German Aerospace Center (DLR) – Institute of Vehicle Concepts

Cost Analysis of Plug-in Hybrid Electric Vehicles including Maintenance & Repair Costs and Resale Values

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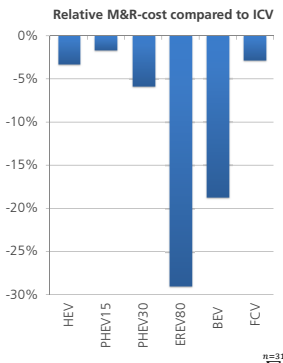
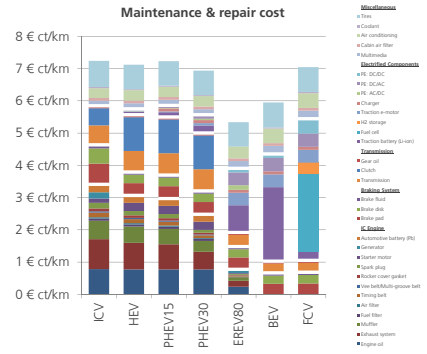
1. Vehicle Characteristics

Parameter	Unit	ICE	HEV	PHEV15	PHEV30	EREV80	BEV	FCEV
Vehicle architecture		Gasoline engine, 2-wheel drive (identical for all), automatic transmission	Parallel hybrid with 2 clutches, automatic trans-mission	Parallel hybrid with 2 clutches, external charge unit, 16 km AER	Parallel hybrid with 2 clutches, external charge unit, 32 km AER	Series hybrid with gasoline engine as range extender, external charge unit, 86 km AER	Central electrical traction motor, single-speed transmission, charge unit	Central e-motor, 700 bar hydrogen storage
Power combustion engine	*kW*	105	68	65	67	72	-	-
Power e-motor	*kW*	-	25	34	34	98	98	98
Battery pack storage	*kWh*	-	1	2.8	5.4	17	25	2
Pack cost	*EUR*	-	760	835	1,545	4,010	5,600	1,160
Curb weight	*kg*	1,220	1,271	1,288	1,307	1,511	1,621	1,683
Electric consumption	*Wh/km*	-	-	43	62	103	128	-
Fuel consumption	*l/100 km*	6.0	3.2	2.0	1.4	1.0	-	[1.0 kg H_2 /100km]

- Considering 7 different powertrain configurations for the C-segment (e.g. Volkswagen Golf)
- Vehicle data based on simulations carried out by Argonne National Laboratory and IFPEN Paris as part of the IEA Implementing Agreement on Hybrid and Electric Vehicles
- Vehicle characteristics serve as input for both the maintenance & repair cost model as well as the TCO-model

2. Maintenance & Repair



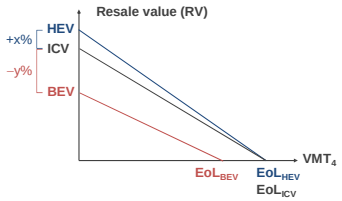


$$C_{M\&R,j,k} = \sum_{i=1}^{n=31} MTBF_{i,j,k} * \left(C_{i,j,k} + T_{i,j,k} * C_{labor}\right) \forall j,k$$

- In a newly developed bottom-up cost model, maintenance and repair cost are assessed
- Taking into account 31 drivetrain components
- Results show that electrified powertrains have significantly lower M&R-cost with up to 30% reduction compared to a conventional vehicle
- Especially batteries and fuel cell systems are cost drivers

3. Resale Value

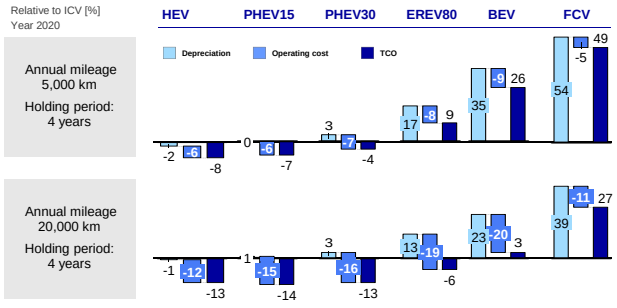
Model	$P_{purchase}$	Relative resale value 10,000 km	20,000 km	30,000 km	40,000 km
Toyota Auris 1.8 Hybrid life	23,950 €	48.9%	42.7%	37.5%	32.3%
Toyota Auris 1.6 life, 3T	19,750 €	42.6%	37.3%	32.7%	28.2%
Delta ICE$_{HEV}$ vs. ICV	21.3%	14.7%	14.7%	14.7%	14.7%
Honda Insight 1.3 Hybrid	20,950 €	47.7%	41.7%	36.6%	31.5%
Honda Civic 1.4	17,790 €	42.4%	37.1%	32.6%	28.1%
Delta ICE$_{HEV}$ vs. ICV	17.8%	12.3%	12.3%	12.3%	12.3%
Mercedes S400H	87,097 €	38.3%	36.0%	33.0%	30.6%
Mercedes S350	81,742 €	31.9%	30.0%	27.5%	25.5%
Delta ICE$_{HEV}$ vs. ICV	6.6%	20.1%	20.1%	20.1%	20.1%



$$RV_{j,k} = P - \left[\left(P * m_{1,j} + c_{1,j}\right) * VMT_k + P * m_{2,j} + c_{2,j}\right]$$

- Newly developed model for assessing the resale value after 4 years
- Based on ADAC-data
- Taking into account
  - purchase price
  - annual mileage
  - vehicle segment
  - drivetrain architecture

4. Total Cost of Ownership



- TCO-model incorporating the previously calculated results
- Results show that
  - parallel hybrid powertrains have cost-advantages compared to an ICV, even for annual mileages of 5,000 km and a holding period of 4 years
  - range-extender vehicles and battery electric vehicles compensate the higher initial purchase price due to lower operating cost for VMTs over 20,000 km

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