REflex
Analysis of the European Energy System

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 TE3 (Transport, Energy, Economics, Environment)

Overview

TE3 (Transport, Energy, Economics, Environment) is a multi-country computer simulation model capable of generating scenarios and suitable for policy analysis. The TE3 model is a simplified representation of the road passenger transport system, with a focus on car travel activity and car powertrain technologies. Given the complexity and uncertainty of the system under study, systems thinking and scenarios analysis are adopted as a guiding research principle and methodology, respectively. The TE3 model has been developed by applying the System Dynamics approach and is implemented in the Vensim® platform. The methodology is mixed, as the model contains elements of other methods. In particular, the modelling exercise underlying TE3 can be divided into three main steps:

(1) Projection of the total car stock by means of an aggregate econometric model;

(2) Simulation of market shares by car technology by means of a discrete choice modelling framework; and

(3) Estimation of energy use and greenhouse gas emissions by means of an accounting framework.

Purpose and model approach

The target model user is a policy-maker with responsibility for transport and environmental issues at the national level. The purpose of the model is three-fold:

(1) To illustrate future development pathways of car technologies;

(2) To estimate key environmental – energy use and greenhouse gas emissions – impacts corresponding to the various pathways; and

(3) To support strategic policy-making by facilitating policy analysis.

The model accomplishes its objective by creating scenarios of the dynamic market penetration of alternative car technologies, taking into account direct and indirect emissions and incorporating a set of policy measures.

In essence, TE3 can be regarded as a hybrid model, as it follows an approach that contains top-down and bottom-up features. Core to the TE3 model is the representation of feedback loops.

The TE3 model is validated with econometrics features such as timeseries analysis, pre- and post-testing.

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Modular structure of the TE3 model

A modular approach, which is illustrated in Figure 1, is implemented with the following interlinked nine modules:

- *Population-GDP*: Incorporate the external projections on population and GDP;
- *Car Stock*: Project car ownership, the resulting aggregate car sales as well as the simulation of the market shares by car technology;
- *Travel Demand by Car*: estimation of travel demand by car and energy;
- *Infrastructure*: Deployment of public refueling and recharging infrastructure;
- *Technology choice*: comprises the model's main behavioral assumptions;
- *Production costs*: Consideration of three broad classes of car attributes - Technical Features, Production Costs and Consumer Costs;
- *Energy*: Consists of three main parts Energy Prices, Electricity Mix and Energy Use;
- *Emission*: Calculation of corresponding GHG emissions divided into six sub-modules - Emission Factors, New Car Emissions, Manufacturing and Scrappage, Tank-to-Wheel (TTW), Well-to-Tank (WTT) and Lifecycle; and
- *Policy*: Facilitation of policy analysis.

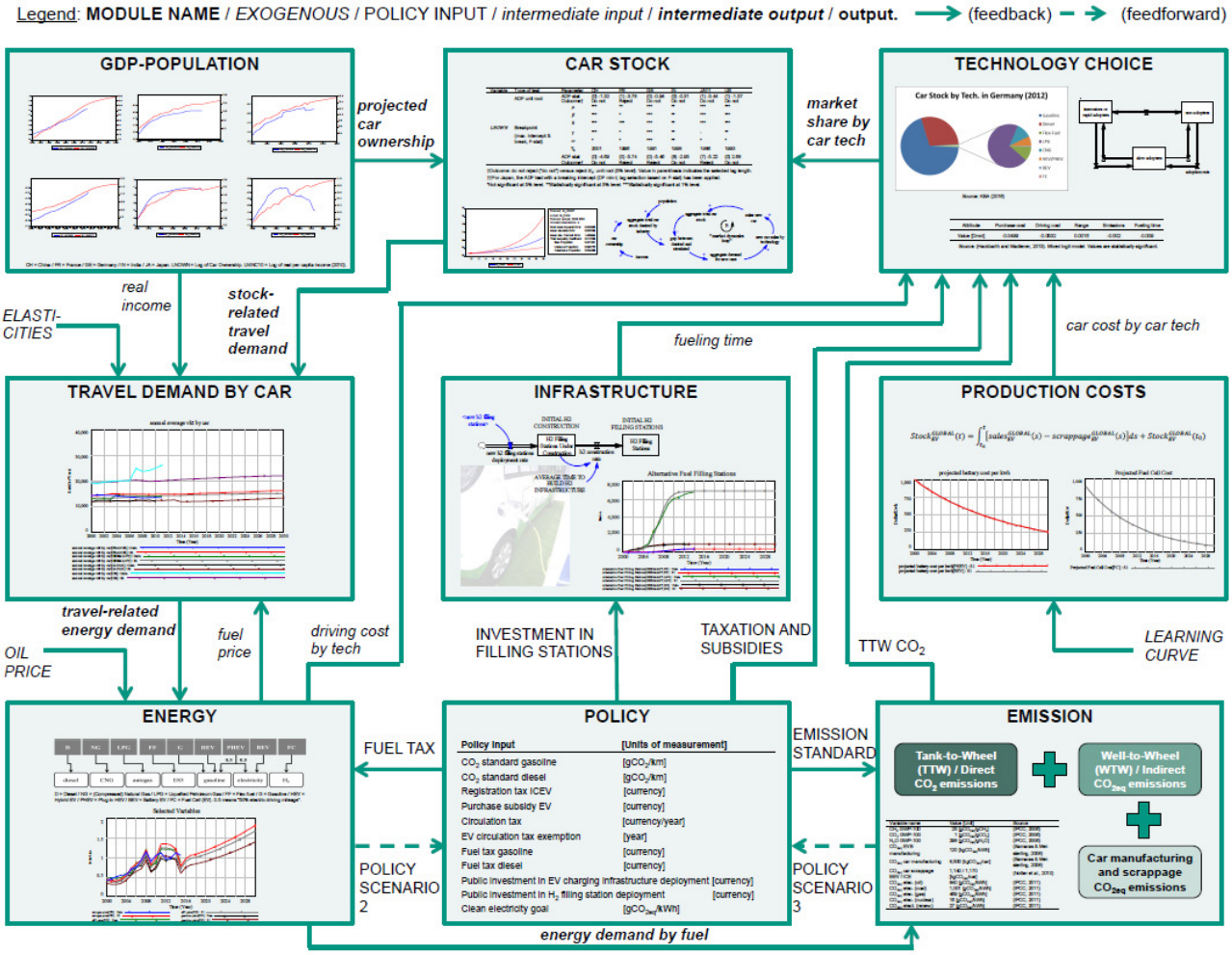

Figure 1: Overview of the TE3 model with modules

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Features

In its current version, the model covers the following:

- Six countries: Germany, France, India, Japan, China and the US.
- Time horizon ranging from the year 2000 to 2050.
- Nine car technologies: gasoline (G), diesel (D), flexible-fuel (FF), liquefied petroleum gas (LPG), natural gas (NG), hybrid (HEV), plug-in hybrid (PHEV), battery electric vehicle (BEV) and fuel cell (FC).
- Seven fuels: gasoline, diesel, ethanol (E85), autogas, compressed natural gas (CNG), electricity and hydrogen (H_2).
- Three types of emissions: CO_2, N_2O, CH_4.
- Four types of emissions analysis based on crude estimates: well-to-tank, tank-to-wheel, manufacturing and scrappage and lifecycle.
- Eleven policy measures including new gasoline and diesel car emissions standards and fuel taxation.

The sets of car technologies (nine elements) and energy sources (seven elements) included in the model are shown in Figure 2. Only PHEVs are assumed to be powered by two different energy sources: gasoline and electricity.

Recent model applications

The TE3 model has been applied to analyse policies concerning inter alia: stricter emissions standards for new conventional cars, electric car subsidies and conventional car purchase taxation. The analysis has been done within project work and has been presented at international conferences and in journals.

TE3 Role in REFLEX

For the transport sector the uptake of alternative car technology in Europe is investigated. We argue that it is not possible to come to a plausible estimation of electric vehicle (EV) market penetration in Europe without the explicit consideration of the global market dynamics related to electric vehicle battery (EVB) development and costs. In particular, EVB cost reductions are dependent on the economies of scale associated with an increasing number of EVs sold worldwide. Hence, the EVB cost is affected by the learning rate and the cumulative production of EVs which is considered in the TE3 model.

Therefore, there is a linkage with another transport model, ASTRA, to include simulated EU sales of EV and PHEV. In this way, key non-European countries and the EU countries are jointly connected, thereby determining their future EV market evolution. This linkage represents the global development of the EVB with the respective experience curves included.

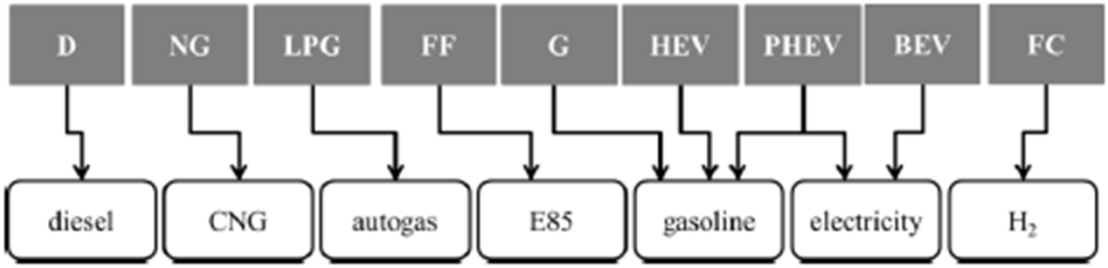

Figure 2: Car technologies and energy sources linkages

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Data

In its current version, the model draws from these main sources of data:

- UN World Population Prospects 2012 projections
- World Bank data
- World Economic Outlook Databases
- Intergovernmental Panel on Climate Change guidelines
- International Energy Agency statistics
- International Road Federation data
- Oak Ridge National Laboratory Transportation Energy Data Book
- Country-specific data sources such as Chinese Statistical Yearbooks, Eurostat, European Environment Agency data, Germany's Destatis, KBA and MOP data as well as US Energy Information Administration, US Bureau of Transportation Statistics
- Car manufacturers catalogue / website information

Selected References

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