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CIC Green Product Certification
Assessment Guide

Ready-mixed Concrete

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USE OF THIS ASSESSMENT GUIDE

This Assessment Guide (the "Guide") details principles, requirements and guides for the quantification and reporting of the carbon footprint of products (CFP) under the Green Product Certification launched by the Construction Industry Council (CIC). The Guide sets the product category rules and benchmark for differentiating "low carbon" construction products in the market.

The CIC Green Product Certification is a voluntary eco-labelling scheme. The carbon assessment framework is based on the ISO Technical Specification 14067:2013 "Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication". Users of this Guide should note that this Certification focuses on a single impact category: climate change. Other environmental aspects along a product's life cycle are beyond the content of this Guide.

This standard may be used by CIC authorised Carbon Auditor and Greenhouse Gas (GHG) Validation / Verification Bodies to conduct carbon audit, reporting, verification according to the requirements set by this Guide. Where a product is certified under the CIC Green Product Certification, it may display the CIC Green Product Certification to show that the product has been independently verified and demonstrates conformance with the assessment criteria detailed in this Guide.

The purpose of the CIC Green Product Certification is the communication of verifiable and accurate information on the carbon footprint of construction materials for clients, designers, contractors and end users to make informed decision. As required by the Trade Descriptions Ordinance the information cannot be misleading. Such information encourages the demand for, and supply of, low carbon products, thereby stimulating the potential for market-driven continuous environmental improvement. Where a company has a product certified as conforming to this Guide, it may gain a marketing advantage in government and business procurement programmes, as well as greater market recognition in general.

GHGs are emitted and removed throughout the life cycle of a product from raw material acquisition through production, use and end-of-life treatment. The quantification and reporting of the CFP under this Certification is based on a life cycle assessment. As such, the CFP report based on this Guide may also offer guidance for manufacturers to design and refine the processing, manufacturing and delivery of their product(s) in reducing GHG emissions, energy consumption, and thereby cost.

While all CIC Guides for the Green Product Certification are voluntary, compliance with all applicable laws and regulations is a required requisite for the marketing of the products using the CIC Green Product Certification.

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1. INTRODUCTION

1.1 Background

The purpose of CIC Green Product Certification (the "Certification") is to promote low carbon construction products in the market, and thus contributing to the transition of Hong Kong to a low carbon economy. With the CIC Green Product Certification, construction practitioners may select low carbon products in a simple and unequivocal manner.

Concrete is the most widely used construction material in Hong Kong. The global consumption of concrete is about 1 tonne per year per every living human being (Flower and Sanjayan, 2007). Due to its large consumption, small reductions of greenhouse gas (GHG) emissions per ton of manufactured concrete can make a significant global impact. This Assessment Guide (the "Guide") sets the product category rules (PCR) and benchmark for labelling low carbon ready-mixed concrete products under the Certification.

This Guide details the principles, requirements and guides for the quantification and reporting of the carbon footprint of products (CFP) under the Certification. The Guide is voluntary, and after verification, enables certified products to display the CIC Green Product Certification to show that it is environmentally preferable.

1.2 Scope

This Guide covers ready-mixed concrete products in accordance with the cube test described in the "Code of Practice for Structural Use of Concrete 2013" published by the Hong Kong Buildings Department (Buildings Department, 2013) or the "General Specification for Civil Engineering Works Volume 2, 2006 Edition" published by the Civil Engineering and Development Department (CEDD, 2006).

Concrete products for special use (e.g. marine structures, dams, etc.) are excluded from the Certification and may be added to this Guide in due course.

This Certification focuses on a single impact category: climate change by quantifying the GHGs generated from the production of ready-mixed concrete in terms of CO_2 equivalents (CO_2e). It covers the six types of GHGs under the Kyoto Protocol (United Nations, 1997), namely, CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) which impact directly on global warming.

The benchmark for ready-mixed concrete products is listed in Table 1 below.

Table 1. Benchmark for Ready-mixed Concrete under the CIC Green Product Certification

Concrete Grade	C30	C35	C40	C45	C50	C60	C70	C80
E_{da}	296	323	350	373	396	443	490	490
Certification Level	($kgCO_2e/m^3$)							
Platinum	<252	<275	<298	<318	<337	<337	<417	<417
Gold	252-280	275-306	298-332	318-354	337-375	337-420	417-465	417-465
Silver	281-310	307-339	333-367	355-391	376-415	421-464	466-514	466-514
Bronze	311-340	340-372	368-403	392-429	416-455	465-509	515-563	515-563
Green	>340	>372	>403	>429	>455	>509	>564	>564

1.3 How to Apply for CIC Green Product Certification

Manufacturers or suppliers interested in CIC Green Product Certification are required to go through the following three major processes: (i) Carbon Auditing; (ii) Verification; and (iii) Certification as shown in Figure 1.

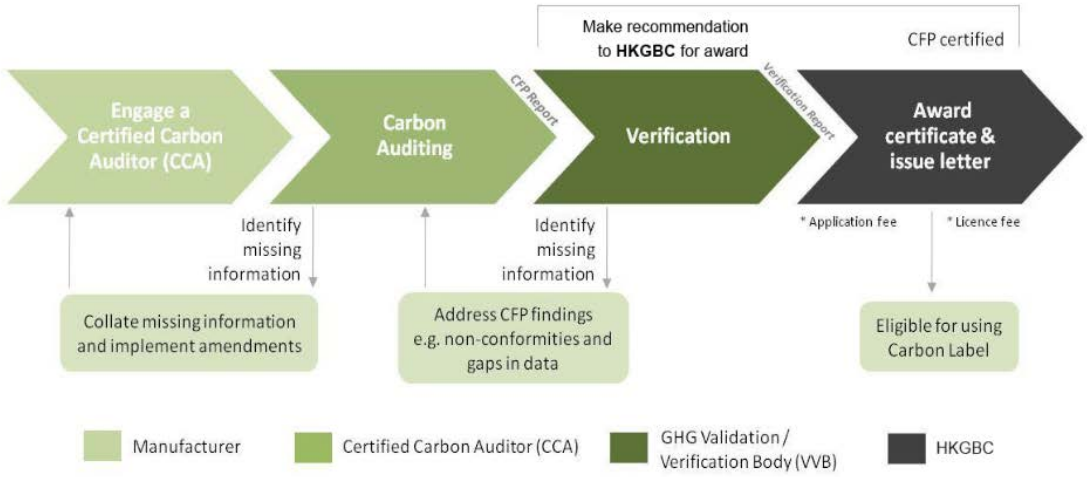

Figure 1. Certification Process

Carbon Auditing

To launch an application[1], the Applicant shall first engage a certified carbon auditor (CCA), either internally or externally, to carry out the carbon auditing and reporting duties. Based on the requirements stated in this Guide and the CFP quantification tool provided, a CFP study report should also be compiled by the appointed CCA detailing the carbon footprint of the studied product throughout the designated life cycle stages. As stated in ISO/TS 14067 (2013), the CFP study according to this Guide shall 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.

Verification

The CFP study report and relevant documentation should then be validated and verified by a GHG Validation / Verification Body (VVB) accredited by Hong Kong Accreditation Service (HKAS) or equivalent accreditation programmes[2], in accordance with ISO 14064-1:2006 "Greenhouse gases -- Part 1: Specification with Guidance at the Organisation Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals"[3] or ISO/TS 14067 (2013)[3]. The Applicant shall provide relevant supporting information as requested by the VVB, and this includes but not limited to the completed CFP assessment, the evidence of raw materials and fuel used, electricity bills, and type of machines used. Verification reports issued by non-accredited VVBs with at least 2-year

[1] An individual application shall be made for a specific product category that fulfils equivalent functions (ISO 14025:2006). Please refer to Table 1.

[2] Accreditation programmes refer to those accredited by the International Accreditation Forum (IAF) i.e. the European co-operation for Accreditation (EA), the InterAmerican Accreditation Cooperation (IAAC), and the Pacific Accreditation Cooperation (PAC) through the Multilateral Recognition Arrangement (MLA).

[3] The operational boundary shall be extended to raw material acquisition and off-site transportation for assessing the carbon footprint at the product level.

experience in CFP auditing are acceptable.

Certification

Once the CFP study report and relevant documentation are verified, Applicants shall submit a completed application form and corresponding application fee to HKGBC. HKGBC would review the submitted CFP study report and relevant documentation and grade the carbon performance of the product(s) (Grades of carbon rating as shown below). Based on the review, HKGBC shall issue the CIC Green Product Certification with a corresponding carbon rating with a validity period of three years. Upon complying with the *Guideline for the Use of the CIC Green Product Certificate and Logos* (the "User Guide"), with the payment of a licence fee, the CIC Green Product Certification with product details may appear for consumer information by print, online or other accessible media. Subsequent to certification, HKGBC may conduct periodic surveillance assessments of the certified product. Licence renewal shall be applied at least two months prior to the licence expiry date. Further information and assistance can be obtained during application. Visit the Web site http://cicgpc.hkgbc.org.hk for more information.

Five Grades of the CIC Green Product Certification

Platinum

Gold

Silver

Bronze

Green

Provisional Certification

Upon the request of Applicants, a provisional Certificate of CIC Green Product Certification (the "Provisional Certificate") might be issued by HKGBC before an official Certificate of CIC Green Product Certification is awarded in emergency circumstances. To apply for a Provisional Certificate, Applicants should provide to HKGBC i) a completed application form and corresponding application fee, ii) a letter that states the emergency circumstances, and iii) a Letter of Recommendation issued from VVB to HKGBC. Once the completed documents reach HKGBC, HKGBC would issue a Provisional Certificate of the product(s) under assessment with a validity period of 4 months within 5 working days.

2. DEFINITIONS & ACRONYMS

2.1 Terms Relating to CFP Quantification and Labelling

Biomass: material of biological origin excluding material embedded in geological formations and material transformed to fossilised material, and excluding peat. Biomass includes organic material (both living and dead), e.g. trees, crops, grasses, tree litter, algae, animals, and waste of biological origin, e.g. manure.

Carbon Dioxide Equivalent (CO_2e): unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide. Mass of a GHG is converted into CO_2e using global warming potentials provided in Annex A.

Carbon Footprint of Product (CFP): sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change.
[SOURCE: ISO 14067:2013, 3.1]

Certified Carbon Auditor (CCA): an individual who is qualified to conduct carbon auditing for a particular product category under this Certification.

CFP Study: study that quantifies the CFP.

Global warming potential (GWP): characterisation factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time as listed in Annex A.

Greenhouse Gas (GHG): gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds.
[note: the list of GHG with their recognised GWP is provided in Annex A of ISO 14067:2013 according to IPCC Fourth Assessment Report]

ICE: Inventory of Carbon and Energy

IPCC: Intergovernmental Panel on Climate Change.

ISO: International Organisation for Standard.

Manufacturer: for the purpose of this Guide these terms comprise both manufacturers of a product as well as material suppliers. These may not necessary be the companies that apply for the CIC Green Product Certification, since certification can also be awarded to retailers of a product. However, data from original manufacturer of the product are required.

Product Category: group of products that can fulfil equivalent functions.

Product Category Rules (PCR): set of rules, requirements and guidelines for development Type III environmental declarations for one or more product categories.

Product System: collection of unit processes with elementary flows and product flows, performing one or more defined functions and which models the life cycle of a product.

System Boundary: set of criteria specifying which unit processes are part of a product system.

Type III Environmental Declaration: environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.
[SOURCE: ISO 14025:2006, 3.2]

V/VB: GHG validation / verification body that provides GHG assertions' validation and verification services.

2.2 Terms Relating to Life Cycle Assessment

Life Cycle: consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life Cycle Assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.
[SOURCE: ISO 14044:2006, 3.2]

Life Cycle Impact Assessment (LCIA): phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.
[SOURCE: ISO 14044:2006, 3.4]

Life Cycle Inventory Analysis (LCI): phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Primary Data: quantified value of a unit process or an activity obtained from a direct measurement or a calculation based on direct measurements at its original source.
[note: primary data need not necessarily originate from the product system under study because primary data may relate to a different but comparable product system to that being studied; primary data may include GHG emission factors and/or GHG activity data.]

Site-specific Data: data obtained from a direct measurement or a calculation based on direct measurement at its original source within the product system.

Secondary Data: data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source such as databases and published literature validated by competent authorities.

Sensitivity Analysis: systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a CFP study.
[SOURCE: ISO 14044:2006, 3.31]

Sensitivity Check: activity of verifying that the information obtained from a sensitivity analysis is relevant for reaching the conclusions and giving recommendations.

2.3 Terms Relating to Ready-mixed Concrete Production

Aggregates: aggregates are hard and granular materials that are often used to provide bulk and strength in concrete. According to the particle size, aggregates passing through a 4.75 mm sieve and predominantly retained on a 75 um sieve are called fine aggregates. The aggregates ranging between 4.75 mm and 75 mm sieve are coarse aggregates which primarily consist of gravel and crushed stone.
[SOURCE: ACI, 2007]

Cement: a hydraulic binder, i.e. a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and which after hardening, retains its strength and stability even under water.
[SOURCE: BS EN 197-1:2011]

Chemical Admixtures: this class of admixtures includes those soluble chemicals that are often added to a concrete mixture for improving the concrete performance and modifying a concrete product to desired properties
[SOURCE: Li, 2011]

Supplementary Cementitious Material (SCM): SCMs refer to the mineral substances that are added to concrete during mixing process. The primary source of SCMs is industrial by-products such as fly ash from power generation plants and ground granulated blast-furnace slag from the iron and steel industry. Substitution of SCMs can reduce the cement content, improve the strength of concrete products and reduce the permeability of a structure.
[SOURCE: Kosmatka et al., 2003]

Fly Ash (FA): FA is the by-product of a coal-based power generating plant. According to the composition, FA can be divided into two categories namely, low calcium FA which uses anthracite coal as the fuel for power generation and high calcium FA which obtained by burning the lignite coal.
[SOURCE: Li, 2011]

Ground Granulated Blast-furnace Slag (GGBS): GGBS is a by-product of iron and steel making. During the production of iron and steel, fuel, ore and limestone are supplied to a blast furnace, i.e. a basic oxygen furnace or an electrical arc furnace. Chemical reactions take place throughout the blast furnace as the materials move downward and the output is molten pig iron, together with the GGBS.
[SOURCE: Li, 2011]

Silica Fume (SF): SF is a by-product of induction arc furnace in the silicon metal and ferrosilicon alloy industries. SF is one of the most commonly used SCM materials in concrete production. The strength gain mechanisms for SF are particle packing and pozzolanic reaction.
[SOURCE: Li, 2011]

Substitution Rate (SR): The percentage of supplementary cementitious materials used to replace the content of cement.

WBCSD: World Business Council for Sustainable Development.

WRI: World Resources Institute.

3. CFP-PCR FOR READY-MIXED CONCRETE

This section sets the PCR of ready-mixed concrete for CFP quantification and reporting under the CIC Green Product Certification following the four phases of life cycle assessment (LCA), i.e. goal and scope, LCI, LCIA, and life cycle interpretation. Applicants should refer to the principles and methodology detailed in ISO/TS 14067 (2013).

3.1 Goal and Scope

Goal of CFP Study

The goal of carrying out a CFP study is to calculate the potential contribution of a specific ready-mixed concrete product to climate change expressed as CO_2e by quantifying all significant GHG emissions and removals over the ready-mixed concrete product's life cycle.

The CFP study reports submitted by Applicants will then be evaluated by HKGBC for product certification purpose. This is facilitated by identical CFP quantification and communication requirements under the same product category as stipulated in Annex D of ISO/TS 14067.

The CIC Green Product Certification aims to facilitate clients, designers, contractors and end users to select low carbon construction products in a simple and unequivocal manner. Consequently, the demand for and supply of low carbon construction products can be stimulated, thereby promoting continuous environmental improvement.

Scope of CFP Study

The functional unit of the ready-mixed concrete products is 1 m^3. The CFP study shall focus on a single impact category i.e. climate change.

System Boundary

The assessment of carbon footprint of ready-mixed concrete under this Certification shall be based on a "cradle-to-site" approach, covering all GHG emissions and removals arising from raw material acquisition and production as shown in Table 2. The emissions from the process of recycling materials, if any, are estimated in the upstream process rather than in the disposal stage.

Table 2. System Boundary for Quantifying Carbon Footprint of Ready-mixed Concrete

System Boundaries	Processes
I. Upstream Processes	▪ Extraction and production of raw materials 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, energy wares and recycled materials to the plant
II. Core Processes	▪ Handling and storage of raw materials: ▪ Front-end loader ▪ Pneumatic transfer ▪ Belt conveyer ▪ Storage bins ▪ Elevated storage silos ▪ Mixing and blending of raw materials: ▪ Weigh hopper loading ▪ Mixing and blending
III. Downstream Process	▪ Transportation from manufacturing to the border of HK (transportation of ready-mixed concrete is conducted domestically, and therefore is excluded in the CFP assessment)

Source: EPD (2012)

3.2 Life Cycle Inventory Analysis

LCI is the phase of LCA involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. This Section states the key principles of CFP quantification, process map of ready-mixed concrete production, the associated sources of GHG emissions, and data requirements for LCI analysis under the CIC Green Product Certification.

Key Principles
The quantification and reporting of a CFP in accordance with this Guide is based on the principles of the LCA methodology provided in ISO 14040 and ISO 14044:

i) Relevance
Select data and methods appropriate to the assessment of the GHG emissions and removals arising from the product system being studied.

ii) Completeness
Include all GHG emissions and removals that provide a significant contribution to the CFP of the product system being studied.

iii) Consistency
Apply assumptions, methods and data in the same way throughout the CFP study to arrive at conclusions in accordance with the goal and scope definition.

iv) Accuracy
Ensure that CFP quantification and communication are accurate, verifiable, relevant and not misleading and that bias and uncertainties are reduced as far as is practical.

v) Transparency
Address and document all relevant issues in an open, comprehensive and understandable presentation of information. Disclose any relevant assumptions and make appropriate references to the methodologies and data sources used. Clearly explain any estimates and avoid bias so that the CFP study report faithfully represents what it purports to represent.

Process Map

The key unit processes of ready-mixed concrete manufacturing within the stipulated system boundary are presented in Figure 2 for CFP quantification. Ready-mixed concrete is composed essentially of Portland cement, sand, coarse aggregates (e.g. gravel, crushed stone) and water. Supplementary cementitious materials (SCM), such as fly ash (FA), silica fume (SF) and ground granulated blast-furnace slag (GGBS), are added to improve the performance of a concrete product. The raw materials are often manufactured outside of a concrete batching plant and then transported to the plant by truck, barge or train. At most of the plants, cement is transferred pneumatically to storage silos by air blower, while the aggregates are transferred to storage bins by belt conveyer, front-end loader or bucket elevator. From the material storages, cement, aggregates and water are fed by gravity to a weigh hopper, where the raw materials are properly mixed and blended. Through the cement hydration process, the blended mixture starts to create a hard and porous substance namely, ready-mixed concrete. The ready-mixed concrete is loaded to a mixer truck and then delivered to site.

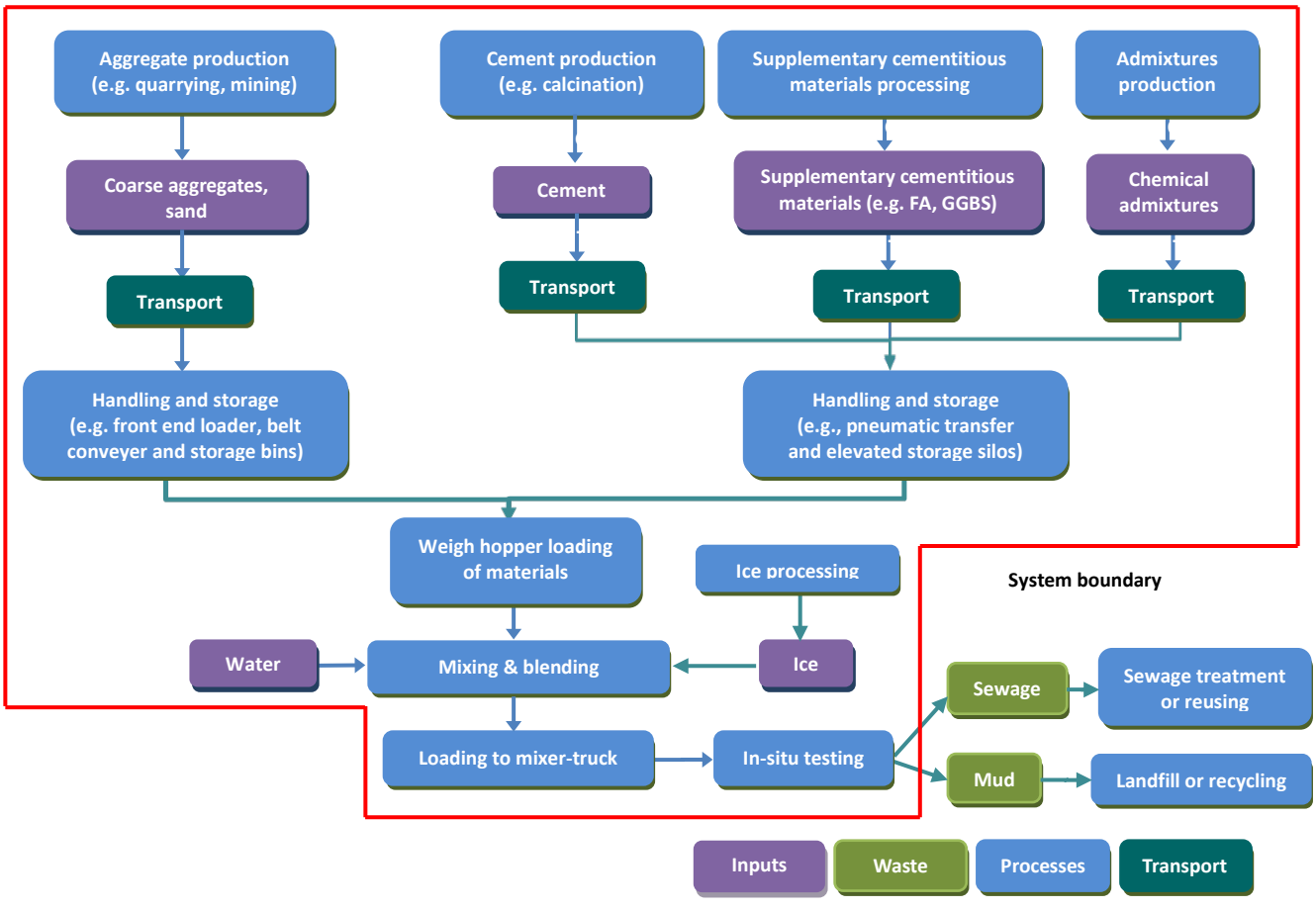

Figure 2. Process Map of Ready-mixed Concrete Manufacturing[4]

[4] The figure shows a typical concrete production process. There are some other technologies, for example the blending equipment on construction site into which the raw materials are quantified manually and fed in with a small amount.

Sources of GHG Emissions

The qualitative and quantitative data for inclusion in the life cycle inventory shall be collected for all unit processes that are included in the predefined system boundary and process map. The assessment and reporting of GHG emissions and removals of ready-mixed concrete are divided into direct emissions and indirect emissions.

Direct vs. Indirect Emissions

The direct emissions stem from sources that are owned or controlled by the material supplier. The indirect emissions originate from sources that are controlled by third parties, but they are nonetheless related to the activities of the material supplier.

WBCSD (2013)

The GHG assessment framework is developed based on the ISO Technical Specification 14067:2013 "Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication". Applicants are required to quantify and report the carbon footprint of a specific ready-mixed concrete product using the CFP quantification tool (in Excel format) provided by our designated operator, the HKGBC.

Direct Emissions

The sources of direct GHG emissions include combustion of fuels.

i) Combustion of Fuels

GHG emitted from combustion of fuels is reported separately, by the following application types, to provide flexibility in the aggregation of emissions:

- Raw material preparation (e.g., bought raw materials, handling and storage)
- On-site transportation
- Equipment
- Room heating / cooling
- On-site power generation

Carbon in fuels is assumed to be fully oxidized. The resulting overestimation of emissions will usually be small and can be neglected in the CFP assessment. The fuels used in concrete production are categorized into conventional, alternative and biomass fuels for carbon footprint quantification and reporting. If the electrical power is generated by third parties where the activities are not owned or controlled by the material manufacturers and suppliers, it should be referred to the "external electricity production" under indirect emissions.

Conventional Fuels

Conventional fuels are fossil fuels including, e.g. coal, petroleum coke, fuel oil and natural gas. The preferred approach is to calculate CO_2e from conventional fuels (the same applies to alternative fuels), based on fuel consumption, lower heating values, and matching CO_2e emission factors. Fuel consumption and lower heating values of fuels should be regularly measured at the plant level. It is important to note that the applied heating value always has to match the status of the fuel, especially with respect to the correct moisture content during its weighing (raw coal or dried coal).

Default emission factors per GJ lower heating value are extracted from IPCC (2006) and listed in the CFP quantification tool. Manufacturers are encouraged to use the plant or country specific emission factors if reliable data is available. The emission factor of fuels shall be based on the total carbon content. Direct calculation of emissions based on fuel consumption (in tonnes) and fuel carbon content (in percent) is acceptable on condition that the material variations in the composition of fuel, and especially its water content, are adequately accounted for.

Alternative Fuels

A variety of alternative fuels are increasingly used which are typically derived from wastes and therefore, without this application, the waste would have to be disposed of in some other forms, usually by landfilling or incineration. Alternative fuels include fossil fuel based fractions, such as waste oil and plastics, and biomass fractions, such as waste wood and sewage sludge. They serve as a substitute for conventional fossil fuels, and IPCC 2006 guidelines for national GHG inventories require the following:

- The amount of GHG taken up in biomass and the equivalent amount of GHG emissions from the biomass at the point of complete oxidation result in zero net GHG emissions when biomass carbon is not converted into methane, non-methane volatile organic compounds or other precursor gases.

- GHG emissions from fossil fuel-derived wastes (also called alternative fossil fuels), in contrast, is not *a priori* climate neutral. Direct GHG emissions from the combustion of fossil alternative fuels shall, therefore, be calculated and included in the total of direct emissions.

- GHG emissions from mixed fuels with biomass and fossil fraction (e.g. pre-treated industrial and/or domestic wastes), a split between the fossil and non-fossil fraction of the fuel should be established and the emission factors applied to the appropriate fractions.

- CO_2e emission factors shall be specified at the plant level where practical. In the absence of any plant or company specific data, manufacturers shall use the default emission factors provided in the CFP quantification tool in accordance with the IPCC.

Emissions from Refrigerants

Some concrete batching plants use refrigerants to produce ice for providing extra water content and controlling temperature of concrete. However, applicants are not required to quantify their CO_2 emissions related to the use of refrigerants, because consumption of ice and the induced emissions are insignificant. However, applicants should be prepared to demonstrate that their ice processing has no significant impact on their overall CO_2 emissions (less than 1% of the plant's overall CO_2 emissions).

Indirect Emissions

Key indirect GHG emissions arising from the production of ready-mixed concrete products include: (i) external production of electricity consumed by concrete manufacturers; (ii) production of bought raw materials and energy wares; and (iii) off-site transportation.

i) External Electricity Production

When a supplier of grid electricity can deliver a specific electricity product with specific life cycle data and guarantee that the electricity sale and the associated GHG emissions are not double counted, life cycle data for that electricity product shall be used. When the supplier of electricity does not provide specific GHG data for the specific electricity product, the GHG emissions associated with the national grid where the life cycle stage occurs shall be used. Where a country does not have a national grid but has several unconnected grids or several countries share a common grid, GHG emissions associated with the relevant grid from which the electricity is obtained shall be used. If specific life cycle data on a process within the electricity supply system are difficult to access, data from recognised databases may be used.

The GHG emissions shall include: the emissions arising from the generation of electricity, e.g. combustion of fuels, and generation of electricity lost in transmission and distribution in the grid; upstream GHG emissions (e.g. the mining and transport of fuel to the electricity generator or the growing and processing of biomass for use as a fuel); downstream GHG emissions (e.g. the treatment of waste arising from the operation of nuclear electricity generators or treatment of ashes from coal fired electricity plants); as well as GHG emissions related to construction, maintenance and decommission of the electricity supply system.

ii) Production of Bought Raw Materials and Energy Wares

GHG emissions and removals associated with the use of raw materials such as cement, fine aggregates, coarse aggregates, etc. in the production of the concrete product shall be calculated by multiplying the consumption of those raw materials by the embodied carbon emission factors adopted from the Inventory of Carbon and Energy (ICE) provided in the CFP quantification tool. Primary emission factors should be used if data are available. Please refer to "Data Requirement" for details about the selection of data sources.

GHG emissions from the mining and production of energy ware such as coal, natural gas, oil, petcoke, etc. used in the concrete manufacturing process should also be accounted for under the indirect emissions. Applicants should apply the emission factor provided by region specific databases or well recognised sources (e.g. Ecoinvent, China Energy Statistical Yearbook, Japan CFP database, etc.).

iii) Off-site Transportation

Applicants are required to specify the mode of transportation (e.g. road, rail, water or aircraft), type of activity data, vehicle type, distance travelled, fuel used, etc. to measure the GHG emissions generated from the off-site transportation associated with the studied concrete product from "cradle to site" (see Figure 3). When transportation is outside Hong Kong or the fuel consumption of non-road transport is not known. The fuel / distance-based approach is applicable to the case. The

transport emissions associated with the concrete product can be measured by adopting the WRI's protocol, namely "Mobile Combustion GHG Emission Calculation Tool[5]" (version 2.5, 2013) or equivalent tool if deemed appropriate. The fuel-based approach only applies to the case when the transportation happens within Hong Kong and the fuel consumption data are known. The fuel-based emission factors can be obtained from the EPD / EMSD guideline, namely "Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong[6]" (2010 Edition). Fuel consumption data can also be estimated based on the energy consumption indicators as provided by EMSD Energy Consumption Indicator[7].

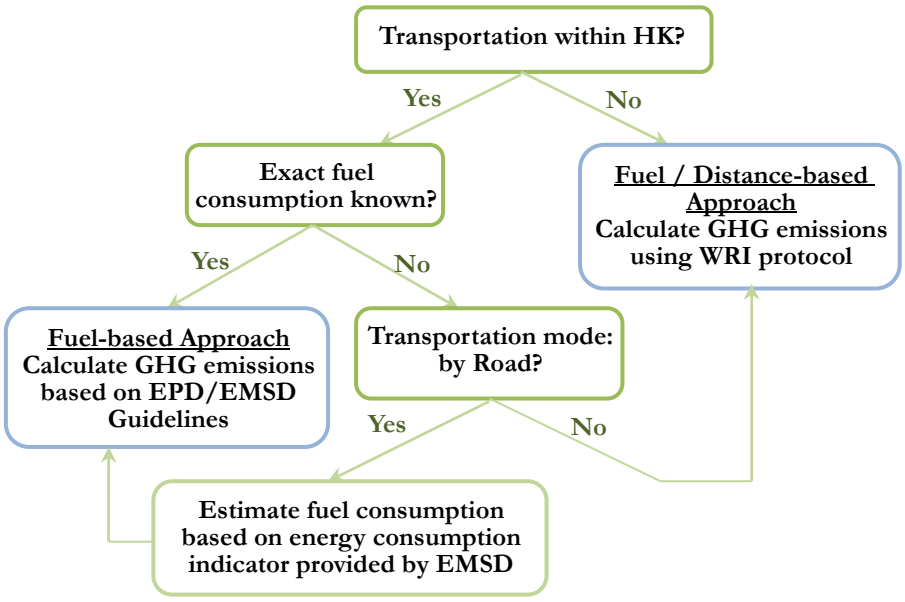

Figure 3. Method Selection for Transportation Emissions Calculation

Note: If the transportation occurs within Hong Kong, the emissions arising product transportation can be ignored based on the "cradle-to-site" system boundary as stipulated in Section 3.1.

[5] The tool is accessible at http://www.ghgprotocol.org/files/ghgp/Transport_Tool_v2%205-1_0.xlsm.
[6] The guideline is accessible at http://www.epd.gov.hk/epd/english/climate_change/files/Guidelines_English_2010.pdf
[7] The indicators are accessible at: http://ecib.emsd.gov.hk/en/indicator_trp.htm

Table 3 summarises the parameters involved, and the data sources for the calculation of carbon footprint of ready-mixed concrete products.

Table 3. Parameters and Data Sources for Calculating the Carbon Footprint of Ready-mixed Concrete Products

Emission components		Parameters	Units	Sources of parameters
Direct Emissions	*Fuels Combustion*			
	Conventional fuels	Fuel consumption Lower heating value Emission factor	t GJ/t fuel tCO_2e/GJ fuel	Measured at plant level Measured at plant level IPCC defaults, or measured
	Alternative fossil fuels	Fuel consumption Lower heating value Emission factor	t GJ/t fuel tCO_2e/GJ fuel	Measured at plant level Measured at plant level IPCC defaults, or measured
	Biomass fossil fuels	Fuel consumption Lower heating value Emission factor	t GJ/t fuel tCO_2e/GJ fuel	Measured at plant level Measured at plant level Default = 0 kg CO_2e
Indirect Emissions	**External electricity production**	Power bought from external grid Emission factor	GWh tCO_2e/GWh	Measured at plant level Applicant-specific value or country grid factor
	Production of bought raw materials and energy wares	Net raw materials and energy wares purchased Emission factor	t tCO_2e/t	Measured at plant level Default factor / Input
	Off-site transportation	Mode of transportation Type of activity data Vehicle type Distance travelled Fuel consumed Emission factor	Measured using WRI protocol / EPD / EMSD Guidelines	

Data Requirements

CFP quantification carried out in accordance with this Guide shall include all GHG emissions and removals of those unit processes within the predefined system boundary that have the potential to make a significant contribution to the CFP. The calculation shall relate system input and output data to the functional unit, i.e. tCO_2e/m^3 of ready-mixed concrete produced. The assessment shall include:

i) contribution from any one source of GHG emissions of more than 1% of the anticipated total GHG emissions associated with the product being assessed; and
ii) at least 95% of the anticipated life cycle GHG emissions and removals associated with the functional unit.

Site-specific data shall be collected for individual processes under the financial or operational control of the organisation undertaking the CFP study, and shall be representative of the processes for which they are collected. Site-specific data should also be used where practicable for those unit processes that contribute significantly to the CFP, but are not under the financial or operational control of the organisation undertaking the CFP study.

Site Specific Data

Site-specific data can be collected from a specific site, or can be averaged across all sites that contain the process within the product system under study. They can be measured or modelled, as long as the result is specific to the process in the product's life cycle.

ISO/TS 14067 (2013)

Secondary data and primary data that are not site-specific data shall only be used for inputs where the collection of site-specific data is not practicable such as GHG emissions in the upstream processes, or for processes of minor importance and may include literature data, such as default emission factors, calculated data, estimates or other representative data. A CFP study should use data that reduce bias and uncertainty as far as practical by using the best quality data available. Primary data such as the embodied carbon emission factors of raw materials and energy wares, based on a plant's operating conditions, estimated by upstream material suppliers and which have undergone third-party verification should have the priority of use in the CFP study. Secondary data based on regional averages and collected from regionally-specific life cycle inventory database should be used when the collection of primary data is not practicable. The use of secondary data shall be justified and documented with references in the CFP study report. When the collections of primary and secondary data are not practicable, the default data from Inventory of Carbon and Energy (ICE) should be used, provided that the manufacturing process and system boundary in the CFP study are identical to the ICE database. Primary, secondary, and ICE data shall be selected to enable the goal and scope of the CFP study to be met.

If allocation of GHG emissions and removals is needed, the inputs and outputs of the product system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them. For instance, should more than one product be transported by a transport system (e.g. truck, ship, aircraft, train), the emissions arising from the transport system shall be divided amongst the products on the basis of: (i) the relative mass of different products being transported; or (ii) the relative volume of different products being transported. Where physical relationship alone cannot be used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships

between them (e.g. economic value). The selected allocation methods shall be documented in the CFP study report in detail and the GHGs taken into account shall be clearly stated.

Applicants undertaking a CFP study should have a data management system and should seek to continuously improve the consistency and quality of their data and retention of relevant documents and other records. Since data collection may span several reporting locations and published references, measures should be taken to reach uniform and consistent understanding of the product systems to be assessed. A check on data validity shall be conducted during the process of data collection to ensure compliance with the requirements of this Guide.

The quantified figures for supporting the assessment of GHG emissions and removals of the product shall be collected and submitted for analysis and verification over a minimum of six months and a maximum of the most recent two years. The CFP results obtained from accredited VVB shall be valid for a maximum period of two years. If a significant change associated with the life cycle GHG emissions and removals of the product is observed, the validity ceases in such situation.

3.3 Life Cycle Impact Assessment

In the LCIA phase of a CFP study, the potential climate change impact of each GHG emitted and removed by the product system shall be calculated by multiplying the mass of GHG released or removed by the 100-year GWP given by the IPCC in units of "kg CO_2e per kg emission" (see Annex A). The CFP is the sum of these calculated impacts which shall be automatically generated in the "performance indicators" using the CFP quantification tool in terms of tCO_2e/m^3 of ready-mixed concrete produced. Where GWP values are amended by the IPCC, the latest values shall be used in the CFP calculations. If the latest IPCC GWP data are not used, this shall be stated and justified in the CFP study report.

3.4 Life Cycle Interpretation

In the life cycle interpretation phase of a CFP study, a CFP study report, for the assessed ready-mixed concrete product, shall be compiled to document the results of the quantification of the CFP study, and to demonstrate that the provisions of this Guide and relevant standards have been met. The results and conclusions of the CFP study shall be documented in the CFP study report without bias. The results, data, methods, assumptions and the life cycle interpretation shall be transparent and presented in sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent in the CFP study.

The CFP study report shall comprise the followings:

- Goal and scope in accordance with this Guide (or modified scope if applicable along with justifications and exclusions, of the CFP study), including but not limited to:
  - Functional unit;
  - System boundary; and
  - Production process map.
- LCI and LCIA:

- General plant information;
- Reporting period;
- Cut-off criteria and cut-offs;
- Choices and assumptions;
- Selected allocation approach;
- Description of data, including decisions concerning data, sources of data, details of individual data, and assessment of data quality, e.g. results of sensitivity analysis and uncertainty assessments;
- Sensitivity check regarding the significant inputs
- Treatment of electricity; and
- Disclosure and justification of value choices that have been made in the context of decisions within the CFP study.

- CFP quantification results:
  - GHG emissions and removals linked to the main life cycle stages, i.e. raw material acquisition; production; and distribution to HK, including the absolute and the relative contribution of each life cycle stage;
  - GHG emissions and removals arising from conventional fossil fuels, alternative fuels and biogenic carbon sources and sinks;
  - GHG emissions and removals arising from direct and indirect emissions according to Section 3.2; and
  - GHG emissions of the product assessed in terms of tCO_2e/m^3 of ready-mixed concrete produced.
- Significant issues based on the results of the quantification of the CFP according to LCI and LCIA phases.
- Evaluation that considers completeness, sensitivity and consistency checks.
- Conclusions, limitations, and recommendations.
- Declaration of the information provided is true and correct.

4. REFERENCES

ACI (2007) *ACI education bulletin E1-07: aggregates for concrete*. Committee E-701 (Materials for Concrete Construction), American Concrete Institute, U.S.A.

BS EN 197-1 (2000) Composition, Specification and Conformity Criteria for Common Cements.

Buildings Department (2013) *Code of Practice for Structural Use of Concrete*. Buildings Department, Hong Kong.

EPD (2013) *Product Category Rules for Unreinforced Concrete,* Version 1.0, The International EPD® System.

Flower, D.J.M. and Sanjayan, J.G. (2007) Green House Gas Emissions due to Concrete Manufacture, *International Journal of Life Cycle Assessment,* 12(5), 282-288.

ISO 14025 (2006) *Environmental Labels and Declarations – Type III Environmental Declarations – Principles and Procedures*.

ISO 14040 (2006) *Environmental Management – Life Cycle Assessment – Principles and Framework*.

ISO 14044 (2006) *Environmental Management – Life Cycle Assessment – Requirements and Guidelines*.

ISO 14064-1 (2006) *Greenhouse Gases – Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals*.

ISO/TS 14067 (2013) *Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication*.

IPCC (2001) *Climate Change 2001: The Scientific Basis*. Intergovernmental Panel on Climate Change, Cambridge University Press. Cambridge, U.K.

IPCC (2006) *Guidelines for National Greenhouse Gas Inventories*. National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change.

Kosmatka, S.H., Kerkhoff, B., Panarese, W.C. (2003) *Design and Control of Concrete Mixtures, fourteenth ed.* Portland Cement Association. Illinois, U.S.A.

Li, Z.J. (2011) *Advanced Concrete Technology, first ed.* John Wiley & Sons. New Jersey, U.S.A.

WBCSD (2013) Greenhouse Gas Protocol, World Business Council for Sustainable Development. Accessed on 3 Oct. 2013 from http://www.ghgprotocol.org

Worrell, E., Price, L. Martin, N., Hendriks, C. Media, L. O. Carbon Dioxide Emissions from the Global Cement Industry. *Annu. Rev, Energy Environ.* 2001, 26, 303-329.

United Nations (1997) *The Kyoto Protocol*. New York: United Nations.

ANNEX A – THE 100 YEAR GWP

The global warming potential (GWP) is an index, based upon radiative properties of well mixed GHGs, measuring the radiative forcing of a unit mass of a given well-mixed GHG in the present day atmosphere over a chosen time horizon, relative to that of carbon dioxide. Table A1 shows the 100-year GWP of GHGs according to IPCC Fourth assessment report. When new data are published by the IPCC, the new data supersede those in Table A1.

Table A1 GWP Relative to CO_2 for the 100-year Time Horizon

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Substances controlled by the Montreal Protocol		
CFC-11	CCl_3F	4,750
CFC-12	CCl_2F2	10,900
CFC-13	$CClF_3$	14,400
CFC-113	CCl_2FCClF_2	6,130
CFC-114	$CClF_2CClF_2$	10,000
CFC-115	$CClF_2CF_3$	7,370
Halon-1301	$CBrF_3$	7,140
Halon-1211	$CBrClF_2$	1,890
Halon-2402	$CBrF_2CBrF_2$	1,640
Carbon tetrachloride	CCl_4	1,400
Methyl bromide	CH_3Br	5
Methyl chloroform	CH_3CCl_3	146
HCFC-21	$CHClF$	151
HCFC-22	$CHClF_2$	1,810
HCFC-123	$CHCl_2CF_3$	77
HCFC-124	$CHClFCF_3$	609
HCFC-141b	CH_3CCl_2F	725
HCFC-142b	CH_3CClF_2	2,310
HCFC-225ca	$CHCl_2CF_2CF_3$	122
HCFC-225cb	$CHClFCF_2CClF_2$	595
Hydrofluorocarbons		
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC41	CH_3F	92
HFC-125	CHF_2CF_3	3,500

HFC-134	CHF_2CHF_2	1,100
HFC-134a	CH_2FCF_3	1,430
HFC-143	CH_2FCHF_2	353
HFC-143a	CH_3CF_3	4,470
HFC-152	CH_2FCH_2F	53
HFC-152a	CH_3CHF_2	124
HFC-161	CH_3CH_2F	12
HFC-227ea	CF_3CHFCF_3	3,220
HFC-236cb	$CH_2FCF_2CF_3$	1,340
HFC-236ea	CHF_2CHFCF_3	1,370
HFC-236fa	$CF_3CH_2CF_3$	9,810
HFC-245ca	$CH_2FCF_2CHF_2$	693
HFC-245fa	$CHF_2CH_2CF_3$	1,030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,640
Perfluorinated compounds		
Sulfur hexafluoride	SF_6	22,800
Nitrogen trifluoride	NF_3	17,200
PFC-14	CF_4	7,390
PFC-116	C_2F_6	12,200
PFC-218	C_3F_8	8,830
PFC-318	c-C_4F_8	10,300
PFC-3-1-10	C_4F_{10}	8,860
PFC-4-1-12	C_5F_{12}	9,160
PFC-5-1-14	C_6F_{14}	9,300
PFC-9-1-18	$C_{10}F_{18}$	>7,500
Trifluoromethyl sulfur pentafluoride	SF_5CF_3	17,700
Perfluorocyclopropane	c-C_3F_6	> 17,340
Fluorinated ethers		
HFE-125	CHF_2OCF_3	14,900
HFE-134	CHF_2OCHF_2	6,320
HFE-143a	CH_3OCF_3	756
HCFE-235da2	$CHF_2OCHClCF_3$	350
HFE-245cb2	$CH_3OCF_2CHF_2$	708
HFE-245fa2	$CHF_2OCH_2CF_3$	659
HFE-254cb2	$CH_3OCF_2CHF_2$	359
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	575
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	580

HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	110
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	297
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	59
HFE-43-10-pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	1,870
HFE-236ca12 (HG-10)	$CH_2OCF_2OCHF_2$	2,800
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	1,500
	$(CF_3)_2CFOCH_3$	343
	$CF_3CF_2CH_2OH$	42
HFE-338pcc13 (HG-01)	$(CF_3)_2CHOH$	195
HFE-227ea	$CF_3CHFOCF_3$	1,540
HFE-236ea2	$CHF_2OCHFCF_3$	989
HFE-236fa	$CF_3CH_2OCF_3$	487
HFE-245fa1	$CHF_2CH_2OCF_3$	286
HFE-263fb2	$CF_3CH_2OCH_3$	11
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$	919
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$	552
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$	374
HFE-356mec3	$CH_3OCF_2CHFCF_3$	101
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$	265
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$	502
HFE-365mcf3	$CF_3CF_2CH_2OCH_3$	11
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	557
	- $(CF_2)_4CH(OH)$ -	73
	$(CF_3)_2CHOCHF_2$	380
	$(CF_3)_2CHOCH_3$	27
Perfluoropolyethers		
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	10,300
Hydrocarbons and other compounds – direct effects		
Dimethylether	CH_3OCH_3	1
Chloroform	$CHCl_3$	31
Methylene chloride	CH_2Cl_2	8.7
Methyl chloride	CH_3Cl	13
Methylene bromide	CH_2Br_2	1.54
Halon-1201	$CHBrF_2$	404
Trifluoroiodomethane	CF_3I	0.4

Source: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html#table-2-14, "Changes in Atmospheric Constituents and in Radiative Forcing", Table 2.14.