Title
Meeting the New CARB ZEV Mandate Requirements: Grid-Connected Hybrids and City EVs

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Andrew Burke

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Meeting the New CARB ZEV Mandate Requirements: Grid-Connected Hybrids and City Evs

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The University of California Transportation Center
University of California at Berkeley

Meeting the New CARB ZEV Mandate Requirements: Grid-Connected Hybrids and City EVs

UCD-ITS-RR-01-02

Affiliate Program Workshop
Presentation Materials

May 15-16, 2001
Buehler Alumni Center, UC Davis

Organizer and Host
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ITS-Davis Affiliate Program Workshop

Meeting the New CARB ZEV Mandate Requirements: Grid-connected Hybrids and City EVs

May 15-16, 2001

Organizer: Dr. Andrew Burke

Scope and Focus

In January 2001, the California Air Resources Board adopted significant modifications to the ZEV Mandate These changes affect the options available to large auto companies marketing cars in California that must meet the requirements of the Mandate starting in 2003 In the new regulations, up to 50% (2% of sales) of the ZEV requirement (4% of sales) may be met with grid-connected, plug-in hybrid vehicles having a 20-mile or longer all-electric range In addition, city EVs that may or may not be freeway worthy are designated for full ZEV credit and can be used to meet the 4% ZEV requirement. In the case of both types of vehicles, there is much less information available concerning their design, cost, and marketing than for full function electric vehicles (FFEVs) -- which have in the past been the focus of meeting the ZEV Mandate This two-day workshop will consider in-depth how the inclusion of the grid connected hybrids and city EVs in the Mandate may affect how it will be met in 2003-2006 In addition, each of the new technology options will be reviewed in terms of vehicle design, utility, cost, and marketing.

Agenda

Grid-connected Hybrid-electric Vehicles

MAY 15, Tuesday A.M. (8:30-12:00)

1. **Welcome (8:30)** (A Burke, ITS-Davis)
2. **Review of the new ZEV Mandate requirements with emphasis on the role of plug-in hybrids (8:45-9:15)** (C Childers, California Air Resources Board (CARB))

BREAK (15 min.)

3 **Design options with emphasis on performance and cost (9:30-12:30)**
   - Emissions and Performance Expectations (E. Kassoy, AD Little/EPRI)
   - ANL/DOE Study (D Santini, Argonne National Laboratory)
   - ITS-Davis EV/HEV Cost Study (M Delucchi/A. Burke, ITS-Davis)

- Auto Industry Perspective Toyota Motor Company (D Hermance, Toyota Technical Center, USA, Inc
- Systems Design Options for Plug-in Hybrids (A Frank, UC Davis/EPRI)

LUNCH (12:30-1:30)

MAY 15, Tuesday P.M. (1:30-5:30)

4. **Batteries for plug-in hybrids with emphasis on cost and cycle life (1:00-2:45)**
    - Nickel metal hydride (D Corrigan, Ovonic Battery Company)
    - Lithium-ion (K Hironaka, Shin Kobe Electric Machinery Co , Ltd)
    - Use of ultra caps with batteries (A Burke, ITS-Davis)

BREAK (15 min.)

5. **Marketing issues & prospects (3:00-4:00)**
    - Commercialization/Market/Customer Issues (D. Taylor, Southern California Edison/EPRI)

6. **Panel discussion of prospects for plug-in hybrids (4:15-5:30)**
    - Speakers from the previous sessions of the day (ARB, EPRI, ITS-Davis, auto industry)

RECEPTION (6:00-6:30) University Club Lounge

DINNER (6:30-9:00) University Club Dining Room

Talk: ***Electrifying Urban America - Is It Really Possible?***
Robert Graham, Manager, Electric Transportation,
Electric Power Research Institute

City Electric Vehicles

MAY 16, Wednesday A.M. (8:30-12:15)

1. **Welcome (8:30)** (A. Burke, ITS-Davis)
2. **Review of new ZEV Mandate requirements with emphasis in role of city EVs (8:35-9:00)** (C. Childers, California ARB)

BREAK (15 min.)

3. **City EV Products – Specification/utility, availability, cost (9:15-10:15)**
    - Toyota e-com (D Hermance, Toyota Technical Center, USA, Inc)

- Nissan Hypermini (M. Teramoto, Nissan Technical Center)
- Ford Th!nk (D. Fabricatore, Th!nk City Project)
- NEVCO Gizmo (C. Watkins, NEVCO)

BREAK (15 min.)

4. **Development of Small Full-Function EVs (10:30-12:00)**
   - ATT Parade (H. Woo, ATT R&D) (20 min.)
   - Solectria Force EV (V. Brachos, Solectria Corporation) (20 min.)
   - Design Options and Simulation Results (A. Burke, ITS-Davis) (20 min.)

Lunch (12:00-1:00)

<u>May 16, Wednesday P.M. (1:00-4:30)</u>

5. **Battery issues for small EVs with emphasis on cycle, calendar life and cost (1:00-2:00)**
   - Lead-acid (K. Snyder, Panasonic-Matsushita) (15 min.)
   - NaMtChl Zebra Battery (C. Dustmann, MES-DEA S.A.) (15 min.)

6. **Marketing issues (2:00-3:00)**
   - Marketing NEVs, CEVs, and Small FFEVs (K. Kurani, ITS-Davis) (20 min.)
   - Car Sharing Possibilities for ZEV Credits (S. Shaheen, ITS-Davis) (20 min.)

BREAK (15 min.)

7. **Panel discussion and wrap-up; new insights (3:15-4:30)**
   - Speakers from previous sessions of the day (ARB, ITS-Davis, battery and auto industry)

Meeting the New CARB ZEV Mandate Requirements:
Grid-connected Hybrids And City EVs
May 15-16, 2001
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Part 1: Hybrid EVs

May 15, 2001

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California Air Resources Board

Meeting the CARB ZEV Requirements
Grid-Connected HEVs and City EVs

Part I: Hybrid EVs

Craig M ders
California Air Re Board
May 15-16,

California Environmental Prote
Air Resources

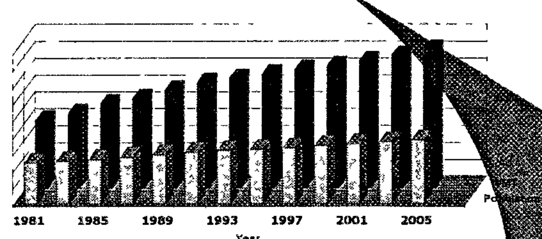
Outline

- The need for ZEVs
- ZEV Regulation Overview
- ZEV Credit Determination
- Grid Hybrids
- Grid Hybrid Challenges
- Mild Hybrids

Why ZEVs?

- Emissions reduction
  - Zero tailpipe emissions
  - Durability- Emissions reduced as ZEV
- Efficiency improvement & CO2 reduction
- Transportation energy source diversity
- Potential Vehicle-to-Grid power generation and ancillary services
- "Secondary Benefits of the ZEV Mandate" (UCD/ ITS & WestStart-Calstart)

Daily VMT Increasing Faster Than Population



December ZEV Regulation Proposal Highlights

- Smoother transitions as requirement increases by incorporating phase multipliers
- New ATPZEV category created
- Reduction in long-term NEV credit
- Modification and phase-out of range cre
- Phase-in of efficiency credit multiplier
- In-service & under-warranty credit
- Require vehicle placement to earn multiple credits

ZEV Regulation Status

- January Board Meeting Key Directives
  - 2X ZEVs beyond Dec Staff Propos n 2012+
  - Phase in LDT2 when determining obl n
  - Modify treatment of Grid-HEVs (move to ATPZEV)
- Staff is presently developing changes in the regulation in response to the Board's requests
- Proposed changes (15-Day Notice) estimated release in Mid June

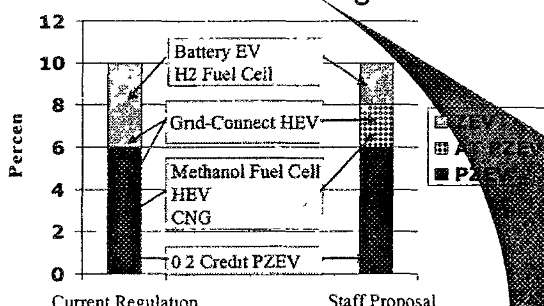
Regulatory Status

- Much of this presentation is ba on proposed amendments to the ZEV ulation released 12/8/00 and considered at t January Board Hearing
- This presentation includes simplifying assumptions regarding ZEV credit determination Please consult regulation f actual determinations

Regulatory Status

- When possible, presentation includes changes reflecting the latest s ff thinking in response to the Board's requests
- These changes have not yet been fi d and will likely change further before t day notice is released
- In particular, staff is still working on
  - Advanced componentry credit for ATPZEVs
  - Grid HEV, and Transportation System credit
- Please withhold formal comment to ARB un after changes are formally released in June

2003- 2008 Manufacturer Obligation



GHEV is an ATPZEV

- All PZEVs and ATPZEVs m t meet
  - SULEV emission standards
  - "Zero" Fuel System Evap Standard
  - OBD II requirement for 150,000 miles,
  - Emissions warranty extension to 15 yea 150,000 miles
- For all HEVs, battery must be included as a warranty item

Why ATPZEVs?

- PZEVs achieve significant emission reduction, but will not neces ily assist with propagation of ZEV-related technologies
- Near-term ATPZEVs expected to be.
  - CNG
  - Mild HEVs
- Longer-term ATPZEVs
  - Grid-HEVs
  - Methanol reformer FCVs
  - Hydrogen ICE

ZEV Requirement Increase

- For example, in 2018 and bey d, ZEV requirement grows to 16%
  - Up to 6% may be PZEV,
  - Up to 5% may be ATPZEV, and
  - At least 5% must be Pure ZEV
- As ZEV requirement grows in 2009- 201 6% PZEV cap remains frozen

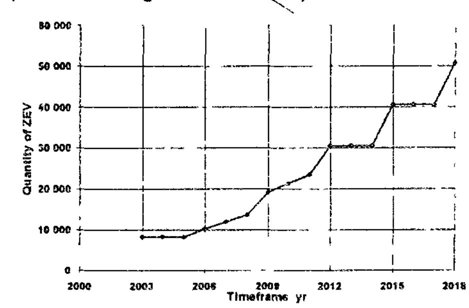
PZEVs in 2006+

- 6% is capped, and may not seem like much, but after phase-in (2006
  [6% / (0 2 credit per vehicle)] = 30
- Estimated number of PZEVs = 380,000
  (large + intermediate mfgs)

2003 Large Manufacturer ZEV Obligation

- IF
  - PZEVs sold = maximum allowance (6%)
  - Large auto manufacturer California sales are 920,000
  - No ATPZEVs placed in service
  - Ignore '01- '02 credit accumulations
  - FFBEV avg credit in '03 is ~4 15
- THEN
  - ZEVs Required =
  [(04) * (CA sales) / ZEV credit]
  =~ 8,900 FFEVs

ZEV Obligation
(Combined Large Manufacturers)



ZEV Credit Determination

Initial ZEV Credit =

{1+[(Range Mult -1) x (Range Mult Phase Out)]} x
{1+[(Eff Mult -1) x (Eff Mult Phase In)]} x
(Transportation System Mult) x
(Early Intro Mult) x
(NEV/LSV discount)

In-Service/Under-Warranty Vehicle Power Source Credit

- ZE Range (20+ mile) vehicles only
- Includes Grid HEVs, NEVs excluded
- Applies to 4th year in service and beyond
- 1/10th original credit (without phase-in mu is earned each year
- ZEV in service and under warranty for 13 yea eventually accumulates in-service under-warra credit equal to original ZEV credit

Early Introduction Multiplier

- Addresses "gap" in availability
- Rewards mfg s for early introduction

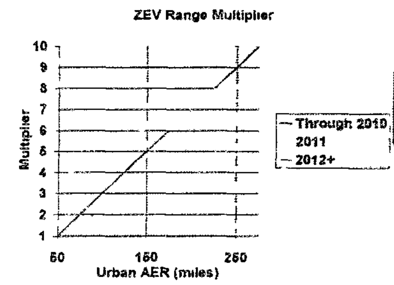
	'01	'02	'03	'04	'05	'06
ZEV & NEV	4	4	1 25	1 25	1 25	1
PZEV & ATPZEV	4	4	4	2	1 33	1

Range Multiplier

- Addresses concerns with range capability of early-year BEVs
- Encourages deployment of longer range vehicles in early years of program
- As market matures, range is de-emphasized*
  - Phase down over 2004-2012 timeframe
  - Caps on max range used for credit determination
    - 225 miles in 2011
    - 175 miles in 2012
- Applies to ZEV and GHEV only

* under consideration

Range Multiplier



Efficiency Multiplier

- Assumes power plant emissions proportional to ZEV energy use
- Also a factor in range performance (go further or reduce battery cost)
- Applies to both ZEVs and ATPZEVs (but no phase-in for ATPZEVs)
- Rewards most efficient and therefore lowest emissions vehicle designs

Efficiency Multiplier: CMPEG Determination

- Gasoline vehicles CMPEG = unadjusted combined EPA fuel economy
- For BEV & ATPZEV, CMPEG = [33,705 whr/gal / (55 * UDDS AC whr/mile) + (45 * HFEDS AC whr/mile)]
- Alt Fuel CMPEG = unadjusted combined EPA fuel economy (uncompensated by "fuel content" factor)

Efficiency Multiplier

VEHICLE CLASS	EFFICIENCY MULTIPLIER
City (EV)	CMPEG/ (1 5 x 45 9)
Subcompact PC	CMPEG/ (1 5 x [illegible]6)
Compact PC	CMPEG/ (1 5 x 30[illegible])
Midsize PC	CMPEG/ (1 5 x 27 0)
Large PC	CMPEG/ (1 5 x 25 6)
Small Truck	CMPEG/ (1 5 x 25 0)
Medium Truck	CMPEG/ (1 5 x 21 4)
Large Truck	CMPEG/ (1 5 x 18 2)

ZEV Range Phase-out Efficiency Phase-in

	'04	'05	'06	'07	'08	'09	[illegible]
Range	1	825	0 60	0 45	0 30	0 25	0[illegible]
Eff	0	0 10	0 35	0 55	0 85	0 90	1 00

2006 ZEV Credit Example. RAV4 EV

- Cert Data
  - UDDS eff = 291 3 AC whr/mile
  - Highway eff = 374 1 AC whr/mile
- CMPEG = [33,705 whr/gal / (55 * UDDS AC whr/mile) + (45 * HFEDS AC whr/mile)] = 102 6
- EFF MULT = CMPEG/ (1 5 x 25 0) = 2 74

2006 ZEV Credit Example. RAV4 EV

Initial ZEV Credit =
{1+[(Range Mult -1) x (Range Mult Phase In)]} x
{1+[(Eff Mult -1) x (Eff Mult Phase In)]} x
(Transportation System Mult) x
(Early Intro Mult) x
(NEV/LSV discount)

2006 ZEV Credit Example. RAV4 EV

Initial ZEV Credit =
{1+[(4 70 - 1) x (0 60)]} x
{1+ [(2 74 - 1) x (0 35)]} x
(Transportation System Mult) x
(Early Intro Mult) x
(NEV/LSV discount)
= ~ 5 17

Year 4+ In-Service/ Under-Warranty Credit
=~0 52 per year

Example. 2006 GHEV ATPZEV Credit

- GHEV credit determination methodology not yet final
- Staff is exploring the possibility of harmonizing GHEV credit determination with other ATPZEVs

Example 2006 GHEV ATPZEV Credit

- This example uses method from December 2000 proposed amendments
- Phase-in multiplier has expired by 2006
- GHEV credit determination based on
  - (ZEV range multiplier) x
  - (efficiency multiplier), and
  - GHEVs also eligible for in-service/ under-warranty credit

Example 2006 GHEV ATPZEV Credit

Per December 2000 Proposal

- GHEVs use 3 5 X actual Urban AER
  - P 20 uses 70 mile range in determination
- Efficiency Multiplier
  - Favors GHEVs based on electric-mode only
  - Assume GHEV will attain ~2 0 X
- P20 credit = ~3 6 initial, plus 0 36/ year (>year 4)

GHEV VS Mild-HEV VS Year

- Assumptions
  - Mild HEV achieves 1 3 X efficiency multiplier
  - GHEV achieves 2 X efficiency multipli

	'01	'02	'03	'04	'05	'06
Early-Intro	4	4	4	2	1 33	1
Mild HEV	1 8	1 8	1 8	0 9	0 8	0 6
P20 GHEV	7 2	7 2	7 2	3 6	4 8	3 6

Grid-HEV Challenges

- Battery pack cost
- Battery pack lifetime
  - GHEV batteries subjected to more aggressive cycling limits than BEVs
- Battery pack warranty requirement
- OBD detailed requirements TBD
- HEV test protocols may need refinement
- Public perception (mild-HEV ads)

GHEV Credit Change Re-cap

- Move from "gold" to "silver" (ATPZEV) category
- Battery warranty requirement re... but GHEVs rewarded for In-Servic... Under-Warranty credit along with ZE...
- Exact basis for credit calculations TB...

GHEVs

- GHEV Prototypes
  - UCD Prototypes
  - GM Triax
  - Volvo HEV
  - Suzuki EV Sport
  - Audi Duo
  - Mitsubishi
  - Renault

EPRI GHEV Study

- ARB co-funded
- Series hybrids fell out of study ...ly on due to poor performance
- Focus shifted to P0, P20, and P60
- Originally mid-size, but now conside... a variety of classes
- Examined performance, cost, consume... acceptance, and commercialization

Real-Life Range P20 & P60 Nomenclature

- Nomenclature Manufacturers ...y choose to refer to P20 and P60 with a differe... nomenclature
- Typical customer "drive cycle" with mat... batteries would likely provide less than 20 ... 60 mile range

Honda Insight

- Emission Standards
  - '01 5 spd- ULEV (61 mpg city/ 6 hwy)
  - '01 CVT- SULEV (57 mpg city/ 5
- Battery monitored by OBD
  - If battery "fails", NOx increase >15% will illuminate OBD MIL
  - Battery warranty voluntarily extended

Toyota Prius

- MY '00 Toyota Hybrid System/ SULEV emissions standard
- Battery
  - OBD monitored
  - Battery warranty also voluntarily extended

Vision for the Future

- Steady, sustainable increase in ZEVs
- Regulatory flexibility encourages diverse transportation technologies including GHEVs
- Clean and healthy air for all Californians

EXTRA SLIDES

Provided for Reference

Abbreviations Used

- LSV Low Speed Vehicle
- NEV- Neighborhood Electric Vehicle (zero-emission LSV)
- CEV City Electric Vehicle
- ZEV – Zero Emission Vehicle
- ZEM- Zero Emission Motorcycle
- PZEV – Partial Zero Emission Vehicles
- AT PZEV Advanced Technology Partial Zero Emission Vehicle
- SULEV- Super Ultra Low Emission Vehicle
- VMT – Vehicle Miles Traveled
- G/mile – grams per mile
- BEV – Battery Electric Vehicle
- HEV – Hybrid Electric Vehicle
- GHEV Grid-connected HEV (same as extended range HEV)
- AER all electric r
- OBD- On Board Diag
- MIL- Malfunction Indica
- EFF MULT- Efficiency M
- DOT Dept of Transportat
- CMPEG- California Miles P Equivalent Gallon
- LEV – Low Emission Vehicle Regulations
- LEV II – 1998 amendments to LEV program

Hybrid Electric Vehicle Performance and Emissions

May 15, 2001

Erin Kassoy
Arthur D. Little

Hybrid Electric Vehicle Performance and Emissions

Meeting the New CARB ZEV Mandate Requirements
Grid Connected Hybrids and City EVs
May 15, 2001

Louis Browning and Erin Kassoy

Arthur D Little

Both Grid Connected and Non Grid Connected Hybrid Electric Vehicles were compared against conventional vehicles

- The results of modeling of HEVs by NREL and UC Davis were used to calculate vehicle performance, efficiency and emissions
- Three HEVs were studied
  - HEV 0 — Charge-sustaining HEV with no all-electric range
  - HEV 20 — Charge-depleting HEV with a 20 mile all-electric range
  - HEV 60 — Charge-depleting HEV with a 60 mile all-electric range
- Work is part of EPRI HEVWG project
- Final Report on Mid-size vehicles will be out in June

HEVs were designed to perform, look and feel like the equivalent conventional vehicle

- MY 2000 Chevrolet Lumina 3 1L was chosen as equivalent conventional vehicle
- All HEVs had the same aerodynamics, frontal area, glider and cargo mass, and accessory loads as the CV
- All HEVs were designed to have similar acceleration, top speed, range, and gradeability as the CV, with some exceptions

---

Some trade-offs were made in performance matching to reduce vehicle costs

- Sustained Top Speed - CV has a top speed of 120 mph, HEVs can maintain 120 mph for approximately 2 minutes, but sustain speeds of over 90 mph
- Gradeability - CVs generally can climb a 7 2% grade at 50 mph for 30 minutes, HEVs can climb 7 2% grade at 50 mph for 15 minutes and at 30 mph for 30 minutes Can climb any highway grade in US at 50 mph
- Passing Performance - Acceleration times for 50 to 70 mph relaxed from 4 8 seconds for CV to 5 1 seconds for HEVs All HEVs had better 0-30 mph and 0-60 mph acceleration times than CVs
- Engine on/off cycles - Constrained to 30 on/offs during FUDS cycle Reduces fuel economy by about 10%, but results in better driveability and customer satisfaction

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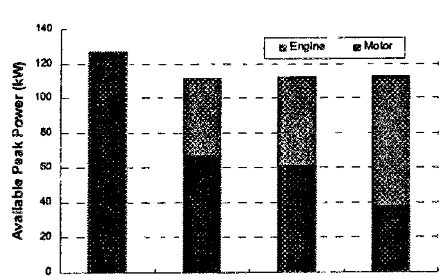
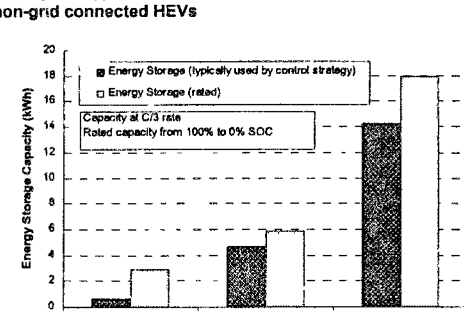
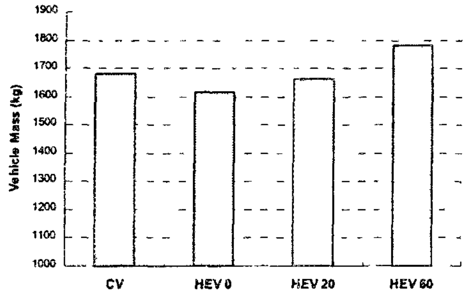
Engine and Motor power of HEVs was slightly less than that of CV, due to more efficient designs



Battery Energy for Grid Connected HEVs much higher than for non-grid connected HEVs



Vehicle mass for the HEV 0 and HEV 20 less than CV due to use of CVT and smaller engine



HEVs had better times in 0-30 mph, 0-60 mph and 40-60 mph accelerations 50-70 mph accelerations and top speed results were somewhat compromised with lower cost HEV designs

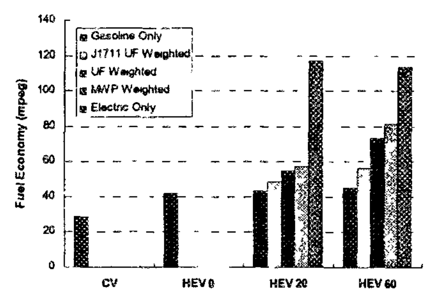
Acceleration Times in Seconds				
Vehicle Design	CV	HEV 0	HEV 20	HEV 60
0-30 mph	3 5	3 1	3 0	3 0
0-60 mph	9 3	8 7	8 9	8 9
40-60 mph	4 6	4 2	4 3	4 3
50-70 mph	4 5	5 2	5 2	5 2
Sustained Top Speed				
mph	120	120	98	97

NREL and UC Davis modeled HEV fuel economy using ADVISOR Several fuel economy measures are defined

- Gasoline Only - Fuel economy when the vehicle is in charge sustaining mode in mpg
- Electric Only - Fuel economy of Grid Connected HEVs when in charge depleting mode Given in kWh/mi and converted to miles per equivalent gasoline gallon using 33 44 kWh/equivalent gasoline gallon
- Mileage Weighted Probability Weighted - Measure of actual all-electric use Determined from 1995 NPTS data
- Utility Factor Weighted - Discounted MWP factors determined by SAE for use in J1711 Assumes vehicle starts each day with a full charge
- SAE J1711 - Uses UF for all-electric usage determination and assumes the vehicle starts 50% of the time with a full charge and the other 50% of time with low SOC

NREL and UC Davis modeled HEV fuel economy using ADVISOR

Mileage Weighted Probabilities — HEV 20 = 39%, HEV 60 = 74%
Utility Factors — HEV 20 = 31%, HEV 60 = 63%



- Battery life and replacement depends upon a number of factors
  - Driving patterns
  - Vehicle electric fuel economy
  - Battery technology
  - Vehicle lifetime
  - Charging frequency
  - Battery controller logic
- Daily driving patterns were determined through interviews of approximately 400 potential HEV owners (market survey)
  - Purchased a vehicle in the last 5 years
  - Regularly parked within 25 feet of an electrical outlet
  - Results binned into three categories
    - short commute
    - medium commute
    - long commute

All-electric operation for the HEV 20 and HEV 60 was derived from daily driving patterns

Based upon being able to drive 20 miles or 60 miles in all-electric operation, annual all-electric mileage was calculated for charging nightly

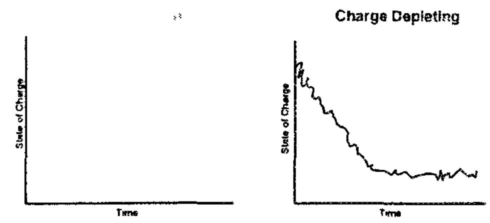
Annual Miles	Commute Distance		
	Short	Average	Long
HEV 20 AE	4,900	5,300	5,400
HEV 60 AE	5,900	10,100	12,900
Total Miles	7,700	13,300	18,000
City Portion	47%	49%	47%

Real world fuel economy is generally less than fuel economy measured using standardized tests

- Fuel economy is reduced due to the following factors
  - Aggressive driving
  - Air conditioning use
  - Open windows
  - Others
- Real World fuel economy discounts are approximated by USEPA for fuel economy guide
  - 10% increase in city fuel consumption
  - 22% increase in highway fuel consumption

Charge Sustaining HEVs have different discharge patterns than Charge Depleting HEVs

Charge sustaining HEVs charge and discharge batteries in a series of shallow discharges while Charge Depleting HEVs discharge batteries while in all-electric operation



NiMH batteries in 2010 are assumed to last longer than today's batteries

- Current NiMH batteries have cycle lives of 800 to 1200 deep discharge cycles before charge capacity drops to 80% of the original capacity
- NiMH batteries have demonstrated 1500 to 2000 deep discharge cycles under controlled laboratory conditions
- "Improvements in positive electrode composition have substantially increased NiMH battery charge acceptance and efficiency (especially at elevated temperature and near the end of charge), with the consequence that average battery operating temperatures will be significantly decreased" - Fritz Kalhammer
- 1750 deep discharge cycles (to 20% SOC) were assumed to be available in 2010

Vehicle lifetimes were defined as 100,000 miles of total vehicle operation or 10 years, whichever came first.

Actual vehicle life might be longer

Vehicle Lifetime			
Commute Distance	Low	Average	High
Total Vehicle Miles	77,120	100,000	100,000
Years of Operation	10 0	7 5	5 6

No replacement is needed for HEV 60   HEV 20 might require battery replacement if user charges nightly and has an average or low commute distance

Charge Nightly				
Commute Distance		Low	Average	High
Total Energy, kWh	HEV 20	13,800	11,100	8,400
	HEV 60	16,900	21,900	20,700
Deep Discharge Cycles	HEV 20	2,900	2 400	1,800
	HEV 60	1,200	1,500	1,400

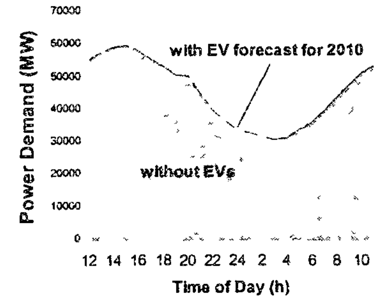
Several alternatives to battery replacement can be implemented

- Smart controller
  - Limit all-electric operation so that vehicle lasts 100,000 miles without need for battery replacement
  - Increases gasoline consumption (~40 additional gallons of gasoline per year on average driving scenario   Ordinarily, 220 gallons per year are used by HEV 20 on average driving scenario)
- Degrade all electric range
  - HEV 20 moves towards HEV 0
- Replace HEV 20 battery with an HEV 0 battery
  - HEV 20 becomes an HEV 0
- Use a larger battery
  - Increases vehicle weight, fuel consumption and initial vehicle cost

Since Grid-Connected Hybrids derive some or all of their energy from electricity, emissions comparisons between HEVs and CVs should include well-to-wheels emissions (both fuel cycle and vehicular)

- Fuel Cycle Emissions include emissions associated with the extraction, processing and distribution of the gasoline or electricity
- Vehicular Emissions include tailpipe and evaporative emissions
- Both smog precursor (NOx + HC) and greenhouse gas emissions were examined

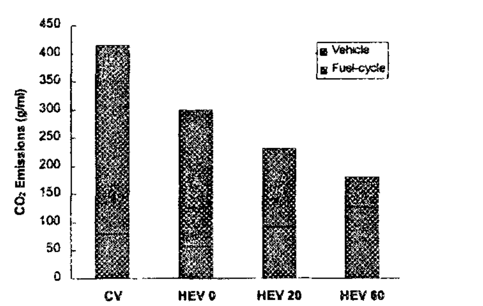
Power generated for HEV charging is small and will be on the generation margin using efficient natural gas fired combined cycle power plants



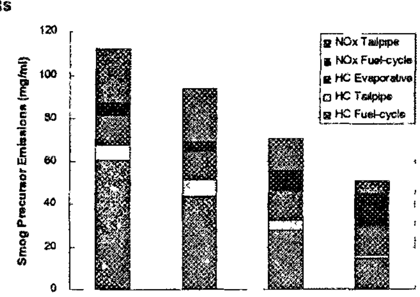
Fuel Cycle Emissions Assumptions

- Plug-in HEVs are charged primarily at night
- Less efficient power generators, older coal and fuel oil power plants cannot readily be turned on and off and cannot satisfy marginal needs
- Nuclear and hydroelectric power plants generally are already at capacity fulfilling the base load and would not be used for marginal needs
- By 2010, many older fossil fuel power plants will have been replaced with new combined cycle turbines
- New power plants and refineries in non-attainment areas will need to meet BACT without emission offsets

For the Average Driving Pattern and Charging Nightly, Greenhouse gas emissions are significantly lower for grid-connected hybrids



For the Average Driving Pattern and Charging Nightly, smog precursor emissions are significantly lower for grid-connected hybrids



- HEVs offer major efficiency improvements as well as substantial reductions in the consumption of petroleum-based fuels and emissions of air pollution precursors (NOx and HC) and carbon dioxide
- Petroleum consumption of an HEV 60 (using gasoline/electricity) can be less than that of the PNGV diesel engine-battery HEV 0 concept vehicles without resorting to costly light-weight construction or body aerodynamics
- HEV 0 technology is in the early commercial stage Relative to mature combustion engines and state-of-the-art EV technology, HEV technology requires only evolutionary advances to meet technical requirements, with the possible exception of batteries

- NiMH batteries are technologically capable, but there are uncertainties regarding their life and costs, especially in plug-in HEV service
- Both the Honda Insight and the Toyota Prius are currently in production in Japan the U S , and Europe Several other automobile manufacturers have announced upcoming models The Renault Kangoo has been announced for launch in 2001 in Europe as a plug-in hybrid
- There are several issues that have been identified that need to be examined for successful commercialization including battery life and packaging

Observations From a DOE HEV Technology Assessment

May 15, 2001

Dan Santini
Argonne National Laboratory

TRANSPORTATION
TECHNOLOGY R&D CENTER

Observations From a DOE HEV Technology Assessment

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CARB ZEV Workshop by
University of California at Davis, ITS
Sacramento, CA
May 15-16, 2001

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Primary sponsor: Dr. Philip Patterson
OTT Planning

Partial support by: David Rodgers
Director, Office of Technology Utilization within OTT

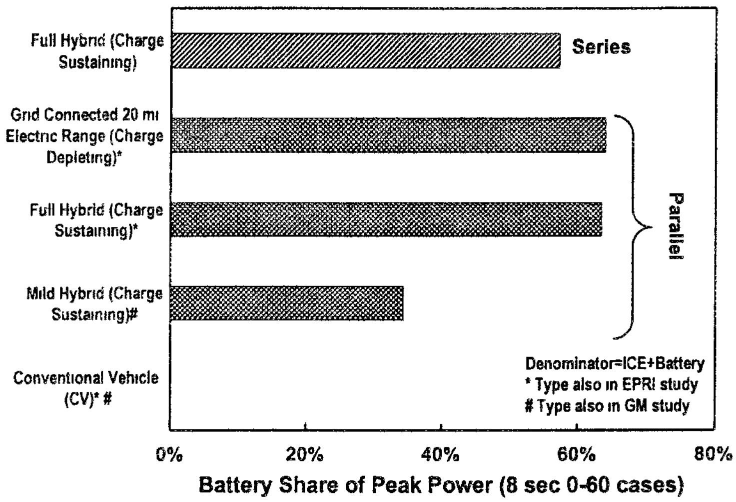
Argonne National Laboratory (ANL) Conducted This HEV Technology Assessment

- ❖ Work started in 1996
  - ➢ Initial work covered full fuel cycle energy assessment
  - ➢ Expanded in 1998 to include cost
  - ➢ Some materials analysis conducted and recycling potential evaluated
- ❖ The assessment involved
  - ➢ Analysis of parallel and series, mild and full charge sustaining, and full charge depleting (grid-connected, 20 mile AER) HEVs
  - ➢ Use of National Renewable Energy Lab's ADVISOR model for vehicle performance simulations
  - ➢ Development of a cost estimation procedure
  - ➢ Use of ANL's GREET model for greenhouse gas analysis
- ❖ Publications/ presentations
  - ➢ 8 presentations/ papers
  - ➢ A report to be published soon

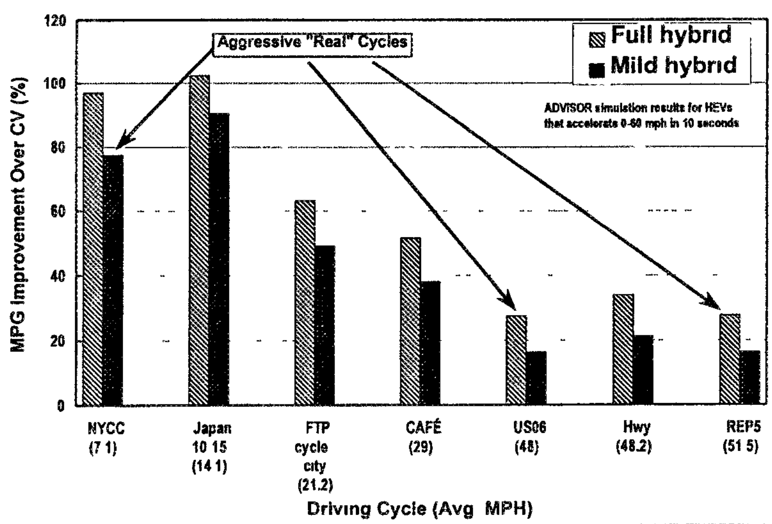
This Presentation Puts the ANL Study Into Context With Respect To:

- ❖ EPRI HEV Working Group analyses
- ❖ Effects of comparable performance rules on MPG gain estimates
- ❖ Comparison of conventional vehicle (CV) lifecycle costs to various HEV types
- ❖ GM-GAPC estimates of MPG gains via hybridization
- ❖ HEV type's impact on lifecycle costs vs. Fuel price

Mild and Full HEVs Differ by Share of Peak Power Provided Electrically



Simulations Suggest Lower HEV In-use MPG Gains Than Certification Tests Imply

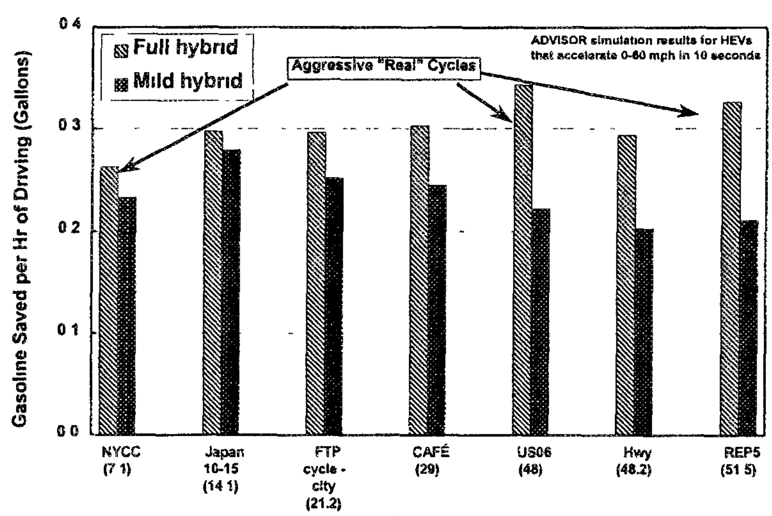


Four Points Can Be Made From the Prior Slide, But Appearances Can Be Deceiving

1. Full hybrids can only double the fuel economy in very congested conditions
2. Mild hybrids provide a very large fraction of the full hybrid fuel economy gains, especially in congested driving
3. Deceptively, the percentage MPG gains of hybridization are greatest in city driving
4. Deceptively, the percentage MPG gains are lower in more aggressive or high-speed driving

(The next slide shows the extent of deception)

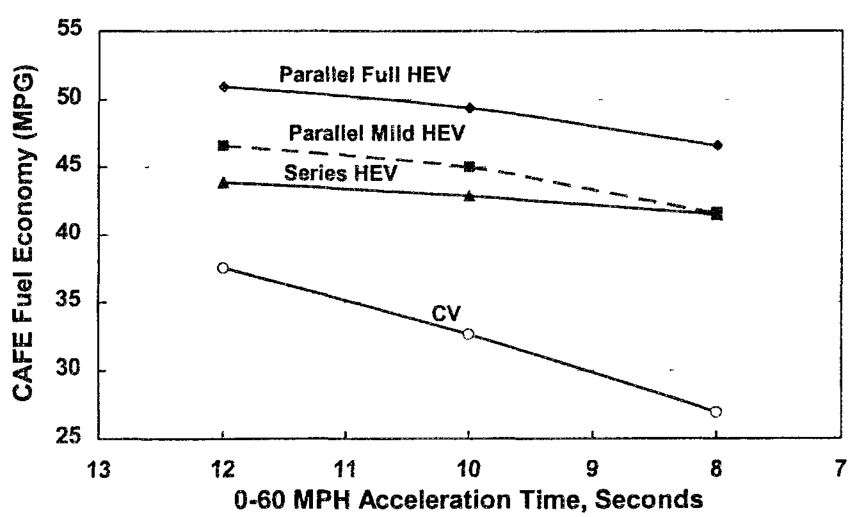
Examining Fuel Savings Per Hour of Driving Is More Instructive Than % Gain



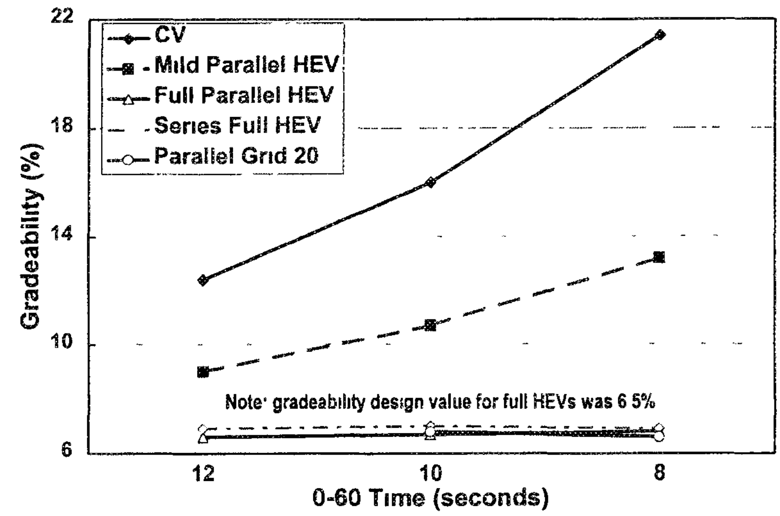
Per Hour Fuel Savings Give a Different Perspective

- Savings per hour are similar for all driving cycles
- Mild vs. full HEV and congested vs. high-speed driving differences become clearer
  - Mild HEVs are nearly as good as full HEVs in congestion
  - Full HEVs clearly save more fuel in high-speed driving
- Compared to CV, mild and full hybrid differences become clearer
  - Gains by mild hybrids are greatest in congested driving
  - Gains by full hybrids are greatest in high-speed driving
  - Gains by full hybrids in high-speed driving are larger for aggressive driving cycles

MPG Penalties For High Performance, Large In CVs, Can Be Small In HEVs



Downsizing HEV's Engine Causes Reduced Continuous Gradeability (and Top Speed)



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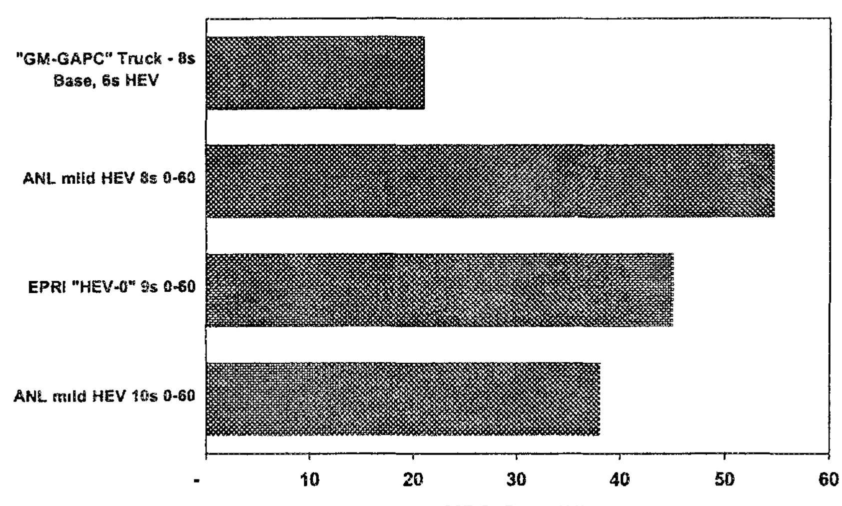
ANL/EPRI MPG Gain Estimates Are Consistent; Differ Notably From GM-GAPC



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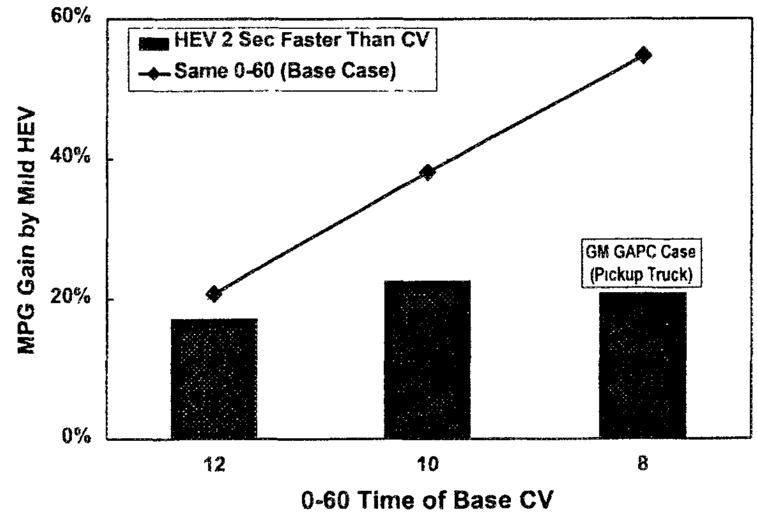
Making ANL HEVs 2 Sec Faster to 60 mph Than CVs Explains Some of the GM/ANL Gap



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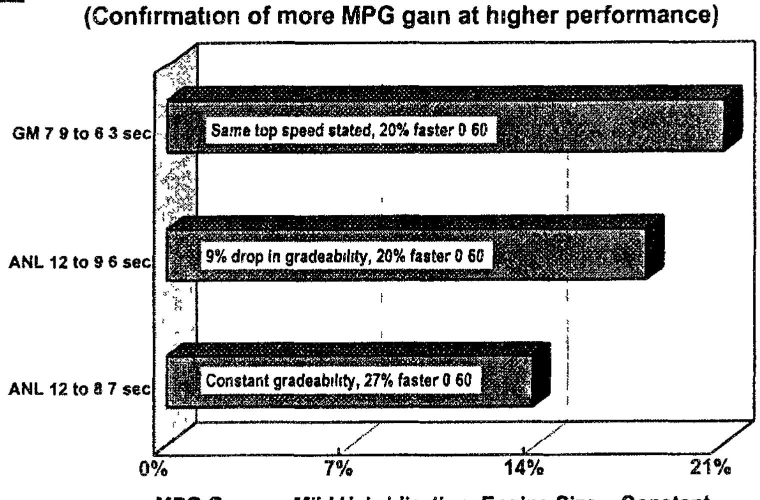
Adjusted ANL Results Show Consistency With GM-GAPC Results

(Confirmation of more MPG gain at higher performance)



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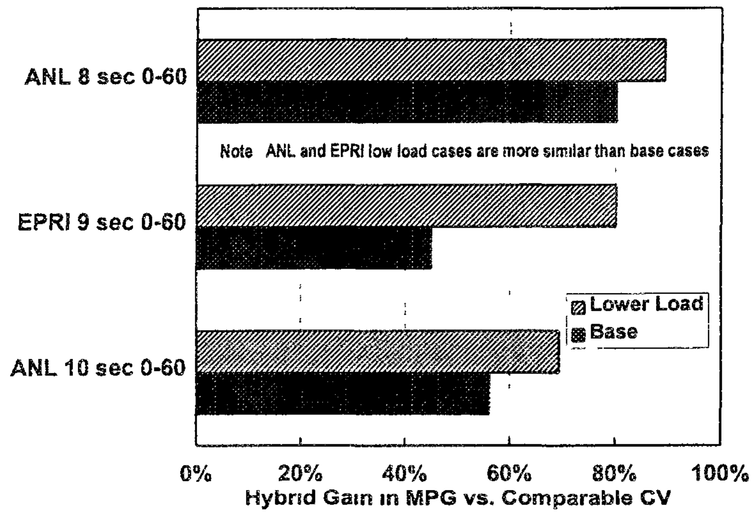
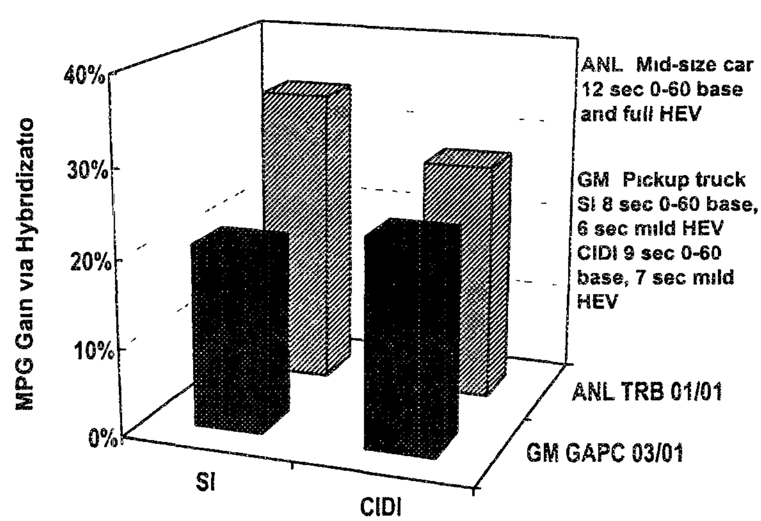
ADVISOR Runs Imply Road Load Reduction Having Positive Synergism With HEV MPG



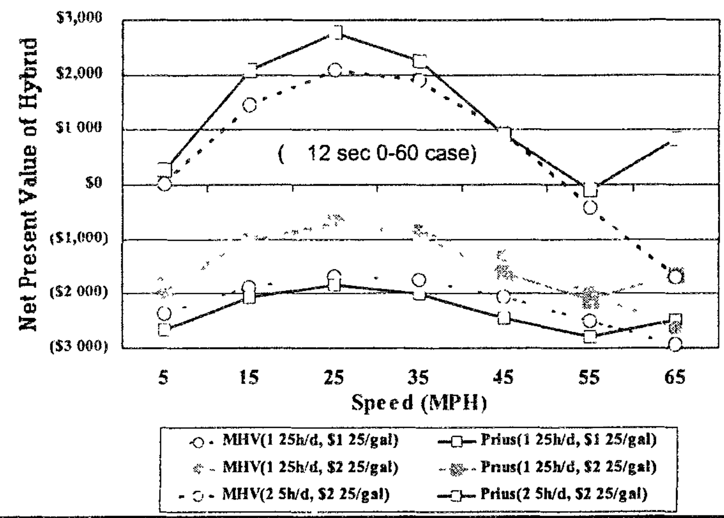
15 Argonne National Laboratory
Transportation Technology R&D Center

In Separate Analyses, GM and ANL Differ On Benefits of Hybridizing With SI and CI Engines

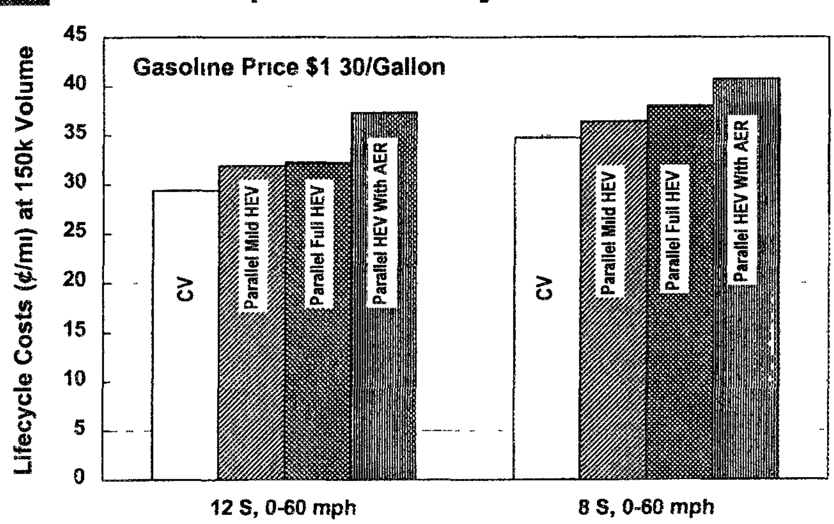


16 Argonne National Laboratory
Transportation Technology R&D Center

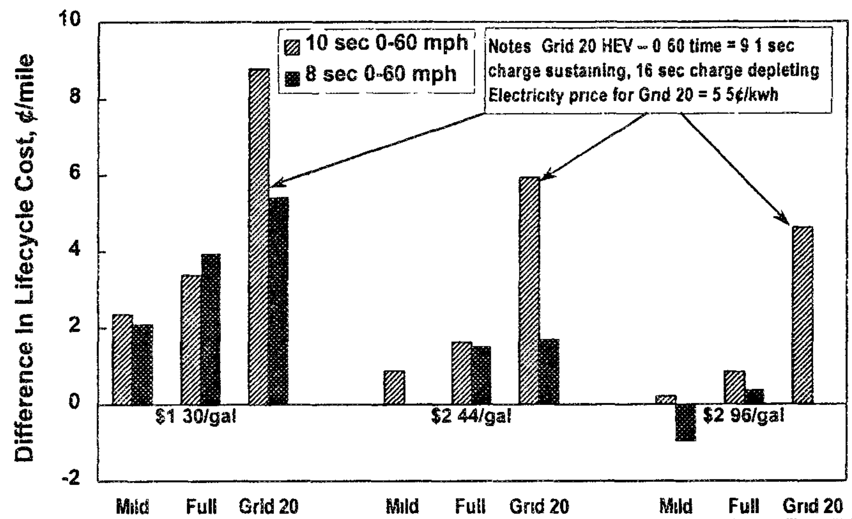
2000 Results Showed Relative Superiority of Full vs. Mild HEV to Depend On Fuel Price



ANL Research Implies That Mild Hybrids Can Compete on Lifecycle Cost Basis



The Desirable Proportion of Electric Power Rises With Rising Gasoline Price



Our Analysis Leads to the Following Conclusions

- At low U.S. gasoline prices, national research should focus on mild hybrids (and 42V systems)
- In comparisons, hybrids cannot be made performance equal, only performance comparable
- The high percentage MPG gains for hybrids in congested driving are deceptive – savings per hour is a better measure
- U.S. driving patterns are not the reason that HEVs will be difficult to market, low gasoline prices are
- GM-GAPC's constraint of performance compatibility in simulating HEV MPG gains raises an issue of consumer valuation of top speed. How large is the market for HEVs with downsized engines?

An Electric-Vehicle Design Performance, And Life-Cycle Cost Model

May 15, 2001

Mark Delucchi
Institute of Transportation Studies, Davis

AN ELECTRIC-VEHICLE DESIGN, PERFORMANCE, AND LIFE-CYCLE COST MODEL

M Delucchi
A Burke
M Miller
T Lipman

Institute of Transportation Studies
University of California, Davis

WHAT WE MODEL IN DETAIL

- Variable costs of manufacturing vehicles
- "Fixed" costs of making vehicles, as a function of production volumes
- Cost and performance of EV drivetrains and batteries
- Vehicle energy use
- Operating costs
- EV designed to meet range and performance requirements

"FIXED" COSTS

- Division costs
  - costs related to manufacturing cost
  - costs per unit
- Corporate costs
  - costs related to manufacturing+division costs
  - costs per unit
  - interest cost
  - corporate profit
- Dealer costs
  - costs related to factory costs
  - costs per unit
  - interest cost
  - warranty cost
- Shipping cost
  - function of vehicle weight
- Sales tax
  - function of vehicle retail price

EV LIFECYCLE COST AND PERFORMANCE

Mid-size vehicle, advanced technology, high-volume production,FUDS

	EV Pb/acid		EV Ni/m-h2		EV:
Range (mi)	65	110	90	165	140
0 - 60, 0% grade (sec)	9 3	9 3	9 3	9 3	9 3
vehicle wt (kg)	1,635	2,354	1,361	1,809	1,273
fuel economy (mpg)	95 5	73 9	87 5	73 9	146 0
vehicle price ($)	24,553	29,422	28,034	35,759	27,678
battery price ($/kWh)	259	202	475	361	337
battery price ($)	3,482	6,003	9,675	16,603	12,993
lifecycle cost (c/mi)	38 31	44 12	53 39	55 36	51 34
present value ($)*	11,632	18,955	21,369	36,974	12,339
breakeven $/gal	2 64	4 14	4 19	6 66	2 77

*Present value of gasoline lifecycle costs, difference between gasoline and EV present value

EXTERNAL COST OF EVs vs. GASOLINE VEHICLES (cents/mile)

	Battery EVs		
	low	*high*	*best*
Noise1	0 00	1 20	0 04
Externalities of oil use2	0 02	0 12	0 04
Climate change3	0 00	0 13	0 06
Air pollution4	0 02	0 21	0 07
TOTAL	**0 05**	**1 67**	**0 21**

1 Assumes range of damages on collectors and principal arterials
2 Assumes 25 mpg
3 Use lifecycle CO2-equivalent emissions at 25 mpg
4 Uses Delucchi $/kg damage estimates, adjusted for estimated differences in exposure

SOCIAL COST OF EVs vs. GASOLINE VEHICLES (cents/mile)

	Difference in costs		
	low	*high*	*best*
Private lifecycle costs	0 0	30 00	10 00
Noise1	0 00	-0 40	-0 01
Externalities of oil use2	-0 20	-1 12	-0 36
Climate change3	-0 00	-0 06	-0 03
Air pollution4	-0 17	-2 11	-0 69
Total externalities	*-0 37*	*-3 69*	*-1 09*
Social cost	*-4*	*30*	*9*

1 Assumes range of damages on collectors and principal arterials
2 Assumes 25 mpg
3 Use lifecycle CO_2-equivalent emissions at 25 mpg
4 Uses Delucchi $/kg damage estimates, adjusted for estimated differences in exposure

Hybrid Electric Vehicles

Myth versus Reality

May 15, 2001

Dave Hermance
Toyota Technical Center, USA, Inc.

Hybrid Electric Vehicles

Myth versus Reality

Toyota Technical Center, USA, Inc

Dave Hermance

May 15 2001

What Does the Market Want?

A significant and growing percentage of customers indicate a willingness to buy an environmentally friendly vehicle,

if and only if, all other attributes are equal

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Myth #1

All "power assist hybrids" are the same

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Power assist HEV Variations

- Architecture
- Performance
- Cost
- Emissions
- Fuel Economy
- Electric Operation

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EEA Analysis

Type	Cost	FE Benefit
Starter/Alternator	$500-700	22%
Motor Assist	$1450	33%
Integrated	$2300-4000	50-52%
Separate 4wd	$2600	28%

Note Costs and Benefits are Drivetrain Only

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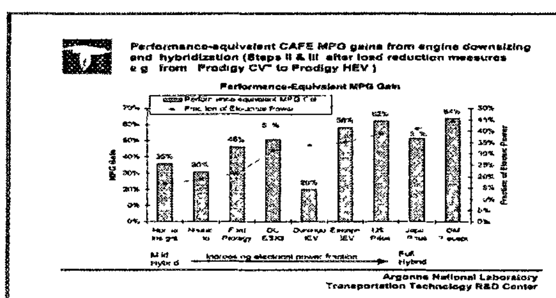
Argonne Labs Analysis



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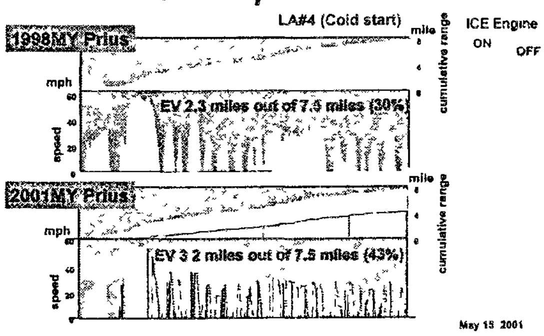
Prius EV-Operation



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Myth #2

Prius could easily be made into a grid-connected HEV

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Reality #2

The unique Prius drivetrain (THS) is not appropriate for a grid-connected application

- Motor is much too small
- Battery energy and power are too small
- No way to carry required battery mass or volume
- Engine is too large
- THS transmission design is inappropriate

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Probable Attributes of Grid-Prius

- Markedly reduced performance in EV mode
  - Slower 0-60
  - Lower top speed
  - Reduced passing performance
- Drastically reduced battery life
- Loss of ICE fuel economy due to mass
- Significantly higher cost

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Vehicle Performance

Comparison of performance for Prius and Grid Prius

	Current Prius/THS	Grid Prius (Prius with e-com battery) (Simulation)	RAV4EV
Usable Energy	~500 Wh	6 8 of 8 4 kWh	29 kWh
Motor/ Generator	Max power 33kW	Max power 40kW	Max power 50kW
Vehicle Weight	1255 kg	1255 + 150 kg	1560 kg
0 - 60 mph	12 5 sec (ICE+EV)	19 3 sec (EV)	18 6sec

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Batterv life/durabilitv

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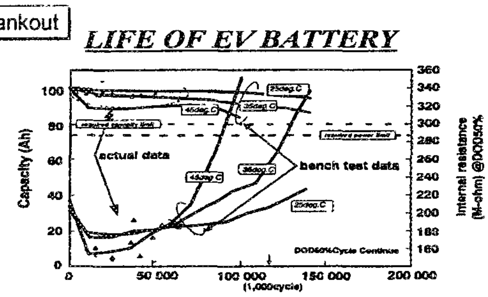

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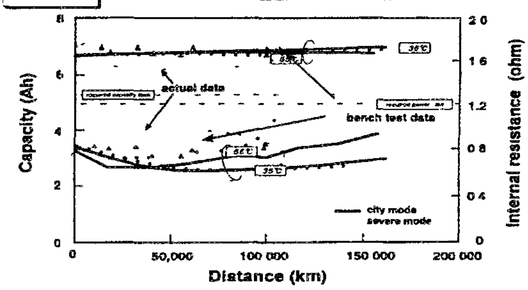
Battery life/durability

blankout ***LIFE OF HV BATTERY***



Myth #3

An HEV-20 will have significant EV use

Reality #3

- AER ≠ Real World (RW) range
- Even 20 mile RW is only ~ 20% VMT substitution if re-charged daily

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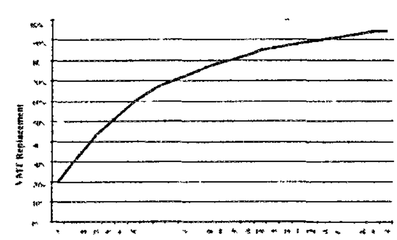
Sierra Analysis of EPA Data



Myth #4

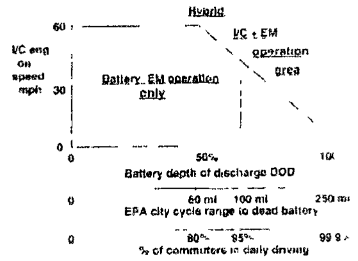
UC Davis Vehicles Are Viable Under Current Regulations

Reality #4

- Control strategy is probably a "defeat device" under EPA/ARB rules
- Emissions claims require averaging EV and ICE emissions
- Performance claims are simulation based, actual is far different
- Published cost estimates neglect critical components

UCD Control Strategy

Proposed Charge Depletion Control Strategy



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UCD Cost Estimates

Powertrain Cost parody of Battery Dominant CDHEV with conventional V-6 GV

- Charge Depletion Hybrid Electric Vehicle UC Davis
- Battery costs @ $150 kwh 15 kwhrs — $2250
- 3 cylinder engine no accessories $ 300
- Automatic Cont Variable Trans — $ 500
Total CDHEV powertrain system $3050

- Conventional Gasoline Vehicle
- V-6 engine and accessories — $1500
- Automatic Transmission and controls — $1200
- Accessories and drive systems $ 500
- Total V-6 Gas Vehicle $3200

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Technical Issues for Grid-HEVs

- Real world control strategy
- Vehicle Performance
- Real world EV/VMT fraction
- Battery Technology
- Cost
- Emissions
- Test Procedure

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EV Performance

EV operation in Grid-HEV depends on architecture

- Slower 0-60
- Lower top speed
- Reduced passing performance

These limitation must be considered in conjunction with real world operation and test procedure

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Regulatory Issues for Grid-HEVs

- 15/150,000 Battery Warranty
- Credit Structure
- Test Procedures

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Test Procedure for Grid-HEV

Issues to be addressed:

- Defeat device treatment for EV operation
  - Emissions for ICE-on in/off mode
  - Safety/system protection issues
- Determination of DF for emission control system
- Evaporative emission during EV operation
- OBD requirements

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Hybrid Electric Vehicle Technology from No Plug to Plug-In to Plug-out Hardware & Control EPRI-HEV WG/UCDavis-HEV Center

May 15, 2001

Andrew Frank
University of California, Davis
Department of Mechanical & Aeronautical Engineering

Hybrid Electric Vehicle Technology from No Plug to Plug-In to Plug-Out Hardware & Control EPRI-HEV WG /UCDavis-HEV center

Andy Alfonso Frank –' The Fonz"
Director HEV Center
Mech Aero Eng
Univ of Ca –Davis
530 752 8120
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Hybrid Electric Vehicle Technologies Addressed by the HEV WG

- Series or Parallel configurations—Only Parallel because of efficiency
- Technology and hardware solutions and system configurations
- Plug to electric company or no plug— Both vehs are considered to evaluate F/E and Emissions - tail pipe and well to wheels
- Control policies and options–discussed
- Energy from the Electric Companies or energies back to the Electric companies can be done How to control? New item to study for the next phase

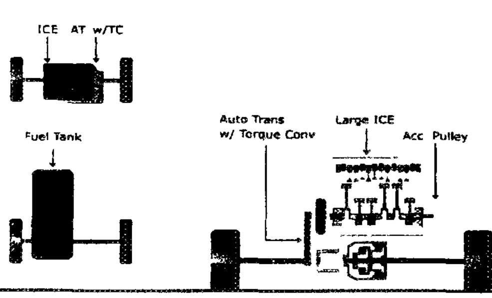
Other points of design and discussion among HEV WG members include

- A single traction motor/Gen or 2 units?—1 EMG selected
- Battery location for HEV 20 and 60? SUV ok, smaller vehicles harder to find a place
- "Turtle Light" and performance limit allowance
- Cabin cooling and heating techniques Low cost soln
- Auxiliary power concepts Mechanical, unless electric is cheaper
- Zero Evaporation concepts-canister or pressurized tank?
- Simplified and low cost emission control concepts
- Battery cooling and heating
- Battery life replacement management and policies

Hybrid Vehicle Technology ZEV (Criteria Emissions) No Plug Type

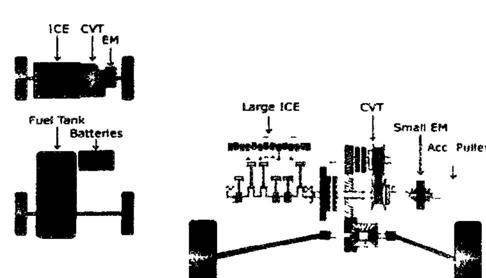
Conventional Gasoline Powertrain Vehicle –CV–

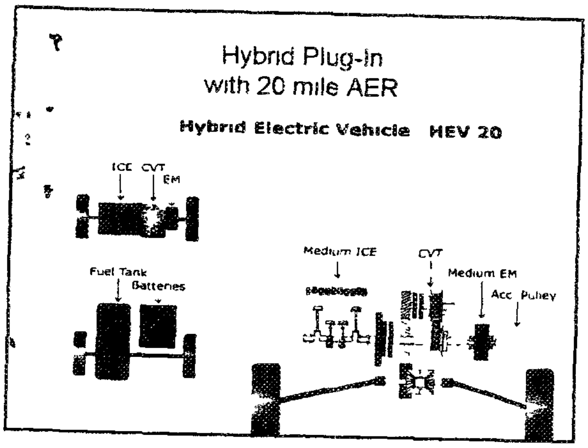
Conventional Gas

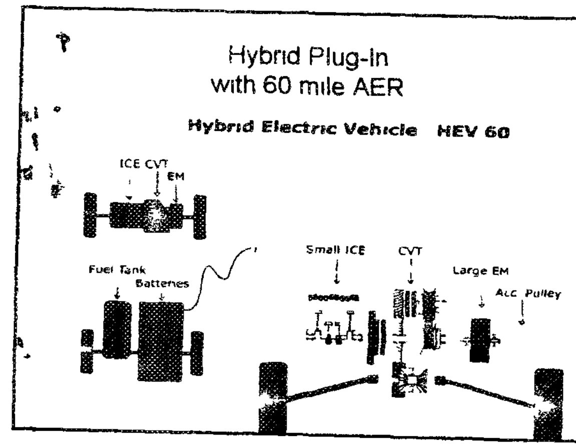


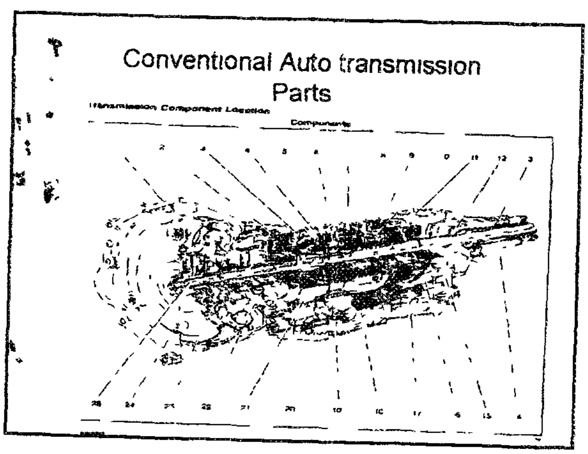
Hybrid with Zero All Electric Range 0 mile AER

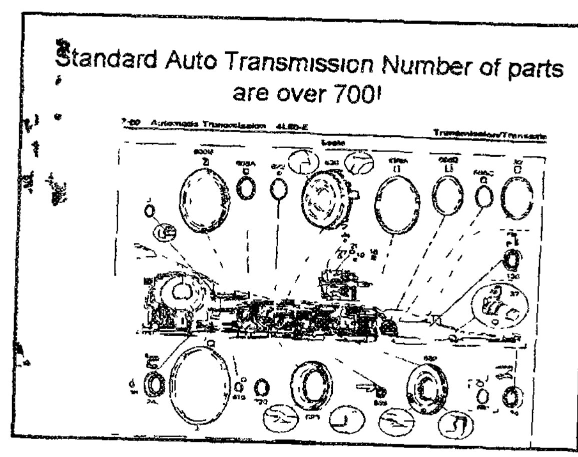
Hybrid Electric Vehicle HEV 0

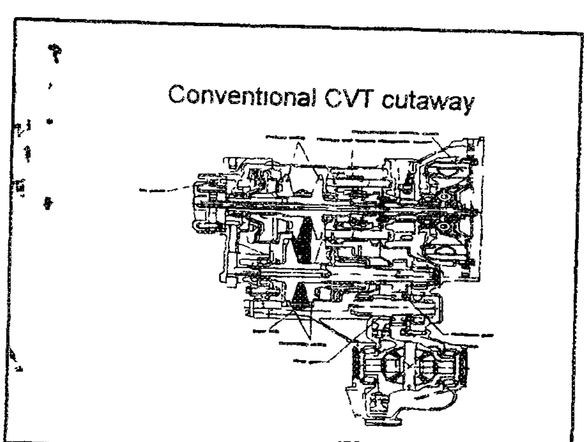


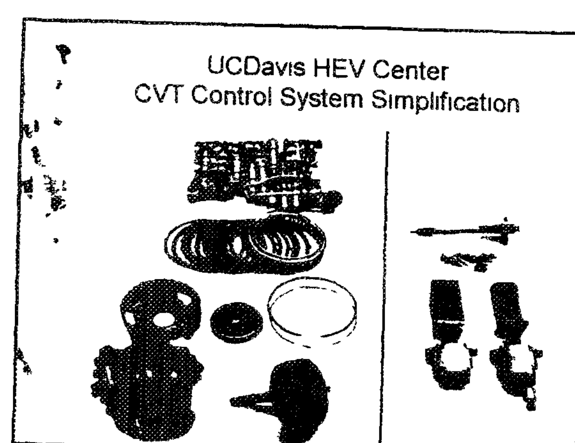

Hybrid Plug-In
with 20 mile AER
Hybrid Electric Vehicle HEV 20
ICE CVT
EM
Fuel Tank
Batteries
Medium ICE
CVT
Medium EM
Acc Pulley


Hybrid Plug-In
with 60 mile AER
Hybrid Electric Vehicle HEV 60
ICE CVT
EM
Fuel Tank
Batteries
Small ICE
CVT
Large EM
Acc Pulley

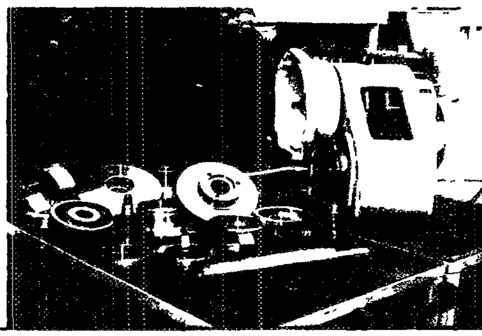

Conventional Auto transmission
Parts


Standard Auto Transmission Number of parts
are over 700!

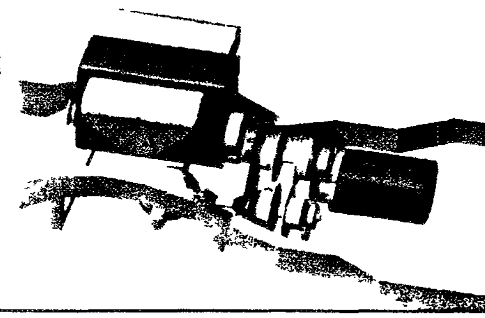

Conventional CVT cutaway


UCDavis HEV Center
CVT Control System Simplification

UCDavis HEV Center
350 hp Continuously Variable Transmission
Parts Count less than 60



UCD HEV Center
Hybrid 350 hp-CVT Chevrolet Suburban Powertrain



UCDavis Hybrid Center HEV 60 Future Truck
Electric operation @ GM proving grounds

UCDavis Hybrid Center
HEV 60's with CVT's
The HEV-1 and Coulomb

Mid size Fuel Economy Calculations Std construction HEV WG

Parameter	Units	CV	HEV 0	HEV 20	HEV 60
UF Weighted SAE J1711					
Weighted Urban	mpgeq	—	—	45.8	52.7
Weighted Hwy	mpgeq	—	—	5[illegible].3	60.8
Composite [a]	mpgeq	—	—	48.5	56.1
UF Weighted	mpgeq	—	—	54.8	73.4
MRP Weighted SAE J1711					
Weighted Urban	mpgeq	—	—	46.8	55.1
Weighted Hwy	mpgeq	—	—	53.4	63.0
Composite	mpgeq	—	—	49.6	58.4
MRP Weighted	mpgeq	—	—	62.6	81.8
Partial Charge Test					
Gasoline Urban	mpg	23.2	40.6	40.9	42.4
Gasoline Highway	mpg	41.4	43.7	47.1	49.7
Gasoline Composite	mpg	28.8	41.8	43.5	45.4
Full Charge Test					
Electric Urban	kWh/mi	—	—	0.280	0.288
Electric Highway	kWh/mi	—	—	0.282	0.288
Electric Composite	mpgeq			117.2	113.9

Miles per gasoline equivalent gallon. Electric fuel economy in kWh/mi is converted to miles per gasoline equivalent gallon using 33.44 kWh/gallon of gasoline.
[a] Also termed mixed fuel economy.
These numbers reflect FTP test results. Energy cost calculations use fuel economies which are discounted with EPA labeling factors. See discussion in Section 5.2.2.4

EPRI-10% reduced mass, 30% lower rolling resistance and 40% improved Aero — all less than ½ of PNGV cars HEV WG

Parameter	Units	CV	HEV 0	HEV 60
UF Weighted SAE J1711				
Weighted Urban	mpgeq	—	—	89.0
Weighted Hwy	mpgeq	—	—	82.3
Composite [b]	mpgeq	—	—	74.4
UF Weighted	mpgeq	—	—	96.0
MRP Weighted SAE J1711				
Weighted Urban	mpgeq			71.9
Weighted Hwy	mpgeq			84.8
Composite [b]	mpgeq			77.1
MRP Weighted	mpgeq			105.4
Partial Charge Test				
Gasoline Urban	mpg	27.7	58.0	58.3
Gasoline Highway	mpg	50.5	69.7	67.1
Gasoline Composite	mpg	34.8	62.7	60.9
Full Charge Test				
Electric Urban	kWh/mi	—	—	0.248
Electric Highway	kWh/mi	—	—	0.227
Electric Composite	mpgeq			142.1

Miles per gasoline equivalent gallon. Electric fuel economy in kWh/mi is converted to miles per gasoline equivalent gallon using 33.44 kWh/gallon of gasoline.
[b] Also termed mixed fuel economy.
These numbers reflect FTP test results. Energy cost calculations use fuel economies which are discounted with EPA labeling factors. See discussion in Section 5.2.2.4

From the Technology Slides HEV WG Conclude That HEV's Have the following Properties

1. No engine idle and Torque Converter—-Electric motor Launch
2. Regenerative Braking is enough to sustain charge in the City with the appropriate engine "turn - on" speed
3. Allows ideal engine operation at 33% efficiency on gasoline today and opens the door to design much higher efficient gasoline engines over 40% efficient that are much simpler than current designs—Toyota Prius-38%
4. Replaces Mechanical complexity with Electronic controls for much higher overall efficiency reliability and lower costs
5. Much lighter powertrain for the same performance HEV 60 powertrain is 1/3 the weight of CV
6. Total vehicle weight of the HEV 60 can be the same as the CV with the use of some better materials
7. With PNGV materials and aerodynamics a 5-6 passenger sedan such as the Lumina can achieve over 100 mpg within today's cost range for these vehicles

Infrastructure---The Achilles Heel of All Alternative Fuel Vehicles

1. Small and midsize 5 passenger Plug-in HEV vehicles and SUV's can use today's **gasoline stations and 120v electric plugs** with GFI to fill tanks and charge batteries at 1 5kw <u>No Infra Prob</u>
2. Large SUV's could use 220v GFI plugs or special 120v plugs with GFI at 3 kw **Rapid charge is <u>not</u>** required since it's an overnight charge and a partial charge **does <u>not</u> affect** <u>performance or range in all plug-in HEV's</u>
3. Completely **<u>automatic charging</u>** systems are easy to design at these low powers Standards needed for all manufacturers No action required of user!
4. Research area for the future HEV WG

General Control Philosophy for parallel HEV's

1. Use E/M/G and batteries for low speed driving and vehicle acceleration and deceleration performance
2. Use gasoline Eng for Steady State speeds and loads
3. These cars are <u>ZEV</u> at low speed <u>city driving</u> but clean efficient highway cruisers with up to 2X or better MPG
4. Gasoline is used at highway speeds with E/M/G for better acceleration, deceleration and engine regulation for minimum fuel and lowest emissions for SS power
5. Parallel HEV's provide opportunities for optimization of many other parameters simultaneously

HEV WG identified 12 control strategy items

- 3 techniques for engine Turn On-T/O, speed, 45, 60, 80 mph
- Ramp down Engine T/O speed/SOC for increased range on electric energy
- Driver interaction allowance for better electric use
- Smart-car trip planning capabilities
- Enhanced electric modes to increase AER
- Better engine Start algorithm development
- CVT optimization for gasoline-EV-regen operation
- Minimize battery replacement strategies
- Mountain mode strategies
- The highlights are discussed in the next few slides

WG Control for battery management of zero AER small batteries HEV 0 to HEV 20

Objective

- Use batteries and EMG to enhance downsized eng for vehicle performance and launch up to about 5 to 10 mph
- Use batteries to collect regenerative braking energy There is enough energy in "normal" city driving to maintain battery SOC
- Aggressive driving for a few minutes will cause "turtle light" to come "on", limiting performance Larger batteries reduce the frequency of the "T"

WG Control of batteries for plug-in long AER, HEV 20 to HEV 60

- Batteries are used for low speed city driving w/o eng (ZEV) unless the batteries are depleted to a certain state then ZEV up to 25 mph ZEV performance 0 to 60 mph in 8 to 9 seconds or less
- Up to 60mph eng "off" until 20 to 60 miles are driven, then batteries will be maintained at about 20% SOC
- Engine controlled to always come "on" above 60 mph
- With Eng "on" EMG and batteries are used to enhance performance like the HEV 0
- Larger battery pack leads to a longer time to "turtle light" HEV 60 may only see Turtle light when driving faster than 100 mph for 20 minutes

WG Control of energy for Fuel Economy

- The battery-EMG is used with the CVT to allow the engine to only operate along an "ideal" line in torque and speed, An IOL This allows the engine to operate at 30% to 38% efficient shaft power from a minimum power to a maximum power
- The gasoline eng is sized to provide enough power for highway **cruise** on a level road, then the battery-EMG is used for acceleration and hill climb Small packs will suffer "Turtle light" if the hill is too long All cars are designed to travel Denver grade w/o Turtle light
- Engine power goes right to wheels for best efficiency
- Mechanical CVT is much more efficient (95%) than Auto-transmissions

Control System to manage the battery SOC as the car is driven

- Can be done by engine "turn on (T/O)" speed – The lower the T/O the more gasoline used and the less electric energy used in city driving
- For highway cruise, one way is to require the engine to make slightly more power than needed to maintain a given speed then to use the EMG to generate enough to keep the batteries at the minimum SOC – about 20% SOC Then wait for the vehicle to park to **plug-in** before charging to "full" SOC Gasoline is not used to charge to 100%—only to maintain SOC
- T/O concept allows battery charging to be automatic
- Driving habits can be used to determine adaptive or predictive control strategy Controls are simpler when batteries are larger

Control of daily energy use to increase battery life

- Can be done by taking less energy per day from the batteries by sustaining at a higher SOC Therefore, the driver goes fewer AE miles per day and covers more miles using gasoline—Degrades HEV 20 to HEV 15 etc
- Battery End of Life (EOL) was defined as 80% capacity for HEV 0 to HEV 20 batteries For HEV 20 to HEV 60 plug-in vehicle batteries EOL can be extended to lower capacity thus extending replacement range Control to extend battery life may be done only after 100,000 miles has been covered
- 150,000 vehicle mile battery life can be accomplished requiring fewer pure electric miles toward the battery end of life

Bi-directional charging to provide Electric Utilities rolling reserves and regulation

- Plug-in HEV's with bi-directional chargers under **utility company control** Then use only the batteries of HEV's to level and regulate the grid
- The user pays 6 cents/kwhr to charge his batts but is deducted 18 cents/kwhr to feed energy to the grid
- This is only possible if energy is taken from batteries
- Running the engine to recharge back to the grid is too expensive—75-80 cents/kwhr, due to gasoline engine component life and cost of fuel
- This concept only makes sense for Plug-in HEV 30 to HEV 60 or higher AER Not HEV-0 or Pure EV of today
- 1 million vehicles plugged in at 1 kw each is 1000 mw —enough to regulate power and prevent rolling black-outs! And the power is already distributed!

Conclusions

- Technology is now possible but not yet completely developed
- The heart of the Technology is the mechanical CVT which has been demonstrated by UCDavis HEV Center, more efficient than manual transmissions
- The larger the battery pack, the more efficient the Plug-In HEV up to a range of about 60 miles The optimum range will increase as battery technology improves
- There are numerous control strategies that the technology can be used to optimize the many parameters not now possible with CV's
- It is possible to integrate Plug-In HEV's with the Electric power grid to improve the system efficiency and **lower the electric energy costs** to all

Conclusion cont.

- Complete automatic control of the vehicle is expected and thus the vehicle is transparent to CV's
- User control of energy management may not be advisable until the public is better informed
- Fleet energy management control is a natural and can greatly reduce fleet operating costs
- All emissions and CO2 can be greatly reduced
- Fuel economy can be further increased by advance gasoline engine design with efficiencies up to 45%
- A shift in the use of fuel (G to E) can mean **higher profits** to Energy Companies Car companies also Gain $
- Plug-In HEV's can lead eventually to advanced alternative power such as F/C and others after infrastructure and technologies are developed

Ovonic Nickel-Metal Hydride Batteries For ZEV-Range HEVs

May 15, 2001

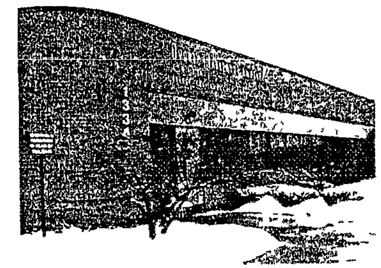
Dennis Corrigan
Ovonic Battery Company

OVONIC NICKEL-METAL HYDRIDE BATTERIES FOR ZEV-RANGE HEVs

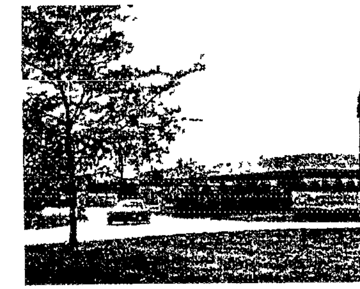
Dennis A. Corrigan
Ovonic Battery Company
Troy, Michigan

ECD ovonics@work

EV/HEV Battery Manufacturing Facilities



GM Ovonic → Texaco Ovonic Pilot Production Facility (Troy, MI)

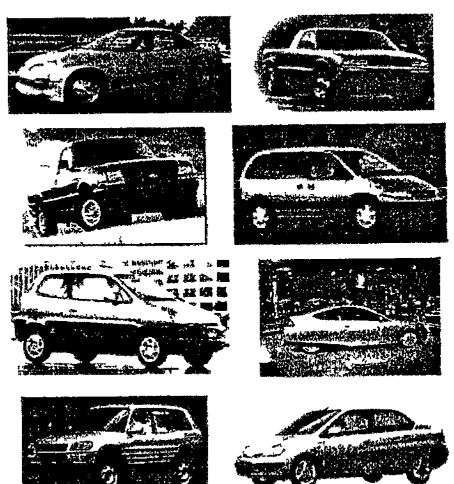


Ovonic Energy Systems Production Facility (Kettering, OH)

ECD ovonics@work

NiMH Production EV/HEVs

- GM EV1
- Chevrolet S10 Truck
- Ford Ranger Truck
- DaimlerChrysler EPIC Minivan
- Honda EV Plus
- Honda Insight
- Toyota RAV4-EV
- Toyota Prius



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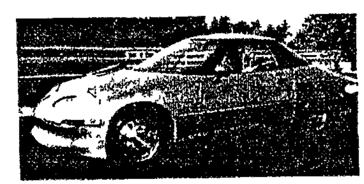
Ovonic NiMH Powered EV1

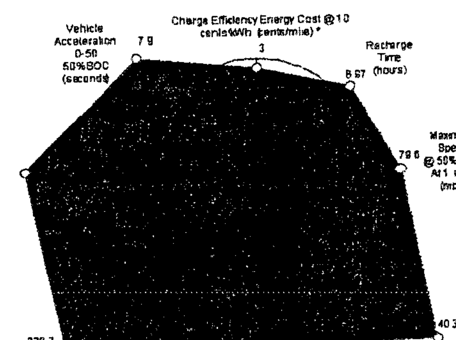


- Range doubled vs PbA

  221 miles @ 45 mph
  140 miles @FUDS

- Meets EVA performance goals

Performance Compared to Goals



DOE Results from EV America Testing

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BARRIERS TO EV MARKET

1 Limited range
2 Slow recharge time
3. Cost

ADVANTAGES OF ZEV-RANGE HEVS

1. Range comparable to conventional ICE vehicle
2 Rapid refueling like conventional ICE vehicle
3 Lower battery cost with smaller battery
4 Emissions reduction similar to EV

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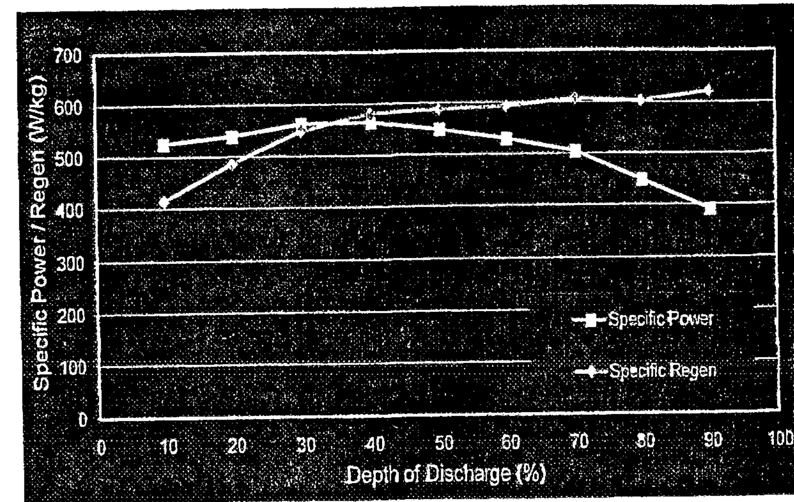
Power Performance of Ovonic NiMH Batteries for Charge-Depletion HEV Applications



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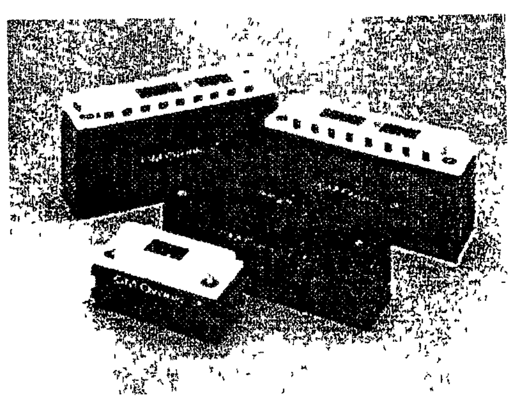
Ovonic NiMH Battery Products

EV Batteries
At 70+ Wh/kg

HEV Batteries
500-1000 W/kg

ZEV-Range
HEV Batteries
65+ Wh/kg
500+ W/kg

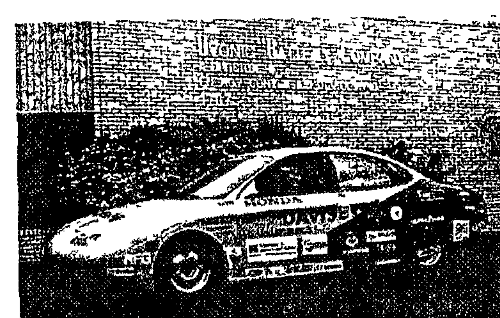


Ovonic Family of Batteries 20Ah to >100Ah

ovonics

UC Davis 1st Place 1997 FutureCar

Ford Taurus Conversion, Charge-Depletion HEV
Powered by 90 Ah Ovonic NiMH EV Batteries



UC Davis "Joule"

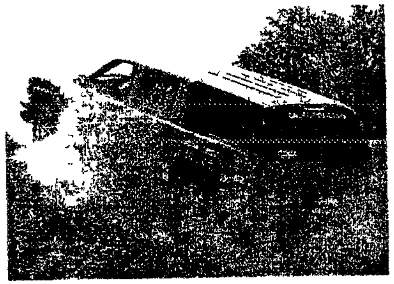
Mileage 49 mpg
vs. 25 mpg Taurus

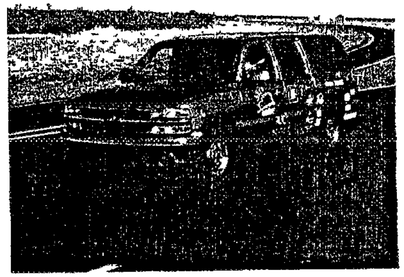
65 mile ZEV range
340 mile total range

ovonics

UC Davis 2000 FutureTruck

Chevy Suburban Conversion, Charge-Depletion HEV
"Sequoia"
Powered by 90 Ah Ovonic NiMH HEV Batteries
2X mileage, 70 mi ZEV range, 450 mi total range





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Charge-Depletion HEV Performance Summary

Vehicle	Joule	Coulomb	Sequoia
Battery Type	EV90	HEV60	HEV90
Battery Capacity (Ah)	90	60	90
Battery Voltage (V)	172	317	317
Battery Energy (kWh)	15 5	19 0	28 5
Battery Wgt Fraction	0 15	0 23	0 16
Battery Power (kW)	49	161	213
Motor Power (kW)	48	75	150
Acceleration Time (s)	14	11	9
ZEV Range (mi)	65	80	70
ICE Mileage (mpg)	25	25	13
HEV Mileage (mpg)	49	62	26
Improvement Factor	2	2 5	2

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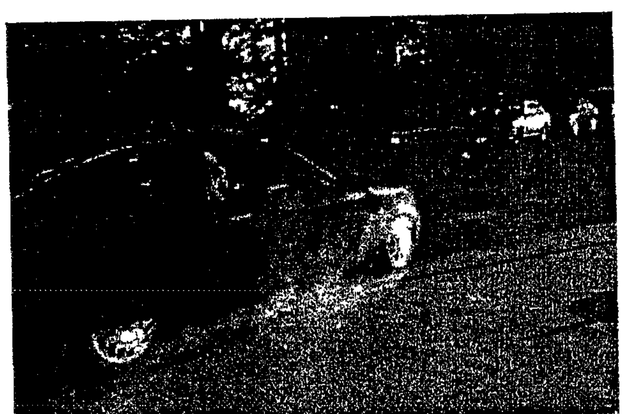
High-Performance Charge-Depletion HEV Powered by 60 Ah Ovonic NiMH HEV Batteries



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BATTERY LIFE ISSUES FOR ZEV-RANGE HEVS

ZEV Range (miles)	Cycle Life (cycles)	Total Lifetime ZEV Mileage (miles)
100	1200	120,000
60	1200	72,000
40	1200	48,000
20	1200	24,000*

*Increased cycle life possible via incomplete recharge strategies

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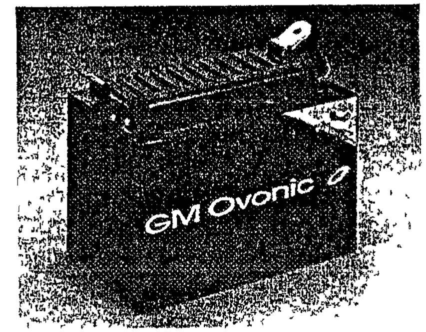
BATTERY SIZE OPTIONS FOR ZEV-RANGE HEVS

Range (miles)	Capacity (Ah)	Voltage (V)	Energy (kWh)
100	100	300	30
60	60	300	18
40	40	300	12
20	20	300	6

Ovonic NiMH 12-HEV-12 Water-Cooled Monoblock Battery



Voltage 12 V
Capacity 12 Ah

Specific Power 1000 W/kg

Reduced Parts Count
Reduced Hardware Cost

Enables lower costs
For smaller batteries

OTHER BATTERY SIZE OPTIONS FOR ZEV-RANGE HEVS

Range (miles)	Capacity (Ah)	Voltage (V)	Energy (kWh)
100	100	300	30
60	100	180	18
40	100	120	12
20	100	60	6

(enables lower battery costs proportional to energy)

SUMMARY AND CONCLUSIONS

- ZEV-Range HEVs mimic EV emissions advantages best with 60+ mile ZEV range
- Significantly better cycle life with 60-mile ZEV range HEV than with 20-mile ZEV range HEV
- 60 mile ZEV range HEV may have lower life cycle cost than 20-mile ZEV range HEV

Manganese-type Lithium Ion Battery for City EVs

May 15, 2001

Kensuke Hironaka
Shin-Kobe Electric Machinery Co., Ltd.

Manganese type lithium ion battery for city EVs

Kensuke Hironaka

Shin-Kobe Electric Machinery Co.,Ltd.

May 15 ,2001

Meeting the New CARB ZEV Mandate Requirements

Grid-connected Hybrids and City EVs

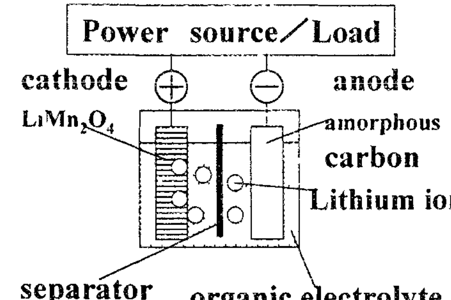
Outline

- Features of Mn type Li ion Battery
- Developments of Mn type Li ion Battery

  Topics: Improvement of cycle life
- Specifications and Characteristics for City EVs
- Summary

Features of Mn Type Li ion Battery

◇ Principle



Cell reactions

$$LiMn_2O_4 + C \underset{discharge}{\overset{charge}{\rightleftarrows}} Li_{1-x}Mn_2O_4 + Li_xC$$

◇ Features

- ○ Mn cathode
  : inexpensive (abundant)
  thermal stability
- ○ High cell voltage
  ・3－4V／cell
- ○ High energy density
  : ＞100Wh／kg
- ○ Good controllability
  ・electrical management
  thermal management

Features of Mn Type Li ion Battery

Comparison of 3 Positive Electrode Materials

Type	Composition	Thermal Decomp T. (℃)	Max Li deposition (mg/g)	Raw Material: Natural Abundance (Mton)	Raw Material: Metal Price ($/kg)
Co	$LiCoO_2$	225	35	8	50
Ni	$LiNiO_2$	180	20	110	9
Mn	$LiMn_2O_4$	350	4	3,500	3

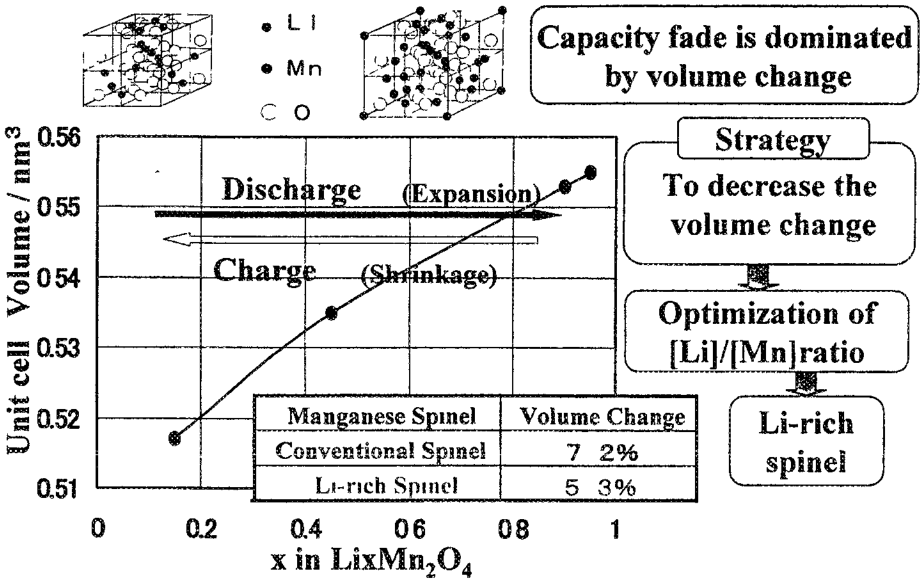
Merits for Mn Type Li ion Battery

- Safety (Thermal Stability, Li Deposition)
- Low Cost (Large Abundance, Low Price)

Weak Point for Mn Type Li ion Battery

- Insufficient Cycle Life Characteristics

Improvement of Cycle Life (Positive Electrode)

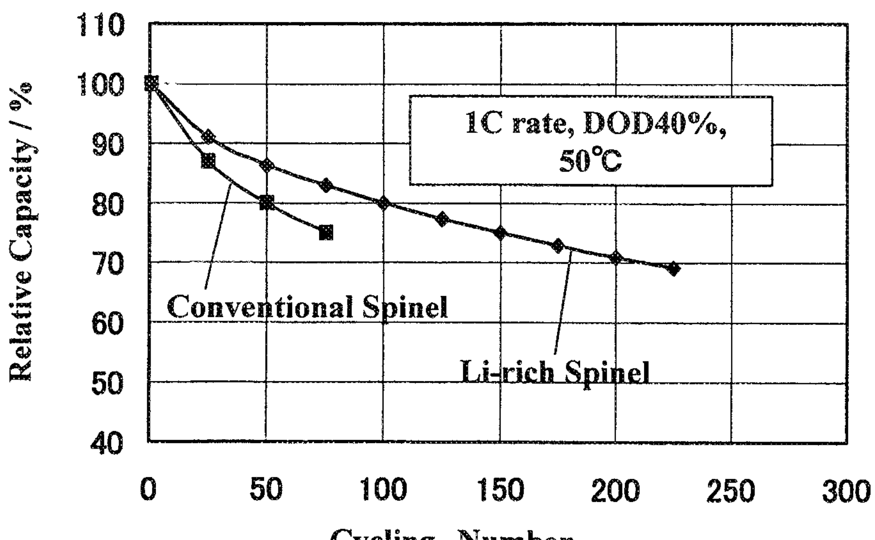


Manganese Spinel	Volume Change
Conventional Spinel	7 2%
Li-rich Spinel	5 3%

Fig.1 Volume change of a unit cell of $LiMn_2O_4$.

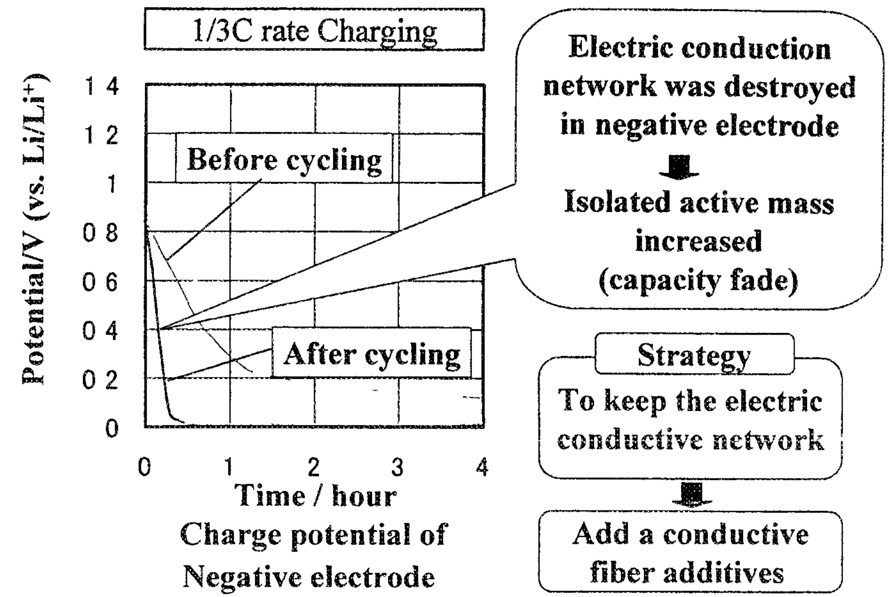
Shin-Kobe Electric Machinery Co., Ltd.

Improvement of Cycle Life (Positive Electrode)



Charge/discharge cycle life characteristics

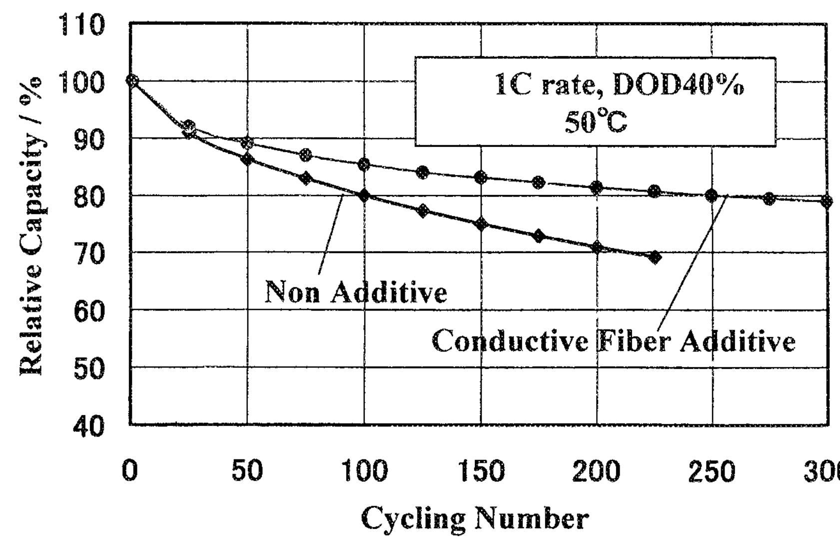
Improvement of Cycle Life (Negative Electrode)



Charge potential of Negative electrode

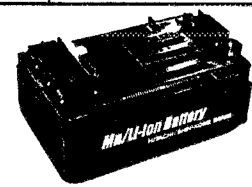
Shin-Kobe Electric Machinery Co., Ltd.

Improvement of Cycle Life (Negative Electrode)



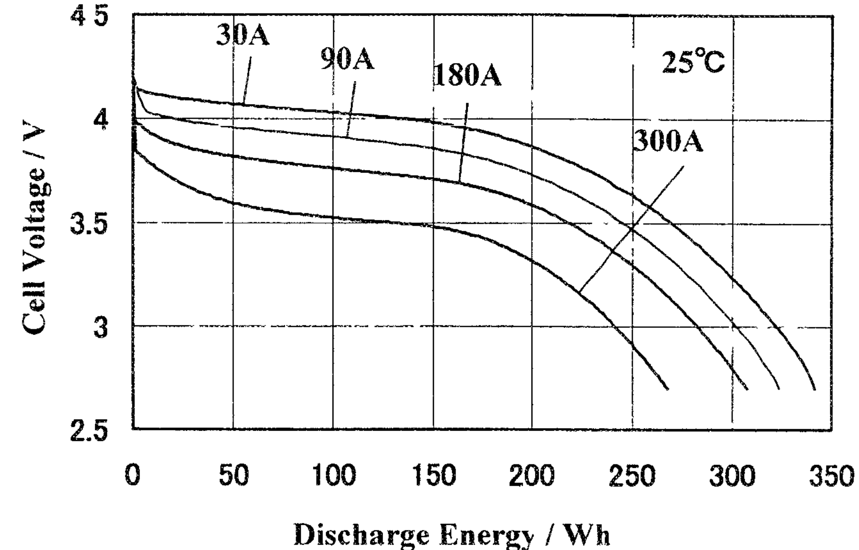
Charge/discharge cycle life characteristics for City EVs

	Single cell	Module
Battery construction	—	8 cylindrical cells in series
Dimensions / mm	Φ67×L410	L440×W290×186
Weight / kg	3 2	30
Capacity / Ah	90	90
Nominal voltage / V	3 8	30
Energy density / $Wh \cdot kg^{-1}$	107	93
Energy density / $Wh \cdot dm^{-3}$	237	114
Power density / $W \cdot kg^{-1}$	470 (DOD85%)	350 (DOD85%)



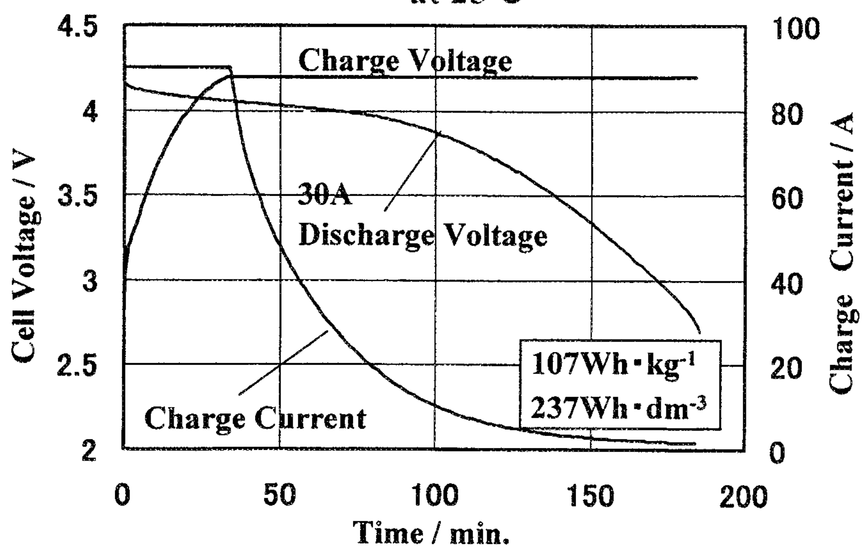
Outside view of a single cell and battery module.
Shin-Kobe Electric Machinery Co., Ltd.

at various discharge rates.



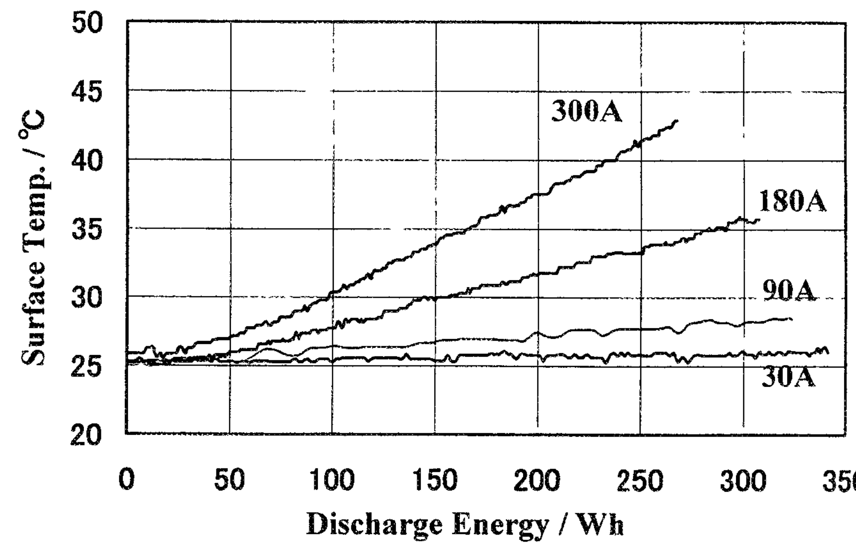
Shin-Kobe Electric Machinery Co., Ltd.[10]

Charge/discharge characteristics for a single cell at 25°C



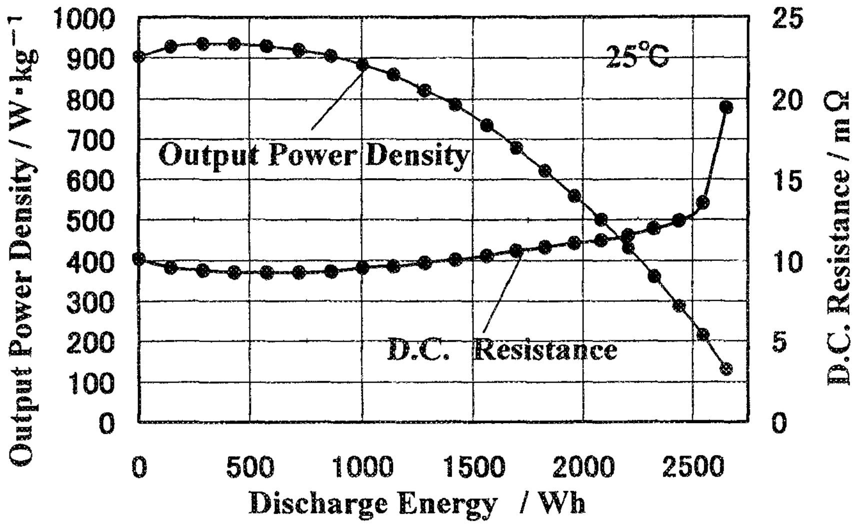
Shin-Kobe Electric Machinery Co.,[9] Ltd.

Surface temperature for a single cell at various discharge rates.



Shin-Kobe Electric Machinery Co.,[11] Ltd.

Output power and internal D.C. resistance for the battery module at 25°C.



14

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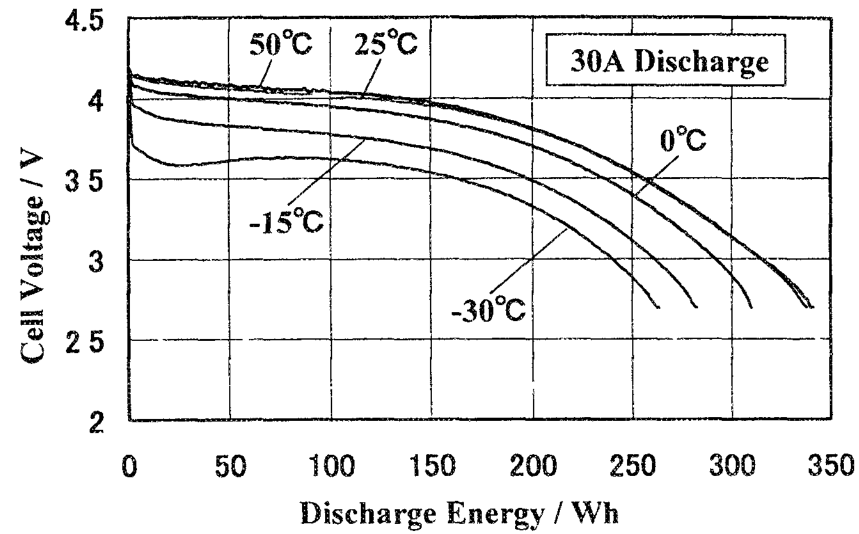
30A Discharge performance for a single cell at various temperatures.



12

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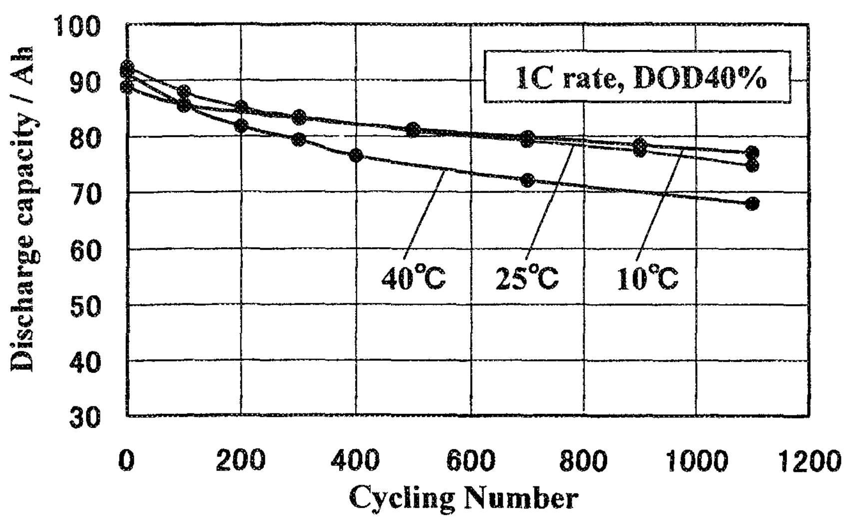
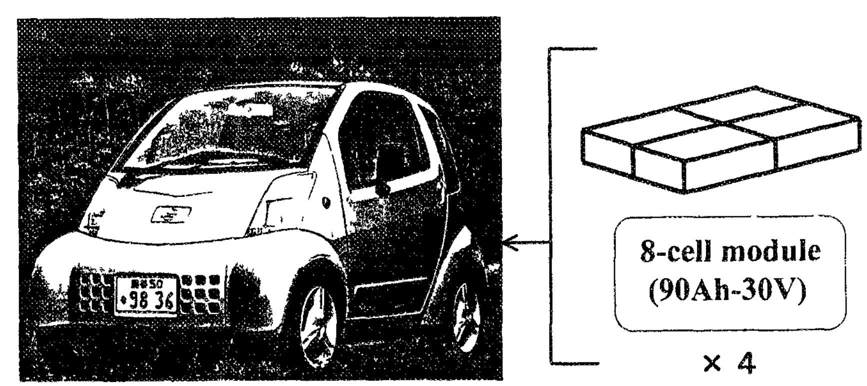
Charge/discharge cycle life characteristics for a single cell at various temperatures.



13

Application of 8-cell module to City EV



Nissan Hypermini
(2-seat compact car)

Shin-kobe
Mn type Li ion Baterry

Summary

- We developed manganese type lithium ion battery.
  - Energy density 93Wh/kg, 114Wh/dm^3 :module
  - Power density 350W/kg (at DOD85%) :module
  - Cycle life more than 1000 cycles (at 25°C)
- These batteries are already used in commercial vehicles "Nissan Hypermini" and are proving their practical applicability.
- Manganese type lithium ion battery will be very promising in future for City EVs which will make large market.
  - Cost, Resources, Performance and Management

Cost-effective Combinations of Ultracapacitors and Batteries for Hybrid Vehicle Applications

May 15, 2001

Andrew Burke
Institute of Transportation Studies, Davis

Cost-effective Combinations of Ultracapacitors and Batteries for Hybrid Vehicle Applications

Andrew Burke
Institute of Transportation Studies
University of California-Davis
Davis, California 95616

Paper presented to
Meeting the ZEV Mandate
Requirements Grid-connected
Hybrids and City EVs
May 15-16, 2001

Outline of the Presentation

- Introduction
- Ultracapacitors vs. Batteries
- Reasons for combining batteries and ultracapacitors
- Combinations studied
- Ultracapacitor characteristics
- Battery characteristics
- Applications studied
- Results
- Conclusions

Ultracapacitors vs. Batteries

Ultracapacitors

- High power and low resistance (2kW/kg, 95%)
- Long cycle life (>100K cycles)
- Cycle life independent of the pattern of SOC
- Long shelf life (>10 years)
- Relatively low energy density (<10Wh/kg)
- Power characteristics independent of SOC

Batteries

- High energy density (30-150 Wh/kg)
- Moderate power (< 5 kW/kg)
- Short shelf life (<1 year w/o recharge)
- Relatively short cycle life (<1K cycles, deep discharge)
- Cycle life can dependent on the pattern of SOC
- Variation of power characteristics with SOC

Reasons for combining Batteries and Ultracapacitors

- In order to get high power in both motoring (discharge) and regenerative braking (charge) the batteries are maintained at an intermediate SOC (approx. 50%)
- Dual high power requirements result in only a fraction of stored energy being available for use
- Ultracapacitors can provide the power when the power density of the battery is less than needed permitting the battery to be discharged over a wide SOC range
- The total energy stored in the battery can be reduced because a greater fraction of the energy is available for use
- The maximum power of the combination is greater for both motoring and regenerative braking
- In some applications, use of a battery with a higher energy density than possible when the battery must meet the maximum system power requirements for both motoring and braking

Combinations studied

- Ultracapacitors with lead-acid batteries
- Ultracapacitors with nickel-metal-hydride batteries
- Ultracapacitors with lithium-ion batteries

Ultracapacitor Characteristics

- Carbon-based, organic electrolyte
- 2.5-3 V/cell
- Energy density 3-5 Wh/kg
- Power density 1.5-2 kW/kg, 95% efficiency

Applications studied

- Mild hybrids (42V)
- Power assist hybrids (200V)

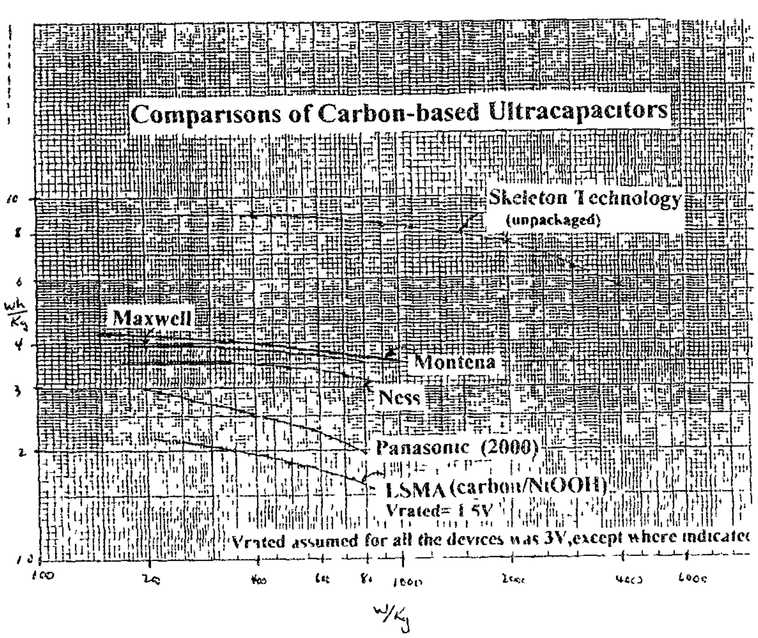
Summary of the characteristics of advanced prototype and commercially available carbon-based ultracapacitors

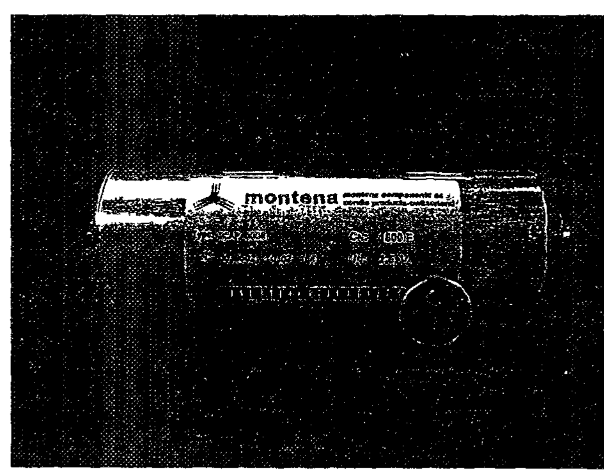
Device	V	C (F)	R (mOhm)	RC (sec)	Wh/kg (1)	W/kg (95%) (2)	W/kg Match Imped	Wgt (kg)	Vol lit
Skeleton Techn R4*	3	47	5 2	24	10 0	9735	>80K	005	003
Maxwell	3	2700	5	1 35	4 8	723	6428	70	62
Ness	3	2650	25	65	5 1	1558	13850	65	534
Panasonic	3	1200	1 0	1 2	4 2	744	6618	34	245
Montena	3	1800	1 0	1 8	5 6	632	5625	40	.30

*unpackaged

(1) Energy density based on E=1/2CV2, Vrated=3V

(2) Power based on P=9/16*(1-EF)*V2/R, EF=efficiency of discharge, V-3V





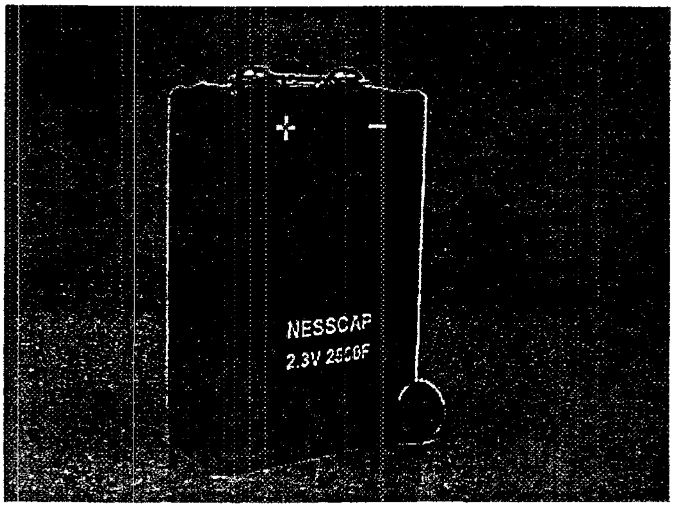
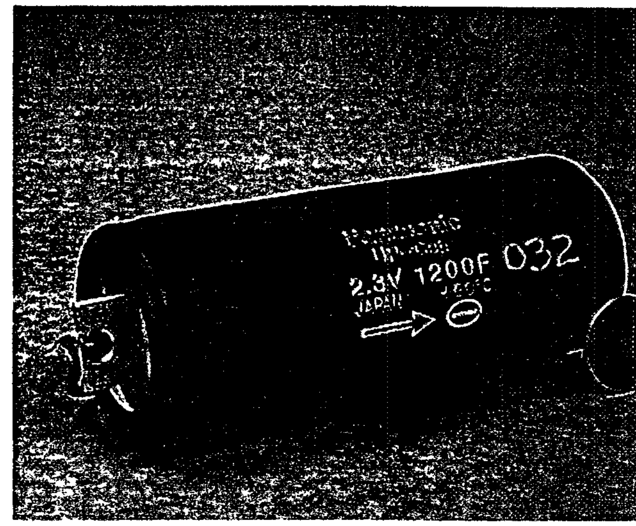


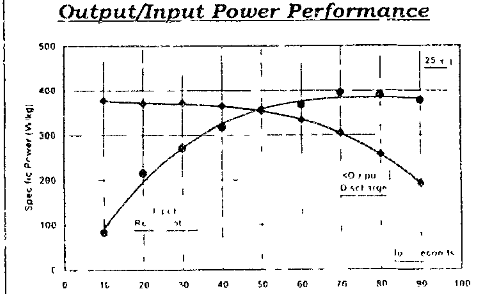
Figure 3 Photograph of the Ness 2 3V, 2500F Capacitor

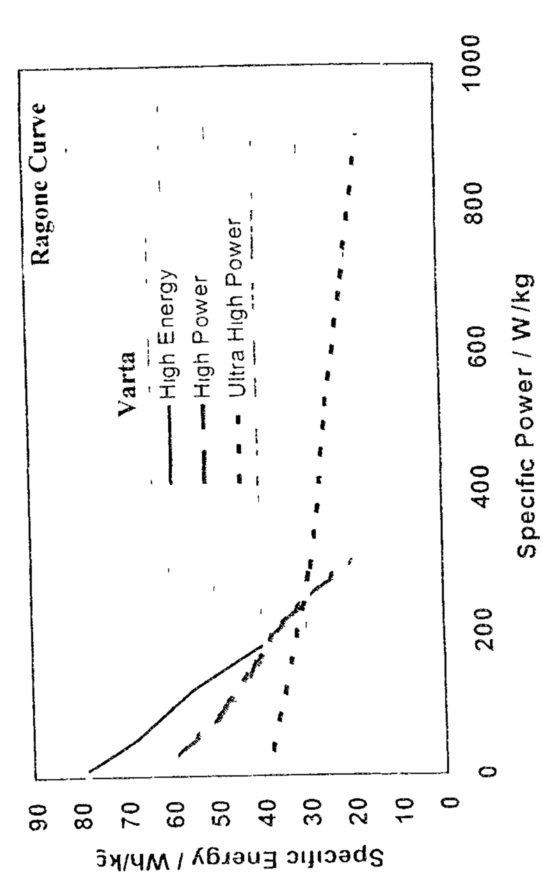


Principal Specification / EC-HV1225

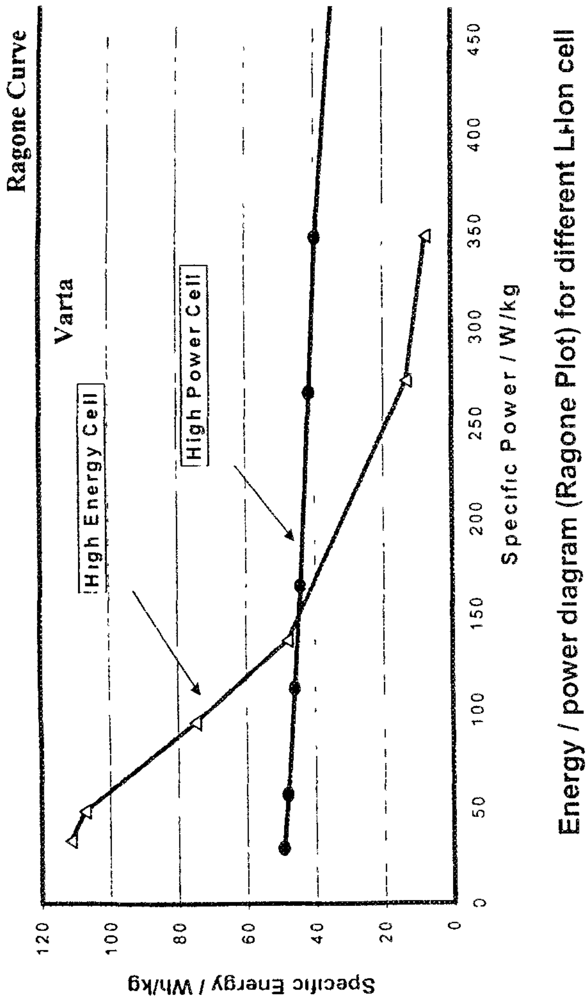
Dimensions	Height	175 mm
	Width	116 mm
	Length	200 mm
Weight		11 4 kg
Nominal Voltage		12 V
Nominal Capacity	3HR	25 Ah
Specific Power (25 C)	DOD50%	360 W/kg

Panasonic





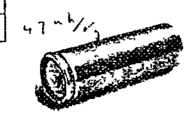
Energy / Power Plot for NiMH cells with different design



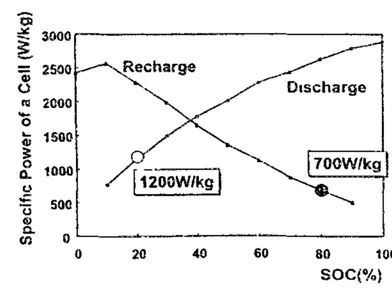
Shin-Kobe

Manganese based Li-ion Cell for HEV

Cathode Material	$LiMn_2O_4$
Capacity (Ah)	3 6
Size (mm)	40 x 108
Voltage (V)	2 5 – 4 1
Weight (kg)	0 3



Power Characteristics of a Cell for HEV



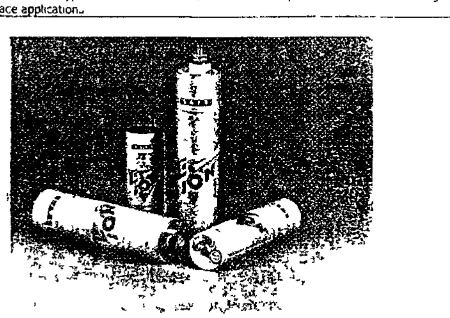
Saft

Table 1 Automotive Lion Cell Characteristics

Cell Type	Diameter (mm)	Length (mm)	Mass (kg)	Max Operating Voltage (V)	C/3 Capacity @Max Voltage (Ah)	Total Energy @ C/3 (Wh/kg)	Total Energy @ C/3 (Wh/l)	Max Power (W/kg) Pulse [1]	Continuous [2]
HE40	54	220	1 05	4 0	41 0	140	290	420	288
MR35	54	220	1 05	4 0	39 0	135	280	880	415
MR26	54	160	0 75	4 0	25 0	115	245	830	385
HP30	54	208	1 05	3 9	31 0	106	234	1190	800
HP12	47	178	0 68	3 9	16 0	85	187	1430	850
HP6	47	104	0 38	3 9	8 00	75	158	1420	760

The maximum voltage of high energy and medium range cells is specified at 4 0V while it is only 3 9V for high power cells Lower voltage (3 9V) results in lower energy (about 15%) but may be needed for HEV due to regenerative spike The HP cells can run at 4 0V under application without regenerative spike

Note 1 Derived power under 18 second pulse @ 50% DOD and 2 7V cut-off
Note 2 Maximum continuous current multiplied by average voltage
Note 3 Saft manufactures other types of lithium ion cells such as medium prismatic D format and high energy for space application.



Configuration of Saft HP LiON Cells

Saft

Power Capability (HEV applications)

Temp	Voc V	% SOC	Discharge Power R 2 Sec mΩ	P Max 2 Sec W/kg	R 18 Sec mΩ	P Max 18 Sec W/kg	Charge Power R 2 Sec mΩ	P Max 2 Sec W/kg
40°C	3 74	70%	1 48	2790	2 13	1938	1 25	1227
	3 64	50%	1 48	2600	2 08	1794	1 46	1450
	3 54	30%	1 55	2150	2 19	1522	1 51	1791
25°C	3 74	70%	1 76	2346	2 57	1606	1 71	894
	3 64	50%	1 74	2145	2 57	1452	1 71	1238
	3 54	30%	1 95	1710	2 94	1134	1 86	1454
0°C	3 74	70%	3 75	1101	5 05	817	3 98	384
	3 64	50%	3 67	1014	5 06	737	3 83	553
	3 54	30%	4 80	694	8 0	416	4 80	563

Note 1 Data from HP12 cell sample (0 68 kg) Not a specification
Note 2 Maximum power calculated as follows
Discharge Pmax = Vmin x Imax with Imax = (Vocv-Vmin)/R
Charge Pmax = Vmax x Imax with Imax = (Vmax Vocv)/R
Vmax = 4 0V and Vmin= 2 7V
Note 3 Short regen spike could reach 4 05V resulting in power acceptance increase of more than 10% at high state of charge
Note 4 Lower cut off voltage (below 2 7V) especially at low temperatures is possible results in higher discharge power

Ultracapacitor Unit Characteristics

200V

100 Wh (useable)

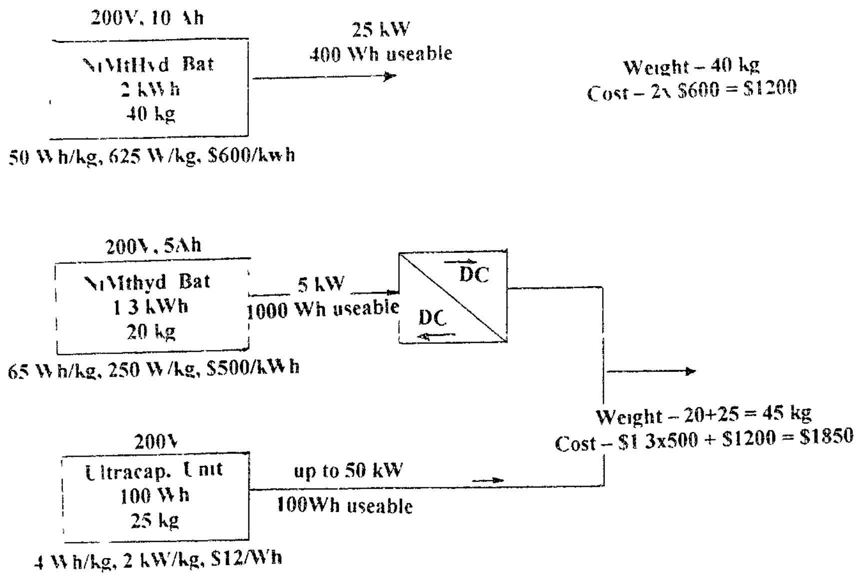
25 kg (4 Wh/kg useable)

up to 50 kW (2kW/kg, 90% charge/discharge

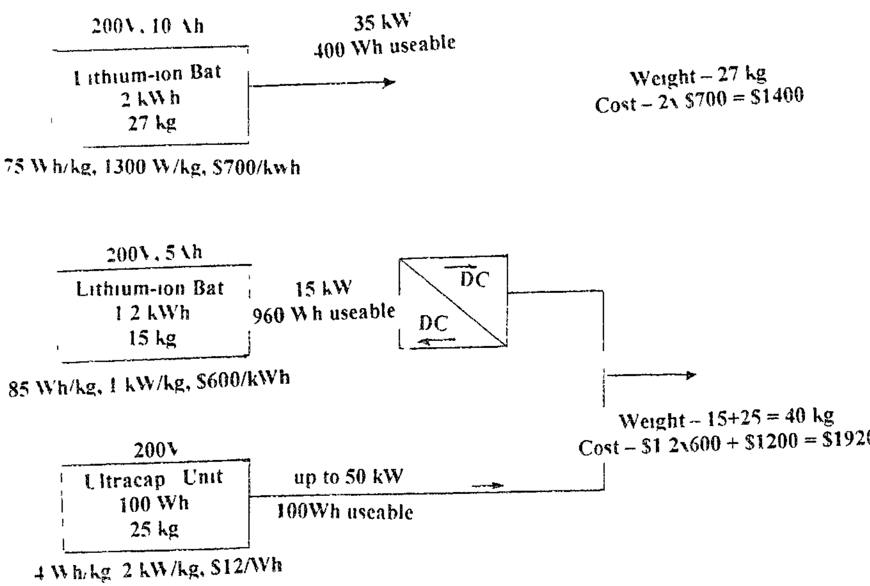
$12/Wh or $1200/unit
(equivalent to $30 for a 2500F cell)

5-10 year cycle and shelf life

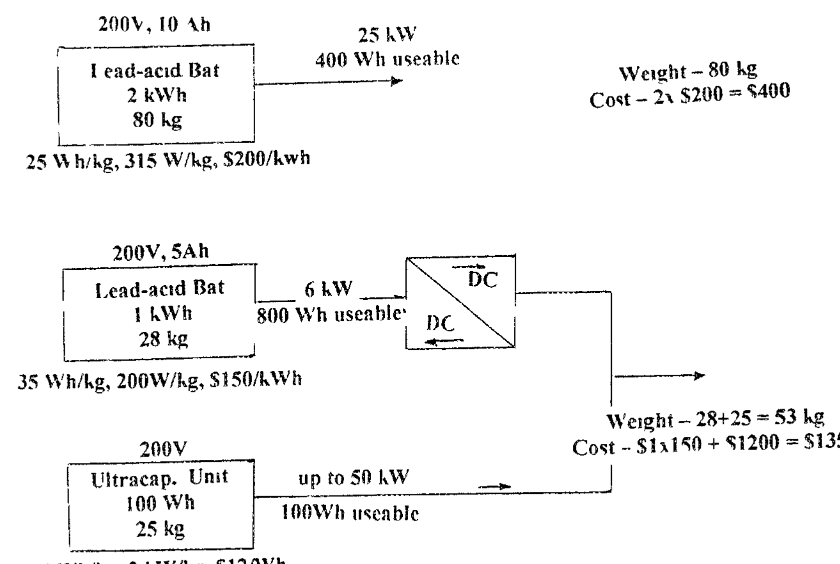
Ultracapacitor - Nickel Metal Hydride Battery



Ultracapacitor - Lithium-ion Battery



Ultracapacitor – Lead-acid Battery



Summary of the Characteristics of Various Batteries with Ultracapacitors

Battery Type	Weight (kg)	Useable Energy (Wh)	Max. power (kW)	Cost ($)
Lead-acid w/o caps	80	400	25	400
Lead-acid with caps	53	800	50	1350
Nickel metal hydride w/o caps	40	400	25	1200
Nickel metal hydride with caps	45	1000	50	1850
Lithium-ion w/o caps	27	400	35	1400
Lithium-ion with caps	40	960	50	1920

Conclusions

- All the battery/ultracapacitor systems are heavier and more expensive than those with the battery alone
- All the battery/ultracapacitor systems are higher power and have more useable energy than those with the battery alone
- The use of capacitors with batteries permits the batteries to be used over their complete SOC
- The use of capacitors results in the same power for vehicle acceleration and braking independent of battery SOC
- Lead-acid batteries benefit most of the use of ultracapacitors and lithium-ion the least
- The lead-acid battery/ultracapacitor combination is particularly attractive in terms of performance and cost
- The use of capacitors should significantly improve the cycle life of lead-acid batteries in charge sustaining hybrids, but the effect on the cycle life of the other types of batteries is not known

Hybrid Electric Vehicle Commercialization, Market Potential, Customer Preferences

May 15, 2001

Dean Taylor
Southern California Edison

Hybrid Electric Vehicle Commercialization, Market Potential, Customer Preferences

HEVWG Study Draft Final Results

May 15 2001
Dean Taylor
Southern California Edison

Several Different Names for HEVs With or Without Plug-In Capability

HEV 0	HEV 20 and HEV 60
Non-grid-connected HEV	Plug-in or grid-connected HEV
Gasoline-only HEV or Fuel-only HEV	Dual Fuel HEV (e.g EV mode for shorter trips and gasoline HEV mode for longer trips)
Power Assist HEV Mild HEV	Extended ZEV Range HEV [b]
Engine Dominant HEV	Battery Dominant HEV
Charge Sustaining HEV	Charge Depleting HEV

The difference between a power assist HEV and a mild HEV is a matter of degree rather than principle with the power assist hybrid having a somewhat larger electric motor and battery For example a mild hybrid's engine may need to turn on at about 1 mph for adequate acceleration while the power assist HEV's engine might need to turn on only at 10 mph The power assist hybrid uses the motor and battery more extensively than the mild HEV for acceleration passing and capture of braking energy
As long as the battery has sufficient charge the Plug-in HEVs operate in EV mode with no engine However when the battery's state of charge is low (e g approximately 20% plug-in HEVs operate like a power assist HEV 0 Other plug-in HEV control strategies are possible to accommodate the goals of the vehicle designer or needs of the driver a number of these strategies are strategies discussed in Section 4 4
A plug-in HEV is sometimes called a battery dominant or charge depleting HEV because the vehicle control strategy software gives first choice to depleting energy from the battery until the battery is low (e g about 20% SOC) At this low SOC the engine is allowed to sustain the battery charge at that level but not charge the battery further so that the use of electricity as a source of propulsion energy is maximized This control approach encourages the user to charge the battery fully each evening in order to realize the environmental energy cost, and energy security benefits of electricity from off-board sources

Overview of Customer Preference Study

- Two teams of the WG worked with ADA to design the format questions, and education slides of the study
  - Customer Preference team (included two automakers)
  - Modeling team (included one automaker UCD NREL ADA others
- 8 Focus Groups
- 1 Pilot Interview

400 + Quantitative interviews
  - 9 independent attributes tested first in trade-off questions
  - Then linked to describe HEV 0 HEV 20 and HEV 60 in full profile trade off questions
  - About 100 direct assessment questions tested other benefits demographics attitudes etc

Customer Based Market Model

Nine Attributes for CBMM

- Vehicle price
- Fuel cost savings
- Trips to the gas station
- Environmental benefits
- Maintenance costs
- Battery life and replacement costs
- Electrical system (infrastructure) upgrade costs
- Government incentives
- Special features/options such as a 110/120-volt outlet to run various "appliances", and pre-heat/pre-cool capability (available with engine on or off)

Examples of Trade-Off and Direct Assessment Questions

Trade off question example
If you had to replace your current Ford Taurus which would you prefer?

Fuel costs $60 per month (25% less than current costs)	Fuel costs $8 per month (90% less than current costs)
Costs $600 per month for 36 months with $3000 down (Total $23 000)	Costs $650 per month for 36 months with $3000 down (Total $24,700)

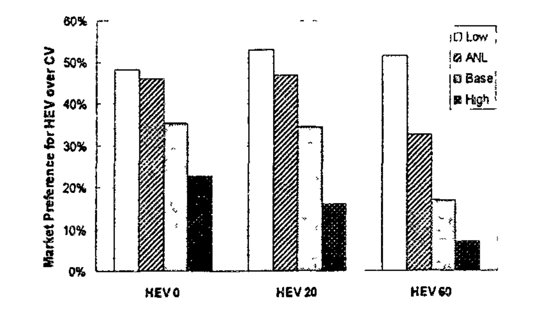
Demographics and direct assessments provide context for the preference results (attitudes sex income education etc) and can also be useful in their own right For example, respondents were asked directly which factors would be most influential in the purchase decision These questions also provided the input to compute the fuel usage trips to the gas station preferred way of purchasing (cash lease etc) and other custom inputs for each respondent

Focus Groups and Quantitative Study Assumptions

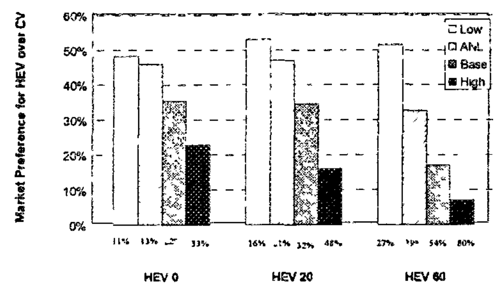
- HEVs have been available in the market for about 10 years
- The technology is safe and reliable
- Skilled mechanics are available
- Performance, interior roominess convenience / comfort features, and resale value is comparable to the equivalent conventional vehicles
- HEVs are produced by many manufacturers in a wide range of styles such that any model can be purchased as an HEV
- Information about HEVs is widely available from the Internet magazines, automakers government, consumer groups and other sources
- The intent was to focus respondents on their preferences with respect to their choice of well-established power train (conventional or several hybrid) options, not on any other differences in the vehicle itself

Market Preference Versus Vehicle Price for Mid- size HEVs

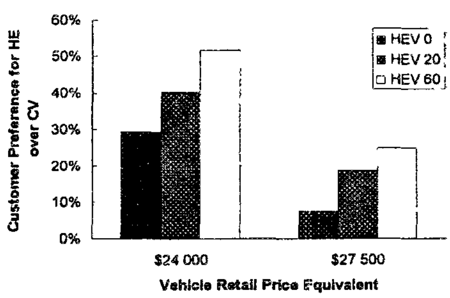
Scenario 1 – Simple Market (HEV 0 vs CV HEV 20 vs CV HEV 60 vs CV)



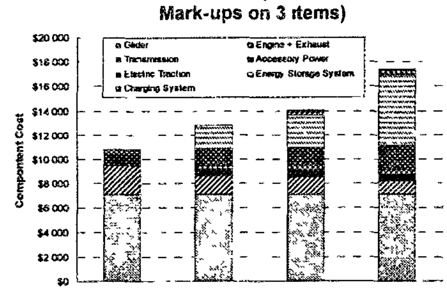
Market Preference Versus Vehicle Price for Mid-size HEVs



HEV Market Potential at Constant Price



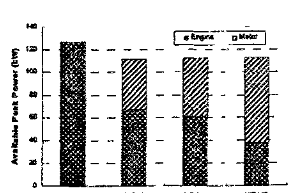
Mid-size Car Component Based Case Costs (Without Mark-ups) or ANL Costs (With Partial Mark-ups on 3 items)



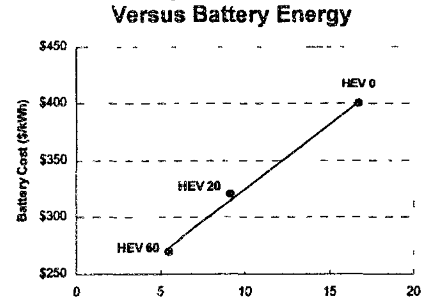
Draft Final

Mid-size Car Specifications

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	6.9	17.9
Batteries	Rated power	kW	—	45	54	90



NiMH Battery Module Costs to OEM Versus Battery Energy

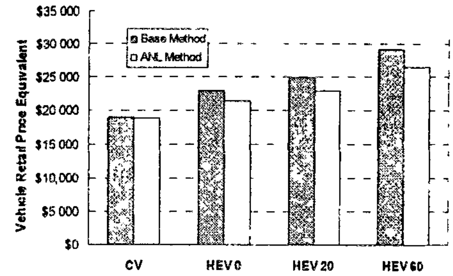


Summary of the Base and ANL Methods

Item	Base Method	ANL Method
Component Costs	Assumes all costs are manufacturer costs for labor and materials	Same cost as Base Method, except it assumes that motor controller and batteries already have a partial mark-up from supplier
Manufacturer Mark-up	All component costs except battery modules are marked-up at 1 5 times component cost	All components manufactured by the vehicle manufacturer are marked-up at 2 times component costs those purchased from an outside vendor are marked-up at 1 5 times component costs
Battery Module Mark-up	Battery module mark-ups are fixed at $800 for the HEV 0 battery $850 for the HEV 20 battery and $900 for the HEV 60 battery	Same as Base Method
Dealer Mark up	All components carry an additional mark up of 16 3% of manufacturer marked up prices	Included in manufacturer mark up
Development costs	Development costs for 2010 component technology (amortized over years of production) are added at $94 per vehicle for the CV $440 for the HEV 0 and $484 for the HEV 20 and HEV 60	Included in manufacturer mark-up

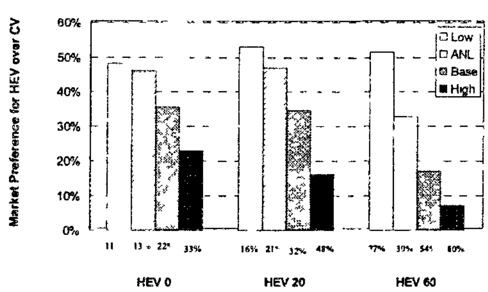
Vehicle Fully Loaded Cost Estimates for the Mid-size Car

Draft Final



Vehicle RPE for the HEV 0 is from $2 500 to $4 000 higher the HEV 20 from $4 000 to $6 000 and the HEV 60 from $7 400 to $10 000 than the comparable CV

Market Preference Versus Vehicle Price for Mid- size HEVs



Low Price Scenario

Draft Final

"Significant uncertainty exists regarding HEV retail price Every OEM prices products differently For example, HEV 0 vehicles are in the early commercialization stage because of the willingness of major automobile manufacturers to subsidize this promising new automotive product While new technology will cost more to produce, final retail pricing will be a function of competition government incentives, cost market demand, benefits of ZEV and CAFE compliance, battery leasing, and other factors the WG did not know how to quantify"

Desire to capture new markets (such as fleets or young buyers) and desire to improve the corporate image (technological or environmental) are examples of how competition result in cross product line subsidies

Federal Incentives and Tax Credits Applicable to HEVs

Policy	HEV 0	HEV 20	HEV 60	Selection Criteria
Federal Tax Credit	Likely $0	Eligibility unclear	10% of purchase price up to $4 000	"primarily powered by an electric motor"
Federal Tax Deduction ᵃ	Likely $0	Up to $2,000	Up to $2,000	Strong case under dual fuel vehicle definition
Federal Tax Deduction for Infrastructure ᵇ	Not eligible	EV chargers eligible	EV chargers eligible	For businesses only
Federal requirement for federal state and alternative fuel provider fleets to purchase AF vehicles	Likely $0	Eligibility unclear	Eligibility unclear	Strong case under dual fuel vehicle definition
Fuel economy fleet standards on automakers (CAFE)	No bonus	Eligible for 2 bonuses	Eligible for 2 bonuses	Dual fuel bonus and PEF bonus

Can claim either tax credit or deduction Both are expiring at end of 2004
$100 000 per location for EV and AFV infrastructure expires end of 2004
Dual fuel bonus factor and petroleum equivalent bonus factor

Draft Final

Tax Credits and Other Incentives Conclusions

Draft Final

Tax credits and other incentives could offset much of the purchase and life cycle cost difference between HEVs (especially plugin HEVs) and conventional vehicles that remain after allowing for the lower energy and maintenance costs of HEVs However, the applicability of most of the existing incentives to the different HEV types is not clear, but should be made clear Generally there appears to be justification for larger incentives going to those HEV types that have greater all electric range because of the larger environmental and energy security benefits associated with all electric vehicle operation

HEV Reductions in Smog-Forming Gases CO2, Energy Use and Petroleum Consumption

- "While desirable reductions of about 15% in smog-forming gases and 25% in CO_2 emissions, energy use and petroleum consumption can be expected for a properly designed HEV 0 a 50% reduction in smog precursors CO_2 and energy use as well as a 75% reduction in petroleum consumption, is predicted for the HEV 60 This is compared to a CV meeting the very clean SULEV emissions standard Specifically ADVISOR simulations show that the petroleum consumption of an HEV 60 (using gasoline/electricity) can be less than that of the PNGV diesel engine-battery HEV 0 concept vehicles and attain the equivalent of 80 mpg without resorting to costly light-weight construction or body aerodynamics "

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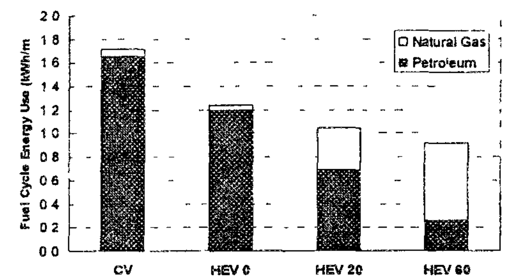
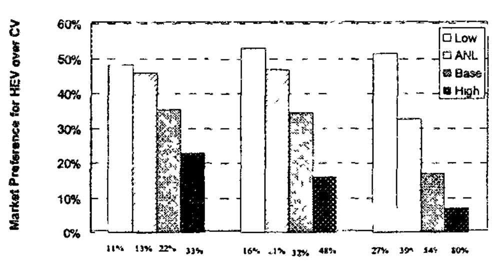
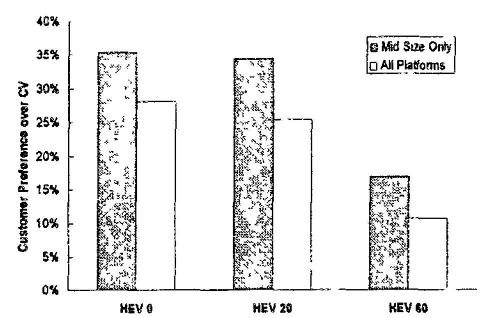
HEV Energy and Petroleum Use Reductions



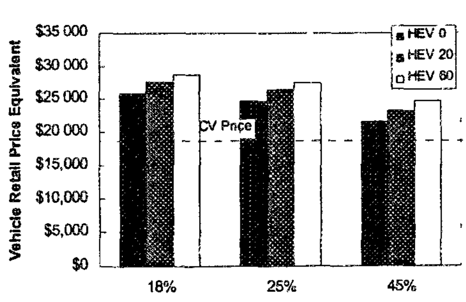
Market Preference Versus Vehicle Price for Mid- size HEVs



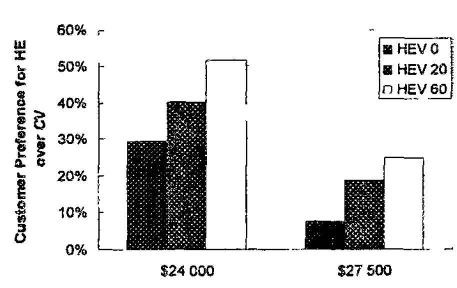
Scenario 1 Base Case Results for Mid-size and All Respondents



Constant Market Potential Versus HEV Price



HEV Market Potential at Constant Price

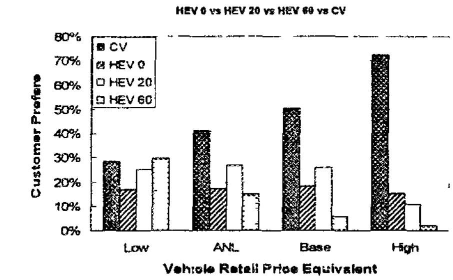


CBM Model Constructed to Be Extremely Flexible

- Market preferences can be predicted for any vehicle described by the attributes
  Market preferences can be roughly estimated for other HEVs with similar prices and attributes -e g hybrid pick-up trucks
- The model can be re-run with a different base case vehicle and new sensitivities
- The model can also estimate complex markets where more than one HEV is offered by OEMs in a market segment Base case was also ran to show this (HEV 0 vs HEV 20 vs HEV 60 vs CV) But it is a very aggressive case for 2010 and more likely for 2015 or later

Preference for HEVs When Choosing 1 Vehicle from all Configurations (2015 Possible Scenario)

HEV 0 vs HEV 20 vs HEV 60 vs CV

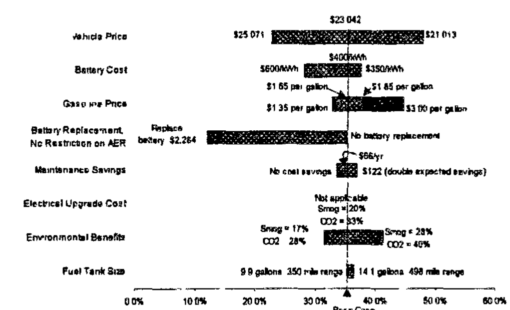


Note each group of four bars adds up to 100%

Detail on Linked Assumptions and Attributes

Vehicle Configuration	CV	HEV 0	HEV 20	HEV 60
Price	$18 984	$23 042	$24 968	$29 053
City/Hwy Charge Sustaining Fuel Economy (mpg)*	20 9/32 3	38 5/32 3	41 7/41 0	38 2/36 8
City/Hwy Electric Fuel Economy (kWh/mi)	–	–	0 30/0 34	0.31/0 35
Gasoline Tank Size (gal) to go 350 miles CS	14 1	9 89	8 38	9 11
Fuel Price ($/gal) Electricity price ($/kWh)	1 65	1 65	1 65(06)	1 65 (06)
Maximum all electric miles out of 100 000 total miles	–	–	31 210	63 224
Battery Price	$0	$2,284	$3 147	$6 879
Replace Battery	No	No	No	No
Gasoline/Electric Combined Maintenance Cost ($/mile)	0 0331	0 0307	0 0307	0 0307
% Smog Reduction beyond SULEV	0%	20%	30%	52%
% CO_2 reduction beyond base	0%	33%	42%	54%
Electrical Upgrade Cost	$0	$0	$0	$200
Extra Features with Engine Off	No	No	Yes	Yes
Extra Features with Engine off	Yes	Yes	Yes	Yes
Charging Every Day	NA	NA	Yes	Yes
Carpool Lane Access	No	No	No	No

Sensitivities : Market Potential for HEV 0 versus Conventional Vehicle



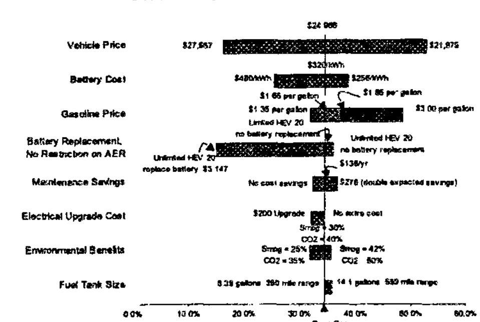
Note bars can not be added

HEV Market Sensitivities for Fuel Price and Battery Replacement

- Fuel price also had a significant effect on market potential If gasoline prices rose from $1 65 per gallon (baseline assumption) to $3 00 per gallon (an 82% increase), market potential for an HEV 0 would increase about 30%, an HEV 20 would increase about 35%, and an HEV 60 would increase about 65%
- On the other side if batteries need to be replaced at 5 years or 50 000 miles, market potential for the HEV 0 is reduced by about two-thirds and the HEV 20 and HEV 60 by about half Battery replacements at 80,000 miles or 120 000 miles were not tested and should not be inferred

Draft Final

Sensitivities : Market Potential for HEV 20 versus Conventional Vehicle



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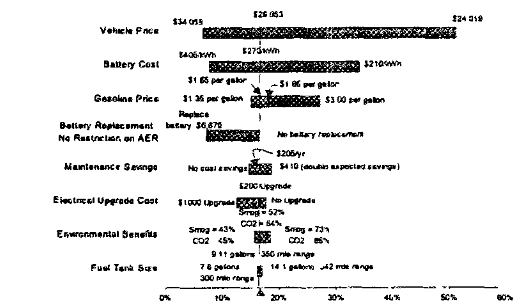
Key Assumption Plug in Each Night

Sensitivities Market Potential for HEV 60 versus Conventional Vehicle



Key Assumption Plug in Each Night

Note bars can not be added

Other Sensitivities

Extra Features Option (Pre heat / Pre-cool for $300 and 120 V outlet for recreational work or home appliances for $300

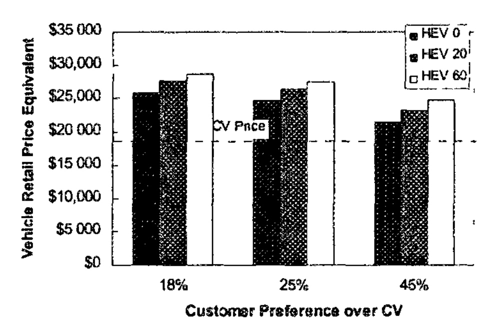
- For the HEV 20 and HEV 60 that can use these features with the engine off (using battery power alone) 41% would choose both an additional 26% would select one feature and 33% would select none
- For the CV and HEV 0 which use these features with the engine on 83% would select no features 16% would select one feature and 1% would choose both features

If electricity prices rose 66% to 10 cents per kWh the HEV 60 fuel cost savings would decrease by $182 per year This is equivalent to a gasoline price of $1 40 per gallon which has little impact on market potential A similar example for the HEV 20 is equivalent to a gasoline price of $1 61 per gallon Because of the high efficiency of HEVs even expensive electricity is expected to have only a small impact on market potential (in the above example)

If seven incentives (e g carpool lane access and free or reserved parking) are available the HEV 20 market potential would increase from 35% to 50% and the HEV 60 would increase from 17% to 30%

Draft Final

Constant Market Potential Versus HEV Price



Why Pay More for HEVs? Ranking of HEV Benefits

HEV Benefit	(7 9 Rank)	Av Score
Fuel cost savings	89%	8 6 ± 3
Reducing maintenance (cost and personal time)	87%	7 8 ± 3
50% longer range *	83%	7 7 ± 3
Leaving every morning with a fully-charged battery	73%	7 2 ± 4
Better handling balanced weight distribution	71%	7 1 ± 4
Reducing air pollution and global warming gases	68%	7 1 ± 4
Better handling lower center of gravity	66%	6 8 ± 4
Quietness (at stops and acceleration)	61%	6 7 ± 4
Reducing dependence of foreign oil	60%	6 5 ± 5
Less vibration and fatigue (at stops and acceleration)	60%	6 6 ± 4
Improved 0-30 and 0-60 mph acceleration	55%	6 8 ± 4
Pre-heat / pre-cool with the engine off	52%	6 3 ± 5
Using 110/120V plug to run electric items with engine off	41%	5 8 ± 5
Avoiding exposure to fumes/spills at gas stations	35%	5 [illegible] ± 5
Attention / pioneer image	33%	5 1 ± 5
Avoiding personal security issues at gas stations	32%	4 4 ± 6

* A 50% longer range was not a design feature of the HEVs in the study but can be accomplished by a larger capacity battery or fuel tank

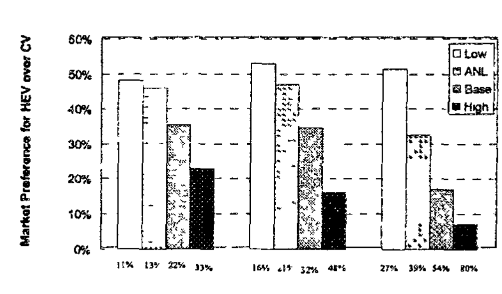
Plugging In Versus Going to the Gas Station

Participants were asked about their preferences for vehicle options on the basis of plugging in versus going to the gas station on a ranking scale of 1 – 9 where 1 = strongly prefer to fuel my vehicle with gas at the gas station and 9 = strongly prefer to fuel my vehicle by plugging it in at home

Ranking	Results
Average with confidence interval	6 9 ± 35
1-3 Ranking	1 1%
4-6 Ranking	35 9%
7-9 Ranking	63 0%

More sophisticated CBMM results for willingness to purchase an HEV 20 and HEV 60 (based on plugging them in each night) show market potential that is generally lower because it factors in vehicle price and cost to upgrade electrical systems

Market Preference Versus Vehicle Price for Mid- size HEVs



Draft Final Conclusions

1 HEV 0 technology is in the early commercial stage Relative to mature combustion engines and state-of-the-art EV technology HEV technology requires only evolutionary advances to meet technical requirements with the possible exception of batteries NiMH batteries are technologically capable but there are uncertainties regarding their life and costs, especially in plugn HEV service

2 All HEVs will cost more to produce than their CV equivalent Estimated increases in the retail price equivalent (RPE) are from $2 500 to $4 000 for an HEV 0 from $4000 to $6000 for an HEV 20, and from $7400 to $10 000 for an HEV 60 Battery costs are the primary reason for this incremental cost

3 Total energy (motor fuel and electricity) and maintenance costs of plug-in HEVs will be less than that for CVs partially offsetting the impact of battery costs Incentives to buyers of HEVs could prowde additional cost offsets but more analysis is necessary to confidently quantify and compare life cycle costs

Draft Final Conclusions (continued)

- 4 The Customer Preference study indicates definite market potential for all HEVs That potential is large if cost equivalence with conventional vehicles can be achieved but even at higher costthere is likely to be significant market potential

  5 People are willing to pay more for an HEV 60 than an HEV 20more for an HEV 20 than an HEV 0, and more for an HEV 0 than a CV its not clear why so many people prefer midsize HEVs over their CV counterparts However ten HEV benefits have a high to strong influence on the purchase decision for most consumers especiallyfor those who prefer HEVs This infers a broad package of benefitsould be marketed

  6 The majority of the people surveyed preferred plugging in a vehicle to fueling at the gas station

Draft Final Conclusions (continued)

7 There are some issues that have been identified that need to be examined for successful commercialization including battery cost and packaging Real world testing must be done regarding life Battery costs while difficult to estimate, appear to be attainable based on what we know today

8 HEV 0 vehicles are in the early commercialization stage because of the willingness of major automobile manufacturers to subsidize this promising new automotive product However there is an unclear commercialization path for plug-in hybrid electric vehicles despite their substantial societal benefits because, in particular, there are no corresponding automakers initiatives presumably because of battery cost and battery replacement concerns However HEV 0s could be a stepping stone to plug-in hybrids

9 The incremental costs for all HEVs are very significant in low and medium volume production (higher than the numbers in this report) Yet there are also very large societal benefits if HEVs are commercialized And the infrastructure issues for HEVs are few compared with alternative fuel vehicles (Even for plug-in HEVs the survey found 86% had relatively easy overnight access to a plug with 120 V systems being relatively hassle free)

Part 2: City and Neighborhood EVs

May 16, 2001

Craig Childers
California Air Resources Board

Meeting the CARB ZEV Requirements·
Grid-Connected HEVs and City EVs

Part II: City and Neighborhood EVs

Craig M [illegible]lders
California Air Re[illegible] Board
May 15-16, [illegible]

California Environmental Prote[illegible]
Air Resources [illegible]

Outline

- BEV Challenges
- Emerging Small BEV Classes
- City EVs (CEVs)
- Neighborhood EVs (NEVs)
- Enclosed ZEMs
- ZEV Credits for Small BEVs
  - NEV Credit
  - CEV Credit

Challenges for BEVs

- Near-term costs are higher than CV
- Establish appropriate incent[illegible]
- Develop necessary infrastruct[illegible]
- Increase public awareness
  - BEV VS HEV

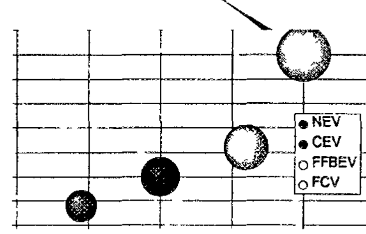
Cost Reduction

- Volume production
  - Vehicle, or
  - Componentry
    - shared components
- Additional battery developments
- Mission-specific BEVs
  - Neighborhood EVs
  - City EVs
- Niche Applications- Shared platforms
  - Postal Delivery Trucks, etc

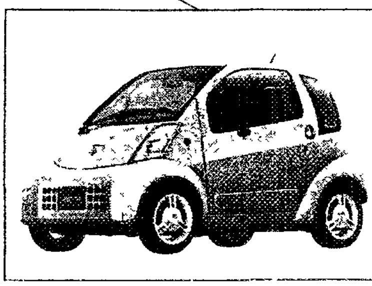
Emerging Small BEV Classes

- City EVs (CEVs)
- Neighborhood EVs (NEVs)
- Zero emission motorcycles
  (including enclosed 3-wheel motorcycles)
- e-bikes, scooters, etc

Range-Speed Graph

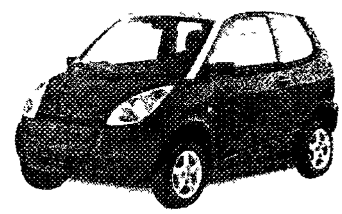


Examples of City EVs



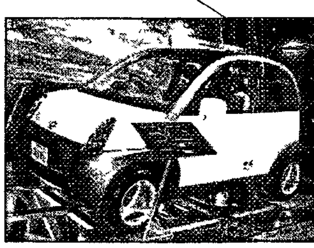
- Nissan Hypermini

Examples of City EVs



- Ford Think City

Examples of City EVs

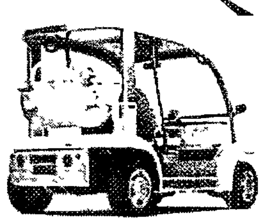


- Honda CityPal

Examples of City EVs

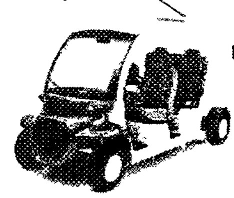
- Toyota e com

Examples of NEVs



- Ford Think Neighbor

Examples of NEVs

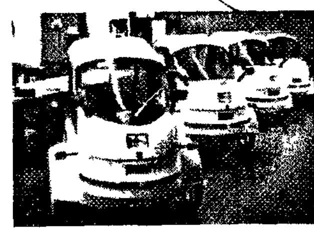


- DC GEM

Examples of NEVs

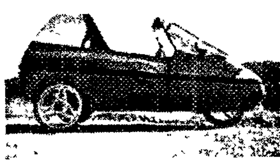
- Dynasty "IT"

Examples of ZEMs



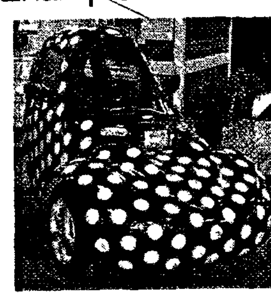
- Gizmo

Examples of ZEMs



- CityEl

Examples of ZEMs



- Corbin Sparrow

Neighborhood EVs (NEVs)

- **USDOT established new Low Speed Vehicle (LSV) category in 1998**
- **LSV created due to increasing c[illegible]ts between state and federal law**
- **Rulemaking initiated in response to Bombardier, Inc. in 1996**

Neighborhood EVs (NEVs)

- **DOT considered 3 options:**
  - Raise motor vehicle threshold to >=[illegible]mph
    - Bombardier original request
  - No change
  - Create new LSV category
    - LSVs in-between Passenger Car and Gol[illegible] Carts
- **Further DOT information on LSV development:**
  http /www nhtsa dot gov/cars/rules/rulings/lsv/lsv html

Neighborhood EVs (NEVs)

US DOT Low Speed Vehicle definition:

- 4-wheel motor vehicle
- Minimum 20 mph
  - Attainable in 1 mile
  - 20 mph selected as "dividing line"
- Maximum 25 mph
- No powerplant definition, so
  - NEVs = LSVs that are zero emission
  - LSVs= Any vehicle meeting DOT regulation

Neighborhood EVs (NEVs)

California Vehicle Code Definition

- 4-wheel
- Min 20 mph Max 25 mph
- <1800 lbs unladen weight

- Vehicle disclosure to purchaser
- Modifications prohibition
- Not allowed on roads posted >35 mph
- Local restrictions

NEV Treatment in ZEV Regulation

- Original 1990 ARB ZEV Regulation
  - NEVs not yet proposed or considered
- 1998
  - NEVs now part of newly expanded definition of "passenger vehicle" that included LSVs
  - Would become eligible for full ZEV credit
- Revised ZEV Regulation (January 2001)
  - NEVs treated separately (credit discounted)

Neighborhood EVs (NEVs)

CA ZEV Credit Earned by NEVs:

	'00	'01	'02	'03	'04	[illegible]	'06
Early Intro Multiplier	4	4	4	1 25	1 25	[illegible]	[illegible]
NEV discount	1	1	1	1	5	5	[illegible]
Resulting NEV Credit	4	4	4	1 25	625	62[illegible]	[illegible]

ARB-Certified NEVs

- Bombardier NV (1998, 1999, 2000)
- GEM (DC) (1999, 2000)
- Dynasty IT (2001)
- (Ford Think Neighbor)
- (Iacocca?)

City EVs

- No concrete definition of CEV
- Usually 2 seat
- ~60 mph range
- ~60 mph top speed
- Battery capacity ~1/3-1/2 of full function BEV or ~9-15 kwhr

  (NEVs usually carry less, typ 8.6 kwhr)
- Must meet all standards applicable to motor vehicles
  - Will most likely be designed and built by large automakers

City EVs

- Usually intended for city (not freeway) travel
- Usually fit Japanese microcar class limits
  - Length < 3400 mm (some < 2500 mm)
  - Width < 1480 mm

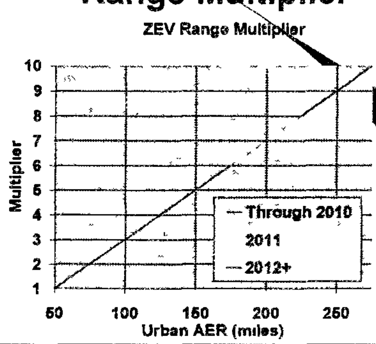
  NOTE some NEVs are larger than City EVs
- Most manufacturers targeting shared or station car applications

ZEV Credit Determination

Initial ZEV Credit =

{1+[(Range Mult -1) x (Range Mult Phase In)]} x
{1+[(Eff Mult -1) x (Eff Mult Phase In)]} x
(Transportation System Mult) x
(Early Intro Mult) x
(NEV/LSV discount)

Range Multiplier



Efficiency Multiplier

VEHICLE CLASS	EFFICIENCY MULTIPLIER
City (EV)	CMPEG/ (1 5 x 45 9)
Subcompact PC	CMPEG/ (1 5 x 28 6)
Compact PC	CMPEG/ (1 5 x 30
Midsize PC	CMPEG/ (1 5 x 27 0)
Large PC	CMPEG/ (1 5 x 25 6)
Small Truck	CMPEG/ (1 5 x 25 0)
Medium Truck	CMPEG/ (1 5 x 21 4)
Large Truck	CMPEG/ (1 5 x 18 2)

2006 ZEV Credit Example: Typ. CityEV

Initial ZEV Credit =

{1+[(1 4 - 1) x (0 60)]} x
{1+ [(1 85 - 1) x (0 35)]} x
(Transportation System Mult) x
(Early Intro Mult) x
(NEV/LSV discount)

=~ <u>1 6</u>

Year 4+ In-Service/ Under-Warranty Credit

=~<u>0 16</u> per year

City EV Proposed changes

- Station car credit multiplier for CEVs
  - Enhances usability of mass transit
  - Freeway capability and long range often unnecessary
  - Amount of additional credit may increase from December proposed revisions (2X)
- New class for eff credit determination

ZEV (Initial) Credit Comparison

	'01	'02	'03	'04	[illegible]	'06	2012
High FFEV Credit	19	19	5 87	5 87	[illegible]	[illegible]	4 25
Typ CEV Credit	5 6	5 6	1 8	1 8	1 8	[illegible]	[illegible]
NEV Credit	4	4	1 25	625	625	[illegible]	[illegible]

NEVs & CEVs

Estimated number of vehicles in 2003:

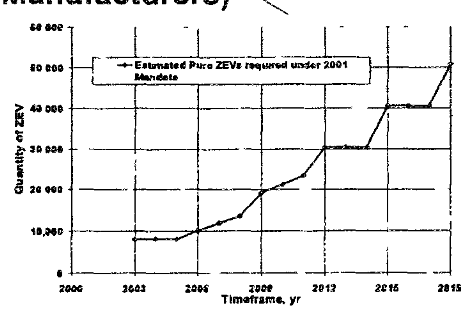
		Without ATPZEV	[illegible]
ZEVs	If 100% Full Function EVs	9,300	[illegible]
	If 100% City EVs	23,500	11,750
	If 100% NEVs	30,900	15,450
PZEVs		94,500	94,500
ATPZEVs		0	10,700

Vision for the Future

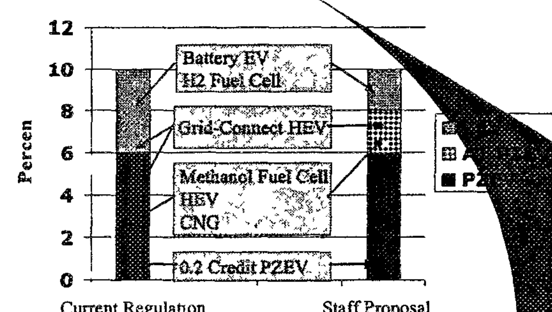
- Clean & healthful air
- Steady, sustainable increase [illegible] ZEVs
- Mission-specific BEVs may pla[illegible]

SPARES

ZEV Obligation (All Manufacturers)



Manufacturer Obligation



EXTRA SLIDES

Provided for Reference

Abbreviations Used

- LSV Low Speed Vehicle
- NEV Neighborhood Electric Vehicle (zero-emission LSV)
- CEV- City Electric Vehicle
- ZEV – Zero Emission Vehicle
- ZEM- Zero Emission Motorcycle
- PZEV – Partial Zero Emission Vehicles
- AT PZEV Advanced Technology Partial Zero Emission Vehicle
- SULEV- Super Ultra Low Emission Vehicle
- VMT – Vehicle Miles Traveled
- G/mile – grams per mile
- BEV – Battery Electric Vehicle
- HEV – Hybrid Electric Vehicle
- GHEV- Grid-connected HEV (same as exten... range HEV)
- AER - all electric r...
- OBD- On Board Diag...
- MIL- Malfunction Indica...
- EFF MULT- Efficiency M...
- DOT Dept. of Transportat...
- CMPEG- California Miles P... Equivalent Gallon
- LEV – Low Emission Vehicle Regulations
- LEV II – 1998 amendments to LEV program

Toyota
EV Commuter (e-com)

May 16, 2001

Dave Hermance
Toyota Technical Center, USA, Inc.

Toyota EV Commuter (e-com)

Toyota Technical Center, USA, Inc

Dave Hermance

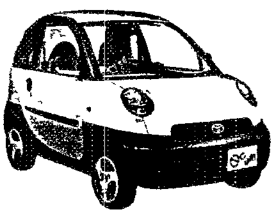
May 16 2001

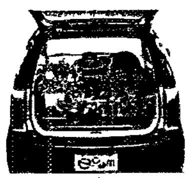
e-com - Features

- 2-door, 2-passenger mini-car
- Local personal transportation concept
- NiMH batteries - ~8 4 kW-hr, 320 pounds
- Regenerative braking
- High efficiency permanent magnet motor
- 60 mph top speed
- 50 mile range (FTP city)

May 16 2001

EV Commuter (e-com)

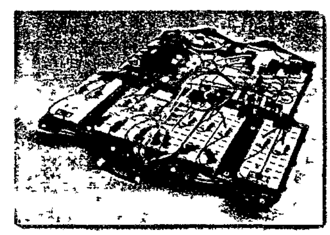




rear view

May 16 2001

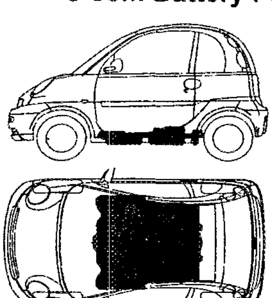
e-com Battery Pack



- 24 12-volt NiMH batteries
- ~8 4 kW-hr capacity

May 16 2001

e-com Battery Pack Location



- Center mounted under vehicle floor pan in a resin carrier
- Maintenance-free
- 1/3 the weight of RAV4-EV battery pack

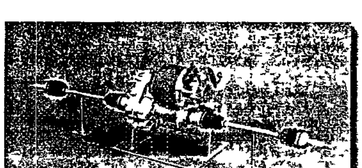
May 16 2001

e-com Placements

- 103 worldwide, 15 in CA
- Demonstrations only
- Japan demos include integrated ITS elements

May 16 2001

e-com Motor



- Front-wheel drive transaxle
- Three-shaft, single-speed reduction gear unit
- Maximum output = 19kw at 2200-3500 rpm

May 16 2001

e-com - Retail Potential

- Limited retail potential due to cost, range, top speed, utility of design
- Not equal to conventional gasoline

May 16 2001

Crayon Project (e-com)

Crayon Project (e-com)

City EV Regulatory Issues

- Credits relative to FFEV
- Cost per credit

May 16 2001

City EV Technical Issues

- FMVSS compliance
- Real-world safety
- Acceleration performance
- Top speed
- Battery choice
- Range
- Recharge time

May 16 2001

City EV Marketing Issues

- Americans don't buy small cars
- Buyer expectations

May 16 2001

What Does the Market Want?

A significant and growing percentage of customers indicate a willingness to buy an environmentally friendly vehicle,

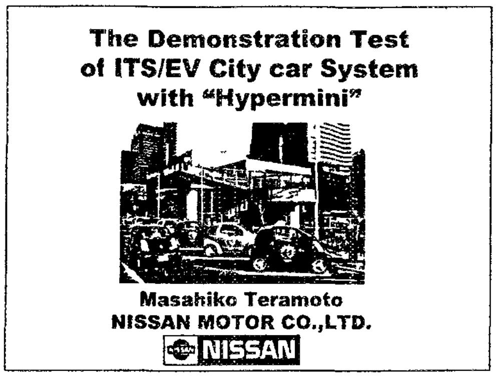
if and only if, all other attributes are equal

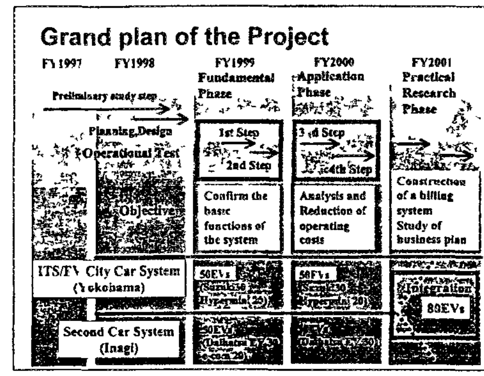
May 16 2001

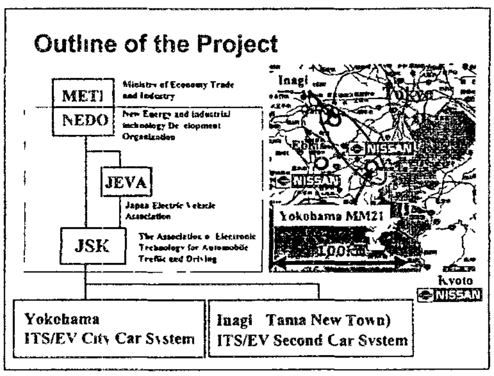
The Demonstration Test of ITS/EV City car System with "Hypermini"

May 16, 2001

Masahiko Teramoto
Nissan Motor Co., Ltd.


The Demonstration Test
of ITS/EV City car System
with "Hypermini"
Masahiko Teramoto
NISSAN MOTOR CO.,LTD.
NISSAN


Grand plan of the Project
FY1997
FY1998
FY1999 Fundamental Phase
FY2000 Application Phase
FY2001 Practical Research Phase
Preliminary study step
Planning,Design
Operational Test
Objectives
1st Step
2nd Step
3rd Step
4th Step
Confirm the basic functions of the system
Analysis and Reduction of operating costs
Construction of a billing system Study of business plan
ITS/EV City Car System (Yokohama)
50EVs
80EVs
Integration
Second Car System (Inagi)


Outline of the Project
METI
Ministry of Economy Trade and Industry
NEDO
New Energy and Industrial technology Development Organization
JEVA
Japan Electric Vehicle Association
JSK
The Association of Electronic Technology for Automobile Traffic and Driving
Inagi
Tokyo
Yokohama MM21
100km
Kyoto
NISSAN
Yokohama
ITS/EV City Car System
Inagi (Tama New Town)
ITS/EV Second Car System

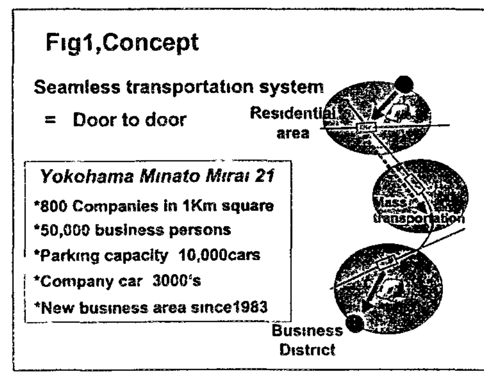


Fig1,Concept
Seamless transportation system
= Door to door
Residential area
Yokohama Minato Mirai 21
*800 Companies in 1Km square
*50,000 business persons
*Parking capacity 10,000cars
*Company car 3000's
*New business area since1983
Mass transportation
Business District

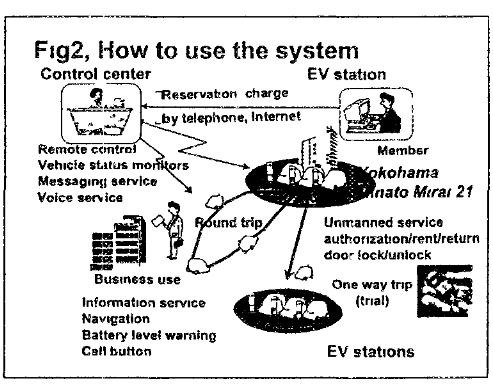


Fig2, How to use the system
Control center
EV station
Reservation charge
by telephone, Internet
Member
Remote control
Vehicle status monitors
Messaging service
Voice service
Yokohama
Minato Mirai 21
Round trip
Unmanned service
authorization/rent/return
door lock/unlock
Business use
One way trip (trial)
Information service
Navigation
Battery level warning
Call button
EV stations

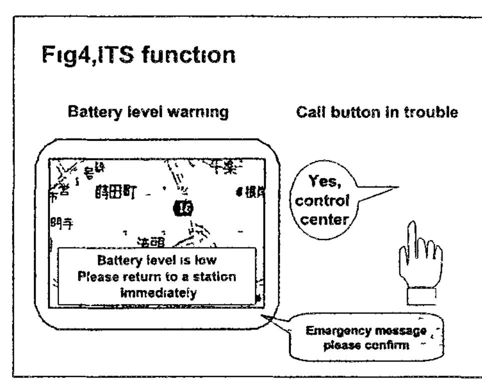


Fig4,ITS function
Battery level warning
Call button in trouble
Battery level is low
Please return to a station
immediately
Yes, control center
Emergency message
please confirm

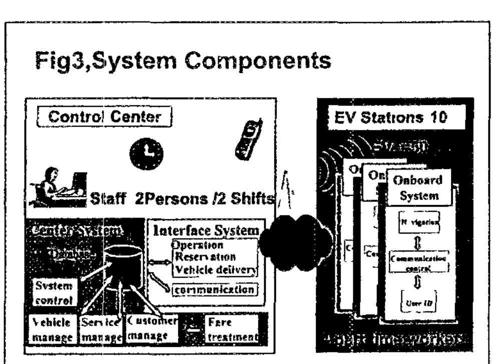


Fig3,System Components
Control Center
Staff 2Persons /2 Shifts
Center System
Interface System
Operation
Reservation
Vehicle delivery
communication
System control
Vehicle manage
Service manage
Customer manage
Fare treatment
EV Stations 10
Onboard System
User ID

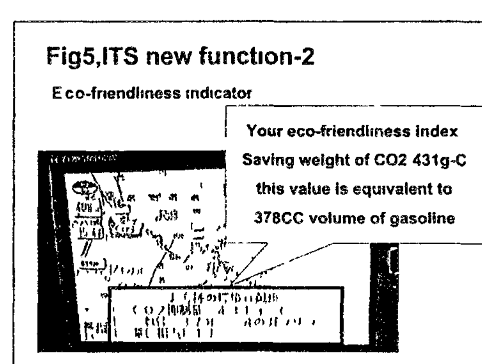


Fig5,ITS new function-2
Eco-friendliness indicator
Your eco-friendliness index
Saving weight of CO2 431g-C
this value is equivalent to
378CC volume of gasoline

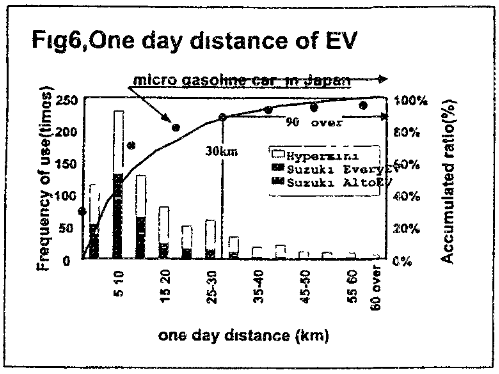


Fig6,One day distance of EV
micro gasoline car in Japan
Frequency of use(times)
Accumulated ratio(%)
90 over
30km
Hypermini
Suzuki Every EV
Suzuki Alto EV
one day distance (km)

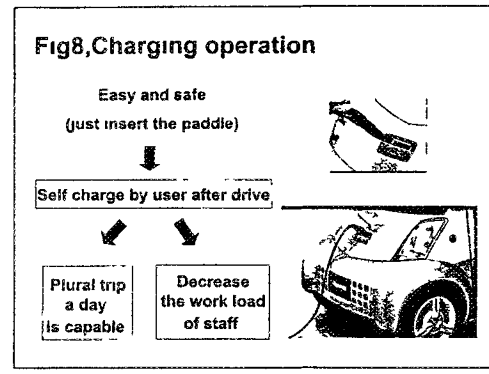


Fig8,Charging operation
Easy and safe
(just insert the paddle)
Self charge by user after drive
Plural trip a day is capable
Decrease the work load of staff

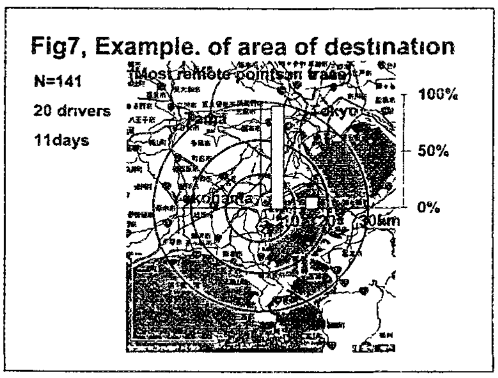


Fig7, Example. of area of destination
N=141
20 drivers
11days
100%
50%
0%

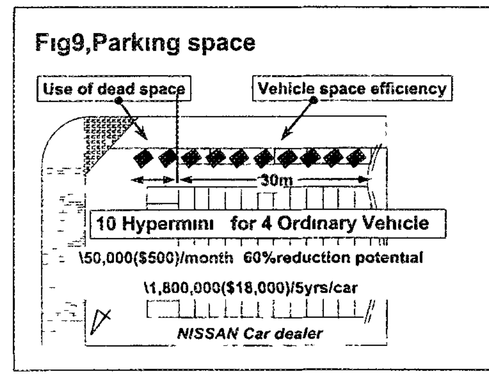


Fig9,Parking space
Use of dead space
Vehicle space efficiency
30m
10 Hypermini for 4 Ordinary Vehicle
\50,000($500)/month 60%reduction potential
\1,800,000($18,000)/5yrs/car
NISSAN Car dealer

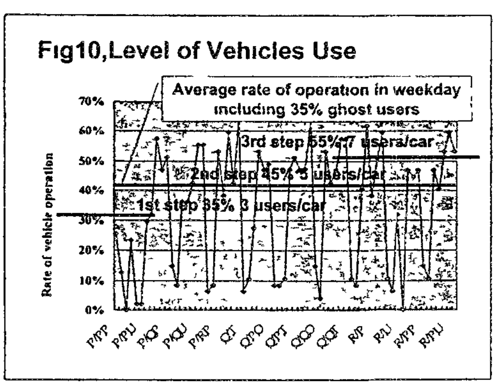


Fig10,Level of Vehicles Use
Average rate of operation in weekday including 35% ghost users
3rd step 55% 7 users/car
2nd step 45% 5 users/car
1st step 35% 3 users/car
Rate of vehicle operation

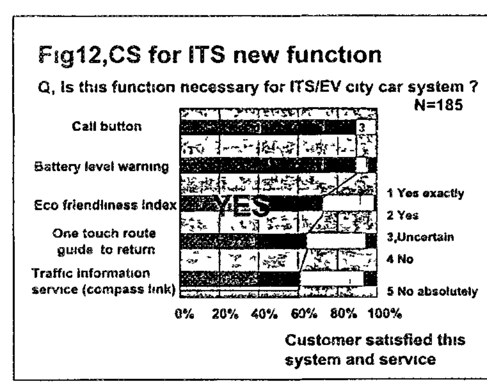


Fig12,CS for ITS new function
Q, Is this function necessary for ITS/EV city car system ?
N=185
Call button
Battery level warning
Eco friendliness index
One touch route guide to return
Traffic information service (compass link)
YES
1 Yes exactly
2 Yes
3,Uncertain
4 No
5 No absolutely
0% 20% 40% 60% 80% 100%
Customer satisfied this system and service

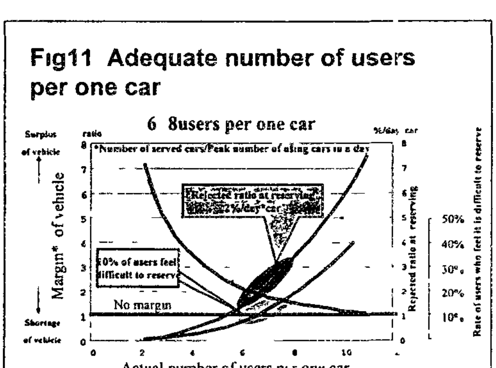


Fig11 Adequate number of users per one car
6 8users per one car
Margin* of vehicle
No margin
Actual number of users per one car

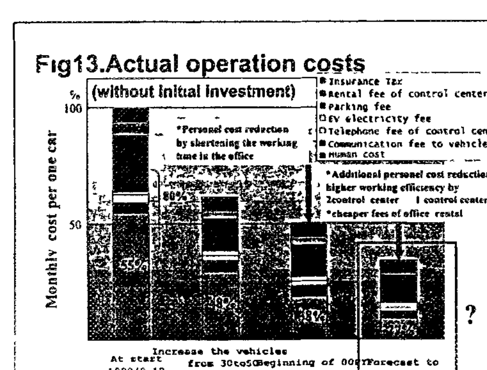


Fig13.Actual operation costs
(without Initial Investment)
Insurance Tax
Rental fee of control center
Parking fee
EV electricity fee
Telephone fee of control center
Communication fee to vehicle
Human cost
Monthly cost per one car
?

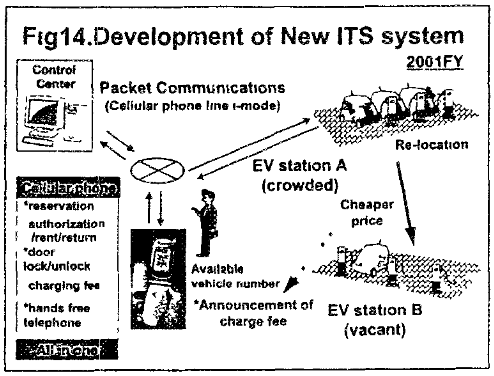


Fig14.Development of New ITS system
2001FY
Control Center
Packet Communications
(Cellular phone line i-mode)
Re-location
EV station A
(crowded)
Cellular phone
*reservation
authorization
/rent/return
*door
lock/unlock
charging fee
*hands free
telephone
All in one
Cheaper
price
Available
vehicle number
*Announcement of
charge fee
EV station B
(vacant)

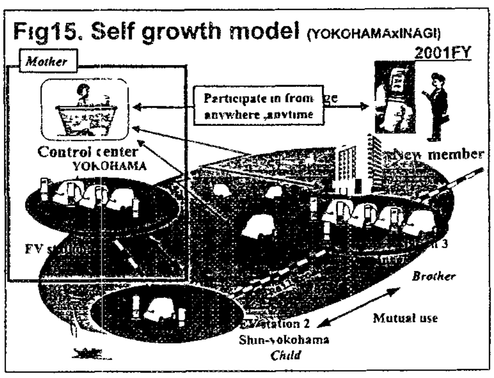
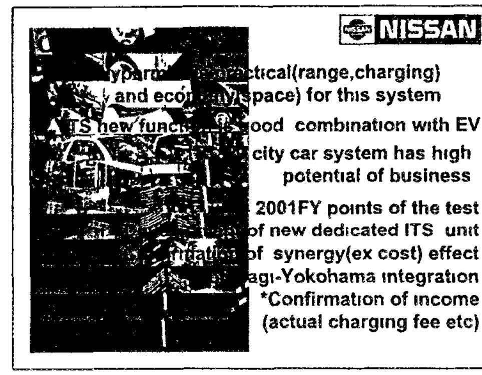


Fig15. Self growth model (YOKOHAMAxINAGI)
2001FY
Mother
Participate in from
anywhere ,anytime
Control center
YOKOHAMA
New member
Brother
Mutual use
Shin-yokohama
Child


NISSAN
tical(range,charging)
pace) for this system
ood combination with EV
city car system has high
potential of business
2001FY points of the test
f new dedicated ITS unit
f synergy(ex cost) effect
agi-Yokohama integration
*Confirmation of income
(actual charging fee etc)

Th!NK

May 16, 2001

David Fabricatore
Th!nk City Project

TH!NK

David Fabricatore
TH!NK city Project Coordinator

An enterprise of Ford Motor Company

S

TH!NK

TH!NK Mobility

TH!NK Technology

TH!NK

Our Vision
- ✓ Create a new sustainable business enterprise
- ✓ Connect with customers in fun & innovative ways

Our Mission
- ✓ Provide innovative solutions for personal mobility
- ✓ Incubate cutting edge technologies

Fresh approaches
Caring for the environment

An enterprise of Ford Motor Company

TH!NK

Environmental Trends

- ✓ "Most cars are used for short trips"
- ✓ 70-80% live in cities and close communities
- ✓ Approx 70% of all car driving is in these areas
- ✓ 1 2 – 1 3 people per car on average
- ✓ With only little / or some luggage

Most cars are larger than needed.

An enterprise of Ford Motor Company

TH!NK

Environmental Trends

- ✓ "Average driving distance lower than 35 miles per day"
- ✓ 73% will be stop-and-go driving by 2010 with average of 20 mph)

Consumer transportation needs are evolving

An enterprise of Ford Motor Company

TH!NK

Conclusion

- ✓ Best selling vehicles in US are SUV's and trucks
- ✓ Big disconnect between customer needs vs purchase decision
- ✓ Many consumers have multi-vehicle fleets – in which vehicles have different utilization patterns

Opportunity to provide specialized vehicles & mobility services that replace regular vehicles

An enterprise of Ford Motor Company

THINK city

An enterprise of Ford Motor Company

THINK city

Pilot Program

Goals

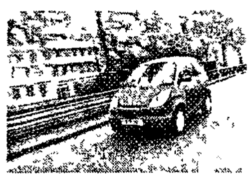
- ✓ Develop the market for the new *city*-class electric vehicle
- ✓ Test the THINK *city* in new niche marketing programs suited to urban vehicles
- ✓ Provide understanding of *city*-class customers prior to launch in 2002
- ✓ Generate positive PR/ awareness
- ✓ ZEV credits – 4 48

An enterprise of Ford Motor Company

THINK city

General Specifications

Seating Capacity		2
Body Dimensions		
	length	9 8 ft.
	width	5 25 ft.
	height	5 1 ft
	luggage	12 4 cu.ft.
Curb weight		2,075 lbs
GVW		2,490 lbs.
Top Speed		56 mph
Acceleration		0–30 mph in 7 secs
Range, city driving		53 miles (est.)



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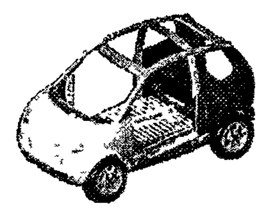
Frame and Body

Lower Frame	Steel frame, 90% high strength steel zinc coated
Upper Frame	Extruded and welded aluminum
Bodywork	Thermoplastic (polyethylene)
Roof	ABS plastic



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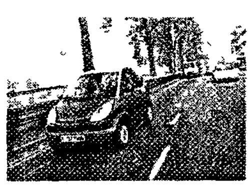
THINK city

Electrical Systems, Motor & Chassis

Propulsion	Nickel Cadmium batteries, 530 lbs, water cooled
Power Storage	11 5 KWh, 100 Ah
Charger	Conductive Internal 190-240V – 14A (3 2/2 kW) air cooled
Charge Time	4 – 6 hours at 14A
Motor Type	Three Phase A/C Induction Motor water cooling
Max. Output	27kW
Voltage	114 volts



Drive	Front Wheel Drive
Tires	155/70 R13
Brakes	front disc brakes rear drum brake

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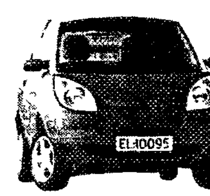
Safety

- Low Center of Gravity
  Steel and Aluminum Safety Frame
- Side Impact Beams in the Doors
  Driver Front Air Bag
- Seatbelts with pre tensioners
- Battery Separated from Passenger Compartment
- Heated Front and Rear Windshields
- Child Seat Tether Anchor



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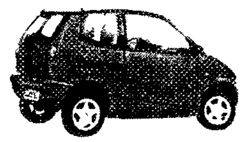
THINK city

Standard Equipment

- Tinted Glass
- 3kW Electric Heater
- Pre Cabin Heating/Cooling
- AM/FM/CD Radio with 2 speakers
- 12V Auxiliary Outlet
- 13" 5-spoke aluminum wheels
- Regenerative Braking



95%+ of Vehicle is Recyclable

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THINK city

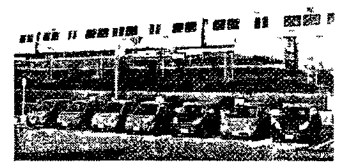
Customer Profile

Private/Retail Customers

- ✓ Urban based, second car
- ✓ Substitute for an older second/third car
- ✓ Environmentally aware – personal priorities
- ✓ Opinion Leaders and innovators

Fleet Customers (private/government)

- ✓ Local driving
- ✓ Anticipated/fixed routes
- ✓ Stop & Go style of driving



An enterprise of Ford Motor Company

For more information

www.thinkmobility.com

An enterprise of Ford Motor Company

NEVCO Gismo

May 16, 2001

Carl Watkins
NEVCO

Presentation by Carl Watkins, Neighborhood Electric Vehicle Company, at:

Meeting the New CARB ZEV Mandate Requirements Conference

The objective of the Air Resources Board is to produce cleaner air There is an urgent need to reduce the use of gasoline by replacing ICE vehicles with zero emission vehicles or ZEVs Fossil fuels should not be used for local transportation where alternative fuels will accomplish the task Electric Vehicles, if designed for specific uses, are entirely capable of accomplishing local, in-town trips Incentives are an effective tool to get ZEVs into use as quickly as possible Any ZEV that eliminates the use of a gasoline vehicle for a large segment of the market should receive equivalent government incentives as other ZEVs

Three wheeled enclosed electric motorcycles can eliminate a large segment of the vehicle miles traveled in ICE vehicles In some ways, they have a better chance of accomplishing this substitution than other types of ZEVs or AFVs Such vehicles as the Gizmo, from NEVCO, and the Sparrow, by Corbin Motors, deserve the same incentives as other EVs They are capable of having at least as much impact as more car-like EVs, and sooner than other EVs that have incentives, because they are more affordably priced and currently available, and they meet large segments of the market

More than 75 percent of all travel can be accomplished by the Gizmo Demographic and statistical information show that most travel is one person traveling alone, and going fewer than 25 miles in a day with a small amount of cargo Most of these trips do not include freeway travel With other considerations of cost and congestion, small single person EVs offer an excellent option for future urban transportation

Demographic Data

In 1990, the National Personal Transportation Survey indicated that 50 percent of all car trips took fewer than 10 minutes. Sixty-five percent of all trips are non-work trips, which account for 59 percent of all vehicle miles traveled It also showed

Non-work Activity	Average Distance
Social/Recreational (Incl Vacation)	11.8
Other Family/Personal Business	7 4
Shopping	5 1

This type of trip can easily be accomplished in a Gizmo or other similar vehicles

Commuter Travel

The Bay Area Commute Profile 2000 revealed the following facts

Over 70 percent of area commuters traveled less than 40 miles
Forty-five percent traveled fewer than 20 miles
The average speed was 30 miles per hour
The average time was 34 minutes
Sixty-seven percent of all commuters travel alone

The Gizmo can accomplish this type of travel at a reasonable price

Because of the limitations in range of EVs, they will almost always be a second or third vehicle This means they will be added to the existing vehicles that a family owns. Where a second or third car is concerned, the 1998 Alameda Exposition survey shows that the mileage requirements are even less stringent, requiring a median distance of only 20 miles This type of application is especially appropriate for the Gizmo

See Attached Graph

Energy Efficiency

The Bureau Of Transportation Statistics keeps records on vehicle "energy intensity" in terms of BTUs per passenger-mile This allows us to make a comparison of vehicles' average efficiency The less energy used per mile, the less pollution is generated Better energy efficiency should be encouraged The Gizmo is designed to accomplish the required driving as efficiently as possible

1996 Energy Intensity by Vehicle Type

Type	BTUs per passenger mile
Automobile	3700
Light truck	4529
Amtrak Trains	2400
Airlines	4100
Transit Bus	4500
Inter-city Bus	1000
Current AFVs	
Hybrid (50 mi/gal)	2280
Honda Plus EV	1300
Gizmo	650

Speed

The first Gizmos were designed to have a top speed of only 30 miles per hour to simplify licensing Our experience was that this was not fast enough to travel on neighborhood arterial roads that feed traffic from one area to another These are the roads that commuters use, and are the same roads that people use when traveling around town At 30 mph, the driver feels uncomfortable because of the actions of other drivers when encountering a delay In order to blend comfortably with normal traffic, a vehicle must be able to attain a speed of 40 mph or more We completely redesigned the Gizmo to meet this requirement

Replacing gasoline vehicles

The type of gas cars that are in most need of replacing are older, more polluting vehicles These are generally driven by people who are less able to pay more for a vehicle That is why a low priced EV is essential for replacing gas vehicles in large numbers

Congestion

For most city planners, increasing congestion is a bigger problem than pollution. By building electric vehicles that are smaller, a better long term solution is possible Bumper-to-bumper stop-start traffic and continual idling are major sources of pollution, which the Gizmo eliminates by being electric, but also by taking up less space and parking easily

Conclusion

If you want to get a large number of ZEVs on the road, you have to make it as easy as possible for people to buy them Because these will all be niche market vehicles, you will need to have a variety of options to meet many people's needs

The effort to get people to switch to ZEVs is about competition between gas vehicles and ZEVs, not among ZEVs themselves

There are millions of cars sold every year CARB is just trying to get a small percentage of those to be clean

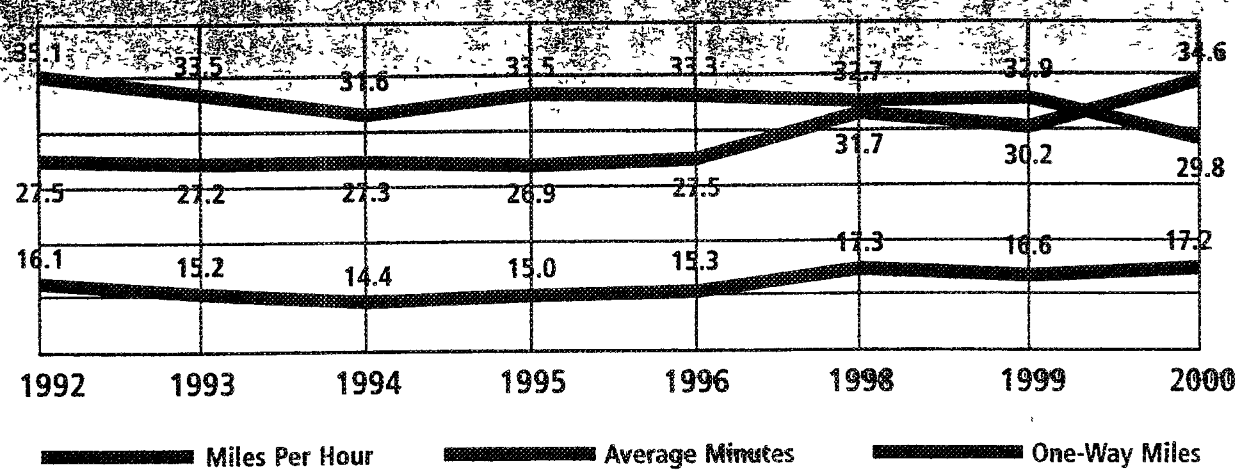
The better each manufacturer does, the better we all will do We all need credibility We all need to help people learn a new way of getting around. It is tremendously difficult to get people to change The auto industry is spending billions of dollars trying to convince people to buy SUVs We need to build momentum by having thousands of people switch to ZEVs every month.

All EVs, whatever the type, need all the incentives they can get

Commute Distance over Time (by mileage)

One-Way Miles	1992	1994	1995	1996	1998	1999	2000
0-5 Miles	29 0%	36 3%	33 8%	32 7%	25 1%	27 6%	27 8%
6-10 Miles	18 3%	18 1%	18 6%	20 0%	20 2%	19 8%	17 2%
11-20 Miles	26 0%	23 4%	24.9%	24.6%	27.5%	26 1%	25 9%
21-40 Miles	20 4%	16 8%	15 2%	16 1%	20 7%	19 0%	22 0%
41+ Miles	6.3%	5.4%	7.6%	6.6%	6.5%	7.5%	7 1%
n=	*1,600*	*3,201*	*400*	*3,188*	*1,171*	*3,572*	*3,608*

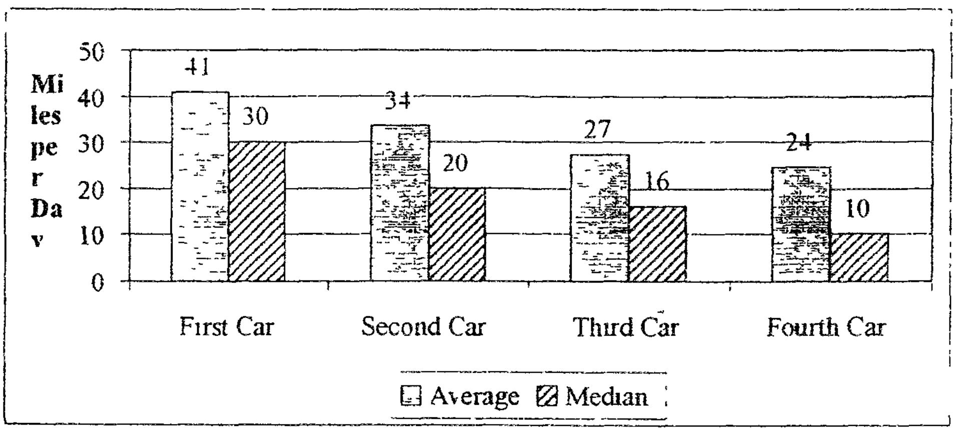
Commute Distance and Time



QUESTION 7 – APPROXIMATELY HOW MANY MILES DOES EACH CAR TRAVEL PER DAY?

Exhibit 11 shows the average number of miles driven per day for the vehicles in the household The median value is also shown The minimum number of miles for all vehicles was 1 mile per day while the maximum varied between 100 and 200 miles per day

Exhibit 11
Average and Median Miles Driven per Day



Development of Affordable Electric Vehicles

May 16, 2001

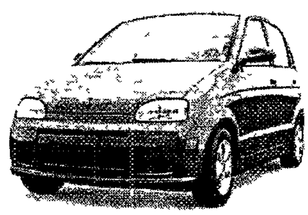
Hyungpyo Woo
ATT R&D

ATT R&D

FACT SHEETS OF

MAY, 2001

PARADE



DESIGN & DEVELOPMENT

Meeting the New CARB ZEV Mandate Requirements
May 15 -16, ITS-UC Davis

Hyungpyo Woo
ADVANCED TRANSPORTATION TECHNOLOGIES R&D Co

ATT R&D

OUTLINES

I What People Want or Expect From Electric Vehicle
- Right Balance of Performance & Price
- Attractive Styling, Economics & Ergonomics
- Safety as the First Priority

II New Approach to Vehicle Design
- New Vehicle Platform Development
- New Manufacturing Method
- New/Carry-over Components Development

Parade, an affordable Electric Vehicle

III Reducing Development Cost

- Use All the Available Resources
- Geographical Advantages
- In-house Engineering Capability
- Outsourcing

IV Current Status

- Financing for Building 40 prototypes for Test
- Discussing with US cities for Manufacturing Facility Setup
- Developing Low Speed Electric Vehicles

AIT R&D Co Midas Venture Tower #211 Janghang 775-1 Ilsan Koyang Kyungk Korea 411 837 Tel +82 31 907 5333 Fax +82 31 907 5344

parade

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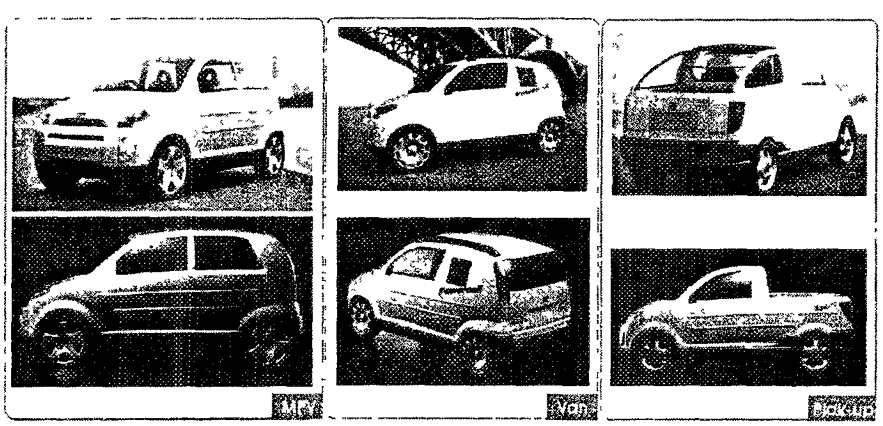
1st Stage - Scale Models



parade

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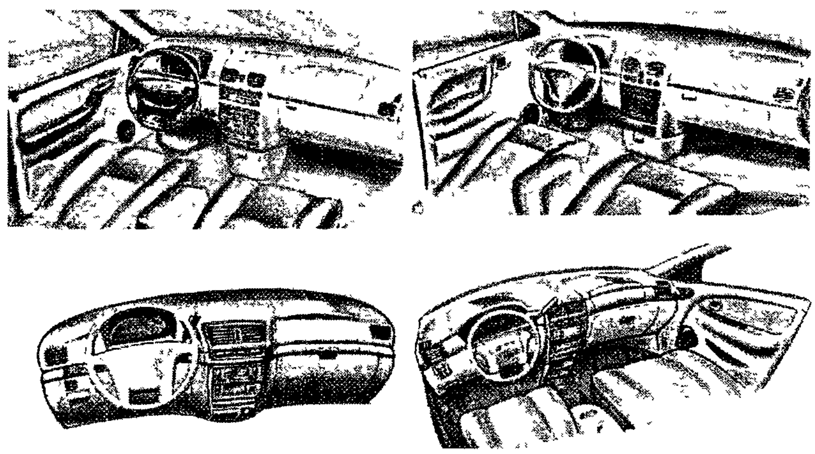
Ideation Sketches



Interior color sketches for MPV

parade

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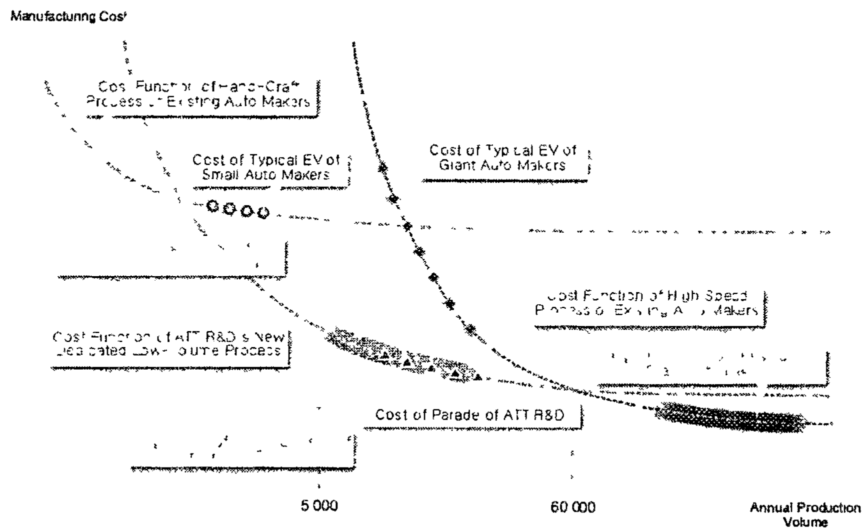
Final Model

Exterior

Manufacturing Costs of Vehicles Affected by Process & Volumes

ATT R&D



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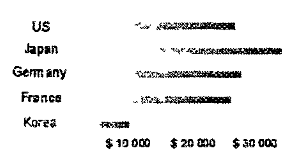
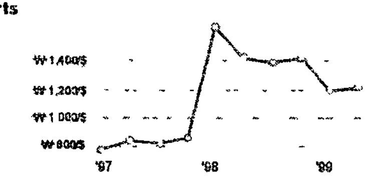
Base Camp in Korea for EV Development

ATT R&D

○ Cost Advantage of Local Services & Parts

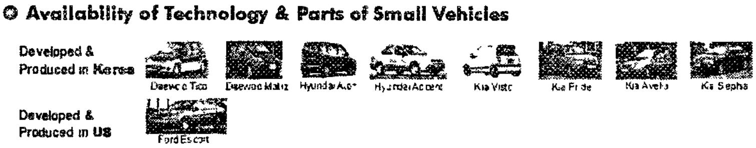


GNP Per-Capita in 1995



Devaluation of Korea's Currency

○ Availability of Technology & Parts of Small Vehicles



Vehicle Models with Wheelbase of 2 500mm or Less

○ Over-supply of Talented Human Resources in Korea

- 4 Korean Auto Makers (Out of 7) were Merged Since 1998
- More Than 30 % of Experienced Design Engineers Changed Career Since 1998
- Early Retirement Programs of Auto Makers Encourage Talented Engineers to Leave

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Parade versus Other EVs in Market

ATT R&D

	EV60 / EV150	Honda EV+	GM EV1
Construction			
Body	Aluminum Intensive Body	Steel Unibody	Aluminum Intensive Body
Drivetrain	Rear Wheel Drive	Front Wheel Drive	Front Wheel Drive
Dimensions/Weights			
Seating Capacity (Front+Rear)	4 (2 + 2	4 2 + 2	2
Exterior Dimensions (L×W×H) in mm	3 550 × 1 650 × 1 620	4 046 × 1 750 × 1 63	4 309 × 765 × 1 28
Wheel-base	2 400 mm	2 53 1 mm	2 5 2 mm
Treads (Front/Rear)	1 430 mm / 1 430 mm	1 501 mm / 491 mm	1 47 mm / 244 mm
Curb Weight	[illegible]	[illegible]	[illegible]
Number of Doors	[illegible]		[illegible]
Performances			
Range by EPA City Mode	[illegible]	[illegible]	[illegible]
Acceleration (0-60 mph)	15 0 sec	17 7 sec	9 sec
Top Speed	24 kph	128 kph	129 kph
Carrying Capacity	320 kg	317 kg	
Purchase/Lease Terms			
Sticker Price	[illegible]	[illegible]	[illegible]
Monthly Lease Price	TBD [1] / TBD [2]	$ 454	$ 424 [3] / $ 499 [4]

Notes: 1 Target Value for EV50 MPV 2 Target Value for EV150 MPV 3 March 1999 Value of GM EV1 with Lead Acid Battery 4 March 1999 Value of GM EV1 with NiMH Battery

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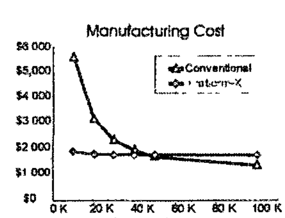
Body-In-White (Summary)

ATT R&D

	Platform-X	Conventional
Primary Material	Aluminum Alloys	Steel
Primary Forming Process	Extrusion Bending, Super plastic Forming	Stamping
Preferred Joint Process	Arc Welding, Riveting, Bonding	Spot Welding



	Number of Parts	Weight	Length of Joint
Platform X	[illegible]	[illegible]	[illegible]
Conventional	Appr 400	~ 300 kg	~ 210 m

	Design Cost	Tooling Cost	Delivery of Tooling
Platform X	$1 million	$ [illegible] million or less	[illegible] months
Conventional	$10 mil	~$50 mil	12~16 months

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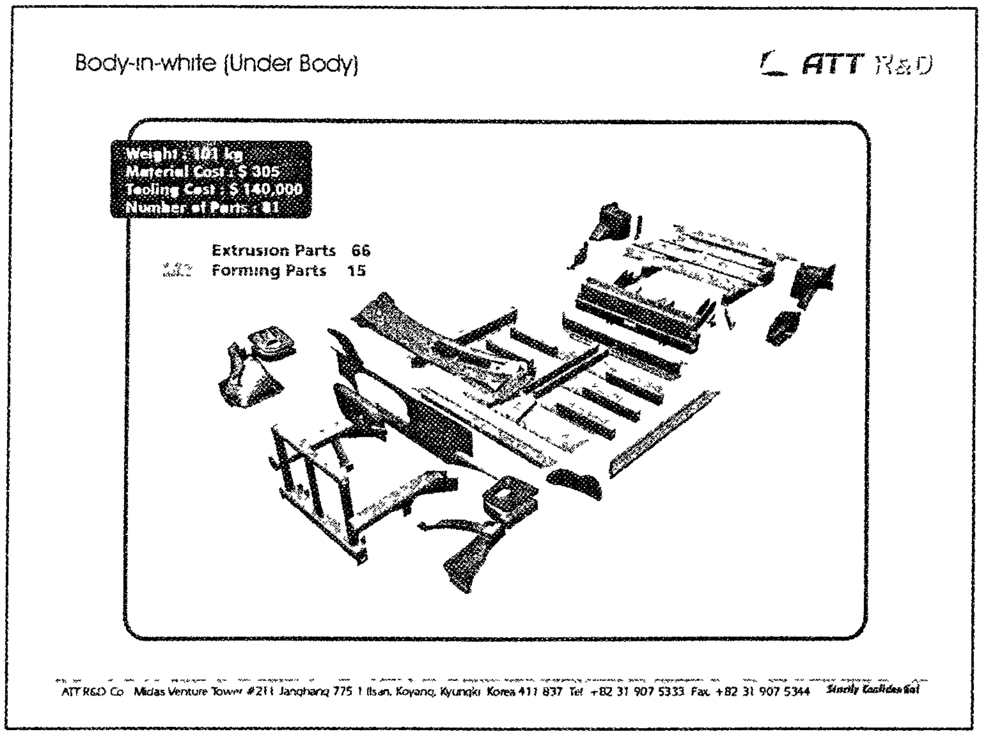
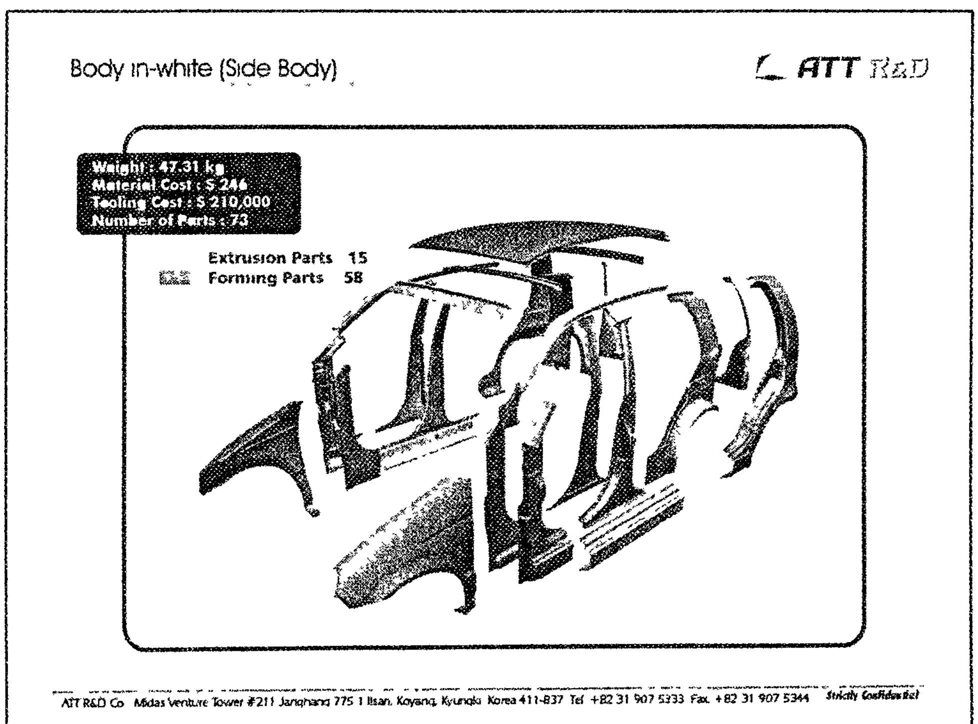

Body-in-white (Under Body)
ATT R&D
Weight : 101 kg
Material Cost : $ 305
Tooling Cost : $ 140,000
Number of Parts : 81
Extrusion Parts 66
Forming Parts 15
ATT R&D Co Midas Venture Tower #211 Janghang 775 1 Ilsan, Koyang, Kyungki Korea 411 837 Tel +82 31 907 5333 Fax +82 31 907 5344 Strictly Confidential

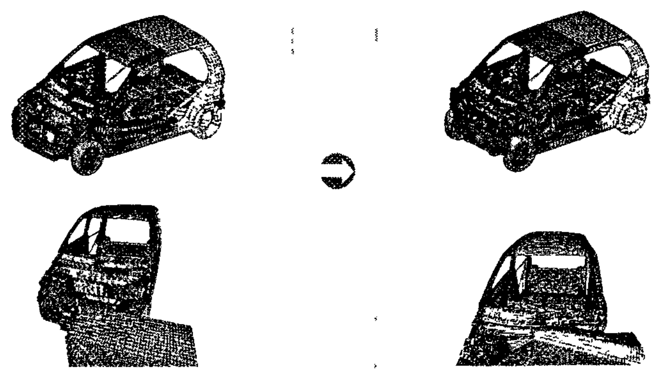

Body in-white (Side Body)
ATT R&D
Weight : 47.31 kg
Material Cost : $ 246
Tooling Cost : $ 210,000
Number of Parts : 73
Extrusion Parts 15
Forming Parts 58
ATT R&D Co Midas Venture Tower #211 Janghang 775 1 Ilsan, Koyang, Kyungki Korea 411-837 Tel +82 31 907 5333 Fax +82 31 907 5344 Strictly Confidential

Vehicle Safety Crashworthiness

ATT R&D

Before Crash

After Crash



Meets or Exceeds : FMVSS 208, US NCAP, Euro NCAP
Overall Rating : ★★★★★

Chassis Design Resources

ATT R&D

Modern Design Tools

- Full CAE Ability from Concept to Production
  - CATIA for CAD operation
  - ADAMS DADS MATLAB for vehicle dynamics analysis
  - NASTRAN ANSYS for finite element analysis

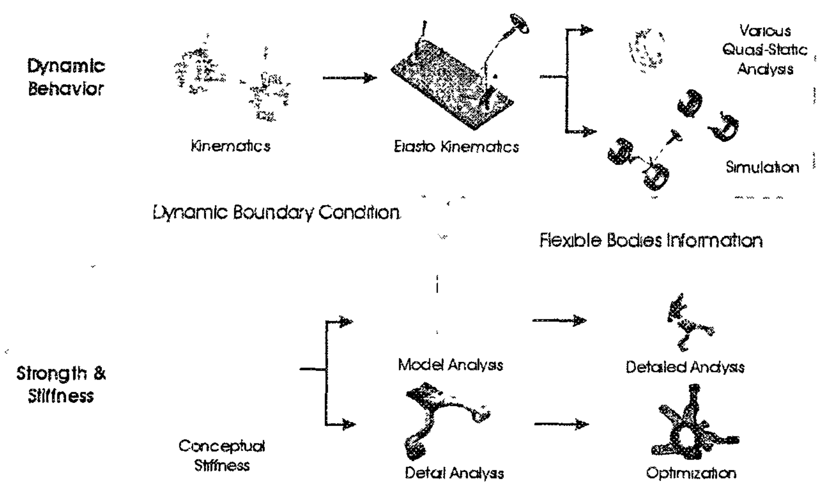
World-Class Manpower

- Highly Qualified Engineers
  - Able to handle both design and analysis
  - Over 10 years experience each in automotive industry
- Design Cycle Experience
  - All of drawing, analysis and test correlation work steps
  - Average 3 majo car program carried out

Slim & Effective Organization

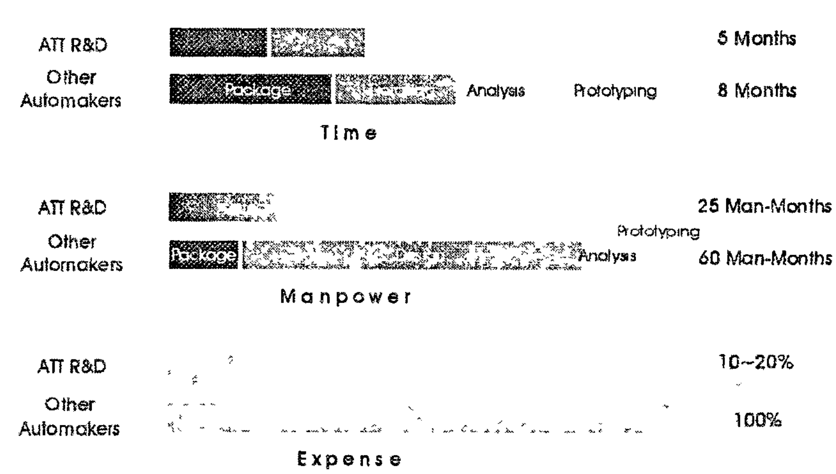
- Tightly Combined Workflow
  - Design, analysis, development and outsourcing within one team
- Well Developed Information Flow
  - Wide knowledge on outsourcing and prototyping
  - Full awareness of simultaneous engineering about production

Chassis Working Process



ATT R&D's Chassis Design Capability

- Resource to Develop New Chassis Platform

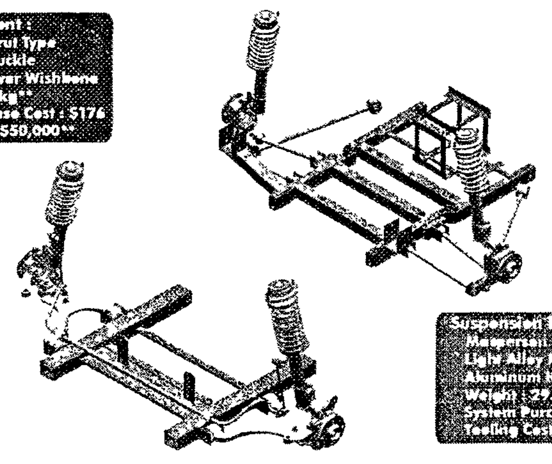


Suspension

ATT R&D

Suspension Front :
- Macpersen Strut Type
- Aluminum Knuckle
- Aluminum Lower Wishbone
- Weight : 26.3 kg**
- System Purchase Cost : $176
- Tooling Cost : $50,000**

* For Left & Right



For Left & Right

Suspension Rear:
- Macpersen Strut Type
- Light Alloy Multiple Link
- Aluminum Knuckle
- Weight : 29.4 kg*
- System Purchase Cost : $169*
- Tooling Cost : $50,000

Lighting Devices

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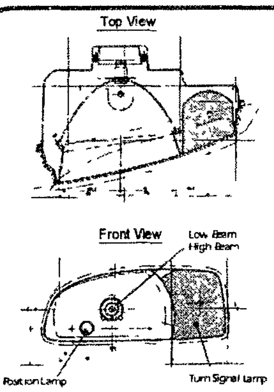
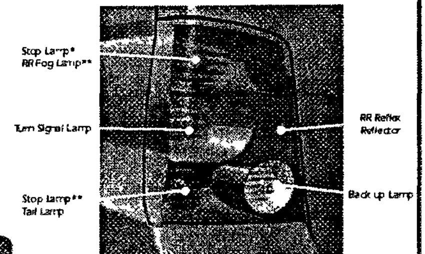


Rear Lamp Clusters
- One-time Tooling Investment for the U.S. & EU
- Development & Tooling Cost : $270,000
- System Purchase Cost : $18 (For Left & Right Units)



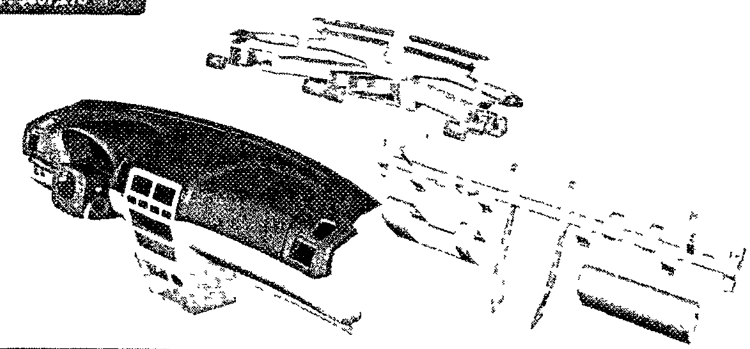
* U.S only
** EU only

Head Lamp Clusters
- One-time Tooling Investment for the U.S. & EU
- MFR-Type Low & High Beam
- Development & Tooling Cost : $315,000
- System Purchase Cost : $36 (For Left & Right Units)

Instrument Panel Assembly

ATT R&D

Weight : 18.5 kg
System Purchase Cost : $129
Tooling Cost : $637,270



Key Elements of Design Concept :
- Symmetric Styling for Cost Reduction (70% Parts Commonly Used for Left and Right)
- Half-Pad Type for Reduced of Tooling
- Vacuum Formed ABS Skin with PP Foam for Soft Feel
- Aluminum IP Core for Reduced Tooling
- Aluminum T-Bar for Reduced Tooling
- Aluminum Knee-Bolster for Safety & Reduced Tooling

Instrument Panel Common Use Concept

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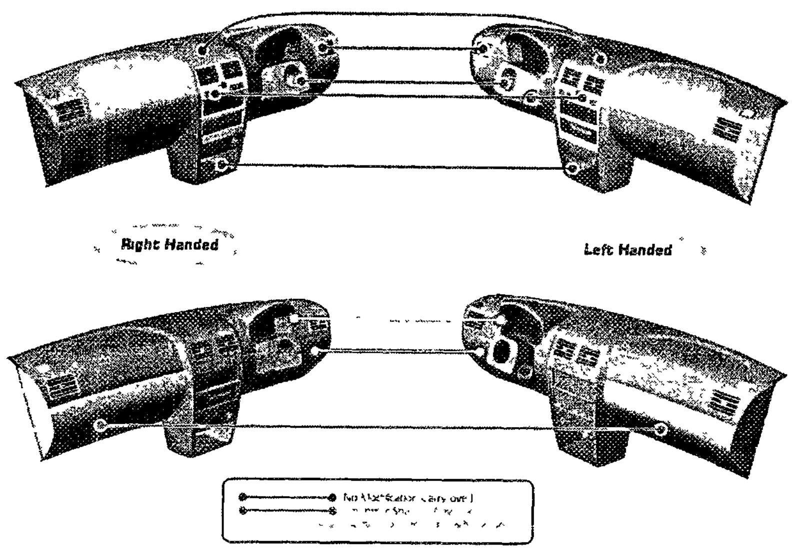

Heating & Air-Conditioning System

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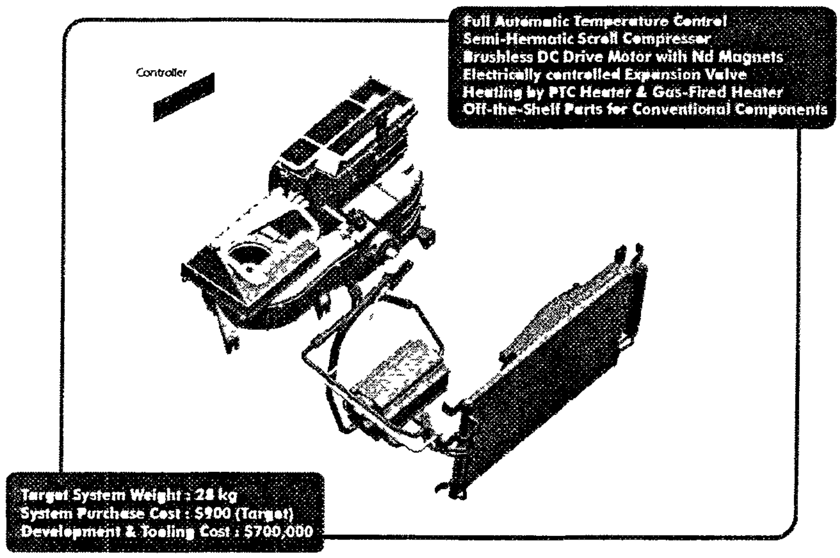
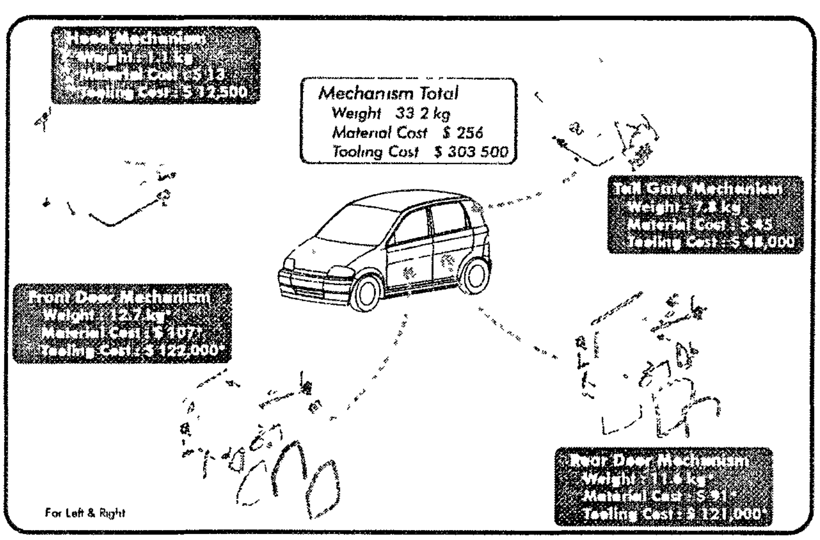
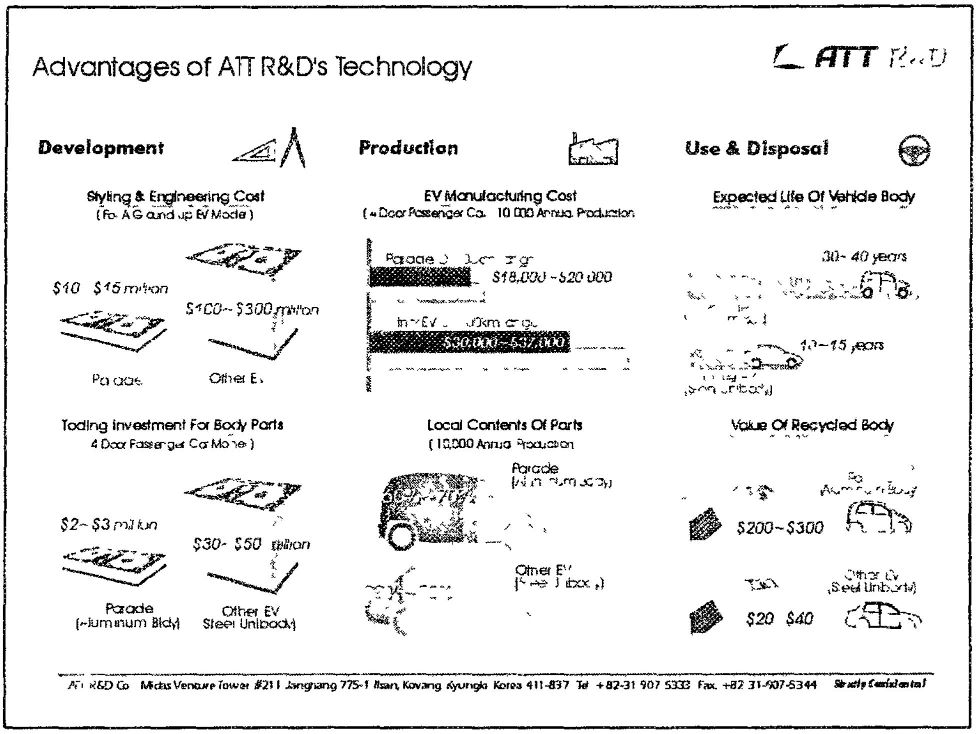


Mechanism for Enclosure Parts

ATT R&D





Parade, an affordable Electric Vehicle

ATT R&D

Current Status of Parade EV Project

- Financing for Building 40 prototypes for Test
- On Going Discussion with US cities for Manufacturing Facility Setup
- Developing Low Speed Electric Vehicles

The Force EV- Solectria's Path to Emerging as a Premier Electric and Hybrid Electric Drive System Component Developer and Manufacturer

May 16, 2001

Vasilios Brachos
Solectria Corporation

Solectria Corporation

The Solectria Force Electric Sedan and Technology Spin-Offs

By Vasilios Brachos

ITS UC Davis

May 16, 2001

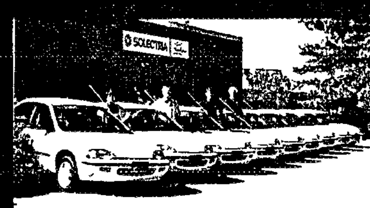
Force Customers

- Electric utilities – SCE, SMUD, Boston Edison, PEPCO, PP&L, etc.
- Universities
- EV demonstration programs – Massachusetts, New Jersey, Connecticut, Vermont, etc.
- Battery Companies – GP, EVonyx
- Individuals nationwide

SOLECTRIA

Solectria is NOT a car company

- Solectria Force introduced to market in 1991
- Geo Metro platform – high MPG, produced domestically
- 300 on the road
- over 3,000,000 miles



SOLECTRIA

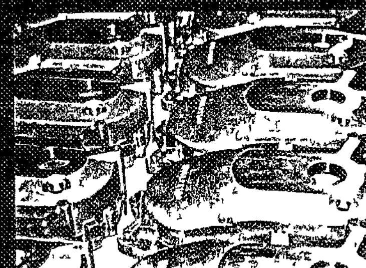
Force – Proven Design

- Dynomometer tested
- EV America tested
- CARB certified
- Crash tested to meet FMVSS – frontal, side, roof

Force Technology Development

SOLECTRIA

- Constant revision and refinement of Force drive system & ancillary components
- Extensive on-road experience with these systems
- All-digital electronics
- Rugged motor-gearbox system



Strategic Partnerships

SOLECTRIA

- Solectria proved it was able to deliver automotive standard quality production
- Manufacturing partners established
- General Motors supplied gliders for last 50 Forces produced

Force as Test Bed

SOLECTRIA

- Battery chemistries - Lead acid, Zinc bromine, Zinc air, Nickel cadmium, Nickel metal hydride
- Fuel Cells – NJ DOT
- SuperCaps – technology from Maxwell, testing by EVermont

Quality Issues

SOLECTRIA

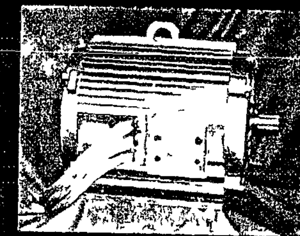
- Many of Solectria's suppliers now ISO qualified
- Solectria's Quality Plan in place

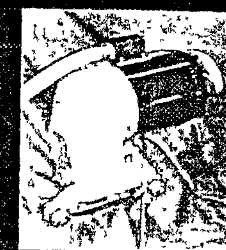
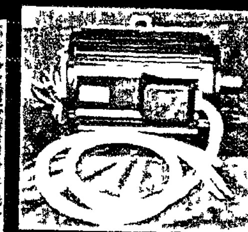
Spin-off Technology

- AC motors - 20kW to 150kW
- DSP motor controller
- DSP battery chargers – 3kW to 9kW
- Hybrid controller - ICE/generator, APUs, microturbines, fuel cells, ultracapacitors
- Grid connected and independent power generation systems

Motors & Transaxles

- Robust, efficient products
- Proprietary designs
- Motors utilize established motor technologies for low cost even at low volumes
- Optimized for OEM customer system requirements

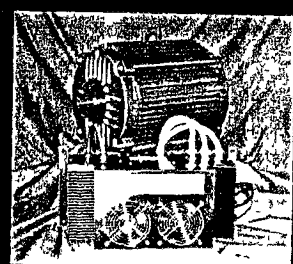
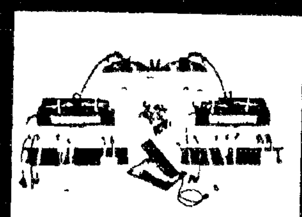


SOLECTRIA

Electric Drive Systems

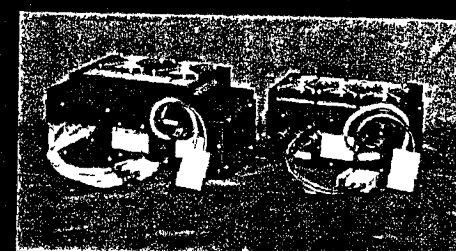
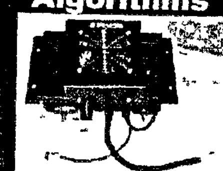
- EV, Hybrid, Fuel Cell
- Wide range of power levels
- Scalable architecture
- Cost-effective design approach
- Proven products (millions of miles)

SOLECTRIA

Power Electronics

- DSP-based Motor Controllers (Inverters)
- DC-DC Converters
- Battery Chargers
- Auxiliary Systems
- Proprietary & Patented Technologies, Software & Algorithms

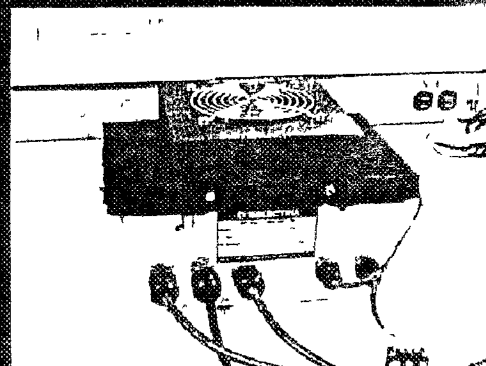



SOLECTRIA

Advanced Energy Systems

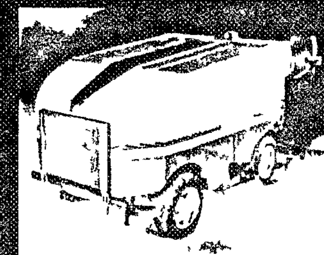
- Power management for various energy sources (generators, storage)
- Inverters/Generator Controllers
- DSP based technology
  - DC-DC Converter

    (shown at right)
- Specialists in AC motor control theory & power factor correction for high quality power
- High reliability for quality power market

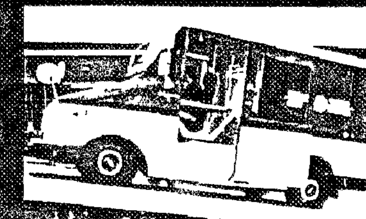


SOLECTRIA

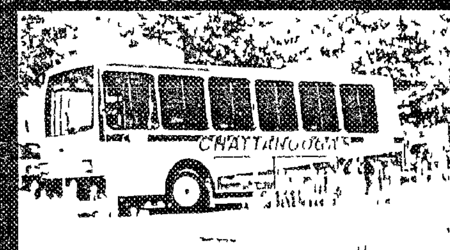
Numerous Niche Vehicle Applications Exist



Resurfice Collect - Ice Resurfacer



Canada Post - LLV



Advanced Vehicle Systems - Shuttle Bus

New York USPS - CitiVan

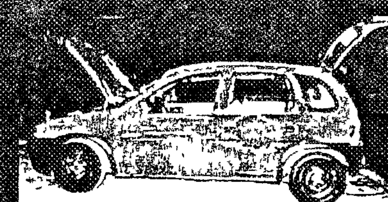
SOLECTRIA

Component Kits

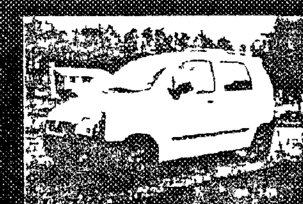
- Canada Post - LLV
- Advanced Vehicle Systems – 22' shuttle buses
- SuperSteel – CitiVan delivery trucks for US Postal Service
- Resurfice – ice resurfacing machines

SOLECTRIA

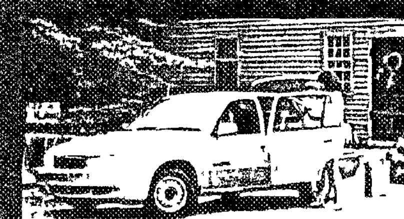
Solectria Drive Systems in Use



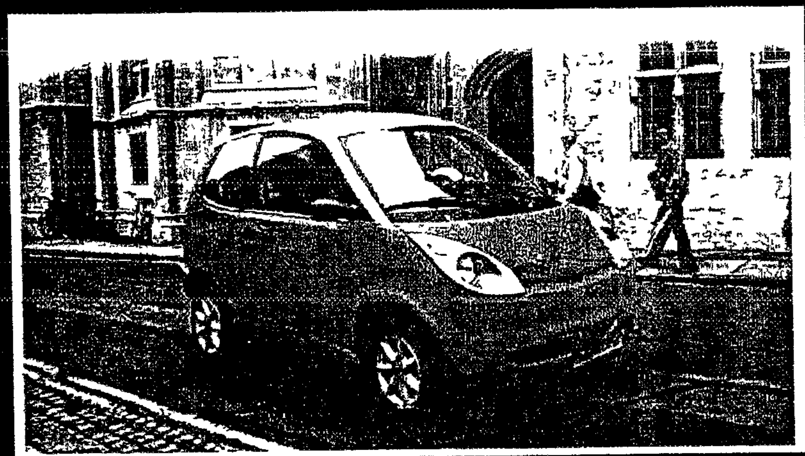
GM S-Car



Suzuki Wagon-R



Solectria's Future – Ford Th!nk City



SOLECTRIA

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Design Options and Simulation Results for Small Full-Function EVs

May 16, 2001

Andrew Burke
Institute of Transportation Studies, Davis

Design Options and Simulation Results for Small Full-function EVs

Andrew Burke
Institute of Transportation Studies
University of California-Davis
Davis, California 95616

Paper presented to
Meeting the ZEV Mandate
Requirements Grid-connected
Hybrids and City EVs
May 15-16, 2001

Outline of the Presentation

- Introduction
- Types of EV designs
- Design Considerations for Small FFEVs
- Characteristics of small ICE passenger cars
- Characteristics of electric passenger cars
- EV design parameters
- Simulation approach (SIMPLEV)
- Simulation results
- Cost considerations and estimates
- Comparisons with grid-connected hybrids
- Conclusions

Types of EV Designs

- Full-function EVs - designed to operate on interstate highways and freeways at speeds up to 75-80 mph (ex EV1)
- City EVs - designed to operate on city arterials at speeds up to 50 mph (ex E-com and Th!nk)
- Neighborhood EVs – designed to operate on city streets at speeds up to 25 mph (ex Dynasty)

Design Considerations for a Small Full-function EV

- Minimum vehicle length that is marketable in large numbers
- Safety- must satisfy the FMVSS tests and be perceived as safe by public and insurance industry
- Have sufficient acceleration performance for merging on freeways and interstate highways (sets power requirement)
- Sufficient range for regional use (probably about 100 miles at highway speeds)

Characteristics of Small/Compact Passenger Cars Using Engines and Gasoline

Model	Curb Weight (lbs)	Length (inches)	Width (inches)	Height (inches)	Max. Hp
CRX	1600	144	–	–	58
Geo Metro	1895	149	63	55	79
Aspire	2060	153	–	–	63
Insight	1856	155	66	53	75
Prius	2728	168	67	59	85
Civic	2359	164	67	54	106
Echo	2150	163	65	59	108
Focus	2715	175	67	56	107
Escort	2478	175	67	53	114

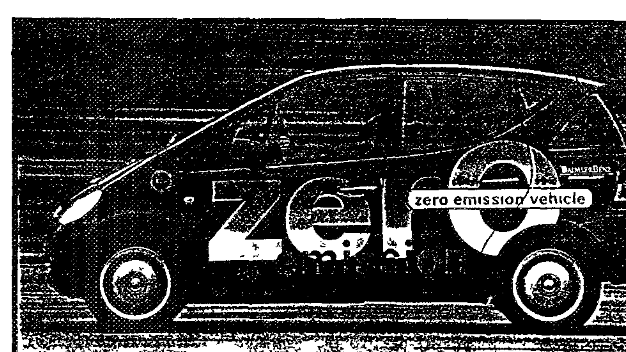
Characteristics of Electric Passenger Cars

Model	Curb weight (lbs)	Length (inches)	Width (inches)	Height (inches)	Max. Hp
EV1	2970	170	70	51	137
Daimler A-Class	3043	109	52	49	67
Th!nk	2112	118	63	61	36
E-com	1694	110	58	63	25
Hypermini	1812	105	58	61	32
Parade	2050	140	–	–	58
Dynasty	1450	140	60	63	20

Small Full-function EV Design Parameters

- Minimum size parameters – length 140-150 inches, width 60-65 inches, height 55-60 inches
- Speed and acceleration – cruising speed of 70-75 mph and 0-60 mph time of 12-15 seconds
- Highway range – 100-125 miles at 65 mph
- Vehicle utility – batteries should be placed outside the passenger compartment and trunk, probably under the vehicle
- Safety – vehicle must pass insurance industry crash tests with excellent rating (not just acceptable)
- Cost – materials selection and manufacturing done to minimize (control) cost consistent with battery selection to meet the range requirement

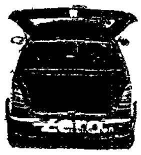
DAIMLERBENZ
AKTIENGESELLSCHAFT



The A-Class Electric Vehicle

Powered by the ZEBRA Battery System

exhaust system no toxic emissions solutely no one disputes the fact that ctric vehicle do not produce local issions However it would be naïve to that electric power is free from pollu n Ultimately the electrical energy necessary to charge the batteries must come from somewhere Depending on how it is produced generating electricity produces different levels of emission In the basin of Southern California where a large amount of electricity comes from nuclear power natural gas or wind energy the production of electricity entails relatively low levels of harmful emissions



Thanks to the vehicle s sandwich structure the entire trunk space is available for luggage

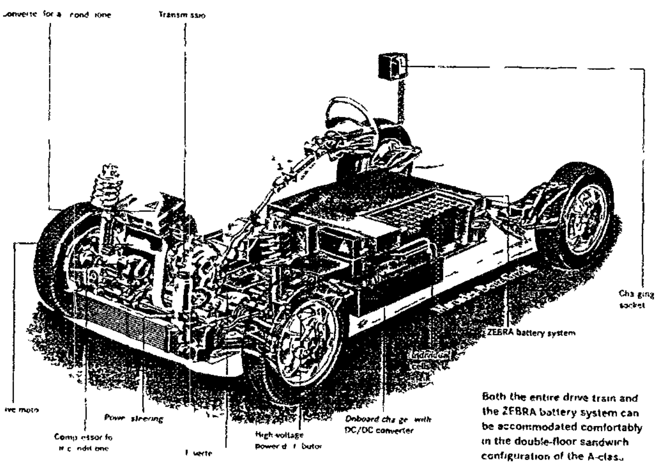
Technical Specifications for the A class EV	
ensions and weight	
al dimensions	
)*	3 575 m/1 719 m/1 601 m
weight	1 380 kg (3 043 lbs)
d	350 kg (772 lbs)
vehicle weight rating	1 730 kg (3 815 lbs)
ants	4
ing performance	
eed	Electronically limited to 80 mph
ration	
mph	16 5 s
	125 miles
or	
	Three-phase induction motor
	50 kW
volutions	9 700 rpm
orque	180 Nm (0 2 600 rpm)

A Breath of Fresh Air for Our Conurbations

California state legislation requires automobile manufacturers to sell zero-emission vehicles in the future

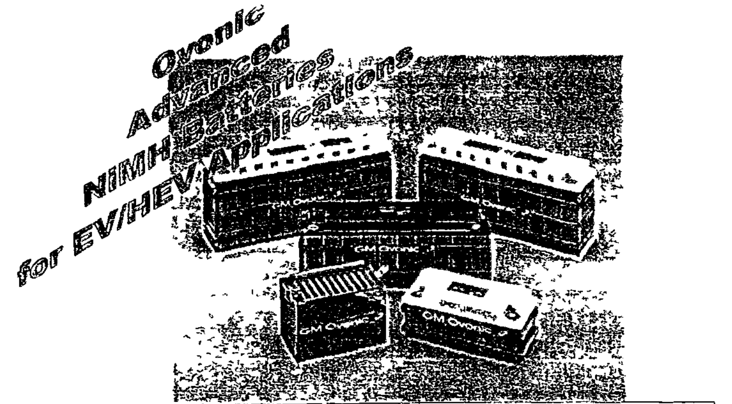
Sounds like the perfect cue for the ZEBRA powered A-class which satisfies such requirements Against this backdrop Daimler Benz will first test a fleet of its new electric cars with customers before it sells the model on a large scale In particular, the inhabitants of the conurbations of Los Angeles and the San Francisco-Oakland area stand to profit considerably from the introduction of electric vehicles with zero local pollutant emissions

The Battery in the "Sandwich" Preserves Interior Space



Both the entire drive train and the ZEBRA battery system can be accommodated comfortably in the double-floor sandwich configuration of the A-class

Ovonic Advanced NiMH Batteries for EV/HEV Applications



	GMO –1 PRODUCTION	GMO – 2 PROTOTYPE	12 HEV-60 PROTOTYPE	7-HEV 28 PROTOTYPE	12-HEV 12* Monobloc PROTOTYPE
Application	EV	EV	HEV	HEV	HEV
No of Cells	11	10	10	6	10
Nominal Voltage (V)	13 2	12	12	7 2	12
Dimensions (mm)					
Length	409	388	388	240	167
Width	102	102	102	102	102
Height	178	175	119	81	125
Weight (kg)	17 7	17 4	11 4	4 3	3 2
Volume (lL)	7 4	6 9	4 6	2	2 2
Capacity (Ah)	85	95	60	28	12
Nominal Energy (C/3 Wh)	1 200	1,200	750	210	150
Specific Energy (Wh/kg)	66	70	68	48	48
Energy Density (Wh/L)	158	171	163	102	71
Specific Power					
50% DOD (W/kg)	220	240	550	550	550
80% DOD (W/kg)	180	200			
Power Density					
50% DOD (W/L)	480	605	1300	1200	800
80% DOD (W/L)	430	534			

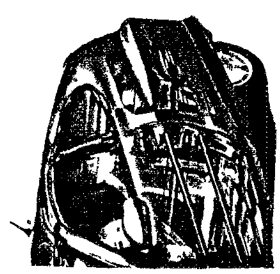
** MONOBLOC LIQUID COOLED

Ovonic Battery Company
A subsidiary of Energy Conversion Devices
1707 Northwood Drive
Troy MI 48084 USA
Email ovonicbattery@ovonic.com
Phone 1 248 362 1750
Fax 1 248 362 0332
www ovonic com

Safety for Small, Light Vehicles is Possible

The Insight's safety engineering is quite extensive Its aluminum body and frame, which incorporate front and rear crumple zones, help protect the occupants in impacts such as full-frontal, offset-frontal, side and rear Dual front airbags,‡ 3-point seat belts and built-in head restraints are all standard equipment

As you can see, the Honda Insight really is different It's smarter A car that takes care of your needs as it takes care of the environment's The kind of car you'd expect from Honda



Simulations

- Simulations done using SIMPLEV
- Vehicle parameters selected to be appropriate for a small full-function EV
- Powertrain power (motor and inverter) selected to meet the acceleration and speed requirements
- Battery sized to meet the range requirement at highway speeds
- Simulations done for advanced batteries –nickel metal hydride, lithium-ion, and sodium metal chloride (Zebra) technologies

Simulation Results

Concept Full-function Small EV
(Cd= .25, Af=2.1 m2, fr= 008)

Battery type	Battery Weight (kg)	Energy Stored (kWh)	Vehicle Test Weight (kg)	Driving Cycle	Range (miles)	Energy Use (Wh/mi)
Nickel metal hydride	239	20	1100			
				FUDS	150	146
				Highway	148	139
				65 mph	113	174
Sodium metal chloride	218	22	1080			
				FUDS	159	144
				Highway	150	138
				65 mph	110	173
Lithium ion	192	22	1054			
				FUDS	143	170
				Highway	165	136
				65 mph	124	172

Acceleration performance motor/inverter 45kW,
0-30 mph 4 sec, 0-60 mph 12 sec, top speed >70 mph

Simulation Results

Insight EV
(Cd=.25, Af= 1.86 m2, fr=.007)

Battery type	Battery Weight (kg)	Energy Stored (kWh)	Vehicle Test Weight (kg)	Driving Cycle	Range (miles)	Ei (W
Nickel metal hydride	188	16	1095			
				FUDS	118	
				Highway	126	
				65 mph	98	

Acceleration performance 48 kW motor/inverter, 204 V
0-30 mph 4 sec, 0-60 mph 11.5 sec, top speed > 70 mph

Cost Considerations

- Cost estimates made for a small full-function EV
- Electric drive power - 45 kW
- Battery energy storage – 22 kWh
- Motor/inverter cost to OEM - $40/kW, $20/kW
- Battery costs to OEM - $350/kWh, $250/kWh, $150/kWh
- Differential OEM costs between EV and ICE cars
- Batteries assumed to last the lifetime of the car

Cost/Price of Na Ni Chloride Batteries (Source MES - DEA)

Year	Production	Price ($/kWh-System)
2000	250 packs	900
2004	4800 packs	450
	large	300
	very large	150

Estimated OEM Cost Differentials between the Small FFEV and ICE Car for Various Battery and Motor/Inverter Costs

Motor/inverter Unit Cost ($/kW)	Battery Cost ($/kWh)	Motor/ Inverter Cost($)	Battery Cost ($)	OEM EV driveline cost ($)	OEM differential cost ($) *
40	350	1800	7700	9500	8300
	250	1800	5500	7300	6100
	150	1800	3300	5100	3900
20	350	900	7700	8600	7400
	250	900	5500	6400	5200
	150	900	3300	4200	3000

- ICE car has a 60 kW engine costing $20/kW to the OEM

Cost Estimate Comparisons for battery-powered Electric and Plug-in Hybrid Vehicles

Vehicle	Engine Power (kW)	Engine/ Trans cost ($/kW)	Electric Motor Power (kW)	Motor/ Inverter Cost ($/kW)	Battery kWh	Battery Cost ($/kWh)	Manufacturing Cost ($) (1) Powertrain (2) Total veh
ICE Escort	67	1154 ($17 22/kW)	–	–	–	–	(1) 1154 (2) 5946
HEV Escort Range 25 miles	35	603	45	1980	5	2675 (Nimth, $535/kWh)	(1) 5258 (2) 10372
EV Escort Range 165 mi	–	–	65	2830 ($44/kW)	21	7541 (Nimth, ($357/kWh)	(1) 10371 (2) 15485
HEV Insight Range 40 miles	40	688	27	1188	6 5	3478	(1) 5354 (2) 10354
EV Insight Range 126 miles	–	–	50	2200	17 5	6248	(1) 8448 (2) 13448

Delta-manufacturing cost compared to an ICE car

- Hybrid (range 25-40 miles) $4400-$5300
- EV (range 130-165 miles) $8400-$9500

Fuel Economy of Small Plug-in Hybrid Vehicles using Lithium-ion Batteries

Vehicle	Battery Weight (kg)	All-electric Range on the FUDS (mi)	Driving Cycle	Fuel economy (mpg)
Concept FFEV	59	38	FUDS	61 7
			Highway	64 4
Insight	59	41	FUDS	67 3
			Highway	71.6

Conclusions

- **Performance** - no problem
- **Packaging** - no problem
- **Safety** - probably no problem with good engineering
- **Cost** - <u>this is the problem</u>, especially battery costs, need to be about $150/kWh

High Power, Long-Life Advanced VRLA for Cycling Application

May 16, 2001

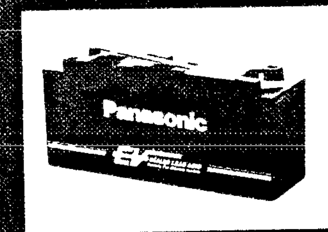
Kent Snyder
Naoto Hoshihara
Panasonic-Matsushita

High-power, Long-Life Advanced VRLA for Cycling Application

Kent Snyder
Naoto Hoshihara
Panasonic-Matsushita

snyderk2 @ panasonic.com

Principal Specifications / EV-VRLA



Dimensions	Height	175 mm
	Width	116 mm
	Length	388 mm
Weight		21.0 kg
Nominal Voltage		12 V
Nominal Capacity	3HR	60 Ah
Specific Power(25 °C)	DOD80%	200 W/kg

Panasonic

Long Cycle Life Advanced VRLA Battery for Vehicle Applications

	EV·VRLA	SV·VRLA	HV·VRLA
Utilization	PEV	NEV	HEV
Characteristics	High Power	High Energy	High Regenerative Power
	Long Cycle Life	Long Cycle Life	Long Cycle Life
Type	EC-EV1260	EC-SV1266	EC-HV1255
	EC-EV1238	EC-SV1242	EC-HV1235
	EC-EV1228	EC-SV1230	EC-HV1225

Panasonic

Characteristics of EV-VRLA Batteries

- ✓Long Cycle Life
  - 1000 Cycles (DST120)
- ✓High Specific Power
  - 200 W/kg at DOD80%
- ✓Rapid Charge Acceptance
  - 10 min. recovery from DOD80% to 20%

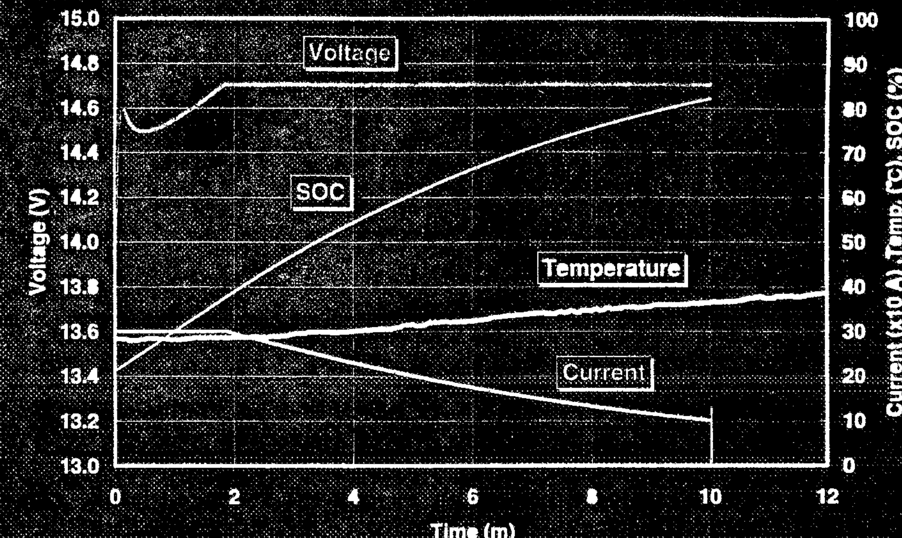
Panasonic

Development Technology of EV-VRLA Batteries

- ✔ **Grid Surface Treatment**
  - Double layer structure of Lead-alloy Sheet
- ✔ **High Power Design**
  - Optimized grid design for high power
  - Thin plate structure and product technology
- ✔ **Long Cycle Life Design**
  - High compression retention performance

Panasonic

Rapid Charge Performance



Panasonic

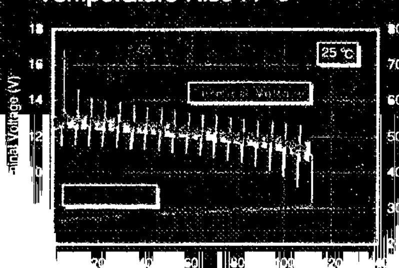
DST120 Performance & Charge Method

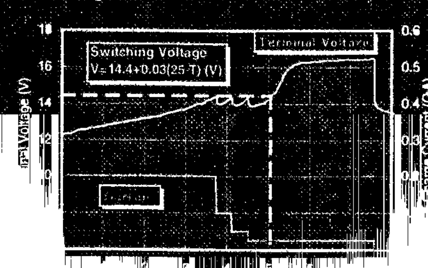
DST120 Discharge Performance

Discharge Capacity :55.6 Ah
Discharge Energy :632 Wh
Maximum Current
Discharge :305 A
Charge :110 A
Temperature Rise :4 °C

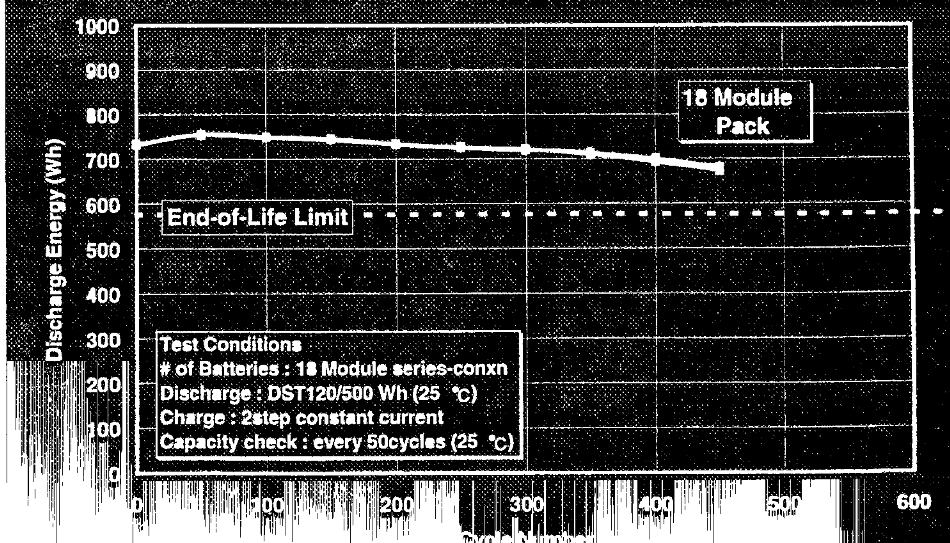
Charge Method (5-step CCC)

1st-4th Step charge: charge current
I_1=12.0 A, I_2=6.0 A, I_3=3.0 A, I_4=1.5 A
switching voltage
V=14.4 V+0.03 V(25-T)
T : battery temperature(°C)
5th Step charge:
charge current I_5= 1.5 A (=I_4)
charge time t_5= 2.5 h



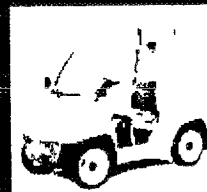


Cycle Life Performance in Vehicle Pack

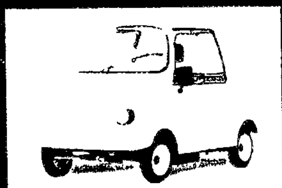


TAKEOKA AUTO CRAFT Co.,LTD.
Mounted type : EC-EV1260 (24 V)

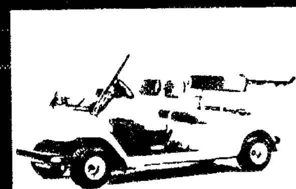
ARACO CORPORATION
Mounted type : EC-SV1242 (72 V)



TAKEOKA AUTO CRAFT Co.,LTD.
Mounted type : EC-SV1266 (48 V)



YAMAHA MOTOR Co.,LTD.
Mounted type : EC-EV1260 (72 V)



Panasonic

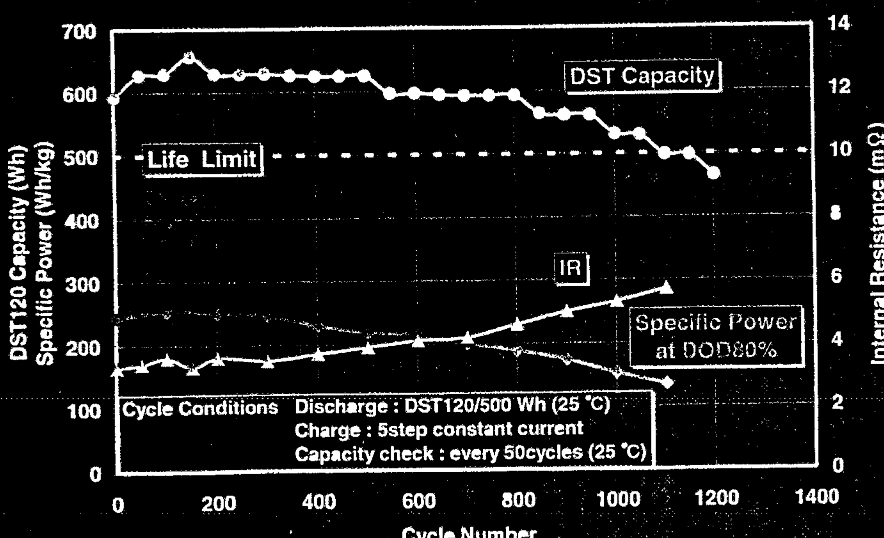
✔**High Energy Density**
100Wh/liter

✔**High Capacity**
10% greater capacity in comparison with EV-VRLA

✔**Long Cycle Life**
Improvement in 1/3C cycle life

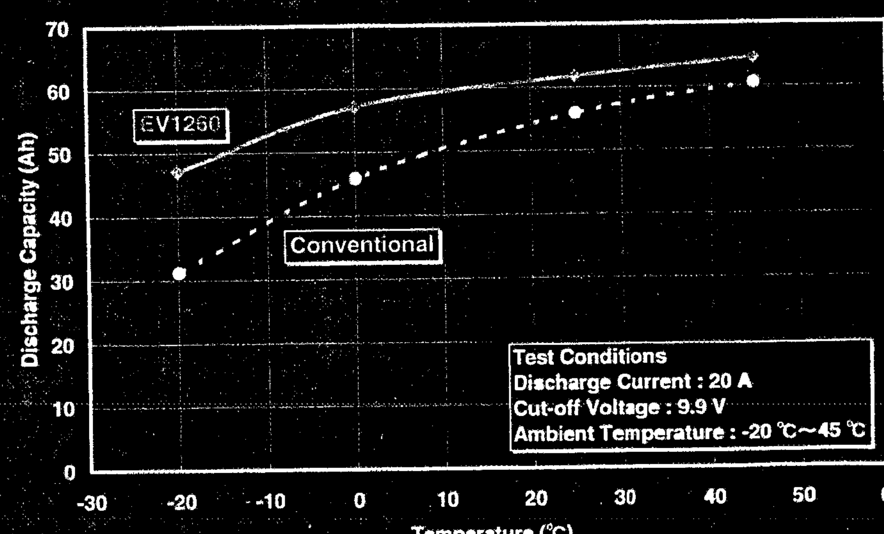
Panasonic

DST120 Cycle Life Performance



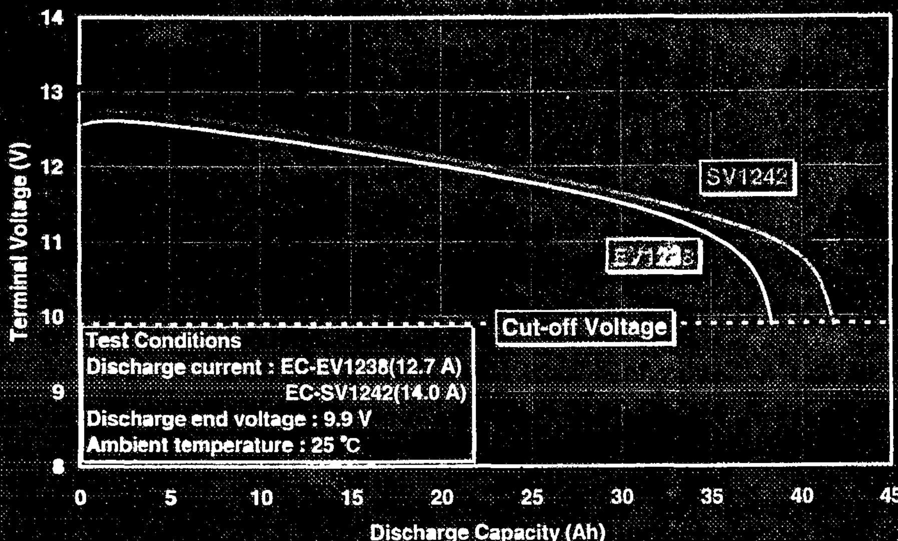
Panasonic

Discharge Performance



Panasonic

Discharge Performance



Panasonic

Principal Specification / EC-HV1225

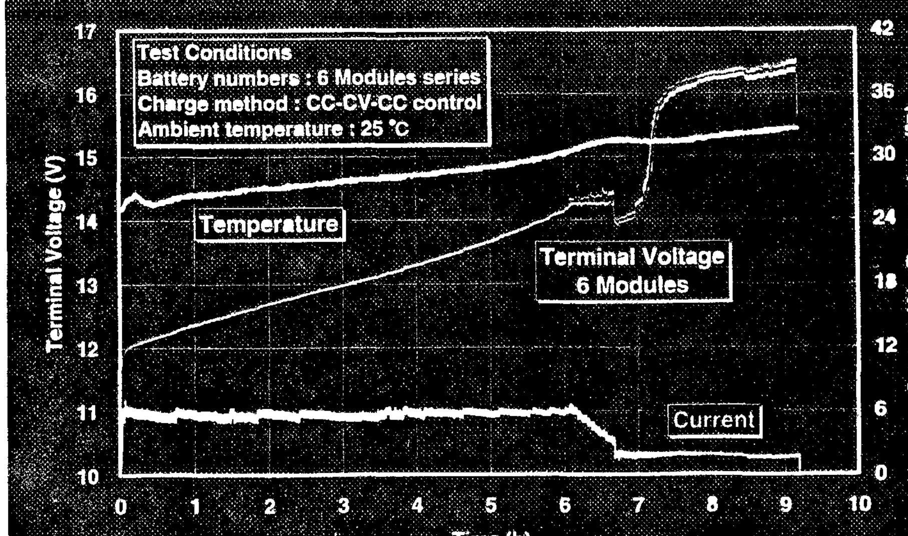
Dimensions	Height	175 mm
	Width	116 mm
	Length	200 mm
Weight		11.4 kg
Nominal Voltage		12 V
Nominal Capacity	3HR	25 Ah
Specific Power (25 ℃)	DOD50%	360 W/kg

Panasonic

Principal Specification / EC-SV1242

Dimensions	Height	175 mm
	Width	116 mm
	Length	261 mm
Weight		14.0 kg
Nominal Voltage		12 V
Nominal Capacity	3HR	42 Ah
Specific Power (25 ℃)	DOD80%	150 W/kg

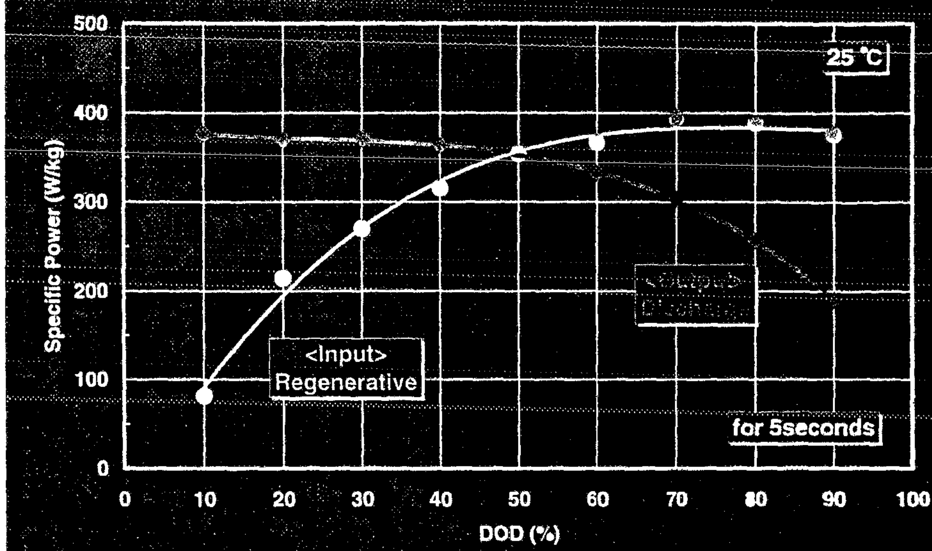
Charge Performance in a Battery Pack



Development Technology of HV-VRLA Batteries

- ✔Optimization of Additives
  - Improved negative electrode active material characteristics
- ✔Optimization of Grid Design
  - Super fine mesh grid for negative plate
- ✔Decreased Internal Resistance
  - Improvement of terminal component, etc.

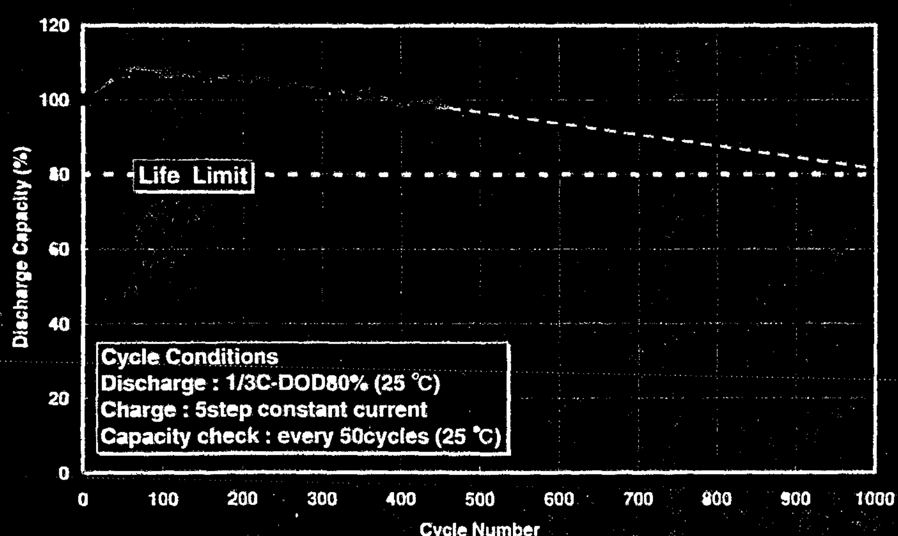
Panasonic



HV1225

Panasonic

Cycle Life Performance



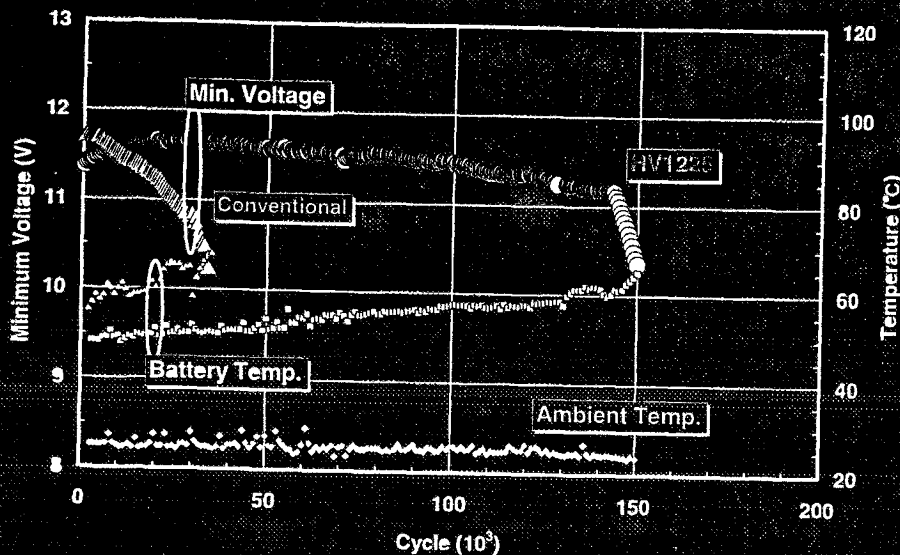
Panasonic

Characteristics of HV-VRLA Batteries

- ✔High Regenerative Power
  - (Output power)/(Input power) ratio = 1
- ✔High Specific Power
  - Over 10C discharge capability
- ✔Long Cycle Life
  - Improved cycle life on HEV*(PNGV)* pattern

Panasonic

PNGV Cycle Life Performance



Panasonic

Summary

✓We are developing long life VRLA batteries for PEV, NEV, and HEV applications

✓We will continue on our path to cost efficient VRLA batteries for EV and HEV applications

We believe our work will contribute to the developing EV market and to the reduction of environmental and energy problems

Panasonic

Output/Input Power Test Profile

- Current : $5C_3A$
- Temperature : 25 °C
- T_1=5 s

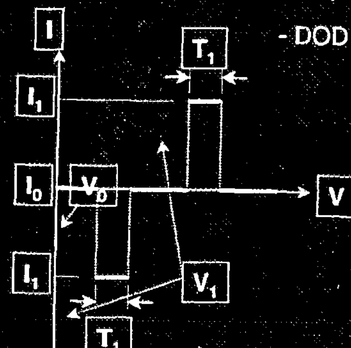
Battery Resistance

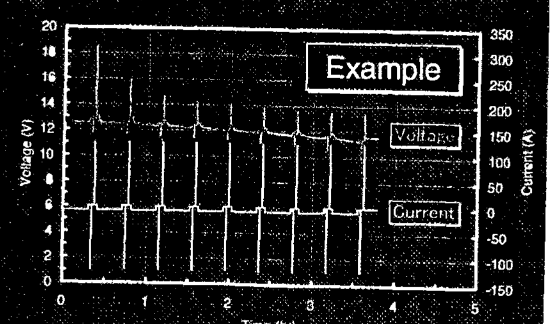
- $I_1=5C_3A$
- $R=(V_0-V_1)/(I_0-I_1)$ [ohm]
- DOD : every 10%

Pulse Power Capability

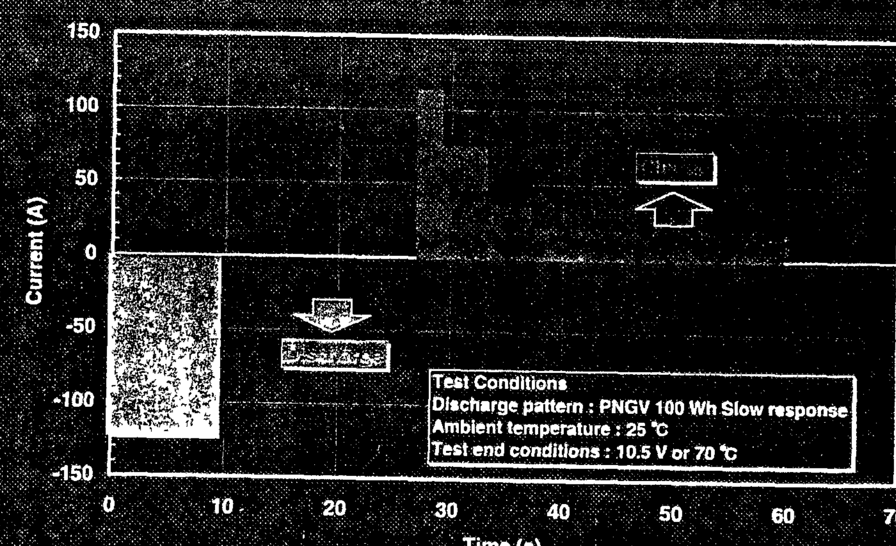
$= V_{cut} \times | OCV-V_{cut} | / | R |$

- Discharge : V_{cut} = 8.9 V
- Regeneration : V_{cut} = 15.3 V





PNGV Cycle Life Test Profile



ZEBRA Battery

May 16, 2001

Cord-H. Dustmann
MES-DEA

MES-DEA | ZEBRA

ZEBRA Battery

Cord - H Dustmann

MES-DEA S A
Stabio, Switzerland

ITS - Davis

Davis, 15/16 05 2001

MES-DEA | ZEBRA

ZEBRA, Best Available High Energy Battery

1 Basic battery chemistry
2 Cell Design
3 Battery Design
4 Battery System Components
 - **BMI** (**B**attery **M**anagement **I**nterface)
 - **MBS** (**M**ulty **B**attery **S**erver)
 - **BC** (**B**attery **C**harger)
5 Safety, durability, recycling
6 ZEBRA powered vehicles
7 Production, conclusion

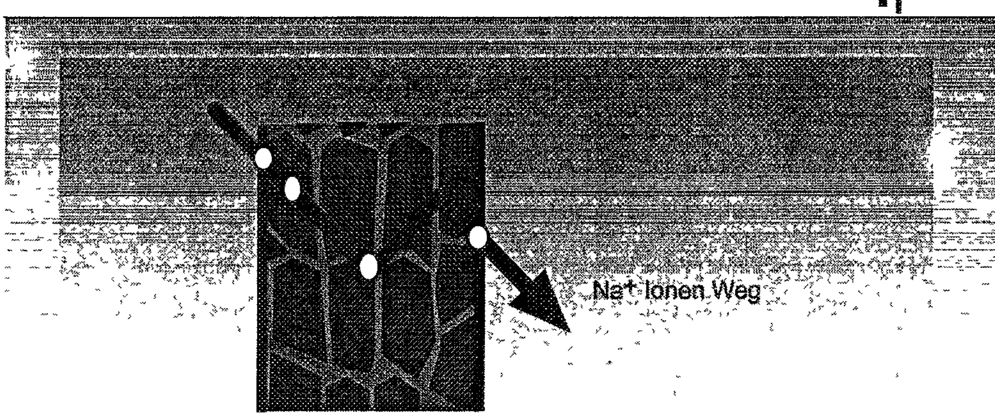
MES-DEA ZEBRA

Periodisches System der Elemente

Periode oder Schale	Zahl der Elemente je Periode	Gruppe I a b	Gruppe II a b	Gruppe II a b	Gruppe IV a b	Gruppe V a b	Gruppe VI a b	Gruppe VII a b	Gruppe VIII	Gruppe 0
K	2 1² = 2	1 H								2 He
L	2 2² = 8	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F		10 Ne
M	2 2² = 8	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl		18 Ar
N	2 3² = 18	19 K 29 Cu	20 Ca 30 Zn	21 Sc 31 Ga	22 Ti 32 Ge	23 V 33 As	24 Cr 34 Se	25 Mn 35 Br	26 Fe 27 Co 28 Ni	36 Kr
O	2 3² = 18	37 Rb 47 Ag	38 Sr 48 Cd	39 Y 49 In	40 Zr 50 Sn	41 Nb 51 Sb	42 Mo 52 Te	43 Tc 53 J	44 Ru 45 Rh 46 Pd	54 Xe
P	2 4² = 32	55 Cs 79 Au	56 Ba 80 Hg	57 La¹) 81 Tl	72 Hf 82 Pb	73 Ta 83 Bi	74 W 84 Po	75 Re 85 At	76 Os 77 Ir 78 Pt	86 Rn
Q		87 Fr	88 Ra	89 Ac²)	104					

Davis 15/16 5 2001 (3)

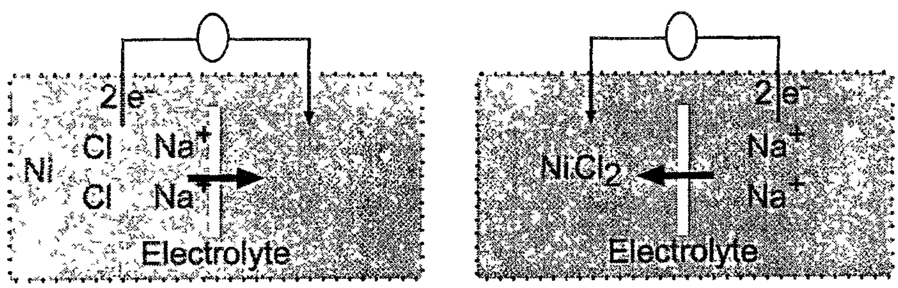
MES-DEA ZEBRA



R Keramik = Σ (interface1 + Kristall + KG + Interface2) + f (Orientierung)
R Keramik ca 6 Ω cm bei 300°C - bei Raumtemperatur > 20 kΩ cm

Davis 15/16 5 2001 (4)

MES-DEA ZEBRA



$$Ni + 2NaCl \longleftrightarrow 2Na + NiCl_2$$

ZEBRA Technology – Basic Electrochemistry

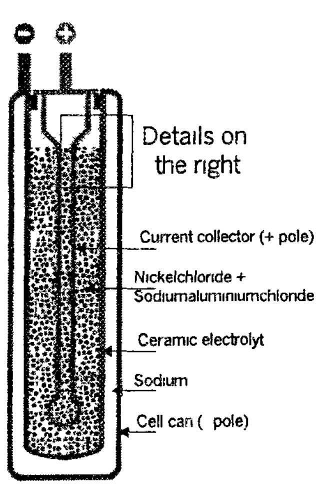
MES-DEA ZEBRA

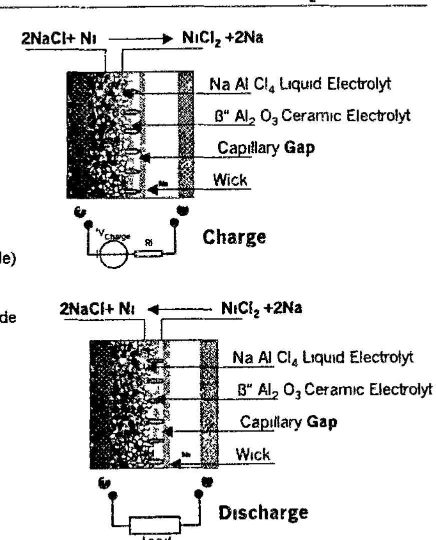
OCV 2 58 at 300°C,

Operating Range

270°C to 350°C,

Typical capacity 32Ah

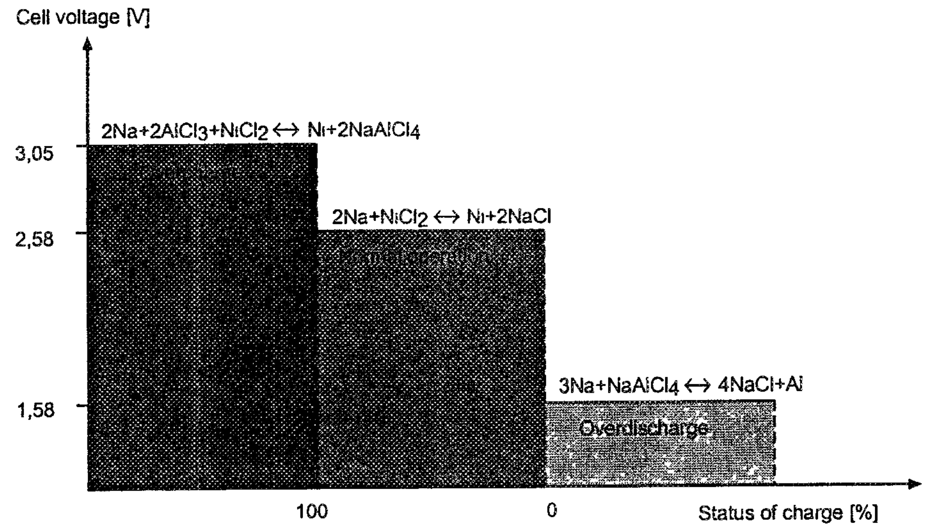




$$2\,NaCl + Ni \rightleftharpoons NiCl_2 + 2\,Na$$

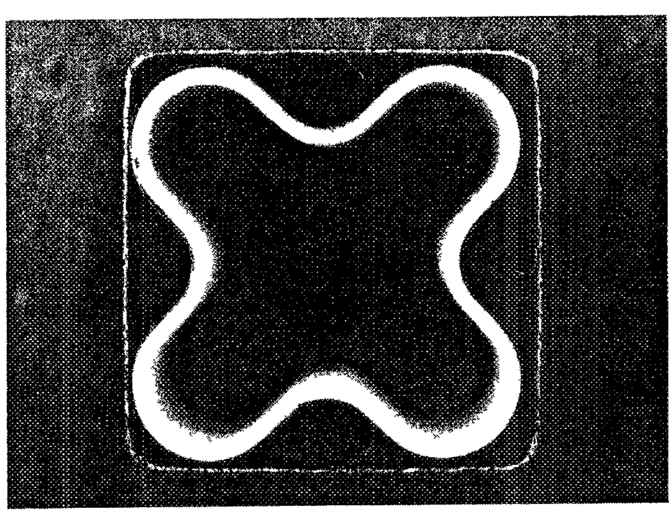
Cell Reaction

MES-DEA ZEBRA



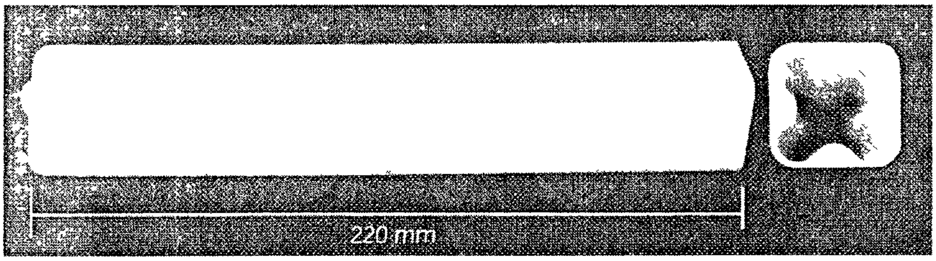
Cell Reaction at 300°C

MES-DEA ZEBRA



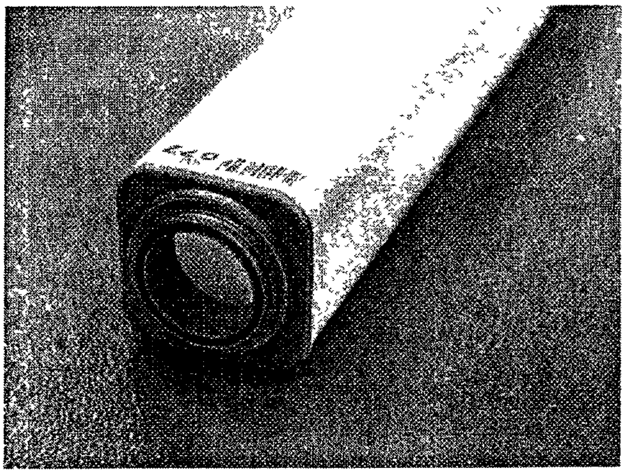
ML1 cell cross section

MES-DEA ZEBRA



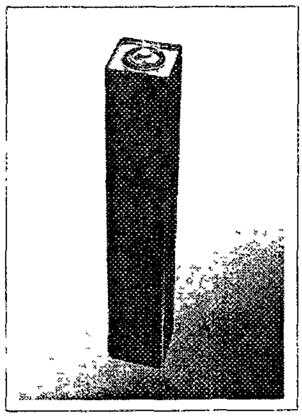
ß"- Alumina Electrolyt

MES-DEA ZEBRA



ß"- Ceramic with TCB

MES-DEA | ZEBRA

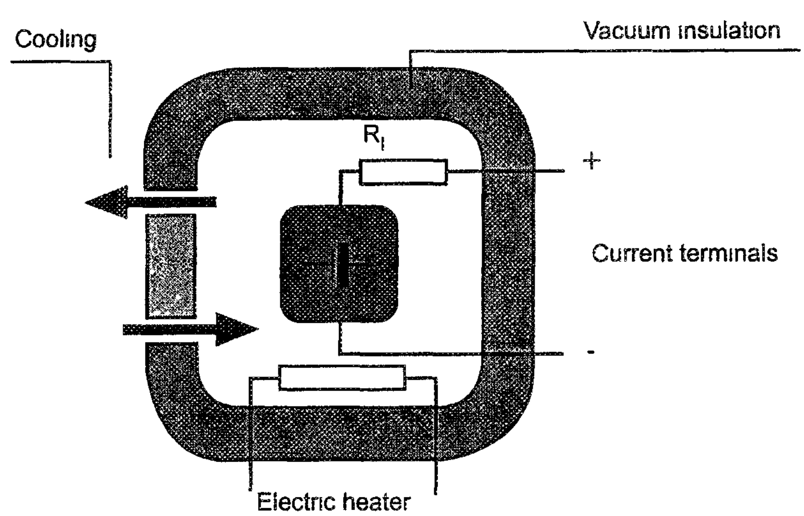


Ni + 2NaCl ⟷ 2Na + NiCl2

	unit	ML3	ML4	ML8
Capacity	*Ah*	32	26	20
OCV	*V*	2 58	2 58	2 58
Normal charge voltage	*V*	2 67	2 67	2 67
Fast charge voltage	*V*	2 85	2 85	2 85
Max Regen Voltage	*V*	3 1	3 1	3 1
Peak power (80% DOD, 2/3 OCV, 30s, 335°C)	*W*	185	155	125
Max current	*A*	+ 112/- 60	90	70
Weight	*g*	705	605	500
Lenght	*mm*	232	198	146
Specific energy	*Wh/kg*	117	110	103
Specific power	*W/kg*	262	256	250

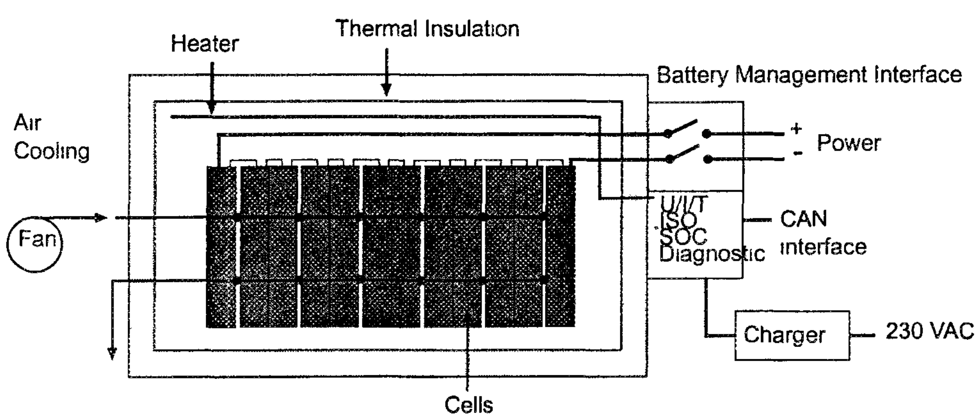
ß"- Ceramic with TCB

MES-DEA | ZEBRA



Heating / cooling System of the ZEBRA Battery

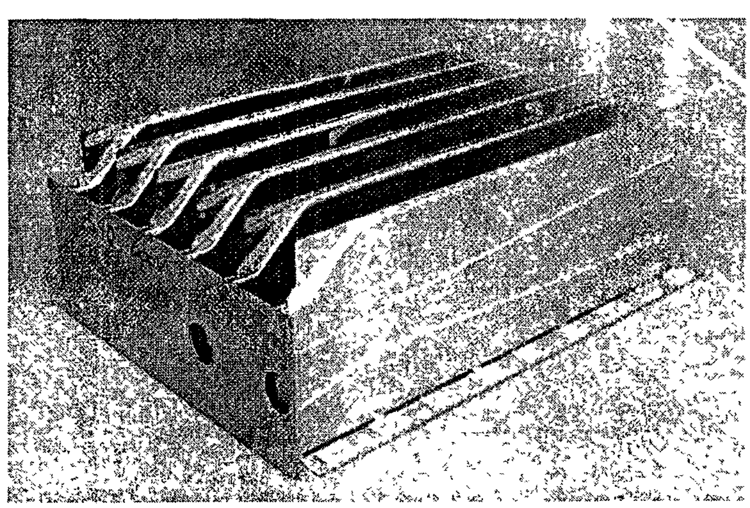
MES-DEA ZEBRA



Up to 16 battery units in parallel (285 kWh / 510 kW)

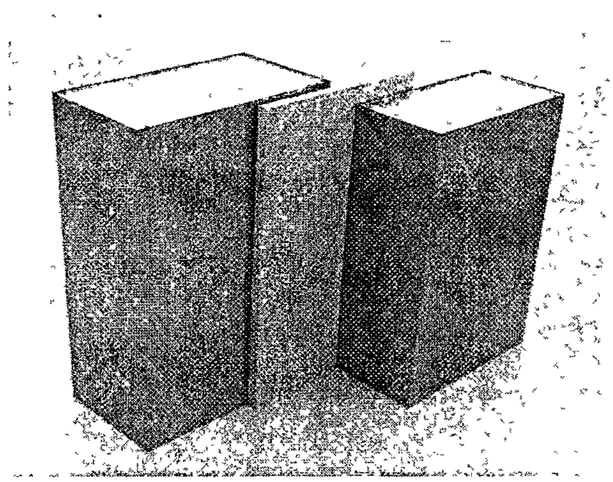
ZEBRA Battery System

MES-DEA ZEBRA



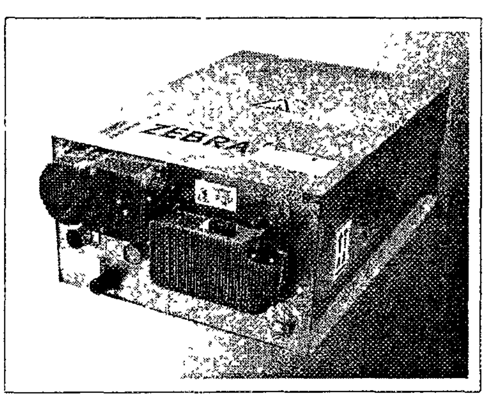
Cooling Plates

MES-DEA | ZEBRA



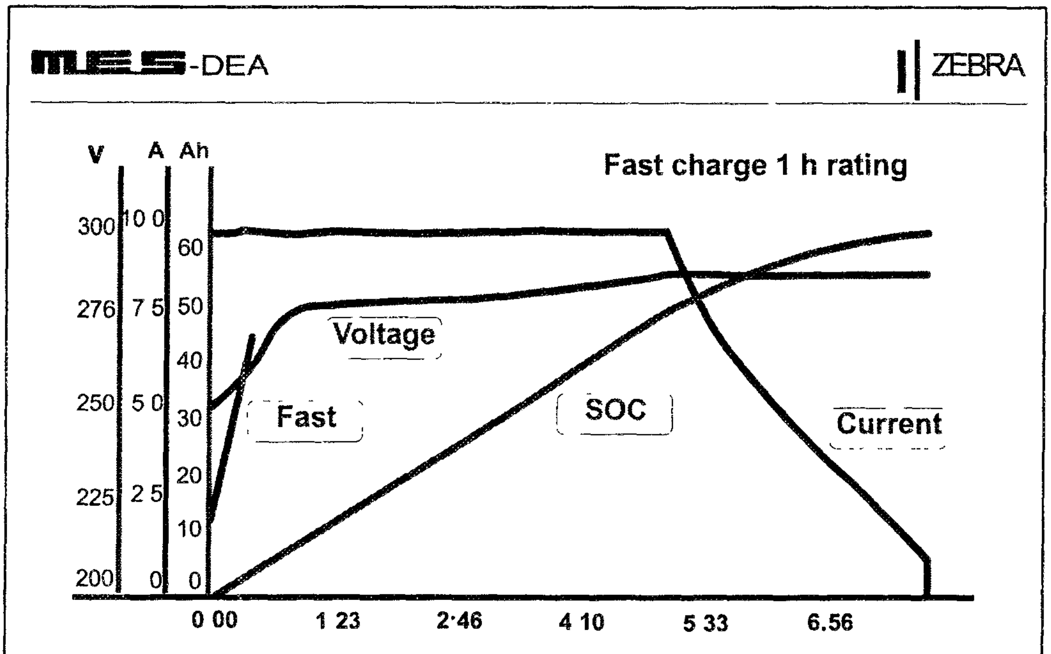
Insulation box

MES-DEA | ZEBRA

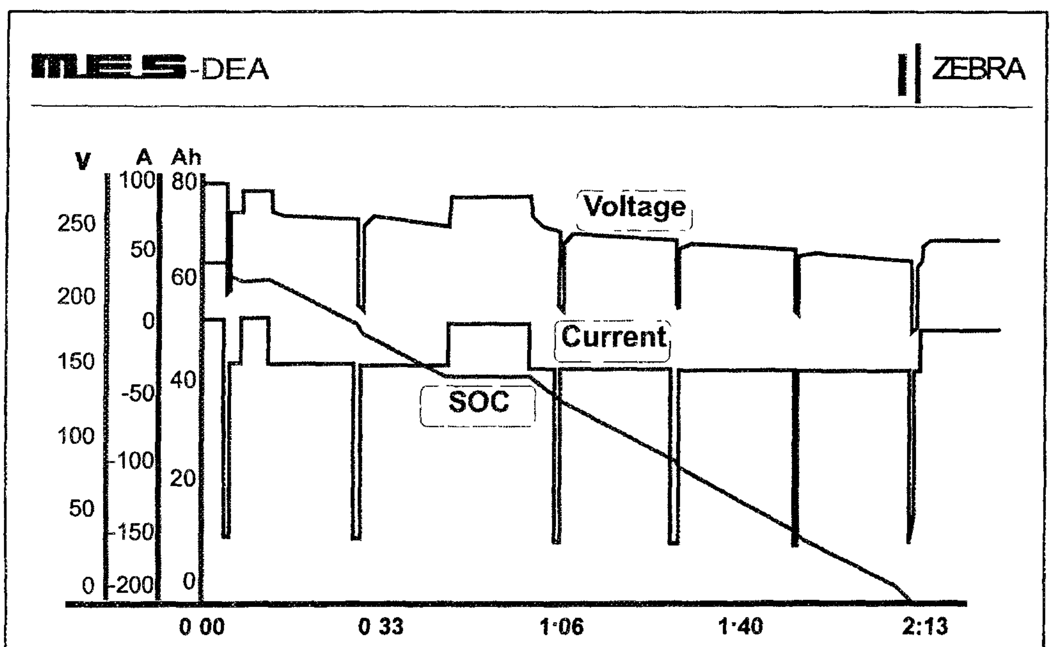


Type		Z5-278-ML-64	Z5-557-ML-32
Capacity	Ah	64	32
Rated Energy	kWh	17 8	17 8
Open Circuit Voltage 0-15% DOD	V	278 6	557
Max discharge current	A	224	112
Cell Type/N° of cells		ML3 / 216	
Weight with BMI	kg	195	
Specific energy without BMI	Wh/kg	94	
Energy density without BMI	Wh/l	148	
Specific power	W/kg	169	
Power density	W/l	265	
Peak power 80% DOD 2/3 OCV 30s 335°C	kW	32	
Ambient temperature	°C	-40 to +50	
Thermal loss at 270°C internal temperature	W	< 110	

Z5 standard Battery with main data

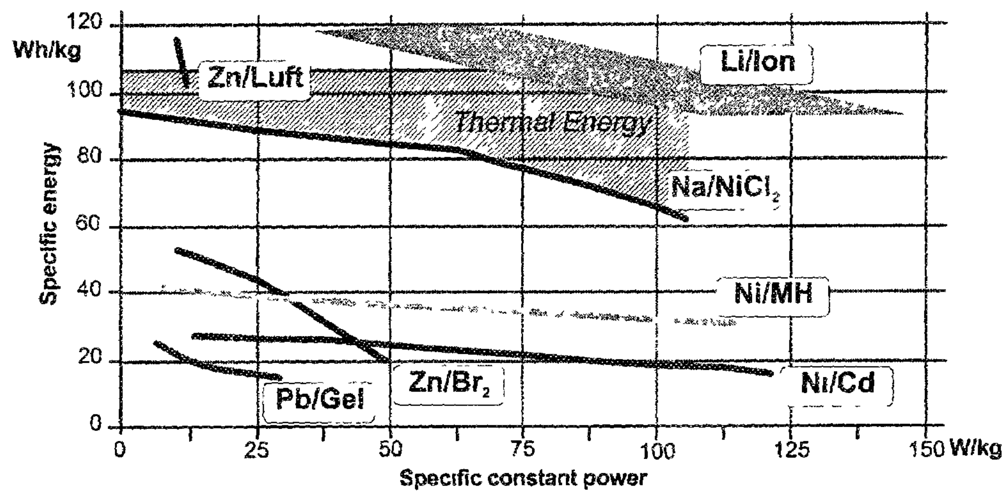


Z5C Normal Charge ın 7 5h



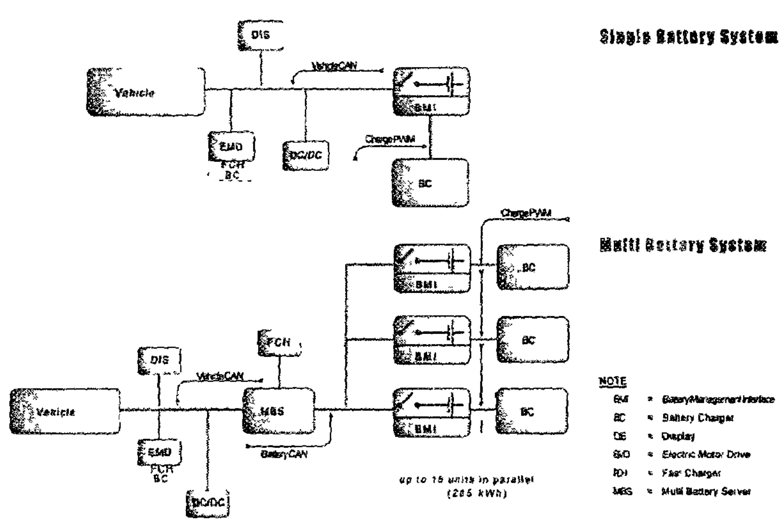
Integrated booster

MES-DEA | ZEBRA



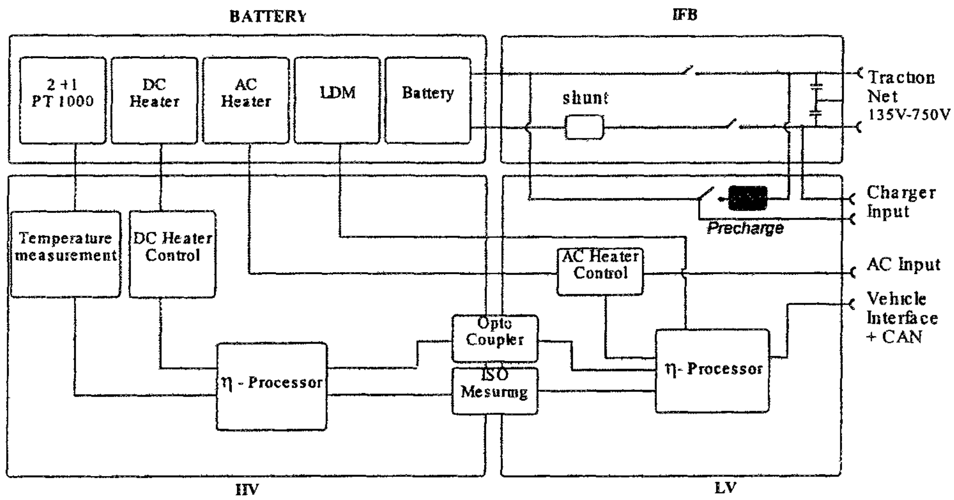
Ragone Diagram for traction batteries

MES-DEA | ZEBRA



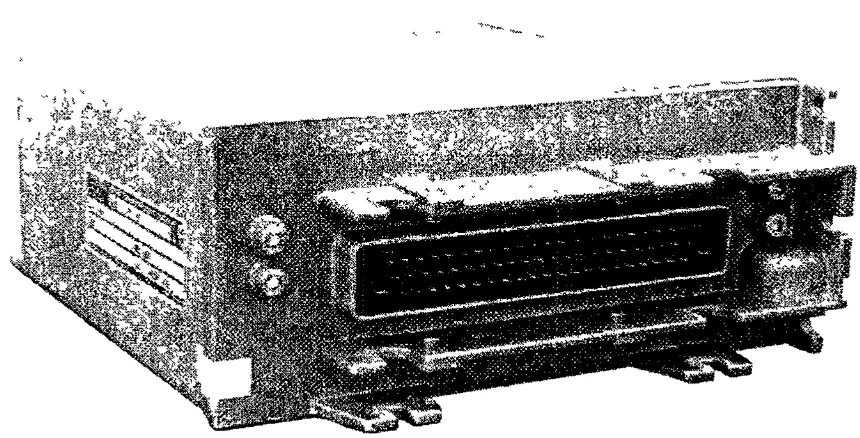
ZEBRA Battery System Design

MES-DEA | ZEBRA



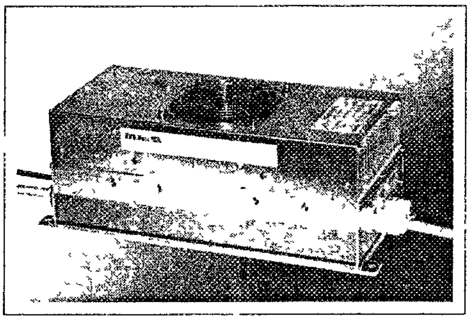
BMI – **B**attery **M**anagement **S**ystem

MES-DEA | ZEBRA



MBS – **M**ulty **B**attery **S**erver

MES-DEA | ZEBRA

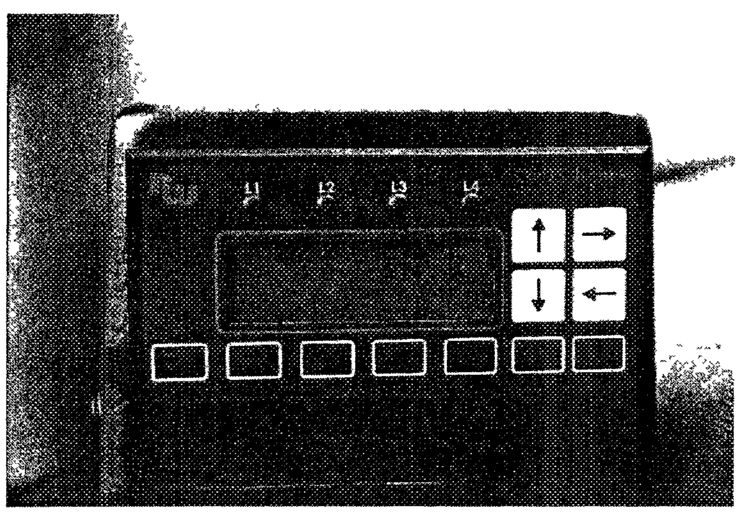


Technical data (Preliminary) — ZEBRA® Chargers

Type	Unit	BC-278-Z-3-A	BC-557-Z-3-A
Output voltage	V	240 to 305	480 to 610
DC output power	W	3300	
Input current AC	A	- 15,5	
Efficiency / load		95%/3 3 kW, 90%/400W	
Protection class		IP 6 5	
Input voltage		170-253VAC, 47-63 Hz	
Control		PWM by BMI	
Cooling		Air	
Ambient temperature		-25°C to 40°C 40°C to 70°C derated	
EMC		95/54/EG	
Weight	kg	ca 8	

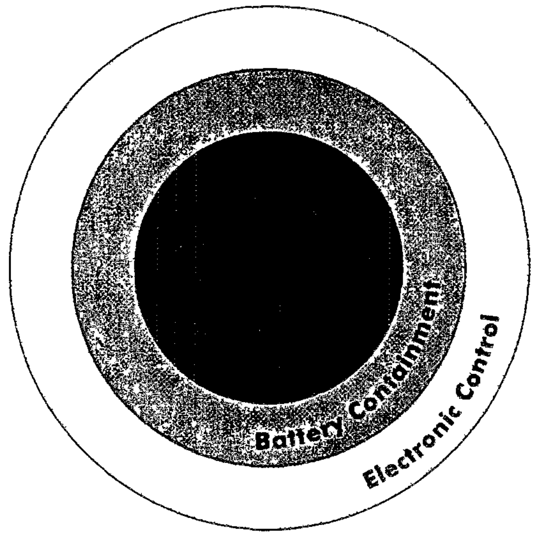
Battery Charger

MES-DEA | ZEBRA



Can Display

MES-DEA ZEBRA

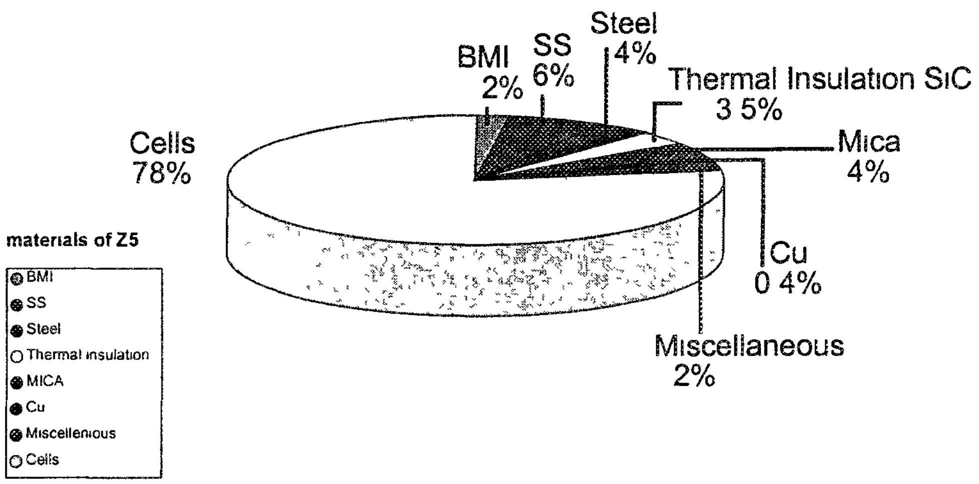


ZEBRA Battery Safety Concept

MES-DEA ZEBRA

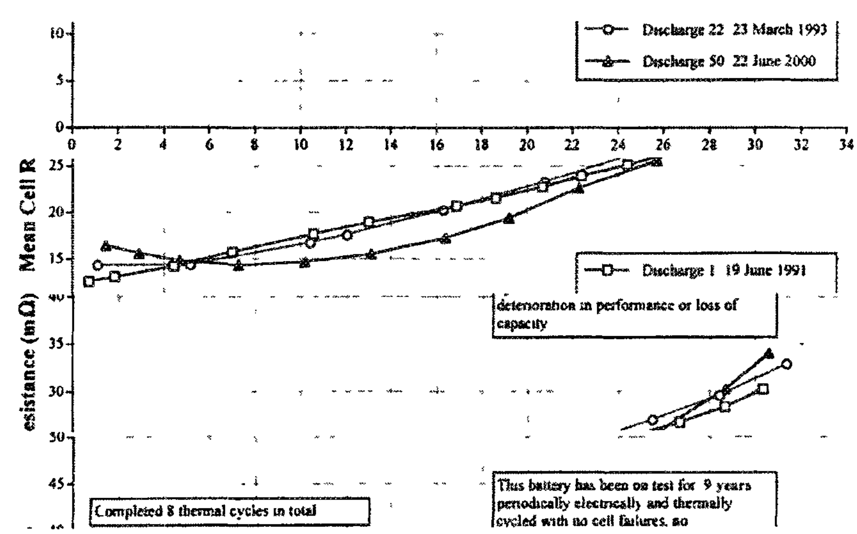
ZEBRA Battery Type Z12 – Crash test at 50 Km/h

MES-DEA ZEBRA



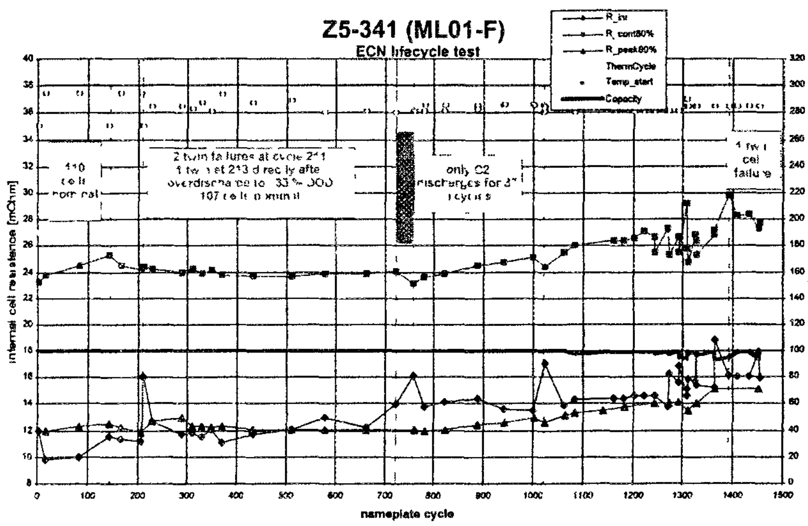
Material of ZEBRA Battery Type Z5 (Weight 195 kg)

MES-DEA ZEBRA



Calendar life

MES-DEA ZEBRA



Cycle life

MES-DEA ZEBRA

Requirements of the Automotive Industry

PW	"soft" Hybrid, 42 V, 1-2 kWh, 10-20 kW
	"power assist" Hybrid, 300 V, 2-4 kWh, 25-40 kW
	"range extender" Hybrid, 300 V, 20-30 kWh, 40-60 kW
Transporter	
(+ minibuses)	300 V, 30-50 kWh, 40-60 kW
Buses	EV, 300 oder 600 V, 90-285 kWh, 80-120 kW
	HEV with EV, 600 V, 35-70 kWh, 60-120 kW
	HEV without ZEV, 600 V, 10-30 kWh, 60-120 kW

MES-DEA | ZEBRA

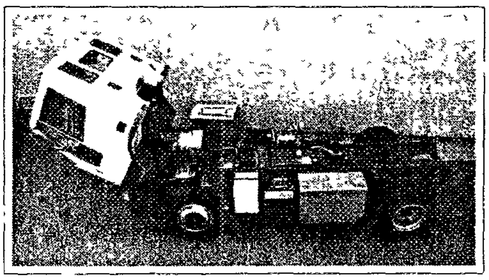
Payload	600 kg
Drive	Asynchronous Motor
Drive Power	40kW at 2000-5000/min
Type of Battery	2 x Z5C
Energy Content	35,6 kWh
Battery Voltage (OCV)	278V
Weight of Battery	400 kg
Maximum Speed E	120 km/h
Range	120-170 km

Vito 108E of DaimlerChrysler with ZEBRA

MES-DEA | ZEBRA

Electric Sprinter for City-Logistic

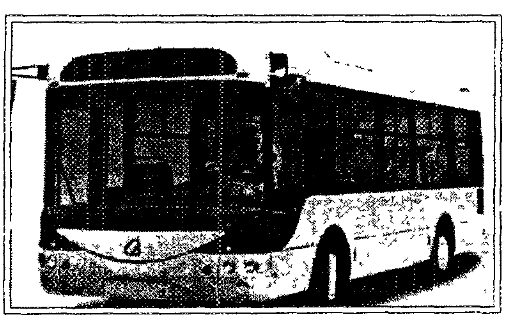
MES-DEA ZEBRA



Payload	9 t
Drive	Continuous Power 38 kW
Drive Power	Peak Power 83 kW
Type of Battery	6 x Z5
Energy Content	102 kWh
Battery Voltage (OCV)	278V
Weight of Battery	1200 kg
Maximum Speed E	70 km/h
Range	150 km

Microvett 15t – Imola, Italy

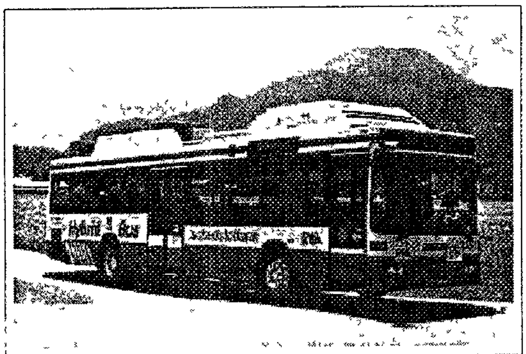
MES-DEA ZEBRA



	Hybrid	Electric
Capacity	10 + 1 Seating 29 Standing	10 + 1 Seatin 29 Standing
Drive	Brushless DC	Brushless DC
Drive Power	50kW	50kW
Type of Battery	2 x Z5C	5 x Z5C
Energy Content	35 6 kWh	89 kWh
Battery Voltage (OCV)	279 V	279 V
Weight of Battery	400 kg	1000 kg
Maximum Speed E	50 km/h	60 km/h

AUTODROMO City Bus in Bologna, Italy In Service

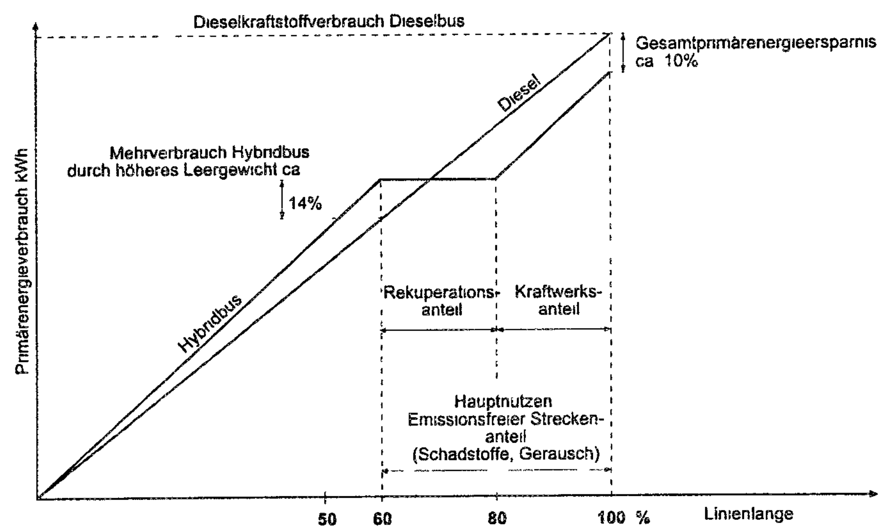
MES-DEA ZEBRA



Capacity	**34 Seating** **68 Standing**
Drive	**2 Asynchron** **Hub Motors**
Drive Power	**150kW**
Type of Battery	**2 x 2 x Z5 A/B**
Energy Content	**68 kWh**
Battery Voltage (OCV)	**2 x 284 = 568 V**
Weight of Battery	**800 kg**
Maximum Speed E	**60 km/h**
E-Range per Charge	**40 - 70 km**

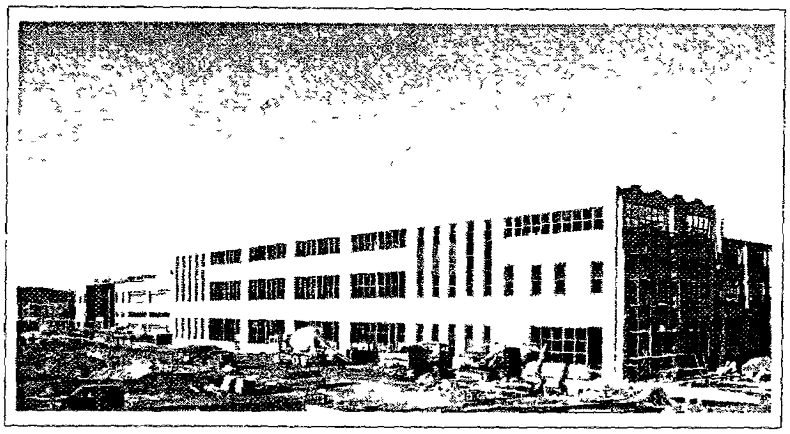
40ft Hybrid Bus from EvoBus operate in Oberstdorf, Germany and in Leiden, Holland

MES-DEA ZEBRA



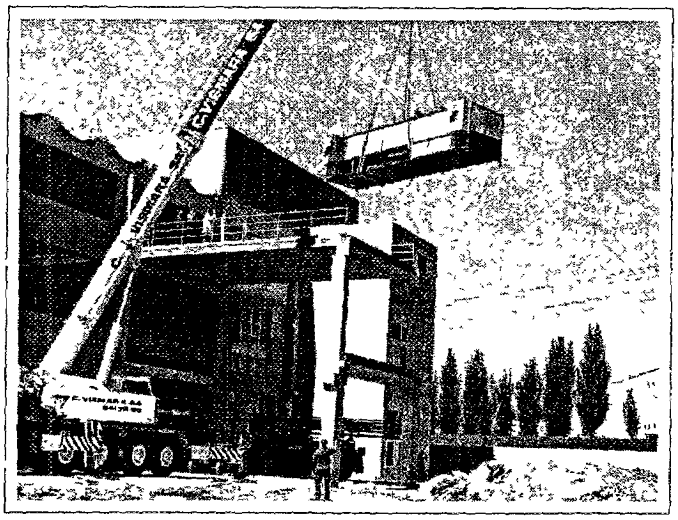
Energiebilanz von Hybridbussen mit ZEBRA Batterie

MES-DEA ZEBRA



ZEBRA Plant - February the 01th 2001

MES-DEA ZEBRA



ZEBRA Plant - April the 24th 2001

Marketing Neighborhood, City, and Small Highway-capable Electric Vehicles

May 16, 2001

Ken Kurani
Institute of Transportation Studies, Davis

Marketing Neighborhood, City, and Small Highway-capable Electric Vehicles

16 May 2001

Ken Kurani
Institute of Transportation Studies
University of California, Davis

Market Segments and Sizes

- Types of small EVs
- Some things we've learned
- Market Segments
  - Who?
    - Where?
- Market Segment Size
  - How many?
- What next?

Studies at ITS-Davis

- Highway-capable EV Market Studies
  - 1991 to 1997
  - Household markets for vehicles and electricity
- Neighborhood Electric Vehicle Studies
  - 1993 to 1995
  - Multi-objective
- Secondary Benefits of ZEVs Report
  - Summer 2000

Other Works

- City EV Station Car User Evaluation
  - 1997
- Consumer Benefits of EVs and Plug-in HEVs
  - 1998
- Consumer Markets for EVs
  - Green Car Institute, 2000

Subsequent Events

- New Types of Vehicles
  - NHTSA Low Speed Vehicle definition
    - Four wheels, 20 to 25mph max speed
    - FMVSS No 500 (49 CFR 571 500)
      - head stop turn signal, and tail lamps, reflectors parking brakes, rearview mirrors windshields, seat belts and VINs
  - Examples
    - GEM Neighborhood EV, TH!NK Neighbor

Subsequent Events

- New types of vehicles
  - City EVs
    - not quite highway-capable
      - top speeds varying from 56 to 62mph
      - none as yet certified to FMVSS for light duty motor vehicles
    - two-seats (so far)
  - Examples
    - Toyota e•com, Nissan Hypermini, TH!NK City

What vehicles have we studied?

	Type	Seating	Speed	Range
Golf car case study	Golf cars	2	18 to 20	15 to 25
Ride n drives	NEVs and CEVs	1 to 4	35 to 75	2to 80
Household trials	NEVs	1 to 2	35 to 40	20 to 35
CA Survey	NEV	2 to 4	40	40
	Comm EV	2 to 7	70	60 to 80
	Region EV	2 to 7	85	120 to 150
City EV	CEV	2	68	40 to 55

Contexts for Decisions

- Land Use
  - Small towns big cities
  - Low-density suburb, medium-density city
- Activity-based Approaches to Travel Analysis
  - Build your own action space

A Few Things we Learned

- Vehicle "choice" shifts
- The effects of constraints on travel decisions
- How far a household can travel in a NEV
- Mode shifts within households
- All places are not equal
- User valuation of vehicle characteristics

Vehicle "Choice" Shifts

	Preferred Body Style	
Type Choice	Non-EV Style	EV Style
Neighborhood EV	6	12
Community EV	5	21
Regional EV	37	81
Range-extend HEV	15	27
Natural Gas	33	52
Gasoline	53	96

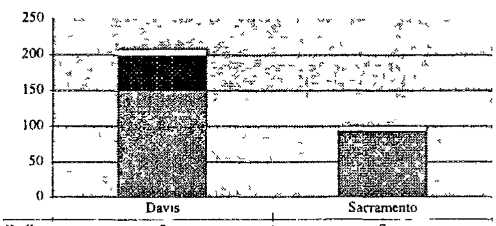
The Effects of Constraints

	Could trip be made another time?		
Serve Passenger?	No	Yes	Total
No	387	244	631
Yes	128	13	141
Total	515	257	772

How far a Household can Travel in a NEV

NEVs in Davis and Sacramento	Percent		
	Mean	High	Low
Trips	41	72	10
Miles	19	43	6

NEV Mode Shifts within Households



	Davis	Sacramento
Walk	9	7
Bicycle	48	0
ICE	151	93

All Places are not Equal

- NEVs can displace many trips and much VMT in households
- Household travel mode splits during NEV tests depend on prior behavior
  - determined in part by local land use and transportation options
- NEVs can displace environmentally superior options for some trips

User Valuation of Characteristics

- Less-than-highway-capable vehicles
  - Users start to group vehicle characteristics
    - Range and Top Speed
    - Passenger Seating and Cargo Capacity
    - Top Speed, Vehicle Size, Handling, and Safety
- A word about Plug-in Hybrids
  - Benefits based on threes systems
    - Environmental, Recharging, Drivetrain

Market Segments

- Small vehicles
  - One or two seats, regardless of range or speed
- Hybrid households
  - City EVs, Small Highway-capable EVs
- LSV-amenable places

Small Vehicles

- Pro
  - One-person households?
    - Over 25 percent of US households (2000 Census)
- Con
  - Small car sales historically tiny
    - Two-seats 1 1 percent of new car sales
    - Automotive News "budget" and "small" cars 21 2 percent of cars
  - Based on the wrong question

Hybrid Households

- Guestimate from 1995 ITS
  - 2 percent combined Neighborhood/Community EV market share
    - Only small and compact sedans, sports car, and compact pickup truck body styles
    - Not LSVs/CEVs
- Guestimate from 2000 GCI
  - Interested?
    - 24 percent LSV, 43 percent CEV
  - 1 percent new LDV market share

LSV Amenable Places

- Markets for LSVs defined
  - primarily by characteristics of the use environment
  - secondarily by characteristics of the user
- Places can be dynamic too
  - do LSVs fit the place, and the plans for the place?
- Infrastructure includes roadway, vehicle maintenance, electricity distribution,

What do We do Now?

- Whose We?
  - Broad coalitions of stakeholders
    - Government
    - Industry
    - Issue Advocates
    - Independent Researchers
- Marketing Green and Social
  - Market Research based on multiple methods, multiple types of exposures

Why Market?

- Build market segments
  - Motivate consumers and producers
  - Facilitate expression of a wider set of household lifestyle goals and values
- Transform Markets
- Avoid gaming of regulations

What do We do Now?

- City EVs, Small Highway-capable EVs and Hybrid EVs
  - Users will figure them out
- LSVs and City EVs
  - Users are constrained as to where they can use such vehicles
    - Market in those places that are suitable
    - Building and retrofitting
      - Palm Desert, PASStown, New Urbanism

Shared-Use Fleets: Lessons Learned

May 16, 2001

Susan Shaheen, Ph.D.
Honda Distinguished Scholar
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New Mobility Center & PATH

SHARED-USE FLEETS: LESSONS LEARNED

Susan A. Shaheen, Ph.D.
Honda Distinguished Scholar
University of California,
New Mobility Center & PATH
ITS-Davis ZEV Mandate Workshop
May 16, 2001

SHARED-USE FLEETS: OVERVIEW

- Carsharing and CarLink Defined
- CarLink I Findings & Management Issues
- Market Opportunities
- Pilot Project Recommendations

WHAT IS CARSHARING?

- Individuals Gain the Benefits of Private Cars without the Costs and Responsibilities of Ownership
- Individuals Access a Fleet of Cars
- Generally, Participants Pay a Usage Fee Each Time a Vehicle Is Used

ROOTS IN EUROPE

- Sefage (1948) of Zurich, Switzerland
- Recent developments began in 1980s
- Over 200 fleets active in 400 cities
- Claim over 125,000 participants
- Mobility (Switzerland, 1987) and StadtAuto (Bremen, 1990)

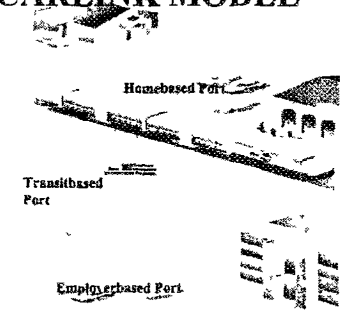
U.S. TRENDS: 1998 TO PRESENT

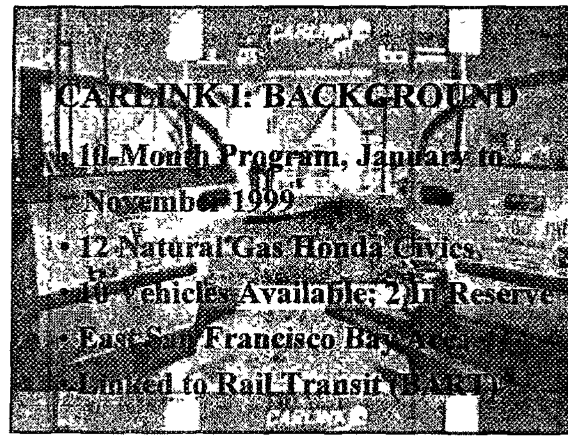
- 8 Carsharing Programs
- 2 Station Car Programs
- 2 Pilot Research Programs
- 9 Planned Programs
- Advanced Technologies
- Partnership Management
- Pioneering ---> Growth & Volume Phase

WHAT IS CARLINK?

- A Commuter-Based Carsharing Program, Linked to Transit
- Public-Private Partnership
- Smart Technologies
- Three User Groups: Homebased Users, Workbased Commuters, and Day Users

CARLINK MODEL





CARLINK I: USER GROUPS

- Homebased Users: $200/Month (Per Vehicle)
- Workbased Commuters: $60/Month (Minimum of Two Participants Per Vehicle)
- Day Users: $1.50/Hour and $.10/Mile

CARLINK I: PROGRAM FINDINGS

- 54 Participants
- 67% Male and 69% Married
- 81% Homeowners and All Employed
- 81% Average Yearly Income of > $50,000
- 36% — 24 to 40 Years of Age
- 59% — 41 to 64 Years of Age
- 75% Bachelor's Degree or Higher

CARLINK I: KEY FINDINGS

- Environmental Concern High
- Reduced Cost & Increased Convenience Key Usage Factors
- Users Wanted More Mixed Fleet (e.g., Pickup Truck)
- Members Would Share Rides More Frequently, If Communication Facilitated

CARLINK I: KEY FINDINGS

- If a Permanent Service, Several Homebased Users Would Sell Personal Vehicles
- Net Reduction in Vehicle Miles Per Day (~20 Miles) for CarLink Commuters
- At Least 20 New BART Trips Generated Per Day

CARLINK I: MANAGEMENT ISSUES

ISSUE ONE

Vehicle Maintenance & Emergencies

RESOLUTION

- Personnel Provide Quick Response
- 24-Hour Roadside Assistance
- Local Dealership for Servicing/Repairs
- Hide-A-Keys in Emergency

CARLINK I: MANAGEMENT ISSUES

ISSUE TWO

Clean-Fuel Vehicle Refueling

RESOLUTION

- **Guidelines for Refueling—1/4 Tank**
- **Fueling Cards**
- **Anticipate Demand**
- **Refueling Training**
- **High-Quality & Multiple Refueling Sites**

CARLINK I: MANAGEMENT ISSUES

ISSUF THREE:

Vehicle Cleanliness

RESOLUTION·

- **Guidelines for Cleaning Own Trash**
- **Personnel or Detailing Company to Service (Wash & Vacuum)**
- **Economic Penalties**

CARLINK I: MANAGEMENT ISSUES

ISSUE FOUR·

Vehicle Insurance

RESOLUTION·

Umbrella Policy Through Organizations Specialized in Shared Fleets (e g , Insurance One & VPSI)

CARLINK I: MANAGEMENT ISSUES

ISSUE FIVE

- **Scheduling & Billing**
- **Smart Access & Vehicle Tracking Technologies**

RESOLUTION·

- **Develop or Purchase Advanced Technology**
- **Integrate Systems, Where Possible**
- **Test Prior to Launch**

CARLINK I: MANAGEMENT ISSUES

ISSUE SIX.

Parking & Lot Assignment

RESOLUTION.

- **Partner to Access Subsidized/Donated Premium Parking**
- **Flexibility with Customers in Identifying Lots**
- **Employ Wireless Management System**

CARLINK I: MANAGEMENT ISSUES

ISSUE SEVEN
Roadside Service

RESOLUTION
Contract with 24-Hour Provider for Emergency Service

CARLINK I: MANAGEMENT ISSUES

ISSUE EIGHT:
Guaranteed-Ride Service

RESOLUTION:
- Provide Guaranteed Taxi or Shuttle Service
- Partner with Region, If Possible, To Access Free, Ride-Home Services (Demand-Management Strategy)

CARLINK I: MANAGEMENT ISSUES

ISSUE NINE:
Lost & Found System

RESOLUTION:
Provide Lost & Found Center for Retrieving Items Left in Fleet Vehicles

CARLINK II: MAY 2001

- Public-Private Partnership: UC Davis, PATH, Caltrans, Honda, and Caltrain
- 27 ULEV Civics Based Out of Caltrain Station
- Homebased Users and Business Subscribers
- Advanced Seamless Technology

CarLink II

MARKET OPPORTUNITIES

- Incentives: Parking & Policy
- Media: Marketing & Social Tool
- Data: Feedback & Customer Understanding

INCENTIVES

- ZEV Mandate Credits for Shared Use Systems
- Parking, Where Limited is Huge Incentive
- Reduced Fares (e.g., Transit)
- Discounts at Local Stores
- Frequent Flyer Miles
- Access to HOV or HOT Lanes

MEDIA: A MARKETING TOOL

- Can Increase Program Interest
- Subsidize Marketing Costs
- Promote Social & Environmental Benefits of Program

AUTOMATED DATA

- Instant Feedback on System Functionality
- Key Information to Improve Service Logistics
- Understanding of Underlying Market Forces

PILOT PROJECTS: RECOMMENDATIONS

- Outline Project Purpose & Design
- Maintain Flexible Partnership Management
- Integrate Smart Technologies
- Employ Economic Signals
- Trial & Reduced User Fees

PILOT PROJECTS: RECOMMENDATIONS

- Adjust User Guidelines As Necessary
- Deploy Top-Notch Clean Fuel Infrastructure
- Apply for Demonstration Grants
- Conduct Nonmonetary Benefits Research

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