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International Transport/Energy Model Comparison Project (iTEM)

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RESEARCH BRIEF
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International Transport / Energy Model Comparison Project (iTEM)

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Summary

This brief outlines an effort begun by the above five organizations to jointly carry out a systematic comparison of transport models that they operate and help maintain (ICCT Roadmap, IIASA MESSAGE, PNNL GCAM and IEA MoMo, with ITS-Davis involved in running and contributing data for comparisons both for GCAM and MoMo). These models, data used in these models, and specific transport/energy scenarios created with these models are being compared. Additional organizations/models could be added in the future. This brief proposes a specific project for funding to continue to make progress in this effort.

Project description, preliminary results, and proposed next steps

In this pilot project, four organizations have preliminarily compared their global transport models to check for similarities and differences in in terms of data sources, assumptions, baseline projections and underlying model structures. The main goal is to better understand how these differences affect the projections and scenarios created by these models and to improve and better align data/assumptions where it makes sense to do so. To date we have made initial progress in comparing base data and projections, but without yet investigating underlying model differences in any detail. We have only partial answers to questions such as: what do these models tell us in a robust fashion about future transport trends and how to achieve sustainable transport futures? How can these models be improved and aligned where appropriate? This research brief shows our progress and outlines our proposed next steps, which will need additional resources to proceed with (described further below).

Preliminary results

Two figures are shown below with some preliminary results of our comparisons. Figure 1 shows the overall transportation fuel use projections to 2040 for the four models being studied, under their "base case" scenarios. Other available projections such as from EIA, Shell and Exxon, are also included for comparative purposes. Most of these models show growth to around 150 Exajoules (EJ) by 2050 but this ranges widely - from 130 to about 200 EJ across models.

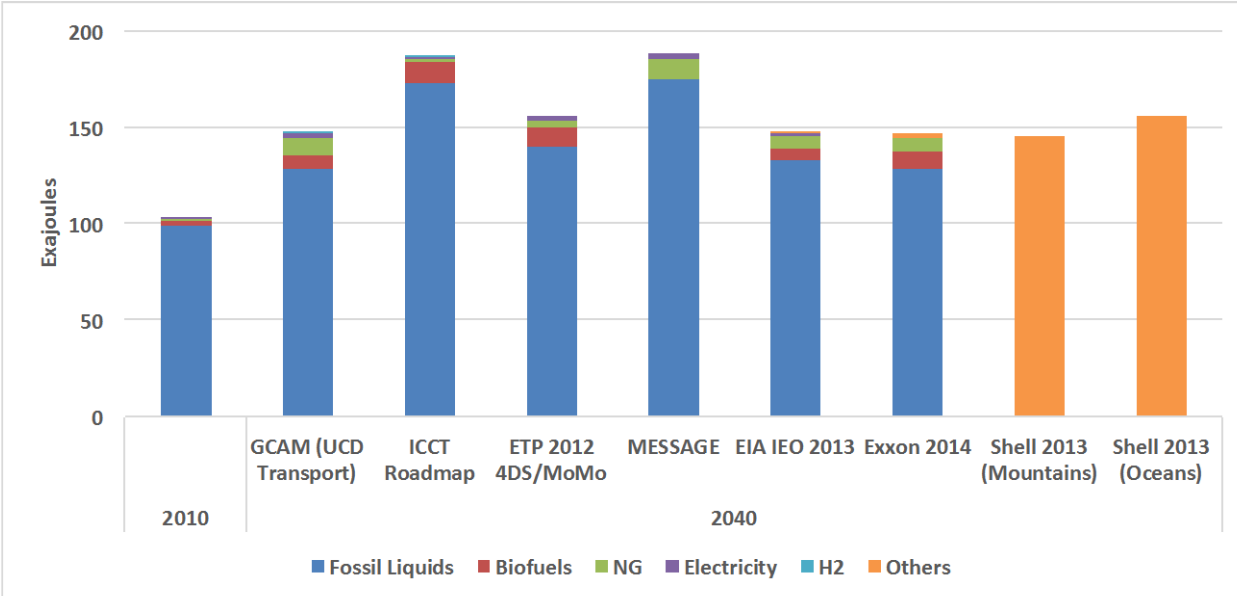

Figure 1. Global transportation projections by fuel type in 2040 across 10 global models

On a regional basis differences across model projections are even more pronounced (figure 2). This reflects variations in fundamental assumptions about the future and projections of key drivers of transportation demands (e.g. income, car ownership growth). However, a detailed comparison with techniques such as decomposition analysis has not yet been undertaken.

The value of continuing this work

As the countries and regions around the world start to implement carbon policies via various policy tools, it is vital to better understand what mitigation can be achieved in the transportation sector, what are realistic and cost- effective pathways and policies to reach agreed targets, and how consumers might respond to the various policy tools in terms of behavioral changes. While transport does not have any official target under the UN Framework Convention on Climate Change (UNFCCC) or other major international agreements, previous studies indicate that if targets like 2°C are to be achieved the global transport sector must begin to embrace long-term emission reduction goals and steps for achieving them. There are a range of different models that have attempted to quantify, with somewhat varying results, the mitigation potential of transport. This project brings key models and modelers together to examine what makes their projections and scenarios similar and different, and to better identify areas of agreement and how a more common outlook can be created.

The iTEM project is motivated by the increasing visibility and use of these models in policy making and target-setting, as well as concerns over differences in projections and findings, which can lead to varying recommendations that may be confusing to policy makers. While some differences are useful, creating a better understanding of how and why these models and projections are different – as well as where possibly better aligning them and creating a common viewpoint on things like targets and needed policies, these organizations realize they can much better inform policy.

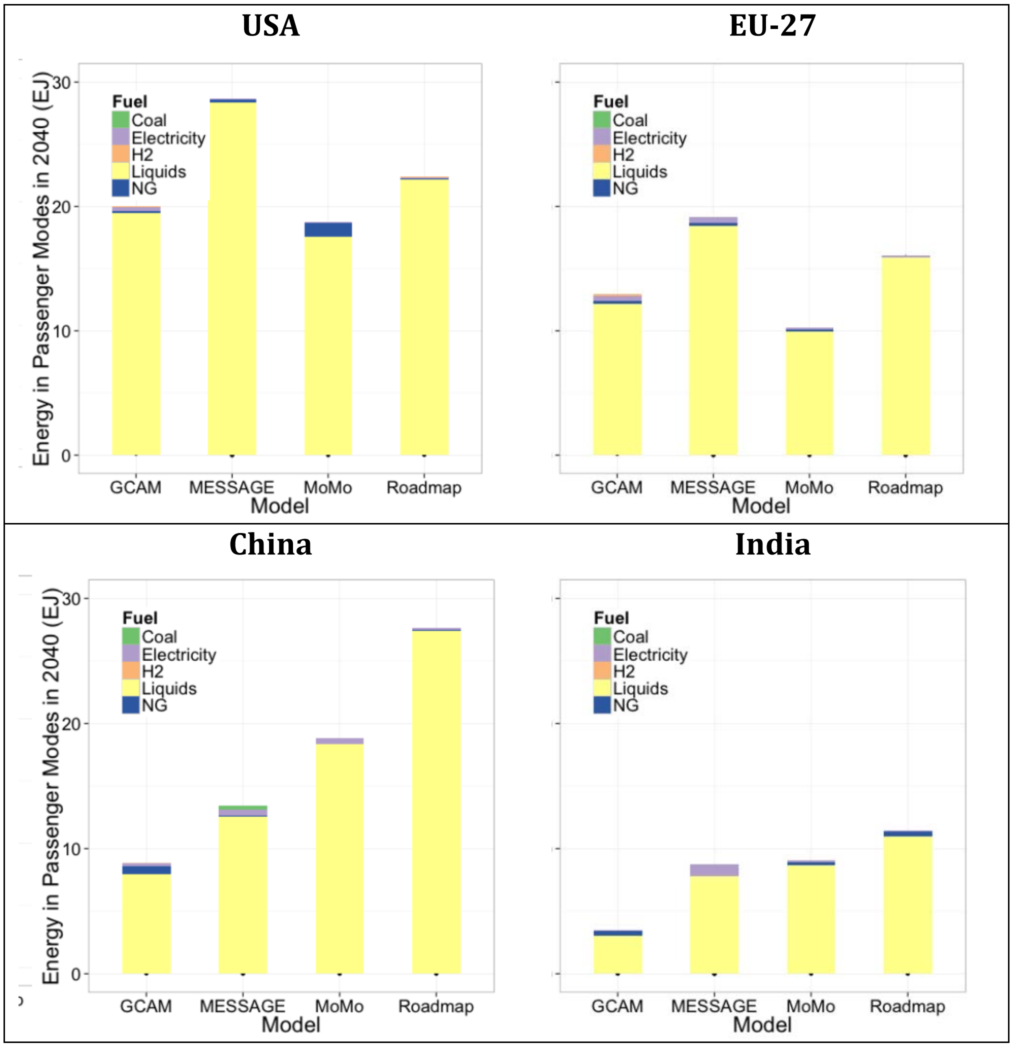

Figure 2. Comparison country/regional transportation projections by fuel type in 2040

Next Steps – project proposal

The modeling groups jointly propose the following next steps:

1) Compare and identify specific differences in underlying assumptions and methodologies. Rerun projections with aligned socio-economic assumptions (population and GDP). (Q1-2, 2014)
2) Workshop of key stakeholders to present and critique results. Identify other assumptions that may be aligned. (Q2 2014)
3) Re-run projections with aligned assumptions. Compare and document projections. (Q2-3 2014).
4) Document differences in projections, underlying assumptions and methodologies. Recommend policy implications. (Q4 2014).

As a very rough estimate, this effort is expected to take 3-4 person months per agency, plus the cost of conducting one workshop and preparation of reports and dissemination of results. This could be completed during 2014 if started early in the year. The organizations involved welcome expressions of interest to be involved and to support this effort.

Annex: Brief Description of the Models

MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact), developed by the International Institute for Applied Systems Analysis (IIASA) in Austria since the 1980s, is a systems-engineering optimization model used for the planning energy systems in the medium to long term, analyzing climate change and other energy/environmental policies, and developing global scenarios (Riahi, Dentener, et al. 2012). MESSAGE is linked with an aggregated macro-economic model, MACRO, to capture the impact of energy price changes and investments consumption, GDP, and energy demand (Messner and Schrattenholzer, 2000). The transport module of MESSAGE-MACRO operates within this combined optimization framework (in order to make vehicle and fuel choice decisions), while the mode-switching algorithms (i.e., passenger demand split between cars, buses, trains, etc.) are based on logit functions, which are more typical of simulation models. Critical recent developments in the area of transport modeling include adding algorithms which take into account travel time and travel money budgets when making mode choice decisions and also for determining total levels of passenger service demand.

The IEA **Mobility Model (MoMo)** is a spreadsheet model developed in Microsoft Excel aimed at estimating and projecting travel indicators, energy consumption, pollutant emissions and greenhouse gases generated for worldwide mobility (Fulton, Cazzola, et al. 2009). It is a technology-rich model, focused on allowing the user to create scenarios with different types of vehicles, fuels, efficiency levels, and travel levels. The model does not feature considerable detail on travel behavior, but uses some basic indicators (such as vehicle ownership around the world as a function of income growth) to drive projections. However the model does have high resolution on travel by mode and can be used to analyze specific “mode shift” scenarios for their impacts on energy use, CO_2, and costs. The model tracks all energy use for all transport modes (except pipeline energy), worldwide, divided into 33 countries/regions. The model is a “what-if” style accounting model based on the “ASIF” (Activity/structure/intensity/Fuel) identity. Projections are either based on the separate IEA AEO model or developed as backcasts to reach a specific target. The model contains two elasticities (income and fuel cost) that can be used for income/price-related analysis but not used in this iTEM project.

The **Roadmap** model has been developed by the ICCT since 2010 for the purpose of estimating current and future well-to-wheel emissions and energy consumption from the transport sector under different policy scenarios. The model was built from the ground up using the best available data from public sources and in-country partners, with much of the data for aggregate regions coming from the IEA's SMP model, and later, MoMo. The model was developed to assess transportation systems in the top eleven vehicle markets and in five aggregate regions, allowing for global analyses that are based on up-to-date policy information and take into account administrative and technical considerations of implementing new policies.

The GCAM-UCD_Transport is the new transportation module in the Global Change Assessment Model (**GCAM**), developed and maintained by Pacific Northwest National Laboratory (PNNL). GCAM is a global integrated assessment model that includes energy, land use, agricultural, forestry and a climate model (Brenkert et al., 2003; Clarke et al., 2008). The code for the transportation module was developed in 2005-2006 by Sonny Kim; the data for the first global model was developed by Page Kyle in 2009; and the current implementation was developed by Gouri Mishra and Page Kyle in 2012-2013 (Mishra et al 2013). The GCAM model is a global, dynamic-recursive, economic equilibrium model that solves in five-year time steps to the year 2095. The transportation sector is divided into passenger and freight services, and the market shares of new technologies are determined based on a nested logit choice mechanism that allows technologies to compete based on costs that include vehicle, fuels, and value of time.

High-level comparison of model structures

Models can produce similar or different projections because of differences in model design, scope, scenario definitions, behavioral assumptions, parameter estimates, exogenous drivers and projections of those drivers, and the structures (such as variable linkages and feedback loops) within the models. Some models explicitly optimize on cost, some use an economic equilibrium approach, some use a disaggregated, bottom-up scenario-based approach. There are strengths and weaknesses in all these approaches, and by comparing models and scenarios produced with these models, much can be learned and the range of projections may in fact be narrowed, agreements on policy impacts achieved, and other insights gained. The following tables summarize key aspects of each model.

Table 1. Basic comparison of model system boundary, resolution, and structure

	GCAM	MESSAGE	MoMo	RoadMap
Regions	14 regions	11 regions	33 countries/regions	
Sectors covered	Transportation is part of an IAM that includes all energy sectors plus land use, forestry, agriculture, and a simple climate model (without feedback mechanism)		Transportation only	
Solution mechanism	Partial equilibrium simulation based model.	Systems-engineering optimization model combined with a macro-economic model and logit mode choice functions.	The model is a “what-if” style accounting model based on the “ASIF” (activity/ structure/ intensity/ fuel) identity.	
Modes of passenger travel	Walking, bicycle, bus, rail, car, truck, two- and three-wheelers (in selected regions), and air (split into short-distance and long-distance).	Light-duty vehicles (cars and trucks), bus, rail (high-speed train, regional train, tram, metro), two-wheelers, airplanes	Light-duty vehicles (cars and trucks), bus, rail (high-speed train, regional train, tram, metro), two-wheelers, airplanes	2&3-wheelers, light-duty vehicles, buses, passenger rail, passenger aircraft. (excludes off-road).
Freight	Trucks, rail, air, international shipping, and domestic shipping by inland waterways	Trucks, freight rail, freight air, international shipping, and domestic shipping by inland waterways	Trucks, freight rail, freight air, international shipping, and domestic shipping by inland waterways	Light-, medium-, and heavy-duty trucks, freight rail, and freight waterborne vessels (domestic and international).
Infrastructure	Not explicitly modeled	Not explicitly modeled	Road/rail Infrastructure required to accommodate traffic growth and the likelihood that this rate of infrastructure growth can be sustained in different countries are estimated and tracked.	Not explicitly modeled

Table 2. Comparison of models drivers and feedback

	GCAM	MESSAGE	MoMo	RoadMap
Socioeconomic Factors and Demand Drivers				
GDP	Ex	Ex	Ex	Ex
Population	Ex	Ex	Ex	Ex
Passenger service demand	En	En	En	En
Freight service demand	En	En	En	En
Mode share	En	En	En	En
Fuels and Vehicle Technologies				
Fuel prices	En	En	Ex	Ex
Energy intensity of fuel production	En	En	Ex	Ex
Shares of fuel types within modes	En	En	Ex	Ex
Efficiency levels of individual technologies	Ex	Ex	En	Ex
Efficiency levels within service, mode, fuel type	En	En	En	En
Consumer behaviors				
Average transit speed	Ex	Ex	n.c	n.c
Travel time budget (mode choice)	Wage rate and mode-specific time value multipliers determine value of time in transit of each mode	Wage rate and mode-specific time value multipliers determine value of time in transit of each mode	n.c	n.c
Travel money budget (mode and technology choice)		X (travel money budget grows with income)	n.c	n.c

En: Endogenous, results are calculated by the models or by authors based on exogenous drivers; Ex: Exogenous, values taken directly from external sources; ExF: Exogenous with feedbacks; NC: Not considered

Sources of Model Documentation

GCAM

- Kyle P, Kim SH (2011) Long-term implications of alternative light-duty vehicle technologies for global greenhouse gas emissions and primary energy demands. Energy Policy 39:3012-3024.
- Girod, B; van Vuuren, DP; Grahn, M; Kitous, A; Kim, SH; Kyle, P. 2013. Climate impact of transportation A model comparison. Climatic Change 118:595-608
- Mishra, G.S., Kyle, P., Teter, J., Morrison, G.M., Kim, S.H., Yeh, S., 2013. Global Transportation Demand and Fuel Use in the new Shared Socioeconomic Pathways (SSPs). Manuscript in preparation.

MESSAGE

- Riahi, K., F. Dentener, et al. (2012). Chapter 17 - Energy Pathways for Sustainable Development. Global Energy Assessment - Toward a Sustainable Future. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria**:** 1203-1306.
- Messner, S., and L. Schrattenholzer (2000). MESSAGE-MACRO: Linking an Energy Supply Model with a Macroeconomic Model and Solving It Interactively, Energy, 25, 267-282.

MoMo

- Fulton, L., P. Cazzola, et al. (2009). "IEA Mobility Model (MoMo) and its use in the ETP 2008." Energy Policy **37**(10): 3758-3768.

RoadMap

- Documentation and model available at: http://theicct.org/roadmap-model#
- Report available at: http://theicct.org/global-transportation-energy-and-climate-roadmap

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NextSTEPS Program website: www.steps.ucdavis.edu