Three Revolutions in Urban Transportation:

How to achieve the full potential of vehicle electrification, automation and shared mobility in urban transportation systems around the world by 2050

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Urban Electric Mobility Track
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Passenger Transport Revolutions

1. Streetcars (~1890)
2. Automobiles (~1910)
3. Airplanes (~1930)
4. Limited-access highways (1930s….1956)

2010+
1. Vehicle electrification
   – low carbon vehicles and fuels
2. Real-time, shared mobility
   – less vehicle use
3. Vehicle automation (2025?)
   – Uncertain impacts
Research undertaken by UC Davis and ITDP, part 3 of a series

Global scenario study to 2050 focused on potential 3 Revs impacts on CO2, energy use, costs

Study supported by UC Davis STEPS Consortium and by Climate Works, Hewlett Foundation, Barr Foundation

https://steps.ucdavis.edu/three-revolutions-landing-page/

Three Revolutions in Urban TRANSPORTATION

How to achieve the full potential of vehicle electrification, automation and shared mobility in urban transportation systems around the world by 2050

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Research supported by:
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Have EVs arrived?
During 2017, the number of PEVs worldwide will likely go over 3 million, with over 1 million in sales this year.
Norway & Netherlands achieved high PEV market shares in 2016, most other national markets around 1-2%.

- Norway 30% in 2016
- Hong Kong 5%
- California 3%
- Switzerland 2%
- Sweden 2.6%
- San Jose 10%
- Shanghai 15%
A plausible PEV rollout scenario based on technology change, incentives & history of previous technology rollouts

<table>
<thead>
<tr>
<th>Generation</th>
<th>Description</th>
<th>Years</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Early policy, converted vehicles, &quot;innovators&quot; &amp; early infrastructure</td>
<td>2010-2015</td>
<td>1-2%</td>
</tr>
<tr>
<td>2nd</td>
<td>Improved batteries, more driving range, &quot;followers&quot; Adequate infrastructure</td>
<td>2015</td>
<td>3-5%</td>
</tr>
<tr>
<td>3rd</td>
<td>Batteries, vehicles, &quot;core market&quot; PEVs competitive</td>
<td>2020</td>
<td>6-15%</td>
</tr>
<tr>
<td>4th</td>
<td>PEVs begin to dominate</td>
<td>2025</td>
<td>15-25%</td>
</tr>
</tbody>
</table>

For 2030:
- California 2025 ZEV goal = 15% / 1.5 million BEVs, FCV & PHEVs

Lithium pack prices per kWh:
- 700
- 300
- 200
- 150
COP Announcement – Paris Declaration on E-mobility

- Released at COP 21, December 5 2015
- Signed by UN Agencies, IEA and many governments
- Commits to “more than 100 million electric-driven cars” on the worlds roads by 2030 as part of achieving a 2-degree target.
- IEA roughly estimates that electric vehicle sales will need to be 25% (~30 million) world wide in 2030 to achieve this target.

- Is this possible? Plausible? What would be needed to achieve such a target?
What does achieving the Paris Declaration targets look like?

- One possible way: 100 models selling 300k/yr each in 2030
Number of electric vehicle models available
The key policies

- Supply side: Encourage production
- Consumer Awareness!!! (and experience)
- Make the up front cost be competitive
- Recharging infrastructure
- Urban advantages (parking, access)
Current E-bike market in the EU

- Average annual growth rate 2013 – 2015: 16%
- 2016: 25% (1.66m units)
- Total stock 12/2016: 8.2 million units
- Expected total stock 12/2017: 10 million units
Car of the future?

Accelerating the Next Revolution
In Roadway Safety

September 2016
Some questions and conflicts

• Automation: lower per-trip costs, lower “time cost” for being in vehicles
  – Just how much cheaper will it be?
  – Private automated vehicles = longer trips?
  – Empty running (zero passengers) of vehicles
  – Resulting relative costs of private vehicles, shared mobility, transit?

• Electrification goes with automation – does it really?
  – Can get the job done with upgraded electrical system (such as hybrids)
  – But electric running will be much cheaper – and durable?

• Ride hailing: cost savings v. convenience and risk
  – Complementary or at conflict with public transit use?
  – Will lower costs reduce the incentive to ride share?
Part 2: our scenarios...we want to explore these interactions and different possible futures
## Rough guide to the three scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Automation</th>
<th>Electrification</th>
<th>Shared Vehicles</th>
<th>Urban Planning/Pricing/TDM Policies</th>
<th>Aligned with 1.5 Degree Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as usual, Limited Intervention</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>1R Automation only</td>
<td>HIGH</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>2R With high Electrification</td>
<td>HIGH</td>
<td>HIGH</td>
<td>Low</td>
<td>Low</td>
<td>Maybe</td>
</tr>
<tr>
<td>3R With high shared mobility, transit, walking/cycling</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>YES</td>
</tr>
</tbody>
</table>
Passenger kilometers of travel by scenario/mode
OECD Europe

- Automated vehicle travel not significant by 2030 in any scenario, but dominates in 2050. Results in much higher travel in 2R.
- Europe remains fairly car dominated to 2050 - modal mix changes in 3R, but mostly due to TNCs. Significant minibus travel. Non-car travel reaches 35% in 3R.
OECD-Europe LDV travel (VKm) by scenario

- 2R vehicle travel rises sharply after 2030 due to lower travel costs from automated vehicles
- 3R vehicle travel flat despite declining vehicle stock, given higher travel per vehicle of public vehicles
OECD-Europe LDV stock evolution by scenario

- 2R stocks nearly completely autonomous by 2050
- 3R stocks strongly decline after 2030, due to lower passenger travel levels, intensive vehicle use and higher load factors
Energy use by scenario, mode

- Far lower energy use in 2R due to EVs, and in 3R due to low LDV mode shares
Urban passenger transport CO2 by scenario, vehicle type, world

4DS electricity shown; in 2DS, CO2 from electricity drops to near zero in 2050

Global CO2 reduction in a 2DS electricity world, 2R/3R v. BAU, in 2050 and cumulative

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2050</th>
<th>2015-2050 cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2R v BAU</td>
<td>82%</td>
<td>37%</td>
</tr>
<tr>
<td>3R v BAU</td>
<td>93%</td>
<td>53%</td>
</tr>
</tbody>
</table>

CO₂ Emissions - World

Gigatonnes

- 0
- 1
- 2
- 3
- 4
- 5

<table>
<thead>
<tr>
<th>Year</th>
<th>BAU 2015</th>
<th>BAU 2030</th>
<th>2R 2030</th>
<th>3R 2030</th>
<th>BAU 2050</th>
<th>2R 2050</th>
<th>3R 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2030</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2050</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Electric vehicles

ICE vehicles
Costs start to deviate across scenario after 2030, 3R 40% cheaper in 2050

- The combination of far fewer vehicles, lower travel/fuel levels, lower infrastructure requirements (roads/parking) makes 3R far cheaper.
- 2R more expensive than BAU due to higher cost of AV/EVs and greater travel
Supportive Policies – critical to success of the scenarios

- **3R Scenario (Automation + Electrification + Sharing):**
  - Compact Urban Development policies
  - Efficient parking policies
  - Heavy investment in transit/walking/cycling
  - VKT fees (incl. congestion & emission factors):