Carbon Audit Toolkit for Small and Medium Enterprises in Hong Kong

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The University of Hong Kong (HKU)
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Preface

The emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) have caused serious global warming and climate change problems to our environment. There is an urgent need to reduce the GHG emissions on a global scale. Many nations, including China, have already set emissions reduction targets. Various GHG control mechanisms have been established to facilitate worldwide emissions reduction, such as emission trading, carbon trading, carbon offset, clean development mechanism etc.

In Hong Kong, the HKSAR Government has been active in developing strategic plans and making progress towards a low-carbon economy. In 2008, the HKSAR Government issued the "*Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes)* in Hong Kong." The Guidelines covers the significant types of GHG emissions commonly found in commercial buildings, i.e. energy consumption, water consumption, paper consumption, waste disposal, and fugitive refrigerant. The Guidelines was revised in February 2010.


By Friends of the Earth(HK)

For a company, the commercial and industrial operations may also cause considerable GHG emissions. This book presents the guidelines specially designed for small and medium enterprises (SMEs) to assess their carbon footprints due to products manufactured and services provided. The information and recommendations provided can facilitate effective management of carbon footprints by enhancing energy efficiency, energy conservation, water conservation, paper recycling, GHG offset plantation, green manufacturing, green management and so on. As a result, SMEs can improve their environmental performance to meet the market demands for green products and services. SMEs can also reduce costs through efficient use of resources and energy. This book is suitable for a wide range of audience, including SME managers, environmental consultants, engineers, carbon auditors, and academics.

Chapter 1

Introduction

Electricity, motor transport, air-conditioning and countless manufactured products have given us much convenience and luxury. However, at the same time, our modern lifestyle is doing harm to the environment. Carbon dioxide (CO_2) emission is the prime reason. Most of what we consume and use in our daily life leads to direct or indirect emissions of CO_2 (see Fig. 1). Carbon dioxide is a greenhouse gas (GHG) that causes global warming and climate change problems (see Fig. 2). Besides CO_2, there are other GHG chemicals and sources, e.g. fugitive refrigerant and unburned fuel gas.

Fig. 1. GHG emissions

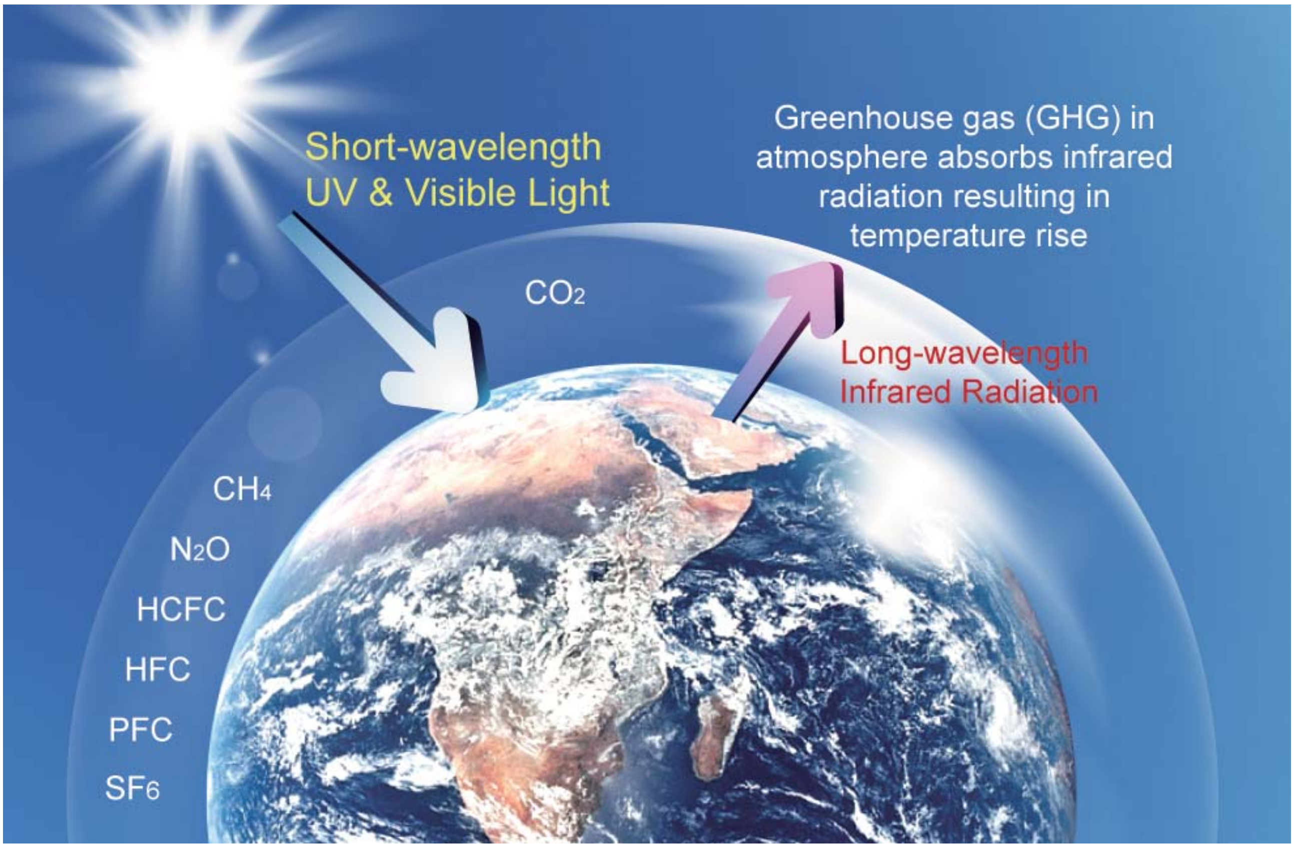

Fig. 2. Greenhouse effect

The CO_2 concentration in the atmosphere is increasing at an alarming rate. The GHG emissions have raised significant awareness worldwide. In order to mitigate the environmental problems, many nations are making continuous efforts in the international arena to establish policies and protocols to control GHGs (Table 1).

Table 1. Key milestones for GHG emissions reduction

Year	Milestone
1990	2nd World Climate Conference: Climate change was recognised as a common concern for mankind.
1992	United Nations Framework Convention on Climate Change (UNFCCC): Mechanisms were proposed for nations to reduce GHG emissions to reach set targets.
1994	Alliance of Small Island States (AOSIS): Proposal was submitted for Annex I parties to reduce 20% GHG emissions by 2005.
1995	1st Conference of the Parties (COP1): It was concluded that a protocol is needed to reduce GHG emissions.
1997	3rd Conference of the Parties (COP3): The Kyoto Protocol was adopted with reduction targets.
2001	6th Conference of the Parties (COP6): Political agreement was adopted for international cooperation for Kyoto Protocol.
2005	11th Conference of the Parties/1st Meeting of the Parties (COP11/MOP1): COP11/MOP1 agreed to extend Kyoto Protocol beyond its 2012 expiration date.
2009	15th Conference of the Parties/5th Meeting of the Parties (COP15/MOP5): An accord was reached but not legally binding. Participants agreed to keep the maximum temperature increase below 2°C.

Presently, more than 190 nations, including China, have ratified the Kyoto Protocol aiming to reduce GHG emissions on a global scale. Developed countries are obligated to offer financial supports to deal with drought, flooding and other climate change impacts in developing countries. There are also alternative schemes that help accomplish emissions reduction (Table 2). Many countries have committed to challenging emissions reduction targets (Table 3).

Table 2. GHG emissions reduction schemes

Scheme	Brief Description
Emission Trading	In a cap-and-trade system, companies can buy and sell allowable emission credits.
Carbon Trading	Carbon trading is emission trading measured in equivalent CO_2 emission.
Carbon Offset	GHG emissions can be offset by funding GHG emissions reduction projects.
Clean Development Mechanism	Under the Kyoto Protocol, the industrialised countries can meet their GHG emissions reduction commitment by investing in ventures that achieve efficient GHG emissions reduction in developing countries.

Table 3. Emissions reduction targets set in different nations and cities

Nation/City	Year	Target
Canada	2020	> 20% 2006 level
China	2020	> 40 - 45% 2005 level
France	2020	> 20 - 30% 1990 level
	2050	> 75% 1990 level
Germany	2020	> 40% 1990 level
	2050	> 80% 1990 level
Hong Kong	2030	> 25% 2005 level
Italy	2020	> 20% 1990 level
Japan	2020	> 8 - 25% 1990 level
Russia	2020	> 20-25% 1990 level
South Korea	2020	> 4% 2005 level
UK	2020	> 20% 1990 level
	2050	> 60% 1990 level
USA	2020	> 4% 1990 level

[Note: The target is based on either absolute emission or GDP intensity.]

More and more entrepreneurs start to realise the importance and benefits of emissions reduction. Carbon audit, therefore, receives much attention recently as it is essential in management of carbon footprints. Large corporations with a strong financial base can afford to set up their own technical teams or employ professionals for consultancy services to quantify and manage their carbon footprints. However, for small and medium enterprises (SMEs), it is not economically justified to specially allocate manpower and financial resources to assess and manage their carbon footprints.

The purpose of the present *Toolkit* is to help SMEs carry out carbon audit by themselves and find out the carbon footprints of their business operations. Based on the carbon audit, SMEs can identify management opportunities to reduce CO_2 emission. Practicing carbon audit and carbon footprint reduction can help SMEs meet consumer demands for environmental-friendly products. As a result, both productivity and competitiveness will increase along with a charming green image.

Carbon footprint is defined as the total amount of direct and indirect emissions of GHGs expressed in terms of equivalent amount of CO_2 emission.

Chapter 2

Greenhouse Gases (GHGs)

Carbon dioxide (CO_2) is a GHG, which allows the incoming short-wavelength solar radiation to pass through but blocks the long-wavelength infrared radiation reflected from the earth (see Fig. 2). The heat trapped in the atmosphere increases the temperature on earth. Besides CO_2, there are other GHGs among the emissions commonly found in the commercial and industrial sectors. The GHG emissions can be classified into three different scopes according to the *GHG Protocol* by World Business Council for Sustainable Development and World Resources Institute (WRI, 2005) as well as the *Guidelines* issued by the Electrical and Mechanical Services Department (EMSD) and Environmental Protection Department (EPD) of the HKSAR Government (EMSD & EPD, 2010). For each scope, the typical emission sources are listed below.

Scope 1 – Direct Emissions

Fuel combustion by stationary equipment (e.g. boiler, electricity generator, welding equipment, flame cutting machine); fuel combustion by private motor vehicles; GHG release (e.g. refrigerant leak, unburned fuel gas discharge); GHG removal (i.e. negative emission, e.g. planting new tree(s)).

Scope 2 – Energy Indirect Emissions

Electricity consumption; town gas consumption.

Scope 3 – Other Indirect Emissions

Use of raw materials; fresh water consumption; waste disposal; public transportation (e.g. subways, trains, buses, trams, taxis, ferries); air travel.

It is noted that the *Guidelines* issued by the EMSD & EPD (2010) targets for buildings in Hong Kong; and the relevant GHG emissions mainly belong to Scopes 1 and 2 for building operations. For the present *Toolkit* developed for SMEs, the Scope-3 GHG emissions become more significant in the overall carbon footprint embodied in products manufactured and services delivered by SMEs.

The global warming effect of a GHG is measured in Global Warming Potential (*GWP*). *GWP* is a relative measure of the global warming effect of a GHG compared with CO_2 of the same mass. Table 4 presents a list of commonly found GHGs and their *GWP* values. Although the *GWP* of CO_2 is lower than that of other GHGs, taking into account the amount of emission, CO_2 contributes about 50% to the total global warming effect. The overall environmental impact of emissions of multiple GHGs can be determined based on the sum expressed in terms of CO_2 equivalent,

$$E_{CO_2\text{-}eq} = \sum_i m_{GHG\text{-}i} \times GWP_i \qquad (1)$$

where $E_{GHG\text{-}i}$ and GWP_i represent the mass and *GWP* of each GHG emitted, respectively.

Table 4. Greenhouse gases and their global warming potential (100-year time horizon)

GHG	*GWP*
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Sulphur Hexafluoride (SF_6)	22,800
Hydrochlorofluorocarbons (HCFC)	77 - 2,310
Hydrofluorocarbons (HFC)	12 - 14,800
Perfluorocarbons (PFC)	7,390 - 12,200

[Ref.: EMSD & EPD, 2010; IPCC NGGIP, 2007; IPCC NGGIP, 2001]

Planting a new tree that will grow taller than 5m can remove CO_2 and the average reduction is 23 kg per year.

Chapter 3

Carbon Audit

In order to properly control and reduce GHG emissions for a company, one should clearly understand the source of each emission and the corresponding amount of CO_2-eq. Therefore, carbon audit is the first essential step. In a carbon audit, the carbon auditor should review all the company activities, raw materials used, waste generated, products, services, among others that may cause direct and indirect GHG emissions.

For a SME, a staff member in the management level who is familiar with the company operations should assist the carbon auditor to complete the audit. Alternatively, the SME colleague can use this *Toolkit* to carry out a do-it-yourself carbon audit. The carbon audit adopts a life-cycle approach to assess the carbon footprint embodied in the SME products and services. As shown in Fig. 3, the boundaries cover the supply chain, starting from raw materials to production, goods/passenger transportation, and finally ending up with waste disposal or recycle (British Standards Institution 2008).

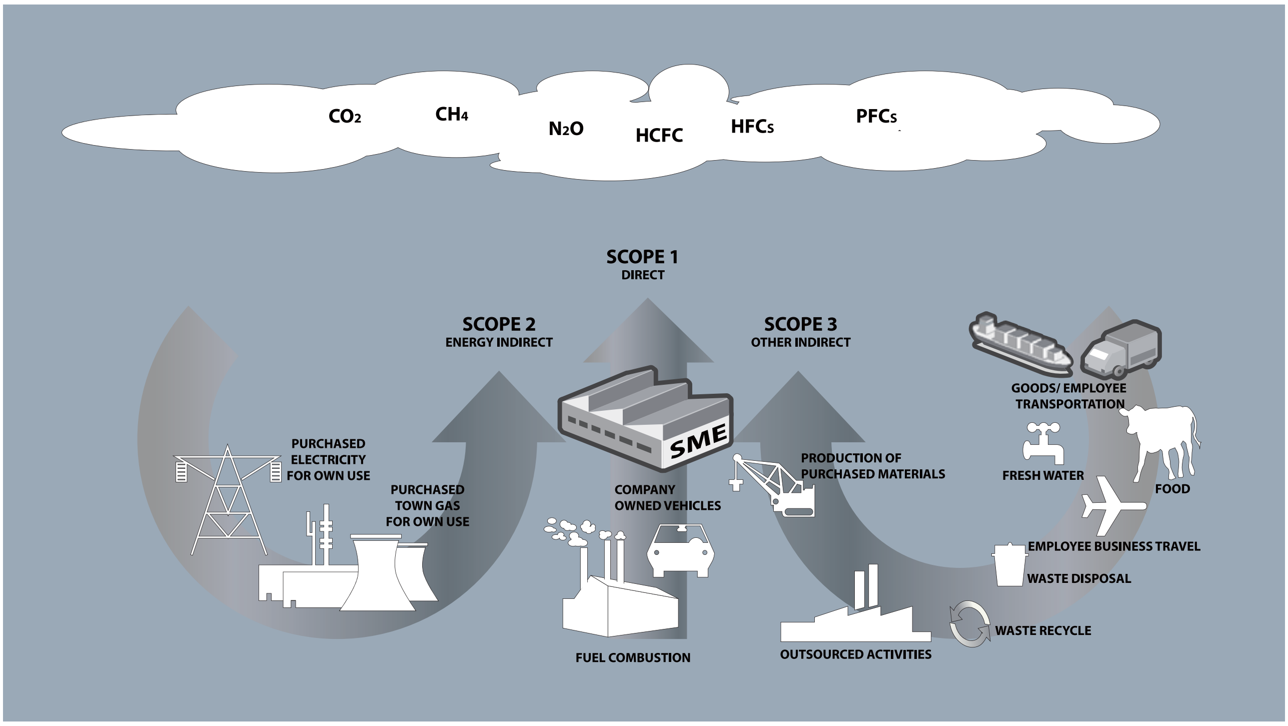

Fig. 3. Factors considered in evaluation of SME's carbon footprint

After reviewing various carbon audit guidelines (Table 5) and conducting an overview of SMEs in Hong Kong, we recommend the following carbon audit guidelines for the SMEs in Hong Kong (Fig. 4):

1. Define scale and scope of carbon audit.
2. Identify operational activities.
3. Choose analysis period (usually at least 12 months to evaluate annual GHG emissions).
4. Use Data Collection Form provided to collect useful information and data.
5. Use Carbon Footprint Calculator provided to quantify GHG emissions and CO_2-eq.
6. Identify emission-intensive activities.
7. Recommend mitigation measures to reduce GHG emissions and carbon footprint.
8. Write report to record the current findings for continual management of carbon footprint.

Useful software and tools, such as Data Collection Form and Carbon Calculator, are provided in the CD attached to facilitate the carbon audit.

Fig. 4. Steps to complete a carbon audit

Table 5. Useful references on carbon audit

Document	Organization	Year
PAS 2050:2008 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, British Standards, 2008	British Standards Institution	2008
Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong	Electrical and Mechanical Services Department (EMSD) and Environmental Protection Department (EPD), HKSAR Government	2010
Emission Factors Database (EFDB)	Intergovernmental Panel on Climate Change - National Greenhouse Gas Inventories Programme (IPCC NGGIP)	2006
The GHG Protocol for Project Accounting	World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI)	2005
CO_2 Emission from Business Travel, Version 2.0. http://www.ghgprotocol.org	World Resources Institute (WRI)	2006

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Carbon Audit - Data Collection Form

Audit Period : From ___________________ to ___________________

Scope 1 Direct Emissions

1. Mobile Combustion Sources			
Vehicle Type	**Fuel Type**	**Consumption / Mileage**	**Unit ***
Motorcycle			L / km
Passenger car, <1,500c.c			L / km
Passenger car, 1,501 – 2000c.c			L / km
Passenger car, 2,001 – 2,500c.c			L / km
Passenger car, 2,501 – 3,000c.c			L / km
Passenger car, >3,000c.c			L / km
LGV, < 2.50T			L / km
LGV, 2.51 – 4.00T			L / km
LGV, 4.01 – 5.50T			L / km
MGV, 5.51 – 10.00T			L / km
MGV 10.01 – 15.00T			L / km
MGV 15.01 – 20.00T			L / km
MGV 20.01 – 24.00T			L / km
HGV 24.01 – 38.00T			L / km
Tractor			L / km
Mini bus			L / kg / km
Coach			L / km
Ships			L / km
Aviation			L / km
Others Mobile Machinery			L / kg / km
*Note: Delete as appropriate.			

2. Stationary Combustion Sources		
Fuel Type	**Consumption**	**Unit**
Diesel		L
LPG		kg
Kerosene		L
Charcoal		kg
Town Gas		Unit
Acetylene		m^3

3. Refrigerant	
Type	**Leakage (kg)**

4. Tree Planting	
No. of new trees that will grow taller than 5m	

Scope 2 Energy Indirect Emissions

1. Electricity	
Company *	**Consumption (kWh)**
CLP / HEC	
CLP / HEC	
*Note: Delete as appropriate.	

2. Town Gas	
Company	**Consumption (Unit)**
Towngas	

Scope 3 Other Indirect Emissions

1. Paper		
Description	**Consumption (kg)**	**Amount Recycled (kg)**

2. Raw Materials for Product Manufacturing		
Type	**Production Method**	**Consumption (kg)**

3. Food	
Type	**Consumption (kg)**
Beef	
Pork	
Chicken	
Fish	
Eggs	
Milk	
Vegetables	
Rice	

4. Plastic Bags	
Description	**Consumption (kg)**

5. Fresh Water	
Supplier	**Consumption (m³)**
Water Supplies Department	

6. Waste & Recycle	
Solid Waste	
Type of Solid Waste *	**Weight (kg)**
General refuse / Office waste	
General refuse / Office waste	
Liquid Waste (Sewage)	
Business Type *	**Disposal (m³)**
Restaurant and Catering Services / Other Business	
Restaurant and Catering Services / Other Business	
Chemical Waste (other than mineral oil)	
Description	**Disposal (kg)**
*Note: Delete as appropriate.	

7. Staff Travel – Air Flight (no need to fill in Origin and Destination if Distance is given)				
Origin	**Destination**	**Trip**	**Distance (km)**	**Class**
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
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		Single / Round		Business / Economy
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		Single / Round		Business / Economy
		Single / Round		Business / Economy

8. Staff Travel – Public Transportation		
Type	**Distance / Expenses**	**Unit ***
MTR		km / HK$
Bus		km / HK$
Minibus		km / HK$
Tram		km / HK$
Taxi		km / HK$
Ferry		km / HK$

*Note: Delete as appropriate.

Chapter 4

Carbon Calculator

The purpose of the carbon calculator is to determine the GHG emissions in terms of carbon dioxide equivalent (CO_2-eq) for individual emission sources as well as the total carbon footprint of a SME. The software of the carbon calculator is included in this *Toolkit*. By entering the data collected in the Data Collection Form, the user can obtain a detailed report on CO_2-eq among the three scopes of GHG emissions.

4.1. Building related factors

In this carbon calculator, the formulas presented in the *Guidelines* by EMSD & EPD (2010) are mostly adopted to handle the GHG emissions due to building related factors. They include Scope-1: direct emissions (fuel combustion, refrigerant leakage and tree planting), Scope-2: energy indirect emissions (electricity and town gas) and Scope-3: other indirect emissions (fresh water consumption, sewage treatment and paper waste disposal). The authors recommend the readers to use this *Toolkit* in parallel with the *Guidelines* by EMSD & EPD (2010).

In general, the amount of direct emission of GHG *i* due to combustion of fuel *j* ($E_{GHG-i,fuel-j}$) is calculated by

$$E_{GHG-i,\ fuel-j} = x_{fuel-j} \times EF_{GHG-i,\ fuel-j} \qquad (2)$$

where x_{fuel-j} is the amount of fuel burned and $EF_{GHG-i,fuel-j}$ is the emission factor. Similarly, the indirect emission of GHG *i* due to purchase of electricity or town gas is calculated by

$$E_{GHG-i,energy-j} = x_{energy-j} \times EF_{GHG-i,energy-j} \qquad (3)$$

where $x_{energy-j}$ is the amount of electricity or town gas purchased and $EF_{GHG-i,energy-j}$ is the emission factor. Useful emission factors are presented in Tables 6 through 9.

Table 6. CO_2 emission factor by fuel type for mobile combustion sources

Fuel Type	CO_2 Emission Factor (kg/litre)
Diesel Oil (DO)	2.614
Unleaded Petrol (ULP)	2.360
Liquefied Petroleum Gas (LPG)	1.679
Gas Oil	2.645
Kerosene	2.429

Table 7. CH_4 and N_2O emission factors by fuel type for mobile combustion sources

Vehicle Type	Fuel Type	Emission Factor (g/litre)	
		CH_4	N_2O
Motorcycle	ULP	1.422	0.046
Passenger Car	ULP	0.253	1.105
	DO	0.072	0.110
Private Van	ULP	0.203	1.140
	DO	0.072	0.506
	LPG	0.248	0.000
Public Light Bus	DO	0.072	0.506
	LPG	0.248	0.000
Light Goods Vehicle	ULP	0.203	1.105
	DO	0.072	0.506
Medium Goods Vehicle	DO	0.145	0.072
Heavy Goods Vehicle	DO	0.145	0.072
Ship	Gas Oil	0.146	1.095
Aviation	Jet Kerosene	0.069	0.000
Other Mobile Machinery	DO	0.0239	0.007
	LPG	0.0036	0.000
	Kerosene	0.0241	0.0076

Table 8. CO_2, CH_4 and N_2O emission factors by fuel type for stationary combustion sources

Fuel Type	Emission Factor		
	CO_2	CH_4	N_2O
Diesel Oil (DO)	2.614 kg/litre	0.0239 g/litre	0.0074 g/litre
Liquefied Petroleum Gas (LPG)	3.017 kg/kg	0.0020 g/kg	0.0000 g/kg
Kerosene	2.429 kg/litre	0.0241 g/litre	0.0076 g/litre
Charcoal	2.970 kg/kg	5.5290 g/kg	0.0276 g/kg
Town Gas*	2.549 kg/unit	0.0446 g/unit	0.0099 g/unit
Acetylene#	3.683 kg/m^3	NA	NA

Note: * *Burning 1 unit of town gas can produce 48 MJ of heat.*

\# *Acetylene is commonly used for flame cutting. The emission factor is 3.683 kg CO_2 per m^3 of acetylene in an ambient condition.*

Table 9. CO_2-eq emission factor for electricity and town gas purchased

Type	CO_2-eq Emission Factor
Electricity supplied by Hong Kong Electric (HEC)	0.84 kg CO_2-eq/kWh purchased
Electricity supplied by China Light & Power (CLP)	0.54 kg CO_2-eq/kWh purchased
Town gas	0.593 kg CO_2–eq/unit town gas purchased

4.2. Raw Material

The use of raw materials involves indirect GHG emissions generated by the raw material suppliers. There are multiple factors causing the GHG emissions including mining, material processing, waste generated and other relevant processes in the production of raw materials. The total emission of a GHG can be determined by

$$E_{GHG-j,\,raw} = \sum_j m_{raw-j} \times EF_{GHG-i,\,raw-j} \quad (4)$$

where $m_{raw\text{-}j}$ is the mass of raw material j consumed and $EF_{GHG\text{-}i,raw\text{-}j}$ is the corresponding emission factor. The values of $EF_{GHG\text{-}i,raw\text{-}j}$ for commonly used raw materials are summarised in Table 10.

Table 10. GHG emission factors of raw materials

Material	Description	GHG Emission Factor
Ammonia	Modern plants; conventional reforming; natural gas as feedstock	1.694 g CO_2 / g
	Modern plants; excess air reforming; natural gas as feedstock	29.7 g CO_2 / g
	Modern plants; autothermal reforming; natural gas as feedstock	30.2 g CO_2 / g
	Modern plants; partial oxidation	36 g CO_2 / g
	Mix of modern and older plants (derived from European average values for specific energy consumption); natural gas as feedstock	37.5 g CO_2 / g
	Mix of modern and older plants (derived from European average values for specific energy consumption); partial oxidation	42.5 g CO_2 / g
	General type	40 g CO_2 / g
Aluminium	Process: Electrolysis	2.15 kg N_2O / tonne
	Production technology: Soderberg process	1.7 g CO_2 / g
	Production technology: Prebaked anode process	1.6 g CO_2 / g
	General type	1.65 g CO_2 / g
Brass	General type	2.61 g CO_2 / g
Bronze	General type	4.41 g CO_2 / g
Cement	Cement production	0.4985 g CO_2 / g
	Clinker production	0.52 g CO_2 / g
	General type	0.51 g CO_2 / g
Copper	General type	3.22 g CO_2 / g
Cotton	Fabric	8.77 g CO_2 / g
	Padding	1.66 g CO_2 / g

Glass	"Typical" raw material mixture is assumed.	0.20 g CO_2 / g
	Glass type: float	0.21 g CO_2 / g
	Glass type: container (flint)	0.21 g CO_2 / g
	Glass type: container (amber/green)	0.21 g CO_2 / g
	Glass type: fiberglass (E-glass)	0.19 g CO_2 / g
	Glass type: fiberglass (insulation)	0.25 g CO_2 / g
	Glass type: specialty (TV panel)	0.18 g CO_2 / g
	Glass type: specialty (TV funnel)	0.13 g CO_2 / g
	Glass type: specialty (tableware)	0.10 g CO_2 / g
	Glass type: specialty (lab/pharmacy)	0.03 g CO_2 / g
	Glass type: specialty (lighting)	0.20 g CO_2 / g
	General type	0.17 g CO_2 / g
Iron & Steel	Process: sinter production	0.07 kg CH_4 / tonne
		0.20 g CO_2 / g
	Electrode consumption from steel produced in electric arc furnaces (EAF)	5 kg CO_2 / tonne
	Process: iron production (blast furnace iron making)	1.35 g CO_2 / g
	Process: direct reduced iron (DRI) production	0.70 g CO_2 / g
	Process: pellet production	0.03 g CO_2 / g
	Steel making method: basic oxygen furnace (BOF)	1.46 g CO_2 / g
	Steel making method: open hearth furnace (OHF)	1.72 g CO_2 / g
	Steel making method: electric arc furnace (EAF); assume production of steel from scrap metal, not from pig iron	0.08 g CO_2 / g
	General: steel making method - global average (65% BOF, 30% EAF, 5% OHF = default allocation of total national steel production among these three steelmaking processes)	1.06 g CO_2 / g
Lead	Source and furnace type: imperial smelt furnace (ISF) production	0.59 g CO_2 / g
	Source and furnace type: direct smelting (DS) production	0.25 g CO_2 / g
	Source and furnace type: treatment of secondary raw materials	0.2 g CO_2 / g
	General: source & furnace type: 80% ISF, 20% DS; applicable when no information is available	0.52 g CO_2 / g

Lime	Production process: lime kiln-calcite feed	0.79 g CO_2 / g quicklime
	Process: lime kiln-dolomite feed	0.91 g CO_2 / g dolomite
	High calcium lime production	0.75 g CO_2 / g
	Hydraulic lime production	0.59 g CO_2 / g
	Dolomitic lime production (developed countries)	0.86 g CO_2 / g
	Dolomitic lime production (developing countries)	0.77 g CO_2 / g
	85% high calcium lime and 15% dolomitic lime production	0.75 g CO_2 / g
	General: 85 % high calcium lime and 15% dolomitic lime production (average of developed and developing countries)	0.76 g CO_2 / g
Magnesium	Raw material: dolomite	5.13 g CO_2 / g
	Raw material: magnesite	2.83 g CO_2 / g
	General type	3.98 g CO_2 / g
Paper & Cardboard	General type	1.55 g CO_2 / g
	Recycled	0.78 g CO_2 / g
Plastic	General type	0.19 g CO_2 / g
Rubber	Synthetic	4.39 g CO_2 / g
	Natural	1.78 g CO_2 / g
Stone	General type	0.06 g CO_2 / g
Timber	General type	0.47 g CO_2 / g
Tin	General type	14.52 g CO_2 / g
Wool	General type	0.19 g CO_2 / g
Zinc	Process: Waelz kiln	3.66 g CO_2 / g
	Process: pyrometeallurgical (imperial smelting furnace)	0.43 g CO_2 / g
	General: process - 60% Imperial Smelting and 40% Waelz kiln is assumed; applicable only in the case that no information is available on zinc production by process.	1.72 g CO_2 / g

[Ref.: IPCC NGGIP, 1996r; IPCC NGGIP, 2006; LOCOG, 2008]

4.3. Food

Food is one of the major factors of GHG emissions in the food processing and catering industries. GHGs are emitted in agriculture, e.g. N_2O emitted from the production and use of nitrogen fertilizers. GHGs are also emitted from crops, e.g. CH_4 from rice cultivation; and livestock, e.g. CH_4 from cattle. The amount of GHG emission can be calculated in terms of CO_2-eq by

$$E_{CO_2\text{-eq, food}} = \sum_j m_{food\text{ - }j} \times SCV_{food\text{ - }j} \times EF_{CO_2\text{-eq, food - }j} \qquad (5)$$

where $SCV_{food\text{-}j}$ and $EF_{CO2\text{-}eq,food\text{-}j}$ are the specific calorific value and CO_2-eq emission factor of a specific type of food, respectively. The values of $SCV_{food\text{-}j}$ and $EF_{CO2\text{-}eq,food\text{-}j}$ of popular food are presented in Table 11.

Table 11. Specific calorific values and emission factors for food

Food Type	Specific Calorific Value, *SCV* (kcal / kg)	Emission Factor, *EF* (g CO_2-eq / kcal)	*SCV* x *EF* (g CO_2-eq / kg)
Beef	1,930	13.82	26,672.6
Pork	2,640	9.03	23,839.2
Chicken	1,670	1.67	2,788.9
Fish	1,000	6.04	6,040.0
Eggs	600	2.93	1,758.0
Milk	130	2.82	366.6
Vegetable	360	0.14	50.4
Rice	3,650	0.80	2,927.0

[Ref.: Eshel and Martin, 2006; Scribd, 2009; HKSAR Centre for Food Safety, 2009; Sakaorat, et al., 2009]

4.4. Plastic bags

In the retail industry, numerous plastic bags are consumed every day. Product packaging also involves intensive use of plastic bags. Plastic bags are commonly made of polyethylene (PE), low-density polyethylene (LDPE) and polyethylene terephthalate (PET). The indirect GHG emission due to the use of plastic bags is calculated by (Simmons C., 2002)

$$E_{CO_2\text{-}eq,\ plastic} = m_{plastic} \times EF_{CO_2\text{-}eq,\ plastic} \qquad (6)$$

where $m_{plastic}$ is the total weight of plastic bags consumed and $EF_{CO2\text{-}eq,plastic}$ is the emission factor equal to 6.25 kg CO_2-eq per kg of plastic bags.

4.5. Waste and Recycle

The general waste contains organic matters, such as paper waste and food waste. In the landfills, the putrescible wastes will be decomposed through anaerobic digestion and CH_4 will be emitted. It is estimated that anaerobic digestion of one tonne of the general waste would generate a total of 100 m^3 of CH_4 (Camp Dresser & McKee International Inc., 2001). It is equivalent to a CO_2-eq emission factor of 1.5 kg CO_2-eq / kg general waste. In an office, the waste is mostly paper waste, which is highly putrescible. The emission factor is 4.8 kg CO_2-eq / kg office waste (EMSD & EPD, 2010). The total GHG emission due to decomposition of waste in a landfill is calculated by

$$E_{CO_2\text{-}eq,\ waste\ \text{-}\ j} = \sum_j \left(m_{waste\ \text{-}\ j} \times EF_{\ CO_2\text{-}eq,\ waste\ \text{-}\ j} \right) \qquad (7)$$

where $m_{waste\text{-}j}$ represents the mass of type-*j* waste dumped and $EF_{CO2\text{-}eq,waste\text{-}j}$ is the corresponding emission factor. It is noted that practising recycling of waste can reduce the amount of waste dumped to the landfill, resulting in a lower carbon footprint.

4.6. Chemical Waste

In Hong Kong, chemical waste is handled at the Tsing Yi Chemical Waste Treatment Centre (CWTC). The recent data show that in 2008, CWTC processed 860 tonnes of solid waste and 41,800 tonnes of liquid waste and the total energy consumption included 15 x 10^6 kWh of electricity and 280 tonnes of diesel oil (EPD, 2009). Based on the above figures, the emission factor ($EF_{CO2\text{-}eq,chem}$) is determined to be 0.210 kg CO_2-eq / kg of chemical waste and the equivalent CO_2 emission is calculated by

$$E_{CO_2\text{-}eq,\,chem} = m_{chem} \times EF_{CO_2\text{-}eq,\,chem} \qquad (8)$$

where m_{chem} is the mass of chemical waste produced. It is noted that if a chemical waste contains waste mineral oil, CWTC will separate the mineral oil for recycling. Therefore, waste mineral oil is neglected in the GHG emission analysis.

4.7. Fugitive emissions

In most commercial air-conditioning and refrigeration equipment, refrigerant is used as the working fluid in a sealed system. In case of leakage, the refrigerant released to the atmosphere may cause a greenhouse effect. A list of refrigerants, refrigerant blends and their *GWP* values are presented in Table 12. The greenhouse effect due to fugitive refrigerant in terms of CO_2-eq can be calculated by

$$E_{CO_2\text{-}eq,\,ref} = m_{ref} \times GWP_{ref} \qquad (9)$$

where m_{ref} and GWP_{ref} is the mass and *GWP* of fugitive refrigerant, respectively.

Table 12. Refrigerants and *GWP* values

Refrigerant/Blend	Chemical Compound	*GWP*
HCFC-21	$CHCl_2F$	210
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
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	97
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,640
HFC-125	CHF_2CF_3	3,500
HFC-134	CHF_2CHF_2	1,100

HFC-134a	CH_2FCF_3	1,430
HFC-143	CHF_2CH_2F	330
HFC-143a	CF_3CH_3	4,470
HFC-152	CH_2FCH_2F	43
HFC-152a	CH_3CHF_2	124
HFC-161	CH_3CH_2F	12
HFC-227ea	CF_3CHFCF_3	3,220
HFC-236cb	$CH_2FCF_2CF_3$	1,300
HFC-236ea	CHF_2CHFCF_3	1,200
HFC-236fa	$CF_3CH_2CF_3$	9,810
HFC-245ca	$CH_2FCF_2CHF_2$	640
HFC-245fa	$CHF_2CH_2CF_3$	1,030
HFC-365mfc	$CF_3CH_2CF_2CH_3$	794
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
R-404A	R-125 / R-143a / R-134a (44% / 52% / 4%)	3,260
R-407A	R-32 / R-125 / R-134a (20% / 40% / 40%)	1,770
R-407B	R-32 / R-125 / R-134a (10% / 70% / 20%)	2,285
R-407C	R-32 / R-125 / R-134a (23% / 25% / 52%)	1,526
R-407D	R-32 / R-125 / R-134a (15% / 15% / 70%)	1,428
R-407E	R-32 / R-125 / R-134a (25% / 15% / 60%)	1,363
R-410A	R-32 / R-125 (50% / 50%)	1,725
R-410B	R-32 / R-125 (45% / 55%)	1,833
R-507	R-125 / R-143a (50% / 50%)	3,300

R-507A	R-125 / R-143a (50% / 50%)	3,300
R-508A	R-23 / R-116 (39% / 61%)	10,175
R-508B	R-23 / R-116 (46% / 54%)	10,350

[Ref.: EMSD & EPD, 2010; IPCC NGGIP, 2007; IPCC NGGIP, 2001]

4.8. Transportation

Burning fuels for local transportation and overseas air travel causes emission of GHGs. For each transportation category, the emission factor that quantifies the CO_2-eq emission per person per unit distance travelled is needed. Thorough reviews have been done for various types of public transportation in Hong Kong. The studies take into account the annual energy consumption, the number of passengers served and the total distance travelled by all vehicles. The emission factor is also specified in terms of CO_2-eq emission per dollar spent in order to facilitate the emission calculation since passengers normally do not record the actual distance travelled but the transportation expenditure for reimbursement. The emission factors applicable for the local transportation in Hong Kong have been determined and summarised in Table 13.

Table 13. Emission factors for public transportation

Transportation type	$EF_{CO2\text{-}eq,trans}\vert_{man\text{-}dist}$ (kg CO_2-eq/man-km)	$EF_{CO2\text{-}eq,trans}\vert_{cost}$ (kg CO_2-eq/HK$)
Mass Transit Railway (MTR)	0.0078	0.0115
Bus	0.0279	0.0493
Minibus	0.0631 (Diesel) / 0.0648 (LPG)	0.0919 (Diesel) / 0.0944 (LPG)
Tram	0.0274	0.0685
Taxi	0.1210	0.0210
Ferry	2.2276	1.478

For each type of transportation, the CO_2-eq emission can be calculated by using either one of the emission factors, whichever is more convenient to use,

$$E_{CO_2\text{-}eq,\,trans} = MD_{trans} \times EF_{CO_2\text{-}eq,\,trans}\Big|_{man\text{-}dist} \quad (10)$$

$$E_{CO_2\text{-}eq,\,trans} = C_{trans} \times EF_{CO_2\text{-}eq,\,trans}\Big|_{cost} \quad (11)$$

where MD_{trans} and C_{trans} represent the sum of man-distance and sum of cost over a certain period of time, respectively.

For air travel, the World Resources Institute (2006) has recommended an emission factor which is a function of the flight distance. The WWF Hong Kong (2009) further adds a business-economic factor to take into account the fact that a business-class passenger occupies more space than an economy-class passenger. The overall calculation is

$$E_{CO_2\text{-}eq,\ flight} = D_{flight} \times EF_{CO_2\text{-}eq,\ flight} \times BEF \quad (12)$$

where

$$EF_{CO_2\text{-}eq,\ flight} = \begin{cases} 0.15 & \text{for short haul } (\leq 500 \text{ km}) \\ 0.12 & \text{for medium haul } (>500, <1{,}600 \text{ km}) \\ 0.11 & \text{for long haul } (\geq 1{,}600 \text{ km}) \end{cases}$$

$$BEF = \begin{cases} 0.9 & \text{for economy class} \\ 1.4 & \text{for business class} \end{cases}$$

and D_{flight} is the distance travelled from Hong Kong to destination city or the distance for the return trip. For easy reference, the values of D_{flight} for popular cities are presented in Table 14. A more complete database is provided in the toolkit software.

Table 14. Flight distance from Hong Kong to other cities

City	D_{flight} (km)	City	D_{flight} (km)
Beijing	1,987	London	9,647
Shanghai	1,254	New York	12,990
Taipei	807	Los Angeles	11,684
Tokyo	2,964	Sydney	7,372

Chapter 5

Environmental-friendly Tips

In this project, the team members reviewed many useful references and conducted field carbon audits for 30 SMEs in Hong Kong. Throughout the study, some practical and effective low-carbon measures have been identified. The readers may study the list below and adopt those applicable to reduce their carbon footprint.

Air-conditioning

1. Use water-cooled air-conditioning system instead of air-cooled system to save electricity by as much as 30% and reduce carbon footprint.
2. Install the outdoor unit of a split-type air-conditioning system in a shaded and cool area wherever possible.
3. Clean air filter regularly to reduce the fan power.

Lighting

4. Use energy efficient lamps; candidate products include T5 fluorescent lamps, compact fluorescent lamps (CFL) and light emitting diode (LED) lamps.
5. Use multiple light switches for separate zones to facilitate partial lighting in a large area when it is only partially occupied.

Office

6. Use paper on both sides for printing and copying.
7. Print draft document in multiple frames per page to save paper.
8. Switch off standby power for office equipment after office hours, e.g. computers, printers, copiers etc.
9. Use occupancy sensors to switch off lighting and air-conditioning in conference rooms and restrooms when they are not occupied.

Catering

10. Use energy-efficient heat pump to supply for both hot water and air-conditioning can easily reduce carbon emission by 50%.
11. Cover lid of soup cooker to reduce heat loss.
12. Minimize standby time of cooking and food processing equipment.
13. Make use of residual heat in cooking equipment; for instance, after switching off an electrical steamer, the hot steam inside the steamer can continue to transfer heat to cook food.
14. Avoid opening refrigerator doors frequently.

15. Use multiple switches to control air-conditioning and lighting in separate zones; when there are not many customers, close some of the zones.

16. Supply water from the bottom of a basin at a low flow rate to save water in cold water thawing of frozen food.

17. Serve more vegetable and less meat to reduce carbon footprint.

18. Post a notice to remind customers to request less rice for lunch set or dinner set as appropriate in a fast food restaurant.

19. Offer boxes for customers to take home any left-over food to reduce food waste.

20. Sweep kitchen floor before washing with water; avoid using water jet to flush solid refuse into drain.

Transportation

21. Avoid driving at exceedingly high speed, rapid acceleration and brake to save 5% carbon emission.

22. Avoid carrying unnecessary heavy item in vehicle; a load of 40-50 kg will increase carbon emissions by 2%.

23. Reduce air travel whenever possible; overseas meeting can be conducted by video-conferencing.

Others

24. Install three-colour coded bins and promote waste recycling.

25. Post energy saving labels to encourage taking stairs rather than using lifts.

26. Use electronic frequency inverters and soft starters if applicable to save energy as well as to prolong equipment life.

By Friends of the Earth(HK)

Carbon Footprint Calculator

Appendix I. Sample Analysis

Brief Description

ABC Company Limited is an interior design company. There are 10 employees. The CO_2 emissions are mainly due to the office operations, local transportation and overseas transportation.

Data Collection

Company Data

General Information
(optional; for calculating performance indicators)

Company name: ABC Company Limited

Address: 123 Carbon Road, Kowloon, Hong Kong

Audit period: from Nov-08 to Oct-09

Total floor area: 250 m^2

No. of staff: 10

Total business hours during the audit period: 2,240 hours

Others

Total power capacity of product produced: ____________ kW

Total weight of product produced: ____________ □ kg □Tonnes

Total weight of food served: ____________ kg

Total weight of cargo delivered: ____________ □ kg □Tonnes

Total man-power: 16,500 man-hours

Gross income: ____________ HK$

Carbon Audit - Data Collection Form

Audit Period : From ____Nov-08____ to ____Oct-09____

Scope 1 Direct Emissions

1. Mobile Combustion Sources			
Vehicle Type	**Fuel Type**	**Consumption / Mileage**	**Unit ***
Motorcycle			L / km
Passenger car, <1,500c.c			L / km
Passenger car, 1,501 – 2000c.c			L / km
Passenger car, 2,001 – 2,500c.c	Petrol	20,000	~~L~~ / km
Passenger car, 2,501 – 3,000c.c			L / km
Passenger car, >3,000c.c			L / km
LGV, < 2.50T			L / km
LGV, 2.51 – 4.00T			L / km
LGV, 4.01 – 5.50T			L / km
MGV, 5.51 – 10.00T			L / km
MGV 10.01 – 15.00T			L / km
MGV 15.01 – 20.00T			L / km
MGV 20.01 – 24.00T			L / km
HGV 24.01 – 38.00T			L / km
Tractor			L / km
Mini bus			L / kg / km
Coach			L / km
Ships			L / km
Aviation			L / km
Others Mobile Machinery			L / kg / km

*Note: Delete as appropriate.

2. Stationary Combustion Sources		
Fuel Type	**Consumption**	**Unit**
Diesel		L
LPG		kg
Kerosene		L
Charcoal		kg
Town Gas		Unit
Acetylene		m^3

3. Refrigerant	
Type	**Leakage (kg)**
N/A	

4. Tree Planting	
No. of new trees that will grow taller than 5m	N/A

Scope 2 Energy Indirect Emissions

1. Electricity	
Company *	**Consumption (kWh)**
CLP / ~~HEC~~	36,000
CLP / HEC	
*Note: Delete as appropriate.	

2. Town Gas	
Company	**Consumption (Unit)**
Towngas	N/A

Scope 3 Other Indirect Emissions

1. Paper		
Description	**Consumption (kg)**	**Amount Recycled (kg)**
A4	400	200

2. Raw Materials for Product Manufacturing		
Type	**Production Method**	**Consumption (kg)**
N/A		

3. Food	
Type	**Consumption (kg)**
Beef	
Pork	
Chicken	
Fish	
Eggs	
Milk	
Vegetables	

Rice	

4. Plastic Bags

Description	Consumption (kg)
N/A	

5. Fresh Water

Supplier	Consumption (m^3)
Water Supplies Department	80

6. Waste & Recycle

Solid Waste

Type of Solid Waste *	Weight (kg)
~~General refuse~~ / Office waste	450
General refuse / Office waste	

Liquid Waste (Sewage)

Business Type *	Disposal (m^3)
~~Restaurant and Catering Services~~ / Other Business	80
Restaurant and Catering Services / Other Business	

Chemical Waste (other than mineral oil)

Description	Disposal (kg)

*Note: Delete as appropriate.

7. Staff Travel – Air Flight (no need to fill in Origin and Destination if Distance is given)

Origin	Destination	Trip	Distance (km)	Class
HKG	Singapore	~~Single~~ / Round		~~Business~~ / Economy
HKG	Chicago, O'Hare	~~Single~~ / Round		Business / ~~Economy~~
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy

		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy
		Single / Round		Business / Economy

8. Staff Travel – Public Transportation

Type	**Distance / Expenses**	**Unit ***
MTR	2,000	~~km~~ / HK$
Bus	4,500	~~km~~ / HK$
Minibus		km / HK$
Tram		km / HK$
Taxi		km / HK$
Ferry		km / HK$

*Note: Delete as appropriate.

Carbon Footprint Analysis

ABC Company Limited

Detailed Breakdown of Carbon Emissions

Descriptions	**Equivalent CO_2 Emissions (kg CO_2-eq)**	**Percentage (%)**
Scope 1 Direct Emission		
Mobile Combustion Sources		
(a) Fuel Consumption Approach		
(b) Mileage Approach	7,003	100%
Stationary Combustion Sources		
Refrigerant		
Tree Planting		
Total in Scope 1	7,003	
Scope 2 Energy Indirect Emissions		
Electricity	19,440	100%
Town Gas		
Total in Scope 2	19,440	
Scope 3 Other Indirect Emissions		
Paper	1,580	18.90%
Raw Materials for Product Manufacturing		
Food		
Plastic Bags		
Fresh Water	34	0.41%
Waste & Recycle		
(a) Solid Waste	2,160	25.83%
(b) Liquid Waste (Sewage)	14	0.16%
(c) Chemical Waste		
Staff Travel		
(a) Distance Approach	4,369	52.25%
(b) Expense Approach	205	2.45%
Total in Scope 3	8,361	

Carbon Emissions Summary

	Equivalent CO_2 Emissions (kg CO_2-eq)	Percentage (%)
Scope 1	7,003	20.12%
Scope 2	19,440	55.86%
Scope 3	8,361	24.02%
Total	34,804	

Performance Indicator

Index	Carbon footprint indicator	
Man-power	2.11	kg CO_2-eq / man-hour
Gross income		kg CO_2-eq / HK$

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