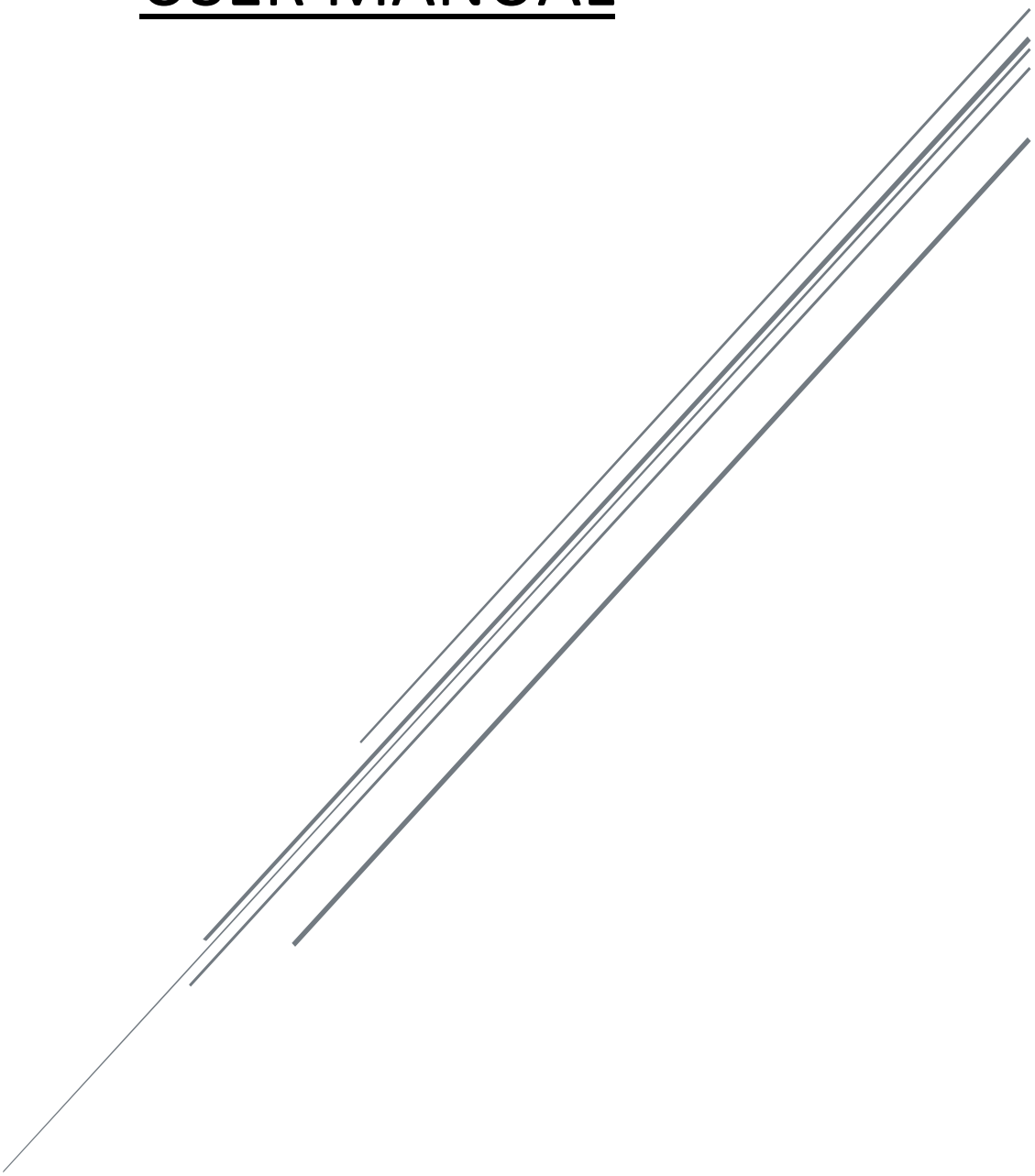
TRANSPORTATION MODEL LIBRARY USER MANUAL



II. Table of Contents

1. INTRODUCTION

This package has been developed to Simulate Different Transportation Models Scenarios for electrification of the vehicle fleet for the reduction of Carbon Foot Print. This package is model of physical Road Transportation which consists of Four kind of vehicles (such as Cars, Light Trucks, Heavy Trucks and Buses) and sub categorized as Petrol Vehicles, Diesel Vehicles, PHeV Vehicles, Biogas Vehicles and Electric Vehicles.

The sub-packages of this model contain the components and sub-components required for small to large scenario simulations. This version facilitates the annual simulation of scenarios and hence the complexity of the component models' equations is kept moderate.

1.1 OBJECTIVE

The Transportation model should be developed to estimate the Swedish CO2 emissions from 2019 to 2035, in a back-casting scenario where fossil-driven transport is gradually abolished and replaced by emission-free transports such as electric cars, electric buses, electric Truck etc. The model is developed in Modelica, the Modelica system dynamics library (within the OpenModelica installer) is used

2. TRANSPORTATION MODEL STRUCTURE

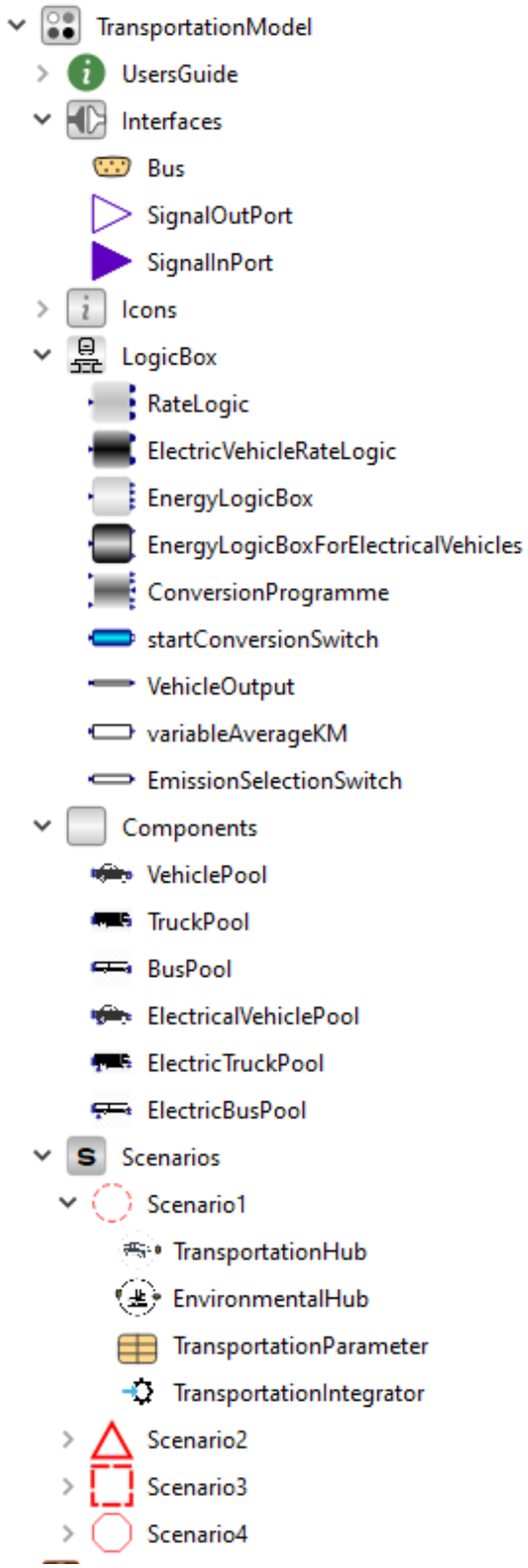


Figure 1: shows the sub-packages contained in the TRANSPORTATION MODEL.

User Guide: A brief guide to the package is provided under the documentation section of this package.

Interfaces: The following connectors are available under this package for transfer of information between models.

-

Signal Out Port: Used for Output signal
- 

Signal In Port: Used for Input signal
- 

Expandable Connector: Expandable Connector use to connect any number of inputs and outputs by specifying the “Tag name” and can be used consistently throughout the model.

Icons: The icons representing the models, packages and connectors are stored in this package for easy replaceability.

Logic Box: This package contains nine classes for performing logic operation for Rates Model, Energy Model, Conversions of Vehicles, Logical Switches etc.

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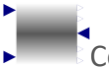
Rate Logic
- 
Energy Logic Box
- 
Conversion Programme
- 

Vehicle Output
- 
Emission Selection Switch
- 
Electric Vehicle Rate Logic
- 
Energy Logic Box for Electric Vehicle.
- 
Start Conversion Switch
- 

Variable Average KM

Components: The following models are available as different vehicles Component (like Cars, Trucks and bus) for Modeling of Transportation Model. These structures to the system provided a vehicle type for the system performance.

-  Vehicle Pool
-  Truck Pool
-  Bus Pool
-  Electrical Vehicle Pool
-  Electrical Truck Pool
-  Electric Bus Pool

Scenarios: It is a model which have four scenarios of Transportation Model i.e., Scenario 1, Scenario 2, Scenario 3 and Scenario 4. Under each Scenario, there are Four modules i.e., Transportation Hub, Environmental Hub, Transportation Parameter and Transportation Integrator. All the data is coming from the resource folder under the transportation model that consist of the Combi-tables. If user get new data for this package, combi-table must be changed with new data.

-  **Transportation Hub**
-  **Environmental Hub**
-  **Transportation Parameter**
-  **Transportation Integrator**

Scenario Description:

Scenario 1: This example comprises of a scenario Where no ban on any fuel is implemented i.e., vehicle growth rate is high and depletion rate is low.

Scenario 2: This example comprises of a scenario Where ban on fuels is implemented as per legislation plan i.e., vehicle growth rate and depletion rate are decided by government

Scenario 3: This example comprises of a scenario Where ban on fuels is implemented as per legislation plan and people are encouraged to use public transport and Society takes initiatives to reduce the traffic volume with cars and stimulate bikes/walking and the use of public transport.

Scenario 4: This example comprises of a scenario Where ban on fuels is implemented as per legislation plan and people are encouraged to use public transport and convert their fossil vehicle to electric vehicle.

3. DISCRIPTION OF MODELING COMPONENTS:

3.1 LOGIC BOX

3.1.1 Rate Logic: Rate logic defines the growth rate and depletion rate of the vehicle before and after ban of fossil fuel. It consists of combi-tables for growth rate and depletion rate and a logical switch that take an action when triggers (i.e., when user enters the fossil ban year) and send data of fossil growth vehicle to electrical vehicle. It has a facility to switch between two different Growth rate and Depletion rates as per user requirement.

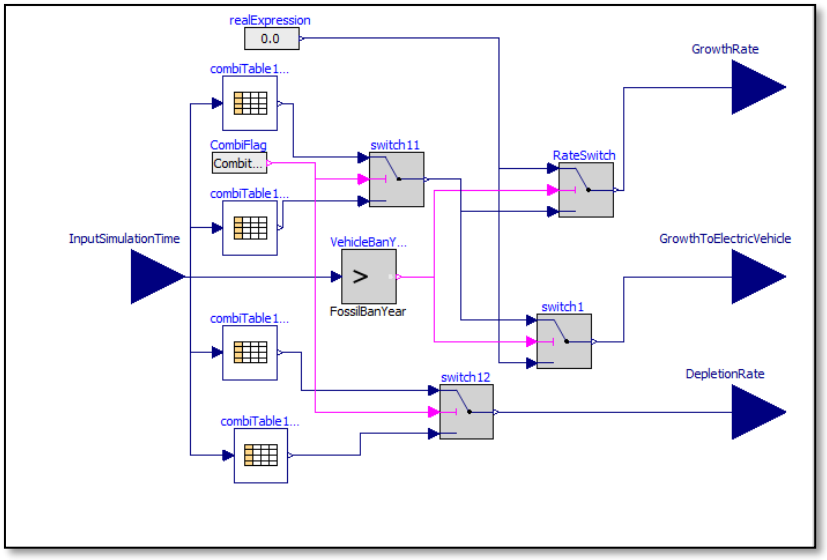


Figure 2: shows the Rate Logic diagram view in the Logic Box package of TRANSPORTATION MODEL.

3.1.2 Electric Vehicle Rate Logic: This logic box operates for electric vehicles in the model. Similar to the Rate Logic, it has its combi-table for growth rate and depletion rate.

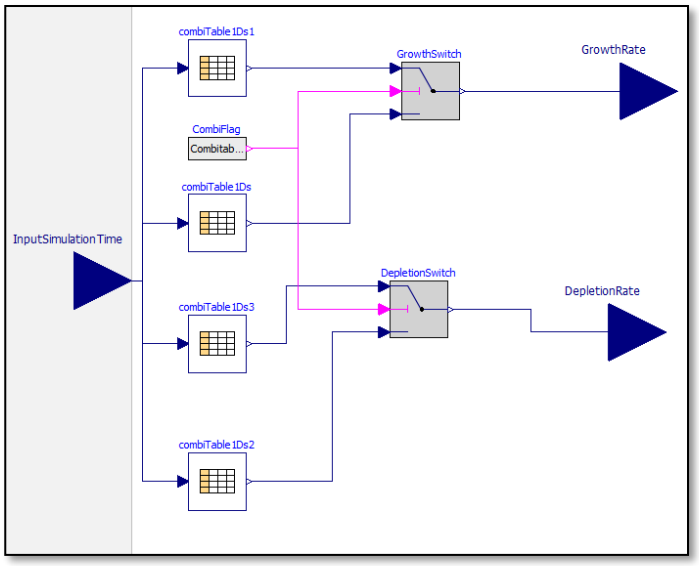


Figure 3: shows the Electric Vehicle Rate Logic diagram view in the Logic Box package of TRANSPORTATION MODEL.

3.1.3 Energy Logic Box: The energy Logic Box model is developed for the calculation of CO2 emission for the diferent kind of Vehicles. The combustion equation is derived from the energy consumed by each vehicle Green house gas emission per Kilo watt hour. The formula is stated below:

- Energyused KWh/yr = (kwh/km) * (efficient Factor) * Fuel Composition (as per energy) * average milage /car(km) * Number of cars (Starting of the year + new registration- scraped)
- Emissions = (Energy use KWh/yr) * (GHG Emissions(grammes/kWh))

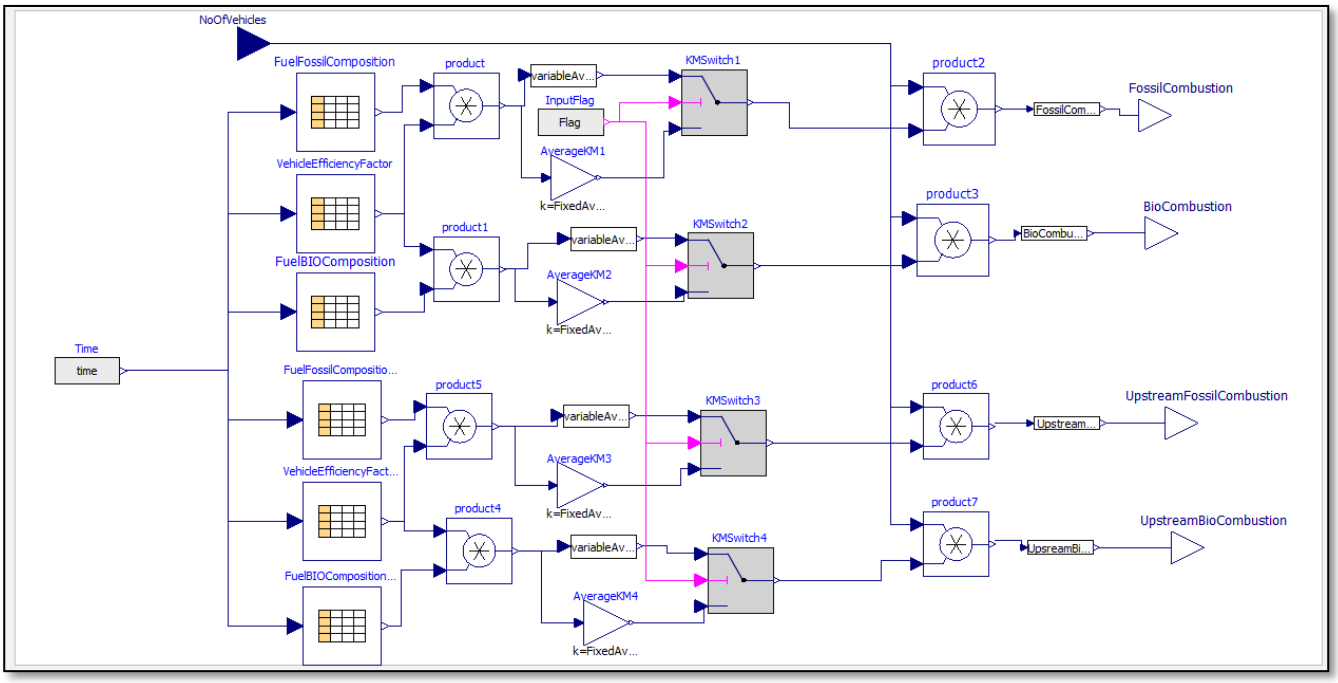


Figure 4: shows the Electric Vehicle Energy Logic diagram view in the Logic Box package of TRANSPORTATION MODEL.

- The above diagram calculates the Fossil and Bio fuel combustion and there respective upstream CO2 emissions.
- Efficient factor and fuel composition comes from combi table are multiplied and the product is multiplied with average KM vehicle. The final vale is multiplied by the total number of vehicles in end of the year.

3.1.4 Energy Logic Box for Electrical Vehicles: This energy Logic Box model is developed for the calculation of CO2 emission for the electric Vehicles. The combustion equation is derived from the energy consumed by each vehicle Green house gas emission per Kilo watt hour. The formula is stated below:

- Energyused KWh/yr = (kwh/km) * (efficient Factor) * Fuel Composition (as per energy) * average milage /car(km) * Number of cars (Starting of the year + new registration- scraped)
- Emissions = (Energy use KWh/yr) * (GHG Emissions(grammes/kWh))

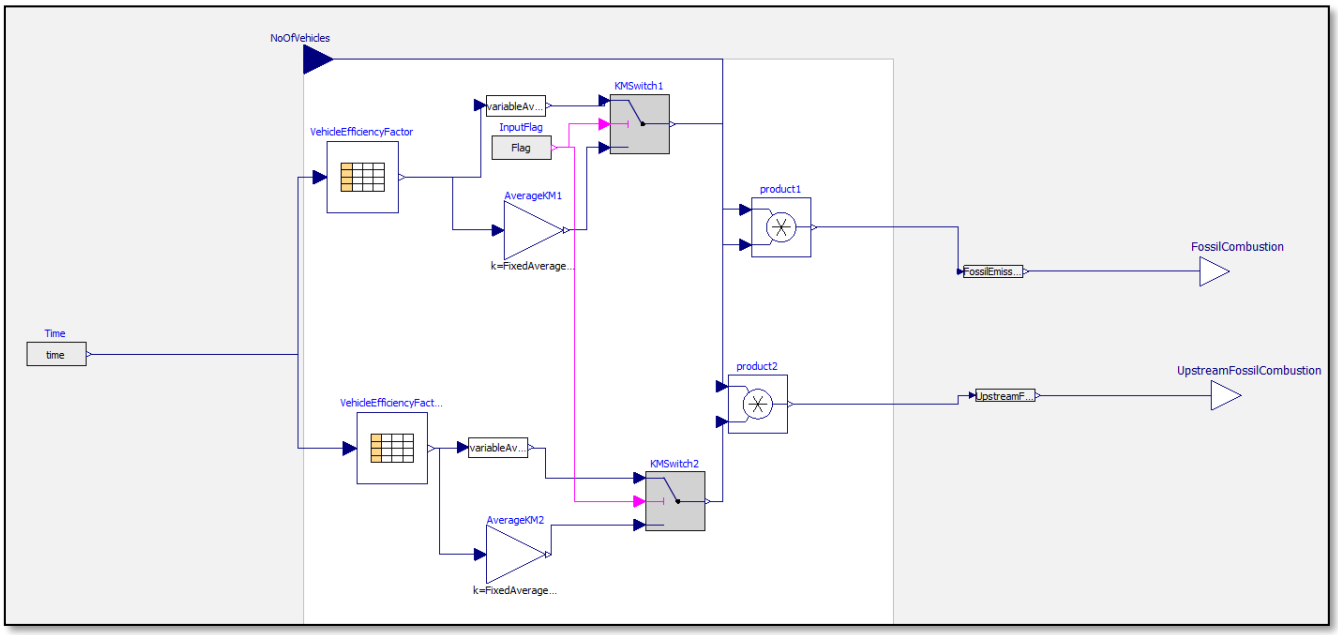


Figure 5: shows the Electric Vehicle Energy Logic diagram view in the Logic Box package of TRANSPORTATION MODEL.

- The above diagram represents the CO2 emission from the electrical vehicles. Since there is no fossil emission from the electric vehicles, so only upstream combustion values are noted.

3.1.5 Conversion Programme: This Numerical logical switch class is used for the conversion of fossil vehicles to electrical vehicles. It contains the input ports like vehicle input port which takes the Number of vehicles at that time instant Growth Rate and Depletion Rate and output port for vehicle growth rate, vehicle Depletion rate and growth rate and depletion rate send to electricle vehicle and if the Conversion Switch in transportation model is true the fossil vehicles will start converted to electrical vehicle.

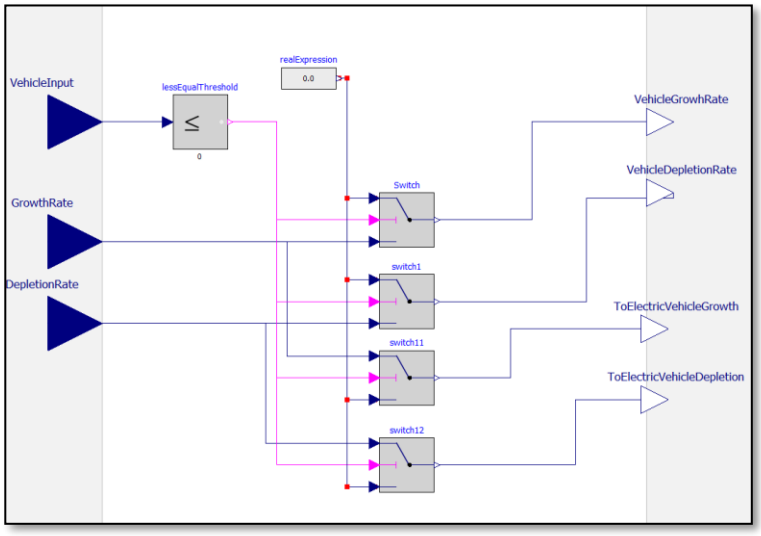


Figure 6: shows the Conversion Program diagram view in the Logic Box package of TRANSPORTATION MODEL.

3.1.6 Start Conversion Switch: It's a simple ON-OFF switch used to active and deactivate the conversion programme.

3.1.7 Vehicle Output: This class ensures that the Number of Output vehicles should never go below zero (Number of vehicles should remain either positive or zero).

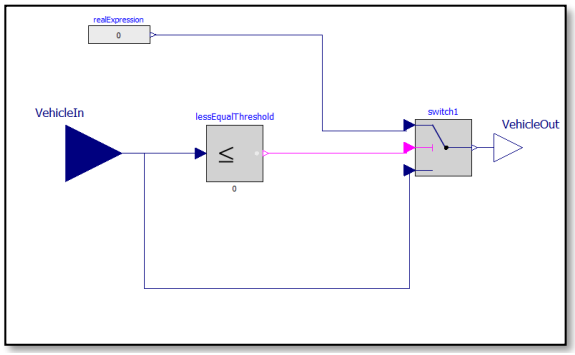


Figure 7: shows the Vehicle Output diagram view in the Logic Box package of TRANSPORTATION MODEL.

3.1.8 Variable Average KM: This class is called when user need to change the average km with respect to time with a fixed percentage.

3.2 COMPONENETS:

3.2.1 Vehicle Pool:

The vehicles pool model is designed using the “level” (general continuous Level model of the System Dynamics methodology with a single inflow and a single outflow. It computes the level by integrating over the difference between inflow and outflow rates). The objective is to maintain the certain level of vehicle. The growth Rate and depletion rates are supplied from Rate logic model to InDepletionRate and InGrowthRate port. The TotalVehicle port is used to maintain constant number of vehicles in the overall car pool. VehicleNos port gives the number of vehicles in the Vehicle level. ToEV port send the converted Fossil Vehicle to Electric Vehicles. The conversion switch initiates the conversion process.

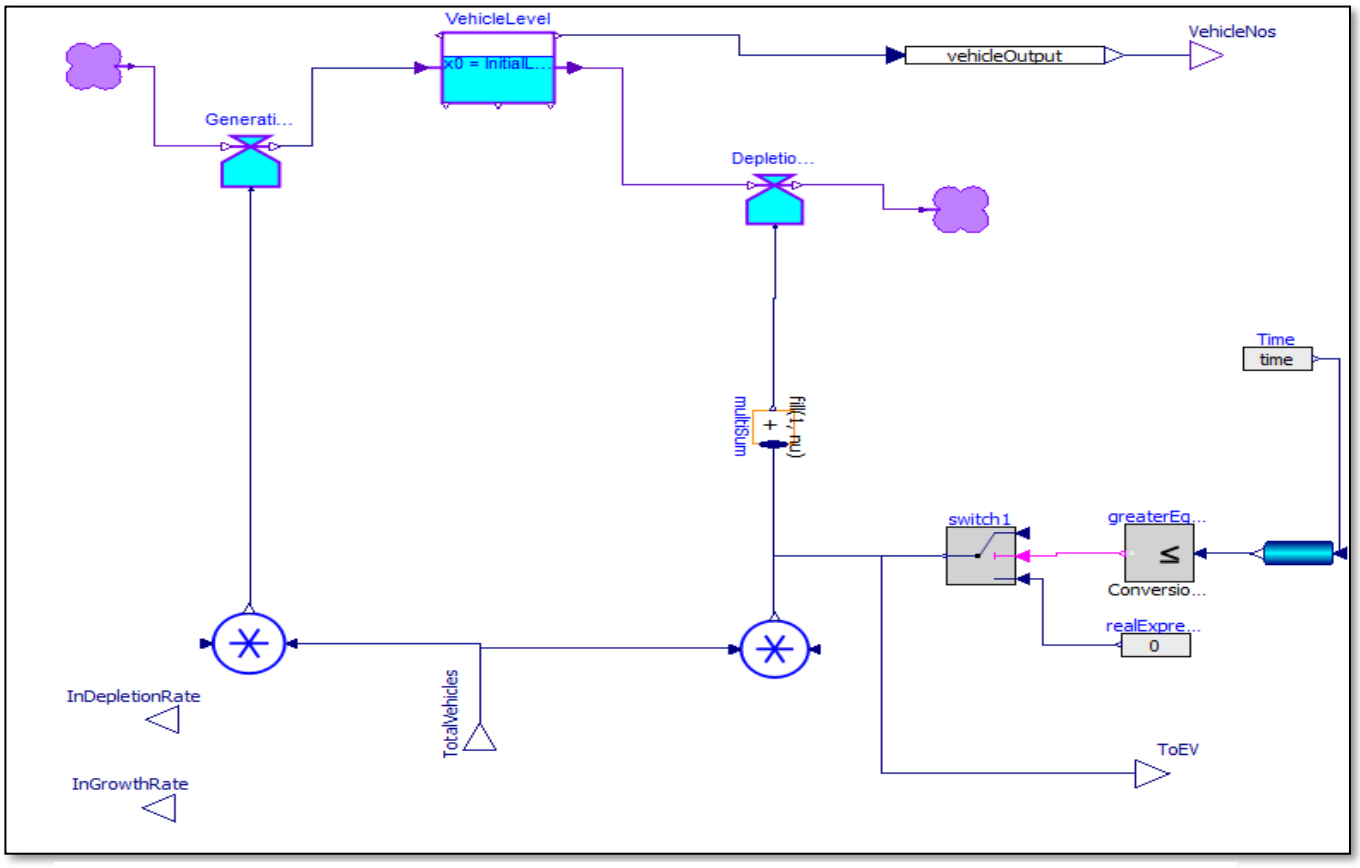


Figure 8: shows the Vehicles Pool Diagram view in the Components package of TRANSPORTATION MODEL.

- **Total Number of Vehicles in the pool:**

Vehicle Nos = Growth Rate of Vehicle – Depletion Rate of Vehicles

Depletion Rate = Depletion rate of its own vehicle + Depletion due to conversion.

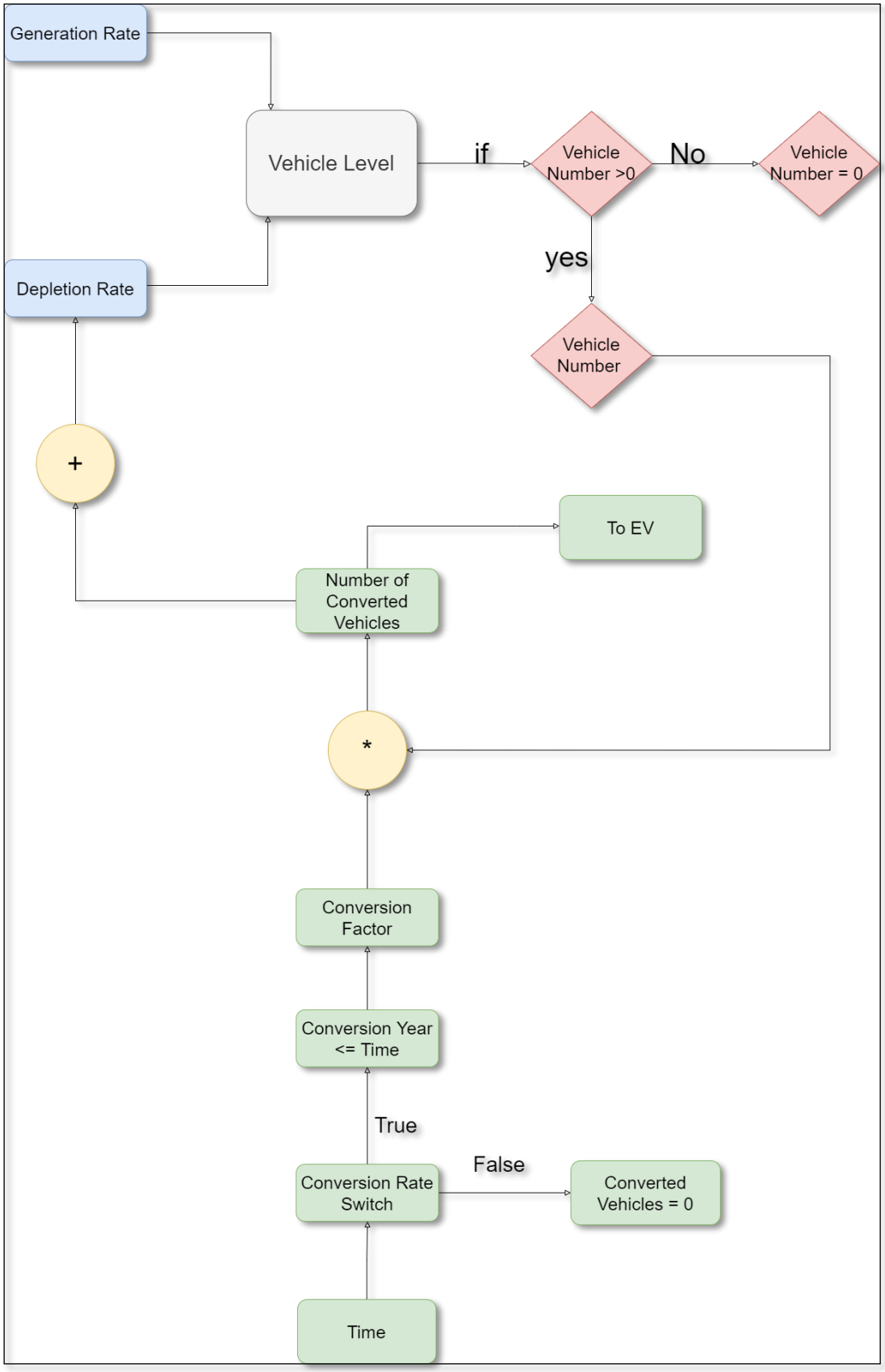


Figure 9: shows the Vehicles Pool Logic Schematics.

3.2.2 Electric Vehicle Pool:

Similar to vehicles pool, Electrical Vehicle pool is designed. With same components used from System Dynamics Library. The ports IndepletionRate, InGrowthRate, Total vehicles and vehicleNos port do the same job as vehicle pool but for the electrical data. FromfossilVehicle port takes the converted fossil vehicle and add it up to the electrical vehicle growth rate.

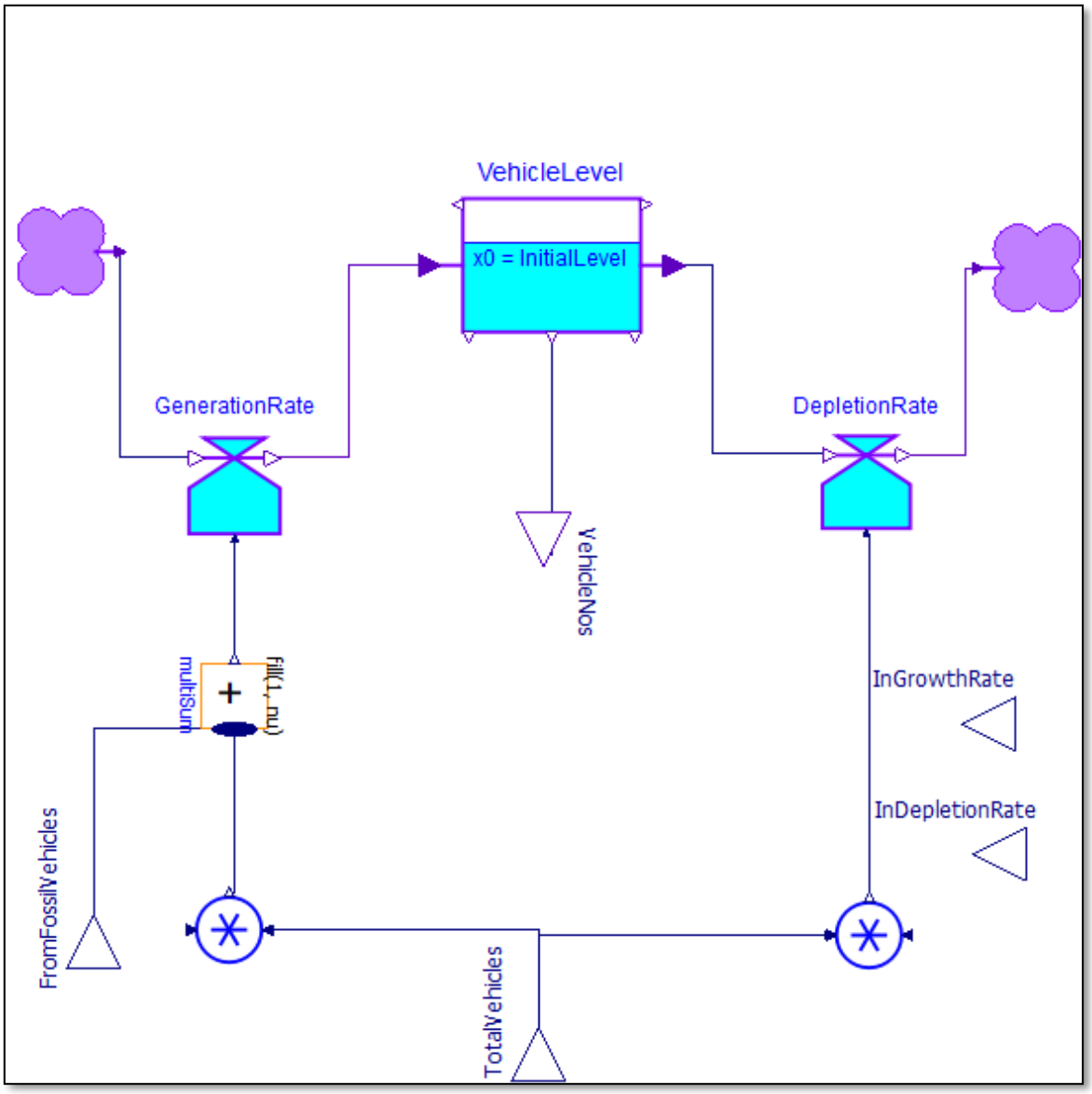


Figure 10: shows the Electric Vehicles Pool Diagram view in the Components package of TRANSPORTATION MODEL.

Formula For Calculating the number of vehicles:

Vehicle Nos = Growth Rate of Vehicles – Depletion Rates of Vehicles

Growth Rate of Vehicle = Growth Rate of the vehicle + Growth Rate for converted Vehicles

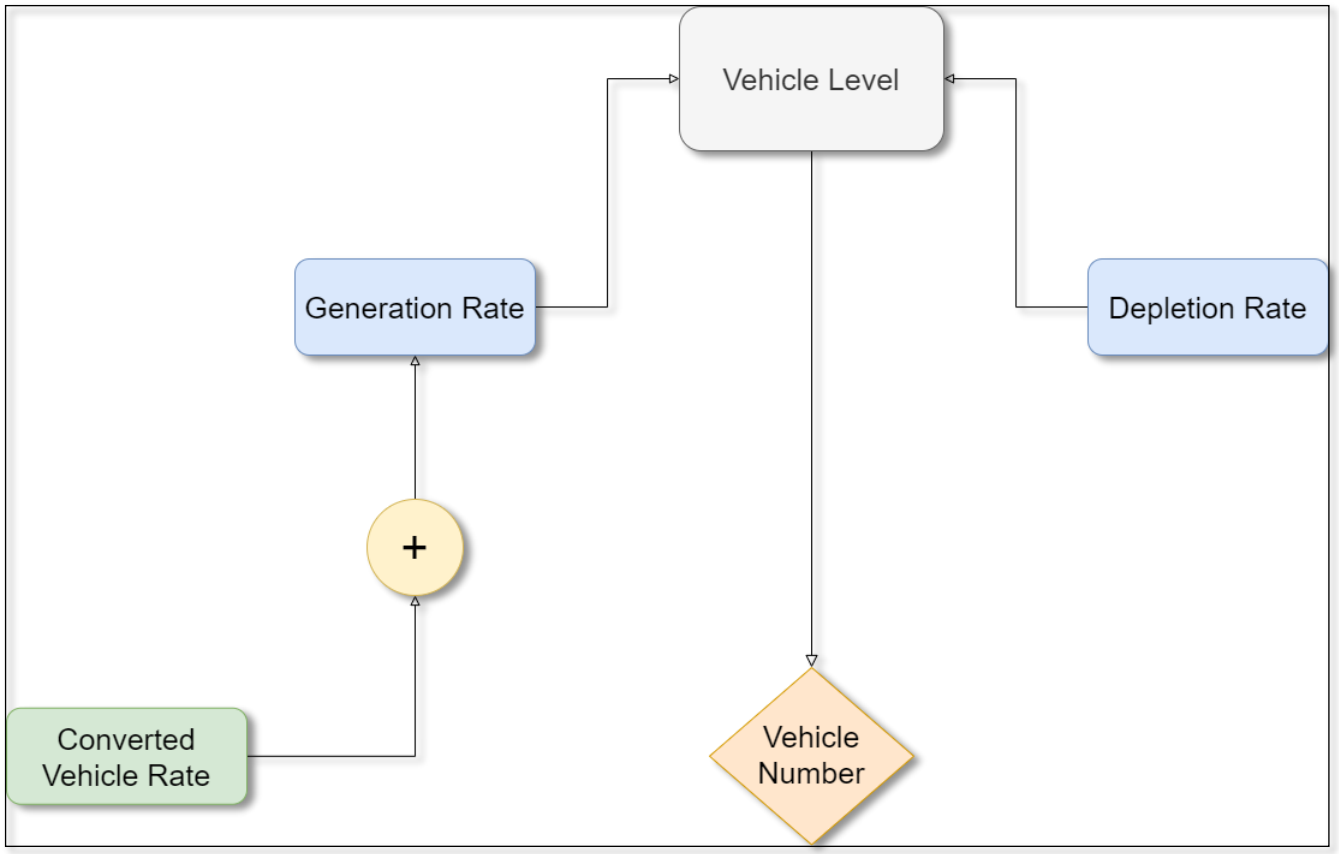


Figure 11: shows the Electrical Vehicles Pool Logic

3.2.3 Truck Pool: Same as Vehicles Pool

3.2.4 Electrical Truck Pool: Same as Electric Vehicles Pool

3.2.5 Bus Pool: Same as Bus Pool

3.2.6 Electric Bus Pool: Same as Electric Vehicle Pool

3.3 SCENARIOS:

3.3.1 Transportation Hub: Transportation Hub consist of all kind of vehicles with their growth rate, depletion rate and conversion model to calculate the number of vehicles in the end of the simulation. The total of individual vehicle is added and send to the vehicles pool to maintain the total number of Vehicle Constant (For ex. If petrol vehicles are ban after 2025, to the growth rate of petrol vehicles will be added to the growth rate of electric Vehicles. That gives the total number of vehicles as a constant number). The vehicle Tag list is sent to Vehicle Port Bus (an expandable Connector) which supply the data to Environment Hub through same tag list

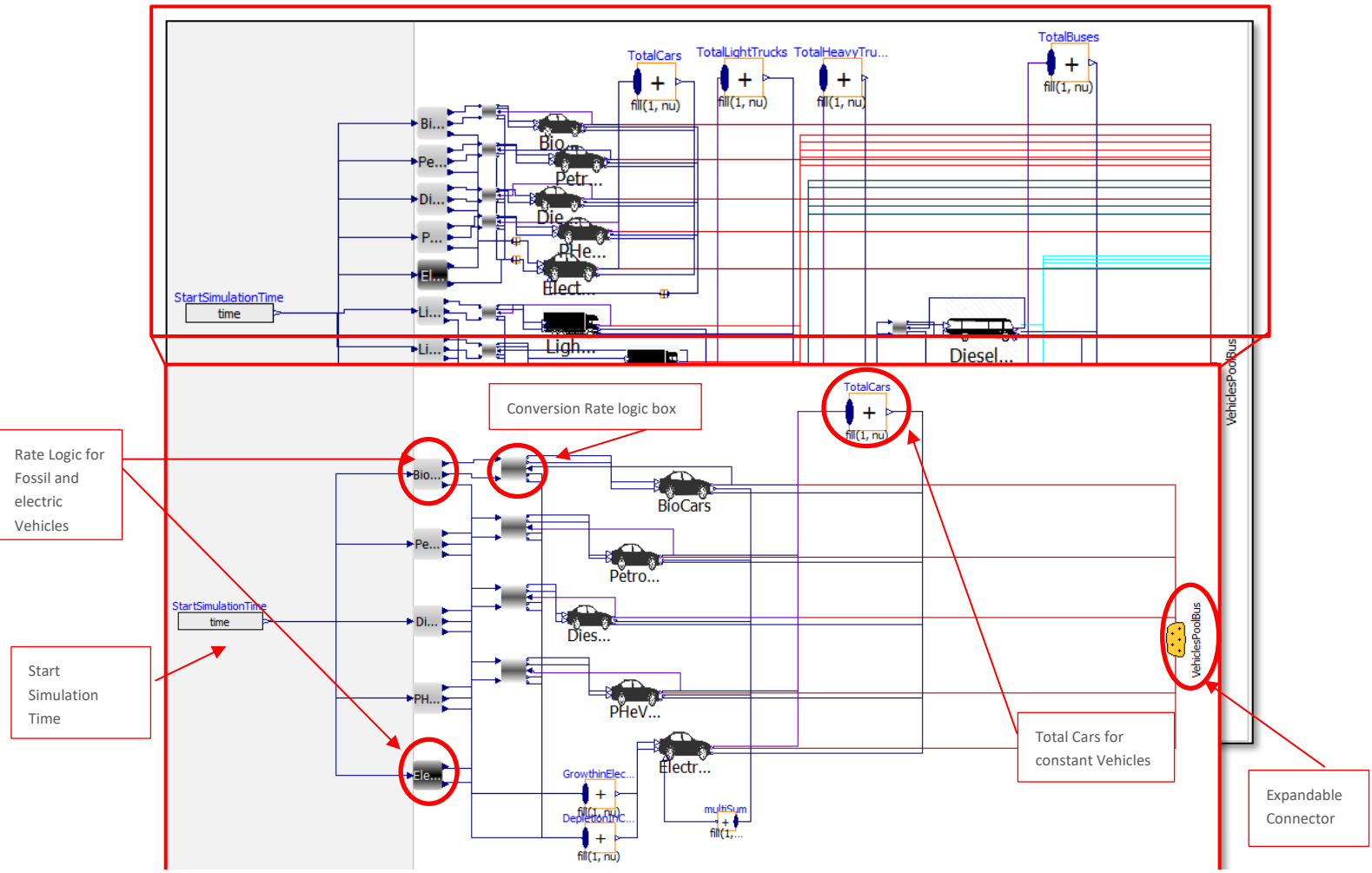
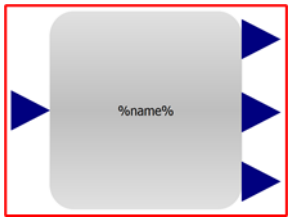
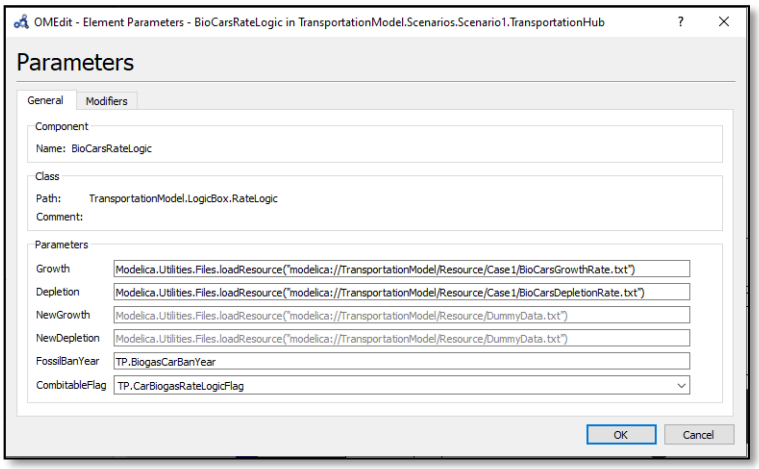
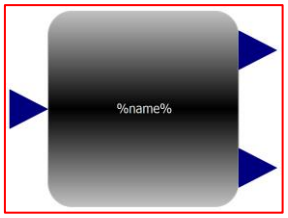


Figure 12: shows the Transportation Hub Diagram view in the Scenarios package of TRANSPORTATION MODEL.

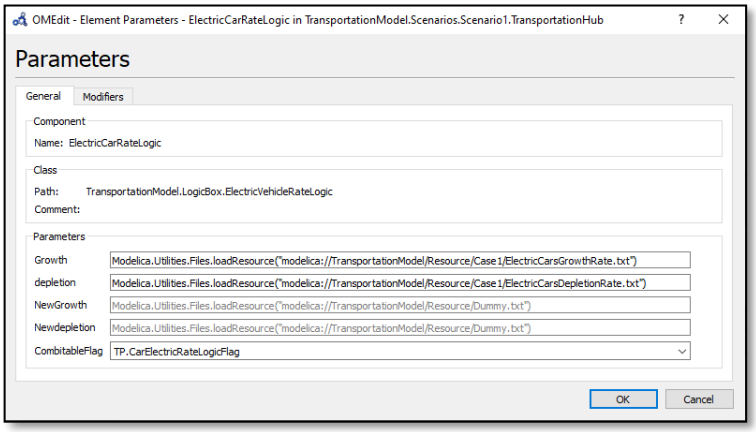


- Growth and Depletion - Combi-table for Growth Rate and Depletion rate for Vehicles
- Fossil Ban Year parameter – To change the Ban year of Fossil fuel
- Combi-table Flag – if True, Changes to new Growth rate and Depletion rate.

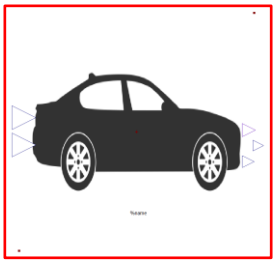




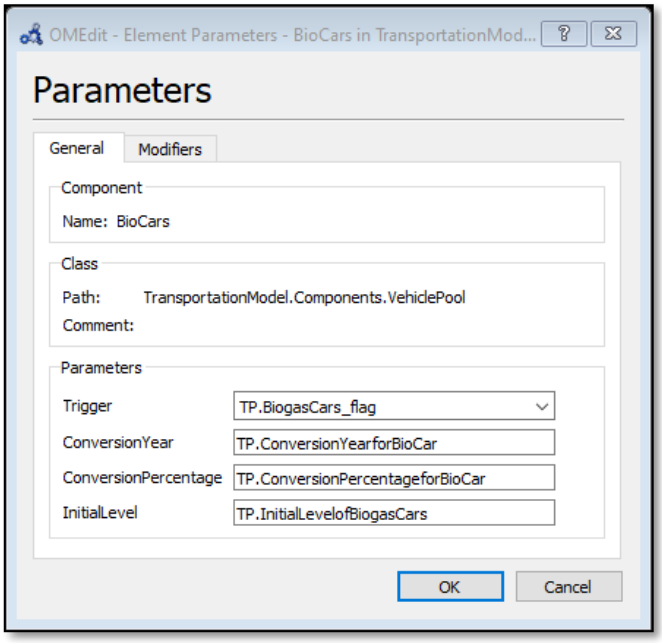
- Growth and Depletion - Combi-table for Growth Rate and Depletion rate for Vehicles
- Combi-table Flag – if True, Changes to new Growth rate and Depletion rate



- All the parameters in the transportation model are linked with Transportation Parameter Model (A record file) with inner and outer keywords and the combi-tables are kept in Resource folder in the package and called in the model using **Modelica.Utilities.Files.loadResources**
- All the parameter and Combi-tables are modified as per the scenario requirement.



- Trigger: This Boolean parameter triggers the Conversion Model.
- Conversion Year: Year when conversion of fossil vehicles to electrical vehicles starts.
- Conversion Percentage: The percentage of vehicles converted to Electrical vehicles.
- Initial level: Initial number of Vehicles in the



3.3.3 Environmental Hub: Environmental Hub consist of all kind of energy model for emissions and the total number of Vehicles (including all types of vehicles). The emissions calculation is done for each kind of vehicle and its emission type (Like fossil, biocomponent and upstream of respective fuel component). The emission calculation is only done for CO2 (in MTon/Year). The Total Number of Vehicles calculation is obtained from Transportation Hub Port (an Expandable Connector) containing a Tag List of all the vehicles. The whole set of data is sent to Display Hub Port for the

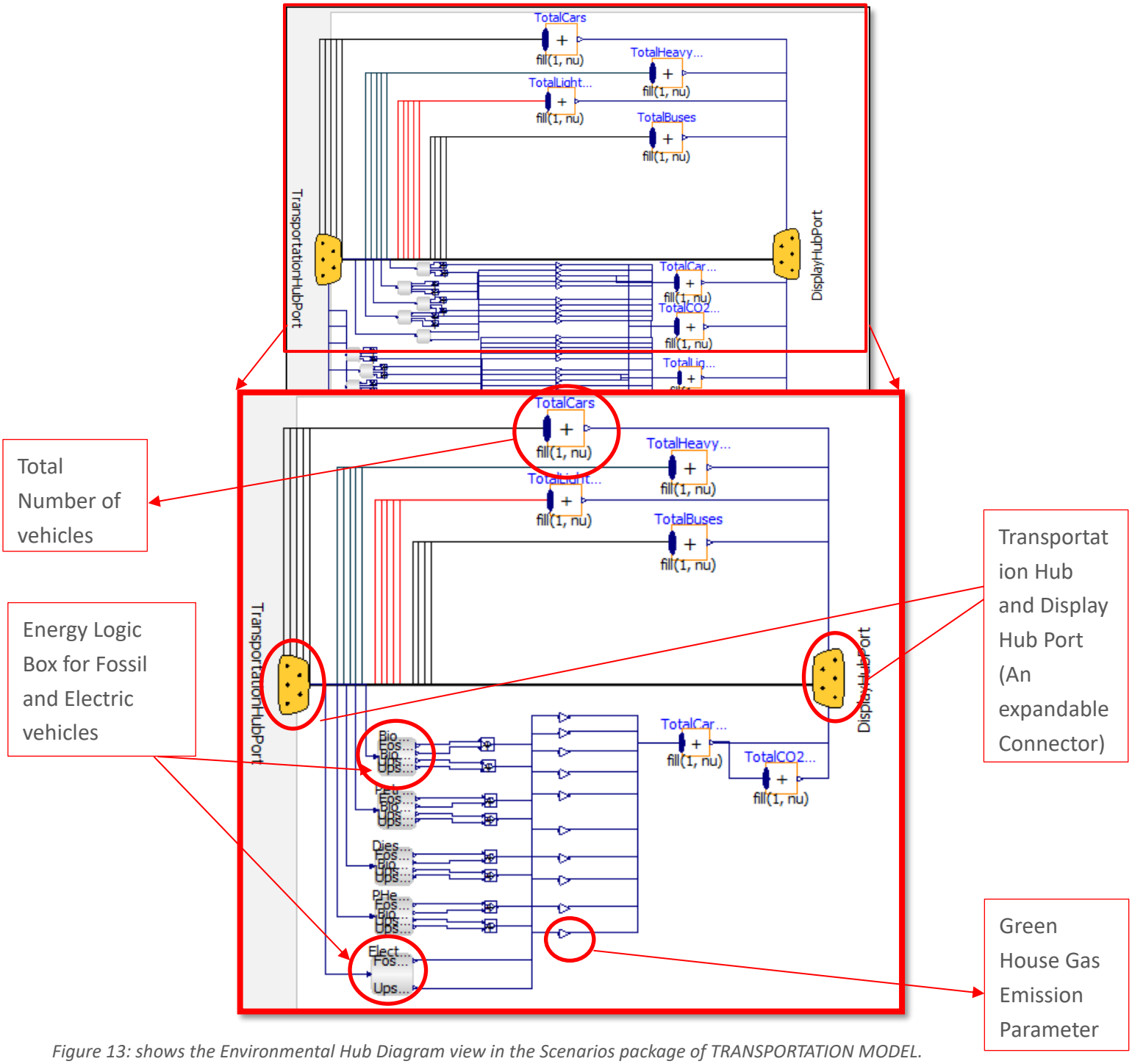
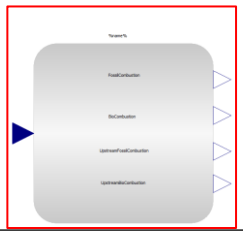
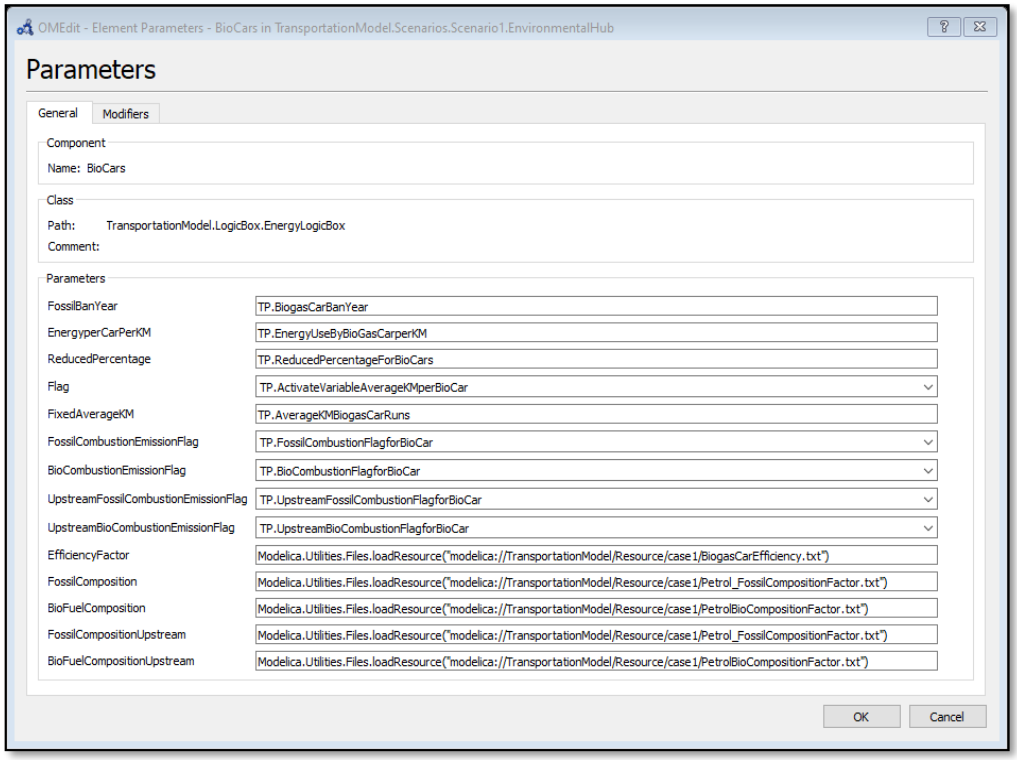
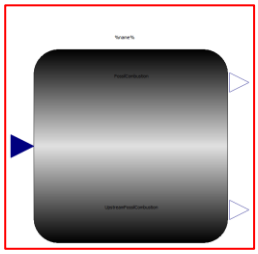


Figure 13: shows the Environmental Hub Diagram view in the Scenarios package of TRANSPORTATION MODEL.

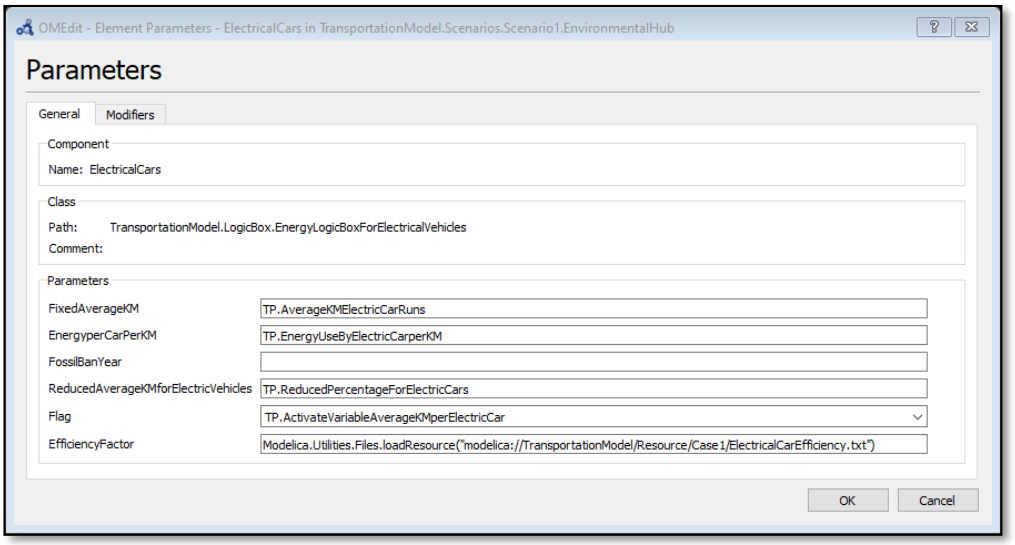


- Energy per Car per KM: Parameter to change energy use per KM for each car in kWh/km
- Reduced Percentage: Parameter to give reduction percentage in average KM.
- Flag: Boolean to active the Variable average KM model.
- Fixed Average KM: Average KM for each vehicle.
- Fossil Combustion Emission Flag: To enable the fossil Combustion of Energy Model.
- Bio Combustion Emission Flag: To enable the Bio combustion Component of Energy Model.
- Upstream Fossil Combustion Emission Flag: To enable Upstream fossil Combustion of Energy Model.
- Upstream Bio Combustion Emission Flag: To enable Upstream fossil Combustion of Energy Model.
- Efficiency Factor: Combi-table for Efficiency Factor for Each Vehicle.
- Fossil Composition: Combi-table for Fossil Composition for Each Vehicle.
- Biofuel Composition: Combi-table for Bio Fuel





- Fixed Average KM: Average KM for a Electric vehicle.
- Energy per Car per KM: Parameter to change energy use per KM for each car in kWh/km.
- Reduced Average KM for Electric Vehicles: Constant reduction of Average KM of a vehicle
- Flag: Boolean to active the Variable average KM model.
- Efficiency Factor: Combi-table for Efficiency Factor for Each Vehicle



3.3.4 Transportation Parameter: All the parameters present in the model are located in one record file name Transportation Parameter. These parameters are called in the Transportation Hub Model and Environmental Hub Model and are linked using inner and outer of a class. Use needs to change the parameter in the record file only and the changes will reflect in all Models.

3.3.5 Transportation Integrator: The transportation integrator connects the Environmental Hub to Transportation Hub and simulates the data from 2019 to 2035 with sample size of one year. The simulation is encoded with the start of 2019 and stop time of 2035.

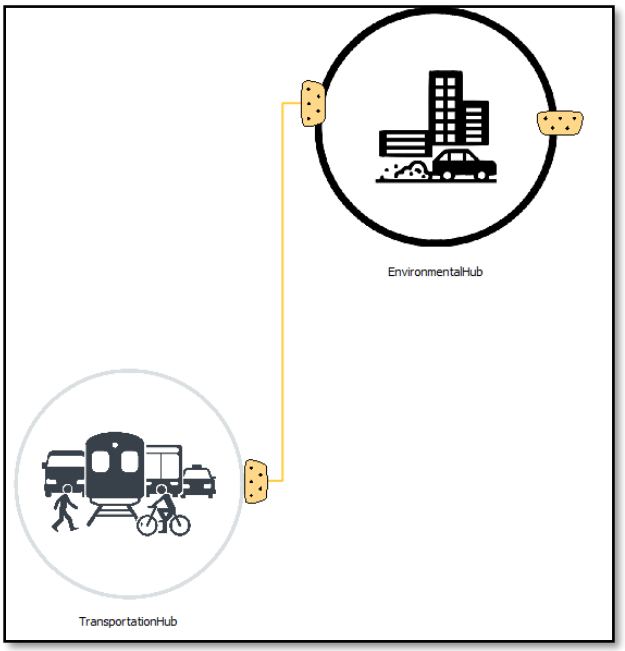


Figure 14: shows the Transportation Integrator Diagram view in the Scenarios package of TRANSPORTATION MODEL.

4. STEPS FOR PERFORMING SIMLULATIONS:

- Open the Transportation Model package
- Set the parameter from the Transportation parameter model
- Open the Transportation Integrator Model. This model is hardcoded to run for the simulation time (Year 2019 to year 2035).
- In environment hub, open the Display hub port to plot the final values of Total vehicles of each kind, CO2 Emissions
- The parameter can also be manipulated from the plotting window with a Sub-model name TP.

5. SIMULATION RESULTS:

5.1 **SCENARIO 1:** This scenario gives a result of a situation which doesn't have any restriction on fuels and have high growth rate and low depletion rate.

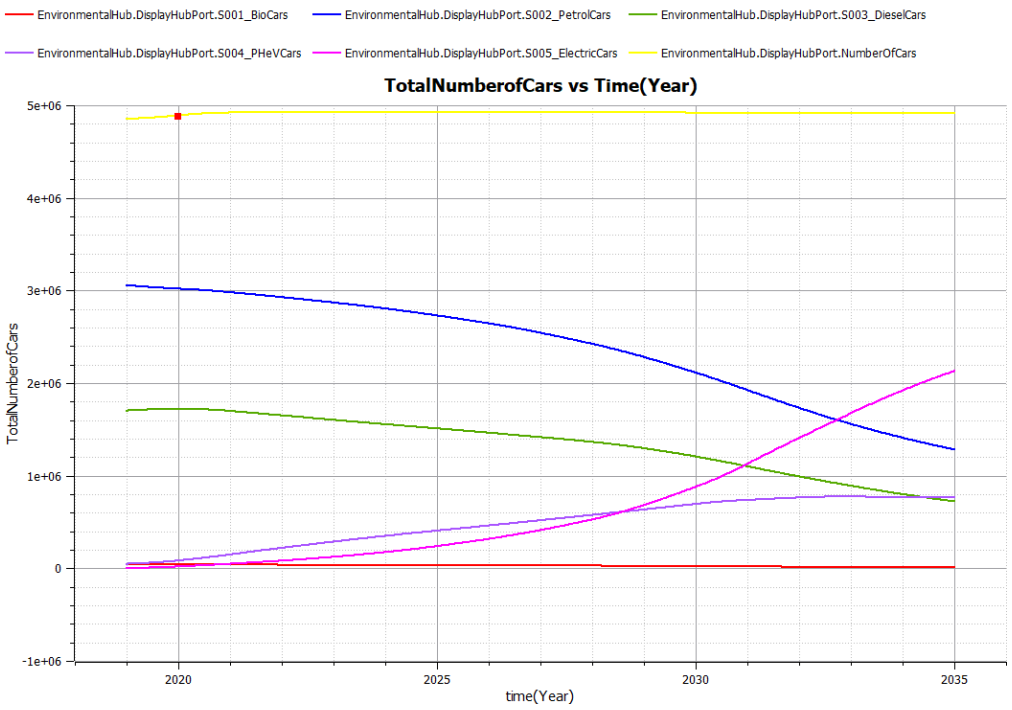


Figure 15: shows the Number of cars vs Time (Years) in Scenario 1.

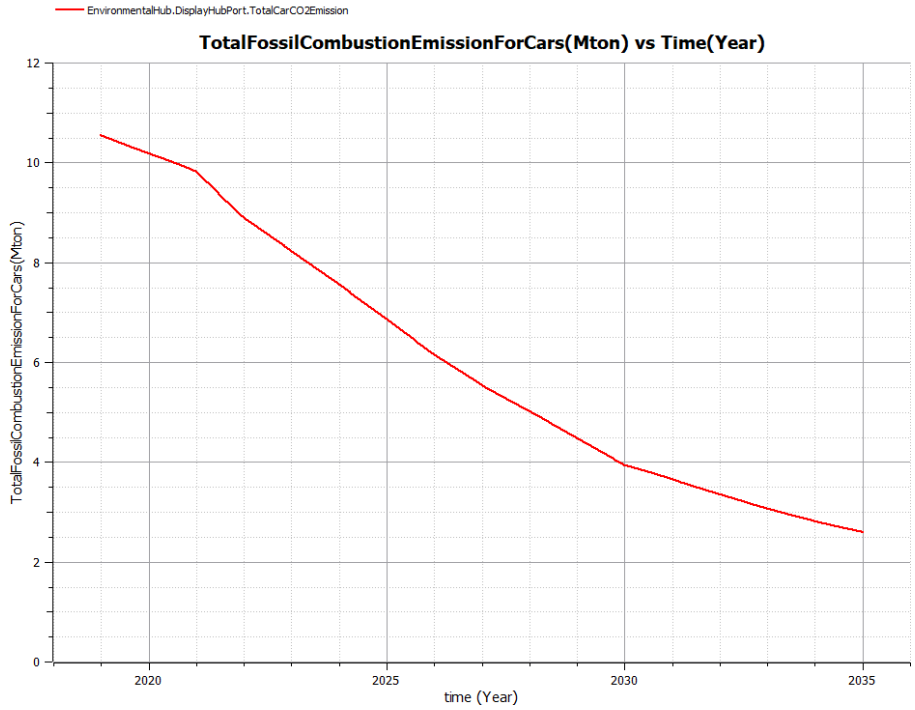
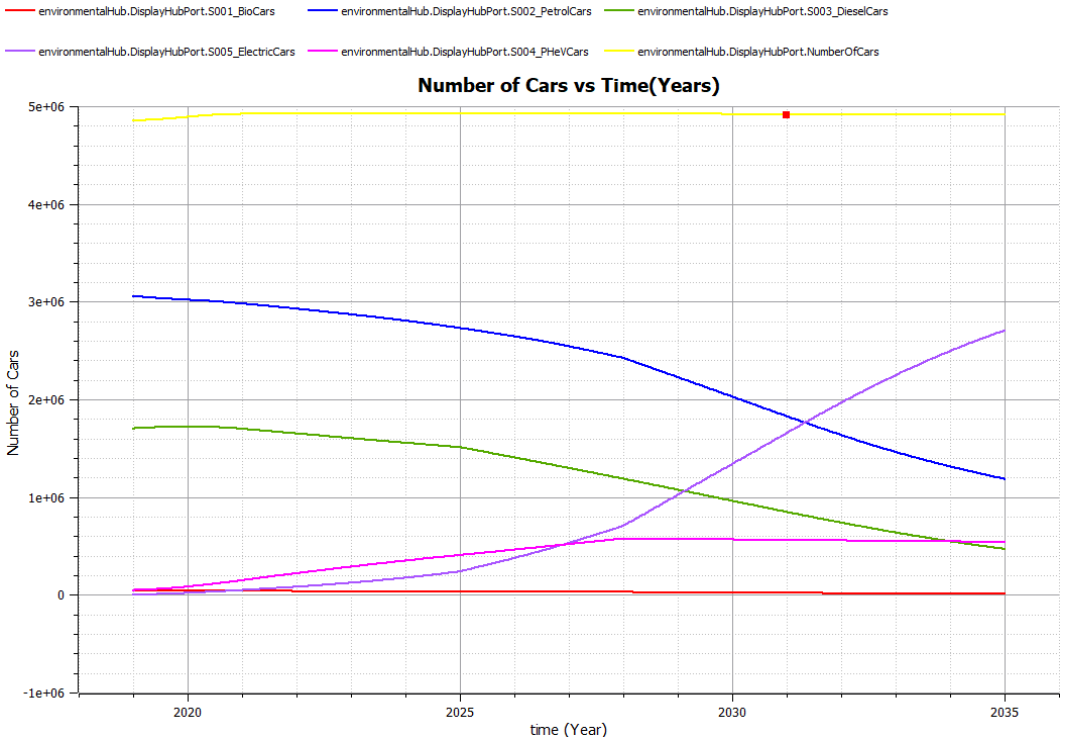


Figure 16: shows the Total Fossil Emission by cars vs Time (Years) in Scenario 1.

5.2 **SCENARIO 2:** This scenario gives a result of a situation which legislation puts a ban on the fossil vehicles on different years.



Car	Fossil Ban Year
Petrol	2028
Diesel	2025
Bio	2030
PHeV	2028

Figure 17: shows the Number of cars vs Time (Years) in Scenario 2.

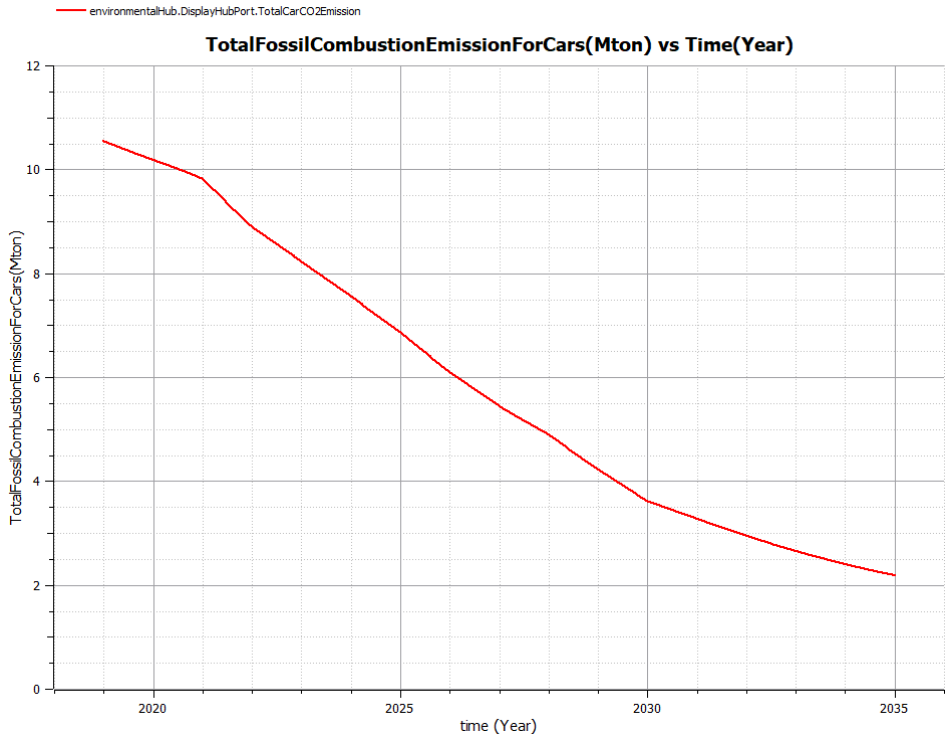
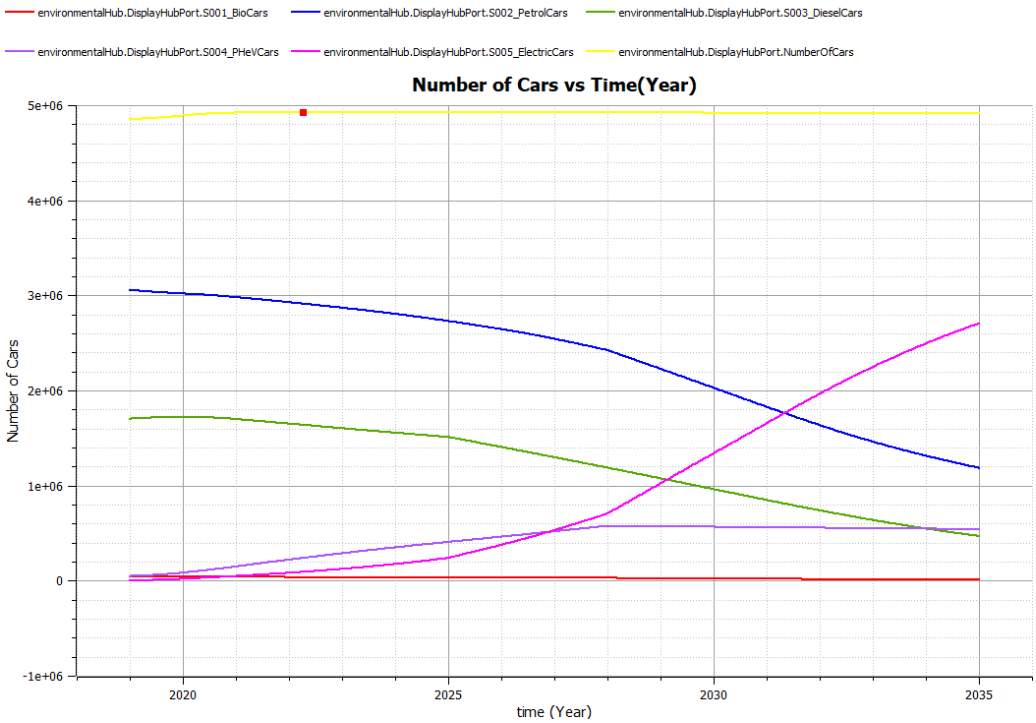


Figure 18: shows the Total Fossil Emission by cars vs Time (Years) in Scenario 2.

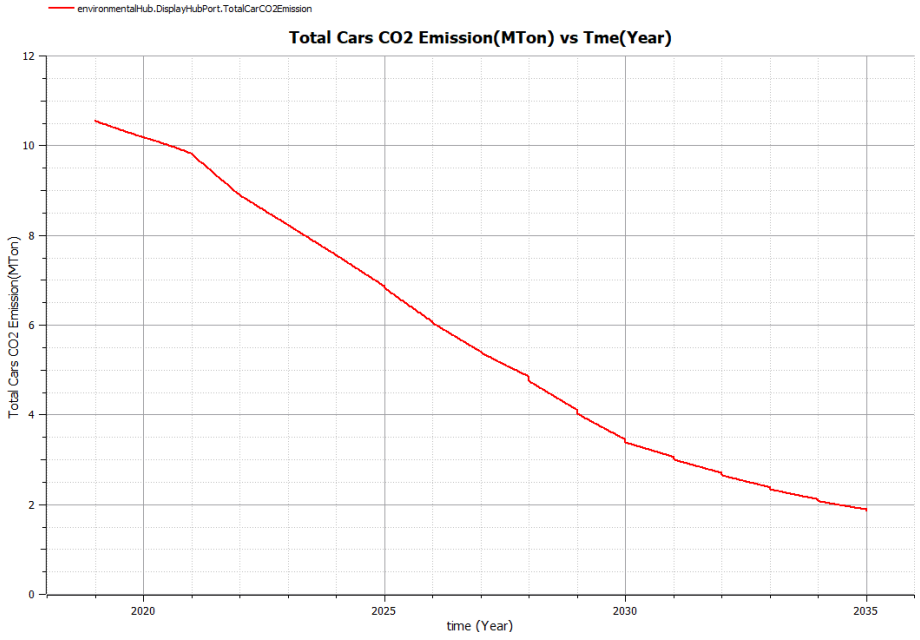
5.3 **SCENARIO 3:** This scenario gives a result of a situation which legislation puts a ban on the fossil vehicles on different years and people are encouraged reduced the traffic density.

The difference can be seen in the CO2 emissions because the number of KM a vehicle runs are reduced by activating the reduce average KM Flag.



Car	Fossil Ban Year
Petrol	2028
Diesel	2025
Bio	2030
PHeV	2028

Figure 19: shows the Number of cars vs Time (Years) in Scenario 3.



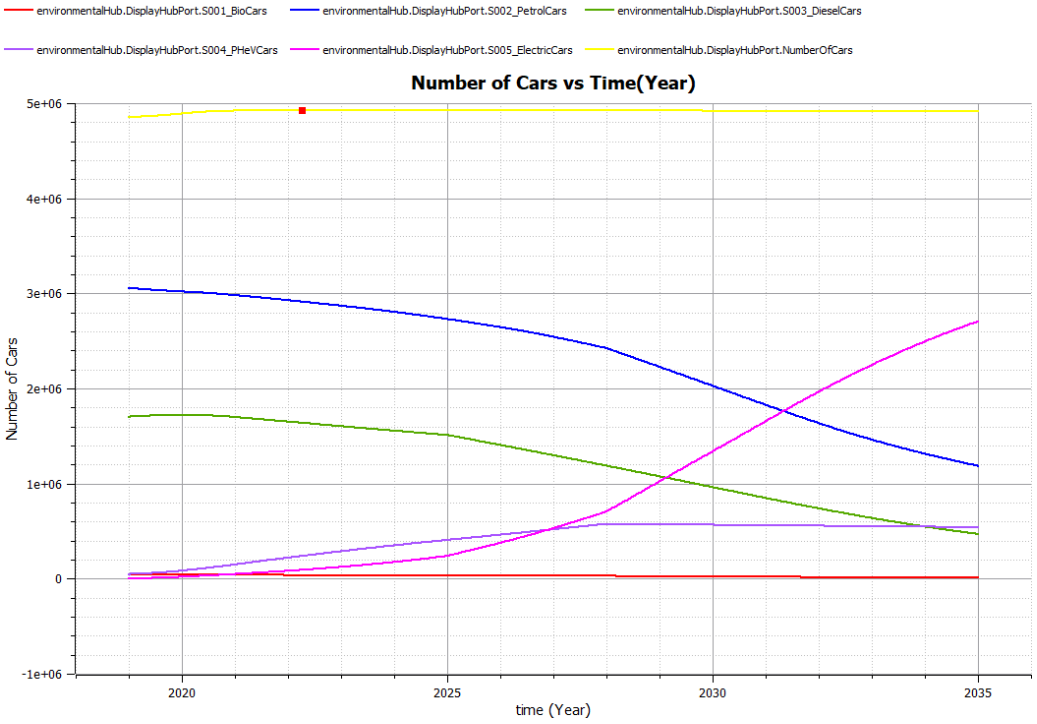
Average driving range km Reduction – 2%

Year of Reduction = Fossil ban Year

Figure 20: shows the Total Fossil Emission by cars vs Time (Years) in Scenario 3.

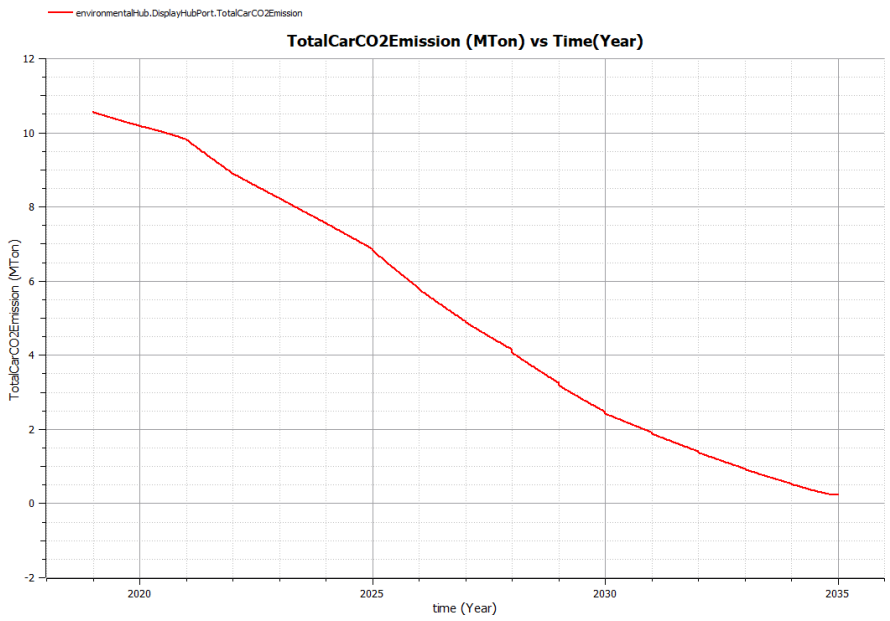
5.4 **SCENARIO 4:** This scenario gives a result of a situation which legislation puts a ban on the fossil vehicles on different years and people are encouraged reduced the traffic density.

The difference can be seen in the CO2 emissions because the number of KM a vehicle runs are reduced by activating the reduce average KM Flag.



Car	Fossil Ban Year
Petrol	2028
Diesel	2025
Bio	2030
PHeV	2028

Figure 21: shows the Number of cars vs Time (Years) in Scenario 4.



Vehicle Type	Conversion %	Conversion Year
Petrol	4.5	2025
Diesel	3.5	2025
Bio	4.5	2025
PHeV	13	2025

Figure 22: shows the Total Fossil Emission by cars vs Time (Years) in Scenario 4.

5.5 COMPARISON OF 4 SCENARIOS:

5.5.1 Comparison of Petrol Cars in all 4 Scenarios:

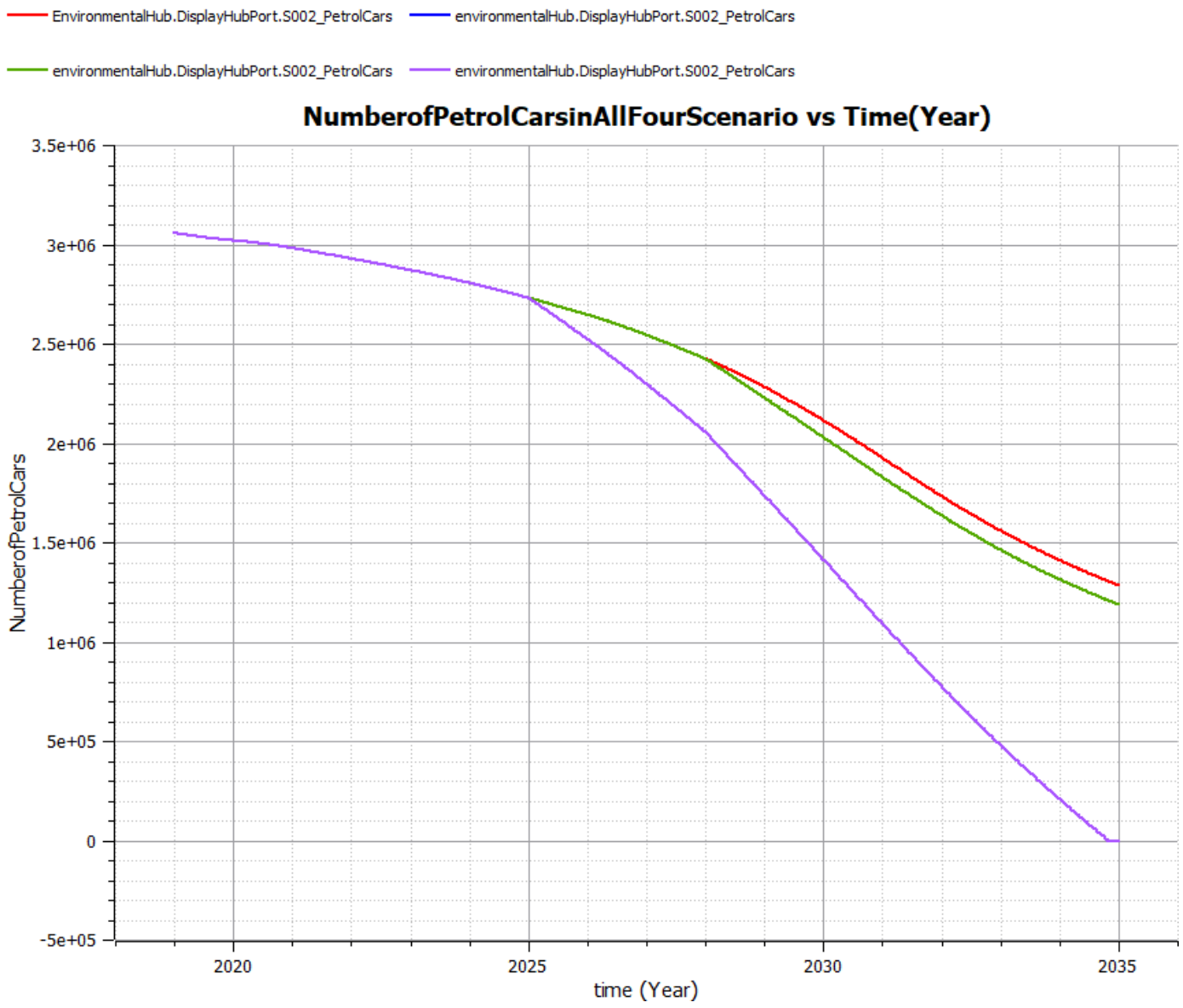


Figure 23: shows the Total Petrol cars vs Time (Years) in All Four Scenario.

Scenario	Fossil ban Flag	Conversion Flag	Average KM Reduction Flag	Legends
1	False	False	False	Scenario 1
2	True	False	False	Scenario 2
3	True	False	True	Scenario 3
4	True	True	True	Scenario 4

5.5.2 Comparison of Fossil Emission For all 4 Scenario:

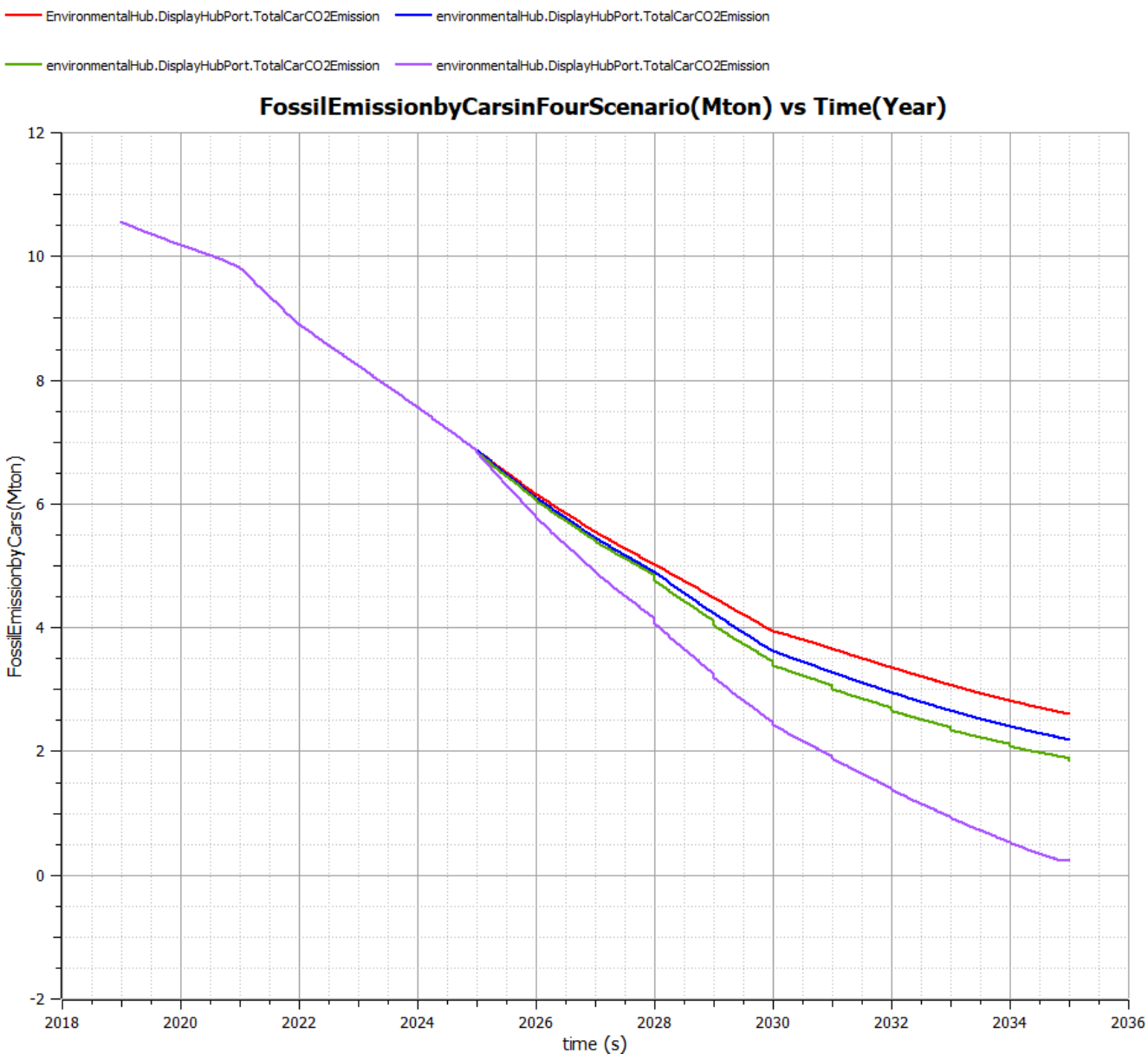


Figure 24: shows the Total Fossil Emission by cars vs Time (Years) in All Four Scenario.

Scenario	Fossil ban Flag	Conversion Flag	Average KM Reduction Flag	Legends
1	False	False	False	Scenario 1
2	True	False	False	Scenario 2
3	True	False	True	Scenario 3
4	True	True	True	Scenario 4