

Clean Automotive Technology...  
Innovation that Works

# EPA Advanced Technologies

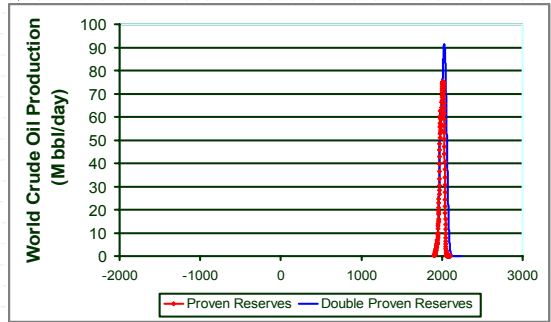
China

November 2004



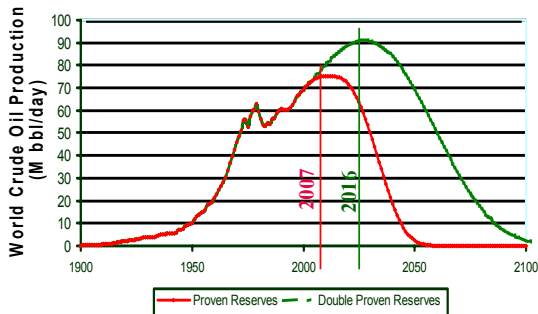
Charles L. Gray, Jr.  
Advanced Technology Division  
Office of Transportation and Air Quality

## World Crude Oil Production



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## Urgency of Our Combined Effort... World Crude Oil Production/Consumption



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## Meeting the Challenge of High Efficiency and Low Emissions

Revolutionary  
Engines

Revolutionary  
Drivetrains



Ultra-Clean &  
Ultra-Efficient  
Vehicles

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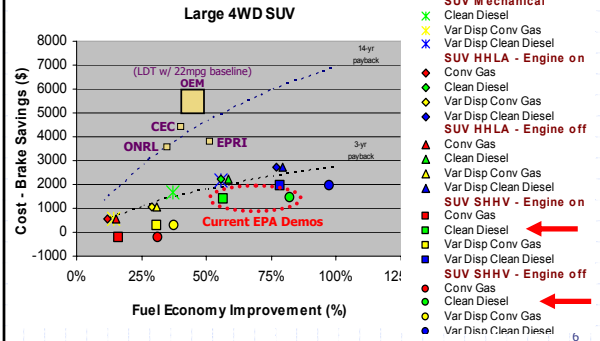
## Economic Analysis

- ◆ We regularly conduct world wide technology assessments
- ◆ With that insight and our own analysis we have concluded that certain technologies make more economic sense (see technical report at [www.epa.gov/otaq/technology/](http://www.epa.gov/otaq/technology/))

**Hydraulic Hybrids and EPA Clean Diesel Combustion Engines** look especially attractive with projected consumer paybacks of 1-3 years at \$1.50/gallon fuel.

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## Comparison of SUV Technologies... Consumer Payback



## EPA Clean Diesel Combustion - Controlling Diesel Engine-out NOx...

### Air Management

- controls peak combustion temperature with boost & EGR (low NOx)

### Fuel and Combustion Management

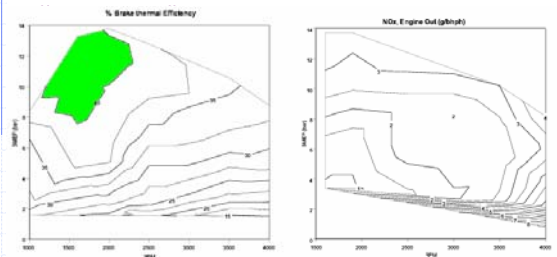
- promotes fast combustion utilizing advanced fuel injection systems for performance, good efficiency, and low smoke/PM

### Conventional Aftertreatment

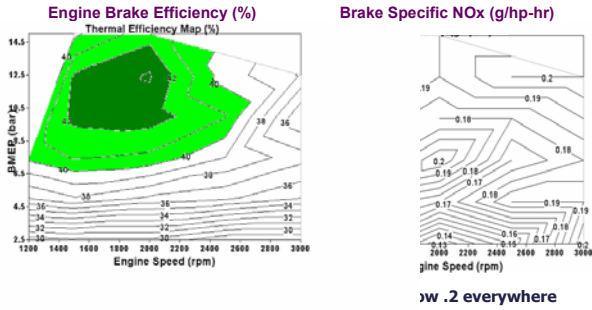
- reduces PM, HC & CO to the level of the standards

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## Diesel Combustion in a Current 1.9L Engine...



## EPA Clean Diesel Combustion (1.9L Multi-Cylinder Evaluation)



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## More Engine Break-Throughs ...

### HCCI Combustion

- 4 cylinder engine working, installed in truck
- Virtually "no" NOx or PM emissions
- Diesel like efficiency from gasoline
- Excellent engine for a series hybrid
- Paper in March 2004 SAE Congress

### Free-Piston Engine

- Great efficiency -Hydraulic power directly from engine
- Clean 4-stroke cycle or High Power 2-stroke cycle
- Capable of Clean Diesel or HCCI combustion
- High Reliability/Low Cost potential: fewer moving parts

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## More Emerging Engine Technologies...

### HyTEC – Hybrid Thermal Energy Converter

- Recovers energy from engine exhaust heat,
- Yields fuel cell efficiency levels at 1/5<sup>th</sup> the cost

### Ethanol-Value

- Diesel-like efficiency, low GHG
- Payback analysis – low cost fuel (E30) still achieves high FE
- Ready for fleet demonstration

### Variable Displacement Engine

- Allows optimum high efficiency use of a small displacement engine while retaining the option for sustained high power when needed

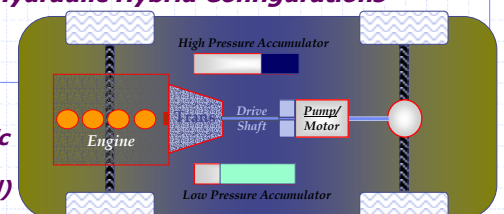
### Variable Compression Engine

- Allows low power, very efficient engines to also provide high power performance

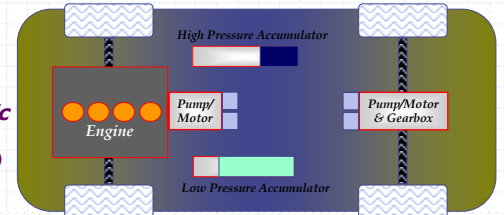
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## Hydraulic Hybrid Configurations

### Mild Hydraulic Hybrid (Parallel)



### FULL Hydraulic Hybrid (Series)



## Historic EPA Hydraulic Hybrid Test Chassis

- ✓ Full Series Hydraulic Hybrid
- ✓ 80+ mpg combined city/highway mpg
- ✓ ~8 seconds 0-60 acceleration time
- ✓ No need for expensive lightweight materials (test weight 3800 lb)
- ✓ Led the way for subsequent demonstration vehicles



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## Focus for Current EPA Demonstration of Hydraulic Hybrid Vehicles

1. **Class 5 Delivery Truck**
  - Hydraulic Assist Hybrid
  - Diesel Engine
  - Package suitable for retrofits
2. **Class 6 Urban Package Delivery Vehicle**
  - Full (series) Hydraulic Hybrid
  - Diesel Engine
3. **Sport Utility Vehicle**
  - Full (series) Hydraulic Hybrid
  - Diesel Engine

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## Urban Delivery Truck – Hybrids through Retrofitting

### Hybrid Assist Hydraulic Hybrid

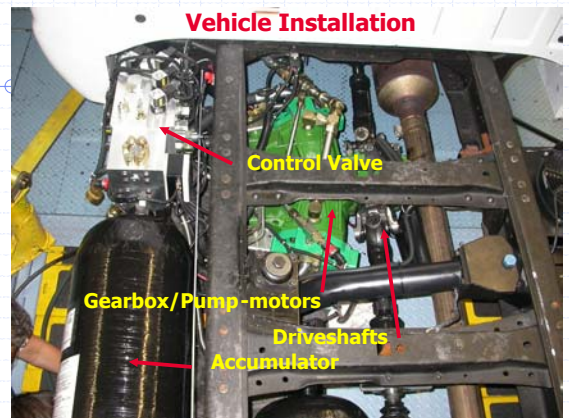
- Demonstrates the ease of retrofitting trucks with hydraulic hybrid technology
- Shows ability to get low hanging fruit (20-30% mpg improvement)
- Gold award for mpg improvement and Silver award for performance at the 2003 Michelin Bibendum Challenge



EPA's F-550 fleet retrofit demonstration vehicle with hydraulic launch assist.



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## Urban Delivery Vehicle - *Full Series Hydraulic Hybrid*

- First-ever full integrated hydraulic hybrid delivery vehicle, targets 70% mpg improvement in city driving
- 2-year payback has attracted serious attention from fleets
- Partnership involving EPA, Eaton, fleet, OEM & Army



Showcasing full hydraulic hybrid systems in an Urban Delivery Vehicle.

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## Full Series Hydraulic Hybrid SUV

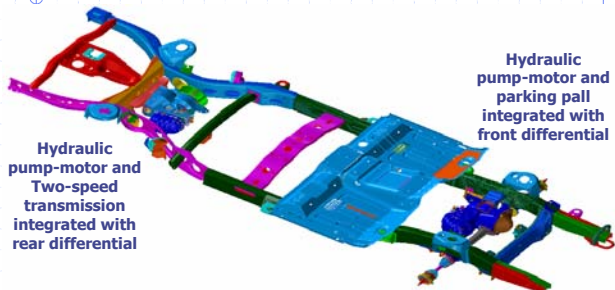
- Full integrated hydraulic hybrid, diesel engine, clean packaging, cost effective, targets 85% mpg improvement
- Excellent 1-3 year payback for consumer
- Best configuration to communicate a vision of production potential



Showcasing the full use of hydraulics in a Ford Expedition.

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## Innovative Integrated Packaging



Hydraulic pump-motor and Two-speed transmission integrated with rear differential

Hydraulic pump-motor and parking pall integrated with front differential

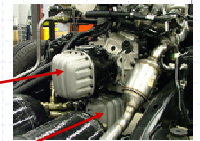
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## Integrated Design...



View from Rear

Engine Pump

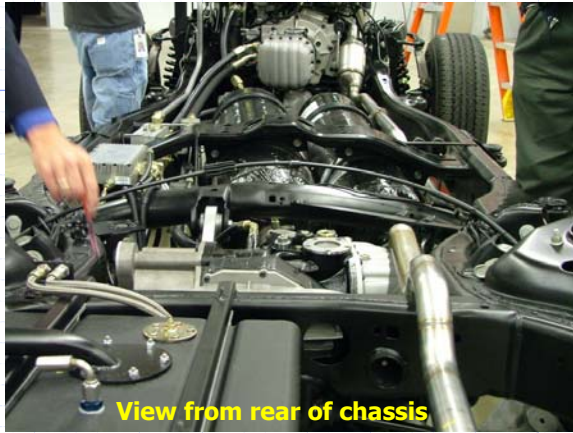


Integrated Front Drive



Integrated Rear Drive w/ 2-speed Trans

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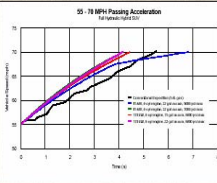
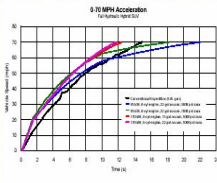


View from rear of chassis



View under chassis from rear of vehicle

**Full Hydraulic Hybrid SUV**  
Projected Performance Examples



**Full Hydraulic Hybrid SUV**  
Projected Design Examples

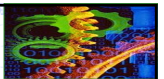
	Medium Engine Package	Small Engine Package
Large 4WD SUV Diesel Engine (213kw)	3.8-liter (213kw)	1.9-liter (213kw)
Accumulator	15 gal	22 gal
Weight Increase	360 lbs (163kg)	125 lbs (57kg)
	Fuel Economy - label values	Fuel Economy - label values
City	32 mpg	33 mpg
Highway	22 mpg	23 mpg
Combined	27 mpg	28 mpg
	Cost Payback	Cost Payback
Cost Increase	\$2,200	\$1,000
Payback	2.5 years	1.1 years
Lifetime Savings	\$4,800	\$6,300
	Performance	Performance
mph acceleration (0-70)	8.9 seconds	11.4 seconds
x sustained speed (at 100%)	108 mph	90 mph
x sustained grade (at 100% at 100%)	9.1%	3.5%
1/4 mile time (at 100% at 100%)	12,000 lbs	6,900 lbs

assumptions: Mature high-volume production, vehicle life of 14 years and 180,000 miles, \$1.50 per gallon fuel price, 7% discount rate, and 20% retail price mark-up

note: See "Progress Report on Clean and Efficient Automotive Technologies Under Development at EPA" (January 2004), at [www.epa.gov/otaq/technology](http://www.epa.gov/otaq/technology)

**Progress Report on Clean and Efficient Automotive Technologies Under Development at EPA - January 2004**  
[www.epa.gov/otaq/technology](http://www.epa.gov/otaq/technology)

For More Information  
[www.epa.gov/otaq/technology](http://www.epa.gov/otaq/technology)



1) 4 page fact sheet

**World's First Full Series Hydraulic Hybrid SUV Presented at the 2004 SAE World Congress - March 2004**

2) 198 page interim technical report

**Progress Report on Clean and Efficient Automotive Technologies Under Development at EPA - January 2004**