NERA
Economic Consulting

Customer Behavior in Response to the 2007 Heavy-Duty Engine Emission Standards: Implications for the 2010 NO_x Standard

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Overview

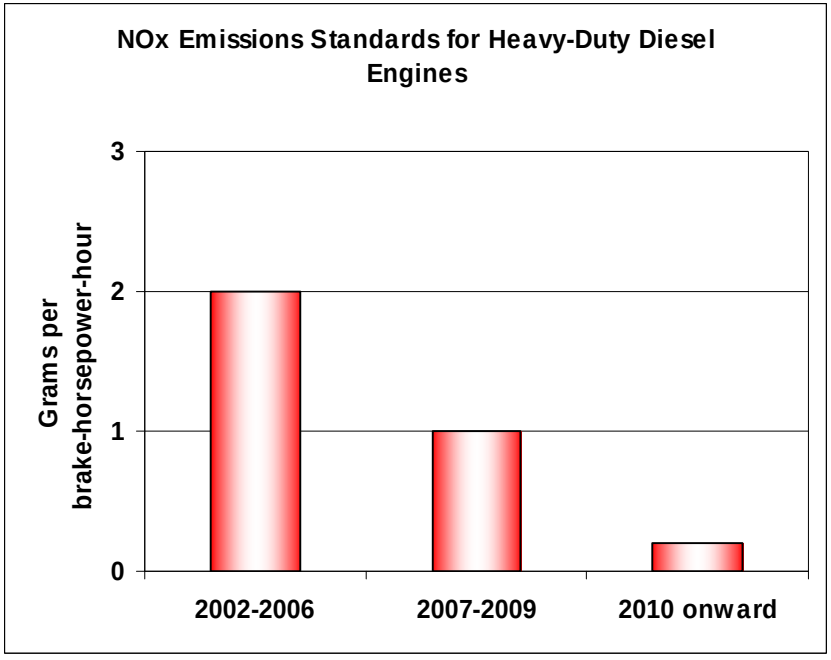
- The NO_x emission standards for heavy-duty engines are scheduled to decline from about 1.0 g/bhp-hr in model years 2007-09 to 0.2 g/bhp-hr in model year 2010 and beyond
  - Increased prices for vehicles meeting the 2010 standard are likely to be substantial (on the order of $7,000-$10,000 per class 8 truck)
  - 2010 compliance technologies also create uncertainties from the customer's perspective
  - These factors (high prices and uncertainties) provide incentives for a "pre-buy" (i.e., higher sales in pre-model years) and "low-buy" (i.e., lower sales in compliance model years)
- Similar circumstances existed for the 2007 emission standards
  - NERA developed detailed estimates of the pre-buy and low buy and the implications for the environmental benefits
  - Environmental benefits decline and the standards are less cost-effective
- Historical sales information related to the 2007 standards seems to validate the NERA estimates
  - Actual sales show pre-buy and low-buy levels and relationships similar to those predicted in the NERA study
- This apparent validation and the similarity of circumstances suggests that the consumer behavior pattern observed for 2007 standards will be repeated for the 2010 standards
  - Standard will require technologies that customers are not familiar with
  - Costs and prices of model year 2010 will increase substantially
  - Customers thus have incentives to increases purchases before 2010 and keep older trucks on the road longer
- The net result of these customer reactions (pre-buy and low-buy) to the 2010 standards would be reduced environmental benefits and less cost-effective standards

Background: History of Heavy-Duty Diesel Engine Emissions Standards

- EPA developed emission standards for heavy-duty engines in the 1990's
  - A particulate matter (PM) standard of 0.1 grams per brake-horsepower-hour (g/bhp-hr) has been in place since 1994
  - An oxides of nitrogen (NO_x) standard of 4.0 g/bhp-hr has been in place since 1998
  - Required a more stringent NO_x standard by 2004
    - Combined standard of 2.4 g/bhp-hr for NO_x and non-methane hydrocarbons (NMHCs)
    - Alternative combined standard 2.5 g/bhp-hr with an additional limit of 0.5 g/bhp-hr for NMHCs
    - Effective limit on NO_x emissions of 2.0 g/bhp-hr
    - These 2004 standards were "pulled ahead" to 2002 by consent decree
- In December 2000, EPA promulgated emission standards and diesel fuel sulfur requirements
  - PM emissions limit of 0.01 grams per brake-horsepower hour (g/bhp-hr) to take effect for the 2007 model year
  - NO_x emissions limit of 0.20 g/bhp-hr to be achieved in all units beginning in the 2010 model year
  - In order to operate advanced emissions reduction technology to meet these standards, the EPA required a reduction in the sulfur content of the diesel fuel
    - Starting in June of 2006, 80 percent of diesel must have sulfur levels no more than 15 ppm

Background: Phase-in of NO_x Emissions Standard

- To phase in the 2010 NO_x emissions limit, the standard applies to 50% of sales for the 2007-2009 model year trucks
  - Averaging, banking and trading ("ABT") provisions are included for the phase in period
  - These ABT provisions result in an effective NO_x emissions standard of about 1 g/bhp-hr from 2007-2009
- The effective NO_x standard was reduced from 2 g/bhp-hr in 2006 to approximately 1 g/bhp-hr from 2007-2009 and will go to 0.2 g/bhp-hr in 2010



Background: Technologies anticipated by EPA in 2000 to meet 2010 NO_x Standard

The 2000 Regulatory Impact Analysis lists several potential technologies that would allow manufacturers to meet the proposed 2010 standard for NO_x, e.g. :

- Engine Gas Recirculation (EGR)
  - Changes engine function in a way that reduces both PM and NO_x
  - Was not expected to be sufficient to meet 2010 standard
- NO_x adsorbers
  - Stores NO_x on a catalyst surface
  - Requires specific temperature and emissions characteristics
  - Expected to be main technology employed to meet 2010 standard
- Selective Catalytic Reduction (SCR)
  - Chemical reaction between ammonia and NO_x reduces to nitrogen and water
  - Ammonia is stored onboard in a separate tank in a specialized form of urea (called Diesel Emission Fluid or "DEF")
    - Need nationwide supply chain for DEF
    - Need incentive to ensure DEF tank is filled
    - Engine could be made so that it only operates at partial power when DEF tank is empty, which could be a safety hazard (e.g. merging on highways)

Background: NO_x Technology Developments since 2000 and Manufacturer Announcements

- EGR
  - New Cooled EGR technology largely used to meet 2007-2009 heavy-duty diesel engine standards for NO_x
- NO_x adsorber
  - Technology did not mature as expected by the EPA
- SCR
  - Currently being used in Europe
  - Supply chain for DEF and incentives to prevent empty DEF tanks
- All heavy-duty diesel engine manufacturers have announced their technology choice to meet the 2010 NO_x standard*
  - Nearly every manufacturer has selected SCR
  - Major exception is Navistar, which will use an advanced version of EGR
- These technologies—and the details of how they will affect engine performance—will be new to truck purchasers and thus create some uncertainties from the purchaser perspective

* Source: http://fleetowner.com/equipment/fork_road_0508/ and http://www.everytime.cummins.com/every/misc/2007_beyond/tech.page?

NERA/AIR Report: Overview of 2005 NERA/AIR Report

- Objectives and background:
  - Key objective: evaluate environmental and economic impacts of 2007 standards
  - Concerns were expressed about large price/cost increases and technological uncertainties from purchaser perspective in meeting the 2007 standard
  - These concerns should give incentives for increased sales pre-2007 ("pre-buy") and decreased sales from 2007 onward ("low-buy")
  - Reduced fleet turnover, in turn, leads to lower emissions benefits and lower cost-effectiveness for the regulation
- Methodology to evaluate empirical significance of anticipated customer behavior
  - Detailed data collection
    - Manufacturer survey of price and cost impacts of 2007 standard for heavy-heavy trucks
    - American Trucking Associations (ATA) fleet survey
    - NERA fleet survey
  - Detailed set of models to estimate environment and economic impacts
    - NERA Price Elasticity Model
    - NERA Scrappage Model
    - NERA Fleet Population Model
    - Emissions Modeling (EPA MOBILE 6, run by AIR)
    - Economic Impact (REMI) Modeling

NERA/AIR Report: Effects of 2007 Standard on New Heavy (Class 8) Truck Prices and Maintenance Costs

- Manufacturer Survey of Price and Cost Impacts of 2007 Standard for Heavy (Class 8) Trucks
  - Three of four major manufacturers surveyed (represent 75% of industry sales)
  - Estimates of cost/price effects include retooling (appropriately amortized), engine and equipment modification, per-vehicle variable costs as well as maintenance costs
  - Survey results include "high" and "low" estimates of +/– 20% for unit costs, +/– 30% for maintenance costs, based on the range of estimates provided by manufacturers
  - Cost estimates do not include increased fuel costs due to ultra-low sulfur diesel fuel requirements

Summary of Manufacturer Survey Results for Heavy (Class 8) Trucks

	Unit Cost	Yearly Maintenance Cost
High Increase	$7,966	$477
Mid Increase	$6,638	$367
Low Increase	$5,310	$257

Note: Unit cost increases include engine, chassis, retooling, and labor costs. Maintenance cost increases include replacement parts, cleaning, and labor costs.

Source: NERA/AIR 2005 Report

NERA/AIR Report: Effects of 2007 Standard on Pre-Buy and Low-Buy

- We used two basic sources of data on pre-buy and low-buy customer plans
  - American Trucking Associations (ATA) Fleet Survey
    - Collected data from 100 heavy-heavy fleets
    - Data included responses to question on whether or not fleets are planning to pre buy (i.e., “yes” or “no”)
  - NERA Fleet Survey
    - Supplemented ATA survey by focused survey on likely magnitudes of pre-buy and low-buy in response to 2007 standards
    - Detailed data collected from eight heavy-heavy truck fleets
- Additional assumptions used to develop estimates
  - Census information (fleet mix by “straight” and “other”)
  - EPA Mobile6 (baseline sales, fleet mix by age, and VMT)
  - Baseline VMT assumed unaltered by 2007 standards
  - Purchase price increases assumed equal to manufacturing cost increases

Summary of Changes (from EPA Baseline) in Heavy (Class 8) Truck Sales Due to the Pre-Buy/Low-Buy Effect Only

2005	2006	2007	2008
+25,234	+78,753	-84,927	-19,150

Source: NERA/AIR 2005 Report

NERA/AIR Report: Full Impacts of Customer Behavior

- NERA Price Elasticity Model
  - NERA model based upon time-series regression
  - Estimated price elasticity is –1.9, i.e., a one percent increase in price is estimated to yield a 1.9 percent decrease in heavy-duty truck sales
- Combined with "pre-buy" and "low-buy" effects, this gives total estimated sales changes

Summary of Total Changes (from EPA Baseline) in Heavy (Class 8) Truck Sales

2005	2006	2007	2008
+25,234	+78,753	-102,237	-47,042
Pre-Buy: +104,077		Low-Buy: -149,272	

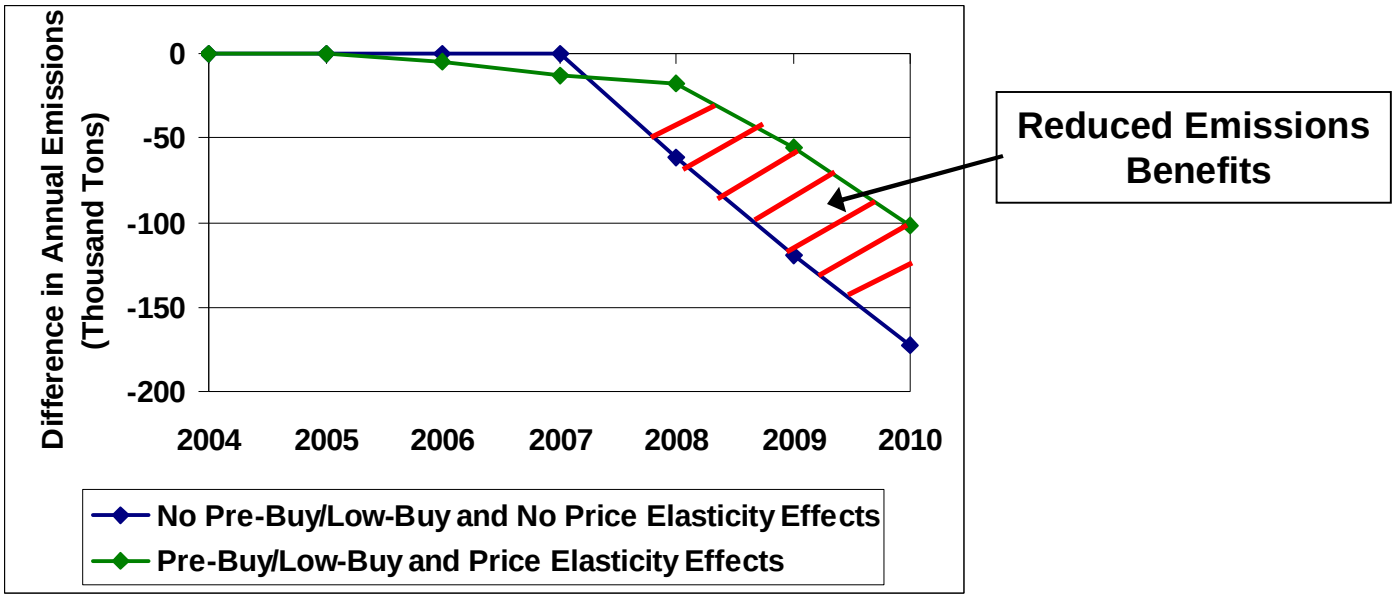
- NERA Scrappage Model and NERA Fleet Population Model
  - Scrappage model develops empirical estimates of the effect of new vehicle prices on current owners of trucks,
  - Fleet population model develops total effects on all vintages of trucks
- Emissions Model
  - AIR used the EPA MOBILE6 model to estimate effects of changes in truck populations on annual emissions (Assuming that total vehicle miles traveled is not changed by the standard)

Source: NERA/AIR 2005 Report

NERA/AIR Report: Environmental Effectiveness

- In combination, these models allowed NERA/AIR to estimate changes in fleet emissions relative to modeling that excluded these pre-buy/low-buy, price elasticity and scrappage effects
- Emissions are significantly higher because of these effects
  - The reduced emissions benefits are striped in red in the graph below

Changes (from EPA Baseline) in Annual NO_X Emissions

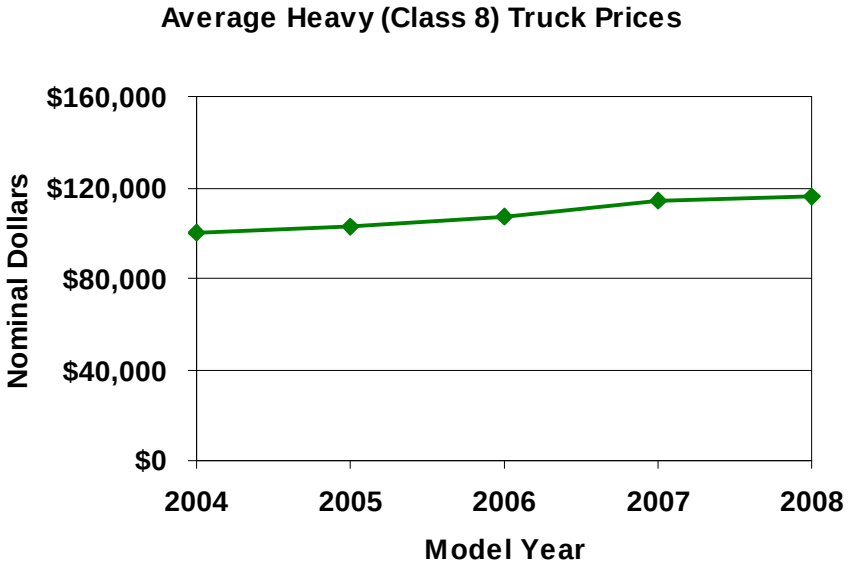


Source: NERA/AIR 2005 Report

Consequences and Comparison: Overview of Predictions and "Actual" Results

- Summary of Predictions from NERA/AIR 2005 Study
  - Price increase of $6,600 per Heavy (Class 8) Truck between 2006 and 2007 model years
  - Sales increase (compared to baseline) of about 104,000 in 2005/2006 and sales decrease (compared to baseline) of about 149,000 units in 2007/2008
    - Ratio of about 2 increased sales for every 3 decreased sales
- Summary of "Actual" Results
  - Price increase of $7,000 per Heavy (Class 8) Truck between 2006 and 2007 model years
  - Sales increase (compared to baseline) of about 120,000 units in 2005/2006 and sales decrease (compared to baseline) of about 183,000 units in 2007/2008
    - Ratio of about 2 increased sales for every 3 decreased sales
- These results do not "prove" that our modeling was correct, but the results are certainly consistent with our expectations

Consequences and Comparison: Price Changes for Heavy (Class 8) Trucks

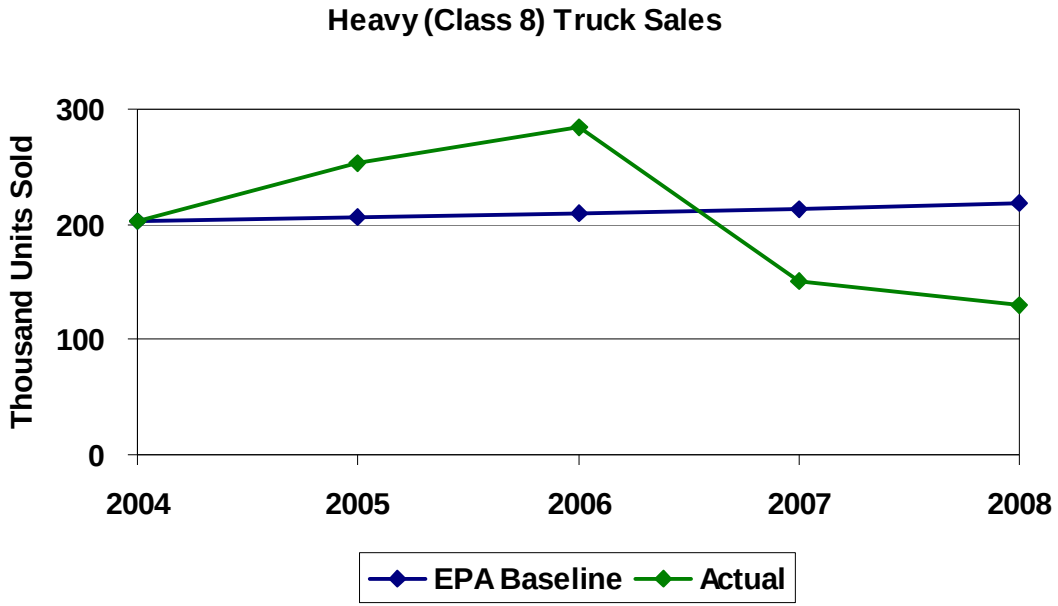


- Price increases were substantial from 2006 to 2007
- Increased costs of meeting the 2007 standard are hard to pick out from the year to year trend
  - Steel and iron prices increased 20% from 2005 to 2006 but only 5% from 2006 to 2007
- Left column shows weighted average price increase calculated from NERA surveys for class 8 truck manufacturers which is similar to the historical price increase from 2006 to 2007*

	NERA Estimated Price Increase in 2007	"True" Price Increase in 2007
Heavy	$6,638	$6,974

* Source: Calculated from PPI for "Trucks, truck tractors, and bus chassis (chassis of own manufacture) 33,001 lb or more" assuming 2004 price of $100,000 and NERA/AIR 2005 Report

Consequences and Comparison: Sales Changes for Heavy (Class 8) Trucks



- EPA baseline class 8 truck sales
  - Takes 1995 sales and increases linearly by 2% of 1995 sales each year
- Actual data on class 8 truck sales from Ward's*
  - 2008 data is through September
  - Scaled up to reflect full year sales
- Data indicates substantial pre-buy in 2005 and 2006
  - Nearly 120,000 additional units purchased beyond baseline
- Magnitude of the low-buy in 2007 and 2008 is greater than the magnitude of the pre-buy
  - Sales have been over 180,000 units below the baseline

* Source: EPA RIA and Ward's U.S. Retail Sales of Trucks

- Changes in sales were predicted rather accurately by the NERA/AIR Report
  - NERA pre-buy is 104,000, compared to "actual" 120,000
  - NERA low-buy is 150,000, compared to "actual" 180,000
  - Both NERA and "actual" show 2 increased sales for every 3 reduced sales
  - EPA baseline does not take into account business cycles or several other factors that should be included in the counterfactual baseline sales

Summary of Changes (from EPA Baseline) in Heavy (Class 8) Truck Sales

	NERA Estimate Class 8		Actual Class 8	
2005	25,324	104,077	45,683	119,072
2006	78,753		73,389	
2007	-102,237	-149,279	-63,164	-182,749
2008	-47,042		-119,585	

Potential Consequences of 2010 Standards

- Predictions from the NERA/AIR report in January 2005 on the effects of 2007 heavy-duty engine emissions standard seem validated by the patterns of heavy diesel truck prices and customer behavior from 2005 to 2008
  - These results suggest that near term conditions (technological uncertainties from the perspective of the customer and large price increases) lead to changes in truck purchaser behavior, which changes the truck fleet and tends to reduce the environmental benefits and cost-effectiveness of emission standards
- Similar near-term conditions seem likely due to the 2010 NO_x emissions standard
  - Technological uncertainties from the perspective of the customer
  - Substantial price/cost impacts
  - The net result would be lower environmental benefits and less cost-effective emission standards for these 2010 standards
- Macroeconomic weakness and a lack of available credit in 2008 and 2009 may prevent a pre-buy
  - Reduced new vehicle sales will mean more older (higher-emitting) trucks on the road
  - These factors could further decrease the environmental benefits and cost-effectiveness of the 2010 regulation

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