Fuel-electricity mix and efficiency in Dutch plug-in and range-extender vehicles on the road

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Monitoring of plug-in hybrids

- **Goal**: provide insight in real-world energy consumption and CO₂ emissions of plug-in hybrid vehicles (PHEVs)

- Project for the Dutch Ministry of Infrastructure and the Environment data
  - Collaboration with Travelcard BV (provider of fuel-passes), Dutch importers of Opel / Chevrolet and Toyota, lease companies and a changing infrastructure & service provider

- Two categories of plug-in vehicles
  - Plug-in hybrids (Toyota Prius Plug-in)
  - Extended range electric vehicles (Opel Ampera / Chevrolet Volt)

- Collection and analysis of data on usage and energy consumption (fuelling and charging)
  - Kms driven between two fuelling events
  - Litres of fuel tanked at fuelling event
  - If available: charging events and kWh charged at charging events
Type approval testing of PHEVs
Electric range is key parameter

- Fuel consumption and CO₂ emissions of PHEVs determined by combining results of two separate tests:

\[
C = \frac{(D_e \cdot C_1 + D_{av} \cdot C_2)}{(D_e + D_{av})}
\]

with:

- \(C\) = combined fuel consumption in l/100km
- \(C_1\) = fuel consumption in l/100km measured on test that starts with a fully charged battery
- \(C_2\) = fuel consumption in l/100km measured on test that starts with a fully depleted battery
- \(D_e\) = electric range of the vehicles
- \(D_{av}\) = 25 km
Monitored vehicles
Type approval data

- Type approval data of the monitored vehicles

<table>
<thead>
<tr>
<th>electric range</th>
<th>test 1 (full battery)</th>
<th>test 2 (empty battery)</th>
<th>overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fuel</td>
<td>CO₂</td>
<td>fuel</td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>l/100km</td>
<td>g/km</td>
</tr>
<tr>
<td>Toyota Prius plug-in</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Opel Ampera</td>
<td>87</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>87</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
Real-world fuel consumption of modern conventional petrol vehicles is 30 – 50% above type approval (TA) value

- 40-50% for petrol vehicles with TA fuel consumption 90 – 125 g/km
- based on similar analyses of fuel-pass data of real-world fuel consumption
- difference has increased over the last 5 years
- origins:
  - difference between driving on road and during test
    - driving pattern (driving style and mix of road types)
    - driving conditions
    - vehicle characteristics
  - increased application of energy saving technologies that perform better on test than on road (e.g. start-stop)
  - increased utilization by manufacturers of test margins

- Lower share of electric driving than on TA test leads to higher average fuel consumption
Monitoring during a transition period

- PHEVs came to the Dutch market in 2012
- In 1st half year charging data lag behind fuelling data due to delays in availability of charging infrastructure
- In total more than 10% of the total Dutch PHEV fleet is covered
  - 540 Ampera / Volt
  - 100 Prius plug-in
Real-world fuel consumption
Total annual fuel use and mileage

- Large spread in fuel consumption
- Lowest values only attainable with high share of electric driving
- Some users do combine large annual mileage with low fuel consumption / high share of electric driving
Spread in real-world fuel consumption and direct (TTW) CO₂ emissions

- Real-world average:
  - Prius: 106 g/km
  - Ampera/Volt: 110 g/km

- Overall average RW fuel consumption of PHEVs in database = 4.6 l/100km
RW fuel consumption of PHEVs
Comparison with conventional vehicles

- Absolute difference between RW and TA somewhat higher than for conventional vehicles
- Relative difference is much higher
- RW/TA ratio of PHEVs determined by:
  - RW/TA ratio for driving on ICE
  - lower share of electric driving than on TA

![Graph showing type-approval and real-world CO2 emissions](image)
Charging behaviour
Analysis of limited part of database for which charging data were available

- 1/3 of vehicles charges once or twice a day
- Majority of vehicles charges less often
Share of kms driven electric
Estimated using combination of data

- On average 22% - 24% of kms are driven on electricity
- This is much lower than shares assumed for determining TA value
- Origins:
  - lack of battery charging
  - RW electric range lower than TA value
Conclusions

- During 2012 PHEVs in the Netherlands on average drove 22 - 24% of their kilometres on electricity
  - Share of ICE-driving is 2 - 3 times larger than on type approval test
- This leads to increased difference between real-world and type approval fuel consumption and CO₂ emissions
  - compared to conventional vehicles
  - leads to erosion of environmental benefit and reduced cost-effectiveness of fiscal stimulation measures

<table>
<thead>
<tr>
<th></th>
<th>TA electric range</th>
<th>share of electric driving</th>
<th>Type Approval</th>
<th>Real World</th>
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<tbody>
<tr>
<td></td>
<td>km</td>
<td>TA</td>
<td>RW</td>
<td>fuel</td>
</tr>
<tr>
<td>Toyota Prius plug-in</td>
<td>25</td>
<td>50%</td>
<td>22 –</td>
<td>2.1</td>
</tr>
<tr>
<td>Opel Ampera / Chevrolet Volt</td>
<td>87</td>
<td>78%</td>
<td>24%</td>
<td>1.2</td>
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</tbody>
</table>
Discussion
Some caveats w.r.t. conclusions from 2012 data

- PHEVs in database are mostly used as company car
  - Not only result of using fuel pass data
  - Most PHEVs in Netherlands are used as company cars, because Dutch fiscal system strongly promotes use of PHEVs in this application
- Users of company cars have no incentive to charge their vehicles
- Availability of charging infrastructure lagged behind during market introduction phase of PHEVs
- Users of PHEVs may have needed some time to adjust behaviour

- Data show that there is significant room for improvement
  - Initiative started by employers, lease companies and importers of PHEVs to improve availability of charging infrastructure and develop incentives that stimulate users of PHEVs to drive electric

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