Pilot Green Transport Fund

Final Report On
Trial of Solar Air-conditioning System for a Shuttle Bus (Hong Kong Science and Technology Parks Corporation)

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Final Report
(Trial Period: 1 April 2014 – 31 March 2016)

Executive Summary

1. Introduction

1.1 The Pilot Green Transport Fund (the Fund) is set up to encourage transport operators to try out green innovative transport technologies, contributing to better air quality and public health for Hong Kong. The Hong Kong Science and Technology Parks Corporation (HKSTPC) was approved under the Fund for trial of one unit of solar air-conditioning system (SAS) on a 29-seat diesel shuttle bus. The SAS was expected to lower the fuel consumption of the bus. Through the tendering procedure stipulated in the Subsidy Agreement, HKSTPC appointed Green Power Industry Ltd to install one SAS on a new 29-seat diesel shuttle bus (hereafter called SAV) for trial.

1.2 The SAV replaced a diesel shuttle bus equipped with a conventional air-conditioning (a/c) system (hereafter called CAV). The CAV was the only conventional vehicle of the same class as the SAV that HKSTPC has. Thus historical data of the CAV, from January to December 2013, would be used in this report to compare with data collected from the SAV.

1.3 PolyU Technology and Consultancy Company Limited (PolyU) has been engaged by the Environmental Protection Department (EPD) as an independent third party assessor to monitor the trial and evaluate the performance of the green innovative technology under trial as compared with its conventional counterpart.

1.4 This report summarizes the performance of the SAV in the 24-month trial as compared with its conventional counterpart.

2. Trial Product and Related Vehicles

2.1 Flexible solar panels, with peak power of 1,320W, are part of the SAS and were installed on the roof of the SAV to supplement the energy needed by an electric compressor of the SAS. The CAV had a conventional a/c compressor mechanically driven by the vehicle's engine.

2.2 Key features of the SAS, SAV and CAV and photos of the SAV are in Appendix 1 and Appendix 2, respectively. The vehicles provided scheduled shuttle services between the Hong

Kong Science Park and Inno Centre in Kowloon Tong and the average daily mileage of the SAV was about 300 km.

3. Trial Information

3.1 The trial started on 1 April 2014 and lasted for 24 months. HKSTPC was required to collect and provide trial information including the SAV operation data and maintenance records. SAV operation data included distance travelled, amount and cost of diesel fuel consumed. Maintenance records included cost and downtime associated with scheduled and unscheduled maintenance of the SAV related to the performance of the SAS. Similar data were also required from the CAV. In addition to the cost information, reports on maintenance work, operational difficulties and opinions of the driver were collected to reflect any problems of the SAS.

4. Findings of Trial

4.1 Operating Costs

4.1.1 The following table summarizes the statistical data of the SAV and the CAV. The average fuel cost of the SAV was HK$0.18/km (ie, about 10%) lower than that of the CAV. Apart from the different data collection periods, the SAV is heavier and has a newer and smaller engine compared with the CAV. While the age and size of engines may affect fuel economy, the gross vehicle weight of the SAV is probably more important here since it is almost 40% heavier. All factors considered, the SAV's better fuel economy is significant but it is difficult to ascertain how much saving in fuel consumption is contributed by the SAS.

Table 1: Key operation statistics of each vehicle (April 2014 – March 2016)

	SAV[1]	**CAV (historical data)**
Total distance travelled (km)	155,153	146,092
Average fuel economy (km/litre)	7.20	6.51
Average fuel cost (HK$/km)	1.57	1.75 [2]
Average total operating cost (HK$/km)	1.57	1.75 [3]
Downtime – a/c system related [4] (working day)	3 (SAS downtime 26 days)	N/A [3]

[1] May 2014 data not used because SAS was not in operation
[2] Calculated using the unit price of diesel used by the SAV in corresponding months
[3] HKSTPC did not provide CAV maintenance information
[4] Downtime refers to the working days that the vehicle is not in operation, which counted from the first day it stops operation till the day it is returned to the operator.

4.1.2 During the trial period, the SAV had three scheduled and one unscheduled maintenances. The three scheduled maintenances were not related to the SAS while the unscheduled maintenance was related to the SAS. Since the trial was about testing the SAS, not the vehicle, therefore, maintenance unrelated to the a/c system was not included in the evaluation of cost and downtime.

4.1.3 Starting from 30 April 2014, the SAS was not operating properly with uncooled air blowing out from the system intermittently, but the SAV was still in operation. The SAV was returned to the SAS supplier for repairing for three days (29-31 May 2014) while a replacement bus was provided by the supplier during these three days with free of charge. No other indirect costs (which may include towing fee, vehicle replacement fee and cost of operation downtime due to maintenance of the SAS) was also required. By estimating from the historical data of the CAV, there was no maintenance required for the air conditioning system. Since no maintenance cost was incurred for the SAV and the CAV, the average total operating costs were the same as their fuel costs which were HK$1.57/km for the SAV and HK$1.75/km for the CAV. Compared with the CAV, the total operating cost for the SAV was about 10% lower.

4.1.4 The SAV had a downtime of 3 days and the SAS had a downtime of 26 days; therefore, utilization rates were 99.6% for the SAV and 96% for the SAS. Although maintenance record of the CAV was not available, estimating from its historical operation data, its utilization rate was close to 100%.

4.2 Performance and Reliability

4.2.1 The driver had no problem in operating the SAV and was satisfied with its performance. He did not receive any complaint from the passengers on the SAS of the SAV. In general, feedbacks from the passengers on the SAV are positive.

4.2.2 Feedbacks from HKSTPC on the SAV are also positive, but HKSTPC has no plan to to replace all existing conventional products with the green product for the time being.

4.2.3 To eliminate the effect of seasonal fluctuations, 12-month moving averages were used to evaluate the trend of the fuel economy of the SAV. The 12-month moving average was almost constant throughout the trial period, indicating that there is no deterioration in fuel economy in the trial period.

5. Summary

5.1 The average fuel cost of the SAV is about 10% (HK$0.18/km) less than that of the CAV. The total operating cost is the same as the total fuel cost because no maintenance cost was incurred. Utilization rate was 99.6% for the SAV, 96% for the SAS and about 100% for the CAV during the trial period. There is no indication that the fuel economy of the SAV has deteriorated during the trial period.

5.2 The SAV driver found no problem in operating the SAV. The SAV was able to cope with its assigned duties.

5.3 The trial results showed that under local operating conditions where air-conditioning is essential, the SAS could meet the SAV's daily air-conditioning requirements. Moreover, the SAS did not cause any problem to the driver during the trial period and was able to cope with required tasks.

Appendix 1: Key Features of the Trial Product and Vehicles Involved

1. Trial Diesel Vehicle (SAV) Installed with Solar Air-conditioning System (SAS)

(a) Solar Air-conditioning System (SAS)

Supplier:	Green Power Industry Ltd
Solar panel type:	Monocrystalline silicon, flexible based
Solar cell efficiency:	21.1%
Solar panel total output:	Max. peak power 1,320W
System controller:	Max. power point tracking, 24V
Electric compressor:	2.12 kW, 24V, brushless DC motor
Additional battery:	210 Ah
Additional Alternator:	110 A

(b) Diesel Vehicle with the SAS (SAV)

Make:	Mitsubishi Fuso
Model:	BE641JRMDA
Class:	Private Bus
Gross vehicle weight:	7,300 kg
Seating capacity:	Driver + 29 passengers
Cylinder Capacity:	2,998 c.c.
Year of manufacture:	2013

2. Conventional Diesel Vehicle with Conventional A/C System for Comparison (CAV)

Make:	Toyota
Model:	BB59RZEMQZ5
Class:	Private Bus
Gross vehicle weight:	5,300 kg
Seating capacity:	Driver + 28 passengers
Cylinder Capacity:	4,104 c.c.
Year of manufacture:	2001

Appendix 2: Photos of Trial Diesel Vehicle (SAV) Installed with Solar Air-conditioning System (SAS)

	
SAV – front view	SAV – end view
	
SAV – side view 1	SAV – side view 2
	
Solar panel, part of the SAS, on SAV roof	SAV – odometer