Why Light Duty Diesels Make Sense in the North American Market

12th DEER Conference
US Department of Energy

August 22, 2006
Agenda

1. Performance: it’s all about torque

2. The diesel value proposition in the US

3. 50-state emissionized diesel cost assessment

4. Summary and conclusions
US consumers have been trained to think about HP, but torque makes a vehicle fun-to-drive.

Torque and Hp Output Curves – Typical US Gasoline V6

“Usable” torque is available over a wide range of engine speeds

Peak Hp is typically achieved at maximum engine rpm’s

Torque . . . .

The force that presses you into the seat when you accelerate
Modern diesels deliver more torque at lower engine speeds . . . where we drive.

**Illustrative V6 Torque Curves**

- **V6 Diesel**
- **V6 Gas**

**Engine Speed**

**Torque (lb-ft)**

**The Benefits of Low End Torque**

**Better acceleration**
- City driving
- Highway passing

**Better towing performance**
- For trucks and SUVs

**New transmissions compliment diesel engines**
- 6+ speed automatics
- Enable diesels to stay in peak torque and fuel efficiency zone

**Diesel Value-Add**

- Peak Torque
  - Below 2000 rpm

**Maximum**
In the US car fleet, consumer demand for torque has increased at nearly 2% per yr.
In the light truck fleet, consumer demand for torque has been increasing at more than 2.5%.

**US Fleet Torque and Hp Development – Light Trucks**

<table>
<thead>
<tr>
<th>Year</th>
<th>Engine Torque (lb-ft)</th>
<th>Horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>120</td>
<td>190</td>
</tr>
<tr>
<td>1994</td>
<td>140</td>
<td>195</td>
</tr>
<tr>
<td>1995</td>
<td>160</td>
<td>200</td>
</tr>
<tr>
<td>1996</td>
<td>180</td>
<td>205</td>
</tr>
<tr>
<td>1997</td>
<td>200</td>
<td>210</td>
</tr>
<tr>
<td>1998</td>
<td>220</td>
<td>215</td>
</tr>
<tr>
<td>1999</td>
<td>240</td>
<td>220</td>
</tr>
<tr>
<td>2000</td>
<td>260</td>
<td>225</td>
</tr>
<tr>
<td>2001</td>
<td>280</td>
<td>230</td>
</tr>
<tr>
<td>2002</td>
<td>300</td>
<td>235</td>
</tr>
<tr>
<td>2003</td>
<td>320</td>
<td>240</td>
</tr>
<tr>
<td>2004</td>
<td>340</td>
<td>245</td>
</tr>
<tr>
<td>2005</td>
<td>360</td>
<td>250</td>
</tr>
</tbody>
</table>

**Graph Notes:**
- Torque: +2.6% annual rate
- Horsepower: +3.3% annual rate
- Pump price run up

*Source: Martec analysis*
A significant number of consumers pay a premium for even more performance over the standard engine . . . and sacrifice fuel efficiency.

**US Gas Engine Torque vs. FE Curve**

- **Diesel Opportunity**
  - Peak torque reached at 40-50% lower RPM
  - 25-35% consumption reduction

Source: Martec analysis

2005 US Fleet Torque vs. Fuel Efficiency – Cars

Optional Engine Metrics
- + 30 lb-ft torque performance
- ~ $29/lb-ft dealer invoice price
- Sacrificed ~ 1.3 mpg fuel efficiency

Source: Martec analysis
In the light truck market, more than 3.5M buyers paid a premium for additional performance.

Optional Engine Metrics
- + 42 lb-ft torque performance
- ~ $18/lb-ft dealer invoice option price
- Sacrificed ~ 1.5 mpg fuel efficiency

2005 US Fleet Torque vs. Fuel Efficiency – Light Trucks

Source: Martec analysis
Diesels now dominate the US heavy-duty pickup truck market.

US Fleet Torque vs. Fuel Efficiency
HD Pickup

Diesel Value Proposition
vs. Standard Gas
- 61% torque improvement
- 28% fuel efficiency improvement
vs. Optional Gas
- 29% torque improvement @ 57% the engine speed
- 54% fuel efficiency improvement

Source: Martec analysis
Diesels are the optional performance engine of choice in Europe.

**EU Fleet Torque vs. Fuel Efficiency**

- **Standard Gas Engine**: 14% torque improvement, 22% fuel efficiency improvement
- **Optional Gas Engine**: 38% torque improvement at nearly half the engine speed, 38% fuel efficiency improvement
- **Diesel Engine**: 72% torque improvement, 22% fuel efficiency improvement

**Diesel Value Proposition vs. Standard Gas**
- 72% torque improvement
- 22% fuel efficiency improvement

**Diesel Value Proposition vs. Optional Gas**
- 38% torque improvement at nearly half the engine speed
- 38% fuel efficiency improvement

Source: Martec analysis
“Europe is different because fuel is so much more expensive.”

Paris, France
- $4.88/ gal. pump price
- 7,500 miles/yr.
- $900 annual fuel bill

Paris, Texas
- $2.10/gal. pump price
- 17,500 miles/yr.
- $2,300 annual fuel bill

Source: Martec analysis
Agenda

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③ 50-state emissionized diesel cost assessment

④ Summary and conclusions
Unlike most of Western Europe, diesel fuel is taxed more heavily than gasoline in the US.

What's up with diesel pricing?

Source: EIA
US fuel refining capacity increases have crept along at <0.7% annual rate since 1990.

US refinery capacity and utilization has consistently exceeded 90% since 1993.

US demand for fuel has increased at a much faster rate since 1995:
- Gasoline demand has increased at 1.7% annual rate . . . .
- With distillate demand increasing at 2.1%

Source: EIA
Europe is exporting excess gasoline to the US, helping to depress pricing relative to diesel.

US gasoline imports have risen dramatically: > 5.5% CAGR

Half of the increased US demand met by imports
• 60% from Europe

While US distillate imports are essentially flat

EIA 2007 Forecast:
$0.07 premium for diesel…most of which is tax delta

Source: EIA
The HD pickup customer buys the diesel for low-end torque; fuel efficiency is a bonus.

**Example HD Pickup Torque Curves**

<table>
<thead>
<tr>
<th>Engine Speed (X100)</th>
<th>Torque (lb-ft)</th>
<th>Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>605/820</td>
<td>Duramax 6600</td>
<td>605/820</td>
</tr>
<tr>
<td>455/617</td>
<td>Vortec 8100</td>
<td>455/617</td>
</tr>
<tr>
<td>360/488</td>
<td>Vortec 6000</td>
<td>360/488</td>
</tr>
</tbody>
</table>

**HD Pickup Truck Market Sales Weighted Metrics**

**Base V8 OHV/SOHC gas engine**
- 364 lb-ft/494 Nm @ 4012 rpm
- Real world FE combined: 13.1 mpg

**Optional diesel engine**
- 587 lb-ft/796 Nm @1849 rpm
- Real world FE combined: 16.8 mpg
- Option price (with auto trans): $6603

**Optional V8/V10 gas engine**
- 456 lb-ft/619 Nm @ 3232 rpm
- Real world FE combined: 10.9 mpg
- Option price (with auto trans): $2250

Source: Company websites
After 4.5 years, the average diesel owner has saved nearly $4200 in fuel vs. the alternative high torque option.
The diesel customer recovers a $4700 trade-in premium after 4.5 years.

Source: Martec analysis
The diesel customer is paying a 20% premium per unit of torque improvement vs. optional gas... but diesel pays you back.

Source: Martec analysis
After 4.5 years, fuel savings have reduced the effective diesel option price by one-third.

HD Pickup Trucks – $/Unit of Torque Improvement (NPV 3-yr. Fuel)

- Diesel Option
  - $4,413
  - +223/61%
  - 587lb/ft

- Gasoline Option
  - $4,250
  - +92/25%
  - 456lb/ft

Source: Martec analysis
At trade-in, the effective cost of 4.5 years of premium performance is about $1,100.

**HD Pickup Trucks – $/Unit of Torque Improvement (NPV 3-yr. Fuel)**

- **Effective option price at 54 mos. less:**
  - Fuel savings
  - Residual value recovery

- **Unit torque gain**
  - **Diesel Option:** +223/61% 587lb/ft
  - **Gasoline Option:** +92/25% 456lb/ft

Source: Martec analysis
The Jetta diesel customer is paying a 38% premium per unit of torque improvement vs. optional gas... but diesel pays you back.

**VW Jetta – $/Unit of Torque Improvement (NPV)**

- **Diesel Option**: +$1,334 Option price
- **Gasoline Option**: +$1,491

Unit torque gain

- **Diesel Option**: +33/27% 155lb/ft
- **Gasoline Option**: +51/42% 173lb/ft

Source: Martec analysis
After 4.5 years, fuel savings have recovered the total Jetta diesel option price.

Source: Martec analysis
At trade-in, the effective cost of 4.5 years of premium performance is about ($1,850).

**VW Jetta – $/Unit of Torque Improvement (NPV 3-yr. Fuel)**

- **Effective option price at 54 mos. less:**
  - Fuel savings
  - Residual value recovery

- **$1,065**

- **+$1,065**

- **($1,862)**

- **Unit torque gain**
  - +33/27% 155lb/ft
  - +51/42% 173lb/ft

Source: Martec analysis
In a coast-to-coast test by Autobild magazine, a diesel SUV delivered on its fuel efficiency promise. The hybrid fell short.

The HEV Loophole: Real World Efficiency Falls Short of Promise

Source: Autobild.de
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High efficiency NOx aftertreatment will be required to create a 50-state light duty diesel market.
Aftertreatment technology has entered the cost optimization phase of development.

5.0L OHV V8 bin 5 gasoline aftertreatment and evap system baseline: $285

Net aftertreatment costs
- SCR ~ $880
- LNT ~ $1415
- With potential for significant reductions through advanced “pre-mix” combustion system development

Source: Martec analysis
Engine architecture drives a range of on-engine diesel costs.

### Construction of Dieselization Costs vs. V8 OHV 2V Baseline

<table>
<thead>
<tr>
<th>Potential Diesel Architecture</th>
<th>Cost Delta vs. V8 OHV 2V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L6 DOHC 4V</td>
</tr>
<tr>
<td>Downsizing credit</td>
<td>($300)(^1)</td>
</tr>
<tr>
<td>Diesel Content</td>
<td></td>
</tr>
<tr>
<td>• VGT turbo and accessories</td>
<td>$1100</td>
</tr>
<tr>
<td>• Advanced diesel FI system</td>
<td></td>
</tr>
<tr>
<td>• Injectors, HP pump, rail (s) and diesel ECM</td>
<td></td>
</tr>
<tr>
<td>• Minor mechanical upgrades</td>
<td></td>
</tr>
<tr>
<td>Net on-engine variable cost delta</td>
<td>$800</td>
</tr>
</tbody>
</table>

**Net variable cost increase with SCR aftertreatment**

- $1,700
- $2,200
- $2,800

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1 Assumes conversion from Fe to Al block

**Only variable costs captured.**
## A potential US full size pickup truck diesel value proposition:

<table>
<thead>
<tr>
<th>Key Assumptions</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel option price – 4.5L DOHC V6</td>
<td>$4,000</td>
</tr>
<tr>
<td>Performance increased 30% vs. class average</td>
<td>432 lb-ft torque</td>
</tr>
<tr>
<td>Fuel consumption reduced 30%</td>
<td>19 mpg</td>
</tr>
<tr>
<td>VMT over 4.5 years</td>
<td>79,000</td>
</tr>
<tr>
<td>Residual value on option = to European typical</td>
<td>64%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customer Value Proposition</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option cost/lb-ft performance +</td>
<td>$40</td>
</tr>
<tr>
<td>Fuel savings – NPV @ 3-year US avg.</td>
<td>($2,580)</td>
</tr>
<tr>
<td>Saved re-fueling stops/month</td>
<td>1.2</td>
</tr>
<tr>
<td>Residual value recovery - NPV</td>
<td>$1,820</td>
</tr>
<tr>
<td>NPV cost for 4.5 years of premium performance</td>
<td>($400)</td>
</tr>
</tbody>
</table>

Excludes urea costs. At 3% dosing rate ~ $185-250 at $1.5-2.0 per gallon retail.
Heavy capital investment necessary to support light duty dieselization already exists in the US.

Existing Manufacturing Capital to Support Light Duty Dieselization

Source: Martec analysis
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We expect substantial growth in the diesel share of North American demand.

North American Diesel Forecast

Diesel pump price relative to regular gasoline

=/-$.07 per gal (EIA reference)

Diesel Share of North American Sales

Calendar Year

Source: Martec analysis
The diesel value proposition, demonstrated in Europe and in the HD pickup segment, will work in the North American light duty market.

**Summary**

Why light duty diesels make sense in the North American market.

- Diesel powered vehicles deliver the kind of performance and durability consumers want . . . and pay a premium to acquire

- They are economically viable for both manufacturers and consumers
  - Low operating cost and time savings
  - High residual value at trade-in
  - Real-world FE in line with promise

- 50-state emissions levels will be achieved through advanced combustion control and aftertreatment systems

- Diesels can deliver near term benefits to the environment and the economy by reducing demand for imported oil

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