Organisational obstacles to reducing carbon emissions in Hong Kong

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ORGANISATIONAL OBSTACLES TO REDUCING CARBON EMISSIONS IN HONG KONG

ABSTRACT

An emerging theme for a nation transiting into a sustainable future is the provision of a low carbon (dioxide) environment. Carbon emission reduction is therefore important for the industry and community as a whole. Buildings contribute immensely to total greenhouse gas emissions, so pragmatic actions need to be taken to cut the amount of carbon emitted by the construction industry. These typically involve strategies such as energy-saving features in the design, construction and operation of building projects. However, a variety of characteristics of the markets and stakeholders involved are suppressing their development.

This paper reports on a series of interviews with a variety of Hong Kong construction project participants aimed at identifying the drivers of, and obstacles to, the construction industry's attempts to reduce carbon emissions. The results confirm the main actions currently undertaken are energy efficiency enhancement, green procurement, research and development activities, waste/water management and other technical measures such as the provision of thermal insulation. The majority of the drivers are economical in nature, suggesting that financial aids, and particularly government incentives, are likely to be useful motivators. Also suggested is the increased promotion of the benefits of environmental sustainability to the wider community, in order to alert the general public to the need for reducing the amount of carbon originating from building usage.

Keywords: Greenhouse gases, emissions reduction, building and construction, obstacles.

INTRODUCTION

There is a world-wide move towards a low carbon (dioxide) environment in recent years, with many governments being determined revert climate change. Of the various sectors affected, the construction industry is a prime target for emission reduction, as one-third of greenhouse gas (GHG) emissions in the world is related to buildings (UNEP, 2009). Also of note, is that GHG generated by the construction and use of building facilities is even higher in major cities due to their high urban densities and populace's pursuit of better living standards. For instance, Hong Kong's buildings contribute approximately 60% of the city's total annual GHG emissions (EPD, 2010). By limiting the emission levels of the construction industry, it is possible to significantly reduce the total environmental damage of a country or city (Zhang, Shen, Love and Treloar, 2000) and thus help in moving towards a low carbon economy.

Acknowledging the impacts caused by rapid urbanisation (Dulal and Akbar, 2013), planners in advanced economies (Hamin and Curran, 2009; Saavedra and Budd, 2009) and developing countries (Ho, Matsuoka, Simson and Gomi, 2013; Kocabas, 2013) are striving to transform urban areas into low carbon cities (Lehmann, 2013), communities (Zhang, Shen, Feng and Wu, 2013) or neighbourhoods (Qin and Han, 2013). Through the development and use of suitable sustainability indicators (Shen, Ochoa, Shah and Zhang, 2011) or carbon indicators (Price, Zhou, Fridley, Ohshita, Lu, Zheng and Fino-Chen, 2013), the environmental performance of a city can be carefully monitored. However, analysis of the environmental burden associated with a building project must take into account its entire life cycle, process or activity (encompassing extracting and processing materials); manufacturing, transportation and distribution; use, reuse, maintenance; recycling and final disposal (Consoli *et al*., 1993). For instance, GHG is released as a result of fuel consumed or a by-product of the process of manufacturing building materials (Buchanan and Honey, 1994) and in the construction of buildings (Yan *et al*., 2009).

Researchers have identified six major sources of emissions relevant to a construction project in the: (i) manufacture of building materials (Seo *et al*., 2001; Gonzalez and Navarro, 2006; Nassen *et al*., 2007); (ii) transport of building materials (Cole, 1998; Nassen *et al*., 2007; Upton *et al*., 2008); (iii) transport of construction plant and equipment (Cole, 1998; Guggemos and Horvath, 2005; Nassen *et al*., 2007); (iv) energy consumed by construction equipment (Suzuki *et al*., 1995; Seo *et al*., 2001; Guggemos and Horvath, 2005; Gonzalez and Navarro, 2006; Upton *et al*., 2008); (v) transport of workers (Cole, 1998); and (vi) disposal of construction waste (Guggemos and Horvath, 2005; Upton *et al*., 2008). Apart from the emissions related to the construction process, the operational emissions due to the use of construction facilities also contribute a substantial proportion of the total GHG emitted.

Achieving the desired emission reduction targets set by a government, therefore, requires the cooperation of the various construction project stakeholders involved as any low carbon policies might increase the initial cost (cf: Liu *et al*., 2013) and affect the way in which an organisation operates. Without understanding the obstacles hindering client/owners and/or contractors in selecting low carbon building materials (Zuo *et al*., 2012) or construction techniques (Hamilton-MacLaren *et al*., 2013), it is difficult to introduce appropriate policies to promote emission reduction. The purpose of this paper, therefore, is to identify the main current practices of the different construction industry participants in relation to carbon reduction measures. Through a series of interviews conducted in Hong Kong, the obstacles faced by each participant in improving these practices are then identified. The paper concludes by outlining the various potential means by which the obstacles may be overcome.

Reducing carbon emissions from buildings

A major theme towards the adoption of sustainable practices has been a call for radical change – *"we need a revolution in the way we build, design and power our homes"* (DCLG, 2007). This can also be heard in Hong Kong too, where calls range from the need for industry leaders, *"sustainable design … is still in its infancy and visionary pioneers are needed to facilitate knowledge exchange, set standards and establish best practice locally"* (Chen *et al*., 2011), to a wider insistence that *"every actor in the building industry … has the ability to make a difference in mitigating the effects of climate change"* (Siew, 2007).

The major thrust, and increasing trend, is for the government to intervene. The government is urged to push industry into more low carbon building practices by using policy, regulation or even legislative specifications, as avoiding fines is always a strong incentive in any industry (cf: Ball, 2002). Similarly, Li and Colombier (2009) argue that the most urgent issue is for enforcing instruments such as taxes and charges, tradable permits and the distribution of information and subsidies to encourage climate change mitigation and sustainable and bioclimatic building designs. This is being implemented in many countries. In the United Kingdom, for example, the Greater London Authority uses the energy policies contained in the London Plan to ensure specific targets relating to energy efficiency and renewable energy are met by the building sector (Day *et al*., 2009).

In China, there are increasing demands from policy makers for a more sustainable society (Li *et al*., 2010). This is demonstrated in its Twelfth Five-Year Plan, which outlines various energy efficiency and low carbon development strategies. Buchanan and Honey (1994) postulated that maximising energy saving and improving energy efficiency are two other feasible short-to-medium term solutions to the problem, with the latter being the most

effective way to reduce carbon emissions when full consideration is given to opportunities that can passively reduce building energy usage (IEA, 2007; Levine *et al*., 2007). Apart from legislated specifications related to energy issues, energy saving and reduction in carbon emissions is also being encouraged by China government policy (Jiang and Tovey, 2010).

A substantial reduction in building energy consumption can be obtained by sustainable urban planning, optimised site planning and design, natural ventilation and suitable orientation, integration of renewable energy sources, and/or bioclimatic architectural design (Harvey, 2006; Salat, 2006). Other alternative proposals include a change in certain key areas of practice, such as the inclusion of environmental parameters in tender evaluations (Sterner, 2002) or using energy performance contracting (Xu and Chan, 2013). On the other hand, energy-efficient refurbishment is also an important means of reducing energy consumption in the building sector (Papadopoulos *et al*., 2002; Hong *et al*., 2006; Yung and Chan, 2012) by improving the insulation of the external envelope of a building, use of environmental-friendly materials, adopting renewable energy sources (Sitar *et al*., 2006) and installing energy-efficient devices (Ürge-Vorsatz and Novikova, 2008). This, together with good post-occupancy management, can significantly reduce the energy consumption of buildings (Tovey and Turner, 2006; Choy *et al*., 2013).

Another way to encourage the adoption of low carbon building practices is to promote the use of green building assessment systems, such as the most widely recognised green building rating system in the United States, the Leadership in Energy and Environmental Design (LEED) model, the Building Research Establishment's Environmental Assessment Method (BREEAM) in the United Kingdom, the Green Star in Australia and the Hong Kong Building Environmental Assessment Method (HK-BEAM). Since the value of energy-efficient projects is currently insufficiently recognised (Cheng, 2005), a single well-developed product-based carbon labelling scheme for construction materials is recommended for the future. Preferrably, to be instigated (or at least acknowledged) by the Government (Ng *et al*., 2013) as this could facilitate the client/owners, design team members and contractors to distinguish between the carbon footprint levels of different construction products.

Possible barriers

However, some characteristics of the markets and end-users involved are actually suppressing the incorporation of carbon reduction and energy-saving features into the design, construction and operation of building projects (Levine *et al*., 2007). According to Carbon Trust (2005), these can be classified as:

a) *Financial cost/benefits:* This concerns the higher initial costs involved. Although there is some understanding of the extra benefits associated with the green measures and that costs may reduce over time, the benefits are generally long term while costs are immediate (Yudelson, 2008). Hence, client/owners still find the higher investment costs involved hard to accept (Sterner, 2002).

b) *Hidden risks:* The additional technological risks, regulatory uncertainties and other hidden problems make the cost of low carbon building projects more uncertain and therefore less predictable over the medium to long term (Wellington *et al*., 2007). For example, renewable energy systems or energy-efficient equipment may not reach their predicted performance standards due to local environmental factors (Jiang and Tovey, 2010).

c) *Real market failures:* Hidden costs/benefits also exist in the form of misplaced incentives (real market failures) and landlords that are unlikely to invest in energy-efficient design and equipment or low carbon materials as they feel that they will probably not be sufficiently well rewarded (Scott, 1997; Schleich and Gruber, 2008).

d) *Behavioural/organisational sub-optimalities:* Occupant behaviour, culture and consumer choice are also major determinants of energy use in buildings (Levine *et al*., 2007).

Research method

To identify the obstacles hindering Hong Kong construction stakeholders in reducing carbon emissions, it is necessary to understand the current policies and practices related to carbon reduction, energy efficiency, construction sustainability, etc. Therefore, the first stage of the research involved an extensive review of relevant regulations, guidelines and reports prepared by the government and industry organisations. In addition, the literature related to the obstacles associated with carbon reduction in other industries around the world was also studied. The findings from these were used to develop an interview protocol for a series of semi-structured interviews to examine stakeholders' general opinions on the current policies and practices of carbon reduction measures, their perceived drivers, obstacles in adoption and the measures needed for their removal.

The interview protocol was piloted with a practitioner and an academic to ensure the questions were intelligible and relevant to the study. The pilot study indicated that, except

for some minor problems in the phrasing of the questions, the interview protocol was of sufficient clarity and relevance to facilitate the interview.

To improve the reliability of the interview findings of the main study, samples were drawn from five stratified groups likely to be affected by any construction industry carbon reduction measures, including client/owners, consultants, contractors, government and members of the community. As carbon emission reduction is still a new phenomenon for some construction stakeholders in Hong Kong, the interviews were restricted to those with some prior knowledge of low carbon policy, planning, design, material, technology and management. A purposive sampling technique was therefore used, with only those known to have prior experience in sustainable or low carbon construction being approached. In anticipation of the Hong Kong general public having only a limited amount of knowledge of the carbon footprint reduction of construction facilities, a small number of academicians was used to bettter inform the stakeholder group.

The main study comprised a total of 19 interviews conducted in Hong Kong. Of these, three were working for major developers, five were from large engineering consultancy firms, one from a renowned local architectural practice, six from medium to large main contractors, two from relevant government authorities in the territory, and an academic from each of two local universities (Table 1). A close scrutiny of their profile reveals that the majority of the interviewees (88 percent) had over ten years relevant working experience in the industry, with five being heads of their organisations, four directors, four managers and two in senior positions indicating that their opinions should be representative and reliable enough for further analysis. Although the robustness of the findings could be improved by having more interviews, the problem in identifying suitable persons with adequate knowledge in the subject matter and seniority to represent the organisational perspective rendered it difficult to increase the sample size.

Face-to-face interviews lasting approximately 45-60 minutes were conducted with the interviewees. The interview questions were open-ended and the interview dialogue was transcripted for subsequent presentation to the interviewees for verification. Acknowledging the differences in opinions between different stakeholders, the analyses were conducted according to the five stratified interviewee groups so as to paint a general picture of current practices and the specific obstacles faced by each stakeholder group. As identified in previous research, the obstacles can be divided into political, economic, social, technological, environmental and legal (PESTEL) aspects. A framework containing these six aspects was therefore employed to help systematically analyse the obstacles and possible improvement areas as identified through the interviews. The resulting recommendations are intended to help progress the industry’s contribution to a lower carbon environment.

STAKEHOLDERS PERCEPTIONS

Client/owners

The three construction client/owner interviewees come from different backgrounds and therefore enabled the benefits of different perspectives to be obtained. Interviewee A1 described a special carbon emission assessment method used by Interviewee A1 based on the risks associated with carbon emissions at different project stages and in which the risks borne by customers and other stakeholders are all examined separately. Interviewee A1 found this assessment method very useful as it contributes to Interviewee A1's success in gaining international recognition in sustainable development. Interviewee A1 occasionally conducts "green questionnaire" surveys of suppliers, contractors and other affected parties to seek improvements in Interviewee A1's green contribution in response to changing technology and varying market expectations. Interviewee A1's company's driver is corporate social responsibility, and its achievements in sustainable development are important for its international reputation. Another driver concerns the ability to make cost savings. Being both the builder and operator of a railway system and other related facilities, the operational cost savings made as a consequence of carbon reduction measures considerably benefits the company. This provides an extra incentive to the company in comparison with other developers in Hong Kong who focus solely on capital construction costs.

Interviewee A2 is responsible for the maintenance of an institutional building and pointed out that, since universities are invariably treated as pioneers in society, they are more willing to take up new technology to mitigate carbon emissions. However, the organisation's limited budget means that old, energy inefficient equipment cannot be immediately replaced with more energy efficient equivalents. Instead, new equipment can only be purchased when the old eqivalent fails, raising the opportunity costs involved.

Unlike Interviewees A1 and A2, Interviewee A3 belongs to a private sector company whose projects include residential buildings and shopping centres. Although Interviewee A3's company does not operate all its own projects, Interviewee A3 considers it to be the leading low carbon building developer in Hong Kong. The property development team of Interviewee A3 hold meetings with different departments four times annually to discuss the green activities of the company and to seek feedback on possible improvments. The major obstacles faced by Interviewee A3's company are the costs and risks associated with its carbon reduction measures. As the intention of some of Interviewee A3's projects is to sell or and lease, the appearance of any carbon reducing equipment needs be taken into consideration. Energy saving is strongly encouraged for shopping centre projects, since this not only reduces energy usage, and hence carbon emissions, but also saves on energy bills.

As with Interviewee A1, CSR is also an important driver for Interviewee A3's company and helps towards its higher ranking in the market. Similarly, Interviewee A3's company is seeking more carbon reduction features for its projects, since their market value is likely to be enhanced by the general public's growing interest in sustainability. For Interviewee A3's company, being a major developer in Hong Kong, the incorporation of carbon reducing features into its shopping malls is influential in prompting tenants to seek similar green features when renting office space in other shopping malls. With such influences, there is a growing interest in green projects in the whole industry, as other developers improve their service quality to satisfy customer demands.

A further point made by Interviewee A3 was that a more detailed assessment system of green technological products and green materials in the market is required and that the HKSAR Government could act as the pioneer to test new technological equipment as a means of alleviating client/owners' concerns of the risks involved.

Consultants

Altogether five people from three large international consultancy firms were interviewed. Nearly all were from the top management of their companies and so their perspectives are mainly an overview of the whole of business practice.

Being involved in the design of construction projects, consultants can use different measures and software to help reduce carbon emissions. An example given is a "project checklist", used to ensure certain standards of environmental impact are met before handing over the design to the client/owner. Another example cited is the "carbon critical design" of value engineering. This is used to avoid overly conservative designs and involves software to estimate the carbon emissions of the design for consultants to identify the main focus areas involved.

As is well known, many client/owners have no interest in green ideas due to the extra costs involved, so it is not surprising that consultants' professional carbon reduction suggestions to client/owners are sometimes ignored. However, the interviewees revealed that some developers are actually "doing very well" with environmental aspects. As a result, consultants tailor the inclusion of green measures based on their perceived acceptability to specific developers.

Another obstacle for consultants concerns the technical aspects involved. Since most green buildings are built in western countries, the data from these building projects may not be applicable to buildings in Hong Kong due to its different climate, practices and regulations,

etc. Hence, the lack of data for design purposes hinders the adoption of carbon reduction measures by consultancy firms.

Interviewee B6 was the sole representative from architectural practice, but with over 20 years of professional experience with various design and research projects – several of which have received awards from different professional organisations. As an experienced architect working on sustainable designs, Interviewee B6 said that carbon reduction is achieved in Interviewee B6's company by its research and development activities and master planning for both new construction and refurbishment projects. Carbon emissions are reduced by simple low-cost architectural design manoeuvres, such as better building alignment for ventilation, use of staircases instead of escalators and effective shading from sunlight. In Interviewee B6's experience, projects with an early and more coordinated involvement of participants provide the best opportunity for implementating green features. The size of project is also important. With a large-scale project, the architect is able to include many green features (e.g. district cooling, building alignment for breezeways, etc.) into the master plan – something that is more difficult to do with a smaller project.

Also stressed is the importance of market thinking. In economic terms, the client/owner forms the demand side while the architect and engineer form the supply side, with public awareness being the catalyst for boosting carbon reduction. According to Interviewee B6, all three aspects of supply, demand and catalyst need to be present for effective increased carbon efficiency.

Interviewee B1, a civil engineer involved in the building sector for more than 30 years, identified the need for a greater allocation of resources to the education of professionals, such as architects, engineers and surveyors, in the industry. Most professionals have not encountered carbon reduction measures during their qualification studies because of their relatively short history in the industry. Hence, professionals with knowledge of sustainable development are crucial to ensure the readiness of the market to adopt sustainability measures. In addition, the curricula of construction-related degrees need a greater emphasis on sustainable development to better prepare graduates for work on green projects.

Contractors

Most of the contractor interviewees agreed that, with the exception of design and build projects, there is little opportunity for them to contribute to emission reductions. This is because contractors are normally involved exclusively in the later stages of construction projects, while many carbon reduction measures can be included only during the design stage. On the other hand, contactors have control over the sourcing of green materials, an

important aspect as the embodied energy in construction materials contributes greatly to the overall carbon emission levels of construction projects. However, most contractors said they found it difficult to source green materials without knowing the actual performance and exact savings in carbon emissions involved. During construction planning, some contractors try to reduce carbon emissions by adopting low emission construction methods, such as good waste planning and water management, etc. However, tight schedules usually prevent contractors from innovating, forcing them to rely on existing methods.

One area where contractors often contribute is in the choice of plant fuel, as many are willing to change from diesel to electricity since this helps avoid the uncertainties created by the fluctuating price of fossil fuels. A similar situation exists with the choice of construction plant and equipment, as those with better energy efficiency are usually preferred in order to save energy costs and carbon emissions. Likewise, with good maintenance, the replacement frequency of construction equipment and amount of carbon emissions are both reduced.

However, quite a number of obstacles are now being faced by contractors. In addition to the lack of certification systems, contractors also have difficulty in measuring the amount of carbon emissions at different stages of different projects due to the lack of a database of the carbon emissions emanating from different construction activities. As with the views of client/owners, contractors are concerned with the performance risks of low carbon emission equipment and associated construction practices. The attitude of subcontractors is another major barrier for contractors as, for much of the time, subcontractors are involved in only certain parts of a project and their interest in adopting carbon reduction measures is therefore quite limited. This accounts for the reluctance of subcontractors to relinquish old building methods. In addition, without any reimbursement, the extra costs associated with carbon reduction measures, in the use of green materials, equipment, etc., profoundly inhibits contractors. To sum up, low carbon construction practices are developing slowly as carbon emission driven environmental impact awareness is still well below that of safety and direct air pollution such as dust emissions. Therefore carbon reduction is seldom, if ever, treated as a main priority.

To improve the situation, contractors are looking for further assistance from the HKSAR Government. As mentioned earlier, a certification system to test green materials would be helpful in order to mitigate the worries of contractors. It would also be useful to have a body to monitor, assess and report the carbon reduction strategies of contractors. Regulation is another effective method. It would be beneficial for the HKSAR Government to increase standards in the Building Energy Code, which has been in use for many years. A similar requirement is needed for plant replacement, such as encouraging the use of Quality Powered Mechanical Equipment. If enforceable carbon reduction standards are stated in legislative specifications, they must be structly followed by industry. Most interviewees agreed that

their companies would be more willing to improve carbon reductions with increased incentives, subsidies and awards by the HKSAR Government. Raising the awareness of carbon reduction is possible for both the general public and the construction industry (e.g. subcontractors) through education. With the support of senior management in the construction industry, it may be possible for market participants to work closer together to produce more creative ideas to bring about a low carbon building environment.

Government

Although many industry participants are asking for further aid from the HKSAR Government, Interviewee D1 pointed out that the government actually already provides several schemes to encourage carbon reduction in the building industry. In order to enhance energy efficiency, the government has launched three programmes:

a) Building Energy Efficiency Funding Scheme – providing financial subsidies on a matching basis to private building owners to conduct energy-cum-carbon audits and energy efficiency improvement projects

b) Green Hong Kong • Carbon Audit campaign – promulgating carbon audit guidelines for buildings in Hong Kong

c) Green Performance Framework – promoting environmental protection and energy conservation of existing government buildings.

In addition to these campaigns, an inter-departmental working group led by the Environment Bureau of the HKSAR Government has been instigated with the aim of combating climate change through the reduction of carbon and other carbon emissions. A consultancy study was also commissioned in 2008 to seek long-term strategies and measures to reduce carbon emissions. In terms of regulations, a Mandatory Energy Efficiency Labelling Scheme for different appliances has been launched and the Building (Energy Efficiency) Regulation and overall thermal transfer value standard of buildings are currently being reviewed. Interviewee D2 also commented that the HKSAR Government is not really free of restraints, pointing out some of the obstacles with which it is faced. Implementing a new policy, for example, is not easy as it involves a lengthy process of several rounds of public consultation, reading of the legislative body, etc.; often resulting in accusations from the public that the Government is slow to react.

Public

Interviewee E2, a construction industry participant for more than 40 years, provided some suggestions involving the HKSAR Government and industry relating to the implementation of carbon reduction measures. Firstly, calling for the HKSAR Government to act as a leader for the whole industry by adopting more carbon reduction features in its own projects, such as public housing, government offices and public facilities. This subsequently increases market confidence and willingness to accept new technologies. Similarly, stating that more resources should be injected by the HKSAR Government to encourage carbon reduction research and development. Information exchange and disclosure should also be encouraged by providing a platform for the industry to exchange ideas and information. More incentives should be provided by the HKSAR Government to encourage developers to adopt green measures, such as extra gross floor area or tax rebates for projects according to the extent of their carbon reduction features. In addition, the HKSAR Government should do more to increase the value of green projects, as once their value is recognised by the public, this will certainly act as an important driver for the developers.

As a member of the board of directors of the Hong Kong Green Building Council (HKGBC), Interviewee E1 argued that the development of HKGBC can actually push the market towards low carbon building practices. If the HKSAR Government encourages more buildings to gain certification from HKGBC, HKGBC will then have more resources to educate the public and expand its scope of assessment to existing buildings and interior designs.

DISCUSSION

Current construction industry practice

Some trends emerge from the interviews that are also reflected in current industry practices:

Client/owner: Different client/owners take different kinds of action – typically, waste/water management, use of more energy-efficient equipment (LED lighting, water-cooled chillers, etc.) and responsible procurement (e.g. the use of green materials).

Architect: Tries to include some green features (e.g. operable panel, green roof and wind catcher) into both new buildings and refurbishment projects and spend some time on research and development activities to seek technological improvements.

Engineer: Apart from the 'project checklist' and 'carbon critical design' mentioned earlier, consultancy firms also provide technical solutions (such as thermal insulators and mixed ventilation) to reduce carbon emissions.

Contractor: Contractors reduce carbon emissions by the procurement of green materials, use of energy-efficient equipment, fuel selection and good maintenance of equipment.

Government: The HKSAR Government is trying to reduce carbon emissions by energy efficiency enhancement schemes (e.g. Buildings Energy Efficiency Funding Scheme, Green Performance Framework), setting up an inter-departmental working group, and consultancy studies to seek solutions and regulatory action.

Obstacles and potential solutions

Table 2 summarises the common obstacles to carbon emission mitigation identified by the interviewees, the most frequent of which are lack of awareness in the market, limited budget and client/owner attitudes. To identify possible solutions, the external factors involved need to be identified and studied (Lv and Wu, 2009). By using the PESTEL framework, different political, economic, social, technological, environmental and legal factors (Gillespie, 2007) can be distinguished. The interviews themselves also enable solutions to be identified by specifically considering the obstacles to, and drivers of, carbon reduction.

In terms of drivers – CSR, cost savings, increases in market value of projects and improved prospects of obtaining further work all have a common motivation – increased profit. This suggests that the most likely way forward is by financial support. Other solutions derived from the study are presented in the Table 3.

Further comments

Another issue worthy of comment relates to market transformation. As intimated by Interviewee B6, carbon emission mitigation practice can be modelled in economic terms as being motivated by consultants (supply-side), public awareness (catalyst) and client/owners (demand-side). Amongst growing public awareness of the need for carbon emission reductions, the building sector is expected to develop solutions that drive a sustainable industry into the future. Such a transformation in the market will be a crucial step in the success or otherwise of the green building movement.

Two additional factors significantly affect the success of carbon reduction efforts. The first concerns the nature of developers. Developers whose business is centred on the leasing market are relatively unwilling to incorporate green features since they will not benefit from any operational cost savings. In contrast, developers who are builder-owners are eager to provide energy-saving features in their projects. The second factor is related to the Government budget. As illustrated earlier, large-scale projects with long-term implications provide a better opportunity to incorporate carbon reduction measures. However, the HKSAR Government's budget is set and presented yearly, which makes it difficult to implement and fund long-term plans or investments for large-scale projects, the political barriers in this case being insurmountable.

Finally, although a certification system for testing different types of building materials will most certainly contribute toward solving the problem, an extensive effort will be needed to initiate and develop such a system. Many suppliers are unwilling to provide information concerning the sources of their products and, even when the information is available, the wide variety of such sources currently makes accurate carbon footprint calculations virtually impossible.

CONCLUSIONS

A refinement of existing mitigation measures is needed in order to alleviate the problems brought about by excess carbon dioxide and other GHG emissions. The study reported in this paper aimed to identify the obstacles to introducing carbon reduction measures into building projects faced by different construction industry participants and to provide suggestions for their improvement. Using information collected from research studies relating to carbon reduction and interviews with different construction industry participants (including client/owners, consultants, contractors, government authorities and citizens), the main obstacles, drivers and barriers encountered by the construction industry in reducing carbon emissions have been presented. This showed that the actions currently taken by the building sector to reduce carbon emissions include green procurement, energy efficiency enhancement, research and development activities, waste/water management and other technical measures such as thermal insulation and mixed ventilation. Most of the drivers that can prompt the industry to improve its low carbon building practices are economical in nature, suggesting that financial aids are likely to be the most useful motivators. In particular, extra incentives from the government are needed.

As a first step to promote sustainable construction in Hong Kong, from April 2011 onward the HKSAR Government is allowing new buildings with BEAM-Plus certification (i.e. a local building environmental assessment model) to earn a maximum gross floor area

concession of no more than 10 percent. On the other hand, the Hong Kong Housing Authority (HKHA) has introduced an Innovative Procurement method to buy in novel ideas from contractors to improve the sustainability and productivity of public housing projects.

Another possible incentive is in the form of a Pay for Carbon Reduction mechanism where contractors would be entitled to a sum of money to compensate their emission reduction efforts at the project level. From the owners or occupants' perspective, a better mortgage deal or a reduction in stamp duty for a low carbon property may increase the demand for this type of building. The HKHA has already developed and piloted the use of a Carbon and Energy Estimation model to assess the life cycle carbon footprint of new public housing estates in Hong Kong. This can easily be extended to private properties to facilitate benchmarking of carbon emissions and energy consumption in the building sector.

Also suggested is an increased promotion of the concept of sustainability to the wider community. Through the Energy Efficiency Labelling Scheme, citizens of Hong Kong have been provided with more information concerning the energy performance of certain electrical appliances. This would undoubtedly encourage the selection of more energy efficient electrical products. Meanwhile, a major challenge lies in a huge stock of existing buildings with poor energy efficiency. More information needs to be given to the owners and occupants regarding the costs and benefits of different low carbon refurbishment solutions so they can decide how to contribute more to carbon reduction. Generating a heightened public interest and demand for a low carbon building sector remains a significant hurdle, yet once overcome will help mobilise the industry's transformation into the future.

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Table 1: Interviewees' background

Name	Position	Type of company
Interviewee A1	Head of Sustainability Development	Property developer and railway company
Interviewee A2	Senior Assistant Director	Estates office of a local university
Interviewee A3	Assistant Technical Manager	Property developer
Interviewee B1	Deputy Chairman	Engineering consultancy firm
Interviewee B2	Director, Corporate Sustainability	Engineering consultancy firm
Interviewee B3	Associate, Corporate Sustainability	Engineering consultancy firm
Interviewee B4	Associate Technical Director	Engineering consultancy firm
Interviewee B5	Assistant Environmental & Corporate Responsibility Manager	Engineering consultancy firm
Interviewee B6	Director of Sustainable Design	Architectural firm
Interviewee C1	Vice Chairman	Contractor
Interviewee C2	System Director	Contractor
Interviewee C3	Group Sustainability & CSR Manager	Contractor
Interviewee C4	Assistant Environmental Manager	Contractor (medium scale)
Interviewee C5	Environmental Officer	Contractor (medium scale)
Interviewee C6	Assistant Environmental Engineer	Contractor
Interviewee D1	Senior Environmental Protection Officer	Main government body
Interviewee D2	Senior Building Service Engineer	Government statutory body
Interviewee E1	Honorary Professor	Educational institution
Interviewee E2	Chair Professor	Educational institution

Table 2: Common obstacles as identified by different interviewees

Aspect	***A1***	***A2***	***A3***	***B1***	***B2***	***B3***	***B4***	***B5***	***B6***	***C1***	***C2***	***C3***	***C4***	***C5***	***C6***	***D1***	***D2***	***E1***	***E2***
Appearance of carbon reducing equipment			‼																
Client/owner's attitude				‼	‼	‼	‼	‼					‼		‼		‼		
Difficulties during implementation																‼	‼		‼
Difficulties in measuring carbon emissions										‼		‼		‼				‼	
Lack of awareness in the market	‼		‼	‼	‼	‼			‼	‼	‼	‼		‼	‼		‼	‼	‼
Lack of data for technology development				‼	‼									‼					
Lack of information exchange platform				‼	‼				‼										‼
Limitation due to project size / type									‼		‼	‼							‼
Limited budget	‼	‼	‼	‼	‼	‼		‼			‼	‼	‼		‼		‼	‼	
Performance risk associated with carbon reduction equipment		‼	‼										‼	‼					
Performance risk associated with green materials										‼		‼	‼	‼			‼		
Stickiness of old methods							‼	‼	‼			‼		‼					
Tight schedule											‼	‼							

Table 3: Different categories of solutions in the PESTEL model

Aspect	***Solution under this category***
Political	o Improve the execution ability of the HKSAR Government
Economic	o Provide financial incentives to the industry
Social	o Educate the professionals involved in the building sector about sustainable development o Raise the awareness of the general public about low carbon concept
Technological	o Spend more resources on research and development o Set up certification system o Expand the scope of the current assessment
Environmental	o Stress the significance of preserving our environment
Legal	o Include environmental parameters in the tender requirement o Set up regulations / legislative specifications to push the green movement o Tighten the current standard about energy efficiency
Other	o Set up a platform for information exchange o Have a pioneer to try the carbon reducing products / green materials