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PIRINC has prepared the enclosed report, *The Diesel Car: A Beautiful Swan Abroad, An Ugly Duckling At Home*.

In recent years, the hybrid car, and, for the longer term, the fuel cell car, have been viewed as technologies that can achieve quantum gains in vehicle efficiency and help reduce US oil consumption. But hybrid cars are a tiny fraction of the market, less than 1% of the light duty vehicle sales last year, while fuel cell cars are years away from commercialization. There is another, proven, commercial technology that already delivers substantial gains in light duty vehicle efficiency, the diesel engine. Although the diesel has a strong share of the car market in Europe, it is nearly completely absent from the US.

Among the reasons for its absence are the lingering memories of the very poor performance and reliability of the diesels hurriedly introduced in the US in early 1980s and their high emissions of certain pollutants, primarily NOx and particulates. Nonetheless, the current generation of diesels performs far better than earlier versions and emissions have been significantly reduced. Both in Europe and the US, emission standards for diesel vehicles are being tightened further. Sulfur specifications for diesel are also being tightened substantially to enable the advanced technologies needed to meet them.

This report focuses on the latest offerings of diesel cars and light trucks and compares them to broadly similar 2005 model year gasoline vehicles and the latest hybrids. The report confirms the clear advantages of diesel relative to conventional gasoline vehicles in terms of miles per gallon, and its current disadvantages in terms of certain emissions.

A "clean" diesel could be very attractive to US car buyers, especially given the persistence of high fuel prices, and make a significant, long-term dent in US oil consumption. Its future is by no means assured but continued progress is being made, improving the odds that diesel could become a significant player in the US market.

If you have any questions or comments, please call John Lichtblau, Larry Goldstein or Ron Gold.

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The Diesel Car: A Beautiful Swan Abroad, An Ugly Duckling At Home

Summary

In recent years, the hybrid car, and, for the longer term, the fuel cell car, have been viewed as technologies that can achieve quantum gains in vehicle efficiency and help reduce US oil consumption. But hybrid cars, though growing rapidly in number, are a very tiny fraction of the market, less than 1% of the light duty vehicle sales last year, while fuel cell cars are years away from commercialization.[1] Yet, while these technologies are receiving most of the public spotlight, there is another, proven, commercial technology that already delivers substantial gains in light duty vehicle efficiency, the diesel engine. Although the diesel has a strong share of the car market in Europe, it is nearly completely absent from the US.

Among the reasons for its absence are the lingering memories of the very poor performance and reliability of the diesels hurriedly introduced in the US in early 1980s and their high emissions of certain pollutants, primarily NOx and particulates. Nonetheless, the current generation of diesels performs far better than earlier versions and emissions have been significantly reduced. Both in Europe and the US, emission standards for diesel vehicles, cars as well as trucks, are being tightened further and sulfur specifications for highway diesel are being tightened substantially to enable the advanced technologies needed to meet them.

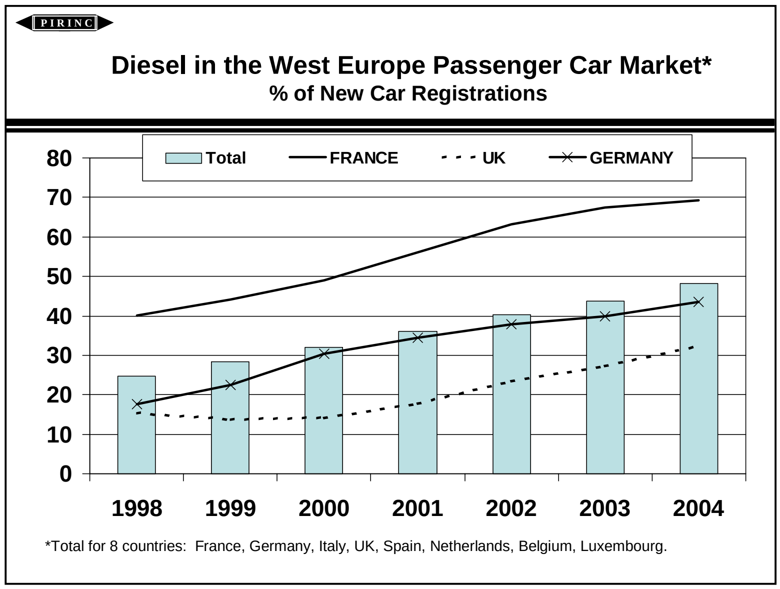
This report focuses on the latest offerings of diesel cars and light trucks and compares them to broadly similar gasoline vehicles and the latest hybrids. The report considers diesel performance in terms of the latest US, California, and for comparative purposes, European Union emissions standards. The report confirms the clear advantages of diesel relative to conventional gasoline vehicles in terms of miles per gallon, and its current disadvantages in terms of certain emissions. Hybrids appear to do better on both counts, although they are far more complex, and less proven commercially than the diesel. A "clean" diesel could be very attractive to US car buyers, especially given the persistence of high fuel prices, and make a significant, long-term dent in US oil consumption. But its future is by no means assured. None of the few diesel vehicles currently on offer meet the latest EPA emission standards for NOx and particulates (although they do meet the higher transitional standards in effect through 2006) and are even further from meeting the latest, pace-setting, California standards. However, continued progress is being made, improving the odds that diesel could become a significant player in the US market.

There is no single policy instrument, or technology to choose from, that by itself can insulate the US economy from oil supply shocks. A portfolio approach is needed and in this regard, a clean diesel can make a contribution. If diesel could approach West Europe's late 1990's share of the light duty vehicle fleet, about 20%, by 2020, not a difficult target since there are no structural barriers to such an increase, transportation fuel savings would amount to about 500 MB/D.

[1] In California, home of the California Fuel Cell Partnership, there are currently 55 fuel cell light duty vehicles on the road

Diesel Cars in Europe and the US

In Europe, the combination of rising oil prices, high gasoline taxes, and in several countries, lower taxes on diesel fuel, has led to growing consumer interest in diesel cars. European Union governments---and European automakers---are looking to diesel to meet fuel efficiency and CO2 emission targets. The chart below shows recent trends in diesel penetration of Western Europe's car market. It shows trends in share of new car registrations in eight European countries collectively and developments in Germany, Europe's largest national car market, France, which has long favored the diesel, and the UK, where there have been no particular tax advantages for diesel use.



In 1998, diesel's share of the combined market was about 25%. In 2004, diesel's share reached nearly 50%, a doubling of market share in just 6 years. In both Germany and the UK, diesel's share of new registrations was below 20%. In 2004, diesel's share of the German market had risen to 44% while its share of the UK market rose to 33%.

In 1998, France showed diesel penetration well above the group average at 40%---a position consistent with its longstanding favorable policy toward diesel. Despite its already high starting point, diesel penetration has moved up much further, to nearly 70% last year.[2]

The US looks very different. Indeed, diesel's role in the light duty vehicle market is so small that only limited data are readily available. The table below show diesel's share of US light duty vehicle sales and the total fleet as projected in the Energy Information Administration's 2005 Annual Energy Outlook Reference Case. As a notation item, the table also shows projections for California made by the California Air Resources Board (CARB).

For 2002, diesel's share of total car and light truck sales was about 2%, concentrated almost entirely in light trucks, where it achieved a 3.9% share (for cars the share was below 1%).

[2] In the 1st half of 2004, the average gasoline price (95 RON) at the pump in France was $4.63/gallon versus an average pump price for diesel of $3.67. The entire difference of nearly $1/gallon is due to the preferential tax treatment of diesel. In the UK, where the tax difference is minimal, the pump price for gasoline averaged $5.11 and diesel $5.23. US pump prices for both fuels were far lower, averaging about $1.83 for gasoline (all grades) and about $1.66 for diesel for the same period.

Diesel in the US Car & Light Truck Fleet % Share in 2002, 2010, and 2020*	2002	2010	2020
Total Cars and Light Trucks			
Sales	1.9%	4.3%	5.6%
Fleet	1.6%	2.8%	4.2%
Of Which Light Trucks			
Sales	3.9%	7.6%	8.8%
Fleet	3.7%	6.0%	7.4%
Note: California Car and Light Truck			
Fleet	1.3%(2000)	0.6%	0.2%

*From the EIA Reference Case 2005 AEO and CARB projections made 9/9/2003

Diesel's share of the total light duty vehicle fleet was 1.6% (3.7% of trucks, 0.4% for cars). The EIA's Reference Case projections call for diesel's share of total vehicle sales to reach 4.3% in 2010 and 5.6% in 2020, with continued concentration in light trucks. Diesel's share of the total light duty vehicle fleet rises to 2.8% in 2010 and 4.2% in 2020. This modest growth is not even remotely in line with European experience, although it is lavish compared with expectations in California. In that State, diesel's share of the car and light truck fleet was 1.3% in 2000, about in line with the national figure of 1.6% in 2002, but is projected to fall to 0.6% by 2010 and nearly disappear at 0.2% in 2020. Indeed, the absolute number of diesel light duty vehicles in California is projected to decline from about 242,000 in 2000 to 146,000 in 2010 and only 56,000 in 2020.

Clearly something beyond decades-old performance memories is holding diesel back and that something is related to environmental concerns regarding the ozone precursor, NOx, and particulates.

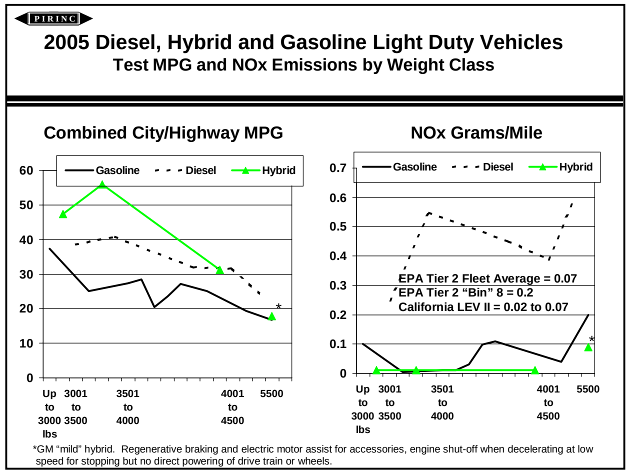
As of late 2004, about 115 million people were living in EPA-designated ozone nonattainment areas with classifications ranging from Marginal to Severe. California accounts for about 25% of the total population in such areas but nearly 100% of the population in areas classified as Severe (all in the Los Angeles South Coast Air Basin) or Serious, the next highest classification. Although the EPA has not completed the process of designating nonattainment areas for particulates, the agency has stated that "---62 million people in 2003 lived in counties with monitors that showed particle pollution levels higher than EPA's health-based standards for PM2.5, PM10, or both." California ranks diesel particulates among the 10 Toxic Air Contaminants posing the greatest health risk in the State. It should be kept in mind that diesel vehicles do better than gasoline vehicles when it comes to certain other pollutants such as carbon monoxide (CO). Currently, however, only 19 million people live in CO nonattainment areas---of which 14.5 million are in the Los Angeles South Coast Air Basin. No CO nonattainment area is classified as "Severe" although the Los Angeles Basin is classified as "Serious."

The Latest Diesels

The chart below focuses on the fuel efficiency and emissions characteristics of the handful of 2005 model year diesel light duty vehicles certified by the EPA.[3] For comparative purposes, the

[3] The EPA does not certify each and every model but instead focuses on the engines. Thus not all models sharing the same engine will have individual certifications.

charts show the same features for this model year's hybrids and roughly comparable gasoline models. The vehicles are grouped by weight class. Due to the small number of diesel and hybrid vehicles, the charts contain extrapolations between certain missing data points.



The left panel shows differences in miles per gallon (MPG) for the vehicles in the different weight classes. In all cases, diesels have higher combined city/highway test MPGs than the conventional gasoline vehicles. Hybrids clearly do even better among the lighter weight vehicles but at the heavier categories, the differences between hybrids and diesels narrow, as do differences between both of these and gasoline vehicles.

In the 3001 to 3500 pound weight class, the Volkswagen New Beetle diesel achieves 39 MPG while the gasoline-powered Jetta with the same 3,250 pound curb weight is rated at 25. The Toyota Prius with the same curb weight achieves a test 56 MPG. The heavier, 4,250 pound Mercedes E320 diesel achieved 31.5 MPG, about the same as the 4,000 pound hybrid Ford Escape (31.2 MPG). The gasoline powered versions of the Mercedes and the Escape---both lighter at 3,750 pounds than their counterparts---tested at 23.6 and 20.4 MPG respectively. Another diesel, the Jeep Liberty was the heaviest at 4,296 pounds, about 50 pounds heavier than the Mercedes diesel but had a significantly lower test result, 24.3 MPG. This was nonetheless significantly above the gasoline version (weighing 4,250 pounds) which achieved only 19.3 MPG.

The right panel shows results for NOx emissions---and illustrates the problems for diesel. In all cases, emissions from diesels are well above those from either hybrids or gasoline vehicles. The lowest emitting diesel still exceeds the EPA fleet average of 0.07 grams/mile for the Tier 2 emissions standards currently being phased in[4]. The lowest emitter among the diesels has emissions above the Tier 2 top permanent "bin 8" limit of 0.2. Moreover, the California standard sets the upper limit at a much lower level, 0.07, the EPA average.[5] Historically California standards set the pace for other states and eventually Federal standards.

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[4] The Tier 2 standards, when fully implemented, eliminate distinctions by vehicle weight, and distinctions between gasoline and diesel vehicles for NOx emissions. The new standards create 8 permanent emission certification levels called "bins" with the highest bin number the least stringent. Manufacturers can choose to certify individual vehicles to any of the bins but there is also an overall fleet standard for NOx of 0.07 grams/mile (the standard for the fifth bin) that must be met. There are two additional temporary bins, 9 and 10, with more lenient standards, especially for NOx and particulates, that expire at the end of 2006.

[5] It should be kept in mind that California sets the pace for certain other states as well. In this regard, the Jeep Liberty diesel (intended to run on zero sulfur high cetane B5 biofuel) cannot be sold in California, New York, Massachusetts, Vermont and Maine.

Focusing solely on the chart, it would appear that hybrids have the advantage over diesels in both MPG and emissions as alternatives to conventional gasoline vehicles. However, there are other considerations. In particular, the current generation of hybrids incorporates some compromises in performance to achieve their test efficiency and emission results. For example, both the Jeep Liberty diesel and the Ford Escape hybrid are SUV's with similar 0-to-60 mph acceleration times (10.5 and 10.7 seconds respectively) but the diesel has a maximum towing capacity of 5,000 pounds versus 1,500 for the hybrid. With respect to the hybrid Toyota Prius, there are reports that at speeds above the EPA's highway test 55 miles per hour (mph), fuel consumption rises significantly. One report indicated that at an average speed of 72 mph, the car averaged 38 MPG---still very respectable but well below the EPA highway rating while a comparable test drive of a diesel did not show a similar deterioration.[6] In terms of risks to consumers, the widespread use of diesel technology in Europe suggests few unknowns regarding current reliability (despite its early 1980s history in the US) while hybrids have not been on the road long enough and in large enough numbers to be sure about what is a new, complex technology.

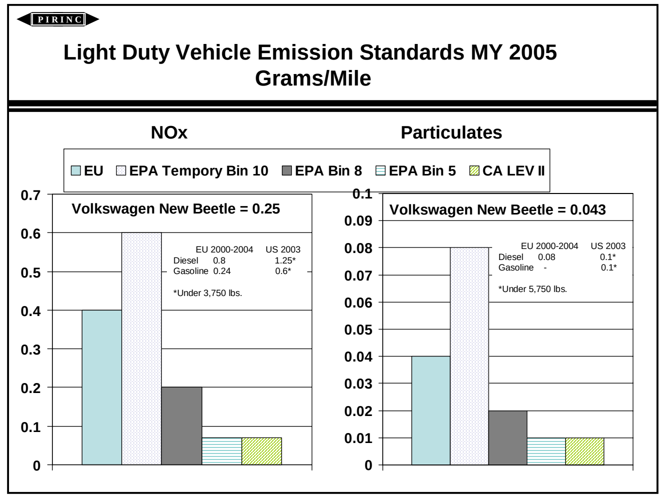
Both alternatives cost more than comparable conventional gasoline models with hybrids somewhat more expensive still. However, the gap will narrow as diesels incorporate costs of meeting the more stringent emission standards coming into effect.[7]

Emission Standards: the European Union and the US

Diesel (and gasoline) cars and light trucks have been getting cleaner but against a moving target as standards both in Europe and the US have continued to tighten. There is a key difference between the regions. In Europe, the tightening is designed to be in line with advances in diesel engine and fuel technology to meet them. In the US, some more limited allowances for diesel are included in Federal standards but California standards have no such provisions. The chart below focuses on the latest NOx and particulate emission standards for diesel light duty vehicles. The table inserts show the prior standards. Also shown are results for the best performing model year 2005 certified diesel, the Volkswagen New Beetle,

The bars in the left panel show for NOx the latest European Union standard (Euro 4 effective 2005), the EPA's temporary (through 2006) bin 10, bin 8, the top permanent level, and bin 5, equal to the required fleet average.[8] The last bar, representing the California LEV II limit is the same height as bin 5. The lowest emitting diesel, the New Beetle, has a certified emission rate of 0.26 grams/mile, well within both the EU standard of 0.4 grams/mile and the EPA's temporary bin 10 limit of 0.6. Its emissions were somewhat above the top permanent bin 8 level of 0.2 and significantly above both the EPA fleet average and California LEV II limit of 0.07.

[6] See the report in USA Today, "Diesel vs. Hybrid: From Detroit to D.C. andd Back," published June 11, 2004.
[7] For a summary discussion of diesel versus hybrid vehicles, including cost estimates see, "Hybrid and Diesel Car Markets," available on the web at: www.hybridcars.com/hybrid-versus-diesel.html.
[8] The EPA and California standards shown are for a duration period of 120,000 miles. The Euro 4 standards have a 5 year or 100,000 kilometer duration, whichever comes first.



From 2000 through 2004, the EU NOx emission limit for diesel cars was 0.8 grams/mile, double the latest limit. The prior limit for diesel was much higher than the limit 0f 0.24 for gasoline cars. The latest limit for diesel, the 0.4 grams per mile level shown in the chart, is also higher than the current, reduced, limit for gasoline cars of 0.128. In the US, the EPA Tier 1 emission standard, applicable through 2003 also had an explicit distinction between diesel and gasoline cars, with a diesel limit of 0.1.25 grams per mile versus a limit for gasoline cars of 0.6. The Tier 2 standards have no explicit higher limits for diesel but the system of “bins” with a top bin level nearly triple the fleet average limit allows some “wiggle room” for limited numbers of diesels to enter the US market---provided their NOx emissions come down to the upper limit. But California’s more stringent approach further narrows market prospects.

The right panel shows the comparable emission limits for particulates. The New Beetle has an emissions level of 0.043 grams/mile, about in line with the latest EU limit and well within the temporary bin 10 limit of 0.08. However, its emissions are nearly double the top permanent bin 8 limit of 0.02 and 4 times the California limit. Under the previous standards, the EU limit for diesel particulates was 0.08, double the current level and the US 0.1. In neither region are particulate emissions from gasoline cars considered an issue.[9]

Current and prospective improvements in diesel (and gasoline) vehicle emissions are linked to advances in engine and emission control technologies. Performance and durability of these technologies in many critical cases are in turn linked to advances in fuel quality, especially sulfur levels. As a result, tightening emission standards are accompanied by tighter sulfur specifications. Thus this first year of the Euro 4 vehicle emission standards is also the first year of the Euro 4 standard for diesel fuel which reduces the maximum sulfur level from to 50 ppm (from a 2000-2004 limit of 350) with an additional requirement that 10 ppm diesel be made available. In 2009, 10 ppm becomes the (Euro 5) overall maximum.[10] In the US, Tier 2 fuel regulations call for widespread introduction of 15 ppm sulfur diesel in 2006 with full implementation in 2007. The sulfur level in the gasoline pool is moving toward a 30 ppm average by 2007.

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[9] California’s emission model estimates for road vehicles show for 2000 an average exhaust PM10 emission rate of 0.01 grams/mile for all gasoline cars on the road versus 0.14 for all diesel cars. The gasoline average in 2000 of 0.01 is in line with the latest California limit.

[10] The same 2005-2009 standards apply to sulfur in gasoline, although in 2004, the sulfur maximum for gasoline was lower than for diesel, 150 ppm vs. 350.

These changes in fuel specifications are in large part designed to "enable" certain sulfur-sensitive advanced technology options, especially nitrogen storage traps and diesel particulate traps.[11] The tighter fuel specifications in Europe have been important in allowing automakers to meet the new diesel emission standards. But US emission standards for NOx and particulates are tighter still, not to mention the even stricter California standards. It remains to be seen just how far and how soon ongoing improvements in emissions performance will allow diesel cars and light trucks to make their mark in the US market.

At the present time, diesel cars and light trucks on offer in Europe of course conform to the Euro 4 emissions standards but, particularly with respect to NOx, would not meet the US permanent Tier 2 requirement. Particulate performance is much closer with advanced technology necessary to do so already entering the market.[12] There is very little current information in the public domain regarding specific current performance characteristics. A report released earlier last year by the EPA reported results from their testing of 5 advanced prototype diesel vehicles with these technologies using ultra-low sulfur diesel fuel.[13] All 5 showed particulate emissions well below the Tier 2 Bin 5 standard with driving "ages" ranging up to 60 thousand miles. The results were more uneven for NOx. Four of the 5 vehicles demonstrated emission rates close to or below the fifth Tier 2 bin (50 thousand mile level of 0.05 grams/mile) level although one vehicle had a rate of 0.26, well above highest permanent bin 50,000-mile level of 0.14. There was no indication how well the vehicles would do compared to the 120,000 mile Tier 2 performance standard. The diesel continues to make progress and improve the odds of achieving a significant presence in the US market.

Implications for Oil Consumption

Other things equal, a shift from conventional gasoline cars and light trucks to diesel reduces oil consumption. As noted earlier, the EIA's 2005 long-range Reference Case projections assume

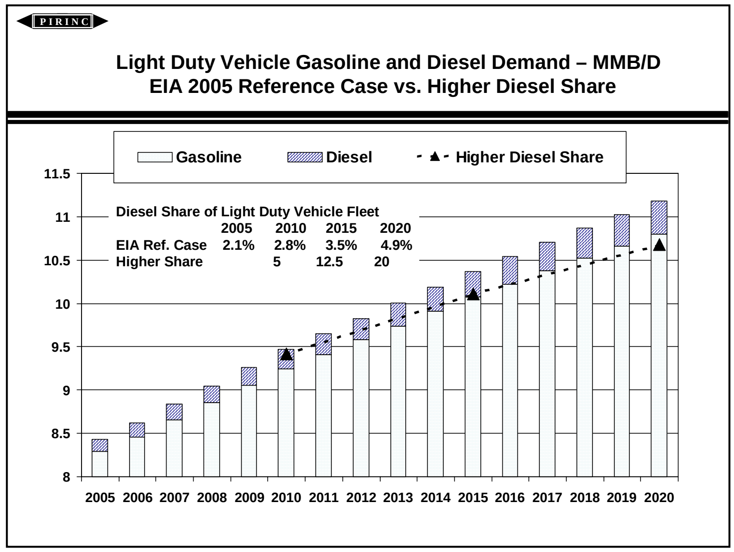
[11] While diesel emissions are the primary focus, advances in NOx control technologies could also enhance prospects for fuel economy gains from advanced, lean-burn, gasoline engines.

[12] The EU is not stopping at Euro 4. A Commission proposal for Euro 5 standards, to take effect no later than 2010, is expected this year with an anticipated focus on narrowing, even eliminating the distinctions between diesel and gasoline vehicles. The German Federal Environmental Agency recommended in July 2003 that the Euro 5 NOx limit for diesel cars be set at the Euro 4 standard for gasoline cars, a 68% reduction, while the limit for particulates should be cut by 90% versus the Euro 4 limit, effectively requiring particulate traps on all vehicles. The Agency's concern is to insure a substantial reduction in fine particulates rather than simply particulate mass. The German proposal for NOx is equivalent to 0.128 grams/mile, above the US Tier 2 fleet average of 0.07 but below the top bin 8 limit of 0.2. The German proposal for particulates is equivalent to 0.004 grams/mile, well below the EPA's bins 2 through 6 limit of 0.01, and the bins 7 and 8 limit of 0.02. See: **Future Diesel: Exhaust gas legislation for passenger cars, light-duty commercial vehicles, and heavy duty vehicles – Updating of limit values for diesel vehicles**, published by the German Federal Environmental Agency in July 2003 and available at http://www.umweltdaten.de/uba-info-presse/hintergrund/FutureDiesel_e.pdf.

[13] EPA Office of Transportation and Air Quality, **Progress in the Development of Tier 2 Light-Duty Diesel Vehicles**, by Joseph McDonald. Report 2004-01-1791. The report is available on the web at: http://www.solarhouse.com/resources/EPAdiesel.pdf

very limited penetration by diesels. The bars of the chart below summarize the Reference Case projections of gasoline and diesel fuel demand by light duty vehicles for 2005-2020 while the first line of the table insert summarizes the share of diesel in the light duty vehicle fleet in five year increments for the period.

Under the Reference Case, light duty vehicle combined gasoline and diesel demand rises from about 8.4 MMB/D in 2005 to about 9.5 in 2010 and to 11.2 in 2020. The dotted line shows the impact of, other things equal, approximately doubling diesel's share of the fleet from 2.8% to 5% in 2010 and then raising diesel's share further to 12.5% in 2015 and 20% in 2020. There are no structural barriers to such an increase. Diesel cars and light trucks are already manufactured by all major vehicle manufacturers (even if not currently sold here) and the fuel production and distribution infrastructure requires is for the most part in place. Moreover, the diesel share of the total car fleet of the West European countries shown in the first chart in 1998 was already up to about 17% and, with annual sales shares escalating from 25% to 50% over the next 6 years, moving much higher.[14]



The average diesel vehicle is assumed to remain about 35% more efficient in terms of MPG (using an average of 26% fewer gallons per mile) than the conventional gasoline vehicle over the entire period. By 2020, combined gasoline and diesel demand is reduced by about 500 MB/D, equivalent to taking about 13 million light duty vehicles off the road, or about 4.5% of Reference Case light duty vehicle demand.[15] Of course higher levels of diesel penetration would produce still greater savings.

It should be noted that the Reference Case projections incorporate minimal improvements in new gasoline or diesel car and light truck MPGs. The projections also have ongoing increases in the driving population and in average miles driven. The overall impact of minimal new vehicle MPG gains and more driving mutes significantly the impact of all but extreme, early, and unrealistic penetration rates for diesel---and/or hybrid and/or fuel cell technologies.

[14] In 1998, diesel's share of the passenger car fleet in France was 32% with, as discussed earlier, share of sales at 40% in the same year, rising to 70% in 2004.

[15] The savings are less on a crude oil equivalent basis, about 300 MB/DOE since diesel has a higher energy density than gasoline.