23.   Cost of fuel

Overview

Target

This view is intended to calculate the cost of fuel per vkm in the vehicle stock at the base year as well as over time. The outputs are calculated using inputs on the cost of fuel per unit energy as well as data on energy consumption and transport activity.

The cost of fuel per vkm is expressed at different levels of detail. The cost is first calculated by powertrain, and then further aggregated (in several steps) by vehicle class, by mode and finally at the sub-modal level within passenger and freight services.

The fuel blends considered by ForFITS are the following: NMT BLEND, GASOLINE BLEND, METHANE BLEND, LPG BLEND, DIESEL BLEND, DME BLEND, HYDROGEN MIX, ELECTRICITY MIX, KEROSENE BLEND and PIPELINE BLEND.

Structure

The left half of the view refers to the base year. The calculations flow starts from the bottom. The initial variable is the user input on cost of fuel per unit energy by fuel blend. Figure 23.1 shows that the model calculates first the cost of fuel per vkm by vehicle class, and then aggregates this across vehicle classes belonging to relevant modes and sub-modes.

Figure 23.1   Cost of fuel at the base year – Vensim sketck
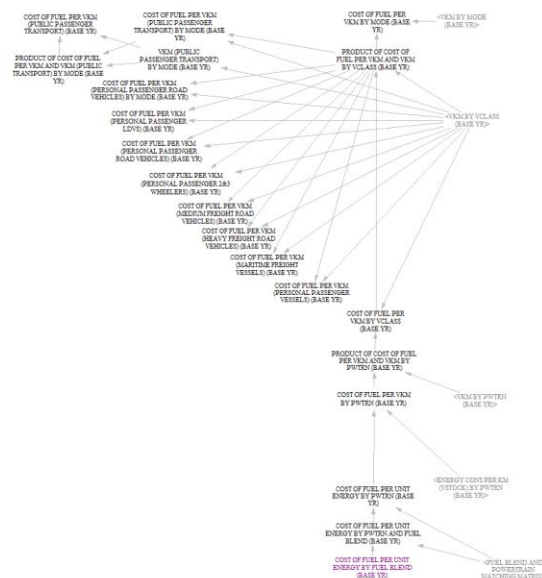
The symmetrical structure on the right half of the view deals with data over time (Figure 23.2). In both cases, the variables containing information on vehicle activity (vkm) enable to perform the weighted averages that switch from one subscript to one above further aggregated.

Figure 23.2 Cost of fuel over time – Vensim sketch
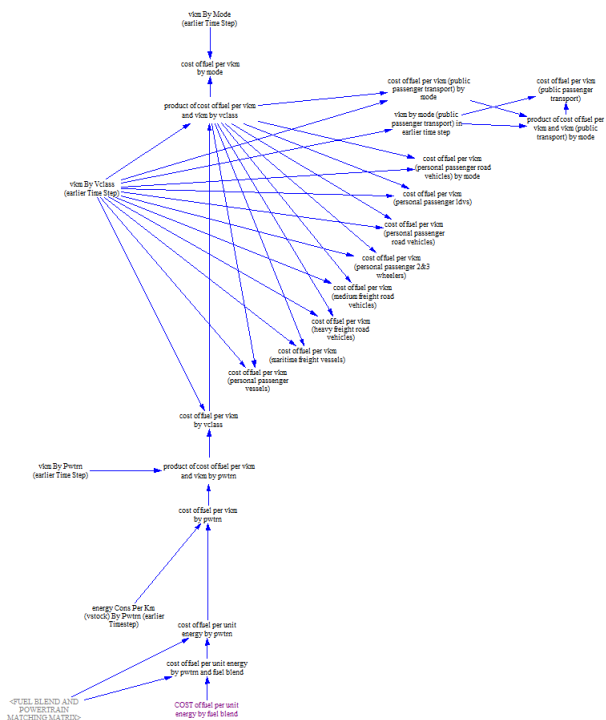
Detailed description of the view

Inputs

The initial cost of fuel per Litre of Gasoline Equivalent (LGE) by fuel blend, as well as its evolution over time, are inputs specified by the user ("User inputs (over time)" sheet of the ForFITS Excel file).

The "FUEL BLEND AND POWERTRAIN MATCHING MATRIX" is a default matrix filled by 1 and 0 elements to link each powertrain with the corresponding fuel blend/s. Plug-in technologies are the only ones involving two fuel blends (ELECTRICITY MIX plus another). In this case the cost of fuel per unit energy takes into account both the contributions.

The energy consumption per km by powertrain in the vehicle fleet is a variable calculated in the view "energy cons by age". It is used here to calculate the cost of fuel per vkm by powertrain.

The different aggregates on transport activity (vkm) are calculated in the view "activity, loads and stock aggregates". These data are necessary to weight the averages of the cost of fuel per vkm across subscripts.

The description of the "demand" views explained that the vehicle activity (vkm) depends on the cost of driving through elasticities. The energy consumption of vehicles (calculated multiplying vkm by the energy consumption per km of vehicles) also does. Since Vensim does not handle easily iterative calculations for data changing simultaneously over the same time step, the estimation of the cost of driving at a given time is assumed to depend on the cost of the fuel blend at that time, but also on vkm and energy consumption data at the earlier time step. This is why the view includes delayed variables for vkm and energy consumption. These delayed variables are initialized with its respective base year values.

Outputs

The cost of fuel per unit energy by powertrain is obtained from exogenous inputs on the cost of fuel by fuel blend and the fuel-powertrain matching matrix. This binary matrix enables to eliminate the FUEL BLEND dimension switching to the POWERTRAIN subscript:

$$Fuel\ cost\ per\ unit\ energy\ by\ powertrain\ (USD/lge) =$$
$$= \frac{\sum_{fuel\ blends} Fuel\ cost\ by\ fuel\ blend \times Fuel\ blend/powertrain\ matching\ matrix}{\sum_{fuel\ blends} Fuel\ blend/powertrain\ matching\ matrix}$$

The cost of fuel per vkm results from the multiplication between the cost per unit energy and the energy consumption per km:

$$Fuel\ cost\ per\ vkm\ by\ powertrain\ \left(\frac{USD}{vkm}\right) =$$
$$= Fuel\ cost\ per\ unit\ energy\ by\ powertrain\ (USD/lge) \times Consumption\ per\ km\ by\ powertrain\ (lge/vkm)$$

The aggregate of the cost of fuel per vkm at the vehicle class level is calculated as the average across the technologies weighted by the vkm run by each one in the vehicle stock:

$$Fuel\ cost\ per\ vkm\ by\ vehicle\ class = \frac{\sum_{powertrains} Fuel\ cost\ per\ vkm\ by\ powertrain \times vkm\ by\ powertrain}{\sum_{powertrains} vkm\ by\ powertrain}$$

where the denominator $\sum_{powertrains} vkm\ by\ powertrain$ is equal to vkm by vehicle class.

Further aggregates are calculated by means of the same operation across vehicle classes in order to provide outputs on the cost of fuel per vkm for each mode and sub-mode of passenger and freight service:

Personal passenger vessels

Vehicle classes A to D of VESSELS mode in PASSENGER service:

$$Fuel\ cost\ per\ vkm\ (personal\ passenger\ vessels) =$$
$$= \frac{\sum_{vclasses\ A\ to\ D} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER,VESSELS] \times vkm\ by\ vclass[PASSENGER,VESSELS]}{\sum_{vclasses\ A\ to\ D} vkm\ by\ vclass\ [PASSENGER,VESSELS]}$$

Maritime freight vessels

Vehicle classes C to F of VESSELS mode in FREIGHT service:

$$Fuel\ cost\ per\ vkm\ (maritime\ freight\ vessels) =$$
$$= \frac{\sum_{vclasses\ C\ to\ F} Fuel\ cost\ per\ vkm\ by\ vclass[FREIGHT,VESSELS] \times vkm\ by\ vclass[FREIGHT,VESSELS]}{\sum_{vclasses\ C\ to\ F} vkm\ by\ vclass\ [FREIGHT,VESSELS]}$$

Heavy freight road vehicles

Vehicle classes D to F of LARGE ROAD mode in FREIGHT service:

$$Fuel\ cost\ per\ vkm\ (heavy\ freight\ road\ vehicles) =$$
$$= \frac{\sum_{vclasses\ D\ to\ F} Fuel\ cost\ per\ vkm\ by\ vclass[FREIGHT,LARGE\ ROAD] \times vkm\ by\ vclass[FREIGHT,LARGE\ ROAD]}{\sum_{vclasses\ D\ to\ F} vkm\ by\ vclass\ [FREIGHT,LARGE\ ROAD]}$$

Medium freight road vehicles

Vehicle classes A to C of LARGE ROAD mode in FREIGHT service:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (medium\ freight\ road\ vehicles) =\\ &= \frac{\sum_{vclasses\ A\ to\ C} Fuel\ cost\ per\ vkm\ by\ vclass[FREIGHT, LARGE\ ROAD] \times vkm\ by\ vclass[FREIGHT, LARGE\ ROAD]}{\sum_{vclasses\ A\ to\ C} vkm\ by\ vclass\ [FREIGHT, LARGE\ ROAD]}\end{aligned}$$

Personal passenger two and three wheelers

Vehicle classes A to D of TWO and THREE WHEELERS modes in PASSENGER service:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (personal\ passenger\ 2\&3\ wheelers) =\\ &= \frac{\sum_{2\&3\ wheelers}\sum_{vclasses\ A\ to\ D} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER] \times vkm\ by\ vclass[PASSENGER]}{\sum_{2\&3\ wheelers}\sum_{vclasses\ A\ to\ D} vkm\ by\ vclass\ [PASSENGER]}\end{aligned}$$

Personal passenger road vehicles

Vehicle classes A to D of TWO WHEELERS, THREE WHEELERS and LDVS modes in PASSENGER service:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (personal\ passenger\ road\ vehicles) =\\ &= \frac{\sum_{2\&3\ wheelers, LDVS}\sum_{vclasses\ A\ to\ D} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER] \times vkm\ by\ vclass[PASSENGER]}{\sum_{2\&3wheelers, LDVS}\sum_{vclasses\ A\ to\ D} vkm\ by\ vclass\ [PASSENGER]}\end{aligned}$$

Personal passenger LDVS

Vehicle classes A to D of LDVS mode in PASSENGER service:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (personal\ passenger\ ldvs) =\\ &= \frac{\sum_{vclasses\ A\ to\ D} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER, LDVS] \times vkm\ by\ vclass[PASSENGER, LDVS]}{\sum_{vclasses\ A\ to\ D} vkm\ by\ vclass\ [PASSENGER, LDVS]}\end{aligned}$$

Personal passenger road vehicles

Vehicle classes A to D in PASSENGER service) by mode (TWO WHEELERS, THREE WHEELERS and LDVS:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (personal\ passenger\ road\ vehicles)\ by\ mode =\\ &= \frac{\sum_{vclasses\ A\ to\ D} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER] \times vkm\ by\ vclass[PASSENGER]}{\sum_{vclasses\ A\ to\ D} vkm\ by\ vclass\ [PASSENGER]}\end{aligned}$$

Public passenger transport by mode

Vehicle classes E and F in case of TWO WHEELERS, THREE WHEELERS, LDVS and VESSELS, and all vehicle classes for RAIL and LARGE ROAD:

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (public\ passenger\ transport)\ by\ mode\ (TWO\ and\ THREE\ WHEELERS, LDVS, VESSELS) =\\ &= \frac{\sum_{vclasses\ E\ and\ F} Cost\ of\ fuel\ per\ vkm\ by\ vclass[PASSENGER] \times vkm\ by\ vclass[PASSENGER]}{\sum_{vclasses\ E\ and\ F} vkm\ by\ vclass\ [PASSENGER]}\end{aligned}$$

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (public\ passenger\ transport)\ by\ mode\ (LARGE\ ROAD, RAIL) =\\ &= \frac{\sum_{vclasses} Fuel\ cost\ per\ vkm\ by\ vclass[PASSENGER] \times vkm\ by\ vclass[PASSENGER]}{\sum_{vclasses} vkm\ by\ vclass\ [PASSENGER]}\end{aligned}$$

Public passenger transport

$$\begin{aligned}&Fuel\ cost\ per\ vkm\ (public\ passenger\ transport) =\\ &= \frac{\sum_{two\&three\ wheelers, ldvs, vessels, large\ road, rail} Fuel\ cost\ per\ vkm\ (public\ transport)\ by\ mode \times vkm\ by\ mode\ (public\ transport)}{\sum_{nmt, two\&three\ wheelers, ldvs, vessels, large\ road, rail} vkm\ by\ mode\ (public\ transport)}\end{aligned}$$

where vkm on public passenger transport by mode is calculated through summing up the vkm across the vehicle classes that belong to public transport in each mode.

Cost of fuel per vkm by mode

$$Cost\ of\ fuel\ per\ vkm\ by\ mode = \frac{\sum_{vclasses} Fuel\ cost\ per\ vkm\ by\ vclass \times vkm\ by\ vclass}{\sum_{vclasses} vkm\ by\ vclass}$$

where the denominator $\sum_{vclasses} vkm\ by\ vclass$ is equal to vkm by mode.

Since the cost of fuel is one of the components that constitute the total cost of driving per vkm, all the outputs calculated in this view are collected in the view "cost of driving" where all the cost components are gathered (cost of fuel, cost of vehicle, cost of crew, and costs due to road pricing).