ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

Summary of International Transport Energy Modeling Workshop (October 2nd, 2014)

The NextSTEPS program at ITS-Davis convened a one-day workshop on international transportation energy modelling (iTEM), focused on comparing the frameworks and scenario projections from four major global transport models:

- Global Change Assessment Model (**GCAM**) by Pacific Northwest National Laboratory (PNNL) and ITS-Davis,
- **MESSAGE-Transport** (Model for Energy Supply Strategy Alternatives and their General Environmental Impact) by the International Institute for Applied Systems Analysis (IIASA),
- Mobility Model (**MoMo**) by the International Energy Agency, and
- **Roadmap** by the International Council on Clean Transportation (ICCT).

Highlights:

- Projections of "baseline" global transportation energy use rise from 98 EJ in 2010 to 160-250 EJ by 2050.
- There are considerable differences in historical data for some modes, both globally and for individual countries (particularly non-OECD countries). Variability in estimates of transportation activity are in most cases much larger than energy differences.
- Global average vehicle ownership rates are projected to range from 270 to 450 per 1,000 people by 2050 with wide ranges across countries: 700 – 1,075 for the US by the middle of the century (US is around 700 today), 100 – 650 for China, and 80 – 380 for India across four models.
- All models rely mainly on GDP to estimate the future demand for freight and hold the base year modal shares (e.g. truck v. rail) roughly constant through 2050. In reality, future evolution will depend on characteristics of products (e.g. type of commodities) being shipped, technologies available for freight and their efficiencies, and policies and infrastructure.
- Current policy commitments toward EVs, PHEVs and H2FCVs (and thus baseline projections) maybe below the numbers suggested by iTEM models as required for meeting climate targets (e.g., 2°C).
- Improvements in data quality and the representation of car ownership and use across the models were identified as priorities.

Modeling transport energy use can either be done by estimating how far people travel and what mode of transportation they choose or by estimating how many vehicles there are and how far each one travels. These are complementary approaches, and in theory they should both lead to the same answer. The former approach, used in "service demand" models, seem more intuitive when one wants to model societal shifts in modes of transportation, either in emerging economies as they develop or in developed economies as they decarbonize; but collecting data on service demand is notoriously difficult. In contrast, vehicle stock models use readily-available vehicle sales data, but are harder to use in future-state, what-if scenarios (particularly in estimating modal shift behaviors) and thus require special attention by experts.

The four iTEM models are different in terms of scope (GCAM and MESSAGE cover all sectors of the energy system vs. MoMo and Roadmap which cover transportation only) and model structure (GCAM and MESSAGE rely on internal drivers, particularly the costs of technology and travel, to project future changes whereas MoMo and Roadmap rely on experts' judgments and detailed analysis of technology and policies to drive long-term changes). Yet, owing to these differences, the models are highly complementary and in some cases can be used jointly to answer questions that no single model can tackle on its own.

The following summary shares some of the comparisons and findings from the workshop.

BASE YEAR (2010)

A key finding of the workshop is that there are considerable discrepancies in historical data in some areas, both globally and for individual countries (particularly China and India). There are many reasons for data discrepancies across models. Calibration to different sources of historical data, or different versions of the same source (specifically the IEA Energy Balances) partly account for differences in global transportation fuel consumption at an aggregate level (around 12 EJ or 10%). Models also make independent assumptions to disaggregate IEA energy balances to individual modes – for example road energy may be allocated to some combination of LDVs, two and three-wheelers, buses, and freight trucks. As a result, mode specific differences are much larger, especially for developing regions where there are relatively few data points for calibration to reconcile the differences.

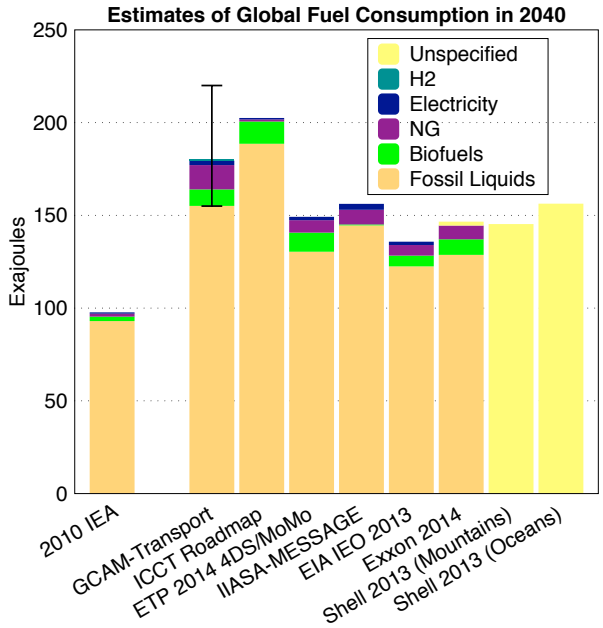
Variability in estimates of transportation activity – vehicle kilometers traveled (VKT) or service demand –

passenger kilometers traveled (PKT), and tonne-km for freight – are often much larger than energy differences. For example, estimated global passenger travel in buses ranges from 6 to 20 trillion PKT across the four iTEM models. Similarly, estimates of global road freight ranges from 9 to 18 trillion tonne-km. These differences reflect differences in model input parameters specifically (a) load or occupancy factors, (b) vehicle kilometers traveled per vehicle, and/or (c) the number of vehicles in operation.

Uncertainty in these input parameters is much higher for developing regions like India where there are no nation-wide travel surveys, systematic traffic counts or vehicle odometer readings, or a disciplined database of on-road vehicles. At the iTEM workshop, it was suggested that for such regions, new types of data may be useful, such as "big data" sources (e.g. smart phone based activity data). More work is needed to identify and integrate such data into databases.

GLOBAL/REGIONAL PROJECTIONS to 2050

Figure below shows the projected global transportation fuel consumption across four iTEM models as well as key projections for 2040 from the Energy Information Administration (EIA), ExxonMobil and Shell. The uncertain bar represents GCAM's estimates across different assumptions of population and GDP growth. Across the iTEM models, global transportation fuel consumption in a "reference" or "baseline" projection is projected to grow by anywhere from 1.5x to 2.5x the 2010 level to reach 160-250 EJ by 2050. All models



project continued importance of liquid fuels – both fossil and bio based – and dominance of developing regions, which account for around two-thirds of consumption by 2050 from around half today.

Some of the variation in projected growth of transportation fuel consumption may be explained by differences in assumed growth in income (per capita GDP) – historically the key driver of vehicle ownership and travel. For example, China's per capita income in 2050 is assumed to range from US$ 25,000 to US$ 42,000 (2005 Dollars, measured in purchasing power parity).

For large regions like China, variation at the sub-regional level in current and projected income, urbanization rates, vehicle ownership, levels of infrastructure, types of industry, etc. – may add values to analysis at a provincial level. Similarly, modeling strata of demographic groups can provide better understanding of vehicle ownership levels, travel behavior, response to GDP growth and policies, etc. Better regional and demographic detail could improve the capacity of each the four iTEM models to predict policy impacts.

LDV and TWO-WHEELER PROJECTIONS

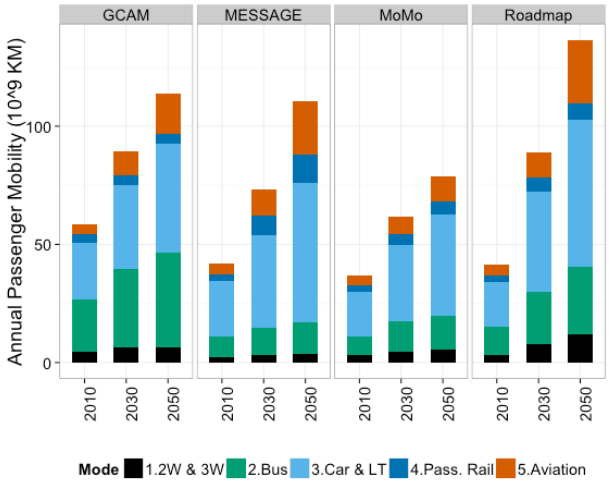
Perhaps one of the largest uncertainties in projecting future fuel use is level of vehicle ownership and use. Globally, baseline projections of global car ownership rates (number of vehicles per 1,000 people) increase from around 150 in 2010 to 270 – 450 in 2050. This implies a growth in on-road stock from around 1 billion to 2 – 4 billion cars in 2050, when the world will have about 10 billion people.

Population and income growths are the key drivers of this expected increase in car ownership, though some models predict ownership as a function of total travel while others estimate it directly from basic population and income data. There are wide ranges across countries: 700 – 1,075 for the US by the middle of the century (US is around 700 today), 100 – 650 for China, and 80 – 380 for India across four models. Modeling saturation in vehicle ownership and use as a function of income distributions, urban form, and infrastructure requirements and constraints, was discussed as an important enhancement that could be made to these models.

The amount of travel per vehicle per year also proved a significant source of uncertainty. For some countries, models had widely varying assumptions for annual vehicle travel, especially for certain vehicle types (e.g. anywhere from 3,000 to 10,000 km per year for motor

scooters in India). These assumptions link the vehicle stock to total activity and fuel use and need to be better understood. Improving the representation of car ownership and use across the models was identified as a priority, perhaps second only to data improvements.

The figure below shows that passenger mobility across all modes is projected to grow by 2x – 3x, with aviation growing the fastest.



FREIGHT PROJECTIONS

All four iTEM models rely on GDP forecasts to project the future demand for freight. Regions have very different starting points for modal shares (trucks vs. rail vs. ship), and projections across the four iTEM models tend to hold the base year modal shares roughly constant through 2050. In reality, future evolution will depend on the characteristics of products (e.g. type of commodities) being shipped, availability of efficient freight technologies, and development policies and infrastructure. For example, policies can affect the type of fuel used (e.g., the upcoming MARPOL Annex VI on regional and global marine fuel oil (HFO) and marine diesel fuel use), as well as commodities transported domestically (e.g., reduced coal use in China to improve air quality and reduce GHG emissions) and internationally (e.g., liquefied natural gas (LNG) and oil exports from US).

CLIMATE and ENERGY POLICY ANALYSIS

Three iTEM models (all except GCAM) submitted a scenario which is consistent with the deep economy-wide decarbonization needed to reach a 2 °C / 450 ppm target by the end of the century. Comparing the results of policy impacts from multiple models with different solution mechanisms can improve confidence when similar outcomes are identified across models. The overall magnitude of transport emissions reduction estimated by iTEM models is consistent with the ranges found by the literature assessment of the IPCC AR5 WGIII, however the iTEM models provide better insight regarding the regional-level policies and measures necessary to mitigate in a manner that is consistent with the global goals. For example, a comparison of iTEM results with current and planned policies suggests that in order to be consistent with the global target of 2 °C / 450 ppm the fleet average (stock) efficiency target for light-duty vehicles should be around 2.0 MJ/km (1.8 – 2.1) for the US and 1.6 MJ/km (1.5 – 1.7) for China in 2030 and 1.4 MJ/km (1.3 – 1.5) for US and 1.3 MJ/km (1.1 – 1.5) for China in 2050[1] in order to achieve emissions pathways consistent with a 2 °C / 450 ppm target. Current and proposed fuel economy standards for new light-duty vehicles in US and China are more or less in line with these increasingly stringent targets, so long as the standards continue to be tightened after 2020/2025.

Another policy insight, as shown in the table below, is the comparison between existing policy commitments for zero-emission vehicles (ZEVs) and partial ZEVs (plug-in hybrid vehicles and hydrogen fuel cell vehicles) and the projected levels that the models suggest need to be on the road by 2020/2025 in order for the transport sector to be consistent with the 2 °C target. This comparison, shown in the table below, suggests that the current policy commitments toward EVs and PHEVs for 2020/2025 maybe below the number of vehicles suggested needed in 2025 by iTEM models.

	China	USA	Global
iTEM	28 million *(2 – 47)*	29 million *(9 – 42)*	113 million *(35 – 180)*
Policy/ Target	5 million by 2020[*]	1 million EVs by 2015[+] 3.3 million by 2025[++]	~20 million by 2020[#]

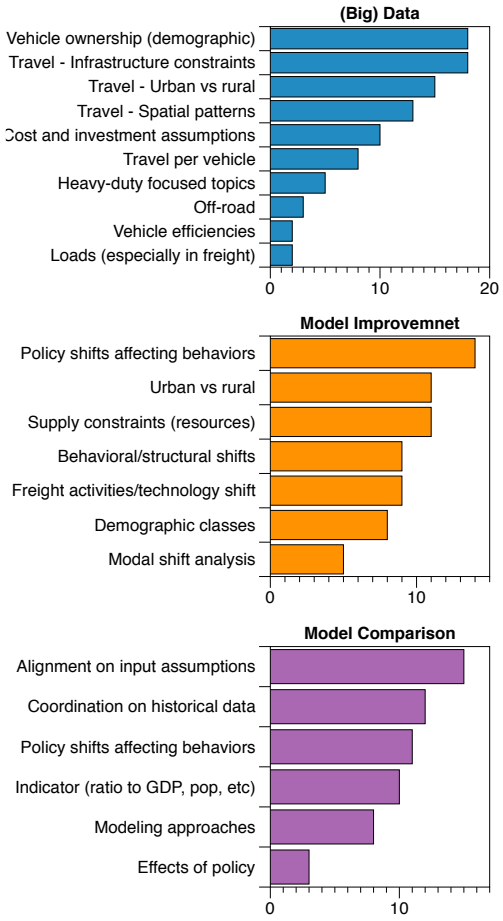
[*] Indus. Dev. Strat. Plan; [+] President's pledge; [++] MOU, 8 states; [#] IEA EVI

In general, the modeled low-carbon scenarios entail much more aggressive market uptake of EVs than targeted by policy commitments to date. This points out the need for stronger, coordinated policies to realize the combined mitigation potential of fuel economy standards and ZEV targets in both the near-term and long-term.

[1] 2 MJ/KM is equivalent to 45.7 miles per gasoline gallon equivalent (mpgge), and 1.3 MJ/KM is roughly equivalent to 70.4 mpgge.

SURVEY of RESEARCH PRIORITIES

A survey was conducted at the end of iTEM workshop seeking inputs for key research priorities in the areas of (big) data collection/development, model improvement, and model comparison. Each participant cast up to two votes in each category, and the results are summarized in the following bar graphs. Overall, experts see importance in improving the quality and the availability of data, as well as making improvement in model structure to enhance our capability of making better projections, especially vehicle ownership and travel behaviors. In future model comparison work, experts see great value in conducting on-going, coordinated efforts in aligning input assumptions and historical data, more analysis of vehicle ownership, and more analysis of policies, among other things.



Overall, the workshop provided considerable insights and an on-going collaboration between modelers will likely bring important benefits. Additional model comparisons and possible future follow-on workshops will be considered, depending on additional resources and commitment.

Acknowledgement

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