Global Energy Demand Intelligence
Road Transport/Future of Mobility

McKinsey&Company Inc.
Asilomar Conference Session II -- Is Global Oil Demand Peaking?
We are building a fundamental energy demand outlook

We developed a cloud-based data cube...

- Greater China
- OECD Europe
- United States
- Latin America
- India
- RoW

- Power
- Light vehicles
- Heavy vehicles
- Aviation
- Steel
- Chemicals
- Refining
- Pulp & paper
- Residential
- Commercial

139 countries, 22 sectors and 55 energy sources

State-of-the-art cloud technology

Web-app for interactive client access

Dedicated 20+ people team of experts & analysts

... to develop our understanding of fundamental demand drivers

POWER:
What will be the impact of improving economics of renewables on the generation mix in 2030?

TRANSPORT:
Will increasing EV penetration trigger a peak in global oil demand for transport in the coming decade?

INDUSTRY:
What will be the scale and magnitude of electrification in industry?
How will the circular economy affect demand for chemicals feedstocks?

BUILDINGS:
Will uptake in use of heat pumps lead to a decline in gas demand?

Road transport accounted for 20% of global final energy demand in 2015, with passenger cars being the largest segment.

Global final energy demand by end-use sector in 2015

- Buildings: 130 million TJ (32%)
- Industry: 160 million TJ (40%)
- Road transport: 84 million TJ (21%)
- Other transport: 28 million TJ (7%)

By road transport segment

- Passenger cars: 45 million TJ (54%)
- Vans & pick-ups: 36 million TJ (42%)
- Trucks: 25 million TJ (25%)
- Buses: 10 million TJ (10%)
- 2&3 Wheelers: 4 million TJ (4%)

By fuel type

- Gasoline: 44 million TJ (54%)
- Diesel: 36 million TJ (44%)
- Natural gas & LPG: 3 million TJ (2%)
- Electricity: 0.2 million TJ (0.3%)
- Other: 0.1 million TJ (0.2%)

We see a peak in global liquids demand by 2037, while road transport peaks already in 2028

Global oil demand, Million barrels per day
Growth of car parc slows down as peak car ownership is expected between 2025 and 2035 in developed world

Peak car drivers
- Drivers for reduced ownership include urbanization, car sharing, e-hailing, better public transport alternatives and regulation

Peak car already reached
- France showed peak ownership in 2011
- Singapore has shown declining ownership since 2008 driven by regulations

Peak car expected
- Remaining developed countries have nearly reached saturation and expect to peak between 2025 and 2035
- Developing countries will follow peak trend (China)

Increasing regulatory pressure is driving efficiency improvements and electrification

**Description of policy**

<table>
<thead>
<tr>
<th>Policy</th>
<th>Target group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulation</strong></td>
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<tr>
<td>Emission limits</td>
<td>OEMs</td>
<td>Strict exhaust emission and fuel economy limits (e.g., Euro 6 and Renewable Energy Directive) aimed to improve ICE vehicle fuel economy (engine technology, aerodynamics, light weight) and promote electrification (super-credits)</td>
</tr>
<tr>
<td>Access regulation</td>
<td>Users</td>
<td>Access Regulation and low emission zones (LEZ) promote sales of newer and cleaner vehicles by restricting access for polluting vehicles in urban areas</td>
</tr>
<tr>
<td>Diesel bans as communicated for Madrid, London and Paris (2025) or entire country (Norway, France)</td>
<td>Users</td>
<td></td>
</tr>
<tr>
<td><strong>Incentives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acquisition subsidies</td>
<td>OEMs</td>
<td>One-off discount on acquisition price via VAT and import tax exemptions or direct subsidy, to compensate buyers for higher acquisition cost of clean vehicles</td>
</tr>
<tr>
<td>Operational subsidies</td>
<td>Users</td>
<td>Feebates encourage clean &amp; discourage polluting technologies</td>
</tr>
<tr>
<td>Non-financial perks</td>
<td></td>
<td>– Encourage: toll exemption, fiscal discounts, free charging</td>
</tr>
<tr>
<td>Technology push</td>
<td></td>
<td>– Discourage: Fuel (excise) tax</td>
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<tr>
<td></td>
<td></td>
<td>Dedicated driving lanes (e.g., bus lanes)</td>
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<td></td>
<td></td>
<td>Dedicated parking spots or free/fast parking permit</td>
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<td></td>
<td></td>
<td>Remove barriers for electrification</td>
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<tr>
<td></td>
<td></td>
<td>– R&amp;D subsidies for OEMs and suppliers to develop technology</td>
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<tr>
<td></td>
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<td>– Charging infrastructure investments</td>
</tr>
</tbody>
</table>

**SOURCE:** European Commission, McKinsey Energy Insights' Global Energy Perspective, team analysis
Electrification and fuel economy gains reduce road transport liquids demand by ~60% in 2050

Impact of road transport drivers on liquids demand (mb/d)

Three global trends reduce energy demand

- Growth of vehicle parc slows down
- Increasing fuel efficiency
- Move to electric vehicles

Population and GDP growth continue increase in fuel consumption, but growth is slowing down thanks to peak car in developed regions.

Regulation enforces improvements in fuel efficiency of ICE-vehicles and drives electrification.

Electrification of cars and other segments is accelerating driven by financial benefits as well as regulation.

Cities are increasingly congested and polluted on the current unsustainable path
Privately owned vehicles

**Massive waste in the current transport system – car example**

<table>
<thead>
<tr>
<th>Car utilization rate</th>
<th>Tank to wheel energy flow - Gasoline</th>
<th>Deaths and injuries per year on road</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8% looking for parking</td>
<td>Energy used to move the person</td>
<td>More than 33,000 in US $300B annually in cost</td>
</tr>
<tr>
<td>0.5% sitting in congestion</td>
<td>Inertia vehicle</td>
<td></td>
</tr>
<tr>
<td>2.6% driving</td>
<td>Rolling resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Auxilliary power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transmission losses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aerodynamics</td>
<td></td>
</tr>
</tbody>
</table>

**Land utilization rate**

- A road reaches peak throughput only 5% of the time... ...and even then, it is only 10% covered with cars
- 50% of most city’s land area is dedicated to streets and roads, parking lots, service stations, driveways, signals and traffic signs

SOURCE: team analysis; Resource Revolution by Heck and Rogers
McKinsey is at the forefront of the global debate about infrastructure & cities

All publications available on www.mckinsey.com
Global megatrends that are impacting the automotive industry and will likely drive significant change to mobility

4 disruptive technology-driven trends will impact the industry

- **Autonomous**
  - Shifting markets and revenue pools
  - Changes in mobility behavior
  - Adoption of advanced technologies
  - New business models for mobility

- **Connected**
- **Shared**
- **Electric**

SOURCE: McKinsey
Some of these trends changing the future mobility systems will have reinforcing effects on each other

Key trends

Reinforcing effects

1. An uptake in shared mobility will accelerate electrification, as higher utilization favors the economics of electric vehicles.

2. Self-driving functionality could lead to a competitive proposition for shared mobility.

3. Self-driving – private and shared – vehicles are likely to increase mobility consumption in which case electric vehicles offer lower total cost of ownership.

4. An uptake in shared mobility will affect public transit.

5. Electric vehicle production at scale could accelerate the battery curve downward.

6. Self-driving electric vehicles will have different usage and hence demand different requirements for charging infrastructure.

7. Increasing renewable penetration could accelerate the attractiveness of electric vehicles.

8. Self-driving vehicles might accelerate the uptake of IoT applications.

SOURCE: BNEF and McKinsey
The end state of the new mobility system will bring significant benefits across all factors and is better than systems in place today

<table>
<thead>
<tr>
<th>Key benefit</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Health and safety**             | - **Reductions in vehicle related deaths** due to both the safety benefits of autonomous vehicles and modal shifts away from private travel  
                                        - Many lives saved due to **reduced air pollution** from vehicles in dense urban environments                                                                                     |
| **Cost and convenience**          | - **Lower cost of door to door travel** compared to existing public transport  
                                        - **More equitable access** to transport services, promoting income equality in urban environment  
                                        - Greater comfort while travelling and less wasted time in transport                                                                                                                  |
| **Environmental impacts**         | - Significant **reductions in the CO2** intensity of transport  
                                        - Opportunity to put public assets such as parking lots and excess road space to productive use as e.g., public parks                                                                 |
| **Benefits to the overall system**| - More efficient transport systems which impose much **lower congestion costs**  
                                        - Enables smart investment in public transport and reduces the need for investment in expensive legacy assets such as metros  
                                        - Future-proofs public infrastructure for an entirely autonomous future                                                                                                         |
| **Ancillary benefits**            | - Stabilisation of the power grid through flexible demand from EVs  
                                        - Improve the attractiveness of the city to global expatriates                                                                                                                  |

SOURCE: BNEF and McKinsey
McKinsey has considerable expertise in cities work, having conducted 500+ projects around the globe over the past 5 years.

Studies 2011 – 2016 (YTD)

Percent of engagements (n=524)

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>North America</td>
<td>31%</td>
</tr>
<tr>
<td>Europe</td>
<td>23%</td>
</tr>
<tr>
<td>Asia</td>
<td>26%</td>
</tr>
<tr>
<td>Africa/ME</td>
<td>15%</td>
</tr>
<tr>
<td>Latin America</td>
<td>5%</td>
</tr>
</tbody>
</table>

Type of engagements

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Development</td>
<td>31%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>23%</td>
</tr>
<tr>
<td>Health Organization</td>
<td>14%</td>
</tr>
<tr>
<td>Sustainability</td>
<td>12%</td>
</tr>
<tr>
<td>Operations</td>
<td>6%</td>
</tr>
<tr>
<td>Others</td>
<td>5%</td>
</tr>
</tbody>
</table>

Engagements

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>66</td>
</tr>
<tr>
<td>2012</td>
<td>99</td>
</tr>
<tr>
<td>2013</td>
<td>86</td>
</tr>
<tr>
<td>2014</td>
<td>121</td>
</tr>
<tr>
<td>2015</td>
<td>148</td>
</tr>
<tr>
<td>2016</td>
<td>~170</td>
</tr>
<tr>
<td>Total</td>
<td>632</td>
</tr>
</tbody>
</table>

1 forecast: 2016 figure subject to final reporting

SOURCE: PSSP client database, FPIS
We think mobility disruption in cities can happen along 3 major trajectories.

**Seamless mobility**
- Rapid social change, system coordination and deployment of mobility solutions results in a **radically different mobility system**.

**Private autonomy**
- Technology change accelerates but social change is slow, resulting in **high uptake of EV/AV but within current ownership models intact**.

**Clean and shared**
- Despite technology readiness, **AV adoption remains very low while EV and shared mobility accelerate**.

SOURCE: BNEF and McKinsey
We have evaluated the cities against 3 criteria most indicative of high EV adoption: a city’s ability & motivation to act and its demographics and car pool

City’s Ability to Act
- Represents how well a city is able to recognize problems and take action to resolve them
- Includes both past and current actions
- Delivers a comprehensive overview through the Governance index and understanding of what the city is doing today through evaluation of financial and non-financial incentives

City’s Motivation to Act
- Represents how motivated a city is to act and solve its mobility problems
- Also includes the pressures and urgency that the city is experiencing to act
- Evaluates the motivation by looking at a city’s positioning (innovative and “green”) and at pressures related to EV adoption motivation (pollution and congestion)

City’s Demographics and Car Pool
- Represents how well a city itself is positioned for high EV adoption
- Includes criteria that evaluate the population and EV and non-EV car market
- Consists of KPIs such as population, GDP PPP per capita, the wealth of the population, EV charging infrastructure availability, EV penetration projected 2025 car sales and average car age
To the starting total of 2,600+ cities we have applied several macro criteria and an index model to derive a list of 30 top cities.

<table>
<thead>
<tr>
<th>City Archetype</th>
<th>Macro criteria applied</th>
<th>Resulting # of Top 30 cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed, dense areas</td>
<td>All urban areas</td>
<td>8</td>
</tr>
<tr>
<td>Developed, suburban sprawl</td>
<td>All urban areas, Governance effectiveness percentile &gt;40, Car sales in 2025 &gt;100k</td>
<td>14</td>
</tr>
<tr>
<td>Developing, dense areas</td>
<td>All urban areas, Population &gt; 3m</td>
<td>8</td>
</tr>
<tr>
<td>Clean and Shared</td>
<td>All urban areas, Population &gt; 3m, GDP PPP per capita above $6k</td>
<td>30</td>
</tr>
</tbody>
</table>

SOURCE: City Selection Model, City Scope, World Bank Governance Index
There are clear indicators that the eTruck uptake will be significantly faster than the electric passenger car uptake.

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Decision factors</th>
<th>Comparison to passenger cars (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td>Positive TCO business case for electric truck</td>
<td>+ Commercial vehicle owners are more TCO conscious than emotional car owners.</td>
</tr>
<tr>
<td></td>
<td>Technological maturity of fully electric powertrains</td>
<td>+ PCs have proven feasibility of electric vehicles.</td>
</tr>
<tr>
<td></td>
<td>Fast turnover of trucks in fleets every 3-6 years depending on mileage</td>
<td>+ Commercial vehicle owners renew fleets at twice the rate as private owners.</td>
</tr>
<tr>
<td></td>
<td>Green corporate image, emission free “green” delivery of goods</td>
<td>+ Commercial vehicles under higher corporate pressure.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Diesel bans in cities (e.g. Paris 2025)</td>
<td>+ Diesel share within trucks much higher than for PC.</td>
</tr>
<tr>
<td></td>
<td>Truck emission targets by 2030</td>
<td>- Less aggressive targets for trucks expected.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Currently limited charging infrastructure for trucks, especially for long haul segment</td>
<td>+ Compared to early PC charging infrastructure already significant infrastructure today.</td>
</tr>
<tr>
<td></td>
<td>Logistic centers can be easily equipped with charging infrastructure</td>
<td>+ On road parking limits access to charging.</td>
</tr>
<tr>
<td>Product availability</td>
<td>Very limited product availability before 2020</td>
<td>+ Compared to slow PC BEV OEM offering, large truck OEMs declared to bring eTruck trucks to the market</td>
</tr>
</tbody>
</table>

SOURCE: Energy Insights Road Transport team
Implications are identified through a systematic 6-step approach to urban mobility

- What standards are required to ensure the inter-operability of connected vehicles?

- What is the impact on urban design themes (e.g. parking) as autonomous vehicles become popular?

- What new infrastructure offerings that Pulse would need to provide?

- What new mobility offerings are available at city level to augment mobility?

- Who would own the autonomous fleets of the future?

- How would they impact current public transit systems?

- How can Pulse deliver interconnected and interlinked multi-modal mobility?

SOURCE: Mobility at a tipping Point, McKinsey Center for Business and Environment, 2015