32.   Energy cons (historical)

Overview

Target

This view concerns exclusively calculations performed at the base year.

The main purpose is to calculate the energy consumption ($litre/vkm$) of vehicles registered in the past. The calculations take into account the difference between weighting information on energy consumption according to the number of vehicles in the stock or according to their activity (vkm).

Since the consumption of vehicles registered in the ten years prior to the base year (age subscripts from ZERO to X) is already available from the inputs entered in the ForFITS Excel file, this view focuses on registrations taking place in earlier years (i.e. for age subscripts above X).

Structure

Figure 32.1 contains the Vensim sketch of the view. Inputs on the consumption of newly registered vehicles up to ten years before the base year enter on the left. Inputs on the consumption of the vehicle stock enter from the bottom right. The calculations start on the top left and end on the top right of the view, flowing through the bottom left and bottom right parts.

Figure 32.1   Vensim sketch of the view
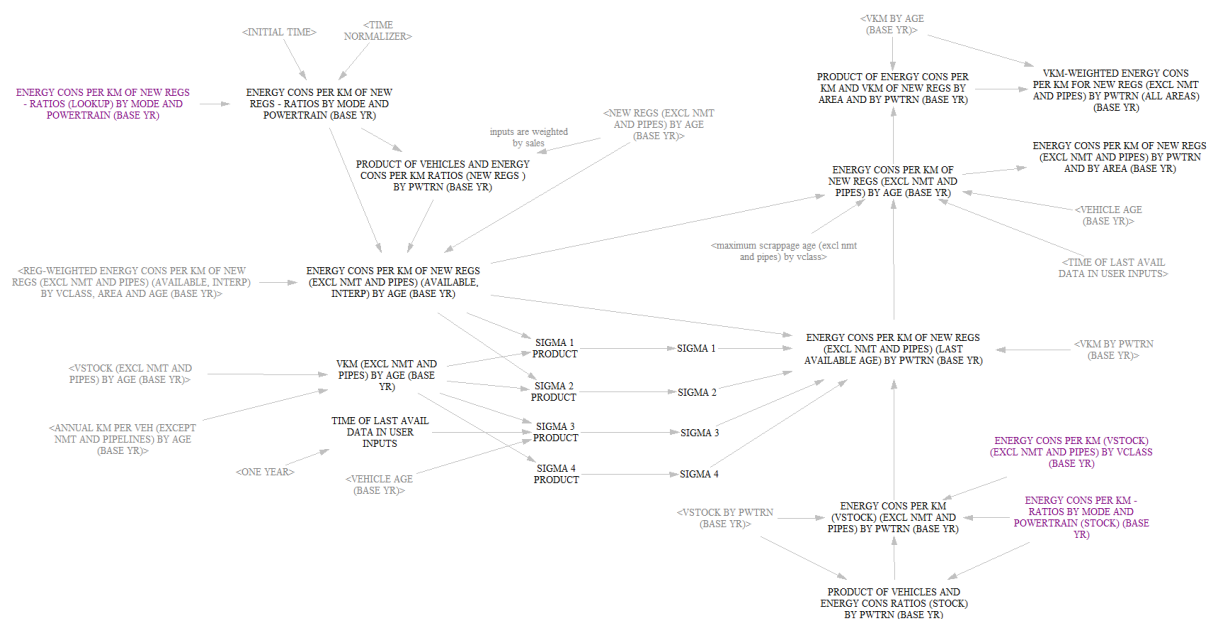
Detailed description of the view

Inputs

The purple variable on the top left of the view contains a map of the user inputs (sheet "User inputs (BASE Y)" of the ForFITS Excel file) characterizing the energy consumption of the historical vehicle registrations (at the BASE YEAR, BASE YEAR-5 and BASE YEAR-10) with respect to energy consumption ratios. This technical input contains information on the ratios between the energy

consumption per vkm of each technology and the energy consumption per vkm reference powertrain ("GASOLINE PI ICE", i.e. the gasoline positive ignition internal combustion engine). The black variable next to the lookup variable contains the same information, interpolating linearly between the values given for the years BASE YEAR, BASE YEAR-5 and BASE YEAR-10.

These ratios and the variable "REG-WEIGHTED ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) (AVAILABLE, INTERP) BY VCLASS, AREA AND AGE (BASE YR)", coming from the view "energy cons (historical, input)" and containing information on registration-weighted energy consumption values of new registrations, are used here to disaggregate by powertrain the energy consumption of each vehicle class.

The input introduced by the user is the average energy consumption ($EC\ (new\ regs)$) of each vehicle class weighted by the number of new registrations (NR) of each technology:

$$Average\ EC\ (new\ regs)\ in\ a\ vehicle\ class = \frac{\sum_{j=1}^{j=n} EC\ (new\ regs)_j \times NR_j}{\sum_{j=1}^{j=n} NR_j}$$

Expressing the average energy consumption of the powertrain technology j ($EC\ (new\ regs)_j$) with the ratios by powertrain (i.e. as $EC\ (new\ regs)_{GASOLINE} \times RATIO\ (new\ regs)_j$), the relationship above becomes:

$$Average\ EC\ (new\ regs)\ in\ a\ vehicle\ class$$
$$= \frac{\sum_{j=1}^{j=n} EC\ (new\ regs)_{GASOLINE} \times RATIO\ (new\ regs)_j \times NR_j}{\sum_{j=1}^{j=n} NR_j}$$

The energy consumption for the reference powertrain technology can be is isolated as follows:

$$EC\ (new\ regs)_{GASOLINE} = \frac{\sum_{j=1}^{j=n} NR_j \times Average\ EC\ (new\ regs)\ in\ a\ vehicle\ class}{\sum_{j=1}^{j=n} RATIO_j \times NR_j}$$

The energy consumption for other powertrain technologies is calculated as the product of the energy consumption of the reference powertrain and the ratios:

$$EC\ (new\ regs)_j = EC\ (new\ regs)_{GASOLINE} \times RATIO\ (new\ regs)_j$$

Figure 32.2 reproduces the methodology mentioned above.

Figure 32.2   Energy consumption by powertrain of new vehicle registrations at the base year
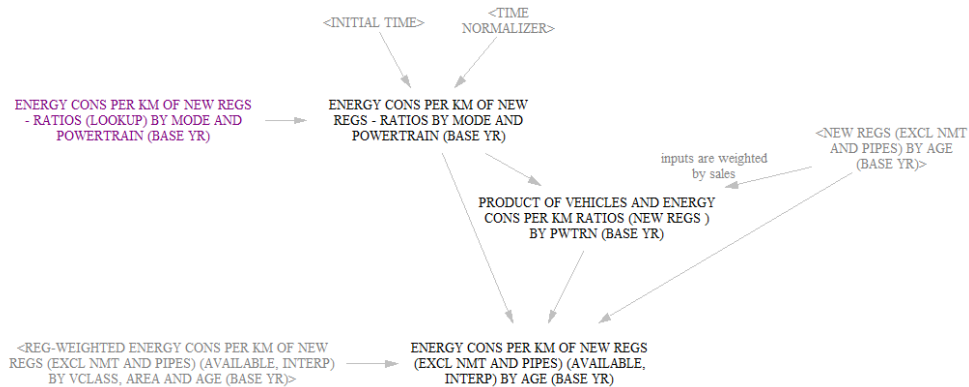
A similar calculation is performed in the bottom right part of the view to determine the energy consumption by powertrain in the vehicle stock at the base year (Figure 32.3).

Figure 32.3   Energy consumption by powertrain in the vehicle stock (total) at the base year
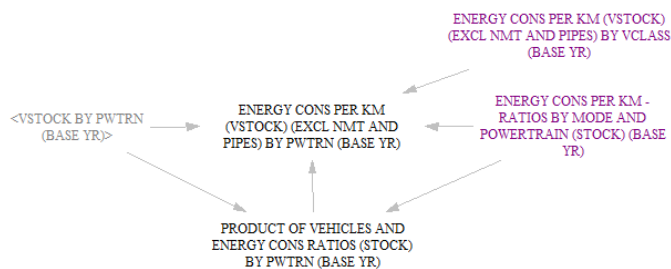
The energy consumption by vehicle class in the vehicle stock at the base year, as well as the ratios comparing the consumption of the different technologies compared to the reference powertrain technology (gasoline-powered positive ignition ICE), are user inputs ("User inputs (BASE Y)" sheet of the ForFITS Excel file). These two variables (in purple) are combined with the vehicle stock by powertrain in the base year (calculated in the view "vehicles, new registrations (historical)") to evaluate the energy consumption per km by powertrain in the vehicle stock at the base year.

The energy consumption ($EC\ (vehicle\ stock)$) by vehicle class is the result of an average, weighted by the number of vehicles in the stock (NV), taking into account the contribution of each technology in the vehicle stock:

$$Average\ EC\ (vehicle\ stock)\ for\ a\ specific\ vehicle\ class\ = \frac{\sum_{j=1}^{j=n} EC\ (vehicle\ stock)_j \times NV_j}{\sum_{j=1}^{j=n} NV_j}$$

Expressing the average energy consumption of the powertrain technology j ($EC\ (vehicle\ stock)_j$) with the ratios by powertrain (i.e. as $EC\ (vehicle\ stock)_{GASOLINE} \times RATIO\ (vehicle\ stock)_j$), the relationship above becomes:

$Average\ EC\ (vehicle\ stock)\ for\ a\ specific\ vehicle\ class$

$$= \frac{\sum_{j=1}^{j=n} EC\ (vehicle\ stock)_{GASOLINE} \times RATIO\ (vehicle\ stock)_j \times NV_j}{\sum_{j=1}^{j=n} NV_j}$$

The energy consumption per km for the reference powertrain technology can be is isolated as follows:

$EC\ (vehicle\ stock)_{GASOLINE}$

$$= \frac{\sum_{j=1}^{j=n} NV_j \times Average\ EC\ (vehicle\ stock)\ for\ a\ specific\ vehicle\ class}{\sum_{j=1}^{j=n} RATIO\ (vehicle\ stock)_j \times NV_j}$$

The energy consumption for the other powertrain technologies are then calculated:

$$EC\ (vehicle\ stock)_j = EC\ (vehicle\ stock)_{GASOLINE} \times RATIO\ (vehicle\ stock)_j$$

Other endogenous inputs used in this view are related to vehicle activity (vkm) by powertrain and by age.

Outputs

The energy consumption per km within the age range X to XXV is assumed to follow a linear pattern. For vehicles older than 25 years (subscript XXV), the consumption is assumed to remain the same as in the case of 25 years old vehicles. This is the value in the last age subscript, EC^*.

The energy consumption by powertrain in the vehicle stock (VS) at the base year (BY) is the average, weighted by vkm, of the energy consumption of vehicles in the stock across all ages:

$$EC\ per\ km\ in\ a\ powertrain\ in\ the\ VS\ (BY) = \frac{\sum_{age\ subscripts} EC\ per\ km_i * vkm_i}{\sum_{age\ subscripts} vkm_i}$$

Splitting the sum in different age ranges and taking into account that the denominator equals the total vkm in the powertrain, it is possible to re-write the equation above as follows:

$EC\ per\ km\ in\ a\ powertrain\ in\ the\ VS\ (BY) =$

$$= \frac{1}{vkm} \times \left(\sum_{i=0}^{IX} EC\ per\ km_i * vkm_i + \sum_{i=X}^{XXIV} EC\ per\ km_i * vkm_i + \sum_{i=XXV}^{t_{max}} EC\ per\ km_i * vkm_i \right)$$

Applying the assumptions mentioned above:

$EC\ per\ km\ in\ a\ powertrain\ in\ the\ VS\ (BY) =$

$$= \frac{1}{vkm} \times \left(\sum_{i=0}^{IX} EC_i * vkm_i + \sum_{i=X}^{XXIV} \left(EC_X + \frac{EC^* - EC_X}{XXV - X} \times (i - X) \right) \times vkm_i + EC^* \times \sum_{i=XXV}^{t_{max}} vkm_i \right)$$

Finally the value EC^* can be isolated as follows:

$$EC^* = \frac{EC\ in\ a\ powertrain\ in\ the\ VS\ (BY) \times vkm - SIGMA\ 1 - SIGMA\ 2 + EC_X \times SIGMA\ 3}{SIGMA\ 3 + SIGMA\ 4}$$

where:

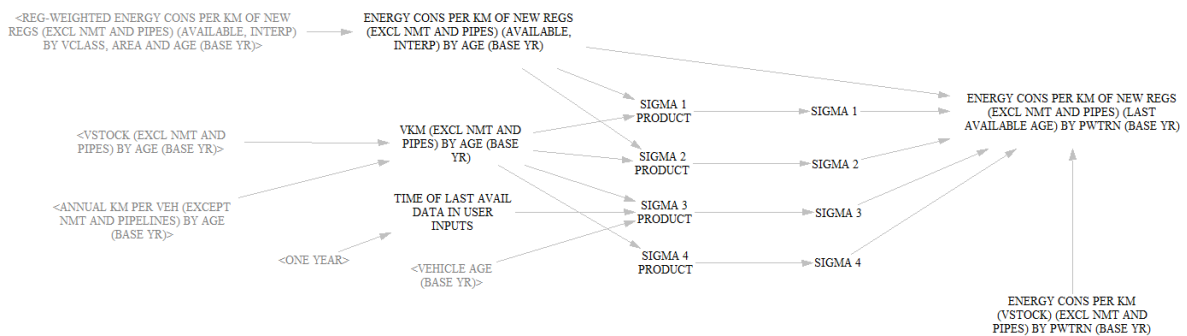$$SIGMA\ 1 = \sum_{i=0}^{IX} EC_i * vkm_i$$

$$SIGMA\ 2 = \sum_{i=X}^{XXIX} EC_X \times vkm_i$$

$$SIGMA\ 3 = \sum_{i=X}^{XXIX} \frac{(i - X)}{XXX - X} \times vkm_i$$

$$SIGMA\ 4 = \sum_{i=XXX}^{t_{max}} vkm_i$$

The calculations mentioned above are located in the centre of the view (Figure 32.4).

Figure 32.4   Energy consumption by powertrain in the vehicle stock (vehicles in each age) at the base year
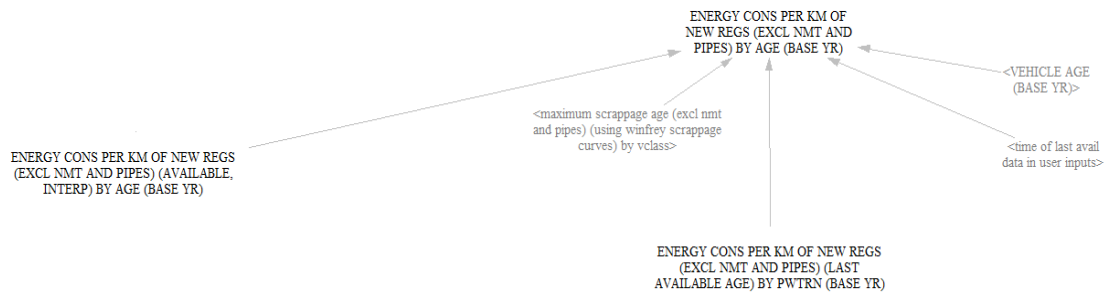

Knowing the EC^* value (variable "ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) (LAST AVAILABLE AGE) BY PWTRN (BASE YR)"), it is possible to evaluate the variable "ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY AGE (BASE YR)":

- age subscripts from ZERO to X are data available from the ForFITS Excel file;
- between age X and the maximum scrappage age, the energy consumption per km is assumed to be linear (between the values of the energy consumption at the subscript X and EC^*);
- if the maximum scrappage age is over XXV, the value of the energy consumption of vehicles older than 25 years is assumed to remain constant and equal to EC^*. The EC^* value is only stored for the age subscript XXV.

The variable "ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY AGE (BASE YR)", associated to the historical vehicle registrations, contains the energy consumption per km by service, mode, area, vehicle class, powertrain and by age (ZERO to XXV) (Figure 32.5).

ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY AGE (BASE YR)

<VEHICLE AGE (BASE YR)>

ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) (AVAILABLE, INTERP) BY AGE (BASE YR)

<maximum scrappage age (excl nmt and pipes) (using winfrey scrappage curves) by vclass>

<time of last avail data in user inputs>

ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) (LAST AVAILABLE AGE) BY PWTRN (BASE YR)

The top right section of this view contains the calculation of inputs in the view "energy cons (ratio by area)". This concerns the average value of the energy consumption across different areas and refers exclusively to newly registered vehicles (age ZERO) at the base year.

The average value of the energy consumption across different areas is calculated weighting by vkm in each area subscript:

$$EC \ per \ km \ of \ age \ ZERO \ vehicles \ (BY) = \frac{\sum_{areas} EC \ per \ km \ of \ age \ ZERO \ vehicles_i * vkm_i}{\sum_{areas} vkm_i}$$

The variable "VKM-WEIGHTED ENERGY CONS PER KM FOR NEW REGS (EXCL NMT AND PIPES) BY PWTRN (ALL AREAS) (BASE YR)" contains the energy consumption per km of vehicles sold at the base year without the subscript area.

The variable "ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY PWTRN AND BY AREA (BASE YR)" is an extraction at age ZERO from "ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY AGE (BASE YR)" and contains the energy consumption per km of the same vehicles, this time defined by area.

Both variables on the right are necessary as inputs in the view "energy cons (ratio by area)" (Figure 32.6).

<VKM BY AGE (BASE YR)>

PRODUCT OF ENERGY CONS PER KM AND VKM OF NEW REGS BY AREA AND BY PWTRN (BASE YR)

VKM-WEIGHTED ENERGY CONS PER KM FOR NEW REGS (EXCL NMT AND PIPES) BY PWTRN (ALL AREAS) (BASE YR)

ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY PWTRN AND BY AREA (BASE YR)

ENERGY CONS PER KM OF NEW REGS (EXCL NMT AND PIPES) BY AGE (BASE YR)