2012 Energy Storage Symposium

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Long-Term Transformation of Transportation
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ECN and Columbia University
Hydrogen versus electricity

• Which energy carrier should we ultimately use in the transportation sector: hydrogen or electricity?
• Main purpose of our study: which of these two types will / should dominate under stringent climate control?
• Our approach: bottom-up energy systems modeling (Hilke Rösler, Ilkka Keppo and Jos Bruggink, funding from NWO ACTS sustainable hydrogen program).
• Are high oil prices enough to transform transportation away from fossils to either of these two options?
Why these two options?

• Currently electric cars appear the great short- and long-term promise for the transport sector.
• But only a decade ago, hydrogen-fuelled cars enjoyed similar popularity as the electric car today.
• We wanted to understand better the rationality behind the “hype cycle” between fuel cell and battery cars.
Why no other options?

• Reservations on global and European applicability of large-scale use of biofuels (costs, emissions, import dependence, food supply, and biodiversity loss).

• Continued reliance on carbonaceous fuels may be possible in a climate-constrained world, by the use of air capture, but technologies in an (early) R&D phase are difficult to handle in energy system engineering models, given the large uncertainties involved.
TIMES and MARKAL

• At ECN, we have extensive experience with TIMES models and their predecessor MARKAL version, and recently chose TIAM because of its global coverage.
• We reduced, refined, improved and updated TIAM to obtain a global model fit for our specific purposes, including with regards to transportation: TIAM-ECN.
TIAM-ECN: structure
TIAM-ECN: features

• Bottom-up energy system cost minimization model.
• Many energy technologies in all main sectors.
• Particular strength in power and transport sector.
• Special module to reflect main climate dynamics.
• Global coverage with regional disaggregation.
TIAM-ECN: Europe
Car types and specifications

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Assumptions for car types simulated in TIAM-ECN.
Car cost assumptions: baseline

Development of investment costs in TIAM-ECN for the four main types of passenger cars of our present interest.
Oil price pressure

Energy use by fuel type (in PJ/yr) for passenger cars in Europe when oil prices are 100 $/bl and 150 $/bl.
Climate control

- Earlier work focused on timing of mitigation (globally and in Europe) in the transport sector.
- Emission abatement pathways, although already ambitious, were not yet as stringent as EC targets.
- Now we impose 20% reduction of CO$_2$ emissions in 2020 and 80% in 2050 with respect to 1990 levels.
Stringent climate control

Energy use (PJ/yr) and distance travelled in vehicle km (G(v)km/yr) by fuel type for cars in Europe under stringent climate policy (100 $/bl oil).
Learning curves for PEM fuel cells

PEMFCs in transportation

Learning curves for SOFCs

SOFCs in different stages

Economies-of-scale, automation, and learning-by-doing are disaggregated.

Improvements for batteries

• To our knowledge no learning curves have so far been published for battery manufacturing.
• Batteries are mature technologies that have been around for decades.
• Yet progress is likely on multiple fronts (lifetime, charging time and capacity density) including costs.
• What are, in our framework, the battery cost improvements necessary for electric cars to dominate?
Battery cost decreases

Distance travelled by fuel type for cars in Europe under stringent climate policy with varying battery cost reduction profiles, relative to the baseline.
Ultra-stringent climate control

Distance travelled by fuel type for cars in Europe under an even more stringent climate policy.
Sensitivity analysis

We performed extensive tests on the robustness of our results with respect to many of our assumptions, including:

- Fuel cell cost reductions prove disappointing.
- Fossil fuel reserves prove limited.
- Lifetime of cars deviates from our central value.
- Diffusion rates of new car types prove lower.
- Certain energy technologies prove limited, including nuclear and CCS (affecting both H₂ and electricity).

While our final results change under these varying assumptions, our main conclusions continue to hold.
Conclusions

• High oil prices alone will not be able to soon transform the transport sector away from fossil fuels.
• Ambitious climate control (in combination with high oil prices, or not) CAN achieve such a decarbonization.
• From an economic perspective hydrogen appears the winner, unless battery costs are reduced substantially.
• Of course, non-economic factors may ultimately be at least as important as costs: infrastructure / networks, travelling distance, consumer preferences, safety, etc.
• Perhaps co-existence, e.g. for different travel ranges.
Working papers


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Wednesday, May 2 – Thursday, May 3, 2012
Columbia University