# Pilot Green Transport Fund

# Final Report On
# Trial of Electric Inverter Air-conditioning System (IAS) for School Bus
# (Jackson Coach Hire Service Limited)

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**Pilot Green Transport Fund**
**Trial of Electric Inverter Air-Conditioning System (IAS) for School Bus**
**(Jackson Coach Hire Service Limited)**

**Final Report**
**(Pair 1 Trial Period: 1 Sep 2016 – 31 Aug 2018)**
**(Pair 2 Trial Period: 1 Feb 2017 – 31 Jan 2019)**

## 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. Jackson Coach Hire Service Limited (JCHS) was approved under the Fund for trial of two units of electric Inverter Air-Conditioner system (IAS) separately installed on two single-deck diesel buses (coaches). Through a tendering procedure stipulated in the Subsidy Agreement (the Agreement), JCHS appointed Tai Chang China Motor Green Power Limited to manufacture and install two IASs with model TCD08Z-II on two new diesel coaches (IAVs) for trial.

1.2 PolyU Technology and Consultancy Company Limited has been engaged by the Environmental Protection Department (EPD) as an independent third party assessor (the Assessor) to monitor the trial and evaluate the performance of the trial vehicles. JCHS assigned an Isuzu diesel coach and a Daewoo diesel coach (CAVs) both installed with conventional air-conditioning system (CAS) as IAVs' conventional counterparts for comparison in this trial.

1.3 This Final Report summarizes the performance of the IAVs in the 24 months of the trial as compared with their conventional counterparts.

2. Trial Vehicles

2.1 Key features of the IAS, CAS, IAVs and CAVs are in Appendix 1 while photos of vehicles are in Appendix 2. The IAV1 provides service as shuttle bus for staff and students of The Chinese University of Hong Kong (CUHK) and as school bus for Quarry Bay School and Kiangsu & Chekiang Primary School. The IAV2 provides shuttle bus service for staff and students of Quarry Bay School in Hong Kong Island East in the first one and half years; in the last 6 months of trial, IAV2 provides shuttle bus service for The Education University of Hong Kong (EdUHK) which is a fixed round route from Ma Liu Shui to EdUHK, located in Ting Kok, New Territories. In the 24-month trial, daily average traveled mileage for providing such services are generally around 131 km and 114 km for the IAV1 and IAV2, respectively.

2.2 According to the IAS' manufacturer, the IAS comprises 2 sets of electric- driven compressor and 4 electric battery packs. The inverter air-conditioners of IAS is driven by the energy stored in the battery packs and the energy output will be controlled by the inverter so as to reduce the fuel consumption. The maximum cooling capacity of the IAS is 36kW. The total weight of the IAS is around 690 kg, while the weight of CAS with model number TCH12U is 243kg, with 38.28kW cooling capacity.

## 3. Trial Information

3.1 Pair 1 trial (IAV1 and CAV1) commenced on 1 September 2016 and pair 2 trial (IAV2 and CAV2) commenced on 1 February 2017. Both trials lasted for 24 months. JCHS is required to collect and provide trial information including the IAVs' operation data, cost and downtime associated with scheduled and unscheduled maintenance of the IAVs. Similar data from the CAVs were also required. In addition to the cost information, operational difficulties and opinions of the drivers were collected and provided to reflect any problems of the IAVs.

## 4. Findings of Trial

4.1 Table 1 summarizes the statistical data of the IAVs and CAVs in the 24 months of the trial.

Table 1: Key operation statistics of each vehicle (September 2016 – August 2018 for IAV1 and CAV1 and February 2017 – January 2019 for IAV2 and CAV2)

| | **IAV** | | **CAV** | |
|---|---|---|---|---|
| | **IAV1** | **IAV2** | **CAV1** | **CAV2** |
| Total distance traveled (km) | 95,778 | 83,229 | 67,083 | 61,120 |
| Daily average traveled distance (km/day) | 131 | 114 | 92 | 84 |
| Fuel cost (HK$) [1] | 453,451 | 389,324 | 295,046 | 431,199 |
| Average fuel cost (HK$/km) | 4.73 | 4.68 | 4.40 | 7.05 |
| Average fuel economy (km/litre) | 2.57 | 2.79 | 2.76 | 1.86 |
| Total operating cost (HK$) | 453,451 | 389,324 | 295,046 | 431,199 |
| Average total operating cost (HK$/km) | 4.73 | 4.68 | 4.40 | 7.05 |
| Downtime (working day) [4] | 0 | 0 [3] | 0 | 0 |

[1] The market fuel price was used for calculation.
[2] In the 24-month trial, there was no maintenance required for IASs and CASs.
[3] Maintenance due to incidents unrelated to the performance of the IAS/CAS was not included for comparison.
[4] Downtime refers to the working days the vehicle is not in operation due to maintenance, which counted from the first day it stops operation till the day it is returned to the operator.

4.2 The above data demonstrated the average fuel cost of the IAV1 was higher than that of CAV1 by HK$0.33/km (i.e., about 8%), while the average fuel cost of the IAV2 was lower than that of CAV2 by HK$2.37/km (i.e., about 34%). Low driving speed and frequently acceleration and deceleration of IAV1 during providing shuttle bus service on CUHK campus caused fuel economy of IAV1 was comparatively poor than that of CAV1 in the 24-month trial.

4.3 In the trial period, there was no maintenance related to IAS's or CAS's performance required for IAV1, IAV2, CAV1 and CAV2, therefore the total operating costs of IAVs and CAVs are same as their average fuel costs. The average total operating cost of IAV1 was HK$0.33/km (about 8%) higher than that of CAV1, while the average total operating cost of IAV2 was HK$2.37/km (about 34%) lower than that of CAV2.

4.4 Since there was no downtime for IAV1 , CAV1 and CAV2; the downtime of IAV2 was not counted due to traffic accident; the utilization rates of the four vehicles were 100%.

4.5 The drivers had no problem in operating the IAVs in general but they were not satisfied with their performance during going uphill. The possible reason for the poor climbing uphill performance is the additional weight of the battery packs and IAC components. JCHS also reflected that the drivers were not satisfied with IAV's performance during going uphill and is not sure if the IAVs help save operational cost. Meanwhile, the IAS manufacturer has already phased out the installed IAS model and no spare parts will be provided. Over 80% passengers interviewed were satisfied or had no comment to the IAV performance.

4.6 Low driving speed, frequent start and stop as well as frequently acceleration and deceleration of IAV1 when providing shuttle bus service on CUHK campus, increased fuel consumption rate.

4.7 To eliminate the effect of seasonal fluctuations, 12-month moving averages were used to evaluate the trend of the fuel economy of the IAVs. During the 24-month trial period, the variation in fuel economy of the IAVs is insignificant and hence there is no indication that the fuel economy has deteriorated during the trial period. However, the fuel economy of IAV2 is much better than that of IAV1.

4.8 In pair 1 comparison, the carbon dioxide equivalent ($CO_2e$) emissions from IAV1 and CAV1 are 98,516 kg and 91,555 kg, respectively and hence there is an increase of 6,961 kg $CO_2e$ emission (which is about 8% increase) in the trial. In pair 2 comparison, the $CO_2e$ emissions from IAV2 and CAV2 are 78,785 kg and 118,039 kg, respectively and hence there is a reduction of 39,254 kg $CO_2e$ emission (which is about 33% reduction) in the trial.

## 5. Summary

5.1 During the 24 months of the trial, the operation data collected showed that IAV2 had lower fuel cost than that of CAV2, with an average fuel cost saving of about 34%. IAV1 had a higher fuel cost than that of CAV1, the average fuel cost of IAV1 was higher than that of its counterpart about 8%. Low driving speed and frequently acceleration and deceleration of IAV1 during providing shuttle bus service on CUHK campus caused higher IAV1's fuel consumption than that of CAV1 in the 24-month trial.

5.2 Since no maintenance was required for IASs and CASs, the average total operating costs of the IAVs and the CAVs are same as their average fuel costs. The utilization rates of the four vehicles were therefore considered as 100%.

5.3 There is no indication that the fuel economy of the IAVs has deteriorated during the trial period.

5.4 The drivers had no problem in operating the IAVs except the unsatisfactory performance of the IAVs' climbing uphill. Same opinion was also reflected from the subsidy recipient. Over 80% passengers interviewed were satisfied or had no comment to the IAVs' performance. The subsidy recipient was not satisfied with the performance of IAVs, and they will not replace their conventional air conditioning system with this inverter air conditioning system.

**Appendix 1: Key Features of Vehicles and the IAS Involved in the Trial**

## 1. Trial Vehicle (IAV) Installed with Trial Electric Inverter Air-conditioning System (IAS)

### (a) Trial Electric IAS

| | |
|---|---|
| **IAS:** | 2 sets inverted air-conditioner and 4 battery packs |
| **Model :** | TCD08Z-II |
| **Make :** | Tai Chang China Motor Green Power Limited |
| **Total cooling capacity :** | 36 kW |
| **Weight of IAS :** | 690 kg (450 kg for 2 sets inverted air-conditioner, 240 kg for 4 battery packs) |

### (b) IAV1 / IAV2

| | |
|---|---|
| **Registration mark:** | CR765 (IAV1) / CH3278 (IAV2) |
| **Make:** | Isuzu |
| **Model:** | LT434PF-6S-V |
| **Class:** | Public bus |
| **Gross vehicle weight:** | 14,800 kg |
| **Seating capacity:** | driver + 65 passengers |
| **Cylinder capacity:** | 7,790 cc |
| **Year of manufacture:** | 2015 |

## 2. Diesel Vehicle (CAV) Installed with Conventional Air-conditioning System (CAS) Used for Comparison

### (a) CAS

| | |
|---|---|
| **CAS :** | 1 set conventional air-conditioning system |
| **Model :** | TCH12U (provided upon purchase of the CAV) |
| **Total cooling capacity :** | 38.28 kW |

### (b) CAVs

| | CAV1 | CAV2 |
|---|---|---|
| **Registration mark :** | TA8220 | SZ8009 |
| **Make :** | Isuzu | DAEWOO |
| **Model :** | LT134P-6S-V | BH117L |
| **Class :** | Public bus | Public bus |
| **Gross vehicle weight :** | 14,500 kg | 16,000 kg |
| **Seating capacity :** | driver + 65 passengers | driver + 65 passengers |
| **Cylinder capacity :** | 7,790 cc | 7,640 cc |
| **Year of manutfacture :** | 2013 | 2014 |

## Appendix 2: Photos of Vehicles

### 1. IAVs Installed with IASs

**IAV1**

| | |
|---|---|
|  |  |
| CR765 – front view | CR765 – rear view |
|  |  |
| CR765 – side view 1 | CR765 – side view 2 |

**IAV2**

| | |
|---|---|
|  |  |
| CH3278 – front view | CH3278 – rear view |

| | |
|---|---|
|  |  |
| CH3278 – side view 1 | CH3278 – side view 2 |

## 2. CAVs installed with CASs used for comparison

**CAV1**

| | |
|---|---|
|  |  |
| TA8220 – front view | TA8220 – rear view |
|  |  |
| TA8220 – side view 1 | TA8220 – side view 2 |

**CAV2**

| | |
|---|---|
|   |   |
| SZ8009 – front view | SZ8009 – rear view |
|   |   |
| SZ8009 – side view 1 | SZ8009 – side view 2 |