Appendix II

EMFAC-HK Modelling Assumptions[1]

This document sets out the key EMFAC-HK assumptions.

The estimate in EMFAC-HK may deviate from the actual situations in future. The user shall revise the default values to ensure that they reflect the actual situations.

1. Population

In EMFAC-HK, the vehicle population forecast function reflects natural replacement as well as the programmes on mandatory retirement of pre-Euro 4/IV and Euro 4/IV diesel commercial vehicles as described in later sections.

Growth Rates

The growth rates for private cars (PC), motorcycles (MC) and goods vehicles were estimated based on the Transport Department (TD)'s latest inputs.

For other vehicle classes, the following assumptions were made:

- As the numbers of franchised buses, public light buses and taxis are regulated by TD and there is no information predicting future trend, their growth rates are assumed to be zero.
- For non-franchised buses and private light buses, as there is no information predicting the future trend, their growth rates are assumed to be zero.

Survival Rates

- Except for franchised buses, the survival rates are composed of a short-term one and a long-term one. Vehicle populations of years 2009-2012 were used to fit the short term survival rates while all available data from 2002 to 2012 (except for taxis which is from 2005 to 2012) were used to fit the long term survival rates. If the projecting year is within 5 years from the default base year, the short term curve will be used, otherwise the long term curve will be used. Population of later years have not been used for estimating natural survival rates because various control measures programmes, for example:

    - subsidy programme for the replacement of catalytic converters and oxygen sensors on LPG/petrol taxis and LPG light buses, conducted between 2013 and 2014; and

    - phasing out programme of pre-Euro IV diesel commercial vehicles implemented between 2014 and 2021,

[1] Changes made in the January 2021 update are highlighted in red colour except misprint, editorial changes or obsolete texts. For previous versions of this document, please visit the EMFAC-HK webpage (https://www.epd.gov.hk/epd/english/environmentinhk/air/guide_ref/emfac-hk.html).

are expected to have changed the natural replacements of vehicles.

- For taxis, due to government subsidized policy to switch them from diesel to LPG, almost none was registered in the years before 2000 and around 300-500 were registered each year after 2003. Hence, the retention rate curves obtained from the 2003-2005 populations are not representative. More accurate natural replacement rates can be obtained further away from these years, so only population data from 2005-2012 were used for the estimation of their survival rates. However, even so, the available ages for taxis are insufficient to obtain accurate curve in the range for older age. Thus, for model years 1998 or before, old population for diesel taxis were used.

- For franchised buses, no replacement is done until the vehicle is forced to retire when it reaches 18 years old. To cater for exemption granted by TD to extend some franchised buses for one more year in 2016, the survival rates are revised to retire franchised buses of 18 to 20 years old.

New Sales

Starting with EMFAC-HK V4.1, the methodology in mitigating sharp anomalies in new sales was deemed unnecessary and disabled for all vehicle classes.

2. Mandatory retirement of pre-Euro IV diesel commercial vehicles[2] (DCV)

Under this programme, the following were taken into account:

a) an ex-gratia payment for phasing out pre-Euro IV DCVs;
b) mandatory requirement to phase out pre-Euro IV DCVs by their first registration dates according to the schedule below; and

Table 1 Phasing out schedule

Emission Standard	Start Time of Non-license renewal
Pre-Euro	2016
Euro 1/I	2017
Euro 2/II	2018
Euro 3/III	July, 2020

c) a 15-year limit on service life of DCV first registered on or after 1 February 2014.

In population forecast function, the pre-Euro 4/IV DCV population are gradually removed from the fleet starting from one year before the non-renewal deadline till one year after that (e.g. from 2019

[2] The term “diesel commercial vehicles” refers to all diesel goods vehicles, light buses and non-franchised buses.

to 2021 for Euro 3/III). The reduction fractions (on top of natural replacement) are 33%, 80% and 100% for the three years respectively.

Also, effective from the model year 2014, the population forecast function will remove DCV equal to or older than 16 years old. For example, starting from the calendar year 2029, DCV with model years on or after 2014 will be removed.

3. Mandatory retirement of Euro IV diesel commercial vehicles[3] (DCV)

The Government will progressively phase out from Oct 2020 to end **2027** Euro IV DCVs. In the model, the number of Euro IV DCVs by model year since the announcement of the programme in October 2018 was assumed to remain unchanged until before the programme starts. Starting from 2021, Euro IV DCVs will be gradually removed from the fleet in order to model the effect of the retirement program.

4. Inspection and Maintenance (I/M) Programme

The existing I/M programme is the Strengthened Emissions Control for Petrol and LPG Vehicles (a I/M programme using remote sensing and dynamometer testing) (the Existing I/M Programme). Data collected for petrol PC and LPG taxis in this programme in 2018 were analysed to estimate their regime growth rates. The result had been incorporated into the model's regime growth rates.

For LPG public light buses and private light buses with gross vehicle weight greater than 3.5 tonnes, due to small data size, 40% and 20% of high/super emitting vehicles are assumed to be repaired to normal emitters due to the Existing I/M Programme respectively.

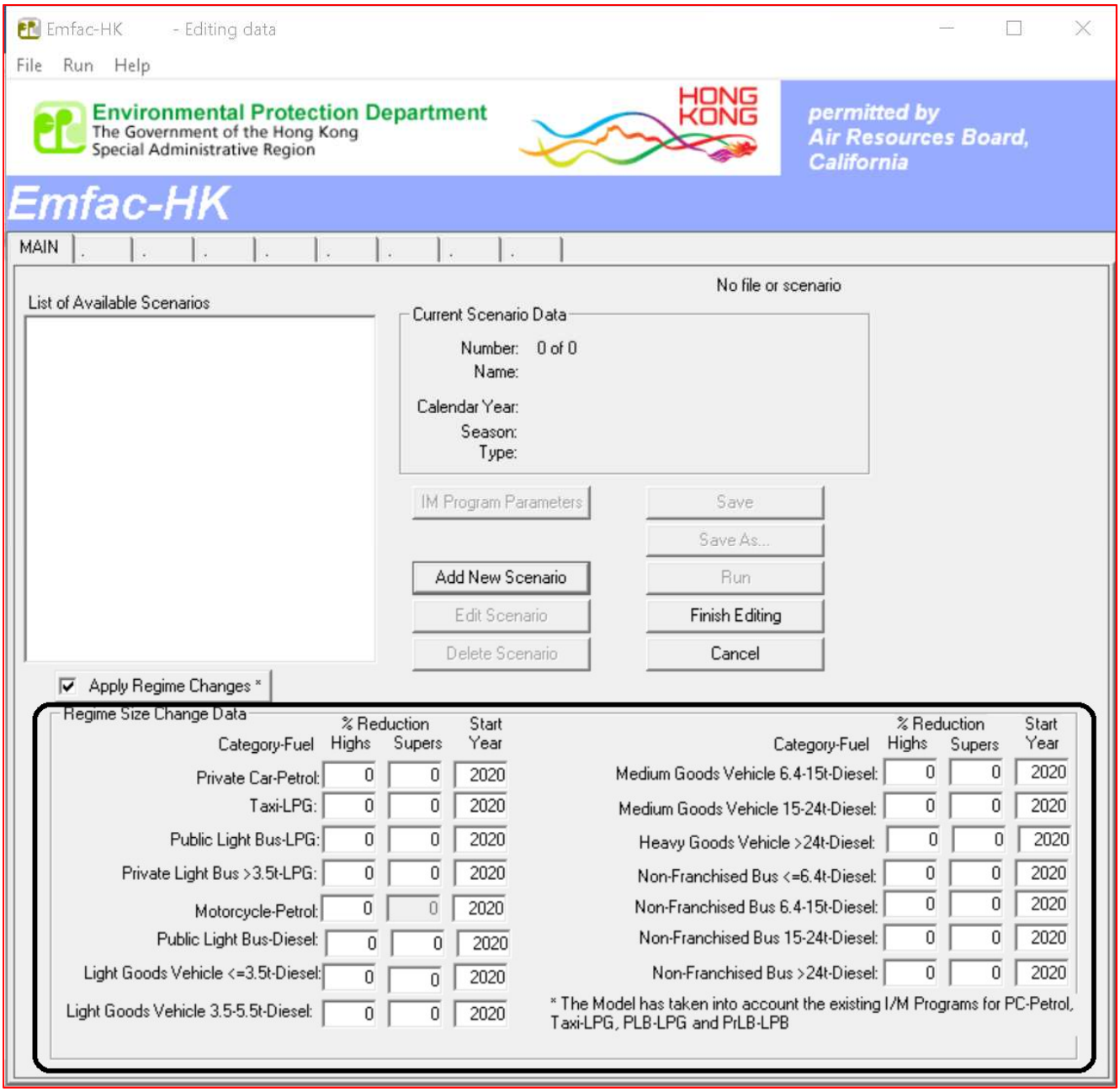
The above default reductions for LPG light buses due to the Existing I/M Programme will continue to apply in the model. However, users will not be able to alter these reductions.

5. Extra I/M Improvement

The % reductions in Figure 1 represent any extra reductions due to new I/M programmes the users would like to apply in addition to the Existing I/M Programmes. By default these reductions are zeros. Users can now change these values in the GUI or INP file. **Note that project proponents or environmental consultants have to provide justifications for any change of the default figures.**

[3] The term "diesel commercial vehicles" refers to all diesel goods vehicles, light buses and non-franchised buses.

Figure 1 – Screen shot in upgraded model showing that the extra reductions due to new I/M programmes for all classes are set to zero by default. Please note that the existing I&M Programme is already incorporated in the model.



Users should note that some technology groups do not have high regime and thus the I/M reduction parameters for high regime are not applicable to them[4].

6. Retrofitting Euro II and III double deck franchised buses with Selective Catalytic Reduction (SCR) devices

[4] See "Regime Assumptions" in later sections for more information.

Technology group (Tech group) fractions of double deck franchised buses for 2017 and beyond were updated in line with the completion of the programme in end 2017.

7. Subsidy programme for the replacement of catalytic converters and oxygen sensors on LPG/petrol taxis and LPG light buses

The vehicles in the tech groups for vehicles with catalytic converters (CAT) replacements were assumed like new ones for emissions of total hydrocarbons (THC), volatile organic compounds (VOC) and carbon monoxide (CO). However, the analysis of LPG taxi emissions showed that little difference was found for their nitrogen oxides (NOx) emissions before and "more than 6 months after" CAT replacement. Hence, the CAT replaced taxis are not treated as new vehicles for NOx emissions. Also, regime growth rates for these tech groups are different from that of the non-replaced one for the LPG light buses but they are the same for LPG Taxis.

8. Regime-Specific Correction Factors

All types of correction factors are applied to high and super regimes as to the normal regime.

9. Technology Groups (Tech Groups)

Due to the splitting of the two original vehicle classes "Medium Goods Vehicles (>15t)" and "Non-franchised Buses (>15t)" into four classes, the below tech groups are either redefined or created in EMFAC-HK V4.3.

Vehicle Class	Fuel	Tech Group Description	Tech Group Index	Remark
Medium Goods Vehicles (15-24t)	Diesel	pre-Euro	153	Redefined existing Tech Groups
	Diesel	pre-Euro DOC Retrofitted	155	
	Diesel	Euro I	154	
	Diesel	Euro II	157	
	Diesel	Euro III	159	
	Diesel	Euro IV	160	
	Diesel	Euro IV - DPF	163	
	Diesel	Euro IV - SCR	164	
	Diesel	Euro V	161	
	Diesel	Euro V - DPF	165	
	Diesel	Euro V - SCR	166	
	Diesel	Euro VI	162	
Non-franchised Buses (15-24t)	Diesel	pre-Euro	53	Redefined existing Tech Groups
	Diesel	pre-Euro DOC Retrofitted	55	
	Diesel	Euro I	54	
	Diesel	Euro II	57	

Vehicle Class	Fuel	Tech Group Description	Tech Group Index	Remark
	Diesel	Euro III	59	
	Diesel	Euro IV	60	
	Diesel	Euro IV - DPF	63	
	Diesel	Euro IV - SCR	64	
	Diesel	Euro V	61	
	Diesel	Euro V - DPF	65	
	Diesel	Euro V - SCR	66	
	Diesel	Euro VI	62	
Heavy Goods Vehicles (>24t)	Diesel	pre-Euro	246	New Tech Groups
	Diesel	pre-Euro DOC Retrofitted	248	
	Diesel	Euro I	247	
	Diesel	Euro II	250	
	Diesel	Euro III	252	
	Diesel	Euro IV	253	
	Diesel	Euro IV - DPF	256	
	Diesel	Euro IV - SCR	257	
	Diesel	Euro V	254	
	Diesel	Euro V - DPF	258	
	Diesel	Euro V - SCR	259	
	Diesel	Euro VI	255	
Non-franchised Buses (>24t)	Diesel	pre-Euro	232	New Tech Groups
	Diesel	pre-Euro DOC Retrofitted	234	
	Diesel	Euro I	233	
	Diesel	Euro II	236	
	Diesel	Euro III	238	
	Diesel	Euro IV	239	
	Diesel	Euro IV - DPF	242	
	Diesel	Euro IV - SCR	243	
	Diesel	Euro V	240	
	Diesel	Euro V - DPF	244	
	Diesel	Euro V - SCR	245	
	Diesel	Euro VI	241	

For all the current tech group definition, please visit our webpage at:

www.epd.gov.hk/epd/english/environmentinhk/air/guide_ref/emfac-hk.html

10. Base Emission Factors and Speed Correction Factors

Real-world vehicle emission measurement data obtained from about 320 vehicles with 200 of Euro IV to VI by using Portable Emission Measurement System (PEMS data) were used to update zero mile emission factors (ZMEFs), deterioration rates (DRs) and the speed correction factors (SCFs). These 320 vehicles were grouped by vehicle make, age, weight, technology type, and other characteristics for the purpose of calculating the emission factors (EFs) in durations of 1 minute and 8 minutes by average speed. Medians of EF at 30 km/hr +/- 5 km/hr for each vehicle for all vehicles within the same technology group are plotted against its mileage to determine ZMEFs and DRs of that technology group. A SCF of a technology group is obtained by fitting the ratios of medians of speed bins, each of 8 km/hr, over the ZMEF for that particular technology group.

11. Regimes Assumptions

Three Regimes are assumed for the following cases:

- For PM, diesel vehicles equipped with DPF except PC; and
- For NOx/VOC/CO, LPG/petrol vehicles.

All other cases only have two regimes.

Remarks:

- All Diesel Euro 6/VI vehicles are assumed to be equipped with DPF and SCR.
- Euro IV and V Diesel Public Light Buses are assumed to be equipped with DPF.
- Tech Group 204 is used for both petrol and diesel private light buses. Above convention for diesel will be followed.

12. NOx Start Emissions for SCR-Equipped Vehicles

The temperature of SCR should be higher than 200ºC for its effective operation, so cold start NOx emissions of SCR-equipped vehicles are much higher than hot running NOx emissions. NOx start emissions for diesel vehicles equipped with SCR in EMFAC-HK V4.2 are revised to be in line with EMFAC2017 developed by the California Air Resources Board (CARB)[5]. That is, a soak-time correction curve is applied to the cold start emission factors. The emission factors are also revised.

13. Hydrocarbons Speciation Updates

Conversion factors for converting THC emission rates to total organic gases (TOG), VOC and methane (CH4) are aligned with EMFAC2017[6].

[5] CARB, California Environmental Protection Agency, EMFAC2014 Volume III - Technical Documentation v1.0.7, 2015.
[6] CARB, California Environmental Protection Agency, EMFAC2014 Volume III - Technical Documentation v1.0.7, 2015 and CARB, California Environmental Protection Agency, EMFAC2017 Volume III - Technical Documentation v1.0.2, 2018.