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Global transport modelling in IAMs: learnings from model comparison

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Comparison of IAM transport models: Participating models, structural equation and common assumptions

Girod, B., Vuuren, D.P., Grahn, M., Kitous, A., Kim, S.H., Kyle, P., 2013. Climate impact of transportation A model comparison. Clim. Change.

Participating models

- GCAM
- GET
- TIMER
- TIMER
- IEA/Momo*

*For baseline only

Scenario harmonization

Baseline scenario

- Population projections: OECD Environmental Outlook
- Income projections: OECD Environmental Outlook

Emission factors and energy system

- Emissions [tCO_2/TJ]: natural gas: 56, liquid fossil-fuels: 71.5, biofuels 22.
- Focus on tank to wheel: Same emissions for fossil-based liquid fuels.
- However: Upstream emissions considered in for carbon tax

Structural equation and output for comparison

$$CO_2e = \underbrace{\sum_{r,t} (Serv_{r,t}}_{Service} \cdot \underbrace{\sum_m (Mode_m \cdot \sum_v (Veh_v \cdot Eff_v}_{EnergyEfficiency} \cdot \underbrace{\sum_{ft} Fuel_{ft} \cdot ef_{ft}}_{CarbonIntensity})))$$

[$GtCO_2$]

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Projection	GCAM	GET	IEA/MoMo	TIMER	POLES
Travel					
Demand	Population, income, service prices	Population and income projections	Population, income-based vehicle purchase and travel trends	Population, income, travel money budget and service prices	Population, income, fuel prices for distance, income for equipment
Mode split	LM of vehicle costs and time value costs based on speed and wage rate	Historical shares and their connection to GDP growth and travel time	Trends of different transport modes	LM of vehicle costs and time value costs based on speed, travel time budget, and travel money budget	Partial substitution through fuel price, partial autonomous dynamics per mode
Freight					
Demand	Total GDP, service prices	Total GDP	Total GDP	Total industrial value added; aircraft connected to air travel; fuel price	Total GDP, fuel prices
Mode split	LM of vehicle costs	Based on historical shares and their connection to GDP growth	Based on trends of different transport modes.	Autonomous dynamics per mode	Partial substitution through fuel price, partial autonomous dynamics per mode
Fuel use					
Energy efficiency	LM for vehicles with different fuels and energy efficiency	Average data for each mode and region for the initial year, thereafter assumptions on annual improvements	Trends in vehicle composition in fleets and load factors.	LM for vehicles with different fuels and energy efficiency, income dependent discount rates	Energy efficiency evolution depends on fuel prices and income per capita; LM for vehicle types on complete costs
Fuel mix	Determined by vehicle and mode shares; LM for liquid fuels	Determined by cost-minimizing the entire global energy system	Determined by vehicle and mode shares	Determined by vehicle and mode shares	Determined by vehicle and mode shares; LM for liquid fuels
Fuel pri	Endogenous	Exogenous	Exogenous	Endogenous	Endogenous

Model assumption
(**common**, not-common, Approach, A, Input, I)

A: Elasticities, trend, TMB, TTB
I: **Income, population,** prices, TTB, travel trends.
A: Logit-model, elasticities, trend.
I: vehicles cost (incl. fuel price), speed, historic shares

A: **Elasticities**
I: **GDP (IVA),** fuel prices, connection to air travel
A: Logit-model, historic shares, elasticities
I: Vehicles costs (including fuel price), historic shares

A: Logit-model for vehicles, elasticity, discount rates, trends
I: Vehicle costs, fuel prices, income (discount rate)

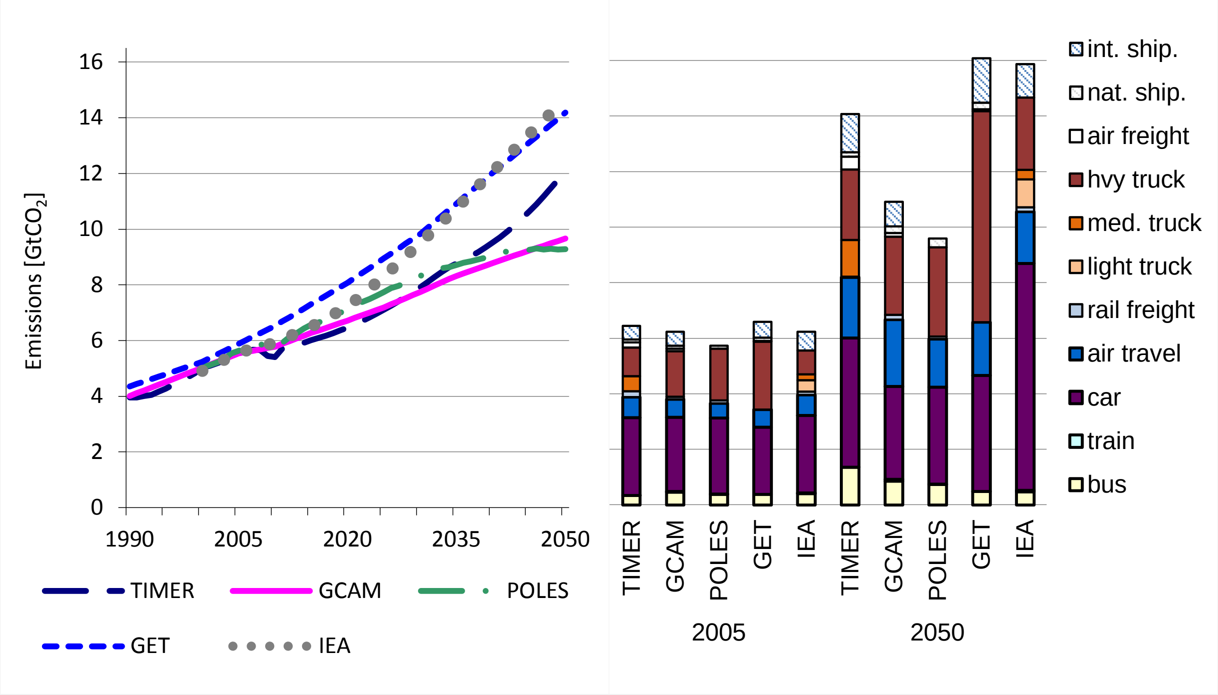
A: Determined by vehicle and modes, logit-model for fuels, cost-optimization
I: **Fuel price.**
A: Endogenous (IAM)

Very different model approaches for travel demand, mode split and fuel use.

Projections for global direct CO_2 emissions from transportation for 2050

Projection of total emissions
(excluding air and water freight)

Contribution of different transport modes

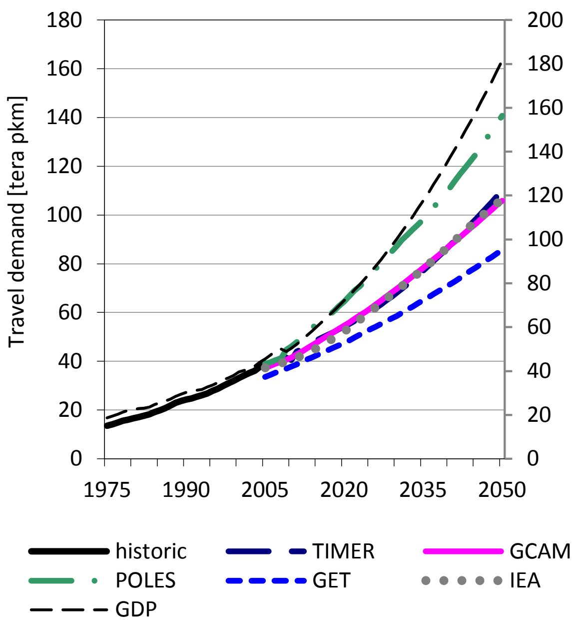


Main findings:

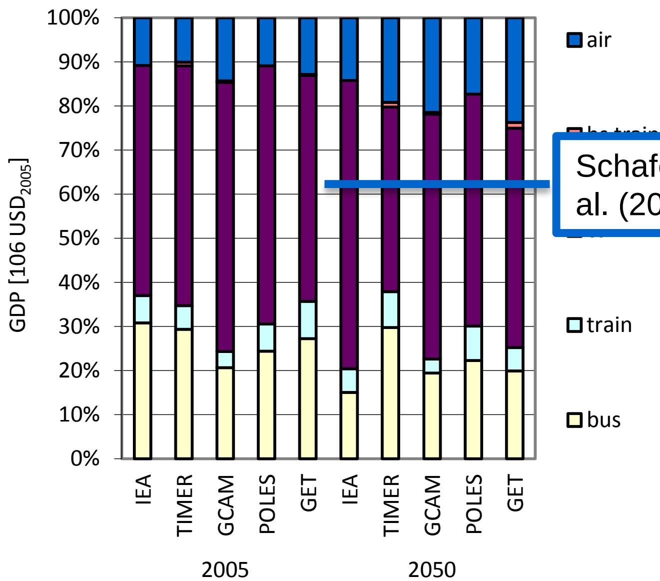
- Cars and heavy trucks contribute to the largest share of total CO_2 emission
- All models project steep increase from air travel
- Increase in CO_2 Emissions by 55% to 145% compared to 2005
- Structural decomposition shows: GCAM & POLES high service demand and high efficiency and decarbonization

Comparison of projections travel demand in the baseline scenarios for 2050

Projection of total travel demand



Modal split for 2005 and projections for 2050



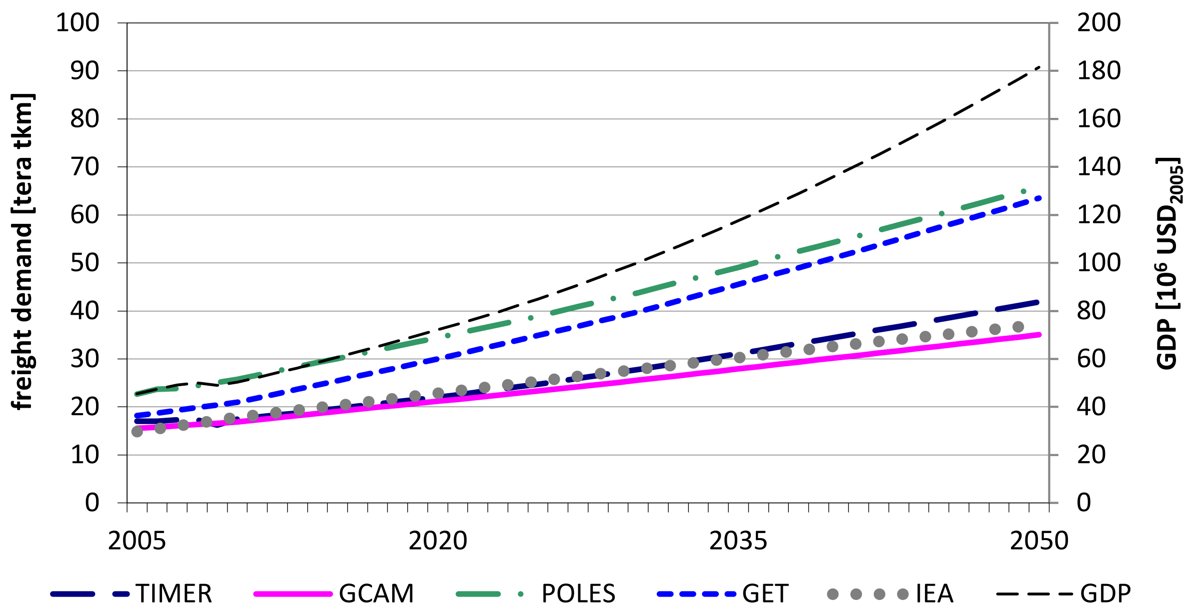
Schafer et al. (2010)

Main findings:

- rapid increase by 130 – 280% compared to 2005
- Decoupling from GDP
- POLES - GET difference explained by car travel
- Except for IEA, all models project a higher air travel growth than car travel demand
- But: all project lower growth up to 2050 (3 – 3.9%) than ICAO for 2006–2036 of 4 to 5.2 %

Comparison of projections for freight demand in the baseline scenarios

Projection of total freigth demand
(without freight shipping and aircraft)

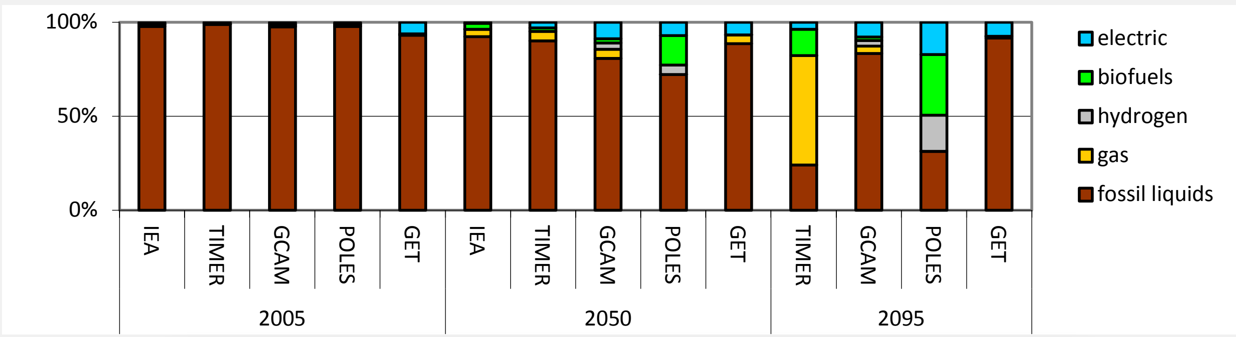


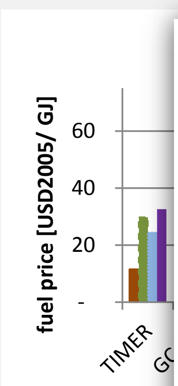
Main findings:

- all models assume stronger decoupling from GDP compared to travel demand
- broad range of projections can be explained by the uncertainty in reliable statistics
- Base year difference
  - heavy trucks (IEA lower estimates)
  - rail (POLES include vehicle weight)

Comparison of projections for fuel demand in the baseline scenarios

Projected trends in fuel use and global fuel prices





Tesla Model S Sales In California: 6,554 Through September 2013

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It's no secret that California is Tesla's leading market for the all-electric Model S sedan.

Now the California New Car Dealers Association has released its third quarter report, which shows that Tesla sold 6,554 cars in California through the end of September, giving it an 11 percent market share in the luxury/sports segment. The standings are roughly where they were at the end of June: Tesla sold

Main findings:

- Up to 2050 all models see fossil fuels dominating
- Very different projections for alternative fuels
- Can be explained by regulatory environment, consumer choice and fuel prices
- Poor data for fuel prices in non-OECD regions
- Fuel prices explain most changes in fuel mix beyond 2050
- Share of electricity remains small

Comparison of global energy intensity projections in the baseline scenarios

Global energy intensity projections (2005 – 2050)

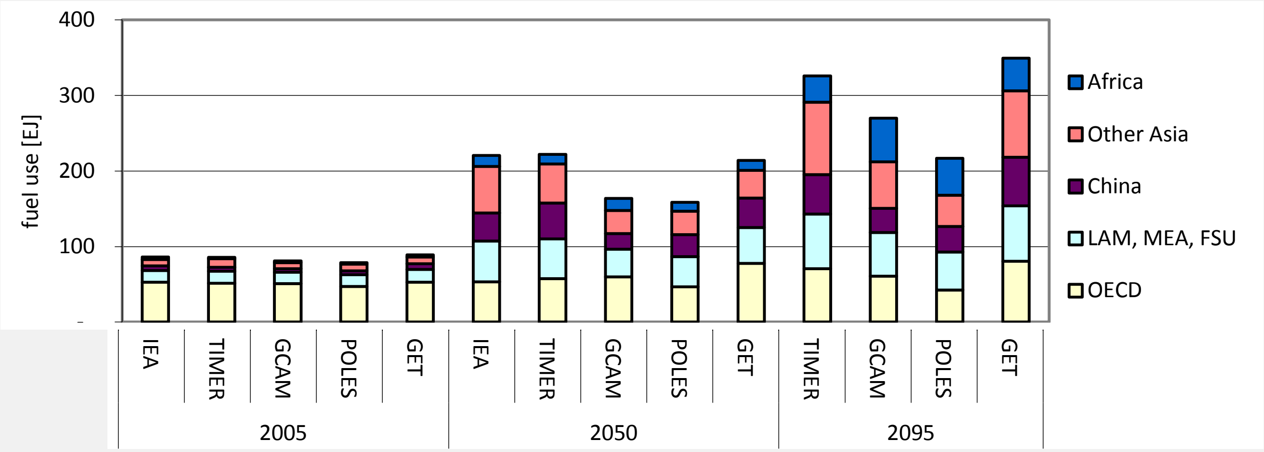
	travel				freight	
	bus	rail	car	air	rail	truck
	2005 [MJ/pkm]				2005 [MJ/tkm]	
IEA	0.50	0.30	2.05	2.54	0.09	2.82
TIMER	0.41	0.33	1.83	2.63	0.37	2.30
GCAM	0.86	0.70	1.65	1.70	0.21	2.48
POLES	0.56	0.17	1.69	1.06	0.16	2.76
GET	0.58	0.30	1.96	2.08	0.47	3.38
2005 to 2050 [average % change per year]						
IEA	-0.5%	-0.4%	-0.5%	-0.9%	0.5%	-0.5%
TIMER	0.9%	0.5%	-0.6%	-1.2%	-2.0%	-0.2%
GCAM	-0.5%	0.1%	-0.9%	-0.2%	-0.4%	-0.4%
POLES	-0.8%	-2.1%	-1.2%	-2.5%	-1.6%	-0.8%
GET	-0.8%	-0.2%	-0.8%	-1.0%	-0.4%	-0.6%
2045 to 2095 [average % change per year]						
TIMER	0.3%	0.5%	-1.0%	-0.5%	-0.3%	-0.6%
GCAM	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%	-0.4%
POLES	-0.4%	-0.5%	-0.7%	-1.0%	-0.5%	-0.5%
GET	-1.3%	-0.2%	-0.4%	-1.0%	-0.4%	-0.7%

Main findings:

- High energy intensity for car, truck and aviation
- Uncertainty in baseline due to occupancy data for non-OECD countries
- All models project high efficiency improvements in the baseline
- Fuel prices and changes in fuel mix explain most of the differences in efficiency improvements

Comparison of regional fuel use projections in the baseline scenarios

Regional fuel use projections for passenger transport and freight (excluding air and water freight). Note: Latin America (LAM), Middle East (MEA) and Former Soviet Union (FSU)



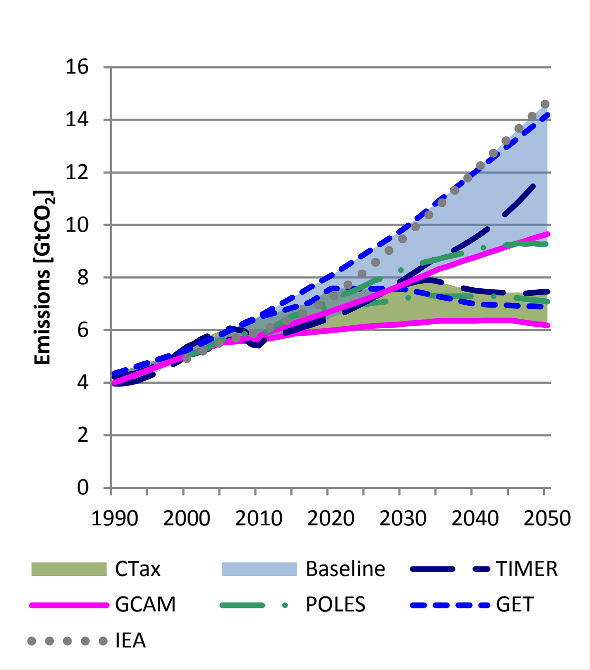
Main findings:

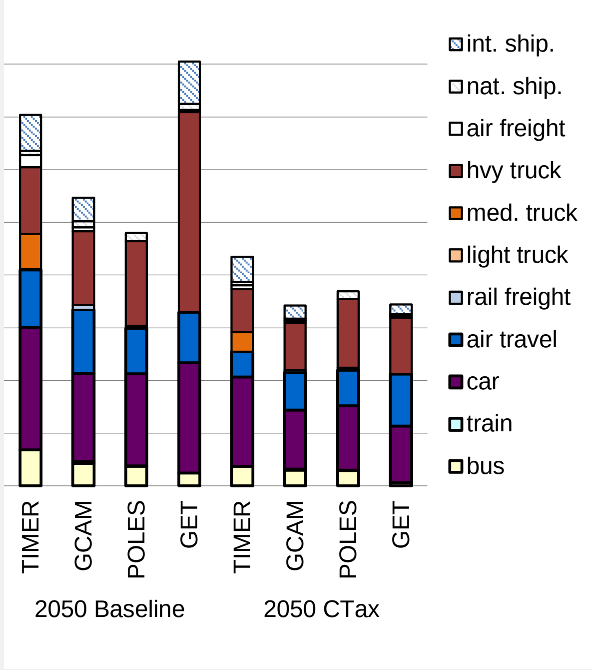
All model project

- stabilization or decrease of fuel use in OECD regions
- decline in the OECD fuel share from around 60 % to 20–23 % in 2050
- steep increase in non-OECD regions → they determine future fuel use
- Africa is projected to amount a similar or larger share of global fuel use than China in the end of the century

Comparison of projections for direct CO_2 emissions from transportation in baseline and mitigation scenarios

Projections for direct CO_2 emissions (1990 to 2050)
(excluding air and water freight)
Carbon tax: 0 in 2015 rising to 200 USD/tCO_2 in 2050





Main findings:

- overall responses similar, but differences where reductions are achieved
- Model with price sensitivity of service demand: significant reduction due to lower demand (especially bus and air travel, lesser extent for car due to high non-energy costs)
- Little contribution from mode shift
- POLES, TIMER: efficiency
- GET and GCAM: fuel mix change
- most reductions come from cars and heavy trucks

Conclusions from model comparison

- Increase in service demand drives total emissions in all models (annual growth of service demand is 2.1 to 2.9 % for travel, 1.8 % to 2.8%for freight, compared to 1.1% to 2.2 % for direct CO_2 emissions)
- Feasibility:
  - Global growth mainly due to non-OECD and approaching transport level observed today in the USA
  - Model consider available energy resources
- Main transport modes for global GHG emission are: cars, air travel, heavy truck (more than 70% in all models)
- Share of air travel in total emission increases, most pronounced in models that consider the increasing value of time costs for travel mode choices
- Other modes (e.g. rail) would be relevant for mitigation (mode shift), but little change in mode split with 200 USD/tCO_2 tax
- Improve understanding required for
  - Transport development in transition and developing countries (saturation level)
  - Response to carbon tax (service demand, mode shift, efficiency, fuel mix)
  - Alternative fuels and fuel prices

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Baseline projections: Service demand also highly sensitive by future changes in travel behavior

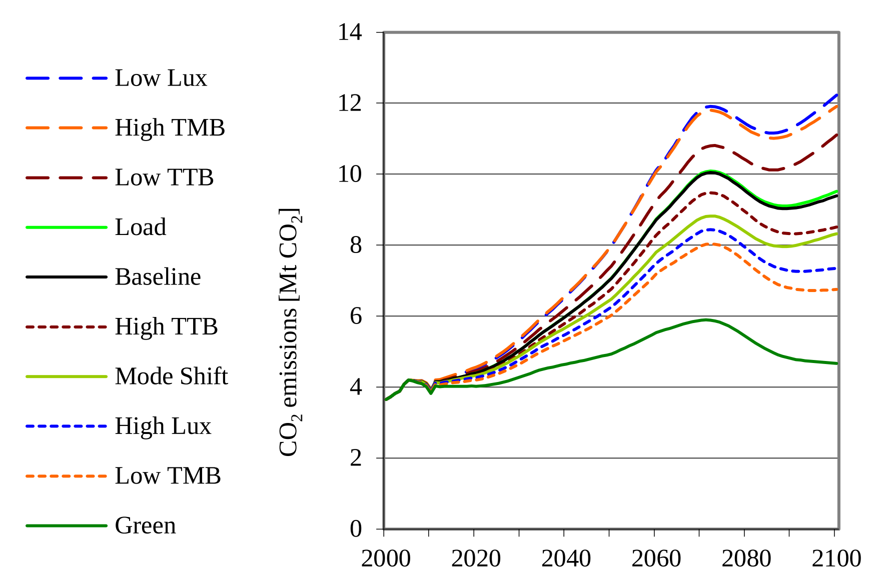
Research question:

Influence of changing travel behavoir: How will TTB, TMB, comfort level (TMB used for better instead of more), perferences and vehicle load evolve?

Approach

Variation in behavoiral variabels based on observed dynamics

Global CO_2 emission from travel for changes behavoiral variables of travel demand



Key finding

- High sensitivity for TMB, luxury level and TTB
- Rebound for load increase
- Combination of „green“ changes results in 50% lower emissions in the end of the century
- Adding a carbon tax of 200 USD per t CO_2 allows for 75% CO2 reduction

Low travel emissions in a B2-world

Article

Girod, B., van Vuuren, D.P., de Vries, B., 2013. Influence of travel behavior on global CO2 emissions. Transp. Res. Part A Policy Pract. 50, 183–197.

Mitigation scenarios: Learnings from “global travel within the 2 degree climate target”

Article

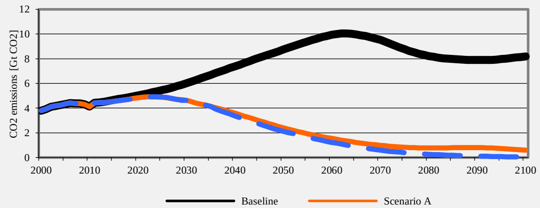
Girod, B., van Vuuren, D.P., Deetman, S, 2012. Global travel within the 2 degree climate target. Energy Policy 45, 152–166.

Exercise

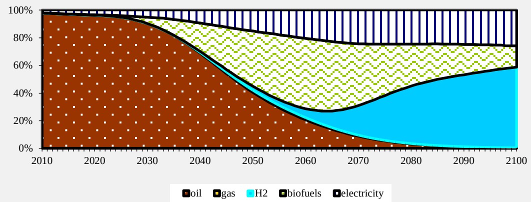
Force TIMER-travel not to exceed 20% of RCP2.6 emissions by increasing carbon tax
Scenario B: Account 30 g CO_2-eq./ MJ for biofuels

Results

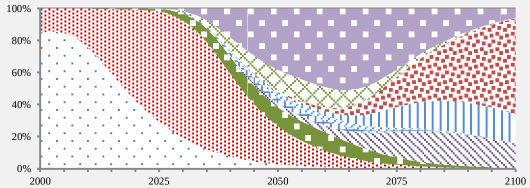
Emissions



Fuel use (scenario B)



Car composition (scenario B)



Finding

- RCP2.6 can be achieved with 280USD/t CO_2 in 2050, with zero emission biofuels.
- Else: > 480USD/t CO_2
- Key technologies
  - PHEV
  - Cryoplane
  - High-speed train
- Mode shift only with very high carbon tax because speed determines mode split
- The policy design matters: RCP2.6 achieved through vehicle incentive without reduction in travel deman[d]

Conclusion for trp. models

- Availability of **low carbon fuels** highly important
- Better representation of **dynamics for key technologies** (PHEV, Cryoplane, high-speed) including spillovers etc.
- Evaluate **potential of mode shift** (driven by infrastructure supply)
- Model impact of **alterantive policy types**: Vehicle emission incentives, tech-push, demand-pull policies, nudging (labels)

Carbon tax will not be the dominant policy design!

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Thank you for your attention

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