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Delivering Zero Carbon Buildings: The Role of Innovative Business Models

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Abstract

Zero carbon building (ZCB) has emerged as an innovative approach to improving building energy performance and reducing building carbon emissions. However, the uptake of the ZCB approach is slow, far from the mainstream practice of building. Previous studies have devoted to analyze the technical feasibility and design issues of ZCB. Some have examined the barriers to the adoption of ZCB practices in the market, social, regulatory and/or financial aspects. However, few have explored the role of business models in the delivery of buildings towards zero carbon. The aim of this paper is thus to examine the effect of business model on ZCB, and to explore innovative business models that can stimulate the uptake of ZCB. The paper first reviews the concepts of ZCB and identifies the challenges to ZCB based on the PESTEL analytical framework. The paper then investigates the conceptual framework of business models for ZCB. Nine key elements of the business model are identified, which include offering, target customer, distribution channel, customer interfaces, resource and core competency, partner network, cost and revenue model. Evidence is collected to substantiate the arguments through case study with one recent ZCB project selected from varied contexts. The results of the case study presented an innovative business model that helps address the challenges to delivering ZCB. The research findings help to demonstrate to practitioners the business potential of ZCB and to guide how innovative business models can help accelerate the uptake of the ZCB approach.

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Keywords: Business model; Zero Carbon Building; Construction industry; Sustainable building

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1. Introduction

The construction industry imposes significant environmental and social impacts. Globally, buildings account for more than 40% of total primary energy use and 24% of greenhouse gas emissions [1, 2]. In addition, the other negative impacts of construction activities such as resources consumption and waste production and disposal are also well recognized [1]. As an unprecedented force, sustainable development has been reshaping the construction industry since the late 1980’s, changing the physical structures and working principles of the organizations, and impelling professionals engaged in all phases of building process rethink their roles in the building delivery process [2]. As an interchangeable term with green or high performance building, sustainable building is built in a resource-efficient manner based on ecological principles and life cycle consideration, with the aim of minimizing environmental impacts and enhancing health issues [2, 3]. In recent years, ZCB has emerged as an innovative approach to reduce negative effects of the building sector. Several countries have set regulatory targets for ZCB. For instance, the UK set ambitious target for the all new homes to be zero carbon from 2016 and to reduce carbon emissions by at least 80% over the 1990 baseline by 2050 [4]. Energy Performance of Buildings Directive (EPBD) of the European Parliament and of the Council specified that by December 2020 all new buildings to be “nearly zero energy” [5]. The US Department of Energy (DOE) set the target of achieving zero energy homes by 2020 and zero energy commercial buildings by 2025 [6].

Numerous studies have been conducted to present the benefits of ZCB [7-9]. Research also has been conducted to provide design and technical solutions for ZCB. Wang et al. [10] compared the possible design strategies for ZCB under Cardiff climate condition. Koch et al. [11] evaluated ZCB at a neighborhood scale and redefined the energy balance of buildings from both the demand and supply side. Despite the literature on the benefits and technical solutions of ZCB, a number of studies have demonstrated the difficulties of implementing ZCB by examining the challenges resided in the building development process. Pan and Maxey [12] examined the challenges to delivering ZCB from the PESTEL analytical framework. Glass et al. [13] identified the barriers of developing ZCB from technological, legislative, economic and social aspect. The reported barriers to ZCB include high up-front cost, limited access to financing, and uncertainty market.

Owning to the challenges faced by ZCB, currently ZCBs only contribute to a very small proposition of the construction market in both developed and developing countries. The industry to date has recorded a limited number of ZCBs with verifiable energy performance data [14]. However, few have examined the uptake of ZCB from the business perspective. The effect of the business strategy on the delivery of ZCB is still vague. Targeting at such knowledge gap, this paper proposed a novel approach to addressing ZCB from the perspective of business model. This paper aims to develop the analytical framework of business model for ZCB and identify innovative business models for successful ZCB delivery. The paper first reviews the concept boundary and challenges to ZCB. It then develops the conceptual framework of business model in relation to ZCB. It finally explored the innovative business model for the delivery of ZCB is explored through a case study with a recent completed ZCB project.

By reviewing the existing calculation metrics within the ZCB definitions, the paper proposed a systems dimensional framework for the definition of ZCB and extracted the features of reviewed definitions. The study also explores the challenges faced by ZCB based on the PESTEL analytical framework. The paper then develops the conceptual framework of business model for ZCB through combining the literature from the management discipline and sustainable construction sector. The case study is applied to explore the innovative business model for ZCB. The case organization is a federal organization which has long term dedicated to renewable energy and energy efficient technologies research and practices. The ZCB project delivered by the case organization will be examined. The resources for case study include the publications regarding the case project, websites, reports and publications on the case organization’ mission and business strategies regarding L/ZCB.

2. ZCB: terminology and challenges

2.1. ZCB: terminology and theory

ZCB is an emerging hot research topic in recent years. However, no consensus has been reached on the definition and concept boundaries of ZCB. A multiple of approaches have been employed to define ZCB. A series of terms sharing similar meanings with ZCB can be found in the literature, which include: zero emission house, zero energy house, zero net energy building, energy self-sufficient house, emission-free house, energy-plus homes and passive houses, eco-building, energy saving house, high performance building, and carbon neutral house [15-18]. As mentioned above, underlying the low up-take of the ZCB is a lack of knowledge of consistent conceptual boundary and theoretical ground of ZCB. This paper takes a review of the definitions and boundaries of ZCB and elaborates ZCB in a seven dimensional framework.

Table 1. A review of ZCB definitions in the dimensional framework

	Balance method	Geographic	Lifecycle	Period	Credit metrics	Building type	Climate
Torcellini et al.[19]	Net Zero Site/source/emission/energy cost	Onsite, offsite	Operation	Yearly	Primary or source energy	Not specify	Not specify
Marszal and Heiselberg [20]	Net carbon emission of primary energy	Grid connected (most)	Operation	Yearly	Building related, user related	Separate for residential and non-residential buildings	Not specify
Sartori et al.[21]	Site energy/ source/energy cost/ emissions/ exergy/environmental credit	Mainly single building	Operation (mainly), embodied energy	Annual (mainly), seasonal or monthly	Weighted demand and weighted supply	Compare between similar functional building	Not specify
Pan[22]	Primary energy (mostly)	On-grid, off-grid, community, city	Nine lifecycle stage	Annual/mont-hly/seasonally	Regulated carbon/energy, user-related unregulated carbon/energy	Residential, commercial, industrial, mix use	Frigid, temperate, sub-tropical, tropical
Riedy et al.[17]	Kg $CO_2e/m^2/yr$	Building scale	Operation	Annual	Scope 1 and 2 emissions	Not specify	Australia
Heffernan et al.[23]	Net zero source/cost/site primary energy	On-grid, off-grid	Operation	Annual	CO_2 emission from regulated energy	Not specify	Cold
Hui[8]	Net zero source energy	On-grid, off-grid	Operation	Annual	Primary energy	Not specify	Not specify
Hernandez [24]	Kwh of primary energy per year	Off-grid	Operation, energy in materials and systems over the life of the building	Annual	Primary energy	Not specify	Not specify

Selected definitions and respective analytical frameworks are summarized in Table 1. It is suggested that in current practice, the most common approach to define ZEB will be the definition of ZCB adopted in this paper. The 'net zero annual primary energy use' is the most frequent used balance measurement method for ZCB. Most definitions (other than Hernandez [26]) only account for energy in the building operation stage and ignore the embodied energy in materials and building systems over the whole life cycle. In most cases, the geographic boundary of the ZCB could be categorized into off-grid and the grid-connected scale. The geographic boundary of concern is implicitly referred to in most cases. The climatic zone where the building is located at has great effect on the technical solution of ZCB. However, to date, most countries seldom develop their specific measurement and benchmarking of ZCB practices. Moreover, different building sector, building function and building status are associated with different assessment methods and emission reduction options [22], existing ZCB policies have prioritized carbon reduction target for different building sectors. However, building type and sector have not been explicitly addressed in the existing ZCB definitions.

2.2. Challenges to ZCB: the business perspective

Previous studies by researchers and other organizations have identified the current challenges/opportunities faced by ZCB based on various analytical frameworks (e.g. [9, 12, 13, 25]). ZCBs are mostly addressed from their technological and environmental perspectives, while other important aspects such as economic and socio-cultural aspects have been examined implicitly in most cases. For explicitly conceptualization of the business environment of ZCB, challenges to ZCB are grouped into six categories based on PESTEL analytical framework in the research, i.e. Political, Economic, Social-cultural, Technological, Environmental, and Legal. PESTEL is a useful strategic analytical tool for conducting market research, understanding business position and development direction. Table 2 thus analyzes the challenges for the delivery of ZCB in the micro-business environment based on the PESTEL analytical framework.

Table 2 Key challenges to ZCB based on PESTEL analytical framework

	Goodier and Pan[26]	IEA-RETD [27]	Pan and Maxey [12]	Glass et al.[13]	Osman and Reilly [9]	Li and Colombier [28]
Political						
Unclear definition of ZCB	√		√		√	
Inconsistent government policies			√		√	√
Limited financing, energy subsidies	√	√		√	√	√
Uncertainty of government's action		√	√		√	
Economic						
Economic instability	√		√			
Current small scale ZCB practice		√				
Long financial pay- back period						√
Uncertain cost/demand for ZCB		√	√	√	√	
Social-cultural						
Limited customer demand		√	√		√	
Lack confidence in new technology	√		√		√	
Lack of financial incentives	√	√		√		√
Imperfect market information			√	√	√	
Behavior constraints	√	√				
Reluctant to vary from traditional design/construction			√		√	√
Hidden costs/benefits for end-user	√					
Fragmented structure of construction sector		√	√			√
Lack of collaborative integration of supply chain	√	√			√	
Technological						
Higher up-front and transaction cost		√	√	√		√
Volume builders' standard house design			√		√	
Inadequate technical, institutional capacities, skills shortage		√	√	√		√
A dearth of available advanced technologies			√	√	√	√
Environmental						
Extreme weather events	√		√			
Legal						
Lack clarity in requirements and expected outcomes			√	√	√	

'Stick'-based legislation			√	√		
Discrepancy between standard and performance	√		√			

This paper takes a business perspective to address the challenges of ZCB delivery. As described in Table 2, the majority of barriers listed above relate to the market, financial and social-cultural aspects. Among the six categories of barriers, the 'social-cultural' seems to hold the most part. The social-cultural barriers are reflected mostly in the customer's awareness and behaviors, the structure of the construction industry, and the information or status of the building market. These factors directly relate to the demand side/ market of the ZCB. Moreover, the financial barriers such as 'high up-front cost and transaction cost', 'limited financing incentives' and 'long financial pay-back period' are reflected in the political, economic and technological category, which reflected the risks of ZCB. Successful business models for ZCB represent situations in which the organizations and activities for the ZCB project are implemented in a way that barriers regarding ZCB are to some extent overcome.

3. Relationship between business model and ZCB

The discussion above implies an approach to address the delivery of ZCBs by relating it to the concept of business model. This research takes the perspective of business model to explain the uptake of ZCB by establishing the conceptual framework of business model for ZCB and identifying the innovative business model for ZCB delivery.

3.1. The Analytical framework of business model for ZCB

The term 'business model' is a relatively young phenomenon that rose to prominence until the middle of the 1990s. The majority of its research is concerned with e-commerce [29]. Despite the numerous studies addressing business model, no consensus exists regarding the definition or nature of a business model. The research on business model for ZCB seems to be scarce. To define business model for ZCB: first, this paper selected several definitions which are cited most in the academic database; second, the research searched for articles from Scopus database and Web of Knowledge database with the term "business model", "construction OR building" and "sustainable" in the title, abstract or keywords field. By combining definitions in the two approaches, the definition of business model applied in the study can be established.

In the first approach, Amit & Zott [30] depicted the business model as "the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities" (p. 511). Chesbrough & Rosenbloom [31] described the business model as "the heuristic logic that connects technical potential with the realization of economic value" (p. 529). Morris et al. [32] defined business model as a "representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (p. 727). Johnson et al. [33] stated that a business model consists of four interconnecting elements, i.e. "customer value proposition, profit formula, key resources and processes" (p. 52). These definitions above highlighted three common themes that are mainly addressed by business model: business strategy, value proposition and delivery, resources and activities that linking the business strategy and value realization.

In the second approach, several articles have attempted to establish the relationship between business model and construction activities, although the term 'business model' was not explicitly defined. These studies have shed light on the understanding and emphasis of business model in the ZCB field. Callcutt [34] and Ball [35] described construction process and delivery mode by the term 'business model'. Pan and Goodier [36] examined the relationship between business model and prefabrication technology, and suggested business model in construction should include risk, financing, process and activities. Brege et al. [37] further extended this viewpoint and constructed the business model with five elements, prefabrication mode, system augmentation, role in the building process, customer, and complementary resources. IEA-RETD [27] regarded a business model in the built environment as the business strategy to invest and value creation process (including revenue, core competencies, customer, sales channel). The literature above reveals the core areas of the business model for construction. Building process and activities are one of the crucial components in business model. It determines the project delivery mode and organization structure. The business strategy in construction captures the logic of initiating a construction activity such as investing in ZCB, which are mainly reflected in the value proposition, customer segment and financial aspects. Moreover, the core competence and complementary resources are the prerequisite of the value proposition and value delivery. Accordingly, the conceptual framework of the business model for ZCB is developed in this paper, as illustrated in Fig. 1.

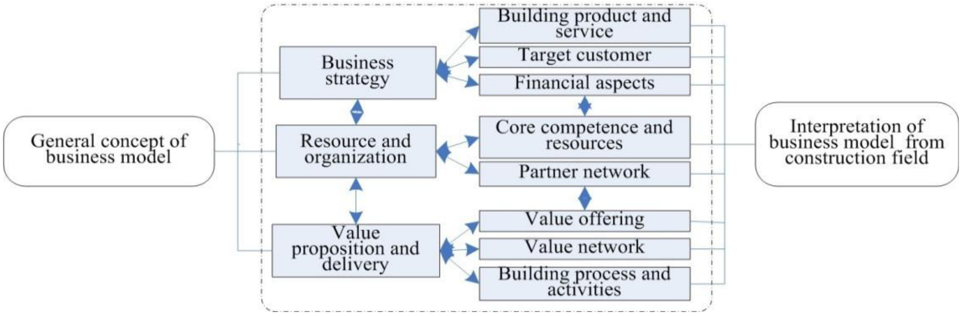

Fig. 1. Conceptual framework of the business model for ZCB

3.2. Case study of business model for ZCB

The literature review above confirms the missing link between business model and ZCB. The industrial practice, nevertheless, appears to be front runner in actively exploring novel business model to address the barriers of the ZCB uptake. The research therefore takes the case study approach to identify the innovative business model for ZCB. The ambitious target towards zero carbon in US resulted in pioneering builders piloting a range of new housing models that can be promoted to a larger market scale. A ZCB project by a major building company in US is thus selected to help elucidate the conceptual model developed above and explore the innovative business type for ZCB.

Located at Colorado, the case project is a 222,000 square foot federal office building that was completed in June, 2010. The building is designed to operate as net zero energy on annual basis. As a demonstration project, the building is created as a replicable prototype for large-scale, cost-competitive, and high-performance net zero energy commercial buildings. Located in the cold, dry climate zone with relative low humidity, the project integrates numerous renewable energy and energy efficient design features, including onsite photovoltaic, underfloor ventilation, triple glazed window, precast concrete insulated panels, labyrinth thermal storage etc.

3.3. Case study results and discussion

The desk study reveals no explicit conceptualization of business model for ZCB. However, the elements in the established conceptual framework can be identified from publications and press released by the organization [14, 38]. Based on the analytical framework of the business model for ZCB, this paper interprets the innovative model adopted by the case project, findings of which are briefly presented in Fig. 2.

As shown in Fig. 2, the project provides a national standard showcase for large-scale office ZCB. The building is established for research work and commercial leasing use. Compared to residential ZCB, zero energy office building is relatively easier to be accepted by office tenants, since office tenants generally have more financial capabilities to afford possible higher tenants and gain more energy savings. The award fee by the owner is awarded to incentive occupants' higher performance during the operation stage. The office user could also enjoy the sustainable image/reputation that brought by ZCB. In this way, the resistance from the customer side is reduced at some extent.

Another group of significant barriers of ZCB building attributes to the current higher cost of ZCB. In the traditional project delivery approach, clients are reluctant to develop a project with higher capital cost and standard. To conquer the financial barriers, the project costing $80 million was funded by a series of appropriations by Congress throughout the building delivery process. The government provided financing support and energy subsidies to the project which cover the costs from the project conception to construction stage (e.g. Power purchase agreement, American Recovery and Reinvestment Act). The developer is responsible for providing equipment such as data center and IT equipment. The long term revenue after commission can be generated from the rent. The developer delivered parts of risks to the municipality in this way.

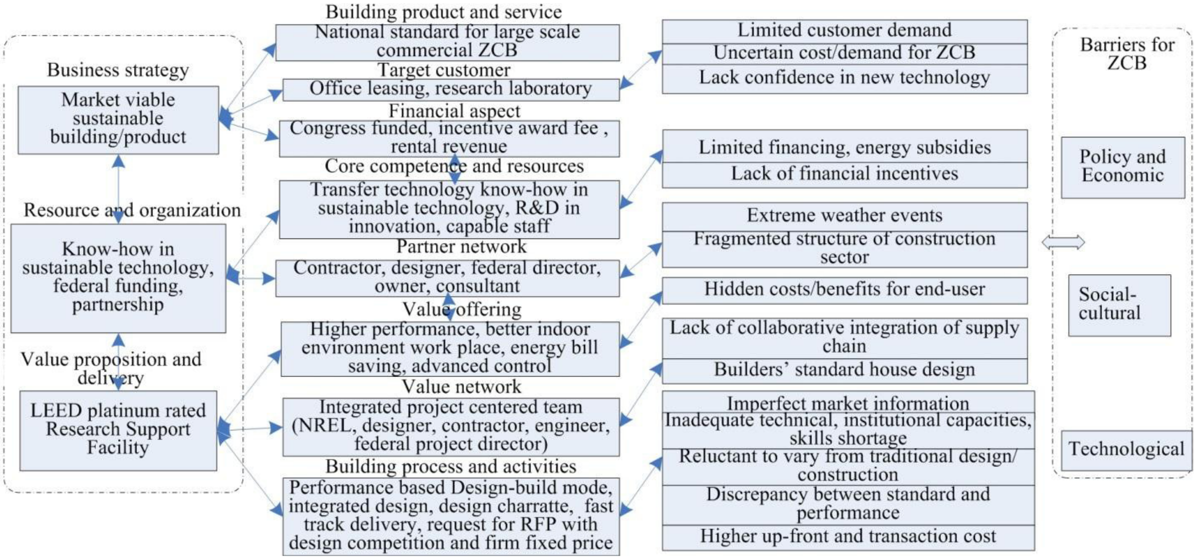

Fig. 2. Business model solution for project RSF

Moreover, the process and activities innovation is one of the highlights of the business model for the project. To delivery maximized value from the fixed budget project, the innovative Request for Proposal (RFP) with design competition approach was applied in the project. The design-build mode is applied in the building delivery process. The tender is responsible for the concept design and construction that satisfies owner's performance requirements. The innovation and superior technology combination generated by contractor is inclined to be introduced in the project. In the performance based design-build approach, owner passed parts of risks to contractor and kept the cost within the financial constraint in a shorter delivery period. The technological barriers of ZCB project can be addressed in this approach.

The value network and partner network are another two innovative components of the business model for the project. The project-centered integrated design approach was applied to make optimal use of various teams' expertise. The design charrette consisting of federal directors, contractors, engineers, consultants, and designers integrated possible solutions to come up with a favorable model. Moreover, the communication within design charrette and the timely feedback during the construction stage are also considered as another two critical success factors. The integrated design approach overcomes the barriers of the fragmented structure of the building industry and deficiency of cooperation within supply chain.

4. Conclusions

ZCB yields significant environmental and social benefits, yet presents various challenges to business promotion. This paper has examined the conceptual boundary of the established definitions regarding ZCB. The challenges to delivering ZCB have then been examined based on the PESTEL analytical framework. The results indicate that social-cultural challenges, such as customers' awareness and behaviors, and the fragmented structure of the construction industry, greatly affect the awareness of customers and builders, and impede the uptake of ZCB. Moreover, the unstable and ambiguous political, legislative and economic challenges also greatly influence the ZCB delivery. The financial challenges such as high upfront cost and limited financing incentives present difficulties for ZCB development.

Business models are analytical tools for the business contexts of ZCB. This paper proposes a conceptual model of the business model for ZCB that comprises of three blocks and nine elements. The case study through the selected real-life ZCB project in US reveals that the business model for ZCB innovate at ‘process and activity’, ‘partner’ and ‘value network’ compared to the traditional business model. The results reveal that the innovative business strategy and process such as integrated design, and performance based design-build mode helps to address the financial, technological and social-cultural challenges to ZCB. The research findings demonstrate that innovative business models of ZCB help to accelerate ZCB delivery and facilitate companies to address challenges to ZCB.

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