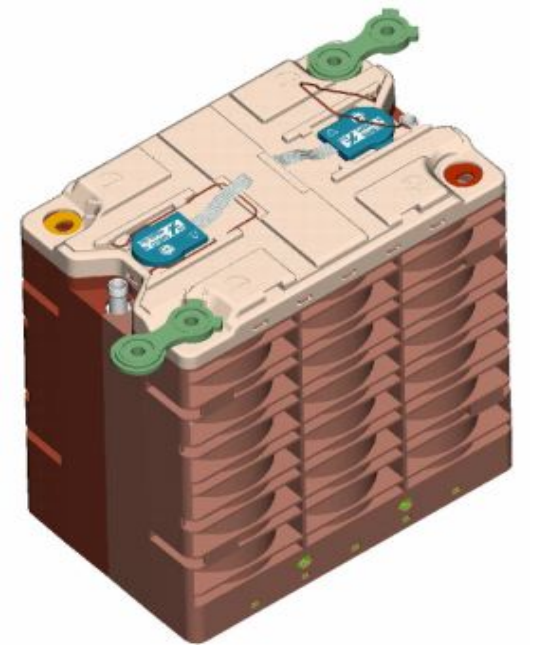

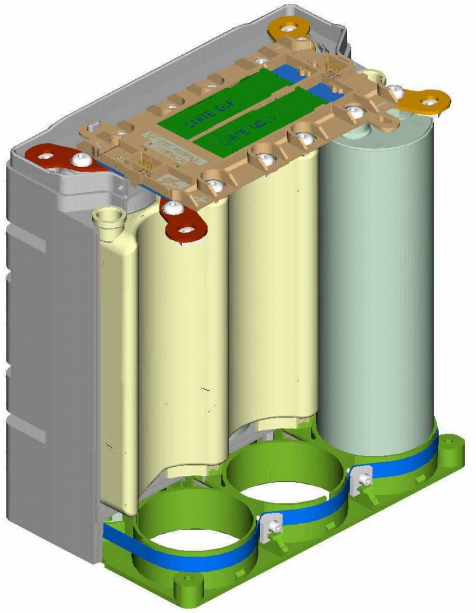

Batteries for Plug-In Hybrid Electric Vehicles

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The Seattle Electric Vehicle to Grid (V2G) Forum

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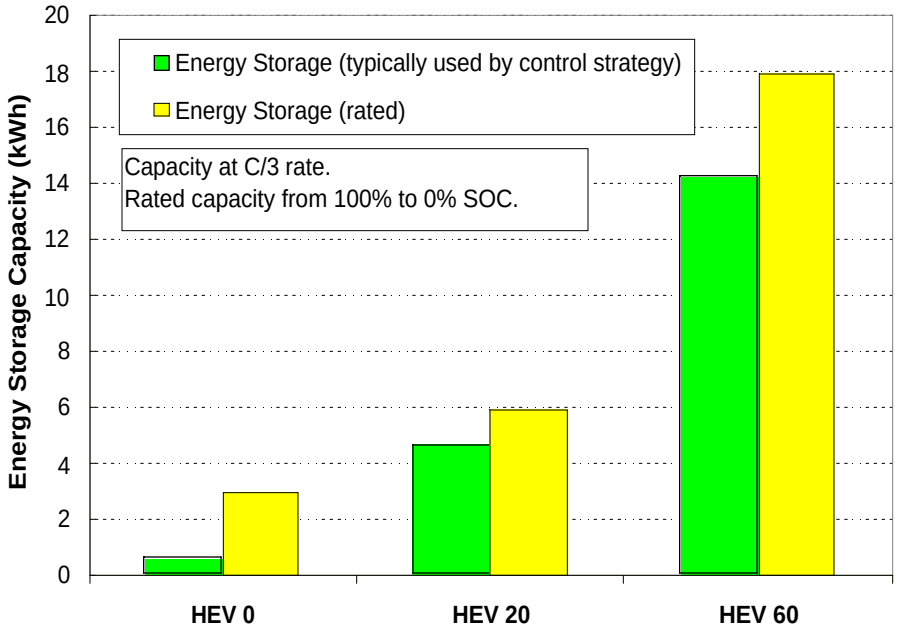
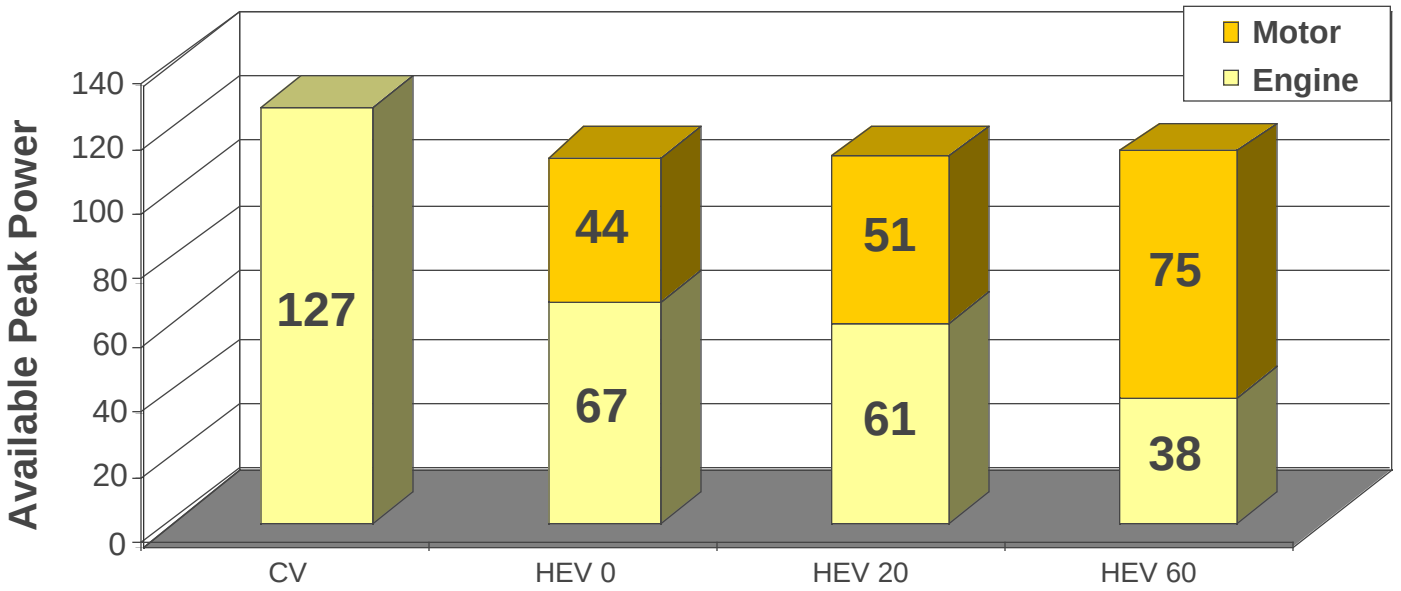
Energy Storage System Requirements

- High capacity, medium power designs are generally preferred
  - Specific Energy > 60 Wh/kg
  - Specific Power 400-750 W/kg
  - P/E Range of 7 to 12
    - Pure EV P/E ratio ~ 2-3
    - Power assist HEV > 20
- High cycle life
- Lower cost than pure power assist batteries



Midsize Sedan Battery Energy

HEV and PHEV Component Relationships



Source: HEVWG

Component	Specification	Units	Vehicle			
			CV	HEV 0	HEV 20	HEV 60
Engine	Power (peak)	kW	127	67	61	38
Motor	Power (peak for 120 seconds)	kW	-	44	51	75
Total Motive Power	Power (peak)	kW	127	111	112	113
Motor	Power (continuous)	kW	-	19	22	32
Batteries	Rated energy	kWh	-	**2.9**	**5.9**	**17.9**
Batteries	Rated power	kW	-	49	54	99

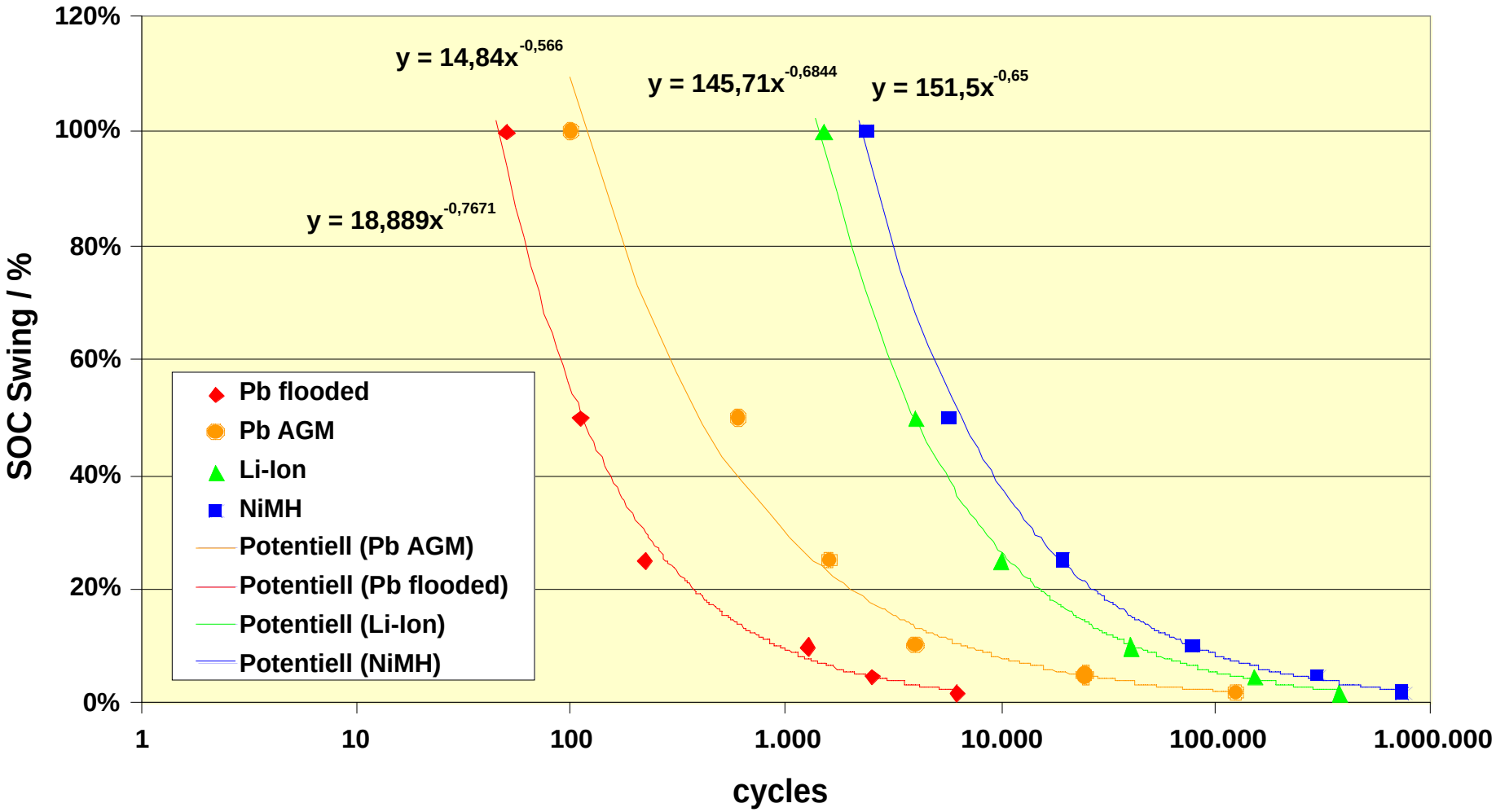
Saft Li-ion VL Module construction (3)

Modules Characteristics

	VLE	VL41M	VL30P*
Dimensions (mm)	242 x 190 x 123		
Weight (kg)	8.0		
Energy (Wh)	880	840	685
Power (W)	3,500	5,000	7,800

Note : Characteristics at 25°C
Power at 50% SOC, 18 s peak current
(*) Under development

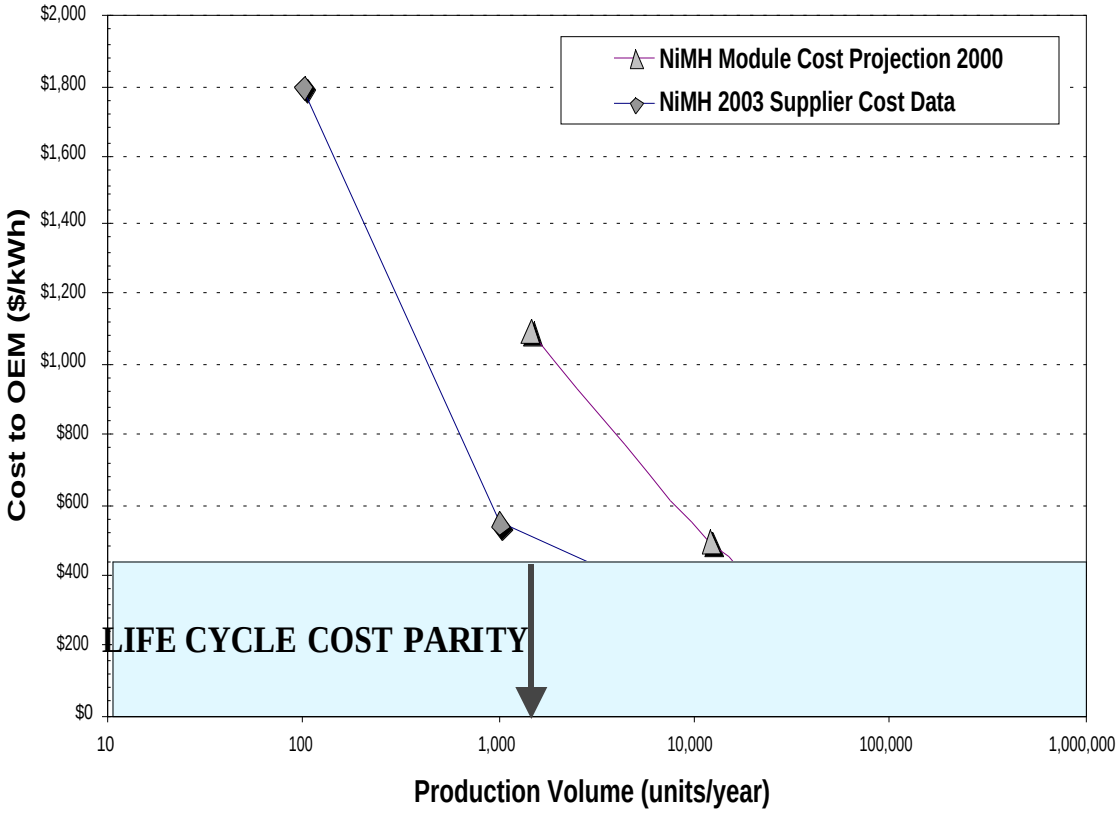
Cycle Life of Different Batteries



Source: VARTA GmbH

Advanced Battery Cost

- Advanced battery market beginning to open up.
- Cost picture is improving
- Increased evidence of sufficient durability
  - Cycle life > 2,500
  - Calendar life > 10 yrs
- Production volume and ability of suppliers to secure contracts critical to continued progress
- Other technologies also improving, moving to market
  - Li-Ion



Estimated price projections (1)

EV battery price targets

Based on a 25 kWh high energy battery system

Price per kWh (Euros)	Medium term 20 000 batteries/year	Long term 100 000 batteries/year
DST cycle (net energy)	400-450	280-300

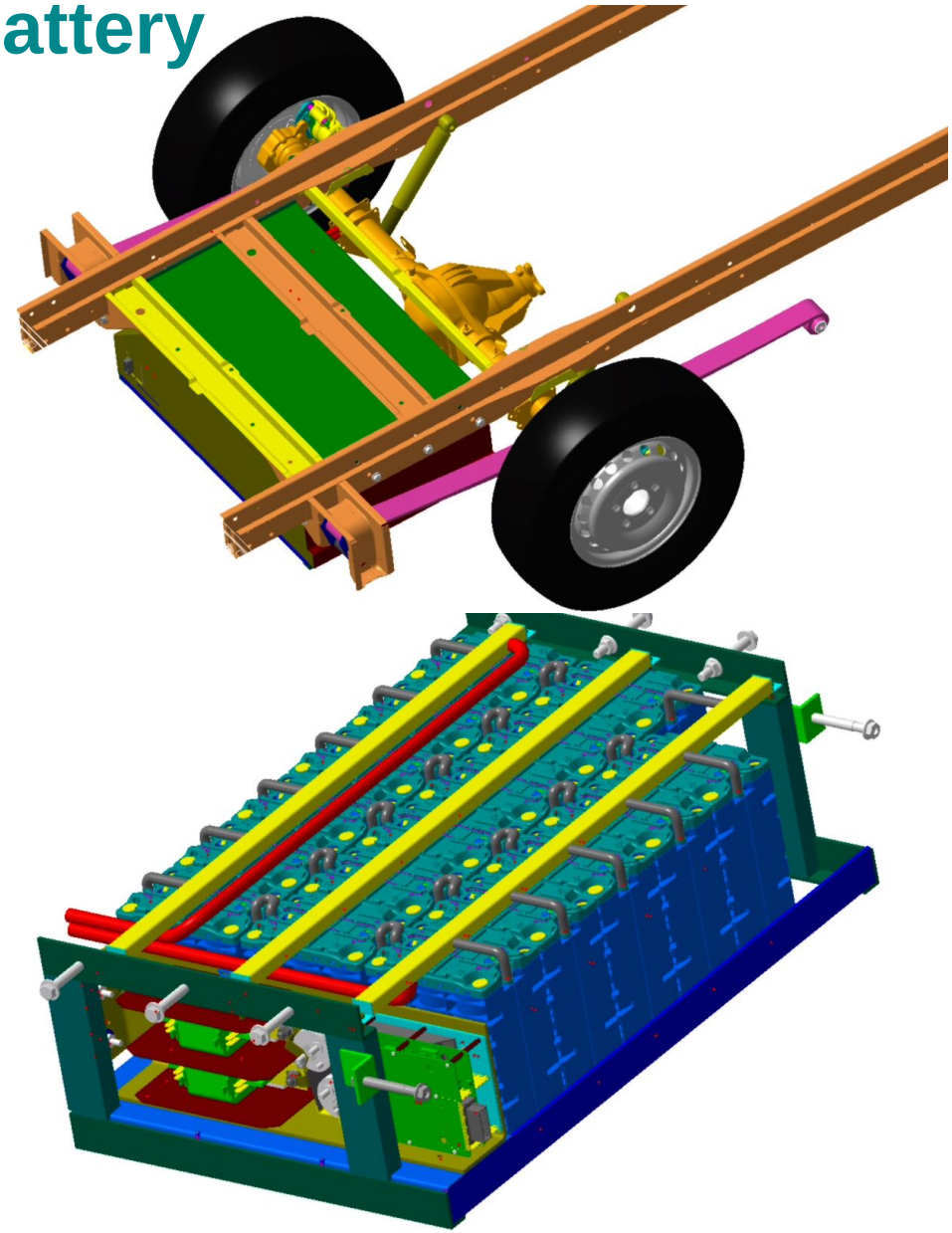
Benefits of PHEV Technology

Derive more than 1 kWh of benefits from 1 kWh of battery energy

- Use highest efficiency electric power system
  - High power electric motors
  - Low impedance, high power battery
  - Minimize energy recirculation
  - Maximize regenerative braking
  - Use grid recharging to minimize fuel converter duty cycle
- Maximize fuel converter (engine) efficiency
  - Engine selection for high efficiency (downsize, alternate cycle, etc)
  - Optimal control of IC engine
  - Eliminate engine idle, low-efficiency engine operation (creep)
  - Reduce transient operation

PHEV Sprinter Li Ion Battery

- Lithium Ion battery
- Module mass of 120 kg
- Energy of 14 kWh
- Peak power of 90-100 kW
- Liquid-cooled for thermal management
- 3.3 kW conductive charger



Thank You

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