A Case Study of Research on Shenzhen Public Transportation Sector's Greenhouse Gas Emissions Quantification and Reporting Methodologies - Quantification of GHGs from the Public Bus Branch Company of the Shenzhen Bus Group Co., Ltd

On behalf of

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Responsible Person

Ms. Constanze Boening

Authors

Shenzhen Low Carbon Development Foundation

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I. Introduction of Shenzhen Bus Group Co., Ltd

Since the first operation of a bus from Qiaoshe in Shenzhen Town, Bao'an County to Dongmen Bus Station in 1975, Shenzhen's public transportation has developed over 40 years and has formed a public transportation system with Shenzhen characteristics. Shenzhen has 3 public transportation companies, namely,Shenzhen Bus Group Co., Ltd (hereinafter referred to as "Bus Group"), Shenzhen Eastern Public Bus Co., Ltd (hereinafter referred to as "Eastern Bus Company") and Shenzhen Western Public Bus Co., Ltd(hereinafter referred to as "Western Bus Company"), where the Bus Group ranks first in the scale with 5,252 vehicles, sharing 39% of the totality and covering 10 vehicle types such as diesel air-conditioned bus, diesel air-conditioned middle bus, diesel and electric double-decked bus etc.

The Bus Group is a Sino-foreign joint stock company, an enterprise wholly engaged in operating public buses authorized by Shenzhen Municipal Government and also the largest bus operating enterprise in Shenzhen. The company has 9 wholly owned and holding companies and 7 shared stock and cooperative companies. Till the end of 2013, subsidiaries of The Bus Group include: Public Bus Branch Company, Longgang Public Bus Branch Company, Bao'an Public Bus Branch Company, Shenzhan Branch Company and Sub-line Branch Company. The group has over 300 routes in total.

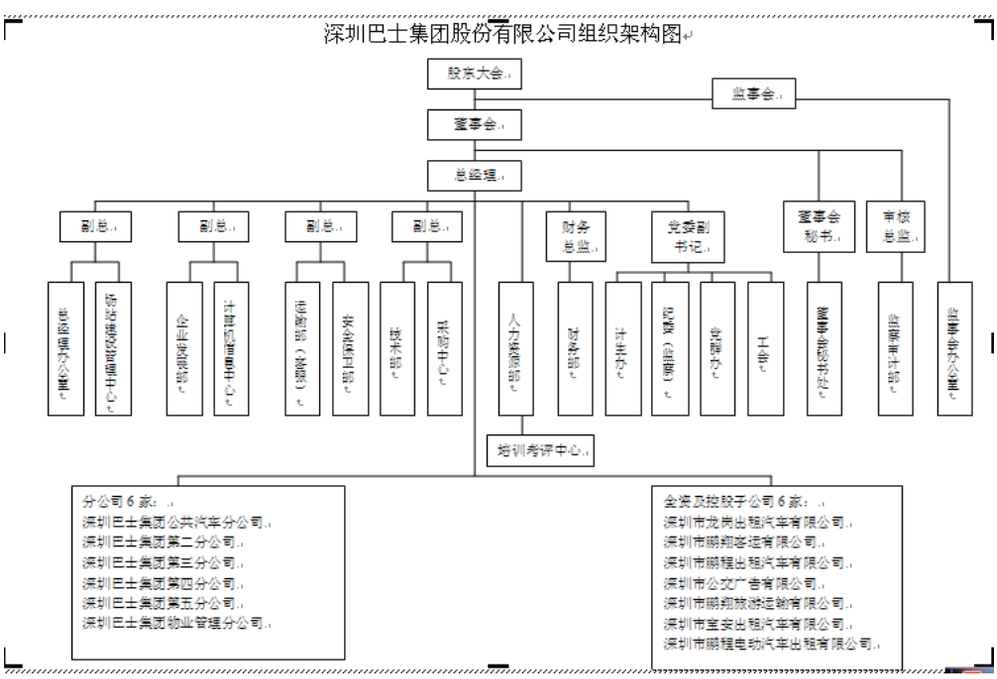

Diagram 1.1 Organizational Chart of the Bus Group

From the perspective of specific operation pattern, since the subsidiaries of the Group have similar organizational forms, Public Bus Branch Company (hereinafter referred as "PBBC") is taken as an example to explain quantification methods for Greenhouse gases (GHG)emissions from public transportation companies.

II Investigation into PBBC of the Bus Group

Site investigation into PBBC is necessary for us to deeply learn about the organizational structure, operation status, vehicle information, energy consumption and carbon emissions etc of the branch company of the Bus Group, to determine the major emissions sources, to analyze features of direct and indirect emissions, to reasonably demarcate the branch company's organizational and operational boundaries, to put up with methods for emission sources identification and activity data collection.

Investigation content is as follows:

1. Basic organizational condition of the PBBC

The PBBC has 5 apartments, 5 canteens, 5 vehicleworkshops, 19 fleets, 1 storehouse and 1 fuel department. Please refer to Diagram 1.2 for the organizational chart.

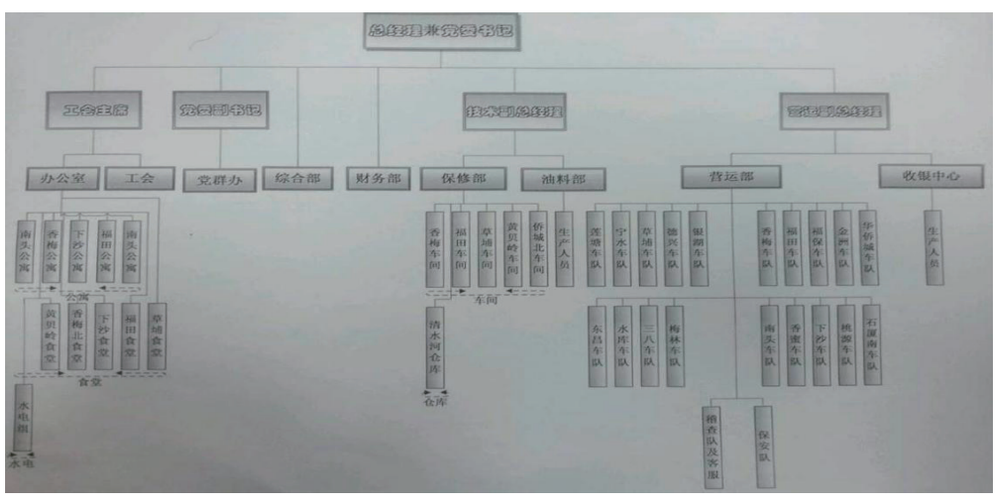

Diagram 2.1 Organizational Chart for the PBBC

The management structure of the PBBC is relatively simple. Since its canteens and apartments are both controlled by the company, its organizational boundary is easy to determine. However, it is found during the investigation that although the fuel storehouse is controlled by the PBBC, the operational range of the fuel storehouse and fuel trucks covers several subsidiaries of the BusGroup, thus it is needed to clarify the determination method for organizational boundary. Through research, it is decided to adopt mastery method for the PBBC. Since fuel storehouse is financially and operationally controlled by the PBBC, carbon emissions from the fuel storehouse belong to the PBBC.

2. Energy Consumption in the PBBC

It is learned from the investigation that energy consumed by the PBBC mainly includes purchased electricity, diesel, gasoline, natural gas etc., and energy consumption and management are mainly categorized into three competent departments: the Office charges statistics of energy consumption within logistics system, which specifically includes energy consumed by material transport vehicles and other internal vehicles, canteens and

apartments; the Maintenance Department charges energy consumption within maintenance system, which specifically includes fuels consumed by workshops, storehouses, vehicle washing rooms and fork trucks; the Operating Department charges energy consumption by the fleets.

3. Carbon Emission Status of the PBBC

Carbon Emissions from the PBBC can be categorized into direct and indirect emissions, where direct emissions include emissions from combustion of diesel, gasoline and natural gas by vehicle and consumption of natural gas and other fuels by cooking utensils in canteens. The company has complete and detailed records of energy consumption by buses, input and output of acetylene from the maintenance workshops (please refer to Diagram 2.2); indirect emissions are mainly emissions from electricity consumption by buildings and new energy vehicles where data of electricity consumed by buildings can be collected by electric meters while that used by new energy vehicles can be certified by third-party power companies.

Diagram 2.2 EAM Management of the PBBC of the Bus Group

During investigation into the PBBC, it is found that staff from the PBBC is not well informed about carbon inventory. Lest emission sources are omitted during carbon emissions liquidation, the research has interrogated and examined emission sources one by one in accordance with the organizational structure and departmental category of the bus company. According to different competent departments, the operational boundary of the subsidiary bus company can be divided into three plates: logistics system, maintenance system and operating vehicle system, where the Office charges data reporting and submission as well as preservation of original data of the logistics system, the maintenance system is charged by workshops and Maintenance Department, the operating vehicles are charged by the company's Operating Department. Please refer to Sheet 2.1-2.3 for statistics of energy consumption within the system boundary.

Sheet 2.1 Statistics Sheet for Energy Consumption in the Logistics System in 2012

Type		Energy Type	Usage	Data Acquisition Method (Bill, Calculation, Estimation, other)	Evidence Type (e.g. Receipt-Paper File, Storehouse Records-Electric File, Fuel Card etc.)	Evidence Keeping Department	Statistics Amount of Energy (If only electricity is used, needless to fill in)	Note (Use Range: collectively used in the Group/ only used in branches)
Office		Electricity	Illumination, Hot Water, Air-conditioner	Bill	Receipt-Paper File	Finance Department		
Canteen		LNG		Bill	Receipt-Paper File	Finance Department	173.15 ton	
Apartment		Electricity	Illumination, Hot Water, Air-conditioner	Bill	Receipt-Paper File	Finance Department		
Production Vehicle	Material Delivery Vehicle	Diesel	Material Delivery	Calculation	Fuel Refilling-Electric File	Fuel Department	4729.5 Liter	Used by 5 vehicles of the Branch Company
		Gasoline	Material Delivery	Estimation	Receipt	Finance Department	3440 Liter	Used by 2 vehicles of the Branch Company, Purchased gasoline
	Maintenance Vehicle and Wrecker	Diesel	Material Delivery	Calculation	Fuel Refilling-Electric File	Fuel Department	3038 Liter	Used by 3 vehicles in the Branch Company
		Gasoline	Material Delivery	Estimation	Receipt	Finance Department	2500 Liter	Used by 2 vehicles in the Branch Company, purchased gasoline
	Fuel Delivery Vehicle	Diesel	Fuel Refilling	Calculation	Fuel Refilling-Electric File	Fuel Department	51842.1 Liter	Collectively used by 13 vehicles of the Group
	Fuel Recovery Vehicle	Diesel	Making Urgent Repair	Calculation	Fuel Refilling-Electric File	Fuel Department	4606.2 Liter	Collectively used by 1 vehicle of the Group

	Cash Register Vehicle	Diesel	Cash Registering	Calculation	Fuel Refilling-Electric File	Fuel Department	83944.8 Liter	Collectively used by 15 vehicles of the Group
		Gasoline	Cash Registering	Estimation	Receipt	Finance Department	5700 Liter	Collectively used by 1 vehicles of the Group
	Meal Delivery Vehicle	Diesel	Meal Delivery	Calculation	Fuel Refilling-Electric File	Fuel Department	24992 Liter	Used by 10 vehicles in the Branch Company
	In-Station Vehicle	Diesel	Making Urgent Repair	Calculation	Fuel Refilling-Electric File	Fuel Department	1346 Liter	Used by 1 vehicle in the Branch Company
	Examiner Vehicle	Diesel	Examining	Calculation	Fuel Refilling-Electric File	Fuel Department	2507.6 Liter	Used by 2 vehicles in the Branch Company
	Public Opinion Collection Vehicle	Diesel	Collecting Public Opinion	Calculation	Fuel Refilling-Electric File	Fuel Department	3243 Liter	Used by 1 vehicle in the Branch Company
	Learner-Driven Vehicle	Diesel	Coaching	Calculation	Fuel Refilling-Electric File	Fuel Department	748 liter	Collectively used by 2 vehicles of the Group

Sheet 2.2 Statistics Sheet for Energy Consumption in the Maintenance System in 2012

Type	Energy Type	Energy Usage	Data Acquisition Method (bill, calculation, estimation, other)	Evidence Type (e.g. Receipt-Paper File, Electric Files, Fuel Card etc.)	Evidence Keeping Department	Statistics Amount of Energy	Note (Use Range: collectively used in the Group/ only used in branches)
Storehouse	Electricity	Illumination	Bill	Receipt-Paper File	Finance Department		
Workshop	Electricity	Illumination	Bill	Receipt-Paper File	Finance Department		
Fork Truck	Diesel	Material Delivery	Other	Non			Used by 8 fork trucks of the Branch Company, diesel used is regarded as that consumed by delivery vehicle
Vehicle Washing Workshop	Electricity	Illumination	Bill	Receipt-Paper File	Finance Department		

Note: Diesel used by fork trucks is directly from that for delivery vehicles, so it is regarded as the diesel used by delivery vehicles. Only the diesel used by delivery vehicles is calculated.

Sheet 2.3 Statistics Sheet for Energy Consumption by Operating Vehicles in 2012

Vehicle Type	Number of Vehicles at the Beginning of a Year	Number of Vehicles at the End of a Year	Energy Type	Statistics Amount of Energy	Note
Purely Electric	26	26	Electricity	1622524.35 KWh	Purchased
Mixed Power	359	359	Electricity	127941.15 KWh	Purchased
			Diesel	8745860.39 Liter	32808876.66 liters in stock, 7961013.5 liters purchased
Diesel Air-conditioned Bus	1171	1128	Diesel	32024029.77 Liter	
Air-conditioned Bus	141	141	LNG	4014183.85 kg	Purchased

Purchased electricity consumed by the PBBC in 2012 was 5746.2182MWh in total, where 175.0466MWh was consumed by purely electric and mixed power vehicles, namely, 5571.1716MWh was used by other departments for illumination and air-conditioned etc.

III Quantification of GHGs from the PBBC

It is seen from the investigation that in the PBBC, the statistics of diesel, gasoline, electricity consumed by vehicles in the operating system is independent from the energy consumption statistics of other departments. Therefore, quantification of GHGs emissions can be respectively conducted in the operating system and non-operating system, namely, the operating system and the supporting system. Now we can define the operating system as the vehicle system operated by enterprises in public transportation sector while the supporting system refers to departments and units serving production (e.g. Office building, maintenance workshops, storehouse, staff canteen, apartments and vehicles for internal transport etc.). To be specific, in the PBBC, the quantification range of GHGs includes:

1. GHG emissions from the operating system of the PBBC

a) Direct emissions from fuel combustion by buses, which is sum of emissions from combustion of diesel, gasoline and LNG consumed by buses, namely, $E_{\text{direct emissions from vehicles}}$=consumed diesel × emission factor of diesel + consumed LNG × emission factor of LNG. Please refer to Sheet 3.1 for Quantification Sheet for Direct Emissions from Fuel Combustion by Buses in the PBBC.

b) Indirect emissions from electricity used by buses is indirect emissions from electricity consumed by operating vehicles, namely, $E_{\text{indirect emissions from vehicles}}$ = Consumed Electricity × Electricity Emission Factor. Please refer to Sheet 3.2 for Quantification Sheet for Indirect Emissions form Electricity Consumption by PBBC.

Sheet 3.1 Quantification Sheet for Direct Emissions from Fuel Combustion by Buses in the PBBC (2012)

Basic Information					Activity Level Data					Emission Factor		Amount of GHG Emissions (tCO_2)	Note
Order Number	Vehicle Type	Number of Vehicles at the Beginning of a Year	Number of Vehicles at the End of a Year	Fuel Type	Value of Activity Level	Unit of Activity Data	Acquisition Methods for Activity Level Data	Evidence Keeping Department	Evidence Type	Value	Unit		
1	Diesel Air-conditioned Bus	1171	1128	Diesel	32024029.77	Liter	Bill	Operating Department		3.10	tCO_2/t fuel	83886.91	Density: 845 kg/m^3
2	Mixed Power	359	359	Diesel	8745860.39	Liter	Bill	Operating Department		3.10	tCO_2/t fuel	22909.78	Density: 845 kg/m^3
3	Gas Air-conditioned Bus	141	141	LHG	4014183.85	kg	Bill	Operating Department		2.68	tCO_2/t fuel	10758.01	

Sheet 3.2 Quantification Sheet for Indirect Emissions from Electricity Consumption by Buses in PBBC (2012)

Basic Information				Activity Level Data				Emission Factor		Amount of GHG Emissions (tCO2)	Note
Order Number	Vehicle Type	Number of Vehicles at the Beginning of a Year	Number of Vehicles at the End of a Year	Consumed Electricity (Unit: MWh)	Acquisition Method for Activity Level Data	Evidence Keeping Department	Evidence Type	Value	Unit		
1	Purely Electric	26	26	Electricity	1622.524.	Finance Department	Bill	0.9344	tCO2/MWh	1516.09	
2	Mixed Power	359	359	Electricity	127.941	Finance Department	Bill	0.9344	tCO2/MWh	119.55	

2. GHG emissions from the supporting system of the PBBC

a) Direct emissions from fuel combustion in the supporting system: fuel combustion in the supporting system of the company includes stationary combustion sources and mobile combustion sources and the resulting direct emissions is the sum of GHG emissions from combustion of diesel, LNG and coal etc consumed by departments and units serving production, namely, $E_{\text{direct emissions from the supporting system}}$=natural gas used in canteen × emission factor of natural gas + diesel used by production vehicles (including fork trucks)×emission factor of diesel + gasoline used by production vehicles (including fork trucks)×emission factor of gasoline. Please refer to Sheet 3.3 for Quantification Sheet for Direct Emissions from Fuel Combustion in the Supporting System of the Public Bus Branch in 2012.

b) Indirect emissions from consumption of purchased electricity and heat in the supporting system: GHG emissions from electricity consumed for illumination by the company's departments such as canteen, office etc, namely, $E_{\text{indirect emissions from the supporting system}}$=electricity used by the supporting system ×emission factor of electricity. Please refer to Sheet 3.4 for the Quantification Sheet for Indirect Emissions from Consumption of Purchased Electricity and Heat in the Supporting System of the Public Bus Branch in 2012.

Sheet 3.3 Quantification Sheet for Direct Emissions from Fuel Combustion in the Supporting System (2012)

Basic Information				Activity Level Data					Emission Factor		Amount of GHGs Emission (tCO_2)	Note
Order Number	Fuel Type	Fuel Consumption Department/	Facility/Activity	Value of Activity Level	Unit of Activity Data	Acquisition Method for Activity Level Data	Evidence Keeping Department	Evidence Type	Value	Unit		
1	Diesel	Production Vehicle in the Fuel Department	Material Delivery Vehicle, Maintenance Vehicle and Wrecker, Fuel Delivery Vehicle, Fuel Recovery Vehicle, Meal Delivery Vehicle, In-Station Vehicle, Examiner Vehicle, Public Opinion Collection Vehicle, Learner-Driven Vehicle, Fork Truck	180994.20	Liter	Calculation	Fuel Refilling Record	Electric file	3.10	tCO2/t Fuel	474.11	Density: 845 kg/m^3
2	LNG	Canteen	Canteen	173.15	ton	Bills	Receipt	Paper File	2.90	tCO2/t Fuel	502.14	
3	Gasoline		Material Delivery Vehicle, Maintenance Vehicle and Wrecker, Cash Register Vehicle	11640	Liter	Calculation	Fuel Refilling Records	Electric File	2.92	tCO2/t Fuel	26.34	775 kg/m^3

Sheet 3.4 Quantification Sheet for Indirect Emissions from Consumption of Purchased Electricity and Heat in the Supporting System (2012)

Basic Information			Activity Level Data				Emission Factors		Amount of GHGs Emissions (tCO_2)	Note
Energy Type	Energy Consumption Department/Unit	Facility/Activity	Electricity Consumption (Unit: MWh)	Acquisition Methods for Activity Level Data	Evidence Keeping Department	Evidence Type	Value	Unit		
Electricity	Canteen, Apartment etc.	Air-conditioner, Illumination etc.	5571.1716	Calculation	Finance Department	Paper File	0.9344	tCO2/MWh	5205.70	

Sheet 3.5 Summary Sheet for GHGs Emissions from the PBBC (2012)

Emission Type		Emission Amount (unit: tCO2)	Percentage
GHGs Emissions from the Operating System	Direct emissions from fuel combustion by buses/taxis	117554.74	94.86%
	Indirect emissions from electricity consumed by buses/taxis of public transportation companies	1635.63	1.32%
GHGs Emissions from the Supporting System	Direct emissions from fuel combustion in the supporting system	1002.59	0.81%
	Indirect emissions from consumption of purchased electricity and heat	3733.67	3.01%
Total Emissions		123926.63	100%

It can be inferred from above that the total emissions from the PBBC in 2012 is 123,926.63 tons where the operating system shares over 96% and the supporting system occupies about 3%.

V Suggestions to improve the quantitative results

1.GHG quantification verification for enterprises will be implemented by the specialized verification team, professional training will be conducted to the relevant staff, and their related responsibilities and rights will be determined as well.

2.Ensure the data accuracy, each responsible authority shall specify data sources, such as purchase receipts, record of measuring instrument, record of usage, computer database record or computer reports, etc., which can prove the reliability of the data and evidence should be investigated, and data will be kept by the relevant authority for the convenience of the future tracking and verification.

3.Establish GHG Information Management Program, program file management includes at least document and records management program, GHG quantification and reporting procedures, and data quality management program;

4.Implementation of general GHG quantification and verification: for data collection / input / processing, data filing, and in term of eliminate general errors caused by negligence during emissions measurement process, moderate rigorous quality inspection is necessary.

5.Uncertainty analysis of GHG should be completed and documented by enterprises. This information is not used to determine the accuracy of inventory calculation, but rather to help enterprises determine the direction and priority of future efforts to improve the accuracy of GHG list, and as guidance on methodological choices.

VI Conclusion

Investigation into the PBBC shows that the company has a relatively simple management structure and clear organizational boundary; its energy consumption is categorized into three competent departments: logistics system, maintenance system as well as operating system. Based on the company's energy management system, its GHGs quantification boundary can be set as operating system and supporting system, direct and indirect emissions from the two systems can be respectively calculated; it can be seen from the quantification of GHGs from the PBBC in 2012 that for public transportation companies, their major emission source is the operating vehicles, which sharing 96% of the total emissions, while emissions from the supporting system is relatively small.

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Capacity Building for the Establishment of
Emissions Trading Schemes in China

Sunflower Tower, Room 860
Maizidian Street 37
100125 Beijing
P.R. China

T +86 10 8527 5589 ext. 111
F +86 10 8527 5591
I www.ets-china.org