APPENDIX F

POTENTIAL CONTROL MEASURES MODELLED FOR THE 2010 FULL ATTAINMENT SCENARIO

APPENDIX F-1

EXAMPLES OF POTENTIAL CONTROL MEASURES MODELLED FOR THE 2010 FULL ATTAINMENT SCENARIO[1]

To provide policy makers with as much information as possible to aid implementation planning, a full attainment analysis of both standards (0.08 4th Max and $PM_{2.5}$ 15/65) is carried out. To estimate full attainment of the ozone standard, additional specified and unspecified control measures are assumed for areas still needing further reductions after the initial set of measures outlined in Chapters 5.0 - 7.0 are applied. After the partial attainment analysis, seventeen areas are estimated to need further NO_x or VOC emission reductions to reach full attainment of the 0.08 4th Max standard. The optional specified control measures described in this section are divided into three sectors: 1) stationary point sources; 2) stationary area sources; and 3) mobile sources (both on-road and off-road) as outlined below.[2] The cost of each measure is generally determined by examining the change in costs for one unit of the controlled source (e.g., one engine for mobile source technology measures, one gallon of fuel for reformulated fuel measures) and the associated tons reduced from that unit. The level of emissions remaining from specific source categories in areas still needing further reductions after the application of the first tier of measures is determined. The potential emission reductions available from the application of a measure are determined by applying a control factor to that level of residual emissions. In some cases, potential further reductions from certain source categories are calculated by estimating the number of units located in these areas. Control measures are then applied to those sources still needing reductions. For some source categories, there is more than one control strategy identified and choices are made as to the most appropriate. The table below outlines the mobile, area and point source measures assessed in this part of the analysis. Tier A in the table refers to control measures and associated emission reductions described in Chapters 5.0 - 7.0 of the main body of the RIA. Tier B refers to the additional control measures and associated emission reductions described in Chapter 9.0 of the RIA.

1 Inclusion of control measures in this analysis does not represent selection of such control measures in future implementation strategies. Measures are included for illustrative purposes only. All costs and emission reductions are estimates.

2 For further information, see ICF (1997), NAAQS Control Measure Analysis, Draft Report , prepared for EPA, Office of Air and Radiation.

It should be emphasized that the following control measures are provided for illustrative purposes only. They are potentially relevant only for those areas of the country suffering from the worst levels of air pollution. Under the Clean Air Act, the primary responsibility for achieving ambient air quality standards falls to the states. Upon the setting of a new standard, the states begin a multi-year, sequenced process of monitoring and planning; the results of which are ultimately found in State Implementation Plans (SIPs). These SIPs are the blueprint of control strategies through which states meet their responsibility. While the federal government maintains primary responsibility for certain sources which are best controlled nationally (e.g., motor vehicles), and the CAA does provide some additional requirements, most decisions about which control strategies to utilize fall primarily to the states. This approach allows control decisions, including costs associated with those decisions, to be appropriately considered at the state and local level.

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Mobile Source Control Measures & Estimated Costs/Reductions[3]

Source Category	Control Measures	Estimated Residual NAA Reductions Available (tpd)	Estimated Average Incremental Cost Effectiveness (per ton, 1990$)
M1 Marine (commercial) Note M-A	Add selective catalytic reduction (SCR)	121.5 NO_x	$6,503
M2 On-road heavy duty diesel Note M-B	Introduce low NO_x engines early	143.3 NO_x	$845
M3 On-road heavy duty diesel Note M-C	New vehicles powered with natural gas	15.1 NO_x	$2,400
M4 On-road heavy duty diesel Note M-D	Repower with natural gas engines	8.6 NO_x	$6,839
M5 On-road heavy duty diesel Note M-E	Repower old units with 2004 standard certified engines	142.1 NO_x	$2,850
M6 On-road heavy duty diesel Note M-F	Aerodynamic devices	17.0 NO_x 1.7 VOC 0.5 SO_2 0.3 $PM_{2.5}$	$197 ($NO_x$) $181 (all)
M7 Non-road diesel Note M-G	Repower uncontrolled with 6.9 g/bhp-hr engine	86.9 NO_x	($167)
M8 Non-road diesel Note M-H	Retrofit engines for NO_x: ceramic coating	246.6 NO_x	$189
M9 Non-road diesel Note M-H	Retrofit engines for NO_x: water injection/emulsion	246.6 NO_x	$910

3 Inclusion of control measures in this analysis does not represent selection of such control measures in future implementation strategies. Measures are included for illustrative purposes only. All costs and emission reductions are estimates.

Source Category	Control Measures	Estimated Residual NAA Reductions Available (tpd)	Estimated Average Incremental Cost Effectiveness (per ton, 1990$)
M10 Diesel locomotives Note M-I	Dual fuel diesel/LNG power	72.9 NO_x 1.6 $PM_{2.5}$	($452)
M11 Diesel locomotives Note M-J	Selective catalytic reduction (SCR)	143.1 NO_x	$2,073
M12 Diesel locomotives Note M-K	Reduced idling scenario at train yards	17.0 NO_x	$7,900
M13 Airports Note M-L	Electric-powered airport GSE	77.2 NO_x 31.6 VOC 5.0 $PM_{2.5}$	$0 for electric See Note M-N for other fuels
M14 Airports Note M-M	Vehicle-free gate	97.8 NO_x 40.0 VOC 6.3 $PM_{2.5}$	$0 narrow body $0 wide body
M15 Airports Note M-N	Reduced engine taxi, aircraft towing, congestion reduction	36.1 NO_x 0.1 $PM_{2.5}$	$0 for reduced taxi portion

NOTE M-A: Assumed 90 percent NO_x reduction for diesel commercial vessels (control factor of 0.1). Cost effectiveness calculated on a per vessel basis. One vessel with reduction of 25 tons NO_x has costs of SCR system ($1.3 million with 12 year lifetime), fluids, and catalyst replacement. Total annualized costs assuming 7 percent interest are $179,577; cost per ton is $6503 (1990$).

NOTE M-B: For this measure, the tons of NO_x reduced was estimated nationwide and multiplied by the ratio (31.43 percent) of residual NO_x in NAA (453,560) to nationwide NO_x from HDDE (1,442,982) to calculate emissions reduced in NAA. NO_x reductions are 0.27 tons/year per truck. A population of 650,000 trucks nationwide could have this measure applied. The cost is $2,000 with a lifetime of 12 years; cost per ton is $845 (1990$).

NOTE M-C: For this measure, the tons of NO_x reduced was estimated nationwide and multiplied by the ratio (31.43 percent) of residual NO_x in NAA (453,560) to nationwide NO_x from HDDE (1,442,982) to calculate emissions reduced in NAA. NO_x reductions are 0.57 tons/year per truck. A population of 32,663 trucks nationwide could have this measure applied. The incremental costs is $12,000 with a lifetime of 12 years. Cost per ton is $2,400 (1990$).

NOTE M-D: For this measure, the tons of NO_x reduced was estimated nationwide and multiplied by the ratio (31.43 percent) of residual NO_x in NAA (453,560) to nationwide NO_x from HDDE (1,442,982) to calculate emissions reduced in NAA. NO_x reductions are 0.4 tons/year per truck and this measure can be applied to 25,835 trucks. Costs assessed include adding LNG tank, purchasing and installing new engine. The truck owner benefits by avoiding the cost of a diesel engine rebuild and by receiving credit for the diesel engine trade-in. Net cost is $24,000 with a lifetime of 12 years; cost per ton is $6,839 (1990$).

NOTE M-E: For this measure, the tons of NO_x reduced was estimated nationwide and multiplied by the ratio (31.43 percent) of residual NO_x in NAA (453,560) to nationwide NO_x from HDDE (1,442,982) to calculate emissions reduced in NAA. NO_x reductions are 0.4 tons/year per truck. Applicable population is 435,000 trucks. Costs assessed include new engine purchase and installation, benefits are rebuild avoided and trade-in value. The incremental cost is $10,000 with a lifetime of 12 years; cost per ton is $2,850 ($1990).

NOTE M-F: This measure assumes installation of an aerodynamic device increases fuel economy by 10 percent and decreases emissions by 10 percent. We estimated that 30 percent of the truck population currently does not have a device installed, and that 50 percent of the trucks included in the HDDE can use such a device for a control factor of 0.985 [i.e., 1-(.3)(.5)(.1)]. Deflector cost is $1,092 with a lifetime of 8 years; cost per ton is $197 (1990$) for NO_x.

NOTE M-G: This measure reduces NO_x by approximately 50 percent. In 2010, the measure is applicable to engines that account for 30 percent of NO_x emissions from this source category, however, only 70 percent of these engines are estimated to be technically feasible for replacement. Thus, the control factor is 0.888 [i.e., 1-(.3)(.7)(.5)]. Costs assessed include purchase and installation of new engine, with benefits of rebuild cost avoided and old engine trade-in. Incremental costs are $10,000 with a lifetime of 10 years. Incorporating fuel savings, cost savings per ton is $167 (1990$).

NOTE M-H: Because these measures reduce NO_x when applied by 30 percent, we have assumed a control factor of 0.7 for NO_x. For water injection/emulsion, the cost estimate includes installation of a system costing $1,150 (1995$) with a lifetime of 6 years for an annualized cost of $241 (1995$). That system is installed on an engine for a reduction of 0.24 tons/year for a cost effectiveness of $1,005 (1995$) and $910 (1990$). For ceramic coatings, installation of a retrofit package with a lifetime of 10 years costs $5,000 for an annualized cost of $712 (1995$). The associated NO_x reduction is 3.4 tons/year for a cost effectiveness of $189 /ton(1990$).

NOTE M-I: Control factors for these measures were estimated as 0.786 and 0.825 for NO_x and PM, respectively [for NO_x, 1-(.95)(.5)(.45); for PM, 1-(.95)(.5)(.368)]. Costs included fuel savings for natural gas compared to diesel, and engine replacement costs. Annual cost savings are $18,877 and tons NO_x reduced per locomotive are 36.3, for a cost savings per ton $452 (1990$).

NOTE M-J: A control factor for NO_x of 0.58 is estimated for this measure. Approximately 95 percent of locomotive emissions come from line haul locomotives, 50 percent of them are eligible for an SCR system, and NO_x emissions are reduced 88 percent after installation of the system [i.e., 1- (.95)(.5)(.88)]. The cost estimate included equipping the locomotive with an SCR system, maintaining that system, and a fuel penalty. Annual cost per locomotive is $106,273 reducing 45 tons per year. Cost effectivenes is $2,073 (1990$) per ton.

NOTE M-K: Assumes diesel fuel cost of $1.34 per gallon (CA April, 1997 average) and a fuel savings of $1.54 * 10^8$ gallons of diesel fuel from reduced idling. A control factor of 0.95 was assumed for NO_x. Approximately 10 percent of locomotive emissions result from idling.; 50% reduction of idling emissions assumed reduced [i.e., 1-(.1)(.5)].

NOTE M-L: For purposes of analysis, a zero cost estimate was used for overall cost calculation. The following assumptions are used to calculate a cost effectiveness (in 1997$): the cost-effectiveness calculation is performed for a bag tractor, for other equipment, both costs and effectiveness will be higher, but the ratio is assumed to be the same; electric tractor cost includes $4,500 battery and $3,500 charger; LPG, CNG, electric are as reliable as gasoline/diesel engines; refueling facility costs are accounted for in LPG/CNG fuel costs; rebuild costs are battery replacement for electrics; unit of fuel mass for electrics is kW-hr, all others in GGE; and CNG/LPG emission rates are based on high quality "conversions."

Cost effectiveness depends on the type of conversion performed as follows:

Cost ($)	Cost ($)	Emission Benefit (tons)	Cost Benefit ($/ton)
Gasoline	$29,925	3.26	$9,193
LPG	$11,603	8.57	$1,354
CNG	$29,588	9.90	$2,989
Electric	-$42,704	17.06	-$2,503

NOTE M-M: For purposes of analysis, a zero cost estimate was used for overall cost calculation. The following assumptions are used to calculate the cost effectiveness (in 1997$) of this measure: gate-based A/C costs are for 110-120 degF system, smaller units may be suitable in some areas; narrow body APU emissions are based on the GTCP85-98DHF APU used on the Boeing 737-300; and wide body APU emissions are based on the PW901A APU used on the Boeing 747-400.

The cost effectiveness depends on the size aircraft serviced. The measure has a net cost savings.

Gate Type	Cost ($)	Emission Benefit (tons)	Cost Benefit ($/ton)
Narrow-Body	-$921,117	60.12	-$15,321
Wide-Body	-$2,034,564	63.57	-$32,005

NOTE M-N: For purposes of analysis, a zero cost estimate was used for overall cost calculation. The following assumptions are used to calculate a cost effectiveness (in 1997$) $41,223 saved for the reduced engine taxi portion of this measure: Boeing B737-300 w/2 GE CFM56-3B engines; 20 minute taxi time; 4 minutes required for engine cool down; 4 minutes required for engine warmup; and costs for manual updates and pilot training marginal.

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Area Source Measures and Estimated Costs/Reductions

Source Category	Control Measures	Estimated Residual NAA Available Reductions (tpd)	Estimated Average Incremental Cost Effectiveness (1990$)
A1 Solvent Utilization - Wood Furniture Surface Coating	Reformulation Hybrid Waterborne Coatings	47.3 VOC	$1,926/ton VOC
	Reformulation Full and Hybrid Waterborne Coatings	32.7 VOC	$2,338/ton VOC
A2 Fuel Combustion - Residential/Industrial/ Commercial Distillate Fuel Note A-A	Low Sulfur Fuel Oil (340 ppm); 80 percent Reduction in SO_x Emissions	59.6 SO_x 0.25 $PM_{2.5}$	$1,910/ton SO_x

NOTE A-A: The cost was assumed to be $1.07 per barrel, which is based on the price differential between distillate oil and low sulfur diesel. The cost effectiveness includes an additional .10 per barrel charge for shipping resulting in a total cost differential of $1.17 per barrel. The cost provided assumes that increased demand will not increase the price differential of low sulfur distillate oil. If distribution is merely reallocated, there should be little price pressure. However, efforts, which result in significant additional production of low sulfur distillate, would likely raise the price differential since the cost of additional desulfurization capability is significantly higher than $2,000/ton. It should be noted that California's efforts to reduce sulfur content of diesel fuel resulted in an increase of approximately .10 per gallon, which equals about $7,100/ton. Note that SO_x and $PM_{2.5}$ values include 5.6 tpd and 0.02 tpd from point source emissions.

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Point Source Control Measures and Estimated Costs/Reductions[4]

Source Category	Tier A RIA Controls	Partial Attain. Estimated Residual Emissions (National Tons)	Partial Attain. Estimated Residual Emissions in NAA	Tier B Controls	Estimated Incremental Emissions Reductions (National)	Estimated Residual NAA Reductions Available from Tier B (tpd)	Estimated Average Incremental Cost Effectiveness
P1 Utility Boilers Note P-A	90% SO_x reduction over Title IV NO_x limit at 0.15 lb/MM BTU	5,250,000 SO_x 3,572,000 NO_x	So_x Not Estimated 355,000 NO_x	90% SO_x reduction over Title IV NO_x limit at 0.10 lb/MM BTU	2,403,000 SO_x 325,000 NO_x	SO_x Not Estimated 83.1 NO_x	$1,358 ton/$SO_x$ $4,436 ton/$NO_x$
P1 Utility Boilers Note P-B	95% SO_x reduction over Title IV NO_x limit at 0.05 lb/MM BTU	5,250,000 SO_x 3,572,000 NO_x	SO_x Not Estimated 355,000 NO_x	95% SO_x reduction over Title IV NO_x limit at 0.05 lb/MM BTU	2,880,000 SO_x 582,000 NO_x	SO_x Not Estimated 150.6 NO_x	$1,720 ton/$SO_x$ $5,885 ton/$NO_x$
P2 Stationary IC Engines Note P-C	Ignition Timing Retard		24,688	Conversion to electric		59.0 No_x 15.7 VOC	$2,000
P3 Industrial Boiler Note P-D SO_2 NO_x	FGD scrubbing .15 lb/MMBtu	178,850 SO_x 120,000 NO_x	SO_x Not Estimated NO_x 47,779	Gas conversion Gas conversion (.05 lb/MMBtu)		50.7 SO_x 82.7 NO_x	All convert at $5,000/ton; 80% at $1,000/ton $2,000/ton

4 Inclusion of control measures in this analysis does not represent selection of such control measures in future implementation strategies. Measures are included for illustrative purposes only. All costs and emission reductions are estimates.

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Point Source Control Measures and Estimated Costs/Reductions (continued)

Source Category	Tier A RIA Controls	Partial Attain. Estimated Residual Emissions (National Tons)	Partial Attain. Estimated Residual Emissions in NAA	Tier B Controls	Estimated Incremental Emissions Reductions (National)	Estimated Residual NAA Reductions Available from Tier B (tpd)	Estimated Average Incremental Cost Effectiveness
P4 Chemical Manufacturing Process Vents (VOC) Note P-E	MACT	170,900	41,000	Lower MACT cutoff to $5,000/ton	7,700 tons	5.3	$3,000/ton
P4 Chemical Manufacturing Process Vents (VOC)	MACT	170,900	41,000	Lower MACT cutoff to $7,500/ton	11,600 tons	8.2	$4,300/ton
P4 Chemical Manufacturing Process Vents (VOC)	MACT	170,900	41,000	Lower MACT cutoff to $10,000/ton	15,500 tons	10.9	$5,500/ton
P5 Chemical Manufacturing Equipment Leaks (VOC)	MACT	19,400	4,700	Dual - mechanical sealed pumps	3,900 tons	2.8	$10,000/ton

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Point Source Control Measures and Estimated Costs/Reductions (continued)

Source Category	Tier A RIA Controls	Partial Attain. Estimated Residual Emissions (National Tons)	Partial Attain. Estimated Residual Emissions in NAA	Tier B Controls	Estimated Incremental Emissions Reductions (National)	Estimated Residual NAA Reductions Available from Tier B (tpd)	Estimated Average Incremental Cost Effectiveness
P6 Chemical Manufacturing Wastewater (VOC)	MACT	155,400	37,500	Lower MACT cutoff to $5,000/ton	38,400 tons	27.4	$3,000/ton
P6 Chemical Manufacturing Wastewater (VOC)	MACT	155,400	37,500	Lower MACT cutoff to $7,500/ton	56,000 tons	39.7	$4,300/ton
P6 Chemical Manufacturing Wastewater (VOC)	MACT	155,400	37,500	Lower MACT cutoff to $10,000/ton	73,000 tons	51.8	$5,500/ton
P7 Petroleum Refining Process Vents (VOC)	MACT	33,000	4,800	Lower MACT cutoff to $5,000/ton	14,000 tons	5.9	$4,000/ton
P7 Petroleum Refining Process Vents (VOC) Note P-F	MACT	33,000	4,800	Lower MACT cutoff to $7,500/ton	23,000	9.7	$4,900/ton
P7 Petroleum Refining Process Vents (VOC)	MACT	33,000	4,800	Lower MACT cutoff to $10,000/ton	26,400	11.2	$5,400/ton

Examples of Potential Control Measures Modelled for the 2010 Full Attainment Scenario
Point Source Control Measures and Estimated Costs/Reductions (continued)

Source Category	Tier A RIA Controls	Partial Attain. Estimated Residual Emissions (National Tons)	Partial Attain. Estimated Residual Emissions in NAA	Tier B Controls	Estimated Incremental Emissions Reductions (National)	Estimated Residual NAA Reductions Available from Tier B (tpd)	Estimated Average Incremental Cost Effectiveness
P8 Petroleum Refining Equipment Leaks (VOC)	MACT	47,400	7,000	More stringent leak detection program	21,300	9.1	$6,500/ton
P9 Petroleum Refining Wastewater (VOC)	MACT	11,000	1,600	Lower MACT cutoff to $5,000/ton	3,300	1.4	$4,000/ton
P9 Petroleum Refining Wastewater (VOC)	MACT	11,000	1,600	Lower MACT cutoff to $7,500/ton	4,900	2.1	$4,700/ton
P9 Petroleum Refining Wastewater (VOC)	MACT	11,000	1,600	Lower MACT cutoff to $10,000/ton	5,000	2.1	$5,000/ton
P10 TSDF Equipment Leaks (VOC) Note P-G	MACT	7,900	1,900	More stringent leak detection program	3,600	2.4	$6,500/ton
P11 TSDF Control Wastewater Tanks (VOC)	RCRA	44,000	10,600	Lower MACT cutoff to $5,000/ton	7,700	5.6	$4,000/ton

Source Category	Tier A RIA Controls	Partial Attain. Estimated Residual Emissions (National Tons)	Partial Attain. Estimated Residual Emissions in NAA	Tier B Controls	Estimated Incremental Emissions Reductions (National)	Estimated Residual NAA Reductions Available from Tier B (tpd)	Estimated Average Incremental Cost Effectiveness
P11 TSDF Control Wastewater Tanks (VOC)	RCRA	44,000	10,600	Lower MACT cutoff to $7,500/ton	11,000	7.9	$4,700/ton
P11 TSDF Control Wastewater Tanks (VOC)	RCRA	44,000	10,600	Lower MACT cutoff to $10,000/ton	15,400	10.9	$5,800/ton

NOTE P-A: National emissions estimated generated using Integrated Pollution Model (IPM). Reductions in residual nonattainment areas were generated by assuming a 33 percent NO_x reduction in the residual nonattainment areas over the values specified in Table D (i.e., the ratio of the NO_x emissions limits of 0.10 to 0.15).

NOTE P-B: National emissions estimated generated using IPM. Reductions in residual nonattainment areas were generated by assuming a 67 percent NO_x reduction in the residual nonattainment areas over the values specified in Table D (i.e., the ratio of the NO_x emissions limits of 0.05 to 0.15).

NOTE P-C: Based on information from Electric Power Research Institute (EPRI) and the NO_x Alternative Control Technology (ACT). Assumed prices are $0.03 per kWh, $2.00 per MM BTU for natural gas, and 6,000 hours of operation per year. Based on information from EPRI, we assumed that 88 percent of the engines could be converted.

NOTE P-D: The NO_x reductions are obtained by the conversion of the unit to natural gas, which is required to obtain the SO_x reductions. This methodology results in a NO_x cost effectiveness of about $2,000 (1990$) per ton.

NOTE P-E: For the chemical industry categories we used the costing methodology presented in the MACT background documents. We estimated national residual emissions from the category (e.g., Process Vents) and then assumed that the portion of emissions in residual nonattainment areas was the same as the ratio of national employment in SIC 28 to employment in SIC 28 in the residual nonattainment areas.

NOTE P-F: For the petroleum refining industry categories we used the costing methodology presented in the MACT background documents. We estimated national residual emissions from the category (e.g., Process Vents) and then assumed that the portion of emissions in residual nonattainment areas was the same as the ratio of national employment in SIC 291 to employment in SIC 291 in the residual nonattainment areas.

NOTE P-G For TSDFs we assumed that the portion of TSDFs in nonattainment areas was identical to that of the chemical industry (i.e., SIC 28).

APPENDIX F-2

EXAMPLES OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROL OF VOCs, NOx, AND PM[1]

INTRODUCTION

Air pollution control and prevention technologies continuously improve. Technologies are in place and successfully performing today that were on the drawing board ten years ago. As the demand for more innovative and cost-effective or cost-saving technologies increases, new technologies will move from the research & development or pilot program phase to commercial availability. Highlighted in the table below are a sample of emerging technologies for many industrial source categories and sources of combustion.

It is likely that many of these technologies will be available in the next ten to fifteen years to employ in air pollution control and prevention strategies as the demand for innovations increases. It is also likely that currently "unknown" technologies and practices will be operational within a decade. Environmental management in business today is quickly becoming a vital part of overall organizational management strategies. Businesses are striving to reduce operating costs through improved efficiency, productivity and reduced material and waste management costs. The ISO14000 Environmental Management Systems movement will be a mature part of business strategies in the near future. Pollution prevention programs are proliferating. In short, the demand for efficiency is causing significant reevaluation of industrial environmental management. The sampling of technologies on the following pages are indicative of the major investments in research and development that is occurring in all parts of the industrial economy.

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SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: On-Road and Non-Road Vehicles

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
TOTAL CAR REDESIGN						
Partnership for New Generation Vehicle[1]	Alternative Vehicle/ Product Redesign	Multi-agency Federal partnership with US automakers and suppliers, and universities to develop advanced manufacturing technologies, near-term vehicle improvements, and prototypes with up to triple efficiency. The partnership is evaluating many of the individual technologies listed below such as lean NOx catalysts, CIDI engine, reformulated or alternative fuels for CIDI, CIDI fuel injection, EGR in addition to improved manufacturing processes that would allow higher temperatures or reduced weight. Other goals include reducing the vehicle weight, aerodynamics, rolling resistance, accessory energy use, and regenerative braking that increase vehicle efficiency and reduce emissions.	X	X	X	Currently narrowing the technology focus to move to 2000 goal of concept vehicles.
Hypercar[2]	Alternative Vehicle/ Product Redesign	Shift from steel-framed, internal-combustion, mechanical-drivetrain platforms to ultralight hybrid-electric platforms. The Hypercar concept was developed by the Rocky Mountain Institute in association with government, industry, and several additional organizations. Such hypercars would be two- to three times lighter, much lower in aerodynamic and rolling resistance, one to three orders of magnitude less polluting, and comparable or superior in other respects such as safety, performance, amenity, and cost. They would also use a fourth to a tenth as much fuel.	X	X	X	R&D. In 1994-95, about two dozen firms committed on the order of $1 billion to the intensely competitive development of ultralight hybrids

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Superplastic Advanced Manifolds[3]	Redesign	Double-wall +manifold offers the potential for substantial reductions in cold-start emissions by allowing the inner tube to heat quickly, resulting in a quicker "light-off" of the catalytic converter, thereby reducing hydrocarbon emissions.	X			Next step is to form full-length sections for evaluations by America's automakers.
Ceramic Technology for Advanced Heat Engines[4]	New technology	Ceramic engine components are desirable for their durability and longevity.				N/A

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
DIESEL ENGINES						
Small Compression Ignition Direct Injection (CIDI) Diesel Engines[5]	Expand applicability of CIDI engines to passenger car market	Research is being conducted into lightweight engine materials, alternative fuels, and catalytic converters in an effort to apply the advantages of CIDI engines (high thermal efficiency, operating flexibility, low start-up emissions) to passenger cars, while controlling negative characteristics (heavy engine components and production of sub-optimal levels of NOx and particulate emissions).	X			CIDI diesel engines are currently in production, but applicability to cars is limited. Advancements in emission controls and light weight engine materials are currently being investigated. Volkswagen introduced their TDI (Turbo-charged Direct Injection) Series in 1996 featuring a computer driven engine. With its precisely regulated fuel injection, turbo-charged air induction, a special cylinder head and manifold, European mileage test show an average fuel economy of 49 mpg with less carbon emitted than most gasoline engines.
Direct Injection (DI) Diesel V6[6]	Introduction of advanced DI engines to the mid- & large size passenger vehicle market	Targeted for the executive car, minivan, multipurpose, and sport utility market, cost effective features include electronic rotary fuel injection, fixed-geometry inlet prot, conventional wastegated turbocharger, cooled EGR, with advanced control algorithms, and an oxidation catalyst. As with the CIDI engine, the V6 DI engine will benefit from current DI engine research of light weight engines and parts and emission control technologies.	X			Installation of the DI V6 engine in an "executive" vehicle has confirmed effective fuel management and noise, vibration, and harshness control (NVH).

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
FUEL CELLS						
Fuel Cell Technologies[7]	Alternative Fuels	Development and demonstration of fuel cell technologies for on- and off-road mobile sources to improve the commercial viability of fuel cells, including improvements in power density, fuel storage, reformer efficiency, system integration, and cost reduction. This program is expected to result in several projects that would support promising fuel cell technologies for on- and off-road vehicles. Fuel cell technologies that will be considered include proton exchange membrane, solid oxide, direct methanol, phosphoric acid, and molten carbonate. Mobile source applications that will be considered in this category include light-, medium-, and heavy-duty on-road vehicles, locomotives, ships, utility vehicles, neighborhood electric vehicles, and other off-road equipment applications. Peripheral technologies involving fuel infrastructure, on-board fuel storage, and hydrogen reforming shall be included if they have potential to advance the commercial viability of fuel cell applications.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $1,000,000 as their share of research funding, of a total expected $5,000,000.
Fuel Cell Vehicle[8]	Alternative Fuels	Chrysler is teaming with Delphi Energy and Engine Management Systems to build within two years a "proof of concept" fuel cell vehicle that runs on gasoline. The technology will be a five-step process to refine gasoline on-board a vehicle. This could improve fuel efficiency by 50 percent, provide up to 400 miles range, be at least 90 percent cleaner, and cost no more than a current mid-size car.	X	X		Prototype Development. Production prototypes may be developed by 2005. Consumers might drive fuel cell-powered cars as early as 2010.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Protein Exchange Membrane Fuel Cell (PEMFC)[9]	New technology	These cells operate at relatively low temperatures (about 200 F), have high power density, can very their output quickly to meet shifts in power demand, and are suited for applications, such as in automobiles, where quick startup is required. According to the U.S. DOE, "they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries in video cameras." Fueling stations are a large obstacle in introducing hydrogen powered vehicles to the public on a large scale. From the best calculations available, fueling stations are cost effective, and they are starting to be built across the country. A fueling station will cost $4.5 million to build, but will produce as well as dispense the fuel. Hydrogen fuel costs 3.8 cents per mile, while gas costs 4.5 cents per mile. 11 pounds of hydrogen would provide a 400 mile driving range for a mid-sized car. The tank for this fuel is 3 times the size of a gas tank, and fueling would take about ten minutes.	X	X	X	Ballard Systems in Vancouver has developed the best fuel cell engine to date. Ballard has produced a 40 foot transit bus with similar horsepower as a standard city bus (275 hp). Pilot programs utilizing these buses are set to begin in Chicago and Vancouver in 1998. Daimler Benz and Ballard have teamed up to form a new company for the development of light vehicles. It is the hope of this new entity to commercialize these vehicles by 2004. The Big Three are working to develop similar technologies with similar timeframes.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
HYBRID VEHICLES						
Hybrid Electric Buses[10]	Alternative Fuels	Advanced Vehicle Systems (AVS) (Chattanooga, TN) is involved in a public/private partnership with CARTA and other institutions such as DARPA, CALSTART, and others to create electric and hybrid/electric busses. Their latest test vehicle is a high speed gas turbine that can run on CNG, diesel, or peanut oil. The gas turbine is quiet, vibration free, and clean burning. Using hybrid technology allows these vehicles to overcome range concerns of transit officials. CAPSTONE developed the gas turbine and expects the addition of a catalytic combuster to allow this vehicle to meet California ULEV standards using diesel fuel.	X	X	X	AVS has approximately 60 vehicles in operation across the US. This latest technology represents the 4th generation of vehicle. Formal introduction of the vehicle is expected in July.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Hybrid Vehicle Powerplant[11]	Alternative Fuels	Galileo Research has been conducting R&D on a new powerplant (HISEN-FPEG) to be used in Hybrid Electric Vehicles. It is expected to provide a small, lightweight, low polluting, low maintenance on-board generator at a low cost that will utilize a variety of available fuels and be very fuel efficient. The HISEN-FPEG generator set is constructed of two directly opposed engine pistons and heads with a linear generator between them. The piston-rod assembly shuttles back and forth in a straight line from compression-ignition to compression-ignition in its opposing cylinders. Attached to the piston-rod assembly are magnets which move within coils that generate electric power. A great deal of friction is reduced within the engine, due to a lack of side forces and the resultant design of only one moving part. The lack of a crankshaft also enables the HISEN-FPEG to achieve various compression ratios, which gives it the ability to utilize a variety of fuels, from gasoline to natural gas and hydrogen to diesel fuel. Computer control of the HISEN-FPEG's ignition timing and fuel injection system also enable ultra low emissions to be achieved.	X	X	X	R&D

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
ELECTRIC VEHICLES AND BATTERIES						
Electric Vehle Battery Development[12]	Alternative Fuels	The United States Advanced Battery Consortium (USABC) and the U.S. Department of Energy (DOE) have dedicated $106 million to continue R&D advanced batteries for electric vehicles. USABC will conduct research to continue cost reduction of mid-term electric vehicle batteries and develop long-term battery technologies.	X	X	X	R&D
Advanced battery technologies and charging systems for Electric Vehicle applications[13]	Alternative Fuels	Development and demonstration of advanced battery technologies and battery charging systems for electric vehicle (EV) applications. This project would finalize the development of a full-sized EV battery pack and demonstrate its feasibility in laboratory tests. Technology enhancements can utilize charging algorithms which decrease charging time and prolong battery life. These units would be able to recharge EVs at 25 kW power rates with recharging times of less than an hour. In this proposed project, the system design would be finalized. One or more chargers would be demonstrated in fleet and/or commercial applications. The proposed project will develop both on-board electronics that will automatically supply battery-charge information and a central management system to control charging of a fleet of EVs. When an EV is needed trip requirements can be matched to an EV with sufficient battery charge and that EV dispatched. The system will also control the charging of the EVs to maximize battery life and minimize power requirements for fleet charging during peak-demand periods.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $1,400,000 as their share of research funding, of a total expected $13,408,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Advanced Inductive Electric Vehicle Charger[14]	Alternative Fuels	Development and demonstration of an advanced EV charger for high-power, fast recharging. Such a system could be used with fleets or at commercial opportunity charging sites. The proposed project will modify five General Motors S-10 electric pick-up trucks to accept this high-power charging, with a six month demonstration. This phase would determine impacts on the electricity supply grid and EV battery performance.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $500,000 as their share of research funding, of a total expected $1,000,000.
Automated Electric Vehicle Charging System[15]	Alternative Fuels	Development of an automated system that would dock, or couple, an EV to a battery charging system. The project will address inductively and conductively coupled systems. This project is expected to build on previous research into such an automated system, resulting in a prototype test unit of a commercially viable system. This project, if successful, will improve the perceived convenience and, thus, commercial viability of EVs.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $150,000 as their share of research funding, of a total expected $350,000.
Electric Vehicles[16]	Alternative Fuels	Demonstration of Electric Vehicles with Rental Car Fleets. The California Department of General Services (DGS), in cooperation with Honda and National Rental Car, is conducting an electric vehicle demonstration at the Sacramento Metropolitan Airport. Electric vehicles are available for specified state agency employees in Sacramento on business. DGS has asked the AQMD if it would be interested in an expanded program at one or more Basin airports.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $200,000 as their share of research funding, of a total expected $500,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Advanced Batteries for Electric Vehicles[17]	Alternative Fuels	This proposed demonstration program will involve at least 500 EVs vehicles equipped with advanced batteries. The project is an incentive program for participating consumers of electric vehicles, who would be expected to pay at least $3,000 for an advanced battery pack option. Cosponsors would provide an incentive to purchase the advanced battery option by contributing about $10,000 per battery pack. The consumers would agree to installation of non-intrusive data-acquisition systems in their EVs and at charging facilities, to be interviewed, and to respond to questionnaires. The project will document the numerous technical and consumer impacts of advanced EVs. The basic program goals are to determine the effect of advanced batteries on travel behavior, vehicle performance, consumer acceptance, charging behavior, utility power systems, and the need for public charging opportunities.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $500,000 as their share of research funding, of a total expected $12,560,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
ALTERNATIVE FUELS						
Medium-Duty CNG Engine Conversion Kit[18]	Conversion to Alternative Fuel	Support for field demonstration of improved software and hardware for a medium-duty CNG engine conversion kit to support the existing medium-duty vehicle population. The SCAQMD previously supported field demonstration of the first generation kit in a contract with Thermo Power Corporation. This kit has operated well in the field. However, improvements in performance and fuel economy are needed if the kit is to be commercially viable. Hardware and software modifications to achieve improved performance and fuel economy are currently being developed. The proposed project would support field demonstration of the second generation kit.	X	X	X	Proposed development with field demonstration. The SCAQMD Technology Advancement program has proposed to provide $40,000 as their share of research funding, of a total expected $180,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Propane/Butane Fuel Blends[19]	Alternative Fuel	Emissions testing on multiple light-duty vehicles using propane/butane blends, which may be cost-effective low-emission alternative fuels for light-, medium-, and heavy-duty vehicles. It is expected that the proposed project will result in emission benefits and help AQMD, ARB, the petroleum industry, and automobile manufacturers identify a potentially clean, cost-effective alternative fuel with capability for wide-scale application to all types of internal combustion engines. Generate data on emissions, lubricant compatibility, combustion chamber and intake valve deposits, component durability, and catalyst durability. Operate and evaluate three or more new vehicles for a minimum of 50,000 miles using selected butane/propane blends. Conduct periodic emission tests during mileage accumulation to determine the effects of operation on regulated emissions, speciated hydrocarbons, and the specific reactivity (ozone-forming potential) of exhaust emissions. At test completion dismantle engines and quantify and rate deposits.	X	X		Proposed R&D. The SCAQMD Technology Advancement program has proposed to provide $65,000 as their share of research funding, of a total expected $325,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Advanced alternative fuel heavy-duty engine technologies[20]	Advanced Technology	Development and demonstration of advanced alternative technologies to reduce emissions from various heavy-duty diesel truck applications. Three areas of development related to heavy-duty trucks, are expected to be included: advanced alternative fuel engine and component technologies; novel alternative fuels; and non-internal combustion engine, non-CFC refrigeration systems for transport trailers. The technologies of interest include: engine combustion chamber design optimization for reduced emissions; direct gaseous fuel injection hardware/software development; closed-loop engine control system sensor/software development. Projects will be sought to evaluate these new fuels and related low emission heavy-duty engine technologies in, preferably, multi-vehicle field demonstrations in Southern California.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $1,300,000 as their share of research funding, of a total expected $2,600,000.
Low Emission, Alternative Fuel Technologies for On-Road Applications[21]	Alternative Fuels and related Technology	Development and demonstration of low-emission, alternative fuel technologies for light-, medium-, and heavy-duty mobile sources. Alternative clean fuels that will be considered include, but are not necessarily limited to, natural gas, propane, methanol, ethanol, hydrogen, and Hythane. In addition, reformulated gasoline and diesel fuels have been developed that produce lower emissions. When used in conjunction with advanced emission controls, additives, and new engine technologies, these appear to have promise to meet some CARB LEV standards.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $750,000 as their share of research funding, of a total expected $2,100,000.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Clean Fuels from Municipal Solid Waste, Biomass, and Other Waste Fuels[22]	Alternative Fuels	Development and demonstration of technologies and/or production processes to synthesize clean alternative fuels from various energy-rich, renewable sources, such as biomass, municipal solid waste, landfill gas, and other low cost or "free" waste fuels. The project is expected to result in pilot-scale production demonstrations, scale-up process design and cost analysis, overall environmental impact analysis, and projections for ultimate clean fuel costs and availability, for alternative fuels that are determined to offer the most promise	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $100,000 as their share of research funding, of a total expected $200,000.
LNG Combustion Technology for Locomotives[23]	Alternative Fuels	Develop and demonstrate, via the GasRail USA program, LNG combustion technology for locomotives capable of reducing NOx emissions by 75% or more compared to conventional diesel technology. In partnership with Southwest Research Institute, the project would optimize a newly developed combustion technology in a multi-cylinder locomotive engine. This will be followed by integration of the combustion system into one or more Metrolink passenger locomotives for operation in the SCAQMD Basin.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $500,000 as their share of research funding, of a total expected $1,325,000.
Injector/ Intensifier System[24]		This system is designed to reduce NOx emissions from heavy-duty diesel vehicles through a new natural gas fuel injector system. The natural gas injector system will be fabricated installed and certified.		X		Pilot-scale demonstration and evaluation.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
ENGINE MANAGEMENT CONTROLS						
Adaptive Control Techniques for Engine Management[25]	On-board engine diagnostics	Non-linear adaptive control techniques control air/fuel ratios more precisely over a wider range of operating conditions and operate catalytic converters over the narrow range in which they are efficient. Adapts to aging or faulty engines and to varying fuel properties such as volatility.	X	X	X	Test vehicle and production facility have been obtained. Engine simulation models have been developed. Preliminary identification models have been developed.
Pressure/ Diaphragm Sensors (Fiber Optics)[26]	New technology	Combustion pressure sensors can be integrated with "smart" ignition systems and direct injection systems in which combustion pressure is used as a feedback parameter for engine control. Diaphragm sensors, in combination with pressure sensors, can be integrated into a "smart" fuel injector for simultaneous benefits of increased injector reliability and lower costs.	X	X		N/A
EXHAUST AFTERTREATMENT						
Exhaust Gas Recirculation[27]	Redesign	This specific technology makes EGR more effective by ensuring EGR is applied at the high loads heavy-duty diesel engines (HDDEs) often run at, and providing an acceptable air flow to ensure the fuel is being burnt efficiently. Continuing work includes assessments of EGR on engine durability, particulate emissions improvements, and transient engine performance.		X		Results show that NOx emissions were almost halved when 15% of the exhaust gases were recirculated. Particulate emissions, however, increased, demonstrating a need for a combustion system to be optimized for very low smoke.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Plasma Treatment of Automotive Exhaust[28]	New technology	Plasma (ionized gas) treatment of lean-burn exhaust emissions in both gasoline and diesel lean-burn engines. Current plasma systems (gas-phase plasma discharges) appear to have low NOx conversion and/or high energy consumption. An alternative approach is being pursued to improve emission reduction and energy consumption.	X	X		Tests confirm the possibility of lean NOx reduction. Major challenges are to reduce energy consumption and ensure the absence of unintended by-products.
Vacuum Insulated Catalytic Converter[29]	Redesign	Using a form of vacuum insulation and phase-change heat storage technology, the converter remains at operating temperatures for more than 24 hours after the engine has been turned off. Potential exists to reduce automotive emissions to ultra-low emission vehicle (ULEV) levels, or even to equivalent zero emission vehicle (EZEV) standards in some cases.	X	X		Tests showed a 80 to 96 percent reduction in HC and CO and a 50 percent reduction in NOx.
Non-Thermal Plasma Reactor[30]	New technology	"Packed-bed reactor" transforms exhaust gas pollutants into less harmful constituents. Simultaneous particulate and NOx removal in diesel engine exhaust	X	X		Test have shown that simultaneous reductions in NOx and PM are achievable. A consortium of diesel engine and equipment manufacturers has been formed to further investigate nonthermal plasma technology.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Lean Burn Catalysts[31]	New technology	Major challenges in this project are the development of a catalyst with the three following attributes: 1) Sufficient and selective lean NOx activity; 2) Robustness, particularly hydrothermal durability; and 3) economically practical. Development of a lean burn catalyst is critical for the commercialization of the lean burn engine.		X		A large number of lean NOx catalyst formulations have been investigated, including unique technologies such as aerogels.
Oxygen Enrichment Membrane[32]	New technology	Membrane system uses DuPont Teflon AF fiber as the oxygen exchange mechanism for a underhood module to feed oxygen-enriched air directly to the engine chamber. The membrane separates ambient air into oxygen-rich and nitrogen-rich streams. The oxygen rich stream is directed to the manifold to improve combustion, while the nitrogen rich stream can be fed into the exhaust as a plasma to reduce NOx emissions.	X	X		N/A
EOLYS System[33]	New technology	Combines the use of a particulate trap with the action of the catalytic additive to ensure that particulates are destroyed during combustion.			X	Reduces nearly 90% of diesel particulate emissions in tests. Rhone-Poulenc has also entered into a technical cooperation agreement with several diesel engine manufacturers in Europe and in the U.S.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
CHA NOx Removal System[34]	Emission Control	This system removes NOx pollutants from small stationary diesel engines. There are currently no feasible controls for these engines.		X		Prototype testing. The prototype will be tested on a 50-hp diesel engine at the CHA laboratory and will also be demonstrated at McClelland Air Force Base on a 50-hp diesel motor generator set for aircraft ground equipment.
Optimized automobile catalyst[35]	Redesign of traditional catalyst	Airflow Catalysts is attempting to reengineer the traditional automobile catalyst. The redesign is an effort to minimize costs by reducing the amounts of costly rare metals in the catalyst. The new design will seek to react all contaminants (NOx, HC, CO) in the same area of the converter, rather than in three separate areas. The company is also seeking to minimize the need for air injection for NOx control.	X	X		Developmental R&D. Preliminary results are expected in June, 1997. Conversation with Airflow Catalyst personnel.

Endnotes

1. Partnership for a New Generation of Vehicles Briefing, North American Vehicle Emissions Control Conference, December 11, 1996.
2. Rocky Mountain Institute.
3. CRADA: Pacific Northwest, Y-12 in Oak Ridge Tennessee, and Lawrence Livermore.
4. Ceramic Technology Project (CTP) (AlliedSignal Corporation) (Allison Engine Company).
5. United States Council for Automotive Research (USCAR); Department of Defense (TACOM / TARDEC); Ricardo North America; AVL LIST GmbH.
6. Perkin's Technology (Engineering consultancy of diesel engine manufacturer VarityPerkins).

7. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

8. Chrysler Corporation; Delphi Energy and Engine Management Systems.

9. Ballard Systems (Vancouver); Allied Signal (CA); Energy Partners (FL); Dow Chemical (MI, AR); Electrochem (MA); International Fuel Cells (CT); H-Power (NJ, CA); Daimler-Benz (Germany); Honda Motor Corp.; Toyota Motor Corp.; Chrysler Corp.; General Motors Corp.; Ford Motor Corp.

10. Conversation with Joe Ferguson, Advanced Vehicle Systems, Chattanooga, TN, May 29, 1997

11. Galileo Research, Inc.

12. United States Advanced Battery Consortium 810-641-1446.

13. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

14. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

15. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

16. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

17. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

18. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

19. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

20. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

21. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

22. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

23. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.

24. Valley Detroit Diesel Allison and Westport Research. This is an Innovative Clean Air Technology (ICAT) .

25. Cooperative Research and Development Agreement (CRADA): USCAR and Los Alamos National Laboratory.

26. Optrand.

27. TNO Road-Vehicles Research Institute.

28. CRADA: Department of Energy's Office of Energy Research at the Pacific Northwest National Laboratory and Low Emissions Partnership (LEP) of USCAR.

29. CRADA; DOE's National Renewable Energy Laboratory (NREL) and Benteler Industries, Inc.

30. Southwest Research Institute (SwRI); AEA Technology.

31. CRADA: DOE's Sandia National Laboratories, Argonne National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Lockheed Martin Energy Systems, and Low Emissions Partnership (LEP) of USCAR.

32. DuPont.

33. Rhone-Poulenc.

34. CHA Corporation. Their co-funding partners are the Sacramento Municipal Utility District, McClellan Air Force Base, and Gerling Applied Engineering.

35. Conversation with Airflow Catalyst personnel.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: **Electricity Generation**

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
THIN FILM PHOTOVOLTAIC (PV)[1]						
Amorphous silicon (a-Si)	Substitution	A solar film on which research efforts is focused because of its potential for increased unit efficiency and ease of manufacturing. Efficiency gains are evident: from less than one percent in 1974 to 10.2 percent in 1994. Researchers are currently seeking laboratory efficiency ratings of 13 percent. Lower efficiency ceiling of a-Si compared to crystalline silicon offset by lower manufacturing costs.	X	X	X	Commercially available but R&D efforts ongoing. Possible enhancements: electron cyclotron resonance deposition, hot wire deposition, and radio frequency glow discharge.
Cadmium telluride	Substitution	A solar film on which research effort is focused due to its likely ease of production, likely improved efficiency and ability to compete with crystalline silicon modules. Laboratory efficiency ratings have reached 16 percent with commercial efficiency of 6 percent. Research indicates manufacturing techniques are likely very low cost, including electrodeposition, spraying, and high rate evaporation.	X	X	X	Commercially available but R&D efforts ongoing. Research efforts are focusing on lowering module costs and increasing reliability.
Copper indium diselenide (CIS)	Substitution	A solar film on which research effort is focused due to its ability to withstand outdoor exposure without significant deterioration. This film also appears easier to produce and gain efficiencies than alternatives. In 1995, a laboratory efficiency rate of 17.1 percent was recorded with 10.2 percent for a production prototype module.	X	X	X	Commercially available but R&D efforts ongoing. Research to better understand alloy properties should simplify fabrication processes.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Thin-layer crystalline silicon	Substitution	A solar film on which research effort is focused because it is likely to blend the production ease of other film technologies with the efficiency of silicon crystals.	X	X	X	Commercially available but R&D efforts ongoing. Research is focused on thinning the film to less than 50 micrometers which should make it financially feasible.
CRYSTAL PHOTOVOLTAIC TECHNOLOGY[1]						
Crystalline Silicon	Substitution	Silicon crystals were the first technology explored and applied to market devices. Research continues because it is the only technology with demonstrated long term reliability, competitive cost, and high efficiency. Newer cells have demonstrated a 24% efficiency rating. Commercial production modules are expected with an efficiency of 14%.	X	X	X	Commercially available (this technology currently dominates the PV market) but R&D efforts ongoing. Research efforts to increase pure silicon modules' efficiencies.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
PHOTOVOLTAIC CONCENTRATOR SYSTEMS[1]						
Gallium arsenide	Substitution	It is possible to increase any solar cell's efficiency by focusing a more direct source of solar energy on it. In application, cells need to withstand extreme conditions in order to see an efficiency increase. This alloy demonstrated an efficiency of 28 percent under concentrated sunlight.	X	X	X	These systems are used primarily in space applications where efficiency gains are important and conditions are harsh; R&D efforts ongoing.
Multi-junction cells (gallium arsenide and III-V alloys)	Substitution	It is possible to increase any solar cell's efficiency by focusing a more direct source of solar energy on it. In application, cells need to withstand extreme conditions in order to see an efficiency increase. This alloy demonstrated an efficiency in excess of 30 percent under concentrated sunlight. The expectation is to exceed 32 percent efficiency.	X	X	X	These systems are used primarily in space applications where efficiency gains are important and conditions are harsh; R&D efforts ongoing.
Thermo PV (TPV)	Substitution	Using superconducting materials to turn solar energy into heat to creates steam to then generate electricity.	X	X	X	R&D efforts ongoing.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
PHOTOVOLTAIC MANUFACTURING[1]						
PV Manufac-turing (PVMat)	Substitu-tion	One of the primary hindrances to PV market acceptance is the difficulty in taking laboratory results and replicating them under real world conditions. A public-private partnership, funded for 5 years at $118 million, sought to address this problem by improving PV manufacturing processes, module development, and balance of system (BOS) components. For example, BOS components account for 50% of the system cost but 99% of repair issues. The goal was to increase PV module supply [currently demand outstrips supply (as of May, firms are taking no further orders for 1997)] and ensure that the U.S. production remains internationally competitive.	X	X	X	Commercially available but R&D efforts ongoing. Goals are lower module cost (estimated 50% reduction) through better processes, such as increased automation to reduce process time and improving power inverters to 98% efficiency with a mean time between failures of 5 years.
Batteries	Substitution	Batteries used to store PV electricity in many PV applications are often the "weak link" in the system. Improved batteries could improve energy availability by upwards of 35%. In addition, improved battery life spans could reduce life-cycle costs by an average of 35%.	X	X	X	Commercially available but R&D efforts ongoing.
Photovoltaics for Military Applications		This technology involves demonstrating the use of photovoltaic technology, reducing the amount of pollutants from fossil-fueled electrical gensets within DOD, and enhancing energy security. The focus will be to develop a modular, standardized power processing center (PPC) that will service multiple source photovoltaic/engine hybrid and demand reduction applications.		X		Pilot

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
STATIONARY FUEL CELLS						
Solid Oxide Fuel Cell (SOFC)[2]	Developing technology	The solid oxide fuel cell generates power electrochemically, avoiding the air pollutants and efficiency losses associated with combustion processes. Fuels cells operate continuosly, generating power as long as natural gas, coal-derived gas, or other hydrocarbon fuels are supplied. The solid electrolyte allows for the simplest of fuel cell plant designs, and requires no external fuel reforming. Capable of using either natural gas or cleaned coal gas, it emits no sulfur pollutants and as much as 60 to 65 percent less carbon dioxide than a conventional coal-burning plant.	X	X	X	Commercial production should commence in 2001.
Phosphoric Acid Fuel Cell (PAFC)[3]	Developing technology	This is the most commercially developed type of fuel cell. It is already being used in such diverse applications as hospitals, nursing homes, hotels, office buildings, schools, utility power plants, and an airport terminal. Phosphoric acid fuel cells generate electricity at more than 40% efficiency, and nearly 85% if steamthat the fuel cell produces is used for cogeneration, compared to 30% for the most efficient internal combustion engine. Operating temperatures are in the range of 400 degrees F. These fuel cells also can be used in larger vehicles, such as buses and locomotives.	X	X	X	ONSI's PC25 converts 1,900 SCF per hour of natural gas into 200 kW of grid-connected or grid-independent premium power and up to 750,000 Btu/hr of useful thermal energy at up to 250 degrees fairhenheit. Fuel cell cogeneration power plants reached their millionth hour of operation in 1996. More than 60 phosphoric acid fuel cell units are in use, providing 200KW of power and useable heat. They are developing a reputation for excellent reliability.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Molten Carbonate Fuel Cell (MCFC)[4]	Developing technology	The molten carbonate fuel cell uses an electrolyte of lithium and potassium carbonates and operates at approximately 650C (1200F). Due to the high temperature involved, noble metal catalysts are not required for the cell electrochemical oxidation and reduction process. Molten carbonate fuel cells are being developed for natural gas and coal based power plants for the industrial and electric utility sectors. Molten carbonate fuel cells promise high fuel-to-electricity efficiencies and the ability to consume coal-based fuels. This cell operates at about 1,200 degrees F. The first full-scale molten carbonate stacks have been tested, and demonstration units are being tested in California in 1996. One project is attempting to demonstrate the use of landfill gas to fuel a molten carbonate fuel cell power plant. In the first phase of the project, a cost competitive, viable gas cleanup system will be developed. In the second phase, the cleanup system will be integrated into a power plant system. The effort will culminate with a demonstration of the gas cleanup system with the complete power plant system.	X	X	X	Demonstration of a MCFC that uses natural gas as the fuel and will use the fuel cell's waste heat, setting total expected efficiency levels at more than 70 percent. The first commercial fuel cell to run on renewable fuel was dedicated in late June of 1996 at a landfill in Groton, Connecticut. The 200 KW fuel cell system will clean up the landfill gas, convert its methane to electricity, and feed it to a nearby power grid. The Santa Clara Demonstration Project is the largest fuel cell power plant ever operated in the U.S. It contains 16 stacks, each capable of producing approximately 125 kilowatts of direct current power. Energy Reserach Corp. intends to build and begin operation of a second demonstration based on the same design.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Proton Exchange Membrane Fuel Cells (PEMFC)[5]	Developing technology	These cells operate at relatively low temperatures (about 200 degrees F), have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications, such as automobiles, where quick startup is required. According to DOE, "they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries in video cameras."	X	X	X	See Mobil Fuel Cells discussion
Alkaline Fuel Cells (AFC)[6]	Devloping technology	Long used by NASA on space missions, these cells can achieve power generating efficiencies of up to 70 percent. They use alkaline potassium as the electrolyte. Until recently they were too costly for commercial applications, but several companies are examining ways to reduce costs and improve operating flexibility.	X	X	X	
Residential Fuel Cells[7]	Future technology	Fuel cell that is small enough to fit into a closet and capable of generating 2-10 kW of power.	X	X	X	Industry is focusing on larger fuel cells at present time. Developers are hoping to get this technology rolling in the next five years.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
WIND POWER[8]						
Improved Airfoil Materials	Substitution	Utilization of wind power necessitates a device (airfoil) which will capture wind energy. By using newer materials and changing the number of blades, improved energy generation and lower costs may be achieved. Improved airfoil design using composite materials (fiberglass, wood/epoxy) and fewer blades (2-3) will reduce system cost while increasing energy conversions/efficiencies.	X	X	X	Commercially available but R&D efforts with new materials are ongoing.
Advanced Airfoil Retrofit	Substitution	Rather than using airfoils designed originally for the airline industry, systems using airfoils designed specifically for wind towers offer substantial savings. One estimate is that substitution of such airfoils onto existing towers causes a 20 - 30 percent increase in electricity generation.	X	X	X	Commercially available but R&D efforts ongoing.
Gearbox	Substitution	The turbine blades' rotation causes wear on a system's gearbox. By using improved gearboxes, it is possible to lower total system cost (gearboxes are approximately 20 percent of total system cost). If as projected, infinitely variable speed tower systems become available, then it would no longer be necessary to maintain a gearbox in a tower system. Improved design and use of composite materials will reduce system cost by increasing the system's life span.	X	X	X	Commercially available but R&D efforts ongoing.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Manufacturing Techniques	Substitution	The manufacture of wind tower components is to date a labor intensive process (airfoils are traditionally hand laid). Development and use of computerized mass production techniques promises to reduce lay-up times and increase orders.	X	X	X	Commercially available but R&D efforts ongoing.
Computer Modeling	Substitution	The first step of wind power is siting the unit; if the unit over- or under-estimates the average wind speed, then the possible power generation capability is negatively impacted. Similarly, use of computers to measure the wind speed and simultaneously adjust the orientation of the wind foils can positively impact the power generation capability. Development of improved computer models that can lower the financial risk of wind power by better estimating the site's energy return is ongoing.	X	X	X	Commercially available but R&D efforts ongoing.
Control and Power Electronics	Substitution	Manual adjustment of individual controls on individual tower systems is expensive and time consuming. By using computers and electronic components on the systems it becomes possible to manipulate an entire farm in real time. It is expected that systems would also able to adjust to extreme weather conditions independently, thus avoiding catastrophic failures.	X	X	X	Commercially available but R&D efforts ongoing.

Endnotes

1. Personal communications with Ken Zweibel, Robert Foster, National Renewable Energy Laboratory, Golden, CO, Dr. Robert Williams, Princeton University; U.S. DOE, "National PV Program Plan for 1996-2000", January 1996; and U.S. DOE, Sandia Lab.

2. Dr. Steven Veyo, Westinghouse (PA); University of Missouri-Rolla; Allied Signal Aerospace (CA); Institute of Gas Technology (OH); SOFCO; Ztek

(MA).

3. International Fuel Cells (CT); Fuel Corp. of America (PA); ONSI Corporation.

4. Energy Research Corp. (CT); M-C Power (IL); International Fuel Cells Corp. (CT); EPRI (CA); DOE (DC).

5. See Mobil Fuel Cells discussion.

6. International Fuel Cells (CT).

7. South Coast Air Quality Management District (CA).

8. Personal communications with Susan Hock, National Renewable Energy Laboratories, Golden, CO.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Solvent Utilization - Surface Coating (Industrial Adhesives)

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Hot melt spray tool[1]	Process redesign	A newly-redesigned, solvent-free, hot melt spray tool is under to development to reduce VOC emissions. Further details not available.	X			N/A
Eastman AQ 1350 polymer[2]	Material substitution	A new water-dispersible hot-melt adhesive raw material, which can form the basis for use in a variety of applications including nonwoven products such as disposable diapers, packaging, bookbinding and labels. Products containing the water-dispersible adhesive are more easily repulped or recycled.	X			Introduced and commercialized in the fall of 1995.
Polyurethane reactive (PUR) technology[3]	Reformulation	New, accelerated-cure versions of hot-melt adhesives technology for recreational vehicle and building components customers has been developed. Also applicable to the profile wrapping segment of the woodworking industry, which can use the adhesives to make window and door components that withstand hot and cold temperatures, rain and snow. Users can increase process speeds, while at the same time produce stronger products in a solvent-free environment.	X			Full-scale demonstration; on verge of commercialization.
Advances in waterborne adhesives[4]	Reformulation	New waterborne adhesives for the flexible packaging industry now meet performance standards previously attainable only with solvent-borne formulations.	X			Commercially-available; strong initial sales in meat and cheese packaging and coffee bag lamination markets; being demonstrated to film converter industry.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Advances in solventless, 100% solids adhesives[5]	Reformulation	New generation solventless, 100% solids adhesives applicable for the film converter industry have been developed. With no solvents to incinerate, film converters can reduce operating costs and increase output by reallocating incineration capacity to other plant operations.	X			Being demonstrated to film converter industry.
Cold lens blocking methods ("Loctite Cold Bloc")[6]	Material substitution	New uv-curing "cold" blocking adhesive enables optical manufacturers to produce lens surfaces that are practically distortion free, and virtually eliminates the environmental concerns (solvents) of the current technique. This technique facilitates easy debonding using a variety of debonding agents and techniques. The adhesive is a significant advance in the lens blocking process, as it eliminates heat-induced blocking strain, which is the most significant problem encountered with current hot pitch blocking methods. Process reduces costly processing time, and is compatible with existing tooling.	X			Developmental R&D.
New UV-cure technology applications[7]	New application	New UV-cure applications are being developed for use in the automotive industry. These applications include coatings for metal and plastics, interior and exterior applications, adhesives, and gasketing.	X			Testing.
Electron Beam (EB) curing[8]	Reformulation/ Process redesign	EB curing with existing technology has already been shown to dramatically reduce or eliminate solvent emissions in wood finishing. Currently, new advances in EB equipment and processes are being developed, including a new, lower-energy EB system and a new transport system for the EB treatment of powders. EB processes result in improved product performance and higher productivity, but require different curing equipment, and in some cases, application may be more difficult.	X			First generation processes are commercially-available; refinements are in developmental R&D/testing.

US EPA ARCHIVE DOCUMENT

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
EB-curable epoxy resins for composites[9]	Material substitution/ Process redesign	Major advancement in the formulation of epoxy resin systems capable of being cured (cross-linked) by ionizing radiation. This development could be the link in making polymer matrix composites and adhesives a cost-effective system for manufacturing a broad range of products in both high-tech and high-volume commercial applications. Further optimization of these resin systems is currently being performed for specific aircraft, aerospace, and defense applications. Substantially reduced manufacturing costs (25-65% less expensive) and curing times; and improvements in part quality and performance.	X			Currently used commercially for plastics, coatings, and food and medical sterilization. Testing now for new applications for composite products.
Non-acrylate Systems[10]	Material substitution	In the research development of UV and EB curable alternatives to acrylates, a number of "new" systems have been developed that reduce emissions, such as cationic systems, alternating free radical induced copolymerization of donor/acceptor type monomers, various hybrid systems, and photoinduced addition reactions for the formation of polymeric networks.	X			Development R&D.
Water-based aerosol adhesive[11]	Material substitution	Based on new technology, a water-based low VOC spray adhesive has been developed that offers bonding strength and heat resistance comparable to many typical solvent-based aerosol products. This adhesive can be used to bonds a range of substrates, including paper, fabrics, plastics, wood, and aluminum.	X			Available for commercial use in the near term.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Dual-cure photocatalyst technology[12]	Material substitution	Low-solvent, low-VOC coatings are being developed that use photocatalysts to react with the coating material and accelerate the curing process. These photocatalysts allow the coatings to cure from liquids to solids quickly under UV or visible light. A family of such photocatalysts is being developed and tested. Major uses include tape adhesives and protective topcoats for aircraft. Development of solventless backing saturants for electrical tape backings has essentially been completed. Optimal dual cure resin formulations have been identified and utilized in preparing complete tape constructions.	X			Full-scale demonstration
Advances in waterborne adhesives[13]	Material substitution	Morton's Water-Based Polymers Technology and Adhesive Technology Groups are involved in developing new and improving on existing Morton products such as: the use of HAP-free solvents for waterborne adhesive products and 100% solids flexible film adhesive laminations.	X			Developmental R&D, pilot research at pilot laminator in Woodstock, IL, in addition to some first round commercially-available products.

Endnotes

1. Adhesive Focus (electronic issue of GLUGURU's quarterly newsletter); Volume III, Issue 1, Winter 1997
2. 1996 R&D 100 Awards Competition. August 28, 1996.
3. National Starch and Chemical Company. 1997.
4. National Starch and Chemical Company. 1997.
5. National Starch and Chemical Company. 1997.
6. International Society for Optical Engineering (SPIE) abstracts; pp.30-35 (no date).

7. RadTech '96 Conference & Exhibition, Keynote Address.

8. RadTech'96 Conference & Exhibition, Wood/Furniture Coatings Session.

9. Researchers at DOE, Oak Ridge, with: AECL Technologies; Applied Poleramic; The Boeing Co.; Ciba-Geigy; E-Beam Services; Lockheed Fort Worth; Lockheed Martin Technologies -- Aero and Naval Systems; Nicolet Imaging Systems; Northrop Grumman; Sandia; and UCB Chemicals; 5/22/96.

10. RadTech' 96 Conference and Exhibition, Formulating Non-Acrylate Systems Session.

11. The 3M Company internet site (not dated).

12. Minnesota Mining and Mfg. Co., St. Paul, MN (3M), in partnership with the U.S. Department of Energy's Office of Industrial Technologies.

13. Morton Water-Based Polymers Technology and Adhesives Technology Groups (May 1997).

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: **Solvent Utilization - Surface Coatings**

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Biomimetic coatings[1]	Reformulation	Synthetic routes are being developed for new water soluble polymers to enable the formulation of effective and durable waterborne protective coatings. The aim is to develop novel water-soluble polymers which on evaporation of water undergo a phase transformation similar to protein molecules where hydrophobic moieties, present in the polymer, form the matrix of the film. This approach to produce zero-VOC solvent systems avoids the water sensitivity and reductions in performance and durability experienced by the current generation of water-based coatings.	x			Developmental R&D.
Acrylic plastisols[2]	Material substitution	Acrylic plastisols are being investigated as a new type of low-solvent industrial coating. Consisting essentially of a dispersion of emulsion or suspension grade polymer in a high boiling solvent-plasticiser, the coating is applied to the substrate and then heated to allow the plasticiser to swell and dissolve the polymer particles. The result on cooling is a tough and flexible coating. The plastisol market has traditionally been dominated by polyvinyl chloride; however manufacturers are searching for alternative polymers. Acrylic polymers offer a number of distinct advantages over polyvinyl chloride such as superior exterior durability and a more favorable environmental image.	x			Completed initial developmental R&D.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Organic protective coatings and application technology[3]	Material substitution and reformulation	High performance, non-toxic, low VOC content coatings for Navy use are being developed, including investigation of low VOC polymer technology to produce low VOC binder systems. Reactive monomers and diluents and low molecular weight resins have been used to develop low viscosity binder systems for future near-zero VOC aircraft coatings. In addition, recent advances in water-borne resin technology has allowed for the development of a high performance water-borne topcoat which goes beyond mere compliance with environmental regulations. Non-toxic inhibitor systems have been developed and formulated into non-toxic aircraft corrosion inhibiting primers. Coating corrosion resistance, physical performance properties and VOC content were evaluated in the development of the best materials. The non-toxic inhibited primers have been optimized, and service evaluation at Navy maintenance facilities is in progress.	x			Field testing/verification.
Dual-cure photocatalyst technology[4]	Material substitution	Dual-cure photocatalyst technology is being researched for a variety of coating and adhesive uses, such as aerospace topcoats, aerospace primers, and solventless manufacture of tape backings. Significant progress has been made in improving the performance of the urethane/acrylate formulation being used for the aerospace topcoat application. Technical challenges have continued with the aerospace primer formulation.	x			Full-scale demonstration
New latex polymer application method[5]	Process redesign	New latex polymer application method eliminates the acetate rinse-out and the resultant solvent-contaminated water waste stream and distillation air emissions.	x			Testing.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Mobile zone spray booth ventilation system[6]	Process redesign	New process design endeavors to reduce the volume of air to be treated from spray paint booths, thereby increasing efficiency and improving air pollution abatement (in particular, reducing VOC emissions). Most of the ventilation air is recycled through the booth to maintain laminar flow; the machinery is located on the supply side of the booth rather than on the exhaust side. 60 to 95% reduction in spray booth exhaust rate should result.	x			Full-scale demonstration engineering and production prototypes have been made.
Magnetically controlled deposition of metals using gas plasma[7]	Process redesign	Methods of spraying materials on a substrate in a controlled manner are being researched in an attempt to eliminate the waste inherent in the present process. Thin layers of secondary material are plated on substrates either by plating or spraying processes. Plating operations produce large amounts of hazardous liquid waste. Spraying, while one of the less waste intensive methods, produces `over spray' which is waste that is a result of the uncontrolled nature of the spray stream. In many cases the over spray produces a hazardous waste.	x?		x?	Developmental R&D.
Safe Yellow IC[8]	Material substitution	A product has been developed for enhancing powder coatings by increasing the flow of the resins, eliminating orange peel and allowing the replacement of more expensive organic pigment on a one for one basis. The manufacturers of this product say it is an improved coating with lower costs.	x			Recently made commercially available.
Advanced Acetylenic Glycol (AAG) technology[9]	Material substitution	To address the need for substrate wetting in waterborne systems, a new-generation surfactant has been developed based on Advanced Acetylenic Glycol (AAG) technology. The AAG technology provides greater flexibility and mobility, as well as other benefits.	x			Recently made commercially available.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Prepolymers and ultralow-viscosity reactive diluents technologies[10]	Material substitution	Two technologies have been developed to help solve formulation problems with decreased levels of VOCs in two-part, solventborne polyurethane coatings. One technology is a process to make narrow-molecular-weight-distribution, isocyanate-terminated polyurethane prepolymers. The other technology is the creation of ultralow-viscosity oxazolidine and aldimine/oxazolidine reactive diluents. Use of these materials achieves low-VOC formulations, controlled reactivity of low-VOC systems and enhanced coating performance, as well as formulation flexibility and ease of use.	x			Testing.
Foam-control agents[11]	Material substitution/ process redesign	More sophisticated foam-control agents are being developed and used as formulators move from solvent-based to waterborne coating systems. Foam is a common problem in waterborne systems, and it can adversely affect the coating's appearance and durability. Prudent use of foam control agents can minimize or eliminate the adverse effects of foam without impacting other surface properties.	x			Developmental R&D and testing.
Water-based, solvent-free and ultrahigh-solids coatings[12]	Material substitution	Water-based, solvent free and ultrahigh-solids coatings are being considered for development for the metal office furniture industry.	x			Developmental R&D.
Water-based coatings[13]	Material substitution	Morton's Water-Based Polymers Technology Group is involved in developing new and improving on existing Morton waterborne products such as: a new water-based, lead-free highway paint; a zero-VOC, waterborne color dispersion paint component; and water-based automotive plastic coatings.	x			Developmental R&D and commercially-available.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Polyol resins, crosslinkers and reactive diluents[14]	Material substitution	Recent developments with polyol resins, crosslinkers and reactive diluents will enable the future formulation of higher-solids, ultralow-VOC coatings and, ultimately, of solventless liquid coatings. In spite of the increasing popularity of waterborne and powder coatings, many companies see a future for higher-solids coatings and are investing in new technology, particularly for industrial (original equipment manufacturer) and special-purpose applications.	x			Developmental R&D.
Micro-emulsion technology[15]	Material substitution	New microemulsion technology creates an effective way to decrease VOC levels up to 50% or more and still maintain effective paint-stripping performance. This solvent technology allows water to be incorporated into hydrocarbon-based paint strippers while making minimal performance sacrifices.	x			Recently commercially available.
High solids aliphatic polyurethane coatings[16]	Material substitution	Three novel approaches to high solids aliphatic polyurethane coatings have been developed: a 100% solids, VOC free, instant setting, aliphatic polyurethane coating system; a high solids mix-and-apply aliphatic polyurethane coating system; and a high solids single component aliphatic polyurethane coating system.	x			Recently commercially available.
Aliphatic isocyanates[17]	Material substitution	Urethane technology provides strong linkage for molecules in coatings, and is finding its way into high-solid, powder, and waterborne technologies. For example, isophorone diisocyanate is gathering strength in the powder coatings market, while use of hexamethylene diisocyanate in waterbased coatings is expected to grow. A family of low-temperature unblocking isocyanates as also been developed, and is being marketed to the painting and coating industry.	x			Recently commercially available.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Waterborne primers[18]	Material substitution	Waterborne primers will be studied at three Ford truck plants and a BMW plant.	x			Field scale testing/verification.
Waterborne clearcoats[19]	Material substitution	Water-based clearcoats are under investigation at Ford.	x			Developmental R&D.
Powder-based primers[20]	Material substitution	GM is working on a prototype powder primer to try on one of its vehicle lines; such a primer would contain no VOCs. New chemistry research is being conducted on both epoxy and polyester powder primers.	x			Developmental R&D, prototype testing.
Clearcoat powder[21]	Material substitution	The Low Emission Paint Consortium is researching the development of a powder clearcoat, although this type of coating has many difficulties to overcome in terms of durability and appearance in comparison with current methods. A trade-off with powder coatings is that powder requires higher bake requirements and new equipment and application systems. Ford is working on a prototype powder clearcoat.	x			Developmental R&D, prototype testing.
Non-ozone depleting sealants for ammunition applications[22]	Material substitution	Research program aimed at investigating solvent-free or solvent-safe case mouth sealants for military ammunition by evaluating state-of-the-art, commercially-available non-ozone depleting sealants. Economic benefits include reduced costs (elimination of toxic ozone-depleting chemicals environmental protection activities), increased production rates, and reduced lot rejection rate (which currently averages 6% per year).	x			Conducting compatibility and long term evaluations, and then functional testing.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
UV/ozone oxidation technique[23]	Process redesign	Technology development and demonstration activity targeted for Department of Defense painting operations to validate the recirculation/partitioning concept used with a novel UV/ozone oxidation technique to eliminate HAP and VOC discharges from paint spray booths and other booth designs. Preliminary results suggest that booth discharge flow reductions of up to 75% can be achieved.	x			Field evaluations in conjunction with additional developmental R&D.
Ultra Filtration[24]	Process redesign/ reuse	Decorative Coatings' technology center at Montataire, France is developing new technologies to improve waterborne paint waste reuse, thereby reducing new paint production and associated emissions. One of its initiatives is wastewater treatment by Ultra Filtration (UF). This is a major project, because up to 12 European sites may be involved. UF is a nonchemical membrane separation process, which separates the effluent into two streams: permeate (the treated water) and concentrate (UF sludge). The pollution level of the permeate is equivalent to that obtained after conventional treatment, but it is completely free of paint solids, which are held in the concentrate. So far, UF has proved to be an efficient solution for treating effluent from waterborne paint production. Industrial application of UF is economical provided that the concentrate is reused in making paint.	x			Prototype testing at multiple plants.
New photoinitiator systems[25]	Material substitution	Ciba is working on advanced photoinitiator systems that enable paints and coatings to dry rapidly without the need for heating or the release of solvents into the atmosphere. Key future research is targeting extending the range of photoinitiators for paints and coatings.	x			Developmental R&D and first generation commercially-available products.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Water-based solder masks[26]	Material substitution	Probimer7 water-based solder masks can help cut down on the use of solvents; these water-based coatings are used on printed wiring boards in the computer industry. In addition, the division's powder coating systems are applied to buildings and cars using electrostatic charge - avoiding the need for a solvent.	x			Developmental R&D and first generation commercially-available products.
Compatible innovative coatings[27]	Material substitution	Ciba is working on developing compatible powder, high solid and waterborne epoxy systems. Examples of areas of research include: new high flow solid epoxy resin for powder coating applications with smoother appearance; and new waterborne epoxy resins and epoxy hardeners with environmental advantages.	x			Developmental R&D.
New applications for powder coating[28]	Material substitution/ process re-design	A full "factory size" powder coat facility has been built to expand the application of powder coating to a new range of users.	x			Full scale demonstration.
Advances in transfer efficiency[29]	Process re-design	Investigations are being made to improve paint coating transfer efficiencies; for example, innovative nozzle designs, air flow, cleaning systems/procedures, and high-volume, low-pressure systems are being analyzed.	x		x	Developmental R&D and testing.
Supercritical CO_2 as a paint solvent[30]	Material substitution	Supercritical CO_2 is being investigated as a replacement for traditional paint solvents, eliminating VOC emissions.	x			Developmental R&D and testing.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Zero-VOC Industrial Maintenance Metal Coating[31]	Reformulation	This zero-VOC coating technology is intended for use as a topcoat on metal furniture. The resin formulation for the coating will be adjusted to provide acceptable drying times, flexibility and hardness, and ultraviolet, chemical and salt spray resistance.	x			Field demonstration and evaluation. The technology is expected to be followed by a full-scale demonstration at a commercial metal furniture manufacturing facility.
Dynamically Optimized Recirculation Coupled with Fluidized Bed Adsorption[32]	Reformulation/ Product Redesign	These two technologies (i.e., dynamically optimized recirculation to continually minimize exhaust volume flow rates; and a fluidized bed emissions control and solvent recovery technology using new adsorbing resins for cost-effective operation) will be used to reduce VOC emissions from coating and solvent operations. An existing paint booth recirculation system on a Steelcase furniture coating line will be modified to include dynamic recirculation.				This technology is being developed and CA EPA's Air Resources Board is confident that it could be commercialized within a few years.

Endnotes

1. Paint Research Association, UK and researchers at Southampton University (Applied Biocomposites Group); 1997.
2. Paint Research Association, UK; 1992.
3. Naval Air Warfare Center Aircraft Division, Warminster, PA., (not dated).
4. 3M, in partnership with the U.S. Department of Energy's Office of Industrial Technologies.
5. Los Alamos National Lab, DOE contract (1995).
6. Mobile Zone Associates, Nashville, TN, DOE (1994).
7. Idaho National Engineering Lab, DOE (1994).
8. Sino American Pigment Systems, working with Specialty Chemical Sales, Cleveland.
9. Air Products and Chemicals; article in PCI, Issue: March 1996.
10. Air Products and Chemicals Inc.; and ANGUS Chemical Co.; article in PCI, Issue: February 1997.

11. Ashland Chemical Co.; article in PCI, Issue: February 1997.

12. IVC Industrial Coatings; article in PCI, Issue: Sept. 1996.

13. Morton Water-Based Polymers Technology Group (May 1997).

14. Eastern Michigan University; article in PCI, Issue: May 1997.

15. Dow Chemical Co.; advertisement in PCI, no date.

16. Madison Chemical Industries, Canada; internet: not dated.

17. Chemical Marketing Reporter, February 14, 1994, p. 4.

18. Modern Paints and Coatings, v83, n7, p. 34(3). July 1993.

19. Modern Paints and Coatings, v83, n7, p. 34(3). July 1993.

20. Modern Paints and Coatings, v83, n7, p. 34(3). July 1993; Du Pont is the only supplier currently providing an all-vehicle powder primer.

21. Modern Paints and Coatings, v83, n7, p. 34(3). July 1993.

22. U.S. Army Armament, Research, Development, and Engineering Center; EnviroSense (March 1996).

23. Advanced Research Laboratory, Penn State University, PA; Research Triangle Institute, NC; EPA's Air and Energy Engineering Research Laboratory; and U.S. Marine Corps, Marine Corps Logistics Bases Envirosense (March 1996).

24. Morton, Decorative Coatings Business Unit (Plants involved are Dormelletto, Italy; Berlin, Germany; Montataire, France); 1995.

25. CIBA Speciality Chemical's Additives Division (May 1997).

26. CIBA Speciality Chemical's Performance Polymers division (May 1997).

27. CIBA Specialty Chemical's Performance Polymers division (May 1997).

28. National Defense Center for Environmental Excellence (May 1997).

29. National Defense Center for Environmental Excellence (May 1997).

30. National Defense Center for Environmental Excellence (May 1997).

31. Aerovironment Environmental Services and Adhesive Coating Company. This is an Innovative Clean Air Technology (ICAT).

32. Air Quality Specialists with two co-funding partners, Steelcase North America and Southern California Edison.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Solvent Utilization - Nonindustrial (Consumer Products)

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	Nox	PM	
Low VOC-Content substitutions	Chemical reformula-tion, product or feedstock substitution, repackaging, and direc-tions for use, consump-tion, storage, or disposal.	Product reformulation and changes in delivery methods to result in low-VOC consumer products. Over 200 categories of consumer products with emission reduction potential have been defined. Substitution to CO_2 propellants, detergent- or water-based solutions, and/or pump sprays vs. aerosols are being targeted. Consumer education and product labeling is also being pursued. CARB estimates an 85% VOC reduction in 2010 from the current consumer product inventory, but has not identified specific technologies.	X			Conceptual/ R&D phase. CARB has established a consumer products working group to establish mid- and long-term control measures. It is comprised of industry, environmental groups, ARB, US EPA, and local AQMDs. First met in Spring 1995.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Solvent Utilization - Degreasing

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	Nox	PM	
Solid State Metal Cleaning[1]	Materials Substitution	This technology involves metal cleaning processes that do not require the use of water or VOCs. The two technical objectives to be achieved involve: (1) developing and transitioning to using a cleaning process for large (and small) aircraft components that does not require the use of water or VOCs; and (2) developing a process that will allow components to proceed directly to the next step in the process for surface washing without the need for subsequent treatments involving water or organic solvents.	X		X	Prototype testing.
Combination Sorption/Catalyst Medium for Destruction of Halogenated VOCs - Dover AFB[2]	Emissions control	This technology involves development, evaluation, and optimization of an adsorbing catalyst that will be pilot tested as an alternative low-cost approach for eliminating air emissions which occur during waste water cleaning operations. Research is focusing on developing and optimizing a single medium which first will act as a sorbent to remove low concentration VOCs at room temperature and then act as a catalyst at about 350EC to destroy the VOC. The two major technical issues involve finding a sorbent that is also catalytically active and controlling the desorption reaction without excessive heat effects (catalyst deactivation).	X			N/A

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	Nox	PM	
Solvent Substitution and Low VOC Cleaners[3]	Substitution	This technology involves identifying low VOC content cleaning solvents for use on Navy aircraft, weapon systems, and ground support equipment and identifying replacements for methylene chloride based chemical paint strippers, such as solvent blend formulations and aqueous cleaners.	X			Implement optimized enzyme cleaners (6/98); implement optimized non-hazardous strippers (12/95; implement optimized low VOC wheel well cleaners (9/96); Implement no VOC A/C exterior cleaners (9/97); implement supercritical CO2 cleaning (9/99); implement lubricant low VOC solvent cleaners (9/99)

Endnotes

1. The Strategic Environmental Research and Development Program (SERDP); the Air Force Material Command, Aeronautical Systems Center, Wright Laboratory, Wright-Patterson AFB [http://es.inel.gov/new/funding/serdp/p2prj019.html].

2. EPA's Air and Energy Engineering Research Laboratory and the USAF. [http://es.inel.gov/new/funding/serdp/fy93cm2.html].

3. Naval Air Warfare Center Aircraft Division Warminster, the USAF, NAWCADWAR, Naval Aviation Depots and the Lead Maintenance Technology Center for Environment, DOE, and aerospace industry. [http://es.inel.gov/new/funding/serdp/p2prj017.html].

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Solvent Utilization - Nonindustrial (Pesticide Applications)

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Biopesticides[1]	Material Substitution	Biopesticides are typically microorganisms, pheromones or other substances found in nature that are generally recognized as presenting lower overall risk than most conventional chemical pesticides. Sixteen new biopesticide active ingredients have been registered for use in California. Examples include: 1-octen-3-ol; Bacillus sphaericus, serotype h-5a5b, strain 2362; and Neem oil.	X			Cal/EPA's Department of Pesticide Regulation registered 16 new reduced risk pesticide active ingredients in 1996.
Integrated Pest Management (IPM)[2]	New Cultural Practices	The purpose of IPM is to maximize the efficiency of pesticide applications, where necessary, and reduce the use of pesticides using a variety of chemical, nonchemical, and cultural techniques. IPM techniques include the use of chemical alternatives, resistant rootstocks, crop rotations, cover crops, biological controls, organic amendments and organic farming to provide competitive yields in the absence of conventional chemical applications. IPM reduces the grower's vulnerability to regulatory actions on pesticides and on pest resistance to chemical controls. US growers have experienced cost savings through the use of IPM techniques. For example, ICF estimated that a grower using IPM techniques iin CA vineyards instead of conventional methyl bromide fumigation may save as much as $340/acre.	X		X	The research base for IPM techniques is increasing, as is the demand for environment-ally friendly production practices.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Resistant Rootstocks and Cultivars[3]	Material Substitution	Resistant plant varieties (i.e., rootstocks and/or cultivars) can reduce or eliminate the need for pesticides. Several such rootstocks have been discovered including nematode resistant varieties of peppers, tomatoes and tobacco. Similarly, scientists recently isolated two genes, the RPS2 gene and the N gene, which fight off diseases and viruses, respectively, in the absence of chemicals.	X			Resistant cultivars are already being widely used in the US and new strains are being developed.

Endnotes

1. California EPA's Department of Pesticide Regulation *News Release*, January 10, 1997. Pesticides are also registered by the US EPA Office of Pesticide Programs.

2. Information on IPM available from EPA 1996, Klonsky 1992, Howe 1994, Liebman and Daar 1995, and McKenry 1995.

3. Sources include the EPA 1996, Institute for Agriculture and Trade Policy 1994, McKenry and Kretsch 1995, and Potter 1996.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Other Industrial Processes - Miscellaneous

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			HC	NOx	PM	
Solventless Pyrotechnic Manufacturing	Product redesign	The goal of this technology is a field demonstration of the cryogenic processing technique as a solventless method to eliminate air pollutant and VOC emissions from the magnesium-teflon-viton (MTV) pyrotechnics manufacturing process. The cryogenic approach would result in fewer explosive operators being exposed to fewer hazardous situations compared to the current process, the solvent disposal cost would be eliminated, and the potential for an accidental ignition would be reduced. The Army has estimated a potential cost savings of $900,000 if their current 600,000 pounds per year "shock-gel" production process for flare decoys were replaced with the cryogenic process.	X			Pilot scale as of FY93

Endnotes

1. Naval Surface Warfare Center, manufacturers of cryogenic grinding equipment, and cryogenic grinding companies. [http://es.inel.gov/new/funding/serdp/41-solve.html].

2. DOD, DOE, Sandia National Laboratories. [http://es.inel.gov/new/funding/serdp/fy93en1.html].

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Waste Disposal and Recycling

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Combined Air and Water Pollution Control System[1]	Emission Control	This system, developed at NASA's Marshall Space Flight Center (MSFC), is a recirculating bioaquatic pollution control system which combines both wastewater and air pollution controls into one system. The system combines exhaust combustion gases with flowing wastewater which is then filtered through a rock/plant/microbial filtering system. The microorganisms living in and around the plant root form a symbiotic relationship with plant roots which results in increased degradation rates and removal of organic chemicals from wastewater.	X			Available for commercial applications. The patent number for this system is 4,959,084.
Pyrokiln Thermal Encapsulation Process[3]	Process Redesign	The Pyrokiln Thermal Encapsulation Process is designed to improve conventional rotary kiln incineration of hazardous waste and may reduce the total dust load to the air pollution control system and the amount of particulate emissions from the stack. The process is designed to immobilize the metals remaining in the kiln ash, produce an easily handled nodular form of ash, and stabilize metals in the fly ash, while avoiding the problems normally experienced with higher temperature "slagging kiln" operations.			X	Field testing/ verification.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Reactor Filter System (RFS)[4]	Emission Control	The RFS technology, developed by the Energy and Environmental Research Corporation (EER), is designed to control gaseous and entrained particulate matter emissions from the primary thermal treatment of sludges, soils, and sediments. RFS was designed to overcome the logistical problems associated with existing air pollution control devices required to control products of incomplete combustion (e.g., size not suitable for transport to remote Superfund sites).	X		X	Pilot-scale testing.

Endnotes

1. This system was developed as part of the NASA Technology Transfer Program.
2. EPA is working with the Membran Corporation to develop this technology.
3. EPA and Svedala Industries, Inc are working together to develop this technology.
4. EPA and the Energy and Environmental Research Corporation are working together to develop this technology.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: <u>Miscellaneous</u>

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
PremAir™ Catalyst[1]	Ozone Destroying Catalyst	A catalyst has been developed by Engelhard Corporation that converts ground-level ozone to oxygen. The catalyst coverts a large percentage of ambient ozone to oxygen by passing ambient air over the surfaces coated with the catalyst. To be effective as pollution control measure, catalyst can be coated on surfaces that come into contact with large volumes of ambient air, including car radiators, air-conditioner condensers and other equipment. An 80% reduction in ambient ozone has been demonstrated on automobile radiators coated with the catalyst with no catalyst deterioration for over 10,000 miles.				Initial research and development efforts have focused on applying the technology to car radiators in order to destroy ozone. In a nine-month testing program conducted last year by Ford Motor Company and Engelhard, the catalysts destroyed a high percentage of the ozone contacted in months of on-road driving. However, the near-term environmental benefit of using the technology on unmodified vehicles (i.e., fans not modified to run while parked) is much less than the potential long-term benefits originally projected. For this reason, Ford decided not to use PremAir catalysts on its vehicles at this time, but is monitoring Engelhard's progress in further developing the technology for automotive applications. Engelhard is also conducting testing and development work on applications in air conditioners and other stationary equipment. SCAQMD is evaluating the effectiveness of applying the catalyst to residential and commercial air conditioning units located in the highest ozone levels in the basin; tests will be conducted this summer on four air conditioning units. The catalyst has also been applied to both radiator and air conditioner on buses in several areas.

<u>Endnote</u>

1. Engelhard Corporation; SCAQMD; David Johnson, E3 Ventures, Inc., May 21, 1997.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Miscellaneous - Other Combustion

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Membrane Gas Transfer Device[1]	Material Substitution	The Membran Corporation has developed a flautist, hollow-fiber membrane technology that dissolves high concentrations of oxygen, methane, or hydrogen into water by exploiting the high gas permeabilities of hollow-fiber microporous membranes. This technology eliminates emissions and the need for costly air pollution control equipment.	X?			This project was accepted into the SITE Emerging Technology Program in July 1994.
Ultra Low-NOx Gas-Fired Burner[2]	Product Redesign	An ultra low-NOx gas-fired burner is being developed to provide NOx emission levels comparable to selective catalytic reduction technology (SCR) at significantly lower costs for industrial air-preheat burners. The commercial availability of this technology would allow new and existing boilers and furnaces that use preheat to obtain a permit under stringent CA regulations without the use of costly SCR technology.		X		This technology has been effectively demonstrated and the CA EPA's Air Resources Board expects that it could be commercialized within a few years.

Endnotes

1. EPA is working with the Membran Corporation to develop this technology.

2. This is an Innovative Clean Air Technology (ICAT). Coen and Company, with co-funding from the Gas Research Institute is developing the ultra low-NOx gas-fired burner.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: Other Industrial Processes - Mineral Products

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Reburn and Enhance Gas Reburn[1]	Emission Control	Reburn and enhance reburn technologies are employed to reduce cement kiln NOx emissions by 40 and 70 percent, respectively. Cement kilns are among the largest, relatively uncontrolled sources of NOx in CA and there is still no acceptable method of reducing their emissions.		X		This technology has been effectively demonstrated and the CA EPA's Air Research Board has recognized it as a potential technology for commercialization within a few years.

Endnote

1. This is an Innovative Clean Air Technology (ICAT) and is funded by Acurex Environmental Corporation with matching funds from the US EPA and Coen Company.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Source Category: **Non-Road Sources - Lawn and Garden Engines**

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	**NOx**	**PM**	
Direct fuel injection for 2-stroke chain saws[1]	Engine redesign	The lubricating oil and the fuel are supplied to the engine separately; emission results for this prototype chain saw were reported as 20 g/hp-hr for HC emissions. Stihl, a major manufacturer of handheld equipment, is developing a prototype mechanical direct fuel injection chain saw. No electronic control system is used. A few of the prototype chain saws have been evaluated in the field and the results were encouraging. NOx emissions are expected to rise, however. Estimates indicate an incremental cost of $200 per unit over traditional chain saws. With expected emission reductions, unit cost is $950/ton of HC.	X		X	Developmental R&D; prototype testing in the field
Vaporizing Carburetor[2]	Fuel Intake redesign	Fuel is vaporized in internal combustion engine to enable effective combustion in lean mode; the technology is relatively simple and cheap compared with catalysts. The Woodside Group, Inc. Has invested over $1 million in the development and testing of the technology applicable to lawn and garden engines, marine engines, and automobile engines. Emission reductions for prototype four stroke small lawn and garden engine and automobile engines were as low as 3 g/hp-hr for HC plus NOx emissions and 0.4 g/mile NOx, respectively. Modest NOx reductions are expected. Technology has much less in-use deterioration in emission than other existing technologies. A few engines equipped with vaporizing carburetor were tested with EPA and major engine manufacturers.	X	X		Developmental R&D; prototype testing; possible commercialization with U.S. firm who manufactures marine engines.

SUMMARY OF EMERGING TECHNOLOGIES FOR LOWER EMISSIONS OR CHEAPER CONTROLS OF VOCs, NOx, AND PM

Technology (Name)	Control Strategy	Description	Emissions Controlled			Technology Status
			VOCs	NOx	PM	
Clean Air Two-Stroke[3]	Product Redesign	This clean air two-stroke engine is being developed for utility engine applications and is expected to substantially reduce emissions of hydrocarbons, carbon monoxide and NOx. The design features an electronically controlled fuel injection system. This engine could achieve substantial emissions reductions from the small utility engine category, which is one of the highest emitting classes of engines.		X		BKM is designing and manufacturing prototype engines and testing them for emissions and durability. Results of an early prototype chainsaw engine showed substantial reductions in emissions. Fuel consumption was also reduced.
Zero Emission Power Sources for Commercial Lawn and Garden Equipment[4]	Alternative Fuels	Development and demonstration of zero emission power sources for commercial lawn and garden equipment. This program is expected to support several projects to develop zero emission alternative power sources for these applications. The projects are expected to develop refuelable electric power supplies, such as hydrogen fuel cells and refuelable batteries, such as zinc-air or aluminum-air, that can meet the needs and requirements of commercial gardeners with respect to availability of electric power, operating convenience, recharging time, operating time on a charge, and power output.	X	X	X	Proposed R&D and demonstration. The SCAQMD Technology Advancement program has proposed to provide $650,000 as their share of research funding, of a total expected $1,300,000.

Endnotes

1. Stihl engineer; other project funded by New York State Energy Research and Development Authority and Swiss Department of Forestry; Orbital prototype.

2. Woodside Group funded for technology development by major engine manufacturer until 1995.

3. This is an Innovative Clean Air Technology (ICAT). BKM Inc. is developing the technology along with funds from a consortium of engine manufacturers.

4. South Coast AQMD, Technology Advancement Plan, Clean Fuels Program www.aqmd.gov/tao.