The Transport Module; Integration in MERGE and Scenario Evaluation

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With car technology data from the PhD of Timur Güel

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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

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MERGE and the Transport Module

Scenarios analyzed:

Baseline (needs more work)

500 ppm CO_2 with emphasis on CCS and Biomass

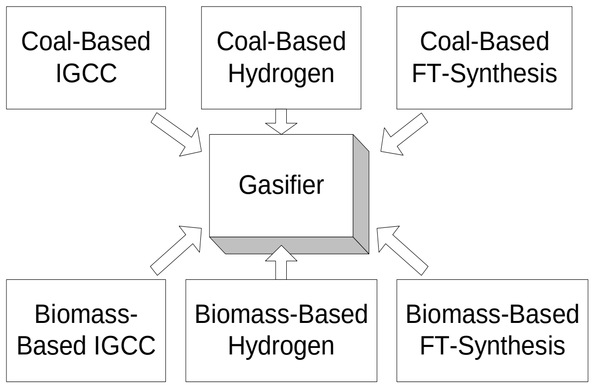
400 ppm CO_2 with emphasis on CCS and Biomass

400 ppm CO_2 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 CO_2 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



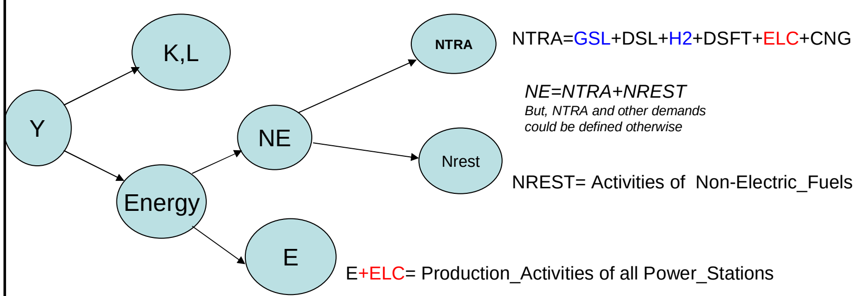
Source: PhD T. Güel

Key learning components personal transport

Assumptions	Initial Cost	Future Cost	
Fuel Cell	250	50	US$/kW
Reformer	90	25	US$/kW
Hybrid Battery System	2‘500	800	US$ per vehicle
FC Hybrid Battery System	3‘250	1‘200	US$ per vehicle
Battery Electric	16‘250	12‘000 ????	US$ per vehicle
Plug-In Hybrid	6‘500	2‘800	US$ per vehicle

Source: PhD T. Güel

Basic energy and economic output flows in MERGE-TRAMOD



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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	DEM = Σ CAP(dmd)
2) Fuel Balance	GSL = Σ(dmd) CAP(dmd)*ma_dmd("GSL")/eff(dmd) H2 = Σ(dmd) CAP(dmd)*ma_dmd("H2")/eff(dmd)
3) Primary Balance	Σ (prc->H2) PRC_ACT*ma_prc("fuel")*eff_PRC=H2

4) Declining and expansion constraints apply

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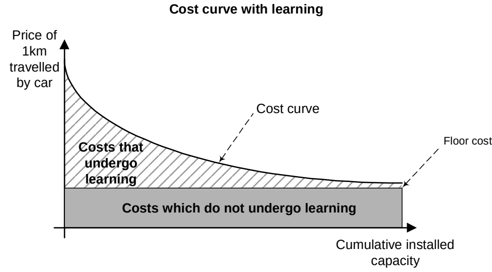
Modeling Experience Curves in TraMod



OBJECTIVE FUNCTION per period and car type:

- Non-learning static cost (e.g., linear)

  FxCst = costkm*ACT(t)

- Learning part of the cost (e.g., non- linear)

  Lrncst(ETL) = acrf*InitLCost*ACT(t)* [CMACT(t)+LSUB/ InitCum+LSUB]**(- β))])* [KS(t)/ KS0]**(- γ))]

- Cumulative activity definition

  CMACT(t)= CMACT(t-1) + nyper*ACT(t)

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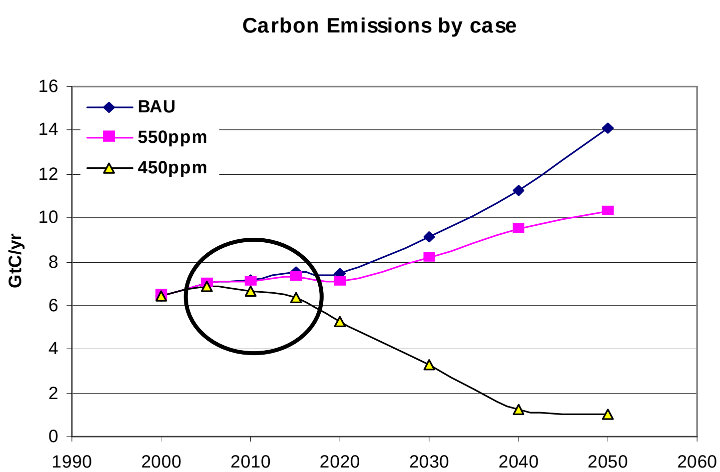
Variables: ACT, CACT, LSUB, KS

First Results of MERGE-TRAMOD



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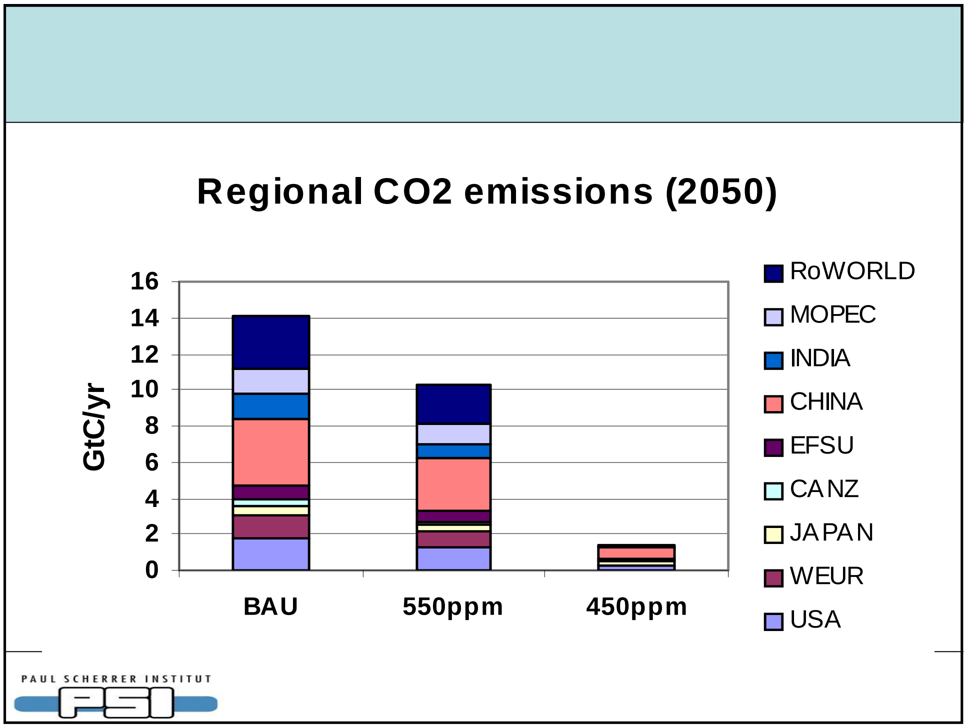
Regional CO2 emissions (2050)
GtC/yr
16
14
12
10
8
6
4
2
0
BAU
550ppm
450ppm
RoWORLD
MOPEC
INDIA
CHINA
EFSU
CANZ
JAPAN
WEUR
USA
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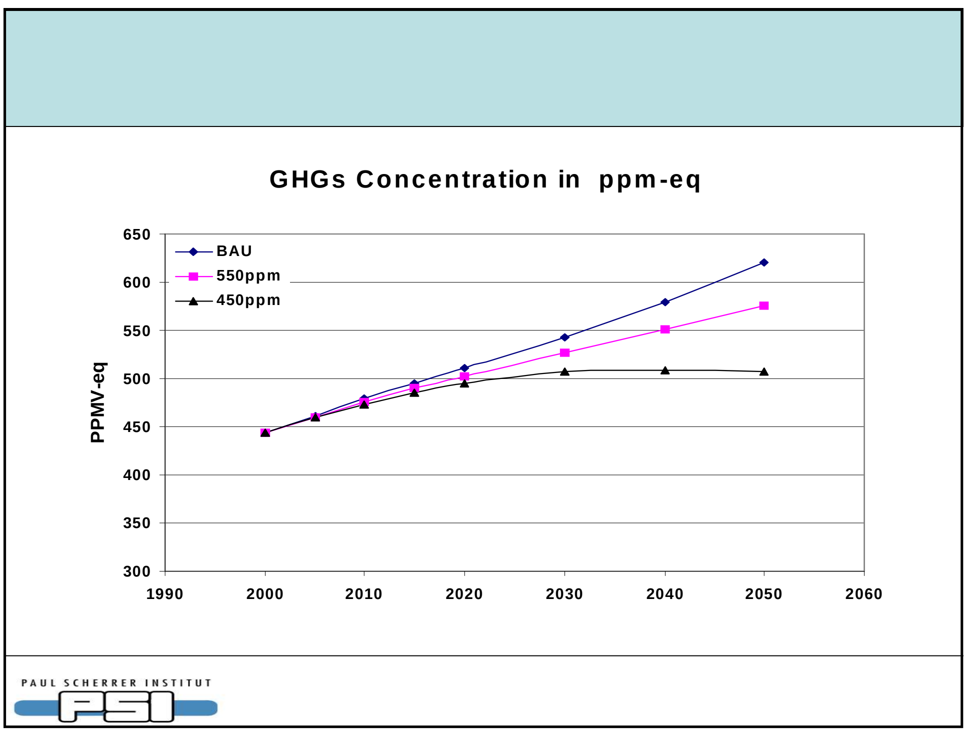
GHGs Concentration in ppm-eq
PPMV-eq
650
600
550
500
450
400
350
300
1990
2000
2010
2020
2030
2040
2050
2060
BAU
550ppm
450ppm
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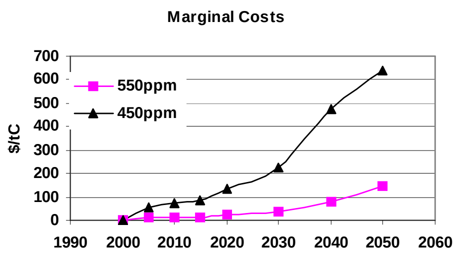

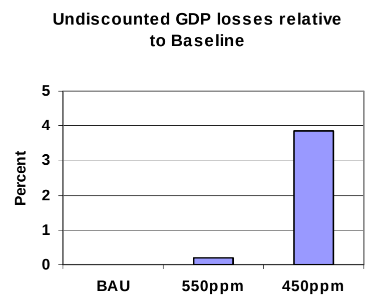

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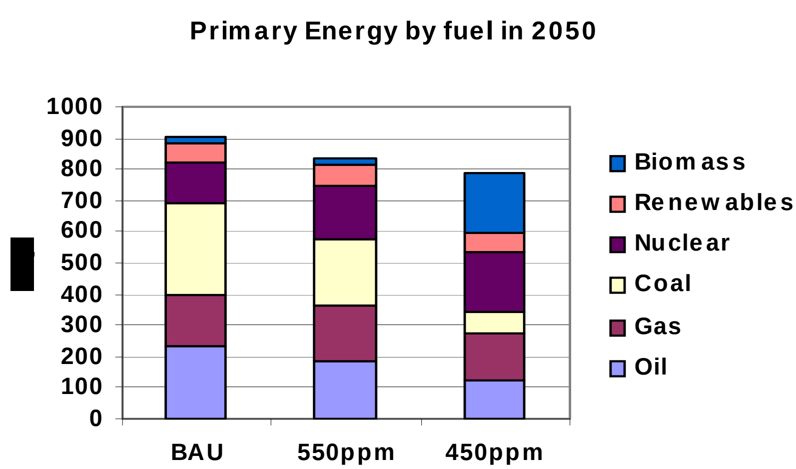

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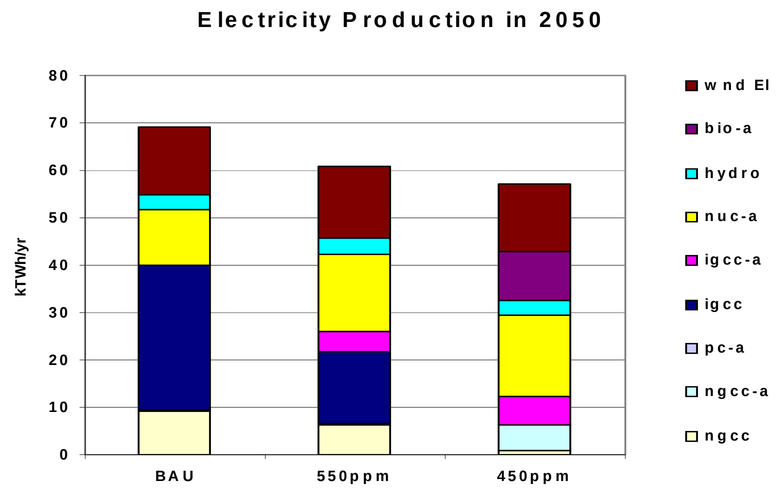
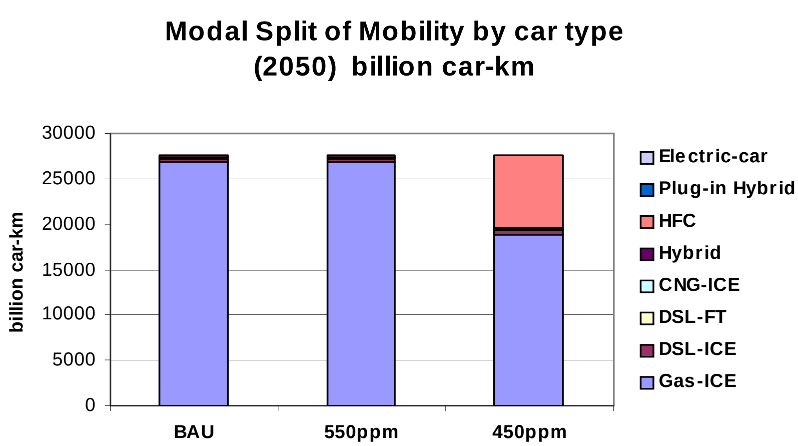
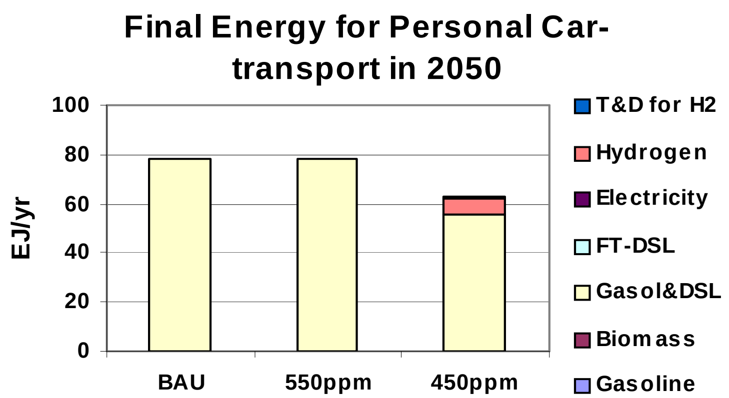


Electricity Production in 2050
kTWh/yr
80
70
60
50
40
30
20
10
0
BAU
550ppm
450ppm
w nd El
bio-a
hydro
nuc-a
igcc-a
igcc
pc-a
ngcc-a
ngcc



Modal Split of Mobility by car type
(2050) billion car-km
billion car-km
30000
25000
20000
15000
10000
5000
0
BAU
550ppm
450ppm
Electric-car
Plug-in Hybrid
HFC
Hybrid
CNG-ICE
DSL-FT
DSL-ICE
Gas-ICE



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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

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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

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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)