FUEL ECONOMY OF HEAVY-DUTY TRUCKS IN THE U.S.A.

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OVERVIEW OF PRESENTATION

- Commercial trucks over 5 tons GVW account for 17% of total transport fuel consumption in USA, and consumption is growing at 2% per year, faster than any other segment.
- Historical data are analyzed to examine growth rates in fuel economy
- Preliminary results of NPC analysis of new technology to improve fuel economy by sub-class is provided. Detailed studies are in progress to estimate fuel economy to 2030.

CLASSES OF HEAVY-DUTY TRUCKS IN USA

- Heavy trucks typically divided into three GVW sub-classes:

  -light-heavy (4.5 to 9 tons) with engines of 6.5 $\pm$ 0.5 L

  -medium-heavy (9 to 25 tons) with engines on 8.5 $\pm$ 1L and

  -heavy-heavy (25+ tons) with engines from 11 to 15L.

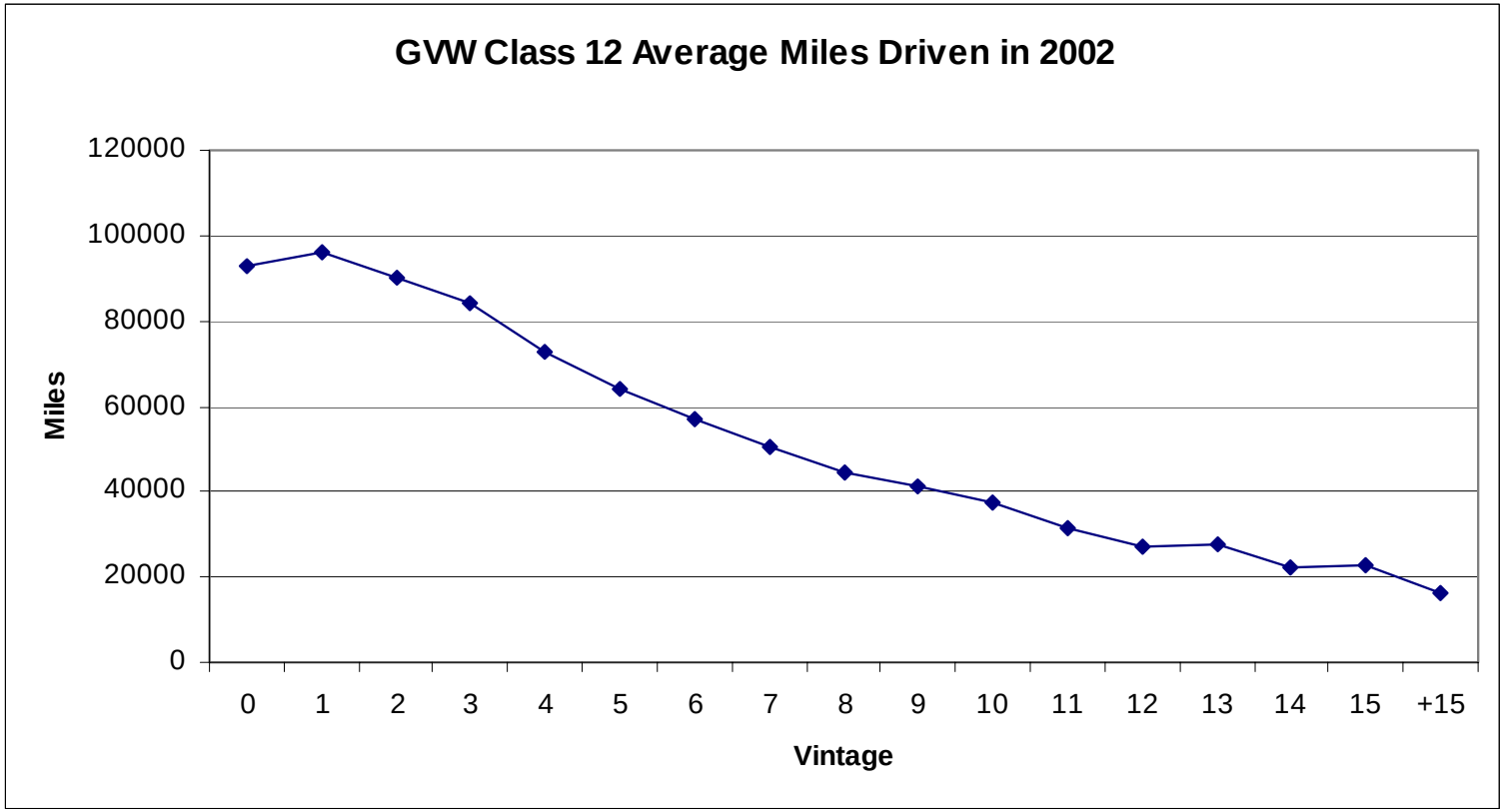
CLASSES OF HEAVY-DUTY TRUCKS IN USA

- Light –heavy vehicles typically used in short haul operation and is now about 80% diesel, but many gasoline engine vehicles in fleet.
- Medium-heavy used in both short and medium haul applications. This segment has been 100% diesel since the early 1990s
- Heavy-heavy used primarily in long-haul or mining/ construction. This segment has always been 100% diesel.

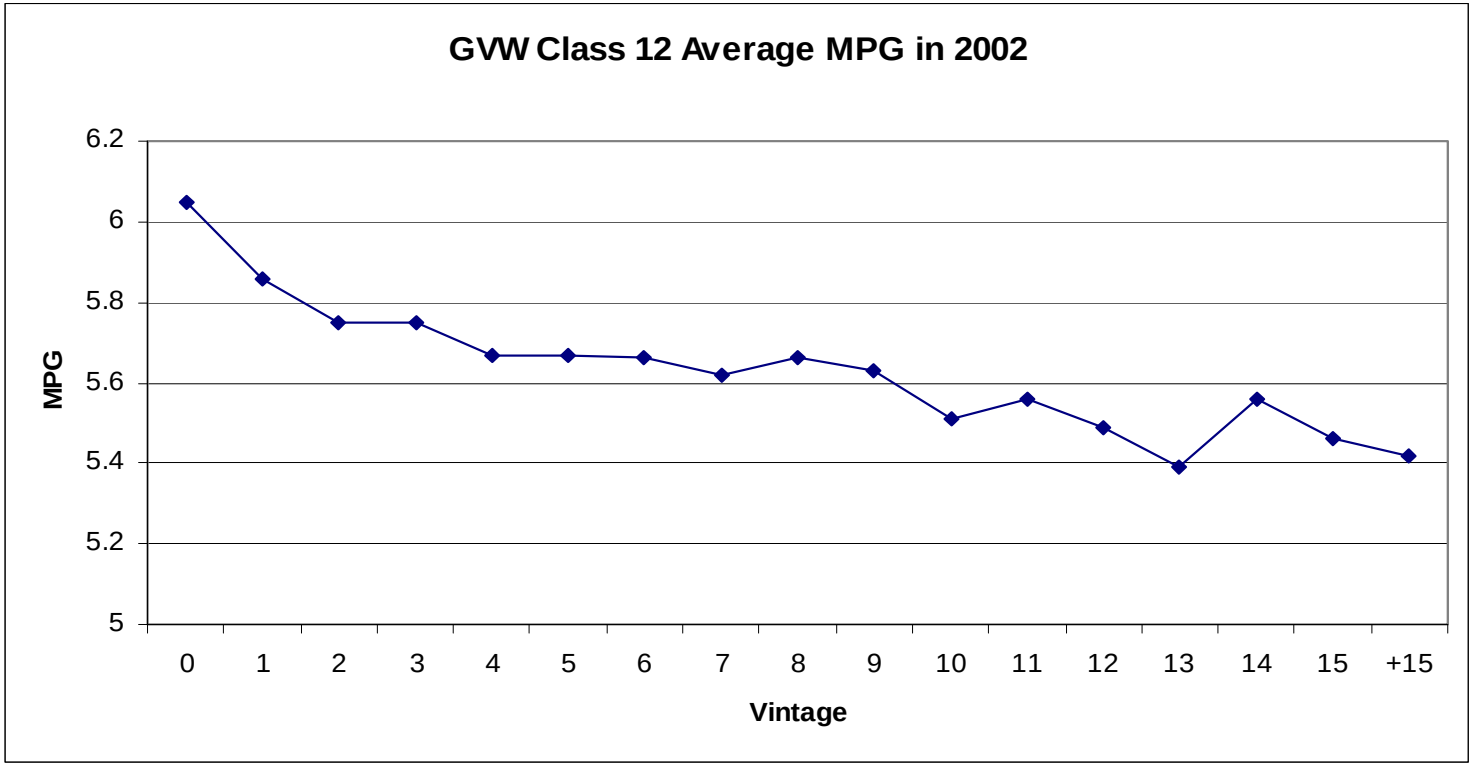
HISTORICAL FUEL ECONOMY GROWTH : HEAVY-HEAVY

- Average new vehicle fuel economy in 2003 was 6.1 mpg (38.6 l/100km).
- Annual growth rate in FE over 15 years was 0.88%, with about 0.6% from engine and transmission, 0.3% from aero/ tires.
- Engine technology primarily in electronic fuel injection and combustion improvements, friction reduction.
- Almost all long haul vehicles have cab fairing, spoilers and second-generation radial tires

ANNUAL MILES BY VINTAGE: HHDT



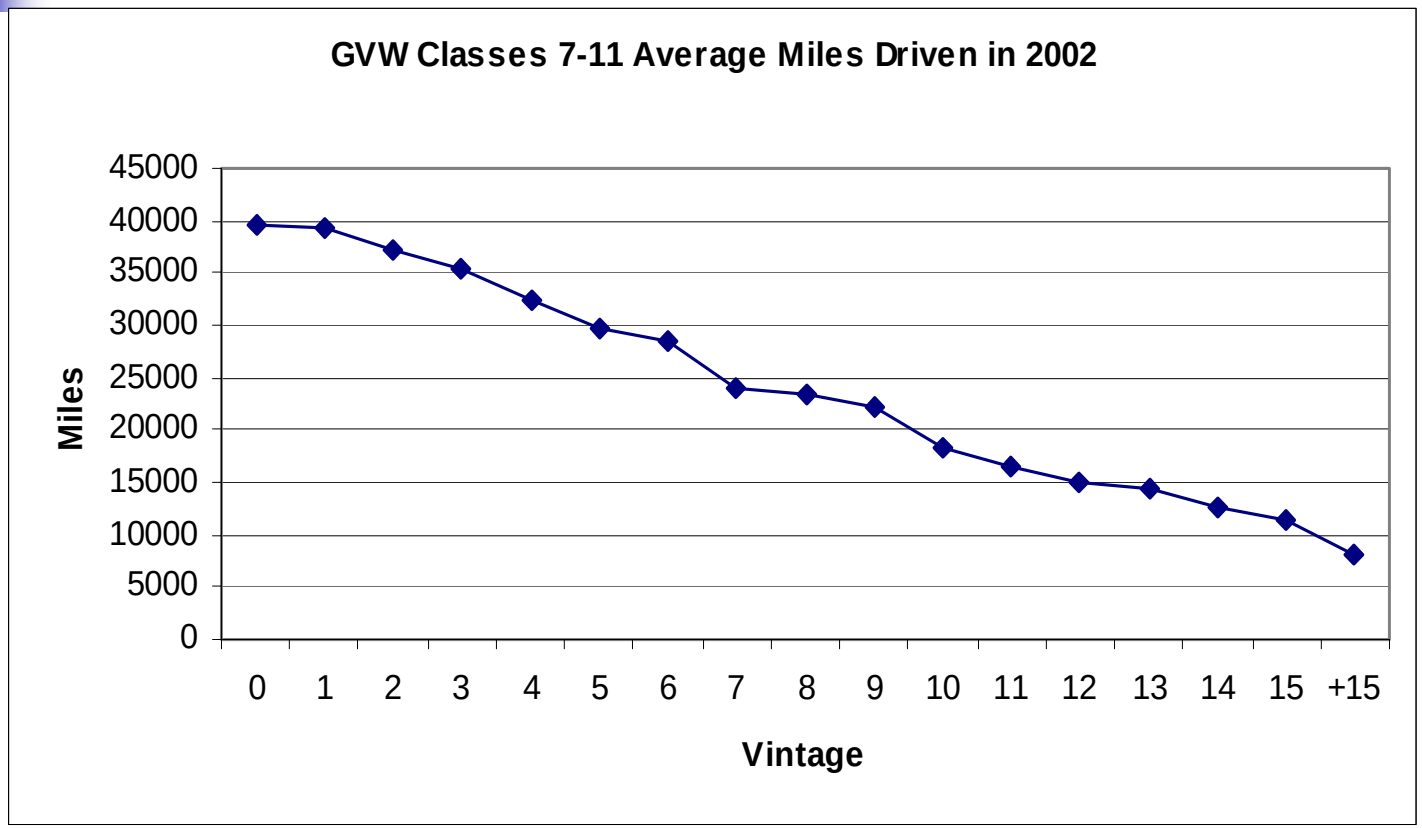
FUEL ECONOMY BY VINTAGE: HHDT



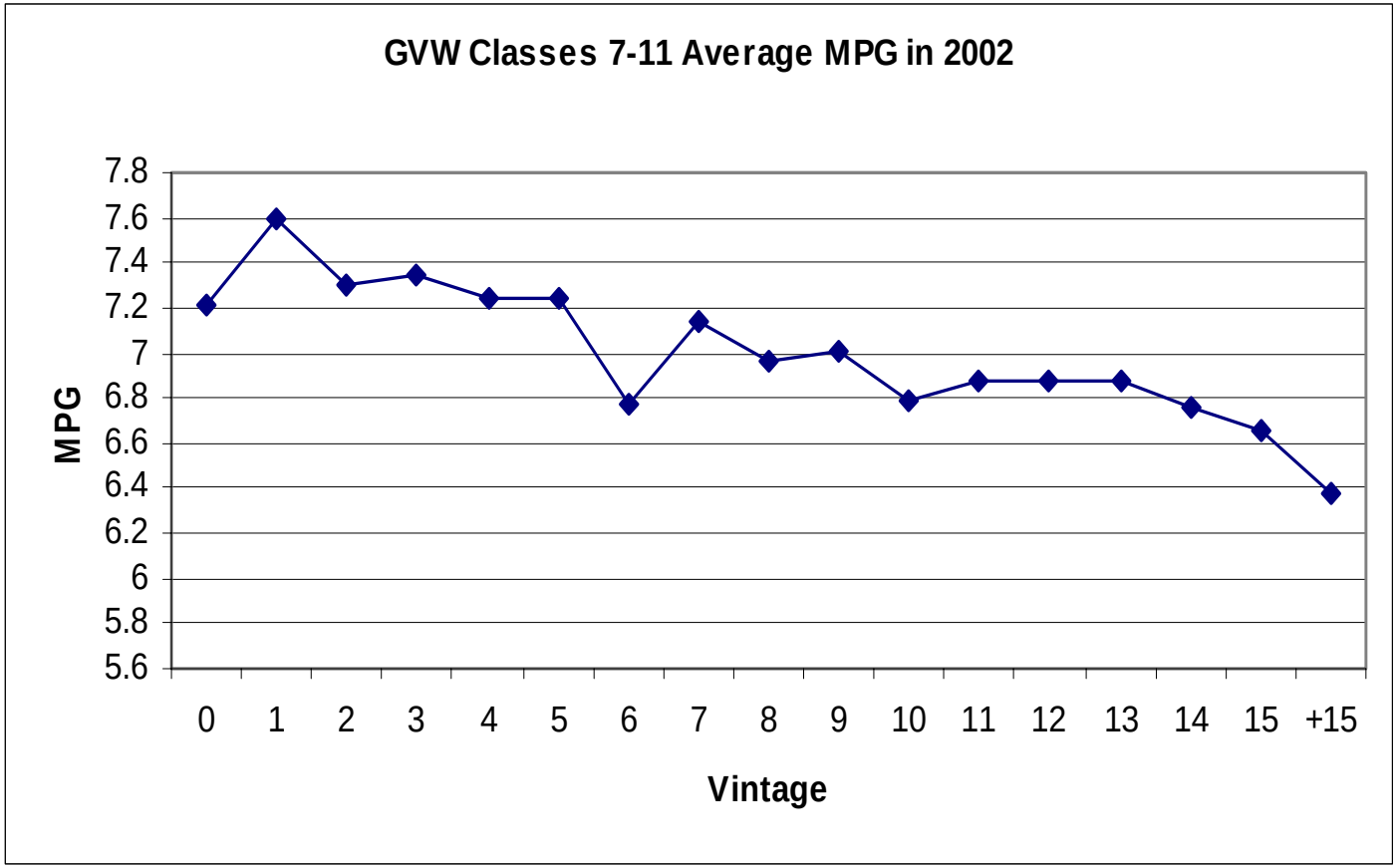
HISTORICAL FUEL ECONOMY GROWTH : MEDIUM-HEAVY

- New truck fuel economy is about 7.6 mpg (31 L/100km). Increase from HHDT small due to different duty cycle (more short-haul).
- Annual fuel economy growth rate slightly higher at 0.97%, with about 0.75% from engines, rest from aero and tire improvement
- Engine changes have included move to 4-valve heads, higher levels of turbo-charging and engine downsizing

ANNUAL MILES BY VINTAGE: MHDT



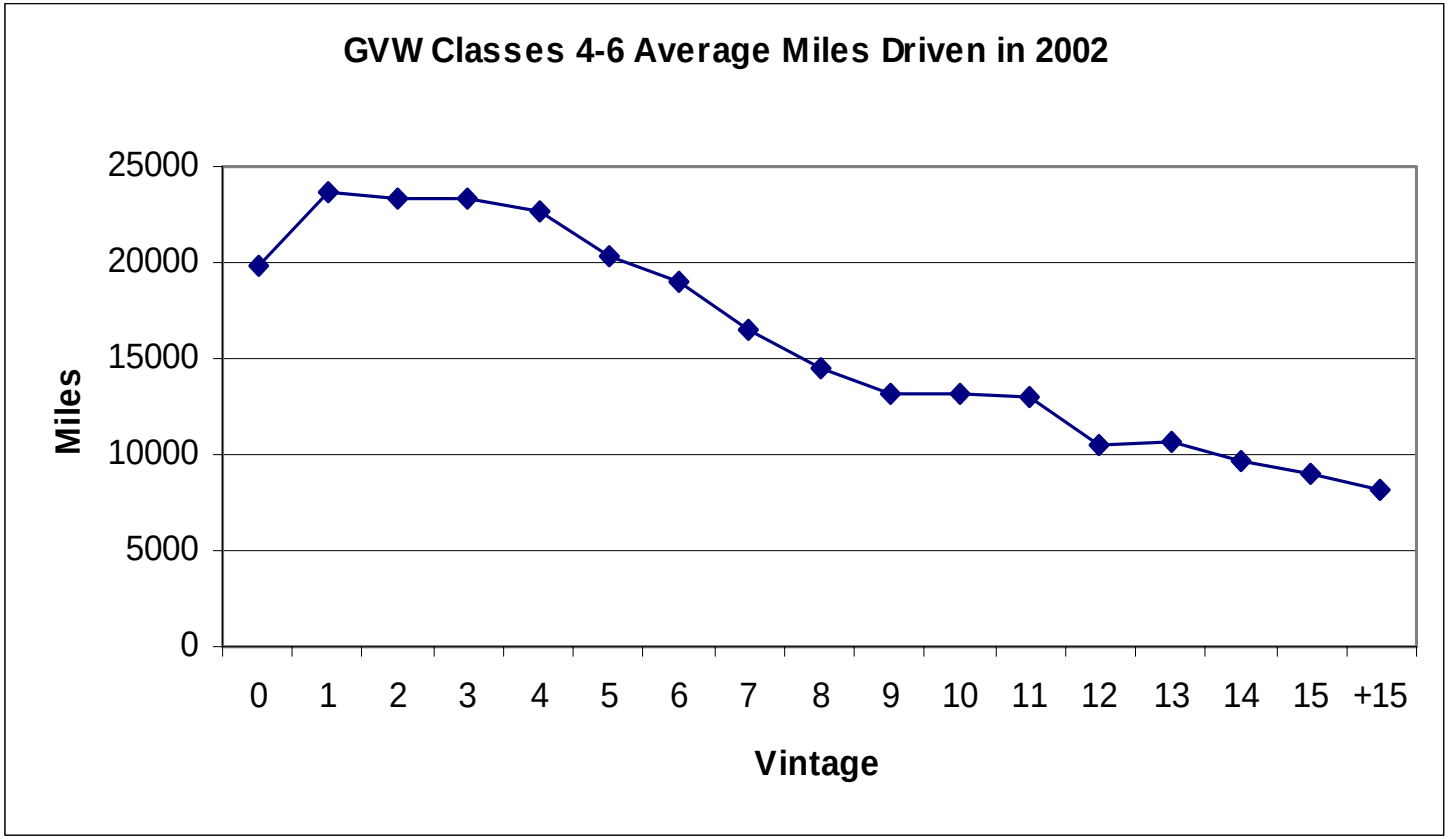
FUEL ECONOMY BY VINTAGE: MHDT



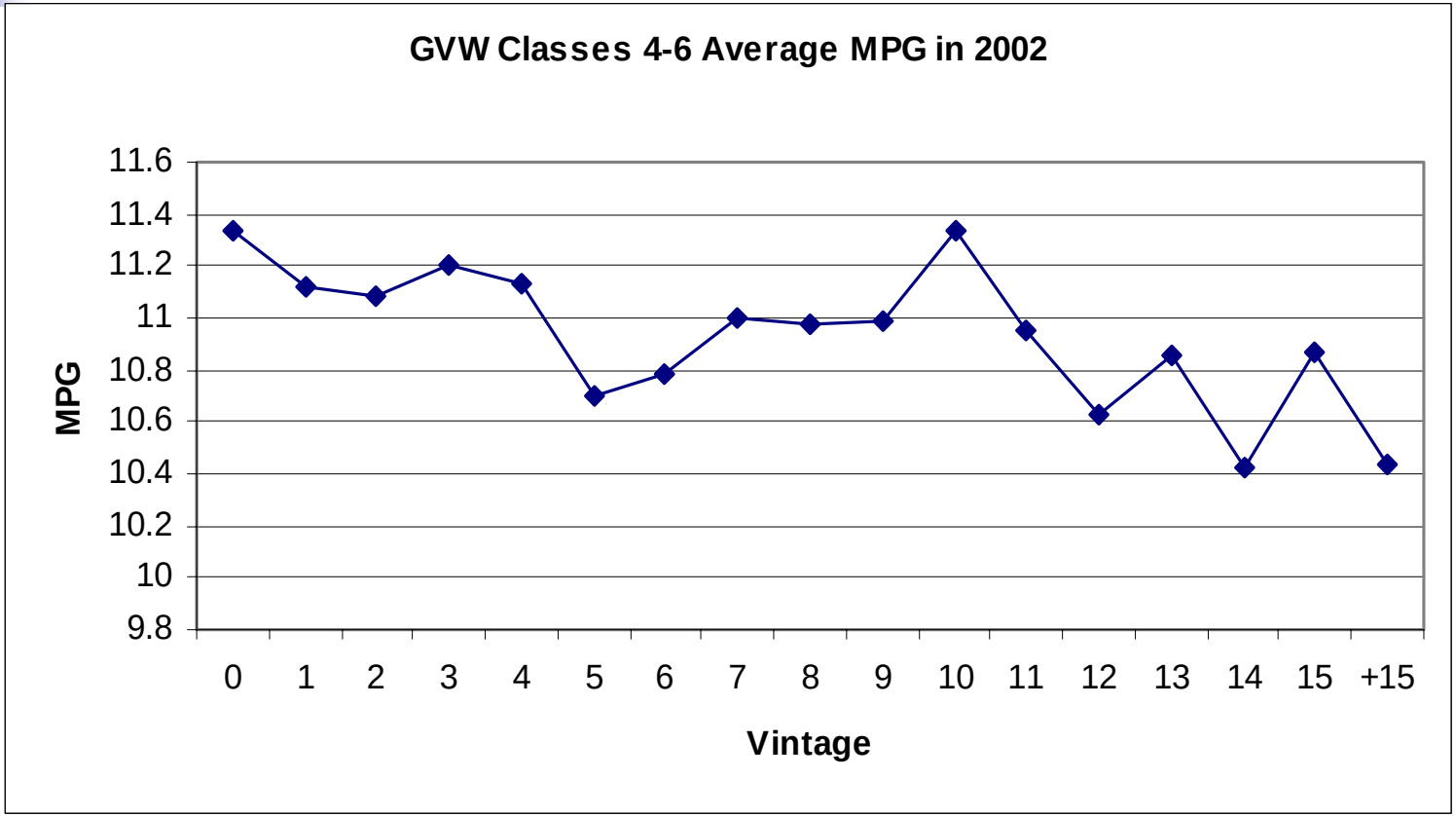
HISTORICAL FUEL ECONOMY GROWTH : LIGHT-HEAVY

- New light –heavy truck fuel economy is 12.4 mpg (19L/100km), mostly large pick-up and van with only small fraction of Japanese delivery trucks with 3L to 4L engines.
- Annual fuel economy growth rate is 1.3% almost all from engine technology.
- Big change is move from naturally aspirated IDI diesels to Turbo-DI in 1990-1995 time frame, significant HP improvements recently.

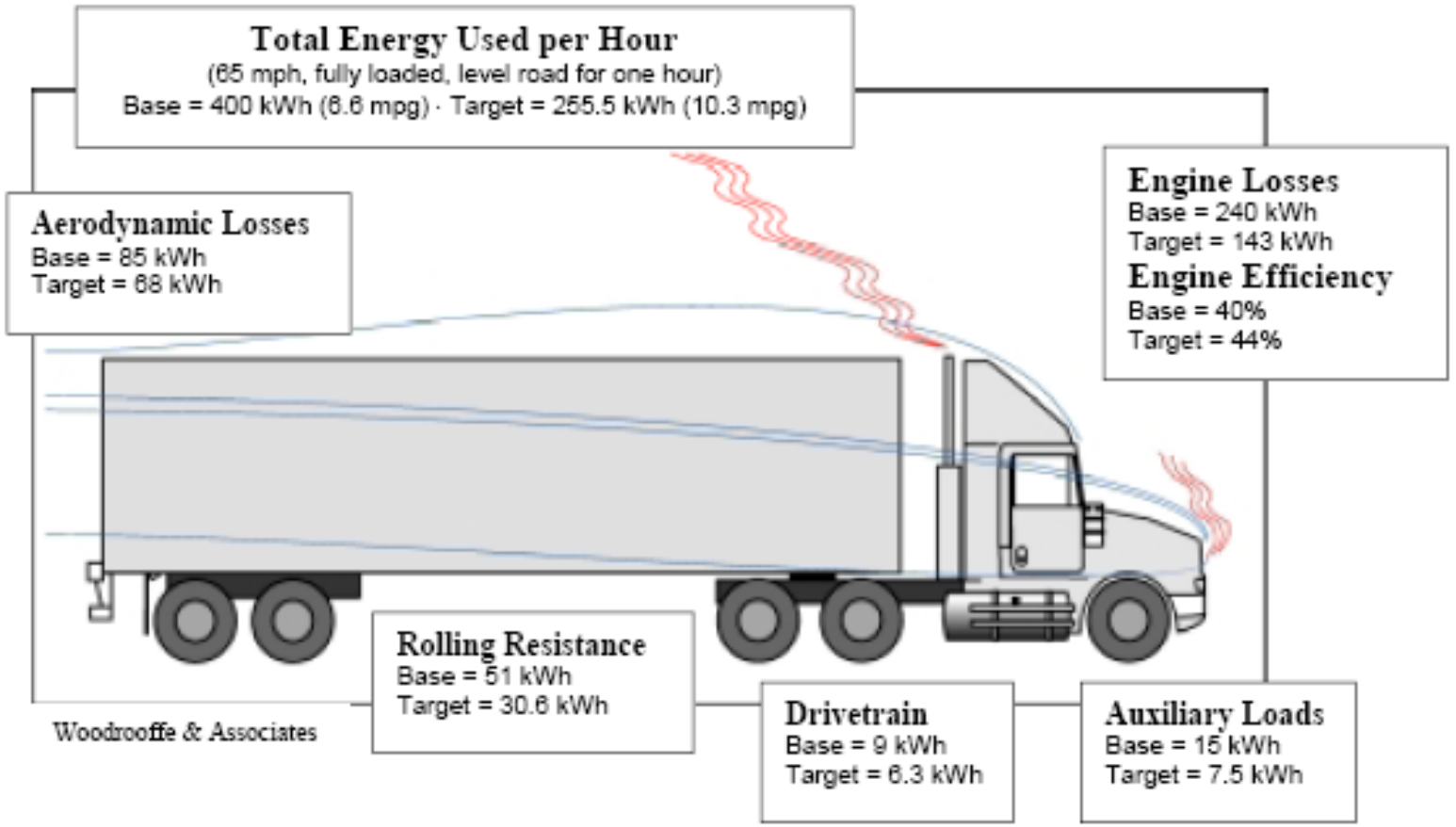
ANNUAL MILES BY VINTAGE: LHDT



FUEL ECONOMY BY VINTAGE: LHDT



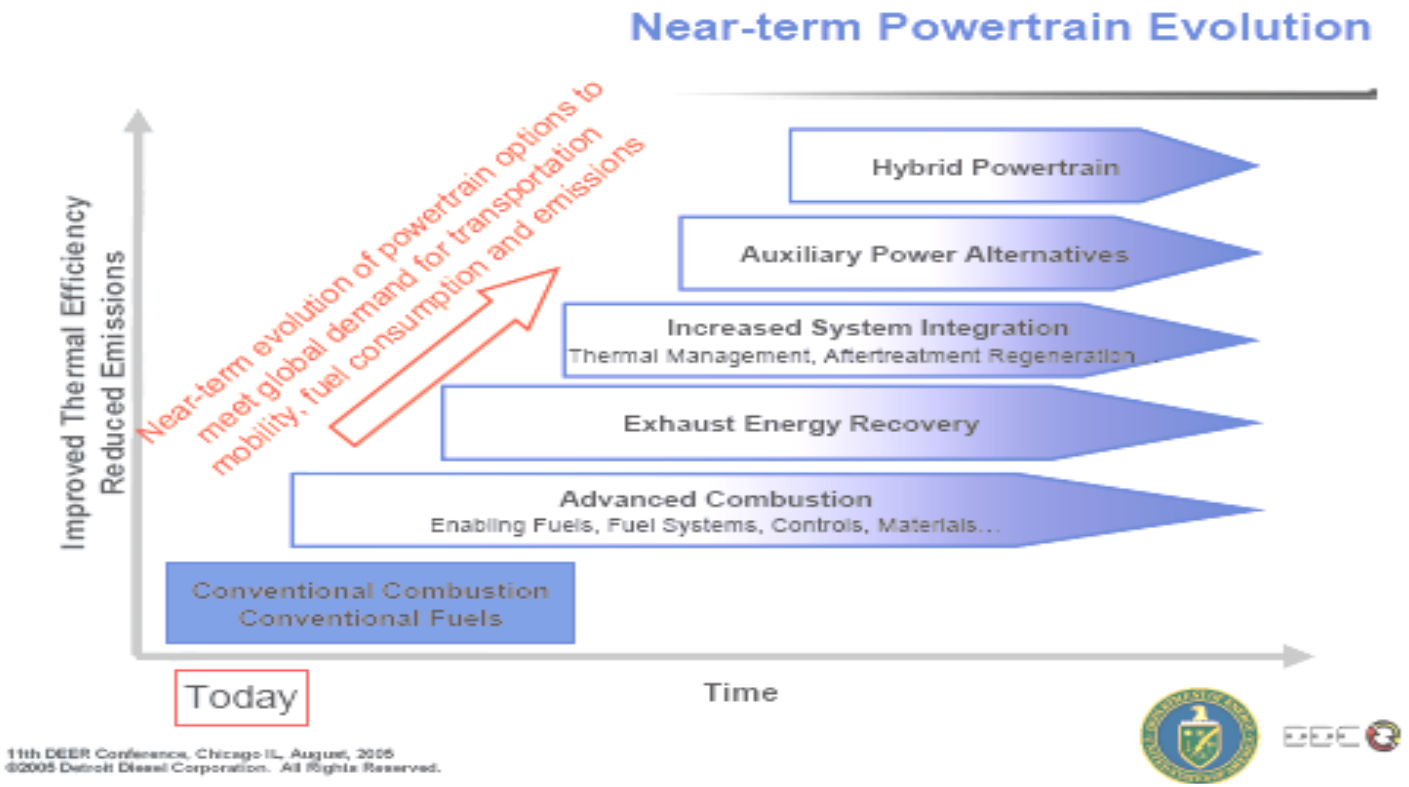
PROSPECTS FOR EFFICIENCY IMPROVEMENT : HHDT



ENGINE PEAK BRAKE THERMAL EFFICIENCY IMPROVEMENT

- Current peak efficiency is about 42% with DOE goal of 50%
- Near term roadmap includes:
  - urea – SCR NOx control
  - series turbo-charging with variable geometry and inter-cooling
  - turbo-compounding (electric?)
  - advanced combustion, higher pressure

ENGINE & SYSTEM THERMAL EFFICIENCY IMPROVEMENT



HYBRID TECHNOLOGY FOR HEAVY-DUTY TRUCKS

- Many hybrid demonstration projects are in progress around the world, mostly for buses.
- Fuel economy benefits form 25% to 45% depending on duty cycle demonstrated in projects for urban vehicles.
- Both mild and “full” hybrids being considered by industry, with mild being more likely.
- Even long haul HHDT can benefit from mild hybrid technology with electrical accessories.

DRAG AND ROLLING RESISTANCE REDUCTION

- Drag reduction potential expected to focus on tractor-trailer integration and more aerodynamic trailers (side skirts and rear spoilers) to 2025.
- Continued progress in tire technology with new polymers and tread designs expected to reduce RRC at same rate as 1995-2005
- Idle reduction with improved engine start ability by plug-in electrical supply likely.

FUTURE SCENARIOS FOR FC REDUCTION TO 2030

- Near term, new emission standards in the US will lead to a fuel economy loss of about 4% due to PM-NOx reduction technology.
- Preliminary classification of technology cost as low (payback less than 3 years), medium (4 to 6 years) or high (>6 years)
- Hybrids appear to be very high cost now but mild hybrids could be a medium cost technology by 2020 with 10 to 12% FE improvement.

COMPOSITE FE IMPROVEMENT BY COST CATEGORY: HHDT

		2010		2020		2030	
		FC %	COST	FC %	COST	FC %	COST
ENGINE		-4	NA	+4	LOW	+6	LOW
		+2	MED	+8	MED	+10	MED
				+13	HIGH	+17	HIGH
AERO		+3	LOW	+6	LOW	+6	LOW
		+5	MED	+10	MED	+10	MED
RRC		+2	LOW	+4	LOW	+6	LOW
ACCESSORY		+1	MED	+3	MED	+3	MED
				+5	HIGH	+5	HIGH

COMPOSITE FE IMPROVEMENT BY COST CATEGORY: MHDT

		2010		2020		2030	
		FC%	COST	FC%	COST	FC%	COST
ENGINE		-4	NA	+3	LOW	+4	LOW
		+2	MED	+7	MED	+8	MED
				+12	HIGH	+15	HIGH
AERO		+1	LOW	+2.5	LOW	+2.5	LOW
		+2	MED	+4	MED	+4	MED
RRC		+2.5	LOW	+5	LOW	+7	LOW
ACCESORIES		+1.5	MED	+3	MED	+3	MED
				+5	MED	+5	MED

CONCLUSIONS

- In the short term (2010) fuel economy of heavy and medium trucks will not improve due to penalty of new emission standards.
- In the mid-term (2020), there is enough low cost conventional technology to continue FE improvement at historical pace of 0.8 to 1 % per year.
- Slowdown inevitable in long term (2030) as low cost conventional technology runs out.

CONCLUSIONS (continued)

- Medium and high cost technologies will not be introduced unless fuel prices become much higher or new policies make introduction mandatory.
- Mild hybrid technology (medium cost) could allow pace of FE growth to be maintained to 2030 if incentives or policies require their introduction