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Candidate Mobile Source Control Measures

LADCO Regional Air Quality Workshop
November 16, 2005

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Outline of Presentation

- Project Objectives
- Technical Approach
  - Emission inventory
  - Qualitative screening analysis
  - Technical and economic analyses of selected control measures
- Preliminary Results
  - Emission inventory
  - Mobile source control measure master list
  - Candidate on-road control measures
  - Candidate off-road control measures
  - Potential emission reduction scenarios
- On-going Effort & Schedule

Project Objectives

- Evaluate candidate emission control measures for mobile sources to support the development of new 8-hour ozone SIPs.
- Identify, screen and assess the feasibility and cost of potential emission control measures for on-road and off-road mobile sources
- Develop White Papers for selected candidate control measures that could be implemented in the LADCO States to improve the air quality in the region.

Technical Approach

- Compile and review base and future year mobile source emission inventories. Identify major emission categories and estimate potential emission reductions of candidate control measures.
- Develop a preliminary master list of potential mobile source control measures.
- Perform qualitative analysis of measures in preliminary master list to screen out less effective control measures for LADCO States based on a set of screening criteria.

Technical Approach (cont.)

- Recommend, discuss and finalize control measure master list based on screening analysis results and LADCO comments.
- Perform technical and economic analyses on selected control measures.
- Present and discuss results of technical and economic analyses.
- Prepare draft technical report and White Papers on selected control measures.
- Discuss and finalize technical report and White Papers.

Emission Inventory

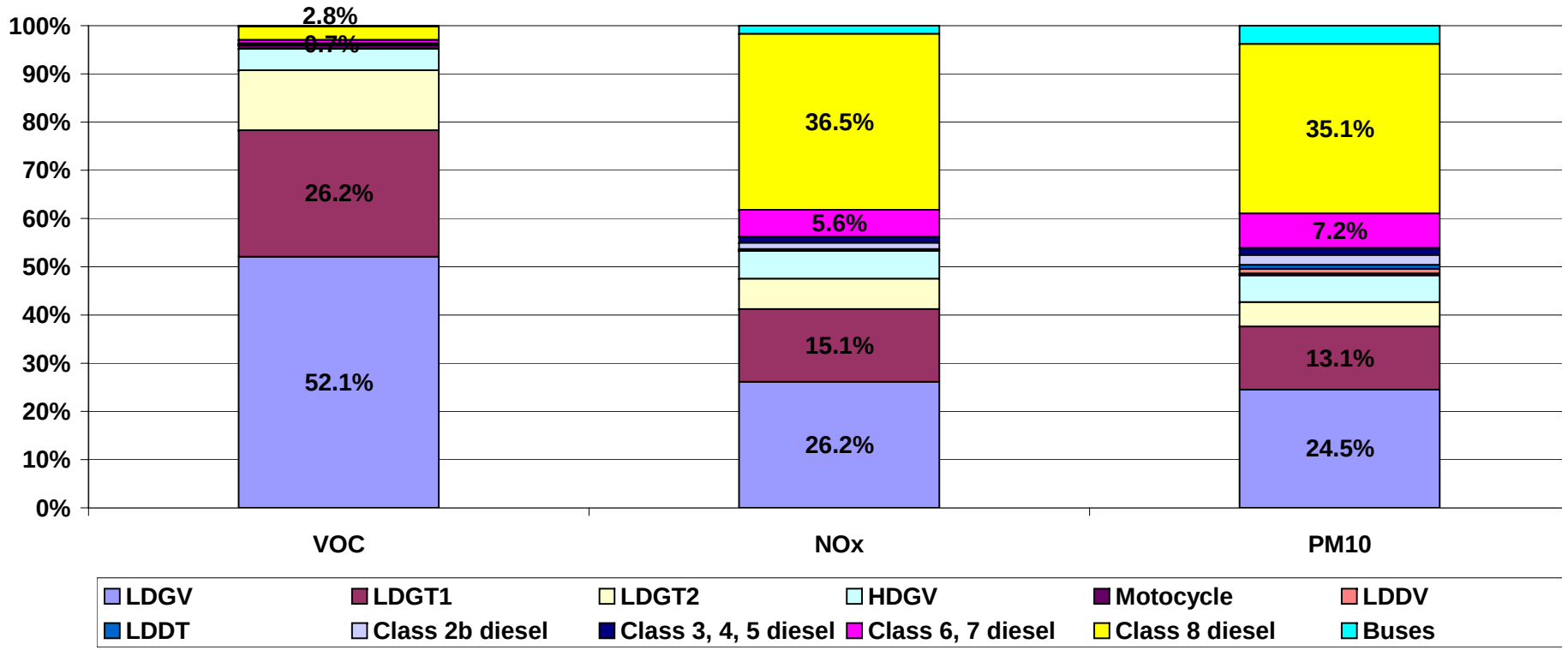
- Estimated CY 2009 mobile source emission inventory was used to assess potential emission reductions of selected control measures.
- LADCO is still revising its 2009 emission inventory.
- CY 2009 on-road emissions by vehicle type were estimated based on:
  - 2002 NEI emission inventory by vehicle types
  - ratio of 2009/2002 emissions for diesel and gasoline vehicles provided by LADCO

Emission Inventory (cont.)

- CY 2009 NONROAD emission inventory was generated from NONROAD model using input & option files provided by LADCO.
- CY 2002 LADCO Base J locomotive and commercial marine emissions were used in the qualitative screening analysis, as the 2009 locomotive and commercial marine emissions are not available.

Emission Contributions to 2009 On-Road Emissions in the LADCO States

(VOC = 1008 tpd; NOx = 1962 tpd; and PM = 48 tpd)



Note: LADCO is currently revising its 2009 Base J on-road emission inventory. Therefore, the emission contributions by vehicle types for the revised 2009 Base J emissions might be different from these data that were projected based on the NEI 2002 emissions.

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Equipment Type	2009 LADCO NONROAD NOx Emissions (tpd)					2009 LADCO NONROAD NOx Emissions (%)				
	CNG	Diesel	Gasoline	LPG	Total	CNG	Diesel	Gasoline	LPG	Total
Construction and Mining	0.00	272.85	2.94	0.71	276.50	0.00%	33.13%	0.36%	0.09%	33.58%
Agricultural	0.01	254.33	1.73	0.01	256.09	0.00%	30.88%	0.21%	0.00%	31.10%
Industrial	4.91	59.53	2.22	66.26	132.92	0.60%	7.23%	0.27%	8.05%	16.14%
Pleasure Craft	0.00	22.24	30.26	0.00	52.51	0.00%	2.70%	3.67%	0.00%	6.38%
Commercial	1.37	33.67	10.80	5.29	51.12	0.17%	4.09%	1.31%	0.64%	6.21%
Lawn and Garden	0.00	13.52	23.73	0.33	37.58	0.00%	1.64%	2.88%	0.04%	4.56%
Recreational	0.00	0.72	8.46	0.05	9.23	0.00%	0.09%	1.03%	0.01%	1.12%
Airport Ground Support	0.00	3.45	0.03	0.04	3.53	0.00%	0.42%	0.00%	0.00%	0.43%
Logging	0.00	1.98	0.06	0.00	2.05	0.00%	0.24%	0.01%	0.00%	0.25%
Railway Maintenance	0.00	1.35	0.02	0.00	1.37	0.00%	0.16%	0.00%	0.00%	0.17%
Underground Mining	0.00	0.64	0.00	0.00	0.64	0.00%	0.08%	0.00%	0.00%	0.08%
Total	6.30	664.29	80.24	72.70	823.53	0.76%	80.66%	9.74%	8.83%	100.00%

Equipment Type	Sum of PM-Exhaust (tpd)					2009 LADCO NONROAD PM Emissions (%)				
	CNG	Diesel	Gasoline	LPG	Total	CNG	Diesel	Gasoline	LPG	Total
Agricultural	0.00	21.59	0.05	0.00	21.64	0.00%	24.82%	0.06%	0.00%	24.87%
Construction and Mining	0.00	18.98	1.04	0.01	20.03	0.00%	21.81%	1.19%	0.01%	23.02%
Pleasure Craft	0.00	0.46	14.63	0.00	15.09	0.00%	0.53%	16.82%	0.00%	17.35%
Recreational	0.00	0.12	11.88	0.00	12.00	0.00%	0.14%	13.65%	0.00%	13.79%
Lawn and Garden	0.00	1.01	7.34	0.00	8.36	0.00%	1.17%	8.44%	0.01%	9.61%
Industrial	0.06	4.47	0.04	0.75	5.32	0.06%	5.14%	0.04%	0.86%	6.11%
Commercial	0.02	3.18	0.68	0.04	3.91	0.02%	3.66%	0.78%	0.04%	4.50%
Logging	0.00	0.13	0.09	0.00	0.22	0.00%	0.15%	0.11%	0.00%	0.26%
Airport Ground Support	0.00	0.22	0.00	0.00	0.22	0.00%	0.25%	0.00%	0.00%	0.25%
Railway Maintenance	0.00	0.14	0.00	0.00	0.14	0.00%	0.17%	0.00%	0.00%	0.17%
Underground Mining	0.00	0.07	0.00	0.00	0.07	0.00%	0.08%	0.00%	0.00%	0.08%
Total	0.08	50.38	35.74	0.81	87.00	0.09%	57.91%	41.08%	0.93%	100.00%

Note: LADCO is currently revising its 2009 Base J emission inventory. Therefore, the revised 2009 Base J emissions might be different from these emission data.

LADCO Aircraft, Commercial Marine, and Locomotive Emissions

	VOC	NOx	PM10
2002 Base J Emissions (tpd)			
Aircraft	1.56	25.79	1.31
Commercial Marine	2.94	387.24	16.91
Locomotives	1.00	340.59	8.66
Emission Contributions to 2002 Off-road Emissions (%)			
Aircraft	0.6%	1.5%	0.9%
Commercial Marine	0.9%	22.0%	12.2%
Locomotives	1.1%	19.4%	6.2%

Note: LADCO is currently revising its 2009 Base J on-road emission inventory. Therefore, the emission contributions by vehicle types for the revised 2009 Base J emissions might be different from these data that were projected based on the NEI 2002 emissions.

Emission Inventory Key Contributors - 2009

- More than 40% of 2009 NOx and PM emissions are from heavy-duty diesel vehicles.
  - Heavy-HDDVs (i.e. class 8 trucks) alone contribute about 35% of both NOx and PM emissions.
- More than 80% of 2009 NOx and 55% of PM NONROAD emissions are from diesel equipment.
  - Construction and agricultural diesel equipment each contribute more than 30% of NOx and 20% of PM emissions.
- Commercial marine and locomotive contribute to about 40% of NOx and 20% of PM emissions of the total 2002 off-road emission inventory.

Qualitative Screening Analysis

- Developed a preliminary master list of control measures for mobile sources.
- More than 70 measures grouped into the following categories:
  - Alternative and conventional fuels;
  - Fleet and equipment modernization programs;
  - Idling restriction/reduction programs;
  - Inspection/maintenance programs;
  - Low-emission vehicles (LEV) programs;
  - Retrofitting programs;
  - Ozone action days/public awareness programs;
  - Intelligent transportation system (ITS) programs; and
  - VMT reduction programs.

Qualitative Screening Analysis (cont.)

- Performed qualitative screening analysis based on:
  - Potential emission reduction (NOx and PM)
  - Emission benefit relative to source category (control efficiency)
  - Technical feasibility
  - SIP creditable (Permanent, Quantifiable, Surplus, Enforceable)
  - Cost effectiveness
  - Implementation feasibility
  - Public acceptability

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Selected Mobile Source Control Measures			
Control ID	**Category**	**Vehicle/Equipment Types**	**Control Measures**
46	Retrofitting	HDDV	Aftertreatment retrofit programs for HD diesel vehicles (DPFs, catalysts, EGRs etc.)
28	Fleet Modernization	LDV	Accelerated replacement of current LD fleets with LEVs or Tier 2 vehicles
51	Retrofitting	Diesel Equipment	Aftertreatment retrofit programs for nonroad diesel equipment (DPFs, catalysts, EGRs etc.)
32	Fleet Modernization	HDDV	Accelerate the turnover of older HDDVs to cleaner late model HDDVs
29	Fleet Modernization	LDV & HDV	Accelerated replacement of current LD and HD fleets with AFVs
20	Equipment Modernization	Diesel Equipment	Accelerated purchase of Tier2/Tier 3/Tier 4 nonroad engines or onroad engines
42	I/M Programs	HDDV	HDDV accelerated reflashing programs
31	Fleet Modernization	HDDV	Repower HDDVs with older, high emitting engines with low emission diesel engines
16	Conventional Fuels	Diesel Vehicles/Equipment	Reformulated diesel fuels (e.g. Fischer-Trope diesel; emulsified diesel; CA diesel)
47	Retrofitting	HDDV	Retrofit programs for HD diesel vehicles to AFVs (NG, dual-fuel etc.)
45	LEV Programs	LDV	ULEV/SULEV/ZEV pilot programs
43	LEV Programs	LDV	LEV programs/requirements for public and private fleets
30	Fleet Modernization	LDV	Buy back and scrap pre-1980 LDVs and high emitters
44	LEV Programs	LDV	Scrappage of high emitter LDVs and replace with LEVs
40	I/M Programs	LDV	LDV I/M programs (IM-240, RSD, ASM, RG240 etc.) - OBD only
25	Equipment Modernization	Agricultural Equipment	Accelerate the turnover of older agricultural engines to Tier 2/Tier3/Tier 4 nonroad engines or onroad engines
67	Intelligent Transport systems	LDV	Speed limit restriction (65mph)

Primary measures of interest.
Secondary measures of interest

Technical & Economic Analyses

- Determine major NOx contributors in 2009:
  - Construction and agricultural equipment by horsepower and technology type
  - HDDV vehicle populations by model year groups based on NOx standards (assumed 2%/year VMT growth from 2002)
- For each selected measure, estimate the cost, cost-effectiveness, and potential emission reduction.
- Develop emission reduction scenarios to estimate cumulative emission reduction potential from several control measures.

Construction Equipment - Major NOx Emission Contributors

Major NOx Emission Contributors in the 2009 Construction Equipment Emissions.			
Equipment Type	**Population**	**NOx Emissions (tpd)**	**NOx Contribution (%)**
R9:750+_Off-highway Trucks	1,500	27.7	10.2%
R8:600-749_Rubber Tire Loaders	6,046	17.7	6.5%
R9:750+_Crawler Tractor/Dozers	1,932	14.4	5.3%
R7:300-599_Excavators	8,204	14.3	5.3%
R6:175-299_Excavators	11,222	12.3	4.5%
R7:300-599_Rubber Tire Loaders	8,241	11.2	4.1%
R8:600-749_Crawler Tractor/Dozers	3,122	10.4	3.8%
R7:300-599_Crawler Tractor/Dozers	6,166	9.8	3.6%
R5:100-174_Tractors/Loaders/Backhoes	20,644	9.5	3.5%
R9:750+_Rubber Tire Loaders	1,008	9.5	3.5%
R6:175-299_Tractors/Loaders/Backhoes	13,736	8.5	3.1%
Other Construction Equipment (<3%)	172,018	127.6	46.7%
Total	253,840	272.8	100%

Agricultural Equipment - Major NOx Emission Contributors

Major NOx Emission Contributors in the 2009 Agricultural Equipment Emissions			
Equipment Type	**Population**	**NOx Emissions (tpd)**	**NOx Contribution (%)**
R8:600-749_Agricultural Tractors	31,270	68.1	26.8%
R7:300-599_Agricultural Tractors	60,432	59.5	23.4%
R6:175-299_Agricultural Tractors	70,097	40.9	16.1%
R7:300-599_Combines	36,051	18.4	7.2%
R5:100-174_Agricultural Tractors	42,069	16.2	6.4%
R4:75-99_Agricultural Tractors	47,732	13.3	5.2%
R6:175-299_Combines	30,233	9.6	3.8%
R2:25-49_Agricultural Tractors	72,373	8.4	3.3%
R3:50-74_Agricultural Tractors	30,145	5.6	2.2%
Other Agricultural Equipment (<2%)	46,671	14.4	5.7%
Total	467,073	254.3	100%

On-road HDDV Population Estimates

2009 H-HDDV Population Estimates in LADCO	
Model Year Group	**Population**
MY 1989 and Earlier	88,148
MY 1990	8,308
MY 1991 - 1997	49,786
MY 1998 - 2001	22,943
MY 2002 - 2006	24,145
Total	193,330

Note:The population estimates for on-road HDDVs (i.e. Class 8 trucks) were estimated based on projected 2009 VMT data from the 2002 FHWA VMT data by facility types with an assumed constant growth rate of 2% per year as suggested by LADCO, vehicle mix fractions developed in a ENVIRON's study for LADCO, and data in MOBILE6 technical support documents.

Technical and Economic Analyses:
Control Measures

- Selected control measures can be grouped as follows:
  - Alternative fuels for HDDVs
    - Natural gas & dual fuel technologies
  - Conventional fuels for diesel vehicles and equipment
    - Emulsified diesel fuel & California diesel fuel
  - Vehicle/fleet/equipment modernization programs
    - Engine repowering and vehicle/equipment replacement for HDDVs or diesel equipment
    - LEV II/accelerated vehicle replacement/scrappage programs for LDVs/LDTs
  - Diesel retrofit programs (focusing on reducing NOx emissions)
    - Lean NOx catalysts & SCR
    - EGR+DPF
  - Accelerated reflashing program for HDDVs, and I/M programs for LDVs

Fleet Modernization Programs

- Federal and CA emission standards for new on-road HD engines, off-road diesel engines, and LDVs/LDTs.
- Applicable to fleet/equipment modernization programs via engine repowering or vehicle/equipment replacement
- Completed fleet modernization measures analysis for on-road HDDVs, and construction and agricultural equipment.
- Working on LEV II/Tier 2 Fleet Modernization for LDVs/LDTs.

On-road HDDV Fleet Modernization Program

Partial Example of Technical & Economic Analyses

	MY1989 & Earlier				MY 1990		
	Diesel Baseline	**MY 1990 Engines**	**MY 2001/2 Engine**	**MY 2002/4 Engine**	**Diesel Baseline**	**MY 2001/2 Engine**	**MY 2002/4 Engine**
NOx (g/bhp-hr)	10.7	6.0	4.0	2.4	6.0	4.0	2.4
Annual Mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 35,000	$40,000	$45,000		$40,000	$45,000
Useful Life (years)	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$4,986	$5,698	$6,411		$5,698	$6,411
Conversion Factor (bhp-hr/mi)	3.11	3.05	2.90	2.90	3.05	2.90	2.90
NOx (g/mi)	33.24	18.30	11.58	6.95	18.30	11.58	6.95
NOx (tons/year)	1.83	1.01	0.64	0.38	1.01	0.64	0.38
NOx Reduction (tons/year)		0.82	1.19	1.45		0.37	0.63
NOx reduction (tons/day)		0.0033	0.0048	0.0058		0.0015	0.0025
Cost-Effectiveness ($/ton)		$6,053	$4,772	$4,423		$15,385	$10,246
One-Year Cost-Effectiveness		$42,492	$33,499	$31,049		$108,000	$71,924

Non-road Equipment Fleet Modernization Program

Partial Example of Technical & Economic Analyses

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0	Tier 2	Tier 0	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx (g/bhp-hr)	9.3	4.655	9.5	4.56	6.9	4.655	6.9	4.56
Average Horsepower (hp)	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	777	777	777	777	777	777	777	777
Incremental Capital Cost		$ 23,750		$ 45,000		$ 23,750		$ 45,000
Useful Life (years)	7	7	7	7	7	7	7	7
Annualized Capital Cost ($/yr)		$3,812		$7,223		$3,812		$7,223
NOx Emission Factor (g/hr)	1303	652	2522	1211	967	652	1832	1211
NOx (tons/year)	1.12	0.56	2.16	1.04	0.83	0.56	1.57	1.04
NOx Reduction (tons/year)		0.56		1.12		0.27		0.53
NOx reduction (tons/day)		0.0022		0.0045		0.0011		0.0021
Cost-Effectiveness ($/ton)		$6,838		$6,430		$14,148		$13,574
One-Year Cost-Effectiveness		$42,603		$40,059		$88,148		$84,570

On-road HDDV NG/Dual Fuel Program

- Replace older diesel engines with new lower emissions NG/Dual-Fuel engines, or retrofit the diesel engines with Dual-Fuel conversion kits.
- NG/Dual-Fuel engines are certified to 2.0 or 2.5 g/bhp-hr of NOx emission level.
- Accounted for LHV of natural gas as compared to diesel.
- Incremental capital cost and incremental fuel cost were estimated. Fuel prices were based on Data from 2005 Annual Energy Outlook.

On-road HDDV NG/Dual Fuel Program

Partial Example of Technical & Economic Analyses

	MY1989 & Earlier			MY 1990		
	Diesel Baseline	**Dedicated LNG**	**Dual-Fuel Engine**	**Diesel Baseline**	**Dedicated LNG**	**Dual-Fuel Engine**
NOx (g/bhp-hr)	10.7	2.0	2.0	6.0	2.0	2.0
Annual Mileage	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$35,000	$30,000		$35,000	$30,000
Useful Life (years)	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$4,986	$4,274		$4,986	$4,274
Conversion Factor (bhp-hr/mi)	3.11	3.11	3.11	3.05	3.05	3.05
Diesel (gal/mile)	0.18		0.03	0.18		0.03
LNG (gal/mile)		0.36	0.31		0.36	0.31
Fuel Cost per Mile	$0.39	$0.60	$0.57	$0.39	$0.60	$0.57
Fuel Cost per year	$19,318	$30,053	$28,733	$19,318	$30,053	$28,733
Added Fuel Cost per year		$10,735	$9,415		$10,735	$9,415
NOx (g/mi)	33.24	6.21	6.21	18.30	6.10	6.10
NOx (tons/year)	1.83	0.34	0.34	1.01	0.34	0.34
NOx Reduction (tons/year)		1.49	1.49		0.67	0.67
NOx reduction (tons/day)		0.0060	0.0060		0.0027	0.0027
Cost-Effectiveness ($/ton)		$3,347	$2,869		$7,415	$6,356
C-E including Fuel ($/ton)		$10,553	$9,188		$23,381	$20,358
One-Year Cost-Effectiveness		$23,493	$20,137		$52,052	$44,616

CA Diesel Fuel Measure for On-road H-HDDVs

Control efficiency: about 6%

Assumed incremental fuel price between $0.10 to $0.20, with an average of $0.15.

2009 LADCO States	NOx Emissions (tpd)			Vehicle Population	Reduction (tpd/veh.)	Incremental Cost ($)	Cost-Effectiveness
	Baseline	w/ CA Diesel	Reduction				
LDDV	1.08	1.0	0.1	40800	0.000002	51	84,045
LDDT	1.56	1.5	0.1	91974	0.000001	68	178,382
Class 2b diesel	25.05	23.5	1.6	1680666	0.000001	119	353,663
Class 3, 4, 5 diesel	24.20	22.7	1.5	353078	0.000004	154	98,967
Class 6, 7 diesel	109.60	102.8	6.8	565913	0.000012	212	48,309
Class 8 diesel	716.45	672.0	44.4	203639	0.000218	626	7,867
Buses	33.20	26.4	6.8	125592	0.000054	652	32,898

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Emulsified Diesel Fuel Measure for On-road HDDVs

Partial Example of Technical & Economic Analyses

- Control efficiency:15-21% - average of 18% was used
- Assumed 15% fuel penalty due to lower energy content

	MY1989 & Earlier		MY 1990	
	Baseline	w/PuriNOx	Baseline	w/PuriNOx
Annual mileage	50,000	50,000	50,000	50,000
Diesel mpg	5.35	5.35	5.54	5.54
Fuel Cost/mile	$0.40	$0.46	$0.38	$0.44
Fuel Cost/year	$19,878	$22,860	$19,179	$22,056
Incremental Fuel Cost/year		$2,982		$2,877
Three Year Grant Amount		$8,434		$8,137
Emission Std (g/bhp-hr)	10.7		6	
Coversion Factor (bhp-hr/mi)	3.11		3.05	
NOx g/mile	33.24	27.26	18.30	15.01
NO tons/year	1.83	1.50	1.01	0.83
NOx Reduction tons/year		0.33		0.18
NOx Reduction tons/day		0.00132		0.00073
Cost-Effectiveness ($/ton)		$9,039		$15,843
One-Year Cost-Effectiveness		$25,568		$44,814

CA Diesel Fuel Measure for NONROAD Equipment

Cost of diesel ($/gal):	2.13	
Increamental Fuel Cost ($/gal)	0.15	
Emission Reduction	6.2	%
Cost-Effectiveness	7000	$/tons of NOx reduced

Equipment Type	Diesel NOx (tpd)	W/ CA Diesel NOx (tpd)	NOx Reduction (tpd)	Equip Population	Emission Reduction (tpd per equipment)	Cost ($/yr)
Railway Maintenance	1.35	1.27	0.08	2,241	0.000037	65
Pleasure Craft	22.24	20.87	1.38	68,922	0.000020	35
Recreational	0.72	0.68	0.04	6,532	0.000007	12
Construction and Mining	272.85	255.93	16.92	253,840	0.000067	117
Industrial	59.53	55.84	3.69	112,663	0.000033	57
Lawn and Garden	13.52	12.68	0.84	73,395	0.000011	20
Agricultural	254.33	238.56	15.77	467,073	0.000034	59
Commercial	33.67	31.58	2.09	206,828	0.000010	18
Logging	1.98	1.86	0.12	1,178	0.000104	183
Airport Ground Support	3.45	3.24	0.21	3,233	0.000066	116
Underground Mining	0.64	0.60	0.04	735	0.000054	94
Total	664.29	623.10	41.19	1,196,639	0.000034	60

Emulsified Diesel Fuel Measure for NONROAD Equipment

Partial Example of Technical & Economic Analyses

Cost of diesel:	2.13	
Increamental Fuel Cost	15%	Assumed 15% fuel penalty due to lower volumetric effciency.
Cost of PuriNOx	2.44	
EPA Reduction (15 to 21%)	18 %	
CARB Reduction	14 %	

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.3	7.63	9.5	7.79	6.9	5.66	6.9	5.66
Average Horsepower (hp)	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	777	777	777	777	777	777	777	777
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	9,662	9,662	18,306	18,306	9,662	9,662	18,306	18,306
Fuel Cost ($/yr)	20,531	23,611	38,901	44,736	20,531	23,611	38,901	44,736
Incremental Fuel Cost/yr		$ 3,080		$ 5,835		$ 3,080		$ 5,835
Four Year Grant Amount		$11,447		$21,690		$11,447		$21,690
NOx Emission Factor (g/hr)	1303	1069	2522	2068	967	793	1832	1502
NOx (tons/year)	1.12	0.92	2.16	1.77	0.83	0.68	1.57	1.29
NOx Reduction (tons/year)		0.20		0.39		0.15		0.28
NOx reduction (tons/day)		0.0008		0.0016		0.0006		0.0011
Cost-Effectiveness ($/ton)		$15,329		$15,006		$20,661		$20,661
One-Year Cost-Effectiveness		$56,979		$55,780		$76,798		$76,798

Retrofit Measures for on-road H-HDDVs

- Lean NOx catalysts
- SCR systems
- EGR+DPF systems

ENVIRON

Lean NOx Retrofits for On-road HDDVs

Partial Example of Technical & Economic Analyses

Cost of Diesel:	2.13
Increamental Fuel Consumption	2%
NOx Reduction	40%

	MY1989 & Earlier		MY 1990	
	Baseline	**Lonestar**	**Baseline**	**Lonestar**
Annual mileage	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 20,000		$ 20,000
Useful Life (years)	8	8	8	8
Annualized Capital Cost ($/yr)		$2,849		$2,849
Diesel mpg	5.35	5.35	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38
Fuel Cost/year	$19,878	$20,276	$19,179	$19,562
Incremental Fuel Cost/year		$398		$384
Emission Std (g/bhp-hr)	10.7		6	
Coversion Factor (bhp-hr/mi)	3.11		3.05	
NOx g/mile	33.24	14.96	18.30	8.24
NO tons/year	1.83	0.82	1.01	0.45
NOx Reduction tons/year		0.55		0.30
NOx Reduction tons/day		0.00220		0.00121
Cost-Effectiveness ($/ton)		$5,182		$9,414
CE Including Fuel ($/ton)		$5,905		$10,682
One-Year Cost-Effectiveness		$36,378		$66,086

EGR+DPF Retrofits for On-road HDDVs

Partial Example of Technical & Economic Analyses

Cost of diesel:	2.13
Increamental Fuel Consumption	3%
NOx Reduction	30%

	MY1989 & Earlier		MY 1990	
	Baseline	**EGR+DPF**	**Baseline**	**EGR+DPF**
Annual mileage	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 23,000		$ 23,000
Useful Life (years)	8.0	8.0	8.0	8.0
Annualized Capital Cost ($/yr)		$3,276		$3,276
Diesel mpg	5.35	5.35	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38
Fuel Cost/year	$19,878	$19,884	$19,179	$19,184
Incremental Fuel Cost/year		$6		$6
Emission Std (g/bhp-hr)	10.7		6	
Coversion Factor (bhp-hr/mi)	3.11		3.05	
NOx g/mile	33.24	23.27	18.30	12.81
NO tons/year	1.83	1.28	1.01	0.71
NOx Reduction tons/year		0.55		0.30
NOx Reduction tons/day		0.00220		0.00121
Cost-Effectiveness ($/ton)		$5,960		$10,827
CE Including Fuel ($/ton)		$5,970		$10,846
One-Year Cost-Effectiveness		$41,834		$75,999

SCR Retrofits for On-road HDDVs

Partial Example of Technical & Economic Analyses

Cost of Diesel:	2.13
Urea Cost (equivalent to % fuel)	2%
NOx Reduction	75%

	MY1989 & Earlier		MY 1990	
	Baseline	**SCR**	**Baseline**	**SCR**
Annual mileage	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 27,500		$ 27,500
Useful Life (years)	8.0	8.0	8.0	8.0
Annualized Capital Cost ($/yr)		$3,918		$3,918
Diesel mpg	5.35	5.35	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38
Fuel Cost/year	$19,878	$19,878	$19,179	$19,179
Urea Cost/year		$398		$384
Emission Std (g/bhp-hr)	10.7		6	
Coversion Factor (bhp-hr/mi)	3.11		3.05	
NOx g/mile	33.24	8.31	18.30	4.58
NO tons/year	1.83	0.46	1.01	0.25
NOx Reduction tons/year		1.37		0.76
NOx Reduction tons/day		0.00550		0.00303
Cost-Effectiveness ($/ton)		$2,850		$5,178
CE Including Urea Cost ($/ton)		$3,139		$5,685
One-Year Cost-Effectiveness		$20,008		$36,347

Lean NOx Retrofits for Non-road Equipment

Partial Example of Technical & Economic Analyses

Cost of diesel:	2.13
Increamental Fuel Cost	2%
Emission Reduction	40%

Excavators	175-300 HP		300-600 HP	
	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar
NOx (g/bhp-hr)	9.3	5.58	9.5	5.70
Average Horsepower (hp)	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59
Activity (hr/yr)	777	777	777	777
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	9,662	9,855	18,306	18,672
Fuel Cost ($/yr)	14,492	14,782	27,459	28,009
Incremental Fuel Cost/yr		$ 290		$ 549
Incremental Capital Cost		$20,000		$37,895
Useful Life (years)	10	10	10	10
Annualized Capital Cost ($/yr)		$2,345		$4,442
NOx Emission Factor (g/hr)	1303	782	2522	1513
NOx (tons/year)	1.12	0.67	2.16	1.30
NOx Reduction (tons/year)		0.45		0.86
NOx reduction (tons/day)		0.0018		0.0035
Cost-Effectiveness ($/ton)		$5,252		$5,141
CE Including Fuel ($/ton)		$5,901		$5,777
One-Year Cost-Effectiveness		$44,797		$43,854

EGR+DPF Retrofits for Non-road Equipment

Partial Example of Technical & Economic Analyses

Cost of diesel:	2.13
Addition Cost for ULSD	0.05
Increamental Fuel Consumption	3%
NOx Reduction	30%

Excavators	175-300 HP		300-600 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.3	6.51	9.5	6.65
Average Horsepower (hp)	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59
Activity (hr/yr)	777	777	777	777
Energy Consumption Factor (bhp-h	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	9,662	9,951	18,306	18,855
Fuel Cost ($/yr)	20,531	21,645	38,901	41,011
Incremental Fuel Cost/yr		$ 1,114		$ 2,110
Incremental Capital Cost		$23,000		$43,579
Useful Life (years)	10	10	10	10
Annualized Capital Cost ($/yr)		$2,696		$5,109
NOx Emission Factor (g/hr)	1303	912	2522	1766
NOx (tons/year)	1.12	0.78	2.16	1.51
NOx Reduction (tons/year)		0.33		0.65
NOx reduction (tons/day)		0.0013		0.0026
Cost-Effectiveness ($/ton)		$8,052		$7,883
CE Including Fuel ($/ton)		$11,378		$11,138
One-Year Cost-Effectiveness		$68,689		$67,243

SCR Retrofits for Non-road Equipment

Partial Example of Technical & Economic Analyses

Cost of diesel:	2.13
Urea Cost (equivalent to % fuel)	2%
NOx Reduction	75%

Excavators	175-300 HP		300-600 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR
NOx (g/bhp-hr)	9.3	2.33	9.5	2.38
Average Horsepower (hp)	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59
Activity (hr/yr)	777	777	777	777
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	9,662	9,855	18,306	18,672
Urea Fuel Cost ($/yr)	20,531	20,942	38,901	39,679
Incremental Urea Fuel Cost/yr		$ 411		$ 778
Incremental Capital Cost		$27,500		$52,105
Useful Life (years)	10	10	10	10
Annualized Capital Cost ($/yr)		$3,224		$6,108
NOx Emission Factor (g/hr)	1303	326	2522	631
NOx (tons/year)	1.12	0.28	2.16	0.54
NOx Reduction (tons/year)		0.84		1.62
NOx reduction (tons/day)		0.0033		0.0065
Cost-Effectiveness ($/ton)		$3,851		$3,770
CE Including Fuel ($/ton)		$4,342		$4,250
One-Year Cost-Effectiveness		$32,851		$32,160

Accelerated Reflashing Program for HDDVs

Partial Example of Technical & Economic Analyses

Cost of Diesel:	2.13
Increamental Fuel Consumption	2%
NOx Reduction	30%

	Medium-HDDVs		Heavy-HDDVs	
	MY1993-MY1998		MY1993-MY1998	
	Off-Cycle Baseline	Reflashed	Off-Cycle Baseline	Reflashed
Annual mileage	50,000	50,000	50,000	50,000
Incremental Capital Cost		0		0
Useful Life (years)	8	8	8	8
Annualized Capital Cost ($/yr)		$0		$0
Diesel mpg	5.35	5.35	5.35	5.35
Fuel Cost/mile	$0.40	$0.40	$0.40	$0.40
Fuel Cost/year	$19,878	$20,276	$19,878	$20,276
Incremental Fuel Cost/year		$398		$398
Emission Std (g/bhp-hr)	6.5	5	6.5	5
Coversion Factor (bhp-hr/mi)	2.15	2.15	2.90	2.90
NOx g/mile	13.98	10.75	18.85	14.50
NO tons/year	0.77	0.59	1.04	0.80
NOx Reduction tons/year		0.18		0.24
NOx Reduction tons/day		0.00071		0.00096
Cost-Effectiveness ($/ton)		$0		$0
CE Including Fuel ($/ton)		$2,236		$1,658
One-Year Cost-Effectiveness		$2,236		$1,658

Potential Emission Reduction Scenarios

- Infinite combinations of selected measures are possible.
- Possible emission reduction scenarios developed for reduction in NOx emissions:
  - On-road H-HDDVs
  - Diesel construction equipment
  - Agricultural equipment
- Scenarios developed based on cost-effectiveness, using assumed penetration rates.
- Details in handouts.

Potential Emission Reduction Scenarios (cont.)

- Show that, via combination of voluntary or incentive and mandatory control measures, there are:
  - sufficient emission sources and vehicle availability to cost effectively reduce 2009 on-road diesel NOx emissions by more than 10%.
  - Sufficient emissions and equipment availability to cost effectively reduce 2009 NONROAD NOx emissions by more than 15%.

Technical/Implementation Issues

- Some of the technical or implementation issues are as follows:
  - Surplus emissions vs. natural turnover rate for fleet modernization programs.
  - Verified/certified vs. unverified/uncertified retrofit technologies.
  - Funding for incentive programs.
  - Implementation and enforcement of mandatory programs.
  - Modeling of control measures for SIP purposes.

On-going Effort and Schedule

- Finalize analyses of remaining selected measures:
  - LEVII vs. Tier 2, and accelerated LEV II/Tier 2 programs
  - I/M and speed reduction programs for LDVs
  - Complete draft control measure summaries
  - Estimate PM and ROG emission reduction potential
- Develop draft final report and White Papers.
- Anticipated Schedule:
  - Finalize other measures – November 21
  - Complete draft control measure summaries – November 28
  - Draft final report – December 12
  - Draft White Papers – December 19
  - Final report and White Papers – 2 weeks after receiving comments on draft final report and White Papers
- Work with LADCO to model selected measures.

Thank you.