CARBON LABELLING SCHEME FOR CONSTRUCTION PRODUCTS: THE BENCHMARK FOR LOW CARBON MATERIALS

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ABSTRACT

Climate change has become a global threat with worrying consequences for many countries. Among various economic sectors, the construction industry consumes 40% of materials entering the global economy and generates significant amounts of greenhouse gases (GHGs) - the main cause of climate change. Particular attention should be attributed to the embodied carbon of construction materials as it could contribute to 70% of GHG emissions at the construction stage and up to 25% of a building's life time energy consumption. It is thus highly desirable to select and use low carbon construction products so as to minimise the GHG emissions arising from the construction industry. In view of this, the Construction Industry Council (CIC) in Hong Kong has initiated a Carbon Labelling Scheme for Construction Products as part of its mission to promote green building practices and sustainable development. This paper introduces the carbon assessment framework of the Scheme, including the product categorisation, principles and system boundary of carbon footprint quantification, benchmarking mechanism, and certification process. The paper also presents the methodology of developing a GHG quantification tools for assessing carbon footprint of products (CFP). As a voluntary scheme in Hong Kong, itaims to provide verifiable and accurate information on the carbon footprint of construction products for industry practitioners to select 'low carbon' materials.

Keywords: *Carbon Footprint; Carbon Labelling; Construction Products; Sustainable Development.*

1. INTRODUCTION

The construction industry accounts for large amount of greenhouse gas (GHG) emissions by consuming great quantity of energy and resources. According to the Hong Kong Ecological Footprint Report 2010 issued by the World Wide Fund (WWF), the construction sector is the second largest contributor to the Hong Kong's carbon footprint in the year of 2007 (WWF, 2010). In response to the Hong Kong Special Administrative Region (HKSAR) Government's carbon reduction target of reducing the carbon intensity by 50-60 percent by 2020 on the basis of 2005 levels, the construction industry has an indispensable role to play.

During the years of the life cycle of construction facilities, GHG emissions are associated with the full life cycle stages: resource extraction, construction materials manufacturing, materials transport, on-site construction, operation and maintenance, and demolition. Researchers and industry practitioners normally pay more attention to the emissions released during the user stage of the construction facility or in maintaining the inside environment through processes like heating and cooling, lighting and operation appliances since these stages consumes much energy over years of usage. However, the carbon embodied in a construction facility should also be concerned as it is hardly to mitigate the embodied carbon once the construction is completed (Monahan and Powell, 2011). Fieldson *et al.* (2009) stress that embodied carbon of construction materials shares a significant portion of the building's life cycle emissions (Figure 1). Therefore, selecting low-carbon materials in the early project stage is highly desirable.

In Hong Kong, the recent strong growth in gross construction volume, together with the ten major infrastructure projects, will continue to drive up the demand for construction services and materials.

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This makes the low carbon construction materials become a pressing demand of local market. However, Hong Kong does not have an authoritative, independent and publicly acceptable evaluation system providing the benchmark of the locally used construction materials. Industry stakeholders are thus calling for a recognised evaluating system indicating the performance of each commonly used construction materials.

In view of this, the Construction Industry Council (CIC) has initiated a research project to develop a Carbon Labelling Scheme for Construction Products (the "Scheme"), as part of the CIC's mission to promote green building practices and sustainable development. The Scheme aims to provide the communication of verifiable and accurate information on the carbon footprint of construction products for client bodies, designers, contractors and end users to select 'low carbon' materials. This paper introduces the carbon assessment framework of the Scheme, including the product categorisation, system boundary of carbon footprint quantification, benchmarking mechanism, and certification process. The current implementation progress and future prospects of the Scheme will also be highlighted.

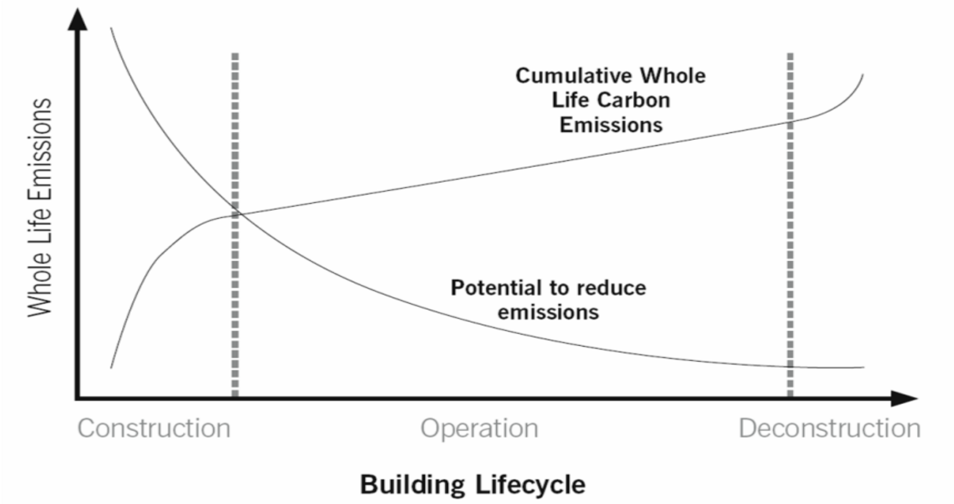

Figure 1: Potential of Reducing Whole Life Emissions during Building Life Cycle
Source: Fieldson *et al.* (2009)

2. CARBON ASSESSMENT FRAMEWORK

2.1. SCOPE AND PRODUCT CATEGORISATION

The Scheme focuses on a single impact category: climate change by quantifying the GHGs generated from the certain life cycle stages of construction materials in terms of carbon dioxide equivalents (CO_2e). It covers the six types of GHGs under the Kyoto Protocol (United Nations, 1997), namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) which impact directly on global warming. Other environmental aspects along the product's life cycle are beyond this labelling Scheme.

Among various types of construction products, the Scheme initially covers the most commonly used construction materials with relatively high GHG emissions to the industry. Cement is extensively used in the construction industry as an essential ingredient in producing concrete. As the production of cement consumes large quantities of fuel and reacts with chemicals under high temperature during manufacturing, especially the kilning process, the cement industry alone generated approximately 5% of the global anthropogenic CO_2emissions (IPCC, 2001). The production of steel products is energy intensive and the iron and steel industry is responsible for about 10% of worldwide CO_2 emissions from fossil fuel use (IEA, 2008), which also accounts for about 5% of the global GHG emissions. Therefore, cement and steel (rebar and structural steel) are covered under the labelling system of the Scheme at the outset.

In accordance with BS EN 197-1:2000 "Composition, Specifications and Conformity Criteria for Common Cements", the CEM I - Portland cement (all strength classes) is the specific type that being evaluated under the Scheme. Portland cement is composed of 90-95% clinker and up to 5% of minor additional constituents. Other types of cement products may be added to the scope of this Scheme in due course.

As for steel products, Non Alloy Steels in accordance with BS EN 10020:2000 "Definition and Classification of Grades of Steel" is covered under the Scheme. It contains by mass more iron than any other single element, having carbon content generally less than 2% and containing other elements. It is applicable to four broad steel product categories that are commonly used in the construction industry namely, (i) steel reinforcing bar; (ii) steel section; (iii) steel plate; and (iv) steel pipe as shown in Table 1.

Table 1: Product Categorisation of Steel under the Scheme

Product Category	**Product Sub-Category**
I. Reinforcing bar	-
II. Steel section	a. Structural section (incl. Universal beam / column, H section, I section, Bearing pile) b. Hollow section c. Bar section (incl. Flat bar, Square bar, Round bar, Tee bar) d. Others (Channel, Angle, Z section, Mesh)
III. Steel plate	-
IV. Steel pipe	-

The quantification and reporting of the CFP under the Scheme is based on a life cycle assessment (LCA) as detailed in ISO 14044:2006. The carbon footprint assessment should therefore include the four phases of life cycle assessment (LCA), i.e. goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and life cycle interpretation.

2.1. SYSTEM BOUNDARY

For a construction material, the full life cycle starts from the resource extraction, construction materials manufacturing, transport, on-site construction, operation and maintenance, demolition, and ends at disposal and recycling (Hammond and Jones, 2008). However, it is not recommended to estimate the full life cycle carbon emission of construction materials because the emissions in the use phase are insignificant, and the emissions from the disposal stage are difficult, if not impossible, to predict. With little manufacturing industry, Hong Kong imports large amount of construction materials from other regions, which makes the transport of material becoming a potential significant source of GHG emissions. The framework of the Scheme is thus determined as "Cradle to Site" that covers the raw material acquisition, manufacturing, transport until the material reaches the boundary of Hong Kong (Figure 2).

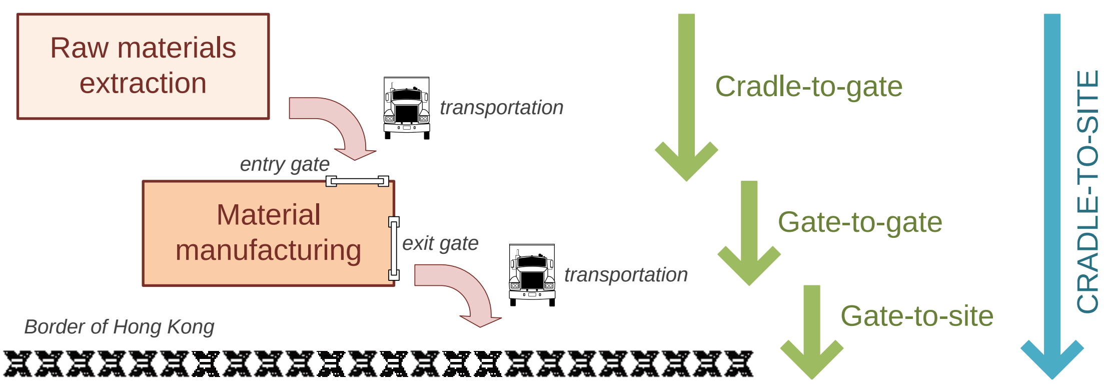

Figure 2: A Cradle-to-Site System Boundary

According to ISO Technical Specification 14067:2013, all the direct and indirect GHG emissions attributed by the processes within the system boundary should be accounted for the carbon footprint of the selected material under the Scheme, including fuel combustions, chemical reactions, energy use, loss to atmosphere of refrigerants and other fugitive greenhouse gases, process operations, service provision and delivery, land use and land use change, waste management, etc. Specific to the cement and steel respectively, the process and source of GHG emissions can be summarised as the following Tables 2 and 3.

Table 2: System Boundary for Quantifying Carbon Footprint of Portland Cement

System Boundaries	Processes
I. Upstream Processes	• Extraction and production of raw material and energy wares used in the production and packaging of the finished product • Transportation of raw materials and recycled materials to the plant • If relevant, recycling process of recycled materials used in the product
II. Core Processes	• Production of raw meal • Production of clinker (calcinations) • Grinding of cement • Storage and packaging for dispatch
III. Downstream Process	• Transportation from manufacturing to the border of HK

Source: EPD® (2010)

Table 3: System Boundary for Quantifying Carbon Footprint of Reinforcing Bar and Structural Steel

<table>
<tr><th>System Boundaries</th><th colspan="2">Processes</th></tr>
<tr><td>I. Upstream Processes</td><td colspan="2">• Extraction and production of raw material and energy wares used in the production and packaging of the finished product
• Recycling process of recycled materials used in the product
• Transportation of raw materials and recycled materials to the plant</td></tr>
<tr><td>II. Core Processes</td><td>• Production of steel including processes in:
➢ Coking plant
➢ Sintering plant
➢ Pelletising plant
➢ Blast furnace
➢ Basic oxygen furnace
➢ Electric arc furnace
➢ Ladle furnace
➢ Reheating furnace of rolling mill</td><td>• Finishing of steel
➢ Casting
➢ Hot rolling
➢ Cold rolling
➢ Storage and packaging for dispatch</td></tr>
<tr><td>III. Downstream Process</td><td colspan="2">• Transportation from manufacturing to the border of HK</td></tr>
</table>

Source: EPD® (2011)

Following the “Cradle to Site” approach, the GHG emissions and removals in the use stage are neglected. As for cement, the irreversible nature of cement products justifies the exclusion of the end-of-life stage. In addition, recarbonisation of cement and concrete is not covered due to lack of accurate and quantifiable data. For steel products, the emissions from the process of recycling steel, if any, is estimated in the upstream process rather than the disposal stage.

2.2. GHG EMISSION SOURCES

The GHGs generated from all unit processes as included in the pre-defined system boundary should be quantified and reported in the assessment of the carbon footprint of product (CFP). The emissions can be divided into direct and indirect GHG emissions. The direct emissions stem from sources that are owned or controlled by the material supplier, whereas the indirect emissions originate from sources that are controlled by third parties, but they are nonetheless related to the activities of the material supplier (Cement Sustainability Initiative, 2011).

The labelling scheme was developed based on the ISO/TS 14067:2013 "Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication". The GHG assessment frameworks of the cement and steel products were established with reference to the "CO_2 and Energy Accounting and Reporting Standard for the Cement Industry" issued by Cement Sustainability Initiative (CSI) in 2011, and the "Calculating Greenhouse Gas Emissions from Iron and Steel Production: A Component Tool of the Greenhouse Gas Protocol Initiative." issued by The GHG Protocol Initiative (2008), respectively. Looking into details of the GHG emission sources of cement and steel over the "Cradle to Site" life cycle stages, the sources could be summarised and categorised as presented in Table 4. One of the major sources of direct emissions is the combustion of fuels, which are burned in either the kiln of cement production or the furnace of steel manufacture. For non-kiln/furnace fuels, they are normally applied for the following usages:

- Quarrying / mining raw materials
- On-site transportation
- Equipment
- Room heating / cooling
- On-site power generation

In the Portland cement production, another major direct emission source is the chemical reaction in the calcinations process, where limestone is calcinated under high temperature (around 1,450^{o}C) and CO_2 is largely emitted contributing 60-65% of total CO_2 emissions in the cement processes (IEA/WBCSD, 2009). On the other hand, steel production also involves some special industrial processes where chemicals containing carbon are burned or decomposed to release CO_2 and CH_4.

Key indirect GHG emissions arising from the production of cement, reinforcing bar and structural steel products include four common categories: i) the GHGs associated with the external electricity consumption; ii) the production of bough materials and energy wares; iii) transportation for raw material and products delivery; and iv) land use change.

Table 4: GHG Emission Sources of Portland Cement and Steel Products under the Scheme

	Direct Emissions	**Indirect Emissions**
Portland Cement	• Raw material calcinations and combustion • Combustion of kiln fuels • Combustion of non-kiln fuels	• External production of electricity consumed by cement manufacturers • Production of bought raw materials, energy wares and clinker • Off-site transportation • Land use change
Steel Products	• Combustion of furnace fuels • Combustion of non-furnace fuels • Industrial processes ➢ Sinter production ➢ Lime production ➢ Steel production ➢ DRI production ➢ Flaring	• External production of electricity consumed by steel manufacturers; • Production of bought raw materials and energy wares • Off-site transportation • Land use change

2.3. *BENCHMARKING MECHANISM*

After quantification, the results of the CFP of the material should be documented and reported in accordance with certain criteria as required by relevant international standards: ISO/TS 14067:2013; ISO 14040:2006; ISO 14044:2006 and ISO 14025:2006.

The reported CFP of the material is then evaluated and differentiated according to the benchmarking against the emissions of the same category of construction material. The Scheme adopts a five-level multiple benchmarking regime as shown in Figure 3. E_m refers to the submitted carbon footprint of product (CFP). E_{da} refers to the average carbon emission value. E_{da} is currently determined by obtaining relevant values from international recognised inventories, such as Ecoinvent, U.S. LCI, Japan CFP Database, WBCSD CSI database, etc. In the long run, the benchmarks would be reviewed and adjusted on a regular basis, and will be adjusted using local data if sufficient data are obtained as the Scheme develops.

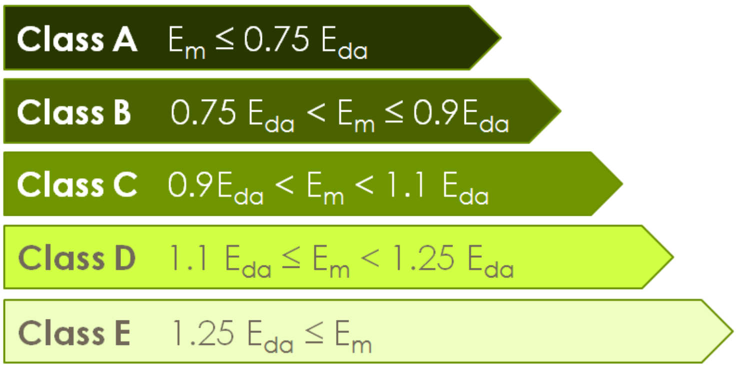

Figure 3: Benchmarking Mechanism of the Scheme

2.4. *CERTIFICATION PROCESS*

As a voluntary carbon labelling system, the certification of the Scheme should follow the communication criteria as stated in the ISO/TS 14067:2013 and the ISO 14025:2006 for Type III Environmental Declaration. This requires the involvement of the independent validation and verification by a third-party body (VVB). In addition, carbon assessment is still novel in Hong Kong and the potential applicant organisation itself may lack the competent professionals to conduct carbon audits specifically for construction materials. This leads to the engagement of certified carbon auditor (CCA) for a particular product category under this Scheme. The engagement of CCA and VVB in the certification is to make sure that the applied material's carbon footprint is correctly, accurately and completely audited, reported and verified. A complete procedure of certification process is presented as below in Figure 4.

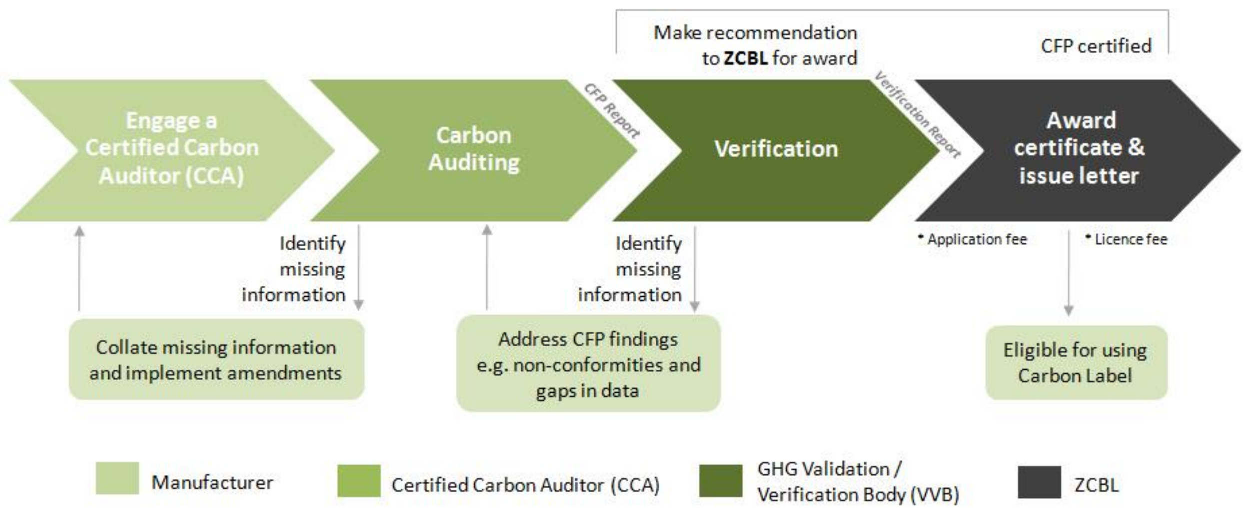

Figure 4: Certification Process of the Scheme

3. IMPLEMENTATION OF THE SCHEME

Based on the developed carbon assessment framework and tremendous preparation work, CIC formally launched the Scheme in late 2013 and now it is open for application.

A set of Assessment Guide and Quantification Tool has been developed for cement and steel, respectively (refer Figure 5 and Figure 6). The Assessment Guide details principles, requirements and rules for the quantification and reporting of the carbon footprint of products (CFP) under the Scheme. With the embedded equations and built-in emission factors, the Quantification Tool provides the applicants a user-friendly tool for data input and results auto-generation. Material suppliers can prepare their product specific carbon inventories using the CFP tool following the guidance of the Guide.

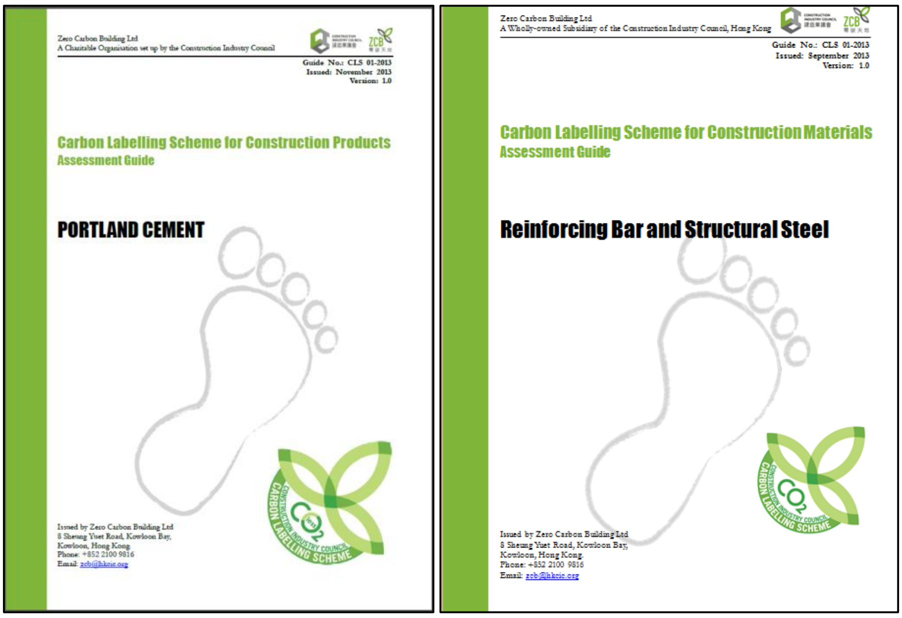

Figure 5: Assessment Guides

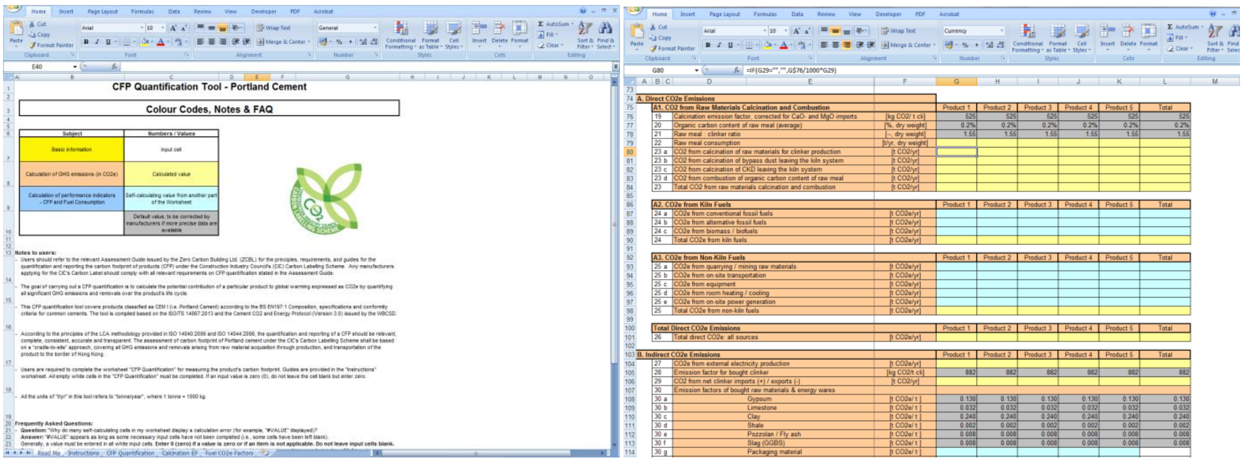

Figure 6: CFP Assessment Tool

For the effective implementation of the Scheme, CIC has carried out a series of proactive strategies including organising seminars, workshops and training programmes to provide basic knowledge on the Scheme and professional trainings on carbon auditing, liaising with relevant industry stakeholders for promotion of the Scheme, launching the online listing service for labelled materials, etc. In addition, CIC is working towards integration of the Scheme into the Hong Kong green building assessment model (BEAM Plus), with which the incentive would encourage developers and designers to consider applying low carbon construction materials with an outstanding grade under the carbon labelling scheme to achieve a good

BEAM Plus classification. More importantly, CIC is lobbying the government agencies and large developers to incorporate the Scheme into their tender assessment, which could further affect the procurement of the contractor and stimulate the market demand of the labelled materials.

4. FUTURE PROSPECTS

The Phase II Research on this project has commenced in early 2014, which develops carbon quantification frameworks for additional 10 construction materials to extend the coverage of the Scheme. For long-term development, the Scheme will not only focus on Hong Kong market but also expand to Asian regions. In order to further enhance the international visibility of the Scheme and attract attention of material manufacturers overseas, CIC will explore various channels to introduce and promote the Scheme. In the long run, CIC will seek support from other relevant organisations, associations and institutes for information sharing to expand the coverage of the promotion. It is expected that the Scheme will be widely recognised by the industry by achieving the incorporation of the Scheme into Beam Plus system, as well as providing incentives in the government procurement plan.

5. CONCLUSIONS

This paper reports a project on developing and implementing the Hong Kong-based Carbon Labelling Scheme for commonly used construction materials. The development of the carbon assessment framework under the Scheme was introduced in the paper, including the coverage of the materials (i.e. cement, rebar and structural steel) in the initial stage of the Scheme and the product categorisation of cement and steel products, the "cradle-to-site" system boundary and the associated GHG emission sources within the system boundary, the benchmark mechanism for grading and differentiating the performance of each material, and the certification process for issuing the carbon label. Based on the outcome of the research, the CIC implements the carbon assessment framework to the industry by launching the Scheme formally in late 2013 with user-friendly assessment guide and calculation tool provided. A series of promotion strategies have been carried out for the smooth implementation of the Scheme. It is anticipated that the continuous development of the Scheme will help the industry stakeholders build strong awareness on carbon footprint and low carbon construction, thus facilitating green building practice and sustainable development of the construction industry as a whole. As a Hong Kong-based voluntary scheme, the CIC Carbon Labelling Scheme for Construction Products intends to encourage the demand for, and supply of, low carbon products, thereby contributing to Hong Kong's transition to a low carbon economy.

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