Making transport clean: cost-optimal decarbonisation options for the transport sector

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Why think about Transport?

Different models show very different behavior for transport!

Source: Own calculations for the RECIPE report 2009
Contents

The ReMIND Model

Transport in ReMIND

First results

Summary and next steps
Contents

- The ReMIND Model
- Transport in ReMIND
- First results
- Summary and next steps
Basics of the ReMIND model
Basics of the ReMIND model

- Ramsey Growth Model: Intertemporal maximization of log(consumption)
- 2005-2100 in 5 year time steps
- Fully coupled macro-economy and energy system in equilibrium
- Heterogeneous capital stocks in energy sector
- Includes technological change through "learning-by-doing": one-factor learning curve

Model Runs:
- Business-as-usual (no climate damages)
- Policy: 50% chance of staying below 2°C global warming (implemented through a 1000Gt CO2 budget from 2005-2100)
ReMIND: Top-Down and Bottom-Up

Macro side consists of constant elasticity of substitution (CES) functions

Energy System Model (ESM) side consists of linear energy-transforming technologies
Contents

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First results

Summary and next steps
Implementation of transport as TD/BU-hybrid

Idea: mixture of CES functions and vehicle technologies
Implementation of transport: Details

Cluster learning:
Different vehicle technologies use the combined cumulative capacity for batteries:

One battery learning stock

Lithium Battery:
Starting cost: 1100 $(2009)/kWh  Learn rate: 15%
Floor cost: 275 $(2009)/kWh

Chronological technology ordering:
Hybrid vehicles > plug-in hybrid electric vehicles (PHEVs)
PHEVs > BEVs
First results: Passenger transport

Transport volume and modal shares:

Bau

Pol: ~50% to reach 2°C

Small volume reduction (~15%)

Natural gas and gasoline hybrids come in after 2050

Air travel strongly reduced, partially replaced by rail
Reality check: History and ReMIND results

Fuel production

Production of middle distillate (used for diesel and kerosene)

- **Bau**:
  - Middle distillate refinery
  - Biomass FT (OT)
  - Biomass FT (REC)
  - Biomass FT (OT)+CCS
  - Biomass FT (REC)+CCS
  - Coal FT (OT)
  - Coal FT (REC)
  - Coal FT (OT)+CCS
  - Coal FT (REC)+CCS
  - Crude oil refinery

- **Pol – 50% 2°C**:
  - Middle distillate refinery
  - Biomass FT (OT)
  - Biomass FT (REC)
  - Biomass FT (OT)+CCS
  - Biomass FT (REC)+CCS
  - Coal FT (OT)
  - Coal FT (REC)
  - Coal FT (OT)+CCS
  - Coal FT (REC)+CCS
  - Crude oil refinery

➤ Total demand for middle distillate is reduced after 2050
➤ Emission reduction is mainly achieved by the replacement of coal Fischer-Tropsch with biomass-FT with CCS
Biomass as main driver?

Changing Biomass availability in 50% 2°C policy runs

Strong effects:
- First BEVs, then H2FCV enter
- Further reduction of air travel
Levelized Costs of Transport

Pol – 140EJ/a Bio

Rising fuel prices for fossils vs. learning for batteries
Contents

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First results

Summary and next steps
Main Takeaways

• Important to consider all scarcities (primary energy, carbon emissions) across the whole energy system, as well as intertemporal effects (technology learning)

Preliminary modeling results:
• Under equal carbon pricing in all sectors, vehicle technologies seem to be minor contributors to decarbonization
• Biomass is a key factor of decarbonizing the transport sector
• Little change in modal shifts, except for decrease of aviation under climate policy

➡️ Reality Check?
Main issues:

- ReMIND is a cost-driven model that optimizes consumption.
- Real-life transport decisions are influenced by many factors:
  - Transport and Land Use policies
  - Habituation and life styles
  - Infrastructure
  - Consumer preferences, early adopters

Possibilities to include "soft factors" and policies:

- Change efficiencies between BAU and POL world to represent changes in land use/infrastructure planning.
- Implement direct feedback of different transport modes to welfare.

Problems of transport modeling


### Car use in cities with incomes of 20-30kUS$

<table>
<thead>
<tr>
<th>City</th>
<th>Share of Private Trips Made by Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hongkong</td>
<td>20%</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>30%</td>
</tr>
<tr>
<td>Berlin</td>
<td>40%</td>
</tr>
<tr>
<td>London</td>
<td>50%</td>
</tr>
<tr>
<td>Sydney</td>
<td>70%</td>
</tr>
<tr>
<td>Houston</td>
<td>90%</td>
</tr>
</tbody>
</table>
Future developments of transport model 1

Old

Transport

Freight

Passenger

Land-based

Aviation

Bus

Car sd

Rail

Car ld

Bus

ICE

hybrid

BEV

New

Transport

Freight

Passenger

Urban

Intercity

Bus

Bike

Car

Tram

Bus

Car

Rail

Plane

ICE

hybrid

ICE

hybr

BEV

H2

ICE

hybr

BEV

H2

σ = 0.5

σ = 1.0

σ = 2
Thank you for your attention!

Please share your thoughts on this work-in-progress