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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 CO_2 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 CO_2 emissions of PHEVs determined by combining results of two separate tests:

$$C = (D_e \cdot C_1 + D_{av} \cdot C_2)/(D_e + D_{av})$$

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

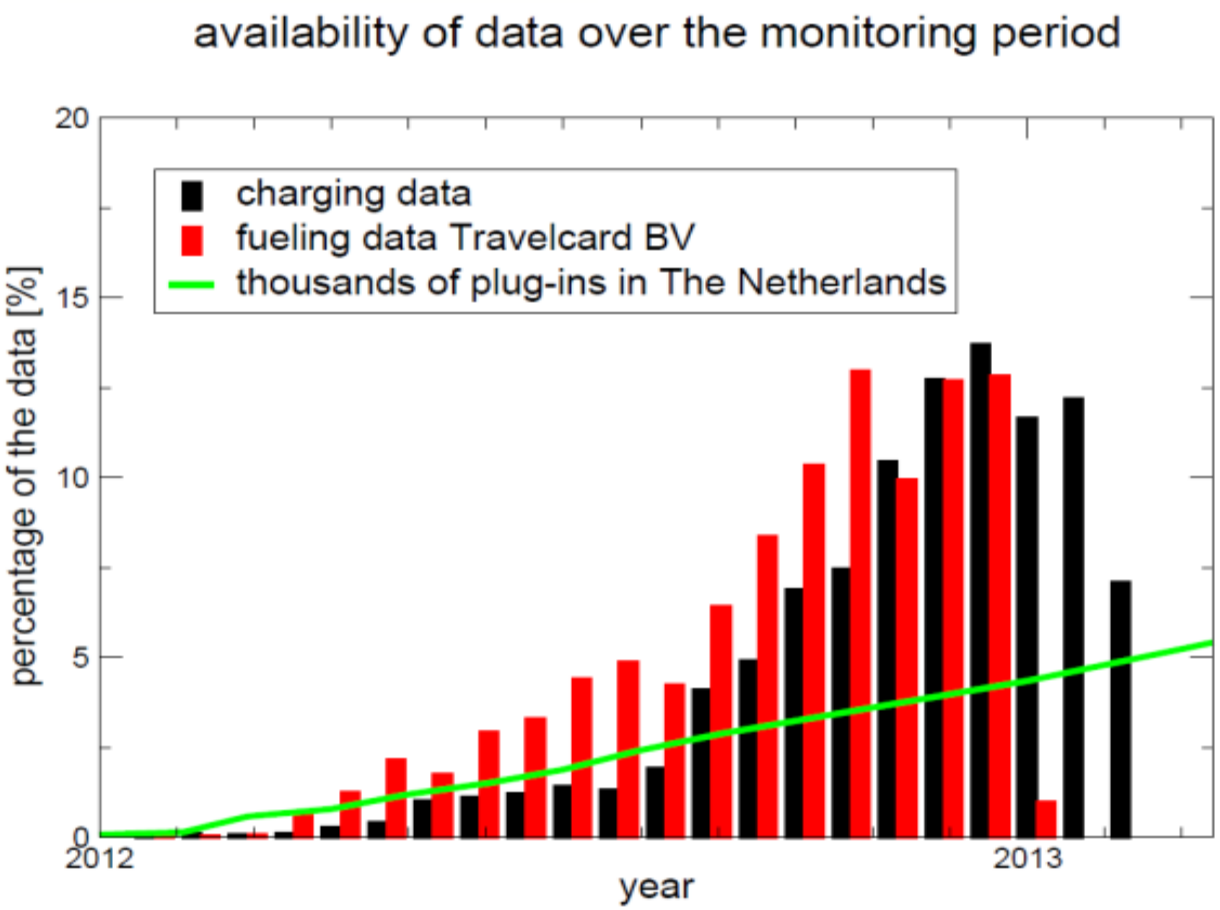
	electric range	test 1 (full battery)		test 2 (empty battery)		overall	
		fuel	CO_2	fuel	CO_2	fuel	CO_2
	km	l/100km	g/km	l/100km	g/km	l/100km	g/km
Toyota Prius plug-in	25	0	0	4.2	98	2.1	49
Opel Ampera	87	0	0	5.2	119	1.2	27
Chevrolet Volt	87	0	0	5.2	119	1.2	27

Real-world fuel consumption

Origins of difference with type approval value

- 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

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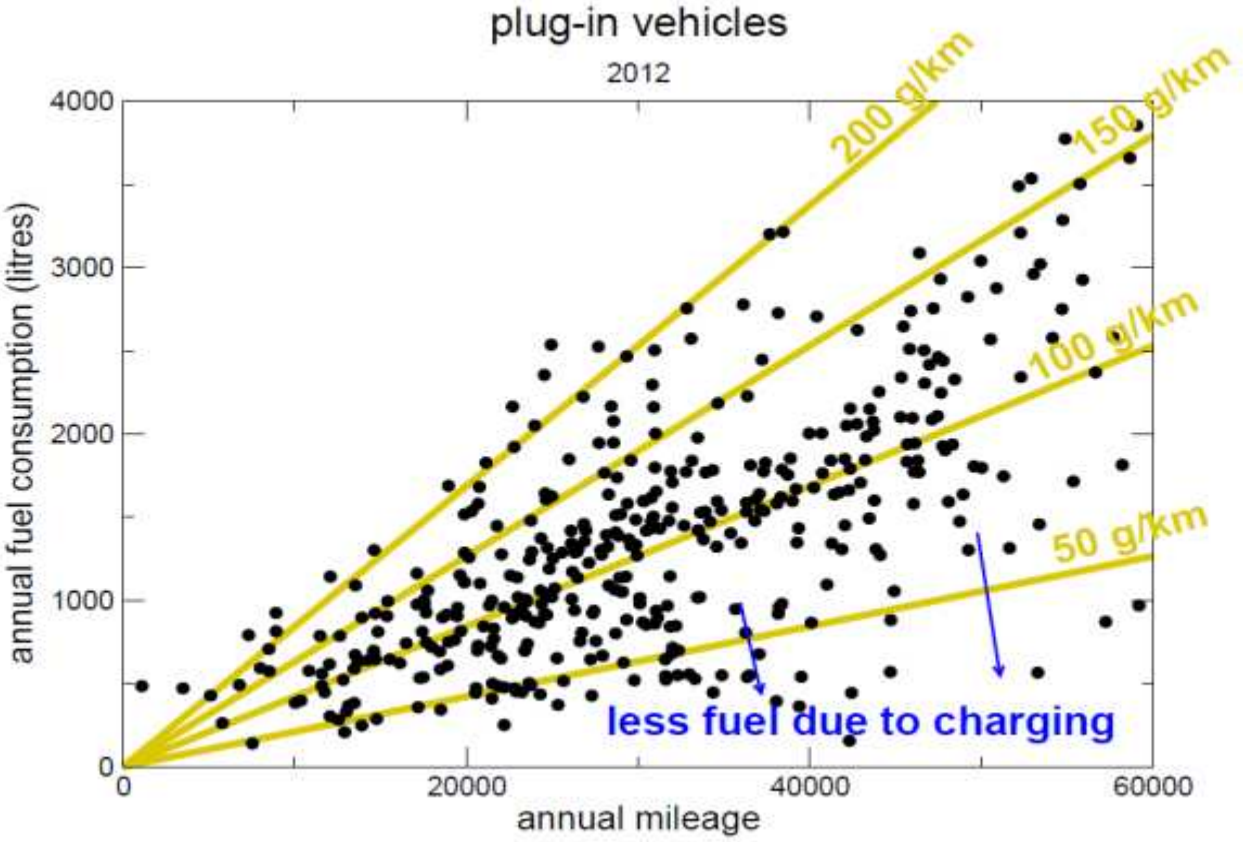
Real-world fuel consumption

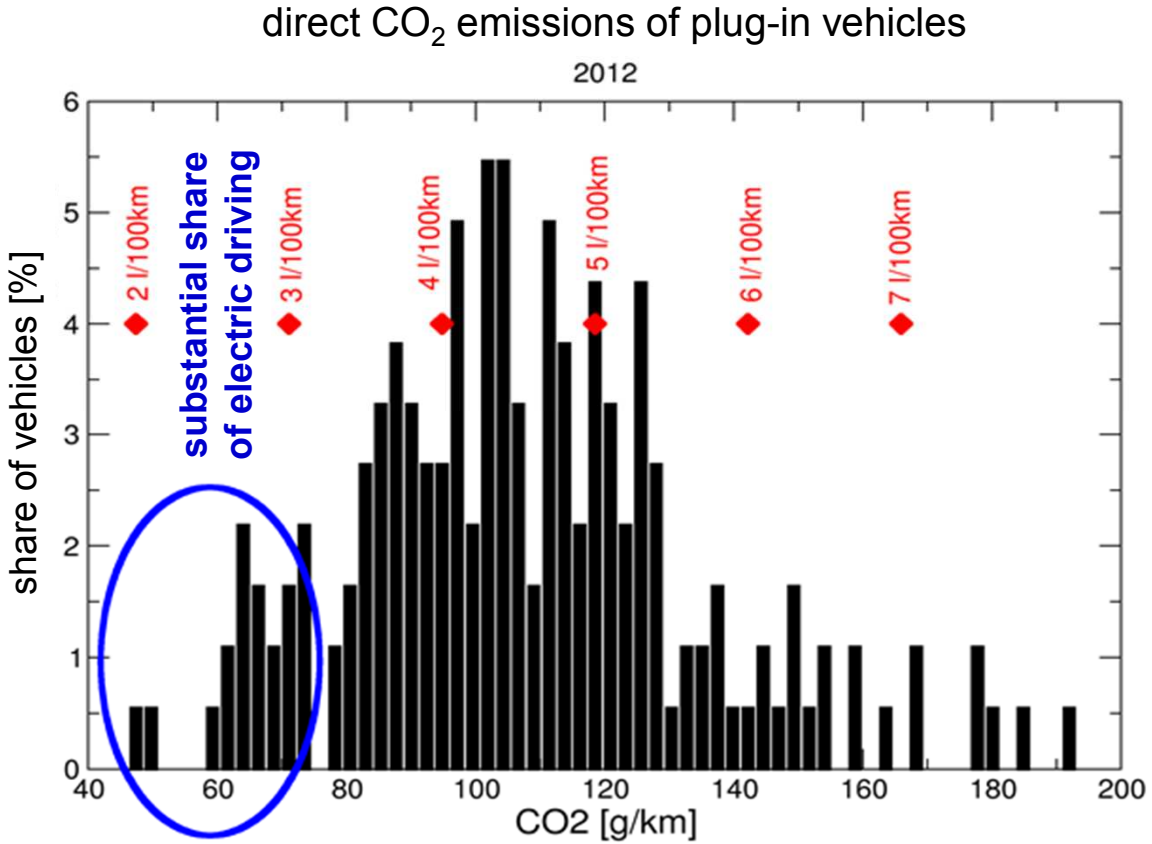
Total annual fuel use and mileage



- 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

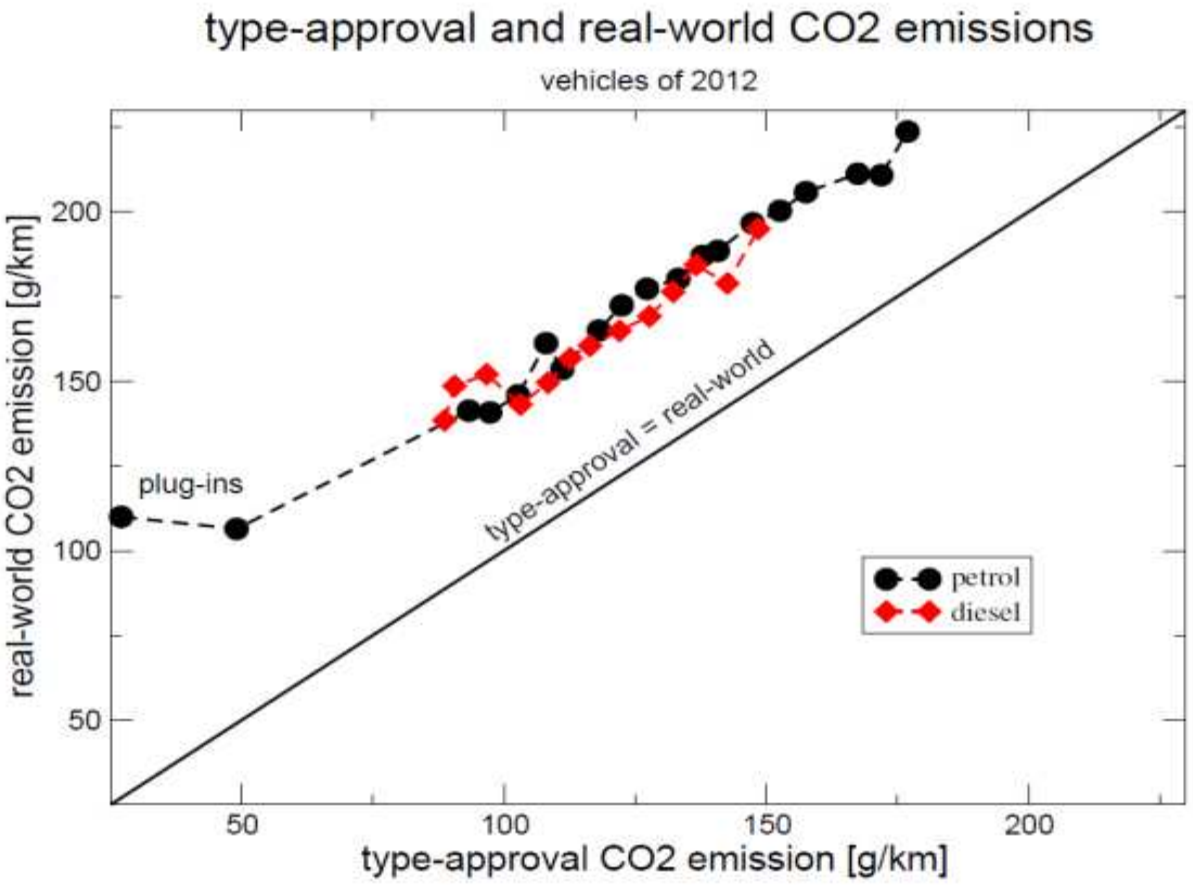
And direct (TTW) CO_2 emissions



- 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

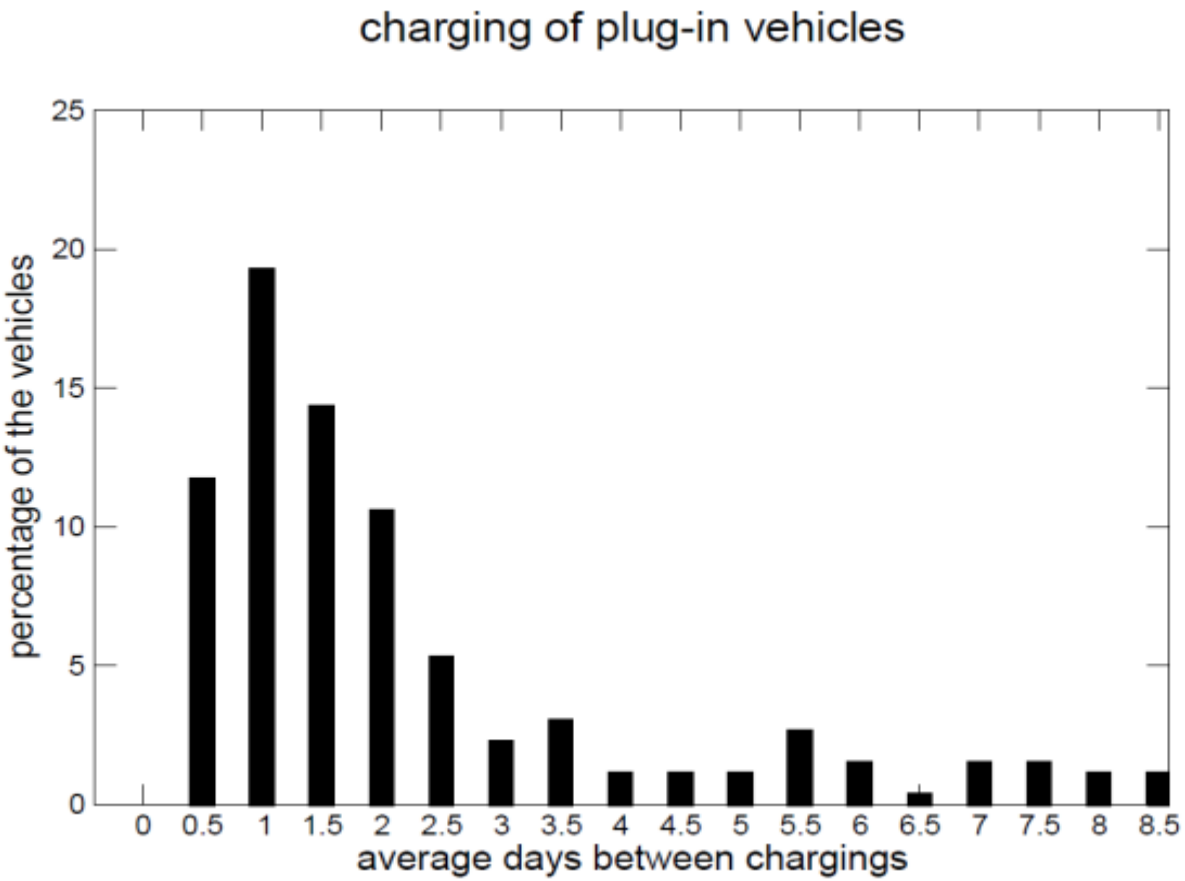
Comparison with conventional vehicles



- 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

Charging behaviour

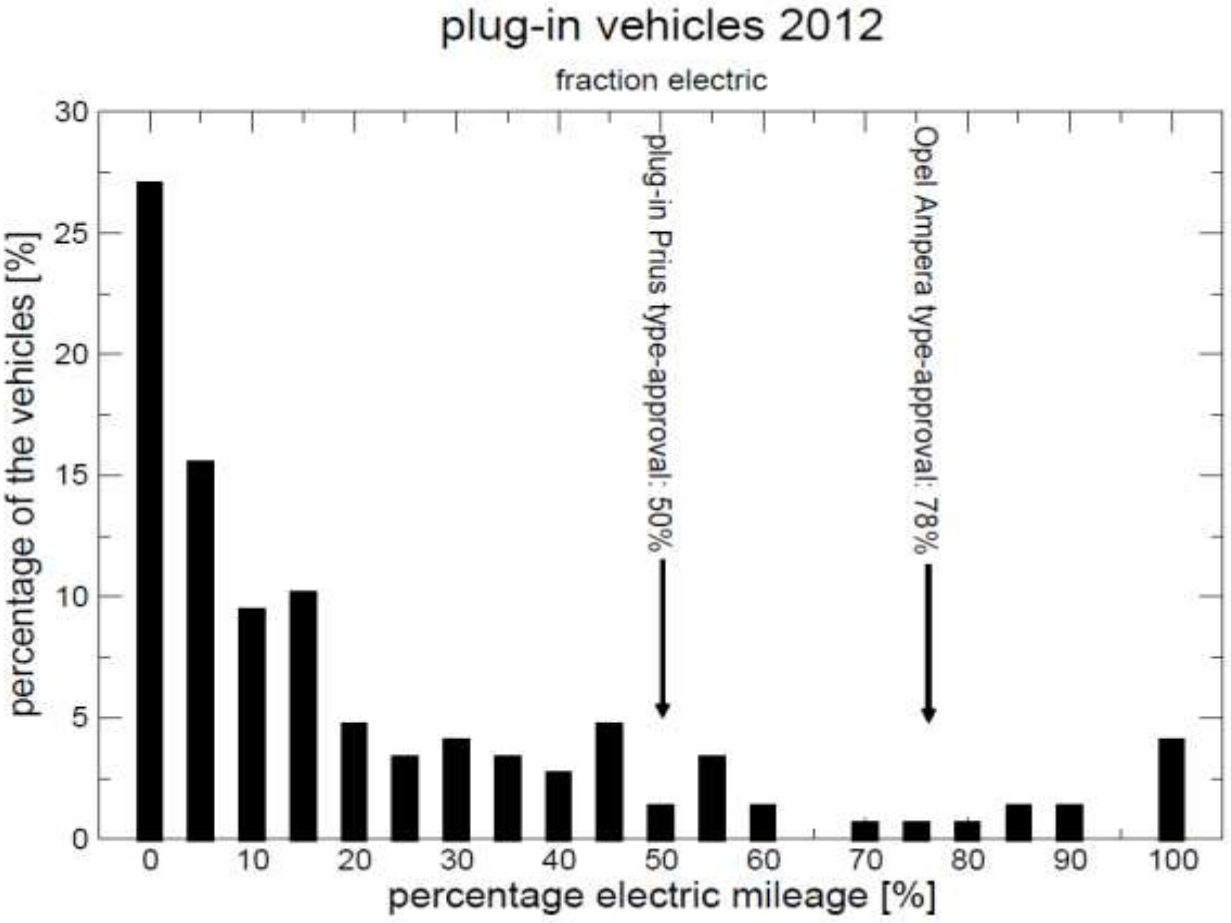
Analysis of limited part of database for which charging data were available



- 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 CO_2 emissions
  - compared to conventional vehicles
  - leads to erosion of environmental benefit and reduced cost-effectiveness of fiscal stimulation measures

	TA electric range	share of electric driving		Type Approval		Real World	
				fuel	CO_2	fuel	CO_2
	km	TA	RW	l/100km	g/km	l/100km	g/km
Toyota Prius plug-in	25	50%	22 – 24%	2.1	49	4.6	106
Opel Ampera / Chevrolet Volt	87	78%		1.2	27	4.8	110

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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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