TECHNICAL NOTE

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SUBJECT:	User Carbon Emissions Research		
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1 Introduction

1.1 Project Objectives

WSP has been asked by the DfT to undertake a review of the methods available to estimate user carbon emissions (focussed on road schemes). The methods that have been considered are alternative approaches to implementing the Transport Analysis Guidance (TAG) requirement to estimate user emissions. The approaches that have been assessed in this research are the Emissions Factors Toolkit (EFT), Transport User Benefit Appraisal software (TUBA) and a bespoke calculation using the TAG data book parameters (referred to in this paper as the 'bespoke approach'). The objectives of the project include:

- A literature review of the underlying evidence informing road user carbon assessments.
- Map the relationships used to calculate carbon emissions in the Emissions Factor Toolkit (EFT), TUBA and TAG.
- Understand how the strategic modelling inputs impact the calculation of carbon emissions in EFT, TUBA and the bespoke approach.
- Understand why there are differences in carbon emissions calculated by EFT, TUBA and the bespoke approach.
- Identify when it is proportionate to use each method and provide guidance on the interpretation of the outputs.

1.2 General Assumptions

The scope of the research is bound by the following assumptions:

- User carbon emissions only (i.e. excludes capital and operating carbon emissions).
- Only considers road users.
- Only considers current DfT endorsed methods (EFT / TUBA / TAG based calculations).
- Focuses on strategic modelling (i.e. microsimulation not considered at this stage).

The versions of software and TAG data book used within the project are:

- EFT version 12.0.1 (November 2023)
- TUBA version 1.9.17.2 with economics file 1.9.22.0
- TAG data book version 1.23 (May 2024) – which has the same fuel consumption rates as the TUBA economics file

2 Overview of the Methods

2.1 EFT Overview

The Emissions Factors Toolkit (EFT)[1] website says that it

> *"…is published by Department of Environment and Rural Affairs (Defra) and the Devolved Administrations to assist local authorities in conducting review and assessment of local air quality as part of their duties under the Environmental Act 1995 as amended by the Environment Act 2021."*

The EFT is a spreadsheet model built in Microsoft Excel and available from the Defra website[2] along with a user manual. The spreadsheet includes macros that implement the calculations that convert the user inputs (including link length, traffic flow, vehicle types and link speeds) into the reported outputs (CO_2 grammes per kilometre and CO_2 tonnes per year). Outputs are recorded within the same spreadsheet in tabular format, but the calculation process is hidden from the user and cannot be modified.

The EFT allows users to calculate road vehicle pollutant emission rates for NO_x, PM_{10}, $PM_{2.5}$ and CO_2 for a specified year, road type, vehicle speed and vehicle fleet composition.

The EFT is updated periodically due to updates to the underlying data, including vehicle fleet composition and emissions factors.

For the purposes of this study an 'unlocked' copy of the toolkit was provided in order to allow the research team to follow the EFT process and calculations between the workbook tabs.

2.2 TUBA Overview

The TUBA software undertakes the economic appraisal of transport schemes in accordance with the DfT's cost benefit analysis guidance. The software implements a 'willingness to pay' approach to economic appraisal for multi-modal schemes with fixed or variable demand.

The User Manual[3] explains:

> *"TUBA undertakes a matrix-based appraisal with either fixed or variable trip matrices. It takes trip, time, distance and charge matrices from a transport model. These matrices may be disaggregated by vehicle type, purpose, and person type. The user also inputs other costs associated with the do-minimum and do-something schemes. TUBA will then calculate the user benefits in time, fuel vehicle operating costs (VOC), non-fuel VOC and charge; operator and government revenues; and the scheme costs, discounted to the present value year. Values calculated from input model data will be interpolated and extrapolated to cover the full appraisal period, as necessary. The output file contains all these results for various degrees of disaggregation and also presents the data in a series of summary tables showing the economic efficiency of the transport system, known as TEE tables. Results are reported as perceived costs and market prices." (p1-1)*

TUBA is a standalone piece of software that was developed and is maintained on behalf of the DfT. The software imports data from transport models and combines these with a control file specifying various economic input values but all of its calculation steps are internal with no opportunity for the user to adjust or modify them. TUBA outputs text files that can be manipulated via spreadsheets.

2.3 Bespoke Approach Overview

The bespoke approach used for this Technical Note utilises an MS Excel spreadsheet in combination with data from the TAG data book.[4] The data book describes itself as:

[1] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/
[2] https://laqm.defra.gov.uk/wp-content/uploads/2024/04/EFT2023_v12.0.1.xlsb
[3] https://www.gov.uk/government/publications/tuba-downloads-and-user-manuals
[4] https://www.gov.uk/government/publications/tag-data-book

“This data book has been prepared for transport modelling and appraisal purposes and should be applied in accordance with wider guidance in TAG.”

To create the bespoke approach spreadsheet the following tables are required from the data book:

- A1.3.9 provides annual estimates of vehicle kilometres by three different fuel types (petrol, diesel and electric) and five vehicle types (car, LGV, OGV1, OGV2 and public service vehicles).
- A1.3.10 provides the annual estimates of fuel efficiency improvements for the same fuel and vehicle combinations.
- A1.3.11 provides the energy consumption parameter values for each year between 2010 and 2089 for petrol and diesel engines to estimate litres of fuel and for electric motors as kilowatt hours for the generated electricity.
- A3.3 provides the CO_2e[5] in kilograms per litre of fuel.

To set up a spreadsheet model to estimate CO_2e using values taken from each of these tables also requires inputs of the number of vehicles as cars, LGVs, OGV1, OGV2 and PSVs per link along with the link speed and length. By defining several relatively simple equations these input values can be converted into energy consumption as litres of fuel per kilometre, fuel consumed in total by type (litres for petrol or diesel and kilowatt hours for electric vehicles) and CO_2e in kilograms.

3 Literature Review

3.1 Reviewed Documents

The user manuals for TUBA and EFT both commonly refer to a series of documents which are relied on for various input data and calculation processes. The manner in which these documents are used in either TUBA or EFT or both has been summarised in a process map attached in Appendix A and each of the documents is considered below.

COPERT II Computer Programme to calculate Emissions from Road Transport (1997), P Ahlvik, S Eggleston, N Gorißen, D Hassel, A-J Hickman, R. Joumard, L Ntziachristos, R Rijkeboer, Z Samaras and K-H Zierock; European Environment Agency

The COPERT software was developed as a standardised method to estimate emissions from transport in the countries of the European Union. The original COPERT was developed as COPERT 85 released in 1989, then COPERT 90 released in 1990 with COPERT II being published in 1997.

The emissions estimation process in COPERT relies on a simple equation:

$$Emissions\ (g) = emissions\ factor\ (g/km)\ x\ vehicle\ kilometres\ per\ year\ (km)$$

With

“The emission factors and vehicle kilometers are in most cases split into certain classes of road types (as the use of the average speed for its calculation implies) and vehicle categories.” (p 7)

Average speed in COPERT II was defined by classification of roads into one of three categories:

- Urban – 20 kilometres per hour.
- Rural – 60 kilometres per hour.
- Highway – 100 kilometres per hour.

The report states:

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[5] CO_2e is used to express the impact of different greenhouse gases in terms of the equivalent (e) amount of CO_2 that would have the same global warming potential.

“Vehicle speed, which is introduced into the calculation via the three road types, has a major influence on the emissions of the vehicles. Different approaches have been developed to take into account the driving patterns. With the emission factors presented in this chapter, the authors propose two alternative methods:

- *to select one single average speed, representative of each of the road types ‘urban,’ ‘rural’ and ‘highway’ (e.g. 20 km/h, 60 km/h and 100 km/h, respectively) and to apply the emission factors taken from the graphs or calculated with the help of the equations, or*
- *to define mean speed distribution curves and to integrate over the emission curves.*

It is evident that the first approach mentioned above is much easier and most likely the one to be chosen by most of the countries.” (p. 9)

A caveat was also introduced:

“However, for many countries the only data known with any certainty is the total fuel consumption of petrol, diesel and LPG, not vehicle kilometers. It is therefore suggested that fuel consumption data are used to check vehicle mileage where they are known and to make a final fuel balance.” (p. 7)

This caveat introduced the protocol of estimating emissions relative to fuel consumed as opposed to distance travelled along with the need to convert grams per kilometre into grams per kilogram of fuel consumed.

ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems – final report (2007), PG Boulter and IS McCrae (Eds); TRL Report 350

The ARTEMIS study considered various European transport related emissions models, of which COPERT is one, to identify why those models were producing different results, including reviewing the data collection methodologies and how uncertainties in the modelling were presented. The study also aimed to develop a harmonised methodology for estimating emissions from transport at the national and international levels such that comparisons could be made between countries more easily and efficiently.

The study observed that:

“All emissions models must take account of various factors affecting emissions, although the manner in which they do so, and level of detail involved, can differ substantially from model to model. One of the commonest approaches is based upon the principle that the average emission factor for a certain pollutant and a given vehicle type varies according to average speed during a trip…

“There is now considered to be a number of limitations associated with average-speed models, one of which is the inability to account for ranges of vehicle operation and emission behaviour which can be observed for any given average speed…

“… the concept of driving cycle ‘dynamics’ has become useful for emission model developers.” (p 6)

In addition to the average speed approach having limitations, it was recognised that:

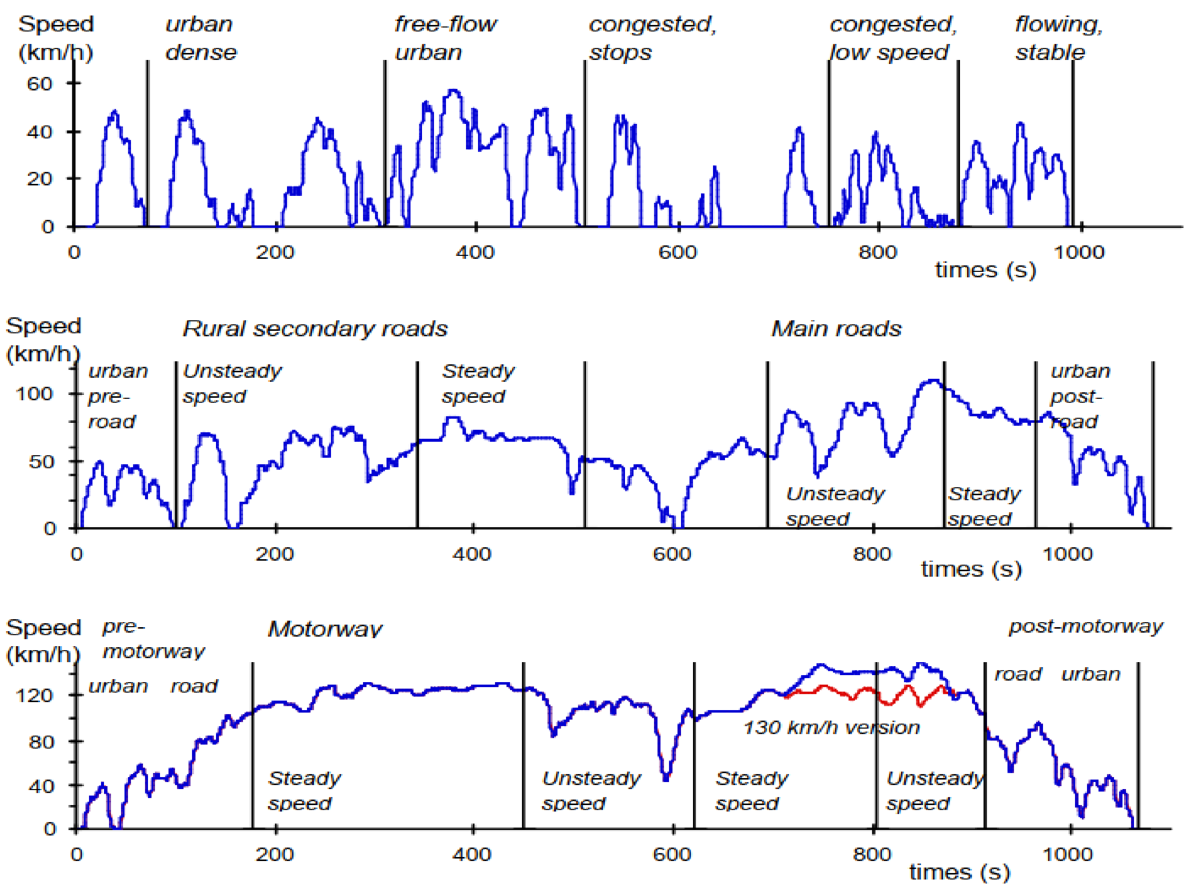
“An accurate and detailed knowledge of actual driving speeds is fundamental for emission estimations and inventories. A review of the speed data available from different sources was conducted by Fantozzi et al. (2005b). The review highlighted the difficulties in obtaining reliable and detailed speed data. Various information is available through measurements, surveys and modelling exercises. However, the data are often limited to average speed values. Speed distributions and speed profiles (or speed x acceleration matrices) can be obtained from instrumented vehicles, but the data are often incompatible with the degree of detail that would be needed.” (p32)

One fundamental issue raised in this statement is the difficulty obtaining reliable and detailed speed data. The study authors felt that differences in data collection techniques at various laboratories across Europe was a potential source of inconsistency between models, especially with respect to vehicles speeds. ARTEMIS introduced the concept of driving cycles as a means to establish reliable emissions factors for different vehicles.

> *"In order to improve the representativeness of the ARTEMIS emission tests, and the comparability of the measurements made in different laboratories, a reference set of real-world driving cycles was developed for use by all the project partners. The development of these driving cycles was conducted in four stages: (i) the observation of vehicle usage and operating conditions, (ii) the analysis of driving conditions, (iii) the analysis of vehicle trips and (iv) the development of representative driving cycles.*
>
> *"In all, 77 vehicles were monitored over 10,300 trips. These trips covered a total distance of 88,000 km and had a total duration of 2,200 hours. Vehicle usage and operating conditions, such as speed, acceleration, engine operation, trip information, gearbox use, and engine thermal condition, were recorded in detail.*
>
> *"Three main real-world driving cycles - 'urban,' 'rural,' and 'motorway' - were then constructed to represent driving according to the respective area/road types" (p 38)*

A representation of the pattern of travel through a drive cycle is shown in Figure 1 below.

Figure 1: ARTEMIS Driving Cycles



Source: Figure B3-1 The ARTEMIS urban, rural and motorway driving cycles, including sub-cycles and starting conditions (Andre, 2004)

A Reference Book of Driving Cycles for use in the Measurement of Road Vehicle Emissions (2009), TJ Barlow, S Latham, IS McCrae and PG Boulter TRL Report 354

TRL was commissioned by the DfT to review how the National Atmospheric Emissions Inventory (NAEI) estimated emissions from transport. To fulfil this task:

"…requires some consideration to be given to the emissions measurement process, an important aspect of which is the definition and application of driving cycles to represent different types of vehicle operation." (p. 1)

The report describes how driving cycles are conducted:

"In tests conducted using a chassis dynamometer the vehicle drive wheels are positioned so that they are in contact with rollers. The rollers can be adjusted to simulate friction losses and aerodynamic resistance. The sampling of exhaust emissions is then performed as the vehicle progresses through a pre-defined driving cycle which is designed to represent a particular type of real-world operation.

"A driving cycle is therefore a fixed schedule of vehicle operation which allows an emission test to be conducted under reproducible conditions. Driving cycles are usually defined in terms of vehicle speed and gear selection as a function of time. A trained driver is employed to follow the driving cycle on the chassis dynamometer, and a 'driver's aid' is provided to ensure that the driven cycle is as close as possible to the defined cycle." (p. 2)

The process of producing speed related emissions factors is:

"A continuous average-speed emission function is fitted to the emissions factors measured for several vehicles over a range of driving cycles with each cycle representing a specific type of driving." (p. 2)

Having defined and explained driving cycles the report considers which data are most appropriate for the UK given its highway characteristics.

EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories, (2019), https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

This report published by the EEA contains technical guidance on preparing national emission inventories, where chapter 1.A.3.b.i-iv covers road transport emissions and 1.A.3.b.i-iv Appendix 4 contains the vehicle emission factors for COPERT that are used by the EFT. The version of this appendix in the 2016 edition of the EEA guidebook is also the original source of data for the TAG fuel consumption parameters.

Section 3.4 of the report describes the detailed methodology for calculating vehicle exhaust emissions, which is the methodology used by COPERT. The EFT generally follows the methodology given for calculating hot exhaust emissions.

ED15103132 - rtp_fleet_projection_NAEI_2020_Base 2022_v1.0 (2022), Ricardo Energy and Environment for the National Atmospheric Emissions Inventory

This spreadsheet contains work undertaken by Ricardo Energy & Environment on UK fleet composition projections. The projections are used in the EFT and used in conjunction with emission factors in COPERT 5.6. An important note is that the fleet data in the workbook refers to vehicles outside of London, with Transport for London providing detailed information on the fleet composition data for London.

The 'Notes' worksheet explains the derivation of the 2022 base fleet projections as follows:

"The Base 2022 projections were derived from the emission projections developed for the 2020 version of the National Atmospheric Emission Inventory programme in March 2022 using information provided by DfT in December 2021 on future sales and activities of new petrol, diesel and electrically-powered cars and LGVs, combined with future forecasts in traffic (vehicle kilometres) including other vehicle types from DfT's National Transport Model."

The worksheet continues to explain that the projections are provided in two formats.

- Basic fleet split
- Car, LGV, Rigid, Artic, Bus, Motorcycle – which provide a more detailed breakdown of fleet composition with each vehicle type then split per Euro class and catalyst status

The worksheet notes state that a typical fleet mix split by vehicle type and road type in each of the Devolved Administrations are provided in the workbook. It then continues to provide information about the source of this data:

> "*For years up to 2020, data are based on the actual road traffic statistics published by DfT; while for future years, data are based on DfT's Road Traffic Forecast for the UK outside of London and projected split between vehicle kilometres travelled by petrol, diesel and electrically-powered cars and LGVs. The traffic forecasts as vehicle kilometres travelled by vehicle and road type are from DfT's Transport Appraisal and Strategic Modelling NTM (National Transport Model) run completed in October 2021 (EEP2019 Core ULEV Uptake, Core GDP & HGV Regs) and are re-based to actual vehicle kilometres in 2019. The fuel splits for cars and LGVs in years up to 2020 are based on trends observed on different road types using Automatic Number Plate Recognition data from DfT's Roadside Survey. For future years, the fuel splits in vkm travelled are based on data provided by DfT's Environmental Analysis in Decemember [sic] 2021. The splits shown for electric cars refer to the combined mileage driven by battery electric vehicles and by plug-in hybrid cars using power from the mains, associated with zero exhaust emissions. The splits for petrol cars include the fraction of mileage done by both conventional petrol and hybrid cars under engine power."*

The second format provided projections for each vehicle type as the proportion of vehicle kilometres travelled by the different Euro emissions standard and hybrid vehicle types for which emission factors are available. The note then provides information about the source of this data:

> *"The fleet composition data are calculated by Ricardo's recently revised NAEI fleet turnover model combined with forecasts in new vehicle sales of cars and LGVs from DfT's Enviromental [sic] Analysis. A major update to the fleet turnover model was made in 2021 from re-analysis of new, more details vehicle registration data and MOT annual mileage by age data from DfT. Details of the NAEI fleet turnover model and assumptions are provided in a report to Defra "The Development of the NAEI Road Transport Fleet Turnover Model (July 2021)". The major changes made are to the survival and mileage with age functions used in the fleet turnover model using the latest evidence. Future sales of new petrol, diesel, hybrid and electrically-powered cars and LGVs were forecast by DfT from a baseline (firm & funded) scenario and does not include measures to phase out sale of ICE vehicles by 2030 or 2035. Policies and measures that underpin these updated datasets include the following:*
>
> *- Renewable Transport Fuel Obligation (RTFO)*
>
> *- Fuel efficiency policies for cars, vans, HGVs and PSVs*
>
> *- Rail electrification*
>
> *- Active travel spending*
>
> *The main reasons for change from the previous (Base 2019r) fleet projections are therefore due to major improvement to the NAEI's fleet turnover model; changes to the forecast assumptions on new vehicle sales and fuel mix by DfT; and re-basing to the latest inventory year (2020)."*

The workbook continues to explain that the fleet composition data is provided in units of vehicle kilometres travelled and considers that newer vehicles travel more miles in a year than older vehicles. It also states that the information is based on national UK fleet data and variations from the national average should be expected.

A note is made on the proportion of vehicles with failing catalysts and filters each year:

> *"A proportion of petrol cars fitted with three-way catalysts are assumed to fail each year; similarly a proportion of Euro 5 and 6 diesel cars fitted with diesel particulate filters (DPF), and Euro 6 diesel cars equipped with Selective Catalytic Reduction (SCR) systems are assumed to fail each year. Please note that separate data blocks of fleet composition data are provided, depending on the pollutant concerned since failing DPFs are assumed only to affect PM and failing SCR systems assumed to only affect NOx. The failure rates are derived from advice provided by DfT and take*

into account EU Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009."

Information is also provided on the split of pollutant emission factors:

"Emission factors of some pollutants are available for different engine size ranges or vehicle weight classes, and thus current national figures on the vehicle mix by engine size or vehicle weight are provided. It is assumed that the size fractions remain constant at 2020 levels in future years, as there is no information available regarding the future trend."

While it is suggested that the fleet composition data is used in conjunction with COPERT 5.6 emission factors, it is noted that the speed-emission factor equations used in the 2020 NAEI and the projections were from COPERT 5.4.

The workbook provides fleet composition projections used in the EFT v12 and the Notes worksheet provides and explains the sources used to calculate the projected data.

Production of Updated Emission Curves of Use in the NTM and WebTAG, 2019, Ricardo Energy and Environment for the DfT

This report covers the work commissioned by DfT to update fuel consumption and emissions curves for use in the National Transport Model using the most up to date information from COPERT. At the time the report was prepared COPERT 5 had been issued and the NAEI and Transport for London had both updated their vehicle fleet projections since the previous estimation of fuel consumption and emission curves in 2014.

The report explains that there are conversions and approximations required to produce curves suitable for use in the NTM and TAG.

"Updated emission and fuel consumption factors expressed as curves varying by speed (v) have been developed for the NTM in the form of a 6th-order polynomial equation:

$$y = \frac{a + bv + cv^2 + dv^3 + ev^4 + fv^5 + gv^6}{v}$$

Fuel consumption curves have been developed for the years 2010, 2015, 2020, 2025, 2030 and 2035 covering each main vehicle category using conventional petrol and diesel fuels and powertrains. Fuel consumption and CO_2 emission curves have also been developed for DfT's Transport Analysis Guidance tool, WebTAG, for the years 2010 and 2015 in the form of a 3rd-order polynomial equation:

$$EF = \frac{a + bv + cv^2 + dv^3}{v}$$

Separate speed emission curves representing the fleet in central, inner and outer London, London as a whole and the rest of the UK have been developed for the NTM and WebTAG.

All the emission curves required a statistical re-fitting of the equations in the different COPERT 5 format to match the requirements of the NTM and WebTAG." (p ii)

A note of caution is sounded in the report:

"The report considers the limitations of the new emission curves in terms of their parameterisations. The curves refer to a relationship between emission factors and average speed of a drive cycle and should not be inferred to represent very localised, instantaneous emission rates at a specific, transient speed." (p. iii)

The objective of the commission was achieved by implementing a two-step process:

"The main task in developing the emission curves for the NTM and WebTAG was to:

a) convert the many separate emission curves provided for the different vehicle sizes and Euro standards of each main vehicle category in COPERT into a single curve for a specific year that is weighted by the fleet compositions for that year, and *b) to refit the curve from the mathematical form of the equation in COPERT to the specific mathematical forms of the equations used in the NTM and WebTAG." (p. 5)*

Emissions factors were calculated at 1 kilometre per hour intervals for each sub-class of vehicle in the COPERT database and then a single curve was produced using a weighting process reflecting the characteristics of the vehicle fleet in the UK. These values were then fitted to the TAG equation

"…using the non-linear least squares fitting function within the R statistical software package." (p. 5)

The report mentions a simplification employed for goods vehicles:

"In the case of HGV and bus and coach emission factors, COPERT provides separate emission curves for different vehicle loadings and road gradients. Emission coefficients for a vehicle at 50% load and 0% road gradient were used in all cases, consistent with the assumption used in the NAEI and considered to be valid, on average, for the UK situation." (p. 5)

The report notes:

"COPERT does not now directly provide curves for fuel consumption or CO_2 emissions, but curves of energy consumption factors in MJ/km versus average speed. Energy consumption can be converted to fuel consumption in mass terms using the net calorific values of petrol and diesel. For consistency with the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016) for road transport, in Table 3-28, values of 43.774 MJ/kg for petrol and 42.695 MJ/kg for diesel were used."

This introduces the potential for inconsistency between the TAG and COPERT CO_2 emission values as TAG calculates fuel consumption in litres per kilometre first and then applies a fixed rate of carbon per litre of fuel consumed. The fuel consumption calculation is:

Equation 1

$$EF = (a + bv + cv^2 + dv^3) / v$$

Where:
EF is defined as kilograms per 100 kilometres[6]
V = speed in kilometres per hour and a, b, c and d are fitting factors.

The reasoning behind simply applying a factor to fuel consumed is given as:

"Ultimate emissions of CO_2 are directly proportional to the amount of fuel consumed. Therefore, emission curves for CO_2 can be derived directly from the curves developed for fuel consumption by a simple factor that accounts for the mass carbon content of petrol and diesel. Such emission curves refer to 'ultimate CO_2' and are defined on the basis that virtually all the carbon present in the fuel consumed will ultimately form CO_2 in the atmosphere even though a small amount will be emitted in less oxidised forms such as carbon monoxide and unburnt hydrocarbons." (p. 10)

The report sets out some of key uncertainties associated with the estimation of emissions curves and these include:

- COPERT emissions factors on the basis the NTM and TAG curves can only be as good as the data they rely on. Ricardo did acknowledge that these are from "good sources" and are regularly updated so the uncertainty about the results is being minimised.
- There is no formal mechanism to include cold start emissions in the calculations.
- Fleet composition into the future.

"Whilst the emission curves developed for the NTM make optimum use of available fleet data in current years, predicting the future fleet is inherently uncertain. Future trends in new vehicle sales and fleet turnover will depend on future economic conditions, fuel prices and consumer behaviour in response to transport and other policies and measures brought in to influence purchasing

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[6] This appears to be incorrect as the same equation in TAG expresses fuel consumption as litres per kilometre.

choice, travel demand and modal shift. A major source of uncertainty in the emission curves for the NTM relates to their relevance to local situations where low emission strategies may be introduced to tackle current levels of air pollution by restricting access to vehicles not meeting minimum emission standards. How these schemes may be introduced is still being considered by local authorities, but apart from London, the emission curves continue to be based on national trends and may not reflect how fleet compositions will develop in some areas in the future. This is an area which will need to be reviewed regularly." (p. 36)

The report concludes:

"It is recognised that the speed-emission curves provided for the NTM and WebTAG are currently the only practical way of defining the variability in emission factors for the different roads and traffic situations represented by the NTM and WebTAG on a national scale.

"The method of parameterising emissions as simple average speed related emission factor functions is a convenient way of expressing how emissions vary with traffic conditions. However, whilst acceptable for national inventory reporting, the method is quite simplistic and prone to high uncertainty for more local scale assessments and potentially as a means of expressing how emissions change in response to changes in traffic conditions…

"Using the average speed-related emission curves to calculate the emission effects of incrementally small changes in speed is pushing them beyond their limits of acceptability. The variability in emission factor at any given average speed cannot be easily quantified but is expected to be high, especially at the low end of the speed range, and dependent of vehicle type and technology. Whilst the speed-emission curves allow the effect of a small change in speed to be estimated, the magnitude of change in emission factor shown by the calculations will not be very meaningful and should be regarded with a high degree of uncertainty.

"How applicable an emission factor calculated from a COPERT-based curve at 40 mph is to a stop-start motorway rather than free-flowing rural road with the same average speed, for example, depends on how much the emission curve at this speed is weighted towards measurements made under each of these different conditions; this is not known, but at these moderate to higher speeds, the COPERT curves are probably more weighted towards, and therefore more applicable to, free-flowing traffic."(pp. 39-40)

"The limitations in the emission curves were considered. The curves refer to a relationship between emission factors and average speed of a drive cycle and should not be inferred to represent instantaneous emission rates at a specific, transient speed and therefore are not representative of very localised emissions from road transport sources." (p.47)

Taken together these statements confirm that the average-speed approach based on drive cycles in COPERT is the most pragmatic approach to estimating emissions, but it has some structural deficiencies which mean it is not appropriate to use in all situations, especially at a very localised scale.

3.2 Summary of Literature

The literature review has discussed the various documents that are relied on for various input data and calculation processes in the EFT, TAG and TUBA. These documents include the COPERT II Computer Programme, the ARTEMIS study, the Reference Book of Driving Cycles, the EMEP/EEA air pollutant emission inventory guidebook, and others.

4 Structure of the EFT, TUBA and TAG

4.1 EFT

4.1.1 EFT Inputs Summary

The EFT requires the following inputs:

- Area – the primary area represented by the model (London, England (not London), Wales, Scotland, Northern Ireland).
- Year – the forecast year to use (2018 to 2050)
- Traffic Format – the level of detail available for the fleet composition on each link. The EFT User Guide Appendix D contains a table showing the different options and how they relate to the full fleet split used by the EFT.
- Link data
    - Road type – whether the link is urban, rural or motorway for non-London areas, or else whether it is central, inner, outer or motorway for the London area.
    - Traffic flow – the total traffic flow for all vehicle types on the link. This can be one-way or two-way flow and can represent any number of hours from 1 to 24 (see ‘No of Hours’ below). For the purpose of annualisation, the EFT assumes that this is an annual average flow.
    - % Vehicle Types – the proportion of each vehicle type on the link. The vehicle types required as inputs depend on which Traffic Format option was selected.
    - Speed – the link speed in kilometres per hour.
    - No of Hours – the time period represented by the traffic flow noting that the value entered here is factored to 8,760 hours to represent the full year (for example, entering 1 produces a factor of 8,760 whereas entering 24 produces a factor of 365).
    - Link length – the link length in kilometres.
    - % Gradient / Flow Direction / % Load – these are optional inputs to define the gradient of the link, the direction of flow (uphill and/or downhill) and the average percentage load of HDVs on the link. The default assumptions are zero gradient, two-way flow and 50% load as an approximation for the proportion of HGVs that are fully loaded or an approximation of proportion of the full load that each HGV is carrying.

By default the EFT uses the NAEI fleet composition projections produced in 2022 (as described in section 3.1). There are options to provide bespoke base fleet compositions and/or Euro fleet compositions. A bespoke base fleet can either be provided in the NAEI format or it can be provided in the TAG format (i.e. consistent with Table A1.3.9 of the TAG data book).

4.1.2 EFT CO_2 Emission Calculation Summary

A flowchart detailing the process through which the EFT calculates the annual CO_2 emissions for a single link is included in Appendix B.

1. The link flow is disaggregated into the full basic fleet split. For example, if the link traffic format provides a proportion of cars, then this is further split by car fuel type. By default this is based on the year, area and road type and the corresponding data in the NAEI fleet composition projections.
2. The direct CO_2 emission factors are calculated for every non-electric vehicle type (including by size class and Euro class) as follows:
    a. The link speed, link gradient and link load are used with the EEA COPERT 5.6 energy consumption (EC) parameters and equation to calculate the energy consumption factor for each vehicle type. The COPERT equation is shown below, where *ECF* is the energy consumption factor in MJ per kilometre, v is the average speed in kilometres per hour and α, β, γ, δ, ε, ζ, η are parameters. All hybrid vehicle types, plug-in, soft and full, use the same factor as the equivalent non-hybrid type, but with a fixed reduction factor applied based on the hybrid type if the link speed is 50kph or less (see 5.1.2 and 5.1.4).

Equation 2

$$ECF = \frac{\alpha v^2 + \beta v + \gamma + \delta/_v}{\varepsilon v^2 + \zeta v + \eta}$$

   b. The energy consumption factor is converted to a CO_2 emission factor (g/km) using the net calorific value of the fuel type to convert energy to fuel mass and then using the CO_2 emission factor of the fuel (kg CO_2 per kg of fuel).

   c. The proportions of vehicle sizes and Euro classes (as taken from the NAEI data or bespoke input) are used to combine the factors into a weighted average CO_2 emission factor for each vehicle type.

   d. Engine efficiency factors, which are described in section 5.1.8, are applied to the factors to account for efficiency improvements in future years.

3. The indirect CO_2 emission factors are calculated for every electric vehicle type and petrol plugin hybrid cars as follows:

   a. For petrol plugin hybrid cars, if the link speed is 50 kph or less an electric proportion of 0.32 is assumed, else 0 is assumed. The electric proportion is 1 for all electric vehicles.

   b. The electric CO_2 emission factors are calculated using the energy consumption values in TAG A1.3.11 and emission factors in TAG A3.3.

   c. The electric proportion is applied to the electric CO_2 emission factors.

4. The annual CO_2 emissions for both direct and indirect CO_2 emissions are calculated as follows:

   a. The CO_2 emission factors are multiplied by the vehicle type flows to give CO_2 emissions per kilometre.

   b. The CO_2 emissions are converted to a rate (g/km per second) based on the number of hours the link flow represents.

   c. The CO_2 emission rates are multiplied by the number of seconds in a year (60 * 60 * 24 * 365) and the link length to calculate the annual CO_2 emissions, which are presented in tonnes/annum.

4.2 TUBA

A flowchart detailing the process used in TUBA to calculate the annual CO_2e emissions can be found in Appendix C.

TUBA takes time and distance skims from transport models for each origin-destination (OD) pair. Factors, discussed in sections 4.2.1 to 4.2.3, convert the inputs into fuel consumed and total CO_2e emissions per km for each OD pair. The matrix demand is then multiplied by the distance matrix and the calculated fuel consumption and emissions factors to produce a total amount of CO_2e emissions in the modelled period. This is then annualised by multiplying by the number of times the modelled hour occurs in a year. For example, a single average interpeak modelled hour can have an annualisation factor of 1,518 to represent 6 interpeak hours on 253 working weekdays of the year. TUBA uses values from an input economic parameters file based on TAG Unit A3.4 to convert the amount of CO_2e emissions into a monetary cost for use in scheme appraisal. The annualisation factors are user defined so can vary by scheme but once coded, are fixed over the appraisal period. It is worth noting that TAG Unit A3 requires the user to ensure that all 8,760 hours of the year are represented by means of annualisation.,

4.2.1 Fuel Consumption / Efficiency

TUBA uses Equation 3 to determine the amount of fuel consumed.

Equation 3

$$Fuel\ Consumed\ (litres\ per\ kilometre) = \frac{a}{v} + b + c \cdot v + d \cdot v^2$$

Where:
v = the average speed of vehicles between a zone pair expressed in kilometres per hour
a, b, c and, are parameters from TAG data book Table A1.3.8 and Table A1.3.11.

The guidance states that the DfT Environment Analysis team provide the information for the electric vehicle energy consumption parameters. Ricardo (2019) was referred to as the source for the fuel consumption parameters relating to liquid fuel. In turn this source references COPERT 5 emission factors which are determined by Emisia EU Environmental Agency through drive-cycle tests.

The forecasts of the a, b, c and d parameters in Equation 3 are provided in Unit A1.3.11 and are based on the forecast fuel efficiency parameters in TAG Unit A1.3.10, the source of which is referenced as the DfT Environment Analysis team.

4.2.2 Proportions of Vehicle kilometres

TAG Unit A1.3.9 gives the vehicle kilometres proportions by fuel type with the source of this information stated as the DfT Environment Analysis team. Under further investigation the 2022 national travel survey is the source for the annual vehicle kilometres by age and powertrain.

4.2.3 Carbon Emissions per Litre of Fuel Burnt

As with the other factors, TAG Unit A3.3 provides the values to convert the amount of fuel used into the amount of carbon emissions. The source for the liquid fuel to CO_2e emission factors in given as the DfT Environment Analysis team. Whereas for the electricity emission factors the Green Book[7] provided by the Department for Energy, Security and Net Zero is stated as the source.

4.3 Bespoke Approach Link-based Calculations

The TAG data book, from which TUBA takes its inputs, includes all of the values that are required to create a bespoke TAG link-based calculation spreadsheet. Given the flexibility and ease of setting up such tools there are many in use for scheme assessments.

These tools have the benefit of being more accessible to users and reviewers as they do not rely on automated processes such as the macros embedded in EFT or the TUBA software but introduce some quality assurance risks for the user and any third-party reviewing outputs from such spreadsheets.

An example of how a bespoke spreadsheet could be specified is shown in Appendix C.

5 Common and Contrasting Elements

5.1 Comparisons of Process Elements

Table 1 compares various elements of the TUBA, EFT and bespoke methodologies for calculating CO_2 and / or CO_2e emissions. CO_2 refers to carbon dioxide emissions that come directly from vehicles, primarily through the combustion of fossil fuels like petrol and diesel. In transport, CO_2 is the main greenhouse gas emitted. CO_2e: includes CO_2 emissions and also accounts for other greenhouse gases emitted by the transport sector, such as methane (CH_4) and nitrous oxide (N_2O). These gases are converted into a CO_2 equivalent using their Global Warming Potential (GWP) to provide a unified measure of their impact on global warming. CO_2e provides a more comprehensive picture of the total climate impact of transport emissions, considering all relevant greenhouse gases, not just CO_2. This is important for understanding and reducing the overall environmental footprint of the transport sector.

Table 1 also includes commentary on some of the more important elements is provided in subsequent sections.

[7] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Table 1: Comparison of TUBA, EFT and bespoke approaches

	Methodology	TUBA	EFT	Bespoke
Process Input	Demand input	For each O/D pair (in matrices): Car (purpose), LGV (by purpose), OGV 1 & OGV 2	For each link: Total vehicles; split by car, taxi, LGV, OGV, PSV and m/c	For each link: Car, LGV, OGV1, OGV2
	Speed input	Calculated in TUBA using time and distance matrices – speeds are flow-weighted averages for each O/D pair	Vehicle speed input for each link by user from model outputs	Vehicle speed input for each link by user from model outputs
	Data input periods	Determined by input matrices (often only AM, IP and PM average or individual hours)	User defined between 1 and 24 hours – e.g. 1 implies the same input for every hour of the year, 24 implies AADT has been input	User defined
Assumption	Annualisation	Determined by user defined factors for user benefits	Internal factoring of the defined hour inputs to full year	User defined using flow data
	Fleet composition and change over time	Fixed to TAG data book using vkm by main fuel type – plugin hybrids are split between ICE fuel and electric and full hybrids are fully apportioned to ICE fuel	Default is NAEI. Allows user to input bespoke fleet split based on NAEI or TAG	Same as TUBA
Parameters	Fuel consumption factors	TAG data book parameters – TAG relates to COPERT 5.0 parameters *(non-electric)* and TAG data book parameters *(electric)*	COPERT 5.6 energy consumption parameters *(non-electric);* TAG data book parameters *(electric)*	Same as TUBA
	Fuel efficiency change over time	TAG data book from the DfT environment analysis team	Engine efficiency factors provided by DfT but unclear how these relate to the TAG data book	Same as TUBA
	Emission factors	TAG data book parameters *(non-electric);* TAG data book parameters *(electric w.r.t. to generation)*	EMEP/EEA Guidebook 2019 CO_2 emission factors *(non-electric);* TAG data book parameters *(electric)*	Same as TUBA
Calculation / Parameters	Data / outputs presented	Energy consumption by vehicle, fuel, year and period; CO_2e by year (traded and untraded); CO_2e by year and period (traded and untraded) [includes EV emissions]	Emission rate by link, emissions by year, by vehicle type (fuel / hybrid). EFT reports CO_2 not CO_2e [NB link (tailpipe) emissions are zero for EVs but CO_2e is reported in final summary table]	CO_2e emissions per link by petrol, diesel or electric (i.e. generation related emissions)
Calculation / Equation	Valuation	Internal to the TUBA process; low, medium and high cost; traded and untraded	External process e.g. GHG workbook	External process e.g. GHG workbook
Assumption	Appraisal period	Modelled years are fixed points in 60-year appraisal period; interpolation and extrapolation are internal processes	Each year has at least one EFT depending on how modelled periods are represented; interpolation and extrapolation undertaken by the user outside of the EFT workbook	Each year has its own spreadsheet; interpolation and extrapolation are exogenous

5.1.1 Fleet composition and change over time

The TUBA fleet split is taken from Table A1.3.9 of the TAG data book, which provides the proportions of fuel types for car, LGV, and HGV vehicle types. The source of this data is stated to be the DfT Environmental Analysis team.

The EFT 'outside London' fleet split is taken from the BEIS UK Fleet Composition Projections (Base 2022/2020 NAEI), which provide the proportions of a basic fleet split and also proportions of Euro classes and vehicle sizes by road type. These projections are derived from the July 2021 NAEI Road Transport Fleet Turnover Model, which itself was based on traffic forecasts from the DfT and information on the future sales and activities of new cars and LGVs from the DfT Environmental Analysis team.

The ultimate source of data for the fleet splits for both methodologies is therefore the DfT, but the more recent TAG data assumes a higher uptake of EVs as shown in Figure 3 and Figure 4 below. The EFT allows users to input bespoke fleet splits in the TAG format, so it is possible to replace the default NAEI assumptions with the up-to-date TAG data. To derive the proportion of plug-in hybrids from the TAG data, the EFT applies NAEI hybrid splits to the Car Petrol and Car Electric proportions (see Figure 2). For this purpose it uses 68% of the plug-in hybrid split to divide 'petrol car' and the other 32% to divide 'electric car'. The NAEI data does not include diesel plug-in hybrid cars, so the EFT does not calculate specific emissions for them – the TAG diesel plug-in hybrid car kilometres are effectively apportioned to conventional and full hybrid diesel cars instead. Table 2 shows an example of how the EFT uses the TAG fleet split.

Figure 2 - EFT split of TAG plug-in hybrid car proportions

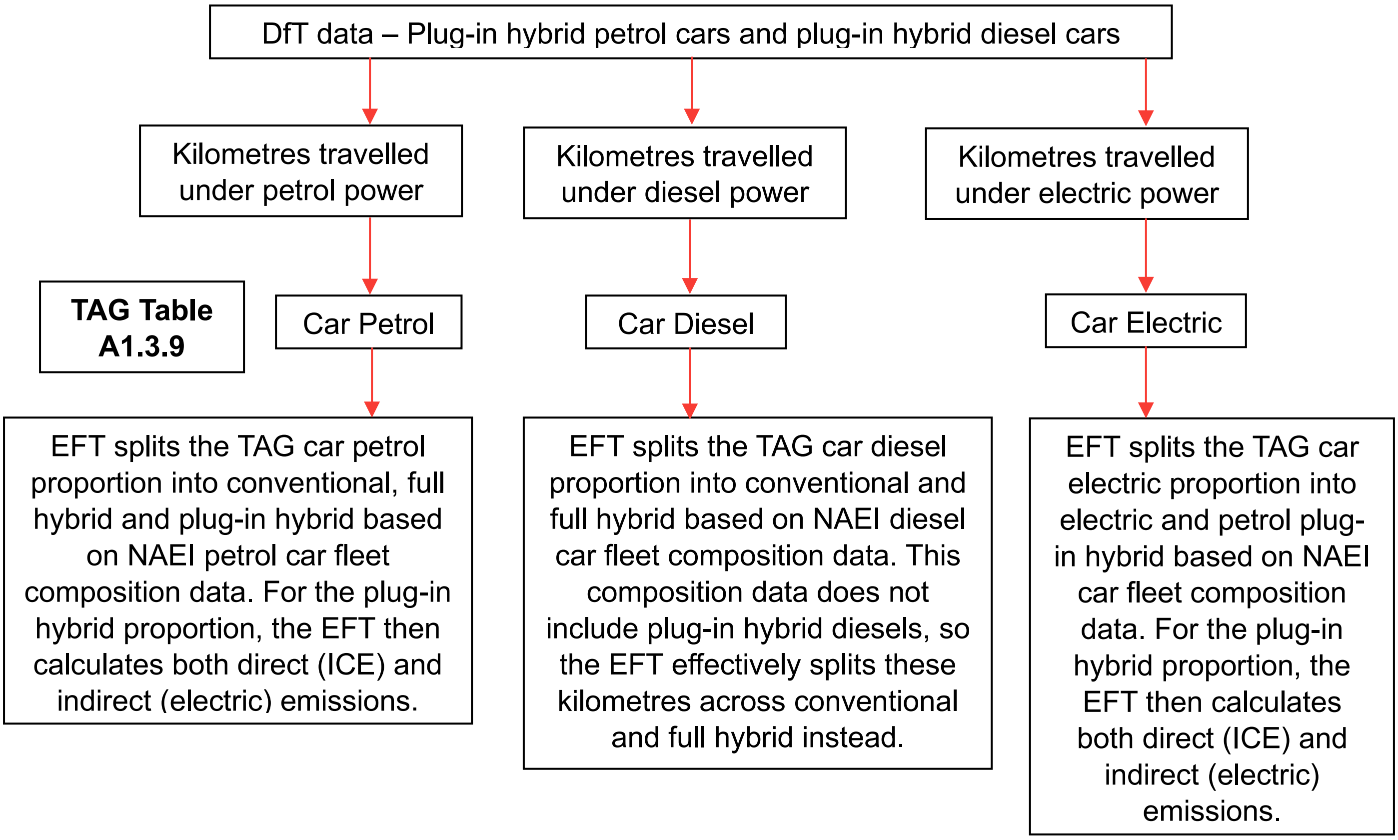
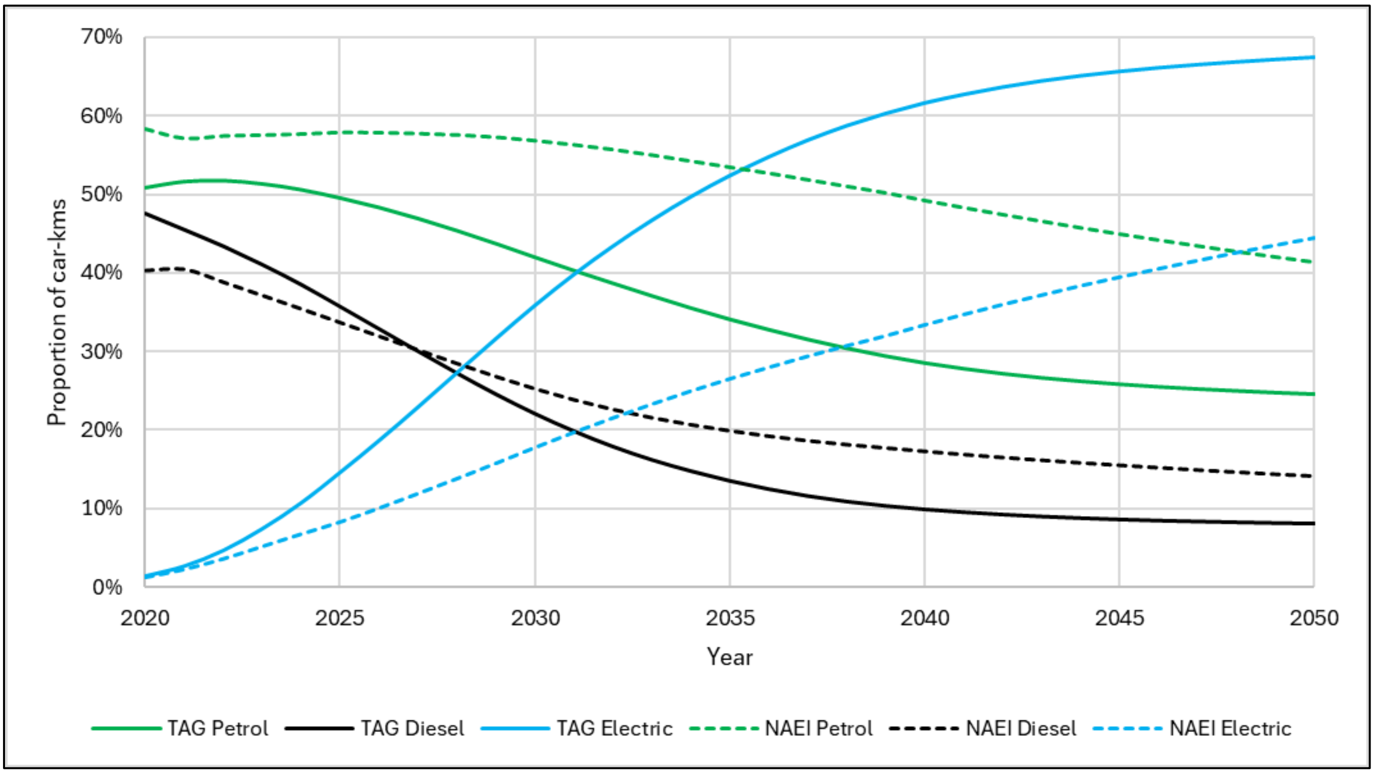


Table 2: Example EFT usage of TAG fleet splits (Year = 2030)

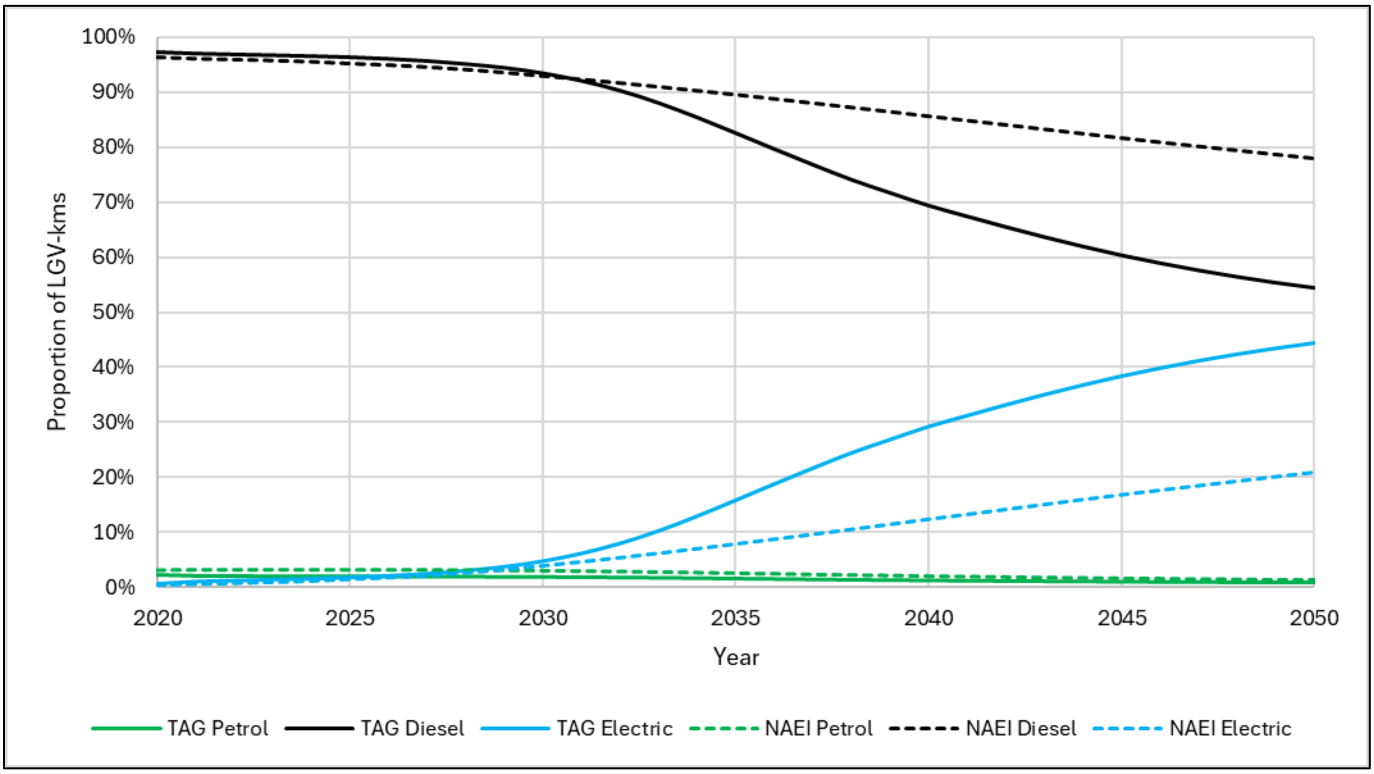
	TAG Fleet Split (Year = 2030)	EFT NAEI Basic Fleet Split (Year = 2030)	EFT NAEI x TAG Split
Petrol Car	**42%**	**60%**	**48%**
Conventional	-	47%	34%
Hybrid	-	5%	3%
Plug-in Hybrid	-	9%	10%
Diesel Car	**22%**	**25%**	**22%**
Conventional	-	24%	21%
Hybrid	-	2%	1%
Electric Car	**36%**	**15%**	**30%**

Figure 3 - Comparison of TAG and NAEI car fuel type proportions



The NAEI proportions shown are for the Urban Road type for England (excluding London). The NAEI data gives different proportions of petrol and diesel vehicles for Rural and Motorway road types, but the electric vehicle proportion is the same across all road types. The NAEI electric vehicle proportion includes both battery electric cars and plug-in hybrid cars using power from the mains (i.e. the car-kms travelled under electric power).

Figure 4 - Comparison of TAG and NAEI LGV fuel type proportions



5.1.2 CO_2e emissions per vehicle kilometre (electric vehicles)

The EFT, TUBA and bespoke approach all use TAG data book values for the CO_2 emission per vehicle-km for electric vehicles. TAG data book Table A1.3.11 gives the forecast electricity consumption per vehicle-km (as sourced from the DfT Environmental Analysis team), and Table A3.3 gives the CO_2 emissions per kilowatt-hour. Table A3.3 values for electricity emissions are sourced from the DESNZ report 'Valuation of energy use and greenhouse gas (GHG) emissions.'

One difference with the EFT is that it applies an electric/ICE ratio when calculating the electric CO_2 emission factor for petrol plugin hybrid cars. It assumes that the electric proportion is 0 if the link speed is greater than or equal to 50kph, else it assumes the proportion is 0.32. The source for this electric proportion assumption is unknown.

5.1.3 CO_2e emissions per vehicle kilometre (non-electric vehicles)

The CO_2 emission per vehicle-km values for non-electric vehicles are based on the following key inputs:

- Fuel consumption factor (FCF) – the mass of fuel consumed by a particular vehicle type travelling at a particular mean speed. This factor is calculated from the following:
    - Energy consumption parameters – the energy consumed by a particular vehicle type travelling at a particular mean speed.
    - Net calorific values of fuel – the energy produced by combusting a given mass of a particular fuel.
- CO_2 emissions from fuel – the mass of CO_2 produced by combusting a given mass of a particular fuel.
- Engine efficiency factors – corrections to take account of future vehicles being more efficient (i.e. consuming less fuel).

5.1.4 Energy consumption parameters

TUBA and the bespoke approach do not calculate energy consumption (EC) directly, as the TAG data book provides a fuel consumption equation and parameters, where parameters are provided by vehicle type.

EFT uses the COPERT EC equation and parameters, where parameters are provided by vehicle type, size and Euro class. For HDVs, parameters are also provided by gradient and load percentage.

The TAG fuel consumption parameters were derived from COPERT 5.0 (2016) EC parameters (described in more detail in 5.1.6) and the EFT uses COPERT 5.6 (2022) values. The only differences in EC parameters between these two versions are with petrol and diesel N1-I (≤1305kg) LGVs and with mopeds and motorcycles.

When the EFT calculates the EC factor for hybrid vehicles (all types), it looks up the factor for the equivalent non-hybrid vehicle (e.g. Car Petrol for Car Petrol Hybrids). If the link speed is less than 50kph it also applies a reduction factor based on the hybrid type. These factors are consistent with those applied in the London Atmospheric Emission Inventory, which were agreed through discussions between Ricardo and TfL based upon studies undertaken and associated empirical data.

5.1.5 Net calorific values of fuel

When the TAG fuel consumption parameters were derived from the COPERT EC parameters, the 2016 EMEP/EEA Emissions Inventory Guidebook net calorific values for petrol and diesel were used. The EFT uses the DESNZ DUKES July 2023 Table A.2 values for petrol (called motor spirit in the DUKES table), diesel (called DERV in the DUKES table), bioethanol and biodiesel, where the EFT then uses these values to calculate the calorific values for E10 petrol (90% petrol, 10% bioethanol) and B7 diesel (93% diesel, 7% biodiesel). Table 3 shows a comparison of these values. Although the base TAG fuel consumption parameter does not account for biofuel mixing, TAG does account for it in the forecast fuel efficiency improvements (see 5.1.8). Therefore both TAG and EFT account for biofuel mixes and their impact on fuel consumption.

It should be noted that E5 petrol (95% petrol, 5% bioethanol) is still sold alongside E10 petrol, and so the average calorific value of petrol in the UK will be between the E5 and E10 calorific values.

Table 3: Net calorific values of fuel

Fuel	**Net calorific value, GJ/tonne**	
	EEA (2016), as used for base TAG fuel consumption	**DUKES A.2 (estimate for 2022)**
Petrol (primary)	43.774	44.599
Diesel (primary)	42.695	43.028*
Bioethanol (primary, renewable petrol)	-	26.800
Biodiesel (primary, renewable diesel)	-	37.200
E5 petrol (blend)	-	43.710
E10 petrol (blend, used by EFT)	-	**42.820**
B7 diesel (blend, used by EFT)	-	**42.594**

**In the EFT, this value is calculated based on a diesel value of 43.000 rather than 43.028 as in DUKES A.2.*

5.1.6 Fuel consumption parameters

The EFT calculates fuel consumption based on the vehicle type/size/Euro class, speed, energy consumption factor and net calorific value of the fuel. TUBA and bespoke approach take the fuel consumption parameters from the TAG data book Table A1.3.8, where those parameters are sourced from Ricardo (2019) 'Production of Updated Emission Curves for Use in the NTM and WebTAG'. The data book Table A1.3.11 contains forecast fuel consumption parameters derived from Table A1.3.8 and the efficiency changes in Table A1.3.10.

The Ricardo report describes how the COPERT energy consumption equation, and parameters were converted into the third-order polynomial fuel consumption equation and parameters reported in the TAG data book and is described in section 3.1 earlier in this technical note. In summary, the COPERT 5.0 parameters (as taken from the 2016 EEA emissions guidebook) were combined with the EEA calorific values of fuel (described above), 2017 DUKES Table A.3 data on fuel density, and fleet split data from the BEIS UK Fleet Composition Projections (Base 2016/2015 NAEI).

The Ricardo report also describes the application of a CO_2 correction factor for petrol and diesel cars that conform to Euro 4 and later standards. This correction factor is described in section 3.4 of the EEA emissions guidebook, and accounts for a divergence in fuel consumption tests used in publications and vehicle excise duty allocation and real-world fuel consumption. The EFT does not include this correction factor in its calculations of fuel consumption for Euro 4 and later petrol and diesel cars.

The difference between the EFT and TAG fuel consumption factors derived from their respective parameters varies depending on the vehicle type, speed, and forecast year. Table 4 shows the highest and lowest percentage differences between the EFT and TAG for each vehicle type, and a brief description of the ranges of speeds and forecast years where the EFT FCF is smaller or larger than the TAG FCF[8].

Table 4: Fuel consumption factor differences between TAG and EFT

Vehicle Type	**EFT FCF difference from TAG FCF (across valid speed ranges and across years 2025-2050)**		
	Lowest % Difference	**Highest % Difference**	**Description**
Car Petrol	-31%	18%	The EFT FCF is generally larger than the TAG FCF for speeds above 50kph before 2035, and smaller than the TAG FCF for other speeds and years.
Car Diesel	-24%	8%	The EFT FCF is generally larger than the TAG FCF between 2025 and 2030, and smaller than the TAG FCF between 2030 and 2050
LGV Petrol	-21%	15%	The EFT FCF is smaller than the TAG FCF within the speed ranges 15-55kph and 110-130kph between 2025 and 2040. Elsewhere it is larger than the TAG FCF.
LGV Diesel	-6%	17%	The EFT FCF is larger than the TAG FCF over the majority of speeds and forecast years.
OGV1	2%	10%	The EFT FCF is larger than the TAG FCF over all speeds and forecast years.
OGV2	10%	20%	The EFT FCF is larger than the TAG FCF over all speeds and forecast years.

5.1.7 CO_2e emission factors from fuel

The TUBA and bespoke approach CO_2e emission factors from fuel are taken from the TAG data book Table A3.3, where the source of this data is stated to be the DfT Environmental Analysis team. The ultimate source of this data is Data Table 2b from the DESNZ report ‘Valuation of energy use and greenhouse gas (GHG) emissions’. These factors vary by year, with the petrol emissions remaining constant after 2022 and the diesel emissions remaining constant after 2031. This aligns with levelling off in the Renewable

[8] In order to simplify the comparison calculations, the EFT FCFs were calculated based on Euro 6 vehicles only. The impact of including the full Euro class split would be very small (<1%).

Transport Fuel Obligation (RTFO) bioblend targets. The notes state that non-carbon GHGs are included and that forecast biofuel blending rates are accounted for. TAG Unit A3 4.2.15 states that 'biofuels are considered to produce zero emissions when combusted, as the carbon released in combustion is offset by the carbon absorbed as the biofuel feedstock was grown'.

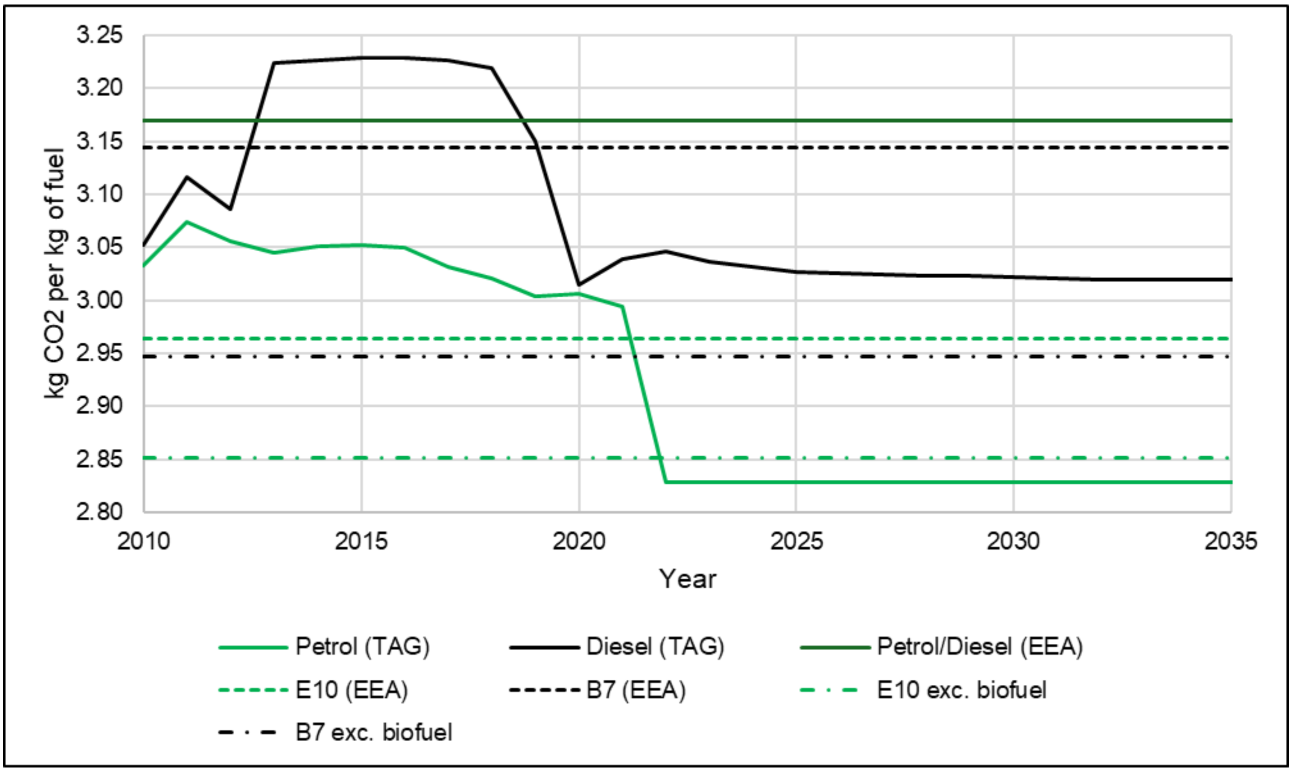
The EFT CO_2 emission factors from fuel are taken from the EMEP/EEA Guidebook 1.A.3.b.i-iv Table 3-12. This is sourced from Table 3-29 in the same report, where the values are based on an equation relating the mass fractions of oxygen-to-carbon and hydrogen-to-carbon to CO_2 emissions (assuming 100% oxidation). It should be noted that although the EFT uses B7 values for the net calorific value of diesel, it uses the standard diesel emission factor given in Table 3-12. A specific B7 emission factor is given in Table 3-29, albeit this is only 0.7% lower than the diesel factor, and therefore would only impact output EFT diesel emissions by 0.7%.

Table 5 shows a comparison of these emission factors for the year 2022. As the TAG factors are based on fuel volume and the EEA factors are based on fuel mass, the TAG factors have been converted to fuel mass based on the fuel densities given in DUKES A.3. Figure 5 shows a comparison of the emission factors over the period 2010-2035, where the fuel density is assumed to be constant past 2022.

Table 5: Comparison of TAG and EMEP/EEA Guidebook CO_2 emission factors

	CO_2 Emission Factors	
	TAG data book	**EMEP/EEA Guidebook 2019**
Kg CO_2 per litre of fuel (2022 CO_2e for TAG)		
Petrol	2.110	-
Diesel	2.530	-
Average density of fuel, litres per kg (2022 values, DUKES A.3 July 2023)		
Petrol	1.340	-
Diesel	1.204	-
Kg CO_2 per kg of fuel (2022 CO_2e for TAG)		
Petrol (used by TAG, assumes some bioblending and excludes biofuel emission)	**2.828**	-
Diesel (used by TAG, assumes some bioblending and excludes biofuel emission)	**3.046**	-
Petrol		3.169
Diesel		3.169
E10 (used by EFT)	**-**	**2.964**
B7 (used by EFT)	**-**	**3.144**
E10 (excluding biofuel emission)	-	2.852
B7 (excluding biofuel emission)	-	2.947

Figure 5 - Comparison of TAG and EMEP/EEA Guidebook CO_2 emission factors (2010-2035)



The main discrepancy between the TAG based and EFT emission factors is that the TAG factors treat biofuels as having zero combustion emissions while the EEA factors used in the EFT do include biofuel combustion emissions. Due to the biofuel emission discrepancy, the TAG petrol factor is 4.6% lower than the EEA E10 factor, and the TAG diesel factor is 3.1% lower than the EEA B7 factor. This means that, for a given fuel consumption, the EFT will consistently give higher CO_2 emissions than TAG.

If biofuel emissions are excluded from the EEA E10 and B7 factors for consistency with the TAG approach, then the TAG petrol factor is 0.9% lower than the EEA E10 (exc. biofuel) factor, and the TAG diesel factor is 3.3% higher than the EEA B7 (exc. biofuel) factor. One possible reason for this remaining discrepancy is that the TAG assumes average petrol and diesel bioblends that are different to the E10 (10%) and B7 (7%) bioblends that the EFT uses.

5.1.8 Engine efficiency factors

The TAG and TUBA efficiency factors are taken from the TAG data book Table A1.3.10. This table includes forecast fuel efficiency improvements by vehicle class and is sourced from the DfT Environmental Analysis team.

The engine efficiency factors used in the EFT were provided to Defra by ‘DfT/HE’ in July 2021 and are applied to the non-electric vehicle emissions. A single factor is provided for each year (i.e. it is not split by vehicle type or fuel type). The DfT notes on these factors stated that they were calculated using separate weighted indices for LDVs and HDVs, as a proportion of TAG consistent indices created using v1.15 of the TAG data book, both based on ICE fuel efficiencies. It is unclear what the index of this factor is (i.e. what a value of 1 represents).

Given that the EFT accounts for the lower calorific value of biofuels directly (see 5.1.5) and also uses TAG-derived efficiency factors which account for the lower calorific value of biofuels, there is potentially some double-counting of the biofuel impact.

5.1.9 Comparison of CO_2e emissions per vehicle kilometre

Table 6 provides a summary of the maximum and minimum parametric differences between TAG and EFT and the general pattern of differences across the tested speeds and years. It shows that the sign and scale of the difference in carbon emissions per vehicle kilometre varies substantially by vehicle type, year and speed.

Table 6: CO_2e emission differences between EFT and TAG

	EFT 'CO_2 emissions per vehicle km' difference from TAG Data Book (across valid speed ranges and across years 2025-2050)		
Vehicle type	**Minimum difference**	**Maximum difference**	**Description**
Car Petrol	-24%	28%	The EFT emissions are generally larger than TAG for speeds above 50kph before 2035, and smaller than TAG for other speeds and years.
Car Diesel	-20%	13%	The EFT emissions are generally larger than TAG before 2030, and smaller than TAG after 2030.
LGV Petrol	-14%	26%	The EFT emissions are smaller than TAG within the speed ranges 15-55kph and 110-130kph between 2025 and 2040. Elsewhere they are larger than TAG.
LGV Diesel	-1%	23%	The EFT emissions are larger than TAG over the vast majority of speeds and years.
OGV1	7%	15%	The EFT emissions are larger than TAG over all speeds and years.
OGV2*	7%	26%	The EFT emissions are larger than TAG over all speeds and years.

*In order to calculate an OGV2 emission curve for the EFT, the relative proportion of rigid and articulated HGVs needed to be calculated from the BEIS UK Fleet Composition Projections used by the EFT. The relative proportion varies based on the road type (Urban, Rural, Motorway). For the purpose of this comparison the Urban road type proportions of rigid and articulated HGVs were used.

5.2 Summary of Main Differences

The above discussion has identified a range of differences and similarities between the three methods to calculate CO_2e and below we summarise those which have an influence over the different results the approaches produce:

- **Different sources and assumptions for fleet composition and fleet composition change over time:** The TUBA and TAG fleet split is based on the TAG data book, which assumes a higher uptake of electric vehicles (EVs) than the EFT default, which is based on the NAEI. The EFT allows users to input bespoke fleet split based on NAEI or TAG, a process that allows users to make their own adjustments to allow for this discrepancy.
- **Different energy consumption parameters and fuel consumption factors:** TUBA and the bespoke approach use the TAG data book fuel consumption parameters, which are derived from COPERT 5.0 (2018) energy consumption parameters, EEA calorific values of fuel, and DUKES fuel density data. EFT uses COPERT 5.6 (2022) energy consumption parameters and DESNZ calorific values of fuel. The difference between the EFT and TAG fuel consumption factors varies depending on the vehicle type, speed, and forecast year. The different fuel consumption factors have a notable impact on the results as fuel consumed underpins the calculations of emissions.
- **Different CO_2 emission factors from fuel:** The bespoke approach CO_2e emission factors from fuel are taken from the TAG data book, which include non-carbon GHGs and account for changing biofuel blending rates. These treat the biofuel element as having zero CO_2e emissions. The EFT CO_2 emission factors from fuel are taken from the EMEP/EEA Guidebook, which are based on an equation relating the mass fractions of oxygen-to-carbon and hydrogen-to-carbon to CO_2 emissions. The EFT assumes fixed bioblends for petrol (10% biofuel, E10) and diesel (7% biofuel, B7), and

does treat the biofuel element as having non-zero CO_2 emissions. The different treatment of the biofuel element means that the TAG petrol factor is 4.6% lower than the EEA factor for E10 petrol and the TAG diesel factor is 3.1% lower than the EEA B7 diesel factor. The difference between the emissions factors has a large and consistent impact on the results as even if the fuel consumption were to match the EFT will give higher CO_2 emissions than an approach relying on TAG data book parameters.

- **Different engine efficiency factors:** The bespoke approach and TUBA efficiency factors are taken from the TAG data book, which include forecast fuel efficiency improvements by vehicle class. The engine efficiency factors used in the EFT were provided to Defra by 'DfT/HE' in July 2021 and are applied to the non-electric vehicle emissions. A single factor is provided for each year, and were calculated using separate weighted indices for LDVs and HDVs, as a proportion of TAG consistent indices created using v1.15 of the TAG data book, both based on ICE fuel efficiencies. The base year of the EFT efficiency factors is unknown, and as such it is difficult to directly compare them against the TAG efficiency factors and their impact on CO_2 emissions.

6 Sample Calculations

6.1 Bespoke Approach versus TUBA

A simple "five links in a line" network was defined to provide input to the three different user carbon calculation methods to consider how the different processes build up their CO_2 emission estimates. The vehicle assumptions were 100 petrol cars with no other vehicles in the assessment. A single assessment year of 2023 was assumed to remove any impact of differential changes to engine efficiency over time which will have on the outputs.

Two scheme options, one increasing the speed on the middle link (link 3) from 60 kph to 112 kph and the other reducing the speeds on links 3, and 4 to 45 kph, were considered to determine how comparing a "do minimum" against a "do something" might impact on an appraisal for a scheme. These scheme options are notional and used simply to demonstrate how the calculations work. The calculations have been applied to a single year without any forecasting to keep the presentation of results as clear as possible.

The calculations that have been undertaken are basically to apply Equation 3 using TAG data book values for each parameter shown in Table 7 and the speed shown for each link. The results are shown in Table 8. This calculation produces a value for litres of petrol consumed per vehicle kilometre. The total vehicle kilometres for each link, is not shown, but is calculated by multiplying the hourly flow by 8,760 (the number of hours in the year) and by the link distance. Multiplying the total vehicle kilometres by the fuel consumption (FC) value provides the total fuel consumed in litres and this is factored by the value shown in Table 5 for the CO_2e per litre of fuel to give the total CO_2e emitted per link per year.

The TAG data book v1.23 parameter values for 2023 taken from table A1.3.11 are shown in Table 7 below.

Table 7: TAG data book v1.23 fuel parameters for 2023

Parameter	Value (litres per km)
a	0.4241505
b	0.0901389
c	-0.0010268
d	0.0000068

Table 8: Bespoke Approach emissions calculations

Link ID	**Length (km)**	**Time (s)**	**Speed (kph)**	**Flow (vehicles/hr)**	**FC (l/km)**	**Total Fuel Consumed**	**Annual CO_2e (t/yr)**
Without scheme							
1	0.5	90	20	100	0.094	40,966.47	86.44
2	2.0	64	112	100	0.064	112,529.29	237.44
3	2.5	150	60	100	0.060	131,579.46	277.63
4	0.5	26	70	100	0.058	25,248.34	53.27
5	0.5	40	45	100	0.067	29,402.78	62.04
Total	6.0	370	58		0.065	339,726.33	716.82
Scheme 1							
1	0.5	90	20	100	0.094	40,966.47	86.44
2	2.0	64	112	100	0.064	112,529.29	237.44
3	**2.5**	**80**	**112**	**100**	**0.064**	**140,661.61**	**296.80**
4	0.5	26	70	100	0.058	25,248.34	53.27
5	0.5	40	45	100	0.067	29,402.78	62.04
Total	6.0	300	72		0.064	348,808.48	735.99
Scheme 2							
1	0.5	90	20	100	0.094	40,966.47	86.44
2	2.0	64	112	100	0.064	112,529.29	237.44
3	**2.5**	**200**	**45**	**100**	**0.067**	**147,013.89**	**310.20**
4	**0.5**	**40**	**45**	**100**	**0.067**	**29,402.78**	**62.04**
5	0.5	40	45	100	0.067	29,402.78	62.04
Total	6.0	434	50		0.068	359,315.21	758.16

Note:
FC = Fuel consumption. For each link this is calculated using Equation 3 and the parameters in Table 7 but for the total row the calculation does not use Equation 3 or Table 7 but is simply total fuel consumed divided by total vehicle kilometres.

For TUBA, three inputs are required:

- Total trips, in this case 100 vehicles are travelling along the total length of all the links. The TUBA input file included 100,000 trips as TUBA outputs are generally reported in kilo units so applying 100,000 removes the impact of rounding to the nearest 1,000 in the outputs;
- Distance, which is 6 kilometres from end to end of the five links;
- Time, which is the total time to travel the 6 kilometres, either 370 seconds in the do minimum, 300 seconds in Scheme 1 and 434 seconds in Scheme 2.

The TUBA economics file used for the assessments aligns with the TAG data book v1.23 but had to be adjusted to match the 100% petrol car assumption in the bespoke assessment as the data book assumes the total car kilometres travelled in 2023 to be split 51% petrol ICE, 41% diesel ICE and 7% electric vehicle. This adjustment removes the diesel and electric vehicles from the results to make them directly comparable to the bespoke calculations.

The TUBA scheme files, which direct the software to the input trip, distance and time matrices were specified to factor a single hour to the year, so the outputs are directly comparable to the link-based approach.

TUBA does not report total travelled distance or journey speed, but it does report total trips, litres of fuel consumed and CO_2e per year. From these values, litres of fuel used per trip can be calculated and fuel consumption per kilometre can be inferred. These are shown in Table 9 below.

Table 9: TUBA derived fuel consumption calculations

	Total Trips per Year	Total consumption (litres)	Litres per trip	Kilometres per trip	Implied fuel consumption	Annual CO_2e (kg/yr)
Without Scheme	876,000	318,716	0.3638	6	0.061	672,517
Scheme 1	876,000	301,453	0.3441	6	0.057	636,091
Scheme 2	876,000	338,502	0.3864	6	0.064	714,268

Table 10 summarises the key results from the Bespoke Link Based and TUBA approaches.

Table 10: Comparison of Bespoke Link Based and TUBA Results

	Bespoke	TUBA	Bespoke	TUBA
Litres of Petrol and CO_2e	**Litres**	**Litres**	**Annual CO_2e (t/yr)**	**Annual CO_2e (t/yr)**
Without Scheme	339,726	318,716	717	673
Scheme 1	348,808	301,453	736	636
Scheme 2	359,315	338,502	758	714
Scheme 1 minus Without Scheme	9,082	-17,263	19	-36
Scheme 2 minus Without Scheme	19,589	19,786	41	42

As can be seen in Table 10 comparing "Scheme 1" to the "Without scheme" results the TUBA calculation produces lower litres of fuel and CO_2e value whereas "Scheme 2" increases fuel consumed and CO_2e. The reason for the "Scheme 1" result is that the average speed to complete a trip through the network, shown in the total rows in Table 8, is more fuel efficient and when this is translated into fuel consumed using Equation 3 produces a lower value per kilometre which in turn produces a lower CO_2e value.

The implication of this result is potentially a critical issue from an appraisal perspective.

Assessing 'Scheme 1' using TUBA compared to the TAG based method gives a CO_2e impact which is not only significantly different in terms of magnitude but crucially a different sign (i.e. a forecast disbenefit rather than a forecast benefit). Although 'Scheme 2' shows a similar CO_2e impact whether TAG or TUBA is used, this is because of the nature of the changes to link speed and overall average speed brought about by the scheme leading to coincidentally similar results.

6.2 Bespoke Approach versus EFT

Taking the same inputs into EFT and controlling the fleet mix to 100 petrol cars the same three scheme options were modelled. The fleet assumptions were entered into the EFT using the NAEI fleet option as this allows greater control over the mix of fuel types. To create the EFT run, each link had a flow of 100 vehicles and the split was defined as 100% cars. The NAEI bespoke fleet tab was modified so all cars were defined as conventional ICE, which represent 78.09% of the vehicles on a rural (not London) link. All other vehicles were retained as their default value as these do not feature in the flow so are not required. This modification to the fleet was implemented as the EFT requires a mix of cars, LGVs and OGVs to be defined as a minimum.

All links were coded as "Rural (not London)" and the NAEI fleet mix was defined as 98% petrol cars, 1% OGV1 and 1% OGV2. The flows for each link were coded as 100% car meaning that all calculations only include petrol consumed by cars.

The outputs from EFT are limited to emissions rates (g/km/s) and total emissions (tons per year) recorded for each link. Table 11 below shows the TAG link-based outputs against their EFT counterparts.

Table 11: Bespoke Approach outputs versus EFT (CO_2e tons per year)

Link ID			
Without Scheme	**Bespoke Annual CO_2e (t/yr)**	**EFT Annual CO_2e (t/yr)**	**% Difference**
1	86.44	108.14	25%
2	237.44	297.48	25%
3	277.63	338.58	22%
4	53.27	66.71	25%
5	62.04	73.42	18%
Total	716.82	884.33	23%
Scheme 1			
1	86.44	108.14	25%
2	237.44	297.48	25%
3	296.80	371.85	25%
4	53.27	66.71	25%
5	62.04	73.42	18%
Total	735.99	917.61	25%
Net impact of Scheme 1	19.17	33.25	
Scheme 2			
1	86.44	108.14	25%
2	237.44	297.48	25%
3	310.20	367.08	18%
4	62.04	73.42	18%
5	62.04	73.42	18%
Total	758.16	919.54	21%
Net impact of Scheme 2	41.34	35.21	

As Table 11 shows EFT consistently produces values that are greater than those from a TAG link-based analysis. The source of these differences is not immediately identifiable due to the lack of output information included in the EFT, specifically litres of fuel consumed by link.

It is possible to infer from the output data how the values for kilograms of CO_2e per litre of fuel consumed shown in Table 5 when converted to kilograms of $CO2_e$ per litre contribute to a substantial proportion of the difference. The values are repeated from Table 5 below to demonstrate how they impact on the calculations.

Table 12: CO_2e kg per litre of petrol

Variable	**TAG**	**EFT**	**Difference**
Petrol kg CO_2e / kg fuel	2.828	2.964	4.81%
Petrol kg CO_2e / litre fuel	2.110	2.211	4.81%

As can be seen in Table 12 the volume of CO_2e produced per kilogram of fuel consumed is 12.058% greater in the EMEP/EEA Guidebook (2019) that EFT relies on compared to that which the TAG data book uses.

Table 13 applies this additional 12.058% increase to the litres of petrol calculated using the TAG link-based approach to recognise this difference.

Table 13: Estimated CO_2e per link

CO_2e per litre of fuel	2.11 kg / l	2.211kg/l	2.211 kg/l	
Without Scheme	**Bespoke (TAG data book Table A3.3) Annual CO_2e (t/yr)**	**Bespoke (Rebased kg / l) Annual CO_2e (t/yr)**	**EFT Annual CO_2e (t/yr)**	**% Difference (EFT / Bespoke rebase)**
1	86.44	90.60	108.14	19%
2	237.44	248.86	297.48	20%
3	277.63	290.98	338.58	16%
4	53.27	55.84	66.71	19%
5	62.04	65.02	73.42	13%
Total	716.82	751.29	884.33	18%
Scheme 1				
1	86.44	90.60	108.14	19%
2	237.44	248.86	297.48	20%
3	296.80	311.07	371.85	20%
4	53.27	55.84	66.71	19%
5	62.04	65.02	73.42	13%
Total	735.99	771.38	917.61	19%
Net impact of Scheme 1	19.17	20.08	33.28	
Scheme 2				
1	86.44	90.60	108.14	19%
2	237.44	248.86	297.48	20%
3	310.20	325.12	367.08	13%
4	62.04	65.02	73.42	13%
5	62.04	65.02	73.42	13%
Total	758.16	794.62	919.54	16%
Net impact of Scheme 2	41.34	43.32	35.21	

The pattern of the differences shown in Table 13 is that much of the difference between the two approaches can be explained by the difference in the assumed CO_2 kg per litre of fuel.

The EFT manual does not discuss which TAG data book it aligns with and only refers to where analysts can download the most recent version. The most recent values are shown in Table 7 and these have been used for the above assessment. As the fuel consumption parameters are updated on an infrequent basis it is likely that there is an inconsistency between the most recent values and those used by the EFT.

To assess whether different input parameters might have been used, earlier versions of the TAG data book were obtained and average fuel consumption per kilometre was produced for speeds between 10 kph and 120 kph. An EFT workbook was also produced for the same speed range. Both processes used 100 petrol cars travelling 1 kilometre. The Bespoke Approach directly produced litres per kilometre of fuel consumed whereas the EFT process produced total CO_2 emissions for each link which was divided by the kilograms per litre value provide an estimate of litres of fuel consumed.

Visual inspection of the plots of the Bespoke Approach calculated values against the implied EFT values for litres per kilometre suggested that the most likely TAG data book that aligns with the EFT is version 1.18 published in May 2022. Figure 6 shows how well the curves fit one another and includes TAG databook v1.23 for comparison.

Figure 6 – TAG databook v1.18, TAG databook v1.23 and EFT fuel consumption

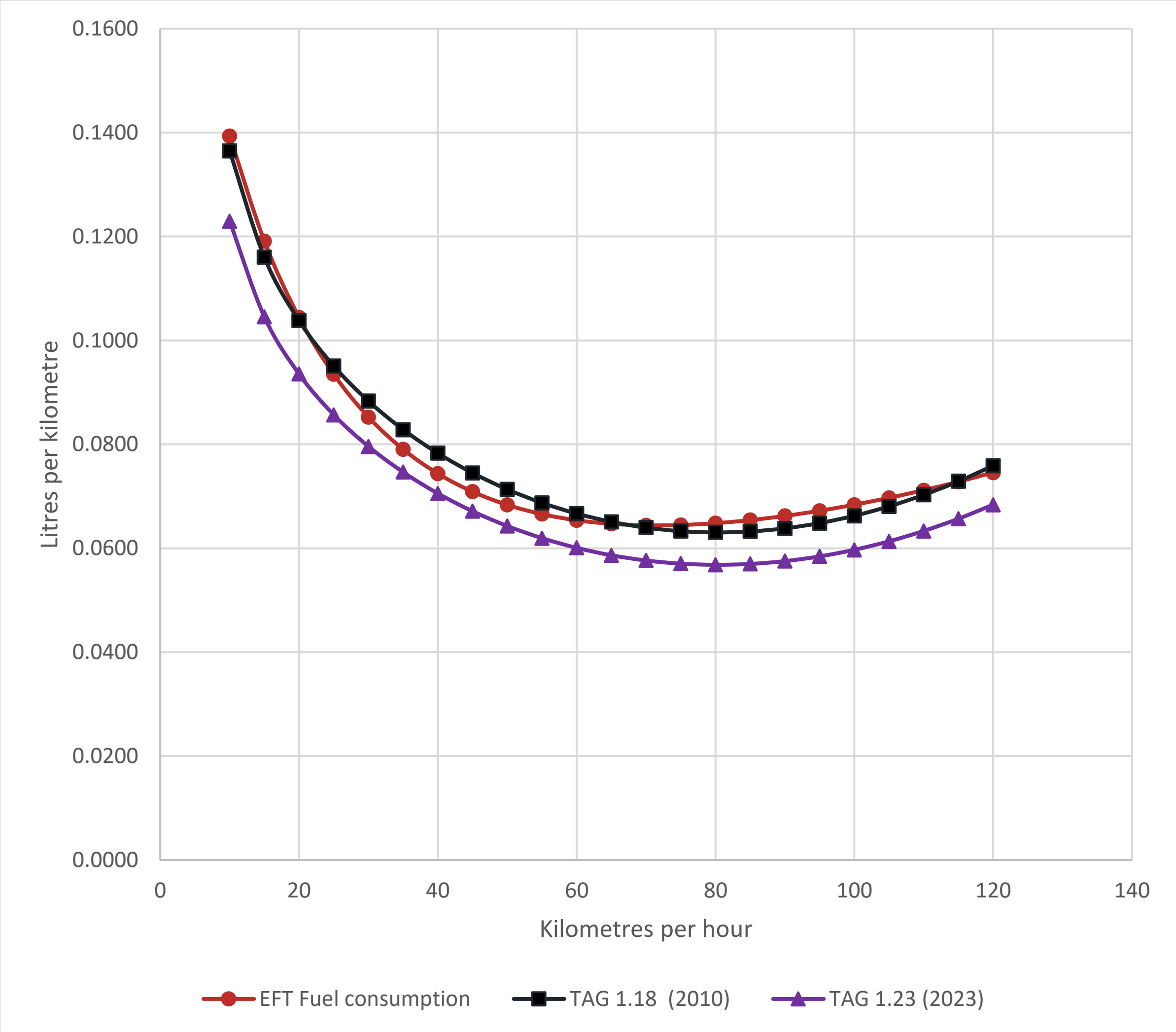


Table 14 below shows the parameter values for both the most recent version of the TAG data book and the version that was contemporary to EFT version 12 when it was being developed during 2022 and 2023 before publication in December 2023 which was TAG data book version 1.18 (May 2022).

Table 14: Comparison of Fuel Consumption Parameters

Parameter	V1.23 for 2023	V1.18 for 2010
a	0.4241505	0.4706705920
b	0.0901389	0.1000251350
c	-0.0010268	-0.0011394100
d	0.0000068	0.0000075462

Applying the revised fuel consumption parameters to the link-based data including correcting the kilograms of CO2 per litre of fuel produced the results shown in Table 15 below.

Table 15: Bespoke Approach CO_2e Results compared to EFT

Without Scheme	**Bespoke Approach original Annual CO_2e (t/yr)**	**Bespoke (rebased kg/l and v1.18 (2010) fuel consumption factors) Annual CO_2e (t/yr)**	**EFT Annual CO_2e (t/yr)**	**% Difference**
1	86.44	100.79	108.14	7%
2	237.44	297.97	297.48	0%
3	277.63	330.66	338.58	2%
4	53.27	64.08	66.71	4%
5	62.04	73.02	73.42	1%
Total	716.82	866.43	884.33	2%
Scheme 1				
1	86.44	100.79	108.14	7%
2	237.44	297.97	297.48	0%
3	296.80	372.46	371.85	0%
4	53.27	64.0866.25	66.71	4%
5	62.04	73.02	73.42	1%
Total	735.99	908.23	917.61	1%
Net impact of Scheme 1	19.17	41.80	33.28	
Scheme 2				
1	86.44	100.70	108.14	7%
2	237.44	297.97	297.48	1%
3	310.20	365.12	367.08	1%
4	62.04	73.02	73.42	1%
5	62.04	73.02	73.42	1%
Total	758.16	909.84	919.54	1%
Net impact of Scheme 2	41.34	43.40	35.21	

As Table 15 combining earlier versions of the TAG data book fuel consumption parameters with adjusting for the different weight of CO_2e can produce much more similar results for all the links in the assessment.

Having established how Bespoke Approach values can be mapped onto EFT values, at least in this example, further analysis is required to determine whether this correction applies more widely to a larger network and still further analysis is required to assess the implications of different vehicle classes and the contribution of different proportions of electric vehicles and hybrid vehicles.

Table 16 shows a summary of the outputs from the three approaches discussed above, and how the adjustments have been applied and compares to the without scheme option.

Table 16: Differences in CO_2e TAG Link-based v TAG Matrix-based v EFT (CO_2e tonnes)

	Bespoke Approach Annual CO_2e (t/yr)	TUBA Annual CO_2e (t/yr)	Bespoke link-based (revised) Annual CO_2e (t/yr)	EFT Annual CO_2e (t/yr)
Without Scheme	717	673	891	884
Scheme 1	736	636	915	917
Scheme 2	758	714	943	919
Scheme 1 minus Without Scheme	19	-36	23	33
Scheme 2 minus Without Scheme	41	42	51	35

As Table 16 shows both link-based tools produce consistently more CO_2e in the with scheme options than the without scheme option whereas, as noted above, the matrix-based approach is more prone to potentially counter-intuitive results.

The link-based approaches can be seen to better reflect the fuel consumption associated with changes to the speeds in both of these scenarios to produce more CO_2e. The difference between the "Without Scheme" and both scheme options also has the same sign (positive) whereas the TUBA result has an opposite sign (one positive, one negative) in this instance. This outcome of the calculations will have a significant impact in an appraisal process.

The TAG link-based approach allows for more immediate analysis of the relationship between fuel consumption and emissions as the EFT does not report fuel consumption either in litres or kilograms. As has been shown, for the worked example, it has been possible to identify some underlying factors that are responsible for the differences between the TAG based approach and the EFT.

7 Conclusions

7.1 Summary of Observations

This Technical Note has provided a summary of the main sources of emissions factors used by TUBA and the EFT and presented in diagrammatic form how those source documents are relied upon by each tool as shown in Appendix A. In addition, there are process maps for the EFT, Appendix B, a TAG data book link-based approach, Appendix C, and TUBA approach, Appendix D

The Technical Note has concluded that the basic building blocks for estimating emissions in both TUBA and EFT are emissions rates developed from driving cycles that are a laboratory-controlled series of combinations of accelerating, cruising and braking designed to represent a range of real-world trips.

The Technical Note has also reported a rudimentary analysis to demonstrate how different approaches to emissions estimation can be applied and considered how the results differ and the reasons for these differences.

This analysis cannot be considered extensive or conclusive, as it is very limited in its nature, but it has demonstrated that TUBA and its use of matrix-based calculations can produce counter-intuitive results whereby a notional scheme that on a specific link would demonstrably increase the fuel consumption and emissions can, in aggregate, appear to reduce both fuel consumption and emissions. This has implications for appraisal as the error can be in both the direction and magnitude of change.

Whilst the counter intuitive result might not be the case for every scheme the fact that it can happen means that using TUBA can be considered unsound for estimating greenhouse gas impacts in an appraisal and also vehicle operating cost impacts, as these rely on fuel consumption calculations, and emissions calculations.

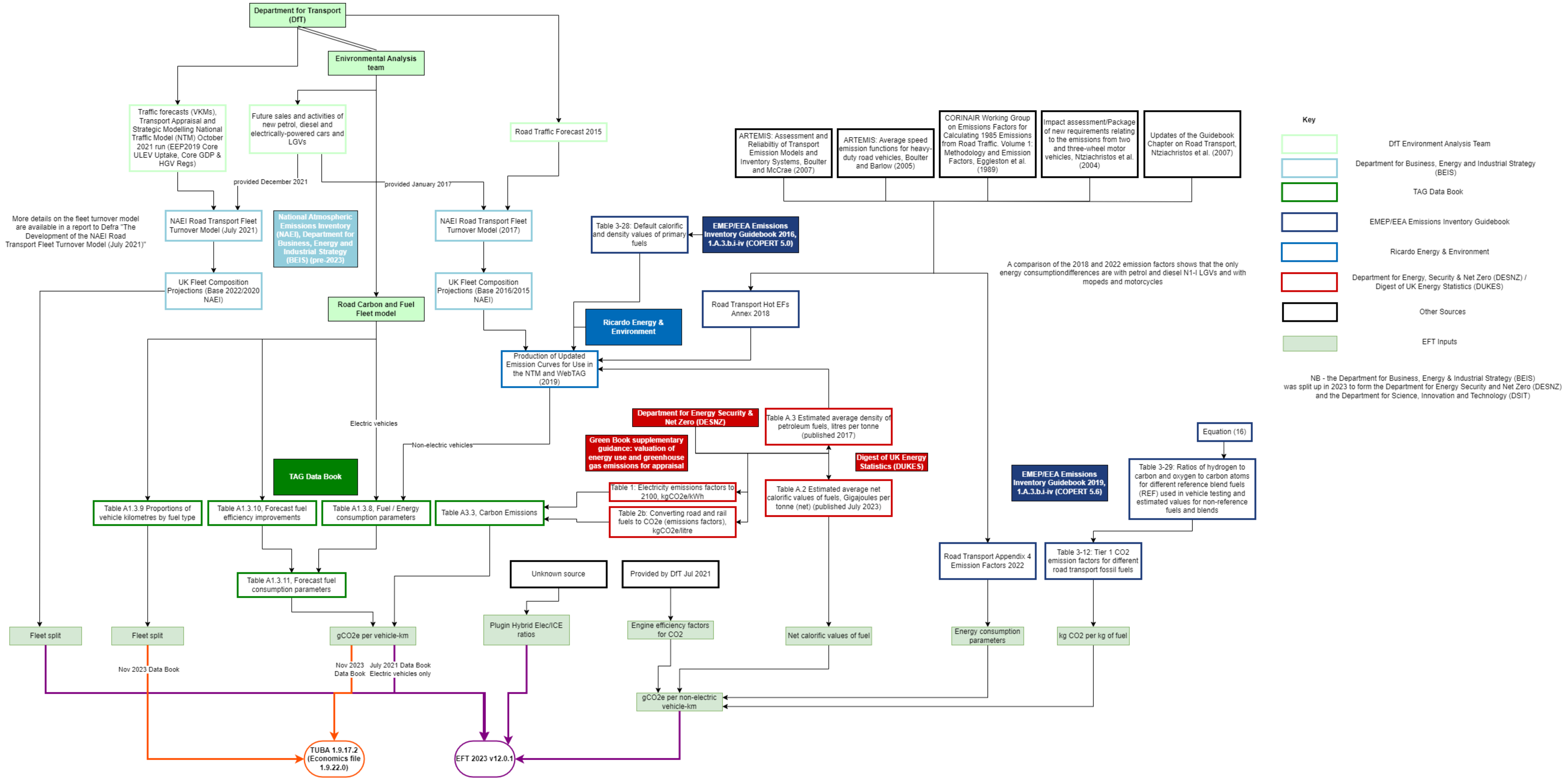
7.2 Recommendation for Further Work

This Technical Note has identified issues that would benefit from further research. Some of these issues are related to the different methods for data input to the different tools and uncertainties associated with the impact these have on analytical work that will be undertaken during scheme appraisals. Other areas of additional work are related to developing a more substantive evidence base upon which to formulate advice including concluding whether guidance to scheme promoters should be modified.

The suggested additional research is listed below:

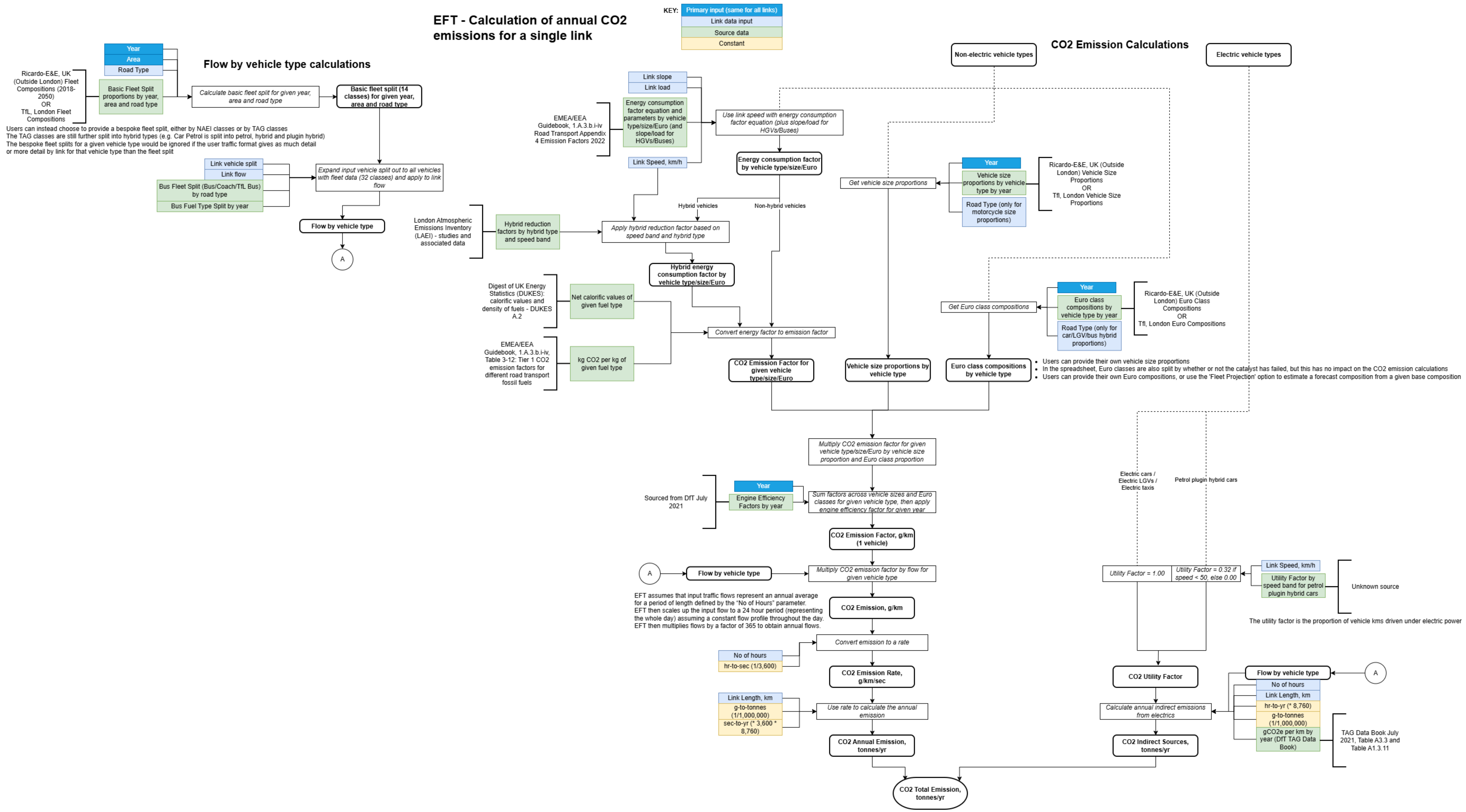
- Investigate the impact of average daily speeds. EFT relies on combining a AADT traffic flow value with a single average daily speed to produce annual emissions per link. Although the guidance from DfT with respect to Large Local Major Schemes and the use of EFT implies that this is not an acceptable approach, the required approach is not explicitly described. From this, it is inferred that modelled periods should be combined in some manner to create a full year assessment. It is suggested that the development of the full year assessment process is investigated and compared with the simpler single average speed to identify the scale of difference between the methods.
- Confirm the process of reconciling fuel consumption between the Bespoke Approach and EFT. As shown above in Figure 6, the implied fuel consumption values in EFT are not consistent with those that can be calculated using TAG. An inconsistent volume of fuel being consumed in combination with different volumes of CO_2 per kilogram or litre of fuel being used in the calculations has been shown to produce a difference between TAG link-based approaches and EFT for one vehicle / fuel type combination. Addition analysis of other vehicle / fuel types should be undertaken to determine the scale of the difference in these categories.
- Review the assumed change over time for fuel efficiency in both EFT and TAG. Although such a review was out of the scope for this report there are different assumptions built into the two approaches that will cause increasingly large differences between the Bespoke Approach and EFT assessments for future years.
- Consider how to implement interpolation and extrapolation using EFT and the Bespoke Approach. As discussed above, TUBA has built in functionality to interpolate between forecast years and a defined method for extrapolation beyond the final forecast year for the remainder of the appraisal period. Neither TAG link-based nor EFT approaches have explicit guidance on these issues. The use of interpolation and extrapolation provide a full estimate of the CO_2 emissions over the appraisal period which leads directly into the monetisation of impacts in the appraisal process. An additional piece of analysis would be to monetise the outputs from EFT.
- Explore how EFT can be used to explicitly report fuel consumption if it is to be used in place of TUBA. The cost of fuel consumed is the input for the user benefits associated with vehicle operating costs. TUBA handles the cost changes within its internal processes so its outputs are consistent across fuel consumption, CO_2e and user benefits appraisal – even if they are incorrect. The EFT does not have these processes within its coding so it would require reconfiguring. Further work would be beneficial to understand how the EFT could provide inputs related to fuel consumption and emissions within the appraisal process.

Appendix A Map of the Sources for TAG and EFT



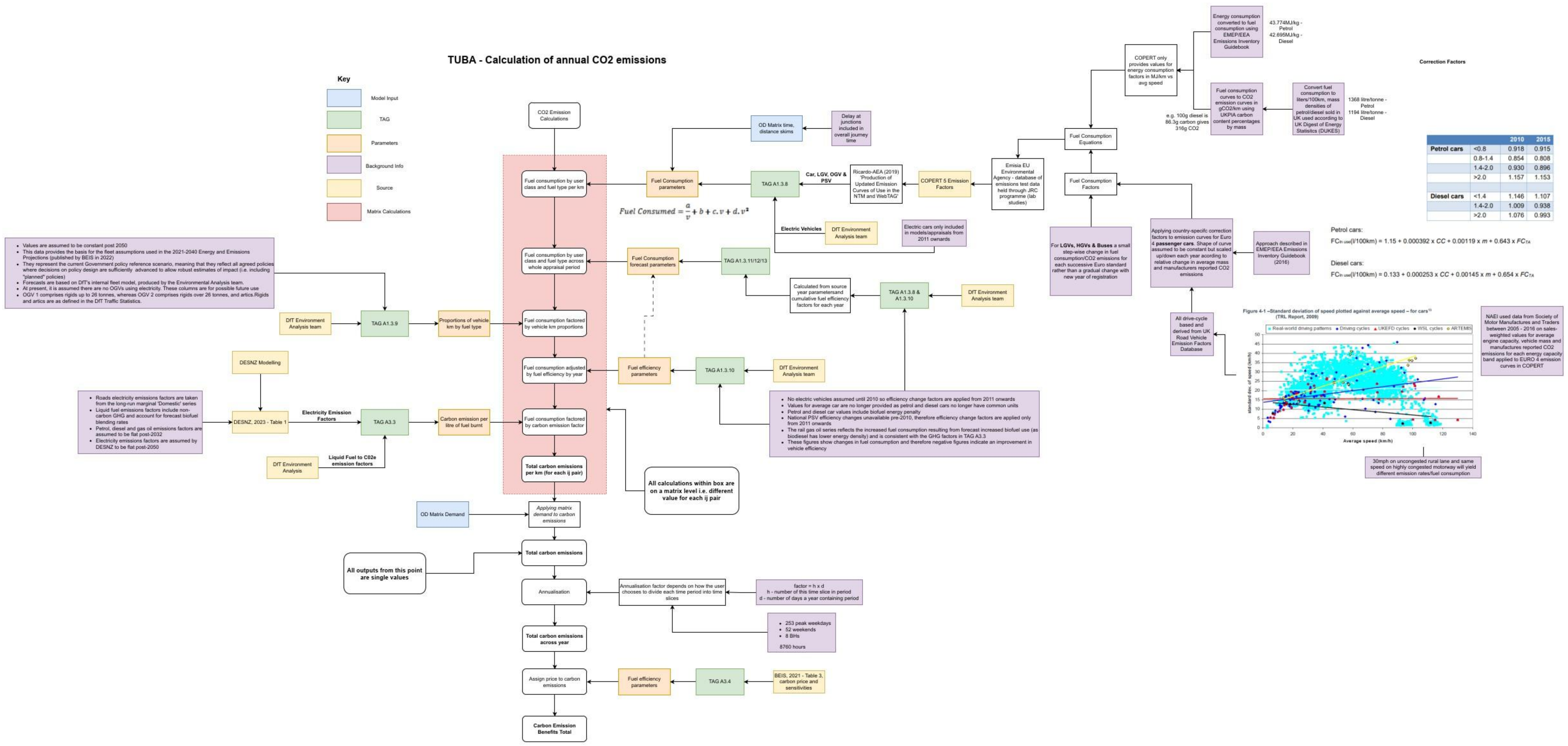
SUBJECT: User Carbon Emissions Research

Appendix B EFT Process Map

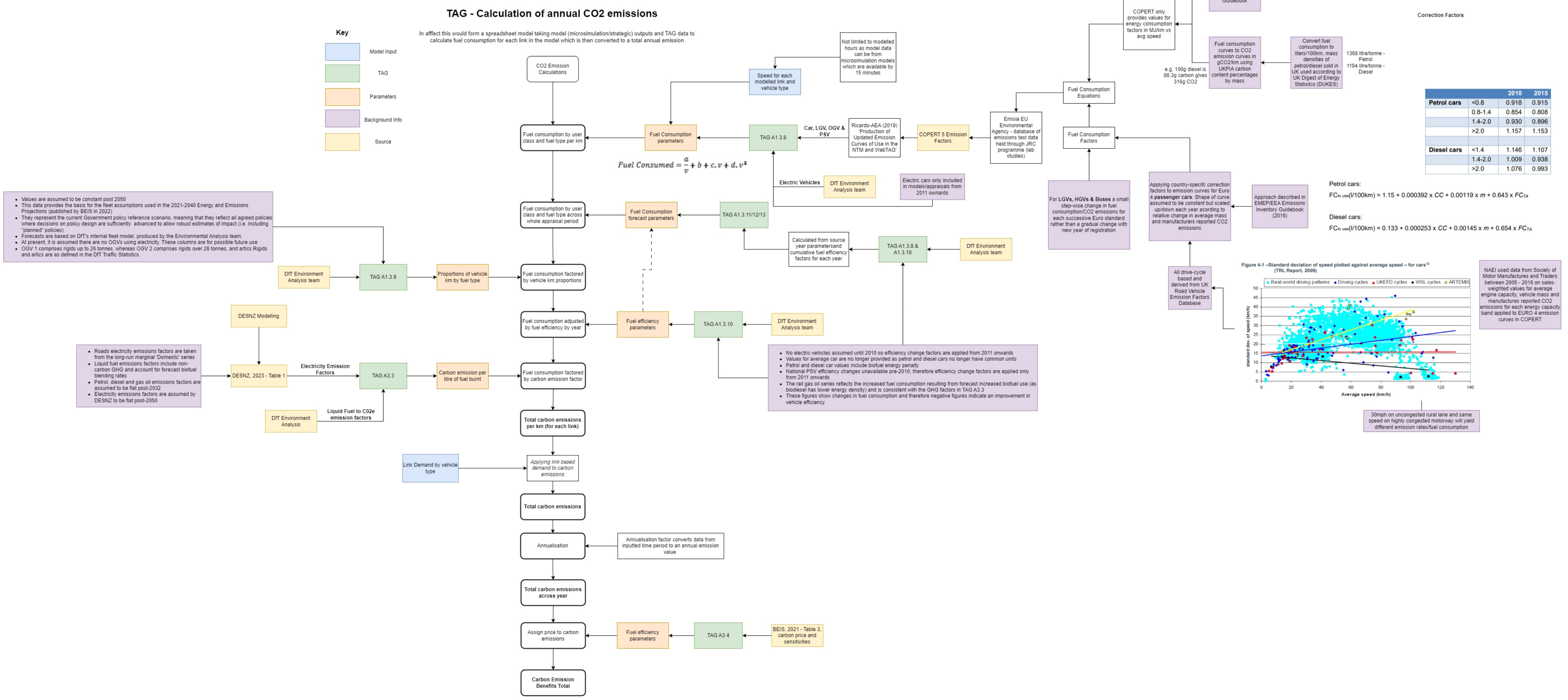


SUBJECT: User Carbon Emissions Research

Appendix C TUBA Process Map



Appendix D TAG Link-based Process Map



		2010	2015
Petrol cars	<0.8	0.918	0.915
	0.8-1.4	0.854	0.808
	1.4-2.0	0.930	0.896
	>2.0	1.157	1.153
Diesel cars	<1.4	1.146	1.107
	1.4-2.0	1.009	0.938
	>2.0	1.076	0.993