The Transport Module; Integration in MERGE and Scenario Evaluation

S. Kypreos

ETSAP, 15.12.2008
Sophia-Antipolis FRANCE

With car technology data from the PhD of Timur Güel

Procedure and Steps to complete the PSI Contribution to ETSAP

1. Development and Integration of a Transport Module in MERGE
2. Separation of a country model within a region of MERGE; input data via an easy to use EXCEL format with GTX and optimization with the new NLP model
3. Solve the detailed MARKAL or MARKAL-MACRO (MM) model of a country using demand, technical data specifications, trade values, fuel prices and other exogenous data from the MERGE solution
4. Plan A: Final integration in a hard-link of a single MM country model within MERGE to directly solve the overall problem (5 periods X 10 yrs)
5. Plan B: Soft-link development to run MERGE and MM for a single region in an iterative algorithm with stabilized demands
6. Completion with a technical report and publication in peer review journals
MERGE and the Transport Module

Scenarios analyzed:
Baseline  (needs more work)
500 ppm CO2 with emphasis on CCS and Biomass
400 ppm CO2 with emphasis on CCS and Biomass
400 ppm CO2 with emphasis on Electric cars

Development of the Transport Module

- TRAMOND needs the demand for mobility, the technical database and is a simple NLP transport module with LBD specifications
- The energy part of this module is coded more simple than in MARKAL:
  - We first balance demand
  - We define then the fuel use
  - We link fuel use with the electric, non-electric and CO2 balances
  - The annualized investment cost of the model are linear functions
  - while the dynamic ETL- costs non-linear
  - The usual expansion and declining constraints apply
Learning Clusters - Electricity & Fuel Sector

Source: PhD T. Güel

Key learning components personal transport

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Initial Cost</th>
<th>Future Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell</td>
<td>250</td>
<td>50</td>
</tr>
<tr>
<td>Reformer</td>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>Hybrid Battery System</td>
<td>2'500</td>
<td>800</td>
</tr>
<tr>
<td>FC Hybrid Battery System</td>
<td>3'250</td>
<td>1'200</td>
</tr>
<tr>
<td>Battery Electric</td>
<td>16'250</td>
<td>12'000</td>
</tr>
<tr>
<td>Plug-In Hybrid</td>
<td>6'500</td>
<td>2'800</td>
</tr>
</tbody>
</table>

Source: PhD T. Güel
Basic energy and economic output flows in MERGE-TRAMOD

\[ NTRA = GSL + DSL + H2 + DSFT + ELC + CNG \]

\[ NE = NTRA + NREST \]

But, \( NTRA \) and other demands could be defined otherwise

\[ NREST = \text{Activities of Non-Electric_Fuels} \]

\[ E + ELC = \text{Production_Activities of all Power_Stations} \]

Basic equations in MERGE

The personal transport sector and other end-use sectors are defined in a more simple way than in MARKAL and a minimum set of equations:

1) Exogenous Demand

\[ \text{DEM} = \sum \text{CAP(dmd)} \]

2) Fuel Balance

\[ \text{GSL} = \sum \text{CAP(dmd)} \times \text{ma_dmd("GSL")/eff(dmd)} \]

\[ \text{H2} = \sum \text{CAP(dmd)} \times \text{ma_dmd("H2")/eff(dmd)} \]

3) Primary Balance

\[ \sum (\text{prc->H2}) \times \text{PRC_ACT*ma_prv("fuel")*eff_PRC=H2} \]

4) Declining and expansion constraints apply
OBJECTIVE FUNCTION per period and car type:

- Non-learning static cost (e.g., linear)
  \[ F_{\text{xCst}} = \text{costkm} \times ACT(t) \]

- Learning part of the cost (e.g., non-linear)
  \[ L_{\text{mcst}}(ETL) = \text{acrm} \times \text{InitLCost} \times ACT(t) \times [\text{CMACT}(t) + \text{LSUB}/\text{InitCum} + \text{LSUB}]^{\beta} \times \left[ \frac{\text{KS}(t)}{\text{KS}_0} \right]^{\gamma} \]

- Cumulative activity definition
  \[ \text{CMACT}(t) = \text{CMACT}(t-1) + n_{\text{yper}} \times ACT(t) \]

Variables: ACT, CACT, LSUB, KS

First Results of MERGE-TRAMOD

Carbon Emissions by case

- BAU
- 550ppm
- 450ppm

GtC/yr

1990 2000 2010 2020 2030 2040 2050 2060
Model development (MERGE-TraMod)

1. MERGE includes electric and non-electric sectors; personal transport; hydrogen and synthetic fuel production

2. The energy system is linked with the macro-economic developments and reflects the climate change impacts

3. The NLP formulation of LBD and LBS is operational

4. R&D is now a decision variable but it can be also an exogenous scenario parameter such that policy simulations on learning subsidies and/or on R&D spending become possible

5. The ETL option reduces significantly the cost of mitigation but needs appropriate policies to get started in real life

6. Changes and recalibration of Baseline needed
Conclusions about H2

1. Strong carbon mitigation policy favors H2 as at high C-taxes biomass to H2 with CCS is a needed and competitive technology

2. At low oil prices conventional and advanced conventional transportation systems remain competitive

3. Appropriate policies like R&D and learning subsidies reduce the initial cost of FC stacks and facilitate their initial penetration before commercialization

4. H2 and electric cars are in strong competition (shown next)

5. Regional circumstances and infra-structure policies will specify the winner

6. In principle, different futures are doable depending on next years policy e.g., on policies supporting specific new technological developments

Learning subsidies of 500 Mio USD for about 40000 batteries change the picture
We reduce the initial cost of a battery from 16250 $/car to 14000 $/car