PHEV and Electric Vehicles

28 October 2010

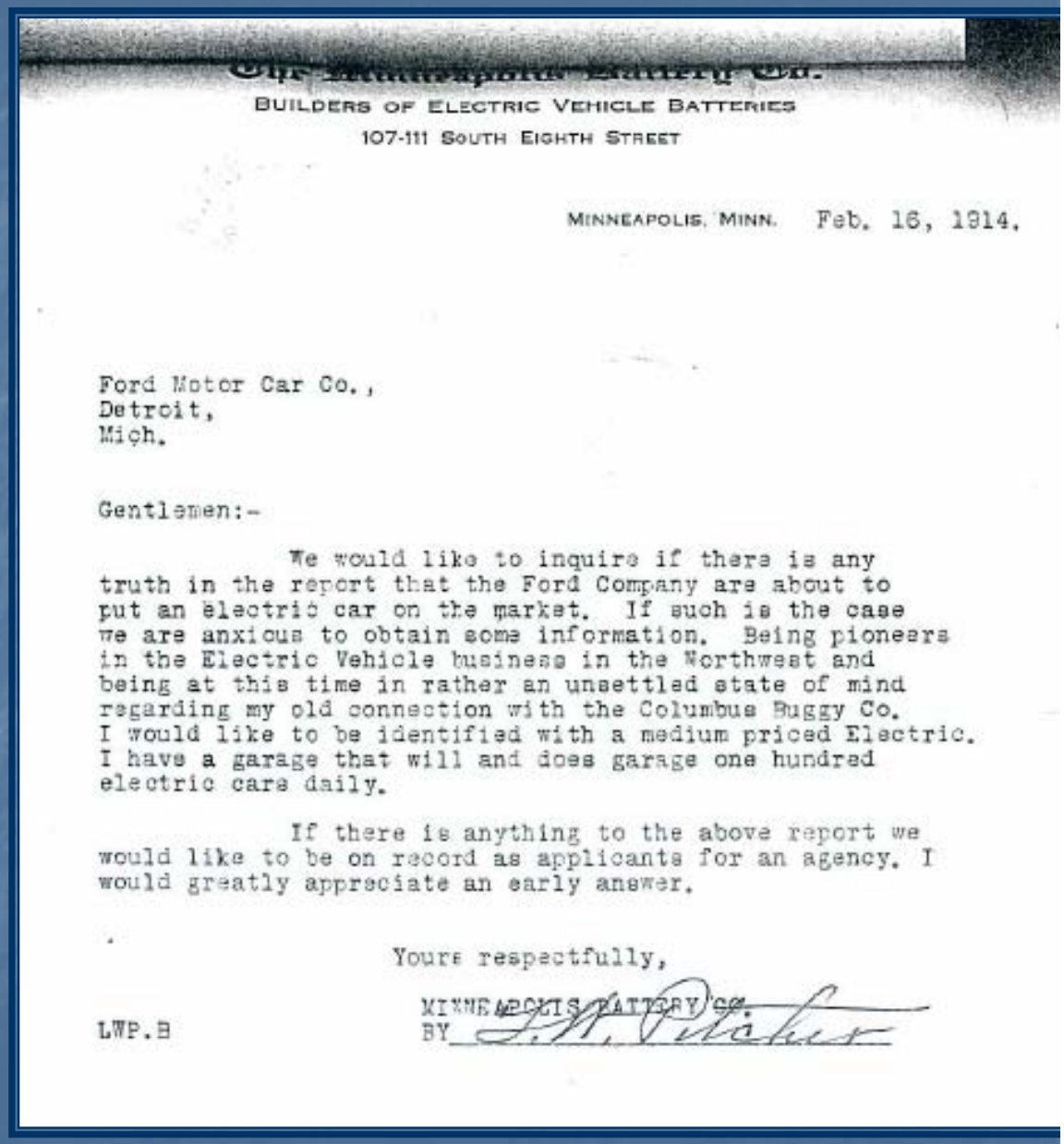
MREP Renewables meet Smart Grid Meeting

Michigan Public Service Commision

Phil Rairigh
Ford Motor Company
Energy Storage Research

Electrification of vehicles: 100 year old vision…

- In the early 1900's more than 27 companies were building electric cars
- In 1914, Henry Ford and Thomas Edison experimented with an electric car using Edison Batteries
- In 1915 the Ward Motor Vehicle Company offered an electric wagon for $875 on an 1yr installment plan for the vehicle and a $10.50/month rental fee for the Edison Storage battery



The Minneapolis Battery Co.
BUILDERS OF ELECTRIC VEHICLE BATTERIES
107-111 SOUTH EIGHTH STREET

MINNEAPOLIS, MINN. Feb. 16, 1914.

Ford Motor Car Co.,
Detroit,
Mich.

Gentlemen:-

We would like to inquire if there is any truth in the report that the Ford Company are about to put an electric car on the market. If such is the case we are anxious to obtain some information. Being pioneers in the Electric Vehicle business in the Northwest and being at this time in rather an unsettled state of mind regarding my old connection with the Columbus Buggy Co. I would like to be identified with a medium priced Electric. I have a garage that will and does garage one hundred electric cars daily.

If there is anything to the above report we would like to be on record as applicants for an agency. I would greatly appreciate an early answer.

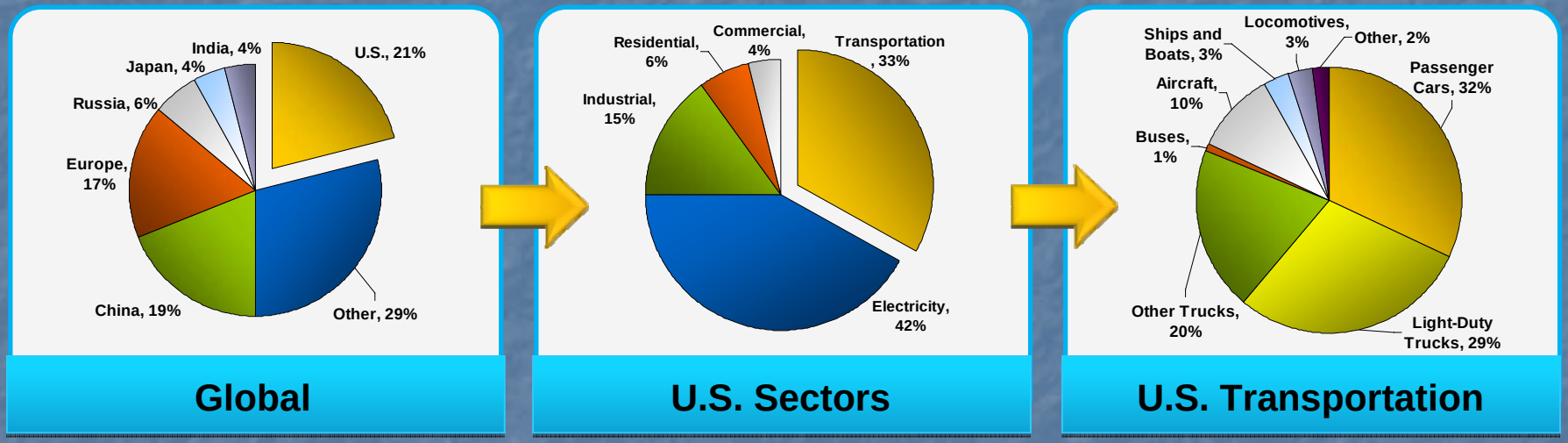
Yours respectfully,

MINNEAPOLIS BATTERY CO.
BY

LWP.B

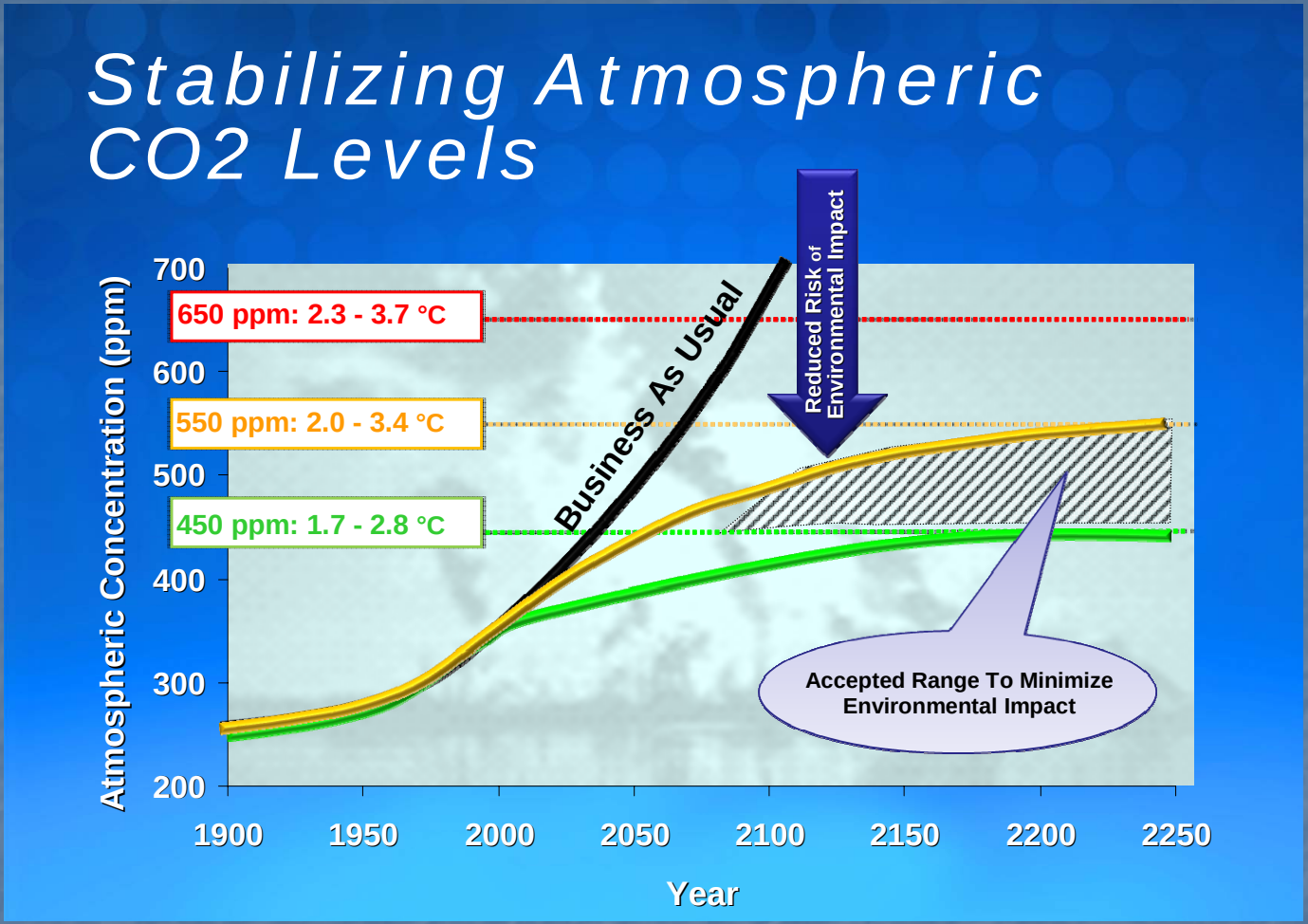
Contributions to CO_2 Emissions is Across Global Regions and Industry Sectors

2005 CO_2 Emissions from Fossil Fuels



- On-road cars (32%) and light-duty trucks (29%), as a portion of the transportation sector (33%), contribute about 20% of US and ~11% of global CO2 emissions
- Vehicles are significant source of GHGs but are often perceived to be the major source

What's Driving Us?



- Simply "not getting worse" is not good enough
- CO2 reduction is required on a global basis going forward
- This is a long term commitment for a sustainable future

Sustainability Strategy – Technology Migration Plan

2007 | 2011 | 2020 | 2030

Near Term

Begin migration to advanced technology

Mid Term

Full implementation of known technology

Long Term

Continue leverage of Hybrid technologies and deployment of alternative energy sources

Near Term

- Significant number of vehicles with EcoBoost engines
- Electric power steering – begin global migration
- Dual clutch and 6 speed transmissions replace 4 & 5 speeds
- Flex Fuel Vehicles
- Add Hybrid applications
- Increased unibody applications
- Introduction of additional small vehicles
- Battery management systems – begin global migration
- Aero improvements
- Stop/Start systems (micro hybrids) introduced
- CNG/LPG Prep Engines available where select markets demand

Mid Term

- EcoBoost engines available in nearly all vehicles
- Electric power steering - High volume
- Six speed transmissions - High volume
- Weight reduction of 250 – 750 lbs
- Engine displacement reduction aligned with weight save
- Additional Aero improvements
- Increased use of Hybrid Technologies
- Introduction of PHEV and BEV
- Vehicle capability to fully leverage available renewable fuels*
- Diesel use as market demands
- Increased application of Stop/Start

Long Term

- Percentage of Internal combustion engines dependent on renewable fuels
- Volume expansion of Hybrid technologies
- Continued leverage of PHEV, BEV
- Introduction of fuel cell vehicles
- Clean electric / hydrogen fuels
- Continued weight reduction actions via advanced materials

Hope for ICE?

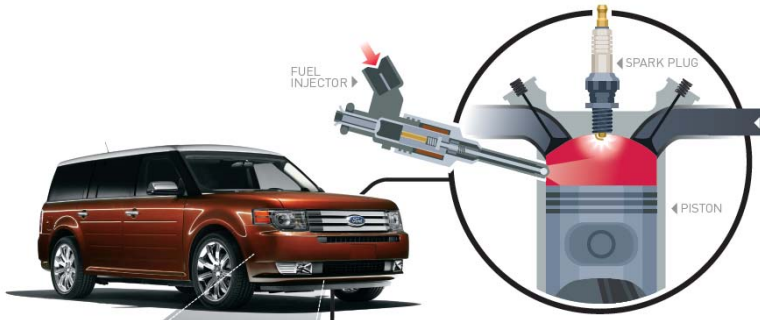
EcoBoost will have an even bigger impact than hybrids...

because we intend to roll it out to most of our fleet.

NOTE !
CHP and advanced TE devices (i.e. Peltier) can eventually push efficiencies dramatically higher

MORE WITH LESS

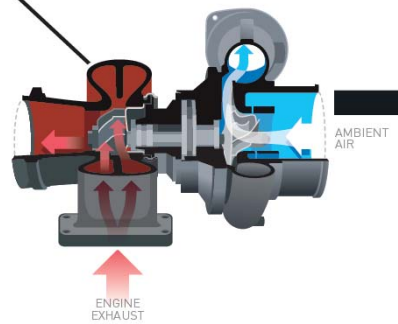
Better fuel economy? Up to 20%. And more power. Simple fact: Even with advanced technologies, the majority of vehicles worldwide will be gasoline powered. That's millions. Ford's new gas-turbo direct-injection engines can help. Here's how Ford's **EcoBoost** does more with less:



DI for Gas?

DIRECT INJECTION

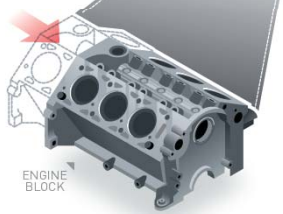
Highly pressurized fuel is injected directly into the combustion chamber of each cylinder rather than traditional mixing with the incoming air in the inlet port. Advantages include: more precise delivery of fuel for lower emissions, improved volumetric efficiency and avoidance of knock for better performance and fuel efficiency.



Turbo: Power for the People

TURBOCHARGING

Energy from the engine's exhaust, that would otherwise be wasted, is utilized to rotate a turbine wheel. The turbine is coupled to a compressor which pressurizes the incoming air, significantly increasing the output per liter of the engine. The traditional disadvantages of "boosting," turbo lag and knock, are mitigated by the synergy with direct injection.



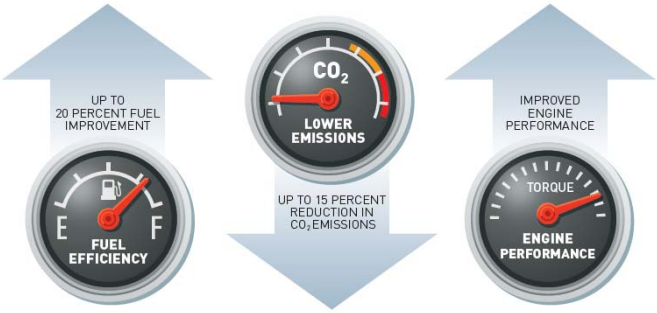
6 = 8, 4 = 6

SMALLER ENGINE BLOCK

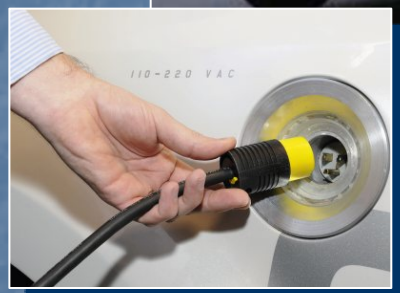
With both factors in the equation, the EcoBoost 6-cylinder engine can produce like an 8; a 4, like a 6. In addition, our 6-speed transmission (available on Ford Edge, and first-in-class for Fusion, Taurus and Taurus X) offers smoother acceleration and better economy. Go farther. Use less.

Fatter Wallet

With EcoBoost's more efficient use of fuel, drivers will experience less trips to the gas pump, while not having to sacrifice performance in order to make the world a better place for all.



Much to Learn Collectively

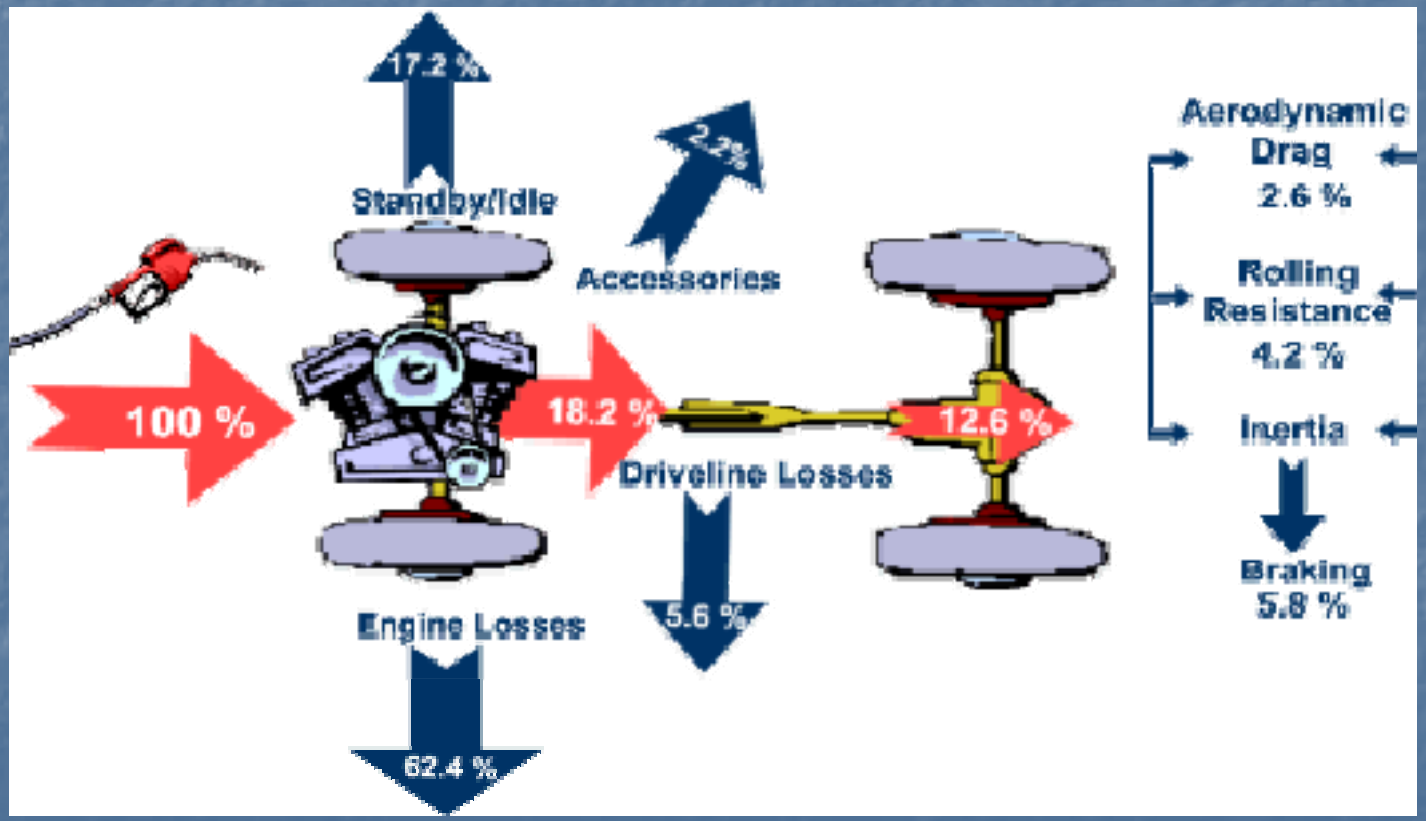


- ✓ **Unique partnership between automotive and utility sectors to accelerate the commercialization of PHEVs and BEVs**
- ✓ **Project goals:**
  - ✓ **Creation of New Business Models**
  - ✓ **Development of open architectures, standards and specifications**
  - ✓ **Create Customer Demand based on realistic expectations**
- ✓ **Diversifies transportation energy supply**
- ✓ **Future Vision:** ***From Independent to Integrated***

Two industries connected by a common fuel … driving our transportation and energy future…

Energy losses

Only about 15% of the energy from the fuel you put in your tank gets used to move your car down the road or run useful accessories, such as air conditioning. The rest of the energy is lost to engine and driveline inefficiencies and idling. Therefore, the potential to improve fuel efficiency with advanced technologies is enormous.

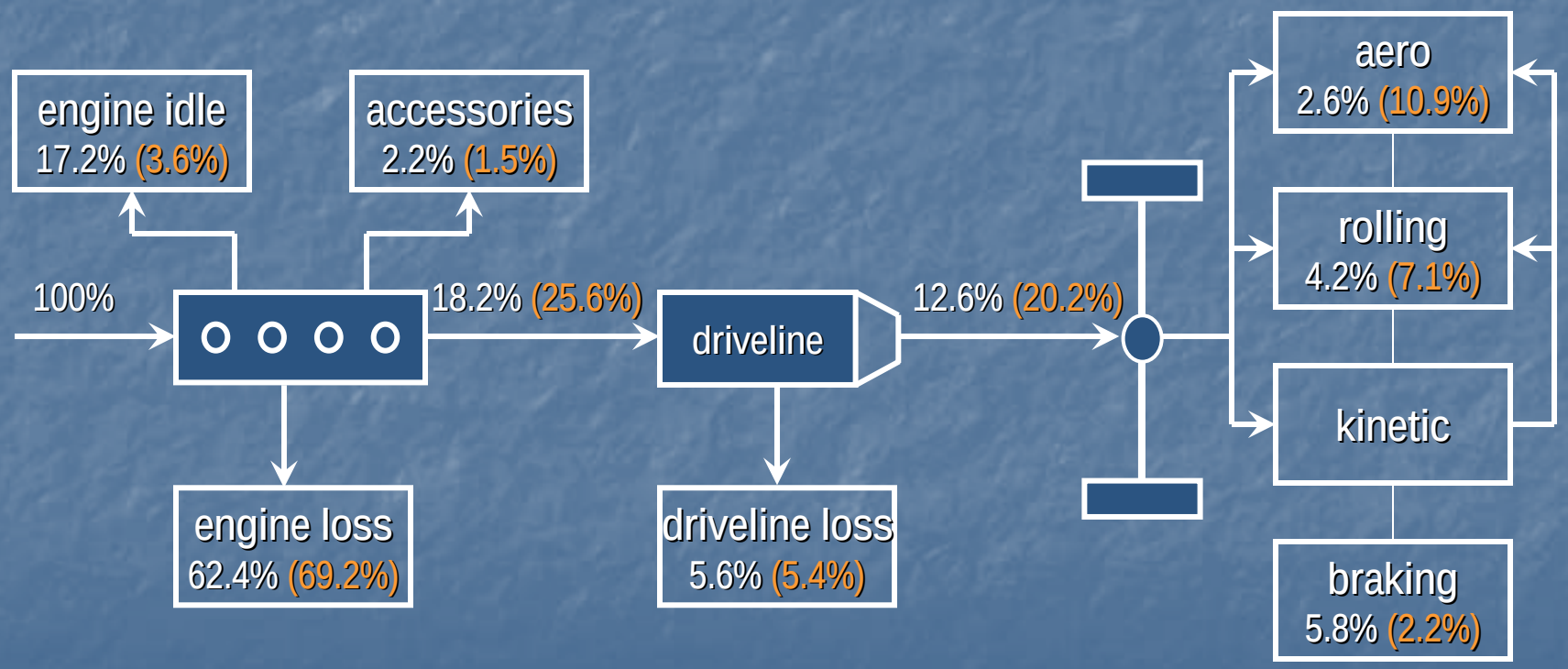


hybrids fix braking loss: series or parallel?

fueleconomy.gov/feg/atv.shtml

Why Hybrid Powertrain

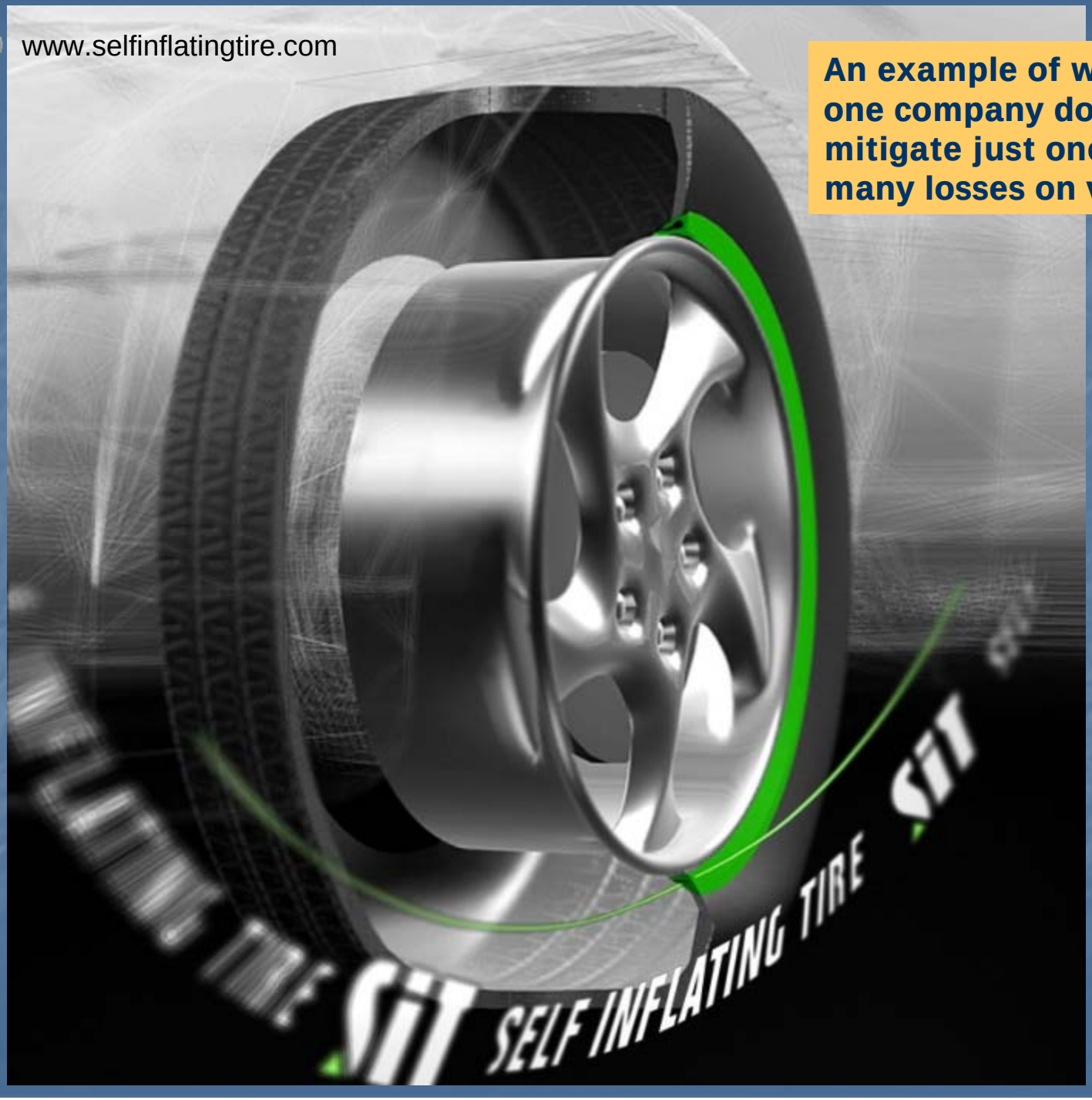
- Conventional Vehicle Energy Utilization



Legend: city (highway)

www.selfinflatingtire.com

An example of what one company does to mitigate just one of the many losses on vehicles…



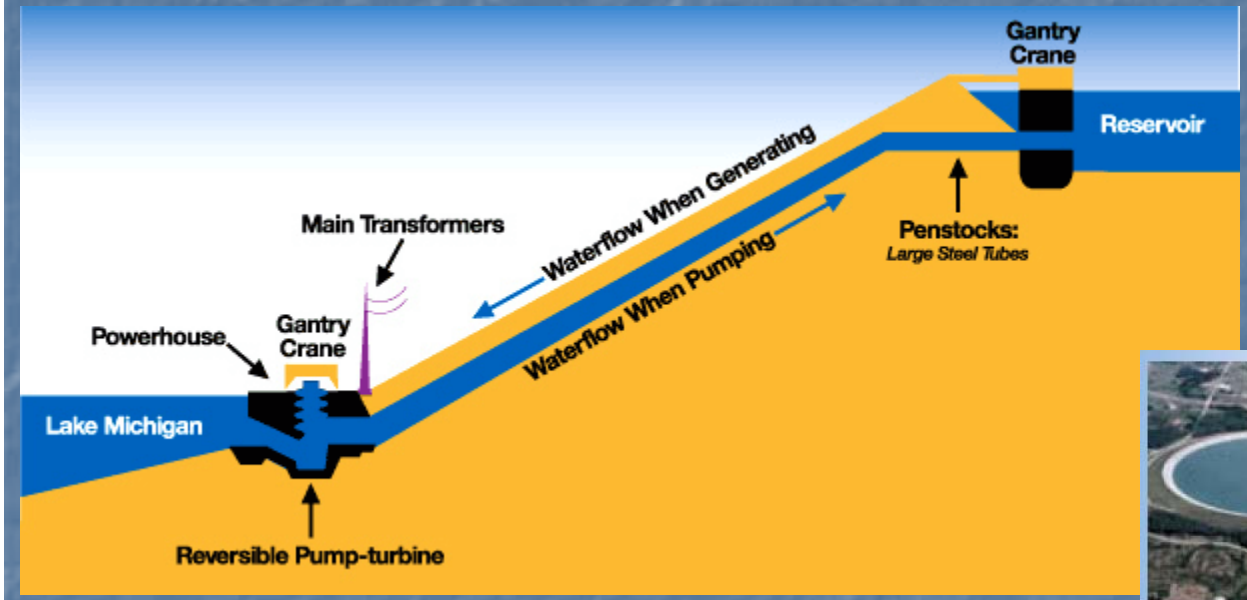
(exit to video)

The value of storing energy for later use…

Consumers Energy
Count on Us

DTE Energy

Ludington Pumped Storage Plant



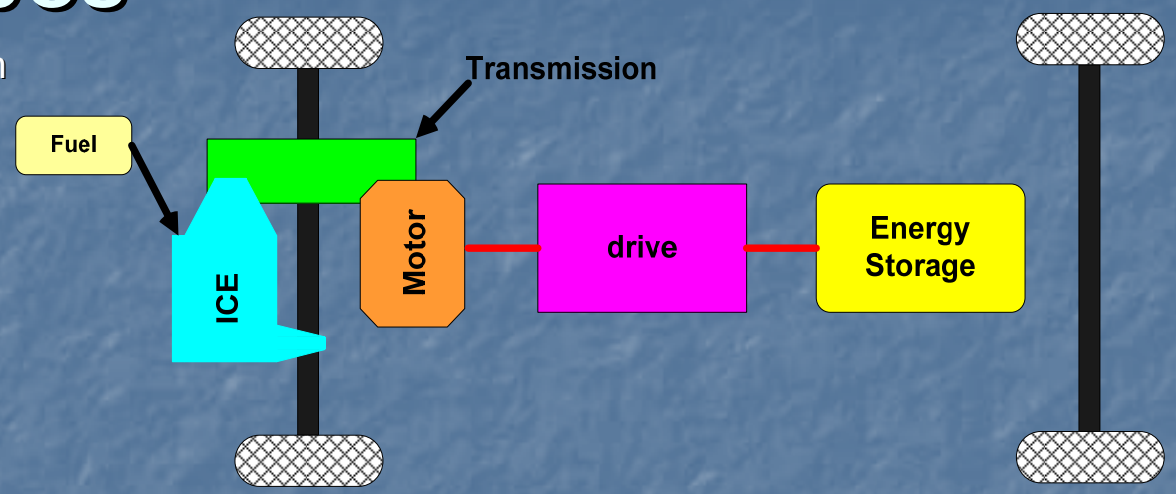
At night, when electric demand is low, Ludington's reversible turbines pump water 363 feet uphill from Lake Michigan. The water is pumped through six large pipes, or "penstocks", to the 842-acre (27B gal) reservoir. During the day, when electric demand is high, the reservoir releases water to flow downhill through the penstocks. The flowing water turns turbines and generators in the powerhouse to make electricity.

Ludington Pumped Storage has a capacity of 1,872 megawatts.

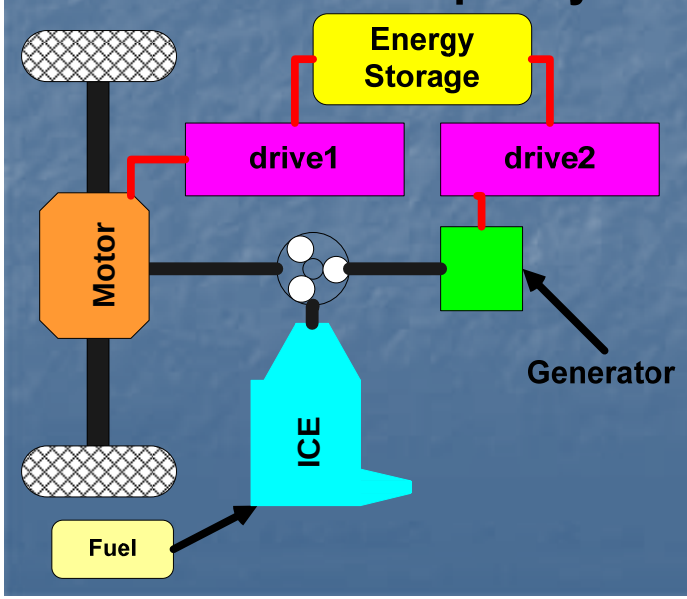
Hybrid Vehicle Types

- Parallel Hybrid:
  - Engine power = mechanical path
  - Motor provides assistance
- Series Hybrid:
  - EV Operation w/Stop-Start
  - High efficiency Regen Braking
  - Engine downsizing
  - Full-size drive needed
- PowerSplit Hybrid:
  - w/ benefits of both
  - Simple transmission

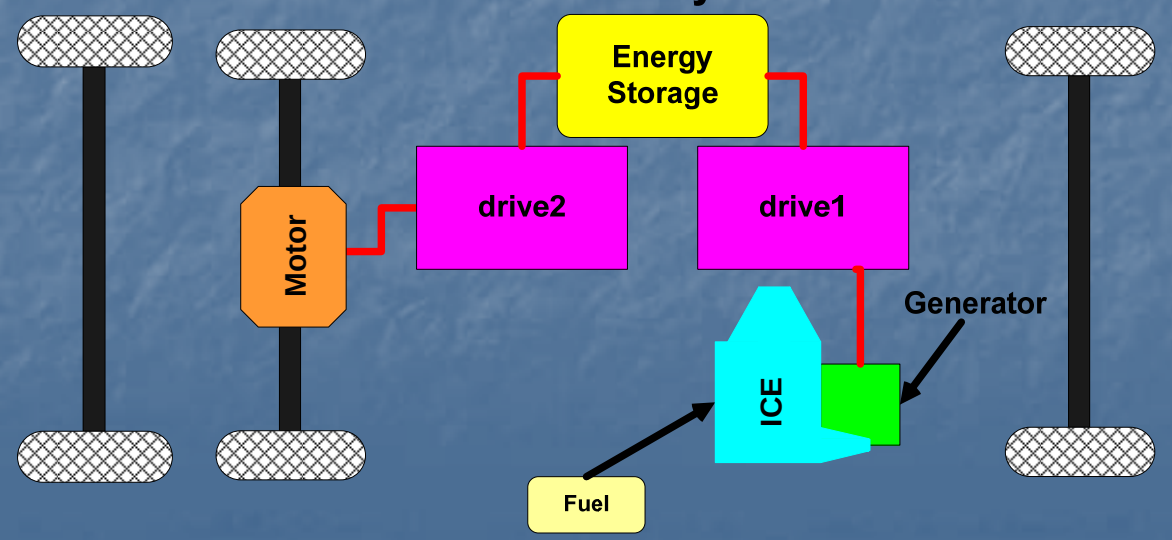
Parallel Hybrid



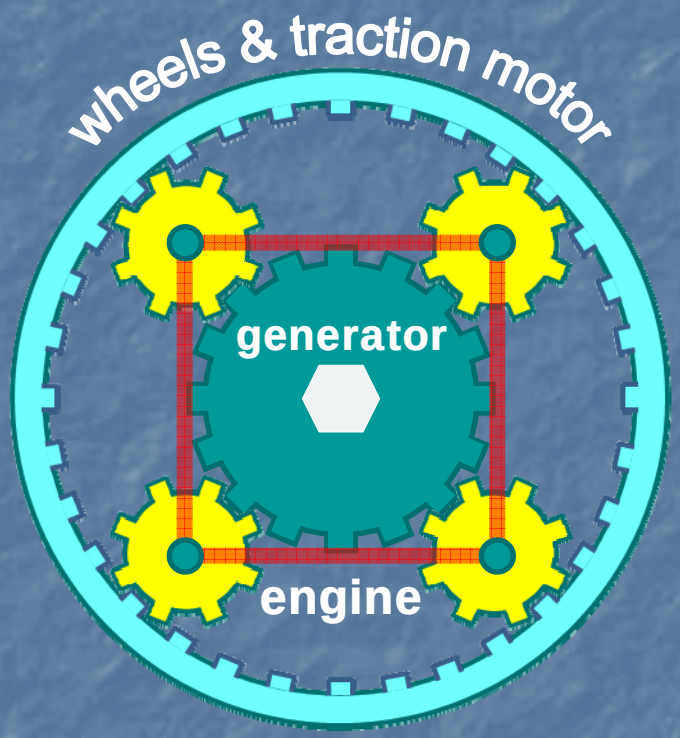
PowerSplit Hybrid



Series Hybrid



The Planetary Gear



Engine locked
(planetary carrier)

Electrification Technologies – Background

Function / System	Engine stop/start	Engine Assist (Downsize)	Regenerative Brake	Electric launch	All Electric Drive	Fuel Economy Improvement
Micro-hybrid (14V)	YES (> 0.3 sec)	Minimal (< 3 kW)	Minimal (< 3 kW)	NO	NO	3-6%
Mild Hybrid (42V)	YES	Modest (< 9 kW)	Modest (< 9 kW)	NO	NO	8%/12%
Medium Hybrid (100+V)	YES	YES	YES (full benefit)	NO	NO	40%
Full Hybrid (300V)	YES	YES	YES	YES	NO	55%+
Plug In Hybrid (based on Blended Full)	YES	YES	YES	YES	No (Blended) Yes (Series)	80%+
Battery Electric Vehicle	YES	No Engine	YES	YES	YES	Infinite

HEV → PHEV → BEV Components

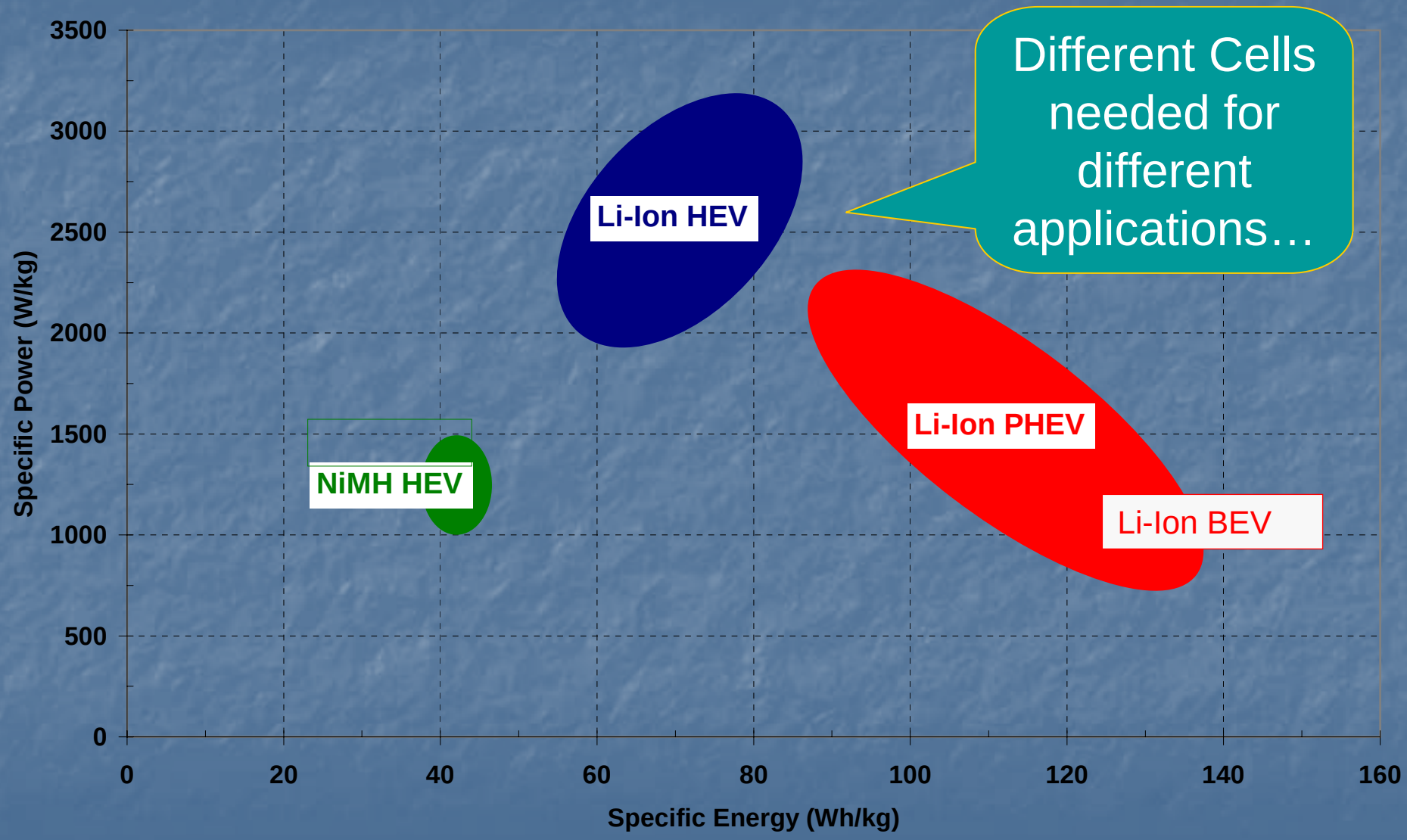
	HEV	PHEV	BEV
Battery	Yes (Power)	Yes (Energy)	Yes (Energy)
Electric AC	Yes	Yes	Yes
DC/DC Converter	Yes	Yes	Yes
Regen Brakes	Yes	Yes	Yes
Motor(s)	Yes	Yes	Yes
Inverter(s)	Yes	Yes	Yes
Transmission	Yes	Yes	No
EV Gearbox	No	No	Yes
Charger	No	Yes	Yes

Multiple Cost Drivers

- Application/Usage (Drive Cycles)
  - Peak to Average Power Ratio
  - Thermal Cycling
  - Power Cycling
  - Desired Range
- Technology
  - Silicon Technology (IGBT, Diodes) – Industry Standards vs. Custom?
  - Power Module Packaging and Cooling Technology
  - Capacitor Technology
  - Sensing Technology
  - Battery Cell Technology
- Commonality and Reuse
  - Power Density – Package Size
  - Fixed vs. Tunable
  - Connection Systems

Total cost can be very high – investment and component cost

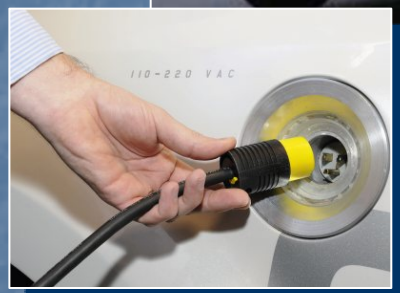
Hybrid Battery Technology Comparison



Realizing The Power of Plugging-In

Two industries (PHEV & BEV) tied together through a common fuel to change the transportation and energy paradigm

Much to Learn Collectively



- ✓ **Unique partnership between automotive, utility, and data sourcing sectors to accelerate the commercialization of PHEVs and BEVs**
- ✓ **Project goals:**
  - ✓**Creation of New Business Models**
  - ✓**Development of open architectures, standards and specifications**
  - ✓**Create Customer Demand based on realistic expectations**
- ✓ **Diversifies transportation energy supply**
- ✓ **Future Vision: *From Independent to Integrated***

Two industries connected by a common fuel … driving our transportation and energy future…

Ford / Utility Partnership Objectives

The PHEV business model is complex, involving connections between auto companies, utilities, government and battery suppliers as a means of arriving at a sustainable solution.

Plug-In Collaboration

Technical Aspect

- Architectures, standards and specifications
- PHEV and grid performance, requirements

Business Aspect

- Accelerating PHEVs and Grid interface solutions in the NA market
- Real world PHEV customer expectations and usage
- Data/modeling for the creation of new vehicle business models

Business Value Models

- **Battery** – Determine a method to lower/offset the cost of the PHEV battery.
- **Vehicle** – Determine optimal battery/vehicle life-cycle match.
- **Customer** – Determine the value a PHEV offers the customer.
- **OEM** – Estimate OEM PHEV costs and net revenue (loss) with aspects of regulatory goals, production and warranty costs.
- **Utility** – Quantify PHEV/Grid value elements benefiting the electric power industry and PHEV owners, who are utility customers.

Overview

Timeline

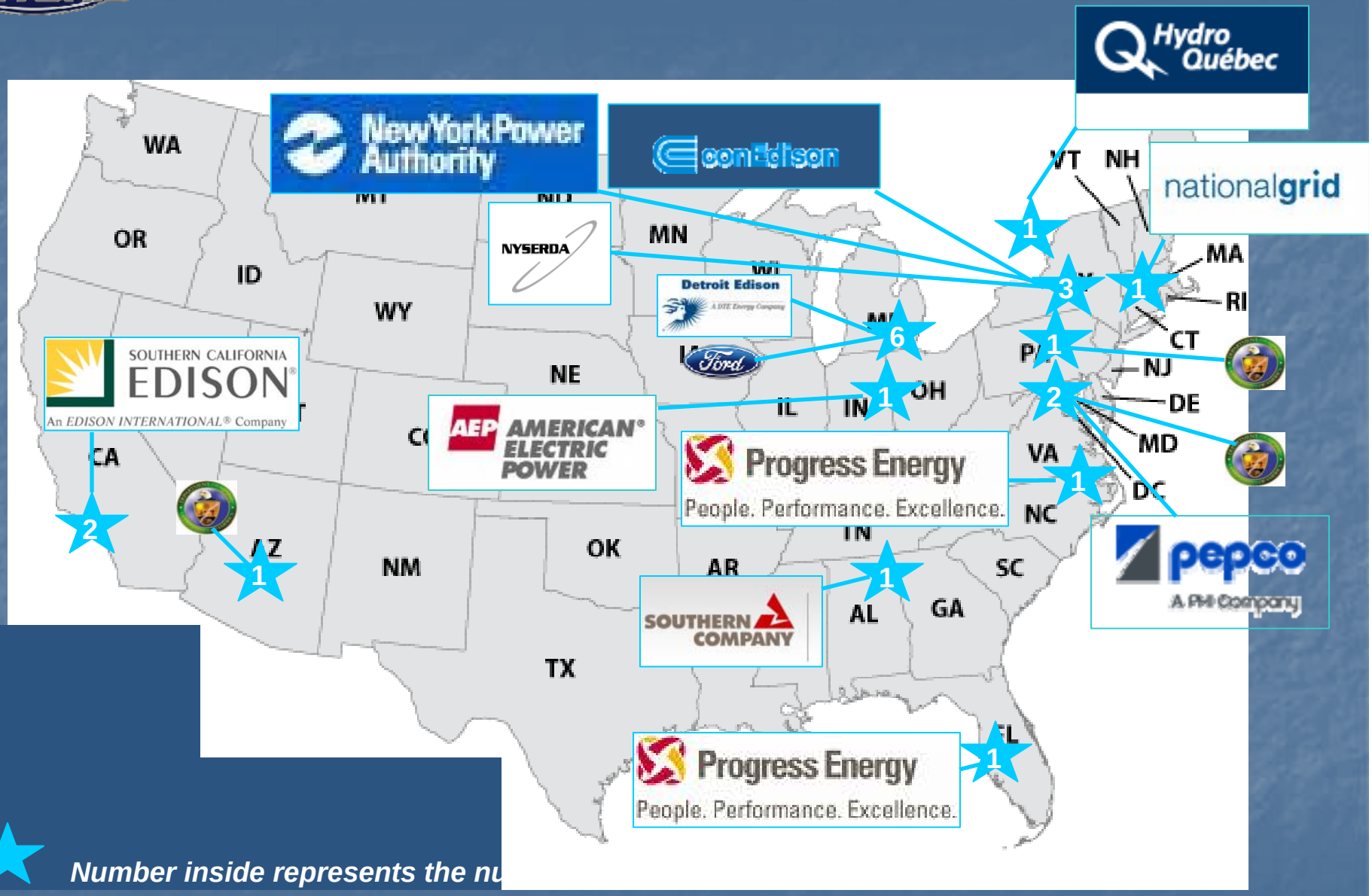
- Start: July, 2007
- Finish: Dec, 2012

Participation

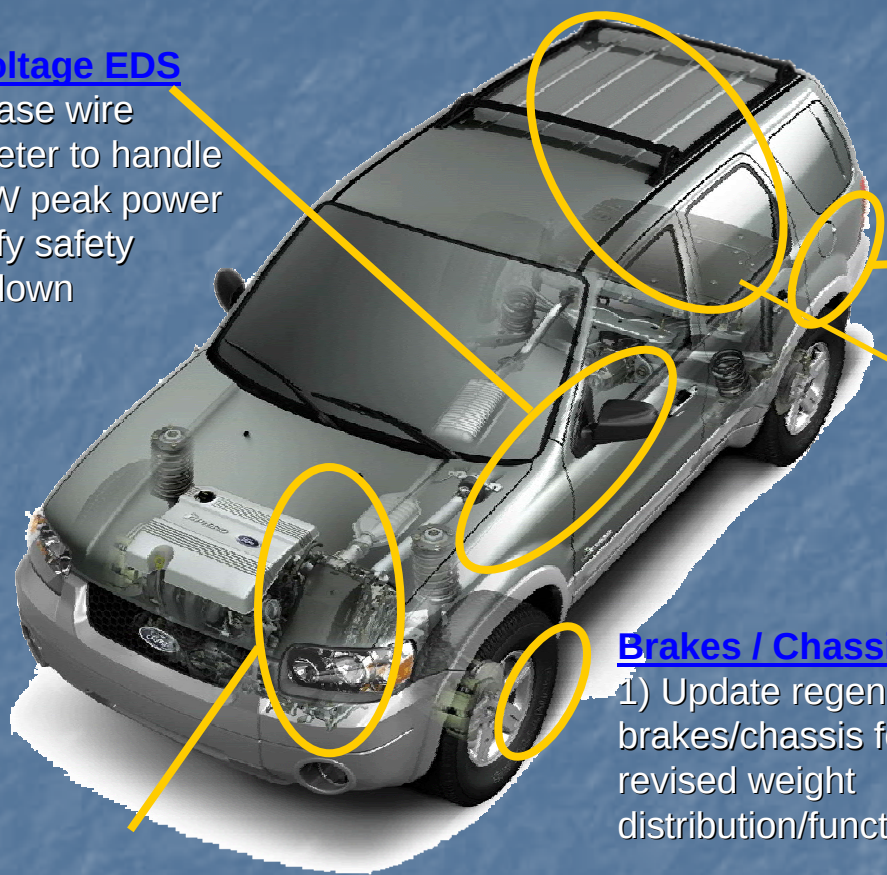
- One PHEV Hybrid Escape for period of three years.
- Vehicle service included.
- Vehicle and Fleet data through Ford Website
- Conferences/planning/collaboration with Ford and utilities across NA

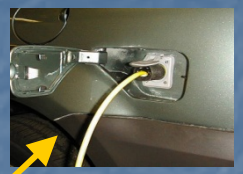
Partners

- Department of Energy
- Johnson Controls-Saft (JC-S)
- Electric Power Research Institute
- Southern California Edison
- Detroit Edison
- NY Power Authority
- Consolidated Energy
- NY State Energy Research & Development Authority
- Progress Energy
- Southern Company
- Pepco Holdings Inc
- American Electric Power
- Hydro-Quebec
- National Grid


PLUG-IN HYBRID
Hydro Québec
New York Power Authority
Con Edison
nationalgrid
NYSERDA
Detroit Edison
Ford
SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL® Company
AEP AMERICAN ELECTRIC POWER
Progress Energy
People. Performance. Excellence.
SOUTHERN COMPANY
pepco
A PHI Company
WA
OR
ID
WY
NE
MN
CA
AZ
NM
OK
TX
AR
AL
GA
SC
NC
VA
MD
DE
NJ
CT
RI
MA
NH
VT
DC
IL
IN
OH
3
1
6
2
Number inside represents the nu

What goes into a PHEV?
Total system approach required...





110 V AC plug-in door

High Voltage EDS

1) increase wire diameter to handle 60 kW peak power
2) Modify safety shutdown

Rear Cargo Area

1) replace production high voltage battery with high energy Li-Ion battery
2) add battery charger
3) add gateway module for plug-in control
4) revise rear structure for added weight and safety performance
5) redesigned suspension for added weight

Brakes / Chassis

1) Update regen and brakes/chassis for revised weight distribution/function

Other Areas

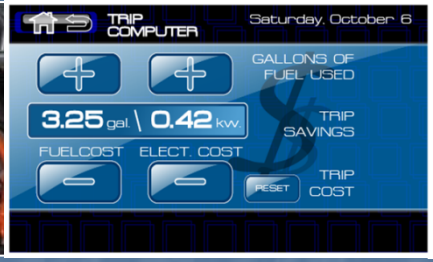
1) Emissions - need revise strategy to meet PZEV w/extended engine off time
2) Climate control - tailoring new approaches for heating vehicle and defrosting during extended engine off time

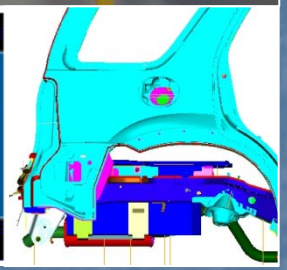
Transaxle/Engine Compartment

1) modify transaxle oil lubrication/cooling circuit for extended engine-off durability
2) add oil to air heat exchanger to increase continuous operating capability of electric machines

Vehicle Integration Progress

PHEV Design Must be Integrated to Meet Standards & Expectations

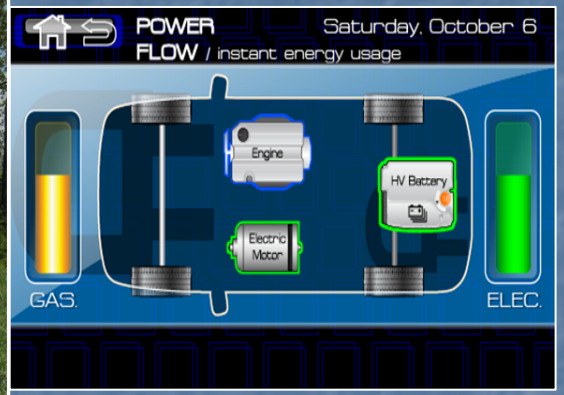




- OEM tools/processes focus on delivery of a safe, reliable, durable and consumer value-driven vehicle:
  - Vehicle structure & crash/responder safety
  - High voltage & battery systems
  - Consumer & utility communications
  - Thermal systems
  - Fuel Economy Emission systems
- Vehicle/Grid Integration Progression:
  - Near Term - G2V charging, G2V & V2G Communication, Smart Connectivity
  - Mid Term – V2H Emergency Back Up Power
  - Long Term – V2G Power Flow

Due Diligence Engineering and Development of PHEVs is Required to Meet Customer Expectations, Gov't Regulations and Ford Standards

PHEV - Features and Specifications



Features:

† Outstanding fuel economy - especially in real-world city driving

† Two-thirds fewer trips to the gas station

† Overnight recharging from standard home electrical outlet

† Interactive vehicle powertrain display

† Capless fuel filler

† Engine off operation during low speed driving

† Regenerative braking

† Flex Fuel (E-85)

Overall Vehicle Specifications:

† Engine: High efficiency 4 cylinder Atkinson cycle

† Li-Ion HV Battery Capacity: 11.5 kW - hr

† Fuel Capacity: 15 Gallons

† Seating: 5 Passengers

† Cargo Room: No compromise - Same as Ford Escape Hybrid

† Fuel Economy: Up to 120 mpg *

† Weight: 3900 lbs

† Max Speed: 102 mph

•Ford Escape Plug-In Hybrid operated in charge depletion mode

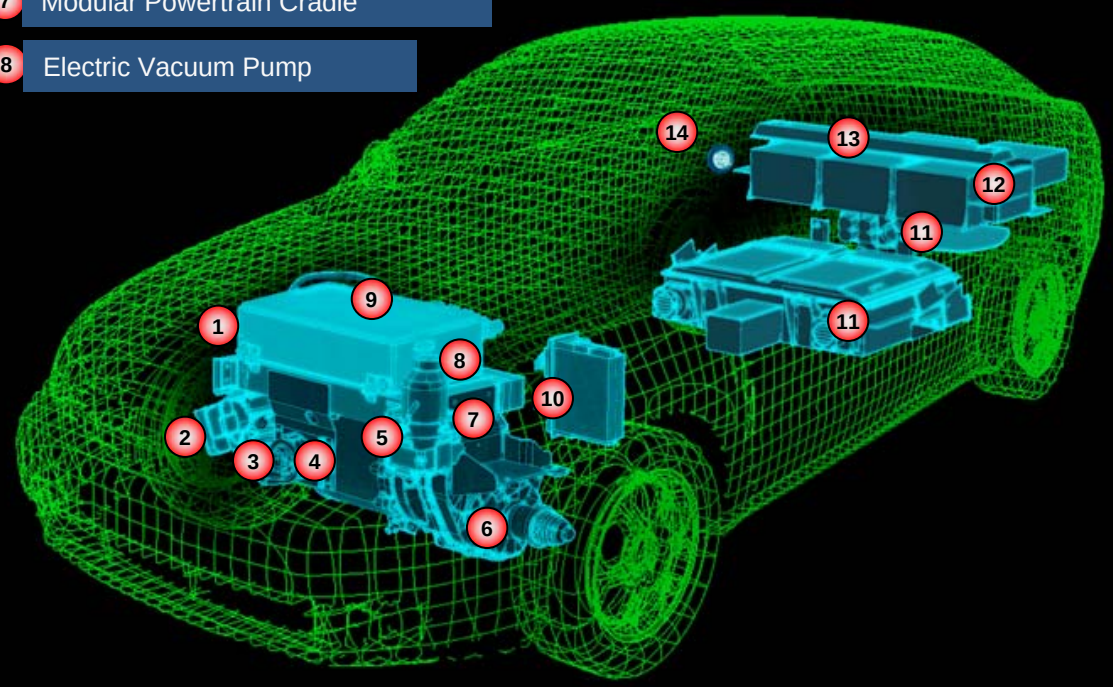
What goes into a BEV?

No ICE, all BEV

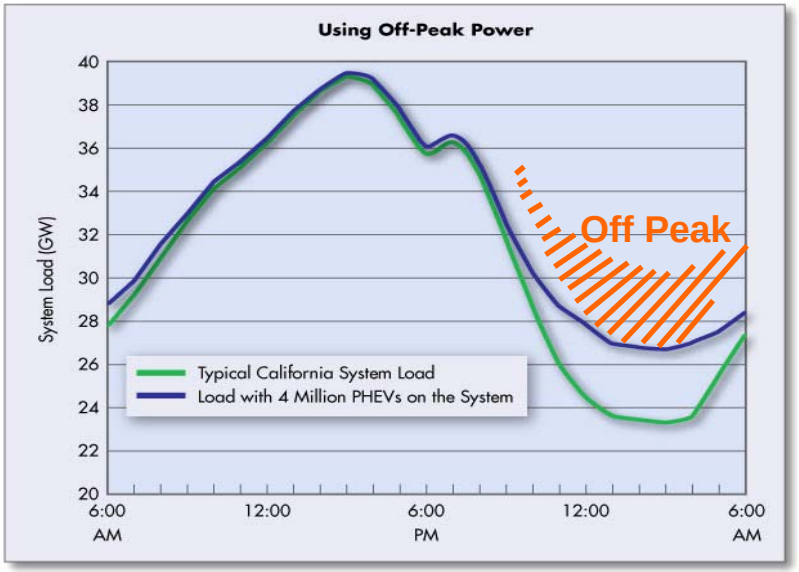
- Powered by an electric motor and high-voltage lithium-ion battery cells
- Targeted range of 100 miles
- Other vehicle systems (e.g., HVAC) also require electric solutions
- 14 new components
- Have to rethink every system

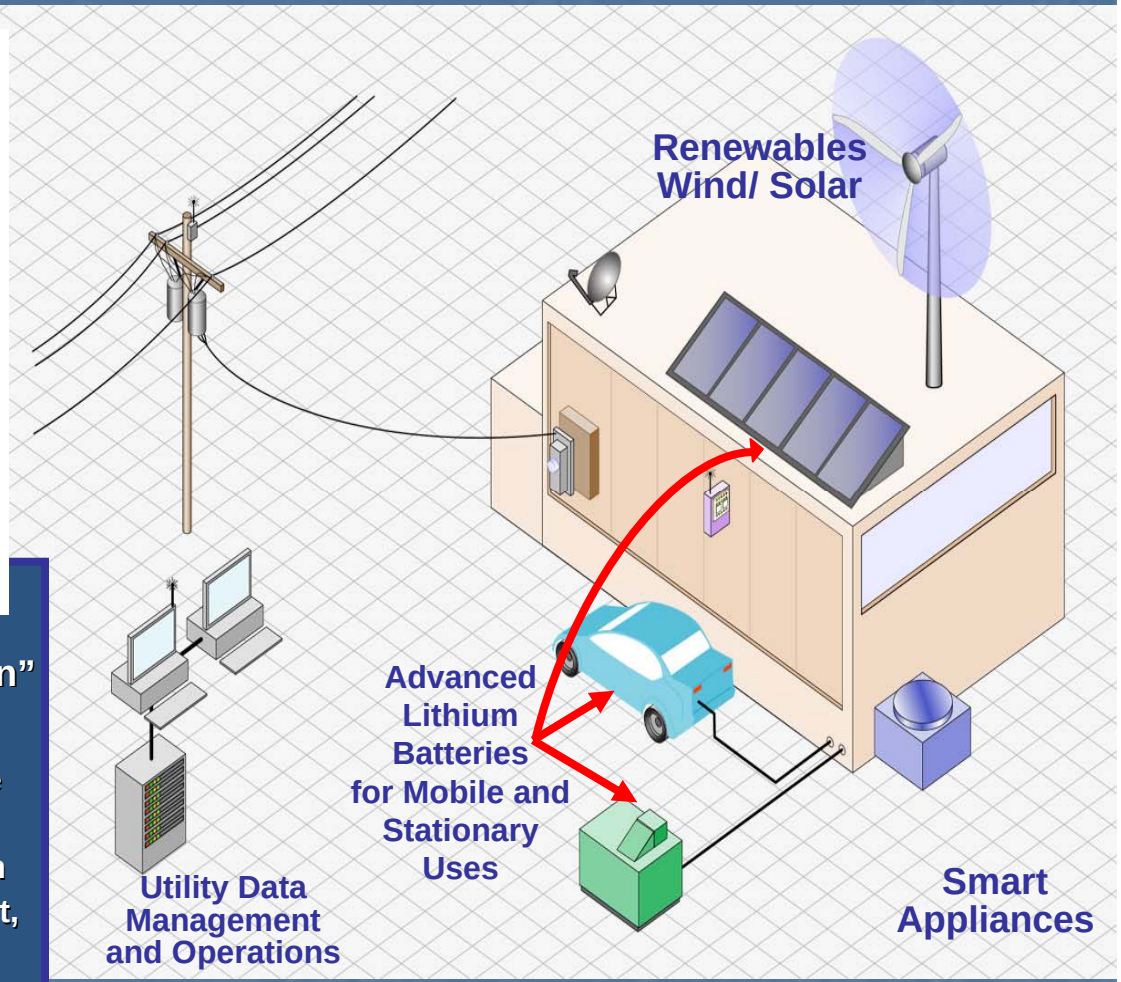
Move from a engine driven hydraulic world to motor/battery driven electric world…

1. Motor Controller and Inverter
2. High Voltage Electric HVAC Compressor
3. Electric Water Pump
4. Traction Motor
5. Electric Power Steering
6. Gearbox
7. Modular Powertrain Cradle
8. Electric Vacuum Pump
9. High Voltage PTC Electric Coolant Heater and Controller
10. Vehicle Control Unit
11. Battery Pack and Battery Cells
12. AC Charger
13. DC-DC Converter
14. Plug in AC



An Aggressive, Pragmatic, Data-driven Vision Utilities & Ford Working Together-





Exploring Customer Value From "Plugging In"

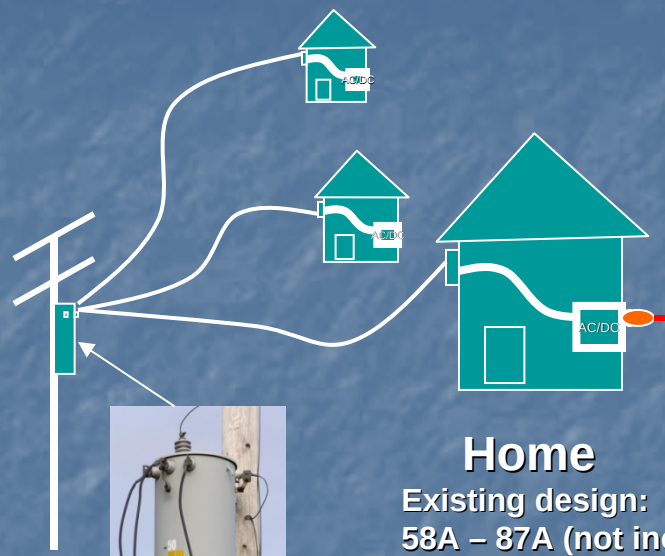
- Use low cost off-peak energy to charge vehicle
- Storing energy in advanced batteries - "drive" the wheels and occasionally "power" the house
- Storing energy on-site from wind/solar generation
- Finding new uses for generation capacity, at night, may help lower future electricity rates
- Night time energy use may help enable renewables
- Finding new uses for "new" batteries may help lower costs of future hybrid batteries

Lower PHEV/BEV acquisition & Ownership Costs?
Utility Value?

Deep Understanding V2G Connectivity

Distribution Substation

Existing design:
29A – 56A/ home*
per standard utility sizing methods

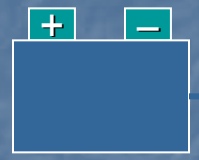


Multiple Home Pole Transformer

Existing design:
31A – 59A/ home*
per standard utility sizing methods

Home

Existing design:
58A – 87A (not including charger)
per NEC220



Battery

Existing battery: capable of charging at the vehicle worst case drive cycle discharge rate.

Charge Plug/Cord Level 1 & 2 available per SAE J1772 ©

Vehicle

Existing wiring: capable of worst case drive cycle

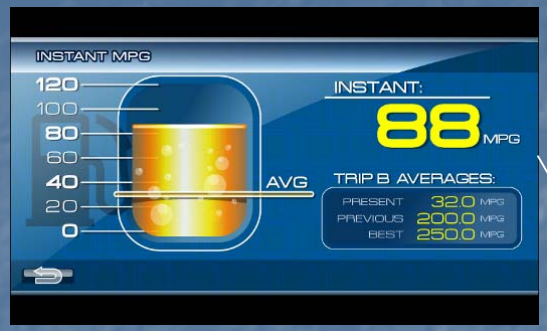
* Multiplication factor (Coincidence factor) varies from region to region and utility to utility.

Considering vehicles with 3.5 kW chargers, based on our understanding of NEC code, the calculated home current requirement will increase by 17% to 25% and each utility component will equally be impacted.

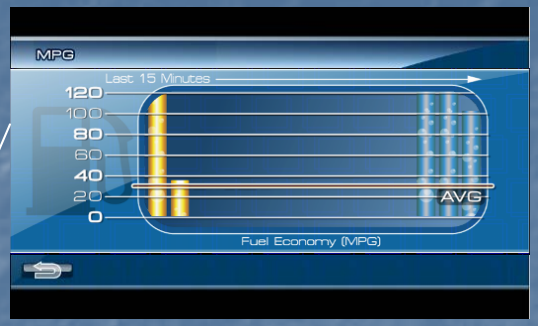
Human Machine Interface (NAV System)

Main Menu

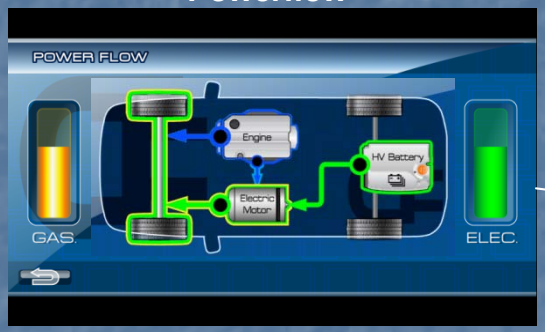
Instant Fuel Economy

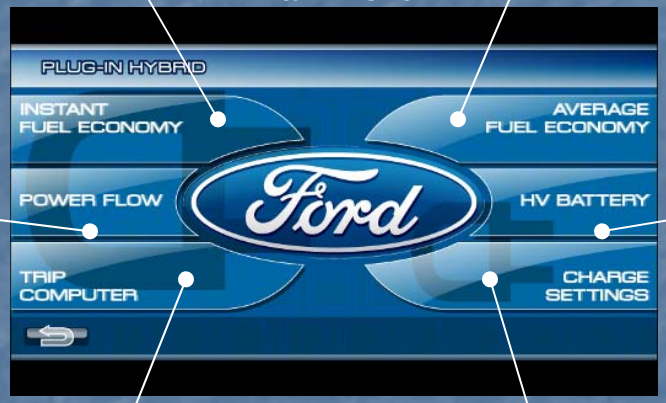


Average Fuel Economy

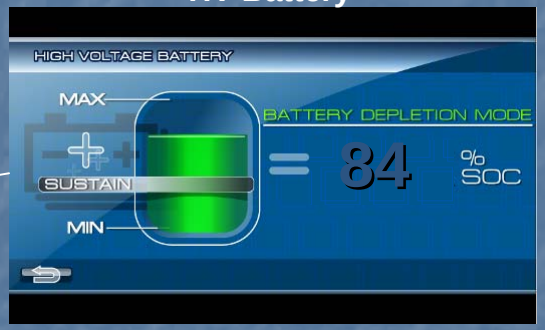


Powerflow

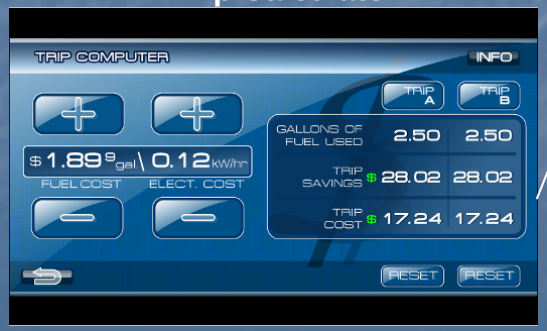




HV Battery



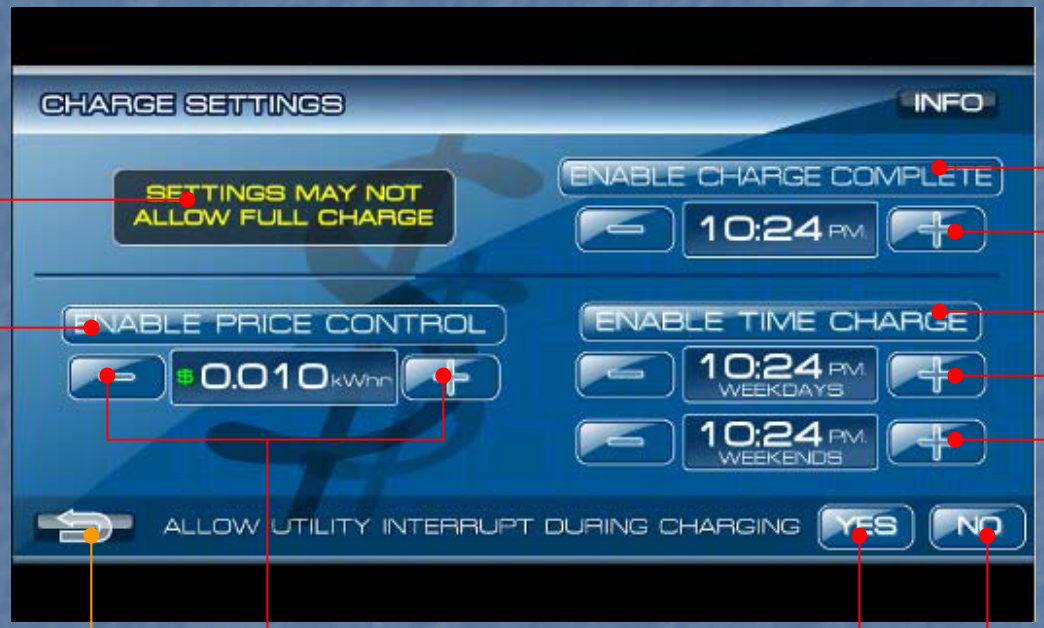
Trip Calculator



Charge Settings

Vehicle to Grid Interface

Charge Settings



Appears when a Settings Conflict occurs

Select Time – Based Charge With End Time

Input Time – Based Charge End Time

Select Time – Based Charge

Input Time – Based Charge Start Time

Allow Utility Company to Interrupt Charge*

Select Price – Based Charge*

Input Price Threshold*

Return to Main Menu

•- Denotes that option is only available if Utility Zigbee interface is present. If option is selected and Zigbee interface is unavailable, vehicle will default to regular charge mode.

Energy Storage comes in a variety of flavors

Electrochemical (aka "batteries")
- *primary vs secondary (rechargeable)*
- *Nickel-metal hydride*
- *Lithium ion (popular research)*
- *Lithium polymer*
- *Lead acid*
- *Nickel cadmium*
- *Zinc air*
- *Flow batteries*
- *Zebra*

Electrostatic
- ultracapacitors or supercapacitors

Hydraulic
- *UPS trucks*

Flywheel
- *Flybrid Systems*

Pneumatic
- *MDI Air Car*

Hydrogen (energy carrier) storage can be...
- *Sodium borohydride*
- *Compressed gas (requires energy to compress)*
- *Liquid (must be preheated)*
- *Metal hydride*

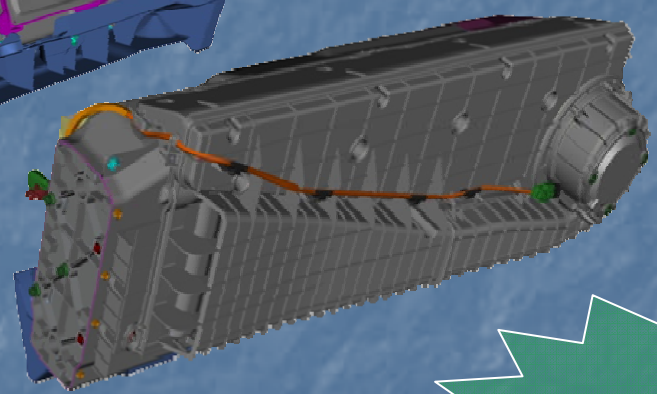
High Voltage Traction Battery

Ford's Gen I to Gen II

17% Fewer Cells

17% Lower Voltage

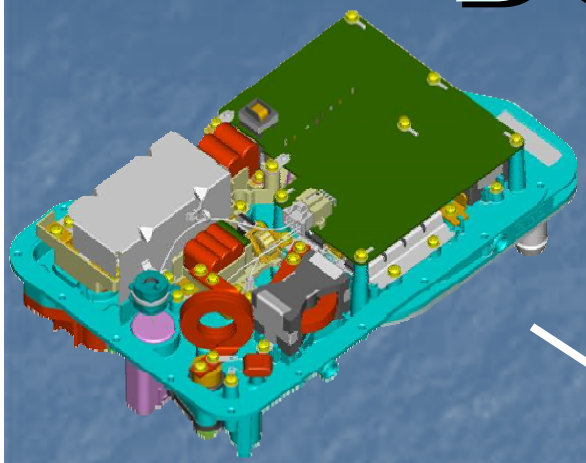
20% More Power Per Cell



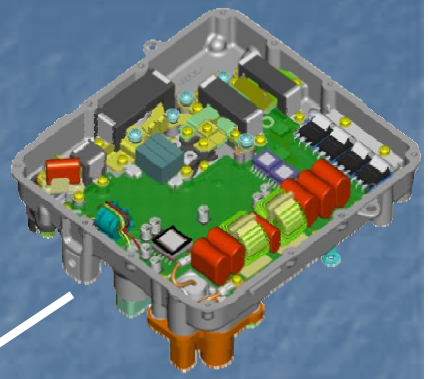
23% Lighter

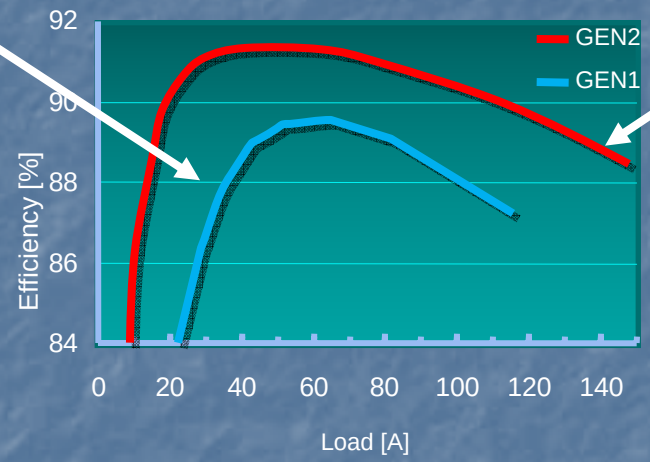
30% Volume Saving

DC/DC Converter



Output current:	**+14%**
Volume:	**-27%**
Weight:	**-42%**





Gen I

4.7 kg

276.8×175×80 mm

Gen II

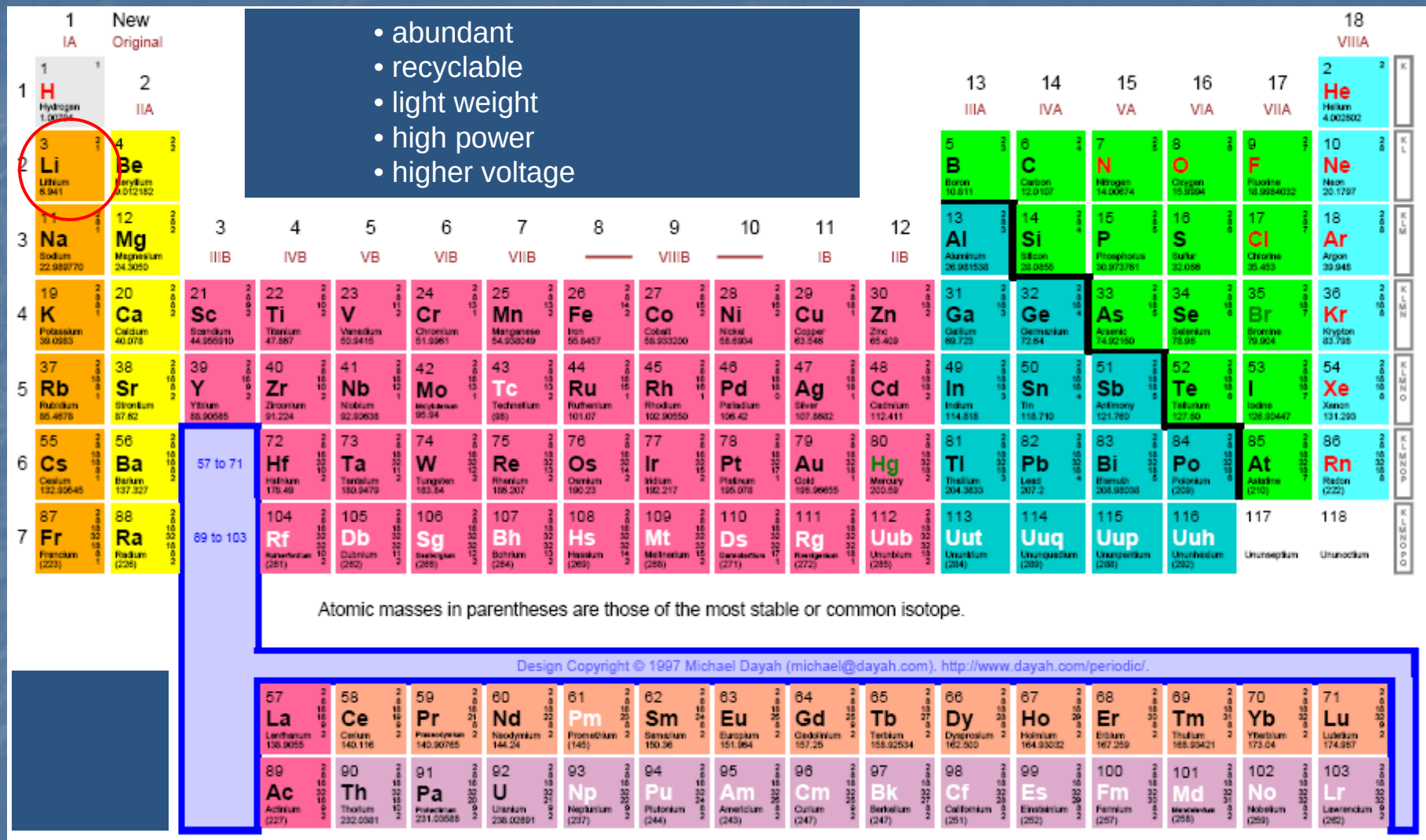
2.7 kg

220×205×63 mm

- All new high efficiency converter via improved magnetics
- Increased output for increased customer features
- Higher switching frequency design for weight and size reduction
- Improved diagnostics and better load mgmt controls via HS-CAN

Why lithium?

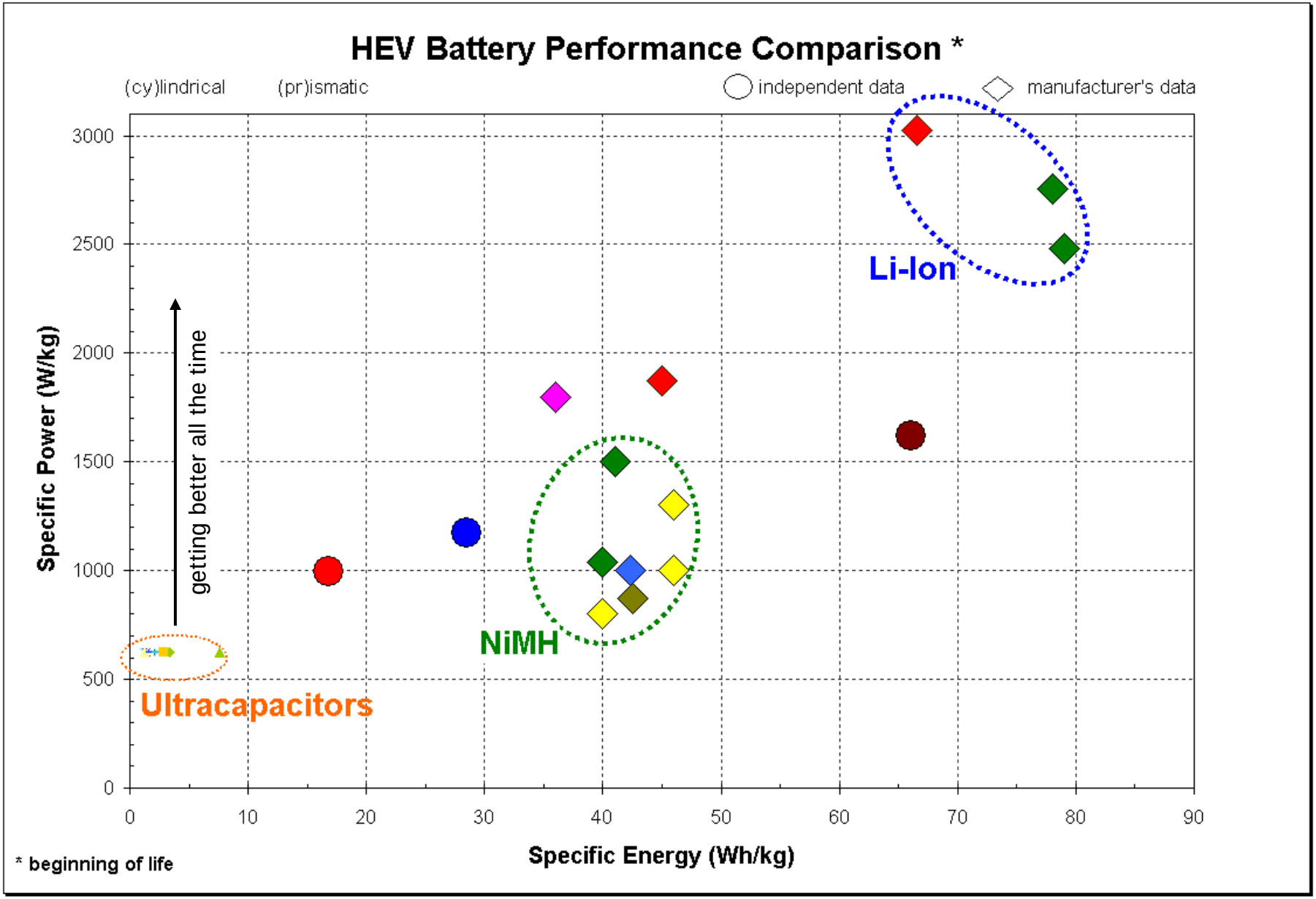
- abundant
- recyclable
- light weight
- high power
- higher voltage



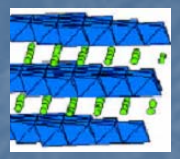
"There's lithium, then hydrogen... then God."

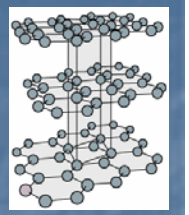
- an engineer who shall remain nameless

HEV batteries



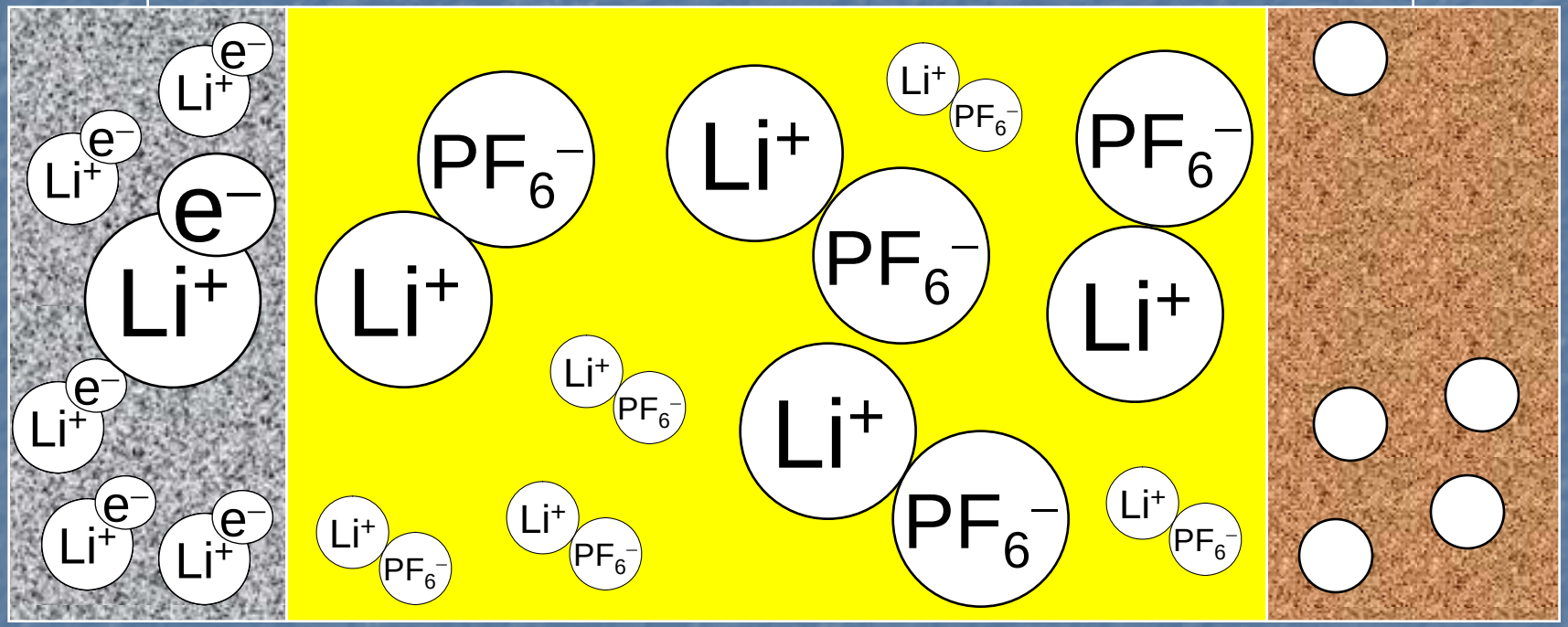
Austen's Lithium Battery





V

discharge



Metal oxide

Electrolyte

Carbon

Positive electrode is full of lithium at the end of discharge

By putting energy into the cell, lithium is forced out of the metal oxide (positive) and into the carbon (negative).

The elusive fast-charge solved?

SCIENCE FRIDAY®
MAKING SCIENCE USER-FRIENDLY™

YOUR HOST IRA FLATOW

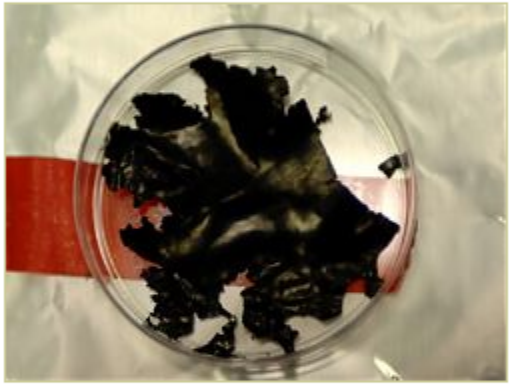
LISTEN
CALL IN 2-4 PM ET
800 989-8255

npr®

Home | Podcast | Blogs | Video | Cool Stuff | Teachers | Archive | About | Log in | Google™ Custom Search | Search

Building a Better Battery (broadcast Friday, March 13th, 2009)

Scientists say a modification to the design of lithium-ion batteries could allow batteries that can charge and discharge in a matter of seconds. Writing in the journal Nature, the team from MIT describe modifying the surface of a sample of lithium iron phosphate to improve the mobility of the lithium ions in the material. Before the processing step, a battery made from one sample of the lithium iron phosphate took six minutes to charge. After processing, batteries using the material were able to charge in under twenty seconds.



A sample of a film carrying a new material that could allow quick charging and discharging of lithium ion batteries. Photo MIT / Donna Coveney

Fast-charging and discharging batteries could be of use in a variety of applications, from portable electronics to advanced cars. We'll talk about the work, and how soon it might be able to find its way into consumer products. Teachers, find more information about using Science Friday as a classroom resource in the Kids' Connection.

Guests

Gerbrand Ceder
Professor of Materials Science and Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

Even if we had a fast-charge PHEV...

- significant infrastructure changes
- new power plants
- larger gage copper
- larger charger

NEWS

MIT fast-charge batteries promise quicker EVs

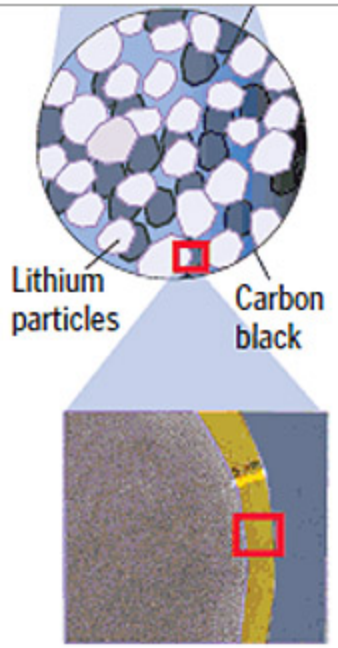
Posted by Clifford Atiyeh March 12, 2009 12:36 PM

Email | Link | Comments (12)

3 SPEED

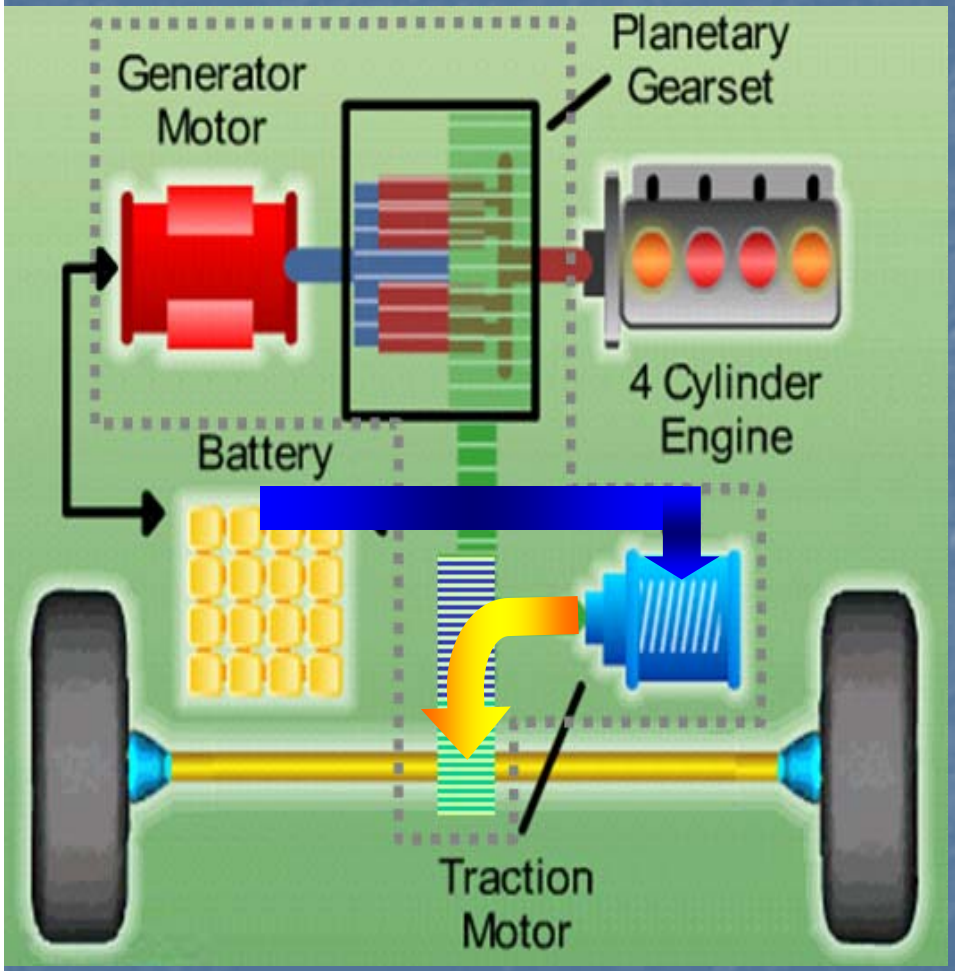
Speed at which battery can charge is limited by how fast the lithium ions can move through the electrodes. To increase this speed, scientists are building electrodes with nano-particle clumps and carbon additives.

To increase this speed even more, MIT researchers are covering the compound with a microscopic crystalized coating that greatly increases mobility of the lithium ions.

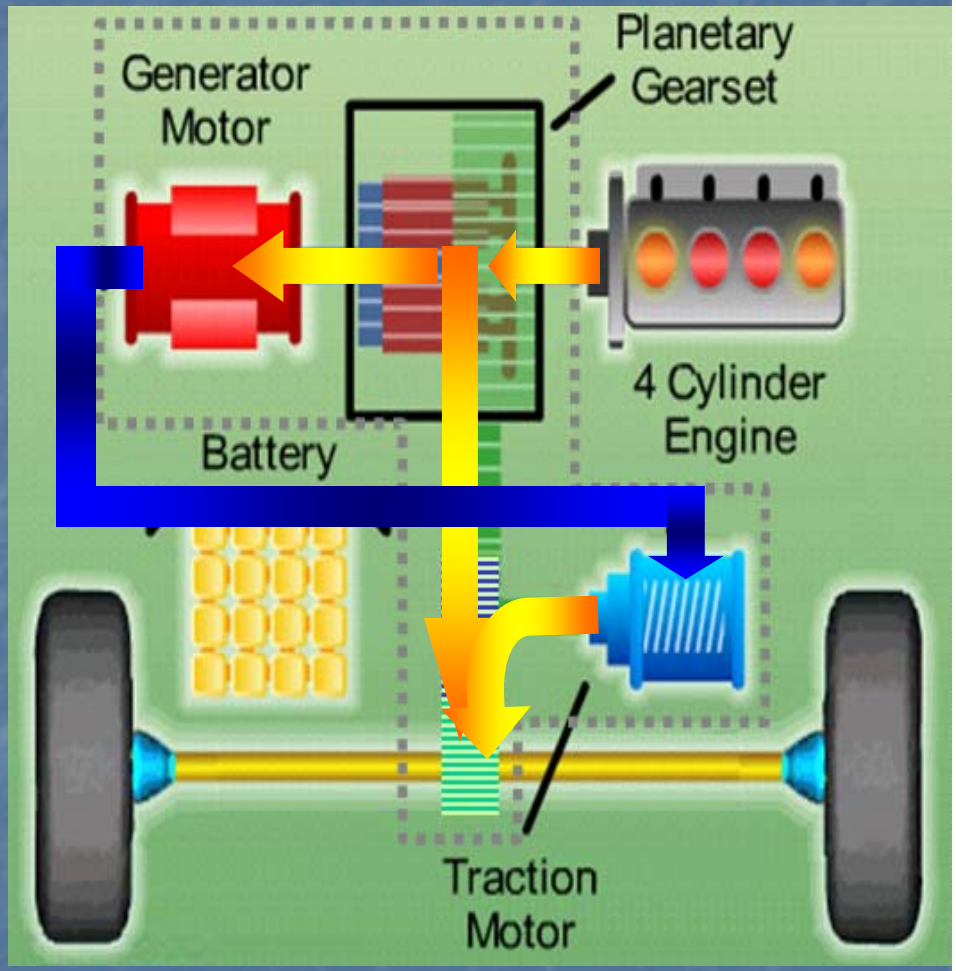


(Globe Graphic)

“Power Split” System Operation



Electric Drive
(up to 47 mph)



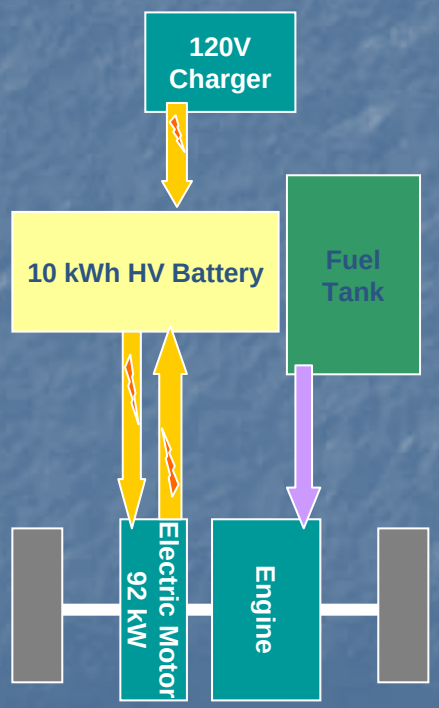
Moderate Speeds and Loads

- Advantages of Power Split Powertrain:
  - Smaller engine with “same” vehicle performance
  - More optimal engine operation
  - Regenerative braking
  - Potentially better fuel economy and emissions
- Disadvantages
  - Cost and weight
  - System complexity

FORD'S BLENDED PHEV IS MORE ROBUST, FLEXIBLE, AND COST-EFFECTIVE THAN GM'S RANGE EXTENDED EV (VOLT)

Escape PHEV

Blended PHEV Architecture



Chevrolet Volt

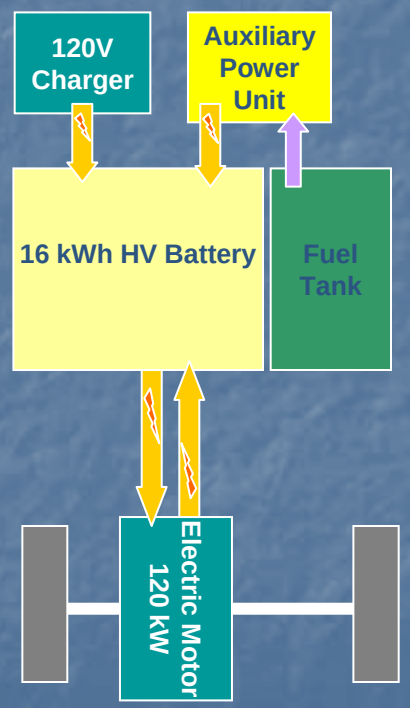
- Battery/Motor always engaged and engine only recharges battery (does not drive wheels)
- Battery/Motor must be sized for all vehicle conditions
- Weight est. 190 kg
- 300 mile range maximum largely dependent on temp and loads
- Top speed raised to 100 mph
- Overnight charge requires 240V
- Battery-only mode: 25 – 50 miles (reduced by high electric loads and cold/hot weather operation)
- After 40 mile max. the engine must run continuously to recharge the battery and avoid compromising performance.

Ford Escape Plug-In Hybrid

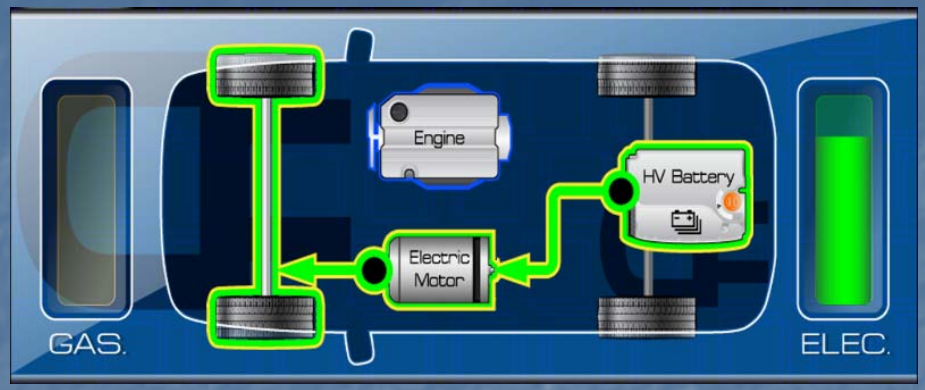
- Battery discharged under first 30 equivalent electric miles then operates like regular HEV
- Weight 130kg
- Battery/Motor sized to optimum efficiency in combination with the engine
- Provides 700+ mile range
- Top electric speed of 62 mph
- Recharges with 120 or 240V easily overnight
- 30 electric equivalent miles after each charge
- Uses engine only at peak efficiency

Volt

Range Extended EV Architecture

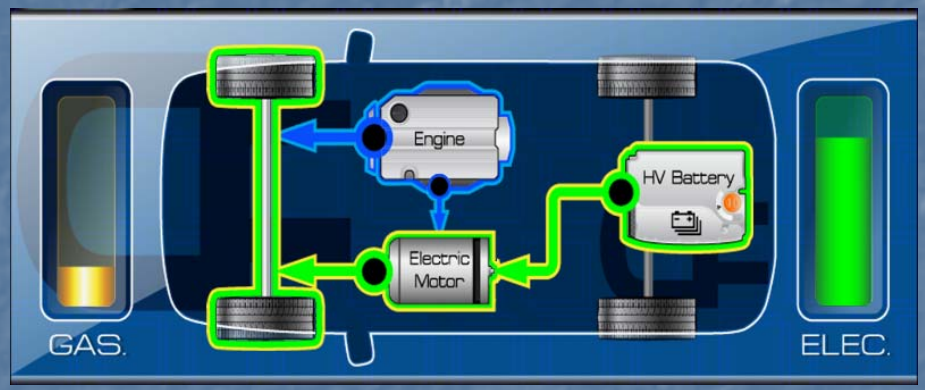


A “Power Split” PHEV System



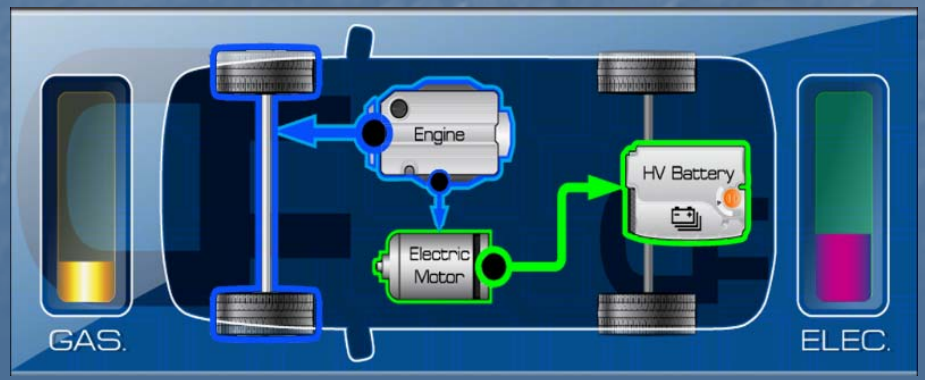
ELECTRIC DRIVE

At urban speeds, the high-capacity plug-in hybrid battery allows for extended battery-only driving distance



BLENDED ELECTRIC/ENGINE DRIVE

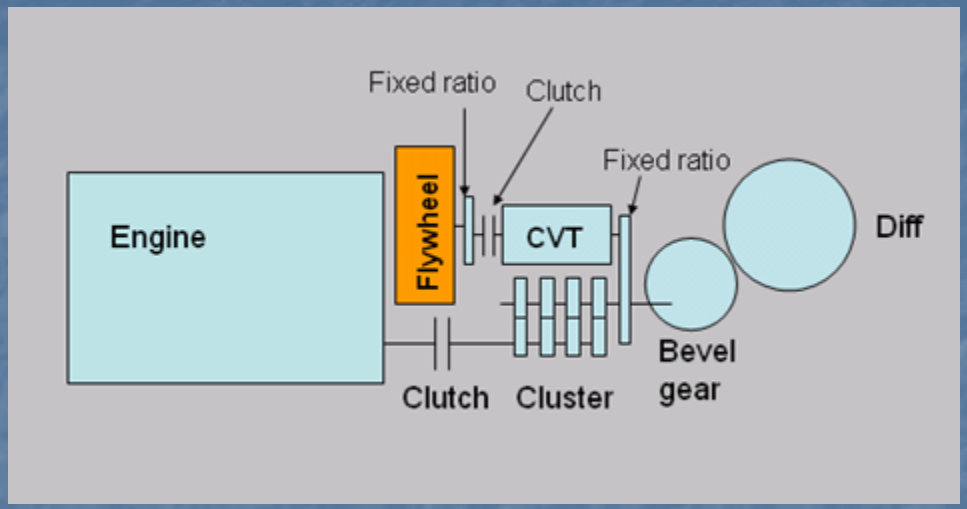
At higher power demands and vehicle speeds, the vehicle automatically switches to blended electric/engine mode, providing propulsion using both the engine and the high-capacity battery



HYBRID DRIVE

In hybrid drive mode, the vehicle continues to operate as a standard hybrid electric vehicle

Flybrid Systems



- A flywheel made of steel and carbon fibre which rotates at over 60,000 RPM inside an evacuated chamber
- The flywheel casing features containment to avoid the escape of any debris in the unlikely event of a flywheel failure
- The flywheel is connected to the transmission of the car on the output side of the gearbox via several fixed ratios, a clutch and the CVT
- 60 kW power transmission in either storage or recovery
- 400 kJ of usable storage (after accounting for internal losses)
- A total system weight of 24 kg
- A total packaging volume of 13 litres

http://flybridsystems.com/

Motor Development International (Air Car)

The need of an extremely economic and ecological car is currently an evidence. More and more cars makers seek this type of vehicle. From these observations and with the advantages of its concept of industrialization, MDI initiated the study of a **low cost, utility clean car**.

The Industrial Concept and light construction technology of MDI allow to reach this challenge. This type of cars is intended to drive in overpopulated and particularly polluted cities.

It is the only vehicle on the market answering these characteristics:

-
- Two minutes refill
- Mono-energy compressed-air in city, dual-energy on road
- Zero Pollution with mono-energy, 30g of CO_2 with dual-energy
- 900Km road range with dual-energy, 100Km with mono-energy
- Car body monoblock made in fiberglass and external chassis for safety

www.mdi.lu/english/

Ventomobile

Wind-powered 'Ventomobile' Places First in Race

ScienceDaily (Aug. 28, 2008) — The solely wind-driven Ventomobile constructed by the InVentus team, a team of some 20 Stuttgart University students of Aerospace Engineering, came in first at the "Aeolus Race" in the Dutch town of Den Helder last Friday.

Personal responsibility... it works!

new MIT study confirms this
velocity matters less than acceleration

About Us | Latest Adventures | Around The World Drive in 78 Days | Fuel Economy Workshops | John's Adventures | World Record Drives | Event Management | Taylor's Tips

Welcome to Fuel Academy

Fuel Economy Training with Expert World Record Breakers Helen and John Taylor

A Life built on passion for Fuel Economy

- **Fuel Economy/Safe Driving Workshops**
- **Fuel Economy/Safe Driving On Road Challenges**
- **Fleet Fuel Economy Education Programs**
- **World and National Record Breaking**
- **Staff Bonding, Team Building Days**
- **Company Fuel Economy Safe Driving Film For Staff, Clientele**

Through education we want to reduce fuel consumption for all drivers globally by at least 10%, resulting in much lower carbon emissions and more money in people's pockets.

One Couple, One Shared Ambition

read their biography

- 46 Speed Driving World Records
- 38 Fuel Economy Driving World Records
  Including **The Guinness World Records Drive Around the World in 78 Days**, experiencing cultural, terrain, climate challenges daily
- National Fuel Economy Records including Asia, Oman, Europe and South Africa
- Founders of the Singapore Book of Records
- Conducting Fuel Economy/Safe Driving workshops and challenges globally, in Argentina, Australia, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Italy, Malaysia, Netherlands, New Zealand, Norway, Oman, Pakistan, Portugal, Singapore, Spain, Switzerland, Thailand, Turkey, UK, USA
- Working together with major corporations around the world, including Shell, Peugeot, Chrysler, Michelin and many, many more.....
- Receiving billions of media hits globally

2008	Guinness Book Round Australia Fuel Economy Overall Record	**Peugeot 308 HDi** Diesel	Averaged 90.75 miles per gallon, 3.13 L/100 km's, covering 14,580 km's round the coastal road route of Australia

www.fuelacademy.com/

1
Drive Smoothly
Aggressive driving can use as much as a third more fuel than safe driving. Avoid accelerating or braking too hard and try to keep your steering as smooth as possible.

2
Use Higher Gears
The higher the gear you drive in the lower your engine speed is, which can improve fuel efficiency. So change up a gear whenever you can, without labouring the engine.

3
Tune and Service Your Engine
A well tuned engine can improve fuel economy by up to 4%, so change your oil and follow your car manufacturer's recommendation on servicing.

4
Keep Your Tyres at the Right Pressure
Correctly inflated tyres are safer and last longer. A tyre that is under inflated by just 1psi can reduce fuel efficiency by as much as 3%. An under or over inflated tyre is also more susceptible to failing.

5
Avoid Carrying Excess Weight
For every extra 100 lbs (45 kg) you carry your fuel efficiency can drop by 1-2%. So keep your boot or back seat clear of unnecessary items that just add weight to your vehicle.

6
Remove the Roof Rack
If you're not using your roof rack, then remove it. They affect the aerodynamic efficiency of vehicles and create drag, reducing fuel economy by as much as 5%.

7
Use the Correct Oil
Always use the recommended grade of motor oil. Using the manufacturer's recommended lubricant can improve fuel efficiency by 1-2%. Higher quality motor oils can help your engine operate more efficiently.

Ford