as well as industry can build upon (Osmani and O'Reilly, 2009: 1918). The L/ZCB agenda could help transform the industry's culture, inculcating more team working (Glass *et al.*, 2008) and partnerships with local councils (Osmani and O'Reilly, 2009).

3.4 Technological aspects

The technological aspects also see challenges as well as opportunities of L/ZCB. Previous research pinpoints that due to concerns regarding on-site renewable energy particularly and the constraints imposed by volume builders' standard house sets, 'Technical and design barriers are one of the main considerations' for L/ZCB (Osmani and O'Reilly, 2009: 1928). These barriers are related to the socio-cultural challenges identified, with evidence that the main issue is not the limitations or cost of L/ZCB technology, but industry's ability to embrace it. Dunster (2012) indicated that solar photovoltaic panels' halving in price within six months during 2012 makes their cost comparable with conventional cladding materials, but the industry has been unable to change its design, sourcing and specification processes at the same rate, whilst 100% renewable/recycled materials can save 10% on the cost of conventional materials to the same L/ZCB standard (NNFCC, 2011). Even greater cost, energy, time and materials savings can be made from off-site L/ZCB construction (Goodier and Pan, 2010) and on-site use of robotics (Glass *et al.*, 2008). Technology such as smart meters supports L/ZCB directly and enables such real-time data collection, whilst the growing field of citizen science and collaborative research enhance opportunities for responsive data collection, analysis and engagement. Organisations such as the Transition Research Network and their ability to tap into viral grassroots socio-cultural technologies such as Transition Streets offer significant potential to go much further than Lowe and Oreszczyn's call to 'share knowledge from the fringes' (2008: 4479).

3.5 Environmental aspects

In the environmental aspects, the main challenge relates to extreme weather effects potentially undermining L/ZCBs. For example, climate change triggers flooding more likely, which requires additional tanking that involves the use of materials such as concrete with high levels of embodied energy and other resources. Also, environmental challenges intersect with socio-cultural factors, e.g. the rebound effect (Jackson, 2009; Pan and Garmston, 2012; Isiadinso *et al.*, 2011), whereby extreme weather such as heat waves leads to the inappropriate bolting-on of air condition to what are otherwise L/ZCBs. The 'resilience agenda' (Glass *et al.*, 2008;) therefore highlights the need for L/ZCB to address adaptation to, as well as mitigation of, climate change and peaking resources (Harty *et al.*, 2007) in order to avoid exacerbating problems associated with extreme weather events, but also dwindling fund resource supplies and terrorism (Glass *et al.*, 2008). To address environmental concerns has introduced opportunities for L/ZCB. Whilst extreme weather events challenge L/ZCB in some respects, the more extreme they are, the more L/ZCB will benefit, as they further raise the growing awareness of climate change and the triple challenge which L/ZCB is uniquely placed to address. Embracing resilience affords L/ZCB opportunities through forward planning, so that problems become solutions.

3.6 Legal aspects

Previous research shows that the views and practices of housebuilders (Osmani and O'Reilly, 2009) and virtually all aspects of the construction industry (Lowe and Orescyn, 2008; Pan and Garmston, 2012) respond to mandatory legislation, rather than policies, voluntary schemes or softer mechanisms (Peterman *et al.*, 2012). This presents a legal challenge to L/ZCB. Also, the relationship between voluntary and mandatory L/ZCB standards is not simple or fixed. Many L/ZCB standards begin as voluntary and become mandatory, as demonstrated by the UK L/ZCB framework (CLG, 2008a,b, 2011). In addition, the greatest legal challenge to L/ZCB concerns enforcement, with Glass *et al.* (2008) critiquing that L/ZCB legislation lacks teeth and Lowe and Orescyn (2008: 4477) suggesting that it needs to be 'vigorously and rigorously enforced' to overcome the lack of resources for regulatory development and implementation. Pan and Garmston (2012) found that a lack of awareness and training among both industry and building control officers created uncertainty and contributed to significant discrepancies between mandatory standards and actual building performance. Furthermore, the legal challenges relate to the 'less-than-responsive planning system' (Goodier and Pan 2010: 4). Nevertheless, mandatory standards are the most potent way to support L/ZCB. The legislation can play a facilitative role for L/ZCB, and often gives rise to new business opportunities and new/adapted business models. Also, the legal-side opportunities may be maximised when the transition from voluntary to mandatory standards occurs within a clear consistent timeframe which achieves wide-ranging buy-in.

4. Business models of L/ZCB

Business models are not new phenomena, and their study is an emerging, contested, interdisciplinary field (Teece, 2010). A typical interpretation of business models is that it 'defines how the enterprise creates and delivers value to customers, and then converts

payments received to profits' (Teece, 2010: 173). Mason and Spring (2011: 1033) noted that until 2000 the notion was restricted to internet businesses at the network level, yet its wider adoption has seen it applied almost exclusively to the firm, leading them to argue for dynamic, networked and performative understandings of business models capable of 'zooming in and out' to investigate their operation at the firm, network and industry levels. Building research has been slow to grasp the importance of business models and lags behind the fields such as business and management where the concept has been developed. Also, building research often mistakenly equates business models with competitive advantage theory (Pan and Goodier, 2012) and presents business models as factual statements, rather than being emergent, dynamic and performative as argued by business model researchers (e.g. Mason and Spring, 2011; Teece, 2010).

4.1 Prospects of business models for L/ZCB

Greater attention to business models should help address the challenges and maximise the opportunities of L/ZCB, which are identified through the PESTEL analysis in this paper. There prospects of business models for L/ZCB are multi-fold. First, part of their value concerns business models' agency to shape actions as well as being shaped by the actions of others within firms, networks and across the industry (Mason and Spring, 2011). For example, business models shape demand as well as respond to it (Teece, 2010; Mason and Spring, 2011). This directly relates to the opportunities and challenges regarding industry's assertion of L/ZCB demand (Lowe and Oreszczyn, 2008; Osmani and O'Reilly, 2009). Second, business models' emphasis on a 'deep understanding of the user' (Teece, 2010:190) and initial findings which contradict these assertions (Bell *et al.*, 2010) highlights the importance of market research and similar work for L/ZCB and as L/ZCB business models emerge they will stimulate market research and other work deepening industry understandings of users. Third, business models may allow government policy and corporate sustainability strategies more agency in shaping L/ZCB, including opportunities to impact on buildings' in-use impacts and occupants' behaviour patterns.

4.2 Business model take-ups in the building industry

There is a need to address business models across the industry as a whole (HM Government, 2010). Teece's (2010: 189) observed that 'long-lived structural elements – choices made perhaps decades ago in different environments – need to be scrutinized especially thoroughly.' Such scrutiny could help create the socio-technical changes needed for L/ZCB. For example, volume builders' use of standard house types could be addressed through developing business models which integrate more responsive designs capable of the pace of changes in the PESTEL aspects. However, there also exist tensions with using business models to support L/ZCB. For example, it is asserted that business models must be 'non-imitable' (Teece, 2010: 192), while the urgency and scale of the multiple challenges require that L/ZCB business models are rolled out as comprehensively as possible.

5. Case study results

The case study company aspired to become a leader in sustainable development. This aspiration has been driven by a long-standing commitment to sustainability initiated by the founder of the company who as early as in 1973 suggested that the society would soon place emphasise on environmental and social impacts above economics. Although there was limited explicit mission of policy relating to L/ZCB, L/ZCB was embedded in its sustainability objectives including the aspiration that all the buildings it developed and/or operated are zero net carbon, water and waste as a minimum.

The desk study revealed no evidence of explicit commitment to business models of L/ZCB. However, there were elements which indicated the potential for this, including aspirations to engage only with organisations aligned with the case study's aspirations, ethics and values, to operate and ensure its suppliers operate in accordance with the UN Global Compact 10 Principles and to be a recognised leader in facilitating learning and professional development with its suppliers. Furthermore, the company's 2011 *Sustainability Report* identified six Core Values of respect, integrity, excellence, trust, innovation and collaboration. These all pointed to the importance of supply chains, public accountability, innovation and collaboration, areas where business models can support L/ZCB innovation.

Through the interviews it became clear that the company was explicitly and actively involved in L/ZCB developments and innovation, going beyond regulatory requirements and shaping policy through positions on the UK Green Business Council and Green Construction Board. For example, the HoS commented, 'there is no definition yet on what certain code levels are for high rises...so we want to be among the first to do that and we also want to be involved in determining what that looks like and how feasible that is.' The interviewees confirmed the PESTEL analysis in identifying uncertainty as a key challenge, including political and economic and definition-related uncertainty. However, this also encouraged their proactivity in shaping emerging definitions of L/ZCB and turning this challenge into an opportunity.

The HoS identified the importance of legislative drivers to push 'quite conservative, traditional industries' forward, while as individuals and a company they were motivated by L/ZCBs' pivotal role in reducing global carbon emissions. The HoSB added, 'the main drivers are really around reputation, staying ahead of the competition, and also ahead of legislation'. L/ZCB provided opportunities to gain 'a competitive edge as a company in winning tenders and also in convincing clients, consumers to purchase and move into places like this' (HoS). L/ZCBs are 'more attractive for end-users...there are lots of benefits, not only in terms of energy reduction, but also... the social and economic benefits of this agenda, and how it can really add value to our business' and 'around health, productivity and wellbeing of the people within those buildings' (HoSB). Economic challenges were also identified, 'one of the main challenges for the wider industry is getting the whole life costs of the building to work with the right players getting the financial benefits of low and zero carbon buildings' (HoSB). The respondents felt that such challenges could be addressed through education as well as government and industry embracing whole life costings. It is clear that these measures could be supported by business models. The HoSB emphasized that, 'the measures introduced are varied but should appeal to large businesses and also embrace SMEs.'

The company's size and scale meant they operated a range of different business models, with larger projects offering more scope for L/ZCB business models, including working closely with suppliers to develop new energy efficient products and to build and manage. The HoS explained, 'working together with our supply chains, we develop, build and manage, so we can also influence our supply chains' longer term sustainability aspirations.' The company also proactively engaged with their clients and customers. The HoSB elaborated, 'we look at how we can make sure that we are educating future customers and consumers or the users of those homes; that they have also got the right information; and that they get the best out of those buildings.'

6. Conclusions

L/ZCB introduces significant challenges to, but also presents unprecedented opportunities for, the building industry to address the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. By employing a systems approach this paper has examined the political, economic, socio-cultural, technological, environmental and legal aspects of the challenges and opportunities. The results indicate that these challenges and opportunities are interactive and dynamic: exist in no isolation but evolve and interact in parallel. Some challenges might be perceived as opportunities and vice versa, depending on the positions and aspirations of different stakeholders. The political and legislation drivers have vital roles to play in fostering changes within the building industry. The environmental and technological aspects are more embedded in mentality of the industry. However, the role of economic and socio-cultural drivers can be enhanced. All these together generate significant prospects of business models of L/ZCB which can support innovative L/ZCB developments, helping forge pathways to sustainable, closed-loop economic and socio-technical systems. However, business models have received little attention within both the literature and practice of L/ZCB. The approaches already being adopted by industry leaders such as those featured in the case study demonstrate the importance of further attention to business models' role in L/ZCB within policy, research and practice. A wide take-up of business models of L/ZCB should help to accelerate L/ZCB practice and enable the building industry to play its full role in addressing the multiple challenges.

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