Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles,
Interim Report, NESCCAF, March 2004

Data Integration and Results

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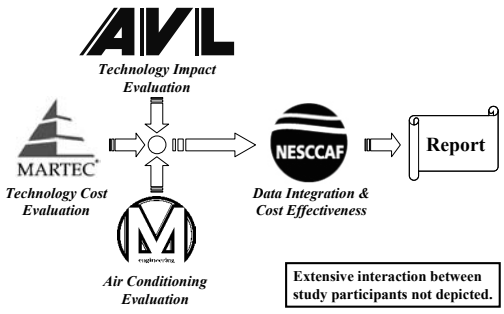
NESCCAF Study Team



Data Integration - Introduction

- Because three independent technical consultants were included on the study team, each tasked with varying components of the overall study, the task of data integration was an essential study element.
- While many integration decisions were achieved through discussion and consensus, NESCCAF served as the overall arbiter and provided key assumptions related to the final data analysis.

Data Integration - Overview (1)

- The data integration process for the study generally flows as follows:
- Step 1: AVL simulation results for individual technology packages are collected.
- Step 2: The technology package costs are assembled using the cost data collected by Martec.
- Step 3: Additional technology "packages" representing moderate (Civic-type) and fully integrated (Prius-type) hybrids are appended to the AVL database.

Data Integration - Overview (2)

- Step 4: The CO_2 impacts (and costs) of non-simulated (or partially simulated) technologies are integrated into the technology package database.
- Step 5: The indirect CO_2 impacts of air conditioning (A/C) usage are integrated into the technology package database.
- Step 6 (not in draft report): CO_2-equivalent methane and N_2O impacts as well as direct CO_2-equivalent impacts of air conditioning usage are integrated into the technology package database.

Data Integration Step 1 - AVL Data

- Step 1 - AVL Database. This step includes no action other than aggregation of the simulation data developed by AVL, as covered in their earlier presentation.

Data Integration Step 2 - Martec Data

- Step 2 - Martec Database. This step also represents the aggregation of "raw" data -- in this case, costing data collected by Martec as covered in their earlier presentation.
- Martec cost data are estimated as costs "to the OEM." To estimate expected consumer costs, a "Retail Price Equivalent" (RPE) adjustment factor of 1.4 is applied to all Martec cost data to estimate the average (across models) expected retail cost impact.

Data Integration Step 3 - Hybrids (1)

- Step 3 - Hybrids. Mild (42V) hybrids were modeled directly by AVL and are included in the Step 1 database.
- Moderate and fully integrated hybrid impacts are estimated separately and appended to the AVL database.
- For the draft report, both impacts and costs are taken from a UC-Davis study by Lipman and Delucchi (*Hybrid-Electric Vehicle Design, Retail and Lifecycle Cost Analysis*, UCD-ITS-RR-03-01, April 2003).
  - Vehicle classes in the EC-Davis report map directly into the NESCCAF study classes.

Data Integration Step 3 - Hybrids (2)

- For the final report, these data will be supplanted by actual certification data and associated costs estimated by Martec.
  - The base Civic and Prius component sizes are scaled both within and across classes to provide class average performance.
  - Costs will vary across classes according to component size.

Data Integration Step 4 - Other Techs

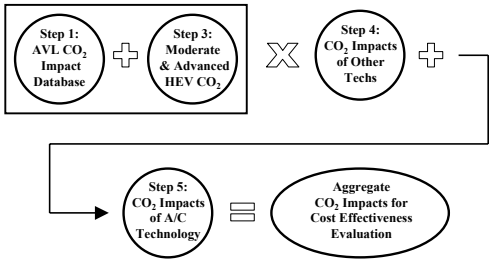
Technology		Transmission Type		
		Automatic	Automated Manual	CVT
Improved Tires	Impact	10% reduction in rolling resistance = 2% reduction in CO_2		
	Cost	$20 to $90 RPE		
Engine Friction Reduction or Improved Lubricating Oil	Impact	Reduced internal friction/lower viscosity oil, 0.5% CO_2 reduction		
	Cost	$5 to $15 RPE		
Aerodynamic Drag Reduction	Impact	8-10% reduction in drag = 1.5-2% reduction in CO_2		
	Cost	$0 to $125 RPE		
Aggressive Shift Logic	Impact	1.5% CO_2 reduction	0.5% CO_2 reduction	None
	Cost	$0 to $50 RPE	$0 to $20 RPE	
Improved Torque Converter or Early Lockup	Impact	0.5% CO_2 reduction	None	
	Cost	$0 to $10 RPE		
Weight Reduction	Impact	5% reduction in mass = 3% reduction in CO_2		
	Cost	$180 to $300 RPE		
Total Potential (without Weight Reduction)	Impact	6% to 6.5% CO_2	4.5% to 5% CO_2	4% to 4.5% CO_2
	Cost	$25 to $290 RPE	$25 to $250 RPE	$25 to $230 RPE
Total Potential (with Weight Reduction)	Impact	9% to 9.5% CO_2	7.5% to 8% CO_2	7% to 7.5% CO_2
	Cost	$205 to $590 RPE	$205 to $550 RPE	$205 to $530 RPE
Average RPE per Percent CO_2	w/o WR	$25	$29	$30
	w/ WR	$43	$49	$51
Assumed Improvement	Impact	5% CO_2 reduction	5% CO_2 reduction	4% CO_2 reduction
	Cost	$125 RPE	$145 RPE	$120 RPE

Potential benefits and costs from literature. Drag, rolling resistance, aggressive shift, and lockup impacts also investigated with CRUISE.

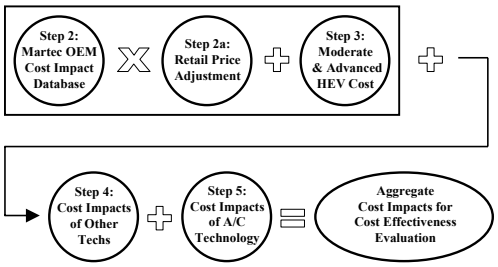
Data Integration Step 5 - A/C Impacts

- The indirect CO_2 impacts of an HFC-134a fixed displacement A/C system are integrated into the baseline 2002 model year impacts.
  - 31.4 g/mi/100 cc compressor displacement.
  - 34 percent A/C "on time."
- The indirect CO_2 impacts of an HFC-152a variable displacement A/C system are integrated into all other technology packages.
  - 15.1 g/mi/100 cc compressor displacement.
  - 34 percent A/C "on time."

Data Integration Summary - CO_2



Data Integration Summary - Costs



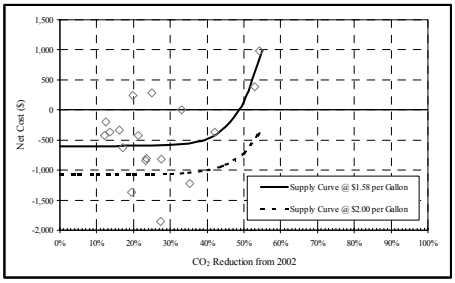
Cost Effectiveness Assumptions

- Because offsetting cost savings accrue through reduced fuel usage, a variety of assumptions are required to estimate the cost effectiveness of technology packages. Generally, these parameters were established by NESCCAF using data from other studies and databases.
  - Fuel cost = $1.58 per gallon ($2.00 per gallon alternative).
  - Payback period = 12 years / 150,000 miles, with an annual mileage declination of 4.5 percent (15,901 miles year 1, 9582 miles year 12 --- 12,500 average annual miles).
  - Discount rate = 5 percent.

Large Car Results (1)

Technology Package	CO_2 (g/mi)	CO_2 Change from 2002 (percent)	Marginal Vehicle Cost ($)	Net Lifetime Cost ($)	Net Cost ($) per ton CO_2
DCP,A6	305.0	12.2%	479	-419	-60
DCP,CVT,EPS,ImpAlt	304.0	12.5%	725	-198	-28
DVVL,DCP,A6	299.9	13.6%	640	-374	-48
CVVL,DCP,A6	291.0	16.2%	864	-338	-36
DCP,DeAct,A6	287.7	17.2%	640	-623	-63
DCP,Turbo,A6,EPS,ImpAlt	279.9	19.4%	73	-1,367	-123
dHCCI,AMT,42V,EPS,eACC	278.1	19.9%	2,486	242	21
gHCCI,DVVL,ICP,AMT,EPS,ImpAlt	273.4	21.3%	1,149	-425	-35
CVVL,DCP,AMT,EPS,ImpAlt	265.9	23.4%	890	-837	-62
GDI-S,DeAct,DCP,AMT,EPS,ImpAlt	265.8	23.4%	925	-810	-60
DeAct,DVVL,CCP,A6,42V,EPS,eACC	260.7	24.9%	2,138	280	20
GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	252.1	27.4%	176	-1,849	-118
CVAch,AMT,EPS,ImpAlt	251.6	27.5%	1,219	-822	-52
CVAch,GDI-S,AMT,EPS,ImpAlt	243.0	30.0%	1,478	-739	-43
gHCCI,DVVL,ICP,AMT,42V,EPS,eACC	232.4	33.1%	2,451	-1	0
GDI-S,Turbo,DCP,A6,42V,EPS,eACC	224.9	35.2%	1,389	-1,225	-61
ModHEV	201.0	42.1%	2,770	-369	-15
AdvHEV	163.2	53.0%	4,346	389	13
HSDI,AdvHEV	158.8	54.3%	5,473	981	31

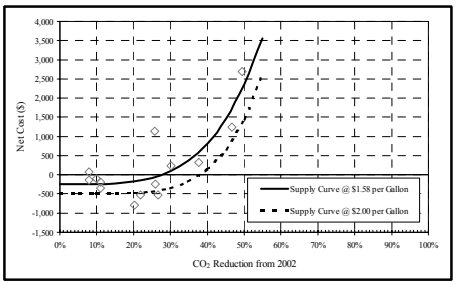
Large Car Results (2)



Small Car Results (1)

Technology Package	CO_2 (g/mi)	CO_2 Change from 2002 (percent)	Marginal Vehicle Cost ($)	Net Lifetime Cost ($)	Net Cost ($) per ton CO_2
DCP,CVT,EPS,ImpAlt	270.5	7.9%	570	68	18
DCP,EPS,ImpAlt	270.3	8.0%	360	-140	-36
DVVL,DCP,A5	264.5	10.0%	521	-105	-22
DCP,A5,EPS,ImpAlt	261.4	11.0%	494	-199	-37
DCP,A6	261.1	11.1%	346	-352	-65
DVVL,DCP,AMT,EPS,ImpAlt	234.5	20.2%	465	-800	-82
gHCCI,DVVL,ICP,AMT,EPS,ImpAlt	229.7	21.8%	841	-521	-49
dHCCI,AMT,42V,EPS,eACC	218.4	25.7%	3,349	1,132	91
CVVL,DCP,AMT,42V-SS,EPS,ImpAlt	217.5	25.9%	1,387	-239	-19
GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	215.7	26.6%	1,128	-530	-41
gHCCI,DVVL,ICP,AMT,42V,EPS,eACC	205.3	30.1%	2,124	230	16
ModHEV	183.3	37.6%	2,695	323	18
AdvHEV	156.4	46.8%	4,195	1,233	54
HSDI,AdvHEV	148.5	49.4%	6,246	2,694	112

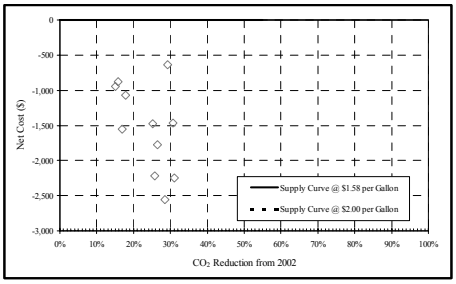
Small Car Results (2)



Small Truck Results (1)

Technology Package	CO_2 (g/mi)	CO_2 Change from 2002 (percent)	Marginal Vehicle Cost ($)	Net Lifetime Cost ($)	Net Cost ($) per ton CO_2
DCP,A6	380.7	15.0%	479	-948	-85
DVVL,DCP,A6	377.0	15.9%	640	-878	-75
DCP,A6,Turbo,EPS,ImpAlt	372.2	16.9%	73	-1,551	-124
DCP,A6,DeAct	367.8	17.9%	634	-1,071	-81
GDI-S,DCP,DeAct,AMT,EPS,ImpAlt	335.5	25.1%	906	-1,479	-79
dHCCI,AMT,EPS,ImpAlt	332.5	25.8%	1,156	-2,219	-116
DeAct,DVVL,CCP,AMT,EPS,ImpAlt	329.8	26.4%	750	-1,773	-91
GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	319.9	28.6%	157	-2,558	-121
DeAct,DVVL,CCP,A6,42V,EPS,eACC	317.2	29.2%	2,157	-638	-30
CVAeh,GDI-S,AMT,EPS,ImpAlt	310.5	30.7%	1,459	-1,463	-64
HSDI,AMT,EPS,ImpAlt	308.6	31.1%	1,585	-2,243	-97

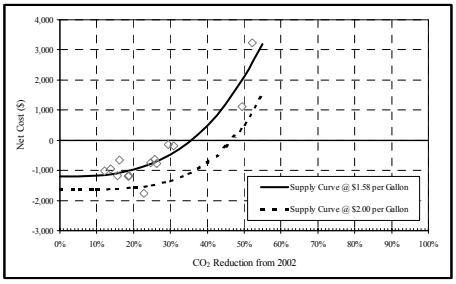
Small Truck Results (2)



Large Truck Results (1)

Technology Package	CO_2 (g/mi)	CO_2 Change from 2002 (percent)	Marginal Vehicle Cost ($)	Net Lifetime Cost ($)	Net Cost ($) per ton CO_2
CCP,A6	452.1	12.2%	339	-1,013	-98
DVVL,CCP,A6	443.8	13.8%	549	-957	-81
CCP,DeAct,A6	434.4	15.6%	543	-1,173	-88
DCP,DeAct,A6	432.1	16.1%	1,120	-658	-48
DeAct,DVVL,CCP,A6,EHPS,ImpAlt	419.3	18.6%	843	-1,205	-76
CCP,DeAct,GDI-S,AMT,EHPS,ImpAlt	417.9	18.8%	890	-1,183	-74
DeAct,DVVL,CCP,AMT,EHPS,ImpAlt	397.6	22.8%	731	-1,770	-91
GDI-L,AMT,EHPS,ImpAlt	388.5	24.6%	1,926	-754	-36
CVAeh,GDI-S,AMT,EHPS,ImpAlt	382.8	25.7%	2,171	-642	-29
DeAct,DVVL,CCP,A6,42V,EPS,eACC	379.2	26.4%	2,136	-769	-34
dHCCI,AMT,42V,EPS,eACC	363.5	29.4%	4,081	-149	-6
GDI-L,AMT,42V,EPS,ImpAlt	356.0	30.9%	3,186	-188	-7
AdvHEV	260.4	49.4%	6,580	1,113	26
HSDI,AdvHEV	246.3	52.2%	9,685	3,243	73

Large Truck Results (2)



Minivan Results (1)

Technology Package	CO_2 (g/mi)	CO_2 Change from 2002 (percent)	Marginal Vehicle Cost ($)	Net Lifetime Cost ($)	Net Cost ($) per ton CO_2
DCP,A6	349.6	12.3%	863	-187	-23
DVVL,CCP,A5	344.2	13.7%	528	-635	-70
GDI-S,CCP,DeAct,AMT,EPS,ImpAlt	320.1	19.7%	759	-905	-70
DVVL,CCP,AMT,EPS,ImpAlt	317.0	20.5%	494	-1,242	-92
CCP,AMT,Turbo,EPS,ImpAlt	316.7	20.6%	1,024	-714	-53
DeAct,DVVL,CCP,AMT,EPS,ImpAlt	308.4	22.7%	638	-1,278	-86
CVVL,CCP,AMT,EPS,ImpAlt	307.3	22.9%	1,108	-848	-56
dHCCI,AMT,EPS,ImpAlt	303.8	23.8%	2,228	-631	-40
GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	298.8	25.0%	1,330	-799	-48
CVAeh,GDI-S,AMT,EPS,ImpAlt	291.8	26.8%	1,809	-469	-27
GDI-S,CCP,AMT,42V,DeAct,EPS,eACC	288.4	27.7%	2,080	-273	-15

Minivan Results (2)