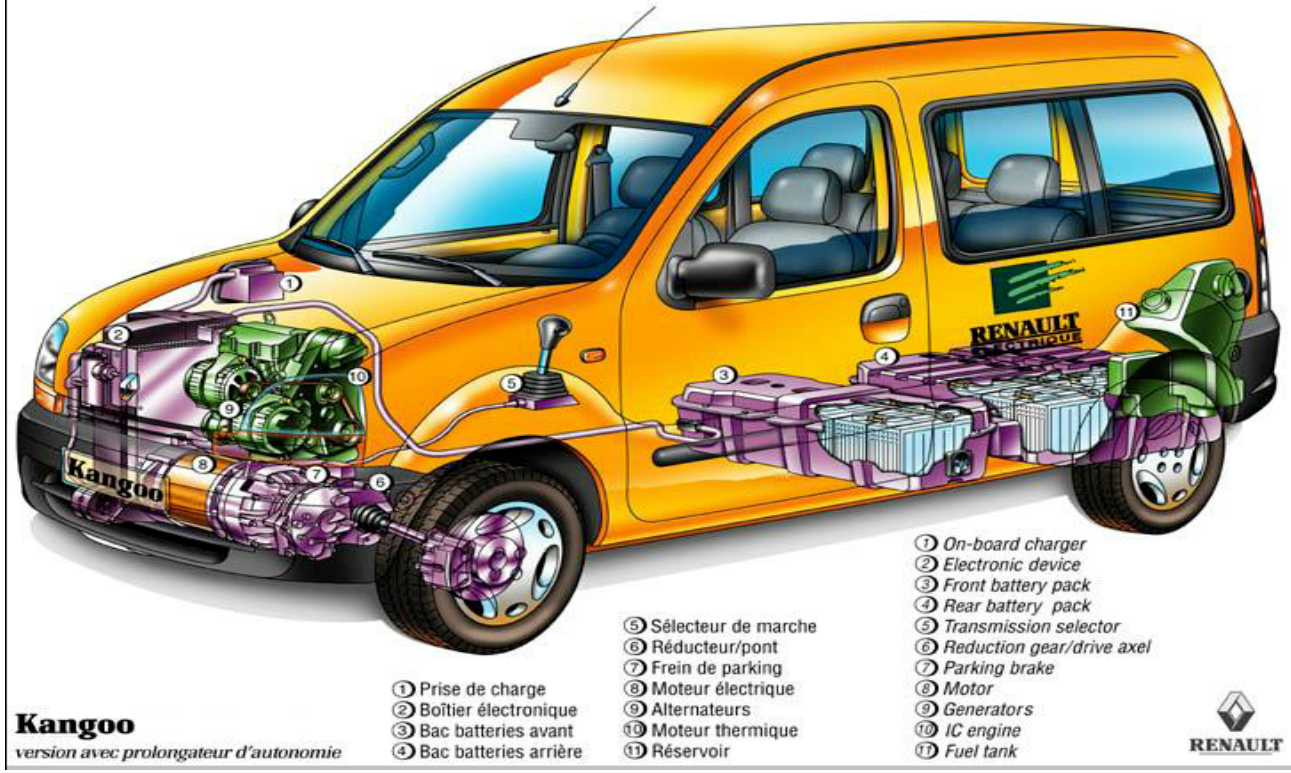

Plug-in HEV Benefits and Costs

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December 5, 2002

Plug-in HEVs - the Best of Both Worlds

- **Fully functional EV (e.g five days a week)**
- **AND a fully-functional engine-dominant HEV (for weekend trips)**
- **Contains all the features consumers love about EVs**
- **Plus the long range and large market potential of HEVs**
- **Unlike all other clean, advanced vehicles the primary infrastructure already exists – 120 V outlet in your garage each night** (86% have access to a plug at home)
- **Plug-in HEV is in-between a full size EV and no-plug HEV**
  - **Engine is smaller than no-plug HEV**
  - **Battery is bigger than no plug HEV (e.g. 6 kWh vs 3 kWh)**

NiMH versions of HEV Midsize Sedans

Technology	Lifetime ZEV miles	Lifetime Gasoline ATPZEV miles	Pack Size (kWh)
HEV 0	0	70,000 +	2.9
HEV 20	30,000 – 40,000	70,000 +	5.9
HEV 60	90,000 – 120,000	70,000 +	17.9

Plug-In HEVs “Bridge the Gap”

- Provide real pure-ZEV miles.
- Address automaker concerns about BEV range limitations, cost and customer interest.
- No technological hurdles.
- Can be available by 2006-07.
- Incremental cost is manageable.
- No additional infrastructure cost.

Plug-In HEVs “Bridge the Gap”

- There is a business case for plug-in HEVs.
- Share a common lineage with other ZEVs, electric drive, energy storage (batteries), cleaner upstream (grid) emissions.
- Enabling technology to plug-in fuel cell vehicles.
- Allow consumers to experience/learn about plug-in ZEV technologies.

EPRI HEV Working Group

- HEVWG Phase 1 – A three year, $2 million study sponsored by EPRI, CARB, SCAQMD, and utilities
- Comprehensive look at 2010 costs, prices, performance, market potential, consumer & societal benefits, commercialization barriers / incentives
- Unusually strong consensus document involving
  - CARB, SCAQMD, USDOE
  - GM, Ford
  - Research groups – ANL, NREL, UC Davis
  - EPRI, SCE, SMUD, NYPA
- Leading researchers: Kalhammer, Frank, Unnasch, et al.

Societal Benefits of an HEV 20

20 miles all electric range per charge

- **Drive 30,000 – 45,000 ZEV miles with a NiMH pack**
- **Plus up to 70,000 – 100,000 ATPZEV gasoline ICE miles**
- **30 - 40% less NOx and ROG than HEV 0**
- **20-30% less CO2 than HEV 0**
- **42% less petroleum** (and trips to gas station) **than HEV 0**

Source: HEVWG

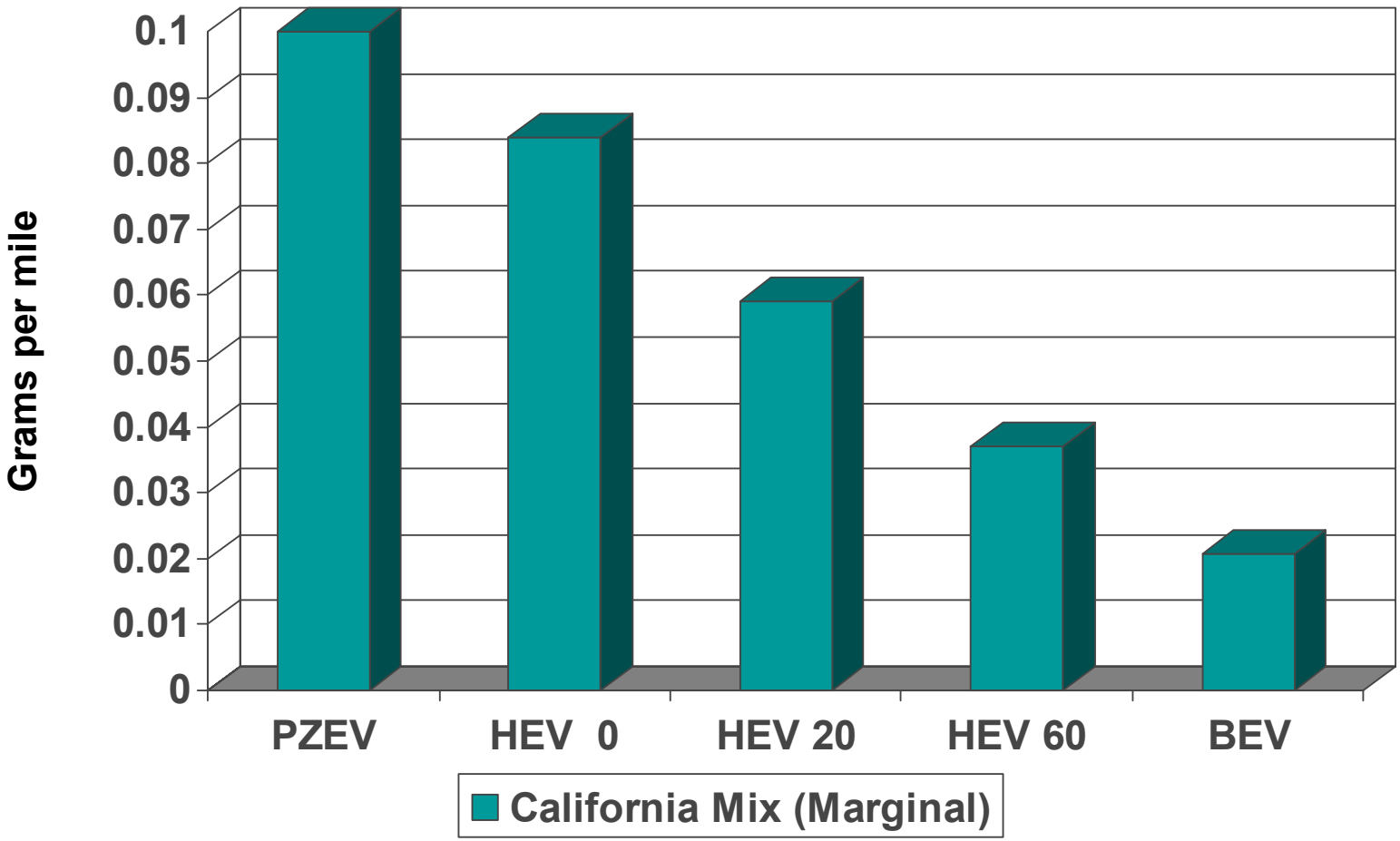
Societal Benefits of an HEV 60

60 miles all electric range per charge

- **= 90,000 – 140,000 ZEV miles with NiMH pack**
- **Plus up to 70,000 – 100,000 ATPZEV gasoline ICE miles**
- **55 – 75% less NOx and ROG than HEV 0**
- **40 – 75% less CO2 than HEV 0**
- **78% less petroleum** (and trips to gas station) **than HEV 0**

Source: HEVWG

NO_x and ROG – California Mix
Well to Wheels, midsize sedan



All vehicles meet the zero-evaporative emissions (0.012 g/mi less than SULEV).

All cars including BEVs have 0.018 g/mi ROG from vinyl, cloth etc.

Source: HEVWG

Renewable energy sources will further reduce emissions of plug-in HEVs and BEVs

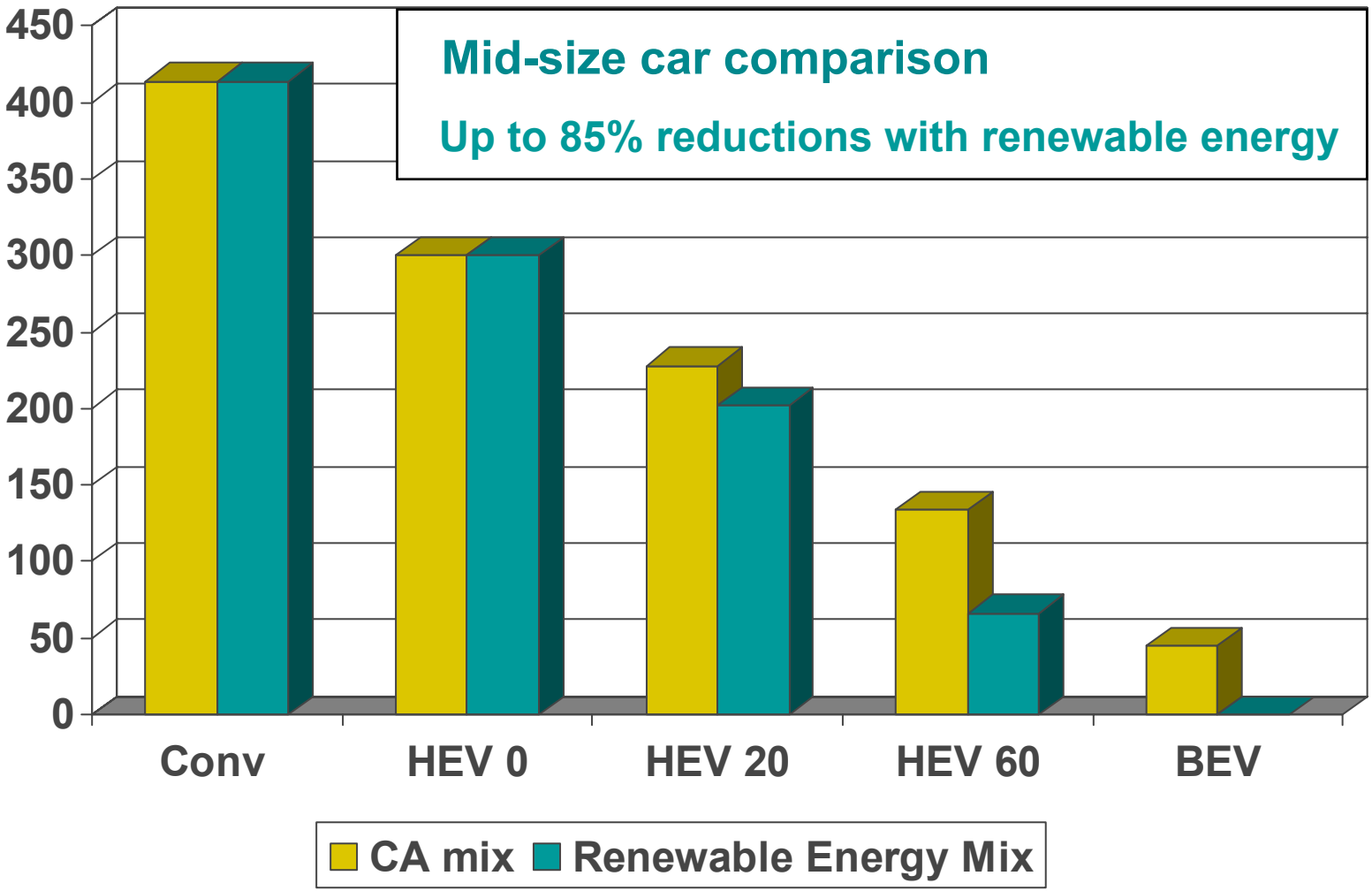
EPRI

Local NOx and ROG Reductions can actually surpass these totals

- South Coast AQMD
  - Grams per mile is near zero for BEVs because any NOx increase from local power plants is off-set by reductions in other users under the cap and trade program (RECLAIM)
  - Plug-in HEV emissions much lower also in SCAQMD
- Purchasers and Owners of Renewable Energy
  - e.g. green energy contracts
  - e.g. rooftop PV solar
  - Plug-in HEVs, like battery EVs, benefit as the grid and non-grid electricity mix gets cleaner and moves to renewable energy
- By accomplishing short daily trips as an EV, plug-in HEVs reduce high levels of cold start emissions and the miles with the poorest fuel economy.

Greenhouse Gas Emissions

Well to Wheels, California Mix, Renewable Energy Mix



Source: HEVWG (Includes adjustment for real world driving)

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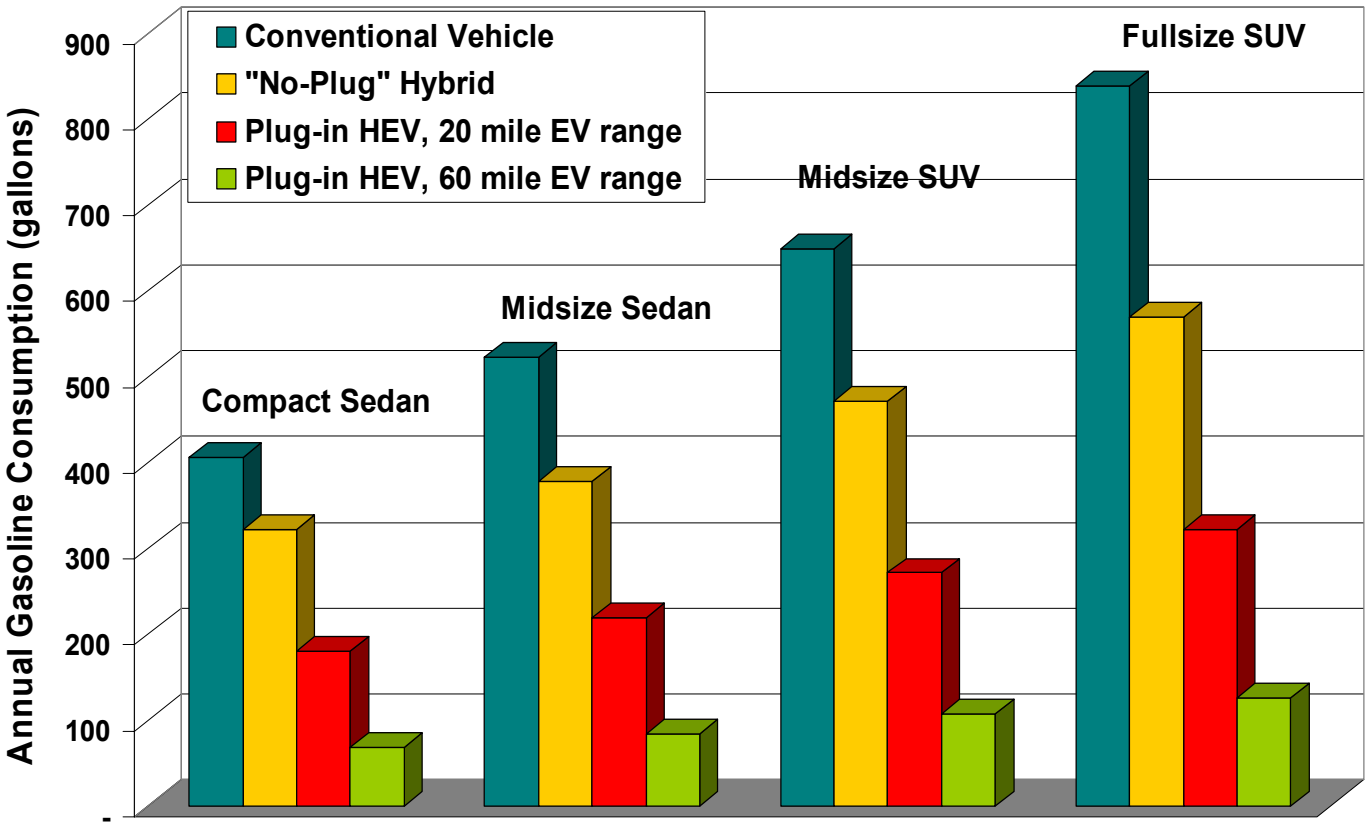
Annual Gasoline Consumption



Up to 85% reduction in gasoline use and trips to gas station.

Midsize car operation & maintenance savings = $5,000 over 100,000 miles.

Source: HEVWG

EPRI

Economic Value of Electric Drive Vehicles

Source: EPRI Roadmap Study

- Assume 25% total plug-in vehicles (BEVs & plug-in HEVs) nationwide by 2025
- DOE – EIA projections for energy use
- $88.9 billion net annual economic benefit
- Dramatic reduction in criteria pollutants = health benefit
- Very large spillover benefits to other industries

Net Economic Benefits	*Billion $/yr (2002$)*
Balance of Trade	$ 26.3 B$/year
GDP Impact	$ 38.3 B$/year
Environmental	$ 9.3 B$/year
Military	$ 7.5 B$/year
Spillover benefits to other industries	Not calculated
Oil Disruption	$ 7.5 B$/year
Labor	440,000 Jobs/yr

email mduvall@epri.com for a copy of this study

EPRI

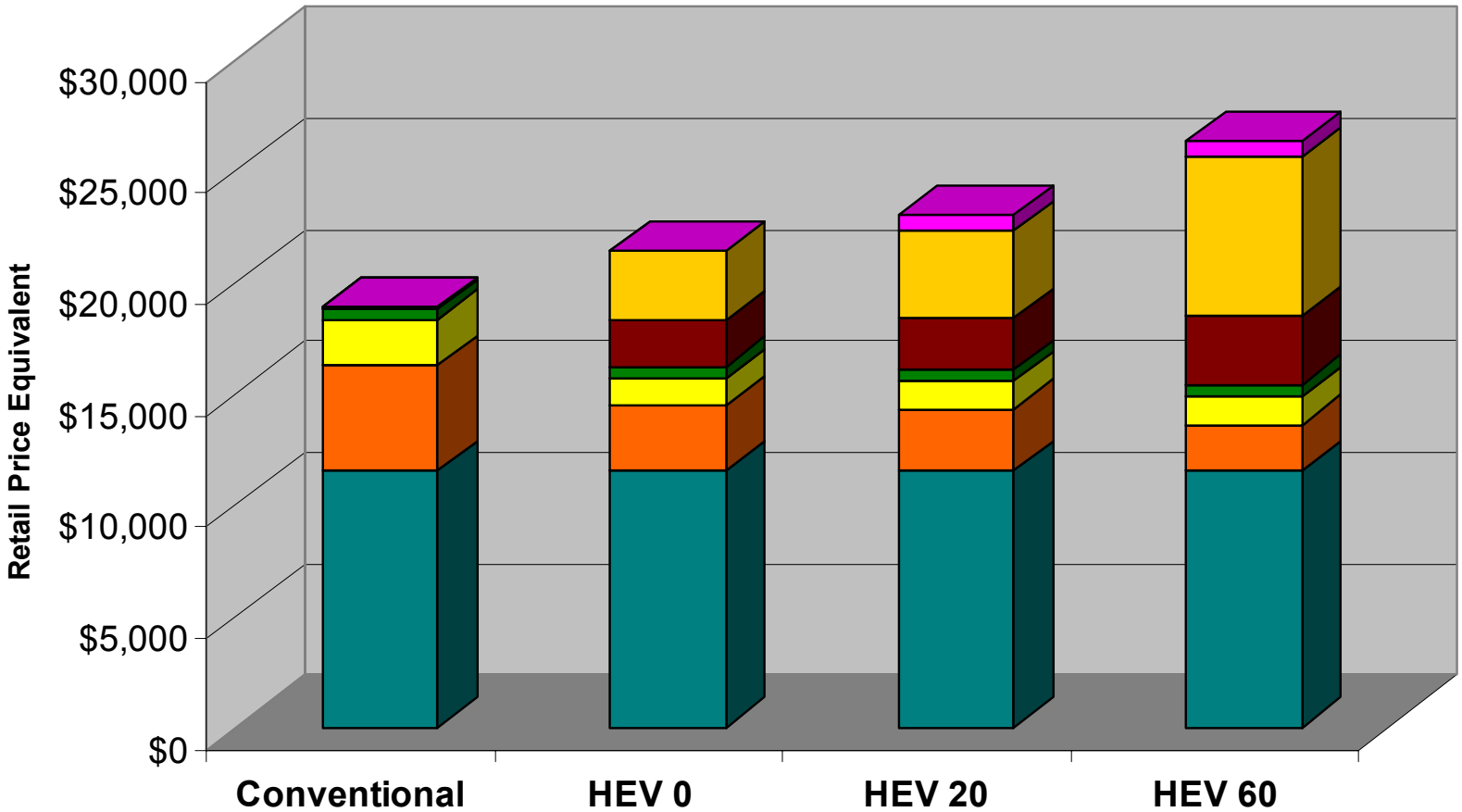
Other Benefits of Plug-in HEVs

- Fuel Cell Vehicles that "Plug-in" can reach market sooner
  - Lower Cost
    - Plug-in FCV has larger battery pack & smaller FC
    - Electricity costs less than hydrogen
    - Near term "power" battery cost goal = $20/kW
    - Long term FC cost goal = $120 /kW
  - Better Performance
    - Instant start w/o fuel cell; higher peak power w battery
  - Longer Life and Better Reliability
    - Lower hours, thermal stresses & start-ups
- Plug-in HEVs enable "vehicle to grid" (V2G)
  - Significant benefits for energy security and power quality with large potential revenue to Plug-in HEV owner.

Midsize Vehicle – Retail Price Equivalent

Argonne National Lab Method

Source: HEVWG



HEV 60 is assigned an extra $200 for electrical upgrade from 15 amp to 20 amp, 120V circuit

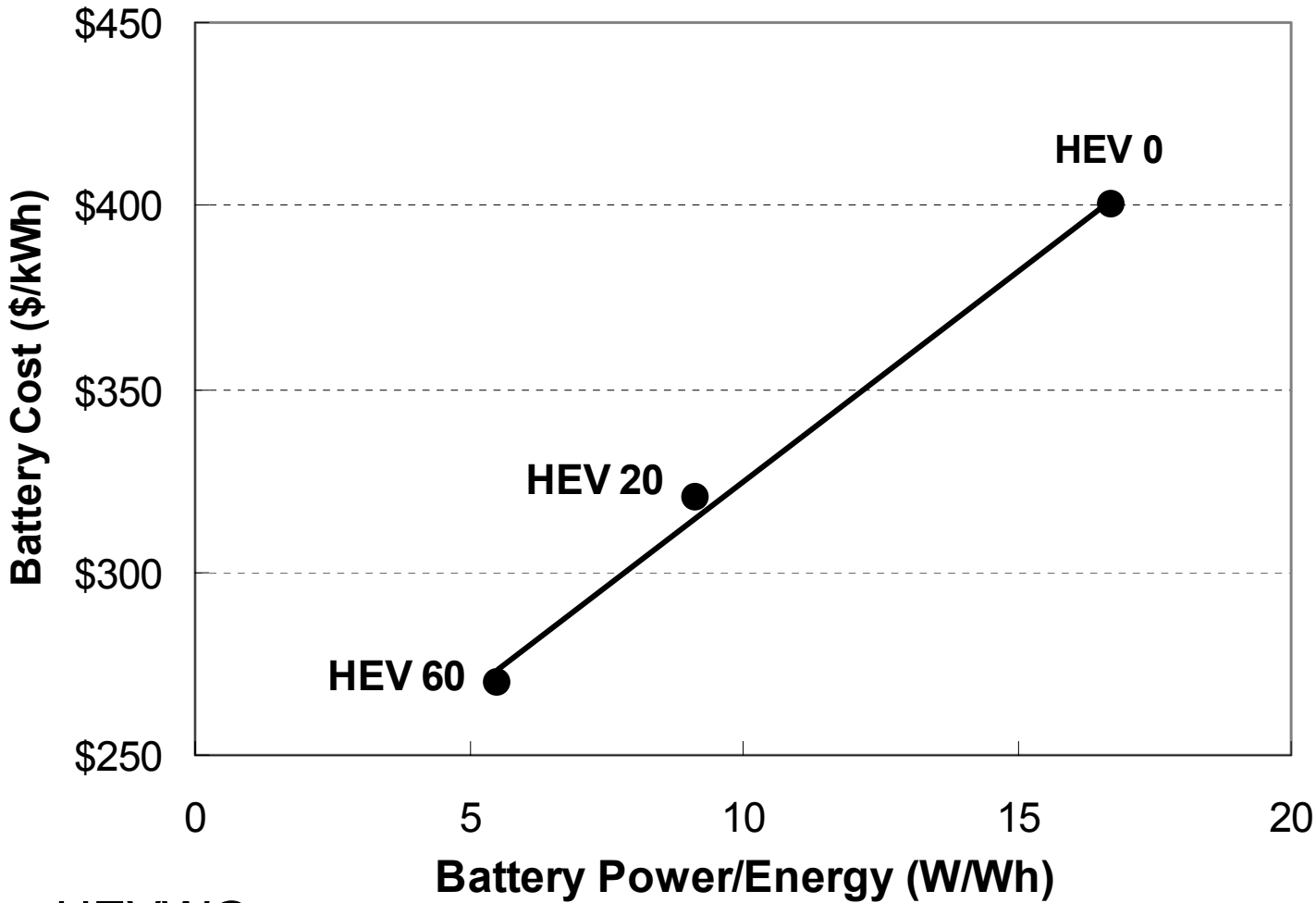
Breakdown of Retail Price Equivalent

Argonne National Lab Method

Component Group	CV	HEV 0	HEV 20	HEV 60
Glider	$ 11,525	$ 11,525	$ 11,525	$ 11,525
Engine + Exhaust	$ 4,715	$ 2,888	$ 2,775	$ 2,078
Transmission	$ 2,090	$ 1,250	$ 1,250	$ 1,250
Accessory Power	$ 420	$ 535	$ 535	$ 535
Electric Traction	$ 80	$ 2,084	$ 2,313	$ 3,077
Energy Storage System	$ 60	$ 3,091	$ 3,916	$ 7,164
On Vehicle Charging System	$ -	$ -	$ 690	$ 690
Total Retail Price Equivalent	$ 18,890	$ 21,373	$ 23,005	$ 26,319

- CV Electric Traction and Energy Storage System is starter battery and starter motor.

NiMH Battery Module Costs to OEM Versus Battery Energy



Source: HEVWG

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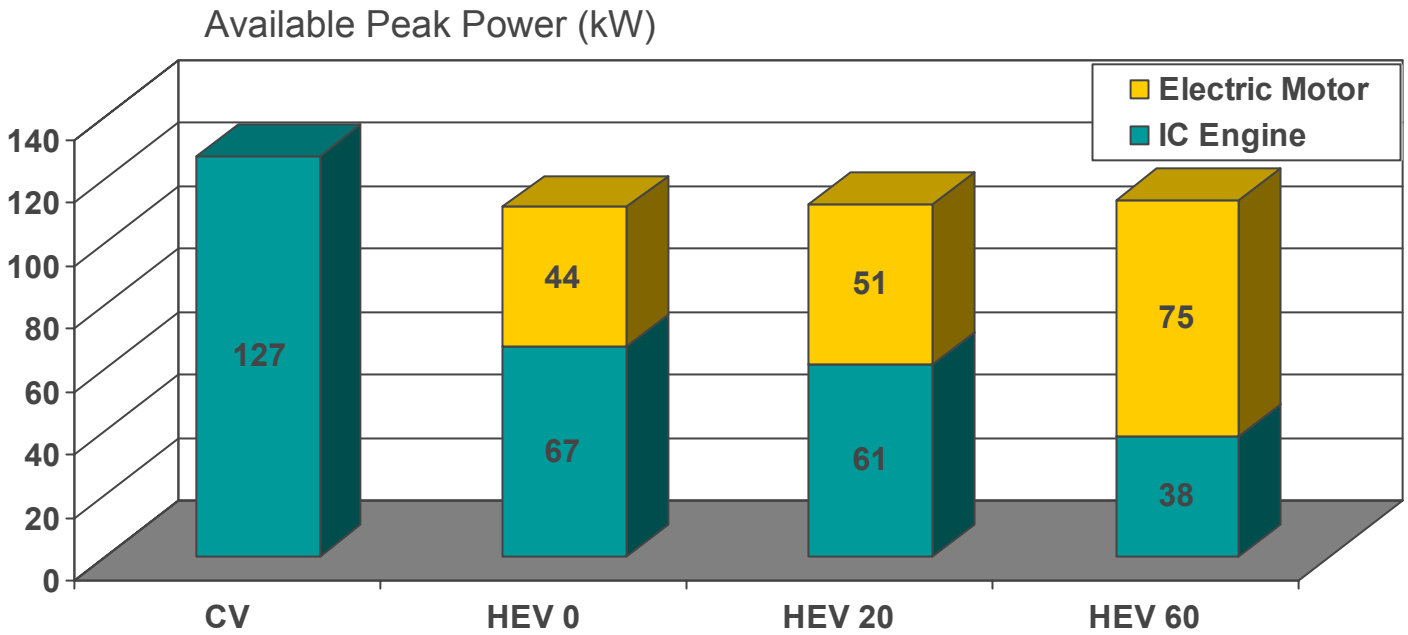
Midsize Sedan Specifications



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

The plug-in HEVs Were Designed to Look, Perform and Feel Like the Equivalent CV

- HEVs had the same aerodynamics, frontal area, glider and cargo mass, and accessory loads as the CV
  - Midsize sedan – MY 2000 Chevy Lumina
  - Compact sedan – MY 2001 Saturn SL1
  - Midsize SUV – MY 2001 Ford Explorers
  - Fullsize SUV – MY 2001 Chevy Suburban
- HEVs were designed to have similar acceleration, top speed, range, and gradeability as the CV
  - Modeling results showed all HEVs had better times 0-30 mph, 0-60 mph and 40-60 mph accelerations.
  - However, modeling results showed 50-70 mph accelerations & top speed results were slightly less

HEVWG Cost Study Results Shows Incremental Cost & RPE is Manageable.

Vehicle Type	Retail Price Equivalent (Argonne National Lab method)	RPE $ difference
Compact Sedan	HEV 0 = $16,400 HEV 20 = $18,400	$2,000
Mid-size Sedan	HEV 0 = $21,370 HEV 20= $22,970	$1,600
Mid-size SUV	HEV 0 = $34,900 HEV 20 = $37,300	$2,400
Full size SUV	HEV 0 = $42,040 HEV 20 = $43,580	$1,540

- Automaker pricing strategies to improve image, capture new markets or maintain existing markets can help
- Existing and proposed tax policies can make a difference.

Other Benefits of Plug-in HEVs

- **PHEVs already use battery renting in Europe and could soon provide supplies for a valuable secondary use market**
- **Are much easier way for OEMs to get the volumes needed to lower NiMH price from today's $900 per kWh to $300 per kWh**
  - 10,000 RAV4 EV or
  - 38,000 HEV 20
- **A solution to range, "energy" battery cost and infrastructure issues**

Conclusion: *Plug-in HEVs as the most viable ZEV product today and in the next ten years deliver*

- **The next best thing to a pure battery EV in terms of low emissions, energy security, and greenhouse gas**
- **A similar ownership experience to a BEV to help people understand the many advantages of ZEV mile driving**
- **An OEM business case and commercialization path to get the high volume cost reductions needed**
  - **Can exceed gold category volumes**
- **Lead technology development and consumers back to the battery EV and forward to the battery–hydrogen fuel cell hybrid.**