The IEA Mobility Model; an introduction and considerations on ACES

Summary of MoMo assumptions, methods, and results

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Outline

I. The IEA Mobility Model
   • A brief history, summary of data sources, the historic database
   • Flowcharts of data linkages
   • Summary of capabilities
   • Regional resolution
   • Modal and vehicle type characterisation

II. Summary of recent results
   • Scenarios in Energy Technology Perspectives 2017 (ETP 2017)
   • Excerpted figures and key messages from: ETP 2017, Global EV Outlook 2017 (GEVO 2017), and from workshop and conference presentations

III. Key parameters and methods to be revisited for ACES
I. Summary of the Mobility Model
## A brief history of the Mobility Model (MoMo)

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>SMP model developed further as IEA Mobility Model (MoMo). MoMo data used for the IEA ETP analysis and ETP 2006.</td>
</tr>
<tr>
<td>2006</td>
<td>Deeper analysis of vehicle technology potential, including PHEVs. Elasticities of travel and ownership with respect to GDP and oil prices.</td>
</tr>
<tr>
<td>2008</td>
<td>Early development of modal shift scenarios. Vehicle, fuel and infrastructure costs.</td>
</tr>
<tr>
<td>2012</td>
<td>Cooperation with UIC on rail data. Expanded coverage of countries and regions.</td>
</tr>
<tr>
<td>2016</td>
<td>Updated aviation module. Updated shipping module.</td>
</tr>
<tr>
<td>2017</td>
<td>Extension to 2100. New approach for freight demand generation.</td>
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</table>
The IEA Mobility Model (MoMo) – What is it?

A spreadsheet model of global transport

• focus on vehicles, transport activity and energy use
• also covers emissions, infrastructure and materials use
• Analysis of scenarios and projections to 2060 (mostly back-casting and “what-if”)
  (extension from 2060-2100 is complete but is current a simple extrapolation of trends)

World is divided in 29 regions, including several specific countries

• All G20 countries except Saudi Arabia, as well as regional blocks (e.g. ASEAN, EU and non-EU Nordics, EU 7, Latin America, sub-Saharan Africa, OETE…)
• Urban and non-urban disaggregation (following UN and national definitions)

MoMo contains a large amount of data on technology and fuel pathways

• Full evaluation of life-cycle greenhouse gas emissions: with and without (I)LUC
• Cost estimates for new light-duty vehicles (LDV), fuels and fuel taxes
• Estimates of transport sector expenditures to 2050: vehicles, fuels and infrastructure
• Module on material requirements for LDV manufacturing
The IEA Mobility Model (MoMo) – What is it?

The analytical tool used for projections of transport activity, energy demand and CO₂ emissions in the IEA

An essential tool for activities on:
- **Energy Efficiency**: Global Fuel Economy Initiative (GFEI)
- **Energy Technology**: Electric Vehicle Initiative (EVI)
- **Cooperative Efforts**: Railway Handbook on Energy Consumption and CO₂ emissions with International Union of Railways

MoMo is shared with:
- Other Directorates in the IEA (e.g. WEO; EEfD)
- the International Transport Forum, who uses it for the formulation of its Transport Outlook
- “MoMo partners”, i.e. sponsors – mainly from the private sector – that provide Voluntary Contributions and/or in-kind support
Who supports the work: MoMo partners
The MoMo historical database - Data sources:

**IEA statistics:** country-level energy demand by mode (road, rail, aviation, shipping) and by fuel over time

**Road:** national statistical offices, vehicle manufacturers associations, vehicle registers, ministries, statistical yearbooks...
- Country-level data on stock, new registrations, mileage and fuel economy, urban & non-urban resolution
- Main focus of the model due to high energy use
- Passenger and Freight modes: 2- & 3-wheelers, PLDVs, LCVs, MFTs and HFTs
- Desegregation by power train types using gasoline, diesel, electricity, and gas

**Rail:** country level data from UIC, urban from UITP and ITDP datasets combined
- Rail: light rail, metro, heavy rail (electric, diesel)

**Aviation:** data from ICAO and JADC, as well as Boeing, Airbus, ICCT
- Commercial aircraft

**Shipping:** activity from UNCTAD, IMO, activity projections based on ITF modelling
- International maritime ships (container, general cargo, oil tankers, bulk carriers, other)
The MoMo historical database – conceptual flowchart:

**Data File**
- **Sales**: Data collection for different vehicle and power train types
- **Stock**: Function of sales and scrappage of old cars OR data collection for different vehicle types and power train types
- **Mileage**: Data collection for different vehicle and power train types
- **Travel**: Function of travel and stock
- **Fuel Economy**: Data collection for different vehicle types

**Assumptions File**
- **Mileage estimate**: Estimate of typical mileage for different vehicle types based on PPP and fuel price
- **Fuel price scale**: Fuel price scale in eight categories based on point-based price survey at country level
- **GDP/capita (PPP)**: Nominal power purchase parity (World Bank)
- **Fuel Economy estimate**: Estimate of typical fuel economy for different vehicle types based on PPP and fuel price or based on Global Fuel Economy Initiative (GFEI)

**Analysis file**
- **FuelEconomyD**: Based estimate, optionally adjusted with factor
- **MileageD**: Based on estimate, optionally adjusted with factor
- **StockD**: Based on stock, optionally adjusted with scrappage age

**ResultD**
- **Result**: Adjusted result for energy consumption for different vehicle types and power trains
- **Result**

© IEA 2017
Regional Coverage

**Historic Database**

**44 countries & regions**

- Annual time steps
- Minimal coverage of 1990-2016
- Some regions extend from 1970-2016

<table>
<thead>
<tr>
<th>Country</th>
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<th>Region</th>
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<tr>
<td>Algeria</td>
<td>Argentina</td>
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<td>Australia</td>
<td>Brazil</td>
<td>Canada</td>
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<td>Chile</td>
<td>China</td>
<td>Croatia</td>
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<tr>
<td>Denmark</td>
<td>EU 7</td>
<td>EU18-EUG4</td>
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<td>France</td>
<td>Finland</td>
<td>Germany</td>
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<tr>
<td>Iceland</td>
<td>India</td>
<td>Indonesia</td>
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<td>Israel</td>
<td>Italy</td>
<td>Japan</td>
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<td>Korea</td>
<td>Malaysia</td>
<td>Mexico</td>
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<tr>
<td>Middle East</td>
<td>New Zealand</td>
<td>Norway</td>
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<tr>
<td>ODA</td>
<td>OETE</td>
<td>Other Africa</td>
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<td>Other ASEAN</td>
<td>Other Latin America</td>
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<td>Philippines</td>
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<td>South Africa</td>
<td>Spain</td>
<td>Sweden</td>
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<td>Switzerland</td>
<td>Thailand</td>
<td>Turkey</td>
</tr>
<tr>
<td>UK</td>
<td>USA</td>
<td>Vietnam</td>
</tr>
</tbody>
</table>

**Being added:**

- Morocco
- Egypt
- Ukraine

**Mobility Model**

**29 countries & regions**

- All G20 countries (except Saudi Arabia), plus other countries and regional aggregates
- 5 year time steps
- Analysis focuses on 2015-2060
Powertrain coverage, by mode

Road vehicles:
- Gasoline ICE
- Diesel ICE
- Gasoline HEV
- Diesel HEV
- Plug-in Gasoline hybrid
- Plug-in Diesel hybrid
- Battery Electric
- CNG
- LNG
- Hybrid fuel cell
- Hydrogen fuel cell

Rail:
- electric, diesel

Aviation:
- jet fuel, CTL, F-T biofuels

Shipping:
- HFO, diesel, biodiesel, LNG, H2
MoMo estimates energy demand based on ASIF approach

ASIF (Activity, Structure, Intensity \rightarrow Fuel use) approach

- Vehicle Activity
- the Structure of the organization of vehicles across services, modes, vehicle classes and powertrain groups
- the energy Intensity of each of the vehicles in this structure

... allow the estimation of Fuel consumption

The calculation is based on Laspeyres identities

\[
F = \sum_i F_i = A \sum_i \left( \frac{A_i}{A} \right) \left( \frac{F_i}{A_i} \right) = A \sum_i S_i I_i = F
\]

- \( F \) \: total Fuel use
- \( A \) \: vehicle Activity (expressed in vkm)
- \( F_i \) \: fuel used by vehicles with a given set of characteristics (\( i \))
  (e.g. segments by service, mode, vehicle and powertrain group)
- \( A_i/A = S_i \) \: sectoral Structure (same disaggregation level)
- \( F_i/A_i = I_i \) \: energy Intensity, i.e. average fuel consumption per vkm (same disaggregation level)
Historic results are calibrated with IEA World Energy Balances
The IEA Mobility Model (MoMo) – simplified model structure

- Generation of transport activity (pkm, tkm, vkm) and vehicle stock
- Derivation of new vehicle registrations by powertrain, characterisation of vehicles by age
- Calculation of the energy use, by fuel
- Estimation of CO₂ and pollutant emissions
The IEA Mobility Model – a network of spreadsheets

Exogenous Inputs

- **GDPandPopulation**
  - Historical & GDP PPP projections from World Bank
  - Population (inc. urban & non-urban) from UN

- **DB Inputs**
  - Compiles calibrated historical road data from MoMo database

- **MoMo Data - Assumptions**
  - Baseline projections of tkm; loads, truck fuel economy

- **Urban_Split**
  - Splits PLDV, bus, LCV and MFT stocks, mileage, and fuel economy, based on ETP 2016 analysis (GIS, Millennium City Databases, literature review, etc.)

Policy and price inputs

- **Fiscal_and_city_level_policies**
  - Estimates impact of fiscal & regulatory policies
  - Modulated by population density distributions

- **DemandGeneration**
  - Translates impact of policies to:
    - Vehicle ownership
    - Vehicle mileage
    - Private vs. public transit mode share
  - Modulates impact in urban / non-urban settings

- **Trucks_Demand_Generation**
  - Estimates impact of logistics / supply chain / operational measures on:
    - Average loads
    - Operational fuel efficiency
    - Mileage
  - Modulates impact in urban / non-urban operations (depending on measure)

Modes

- **2_3_Wheelers**
- **PassVehicles**
- **Bus**
- **Air**
- **Rail**
- **RoadFreight**
- **Shipping**

Outputs and Summaries

- **Master**
  - Summary of high-level results, by region, across all modes and fuels

- **All_Data_and_Estimates**
  - Summary of results across all modes and fuels

- **Output**
- **Output_U**
- **Output_NU**

- **Infrastructure**
  - Estimates material needs in a given scenario
  - Infrastructure build-out impacted by avoid-shift

- **Costs_and_Investments**
  - Estimates costs, including:
    - detailed estimates of LDV costs
    - estimates for all other modes
    - infrastructure costs (capital, O&M)
    - estimated fuel costs (all fuel types)
Analytical capabilities

MoMo has a user interface that allows

- What-if scenario building and back-casting
- Use of elasticities for ownership and mileage
- Mode shift scenario building for passenger travel

MoMo also estimates material requirements and emissions

- Analysis of future vehicle sales (e.g. EVs, fuel cells) and how they impact materials requirements (e.g. precious metals) is possible (currently being expanded / updated)
- Full life-cycle analysis for GHG emissions from LDVs (including manufacturing) can be calculated

Recent MoMo capacity developments include

- Urban & non-urban travel splits using data from a global set of mobility surveys
- Land transport infrastructure requirements in support of travel demand growth
- Fuel cost, T&D, storage and distribution infrastructure assessment
- Cost estimations from vehicle, fuel and infrastructure investments
Ownership – data shown refer to urban areas

Personal vehicles [including 2-wheelers]
Passenger demand generation

Other relationships (selected examples) – urban data

Personal vehicle mileage

Pkm share on PT

- OECD
  - OECD North America
  - Canada
  - Mexico
  - USA
  - OECD Europe
  - France
  - Germany
  - Italy
  - UK
  - EU18-EUG4
  - EU Nordic
  - Non-EU Nordic
  - Non-EU OE2
  - OECD Pacific
    - Australia and NZ
  - Japan
  - Korea
  - Other OECD
  - Non OECD
  - EU 6
  - OETE
  - Russia
  - ATE
  - China
  - ODA
  - ASEAN
  - India
  - Middle East
  - Latin America
  - Brazil
  - Other Latin America
  - Africa
  - South Africa
  - Other Africa

- GDP (2000 USD PPP) per capita

- OECD
  - OECD North America
  - Canada
  - Mexico
  - USA
  - OECD Europe
  - France
  - Germany
  - Italy
  - UK
  - EU18-EUG4
  - EU Nordic
  - Non-EU Nordic
  - Non-EU OE2
  - OECD Pacific
    - Australia and NZ
  - Japan
  - Korea
  - Other OECD
  - Non OECD
  - EU 6
  - OETE
  - Russia
  - ATE
  - China
  - ODA
  - ASEAN
  - India
  - Middle East
  - Latin America
  - Brazil
  - Other Latin America
  - Africa
  - South Africa
  - Other Africa
  - WORLD
  - EU27

- Private vehicle mode share

- GDP (2000 USD PPP) per capita
Strong correlations exist at the city level between population density and private vehicle modal shares.
II. Summary of recent results
Per capita transport energy use by country and by fuel, 2015

This map is without prejudice to the status of or sovereignty over any territory, to the delineation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: ETP 2016
Transport activity: modal choice

Energy intensity of different modes of transport, 2015

Air and light road passenger modes are more energy intensive than public (‘mass’) transport. Light and medium road freight modes are more energy intensive than large road vehicles, rail and shipping.
Measures are needed across the developed and developing world.

Well-to-wheel greenhouse gas emissions in OECD and non-OECD countries by scenario, 2015-2060

B2DS target requires alternative transport fuels, efficient vehicles, and changed transport behavior. Emission reductions of 90 percent (OECD) and 66% (non-OECD) below 2015 levels are needed.
Rapid electrification of light-duty fleet drives deep decarbonisation

By 2060, the share of alternative powertrain vehicles in the global LDV stock will reach 94% in the B2DS and 77% in the 2DS.
Scenario definitions

The **Reference Technology Scenario (RTS)** provides a baseline scenario that takes into account existing energy- and climate-related commitments by countries, including Nationally Determined Contributions pledged under the Paris Agreement. The RTS — reflecting the world’s current ambitions — is not consistent with achieving global climate mitigation objectives, but would still represent a significant shift from a historical “business as usual” approach.

The **2°C Scenario (2DS)** and the **Beyond 2°C Scenario (B2DS)** each sets out a rapid decarbonisation pathway in line with international policy goals. The 2DS has been the main climate scenario in the ETP series for many years, and it has been widely used by policy makers and business stakeholders to assess their climate strategies. For the first time, the B2DS looks at how far known clean energy technologies could go if pushed to their practical limits, in line with countries’ more ambitious aspirations in the Paris Agreement.

- The RTS is aligned with the WEO NPS at a high level
- The 2DS may be merged with the WEO Sustainable Development Scenario (SDS) in the near future
- The 2DS has an energy sector budget of 1170 Gt CO₂, and the energy system reaches (near) net carbon neutrality in the 2080s
- The B2DS has an energy sector budget of 750 Gt CO₂, and the energy system reaches net carbon neutrality around 2060
Coupling EVs with renewable power can transition transport to near-zero $CO_2$ emissions. If coupled to low-carbon power, the high energy efficiency of EVs offers prospects for substantial $CO_2$ emissions reductions. This complements their air quality, energy security and noise reduction benefits.
Ambitious policy action is needed across all transport modes

Well-to-wheel greenhouse gas emission reductions by mode 2015-2060

The Beyond 2°C Scenario envisages GHG reduction by 89% below 2015 emission levels

The 2°C Scenario maps an emission decrease of 54% over the same period
III. Approaches that need to be revisited to better model ACES
thanks to Robin Chase for summarizing many of the key aspects
Passenger vehicle use cases lead to usage profiles

<table>
<thead>
<tr>
<th>Privately owned</th>
<th>Mobility service fleets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human driver</td>
<td>Autonomous driven</td>
</tr>
</tbody>
</table>

Four quadrants simplify key impacts of shifts in major parameters that can be addressed within MoMo