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Monitoring and assessment of CO_2 emissions in inland transport to facilitate climate change mitigation
The UNECE ForFITS model - Capacity Building Workshop in Montenegro
19-20 November, Pogdorica (Montenegro)

Evaluating CO_2 emissions in inland transport and climate change mitigation

ForFITS: a monitoring and assessment tool "For Future Inland Transport Systems"

The ForFITS input file and its setup for the pilot case of Montenegro

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ForFITS model: data requirements

Even if ForFITS has the capacity to adapt to different levels of data availability, the model does require a substantial amount of data, for:

- the characterization of the transport system in the base year (historical inputs)
- the definition of the context in which the transport system should evolve (projections)

Information on the initial and final times, the characterization of the areas, and the selection of the modelling approach for the powertrain choice (exogenous or endogenous), are also firm needs

Minimum data requirements (other inputs are defined by default data and can be modified)

Historical inputs

- GDP, population
- Vehicle stock: number of vehicles by powertrain, average travel and loads, average fuel consumption
- New vehicle registrations: same detail used for stocks needed for the base year, 5 and 10 years earlier (data in between are taken into account with linear interpolations)

Projections

- GDP and population
- Fuel prices (cost and taxation)
- Vehicle shares between two and three wheelers
- Pkm shares for different public transport modes (e.g. due to the construction of urban rail)
- Modal shares of light road freight vehicles
- Evolution of the network extension for pipelines
- With endogenous powertrain selection (optional), discount rate and powertrain shares

Need for coherence for inputs on each AREA, SERVICE, MODE, VEHICLE CLASS and POWERTRAIN

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ForFITS model: default data

A wide set of default data are included in the ForFITS Excel file

These default data are used to characterizing several parameters of the ForFITS model

They concern the following input categories:

M Data absolutely required
Corresponding to the minimum data requirements

A Inputs expected to be introduced by the user
The default value in ForFITS is for guidance only
This category includes policy inputs that allow exploring different scenarios

B Input containing technical information (e.g. technological potential and costs by powertrain)
These data may be maintained unchanged
The defaults are set on the basis of research activities involving literature reviews and statistical analyses (further information on this is provided in the relevant section of the ForFITS manual)

C Inputs on structural characteristics of the model
Unless the users acquired significant experience with the model, these inputs shall not be modified: changes to these inputs will result in significant modifications to the model behaviour

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ForFITS model: data requirements

(2/3)

Full data requirements

TIME PERIOD ANALYZED

- **Initial and final projection times**
  - Base year and final year

INITIAL CONDITIONS

- **Initial transport system**
  - **Vehicle stock**
    - **Vehicles**
      - Number of active vehicles — M
      - Powertrain group shares in each vehicle class — M
    - **Travel**
      - Annual travel per vehicle — M
    - **Load**
      - Vehicle load — M
    - **Fuel consumption**
      - Vehicle fuel consumption — M
      - Fuel consumption gap by powertrain group — C
  - **New vehicle registrations**
    - **Base year**
      - **Vehicles**
        - Newly registered vehicles — M
        - Powertrain group shares in each vehicle class — M
      - **Fuel consumption**
        - Vehicle fuel consumption — M
        - Fuel consumption gap by powertrain group — C
    - **Base year-5**
      - **Vehicles**
        - Newly registered vehicles — M
        - Powertrain group shares in each vehicle class — M
      - **Fuel consumption**
        - Vehicle fuel consumption — M
        - Fuel consumption gap by powertrain group — C
    - **Base year-10**
      - **Vehicles**
        - Newly registered vehicles — M
        - Powertrain group shares in each vehicle class — M
      - **Fuel consumption**
        - Vehicle fuel consumption — M
        - Fuel consumption gap by powertrain group — C
- **Economic & demographic data**
  - **Base year**
    - Population — M
    - GDP — M
    - GDP deflator — M

ECONOMIC AND DEMOGRAPHIC INPUTS (PROJECTIONS)

- **Economic & demographic data**
  - **Over time**
    - Population growth — M
    - GDP growth — M

TRANSPORT SYSTEM CHARACTERISTICS

- **Transport system over time**
  - **Passenger**
    - Area characterization — M
    - Passenger transport system index — A
    - Environmental culture index — A
  - **Freight**
    - **Constant parameters**
      - Haul length — B
      - Vehicle capacity ratios — B
      - Load factor ratios — B
      - Hauls per vehicle ratios — B
    - **Base year**
      - Shares of tonnes lifted by good type — M
      - Shares of tonnes lifted by transport distance
      - *Short & medium distance / all* — A
      - *Short distance / short + medium* — A
      - *Very large distance / large + very large* — A
      - Shares of tonnes lifted by transport zone — A
    - **Over time**
      - Shares of tonnes lifted by transport zone — A
      - Tonnes lifted by haul distance — A
      - Shares of tonnes lifted by good type — A
      - Shares of tonnes lifted by large-freight sub-mode — A

PRICES AND TAXES (BASE YEAR AND PROJECTIONS)

- **Fuel prices and taxes**
- **Fuel cost**
  - Base year — M
  - Over time — M
- **Fuel taxes**
  - Base year — M
  - Over time — M
- **Road pricing**
  - Cost of vehicle-km — A

FUEL CHARACTERISTICS (BASE YEAR AND PROJECTIONS)

- **Fuel characteristics: CO2 emission factors**
  - Base year — M
  - Over time — A

FUEL CONSUMPTION (PROJECTIONS)

- **All modes but air, NMT and pipelines**
  - **Fuel consumption characteristics**
    - Index of performance — A
  - **Fuel consumption characteristics by powertrain**
    - Passenger two wheelers — B
    - Passenger three wheelers — B
    - Passenger LDVs — B
    - Passenger vessels — B
    - Passenger large road — B
    - Passenger rail — B
    - Freight two wheelers — B
    - Freight three wheelers — B
    - Freight LDVs — B
    - Freight vessels — B
    - Freight large road — B
    - Freight rail — B
- **Air transport**
  - Fuel consumption per km — A
- **Pipelines**
  - Energy consumption per km — A

TECHNOLOGY CHOICE (PROJECTIONS)

- **Powertrain technology choice switch**
  - Choice switch (endogenous / exogenous) — M
  - Discount rate — M
- **A) EXOGENOUS TECHNOLOGY CHOICE INPUTS**
- **Powertrain technology & ICE fuel: shares**
  - Powertrain technology — M
  - ICE fuel — M
- **B) ENDOGENOUS TECHNOLOGY CHOICE INPUTS**
- **Powertrain technology & ICE fuel: availability**
  - Powertrain technology — M
  - ICE fuel — M
- **Vehicle costs by powertrain group** — B

VEHICLE & POWERTRAIN COSTS (PROJECTIONS)

- **All modes but air, NMT and pipelines**
  - **Vehicle costs by powertrain group**
    - Passenger modes — A
    - Freight modes — A
- **Air transport**
  - Air vehicle cost (base year) — B
  - Air vehicle cost (over time) — B

MODAL SHARES (EXOGENOUS PROJECTIONS)

- **Modal shares**
  - Modal shares between 2- and 3-wheelers — M
  - Pkm shares in public transport modes — M
  - Vehicle shares in light road freight modes — M

VEHICLE CLASSES (EXOGENOUS PROJECTIONS)

- **Vehicle shares within modes & sub-modes**
  - Personal passenger two wheelers — A
  - Personal passenger three wheelers — A
  - Personal passenger LDVs — A
  - Personal passenger vessels — A
  - Public passenger NMT — A
  - Public passenger two wheelers — A
  - Public passenger three wheelers — A
  - Public passenger LDVs — A
  - Public passenger vessels — A
  - Public passenger large road — A
  - Public passenger rail — A
  - Air passenger — A
  - Medium road freight vehicles — A
  - Heavy road freight vehicles — A
  - Freight two wheelers — A
  - Freight three wheelers — A
  - Freight LDVs — A
  - Freight vessels (maritime/deep sea) — A
  - Freight rail — A
  - Freight air — A
  - Freight pipelines — A

OTHER INPUTS (PROJECTIONS)

- **Pipelines**
  - Distance travelled/network extension — M
- **Crew costs**
  - Crew cost per day (base year) — B
  - Crew cost per day (over time) — A

DEMAND GENERATION PARAMETERS

- **Passenger**
  - **Drivers as fucntions of GDP per capita**
    - Personal passenger vehicles (PPV) per capita — C
    - Pkm share on PPV in PPV + public transport — C
    - Pkm share on air mode in total pkm — C
    - People per active bike — C
    - Personal vessels (boats) per capita — C
  - **Environmental culture multipliers**
    - Personal passenger vehicles (PPV) per capita — C
    - Personal passenger LDVS — C
    - Pkm share on PPV in PPV + public transport — C
    - Pkm share on air mode in total pkm — C
    - People per active bike — C
  - **Vehicle travel cost multipliers**
    - Personal passenger vehicles (PPV) per capita — C
    - Personal passenger LDVS — C
    - People per active bike — C
    - Personal vessels (boats) per capita — C
  - **Elasticities as functions of GDP per capita**
    - Annual personal vehicle travel to cost of driving — C
    - Pkm on public transport vehicles to cost of driving — C
    - Pkm on air vehicles to cost of driving — C
- **Freight**
  - **Drivers as fucntions of GDP per capita**
    - Share of light vehicles in total road freight — C
  - **Elasticities**
    - Tkm to the cost of tkm — C
    - Load factors to the cost of tkm — C

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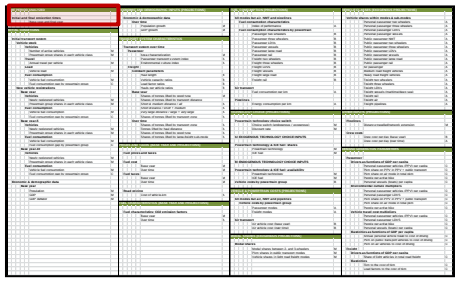
Inputs on the time period modelled



Modelling switches

Modelling switches and setup parameters

Initial and final projection times

Base year and final year

	BASE	FINAL
YEAR	2010	2040

Powertrain technology choice switch

Choice switch (endogenous / exogenous)
(either exogenous, requiring powertrain shares directly, or endogenous, requiring inputs on powertrain availability)

POWERTRAINS	endogenous (from model)

=> inputs on powertrain shares in the 'Pwtrn shares (over time)'

Discount rate
(required to perform endogenous technology choice)

Discount rate	25%

Notes on the inputs on the time period modelled

- Base year: always the same (consistency for all inputs needed)
- Inputs over time needed for the whole period
- All variables are calculated over this time period

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Inputs on the initial conditions (base year)

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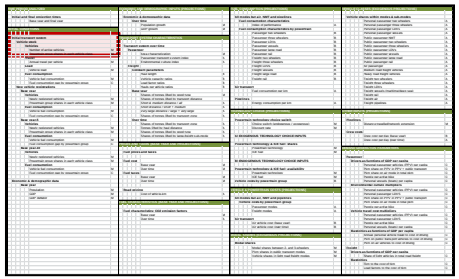
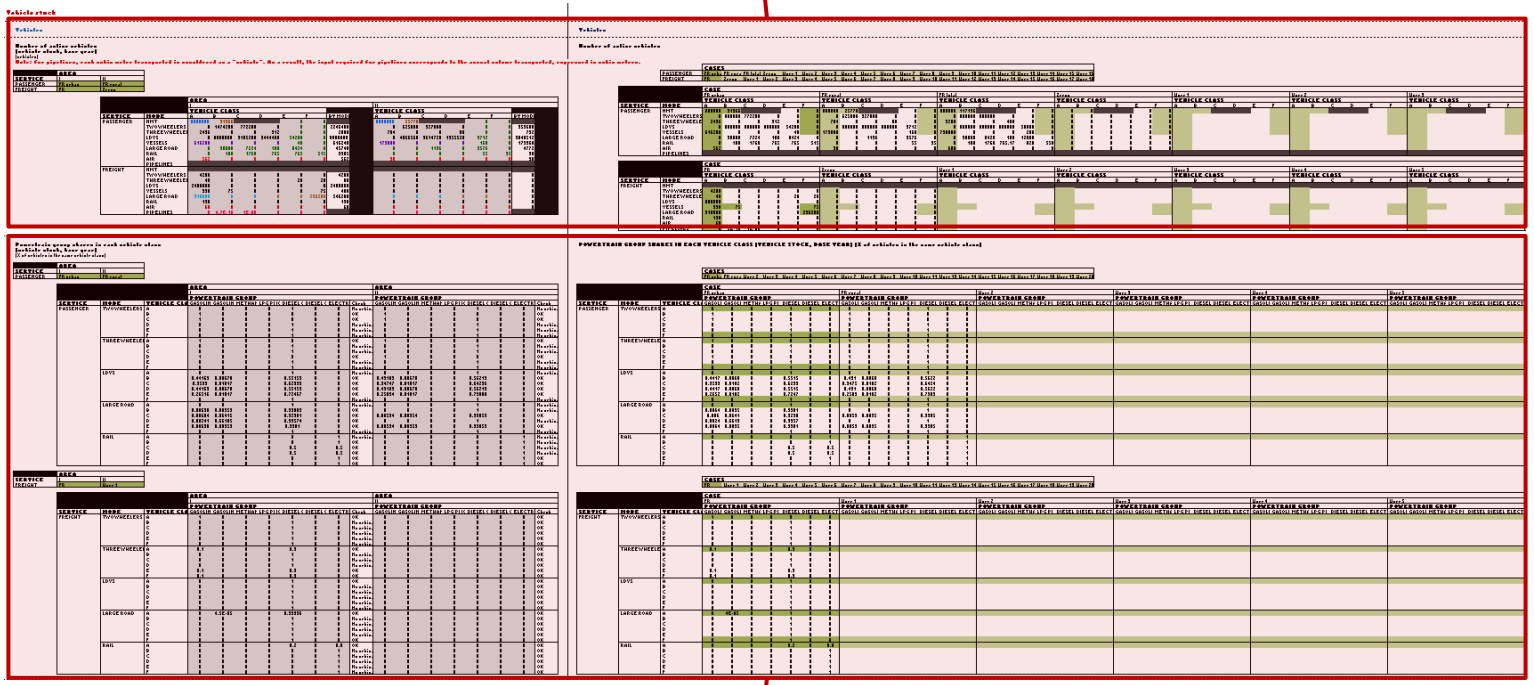


User inputs (BASE Y)

Number of active vehicles (vehicle stock): information for passenger and freight LDVs published by Monstat. Distribution across vehicle classes limited to minimum data requirements in ForFITS. Passenger rail based on information available on Wikipedia (passenger and freight). Air and vessels not taken into consideration.



Road: shares of vehicles in stock by powertrain based on expert judgement from Radoje Vujadinovic (University of Montenegro). Trucks and buses 100% diesel. Rail: information based on Wikipedia (passenger and freight).

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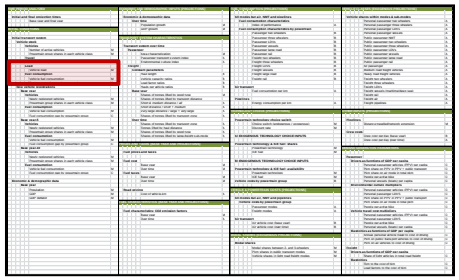
Inputs on the initial conditions (base year)

(2/3)

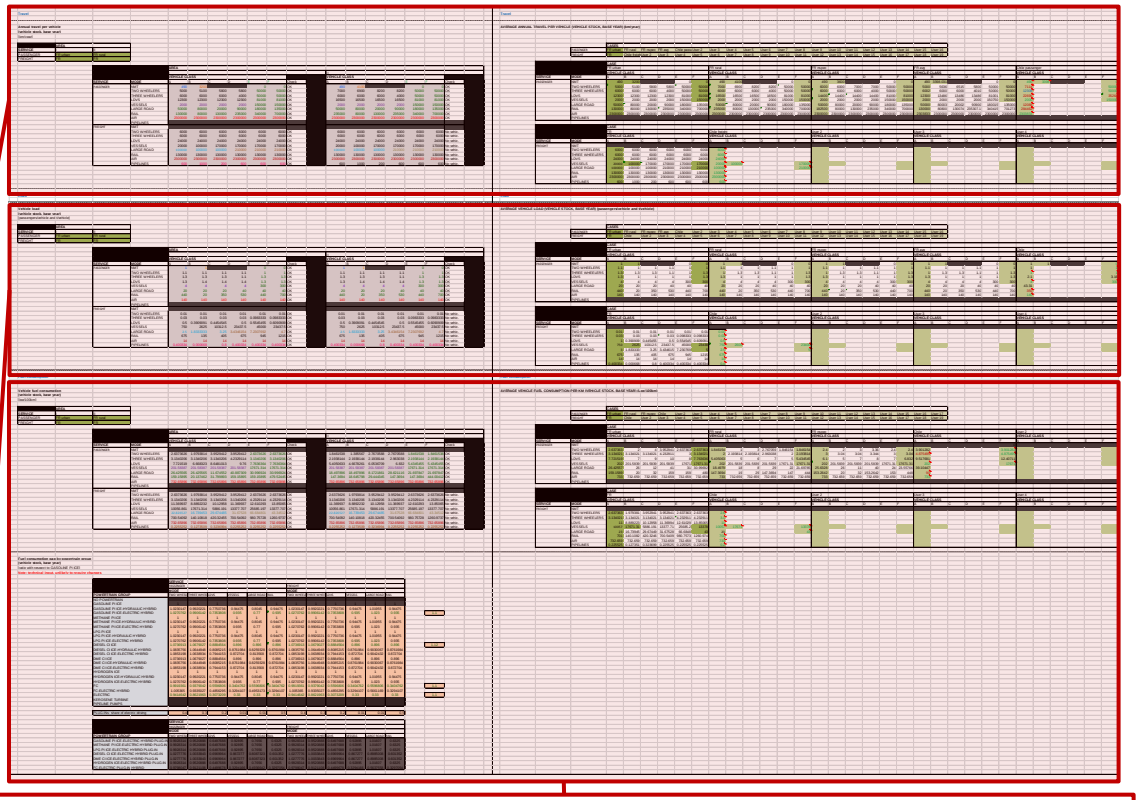


User inputs (BASE Y)

Note: Monstat publishes some information on pkm and tkm that do not refer to the whole passenger and freight transport systems. This information was not used here to calibrate travel and load data

Vehicle travel: estimates based on assumption on speed (km/h), time of vehicle usage (hours/day and days/week), analogies with other European data and expert judgement from Radoje Vujadinovic (Univ. of Montenegro). European data available in ICCT roadmap model. Rail checked against UIC pkm and tkm data.

Vehicle loads: assumed on the basis of vehicle class characteristics and analogies with other European countries, considering higher loads for lower incomes. European data available in ICCT roadmap model. Rail checked against UIC pkm and tkm data.



Fuel consumption per km: estimates based on expert judgement from Radoje Vujadinovic (University of Montenegro). Information broadly consistent with Eastern European data from detailed IEA report for LDVs, IEA publications (e.g. on energy efficiency indicators, such as IEA, 2004). Total fuel consumed checked against IEA statistics on energy use in transport. Technical estimates based on Kenworthy, 2003 used as comparative reference. Continental data available in the ICCT roadmap model.

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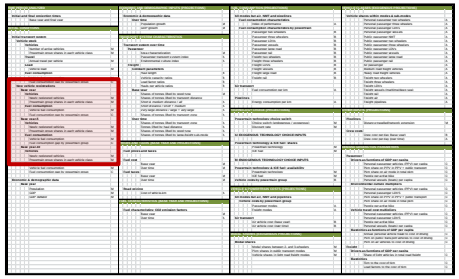
Inputs on the initial conditions (base year)

(3/3)

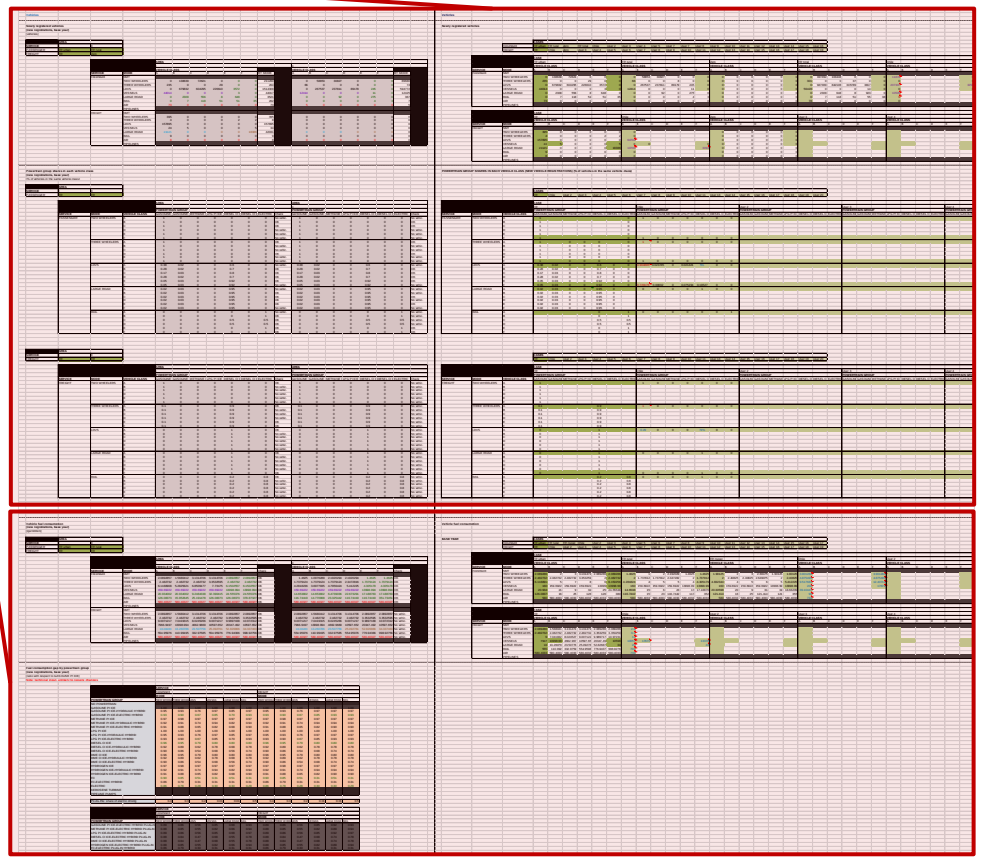


User inputs (BASE Y)

New vehicle registrations: similar tables for base year, base year-5 and base year-10

New vehicle registrations: based on expert judgement from Radoje Vujadinovic (University of Montenegro) and analogies with other European data (ratio amongst new registrations and vehicle stock). Maximum scrappage age checked for coherence with Nikolic (2009). Shares of vehicles by powertrain based on based on expert judgement from Radoje Vujadinovic (University of Montenegro). Resulting fuel consumption checked against IEA statistics on energy use in transport by fuel.

Fuel consumption per km: expert judgement from Radoje Vujadinovic (University of Montenegro), broadly consisent with Eastern European data from detailed IEA report for LDVs. Resulting fuel consumption checked against IEA statistics on energy use in transport by fuel. Ratios amongst fuel consumption per km different powertrains based on technical estimates. Continental data available in the ICCT roadmap model.



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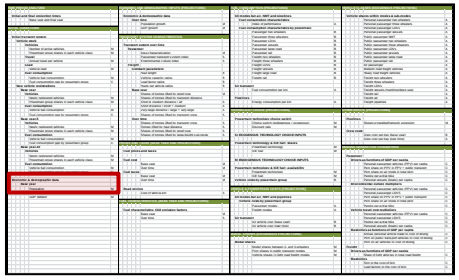
Economic and demographic data (base year)

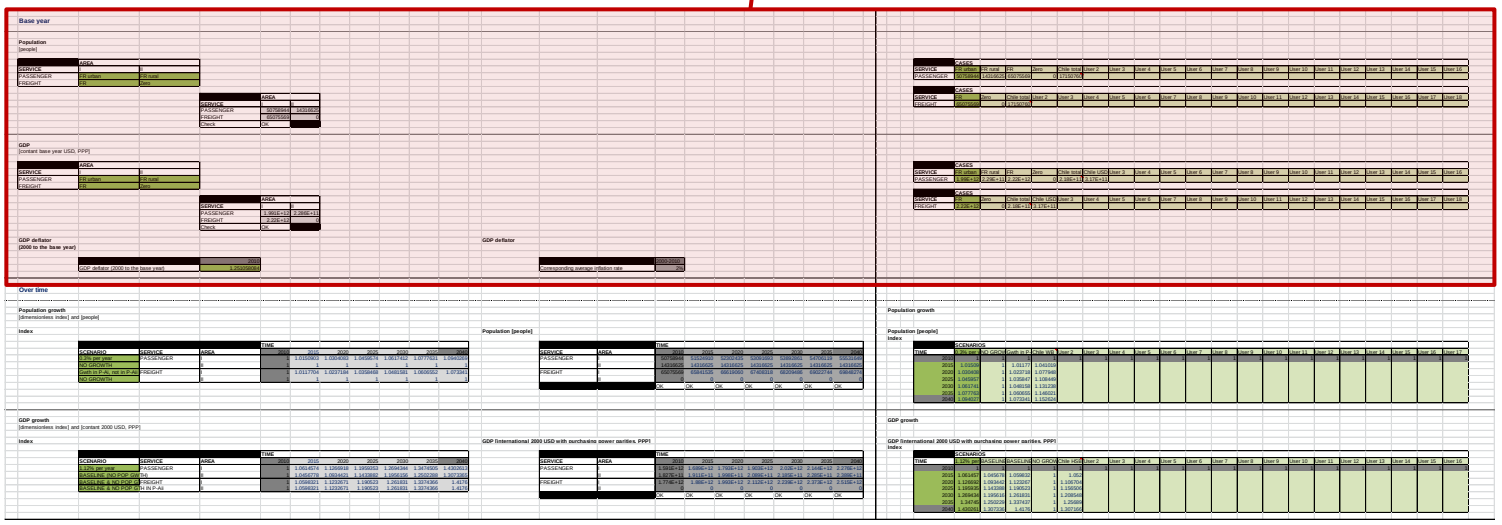


Socio-economic data

BASE YEAR

Population: data from World Bank, also available from UN

GDP: data from World Bank (current USD and deflator)



PROJECTIONS

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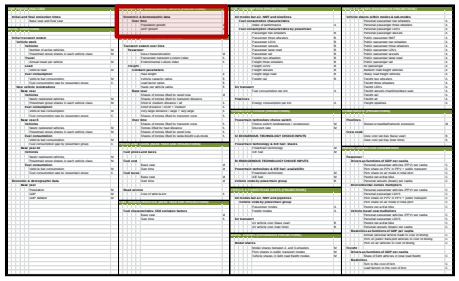
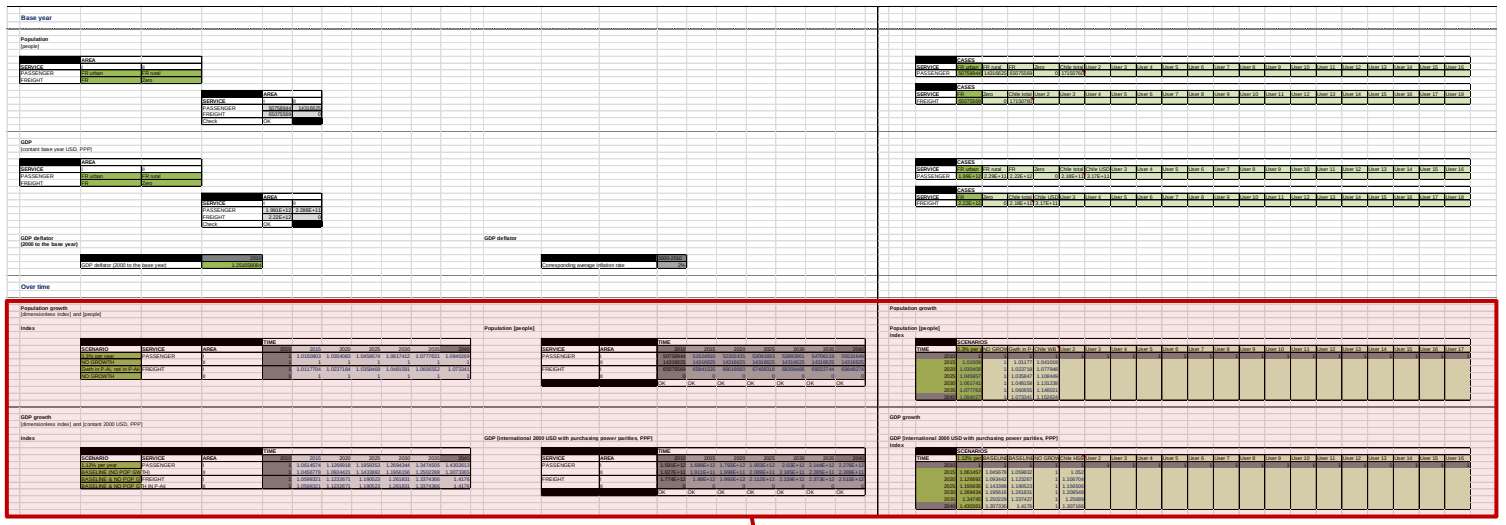
Economic and demographic data (projections)



Socio-economic data

BASE YEAR



PROJECTIONS

Population: currently based on assumptions. Population projections available from UN and other sources (see GDP)

GDP: currently based on assumptions. Projections taken from non-EU European countries from OECD study

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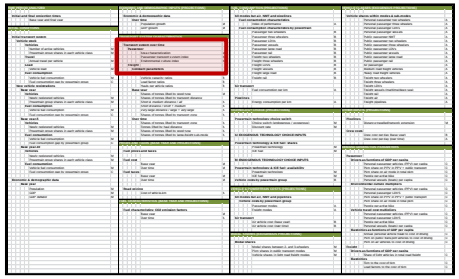
Passenger transport system over time

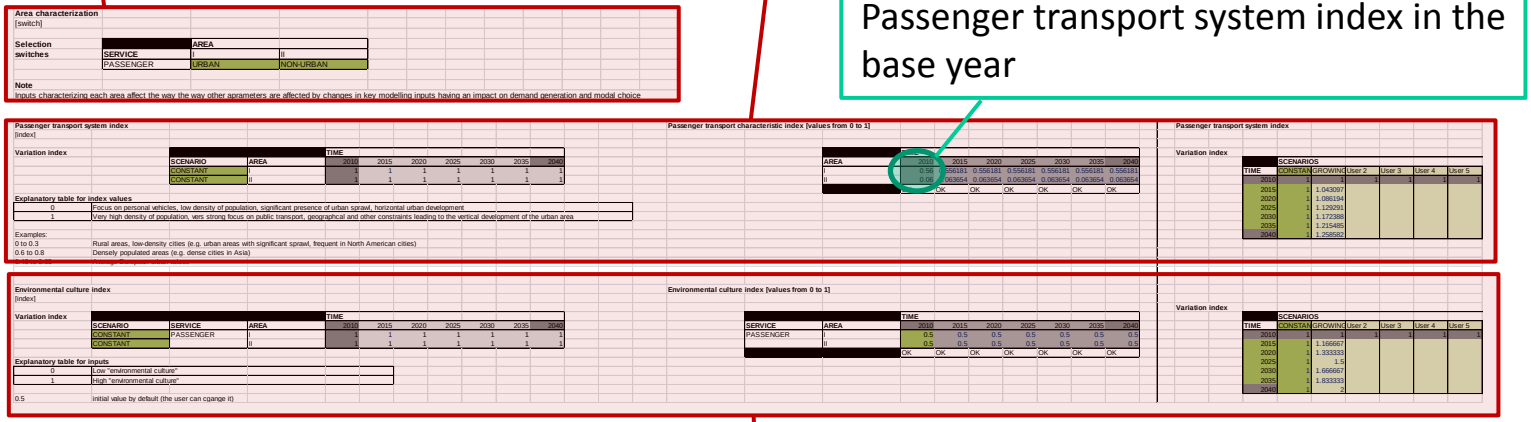


Transport system (over time)

Area characterization
Urban, non-urban, or non specified

Passenger transport system index
0 Focus on personal vehicles, low density of population, significant presence of urban sprawl, horizontal urban development
1 Very high density of population, strong focus on public transport, geographcal and other constraints leading to the vertical development of the urban area

Passenger transport system index in the base year



Environmental culture index: behavioural aspects, initialized to 0.5 in the base year
0 → Low "environmental culture“; 1 → High "environmental culture"

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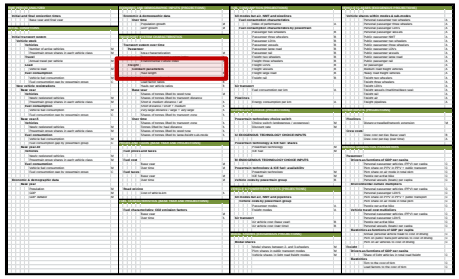
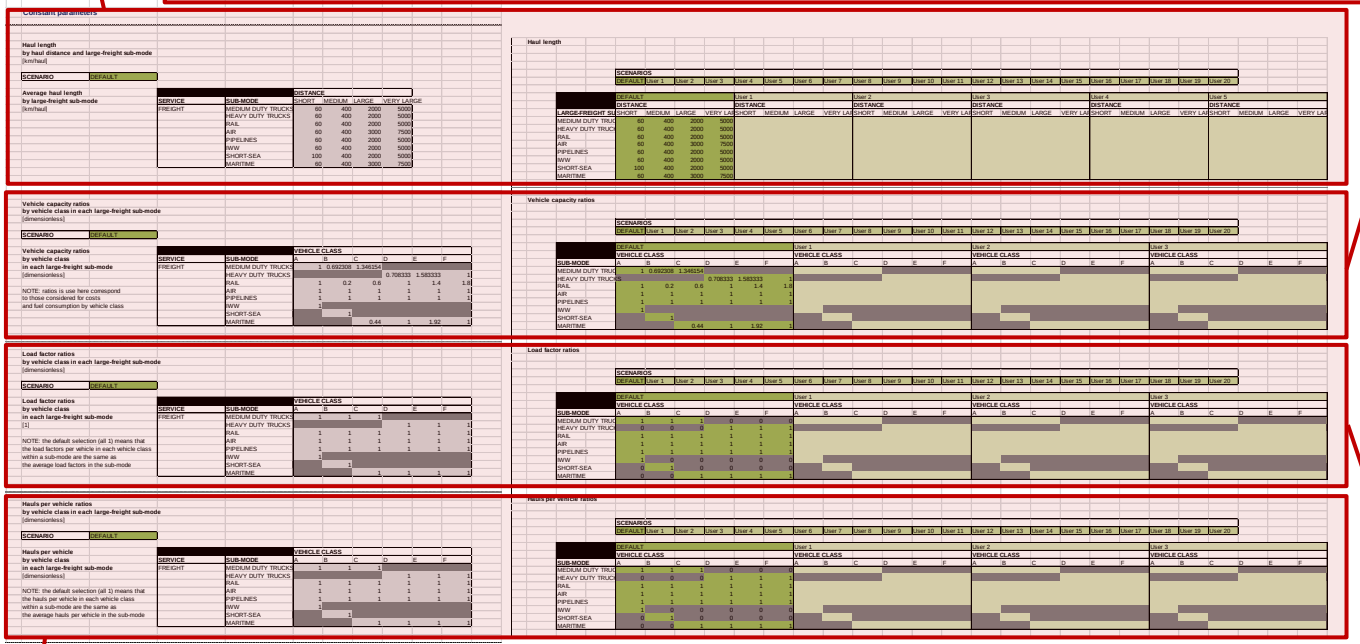
Freight transport system over time
Constant values



Transport system (over time)

Haul length: defined as average distance for each large-freight sub-mode

Vehicle capacity ratios: defined by default according to the default vehicle classification. Vehicles in classes A (and sometimes F) represent the average of each large-freight sub-mode and are used as reference for the ratio (value = 1)



Load factor ratios: currently assumed = 1 to reflect the same load factor in all classes

Hauls per vehicle ratios: currently assumed = 1 to reflect the same hauls in all classes

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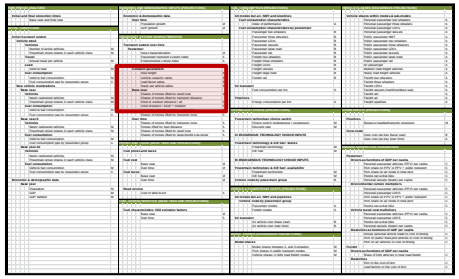
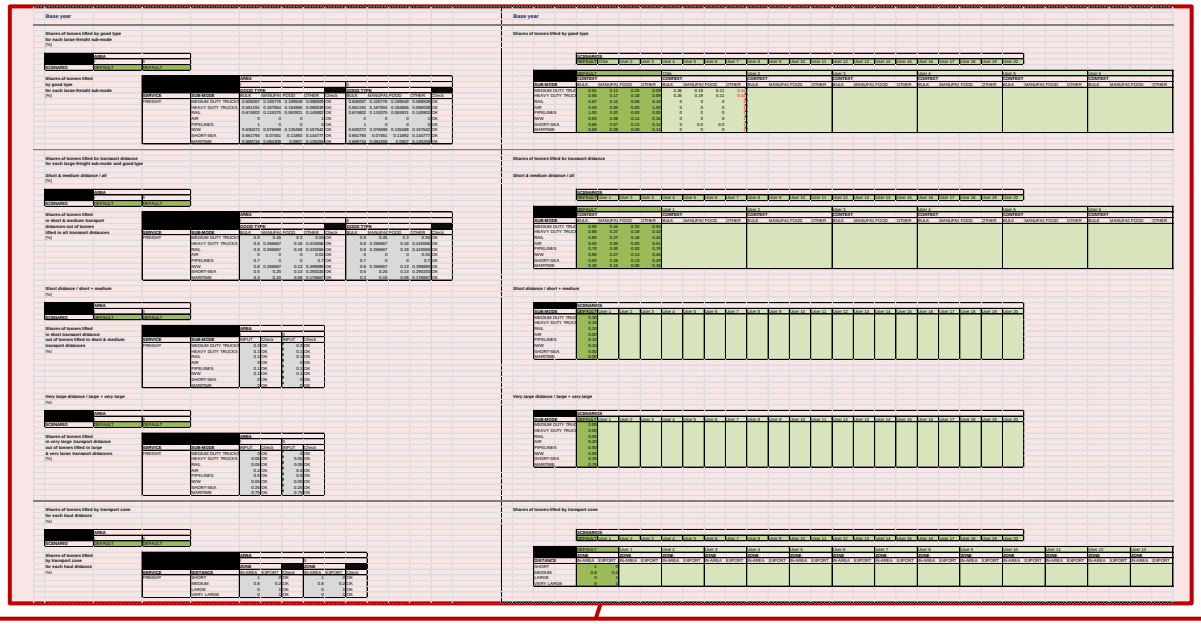
Freight transport system over time

Base year



Transport system (over time)



Shares defining the structure of the freight transport system in the base year

- tonnes lifted by good type
- transport distance, divided amongst: a) short & medium distance transport in all large-freight transport, b) short distance in short + medium, c) very large distance in large + very large
- transport zone, to take into account the relevance of imports and exports with respect to local consumption

Information based on Eurostat data (EU averages) checked against WTO data elaborated adding estimates on unit costs of different traded commodities

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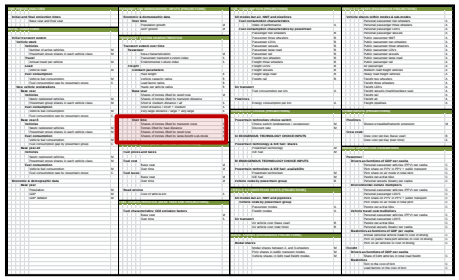
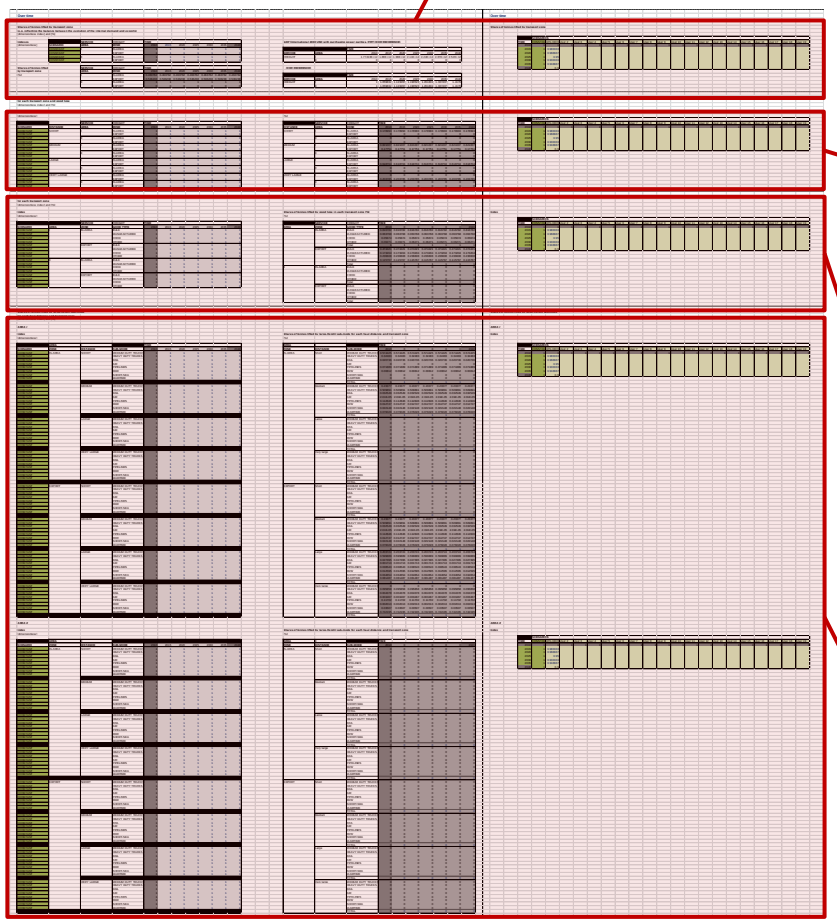
Freight transport system over time

Over time



Transport system (over time)

Evolution of the shares of tonnes lifted by transport zone (reflecting the balance between the evolution of the internal demand and exports)



Scenario-related inputs
Reference data are constant by default

Evolution of shares of tonnes lifted by haul distance for each area and transport zone (reflecting higher/lower importance of different haul distance, e.g. to mimic growth in local sourcing)
Policy input

Shares of tonnes lifted by good type (reflecting changes in the structure of the economy, such as shift from primary materials to manufactured goods)

Shares of tonnes lifted by large-freight sub-mode (reflecting changes in the competitiveness of different large- freight sub-modes over other options)

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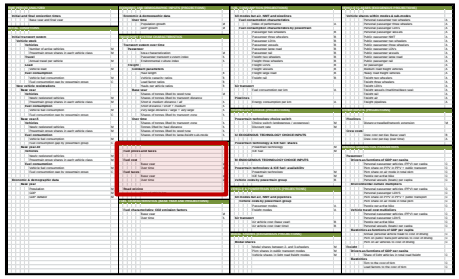
Prices and taxes (projections)



User inputs (over time)

Fuel costs before taxes: calculated ion the basis of cost after tax and tax rates
Information available from GIZ (international fuel prices and taxes, 2009 and 2013) and World Bank, 2012 (quoting GIZ 2010 data)

Cost per vkm due to taxation that is specific to each vkm by road modes
Zero by default (no road pricing)
Need for weighted averages to be properly working

Fuel taxation: available from and GIZ (international fuel prices and taxes, 2009 and 2013) and World Bank, 2012 (quoting GIZ 2010 data)

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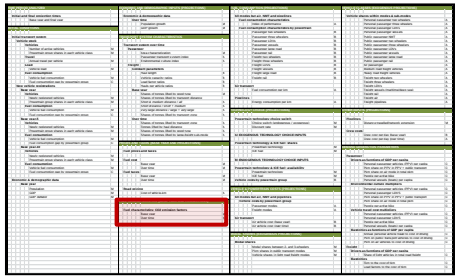
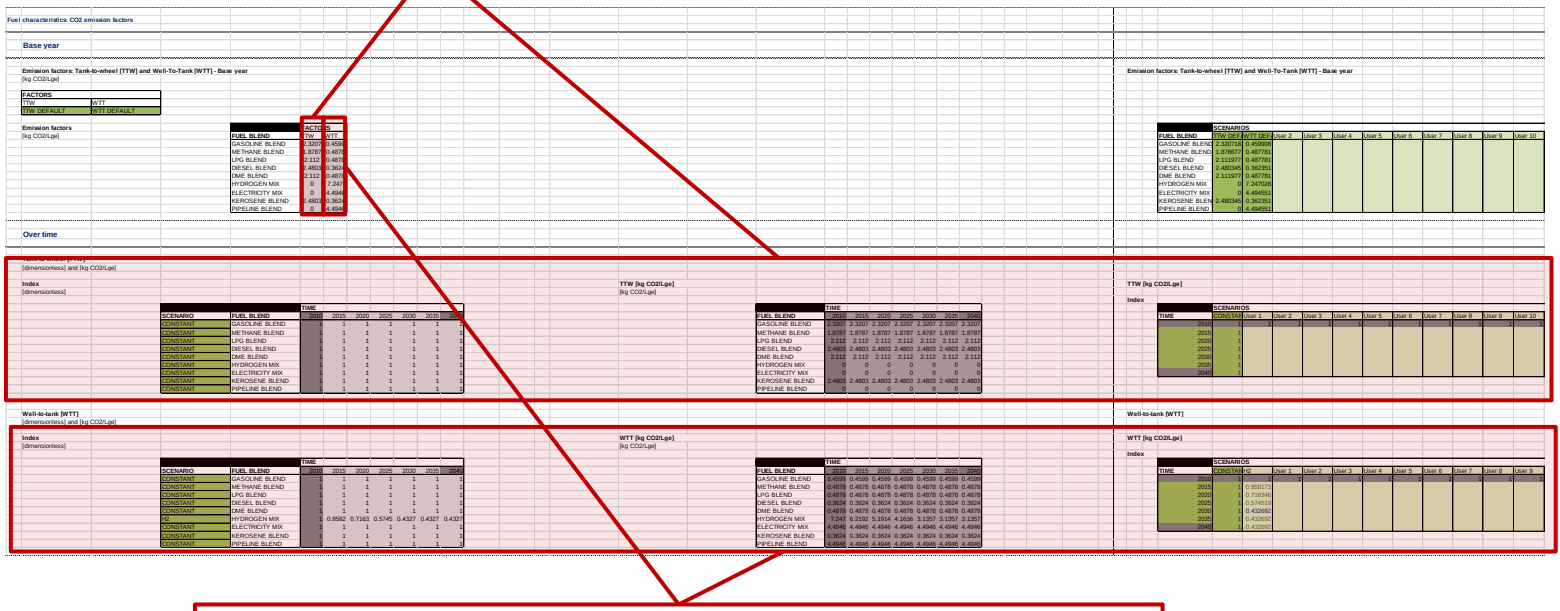
Fuel characteristics (base year and projections)



User inputs (over time)

Tank-To-Wheel (TTW)
Base year data based on IPCC emission factors
Projections: scenario-related inputs



Well-To-Tank (WTT)
Need for data referring to fuel blends, not specific fuels
This means that emission factors shall take into account for expected alternative fuel shares in projections
Current defaults refer to conventional fuels

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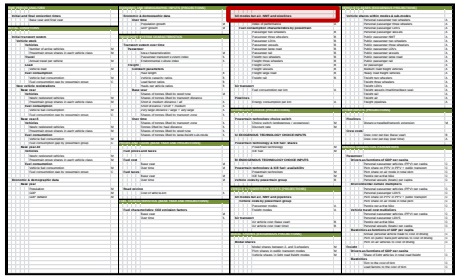
Index of performance



User inputs (over time)

- Needed to consider cases where the fuel consumption reduction potential is partly used to increase vehicle performance
- It can be based for instance on the expected evolution of vehicle power over time
- By default, this is set to remain constant

Index of performance
(excluding air, NMT and pipelines)

Index
[dimensionless]

			TIME						
SCENARIO	SERVICE	MODE	2010	2015	2020	2025	2030	2035	2040
CONSTANT	PASSENGER	TWO WHEELERS	1	1	1	1	1	1	1
CONSTANT		THREE WHEELERS	1	1	1	1	1	1	1
CONSTANT		LDVS	1	1	1	1	1	1	1
CONSTANT		VESSELS	1	1	1	1	1	1	1
CONSTANT		LARGE ROAD	1	1	1	1	1	1	1
CONSTANT		RAIL	1	1	1	1	1	1	1
CONSTANT	FREIGHT	TWO WHEELERS	1	1	1	1	1	1	1
CONSTANT		THREE WHEELERS	1	1	1	1	1	1	1
CONSTANT		LDVS	1	1	1	1	1	1	1
CONSTANT		VESSELS	1	1	1	1	1	1	1
CONSTANT		LARGE ROAD	1	1	1	1	1	1	1
CONSTANT		RAIL	1	1	1	1	1	1	1

Index of performance

Index

	SCENARIOS																				
TIME	CONSTAN	GROWING	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	User 13	User 14	User 15	User 16	User 17	User 18	User 19	User 20
2010	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2015	1	1.033333																			
2020	1	1.066667																			
2025	1	1.1																			
2030	1	1.133333																			
2035	1	1.166667																			
2040	1	1.2																			

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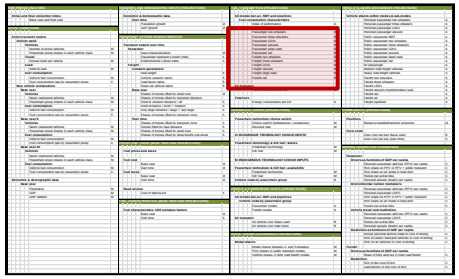
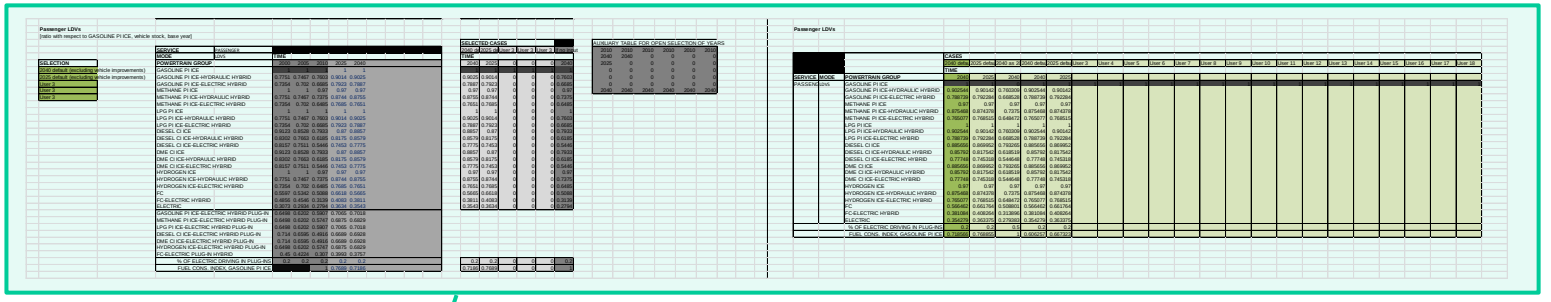
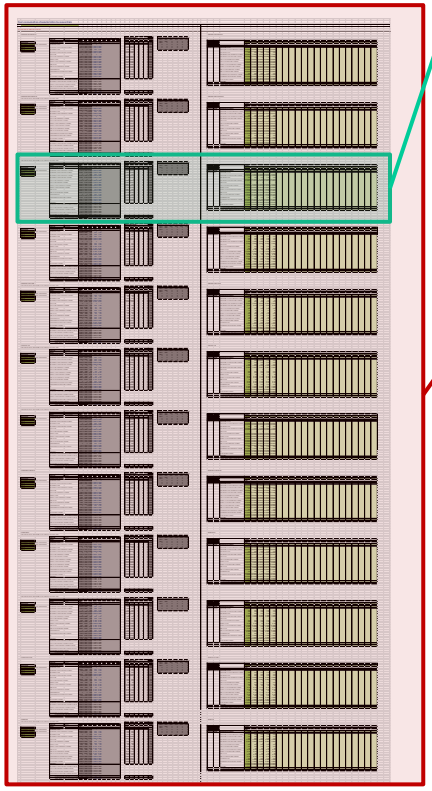
Fuel consumption characteristics by powertrain



Pwtrn potential





Fuel consumption evolution by service, mode and powertrain
Tables containing information on the energy saving potential of each powertrain technology

- Comparative index with reference technology (GASOLINE PI ICE)
- Index to consider evolution of GASOLINE PI ICE technology due to technology-specific improvements over time
- For plug-ins, information on the share of electric driving (reflecting battery capacity)

Default assumptions are based on a large amount of published information and coupled with vehicle costs: see UNECE, 2012 (Tables 7 and 8)

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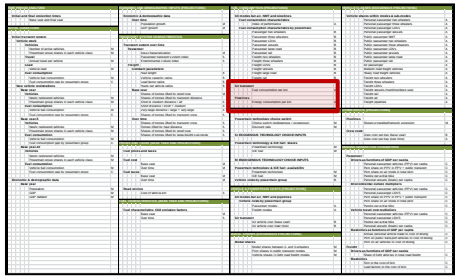
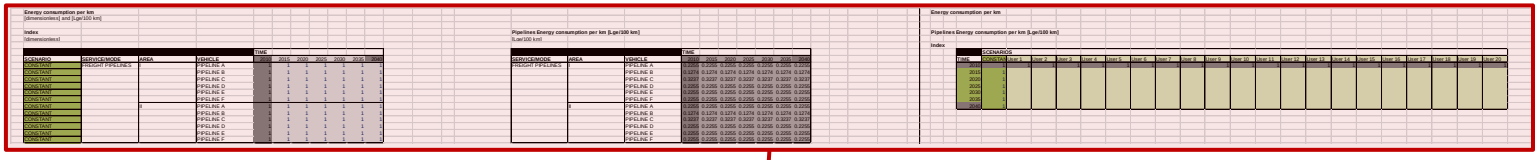
Fuel consumption projections
Air and pipelines



User inputs (over time)

Air transport: base year consumption entered as part of the base year information
Projections of fuel consumption per km entered here, through an index
Default scenarios include constant values and evolution along the trend of the past decade
Other technical estimates (e.g. based on literature assessing the fuel consumption of aircrafts) are appropriate



Pipelines: base year consumption entered as part of the base year information
Projections of fuel consumption per km entered here, through an index
Default evolution: constant values of consumption per km
Other technical estimates would be appropriate
Note: for pipelines, each cubic metre transported is considered as a "vehicle". Fuel consumption values should refer to the movement of this unit over 100 km

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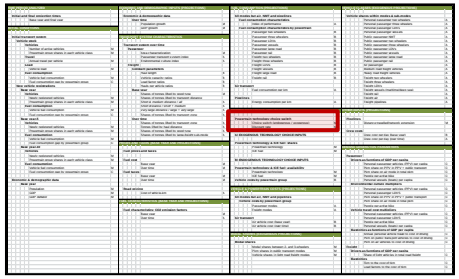
Powertrain technology choice switch



Modelling switches

Modelling switches and setup parameters

Initial and final projection times

Base year and final year

	BASE	FINAL
YEAR	2010	2040

Powertrain technology choice switch

Choice switch (endogenous / exogenous)
(either exogenous, requiring powertrain shares directly, or endogenous, requiring inputs on powertrain availability)

POWERTRAINS	endogenous (from model)

=> inputs on powertrain shares in the 'Pwtrn shares (over time)'

Discount rate
(required to perform endogenous technology choice)

Discount rate	25%

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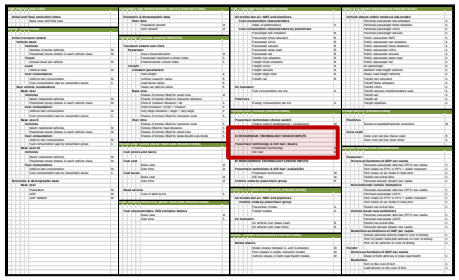
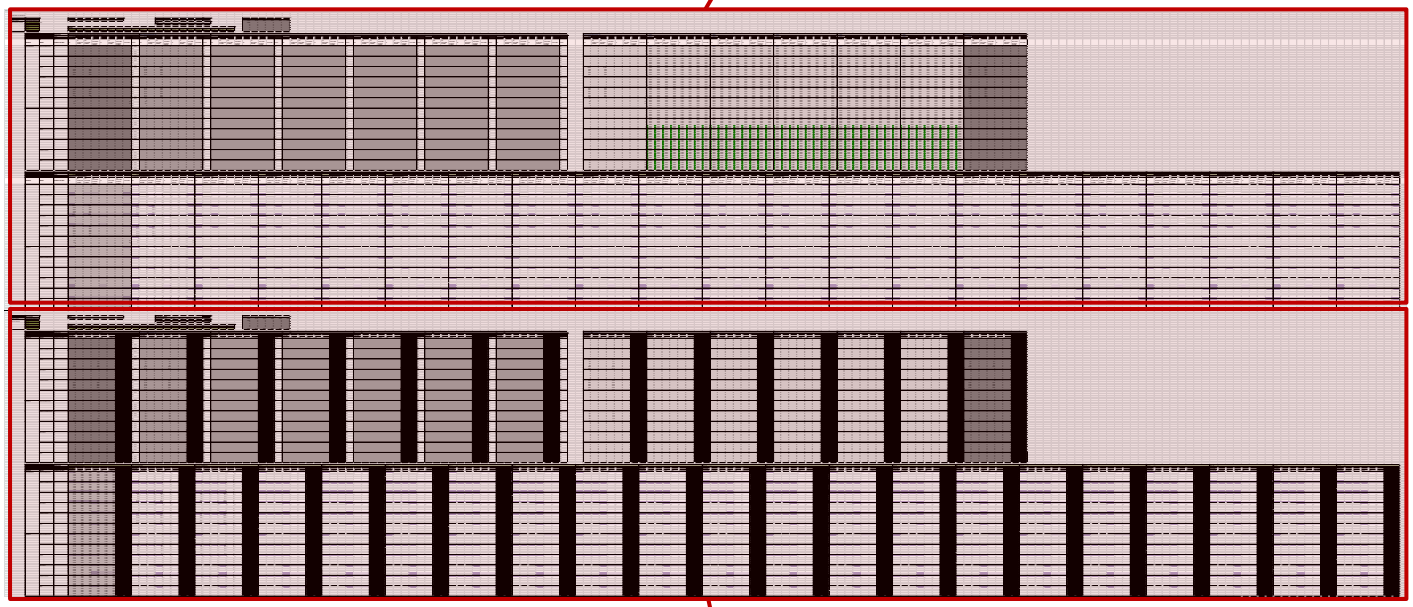
Powertrain technology & ICE fuel: shares



Pwtrn shares

Direct input of powertrain shares (EXOGENOUS POWERTRAIN CHOICE)
Region-specific inputs depend on local characteristics and user-driven scenarios
Default available: constant shares (base year shares self-calculated with other user inputs)

Powertrain technology
ICE, ICE-HYDRAULIC HYBRID, ICE-ELECTRIC HYBRID, ICE-ELECTRIC PLUG-IN HYBRID, fuel cell (FC), FC-ELECTRIC HYBRID, FC-ELECTRIC PLUG-IN HYBRID, ELECTRIC



ICE fuel: inputs on shares of ICE powertrains by fuel (GASOLINE, METHANE, LPG, DIESEL, DME, HYDROGEN)

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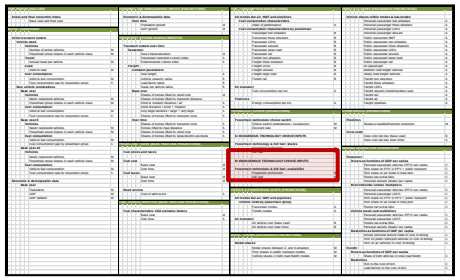
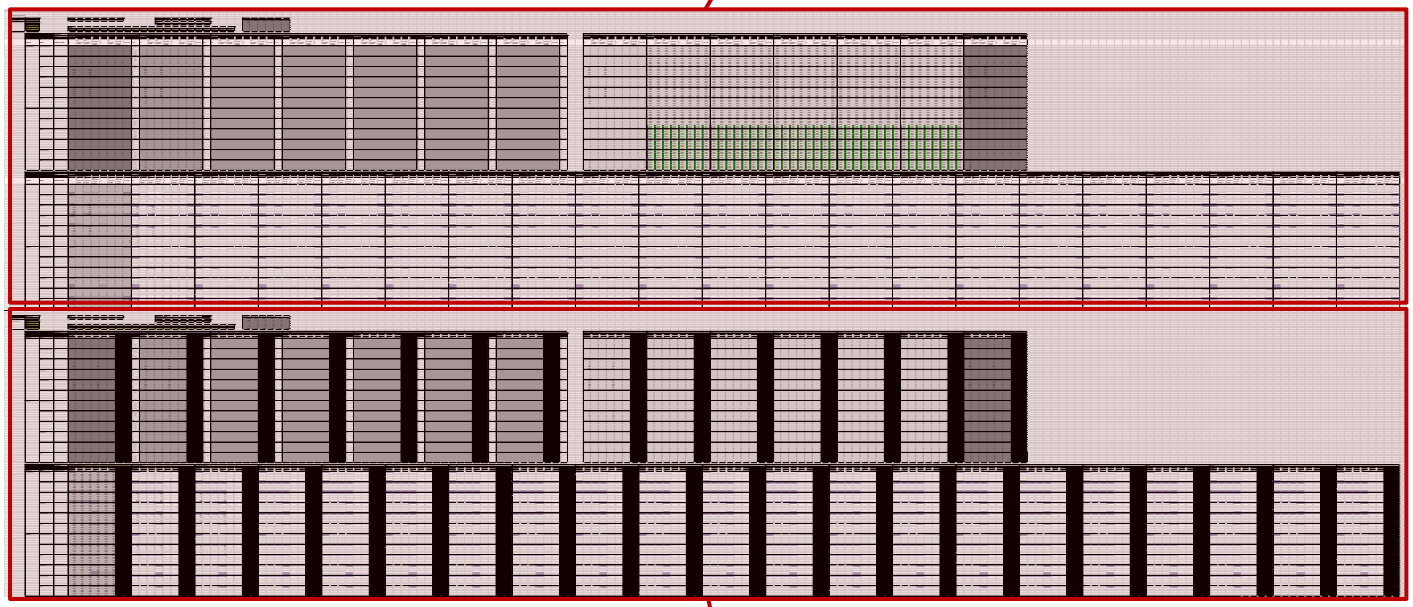
Powertrain technology & ICE fuel: availability



Pwtrn availability

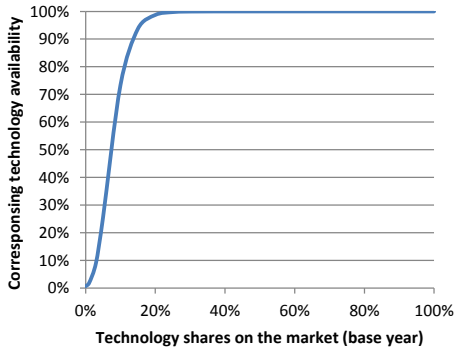
ENDOGENOUS POWERTRAIN CHOICE, same structure of Pwtrn shares
Region-specific inputs depend on local characteristics and user-driven scenarios
Default available: full availability, double than base year

Powertrain technology
ICE, ICE-HYDRAULIC HYBRID, ICE-ELECTRIC HYBRID, ICE-ELECTRIC PLUG-IN HYBRID, fuel cell (FC), FC-ELECTRIC HYBRID, FC-ELECTRIC PLUG-IN HYBRID, ELECTRIC



ICE fuel: inputs on shares of ICE powertrains by fuel (GASOLINE, METHANE, LPG, DIESEL, DME, HYDROGEN)

Availability: default values for the base year based on the curve below (roughly estimated with values for hybrids and diesels)



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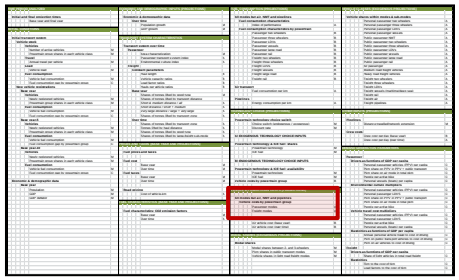
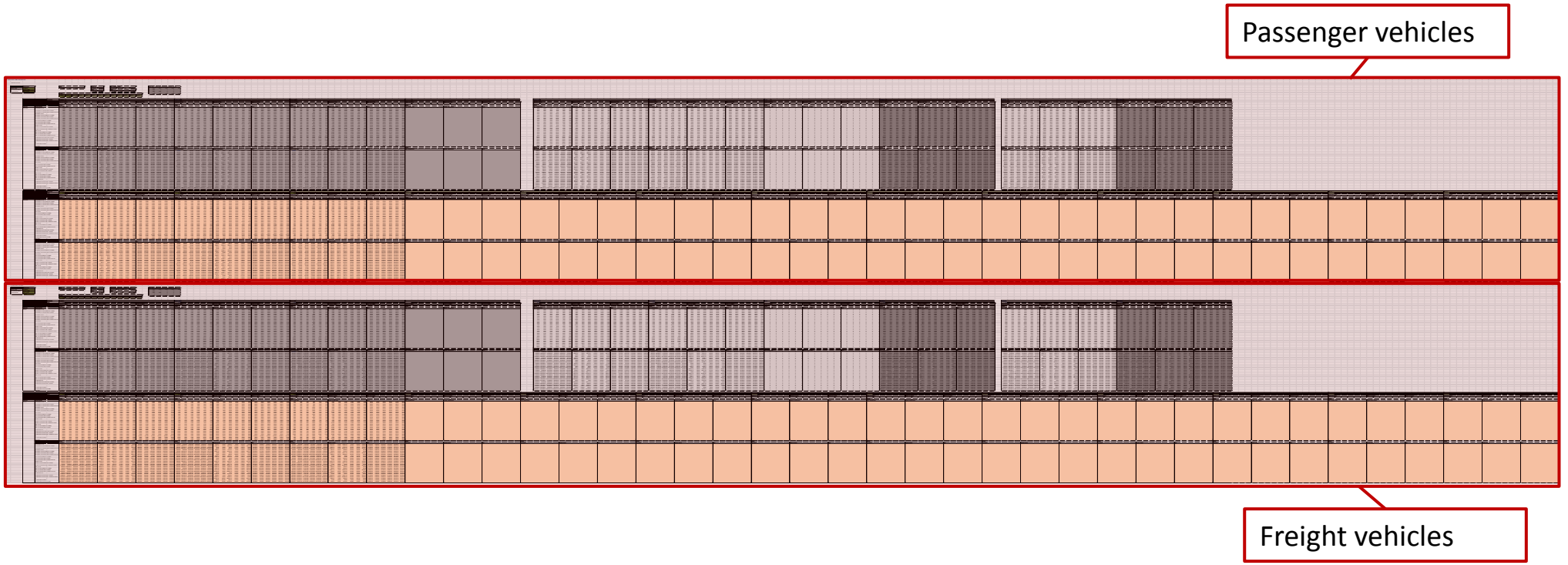
Powertrain cost



Cost inputs by pwtrn

Most complex input tables
Contains information on costs , linked to information on potentials
All powertrain technologies included
All data are based on technical estimates, suitable for developed countries (default values based on technical assessments available for developed countries): see UNECE, 2012 (Tables 7 and 8), for reference on sources used
Costs may be lower in developing countries, for the same potentials (labour cost difference, possibility to take advantage of technologies already exploited at large scale level)



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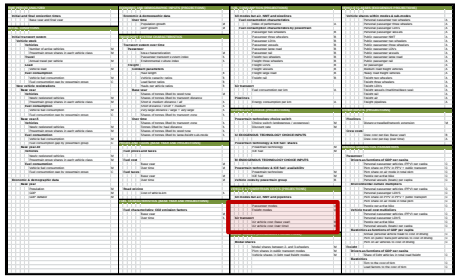
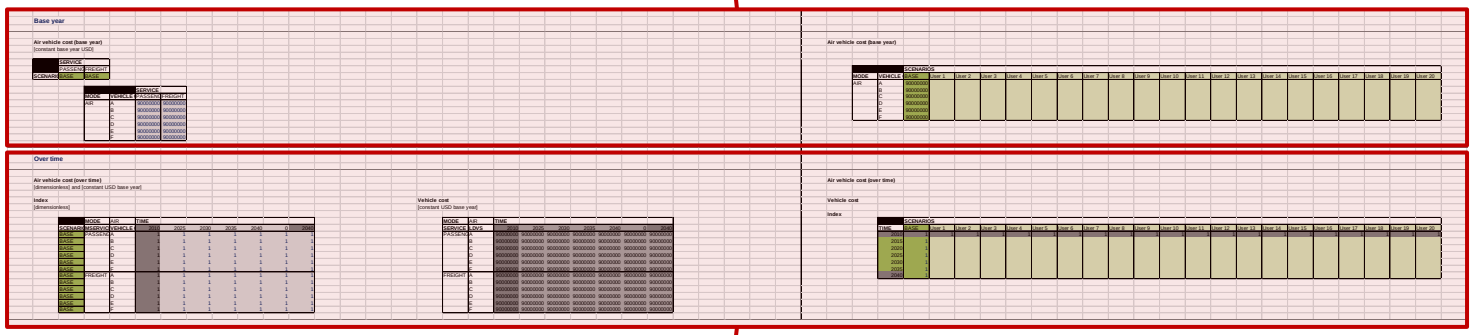
Air vehicle costs



- To be associated with technological potential for fuel savings in aviation
- Currently not characterized beyond information on the order of magnitude of the cost of an airplane (based on figures released by the main aviation companies for civil aircrafts)

Base year



Projections (constant by default)

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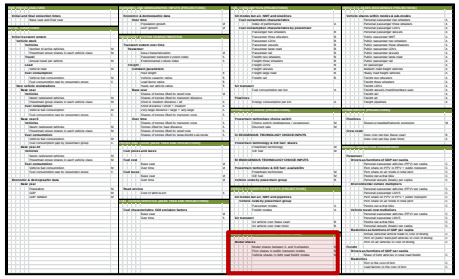
Modal shares

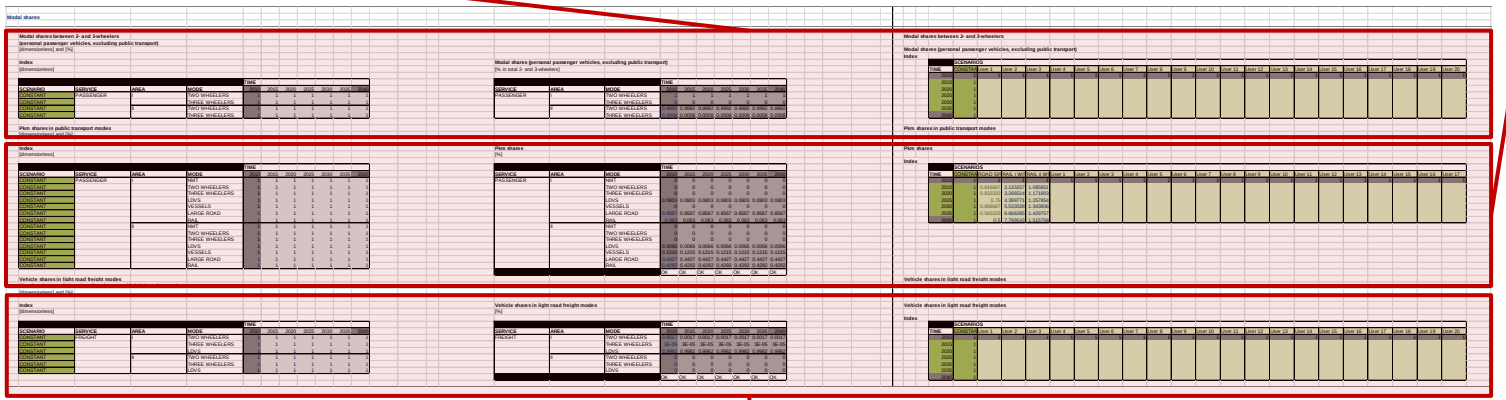


User inputs (over time)

Needed to characterize modes beyond the detail achieved in the demand generation module

Modal shares between 2- and 3-wheelers

Pkm shares in public transport modes



Vehicle shares in light road freight modes

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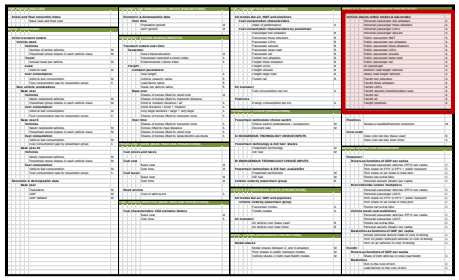
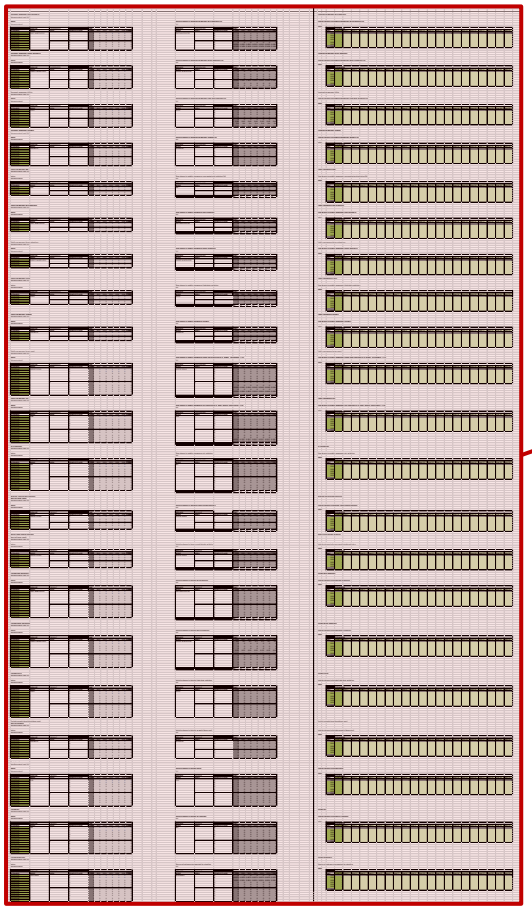
Vehicle shares



User inputs (over time)

Needed to characterize vehicle classes beyond the detail achieved in the demand generation module



Personal passenger two wheelers
Personal passenger three wheelers
Personal passenger LDVs
Personal passenger vessels
Public passenger NMT
Public passenger two wheelers
Public passenger three wheelers
Public passenger LDVs
Public passenger vessels
Public passenger large road
Public passenger rail
Air passenger
Medium road freight vehicles
Heavy road freight vehicles
Freight two wheelers
Freight three wheelers
Freight LDVs
Freight vessels (maritime/deep sea)
Freight rail
Freight air
Freight pipelines

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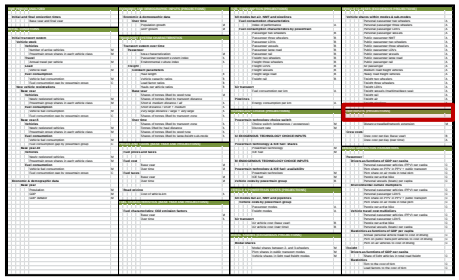
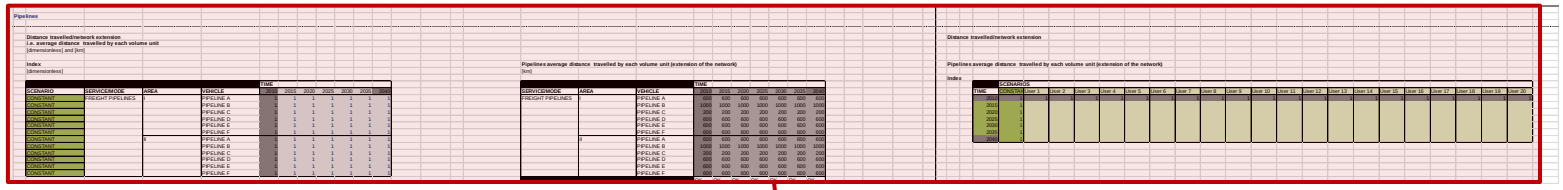
Pipelines: distance travelled/network extension



User inputs (over time)



Pipelines: distance travelled/network extension
Evolution of the average distance travelled by each volume unit transported by pipeline
Base year data entered earlier (‘User inputs (BASE Y)’ tab).

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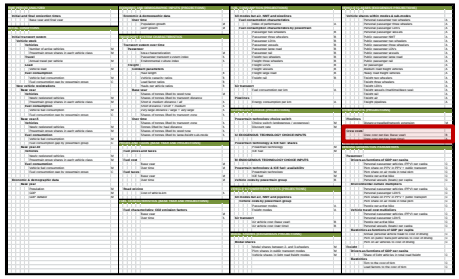
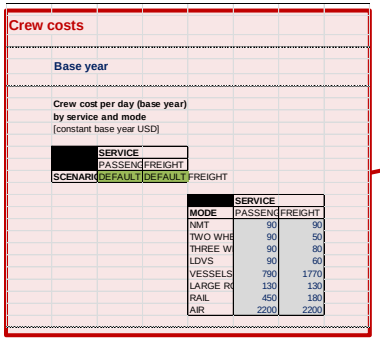
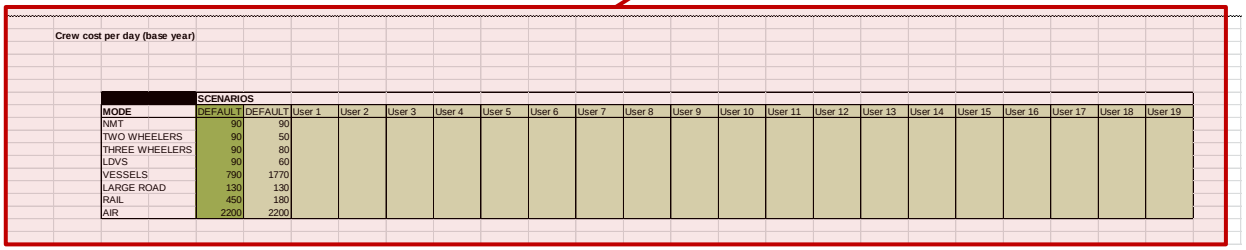
Crew costs



Other costs



Default data containing assumptions on the average cost per day of crew costs, considering an indicative number of people in the crew for public transport and air transport vehicles and an indicative gross salary per month.
Defaults are calibrated on an estimation of likely European values.



Crew cost per day over time
Evolution of the crew cost over time (e.g. due to changes in labour cost and income profiles)
Not a major transport input, maintained constant (in constant prices) by default

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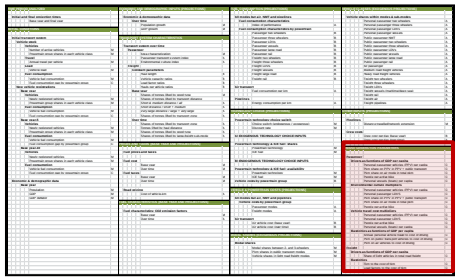
Demand generation control parameters



Data in the sheet **Demand generation parameters**

They include information on the faimilies of driving curves used in the model (e.g. for vehicle ownership) and on all elasticities.

Passenger

- Drivers as functions of GDP per capita

Personal passenger vehicles (PPV) per capita, pkm share on PPV in PPV + public transport, pkm share on air mode in total pkm, people per active bike, personal vessels (boats) per capita

- Environmental culture multipliers

Personal passenger vehicles (PPV) per capita, PP LDVS, pkm share on PPV in PPV + public transport, pkm share on air mode in total pkm, people per active bike

- Vehicle travel cost multipliers

Personal passenger vehicles (PPV) per capita, personal passenger LDVS, people per active bike, personal vessels (boats) per capita

- Elasticities as functions of GDP per capita

Annual personal vehicle travel to cost of driving, pkm on public transport vehicles to cost of driving, pkm on air vehicles to cost of driving

Freight

- Drivers as functions of GDP per capita: share of light vehicles in total road freight
- Elasticities: tkm to the cost of tkm, load factors to the cost of tkm