This project has received funding from the European Union's Horizon 2020 research and innovation programme [GA-No. 691685].

REFLEX

Analysis of the European Energy System under the Aspects of Flexibility and Technological Progress

MODEL DESCRIPTION OF ASTRA

ASTRA (ASsessment of TRAnsport Strategies)

ASTRA is a strategic model based on the Systems Dynamics Modelling approach simulating the transport system development in combination with the economy and the environment until the year 2050. The model is made of different modules that interact among each other with direct and feed-back effects.

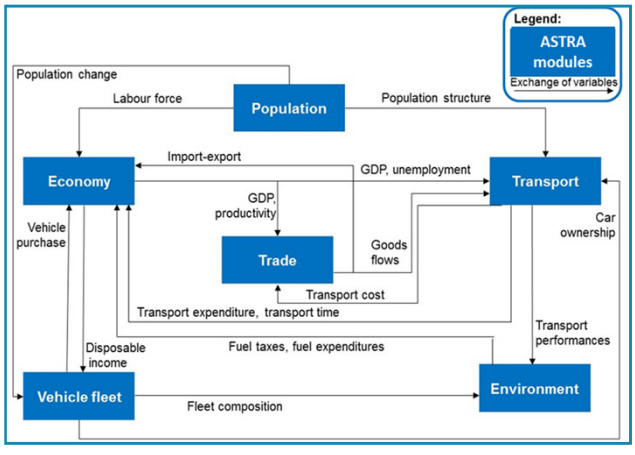
Strategic assessment capabilities in ASTRA cover a wide range of transport measures and investments with flexible timing and levels of implementation. The ASTRA model has been successfully used for the following applications:

- Transport policy assessment: pricing, taxation (on fuel or vehicle), emissions and efficiency standards, infrastructure projects
- Technology and scenario analysis: alternative vehicle technology (e.g. electric and fuel cell vehicles), integrated energy and transport policy (e.g. vehicle efficiency improvement)
- Renewable policy assessment: subsidies, feed-in tariffs, investment strategies
- Climate policy assessment and energy price trends

A strong feature of ASTRA is the ability to simulate and test integrated policy packages and to provide indicators for the indirect effects of transport on the economic system, e.g. GDP growth or employment. Geographically, ASTRA covers all EU 28 Member States plus Norway and Switzerland.

Model structure

As illustrated in the following figure, ASTRA consists of different modules, each related to one specific aspect such as the economy, transport demand or the vehicle fleet.



The main modules cover the following aspects:

- Population and social structure (age cohorts and income groups)
- Economy (e.g. input-output tables, employment, consumption and investment)

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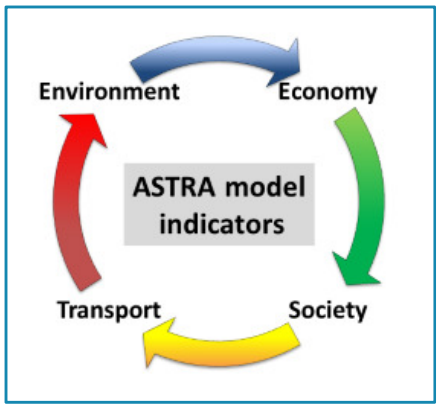
- Foreign trade (inside EU and to partners from outside EU)
- Transport (including demand estimation, modal split, transport cost and infrastructure networks)
- Vehicle fleet (passenger and freight road vehicles)
- Environment (including pollutant emissions, CO_2 emissions, fuel consumption).

The economy module simulates the fundamental economic variables. Some of these variables (e.g. GDP) are transferred to the transport generation module, which uses the input to generate a distributed transport demand. In the transport module, demand is split by mode of transport. The traffic performance by mode is associated with the composition of the fleet (computed in the vehicle fleet module) and the emissions factors (defined in the environmental module), in order to estimate total emissions.



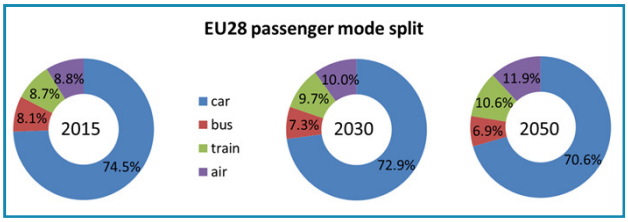
Several feedback effects take place in the ASTRA model. For instance, the economy module provides the level of income to the fleet module, in order to estimate vehicle purchase.

The economy module then receives information on the total number of purchased vehicles from the fleet module to account for this item of transport consumption and investment.

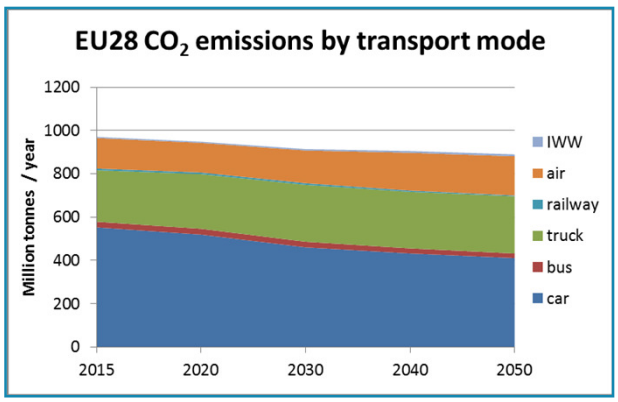
Furthermore, changes in the economic system immediately feed into changes of the transport behaviour and alter origins, destinations and volumes of European transport flows.

Model Output

The indicators that ASTRA can produce cover a wide range of impacts; in particular transport system operation, economic, environmental and social indicators.



The environment module uses input from the transport module (in terms of vehicle-kilometres-travelled per mode and geographical context) and from the vehicle fleet module (in terms of the technical composition of vehicle fleets), in order to compute fuel consumption, greenhouse gas emissions and air pollutant emissions from transport. ASTRA also estimates the upstream emissions (well-to-tank) due to fuel production and vehicles production. Therefore, well-to-wheel emissions can be provided as well.



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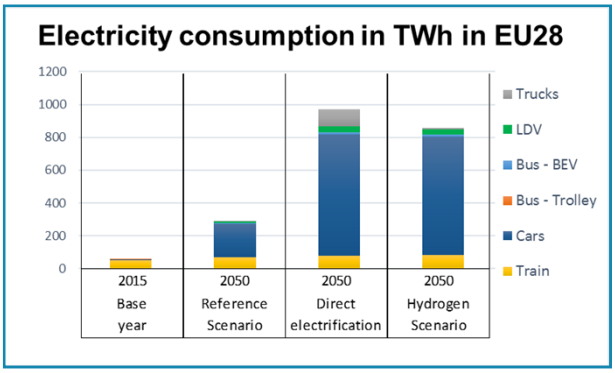
ASTRA is calibrated to reproduce major indicators such as transport performance, fuel consumption, CO_2 emissions and GDP according to the main European reference sources such as Eurostat until 2015 and the EU Reference Scenario (European Commission, 2016) for future trends.

By simulating different policy bundles and framework conditions, ASTRA enables the comparison of different scenarios concerning, e.g., the diffusion of technologies, emission reductions, energy demand by energy carrier, required investments, etc.

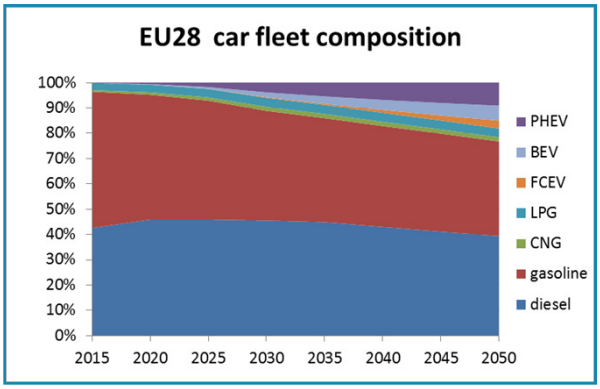


Role and enhancement in REFLEX

Within REFLEX, ASTRA provides the estimation of final energy consumption for different energy carriers relevant for the transport sector. In order to support this analysis, the model has been enhanced taking into account the requested technical transition of vehicle fleets for all transport modes from fossil fuels towards renewable energy carriers as well as new mobility concepts and behavior change towards active modes.

Road vehicle fleet

The diffusion of alternative drive technologies is simulated separately for different vehicle categories. These categories comprise private and commercial cars, light duty vehicles, heavy duty vehicles in four gross vehicle weight categories, urban buses and coaches. Based on the technical characteristics of available fuel options today and in the future and the heterogeneous requirements of the different users, a set of fuel options is available for each vehicle category. Technologies cover gasoline, diesel, CNG, LNG, LPG, battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), fuel cell electric vehicles (FCEV) and trolleys for urban buses and long-distance trucks.



For each road vehicle category, new vehicle purchases are split into fuel types. This split is generated in diffusion models based on an adapted Total Cost of Ownership (TCO) calculation. Total costs comprise fuel costs, annual vehicle and registration taxes, road charges, maintenance costs and discounted average investment costs which are implemented using learning curves for the new technologies. Filling and charging station infrastructure is considered as well in the decision via fuel procurement costs based on the density of the filling or charging station infrastructure for each country and the average range per charge or filling. The probability of the choice of a certain fuel option is finally estimated with a discrete choice approach using logit functions.

Non-road vehicle fleets

Non-road vehicle fleets like inland waterways, maritime ships, air planes and railways are also

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modelled, however, in less detail due to a lack of detailed statistics, long average lifetimes, and only few renewable fuel options imaginable for the time horizon until 2050. As alternative fuel options, ASTRA considers blended kerosene with biofuels for planes, an increasing share of electrified traction for railways, and biodiesel and LNG for maritime ships and inland waterways.

New mobility concepts and behavior change

New mobility concepts are a further development in the transport system that is taken into consideration in ASTRA. The number of car-sharing users grew rapidly in many EU member states within the last ten years and active modes are becoming more popular in several cities. Therefore, specific algorithms have been implemented in ASTRA to simulate the diffusion of car sharing mobility services and their impacts on mobility indicators; furthermore, active passenger transport modes has been explicitly considered in terms of walking and cycling mode in urban areas.

Investments in infrastructure

Transport system investments are also modelled in ASTRA. For example, deployment of filling station infrastructure is fed in via exogenous data, but can also develop dynamically in the model based on the scenario e.g. assuming a certain ratio of charging points per battery-electric vehicle. Required investments in transport infrastructure depend endogenously on the transport activity development and are additionally increased in case of policies like an improvement of public transport.

Coupling with other models

In REFLEX, the ASTRA model is coupled with the models FORECAST, eLOAD, ELTRAMOD and TE3 to simulate feedback mechanisms between electricity consumption patterns and prices as well as global learning effects for new vehicle technologies.

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