IA-HEV Task 15.
Plug-in Hybrid Electric Vehicles.
Phase 1 Findings & Phase 2 Recommendations

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2008–2012 Task 15 Investigations

- Cold Temperature Behavior (Charles Thibodeau)
- Li-ion Battery Chemistry Issues (Isobel Davidson, Dan Santini, Bernd Propfe)
- Charging Plug-in Vehicles with Wind (Charles Thibodeau, David Dallinger)
- Powertrain Attributes (Aymeric Rousseau, François Badin)
- Battery Pack Attributes (P. Plotz, B. Propfe, A. Rousseau, F. Badin, D. Santini)
- Vehicle Lifetime Use Costs (B. Propfe, D. Santini)
- Policy Issues and Marketability (P. Plotz, B. Propfe, M. Pasquier, D. Santini)
- Group administration, communication, and coordination by the Operating Agent (Charles Thibodeau, Dan Santini)

Personnel

- François Badin (France), IFP Energies nouvelles
- Maxime Pasquier (France), Ademe
- David Dallinger and Patrick Plotz (Germany), Fraunhofer Institute for Systems and Innovation Research
- Bernd Propfe (Germany), Institute of Vehicle Concepts at the German Aerospace Center
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Experts' Consensus Findings

- High fuel prices are important to financial viability and political support of electric drive.
- 15-50 km design range Parallel- &/or Input-Split(IS)-PHEVs were estimated to be least total cost (TCO) to electrify km.
- 30-70 km Output-split & Series Range-Extended Electric Vehicles (REEVs) & 150 km AEV had higher TCO.
- REEVs &/or AEVs require development of a less expensive next generation of batteries, and/or even higher oil prices.
- For personal use, the plug-in vehicles evaluated best fit suburbs and towns, not dense core city markets.
- For cost effectiveness, intensive use (both days per year and kilometres/day of use) is required.

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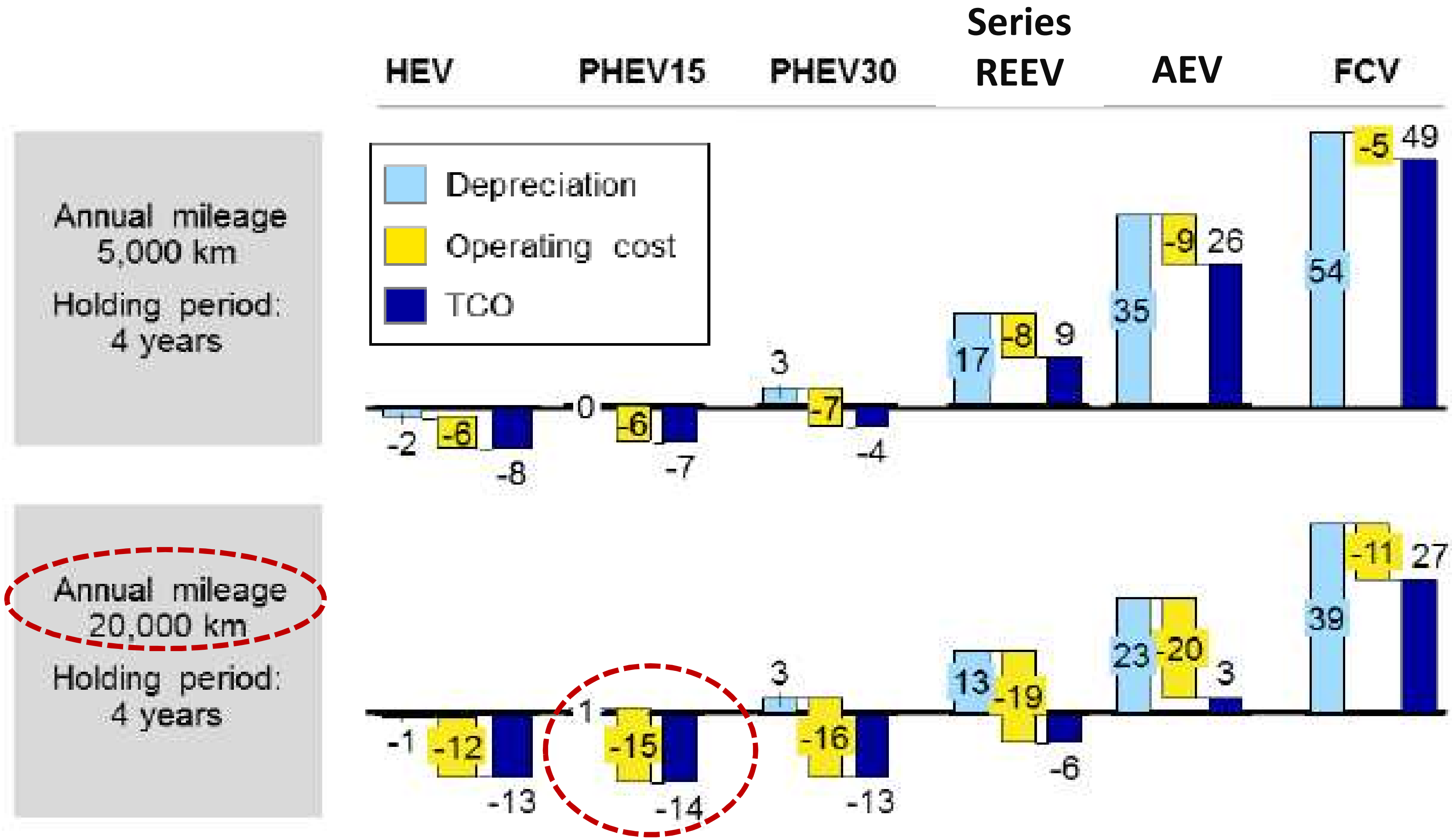
Technical Findings Summary

- With today's li-ion options, broad trade-off and detailed powertrain investigations support 5-10 kWh pack PHEVs.
- Battery pack cost per kWh plummets from 1 kWh HEV "power" packs to 5+ kWh PHEV and EV "energy" packs.
- Battery design trade-offs/constraints cause high kW to be available in packs of 10 kWh & up, encouraging 70 km+ REEVs with significant all-electric capability (100+ kW).
- PHEVs with ~ 60 kW packs are capable of everyday all-electric driving, save significant non-battery costs vs. REEVs.
- Inter-city highway driving range for affordable AEVs is impractical for many, especially at temperature extremes.
- Charging strategies should avoid use of coal electricity.
- V2G is a long-term possibility, not a short term market pull.

DLR estimated HEVs & PHEVs to have lower TCO than petrol ICE. A PHEV15 had lowest TCO if used intensively



German case TCO comparison vs. ICE (in %) in the year 2020

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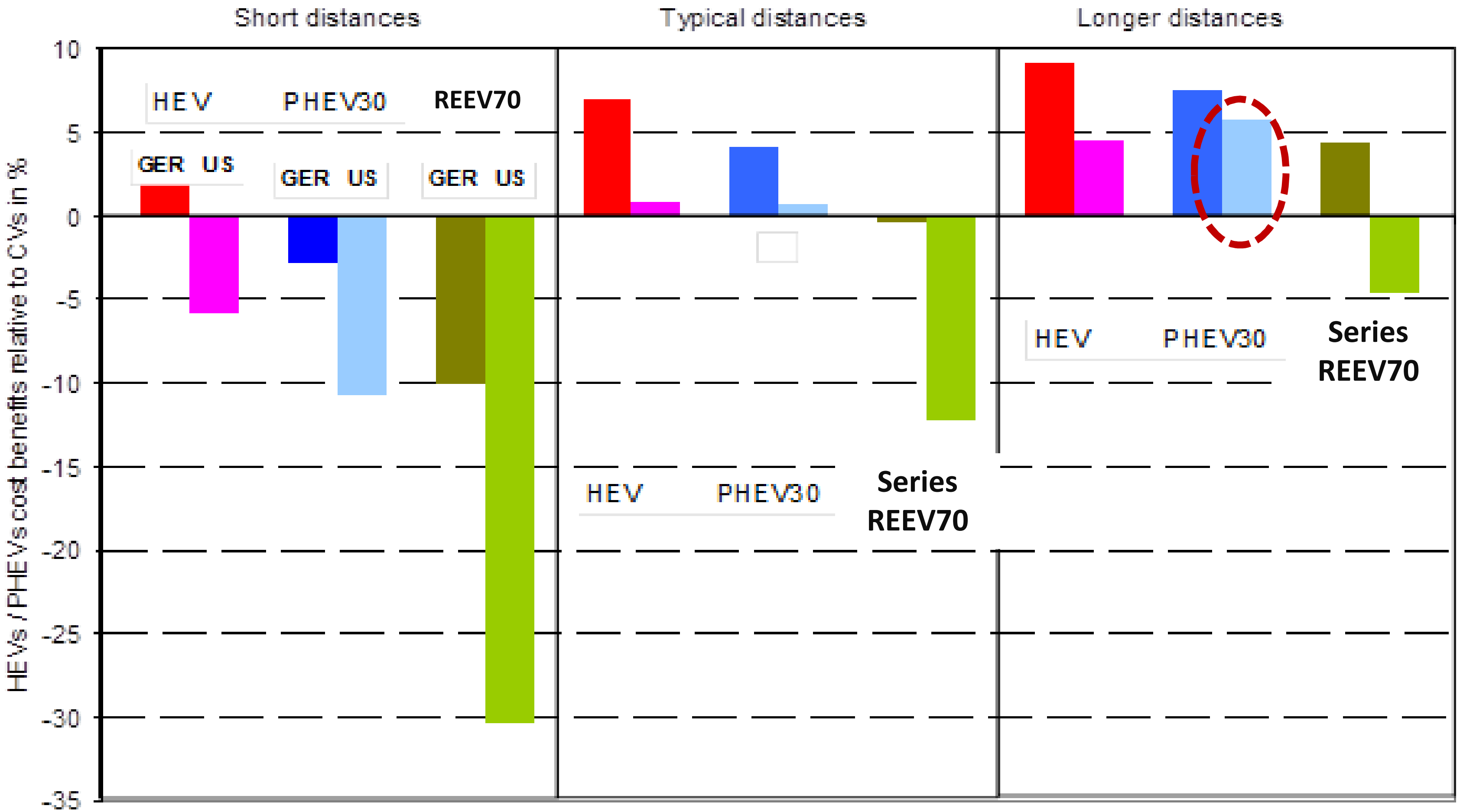
In a team comparison for U.S. & Germany, an intensively used PHEV30 had highest net benefit in U.S.



% change of HEV, PHEV & REEV TCO vs. CV, by drivetrain & km/yr

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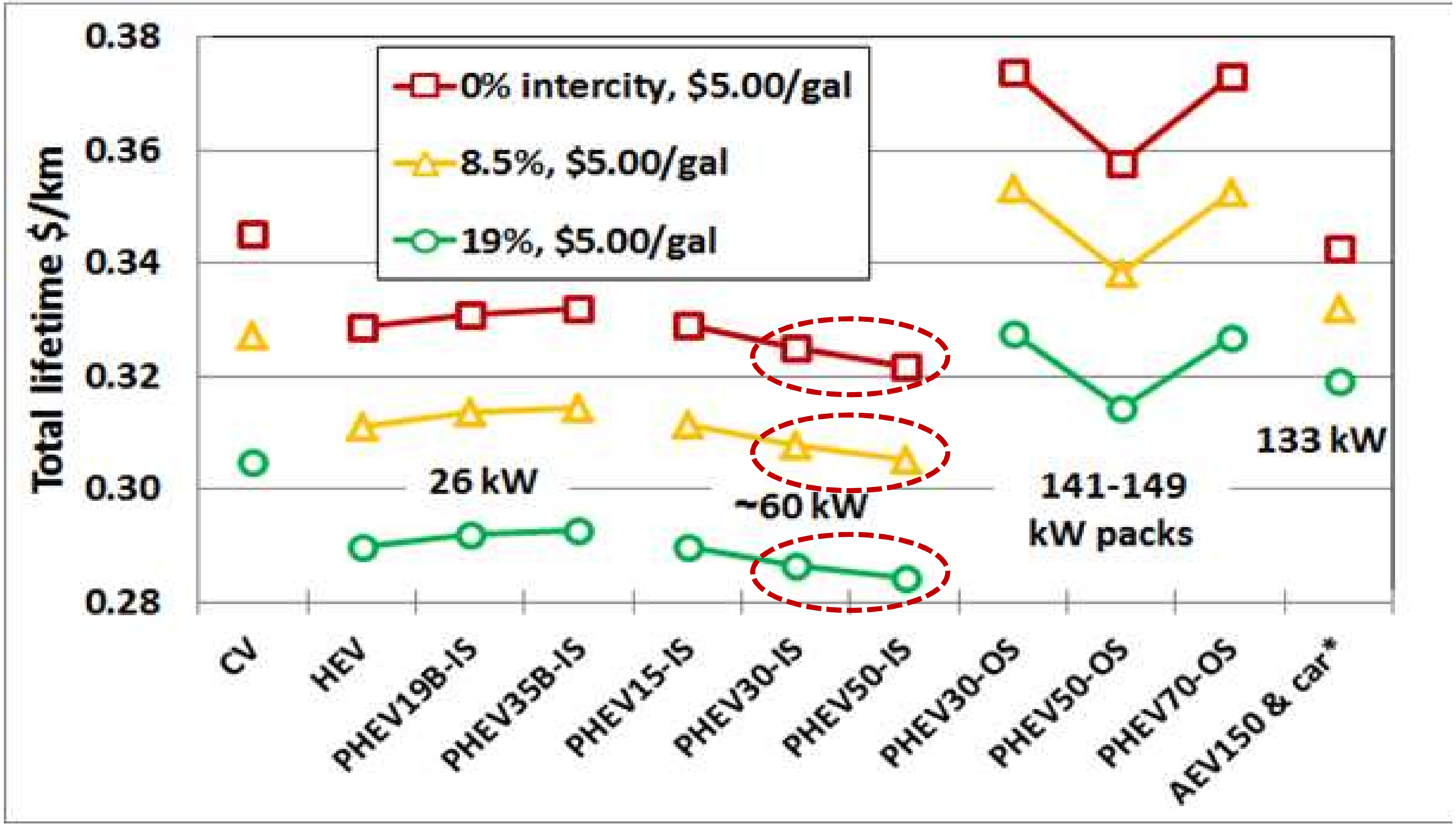
A U.S. study projected 30-50 km range 60 kW input split PHEVs to have lowest cost if gasoline prices rise ~ 40%



10 yrs urban driving 16,300 km/year; inter-urban driving - 0 km/year (red), 1,510 km/year (yellow), or 3,810 km/year (green)

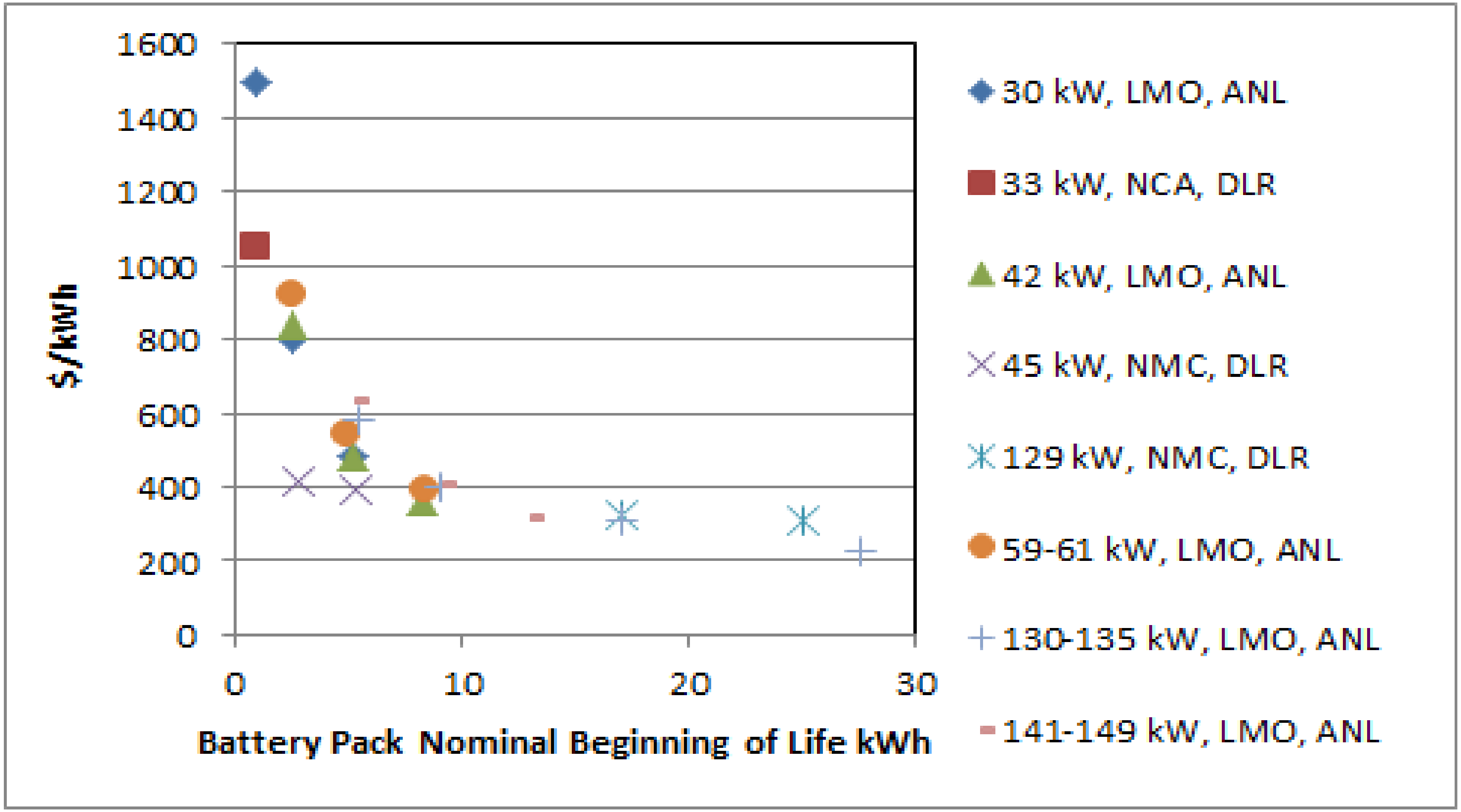
As gas price, daily driving, charging frequency & intercity use vary, lowest cost options change

$/L for gas	km/day group	% days	Charge /day	Inter-city %	CV	HEV	PHEV 15 IS	PHEV 50 IS	AEV 150
0.92	48-80	72	1	all					
0.92	48-80	72	1+	all					
0.92	48-80	90	1	all					
0.92	80-160	72	1	all					
0.92	80-160	72	1+	all					
0.92	80-160	90	1	all					
1.32	48-80	72	1	all					
1.32	48-80	72	1+	all					
1.32	48-80	90	1	all					
1.32	80-160	72	1	0					
1.32	80-160	72	1	8.5					
1.32	80-160	72	1	19.5					
1.32	80-160	72	1+	0					
1.32	80-160	72	1+	8.5					
1.32	80-160	72	1+	19.5					
1.32	80-160	90	1	0					
1.32	80-160	90	1	8.5					
1.32	80-160	90	1	19.5					

Prior slide

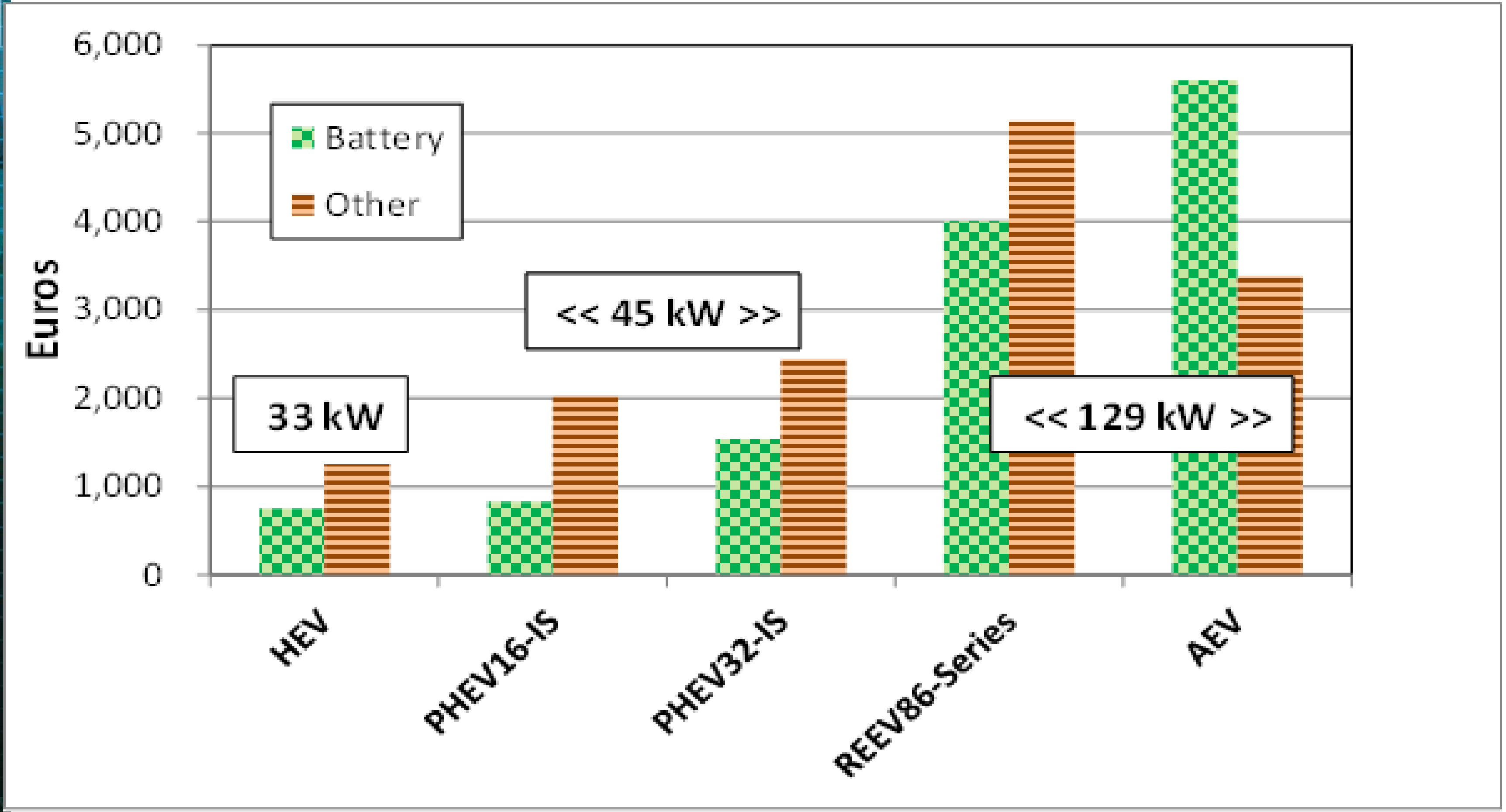
Estimated lowest cost powertrain for specified patterns of use (ANL)

PHEV enabler: Battery pack costs per kWh plummet from 1 kWh HEV "power" packs to 5+ kWh PHEV and EV "energy" packs



Modeled battery pack $/kWh cost estimates, DLR & Argonne

It is not just the battery. Other powertrain costs for HEVs, PHEVs and REEVs are greater.



Contributions to increment in PEV price over CV: battery vs. other powertrain changes, DLR German estimates

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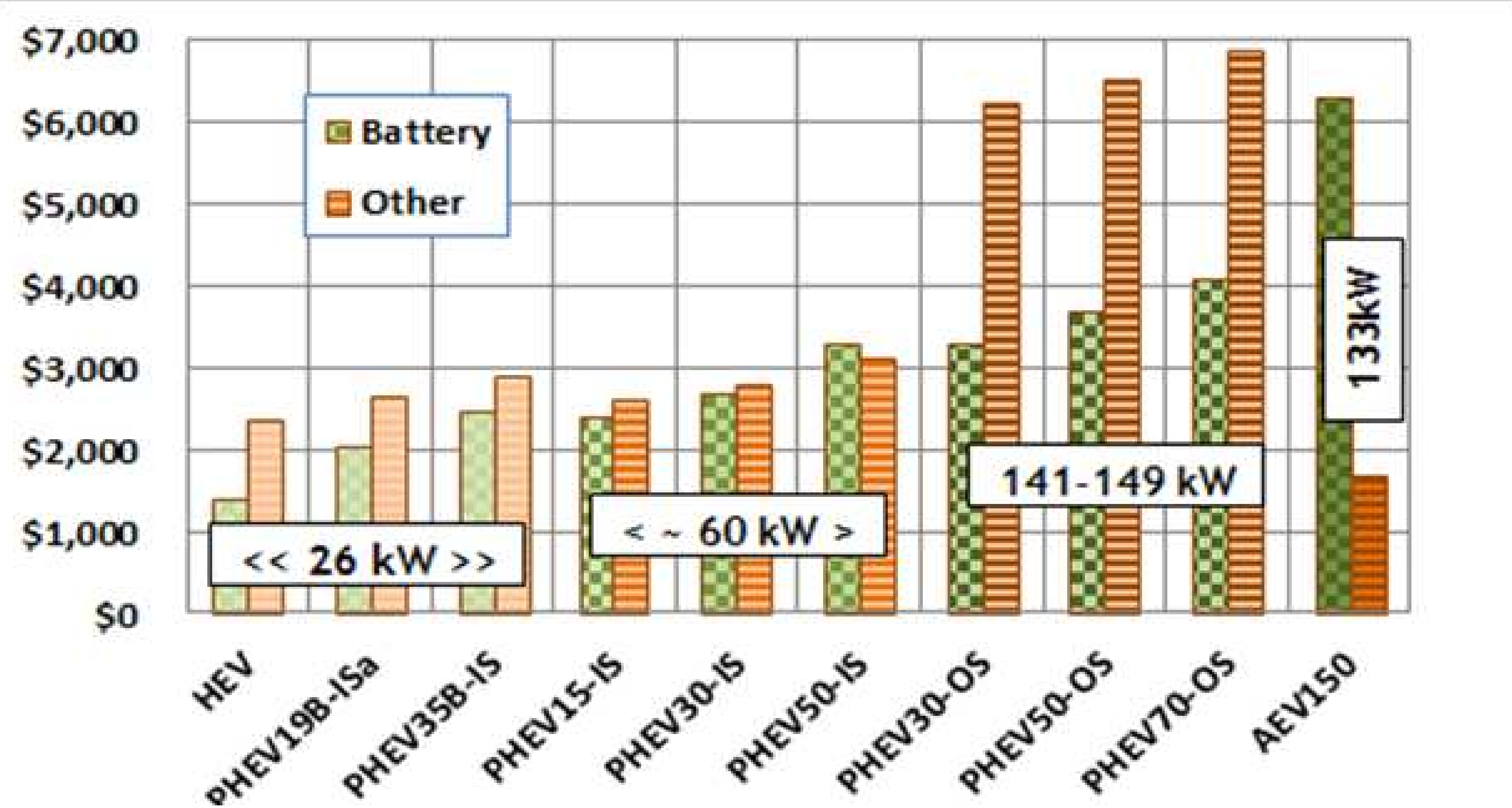
With high complexity, the output split non-battery costs to be an REEV with > 100 kW are very high. Pack kW are not as costly.



Contributions to increment in PEV price over CV: battery vs. other powertrain changes, Argonne U.S. estimates

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Phase 2 Recommendations

- Conduct systematic cost methodology comparison.
- Compare full-function HEVs, PHEVs and REEVs to advanced conventional powertrains (Clean diesel, TDI petrol, CNG).
- Study powertrain depreciation attributes and impact on vehicle lifetime use costs, particularly battery replacement.
- Using consistent methodologies, evaluate potential causes of changes in market(s) size - oil prices, battery pack costs, electricity cost, infrastructure cost, consumer adaptation.

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Phase 2 Recommendations

- Track, evaluate, and/or study methods to desirably alter charging behavior.
- Study lithium-ion battery chemistries as enablers of more lifetime cost-efficient micro HEVs and mild HEVs.
- Examine whether a standard peak battery pack and electrical machine power level for both HEVs and PHEVs can cost-effectively spread component costs across HEV & PHEV platforms.
- Simulate different vehicle platforms.

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Task 15 Country Expert Papers Sample (EVS26)

Fuel Consumption Potential of Different Plug-in Hybrid Vehicle Architectures in the European and American Contexts.

A. Da Costa et al (F. Badin, A. Rousseau)

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

B. Propfe et al (D. Santini)

An Analysis of Car and SUV Daytime Parking for Potential Opportunity Charging of Plug-in Electric Powertrains

D. Santini, Y. Zhou, and A. Vyas

Vehicle Charging Infrastructure Demand for the Introduction of Plug-in Electric Vehicles in Germany and the US.

T. Gnann, P. Plotz, F. Kley

Effect of Demand Response on the Marginal Electricity used by Plug-in Electric Vehicles.

D. Dallinger, M. Wietschel and D. Santini

Impacts of PHEV Charging on Electric Demand and Greenhouse Gas Emissions in Illinois.

A. Elgowainy et al (D. Santini)

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