Hybrid Electric Vehicles

Robert D. Brown
Ford Motor Company

Mobile Sources Technical Review Subcommittee
February 12, 2003

What Will Ford's HEV Provide?

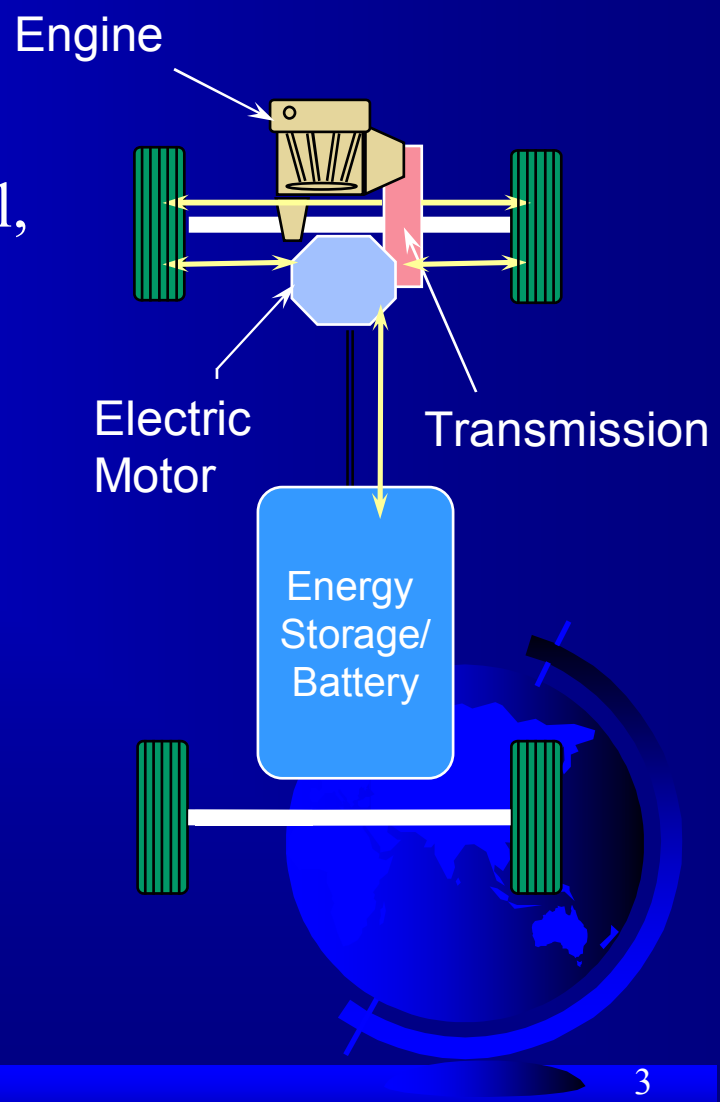
- **Improved Fuel Economy:** 52 - 56% fuel economy improvement over a conventional powertrain.
- **CO_2 Reduction** Potential: Up to 36%.
- **Increased Range:** 500 miles or more between fuel stops.
- **Better Acceleration:** Performance like a V6 from an I4.
- **Reduced Emissions:** Achieve strict SULEV standard (7.5 times cleaner than LEV).

How do HEVs Work ?

A Hybrid Electric Vehicle combines:

- A chemically fueled (gasoline, diesel, or alternative) internal combustion (IC) engine
- Electric motor(s)
- An energy storage device (battery)
- Regenerative braking

The combined system improves the overall vehicle efficiency to increase fuel economy and reduce tailpipe emissions.



Essential Hybrid Operations

- **Engine Downsize :**
  Performance is retained by supplementing the power of the IC engine with the electric motor
- **Regenerative Braking:**
  Recharges the batteries thus recovering energy that would otherwise be lost as heat
- **Electric Launch & Drive**
  Propels the vehicle without turning on the IC engine

	Engine Shutdown & Restart	Engine Downsize	Regenerative Braking	Electric Launch
Conventional IC Engine				
Engine with Electric Accessories				
Engine with Integrated Starter/ Alternator				
Full Hybrid Powertrain				

HEVs

Hybrid Solutions

Fuel Economy Hybrids

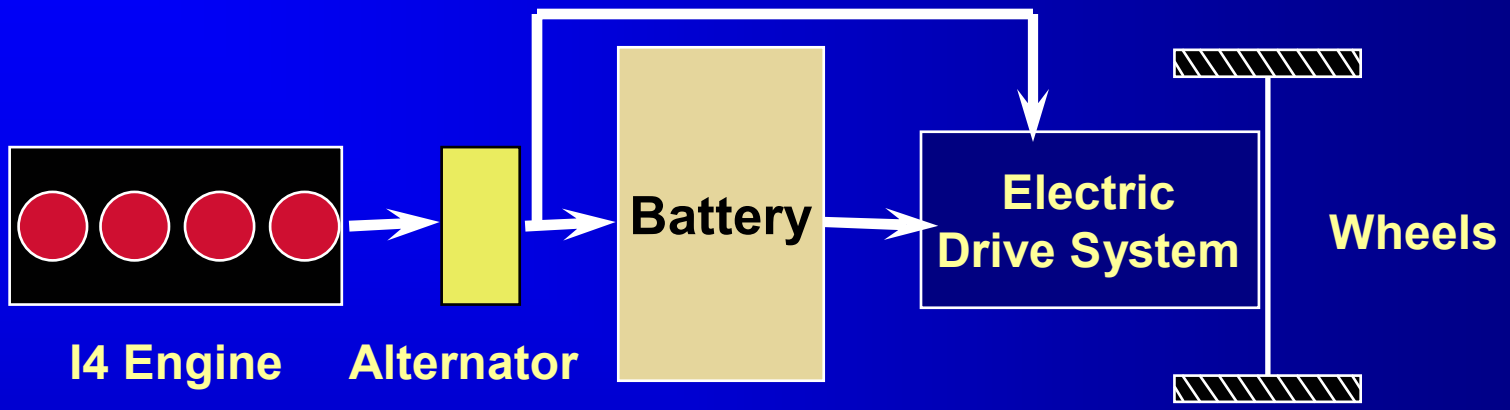
- Conventional-type vehicles with at least one electric motor added for energy recapture, performance boost, and engine starting
- Small battery pack reduces weight penalty, improving performance
- Range is equal to or better than conventional vehicles

Hybrid Solutions

Range Extender Hybrids (Series Hybrid)

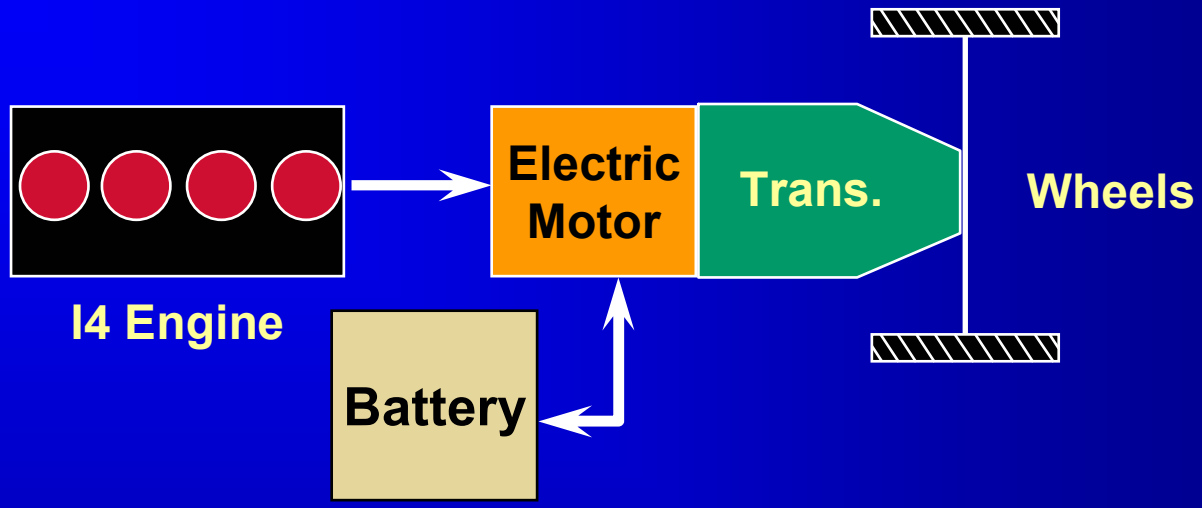
- Electric-type vehicles with a small engine/generator device added as insurance in case vehicle is driven beyond the range capability of the battery
- Large battery pack allows for significant engine-off, zero emissions range, ideal for polluted city centers
- The small generator set is not capable of meeting the average power requirement, so battery charge typically drops over time, requiring a plug-in recharge

Series Hybrid System



- Electric drive motor integral with transaxle
- IC engine operates generator to provide electricity to the motor and to recharge the battery pack
- Gasoline engine can be modified to run Atkinson cycle to improve efficiency
- High technology battery storage for high energy density

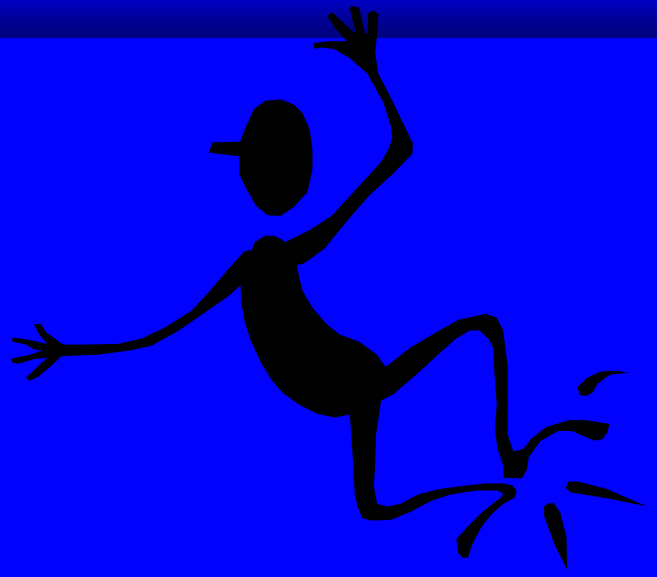
Parallel Hybrid Architecture



- Both the engine and motor are connected to the drivetrain
- Electric motor can be packaged within transmission bell housing
- Disconnect clutch between the engine and transmission to allow electric launch without starting the engine
- Advanced battery energy storage for high power density

What Do Customers Want?

- An environmentally friendly, competitively priced vehicle
- A combination of:
  - Exciting performance
  - High fuel economy
  - Superior quality
  - Low emissions
  - High recycleability
  - An uncompromised package
- Convenient operation:
  - Extended range
  - No special fuel or daily plug-in



HEV Functional Targets (Versus Conventional Escape)

	Conventional Escape 4x2		HEV Escape 4x2
	2.0 I4 MT	3.0 V6 AT	Full Hybrid
Performance			
- 0-60 mph (sec)	~11.9	10.4	10.4-10.7
- Trailer Tow (lbs)	1,000	3,500	1,000
Fuel Economy [1/]			
- Metro Highway (mpg)	29.1	25.0	38-39
- % > base	16%	BASE	52-56%
Emissions	LEV	LEV	SULEV
Refueling Interval (miles)	400	370	500 or more

1/ Metro Highway. HEV Fuel Economy numbers are directional estimates.

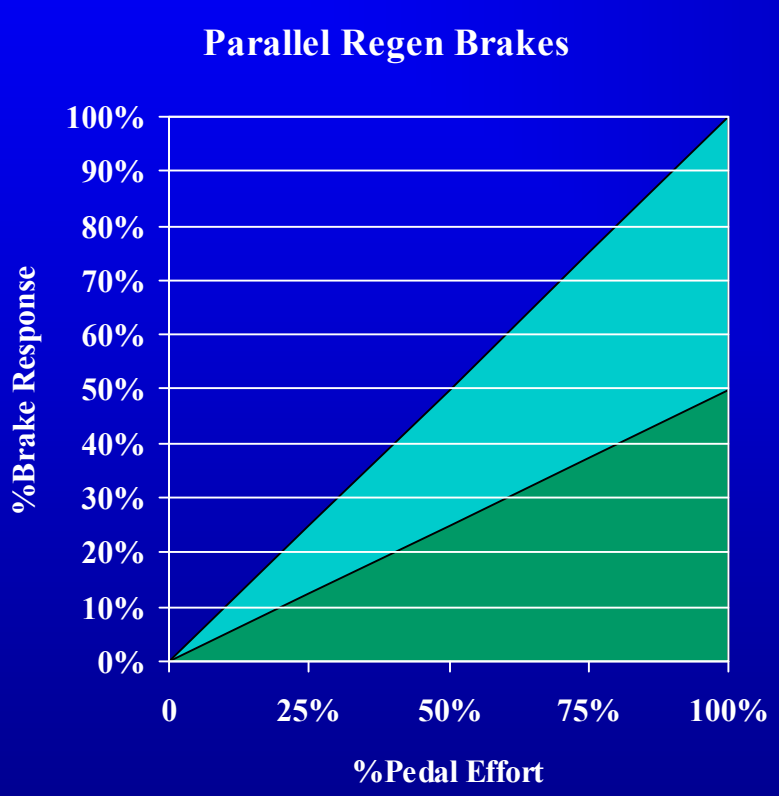
Battery

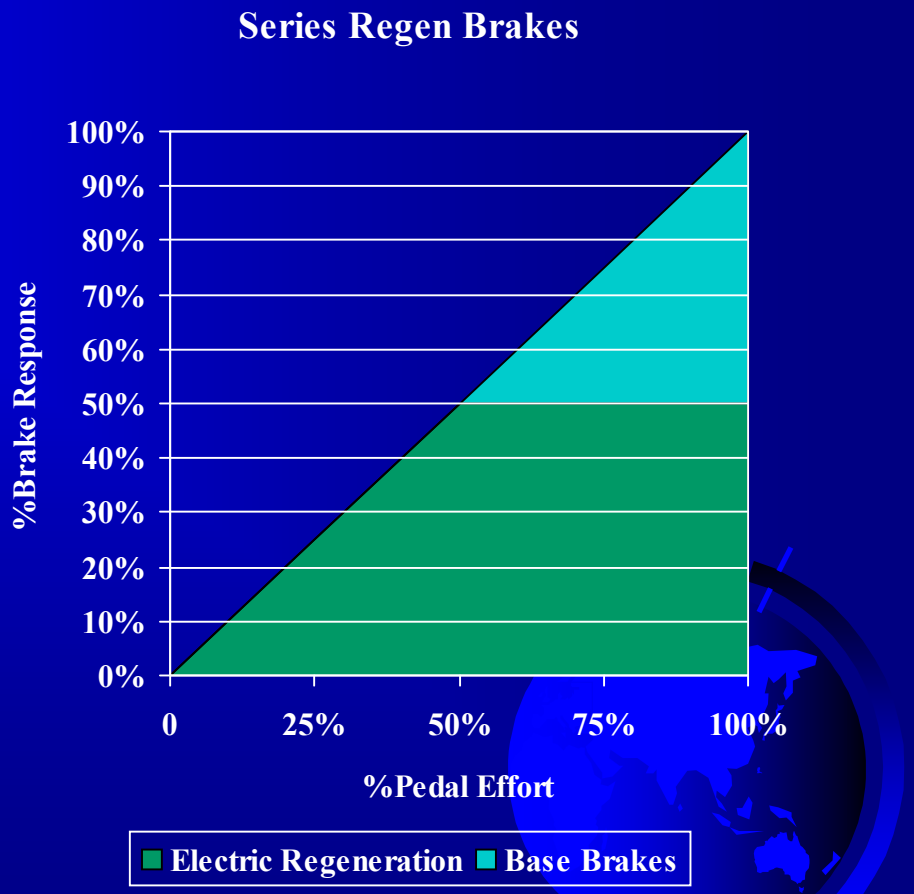
- Sanyo is the exclusive battery supplier
- 300 Volt nickel-metal hydride traction battery pack
- Runs the vehicle in pure electric mode and provides engine boost
- Packaged in the rear with no loss of usable space
- Designed with safety as a top priority

HEV Powertrain

- Efficient I4 engine with Atkinson cycle
- Transaxle integrates planetary gears with two motor/generators
- Provides efficiency and the smooth power flow functionality of an electric CVT
- Operates in a series, parallel or compound mode

Regenerative Braking –Parallel vs. Series





HEV System Controller

- Highest level control in the logical hierarchy Controls:
  - PCM (engine)
  - TMU (Transmission/motor)
  - Battery and Braking System
- Provides optimal balance among performance, FE and emissions.
- Hierarchical, modular design with built in robustness and diagnostics.
- Optimized through the use of modern control theory and development tools.

Public Website

www.hybridford.com

HEV Service Challenges

- 300 volt electrical system versus 12 volt conventional
- Complex/new system interactions
- Unique Components
  - –PowerSplit Transmission
  - –Traction Battery
  - –Control Modules
    - Traction Inverter
    - Series Regeneration Brakes
    - Vehicle System Controller
  - –DC - DC Converter

End of Presentation