Transport and Environment

EUTRM user guide

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User Guide and Model Manual

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Authorisation and Version History

Version	Date	Authorised for release by	Description
0.1	16/12/16	Jon Stenning	First version of model documentation
1.0	27/01/17	Jon Stenning	Incorporates refinements and additional content on HDV and aviation methods
1.2	20/02/17	Jon Stenning	Made consistent with v1.2 of the EUTRM
1.3	14/03/17	Jon Stenning	Final version

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1 Overview

This user guide provides an overview of the European Union Transportation Roadmap Model (EUTRM), how to use the model and information on key inputs and how they were constructed. This chapter sets out a detailed explanation of how the model operates, key differences from the ICCT's own GTRM model (which was the original model upon which the EUTRM is based) and how the user can interact with the model. The guide also includes a step-through guide of the user-facing parts of the model (Chapter 2), and substantial appendices providing exhaustive detail in terms of the model classifications (Appendix A), a full list of data tables within the EUTRM (Appendix B), detail on the data filling techniques employed to enhance available historical data and projections (1.11.1.1.1.Appendix C) and detail on the added treatment of second-hand vehicle sales within the model.

This guide does not seek to explain in full the interlinkages within the model, and how each and every step is estimated; while this chapter provides a summary of the process of the model, further detail should be sourced from the ICCT's *GTRM Model Documentation and User Guide*[1] as required.

1.1 The ICCT's Global Transportation Roadmap Model (GTRM)

The GTRM v1.0 (the basis for the EUTRM) was developed by the ICCT to assess the implications of different transport policy options on system-wide emissions across 16 world areas.

Functionality

The GTRM is an excel-based tool which includes a detailed representation of vehicle stock, energy demand and emissions. The model is structured into a series of mode-specific input and calculation sheets. The input sheets include assumptions and calculations of key characteristics of the stock (sales, load factors, average annual distance travelled per vehicle etc.) which are used to estimate the stock needed to meet transportation demand, fuel/energy demand and (via emission factors) different types of emissions.

The model includes two separate scenarios presented side-by-side:

- the 'base case' includes all announced transport policies but assumes no further changes beyond those policies in terms of changes to vehicle fuel efficiency or fuel/engine technology types.
- the 'trajectory case', in addition to the policy in the base case, can be customised to test the effects of alternative policy scenarios on greenhouse gas emissions and local air pollution.

Within the trajectory case the user can turn on and off a series of set policy levers and compare the results to the base case. There are 12 policy levers which impact on fuel blends, electricity generation and characteristics of transport demand (such as fuel efficiency and mode shift). A more detailed explanation of these levers is included in Chapter 2.

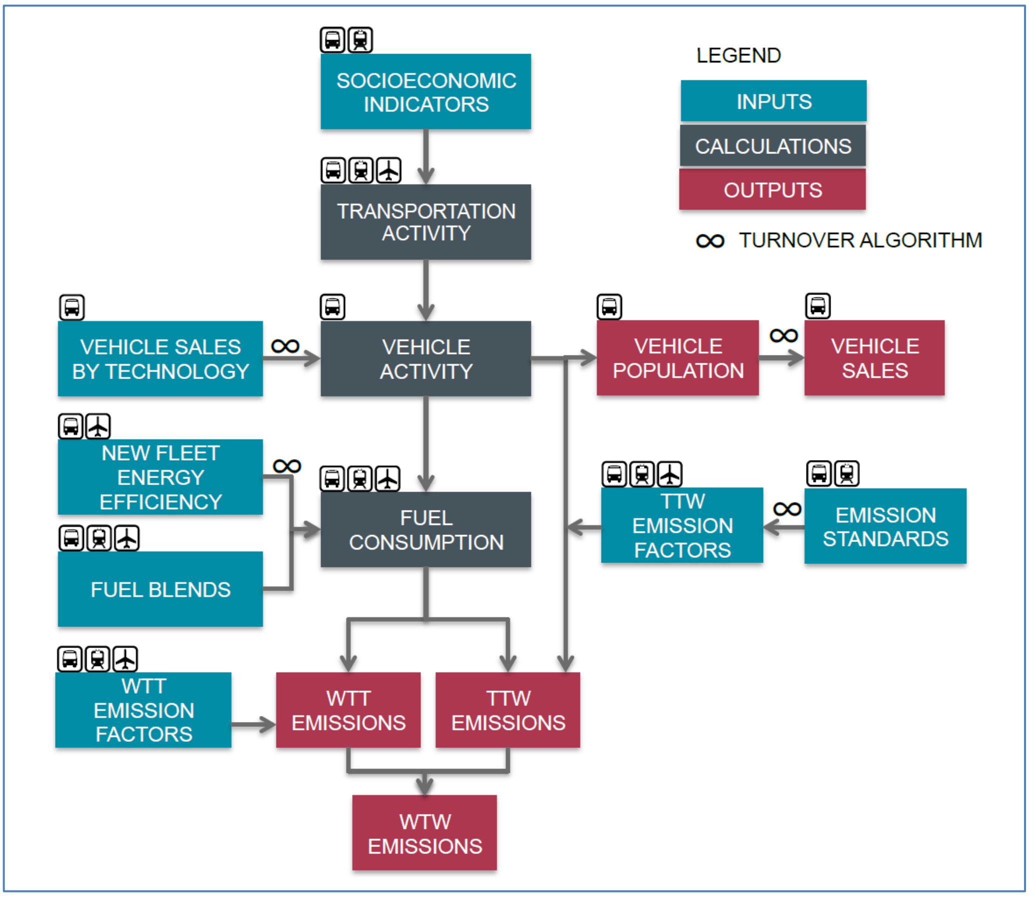
[1] http://www.theicct.org/info/assets/RoadmapV1/ICCT%20Roadmap%20Model%20Version%201-0%20Documentation.pdf

The user can view the model outputs through a straightforward interface. Interactive charts and tables display key model outputs and parameters such as sales, stock, energy demand, modal shares, activity, and detailed emissions.

The model structure

The GTRM includes a disaggregated representation of vehicle stock, energy demand and emissions across 16 world areas[2] and 11 modes of transport[3]. It models changes in transportation activity based upon exogenous forecasts of population, GDP and relative fuel prices (as well as assumptions on load factors and distances travelled per vehicle). For road transport, the vehicle stock and new sales are determined by depreciating the stock from the previous time period and calculating unmet demand from this existing stock (which is assumed to be met by sales of new vehicles). From this the characteristics of the vehicle stock in terms of fuel efficiency can be determined, and total fuel consumption (across all transport modes) calculated. Emissions factors are then used to calculate total emissions of different types. Figure 1 below sets out a stylised flowchart of the key linkages in the model.

Figure 1 Stylised flowchart of GTRM model interactions



Source: ICCT Global Transportation Roadmap: Model Documentation and User Guide

[2] United States, EU-27 (27 member states included in the European Union), China, India, Japan, Brazil, South Korea, Mexico, Canada, Australia, and Russia. The model also considers five broader regions – Latin America-31, non-EU Europe, Asia-Pacific-40, Africa, and the Middle East.

[3] light duty passenger vehicles (LDVs), buses, two-wheel vehicles (2W), three-wheel vehicles (3W), light heavy duty trucks (LHDTs), medium heavy duty trucks (MHDTs), heavy-heavy duty trucks (HHDTs), passenger rail, freight rail, aviation and marine

The model does not operate as a full stock model; i.e. it does not individually record the characteristics of each cohort of new vehicles and age that cohort over time. Instead the key driver of the stock and emissions results is total demand for transport, and stock averages and distributions are applied to that demand to estimate the impact in terms of vehicle stock required to meet demand and the emissions that such a stock would emit.

Vehicle sales, one of the outputs of the model, are calculated as the difference between total demand for vehicles (measured in vehicle kilometres) and the supply from the existing stock. However, these sales are not used in the calculations of the age profile (which is subsequently used to estimate emissions). The age profile of the stock is based upon a separate exogenous assumption on changes in vehicle sales over time, as well as survival rates and the annual average distance accumulation (which measures the average distance travelled by vehicles of different ages, as a percentage of the distance travelled by new vehicles in a given time period). The GTRM model uses an assumption of 5% per annum increase in vehicle sales; however this assumption is extremely unlikely to hold in the European case, and in the adapted EUTRM instead sales are assumed to remain constant throughout the projection period.

1.2 Changes in the EUTRM

The updated model is broadly similar in operation to the GTRM model, although several notable changes have been made. These are briefly outlined below.

Adding 30 European states

The primary change in the EUTRM was to alter the geographical coverage to 30 European countries (the EU28 plus Norway and Switzerland). Historical data on the different modes of transport was sourced from the EU Pocketbook[4], TRACCS[5] database, TREMOVE[6] model, ICCT Pocketbook[7] and PRIMES[8] reference scenario. Data on emission factors was sourced from JEC Well-to-Wheels (WTW) study[9] and the GLOBIOM[10] model (more detail on data sources can be found in Chapter 3). In some cases, missing years or regions were estimated using a range of techniques (this is described in more detail in 1.11.1.1.1.Appendix C).

Including a treatment of second-hand vehicle trade

The GTRM model includes only sales of new vehicles; the impact of second-hand trade is likely to be only small in the context of the large world areas that the model uses (where most trade would occur within, rather than across,

4 EU Statistical pocketbook (2016) by DG Mobility and Transport. Available at: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2016_en

5 TRACCs (2013) is a transport database by EMISIA S.A. Available at: http://traccs.emisia.com/index.php

6 TEMOVE v3.3.2 (2010) is a EU-wide Transport Model. Available at: http://www.tmleuven.be/methode/tremove/home.htm

7 European vehicle market statistics (2015/16) by ICCT. Available at: http://www.theicct.org/european-vehicle-market-statistics-2015-2016

8 EU Reference Scenario (2016) by European Commissions. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

9 JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, JEC Well-To-Wheels Analysis, Version 4.a. (2014) has detailed data on WTW emissions.

10 GLOBIOM model (2016) is used to analysis the land use change impact of biofuels consumed in the EU

those areas). However, at a European country level, second-hand vehicle trade can have a substantial impact upon the characteristics of the stock.

The inclusion of second-hand vehicle trade in the EUTRM better reflects the characteristics of the national-level vehicle fleet, allowing more accurate estimation of energy demand and emissions.

The analysis makes one key assumption; it assesses only the *net* vehicle trade position for each country. The model differentiates between net importers and net exporters, but does not individually model each bilateral import and export flow. This approach does make a simplifying assumption that second-hand vehicles traded between two European states have similar characteristics. (and so cancel out in terms of impact on the characteristics of the national stock). This simplification was made to make the trade data more robust when determining the age distribution of vehicles being traded as it came from the importing side of the distribution.

A country which is a net exporter of vehicles will have lower implicit survival rates, as additional vehicles will be removed from its stock beyond the number of vehicles that are naturally retired. This higher rate of removal of vehicles will increase the number of new vehicle sold to meet transportation demand. As a result, a larger number of new vehicles, with improved fuel-efficiency, will be added to the fleet.

Modelling the effects of second-hand vehicle trade on a net exporter is relatively straightforward, as more vehicles leave the stock – so the impacts are modelled through altered survival rates. The treatment for net importers is more complex, as the characteristics of vehicles being imported matters. To model this in the EUTRM, bilateral trade relationships between European countries have been estimated. Through this trade data, the characteristics of imported vehicles are estimated, by taking the characteristics of vehicles from the exporting country and adjusting the average characteristics of the importing country accordingly. More detail on the methodology underpinning the second-hand vehicle trade treatment is set out in Appendix D.

Removal of 3W vehicle classification

3W classification was removed from the EUTRM as the mode represents an extremely small part of the European vehicle stock, and no data is published on 3W in the sources identified.

Adjusted HDV weight classifications

The GTRM combines vans and light heavy duty trucks into the LHDTs. This limits the ability to model the effects of policy targets for vans (i.e. light commercial vehicles <3.5t), which is the subject of explicit EU policy. In the EUTRM, vans have been given their own classification, light heavy duty vehicles (LHDVs). In order to limit the changes required to the underlying model, two categories in GTRM; LHDTs and MHDTs, were combined into the renamed MHDVs category, maintaining 6 road transport vehicle modes in the EUTRM. For consistency, the HHDTs category was renamed HHDVs.

Reflecting the cross-border nature of HDV movements

In an EU context, the movement of HDVs across borders has implications for the characteristics of vehicles traversing the roads of each Member State, unlike in the GTRM where road freight movements are almost exclusively contained within the defined geographies. The EUTRM uses data on HDV activity from EU Pocketbook, which measures territorial activity (that is, movements across or within a Member State *regardless of the point of origin of the HDV*), in order to reflect the fact that many vehicles that are registered in a particular Member States move across Europe delivering freight. However, all data on vehicle characteristics is based upon nationality data (i.e. HDVs registered in a given country, regardless of where they operate). For example, HDV activity for France records all HDV transits across France, including a Polish HDV travelling across France to the UK, while the vehicle characteristics are constructed using data only on French-registered trucks. The EUTRM adjusts fuel efficiency by fuel type and share of annual sales by fuel/engine technology associated with a given Member State to take account of this. It does so using data from the EU Pocketbook on *haulage by vehicles registered in the reporting country* (Table 2.2.4a); the difference between this figure and total haulage activity in a given region is carried out by non-domestic HDVs, for which the 'average' characteristics are calculated by pooling all non-domestic HDV activity across the EU and working out the share of annual sales by fuel/engine technology and fuel efficiency by fuel type of this pool. The characteristics of the domestic and non-domestic fleet are then weighted together to create estimates of vehicle characteristics on a territorial, rather than nationality, basis.

Improving projections of future aviation activity

The GTRM used 2005-based projections of future fuel burn to reverse-engineer projections of total revenue passenger kilometres. However, this method substantially over-estimated more recent history (2010 and 2015) and suggested very strong future growth in aviation demand. The EUTRM retains this methodology, but as an 'alternative' to the default method, which uses projections of growth in VAT receipts from aviation from a DG TAXUD study[11] to estimate future demand. Where data is missing for some countries, growth rates from proxy countries (based upon similar observed historical growth rates) have been used.

Updating key assumptions

In addition to the updating of data and projections in response to changes in the classifications outlined above, a number of key assumptions were updated in the model to more accurately reflect the European context; one such example is the exogenous assumption on vehicle sales (as discussed at the end of the previous section).

1.3 The model outputs

The model has five key outputs: Vehicle sales, WTT emissions, TTW CO2 emissions, TTW emissions (non-CO2) and WTW emissions. The method by which these are estimated is set out below.

Vehicle sales

Vehicle sales are calculated as the demand for vehicle transportation that cannot be met by the existing stock (effectively the difference between demand and current supply). Changes in demand for modes of transport are driven by growth in fuel-price-adjusted GDP (proxying a wealth effect)[12], converted to demand for vehicle kilometres travelled (VKT) by incorporating load factors. Historical stock data is aged (through the application of survival rates) and adjusted for the fact that older vehicles are typically driven less than newer ones. The difference between the two (divided by the average distance

[11] Study on VAT rules for passenger transport, Final Report (2014)

[12] In the GTRM model, the elasticities between GDP and transport demand are held constant throughout the projection period, and a doubling in GDP (as seen over 2015-50) leads to an approximate doubling in demand for transport and vehicles on the road. This is not feasible in a European context, so the EUTRM caps vehicles per capita and thereby limits growth in demand for road transport.

driven by new vehicles) gives the demand for new vehicles; and in the EUTRM this is met by sales of either new or second-hand vehicles.

TTW emissions (non-CO2)

TTW emissions (non-CO2), measured in grams of non-CO2 pollutant per megajoule (g/MJ), is a product of the age distribution of vehicle activity and vehicle emission factors. The age distribution is used to identify how much of total vehicle activity is carried out by vehicles who have emissions constrained to different standards set by the EU, which in turn is used to calculate the average emission factors.

TTW CO2 emissions

TTW CO2 emissions, measured in gCO2/MJ, are calculated as the product of fuel carbon content and energy consumption by fuel type. Energy consumption by fuel type is calculated as the average fuel economy of the vehicle fleet (by fuel/engine technology) multiplied by the VKT share by fuel/engine technology.

WTT emissions

WWT emissions (measured g/MJ) are calculated in a broadly similar way to the TTW CO2 emissions; energy consumption by fuel type is multiplied by WTT emission factors (also disaggregated by fuel type).

The methodology for WTT emissions (g/MJ) isn't much different to the TTW CO2 emission factors. The only difference is the inclusion of WTT emission factors by fuel type.

WTW emissions

These are calculated as the sum of the three different types of emissions (and measured in g/MJ).

2 User Guidance

2.1 Key parts of the user interface

There are four primary sheets in the spreadsheet model that a typical user will interact with;

- Outputs
- Inputs
- Output Viewer
- Country Data

This chapter focuses on how a typical user should interact with these key parts of the model. While a user designing and implementing their own scenarios will require a fuller understanding of the various sheets in the model, that is not the aim of this chapter; a full list of all tables within the model can be found in Appendix B.

2.2 Outputs

The user can switch on or off policies (effectively adding or removing them from the scenario) via the policy lever control panel. The user can use the dropdown bars (as shown in Figure 2) to set the policy lever to *TRUE* or *FALSE*. The model will then overwrite any baseline trajectory data in the model with the relevant policy data found in the 'Inputs' tab.

Figure 2 Policy lever control panel

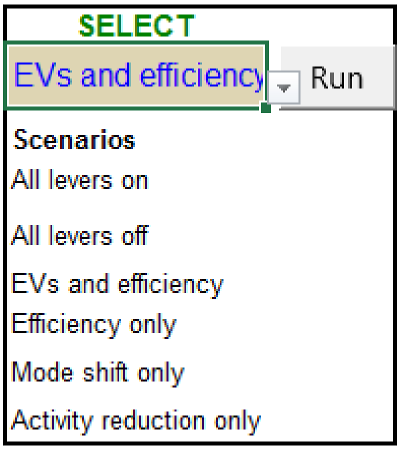
SELECT "TRUE" TO INCLUDE LEVER IN

LEVER	All	LDV	HDV	Other on-road	Rail	Aviation	Marine
Vehicle Fuel Economy		TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Low Carbon Fuels	TRUE						
Electric Drive Vehicles		TRUE	FALSE	FALSE	TRUE		
Grid Decarbonization	TRUE						
Mode Shift	TRUE						
Activity Reduction / MBM	TRUE					TRUE	TRUE
Emission Standards		TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Low Sulphur Fuels	TRUE						

There are five scenarios[13] in the EUTRM which correspond to different groups of policy levers being activated. The user can select one of these scenarios from the drop down menu and hit run instead of activating individual policy options. This will update the table in Figure 2.

[13] All levers on, all levers off, EVs and efficiency, efficiency only, mode shift only, activity reduction only.

Figure 3 Scenarios

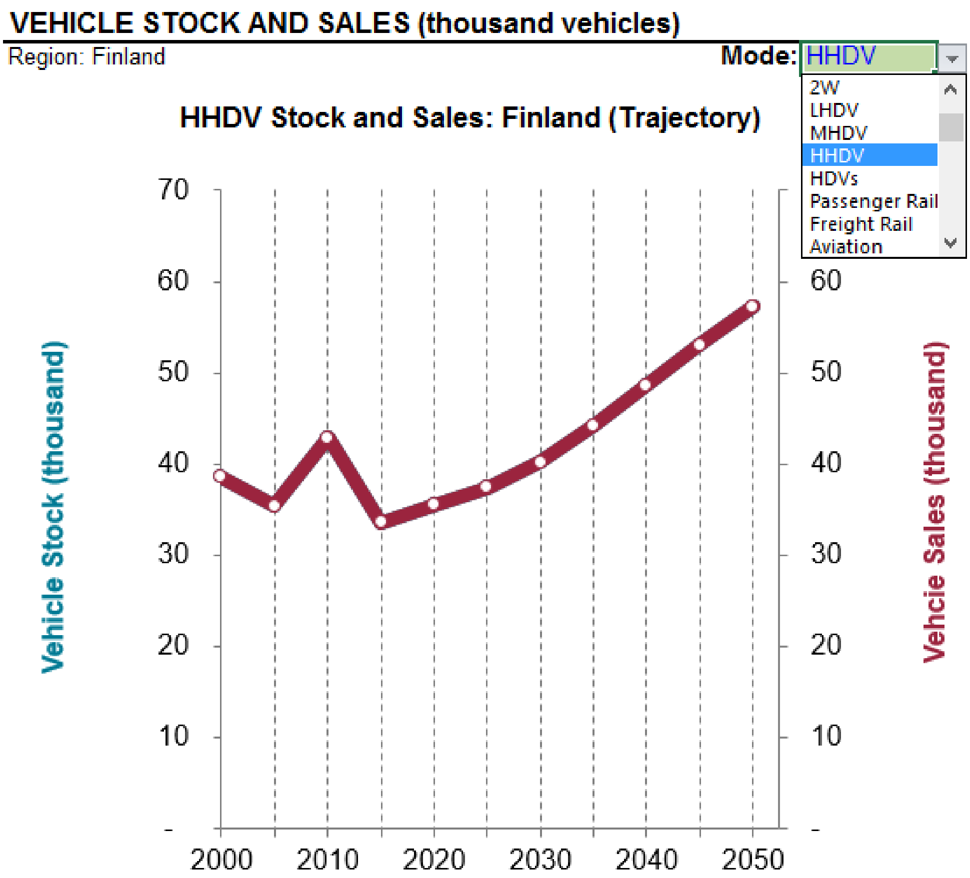


The output charts in this section will display data on a region, pollutant, mode, and case in accordance with the user's selection from the dropdown menus in Figure 4.

Figure 4 Output selection

The charts display trajectory and base case emissions, country emissions by mode, passenger activity by mode, freight activity by mode, vehicle stock and sales, share of vehicles sales by engine technology, new fleet fuel efficiency, fuel consumption and savings, all consumption by mode in 2010 by region and all consumption by mode by region. To the right of the charts is a series of tables which display the relevant data.

For quick customisation of charts and tables there are other dropdown menus. The first is located under the title *Vehicle Stock and Sales*.



The next is found under the *New fleet fuel efficiency* and *Fuel consumption and savings* headings. Under *New fleet fuel efficiency*, the user can select the units[14]. For *Fuel consumption and savings* the mode, fuel type and energy unit can be chosen.

2.3 Inputs

The input sheet starts with a navigation table (Figure 5) which allows the user to jump to different policy lever inputs. The yellow button to the right will take the user back to the 'Output' tab.

Figure 5 Navigation table

↓↓↓	JUMP TO POLICY LEVER	↓↓↓	
PASSENGER VEHICLE FUEL ECONOMY	LOW Sulphur FUELS	TRAVEL DEMAND MANAGEMENT	CLICK HERE TO TURN LEVERS ON OR OFF
FREIGHT TRUCK FUEL ECONOMY	ELECTRIC DRIVE VEHICLES	AVIATION MBMs	
RAIL, AVIATION, & MARINE EFFICIENC	GRID DECARBONIZATION	LOAD FACTORS	
LOW CARBON FUELS	MODE SHIFT	IN-USE FUEL EFFICIENCY	

Table 1 gives a brief description of the policy levels, how the user can edit them, what the policy baselines already within the model are and potential considerations for further scenario modelling.

[14] MJ/km, L/100km, km/L, mpg and CO2/km

Table 1 Policy levers

Policy Lever	Description	EUTRM's policy baseline	Considerations
Passenger vehicle fuel economy (CO_2/km)	The user input is future fuel economy values for new vehicles by region and year (can be used to model different fuel economy standards) Figures can be inputted into either the trajectory or base case Fuel economy for LDVs are an average across petrol, diesel, non-plug-in hybrids, CNG and LPG. Fuel economy for other modes (including freight trucks) must be entered separately for petrol and diesel Difference between test-cycle and in-use efficiency not explicitly included in this lever, but can be adjusted separately in the mode-specific tab (See cell O363 in 'LDV input')	95 gCO_2/km implemented in the model for 2020 (policy target for 2021) 2020, 147gCO_2 for vans Difference between test-cycle and in-use efficiency set per figure below: 2000: 10% 2010: 24% 2015: 35% 2020: 49% *These figures are only used to adjust LDVs and LHDVs since other mode are extracted from TRACCS database which measures fuel economy from in-use (real world) efficiency*	Model implications of EU fuel economy targets for LDVs, 2W and buses
Freight Truck Fuel Economy	As above	As above	Model implications of EU fuel economy target for different freight modes

Rail, Aviation & Marine Fuel Efficiency	Like policy lever above User input is the annualised rate of reduction in fuel consumption for each mode There is a trajectory and base case the user can edit Rail and aviation efficiency can be adjusted by region and year Figures for rail improvements apply only to the diesel share of energy consumption There is no region dimension to marine improvements; a 30-state average figure must be entered	Aviation fuel efficiency set at an annual reduction rate of 0.2666% from 2015 to 2030. To take account of ICCT[15] data of a 4% reduction by 2030 from 2015. Shipping rate for Energy Efficiency Design Index (EEDI) improvements are set out below: Pre-2015: 0 2015-2019: 10% 2020-2024: 20% 2025: 30%	Model the future reduction in fuel consumption of rail, aviation and marine transport
Low Carbon Fuels	The user can set a regulatory treatment – affects the estimation of the WTT emission factors from biofuels The three treatments are no benefits [from biofuels], no LUC and with LUC (and iLUC) The user can decide whether to include Biofuel offset, if 'Yes' the TTW CO2 emission will be zero WTT CO2 emission factors are calculated as a weighted average depending on	Based on new EU regulation, the total percentage of biofuels was set to 7% in both biodiesel and bioethanol from 2020 onwards. In some MS a higher biofuel commitment was set per individual countries' intentions/commitments to biofuels, information was part of a European Commission Impact Assessment[16]. GLOBIOM estimates the share of production of different biofuel feedstocks	Greater number of advanced biofuels contributing towards the 7% cap on food-based biofuels. Especially post 2020 – potentially also later increases in total biofuel content in fossil fuels.

[15] http://www.theicct.org/sites/default/files/publications/ICCT-ICAO_policy-update_feb2016.pdf

[16] European Commission (2016) "Commission Staff Working Document – Impact Assessment". Available here.

	the global share of conventional and various unconventional (heavy oil, oil shale, CtL, GtL) fossil fuels. The shares of these are inputted from EIA forecasts (IEA, 2011) The user can only edit fuel blends in the trajectory case relative to the base case The user can choose to increase the percentage share of biofuels in petrol and/or diesel. A dropdown menu allows the user to see the percentage mix of biofuels in the base case For example, the user can input a figure of 5% into sugar ethanol in each period, this will then reallocate 5% of the fuel blend mix from petrol to sugar ethanol	under the 7% cap. These shares were used to estimate the fuel blend mix in the base case. No further fuel blend increases are included beyond this as a policy lever.	
Low Sulphur Fuels	The user can edit the sulphur content of diesel fuel which reduces the tailpipe emissions of PM and SO2	Assume an average of 10ppm every year between 2010-2050	Further reductions of maximum sulphur content of diesel
Electric Drive Vehicles	The user can adjust the share of sales of passenger electric vehicles in the trajectory case Adjustments to the sale of other on-road modes can be made in the mode-	0% increase in electric drive vehicles	Model the impact of increased share of sales of electric vehicles

	specific input tabs – not included in policy lever.		
Grid Decarbonization	The user can enter values to represent a reduction (from the baseline) in the overall carbon dioxide intensity of electricity The inputted percentage reduction in carbon intensity is applied across all pollutants and regions – "this simplifying assumption models the general effect of increasing the mix of renewable electricity in the grid and thus reducing local air pollutants along with GHGs".	Electricity carbon dioxide intensity (g/MJ) – reduction from baseline is set to zero A separate spreadsheet tool has been constructed (see note on WTT Emission Factors for Electricity) to allow the user to change sources of electricity – this data can be bought directly into the model via the fuel tab. This method will override the percentage reductions specified through the policy lever.	Model the implication of higher electricity generation from renewable resources
Mode Shift	The user can use this policy to shift the passenger/freight activity from high carbon modes (LDVs and HDVs) to low carbon modes such as public transport, motorcycles, non-motorised transportation (NMT) and freight rail There are six different mode shifts of which the user can enter a desired percentage This will reduce emissions, calculated as the difference in emissions per unit of activity times the volume of activity shifted	Set at zero	Model the effect of more public transport usage (move from LDV to rail or bus).

	The table on the right will (cell reference: P937) calculate the volume of activity shifted in billions of pkm/tkm. Hence these figures also represent the level of transit, freight rail or NMT that would be required to offset the reduction in LDV or HHDV activity The table to the far right estimates the percentage reduction needed annually to model a constant absolute shift in activity. The figures in this table can then be copied across to the initial table (on the far left) and entered.		
Travel Demand Management	By reducing the transport (LDV) activity, average trip length or improving freight logistics the user can slow the growth of transportation activity The user can enter percentage changes in passenger km or ton km by specific region and projected year. The average trip length is applied to LDVs and 2W only The model estimates trajectory case transportation activity as equal to baseline activity. Then it is adjusted according to reductions in activity and average trip lengths (as set out above).	Set at zero	Model the effect of greater urbanization through reducing the average trip length.

Aviation Market Based Measures (MBMs)	Models the effect of MBM on demand for aviation The user can reduce the total aviation activity in both the trajectory and base case by entering percentages for a given region and period.	The GTRM model included estimates for reductions due to the implementation of the EU ETS, and these have been retained[17]	Increased deployment of MBMs to reduce aviation activity
Load Factors	The user can adjust the load factors as a percentage increase from the base case for LDV, Buses or HDV The implication of load factors in the model is to estimate vehicle activity from passenger/freight transportation activity Therefore, an increase in the load factors will reduce the amount of vehicle activity Percentage increase in HDV applies to all freight vans and trucks (LDHV, MHDVs and HHDVs).	Set to zero	This can be used to model improved congestion management policies or logistics.
In-use Fuel Efficiency (fuel consumed per VKT) (e.g. due to congestion relief strategies)	This policy lever gives the user the option to increase (in the trajectory case) or decrease (in the base case) the in-use fuel consumption of on-road vehicles	Set to zero	Congestion relief strategies could drive improvements in in-use fuel efficiency.

[17] The EU ETS does not explicitly set out to reduce aviation activity; instead it is designed to encourage lowest-cost adoption of emissions-reducing technologies. For the aviation sector, this might include reducing activity, but is more likely to include reducing emissions associated with activity (e.g. through the increased use of biofuel) or purchasing greater volumes of emissions permits (forcing emissions reductions in other sectors where the associated costs are lower).

	The relative change in in-use fuel consumption is applied across all on-road modes (both passenger and freight, excludes fuel cell and electric passenger cars)	

2.4 Output viewer

This sheet provides a set of charts and tables that allow the user to analyse a range of key parameters in more depth. The dropdown menus and filters allows the use to populate the charts with data that would otherwise be hard to find in the model. The tab offers a high degree of flexibility to compare parameters across modes/regions. The user has four options:

- Compare a parameter in one region across several modes
- Compare a parameter for one mode across several regions
- Compare two parameters for one mode across several regions
- Compare a parameter over time across modes and regions

To step through how to use this tab an example for the second option will be given. A filter in the table (in Figure 6) will allow the user to select specific regions. The user can then choose one mode and one parameter from the dropdown menus.

Figure 6 Compare a parameter for one mode across several regions

COMPARE ONE PARAMETER ACROSS SEVERAL REGIONS

Mode: LDV **Parameter:** WTW CO2e/vkm

TRAJECTORY CAS

Region	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Belgium	319.3	299.4	494.0	503.8	608.7	628.9	587.6	568.8	559.8	553.7	549.5
Bulgaria	306.9	301.7	315.6	474.0	845.2	834.7	788.0	747.6	719.0	694.1	668.3
Czech Republic	341.0	314.6	443.9	508.9	988.3	872.7	821.2	781.9	745.3	717.1	699.8
Denmark	340.6	318.0	323.0	473.1	898.2	807.1	771.7	748.0	730.5	716.0	705.0
Germany	420.6	472.4	553.3	563.9	713.5	703.3	636.4	605.9	592.4	585.9	582.5
Estonia	314.8	308.4	299.7	292.9	789.5	771.6	740.6	713.9	688.0	659.9	635.2
Ireland	315.5	301.5	362.3	467.1	735.0	716.5	683.4	662.8	647.6	634.9	625.9
Greece	308.9	301.5	336.5	310.0	701.2	680.1	658.1	642.7	632.3	624.9	620.0
Spain	348.9	342.9	522.4	289.6	744.4	718.0	675.9	651.8	637.8	629.6	624.7
France	359.4	369.1	573.1	626.9	742.8	723.8	687.2	668.5	659.6	655.3	653.1
Croatia	307.2	305.3	300.8	346.6	893.6	862.5	802.5	769.5	749.2	734.1	723.4
Italy	334.7	315.1	449.9	423.5	664.2	644.2	610.3	591.1	580.2	573.1	568.4
Cyprus	304.8	298.7	345.1	361.8	758.1	743.2	715.5	691.7	668.4	646.3	629.0
Latvia	337.9	343.9	413.3	410.7	793.9	774.7	740.2	706.0	675.4	645.9	623.2
Lithuania	289.8	316.5	425.4	449.2	796.6	780.3	756.1	733.9	707.6	664.1	625.6
Luxembourg	336.6	305.4	388.4	537.3	779.6	745.9	688.1	658.8	639.8	623.7	613.3
Hungary	316.7	309.0	474.2	539.6	659.4	659.4	620.0	589.0	571.2	561.1	554.9
Malta	301.0	299.3	287.9	425.3	760.0	744.5	716.2	692.1	669.1	647.5	630.6
Netherlands	329.8	318.6	397.2	449.4	861.0	824.5	791.9	772.4	759.4	749.4	741.7
Austria	448.8	456.3	746.3	715.5	770.2	738.0	682.6	650.6	632.6	621.9	615.5
Poland	328.4	336.2	514.0	504.4	947.1	928.2	898.4	870.0	839.1	802.9	769.7
Portugal	308.8	292.8	487.5	400.6	889.5	870.3	842.0	824.8	814.6	807.6	802.5
Romania	333.3	332.1	402.0	425.3	634.1	654.9	625.9	593.9	571.5	557.7	549.1
Slovenia	319.3	303.0	374.0	365.9	567.6	721.8	673.5	643.5	625.0	611.8	602.5
Slovakia	328.0	331.6	450.1	532.8	767.2	741.9	700.7	672.8	647.1	625.2	612.0
Finland	353.9	338.2	447.0	1,107.1	1,280.4	1,248.8	1,187.7	1,146.4	1,118.7	1,096.6	1,079.2
Sweden	514.3	471.4	581.7	1,076.2	1,267.0	1,246.9	1,176.8	1,133.5	1,106.2	1,085.6	1,070.7
United Kingdom	341.0	326.8	414.1	473.8	756.1	723.2	669.4	641.1	626.1	618.2	614.0
Norway	364.5	343.8	446.1	457.1	694.9	657.5	613.7	588.4	571.5	560.6	553.5
Switzerland	396.6	369.9	466.5	536.1	849.4	812.7	752.6	709.3	671.2	637.6	615.4
Europe-30	**362.9**	**365.0**	**490.9**	**523.5**	**765.6**	**745.7**	**701.6**	**676.7**	**660.7**	**649.6**	**642.0**

This data can be viewed in the charts below the table in the model. The rest of the options operate in a similar fashion.

2.5 Country data

This sheet neatly summarises the main inputs and outputs of the EUTRM for a selected country. It allows the user to quickly check the model results against the inputs through a set of concise tables. The sheet contains 3 dropdown options which are as follows:

- Select Region
  Changes the country to display results for.

- Select Fuel Efficiency Unit & mode
  Allows the users to select the units to present the fuel efficiency data and a switch between the different on-road vehicle modes.

- Select Pollutant
  Allows the user to select the pollutant to display for emissions by mode tables.

3 Data Sources

This section sets out the input parameters within the model and the sources of data used. It is broken down into three sections;

- socioeconomic parameters,
- transportation parameters
- emission parameters.

In nearly all cases more than one data source was used and data processing techniques were employed to fill gaps (in country and/or temporal coverage). The methods used to estimate missing data are set out in full detail in 1.11.1.1.1.Appendix C.

3.1 Socioeconomic parameters

The socioeconomic parameters are the starting point of the model calculations. They are used to estimate future passenger and freight transportation activity.

Table 2 Socioeconomic parameters

Socioeconomic Parameter	Source for historical data	Source for projections
Population	PRIMES US Census Bureau, International Data Base (IDB)	PRIMES US Census Bureau, International Data Base (IDB)
GDP	PRIMES, OECD, and IMF WEO	PRIMES, OECD, and IMF WEO
Fuel price	European Commission Weekly Oil Bulletin (ECWOB) World Bank (WB) Development Indicators	IEA WEO (2016), EIA AEO (2016), ArrowHead Economics, IHS Global Insight (IHSGI)

The initial source for GDP projections was the EU PRIMES 2016 baseline, but it was felt that these presented an overly-optimistic view of future GDP growth, so alternative sources were identified. In the final projections, for most countries, whichever of PRIMES and OECD showed lower projected growth was used, while IMF WEO projections were used for Norway and Switzerland. For fuel prices, European Commission Weekly Oil Bulletin (ECWOB) data was used for most regions. World Bank (WB) Development Indicators (pump price for diesel/gasoline) were used to fill the gaps (including data for Croatia, Norway and Switzerland). Fuel prices are inclusive of taxes. Projections of fuel prices are based on projection of crude oil prices from the IEA, EIA, ArrowHead Economics and IHGSI.

In total seven scenarios are available to project fuel prices. Three came from the IEA; New policies, Current policies and 450 scenarios. The other four were sourced from a comparison table in EIA AEO (2016). The user can choose which set of projections to use within the model.

3.2 Transportation parameters

The transportation parameters are the bulk of external data used in the model. Set out below is a short description of the parameters and a table containing the sources for history and projected data. Passenger rail, freight rail, aviation and marine are excluded from some of the parameters outlined, as these are treated differently within the EUTRM and do not require the same set of parameters as is used for road transport.

Total passenger transportation activity (TPTA) and mode share

Historical total passenger transportation activity (measured in billion passenger-km) was drawn from existing data. Projections are driven by fuel price adjusted GDP (FPA-GDP) growth[18].

Table 3 TPTA and Mode Share

Mode	History	Projections
LDV	EU Pocketbook	*Model Calculation*
2W	TRACCS	*Model Calculation*
Buses	EU Pocketbook	*Model Calculation*
Passenger rail	EU Pocketbook	*Model Calculation*

The mode share for transportation activity was calculated by dividing mode-specific transportation by TPTA.

Total freight transportation activity (TFTA) and mode share

Total freight transportation activity (measured in billion metric ton-km) was calculated using the same function as TPTA with different values for the regression parameters in the model calculation.

Table 4 TFTA and Mode Share

Mode	History	Projections
LHDVs	TREMOVE	*Model Calculation*
MHDVs	EU Pocketbook	*Model Calculation*
HHDVs	EU Pocketbook	*Model Calculation*
Freight rail	EU Pocketbook	*Model Calculation*

The EU Pocketbook was the primary source for Freight Transportation Activity as it records data based on the territoriality principle. This means that transportation activity is recorded based on the national territory it is travelling in, not the nationality of the haulier.

Vehicle stock

[18] GDP projections are adjusted to take account of the impact of changes to fuel prices on household expenditure; the fuel-adjusted GDP projections are therefore a proxy for changes in household wealth, *taking into account the cost of owning/running a vehicle*

Historical vehicle stock (measured in millions of units) for all road transport modes was collected from two sources as shown below; projections are calculated in the model on the basis of the demand for road transport.

Table 5 Historical vehicle stock

Mode	History	Projections
LDVs	EU Pocketbook	*Model Calculation*
2W	EU Pocketbook	*Model Calculation*
Buses	EU Pocketbook	*Model Calculation*
LHDVs	TRACCS	*Model Calculation*
MHDVs	TRACCS	*Model Calculation*
HHDVs	TRACCS	*Model Calculation*

New vehicle registrations

Historical new vehicle registrations are measured in millions of euros. Projections are calculated as the difference between total road transport demand and the supply of road transport vehicle kilometres. The inclusion of second-hand vehicle trade will alter projected new vehicle registrations. New vehicle registrations for net importers would decrease as more demand is met through imported second-hand cars. Conversely, new vehicle registrations for net exporters would increase as the supply of road transport vehicle kilometres reduces due to exported vehicles. Hence, more new vehicle registrations would be needed to meet demand.

Table 6 Historical new vehicle registrations

Mode	History	Projections
LDVs	EU Pocketbook	*Model Calculation*
2W	EU Pocketbook	*Model Calculation*
Buses	EU Pocketbook	*Model Calculation*
LHDVs	TRACCS	*Model Calculation*
MHDVs	TRACCS	*Model Calculation*
HHDVs	TRACCS	*Model Calculation*

Bilateral Trade

Historical bilateral trade is estimated by utilising existing estimated bilateral trade relationships between large importing and exporting states for LDVs and TRACCS data on second-hand vehicle registrations. It was assumed that the general relationship between countries for import and export of LDVs would closely mirror the import and export of other vehicles. For the purposes of estimating bilateral trade relationships, second-vehicle registrations is used as a best estimate for the quantities of vehicles imported. The bilateral trade relationships estimated from historical data are assumed to hold for all time periods.

Table 7 Bilateral Trade Relationships

Mode	History
LDVs	T&ML BTM[19], TRACCS
2W	T&ML BTM, TRACCS
Buses	T&ML BTM, TRACCS
LHDVs	T&ML BTM, TRACCS
MHDVs	T&ML BTM, TRACCS
HHDVs	T&ML BTM, TRACCS

Survival Rates

Historical survival rates for all vehicle types are estimated for all modes from TRACCS and are adjusted for import and export activity. Using the estimated bilateral trade matrices the total amount of exports as a percentage of vehicle sales was estimated and then applied to discount the survival rates of vehicles. Likewise, the total amount of imports as a percentage of total vehicle stock was estimated and then applied to inflate the survival rate to account for the replacement of vehicles of varying ages. The average survival rates estimated from the five years of available TRACCS data are assumed to hold for all time periods.

Average annual distance travelled per vehicle

Average annual distance travelled per vehicle (measured in km) was collected for all modes from TRACCS. The last data point from TRACCS (2010) is held constant to 2050 for all modes apart from LDVs. Projections of average annual distance travelled per vehicle for LDVs are calculated based on vehicles per capita (VPC). The higher the number of vehicles per capita the smaller the average annual distance travelled per vehicle.

Table 8 Average annual distance travelled per vehicle

Mode	History	Projections
LDVs	TRACCS	*Model calculation*
2W	TRACCS	*2010 held constant to 2050*
Buses	TRACCS	*2010 held constant to 2050*
LHDVs	TRACCS	*2010 held constant to 2050*
MHDVs	TRACCS	*2010 held constant to 2050*
HHDVs	TRACCS	*2010 held constant to 2050*

[19] Relationships between importing and exporting states were estimated using information from Transport and Mobility Leuven's 2016 paper, "Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV CO2 regulations."

Load factors for both passenger and freight

Table 9 Load factors

Mode	History	Projections
LDVs	TREMOVE	*2010 held constant to 2050*
2W	TREMOVE	*2010 held constant to 2050*
Buses	TREMOVE	*2010 held constant to 2050*
LHDVs	*Model calculation*	*2010 held constant to 2050*
MHDVs	TREMOVE	*2010 held constant to 2050*
HHDVs	TREMOVE	*2010 held constant to 2050*

Historical load factors for both passenger and freight for all modes are extracted from TREMOVE for all road transportation apart from LHDVs. Load factors for LHDVs were calculated from other transportation parameters in the model to ensure consistency between different data sources. The calculation was passenger (or freight) transportation activity divided by the vehicle stock multiplied by the average distance travelled per vehicle. Projections for load factors are assumed constant from 2015-50.

Annual distance accumulation by age

Annual distance accumulation by age is the percentage distance travelled at age X compared to the distance travelled by a new vehicle in the same time period. This reflects the fact that an older vehicle is driven less annual mileage (on average) than a newer one.

Table 10 Annual distance accumulation by age

Mode	Source
LDVs	TRACCS/Ricardo-AEA[20]
2W	TRACCS
Buses	TRACCS
LHDVs	TRACCS/ Ricardo-AEA
MHDVs	TRACCS
HHDVs	TRACCS

[20] Improvements to the definition of lifetime mileage of light duty vehicles. Report for European Commission (DG Climate Action). Ref: Ares (2014)2298698ED. Available at: https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_mileage_improvement_en.pdf

An average was calculated based on data for gasoline and diesel vehicles taken from TRACCS, up to 30-year-old vehicles. Data for the UK was sourced from a UK MOT database commissioned by Ricardo-AEA for two modes of transport. An average between gasoline and diesel was calculated from the Ricardo-AEA data, up to 19-year-old vehicles. Data from both sources was extended up to 40-year-old vehicles by holding constant the value attributed to the oldest single year of age from the two sources.

Fuel economy for new vehicles by fuel type

Fuel economy for new vehicles by fuel type (measured in gCO2/km) historical data was collated from the ICCT Pocketbook (2015/16) and TRACCS. This parameter is one of the policy levers in the model. Therefore, the assumptions made for projection are consistent with announced policy. Where announced policy is not available the fuel economy in 2015 is held constant to 2050.

Table 11 Fuel economy for vehicles by fuel type

Mode	History	Projections (policy baseline)
LDVs (all fuel types)	ICCT Pocketbook	95 gCO2/km from 2020-50
2W (petrol/diesel)	TRACCS	None (2015 held constant to 2050)
Buses (petrol/diesel)	TRACCS	None (2015 held constant to 2050)
LHDVs (petrol/diesel)	ICCT Pocketbook	147 gCO2/km from 2020-50
MHDVs (petrol/diesel)	TRACCS	None (2015 held constant to 2050)
HHDVs (petrol/diesel)	TRACCS	None (2015 held constant to 2050)

Share of new vehicle sales by fuel/engine technology

Historical data on the split of new sales by different fuel/engine technologies was sourced from the ICCT Pocketbook and TRACCS, while the primary assumption made for the projections was that, in the absence of incontrovertible evidence to the contrary, these shares will not change in the future.

Table 12 Share of new vehicle sales by fuel/engine technology

Mode	History	Projections
LDVs	ICCT Pocketbook	2015 held constant to 2050
2W	TRACCS	2015 held constant to 2050
Buses	TRACCS	2015 held constant to 2050
LHDVs	TRACCS	2015 held constant to 2050

MHDVs	TRACCS	2015 held constant to 2050
HHDVs	TRACCS	2015 held constant to 2050

Share of vehicle activity by fuel/engine technology in 2000

Share of vehicle activity by fuel/engine technology in 2000 (%) is directly used in the TTW SO2 composite emission factors and TTW energy consumption calculations.

Table 13 Share of vehicle activity by fuel/engine technology in 2000

Mode	All time periods
LDVs	TREMOVE
2W	TREMOVE
Buses	TREMOVE
LHDVs	TREMOVE
MHDVs	TREMOVE
HHDVs	TREMOVE

Share of VKT in urban areas

Share of VKT in urban areas (%) is based on the historic and projected population in urban areas, taken from an updated UN publication

Table 14 Share of VKT in urban areas (%)

Mode	History	Projection
Road transportation for both passenger and freight	UN World Urbanization Prospects: The 2014 Revision	UN World Urbanization Prospects: The 2014 Revision

Energy intensity for passenger and freight rail

The treatment for passenger and freight rail in the EUTRM varies from the road modes. Historical energy intensity for passenger and freight rail (measured in MJ/passenger-km) is calculated from available data in TRACCS. While projections are based on a model calculation.

Table 15 Energy intensity

Mode	History	Projections
Passenger rail	TRACCS	*Model calculation*
Freight rail	TRACCS	*Model calculation*

Diesel share for passenger rail and freight rail

Historical diesel share for passenger rail and freight rail (%) is a percentage of diesel rail activity as a total of diesel and electricity rail activity. Projections for diesel share are calculated in the model.

Table 16 Diesel share

Mode	History	Projections
Passenger rail	TRACCS	*Model calculation*
Freight rail	TRACCS	*Model calculation*

Energy efficiency for new aircrafts

Energy efficiency for new aircrafts (RPK/kg jet fuel) in the EUTRM is set in each region to the EU average, based on data from the latest SAGE[21]report (v1.5).

Total annual aviation travel activity

Historical total annual aviation travel activity (billion revenue passenger-km) was reverse-engineered based on UNFCCC data by Member State on tank-to-wing emissions (by applying emissions factors to get to fuel consumed and then applying average fleet efficiency to get to travel activity). The methodology used is set out in more detail in 1.11.1.1.1.Appendix C. The projections can be calculated using one of two methods; in the default case, growth rates are taken from a DG TAXUD study[22] on projected changes in VAT receipts from aviation to 2030, and growth to 2050 is extrapolated out at the same rate as that expected over 2010-30. For the countries that have no data in the study, proxy countries are identified based on similarities in historical growth rates and geographical proximity, and the projected growth rates for the partner country is used to extend the existing historical data. In the alternative methodology, historical total annual aviation travel activity (billion revenue passenger-km) was calculated using SAGE data for the EU27. The SAGE data for the 30 regions was calculated in accordance to the shares of aviation passenger transportation activity data from TRACCS. The methodology used is set out in more detail in 1.11.1.1.1.Appendix C. Projections are determined from SAGE using an unconstrained growth scenario (i.e. infrastructure growth parallels industry and demand growth).

Emissions for marine

The IMO CO2 projection figures were updated from the 2014 Third IMO GHG Study data and were representative of global emissions. A share of European maritime activity was needed to recalibrate the emissions to be European specific. The European share of world tonnage, from the United Nations Conference on Trade & Development (UNCTAD) publication Review of Maritime Transport 2015, was used as a proxy.

3.3 Emission parameters

Fuel blends

Historical data sourced from Eurostat was used as a proxy for fuel blends (given the minimal take up of pure biofuel or electric vehicles). The shares across the different types of biofuels were estimated based upon GLOBIOM production shares, extracted from their 7% scenario.

Projections of fuel blends (%) for each region are calculated based on national biofuel commitments, EU-mandate and GLOBIOM production shares. The

[21] System for assessing Aviation's Global Emissions (SAGE) is a model to predict aircraft fuel burn and emissions from commercial flights. Further information available here: https://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/sage/.

[22] Study on VAT rules for passenger transport, Final Report (2014)

Impact Assessment[23] from the European Commission on biofuel mandates was initially used to calculate the total biofuel commitment for each region. The shares of different biofuel types were then calculated using the production shares in GLOBIOM under their 7% scenario. The scenario follows the EU's policy to cap food-based biofuels at 7% and set a target for advanced low-iLUC (indirect Land Use Change) biofuels at 0.5%. Where biofuel commitments from countries wasn't available, the biofuel blend of total conventional fuel was set at 7%. If the mandate was over 7%, then the additional amount was evenly shared between the advanced biofuel pathways (cellulose ethanol and cellulosic/waste biodiesel). If the regional biofuel mandate was less than 7%, a new share was calculated using GLOBIOM projections.

Table 17 Fuel blends

Biofuel type	History	Projection
Starch ethanol	GLOBIOM/Eurostat	GLOBIOM/Impact Assessment
Sugar ethanol	GLOBIOM/Eurostat	GLOBIOM/Impact Assessment
Cellulose ethanol	GLOBIOM/Eurostat	GLOBIOM/Impact Assessment
Vegetable oil-based biodiesel	GLOBIOM/Eurostat	GLOBIOM/Impact Assessment
Cellulosic/waste biodiesel	GLOBIOM/Eurostat	GLOBIOM/Impact Assessment
Low sulphur biodiesel	*Model calculation based on sulphur content*	*Model calculation based on sulphur content*

WTT emission factors

WTT emission factors (g/MJ) by fuel type were drawn from the JEC WTW study for CO2, CH4 and N2O pollutants. Other minor pollutants were sourced from EPA US MOBILE. WTT CO2 emission factors for biofuels has two sources, JEC WTW and GLOBIOM, and the user can choose which source to use. This allows the user to either exclude (JEC WTW) or include (GLOBIOM) the impact of land use change (LUC) (including direct and indirect) on emissions factors.

Table 18 WTT emission factors

Fuel type	All time periods
Gasoline	JEC WTW
Starch ethanol	JEC WTW /GLOBIOM
Sugar ethanol	JEC WTW /GLOBIOM
Cellulose ethanol	

[23] https://ec.europa.eu/transparency/regdoc/rep/10102/2016/EN/SWD-2016-418-F1-EN-MAIN-PART-3.PDF

Conventional diesel	JEC WTW
Vegetable oil-based biodiesel	JEC WTW /GLOBIOM
Cellulosic and waster biodiesel	JEC WTW /GLOBIOM
Low sulphur biodiesel	JEC WTW /GLOBIOM
CNG	JEC WTW
LPG	JEC WTW
Hydrogen	JEC WTW
Jet fuel	*Set equal to gasoline*
Residual fuel	*set equal to gasoline*

WTT emission factors for electricity

WTT emission factors for electricity (g/MJ) vary for each region and pollutant. Historic WTT emission factors were drawn from the JEC WTW study whilst a straightforward off-model spreadsheet tool was created so that emission factors for CO2, CH4 and N2O in projected years can be calculated according to user-inputted assumptions on generation mix. The tool uses historic JEC WTW figures, which can be updated if more recent data becomes available.

Share of world fossil fuel liquids consumption by source

Share of world fossil fuel liquids consumption by source (%) splits consumption of conventional oil and unconventional oil – extra heavy oil, oil sands, coal-to-liquid (CtL) and gas-to-liquid (GtL). In the GTRM the data was drawn from the EIA International Energy Outlook (IEO) (2011). Subsequent updates of the IEO have not updated this series, so the 2011 figures remain the most up-to-date available.

Fuel energy and carbon content

Fuel energy and carbon content data was partially updated based upon new data from the JEC WTW study. However, not all required data was available, and where updates have not been found the original data used in the GTRM has been retained.

Introduction of emission standards

Data on the year of introduction of different emission standards have been updated for all 30 regions from transportpolicy.net[24] using “implementation date all vehicle sales and registrations”.

Fuel sulphur content

Fuel sulphur content measured in parts per million (ppm) was assumed to be consistent across all 30 regions; historical data was sourced from transportpolicy.net. Projected years are assumed to adhere to the latest emission standard of 10ppm of sulphur content.

TTW emission factors

TTW emission factors in the GTRM were extracted from US EPA MOBILE6. The data represent average lifetime emission factors and include deterioration over the life of the vehicle. These factors will not be updated for the EUTRM.

[24] A joint effort by the ICCT and diesel.net. LDV, 2W and HDV emission standards available at: http://transportpolicy.net/index.php?title=Category:Emissions_Standards

Emission standards for passenger and freight rail

Updated information from transportpolicy.net[25] shows that the latest EU directive on locomotives is aligned to tier 4. Therefore, the EUTRM will set update emission standards with this new information.

TTW emission factors for average fleet for passenger and freight rail

TTW emission factors for average fleet for passenger and freight rail are extracted from an EPA report 2009[26]. It contains assumptions about average (TTW) local air pollutant emission factors for locomotives that meet certain tier standards.

Biofuel blend for aviation

Although the European Advanced Biofuel Flightplan[27] sets EU-wide aims to include blended biofuel in aviation fuel, there is a lack of binding EU targets, and as a result the model assumes that biofuel blends will remain at 0% through to 2050.

TTW emission factors (g/km) for aviation

TTW emission factors (NOx/SO2/CO) measured in g/km for aviation are based on data from the latest SAGE report. Emission factors are a product of g of specified pollutant (NOx/SO2/CO) per kg of jet fuel and the fuel density (g/MJ).

CO2 emission savings (%) for marine

CO2 emission savings (%) (low and high estimates) for marine are extracted from International Maritime Organisation's (IMO) 2009 GHG study for both history and projections.

TTW emissions for marine

TTW emissions for marine (lower bound and upper bound) measured in million metric tons are extracted from the IMO 2009 GHG study.

[25] http://transportpolicy.net/index.php?title=EU:_Locomotives:_Emissions

[26] Technical Highlights Emission Factors for Locomotives (2009). EPA. Available at: https://nepis.epa.gov/Exe/ZyNET.exe/P100500B.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000010%5CP100500B.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

[27] European Advanced Biofuel Flightplan. Available at: http://ec.europa.eu/energy/node/76

Appendices

Appendix A Model classifications

Below are two tables which list the classifications used in the EUTR

Region
Belgium
Bulgaria
Czech Republic
Denmark
Germany
Estonia
Ireland
Greece
Spain
France
Croatia
Italy
Cyprus
Latvia
Lithuania
Luxembourg
Hungary
Malta
Netherlands
Austria
Poland
Portugal
Romania
Slovenia
Slovakia
Finland
Sweden
United Kingdom
Norway
Switzerland
EU28
Europe-30

Mode
All
LDV
Bus
2W
LHDV
MHDV
HHDV
HDV
Passenger Rail
Freight Rail
Aviation
Marine

Fuel Type
All
Gasoline
Starch Ethanol
Sugar Ethanol
Cellulosic Ethanol
Conventional Diesel
Low-Sulphur Diesel
Vegetable oil-based Biodiesel
Cellulosic/Waste-oil Biodiesel
CNG
LPG
Hydrogen
Electricity
Jet Fuel
Residual Fuel
Fuel Type
All
Gasoline
Starch Ethanol

Fuel/engine technology
Gasoline Conventional
Gasoline Hybrid
Gasoline Plug-in Hybrid
Diesel Conventional
Diesel Hybrid
Diesel Plug-in Hybrid
CNG
LPG
Fuel Cell
Electric
All

Vehicle type
Gasoline
Diesel

Pollutant
CO2e
CO2
CH4
N2O
NOx
CO
PM10
PM2.5
BC
SO2

Year
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

Emission Standard
Uncontrol
Engine Mods
Euro 1
Euro 2
Euro 3
Euro 4
Euro 5
Euro 6
SULEV

Table 19 Model classifications A

Region	Mode	Vehicle type	Fuel/engine technology
Belgium	All	Gasoline	Gasoline Conventional
Bulgaria	LDV	Diesel	Gasoline Hybrid
Czech Republic	Bus		Gasoline Plug-in Hybrid
Denmark	2W		Diesel Conventional
Germany	LHDV		Diesel Hybrid
Estonia	MHDV		Diesel Plug-in Hybrid
Ireland	HHDV		CNG
Greece	HDV		LPG
Spain	Passenger Rail		Fuel Cell
France	Freight Rail		Electric
Croatia	Aviation		All
Italy	Marine		
Cyprus			
Latvia			
Lithuania			
Luxembourg			
Hungary			
Malta			
Netherlands			
Austria			
Poland			
Portugal			
Romania			
Slovenia			
Slovakia			
Finland			
Sweden			
United Kingdom			
Norway			
Switzerland			
EU28			
Europe-30			

Table 20 Model classifications B

Pollutant	Fuel Type	Year	Emission Standard
CO2e	All	2000	Uncontrol
CO2	Gasoline	2005	Engine Mods
CH4	Starch Ethanol	2010	Euro 1
N2O	Sugar Ethanol	2015	Euro 2
NOx	Cellulosic Ethanol	2020	Euro 3
CO	Conventional Diesel	2025	Euro 4
PM10	Low-Sulphur Diesel	2030	Euro 5
PM2.5	Vegetable oil-based Biodiesel	2035	Euro 6
BC	Cellulosic/Waste-oil Biodiesel	2040	SULEV
SO2	CNG	2045	
	LPG	2050	
	Hydrogen		
	Electricity		
	Jet Fuel		
	Residual Fuel		

Appendix B Data tables in the EUTRM

Table 21 shows each subheading and data tables that is contained within the *'Input'* and *'Calc'* sheets for each road mode. However, the treatment is not entirely consistent across each road mode, Table 22 shows the additions/changes included in the treatment for LDV vehicles and Table 23 shows the additions/changes for freight road modes in comparison to the list in Table 21. Table 24 contains the data tables for passenger and freight rail and Table 25 contains the data tables for aviation and marine.

Table 21 Data tables for all road modes

Sheet	Subheading	Tables
'Input' for each road mode	Vehicle activity	Historical vehicle stock (million)
		Historical vehicle sales (million)
		Load factor (passenger/vehicle)
		Average annual distance travelled per vehicle (km)
		Share of VKT in urban areas (%)
	Share of new vehicles sales by fuel/engine technology (%)	Gasoline ICE/hybrid
		Diesel ICE/hybrid
		Gasoline plug-in hybrid
		Gasoline plug-in hybrid
		Diesel plug-in hybrid
		Diesel plug-in hybrid
		CNG
		LPG
		Fuel cell
		Electric
		All (error checking tables)
	Share of vehicle activity by fuel/engine technology in 2000	Share of vehicle activity by fuel/engine technology in 2000
	Fuel consumption by fuel/engine technology (MJ/km) – fleet average vs. new fleet in 2000	Variation in fleet average fuel consumption relative to new vehicles sold in 2000

	Annual VKT by fuel/engine technology	Annual VKT/vehicle of battery electric vehicles relative to ICE
	Average fuel consumption (MJ/km) – new fleet	In-use fuel consumption adjustment
		Fuel consumption: gasoline and diesel ICE/hybrid
	Fuel consumption by engine technology (MJ/km) – new fleet	New vehicle fuel consumption gasoline ICE/hybrid
		New vehicle fuel consumption diesel ICE/hybrid
		Fuel consumption fuel cell
		Fuel consumption electric
	Miscellaneous inputs	Fuel consumption differential – LPG/CNG gasoline
		VKT share of electric drive for plug-in hybrids (% that is electric)
	Emission factors	TTW emission factors for average fleet (g/km) – gasoline vehicles
		TTW emission factors for average fleet (g/km) – diesel vehicles
		TTW emission factors for average fleet (g/km) – other vehicles
		Country adjustment factors
	Introduction of emission standards – gasoline vehicles	Emission standards – introduction year
		Emission standards – VKT share in introduction year
		Emission standards – year when standard is applicable to 100% of the fleet
		(tables to the right are intermediate calculations

		and should not be edited or deleted)
	Introduction of emission standards – diesel vehicles	Emission standards – introduction year
		Emission standards – VKT share in introduction year
		Emission standards – year when standard is applicable to 100% of the fleet
		(tables to the right are intermediate calculations and should not be edited or deleted)
‘Calc’ for each road mode	Vehicle activity, vehicle stock, and vehicle sales	Total annual passenger travel activity (billion passenger-km)
		Annual vehicle activity (billion vehicle-km)
		Total vehicle stock (million)
		Total annual new vehicle sales (million) – intermediate calculation
		Total vehicle sales (million) – actual values
		Total annual new vehicle sales (million)
	Share of vehicle activity by fuel/engine technology	Gasoline ICE/hybrid
		Diesel ICE/hybrid
		Gasoline plug-in hybrid
		Diesel plug-in hybrid
		CNG
		LPG
		Fuel cell
		Electricity
		All (error checking tables)
	Fuel consumption by fuel/engine technology (MJ/km) – fleet average	Gasoline ICE/hybrid
		Diesel ICE/hybrid
		Gasoline plug-in hybrid
		Diesel plug-in hybrid

		CNG
		LPG
		Fuel cell
		Electricity
	TTW energy consumption by fuel type/energy source (PJ) – 10^15	Gasoline
		Starch ethanol
		Sugar ethanol
		Cellulosic ethanol
		Conventional diesel
		Low-sulphur Diesel
		Vegetable oil-based biodiesel
		Cellulosic/waste-oil biodiesel
		CNG
		LPG
		Hydrogen
		Electricity
		All
	VKT fractions by emission level bins – gasoline vehicle	VKT fraction with: Uncontrol
		VKT fraction with: Engine mods
		VKT fraction with: Euro 1
		VKT fraction with: Euro 2
		VKT fraction with: Euro 3
		VKT fraction with: Euro 4
		VKT fraction with: Euro 5
		VKT fraction with: Euro 6
		VKT fraction with: SULEV
		(for each standard, there are two extra support tables to the right; a trajectory case and base case)
		VKT fraction with: All
	TTW emission factors (g/MJ) – gasoline vehicles	TTW emission factors: CO2

		TTW emission factors: CH4
		TTW emission factors: N2O
		TTW emission factors: NOx
		TTW emission factors: CO
		TTW emission factors: PM10
		TTW emission factors: PM2.5
		TTW emission factors: BC
		TTW emission factors: SO2
	VKT fractions by emission level bins – diesel vehicles	VKT fraction: Uncontrol
		VKT fraction: Engine mods
		VKT fraction: Euro 1
		VKT fraction: Euro 2
		VKT fraction: Euro 3
		VKT fraction: Euro 4
		VKT fraction: Euro 5
		VKT fraction: Euro 6
		VKT fraction: SULEV
		(for each standard, there are two extra support tables to the right; a trajectory case and base case)
		VKT fraction: All
	TTW emission factors (g/MJ) – diesel vehicles	TTW emission factors: CO2
		TTW emission factors: CH4
		TTW emission factors: N2O
		TTW emission factors: NOx
		TTW emission factors: CO

		TTW emission factors: PM10
		TTW emission factors: PM2.5
		TTW emission factors: BC
		TTW emission factors: SO2
	TTW composite emission factors (g/MJ)	CO2 composite TTW emission factors
		CH4 composite TTW emission factors
		N2O composite TTW emission factors
		NOx composite TTW emission factors
		CO composite TTW emission factors
		PM10 composite TTW emission factors
		PM2.5 composite TTW emission factors
		BC composite TTW emission factors
		SO2 composite TTW emission factors
	WTT emission factors (g/MJ)	WTT emission factors: CO2
		WTT emission factors: CH4
		WTT emission factors: N2O
		WTT emission factors: NOx
		WTT emission factors: CO
		WTT emission factors: PM10
		WTT emission factors: PM2.5
		WTT emission factors: BC
		WTT emission factors: SO2

	TTW emissions by pollutant (CO2 is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	WTT emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	WTW emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2-equivalent emissions
		CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	Sulphur effects – gasoline vehicles	Sulphur effect multiplier for TTW emission factors – gasoline vehicles
		Sulphur effects – gasoline HDV PM
		Sulphur effects – diesel HDV PM

	Sulphur effects – diesel vehicles	Sulphur effect multiplier for TTW emission factors – diesel vehicles

In the LDV input sheet there are two additional *subheadings 'Share of vehicle stock by fuel/engine technology'* and *'Annual VKT per vehicle to gasoline/engine technology'* with nine tables each. In the *'Average fuel consumption (MJ/km) – new fleet'* table there is a name change, the *'Fuel consumption (MJ/km) engine technology'* is not for gasoline and diesel ICE/hybrid only (as in the other sheets), instead it is for *all engine technology*. The *'Fuel consumption by engine technology (MJ/km) – new fleet'* are calculation tables only that are not to be edited, these are greyed out in the model. In the *'LDV Calc'* sheet under the subheading *'Vehicle activity, vehicle stock, and vehicle sales'* there is an additional table which calculates *'Annualized growth in baseline passenger travel activity (billion passenger-km)'*. Tables under the '*Sulphur effects – gasoline vehicles'* subheading change from HDV (for buses) to LDV. It is important to note that these two tables *'Sulphur effects – gasoline LDV/HDV PM'* and *'Sulphur effects – diesel LDV/HDV PM'* do not exist for 2W or the freight modes. The differences mentioned above are listed in the table below (Table 16).

Table 22 Difference for LDV data tables

Sheet	Subheading	Tables
LDV inputs	Share of vehicle stock by fuel/engine technology	Gasoline ICE/hybrid
		Diesel ICE/hybrid
		Gasoline plug-in hybrid
		Diesel plug-in hybrid
		CNG
		LPG
		Fuel cell
		Electric
		All
	Annual VKT per vehicle relative to gasoline/engine technology	Gasoline ICE/hybrid
		Diesel ICE/hybrid
		Gasoline plug-in hybrid
		Diesel plug-in hybrid
		CNG
		LPG
		Fuel cell
		Electricity
		All

	Average fuel consumption (MJ/km) – new fleet	In-use fuel consumption adjustment – LDVs Fuel consumption (MJ/km) engine technology: all (calculation tables only)
	Fuel consumption by engine technology (MJ/km) – new fleet (calculation tables only)	Gasoline and diesel ICE/hybrids Diesel ICE/hybrids Fuel cell Electric
LDV calc	Vehicle activity, vehicle stock, and vehicle sales	Annualized growth in baseline passenger travel activity (billion passenger-km)
	Sulphur effects – gasoline vehicles	Sulphur effect multiplier for TTW emission factors – gasoline vehicles Sulphur effects – gasoline LDV PM Sulphur effects – diesel LDV PM

There are a few minor additions in the '*Input'* sheets for the freight modes to be aware of. The units for the load factor are different, instead of passengers per vehicle it is measured in metric tons per vehicle. There are additional tables to the right of each table under the subheadings '*Introduction of emission standards – gasoline vehicles' and 'Introduction of emission standards – diesel vehicles'* which are used for intermediate calculations. In the '*Calc'* sheets there are two unit changes; *'Total annual freight travel activity'* is measured in billion metric ton-km and *'Annual vehicle activity'* is measured in billion vehicle-km, instead of passenger-km. Emission standards for freight vehicles are numbered using Roman numerals (II instead of 2). Under the subheading *'VKT fraction by emission level bins – gasoline vehicle'* and *'VKT fraction by emission level bins – diesel vehicle'* there are two additional support tables to the right; a trajectory case and base case. The difference is listed in the table below (Table 17).

Table 23 Difference for freight road modes data tables

Sheet	Subheading	Tables
LHDV, MHDV, HHDV inputs	Vehicle activity	Payload (metric tons/vehicle)
LHDV, MHDV, HHDV calc	Vehicle activity, vehicle stock, and vehicle sales	Total annual freight travel activity (billion metric ton-km)

		Annual vehicle activity (billion vehicle-km)
	VKT fractions by emission level bins – gasoline vehicle	VKT fraction with: Uncontrol
		VKT fraction with: Engine mods
		VKT fraction: Euro I
		VKT fraction: Euro II
		VKT fraction: Euro III
		VKT fraction: Euro IV
		VKT fraction: Euro V
		VKT fraction: Euro VI
		VKT fraction with: SULEV
		(for each standard, there are two extra support tables to the right; a trajectory case and base case)
		VKT fraction with: All
	VKT fractions by emission level bins – diesel vehicles	VKT fraction: Uncontrol
		VKT fraction: Engine mods
		VKT fraction: Euro I
		VKT fraction: Euro II
		VKT fraction: Euro III
		VKT fraction: Euro IV
		VKT fraction: Euro V
		VKT fraction: Euro VI
		VKT fraction: SULEV
		(for each standard, there are two extra support tables to the right; a trajectory case and base case)
		VKT fraction: All

The treatment for passenger rail and freight rail is identical apart from the units of the first input parameter. For passenger rail, *'Energy intensity'* is measured in MJ/passenger-km and for freight rail it is measured in MJ/ton-km.

Table 24 Data tables for Passenger and Freight Rail

Sheet	Subheading	Tables
Passenger rail and Freight rail	Input parameters	Energy intensity (see text above)
		Diesel share (%)
		TTW emission factors for average fleet (g/MJ)
		Country adjustment factor
		Emission standards – introduction year
		Emission standards – VKT share in introduction year
		Emission standard – year when standard is applicable to 100% of the fleet
		(tables to the right of emission standards are intermediate calculations and should not deleted)
	Passenger activity and energy consumption	Total annual passenger travel activity (billion passenger-km)
		Total energy consumption (PJ) – 10^15
	VKT fraction by emission level bins	VKT fraction with: Tier 0
		VKT fraction with: Tier 1
		VKT fraction with: Tier 2
		VKT fraction with: Tier 3
		VKT fraction with: Tier 4
		(for each standard, there are two extra support tables to the right; a trajectory case and base case)
		VKT fraction with: All
	TTW emission factors – diesel locomotives (g/MJ)	TTW emission factors: CO2
		TTW emission factors: CH4
		TTW emission factors: N2O

		TTW emission factors: NOx
		TTW emission factors: CO
		TTW emission factors: PM10
		TTW emission factors: PM2.5
		TTW emission factors: BC
		TTW emission factors: SO2
	WTT emission factors – diesel locomotives (g/MJ)	WTT emission factors: CO2
		WTT emission factors: CH4
		WTT emission factors: N2O
		WTT emission factors: NOx
		WTT emission factors: CO
		WTT emission factors: PM10
		WTT emission factors: PM2.5
		WTT emission factors: BC
		WTT emission factors: SO2
	TTW emissions by pollutant (CO2 is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	WTT emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are	CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions

	measured in thousand metric tons)	CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	WTW emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2-equivalent emissions
		CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	TTW energy consumption by fuel	Conventional diesel
		Electricity
		All

Table 25 Data tables for Aviation and Marine

Sheet	Subheading	Tables
Aviation	Input parameter	Energy efficiency for new aircraft (RPK/kg jet fuel)
		Biofuel blend (oil-based) (%)
		Biofuel blend (advanced) (%)
		(to the right of each biofuel blend there is one additional table where the user can input biofuel blends under the policy scenario, these will be read into the model when ‘Low carbon fuel’ policy is set to TRUE)
		TTW CO2 emission factors (g/MJ)
		TTW CH4 emission factors (g/MJ)

		TTW N2O emission factors (g/MJ)
		TTW NOx emission factors (g/MJ)
		TTW CO emission factors (g/MJ)
		TTW PM10 emission factors (g/MJ)
		TTW PM2.5 emission factors (g/MJ)
		TTW BC emission factors (g/MJ)
		TTW SO2 emission factors (g/MJ)
	Passenger activity and energy consumption	Demand elasticity with GDP (RPK growth/GDP growth)
		Total annual aviation travel activity (billion revenue passenger-km)
		Fleet average energy efficiency (RPK/kg jet fuel)
		Total energy consumption (PJ) – 10^15 J
	Calculation process (found to the right of the above tables)	SAGE/AEDT estimates fuel burn (Tg) and energy (PJ)
		SAGE/AEDT central estimates fuel burn (millions of metric tonnes)
		Jet fuel density
		Regional fuel intensity (2005) (MJ/RPK)
		Allocated fuel burnt (millions of metric tonnes)
		PPPGDP projections (2015 EURO billions)
		Estimated RPK (billion revenue passenger-km)
	TTW emissions by pollutant (CO2 is measured in million metric tons and all other	CO2 emissions
		CH4 emissions
		N2O emissions

	pollutants are measured in thousand metric tons)	NOx emissions CO emissions PM10 emissions PM2.5 emissions BC emissions SO2 emissions
	WTT emissions by pollutant (CO2 is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2 emissions CH4 emissions N2O emissions NOx emissions CO emissions PM10 emissions PM2.5 emissions BC emissions SO2 emissions
	WTW emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2-equivalent emissions CO2 emissions CH4 emissions N2O emissions NOx emissions CO emissions PM10 emissions PM2.5 emissions BC emissions SO2 emissions
Marine	Input parameter	CO2 emissions savings (%) – low estimate CO2 estimates savings (%) – high estimates
	Emission projections	TTW emissions (lowerbound) (million metric tons) TTW emissions (lowerbound) – from IMO (million metric tons) TTW emissions (upperbound) (million metric tons)

		TTW emissions (upperbound) – from IMO (million metric tons)
		TTW emission reduction from market-based measures (MtCO2)
		IMO_DNV
		Emission (final) – (million metric tons)
		IMO
	Turnover module	Improvement in global new fleet efficiency
		Lowerbound
		Upperbound
		“Turnover” model
	TTW emissions by pollutant	*tables by pollutant are shaded in (no formulae or inputted data)*
	WTT emissions by pollutant	*tables by pollutant are shaded in (no formulae or inputted data)*
	WTW emissions by pollutant	*tables by pollutant are shaded in (with formulae)*
Second hand treatment		2nd hand imports as share of total sales
		2nd hand imports as share of total sales (0-5 year)
		2nd hand imports as share of total sales (10-15 year)
		2nd hand imports as share of total sales (15-20 year)
		Share of imports by country of origin (total)
		Share of imports by country of origin (0-5 year)
		Share of imports by country of origin (5-10 year)
		Share of imports by country of origin (10-15 year)

		Share of imports by country of origin (15-20 year)
Survival	General distributions	Survival rate – Weibull distribution coefficients
		Survival curves
		Survival rates at age X
		Share of vehicles retiring at age X
		Annual distance accumulation rate
		Absolute VKT for vehicles y years old given an annual % increase in sales (VKT) (RPK for aviation)
		VKT share by age (%) (RPKT for aviation)
		Share of VKT by vehicles older than X years (RPKT for aviation)
	Association of distributions to regions	Share of VKT by vehicles older than X years – LDVs
		Share of VKT by vehicles older than X years – buses
		Share of VKT by vehicles older than X years – 2Ws
		Share of VKT by vehicles older than X years – LHDVs
		Share of VKT by vehicles older than X years – MHDVs
		Share of VKT by vehicles older than X years – HHDVs
		Share of VKT by locomotives older than X years
		Share of RPKT by aircraft older than X years
Config	System configuration	Global warming potential

		PM conversion
		Sulphur ppm
		Mode type
		Name ranges
		Lists
		Unit type
		Convert from year to date format
		Gasoline unit conversion
		Diesel unit conversion
		Unit conversion
Emission inventory	WTW emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2-equivalent emissions
		CO2 emissions
		CH4 emissions
		N2O emissions
		NOx emissions
		CO emissions
		PM10 emissions
		PM2.5 emissions
		BC emissions
		SO2 emissions
	TTW emissions by pollutant (CO2 and CO2-equivalent is measured in million metric tons and all other pollutants are measured in thousand metric tons)	CO2-equivalent emissions
		CO2 emissions
		NOx emissions
		PM2.5 emissions
		BC emissions
	TTW energy consumption	TTW energy consumption (PJ) – 10^15
		TTW energy consumption (Mtoe)
		TTW energy consumption (Mboe/day)

Appendix C Data filling methods used

C.1 Methodology notes

Much of the data collected for the EUTRM was incomplete, in the sense that it was not available for all countries and/or years that were required. Where this was the case data filling techniques were applied to construct a complete dataset. This appendix sets out the detailed methods used to construct each dataset. This section follows the same layout at Chapter 3, with three sub sections covering socioeconomic, transportation and emission parameters.

C.2 Socioeconomic method notes

Population

Data sources	Dimensions available
PRIMES	28 regions x 2000-50
U.S Census Bureau, International Data Base (IDB)	2 regions x 2000-50

Population data was taken directly from PRIMES, and was available for all required countries and time periods.

Output Population x 30 regions x 2000-50

GDP

Data sources	Dimensions available
PRIMES	28 regions x 2000-50
OECD	30 regions x 2000-50
IMF World Economic Outlook (WEO)	2 regions x 2000-21

Projections from PRIMES were judged to be rather over-optimistic; these were cross-checked against OECD projections[28], and whichever had the slower average growth rate over 2000-50 in each country was used. PRIMES does not include data for Norway (NO) and Switzerland (CH) so IMF WEO data was used.

The PRIMES data was re-based from 2013 € to 2015 € using the AMECO price deflator, while OECD growth rates were applied to historical data from PRIMES where OECD was the preferred source.

IMF WEO projections[29] for NO and CH, in national currency, were converted to 2015 € using bilateral exchange rates from Eurostat. To complete the projections, the average annual growth rate between 2000-2021 was calculated and applied annually up until 2050.

Output

[28] OECD.Stat (May, 2014) "Economic Outlook No. 95. Available here: http://stats.oecd.org/index.aspx?DatasetCode=EO95_LTB

[29] International Monetary Fund (April, 2016) "World Economic Outlook Database". Available at: https://www.imf.org/external/pubs/ft/weo/2016/01/weodata/index.aspx

GDP x 30 regions x 2000-50

Historical fuel prices

Data sources	Dimensions available
European Commission Weekly Oil Bulletin (ECWOB)	Gasoline/Diesel x 30 Regions x 2001-15
World Bank (WB) Development Indicators	Gasoline/Diesel x 30 Regions x 2000, 02, 04, 08, 10, 12 and 14

ECWOB is the primary data source, but lacks data for all countries for 2000 and for Croatia, Norway, and Switzerland for all years. Prices are inclusive of taxes.

To estimate the missing data, World Bank data was used. Weekly prices were converted to an annual average and divided by 1000 to calculate price per litre. WB data covered 2000-04, so an annual average growth rate over this period was calculated, and applied to ECWOB data to estimate fuel prices in 2000 based on 2005 values.

Fuel prices for Croatia, Norway and Switzerland were estimated by calculating a ratio between Croatia and a close comparator (Slovenia, Sweden and Germany respectively) within the WB dataset in the years that were the closest match to the required years. This ratio was then applied to ECWOB data for the comparator to estimate fuel prices for the missing countries.

Outputs Gasoline/Diesel x 30 Regions x 2000-15

Projected fuel prices

Data sources	Dimensions available
IEA World Energy Outlook (WEO, 2016)	Crude oil price x 2015, 2020, 2030 and 2040
EIA Annual Energy Outlook (AEO, 2016)	Crude oil price x 2015, 2030, 2035, 2040
ArrowHead Economics	Crude oil price x 2015, 2030, 2035, 2040
IHS Global Insight (IHSGI)	Crude oil price x 2015, 2030, 2035, 2040

The model includes four separate scenarios for projected fuel prices, drawn from the four sources above.

Where data was missing for particular years, a simple interpolation was applied using the prices five years either side of the missing data point. Data for 2045 and 2050 were constructed by holding constant 2040 values in all scenarios.

Output Crude oil price projections x 4 scenarios x 2015-50

C.3 Transportation method notes

TPTA and mode share

Data sources	Dimensions available
EU Pocketbook	LDVs, Buses and Passenger Rail x 30 Regions x 2000-14
TRACCS	2W x 30 Regions x 2005-10

Missing data for 2015 from the EU Pocketbook was estimated based on an average growth rate calculated over 2009-14 for each mode and region, applied to the 2014 data. To estimate 2000 and 2015 for 2W from TRACCS, a five-year average growth rate was calculated. The growth rate was applied to 2005 to estimate 2000 and applied to 2010 to estimate 2015.

The historical mode share calculation was straightforward as each mode was calculated independently. The mode share was held constant to 2050, although this can be changed in the policy lever.

Output All modes x 30 regions x 2000-15

TFTA and mode share

Data sources	Dimensions available
EU Pocketbook	MHDV and HHDV x 30 Regions x 2005-14, freight rail x 30 Regions x 2000-14
TREMOVE	All freight x 30 Regions x 2000-15

The EU Pocketbook records MHDV and HHDV truck movements combined, using the territorial principle. Because freight movements are more accurately reflected by this measure, the Pocketbook is the primary source of data for the EUTRM, despite missing data including 2005 for some countries and Malta for all years.

To disaggregate the activity of MHDVs and HHDVs in EU Pocketbook the ratio between the two categories in the TREMOVE data was used. The percentage share of activity for each mode was calculated and held constant from 2015 to 2050.

To estimate data for 2000, an annual average growth rate over 2005-10 was calculated and applied to 2005 to backcast to 2000; to estimate 2015 a growth rate calculated over 2009-14 was projected forwards by one year. In some cases, where data was available in 2005 the five-year growth rate between 2006-11 was used.

To estimate MHDV and HHDV data for Malta, a ratio was calculated from the TREMOVE data between Malta and Italy (used as a comparator), over 2000-14. This ratio was then applied to the Italy data from the EU Pocketbook to estimate data for Malta (using the 2014 ratio as a proxy for 2015).

To estimate the tonnes-km (tkm) for LHDVs on a territoriality basis, a ratio was calculated between HDVs data from the EU Pocketbook and HDVs data from

TREMOVE. The ratio was then applied to LHDVs data from TREMOVE to give an estimate for LHDVs.

To estimate rail for 2015 an annual average growth rate was calculated based on the EU Pocketbook data for 2009-14 and applied to 2014.

Output TFTA x 30 regions x 2000-15

Mode share x freight modes x 30 regions x 2000-50

Historical vehicle stock

Data sources	Dimensions available
EU Pocketbook	LDV, Two-Wheelers (2W) and Buses x 30 Regions x 2000-14
TRACCS	LHDVs and MHDVS, HHDVS x 30 Regions x 2005-10

To estimate missing data in EU Pocketbook for 2015 an annual average growth rate was calculated over 2009-14 and applied to 2014.

To estimate missing data in TRACCS for other modes an average growth rate was calculated over 2005-10 and applied to available years (2005 and 2010) to get an estimate for 2000 and 2015 respectively.

Output All modes x 30 regions x 2000-15

Historical new vehicle registrations

Data sources	Dimensions available
EU Pocketbook	LDV x 30 regions x 2000-15, 2W x 30 regions x 2000-14 and buses x 30 regions x 2004-15 LHDVs, MHDVs, HHDVs x 30 regions x 2010-15
TRACCS	LHDVs, MHDVs, HHDVs x 30 regions x 2005-10

The first step was to estimate 2000 for LDVs and 2Ws from the EU Pocketbook. To do so the ratios between a region missing historical data and a region with full historical data available (within the same vehicle category) was calculated (see Table 26 for comparator regions used). These comparators were based on a combination of similar observed historical growth rates (in new vehicle registrations) and geography/socioeconomic characteristics.

The average five-year growth rate of the ratios was calculated and applied to the earliest ratio to get estimated ratios for 2000. The ratios were applied to the data for the comparator regions to give estimates for the missing regions. This process was repeated for all 11 regions with missing data in LDVs and for all 7 regions with missing data in 2Ws.

2015 data for 2W in EU Pocketbook was estimated using an annual average growth rate, calculated over 2009-14 and applied to 2014.

2000 data for buses was estimated based on EU Pocketbook data, by applying an annual average growth rate calculated over 2004-09.

Absolute figures for HDVs were used from TRACCS for 2005-10, 2000 was assumed the same as 2005. However, to extrapolate to 2015, the growth rate was calculated from EU Pocketbook between 2010-15 and applied to the 2010 data in TRACCS. A separate growth rate was calculated for each mode and each region except for regions in the EU Pocketbook where MHDVs and HHDVs were aggregated in LHDVs (Bulgaria, Croatia, Cyprus, Malta). In this special case the LHDV average growth rate was used for extrapolation of MHDVs and HHDVs.

Table 26 Comparator countries

Country with missing data	Comparator country used
Bulgaria	Germany
Czech R	Belgium
Estonia	Finland
Latvia	Finland
Lithuania	Denmark
Hungary	Croatia
Malta	Italy
Poland	Germany
Romania	Germany
Slovenia	Austria
Slovakia	Austria

Output All modes x 30 regions x 2000-15

Average annual distance travelled per vehicle

	Data sources	Dimensions available
TRACCS		6 modes x 30 regions x 2005-10

In the absence of alternative data, average annual distance travelled per distance was assumed to be constant where values were missing; so 2000 was assumed to be the same as 2005 (on a country-by-country basis) and all years after 2010 were assumed to have the same value as 2010. The only exception to this is LDVs, where projections of average annual distance travelled per vehicle for LDVs are calculated based on VPC[30].

Output 6 modes x 30 regions x 2000-50

[30] VKT/year=a+b.(VPC)^c

The variables are determined by ICCT (no reference given) so that a = 9336 b = 2228 and c = -0.59.

Load factors for both passenger and freight

Data sources	Dimensions available
None (based on model calculation)	6 modes x 30 regions x 2000-15

As described in Chapter 3, load factors are based on an accounting identity[31], which uses other input parameters in the model, for all historical years. Projected load factors are assumed to be constant at 2015 values.

Output 6 modes x 30 regions x 2000-50

Annual distance accumulation by age

Data sources	Dimensions available
TRACCS	6 modes x 30 regions x 1-30 years old (2010)
Ricardo-AEA	LDVs and LHDVs x UK x 1-19 years old (2012-13)

The TRACCS database has total distance (km) travelled by age of vehicle for all modes (except passenger rail, freight rail, aviation and marine) and all regions. The Ricardo-AEA report used a UK MOT database to gather annual mileage (km) by age on LDVs and LHDVs from 1-19 years old. Both data sources present data in absolute mileage, the model required the data to be indexed to the first year.

For each mode and region (except the UK) TRACCS was the primary data source; an average was taken of the total distance (km) travelled by age of vehicle of gasoline and diesel vehicles. However, because this data is based on the year of sale, rather than the age of individual vehicles, distance driven for new (0 year old) vehicles as reported in TRACCS is very low. This reflects the fact that across stock of new vehicles that are being reported on, some will be sold at the start of the year (and so accumulate a full years' worth of mileage) while others will be sold at the end of the year (and have only a few months to accumulate mileage), and an average is calculated across all of these vehicles. To address this, the processing takes 1 year old vehicles as the basis for the mileage accumulation (and the reference point for the indexing), and annual average distance for new vehicles is set to be the same as for 1 year old vehicles. The TRACCS data includes up to 30 years of age, while the EUTRM requires data up to 40 years of age; the distance accumulation is therefore held constant for all ages above 30.

For LDVs and LHDVs an average of the annual distance accumulated by age was again taken between gasoline and diesel vehicles from the Ricardo-AEA data. This was then indexed by dividing each subsequent year by the annual distance by a 1 year old vehicle. The annual distance travelled in the year was set to the distanced travelled in the second year for the same reason as set out above for LDVs The last data point from Ricardo-AEA was the distance accumulated by a 19 year old vehicle; this was held constant up to a 40 year old vehicle.

Output

[31] Load Factors=(Passenger Transportation Activity)/(Vehicle Stock × Avg.Distance Travelled per Vehicle)

6 modes x 30 regions x 1-40 year olds (2010, 2012-13)

Fuel economy for new vehicles by fuel type

Data sources	Dimensions available
ICCT Pocketbook	LDVs x country groupings x 2001-14
TRACCS	2W, buses, LHDVs, MHDVs, HHDVs x 30 regions x 2005-10

The ICCT Pocketbook data for this variable has much missing data. Data for LDVs is available between 2001-14 and for LCVs 2009-2014. Fuel economy is measured in gCO2/km using the New European Driving Cycle (NEDC) and only applied to new vehicle registrations. The fuel economy data from TRACCS is measures (in L/100km) the real-world efficiency rather than a laboratory test-cycle; this has implications when updating the adjustment tables, which measure the difference between test-cycle and real-world efficiency

Estimating missing fuel economy data for LDVs

The country coverage in the ICCT Pocketbook varies by time period; there is data for each MS in the EU15[32] covering 2001-14, an EU12[33] aggregate between 2001-12, an EU13[34] aggregate over 2013-14, and data for NO and CH over 2013-14.

EU12 and EU13 aggregate data was used to represent all EU13 MS. The EU12 fuel economy was used for EU13 MS between 2001-12 and EU13 fuel economy was used for EU13 MS between 2013-14.

For all regions, the fuel economy in 2000 was missing. For the EU13 MS the average growth rate between 2001-06 (of EU12 aggregation) was calculated and applied to 2001 data to estimate 2000. For the EU15 MS the average growth rate between 2001-06 (growth rate varied for each EU15 MS as per fuel economy data) was calculated and applied to 2001 data.

For all regions, the fuel economy in 2015 was missing. For EU13 MS the average growth rate between 2009-14 (of EU12 aggregation/EU13 aggregation) was calculated and applied to 2014 data. For EU15 MS the average growth rate between 2009-14 (growth rate varied for each EU15 MS as per fuel economy data) was calculated and applied to 2014 data.

Fuel economy data for Norway and Switzerland for missing years was filled using the growth rate of the EU28-average (for Norway) and Germany (for Switzerland). This decision was based on similarities in observed fuel economy in the years 2013-14.

The final step was to set 2020 for LDVs equal to the fuel economy of 2015. Then in each subsequent five-year interval set fuel economy equal to 95gCO2/km as per the new policy target (2021). Fuel economy for LHDVs after 2015 were set to 147gCO2/km as per the new policy target (2020).

[32] The EU15 refers to the first 15 countries to join the EU; Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom, Austria, Finland and Sweden

[33] The EU12 are the next 12 MS to join the EU after the EU15; Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia

[34] The EU13 is the EU12 plus Croatia (reflecting the shift from the EU27 to the EU28)

Estimating missing fuel economy for the other five modes

An annual average growth rate was calculated for each mode and region from the TRACCS data and used to extrapolate the data forwards to 2015 and backwards to 2000.

The fuel economy figures were converted to CO2g/km from L/100km using conversion factors in the EUTRM ‘Config’ tab.

Output LDVs x 30 regions x 2000-50

Share of new vehicle sales by fuel/engine technology

Data sources	Dimensions available
ICCT Pocketbook	LDVs x country groupings x 2001-14
TRACCS	2W, buses, LHDVs, MHDVs, HHDVs x 30 regions x 2005-10

Data for LDVs is available between 2001-14 from ICCT Pocketbook. In the ICCT Pocketbook the share of new vehicle registrations is broken down into six categories:
Diesel ICE

Hybrid (excl. plug-in hybrid)

Plug-in Hybrid (2014 only)

Battery electric/Fuel cell

Natural gas (mono-/bivalent, incl. LPG)

Flex-Fuel (ethanol/gasoline)

The EUTRM combines ICE and hybrids in a single fuel/engine group. Data from TRACCS (for all other modes) is missing for 2000 and 2015.

Estimate missing years for LDVs

Data from the ICCT Pocketbook is by country for the EU15 over 2001-14, an EU13 aggregate covering 2013-14, EU12 aggregate between 2001-12 and for NO and CH over 2013-14.

EU12-13 aggregate data was used to represent all EU13 MS. The EU12 fuel economy was used for EU13 MS between 2001-12 and EU13 fuel economy was used for EU13 MS between 2013-14.

Annual average growth rates were used to extrapolate missing values (2001-06 was used to estimate 2000 and 2009-14 to estimate 2015). Data on total sales/registrations by type was used for this extrapolation, rather than shares, as this series was more stable.

A time series was also available for Norway and Switzerland between 2013-14. This was extrapolated forwards to 2015 and backwards to 2000 using the growth rates of EU28-average (for Norway) and DE (for Switzerland).

Once the absolute levels were constructed for 2000-15, the data was converted into shares and held constant to 2050.

Estimate missing years for all other modes

2000 and 2015 figures were estimated from TRACCs data using annual average growth rates over the five years of data available. These figures were then converted to shares and held constant to 2050.

Output LDVs x 30 regions x 2000-50

Share of vehicle activity by fuel/engine technology in 2000

Data sources	Dimensions available
TREMOVE	LDVs, 2W, buses, LHDVs, MHDVs, HHDVs x Diesel, gasoline, CNG and LPG x 30 regions x 2000

The total vkm for each fuel/engine technology (diesel, gasoline, CNG and LPG) for a given mode was taken from the TREMOVE data. This was then divided by the total vkm for the same mode.

This was repeated for each region and mode combination. The HDV data was subject to the adjustments as set out in Chapter 1 to take account of the fact that the raw data considered only the nationally-registered stock, and to adjust these figures to take account of the characteristics of the volume of non-domestic activity that took place

Output LDVs, 2W, buses, LHDVs, MHDVs, HHDVs x Diesel, gasoline, CNG and LPG x 30 regions x 2000

Share of VKT in urban areas

Data sources	Dimensions available
UN World Urbanization Prospects: The 2014 Revision	Percentage population living in urban areas x 30 regions x 2000-50

Values were directly imported from the source into the model.

Total annual aviation travel activity

Data sources	Dimensions available
UNFCCC	TTW CO2 emissions x 30 regions x 2000-14
SAGE/AEDT	Fuel burnt x Europe x 2000-50
DG TAXUD	VAT Revenues from Transport Sector x 24 regions x 2010, 2020 and 2030

Estimating history activity from UNFCCC International Aviation and Domestic Aviation CO2 (items 1.A.3.a and 1.D.1.a in the UNFCCC reports) emissions were summed to give total TTW CO2 emissions by region. TTW CO2 emissions was divided by the CO2 emission factor in the model (72.66 g/MJ) to give total energy consumption. The final step was to multiply by fleet average energy efficiency (from the model) to give estimates of activity (in revenue passenger kilometres).

Estimating activity projections from DG TAXUD Projections through to 2050 were estimated using the growth rate of VAT revenues in a DG TAXUD paper[35], using data on the transport sector from the business as usual scenario. The 2010-20 growth rate was applied to 2010 aviation activity (from UNFCCC) to estimate 2020. The 2020-30 growth rate was applied to the 2020 value to estimate 2030, and 2025 was calculated as

[35] Study on VAT rules for passenger transport, Final Report (2014)

an average between 2020 and 2030. 2050 was estimated using the average growth rate between 2010-30, and 2035, 2040 and 2045 were interpolated assuming constant progression towards the 2050 value. The six regions with missing data in the DG TAXUD paper used the VAT growth rates of other countries that had similar historical growth rates in aviation activity (as taken from UNFCCC) as a proxy (see Table 27).

Existing treatment of activity projections

The original method, as used in the GTRM, has been maintained as an option in the model. Using this methodology, the EUTRM estimates activity projections based on total fuel burnt from SAGE/AEDT. From the fuel burnt and regional fuel intensity the model calculates a European wide aviation activity projection up to 2050. It then makes use of GDP projections to allocate activity amongst the 30 regions. Finally, an adjustment factor is applied so that total fuel consumption matches SAGE/AEDT initial estimates.

Output

Aviation activity x 30 regions x 2000-50 (and a switch between SAGE and VAT estimates)

Table 27 Proxy countries

Country with missing data	Proxy country
Denmark	Netherlands
Ireland	Luxembourg
Malta	Cyprus
United Kingdom	Netherlands
Norway	Finland
Switzerland	France

Energy intensity for passenger and freight rail

Data sources	Dimensions available
TRACCS	Energy consumption for passenger x 30 regions x 2005-10
TRACCS	Energy consumption for freight x 30 regions x 2005-10
TRACCS	Passenger activity x 30 regions x 2005-10
TRACCS	Freight activity x 30 regions x 2005-10

The historic dataset was completed by using 2005 as a proxy for 2000. 2015 was estimated based on a five-year average growth rate (2005-10). This was done for energy consumption (million kWh) for passenger and freight, passenger activity (passenger-km) and freight activity (ton-km). A common energy unit was needed, thus energy consumption for electric trains was converted from kilowatt hours (kWh) to MJ and energy consumption for diesel trains was converted from tonnes of oil equivalent (toe) to MJ for diesel trains (see Table 28 for conversion rates).

Total energy consumption of passenger rail was calculated by summing across diesel and electric trains. Passenger activity divided this to give energy intensity for passenger rail (MJ/passenger-km). The same method was used to calculate the energy intensity of freight rail, except total energy consumption (for freight) was divided by freight activity to give energy intensity (MJ/ton-km).

Table 28 Energy conversions

	MJ
kWh	3.6
Toe	41868

Output Energy intensity for passenger and freight rail x 30 regions x 2000-15

Diesel share for passenger and freight rail

Diesel share (%) for passenger and freight rail used the same sources as parameter above (energy intensity). Passenger diesel share was calculated by diving the energy consumption (of diesel) for passengers by the total energy consumption (of diesel and electric) for passengers. The same was done for freight diesel share.

Output Diesel share for passenger and freight rail x 30 regions x 2000-15

CO2 emission projections for Maritime

Data sources	Dimensions available
IMO GHG study (2014)	Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP) scenarios x CO2 emissions x 2000-50
climate4impact.eu	Mapping of scenarios

The IMO CO2 projection figures were updated from the 2009 Second IMO GHG Study to the 2014 Third IMO GHG Study data. To extract equivalent data, this required a mapping from the IPCC Special Report on Emission Scenarios (SRES) scenarios to the various scenarios used in the 2014 IMO publication (which are based on the Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSPs) scenarios). Guidance was taken from the climate4impact.eu website. A1B was mapped to the 2014 IMO scenario 5 to give data for the upper bound. B2 was mapped to the 2014 IMO scenario 2 to give data for the lower bound.

European share of emissions for Maritime

Data sources	Dimensions available
United Nations Conference on Trade & Development (UNCTAD) publication Review of Maritime Transport 2015	Marine imports and exports x European x 2014

To estimate the 30 regions', share of maritime emissions, data from the United Nations Conference on Trade & Development (UNCTAD) publication Review of Maritime Transport 2015, was used. A simple average was taken of the 'loaded' (exports) and 'unloaded' (imports) figures for European share of world tonnage to be used as the estimate (19%) (Figure 1.4 (c)). This estimate assumes that emissions are proportional to tonnage.

C.4 Emission method notes

Fuel blends

Data sources	Dimensions available
Eurostat	Share of renewable energy in fuel consumption for transport x 29 regions x 2004-14
GLOBIOM	Share of production of starch ethanol, sugar ethanol, vegetable oil-based biodiesel and cellulose/waste oil biodiesel under the 7% biofuels baseline
Impact Assessment on biofuel mandate from European Commission	Biofuel commitment x 21 regions x 2010-20
Ricardo Energy & Environment (SULTAN model)	7% food-based biofuel limit and 0.5% target for advanced biofuels (with possibility of more) x 2020-50

Historical data sourced from Eurostat was used as a proxy for fuel blends (given the minimal take up of pure biofuel or electric vehicles). 2014 data was held constant as an estimate of 2015, while 2000 was assumed to hold the same value as 2004. Data was missing for Switzerland, and estimated by assuming a fuel blend in line with the EU (29) average. In the absence of data on the split of biofuel by type, this was estimated based upon GLOBIOM projections.

The projections were constructed based on announced policy. In 2015 EU decided to cap food-based biofuels at 7% and target advanced biofuels at 0.5%. they also stated that no further biofuels policy would be implemented; hence in the model the policy is held constant through to 2050.

For countries that did not feature in the Impact Assessment on biofuel mandates, total bioethanol and biodiesel were set at 7% each. The breakdown across starch, sugar, and cellulose (ethanol) was calculated based on GLOBIOM production shares under the 7% biofuel baseline. The GLOBIOM study did not include the share of production of cellulosic ethanol, only starch and sugar. Therefore, the residual was evenly distributed across these three categories. The breakdown across vegetable oil-based biodiesel and cellulose/waste biodiesel was calculated using the GLOBIOM production shares under the same baseline.

Countries that featured in the Impact Assessment were treated in one of two ways, depending on whether their biofuel mandate was greater than or less than the 7% policy. If a regions mandate was over 7% then the initial shares, calculated above, were used and the excess biofuel commitment was split evenly across cellulose ethanol and cellulose/waste biodiesel (as no more can be food-based). If the biofuel mandate for a country was less than the 7%

assumption the breakdown across bioethanol and biodiesel pathways were recalculated based on GLOBIOM production shares.

Where fuel blends in 2015 (from Eurostat) were higher than the assumed fuel blend in 2020, the 2015 value was held constant to 2050, to reflect the fact that a country is unlikely to reduce biofuel blend in the future; it primarily affected countries which did not feature in the Impact Assessment.

Outputs

Starch ethanol, sugar ethanol, cellulosic ethanol x 30 regions x 2020-50

Vegetable oil-based biodiesel and cellulose/waste oil biodiesel x 30 regions x 2020-50

WTT emission factors

Data sources	Dimensions available
JEC WTW	CO2, CH4 and N2O x all fuel type
GLOBIOM	CO2 x biofuels
US EPA MOBILE 6 model	NOx, CO, PM10, PM2.5, SO2 and BC x all fuel types

The JEC WTW study has emissions on major pollutants (CO2, CH4 and N2O) for all fuel types except jet and residual fuel. The time horizon of JEC WTW is 2020-2025 as the technologies considered are those that have the potential to become commercially available in that period. Statistical data are from 2011 for natural gas production. GLOBIOM only has WTT CO2 emissions for biofuels and US EPA MOBILE6 is used for its coverage of minor pollutants (NOx, CO, PM10, PM2.5, SO2 and BC), which represent conditions in the US in 2010. In the EUTRM the WTT emission factors do not vary across time or region the model.

Treatment for fuel types (except biofuels)

Figures from JEC WTW study were brought into the model for all major pollutants for gasoline, conventional diesel, CNG (EU-mix), LPG and hydrogen. Gasoline, conventional diesel, CNG and LPG were directly entered into the model whereas hydrogen was averaged across natural gas from both thermal and electrolysis processes.

The treatment for jet fuel and residual fuel has not been changed from the GTRM. WTT emissions for jet fuel are equal to the WTT emissions for gasoline and WTT emissions for residual fuel take the same values as the GTRM (based on US conditions in 2010).

Table 29 Fuel type

Fuel type	Pollutant covered	JEC WTW code	Description
Gasoline	CO2, CH4 and N2O	COG1	Crude oil from typical EU supply
Conventional Diesel	CO2, CH4 and N2O	COD1	Crude oil from typical EU supply
CNG	CO2, CH4 and N2O	CNG	EU-mix natural gas supply

LPG	CO2, CH4 and N2O	LPG	LPG from remote natural gas field
Hydrogen	CO2, CH4 and N2O	GMCH1 and GxELx_xHx	EU-mix natural gas supply using thermal process and natural gas from Russia pipeline using electrolysis process
Jet Fuel	CO2, CH4 and N2O	*set equal to gasoline*	
Residual Fuel	CO2, CH4 and N2O	*set equal to values in GTRM*	

Emissions in JEC WTW study are measured in gCO2eq/MJ. Emission for CH4 and N2O were converted from gCO2eq/MJ to g/MJ using global warming potential coefficients from the IPCC (see Table 30).

Table 30 Global warming potential

Pollutant	GWP
CO2	1
CH4	25
N2O	298

Treatment for biofuels

Biofuels, such as starch ethanol, sugar ethanol, cellulosic ethanol, vegetable oil-based biodiesel, cellulosic/waste-oil biodiesel are treated differently in the model to include the change in WTT emission factors (only for CO2 emissions) when LUC is included in the estimation process. JEC WTW figures for biofuels include no LUC impacts and GLOBIOM figures include LUC (both direct and indirect). JEC is used for all major pollutants and GLOBIOM is used only for CO2. If more than one pathway appears in the cells below (in Table 25) an average was taken.

Table 31 Biofuel type

Biofuel type	GLOBIOM (with LUC)	JEC WTW code (no LUC)	JEC WTW description
Starch ethanol	Wheat ethanol, maize ethanol, and barley ethanol	WTET1a/b, WTET2a/b, WTET3a/b, WTET4a/b, WTET5 CRET2 CRETus BRET2	Average of Wheat ethanol Average of Corn (maize) ethanol EU-mix barley

Sugar ethanol	Sugar beet ethanol	SBET1	EU sugar beet
	Sugarcane ethanol	SCET1	Brazil sugar cane
Cellulosic ethanol	Straw ethanol	STET1	EU wheat straw to ethanol
		WW/WFET1	EU farmed waste/wood ethanol
Low-sulphur diesel			
Vegetable oil-based biodiesel	Sunflower oil biodiesel	SOFA	Sunflower to biodiesel
	Palm oil biodiesel	POFA	Palm oil to biodiesel
	Rapeseed oil biodiesel	ROFA/ROFE	Average of Rapeseed to biodiesel
	Soybean oil biodiesel	SYFA	Soy bean to biodiesel
Cellulosic biodiesel	Forest residue biodiesel	*see methodology below*	-
	Short rotation plantation biodiesel		
	Miscanthus biodiesel		
Waste-oil biodiesel	*see methodology below*	WOFA	Waste oil biodiesel

Where data for biofuel type was missing the estimation, process involved calculating the percentage difference across GLOBIOM and JEC WTW data. The percentage difference was then applied to the available source to estimate a figure for the missing data. For example, percentage difference was applied to waste oil biodiesel from JEC WTW to get an estimate for waste-oil biodiesel in GLOBIOM.

Output Minor and major pollutants x all fuel types

WTT emission factors for electricity

Data sources	Dimensions available
JEC WTW	CO_2, CH_4 and N_2O x type of generation

WTT emission factors for electricity production (g/MJ) from JEC WTW is available for major pollutants by type of generation. There are 7 types of generation; heavy fuel oil, hard coal, natural gas, biogas, wood, nuclear and wind. Statistical data on European electricity production from JEC WTW is from 2009. There is an off-model tool which includes an additional two types of generation, solar and hydro. Wind, solar and hydro is emission factors are set to zero.

Output	Major pollutants x generation mix x 2000-50s

Appendix D Second hand vehicles treatment in the EUTRM

The ICCT's GTRM model does not take any account of bilateral trade in second-hand vehicles, as it is assumed to be negligible between the 16 world areas within the model. However, at a European country level trade in second hand vehicles can have a substantial affect upon the characteristics of a national vehicle stock. The impacts are upon five distinct areas of the model; survival rates, new vehicle sales, vehicle stock by type, fuel efficiency and emissions factors, and each of those are discussed in turn in this Appendix. However the first step is to estimate the extent of bilateral trade, and this is the first topic covered below.

D.1 Estimating bilateral trade

A number of different sources were combined to estimate bilateral trade between the 30 countries in the EUTRM, including;

- TRACCS 2013 Transport Database
- Estimated bilateral trade relationships and import/export data from the DG Climate Action Report, "Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV CO2 regulations"
- Estimated and reported EU second-hand vehicle import/export data from the DG Climate Action Report, "European second-hand car market analysis"
- Eurostat Comext data for historical vehicle imports and exports for left-hand-side driving countries was used to estimate the trade flows and volume of imported and exported cars for left-hand-side driving EU states.

Relationships between major importing and exporting states were estimated using data from previous estimates of bilateral trade of second hand LDVs within the EU. From these estimates shares of total imports from each exporting state were calculated. For the purposes of estimating bilateral trade relationships, it is assumed that the trade in LDVs approximates the trade of other vehicle types.

TRACCS data for second-hand vehicle registrations were used to estimate the total number of vehicles being imported into net importer states. It is assumed that second-hand vehicle registration reported in the TRACCS database is primarily of imported vehicles. The gross number of second-hand vehicles estimated from the TRACCS database was applied to the shares of vehicle imports estimated from other data sources available. This method was used due to the variety of reporting methods and standards in available data. A general relationship between states was established and a more reliable estimate of the total number of vehicles exchanged was used to estimate this relationship. For left-hand-driving member states the same method was used but the bilateral relationships are estimated using Eurostat Comext data.

The TRACCS database includes information about the age of registered vehicles in each country. This data was used to determine 5-year age profiles of registered vehicles in each country. The share of total vehicles in each age category was determined and then applied to the bilateral trade matrix to determine an estimate of the age profiles of imported and exported vehicles.

In constructing this bilateral trade matrix, there were two primary simplifying assumptions:

- All second-hand trade is assumed to be within the European region.
- The bilateral trade relationships for second hand vehicles will be held constant within the model for all time periods. This will be constructed based on the average of recent historical data.

The result of this process was a series of matrices (one for each five-year age profile of vehicle age) which showed bilateral trade between each country in the EUTRM.

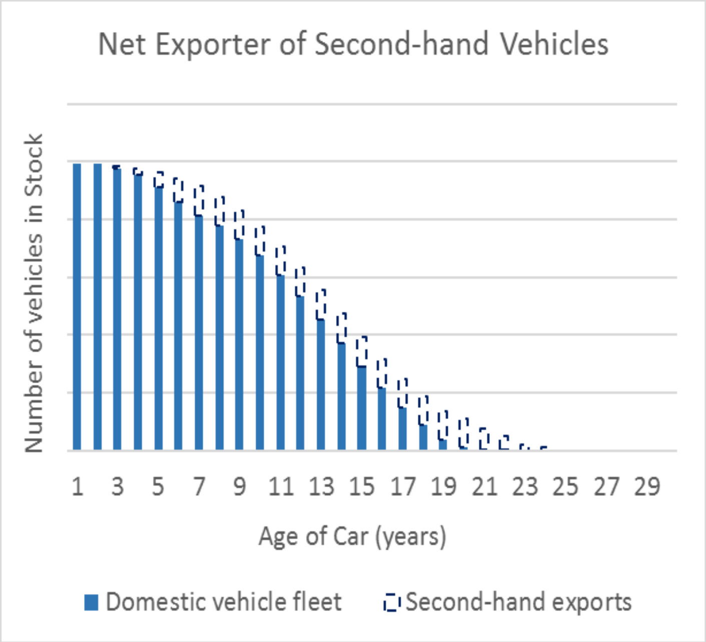
D.2 Survival Rates

Survival rates measure the rate at which vehicles of different ages leave the stock. They typically represent the rate at which vehicles are retired from the stock (due to mechanical failure or being exported).

However, the addition of explicit treatment of second-hand vehicle trade adds additional complication to the calculation of such rates. The first required step was to construct survival rate data for each country's vehicle stock which does not include the impact of second hand vehicle trade, and the second step then was to use the bilateral trade matrices to adjust the survival rates to reflect the impacts of second hand trade.

This was done by utilising TRACCS data for total vehicle stocks and total vehicle deregistration. This data provides an estimate of the probability of each vehicle type (for each age) being on the road the following year ('surviving'). The estimation of bilateral trade is used to calculate the shares of imports and exports as a share of total vehicle sales. The change in total vehicle stock created by net imports or net exports for each country was then added or subtracted to the estimated survival rates

For net exporters, additional vehicles were deregistered from the stock beyond those would be "naturally" retired at a given age, which increased the rate of retirement for vehicles in that country. This is then fed into the model through a downward shift in the survival rate curve as exports accelerate the rate at which vehicles leave the stock (see **Error! Reference source not found.**).



The shift in the survival rate curve will increase the volume of new sales required to meet the current stock, leading to an increased take up of new more efficient vehicles and resulting in a more fuel efficient vehicle fleet than if trade was not accounted for.

For net importers, the introduction of older vehicles will also change the age distribution of vehicles in the stock but in this case, this is not a simple correction to the survival rate curve as the properties in terms of age and source country make a considerable impact on the variables that are currently determined through the survival curve. As such, beyond the adjustment to the age of vehicles in the stock, more direct adaptations will be required to achieve the desire model responses. Outlined below are the propose methodologies to fully take account of the impact of second hand vehicles.

D.3 Fuel Efficiency

The calculation of the current fleet fuel efficiency in the GTRM (for 2005 onwards) is given as follows:

$$Average\ Fleet\frac{MJ}{km} = Survive\ 5\ Yrs\ *5\ Year\ Fleet\ Average\frac{MJ}{km} + (1 - Survived\ 5\ Yrs)\ \times (new\ vehicle\ \frac{MJ}{km_t} + new\ vehicle\ \frac{MJ}{km_{t-5}})/2$$

In accounting for second hand vehicles, it was necessary to adapt this formula to adjust for the proportion of the stock which is imported and the age of the vehicle when they entered the stock and where they are imported from. The bilateral trade matrices are then used to estimate the impact upon the average fuel efficiency of the fleet according to the following formula;

$$Average\ Fleet\frac{MJ}{km} = Survive\ 5\ Yrs * 5\ Year\ Fleet\ Average\frac{MJ}{km} + (1 - Survived\ 5\ Yrs) \times \left(\%\ new\ vehicles \times \frac{new\ vehicle\ \frac{MJ}{km_t} + new\ vehicle\ \frac{MJ}{km_{t-5}}}{2}\right) + \left(\%\ 2nd\ vehicles\ (5yr) \times \frac{\sum_{r=1}^{30}\left(new\ vehicle\ \frac{MJ}{km_{r,t-5}} + new\ vehicle\ \frac{MJ}{km_{r,t-10}}\right) \times Sale\ Share_r}{2}\right) + \left(\%\ 2nd\ vehicles\ (10yr) \times \frac{\sum_{r=1}^{30}\left(new\ vehicle\ \frac{MJ}{km_{r,t-10}} + new\ vehicle\ \frac{MJ}{km_{r,t-15}}\right) \times Sale\ Share_r}{2}\right) + \left(\%\ 2nd\ vehicles\ (15yr) \times \frac{\sum_{r=1}^{30}\left(new\ vehicle\ \frac{MJ}{km_{r,t-15}} + new\ vehicle\ \frac{MJ}{km_{r,t-20}}\right) \times Sale\ Share_r}{2}\right)$$

$Average\ Fleet\frac{MJ}{km}$ = average fleet efficiency in the net importer country
t = Year
r = exporting country
$Survived\ 5\ Yrs$ = % of new vehicles that survive at least 5 years.
$\%\ new\ vehicles$ = Share of new vehicle of total sales in the importing country.
$new\ vehicle\ \frac{MJ}{km_{r,t}}$ = new vehicle efficiency of vehicles in exporting region r and year t
$\%\ 2nd\ vehicles\ (Xyr)$ = Share of second hand vehicles of age X years total sales in the importing country.
$Sale\ Share_r$ = % of second hand vehicle imports of exporting country r in the total imports of second hand vehicles in the net importer country.

In summary, the adjustment to fuel efficiency of the fleet in each period reflects the weighted average efficiency of the surviving stock in the previous period and the new vehicle sales and second hand vehicles imported from other European countries which have replaced the retired stock over the 5-year period.

However, given the limitations of the time periods covered by the GTRM, this method can only be fully implemented for 2020 onwards. For 2005 – 2015, an assumption is made of the relative efficiency of pre-2000 vehicles.

D.4 Emissions Factors

In the GTRM, the emissions factors are defined per the rollout of EURO emission standards. Due to the consistent deployment of the EURO standards across the EU, the adjustment to the proportions of stock for each standard should be quite straightforward. This can be achieved by using the new adjusted survival rate curves calculated with second hand vehicle included.

D.5 New Vehicle Sales

Sales in the GTRM model are calculated as follows:

$$Sales = \frac{Current\ Stock - \ Old\ Stock\ \times \left(1 - \frac{1}{Av\ Retire\ Age}\right)^5}{\left(\left(1 - \frac{1}{Av\ Retire\ Age}\right)^4 + \left(1 - \frac{1}{Av\ Retire\ Age}\right)^3 + \left(1 - \frac{1}{Av\ Retire\ Age}\right)^2 + \left(1 - \frac{1}{Av\ Retire\ Age}\right) + 1\right)}$$

Av Retire age = Fleet Average Retirement age = SUMPRODUCT (age of retirement X, share of vehicles retiring at age X)/SUM (Share of vehicles retiring by age)

To take account of second hand vehicle trade, sales are adjusted by changing the rate of vehicles retiring in the stock due to the exports of vehicles. However, for net importers, the difference between current stock and the previous period's stock are now fulfilled by a combination of new sales and imported vehicles; for historical years, shares of total sales attributable to new and second hand vehicles are calculated, and these are held constant through the projection period, such that total sales = new sales + second hand sales.

D.6 Vehicle stock by vehicle type

For net importers, the importing of second hand vehicles alters the composition of vehicle powertrains in the vehicle stock as the imported vehicle will reflect the composition of the older vehicle in the exporting countries. Therefore, in each period the shares of vehicle types are adjusted for net importer countries.

The treatment assumes that the vehicle type mix of second hand vehicles exported of a given age reflects the vehicle type mix of new vehicles in the exporter country when the exported vehicle was new. For example, in 2020 10-year-old cars exported from Germany to Poland would have the characteristics of new German car sales from 2010.