THE NEED FOR IMMEDIATE REDUCTIONS IN SHORT-LIVED POLLUTANTS AND THE ADOPTION OF GENERIC "EARLY ACTION" MEASURES

This is a preface to a much longer document that provides information on a wide range of policies and measures that could be adopted to reduce global warming. The purpose of this preface is to highlight two major shortcomings of the staff proposals, to wit:

First, the measures evaluated seems to be restricted to actions focused only on the greenhouse gases listed under the Kyoto Protocol. Such a narrow approach clearly contravenes AB 32, whose authors revised the definition of "greenhouse gas" specifically to assure that short-lived pollutants that cause global warming, such as black carbon, tropospheric ozone and carbon monoxide, would be addressed. Both Senate Pro Tem Perata and Speaker Nunez wrote to Chairman Sawyer to leave no question that there was awareness at the policy level of this coverage.

Second, the proposals are all narrow in scope and ignore generic "early action" measures that could influence behavior broadly. These would include taxes, feebates, labels, liability regimes and the like. While it is understandable that the staff is reluctant to propose possibly controversial initiatives, excluding generic measures from even mention is ill conceived, given the unprecedented risk posed to California and the world by global warming.

Taken together, these two qualities of the proposals bespeak an ignorance of or insensitivity to the rapidly accumulating evidence that several positive feedbacks are underway, increasing the likelihood that one or more tipping points will be reached beyond which the climate under which civilization has evolved will be irretrievably lost. The proposal falls far short of the ambition and vision demonstrated by the legislature's passage of not only AB 32 but nearly a dozen other measures designed to construct a broad-based, muscular response to the threat of global warming. The Board would be well advised to review the breadth and depth of the measures and embrace the sense of urgency and scope evinced by the legislature.

I regret that the longer, principal document is in a draft format. Unfortunately, the time between the announcement of an expanded set of proposed early actions and the deadline for comments did not permit comprehensive revisions and corrections. These are now underway and will be submitted when complete.

Overview of Recommendations

+ Land based motor vehicles

* Reconstitute the zero emission vehicle program, if necessary requiring deployment of advanced technologies in medium- and heavy-duty applications.

* Focus on measures to alter landuse and commuting patterns.

+ Vessels

* Identify a mechanism for, if necessary, piercing international maritime regimes to require global elimination of bunker fuel and adoption of cleaner engines.

+ Aircraft

* Assess the contribution of aircraft to the global burden of black carbon and develop control measures.

+ Electricity generation and fossil combustion

* Impose a single output based feebate reflecting source contributions to global warming and the ill health burden or multiple fees that do the same, with collected fees being rebated to non- or low-polluters.

+ Methane

* Install anaerobic digesters on all waste lagoons, including publicly owned treatment works.
* Install methane gas collection stems on all current or former waste disposal sites of larger than de minimis size.
* Impose a "take back" program requiring vendors to collect product packages and goods, such as tires and appliances, that have reached the ends of their useful lives.

+ Black carbon

* Substitute gasification or other means of waste utilization in lieu of open burning.
* Retrofit all trucks serving the ports of Long Beach, Los Angeles, Oakland, San Francisco and Stockton with control devices.

* * *

Positive Feedbacks that are in Motion

+ Stratospheric cooling in the Arctic and Antarctic.

+ Arctic and Antarctic melting.

+ Tundra and permafrost thawing.

+ Tropospheric ozone increasing.

+ Coral bleaching and death.

+ Phytoplankton declining.

+ Oceans acidifying.

The Need to Reduce Short-Lived Pollutants
That Cause Global Warming

+ Because of the positive feedbacks that are in play, climate benefits need to be realized as quickly as possible.

+ Reducing the long-lived greenhouse gases listed under the Kyoto Protocol will fail to deliver near-term, substantial climate benefits. Except for ozone, their putative lifetimes range from 50 to 50,000 years. Real atmospheric lifetime are actually much longer. The atmospheric concentrations of F-11 and F-12 illustrate this point. Emissions of these two chemicals, which cause both stratospheric ozone depletion and global warming, began as early as the mid-1970s in response to the 1974 Rowland-Molina early warning and accelerated after adoption of the Montreal Protocol in1987. Yet today, atmospheric concentrations of –11 and -12 have declined only a few percent. There will be a similar lag time when emissions of longer-lived greenhouse gases are reduced.

+ Again, the lifetimes of atmospheric pollutants are putative, not real. For example, a gas may be said to have a lifetime of 50 years because 2 percent of it is removed from the atmosphere in one year by, for example, reaction with the hydroxyl radical. However, in the second year, only 2 percent of the remaining 98 percent is removed, not 2 percent of the original 100 percent. Thus, after 50 years, one-third of the original amount remains. After another 50 years, one-third of one-third will remain. As a consequence, truly long-lived pollutants–including carbon dioxide, with a lifetime of 50 to 3,000 years--have, in effect, infinite lifetimes.

+ Reducing emissions of short-lived pollutants that cause global warming will produce climate benefits within months or years. Reductions may or may not be adequate to counter the warming caused by longer-lived gases so they too must be reduced.

+ Some of the shorter-lived pollutants that cause global warming, especially black carbon and tropospheric ozone, disproportionately warm the Arctic, Antarctic and nearby regions. In these regions, reducing emissions of shorter-lived greenhouse gases may offset some of the warming and melting despite increasing concentrations of longer-lived greenhouse gases globally.

+ Reducing emissions and, hence, atmospheric concentrations, of shorter-lived pollutants that cause global warming, will produce health and non-climate environmental benefits because many of them cause human death and illness, as well as forest decline, crop losses and a variety of other damages.

+ Generic requirements

* Regulations are of demonstrated and extreme effectiveness in curbing harmful activities (e.g. the ban on aerosol uses of CFCs and mandated vehicle emission limits). Where specific substances, sources and mitigating acts can be readily identified, regulations should be a preferred tool.

* In contrast, emissions trading schemes have failed in each instance where they have been employed (sulfur dioxide under the 1990 Clean Air Act Amendments, leaded gasoline prior to the 1990 amendments, RECLAIM in southern California, carbon dioxide emissions in Europe, carbon equivalent remissions under the Clean Development Mechanism (CDM) provisions of the Kyoto Protocol, emissions under the California LEV/ZEV program and fuel economy under the Corporate Average Fuel Economy (CAFE) program, to name a few).

* There is widespread sentiment in support of a generic mechanism that would emulate the dynamic nature of the competitive market and place constant, dynamic pressure on polluters to reduce emissions of pollutants that cause global warming. Options that could produce such results if properly drafted could include --

> taxes
> feebates
> labels
> liability
> criminal and civil sanctions
> negotiated agreements

There is one specific class of short-lived pollutants that cause global warming susceptible to immediate action for climate benefits: namely, the industrial gases that destroy stratospheric ozone, chlorofluorocarbons (CFCs), and their substitutes.

The Need to Reduce Emissions of Chlorofluorocarbons
And Their Substitutes That Cause Global Warming

+ Chlorofluorocarbons and their hydrofluorocarbon substitutes destroy stratospheric ozone which, in turn, causes stratospheric cooling.

+ Cooling in the stratosphere causes warming in the troposphere.

+ Because of the extreme cold in the Arctic and Antarctic, stratospheric ozone depletion in those regions is greater than the global average, and reaches an extreme with the springtime creation of the ozone "hole" in the Antarctic. Thus, warming in polar regions is disproportionately caused by CFCs and HCFCs (as well as other short-lived pollutants such as tropospheric ozone and black carbon).

+ The lifetimes of hydrofluorocarbon substitutes for CFCs is short (on the order of 20 years or less), so reducing emissions will reduce concentrations, and thus deliver climate benefits, over a nearer term.

+ Some CFC substitutes (e.g. HFC-134a) that do not destroy stratospheric ozone do cause global warming. Because they have short lifetimes, reducing emissions would produce near term climate benefits.

+ Chlorofluorocarbons, hydrochlorofluorocarbons and their hydrofluorocarbon substitutes are already subject to reductions in production and consumption under the Montreal Protocol, as well as a number of national and multi-national reduction programs. For this reason, substitutes have already been identified and tested and could be rapidly deployed.

+ In addition, HFC-134 is subject to a European Union ban in new cars effective in 1011 and in all cars effective in 2017. German car-makers have announced that their vehicles will use carbon dioxide as a refrigerant.

Actions That Could be Taken to Reduce Emissions of CFCs and the Substitutes that Cause Global Warming

+ The timelines, production and consumption (and thus release into the atmosphere) provisions of the Montreal Protocol were developed in the context of protecting the stratospheric ozone layer, largely ignoring the global warming impacts of CFCs, HCFCs and their substitutes on global warming.

+ As a consequence, production–and therefore emissions–of HCFCs that cause global warming have increased sharply, outstripping earlier projections, at a time when the Kyoto Protocol calls for reductions in emissions of greenhouse gases.

+ The Montreal Protocol was drafted as a non-preemptive instrument so that more stringent requirements could be adopted by individual governments.

+ Although CFCs and HCFCs are scheduled to be eliminated, the deadlines for HCFCs is not until mid-century.

+ "Banked" CFCs, HCFCs and other substances that cause global warming are not currently required by international agreement to be captured and destroyed. Future emissions, and therefore atmospheric concentrations, could be reduced by instituting a global requirement for capture and destruction of CFCs, HCFCs, HFCs and other substitutes that cause global warming. Many of these are "banked" in refrigerators, air conditioners, rigid foams and other places.

+ Some nations, most notably Germany, require banked ozone-destroying gases to b e captured and destroyed at the time of disposal (although enforcement of this requirement is said to have been spotty).

+ Europe has adopted a ban on the use of HCF-134 in new cars in 2011 and in all cars in calendar year 2017. German manufacturers have developed mobile air conditions that use carbon dioxide as a refrigerant.

+ On the theory that use of ozone-destroying chemicals as "feedstocks" consumes CFCs and therefore results in only insignificant releases to the atmosphere, such uses are exempted from the Montreal Protocol. In fact, substantial amounts of substances that cause ozone destruction or global warming (e.g. HFC-23) are being vented, when they could be captured and destroyed with relative ease and comparatively little expense.

+ Current bans on production and release of CFCs are being circumvented by smuggling and other illegal activities. Il-legalizing CFCs and HCFCs altogether would facilitate enforcement of prohibitions.

Conclusions

+ CFCs and HCFCs

* Ban releases of CFCs and HCFCs, effective Jan. 1, 2010.
* Prohibit use of HCFCs except in a totally enclosed manner, effective Jan. 2015.
* Prohibit production of HCFCs, effective Jan. 1, 2015.

+ HFCs
  * Ban releases HFC-134, effective Jan. 1, 2010.
  * Ban production of HFC-134, effective Jan. 1, 2015.

Twenty years ago, the world stood with respect to stratospheric ozone depletion in much the same position that it does today with regard to global warming. There are lessons to be learned from our experience in 1987 and the intervening years that can usefully be applied today as the reality of global warming has become indisputable.

There were scientists then who insisted then that stratospheric ozone depletion was a fraud. Some of those same scientists not only continue to maintain that ozone depletion is a fraud, but say the same is true of global warming. In 1997 the arguments and conclusions of naysayers--who today in the context of global warming like to call themselves “skeptics” or “contrarians”-- were rejected by the mainstream science community and policy makers throughout the world, and so, too, should they be spurned today. They are simply wrong, and to heed their advice would place the world at grievous risk–a proposition that we as a global community chose to reject 20 years ago, as we should now.

The world’s experience in reducing emissions of ozone-depleting chemicals is also instructive in the context of global warming. The atmospheric lifetimes of the most powerful ozone destroyers, F-11 and F-12, are more than a century. So, too, is this the case with the greenhouse gases listed under the Kyoto Protocol. Except for methane, their lifetimes range from 50 to 50,000 years.

Moreover, these "lifetimes" are apparent, not real. A substance may be said to have a lifetime of 50 years because 2 percent of its atmospheric concentration is removed annualy. However, in the second year, two percent of the remaining 98 percent--as opposed to the original 100 percent--is removed. At the end 50 years, the amount remaining in the atmosphere is one-third of the original 100 percent. For substances with truly long lifetimes, the true removal period is infinity, or forever.

Reductions in emissions of F-11 and F-12 first started after the publication in 1974 of the papers in which Drs. Molina and Rowland concluded that these chemicals were destroying stratospheric ozone. The United States banned their use in aerosols, which reduced U.S. releases by about one-third.

Emission reductions accelerated after adoption of the Montreal Protocol in 1987. Despite the rapid and steep reductions in emissions in the 33 year period, however, atmospheric concentrations of F-11 and F-12 have declined only a few percent. Yes, the ozone layer is recovering. And, yes, the Antarctic ozone hole seems to be stabilizing and recovering. But ozone-destroying industrial chemicals will never be fully washed from the global atmosphere.

The same is true in the context of global warming. If emission reductions are focused wholly on carbon dioxide and the other long-lived greenhouse gases, climate benefits will be realized only in the distant future.

Nature provided humanity with a warning in the 1980s: the Antarctic ozone hole. Levels of ozone drop precipitously in only a few days because the temperature drops to levels that trigger solid phase chemistry. Ozone does not simply decline. It drops precipitously, creating an essentially ozone-free environment that is roughly the size of North America and the height of Mt. Denali.

Such step-wise changes are the rule in nature, not the exception. Recent findings suggest that positive feedbacks that can cause such runaway reactions have begun with respect to global warming: there is stratospheric cooling in the Arctic and Antarctic, melting in the Arctic and Antarctic, thawing of tundra and permafrost throughout the Arctic regions, increased formation of tropospheric ozone, bleaching and death of coral, declines in phytoplankton and acidification of oceans.

To fend off the threat of changes in climate comparable to the destruction that triggers the Antarctic ozone hole requires a focus on pollutants that, directly or indirectly, cause global warming that have short lifetimes. These include methane, tropospheric ozone, carbon monoxide, black carbon and, of course, the HCFCs and the CFC substitutes.

Policies addressing CFCs, HCFCs and their substitutes developed largely in isolation of their impacts on global warming. In retrospect, that was a mistake. HFC-134 is a powerful greenhouse gas, and its contribution to global warming today could have been avoided had that been taken into account in the wake of the Montreal Protocol, and a different refrigerant adopted. F-22, which was widely viewed as the transition substitute, is also a powerful greenhouse gas.

Because F-22 is subject to a global phaseout and because -134 is subject to a ban on its use in Europe, substitutes have been developed and could be deployed on an accelerated timetable.

We believe it is now time to harness reductions in emissions of CFCs, HCFCs and their replacements to the cause of global warming. Specifically, it is time to –

+ With respect to CFCs and HCFCs

* Ban releases of CFCs and HCFCs, effective Jan. 1, 2010 or sooner.
* Prohibit use of HCFCs except in a totally enclosed manner, effective Jan. 2015 or sooner.
* Prohibit production of HCFCs, effective Jan. 1, 2015 or sooner.

+ With respect to HFCs

* Ban releases HFC-134, effective Jan. 1, 2010 or sooner.
* Ban production of HFC-134, effective Jan. 1, 2015 or sooner.

+ With respect all of the above --

* Adopt programs that require all products, including refrigerators, air conditioners, motor vehicles foams and other products containing more than a de minimis amount of such substances to be disposed of only in a certified facility that removes and destroys the substance, starting January 1, 2009 or sooner.

We are scientists not makers of public policy. But we are also a residents of the planet, as we were in 1974 and in 1987.

Twenty years ago, the residents of the world collectively acknowledged the threat to the planet and humanity posed by industrial chemicals that were destroying a fundamental element in which life evolved and resolved to act, thus stepping back from the brink of grave injury. Today, it is time to reaffirm that human actions can alter the global environment for the worse–and to, once again, step back from the brink. We can, and should, do that once more by attacking today the same chemicals that were addressed 20 years ago–but better.

The largest single obstacle to eliminating emissions from motor vehicles is the status quo. Change, however preferable it might seem from a health or environmental perspective, is invariably—and perhaps correctly--viewed as a threat, especially by established industries such as vehicle manufacturers and petroleum refiners. This, in turn, impedes our ability to evaluate emissions control options, such as the infusion of zero emitting vehicles.

Trends in Total Particle Number Emissions from Vehicles and Aircraft

Using fuel sales for jets and VMT for vehicles, trends in the emission of total number of particles are identified.

VEHICLES

Approach

Total volume and number concentrations of particles in engine exhaust were reported for a number of modern (post-1990) and older (pre-1990) heavy-duty (HD) and light-duty(LD) diesel and SI engines [1]. Assuming a particle density of 1 g/cc across the particle size range, the total number of particles per gram of PM emitted may be calculated. Emission factors (g/mi) for similar technology are also available in the literature. Specifically, emission factors for $PM_{2.5}$ for modern (1995-present) heavy- and light-duty engines were recently reported by HEI [2]. Emission factors for $PM_{2.5}$ for older (pre-1995 engines) heavy- and for $PM_{2.0}$ for light-duty (1977-1983 catalyst-equipped cars) have been reported by Gertler et al. and Hildemann et al., respectively [3, 4]. The emission factors and the particle number emissions per gram of PM emitted allow for the estimation of total particle number emissions per mile traveled. When multiplied by VMT, a trend in the total number of particles emitted over time as the technology has evolved may be calculated.

Although it is recognized that emission factors vary greatly across the fleet, which contributes to the VMT's reported, some simplifications and broad assumptions were necessary in order to make the calculations in this document manageable. One assumption was the use of fleet average emission factors illustrated in Figure 1 a,b and taken from the citations given above. These values are also given in Table 1 and are believed to be extremely conservative and almost surely under-estimate true emissions.

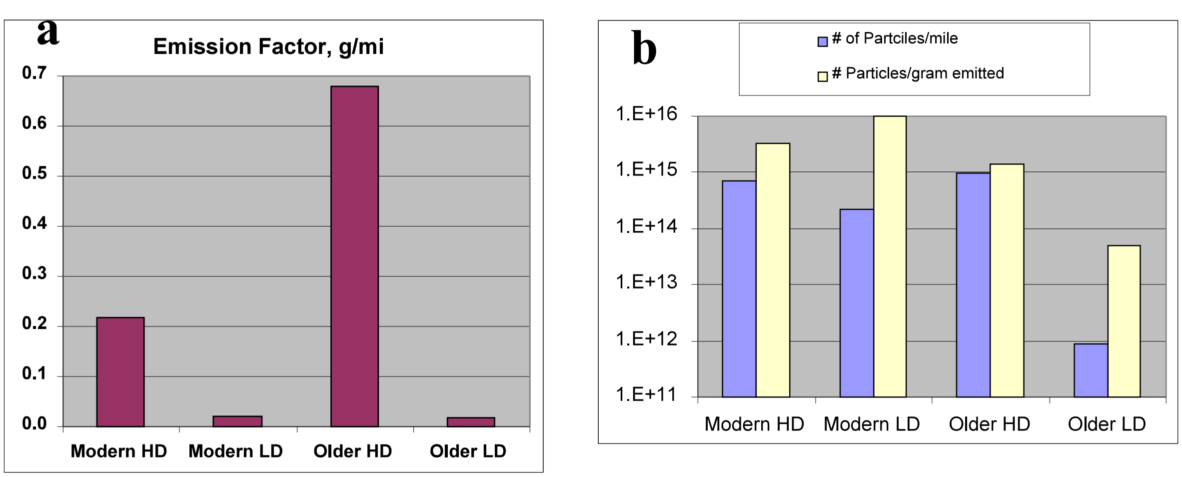


Figure 1 a,b. Assumed Emission Factors for the HD and LD Fleet. *Numbers apply to both US and CA fleets.*

Volume and Number Concentrations

Similarly, volume and number concentrations vary greatly as a function of engine and operating conditions. In this analysis, conservative concentrations, illustrated in Table 1, were chosen from the available data [1]. These were measurements conducted with an Electrical Aerosol Analyzer for engines ranging from 1970 to 1995 models. The volume concentrations for modern HD diesel engines ranged from approximately 300 m^3/cc to nearly 8,000 m^3/cc. These values were measured from a 1995 and a 1991 DI diesel engine. For older HD diesel engines, measurements for a 1970 IDI diesel, a 1984 IDI diesel, and a 1988 DI diesel ranged from approximately 2,000 m^3/cc to 200,000 m^3/cc. The volume concentrations for SI LD engines came from measurements on a 1970 and a 1993 engine. The modern 1993 engine had volume concentrations from nearly 10 m^3/cc to 200 m^3/cc. In contrast, the older 1970 SI engine had emissions of 1,000 m^3/cc to 100,000 m^3/cc.

Table 1. Engine Emission Parameters Found in Existing Literature.

MODERN ENGINES, > 1990's				
	units	**Heavy-duty**	**Light-duty**	**Ref.**
Emission Factor	**g/mi**	**0.217**	**0.022**	**2**
Volumen Concentration	**µm3/cc**	**3000**	**50**	**1**
Number Concentration	**#/cc**	**1.0E+07**	**5.0E+05**	**1**
No. part./unit mass	**#/g**	**3.3E+15**	**1.0E+16**	
Number emission factor	**#/mi**	**7.2E+14**	**2.2E+14**	
OLDER ENGINES, ~1980's and older				
Emission Factor	**g/mi**	**0.678**	**0.018**	**3, 4**
Volumen Concentration	**µm3/cc**	**5.0E+04**	**1.0E+04**	**1**
Number Concentration	**#/cc**	**7.0E+07**	**5.0E+05**	**1**
No. part./unit mass	**#/g**	**1.4E+15**	**5.0E+13**	
Number emission factor	**#/mi**	**9.5E+14**	**9.0E+11**	

The number concentrations for the same engines cited above also varied widely as a function of engine type and operating conditions. One exception was the SI 1970 engine, for which values were not reported. The modern diesel engine number concentrations ranged from 10^7 to 10^9. 10^9 number concentrations were those observed by Bagley et al. (1996) in their HEI work [5]. The older technology diesel emitted similar number concentrations and these ranged from 2X10^7 to 2X10^8. Number concentrations for SI engines were only available for the 1993 unit. These ranged from 2X10^5 to 10^6.

Example

In a conservative approach, we assume that the lower number concentration of 10^7 part./cc is representative of all modern diesel engines in the fleet. Similarly, the volume concentration for a modern diesel engine is on the order of 3000 m^3/cc. The resulting total number of particles, *n*, per gram of particulate matter, *m*, emitted assuming a spherical particle of average unit density, 1 g/cc may be determined as follows:

$$[(10^7 \text{ \#/cc}) / (3000 \text{ m}^3\text{/cc})] \text{ X } (10^{12} \text{ m}^3\text{/cc}) = 3.3\text{E}^{15} \text{ particles/gram}$$

The number emission of particles per unit mass may be calculated for the light-duty fleet in a similar approach. Assumed values and results were summarized in Table 1.

Results

If we then multiply the number of particles per gram of PM by the corresponding emission factor and VMT, an estimate of the total number emission trends due to on-road sources may be obtained. The VMT's for vehicles in the US and in California are illustrated in Table 2 [6]. For the CA fleet, the total VMT's by type of vehicle and model year corresponding to the present exercise is shown in Table 3.

Table 2. VMT Trends.

VMT (miles)				
year	US heavy-duty	CA heavy-duty	US light-duty	CA light-duty
1960	2.89E+10	1.33E+09	5.87E+11	6.89E+10
1970	6.22E+10	2.19E+09	9.20E+11	1.13E+11
1980	1.08E+11	6.47E+09	1.12E+12	1.35E+11
1985	1.24E+11	1.08E+10	1.26E+12	1.79E+11
1990	1.46E+11	1.50E+10	1.42E+12	2.20E+11
1996	1.83E+11	1.42E+10	1.47E+12	2.32E+11
1999	2.03E+11	1.36E+10	1.57E+12	2.48E+11

Table 3. CA Fleet.

Statewide Daily Vehicle Miles Traveled / 1000

	Model Years Pre-1990		Model Years 1990-1999	
Calendar Year	Light Duty	Heavy Duty	Light Duty	Heavy Duty
1960	188,837	3,653	n/a	n/a
1970	309,693	5,991	n/a	n/a
1980	368,751	17,723	n/a	n/a
1985	491,350	29,641	n/a	na/
1990	530,789	36,753	72,362	4,454
1996	308,752	20,399	327,284	18,469
1999	234,114	13,806	444,616	23,450

Sources: Draft EMFAC2001 V 2.08;
VMT for CY1960 estimated from information in Caltrans Motor Vehicle Stock, Travel and Fuel Forecast, 2001 edition

Figure 1 shows a comparison of the VMT trends for the diesel and gasoline fleets in CA and in the US. For both categories, the VMT's steadily increased over time, with the gasoline vehicle VMT being approximately one order of magnitude larger than HD VMT's for the US. In CA, LD VMT's in 1960 were nearly two orders of magnitude larger than HD. In time, this difference decreased. Presently, VMT's for the HD section of the fleet included in this analysis appear to level off due to a downward trend in the VMT for the older models. The figure also shows that over the same time period, HD VMT's have increased at an accelerated pace relative to LD VMT's.

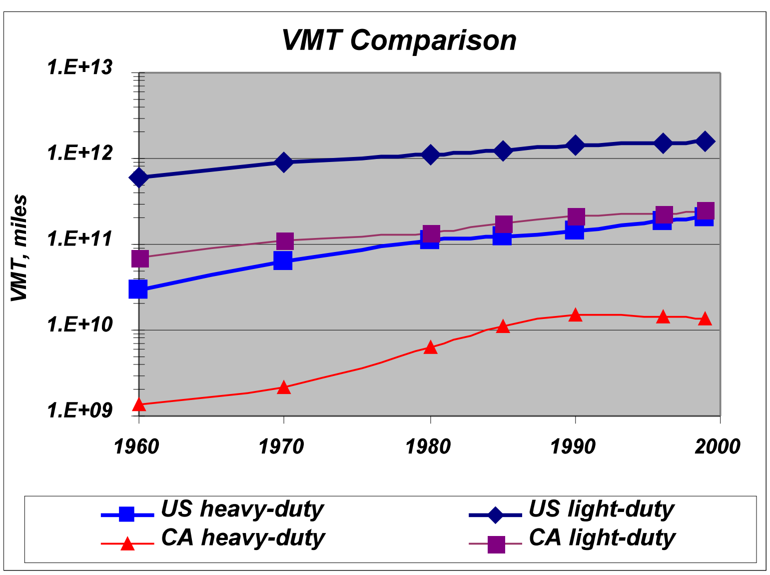


Figure 1. VMT Trend Comparison for Heavy- and Light-duty Fleets.

The trend in total particle emissions for gasoline vehicles considering CA VMT's only is illustrated in Figure 2. Although total VMT's for the US fleet exist, the characteristics of the US fleet given in the format of Table 3 were not available. Thus, from this point forward, discussions will pertain to the CA fleet explicitly. Initially, the total number of particles emitted was in proportion to VMT. In this analysis, the period from 1985 to 1990 represents the transition from older to modern technology SI engines. And, for the number concentrations to be the same, modern SI engines, even those equipped with catalyst, which have significantly lower volume concentrations (i.e., lower mass emissions) must emit nearly three orders of magnitude more particles per gram of total PM. Table 3 offers the calculated values for the previous results.

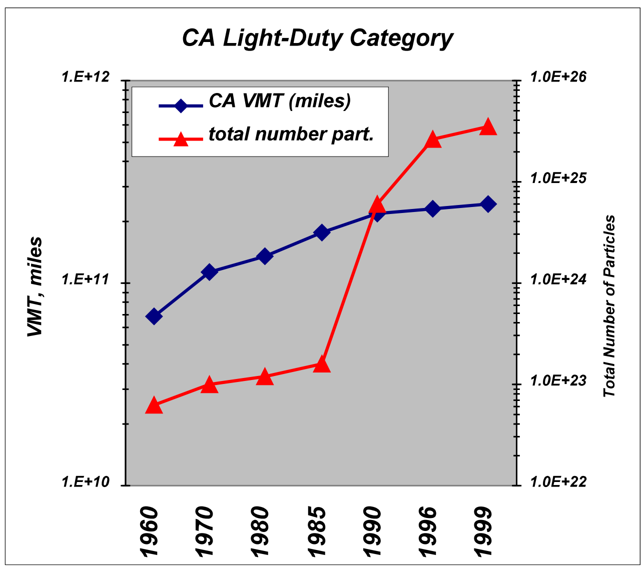


Figure 2. Trend in Total Emission of Particles (number) for CA Light-duty Fleet.

Table 3. Calculated Particle Emissions Based on CA VMT Trends, Emission Factors, and Number and Volume Concentrations reported in the Literature.

Total Particle Number Emissions in California		
year	*heavy-duty*	*light-duty*
1960	*1.27E+24*	*6.20E+22*
1970	*2.08E+24*	*1.02E+23*
1980	*6.14E+24*	*1.21E+23*
1985	*1.03E+25*	*1.61E+23*
1990	*1.39E+25*	*5.99E+24*
1996	*1.19E+25*	*2.64E+25*
1999	*1.10E+25*	*3.58E+25*

Similar results for the diesel HD contributions are shown in Figure 3. In the case of the HD fleet in CA, on a per mile basis, both modern and older emit an equivalent number of particles per mile traveled. The apparent reduction in total particle number results from a combination of the reduction in g/mi emissions for modern engines and the decrease in older HD VMT's.

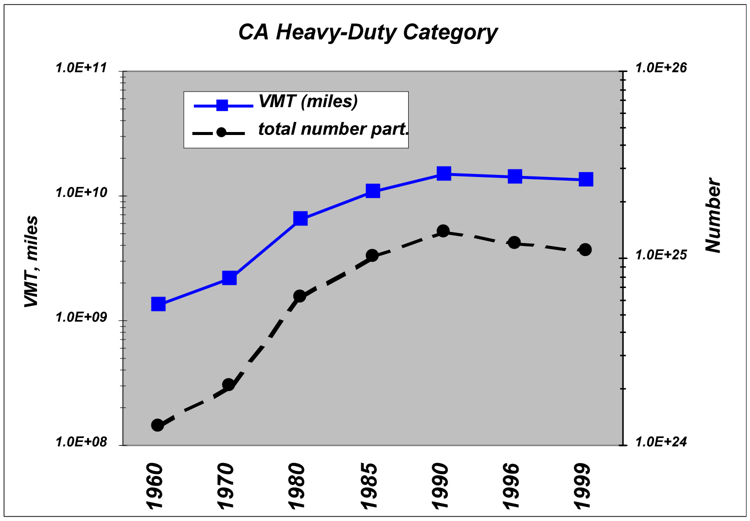


Figure 3. Trend in Emission of Particle (number) for CA Heavy-duty fleet.

Figure 4 illustrates a comparison of total particle emission trends approximately for diesel and gasoline vehicles. Although historically diesel particle number emissions have been consistently higher than gasoline emissions, the combination of more VMT's for gasoline vehicles and the emission of a larger number of particles per mass of particulate matter emitted by modern light-duty engines has contributed to a consistent increase in recent years. The increase in VMT and number of particle per unit mass have overwhelmed the significant reductions in mass emissions per distance traveled for late-model gasoline vehicles.

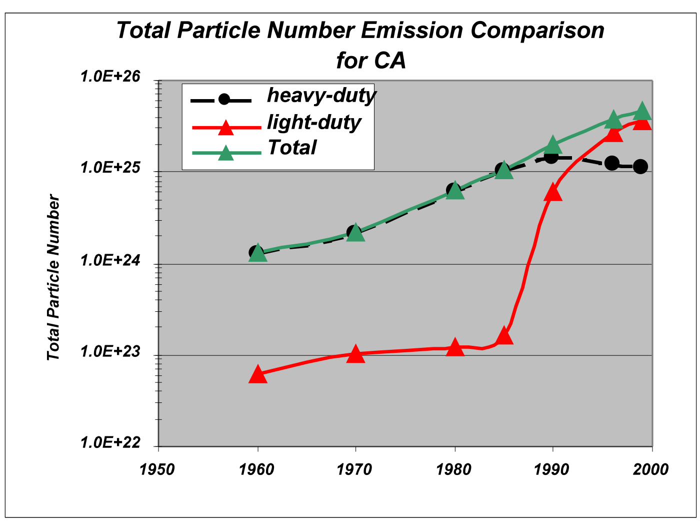


Figure 4. Particle Number Emission Trend Comparison for Heavy- and Light-duty Fleets.

JET ENGINES

The projection of particle number emissions from jet engines is simplified when using the number of particles emitted per unit mass of jet fuel used, which have been reported [7]. If this emission factor is assumed constant as a first-order approximation and multiplied by the total jet fuel use in the US, then the contribution of jet engines to the total particle number emissions may be calculated. The assumed values for specific gravity of jet fuel is 0.81 and the emissions of ultrafine particles from aircraft are on the order of 2×10^{15} particles/kg of fuel [7, 8]

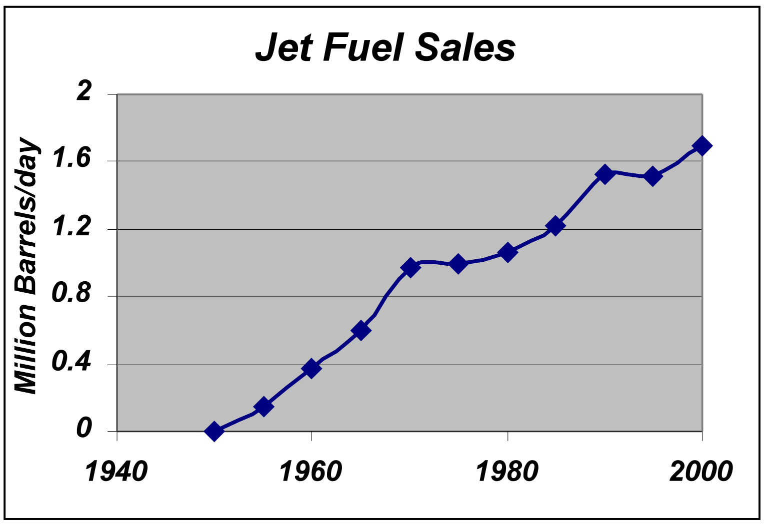


Figure 5. End-Use Sector Jet Fuel Use Trend.

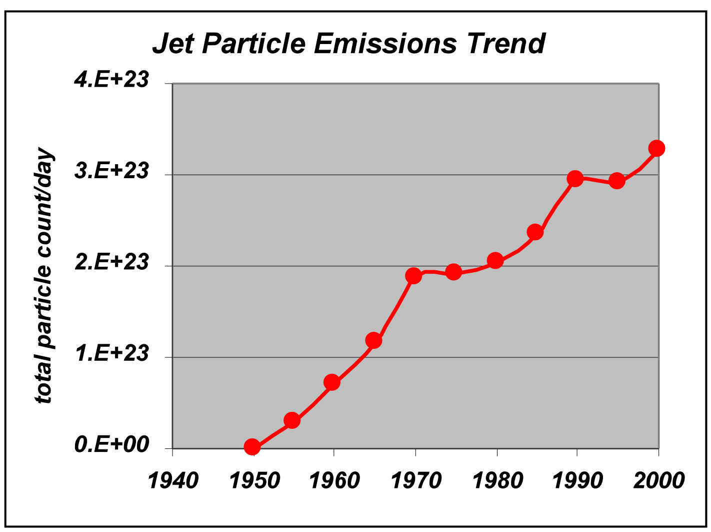


Figure 6. Trend of Particles in Aircraft Exhaust.

REFERENCES

1. Kittelson, D. B. (1998). "Engines and Nanoparticles: A Review," *J. Aerosol Sci.,* **29**, 5/6, pp. 575-588.
2. Gertler et. al., 2002, HEI Report 107.
3. Gertler et al., 1995a
4. Hildemann et al.
5. Bagley, S.T., Baumgard, K.J., Gratz, L.G., Johnson, J.H., and Leddy, D.G. (1996) Characterizatoin of fuel and aftertreatment device effects on diesel emissions. Health Effects Institute (HEI), Research Report No. 76.
6. Baumgard and Johnson (1996)
7. Ward's Motor Vehicle Facts and Figures 2001, Travel Trends, Vehicle Miles of Travel and Fuel Consumption, pp. 70 – 71.
8. Karcher, B., R.P. Turco, F. Yu, M.Yu, M.Y. Danilin, D.K. Weisenstein, R.C. Miake-Lye, and R. Busen. (2002), "A Unified Model for Ultrafine Aircraft Particle Emissions," *J. of Geophy. Res.,* **105**, D24, pp. 29,379-29,386.
9. Material Safety Data Sheet, Chevron Jet Fuel, http://library.cbest.chevron.com

APPENDIX

Total Particle Number Emissions in California			
year	heavy-duty	light-duty	Total
1960	1.27E+24	6.20E+22	1.33E+24
1970	2.08E+24	1.02E+23	2.18E+24
1980	6.14E+24	1.21E+23	6.26E+24
1985	1.03E+25	1.61E+23	1.04E+25
1990	1.39E+25	5.99E+24	1.99E+25
1996	1.19E+25	2.64E+25	3.83E+25
1999	1.10E+25	3.58E+25	4.68E+25

CALIFORNIA NUMBERS

HEAVY-DUTY (trucks)		
year	VMT (miles)	total number part.
1960	1.33E+09	1.27E+24
1970	2.19E+09	2.08E+24
1980	6.47E+09	6.14E+24
1985	1.08E+10	1.03E+25
1990	1.50E+10	1.39E+25
1996	1.42E+10	1.19E+25
1999	1.36E+10	1.10E+25
LIGHT-DUTY (passenger cars)		
year	CA VMT (miles)	total number part.
1960	6.89E+10	6.20E+22
1970	1.13E+11	1.02E+23
1980	1.35E+11	1.21E+23
1985	1.79E+11	1.61E+23
1990	2.20E+11	5.99E+24
1996	2.32E+11	2.64E+25
1999	2.48E+11	3.58E+25

	Jet Fuel				
Year	Million Barrels/Day	Barrels/Day	liters/day	kg/day	part./day
1950	0	0	0	0	0
1955	0.15	150,000.00	1.8E+07	1.4E+07	2.9E+22
1960	0.37	370,000.00	4.4E+07	3.6E+07	7.1E+22
1965	0.6	600,000.00	7.2E+07	5.8E+07	1.2E+23
1970	0.97	970,000.00	1.2E+08	9.3E+07	1.9E+23
1975	0.99	990,000.00	1.2E+08	9.5E+07	1.9E+23
1980	1.06	1,060,000.00	1.3E+08	1.0E+08	2.0E+23
1985	1.22	1,220,000.00	1.5E+08	1.2E+08	2.4E+23
1990	1.52	1,520,000.00	1.8E+08	1.5E+08	2.9E+23
1995	1.51	1,510,000.00	1.8E+08	1.5E+08	2.9E+23
2000	1.7	1,700,000.00	2.0E+08	1.6E+08	3.3E+23

In an attempt to assess what gains in emissions reductions could be achieved by a quite gradual deployment of zero emitting vehicles, we developed a scenario in which they were first required of heavy, medium and light-duty fleets of vehicles that are or could be centrally fueled and travel fixed routes (e.g. school buses, delivery vans, etc.). Then, ZEV requirements were gradually extended to the fleet as a whole, according to the following scenario:

+ Assume that starting in 2005, transit and school buses will be replaced by ZEV fuel cell buses, starting at 1 percent per annum in the> fist year, 2 in the second, and so on, reaching 10 percent per annum in2005.

+ Assume that starting in 2009, 1 percent of medium and light duty vehicles that are in heavy use and centrally fueled--UPS vans, taxis, etc.--will be replaced by ZEV fuel cells.
+ Assume that by 2014 road-ready fuel cell ZEVs are available and so are hydrogen refueling stations (of course, we know that they're available now, the obstacle is cost) for the full range of road applications: heavy, medium and light duty

+ Assume that starting in 2014, ZEVs will be phased in for the entire light duty fleet, starting, with 10 percent of sales, then 20 percent, etc. completing fleet turnover by 2024.

This scenario was modeled using the California on-road motor vehicles emissions model (EMFAC). The complete results are displayed below. In brief, however, they demonstrate that with 100 percent penetration of the light duty fleet by ZEVs in 2030, emissions would be reduced by 29 to 45 percents, depending on the pollutant for conventional pollutants. Assuming that carbon monoxide bears the closest relationship to carbon dioxide, the CO2 reduction would be 45 percent from 2030 baseline.

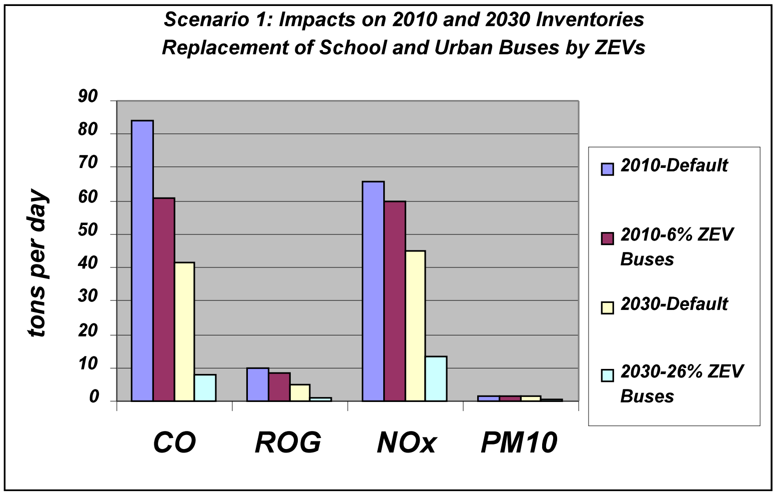
Cost

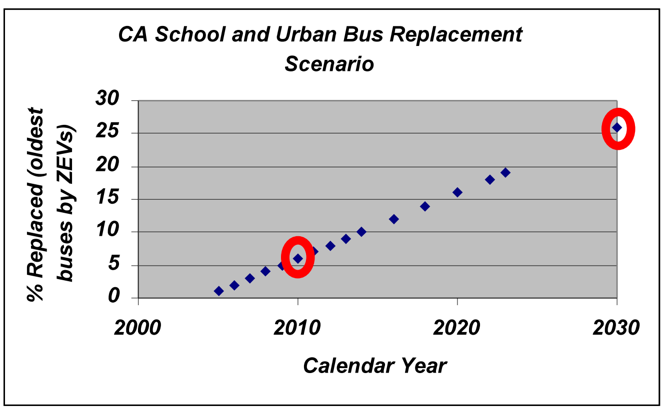
Of course, the principal objection to the adoption of fuel cell-hydrogen or similar ZEV technologies is cost. However, it is quite clear—indisputable, in fact—that as experience increases, per unit costs fall dramatically. Consider, for example, the experience with solar photovoltaics (insert graph from http://www.etsap.org/newslet/issue5/img/1.gif), wind turbines (graph from http://www.iset.uni-kassel.de/extool/2_3_Durstewitz.pdf) or generic technologies (insert graph from http://www.netmba.com/strategy/experience-curve/)
In each case, provide the website as a footnote.

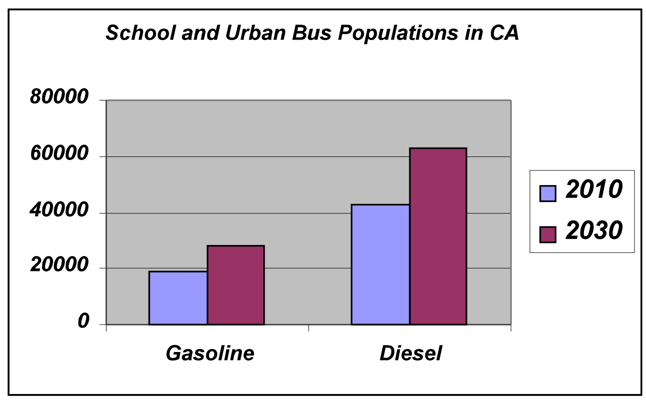
Money, of course, is merely one way of measuring cost and, in some respects, the least helpful because it excludes human values such as health and, indeed, species survival.

Scenario 1: Replacement of transit and school buses by ZEVs starting in

2005







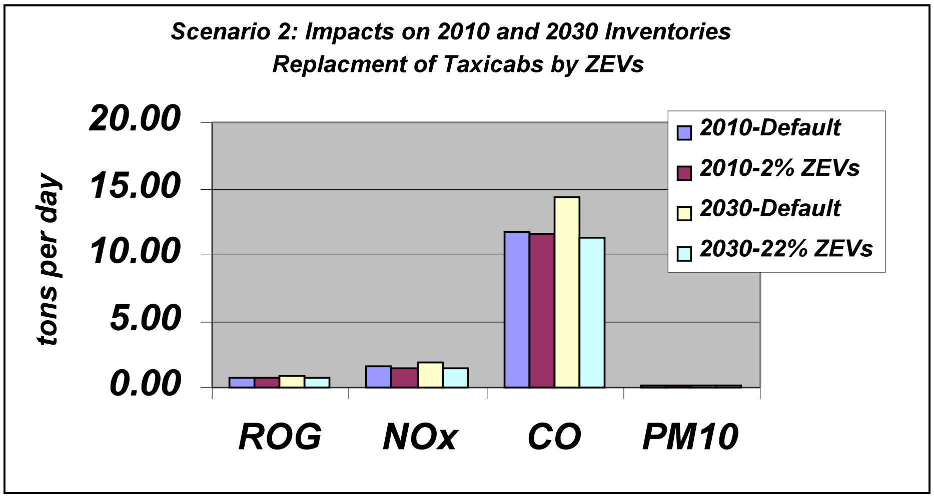
tons/day

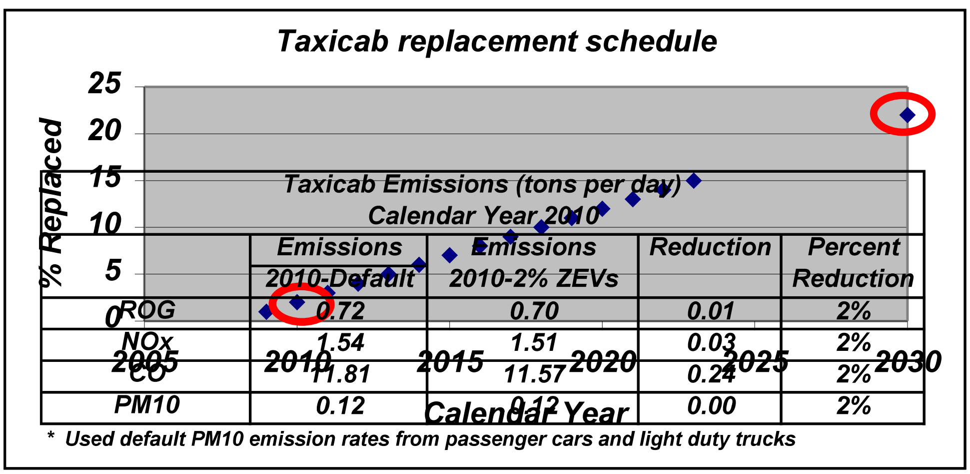
	CY2010 Urban + School Bus Emissions			
	2010-Default	2010-6% ZEV Buses	Difference	Diff (%)
CO	84.2	60.58	23.62	28%
ROG	10.1	8.64	1.46	14%
NOx	65.67	59.84	5.83	9%
PM10	1.5	1.38	0.12	8%

tons/day

	CY2030 Urban + School Bus Emissions			
	2030-Default	2030-26% ZEV Buses	Difference	Diff (%)
CO	41.72	7.67	34.05	82%
ROG	4.75	1.13	3.62	76%
NOx	44.83	13.38	31.45	70%
PM10	1.33	0.69	0.64	48%

Scenario 2: Replacement of Taxicabs by ZEVs starting in 2009





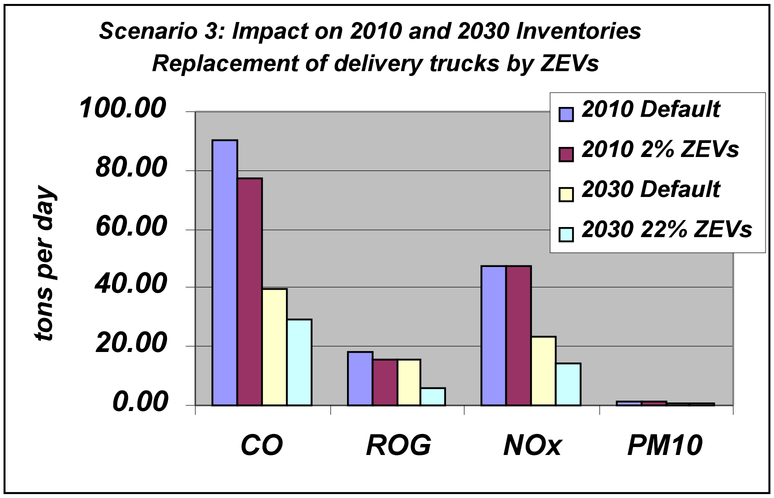
Taxicab Emissions (tons per day) Calendar Year 2010				
	Emissions 2010-Default	Emissions 2010-2% ZEVs	Reduction	Percent Reduction
ROG	0.72	0.70	0.01	2%
NOx	1.54	1.51	0.03	2%
CO	11.81	11.57	0.24	2%
PM10	0.12	0.12	0.00	2%

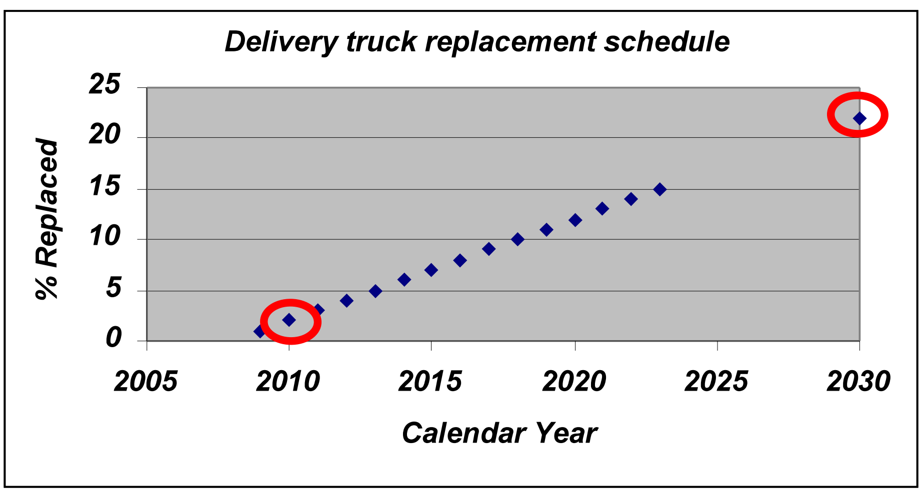
* Used default PM10 emission rates from passenger cars and light duty trucks

Taxicab Emissions (tons per day) Calendar Year 2030				
	Default 2030-Default	Emissions 2030-22% ZEVs	Reduction	Percent Reduction
ROG	0.88	0.68	0.19	22%
NOx	1.88	1.46	0.41	22%
CO	14.41	11.24	3.17	22%
PM10	0.15	0.12	0.03	22%

* Used default PM10 emission rates from passenger cars and light duty trucks

Scenario 3: Replacement of Delivery Trucks starting in 2009
These are light heavy-duty vehicles (GVW between 8501 and 14,000 lbs)





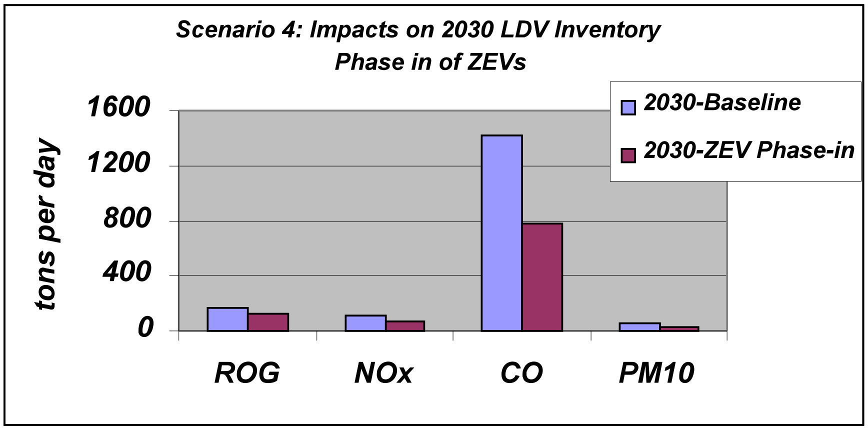
2010 and 2030 Gasoline and Diesel Truck (8,501 - 14,000 lbs GVWR) Emissions (in tons per day) with 2% and 22% ZEV Populations, Respectively

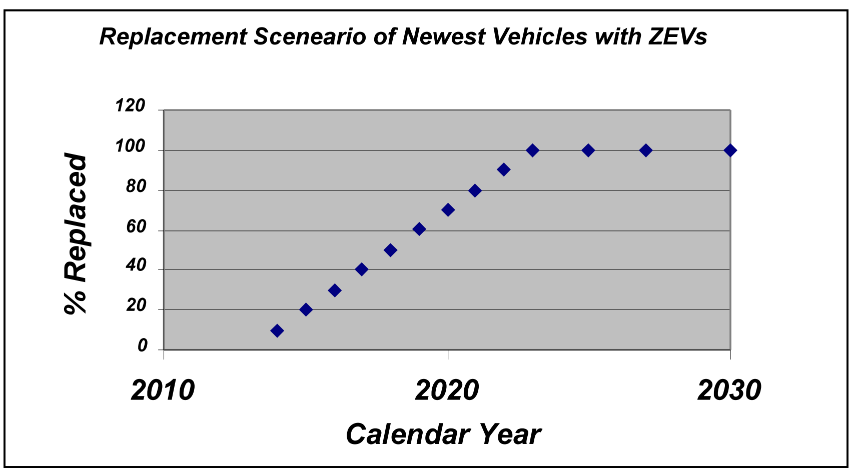
	2010 Default	2010 2% ZEVs	2030 Default	2030 22% ZEVs
CO	90.30	76.96	39.52	29.17
ROG	18.45	15.67	15.49	5.97
NOx	47.69	47.14	23.10	14.04
PM10	1.010	1.000	0.900	0.810

** Assume ZEV trucks replace oldest trucks in fleet*

*** Only the Exhaust portion of PM10 was reduced by the Zev percentages; default values of tire and brake PM10 were used*

Scenario 4: Replacement of LDVs by ZEVs starting in 2014





Light Duty Fleet Emissions (tons per day)
Calendar Year 2030
ZEV Phase-in from 2014-2023; 100% ZEVs thereafter

	2030-Baseline	2030-ZEV Phase-in	Reduction	Percent
ROG	173.7	123.7	50.0	29%
NOx	107.4	68.3	39.0	36%
CO	1417.2	774.8	642.4	45%
PM10	49.9	28.4	21.5	43%

Transport: Reducing the Use of Vehicles

Until zero emitting vehicles become a reality, emissions from cars, trucks and buses–especially cars--will be a factor of two variables:

The amount of pollution a vehicle emits each mile it is driven; and,

The number of miles it travels.

This section focuses on the second of these two factors, exploring measures and technologies that can reduce travel, principally of cars and light trucks.

Americans drive as much as they do because they have no choice. Possibly some prefer sitting behind the steering wheel in bumper-to-bumper traffic crawling along a multi-lane interstate highway, but the vast majority would be just as happy to make the journey from point A to point B with the same speed, safety, comfort and convenience of driving a car, especially if it saved money. There are some places where that can be done, and a few are in the United States.

The Health Benefits of Reducing Traffic

A natural experiment in Atlanta demonstrated unequivocally that reducing vehicle traffic by increasing trasit ridership would have immediate and substantial health benefits. This occurred in 1996, when the summer Olympics were held in Atlanta.

Anxious to lessen the typical summer levels of smog, some of the nation's worst, Atlanta officials asked drivers to park their cars. They also closed the downtown area to car traffic, added buses and trains, and aggressively promoted flexible work schedules, car-pooling, and telecommuting. It all worked.

Weekday 1-hour morning peak traffic counts in Atlanta decreased 22.5 percent overall during the Olympic Games, while public transit ridership rose 217 percent. Peak ozone concentrations fell by 13 percent, and so did visits to hospital, doctors and emergency rooms for asthma complaints. Among children aged 1 through 16 in the Medicaid claims files, the number of asthma emergency care visits declined 41.6 percent. Among HMO enrollees, the decrease was 44.1 percent, while citywide hospitalizations for asthma were off 19.1 percent and visits to the two pediatric emergency departments dropped 11.1 percent.[1] (These improvements in public health occurred even though the levels of ozone and other pollutants were below the health-based standards established by the Environmental Protection Agency for criteria pollutants.[2])

Other studies have confirmed this relationship between traffic volume and health.

A 15-year study in Toronto that compared daily hospital records with pollution levels found that when ozone rose, so did emergency or urgent care admissions for croup, pneumonia, asthma and acute bronchitis/bronchiolitis.[3] A similar study in Brisbane of 41,127 hospital admissions between 1987 and 1994 found that "Ozone was consistently associated with admissions for asthma and respiratory disease – with little evidence of a threshold."[4] Researchers in Houston, Texas found a similar association between increased ozone and emergency room visits for asthma.[5]

For adults with severe asthma, the risks are even greater. In Barcelona, researchers followed 1,078 severe asthmatics who visited a local emergency room. When ozone levels were higher, so was their risk of dying.[6] In Paris, a panel of 60 severe adult asthmatics were followed over a 13-month period. When ozone concentrations increased, asthma attacks rose, each of which was verified by an attending physician.[7] Similarly, the need for for medication by asthmatic children attending summer camp was directly related to the ozone levels.[8]

System Descriptions

There are four general methods of reducing VMT:

Alter land use patterns;

Internalizing the full costs of vehicle operation;

Managing traffic; and,

Enhancing public transportation systems and their use.

Altering land use patterns. Research clearly shows that gasoline use increases as urban density decreases, simply because people have farther to travel. Land use patterns can be changed in ways that significantly reduce vehicle miles traveled while improving quality of life with nearby amenities, pedestrian malls and preserved undeveloped land. There are many ways to go about this, including limiting development on urban fringes; offering location-specific mortgages that reward homeowners for buying in certain areas; creating more densely populated, mixed-use neighborhoods; changing vehicle rights-of-way to pedestrian malls, reducing the number of parking spaces and encouraging telecommuting.

Internalizing costs. Internalizing the costs of driving means shifting the burdens created by traffic from the victim to the consumer. Currently, the externalized costs of driving–death and illness due to air pollution, for example--in the U.S., in the form of both explicit and implicit subsidies, are estimated to range from $3.00 to $7.00 per gallon of gas consumed.

One example of these costs is "free" parking. In the U.S., roughly 90 percent of employee parking is either subsidized by the employer or is free. Many areas have begun to increase the cost of parking to drivers, thus internalizing the costs. Alternatively, some employers have implemented "cash out" policies, providing employees with the cash value of parking. This removes the cost of parking and allows employees to spend the money on other modes of travel. The Tax Relief Act of 1997 changes the U.S. tax code to allow employees to accept cash in lieu of parking benefits.

Other externalized costs of driving include the costs of local roads; policing and motorist protection; uninsured accidents; noise; vibration damage to structures; pollution damage to human health, crops and structures; and petroleum industry subsidies. In many countries, gasoline taxes internalize far more of these costs than in the U.S. In 1996, Americans paid an average of $1.28/gallon, while Canadians paid $1.80, Germans paid $4.32, Britons paid $3.47, the French paid $4.41, Japanese paid $3.77 and Indians paid $2.25. On average, European fuel taxes are five to ten times higher than U.S. taxes. In some cases, there are special levies on vehicles and their operation expressly designed to shift the monetary burden from the public to drivers. In Sweden, for example, motor vehicles are taxed differentially based on their environmental qualities (e.g. sulfur content).

Traffic Management. Traffic management strategies to increase vehicle occupancy include car pool, or high-occupancy vehicle (HOV) travel lanes and advanced sensing systems at traffic lights to reduce congestion. Many cities have also expanded the size of cyclist and pedestrian rights-of-way, while reducing street width and intersection size.

Increasing Public Transit Use. Rather than decreasing the demand for mobility, public transportation competes directly with the automobile by providing an alternate means of mobility. The use of public transportation can be enhanced by--

Expanding public transit systems or making them more user friendly;

Increasing public awareness and acceptance of public transit; and, Subsidizing the cost of consumers' use of public transit.

Public awareness can be raised through traditional advertising campaigns, publicity events and "free-ride" days that familiarize the public with transit systems. Subsidization of public transit commuting costs, either directly or through company programs, has also been effective in increasing transit use levels. Often, enhancements to transit systems are most effective when coupled with other mechanisms, such as reduced parking availability, increased parking costs or increased tolls.

Promotion of car and van pooling also increases vehicle occupancy and reduces vehicle miles traveled. Government agencies, private corporations and other institutions have offered this strategy.

Greenhouse Gas Reduction Potential.

The average gasoline fueled passenger car emits CO_2 equivalent greenhouse gas emissions at a rate of about 530 grams per mile (gpm), considering the fuel cycle, direct vehicle emissions and materials. Thus, approximately one ton of CO2 equivalent greenhouse gases will be emitted for each approximately 1800 miles of driving. Conversely, for each 1800 miles of driving displaced by the strategies discussed above, approximately one ton of greenhouse gases can be eliminated.

Through its Transportation Partners program, EPA has been working with local organizations to implement VMT reduction policies, and with data from this work the agency has estimated ranges of VMT reductions which could be achieved.

Modified land use policies are estimated to be capable of reducing national VMT in the range of 7 million to 20 million miles per year. Reductions of this magnitude would reduce GHG emissions by approximately 4,000 to 11,000 tons per year. In California, with approximately 12 percent of the vehicle fleet, this would be 480 to 1320 tons per year.

Investments in existing public transit systems are estimated by EPA to be capable of potentially reducing VMT by approximately 2.5 million to 20 million miles. Ignoring any increase in GHG emissions from the public transit vehicles for the sake of simplicity, VMT reductions of this magnitude would reduce GHG emissions by between 1,400 and 11,000 tons per year; for California, this would be 168 to 1320 tons per year. There is a large variation in the GHG emissions of the different urban transit systems.

City-wide carpooling and vanpooling initiatives are estimated to be capable of reducing VMT by between 8 and 17 million miles. Such reductions in VMT could eliminate between 4,500 and 9,500 tons of CO_2 equivalent GHG emissions annually; for California this would eliminate from 540 to 1140 tons per year.

Impact on Emissions of Conventional Pollutants

On-road vehicles also emit criteria and toxic pollutants in approximate proportion to each mile driven. Depending on its driving characteristics, a typical car traveling at an average speed of 25 MPH will in the year 2000 emit NO_X at a rate of 1.1 gpm, VOCs at roughly 1.3 gpm and CO at roughly 9.5 gpm. Using the same EPA estimates of VMT reductions, these programs would result in the following approximate emissions reductions in California:

1. For land use policies: between 1 and 3 tons of NO_X, between 1 and 3 tons of VOCs, and between 9 and 25 tons of CO.

2. For public transit investments: between 0 and 3 tons of NO_X, between 0 and 3 tons of VOCs, and between 3 and 25 tons of CO.

3. For carpooling and vanpooling programs: between 1 and 2 tons of NO_X, between 1 and 3 tons of VOCs, and between 10 and 21 tons of CO.

Costs and Cost Effectiveness

The costs of these policies to reduce VMT are difficult to measure because they are borne by different entities and many of them are non-monetary. For example, a “feebate” system that taxed development outside of urban areas and subsidized redevelopment of urban areas would be revenue neutral. However, the policy would result in transfers of wealth among individual entities and businesses that would be perceived by many as costs. Further, a person preferring to live in a rural setting (and work in the city) who did not do so in reaction to the feebate policy, would have incurred some cost. And a person, who moved from a rural area to a mixed-use neighborhood and found life more enjoyable there, would have received a benefit. These costs and benefits are real, but impossible to measure.

Feasibility

The feasibility of these policies varies widely. Investments in, and advertisement of, public transit, subsidized commuter costs on public transit, vanpooling, high-occupancy vehicle lanes and other measures are in wide use today. Other measures face significant obstacles. Internalizing additional costs of driving, for example, is extremely unpopular with the public—and thus with legislators.

Case Studies: Portland, Oregon

Portland, Oregon, is one of the few major metropolitan areas in the United States that has consistently pursued the objective of mixed use development combined with limits on growth and increased public transit. Comparing Portland’s experience that of another rapidly growing metropolitan area, Atlanta, crystallizes the air quality impacts of metropolitan planning and transit use and air quality that can be attributed at least in part to land-use decisions.

In a 1997 report, the California Air Resources Board lavished praise on Portland’s transportation system. “Portland is well-served by both bus and lightrail transit [with] convenient and attractive pedestrian facilities,” the report said. “Downtown Portland consists of relatively small blocks of buildings placed on a gridded street pattern, and is surrounded by older residential neighborhoods, sprinkled with a variety of commercial businesses. Each work day, 23 percent of all downtown workers commute by transit, increasing to more than 40 percent during peak commute periods. Partly as a result of these reduced driving rates, the city has experienced no violations of federal ozone standards since 1988, compared to a prior violation record of one day out of every three to five days.”[9]

By contrast, it is unlikely that any metropolitan area in the United States has encountered greater difficulty with growth in vehicle miles traveled than Atlanta. Described by one of the city's own newspapers as a “poster child” for sprawl, Atlanta has acquired a national reputation for runaway growth.[10] Much of that growth is fed by the immense amount of inexpensive raw land available for development. As Atlanta’s outer reaches have spread further and further from the city center, the daily per capita vehicle miles traveled have climbed steadily, jumping from 32.1 in 1992 to 35.8 in 1998.

In 1979, the voters of Portland and 26 other jurisdictions in the region approved a referendum to create the Portland Metropolitan Area, or Metro, an elected regional government with authority over land- use, transit systems, and other cross-jurisdictional issues.

In 1992, Metro launched a Region 2040 Growth Concept process to plan for a population expected to double to 2.5 million in the next 45 years. This growth had spurred concern about the potential impacts of new development in outlying suburbs on quality of life, traffic congestion, and air pollution. Metro solicited extensive public involvement, including telephone surveys, numerous workshops, and meetings with stakeholder groups. Participants expressed a strong preference for a high-quality transit system, a wider choice of living environments, and containing new growth within the existing urbanized area and a few satellite suburban areas.

During the development of the 2040 Growth Concept, planners evaluated several different land use and transportation scenarios using Metro's enhanced transportation demand model. The 2040 plan alternative that was selected for the plan was compared to other land use and transportation scenarios. According to this analysis, the plan is expected to result in 15 to 20 percent less motor vehicle pollution in the region than more auto-oriented development would produce

The final 2040 Growth Concept, adopted in 1994, focused about two-thirds of expected future development within Portland's locally established urban growth boundary through infill, mixed use, and higher-density development. About one-third of this new growth is to consist of compact neighborhoods and sub-regional centers, situated near transit stations and corridors that are served by high-capacity rail. Another one-third of the growth is to occur in smaller satellite cities outside the urban growth boundary.

Clearly Portland's rigorous land use and transportation planning requirements benefit local air quality. Consider the following:

Regional transit rider ship has increased 30 percent since 1990 due to significant investments in three new light rail lines and a variety of other measures to encourage use.

Personal auto travel has leveled in Portland, though it is climbing elsewhere.

Nearly 5,000 new housing units have been constructed in downtown Portland since 1988.

The city plan encourages bicycle parking and construction of bikeways, so the modal share for bicycle use has increased from 1 to 2 percent of all trips.

A comparison of vehicle miles traveled (VMT) in Atlanta and Portland illustrates how Portland's growth management and transit-oriented development have helped minimize VMT growth. A study by the Taubman Center for State and Local Government found Atlanta's VMT are increasing at a rate faster than that of population growth. In Portland, however, just the opposite is occurring: VMT is decreasing in comparison to the population. (See Table 1)

Table 1
Population and VMT, Atlanta and Portland, 1990-1995[11]

Metro Area	Population 1995	Percent Annual Growth 1990–95	VMT 1995	Percent Annual VMT Growth 1990–95	VMT per Capita
Atlanta, Georgia	3038050	2.7 %	105218 456	4.4 %	34.6

Metro Area	Population 1995	Percent Annual Growth 1990–95	VMT 1995	Percent Annual VMT Growth 1990–95	VMT per Capita
Portland, Oregon	1050418	2.1 %	20413000	1.9 %	17.2

Source: Arnold M. Howitt and Elizabeth M. Moore, "Linking Transportation and Air Quality Planning: Implementation of the Transportation Conformity Regulations in 15 Nonattainment Areas," Taubman Center for State and Local Government, John F. Kennedy School of Government, Harvard University (Cambridge, Mass., March 1999).

Data produced by the Federal Highway Administration paint a somewhat different picture, showing increases in per capita VMT in both cities. However, per capita VMT increased in Atlanta at twice the rate of Portland. (See Table 2)

Table 2
Per Capita VMT, Atlanta and Portland, 1992-1998

Metro Area	Per Capita Daily VMT - 1992	Per Capita Daily VMT - 1998	Percent Change 1992–98
Atlanta, Georgia	32.1	35.8	11.5
Portland, Oregon	20.2	21.1	4.5

Source: Federal Highway Administration, U.S. Department of Transportation, *Highway Statistics Series*, http://www.fhwa.dot.gov/ohim/ohimstat.htm

These differences in VMT appear to translate directly into automobile emissions of air pollutants such as carbon monoxide and ozone. Since 1988, Portland has achieved substantially greater reductions in carbon monoxide and ozone levels than Atlanta has. (See Table 3.)

Table 3
Carbon Monoxide and Ozone Air Pollution Reductions in Parts per Million, Atlanta and Portland, 1988–1997

Area/Pollutant (% Reduction, 1988–97)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Carbon Monoxide Atlanta (-22%)	*5.5*	*6.2*	*5.4*	*6.5*	*5.1*	*4.9*	*5.3*	*4.5*	*3.7*	*4.3*
Carbon Monoxide Portland (-39%)	8.9	8.2	8.5	9.1	7	6.3	7	5.7	6.1	5.4

Area/Pollutant (% Reduction, 1988–97)	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Ozone - 8 hr Atlanta (-9%)	*0.11*	*0.1*	*0.11*	*0.1*	*0.1*	*0.1*	*0.1*	*0.11*	*0.1*	*0.1*
Ozone - 8 hr Portland (-14%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ozone - 1 hr Atlanta (-13%)	*0.15*	*0.11*	*0.14*	*0.12*	*0.12*	*0.14*	*0.11*	*0.14*	*0.12*	*0.13*
Ozone - 1 hr Portland (-27%)	0.11	0.1	0.12	0.1	0.1	0.1	0.1	0.12	0.1	0.1

Source: U.S. Environmental Protection Agency, National Air Quality and Emissions Trends Report, 1997.

Although it would be simplistic to attribute all of the changes in ambient concentrations of these pollutants to a single local strategy, there is no doubt that when each person in Atlanta drives nearly 15 miles per day more than each person in Portland, it affects the cities' relative air pollution levels. How much of the differences between Atlanta and Portland can be attributed to land use is uncertain. But surely some of the reductions in Portland can be assigned to its land use and transit policies, while some of the continued emissions in Atlanta can be assigned to its lack of land use and transit policies.

Case Studies: Chattanooga, Tennessee

Another example illustrates that a city can thrive without losing its attainment status. Chattanooga, Tennessee, the urban core of a metropolitan area of roughly one-half million, is one of the few American cities of that size that meets federal air quality standards for all criteria pollutants. This is due at least in part to concerted efforts by local government and business leaders to redevelop the city, especially its center, in ways that minimize environmental impacts.

Described as "America's Dirtiest City" in 1969, Chattanooga and its manufacturers invested $40 million in pollution control equipment to comply with the CAA. At the same time, many of Chattanooga's industries that historically fed parts and materials to the auto, home construction and power engineering industries, fell into decline for reasons unrelated to air pollution control. Factories closed, some because they were obsolete, others because the domestic industries that they supplied were themselves shrinking.

Local leaders say the city hit rock bottom in the early 1980s, when downtown stores were virtually all shuttered and the streets were unsafe. The city launched a rebuilding effort in 1981, and by 1984 the Lyndhurst Foundation and the new Chattanooga Venture were collaborating in the Vision 2000 program to engage all city residents in imagining a future for their city. A remarkably progressive agenda emerged, calling for downtown and riverfront development, improved inner-city, housing, and 233 sustainable projects.

The Riverwalk has arguably had the greatest impact on Chattanooga's revitalization. It replaced the abandoned, rotting buildings on the Tennessee River with seven miles of urban parkland that cuts through the heart of the city with playgrounds, performance spaces, fishing piers and leaf-shaded walkways. Chattanooga's downtown anchor is the $45 million Tennessee Aquarium, surrounded by warehouses that have been reclaimed as smart shopping malls, newly renovated affordable apartment buildings, and restaurants sandwiched within the rough walls of old factories. Through the newly enfranchised Chattanooga Neighborhood Enterprise, 3,460 units of inner-city housing have been built or renovated through a fully public planning process.

To get around the new user-friendly downtown, in 1993 Chattanooga created a unique seventeen-vehicle electric shuttle bus service, described by one magazine as "a vital part of downtown redevelopment, helping keep the streets unclogged. Commuters are encouraged to leave their cars in parking garages on the outskirts of town, then take the shuttle in. City officials say the shuttle moves a third of the ridership at a tenth the cost of their own much larger diesel service."[12] In fact, Chattanooga has become the world's electric bus capital, exporting the twenty-two-passenger models made in town by Advanced Vehicle Systems to seed similar shuttle programs in fourteen other cities.

Case Studies: Curitiba, Brazil; Bogota, Columbia; Cornell University

Curtitiba, Brazil: In the 1960s, Curitiba, Brazil was like any other city in a developing nation, grappling with the rapid growth and development in the face of a rather erratic and unreliable transport system. The situation changed dramatically in the wake of a public outcry over plans to build a multi-lane highway that would shade and split the city's historic center. Another ongoing project called for the widening of the city's main thoroughfare, which required that practically all its buildings, from the newest to the oldest, be demolished.[13] In response, officials conducted a contest to develop a city plan. The the winner, architect and city planer Jaime Lerner, shortly afterwards became mayor and set about implementing the plan. That started the process of turning Curitiba into the Capital Ecológica, or Environmental Capital.

Curitiba had a history of attempting to deal with growth and protect its urban environment. One of the earliest products of environmental concern in Curitiba was the "Agache Plan," one of Brazil's first urban master plans. Adopted in the 1940's, it attempted to deal with the Curitiba's congestion, sanitation and housing, but couldn't cope with the 7 percent annual increase in population during the 1950's and 60's.[14]

In response to this growth, the city adopted the Lerner's Urbanism Preliminary Plan 1965, in which the planning of roads, public transit and land use became, in the words of one official document, "weapons for dominating and directing growth."

"Curitiba stepped forward," continued this official account "in the search for open spaces, green areas, (and) historic preservation."[15] With the election of Jaime Lerner as Mayor, the plans became realities.

In 1972, Curitiba transformed its main street into a street for pedestrians, closing it to vehicles and launching a radical change in the street grid of the city's entire urban area. In 1971, Curitiba launched a program for the creation of parks and the planting of trees along its streets and other public places, from a square meter of green area per inhabitant, the city was able to boast over 50 square meters per inhabitant.[16]

The sustainable transportation system that evolved has become a model for both developed and developing countries alike. The system views land use, road network and transportation planning as key developmental tools for coordinated growth. Central to the plan was the development of a transportation system that used existing streets with only very minor physical modifications.

The main mode of transport in Curitiba was buses. Instead of replacing it with more capital-intensive projects such as subways or rail-based systems, the city developed a surface based bus system,in whch private firms provided buses, drivers, maintenance and capital, while the city conducted route planning, roads, terminals, scheduling and enforcement of standards. The system collects a flat "social fare," in which shorter trips effectively pay for longer trips, making it possible for low-income suburban residents to use the system.

Replacing the erratic system of transportation with one of high quality, reduced travel time and increased convenience, thus decreasing reliance on private cars. Direct "inter-district" connections between corridors allowed passengers to travel directly between points without passing through the city centre, while arterial roads containing public transit rights of-way were flanked with high-density zoning.

Bogota, Columbia. Curitiba's transportation system proved so successful that it was soon being extended to other cities. For example, between January 1998 and December 2000, Bogota, Colombia developed and implemented a Curitiba-like bus rapid transit (BRT) system called Transmilenio. It includes exclusive busways on major arterial roads, together with roads for feeder buses, stations, and complementary facilities. The system carries up to 45,000 passengers per hour per direction. Services are operated by private consortia of traditional local transport companies, associated with national and international investors procured under competitively tendered concession contracts on a gross cost basis

By May 2001, less than 3 and one-half years after its inception, Transmilenio carried 360,000 trips per weekday, without operating subsidies at a ticket cost of US$ 0.36. Productivity was high, with 1,945 passengers per day per bus and 325 km per day per bus. Fatalities from traffic accidents had been eliminated, particulate emissions in the corridors reduced by up to 30 percent, and user travel time reduced by one-third.

Cornell University. Cornell University implemented a traffic reduction program in 1991 that included increased on-campus parking fees and incentives to use alternate modes of transportation. Two primary alternatives were developed: RideShare offers cash rebates to faculty and staff who carpool to work and OmniRide subsidizes bus transit for faculty and staff. Over one-third of the faculty and staff participate in the program, resulting in a 26-percent reduction in the number of vehicles coming to the campus daily. Cornell engineers estimate that the program reduces VMT by approximately 10 million miles each year, and reduces annual CO_2 emissions by 6.7 million pounds, NO_X emissions by 34,000 pounds, VOCs by 59,000 pounds and CO by 651,000 pounds.

Congestion Charging

Congestion charging is the act of charging a fee (fixed or variable) for vehicles to drive on certain roads at certain times of the day. Cities are an attractive place for VMT reduction strategies because there are alternative ways to get downtown - primarily public transit or carpooling - and because of the multiple benefits of reduced air pollution, traffic noise, and congestion.

Brennan Walsh of the National Commission on Energy Policy, a bipartisan group dedicated to developing an energy strategy to improve the environment, the economy, and U.S. national security, recently examined congestion charging and its potential for reducing emissions. That paper, which concludes that it is a valuable tool with widespread potential applicability, is reprinted below.

> *As a starting point, we examine the successful London charging program that began this year. This program establishes a small fee for vehicles entering a small section of London's congested downtown area and redirects the revenues towards improving the existing public transportation system. One of the major conclusions we derived from the London program is that congestion pricing does more than just shift VMT; it actually reduces it. Applying preliminary results from London's program to major U.S. cities with high levels of congestion and air pollution, we estimate that the top ten most congested cities in the U.S. would experience a combined reduction of 3.2 million barrels of oil and 3.8 billion pounds of carbon dioxide per year. While these reductions are not large, we believe that the implementation of such a program could establish a policy framework for dampening the growth of VMT in and around major U.S. cities.*

Background

Congestion charging is one of the few policy tools available of achieving large, short-term shifts away from private transport and in favour of public transport and carpooling. VMT has become a serious problem because it reduces the improvements that have been made in vehicle fuel efficiency and pollution control technologies. This trend will continue to increase air pollution, greenhouse gas emissions, and the U.S. dependence on foreign oil unless policy action is taken to encourage people to drive less. This paper looks at congestion charging as one possible solution.

On February 17, 2003, London Mayor Ken Livingstone implemented a congestion charging scheme for downtown London. The program requires all vehicles driving in 8 square miles of central London (Figure 1.1) between 7 am and 6:30 pm to pay a flat rate of £5 (~$8) per day. This policy is enforced by nearly 700 different video cameras located throughout the charging zone using an Automatic Number Plate Recognition (ANPR) computer system. ANPR aims to capture the license plates of those who break the law and send them an £80 (~$120) Penalty Charge Notice (PCN) in the mail. London Mayor Livingstone has stated that all revenue gathered from the program will be used to improve the existing public transit system. This plan does not apply to emergency vehicles, motorbikes, mopeds, buses, coaches, taxis, firefighters, residents, and National Health Service vehicles. There is also a special exemption for alternative fuel vehicles including CNG, LPG, electric, hybrid, and fuel cell vehicles.

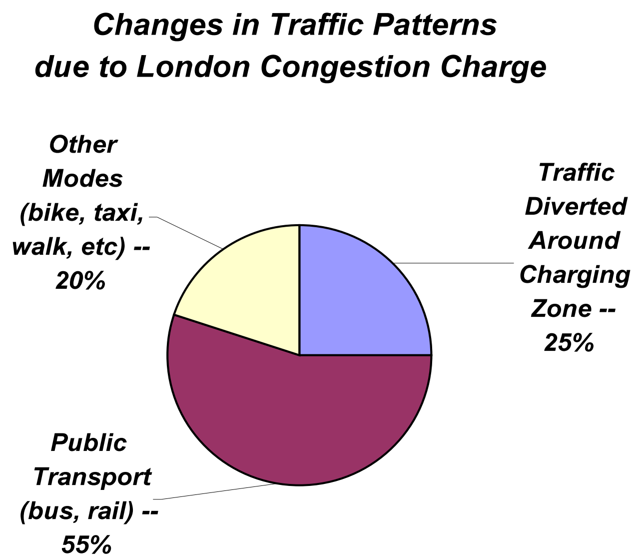
Figure 1.1 – Affected London charging zone.

According to the six month assessment prepared by the Transport for London, the number of motor vehicles entering the zone during charging hours is down 16% and overall congestion during charging hours has fallen by about 30%. Driving time has also significantly decreased. Based on surveys taken from all over greater London, the time taken for journeys into and out of central London has been reduced by about 14%. Public bus use increased by about 15,000 extra passengers per day during the peak morning period. The program is on course to generate about £68 million for the public transportation system by the end of 2003.

Vehicle Miles Traveled (VMT)

According to Transport for London's six month report, about 60,000 fewer vehicles per day entered into the charging zone. Of this quantity, estimates are that 20-30% of the reduction came from vehicles diverted around the zone, 50-60% of the reduction came from people who switched to public transport (i.e. bus & tube), and 15-25% of the reduction came from people who used other modes of transportation (i.e. taxi, bicycle, motorcycle, & walking). For the purposes of this analysis, we selected the following midpoints: public *transportation 55%, other alternatives (biking walking, carpooling) 20%, diverted traffic around the zone 25%. In sum, of the traffic that did not enter the charging zone, three-quarters of the people found alternative means of reaching their downtown destinations, while one-quarter continued to drive, but went around the charging zone rather than through it. The net result by our calculations is a decline in total VMT of about 1%, which accounts for the increase in VMT from those drivers that choose to travel around the charging zone rather than taking the presumably more direct route through the charging zone. A one percent decrease in VMT associated with the charging zone is projected to save about 100,000 barrels of oil per year, and 138 million pounds of CO2 annually.*[1]

Figure 1.2 – Changes in Traffic Patterns by Congestion Charge



Studies by London-based businesses reinforced the finding that vehicles are diverted but people find other means to reach their destinations in downtown London. A study was recently published by an American research firm Georgeson Shareholders & Co., which showed that London businesses are largely in favor of the congestion charge. The study, commissioned by the lobbying group London First, surveyed about 500 businesses of all different sizes and sectors. Of these 500, "Almost three-quarters of companies – 71% - say that congestion charging has had no discernible impact on their bottom line." Thus it appears based on initial data that congestion charging is effective at removing vehicles from the zone but not necessarily people from the zone.

[1] These numbers were estimated based on some of the following assumptions. First, this model assumes that the vehicles diverted around the ring *increased* overall VMT by 3 miles per vehicle per day. Second, the vehicles that switched to public transport and a percentage of the vehicles that switched to other modes of transportation (exempt taxi) were estimated to *decrease* overall VMT by 14 and 2 miles per vehicle per day respectively. Taxis do not reduce VMT so they were excluded from the calculation. Third, all of the results from this spreadsheet are based on the assumption that Londoners travel roughly 18 billion miles a year (Daily Policy Digest) by car with an average vehicle fuel efficiency of about 32 miles per gallon (Walsh). Finally, it is assumed that every gallon of gasoline burned generates 28 pounds of CO_2 (ACEEE). See Appendix A.

Applications in Other Cities

Congestion charging programs already exist in Singapore, Melbourne, Toronto, and Norway (Trondheim, Bergen, and Oslo). Singapore's program has different charges on different roads at different times of the day based on traffic volume. Melbourne has implemented a toll road that links three of its arterial freeways. Toronto has an interesting program that charges vehicles on a per kilometer basis so that those who contribute more to the congestion also pay more money. Finally, Trondheim has an electronic toll system that charges vehicles every time they pass through the toll but it is designed to give a discount to people who cross the ring multiple times. Most of these programs use overhead gantries which deduct the appropriate fee from either an electronic tag (e-tag) or cash card that is mounted on the windscreen of the vehicle.

All of these programs have improved traffic within the charging area. Significant improvements have been seen in the reduced number of vehicles on the road, the increased average vehicle speed, and the increased number of people per vehicle (suggesting increased carpooling). Air pollution, noise, and safety seem to have improved within these charging zones as well. Apart from some initial technology glitches, all of these programs have been remarkably successful at enforcing the fee.

Candidate Cities in the U.S.

Congestion is a large and growing problem in major and minor U.S. cities. According to the Texas Transportation Institute's (TTI) 2002 Urban Mobility Report, "congestion is growing in areas of every size." With congestion measured as a time delay, the TTI study found that the average annual delay per peak road traveler in the U.S. increased from 16 hours in 1982 to 62 hours in 2000. To put this in perspective, this delay equates to about 1.2 extra hours out of each travelers week spent in the car. In addition, "passenger-miles of travel increased over 85 percent on the freeways and major streets and about 25 percent on the transit systems." Finally, from an economic standpoint all of this congestion costs about $67.5 billion in 2000. This is the value of 3.6 billion hours of delay and 5.7 billion gallons of excess fuel consumed.

According to the Department of Energy's Transportation Energy Data Book, Americans drive about 2.6 trillion miles per year in automobiles, light trucks, and SUVs. These 10 most congested cities account for between about .5% and 2.8% of this annual VMT. If charging programs were implemented in all 10 cities and our preliminary assessment of London's 1% reduction in daily VMT could be realized, then roughly 3.2 million barrels of oil would be saved per year. This would also reduce carbon dioxide emissions by about 3.8 billion pounds per year.

Table 1.1 – U.S. Top Ten Most Congested Cities.

City	Population (Million)	Annual Person-Hours Delay (Million)
Los Ang. CA	12.6	792
NY - NE NJ	17.1	400
Chicago	8.1	221
San Francisco	4	167
Dallas	3.8	141
DC-MD-VA	3.5	123
Houston TX	3.3	121
Detroit MI	4	101
Atlanta GA	2.9	97
Boston MA	3	85

London's congestion charging program attempts to encourage commuters to stop driving their cars and instead use an alternative means of transportation. It also tries to avoid negative consequences, such as creating more traffic in other areas, encouraging sprawl, and disrupting local businesses. Some cities are more suitable for charging than others. Ideally, a congestion charging program would target major cities that have high levels of congestion and air pollution, as well as multiple alternative means of entry other than the single occupancy vehicle. The most attractive cities typically have compact downtowns well served by public transit.

Based on these considerations, the top ten most congested cities in the U.S. were grouped according to their suitability for congestion charging. Boston, San Francisco, and New York City seem to be the most suitable for charging zones. These cities are all very dense and can be charged successfully over a large area. Atlanta, Houston, and Los Angeles on the other hand have a more challenging task because their city centers are spread out over a larger area. The remaining cities – Chicago, DC, Detroit, and Dallas – have characteristics of both of these categories where a charging zone may or may not be effective depending upon how it is implemented. All of these cities have significant concentrations of ground-level ozone that can lead to severe respiratory and other health *problems. Using these criteria, we analyzed detailed maps of these cities and developed what we thought were suitable charging zones in each. Table 1.2 below gives a summary of all of these findings:*

Table 1.2 – Evaluation of top ten congested U.S. Cities.

City	Public Transit?	Centralized Downtown?	U.S. Classification Ozone Non-Attainment	Size of Proposed Charging Zone[17]
Los Ang. CA	Yes	Un-centralized	Extreme	9 sq. miles
NY - NE NJ	Yes	Centralized	Severe	8 sq. miles
Chicago	Yes	Moderate	Severe	9 sq. miles
San Francisco	Yes	Centralized	Other	8 sq. miles
Dallas	Yes	Moderate	Serious	2.5 sq. miles
DC-MD-VA	Yes	Moderate	Severe	20 sq. miles
Houston TX	Yes	Un-centralized	Severe	2.5 sq. miles
Detroit MI	Yes	Moderate	-	1.5 sq. miles
Atlanta GA	Yes	Un-centralized	Serious	8 sq. miles
Boston MA	Yes	Centralized	Serious	2 sq. miles
London	**Yes**	**Centralized**	**N/A**	**8 sq. miles**

Conclusions

Overall, congestion charging in London has been a success. The number of motor vehicles entering the zone during charging hours has fallen by 16% and overall congestion is down 30%. Public bus use has increased by 15,000 extra passengers per day during the peak morning period, and the program is on course to generate £68 million for the public transportation system by the end of this year. The program has also been effective at deterring vehicles but not people. Nearly three quarters of the 500 businesses surveyed within the zone have seen no impact on their bottom line.

Our analysis quantified the VMT reduction based on Transport for London's six month data on diverted traffic to other modes. We found that the program reduced daily London VMT by roughly 1%. We estimate that by applying a congestion charge (realizing the same results) in the top ten most congested cities in the U.S., there would be a combined reduction of 3.2 million barrels of oil per year. This would also reduce carbon dioxide emissions by roughly 3.8 billion pounds per year.

GAS FROM ANIMAL WASTE INCLUDING HUMANS

Human Sewage

As those who have driven or walked near an uncovered sewage treatment plant can attest, they produce methane, and lots of it. As is so often the case, that noxious smell is an unexploited source of energy, for it can be used to fuel vehicles, provide heat and light or generate electricity.

Publicly owned treatment plants, or POTWs, as sewage plants are more politely called,

Emissions Reductions from Wastewater

There are two fundamental ways to reduce methane emissions from municipal sewage treatment plants:

improving wastewater treatment practices (domestic and industrial) and

installing anaerobic digesters in combination with collection and either flaring--or the much more preferred option--cogeneration

According to the California Energy Commission, there are 242 sewage treatment plants in California. Of these, 22 capture and utilize methane, 10 to generate roughly 38 MW of electricity and 12 heat water to warm the digester. The remaining 220 sewage either do not recover biogas or do not have anaerobic digesters.

Among the more innovative and advanced gas recovery systems is in Riverside, California, where the POTW treats an average of 33 million gallons of sewage per day, utilizing anaerobic digestion.

Starting in April 2005, the city began adding collected grease wastewater to the existing anaerobic digesters to generate methane gas. The methane gas is then fed into an on-site cogeneration facility that produces electricity for the plant. T

The Commission estimates that about 36 MW could be generated at these 220 sewage plants. Biogas to electricity potential is estimated from existing 220 sewage treatment plants. Most of the potential is relatively small: 168 plants have generating potential of less that 200 kilowatts.

Anaerobic digestion of animal waste

Two major greenhouse pollutants, methane--familiar to most as natural gas--and nitrous oxide, are emitted by livestock manure and, in some cases, the animals themselves.

Ways to Reduce Emissions of Methane from Livestock Manure

Like so much other waste, manure from livestock is in actuality a resource that hasn't been exploited. Cattle, sheep and other animals feeding in pasture produce very little methane, because the waste decomposes in place, fertilizing the fields. Where livestock are held in pens, the manure pools, producing odors that can be overpowering and, with them, methane.

Pooled manure, whether of humans or livestock, can be "digested" to produce methane, or natural gas, that can be used to run cars and trucks, generate electricity or simply burned to provide heat. Although pigs and diary cattle account for most manure emissions, other animals--sheep and buffalo, for example-- also contribute. So, too, to chickens, turkey and other poultry.

Small scale digestion systems can be used in developing nations where herds are small, while much larger ones can be, and are, used in developed nations, where the number of animals can numbers in the thousands.

The type of digester will vary according to the waste, the location and the intended use of the methane. There are complete-mix, plug-flow, fixed-film, and large-scale covered lagoon digesters, as well as dome, polyethylene bag, small-scale covered lagoon, and flexible-bag versions.[18] The conversion efficiency can range from 50 to to 85 percent. The gas can be used to light or heat a small farm or generate electricity or run machines on a larger one. All do essentially the same thing, however: convert a noxious waste into energy that can be used.

Ways to Reduce "Enteric" Emissions of Methane from Livestock

As livestock, principally ruminants such as cattle, digest their food methane is formed. Ways to reduce it fall into four categories:

Increase the food's energy content and digestibility;

Increase animal productivity or growth by using, for example, antibiotics or hormones;

Optimize feed conversion by eliminating nutrient deficiencies;

Improve the management of herds by, for example, using intensive grazing.

Although it is both technologically and economically feasible to reduce methane emissions from animal sewage as well, the California Energy Commission estimates that less than 1 percent of the potential is being exploited. This was not always the case.

In the late 1970s and early 1980s, the tax incentives of the encouraged the construction of about 18 commercial farm scaled digesters for energy production in California. Only 5 of those systems are running today. Three are on pig farms and two at dairies, generating a total of 0.37 megawatts.

The Commission estimates that the total potential in the state is more than 105 MW. Energy can be produced not only from pig and cattle waste, but also from chickens, turkeys, sheep and lambs as well. California dairies have 1.4 million milk cows, the second largest number among the states, with 2,308 dairy farms.

Options for Mitigating Emissions of Nitrous Oxide and Soil Carbon From Cropland

Often, emissions of nitrous oxide result from over-fertilization, so emissions can be reduced while maintaining yield and saving the grower money. The U.S. Environmental Protection Agency identified ways to reduce emissions that would maintain productivity.

Mitigation Options

Split fertilization

– Application of same amount of nitrogen fertilizer as in baseline but divided into smaller increments during crop uptake period to better match nitrogen application with crop demand and reduce nitrogen availability for leaching, nitrification, denitrification, and volatilization.

Simple fertilization reduction

– Reduce nitrogen-based fertilizer application by 10 percent;

– Same, by 20 percent;

– Same, by 30 percent.

Nitrification inhibitor

– Reduces nitrogen, thus increasing overall plant uptake, which, in turn cuts emissions.

"No-till" tillage

– Conversion from conventional tillage to no till, leaves soils undisturbed, so more crop residue is retained and emissions reduced.

REDUCING METHANE EMISSIONS FROM THE OIL SECTOR

Historically, natural gas emissions in the oil sector have correlated closely with oil production, and global release of methane from oil are projected to increase by more than 80 percent by 2020.

There are essentially three ways to reduce emissions of natural gas from oil production and refining:

Flare, or burn, the gas;

Put the gas to some use, such as generating heat or electrcity; and,

Reinject the gas into to oil well to boost, or enhance, their productivity.

Flaring in Place of Venting: Offshore and Onshore

Burning, or flaring, gas is in a sense, a waste of a fuel, but it does produce a climate benefit. Flaring cuts methane emissions by 98 percent, converting a powerful greenhouse gas into carbon dioxide, which is much weaker. Moreover, methane also reacts in the atmosphere to form tropospheric ozone, also a greenhouse gas that is much more powerful than carbon dioxide.

Using Methane

Methane can be put to use instead of being burned, reducing emissions by about 90 percent at a given sources. Offshore, it can be used to run engines and pumps, provide heat or light or converted to methanol or liquefied natural gas.

Re-injection

Gas captured from oil field operations can also be reinjected into the oil field to boost pressure and thus enhance oil production.

REDUCING METHANE EMISSIONS FROM THE OIL SECTOR

Historically, natural gas emissions in the oil sector have correlated closely with oil production, and global release of methane from oil are projected to increase by more than 80 percent by 2020.

There are essentially three ways to reduce emissions of natural gas from oil production and refining:

Flare, or burn, the gas;

Put the gas to some use, such as generating heat or electrcity; and,

Reinject the gas into to oil well to boost, or enhance, their productivity.

Flaring in Place of Venting: Offshore and Onshore

Burning, or flaring, gas is in a sense, a waste of a fuel, but it does produce a climate benefit. Flaring cuts methane emissions by 98 percent, converting a powerful greenhouse gas into carbon dioxide, which is much weaker. Moreover, methane also reacts in the atmosphere to form tropospheric ozone, also a greenhouse gas that is much more powerful than carbon dioxide.

Using Methane

Methane can be put to use instead of being burned, reducing emissions by about 90 percent at a given sources. Offshore, it can be used to run engines and pumps, provide heat or light or converted to methanol or liquefied natural gas.

Re-injection

Gas captured from oil field operations can also be reinjected into the oil field to boost pressure and thus enhance oil production.

PUTTING OUT FIRES

To reduce destruction of the stratospheric ozone layer by chlorofluorocarbons (CFCs) and halons, substitutes were developed and have been adopted that, while ozone "friendly," are powerful causes of global warming. Many of these greenhouse gases--hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used in devices to extinguish or suppress fires and explosions, and are included in the Kyoto Protocol's "bag of six" pollutants.

Just as HFCs and PFCs can replace CFCs, so too can other chemicals--which are both ozone and global warming "friendly--be substituted. In addition, most emissions from fire-extinguishing result from leaks and "total flooding" discharges, whether both accidental or to extinguish fires. Thus, emissions can also be reduced by using different technologies and practices. Potential options include--

Inert Gas Systems

Inert gas systems extinguish fires using argon, nitrogen, or a blend of the two, sometimes incorporating CO2 as a third component. Inert gas systems provide both fire protection and life safety/health protection equivalent to HFCs in most ordinary fires hazards, including those in electronics and telecommunications applications.

Although inert gas systems are effective at extinguishing fires, they discharge more slowly than HFC systems (60 seconds or more compared with 10 to 15 seconds), so in areas where a rapidly developing fire is likely, inert gas systems are not recommended. Still, ven in these cases, new devices that recognize and extinguish fires before they have a chance to spread can be used.

Water Mist Systems

Unlike traditional water-spray systems or conventional sprinklers, water "mist" employ extremely fine droplet sprays from specially designed nozzles to produce much smaller droplets under low, medium, or high pressure to extinguish fires, using much less water. In some applications, such as aboard ships, they can be brought into action faster than HFC systems because there is less concern about applying water mist in situations where openings to the space are not all closed—which in turn leads to reduced fire damage. In addition, unlike HFC systems, which are usually limited to a single discharge of agent, most water mist systems have an unlimited water supply in land-based operations, and at least 30 minutes of potable water discharge followed by an unlimited amount of seawater for marine applications.

Water mist systems are currently used aboard ships, in storage and machinery spaces, and combustion turbine enclosures as well as flammable and combustible liquid machinery applications.

Fluorinated Ketone (FK-5-1-12)

A relatively new addition to the inventory of fire extinguishing agents is 1,1,1,2,2,4,5,5,5-nonafluoro-4-(trifluoromethyl)-3-pentanone, commonly referred to as FK-5-1-12. It is a fluorinated ketone with an atmospheric lifetime up to 2 weeks and a 100-year global warming potential of about 1, making it no more powerful than carbon dioxide. It was approved in 2002 and 2003 under the U.S. Environmental Protection Agency's SNAP, or Significant New Alternatives Policy, program as a replacement for halons.

There are other alternatives to fire supression chemicals or systems, including--

recovery and reuse of HFCs,
improved detection systems,
fine aerosols, and
inert gas generators.

The Most Powerful Greenhouse Gas of All

Many pollutants that cause global warming last a long, long time. Carbon dioxide, for example, lasts 50 to 3,000 years, and after 1,000, roughly one third is still in the system. None, however, rivals the 50,000 year life of sulfur hexafloride, or SF6.

SF6 is colorless, odorless, non-toxic and, most importantly, non-flammable. Because SF6 is a dielectric, or electrical insulator, it is used in high-voltage circuit breakers, switchgear, and other electrical equipment, sometimes replacing polychlorinated biphenyls, which were partially banned in the 1970s.

The global warming potential of SF6 is 22,200 times that of carbon dioxide. Older equipment, such as a single circuit breaker, can contain up to 2,000 pounds of SF6--the rough equivalent of 44 million pounds of carbon dioxide--while modern breakers usually contain less than 100 pounds. Thus, one option for reducing emissions is simply to replace older devices.

Globally, the electric power industry uses roughly 80 percent of all SF6. In theory, none of it should be emitted into the atmosphere, because the uses are--or should be--totally enclosed. In reality, however, there are significant leaks from aging equipment that utilities fail to replace, and from releases during equipment maintenance and servicing.

In the words of the U.S. Environmental Protection Agency--

> The electric power industry has an enormous opportunity to help reduce the nation's SF6 emissions through cost-effective operational improvements and equipment upgrades.
>
> The options for reducing emissions are quite straight forward:
>
> Leak Detection and Repair: if consistently and aggressively implemented in the U.S., SF6 emissions could be reduced by 20 percent;
>
> Use of Recycling Equipment: recycling could eliminate 10 percent of total related emissions from the U.S. electric industry;
>
> Employee Education/Training: by how much SF6 emissions could be reduced throughtraining and an aggressive corporate policy of minimizing releases in unclear, but without question, it is substantial.

Reducing Industrial Pollution

The term “industry” scarcely captures the richness and diversity of the activities that it encompasses, as well as their importance to our national well being. Were it not for “industry,” America would lack not only cars and trucks, but also roads on which to drive them. There would be no books or newspapers, for lack of not only paper, but ink as well. Crops would still grow, but more slowly.

“Industry” starts with mines two miles deep into hills of New Mexico and runs to the mills tucked into snowy valleys of New Hampshire. It includes everything from the extraction of natural resources to their ultimate shaping into finished products.

Because industrial activities are so different, one from the other, it is impossible to arrive at any single solution — or even any single set of solutions — to the variety of pollution challenges that they present. What might work to reduce emissions in the cement industry — blended cement, for example — is utterly meaningless to a producer of steel.

This is not to say, however, that there are no ways to reduce emissions of Kyoto and non-Kyoto pollutants alike. There are, and many of them can save money as well.

Of the many activities that produce pollution, some of those most accessible to controls are in the industrial sector. Because technologies for extracting, refining and processing raw materials and for building a variety of finished goods are extremely energy intensive, the opportunities for reducing carbon dioxide, as well as black carbon, ozone and its precursors, as well as toxics, is extraordinarily large. Moreover, unlike motor vehicles whose pollution is regulated largely by rules from Washington (or in he case of California, Sacramento) powerplants and industries are susceptible to local and state guidance.

Steam Production

Despite the diversity of industrial activities, about two-thirds of the sector’s emissions result from producing steam and process heat from fossil fuel combustion, while the remaining third results from providing electricity for such uses as motors, electric furnaces, ovens and lighting. A large majority of CO_2 emissions from the industrial sector result, not from industrial processes, but from the combustion of fossil fuels to produce steam, process heat and electricity.

Because of the enormous range of activities, only a few activities have been selected for more detailed examination. These include the following:

Cement,
Pulp and paper,
Petroleum refining,
Chemicals and
Boilers

¨ *Cement Industry*

Overview

Manufactured commercially in at least 120 countries and almost every state in the U.S., cement is mixed with sand and gravel to make concrete, which is used to build offices, stores, roads and, in countries where supplies of wood are in short supply, homes. Cement production is an energy and raw material intensive process resulting in the generation of substantial amounts of CO_2 and toxic air pollutants.

Three basic strategies can reduce emissions of at cement plants:

fuel switching, especially from coal, used tires or hazardous wastes to natural gas;

improvements in energy efficiency; and,

changes in product specifications.

The cement industry, even in California, relies heavily on coal for its energy; therefore, air pollution emission could be reduced across the board by switching to natural gas or other fuels Improvements in energy efficiency will have the same effect. Energy efficiency gains may be attained by applying more energy efficient process equipment and by replacing old installations with newer plants.

By far the largest proportion of energy consumed in cement manufacturing consists of fuel used to heat the kiln and, therefore, the greatest gain in reducing energy would come from improved fuel efficiency, specifically by replacing some older wet kilns with new, "pre-calciner" kilns.

The raw material for cement is limestone, or calcium carbonate--seashells deposited millions of years ago. One of the first steps in cement production is to "decarbonize" it, or drive off the carbon dioxide that it contains by burning. Older kilns do this in a huge rotating kiln in which the mass of materials is so wet that the process takes roughly 30 minutes and large amounts of energy. In a pre-calciner the material is heated while dry, so the process takes place in seconds, saving immense amounts of fuel and, hence, pollution.

Emissions can also be sharply reduced by substituting other materials for limestone to produce so-called "blended" cements. Substitute materials include blast furnace slag from steel mills and fly ash from coal-fired power plants. Blended cement sets a bit more slowly, but produces and stronger and longer-lasting concrete. In some nations (e.g. The Netrherlands), all concrete is made from blended. cement.

Because states are large consumers (directly and indirectly) of cement through their respective departments of transportation (DOTs) they can effectively dictate its composition by establishing product standards. By setting standards for concrete strength and curing time, the use of blended cements could be increased. DOTs can be stimulated to take a more active role in the use and prescription of blended cements in building and construction codes to generate a market-pull effect for blended cements.

CalTrans has been working on developing a specification for blended cement, but slowly--very slowly.

Industrial Boilers and Motors

Industrial boilers burn fossil fuels or materials such as process gases, to generate hot water or steam for a variety of uses, ranging from reforming chemicals to pulping paper. Electric motor systems convert electricity into mechanical energy and are used in most manufacturing processes. Boiler type, efficiency, and fuel type all affect the quantity of pollution emitted by boilers, while for motor systems, the efficiency (and hence indirect emissions) is dependent on the overall system design, the efficiency of individual components, system controls, and operation and maintenance practices.

Boilers account for about one-third of manufacturing energy use in the U.S., while machine drives, primarily electric motors, represent another 10 percent. Boilers also account for the majority of on-site energy use in the chemical, paper, and food industries. Large boilers are typically found in the pulp and paper, chemicals and petroleum refineries, while smaller boilers are used in not only these industries, but a wide range of food, and miscellaneous manufacturing (car, industrial machinery).

There are several different types of boilers including natural draft, forced draft, hot water, low or high-pressure steam, and fire tube or water tube. A network of insulated pipes delivers steam (or hot water) to provide heat or mechanical energy for a variety of process and space heating applications. Once the heat has been extracted from the steam, the steam has condensed into water (condensate) and is collected in a steam/condensate trap and returned through another network of pipes back to the boiler where it is cyclically reheated.

Motors drive equipment such as pumps, fans, air compressors, cutters, presses, grinders, material handling systems, and other process equipment. A motor system typically consists of an electric motor, a belt or transmission device and the driven equipment. For example, a compressed air system typically includes an electric motor belt driven reciprocating or screw compressor, a storage tank, and a distribution system.

Industrial boilers not only emit carbon dioxide, but large quantities of oxides of nitrogen, carbon monoxide and, depending on the fuel, black carbon. Oil and natural gas are the most common fuels.

Emissions from industrial boilers can be reduced through a number of strategies.

Improve boiler efficiency

Improve operating efficiency

Switch fuel

Cogeneration of heat and power (CHP)

Improve Electric Motor Systems

Boiler Efficiency Improvement

Emissions from boilers can be decreased by improving boiler efficiency, and this is accomplished through proper boiler maintenance and equipment upgrades. (Indeed, when Sweden adopted a feebate system for emissions of oxides of nitrogen from boilers, some employers began offering bonuses to employees that reduced emissions through careful attention to maintenance.) are crucial to maintain a boiler at maximum efficiency. Properly operating boilers produce steam with overall thermal efficiencies of greater than 85 percent.

Increasing, or at the very least maintaining, boiler efficiency requires approaches such as minimizing excess air, soot blowing, economizer feedwater heating, air preheating, and boiler monitoring and feedback control. A boiler tune-up can increase the boiler efficiency one to two percent by minimizing excess air while still providing optimum combustion.

Tune-ups are typically conducted annually, but monitoring smokestack concentrations of oxygen and carbon monoxide, with feedback controls not unlike those used on modern cars, continuously maximize boiler efficiency across a wide range of loads.

Another indicator of inefficient--and, hence money wasting and polution producing operation--is high stack gas temperature, which can be improved with devices such as feedwater heaters, often called "economizers" because they save fuel, and air heaters.

Soot blowing in oil and coal fired boilers helps maintain the ability of the boiler tubes to transmit heat. A 10 percent increase in boiler efficiency will generally increase overall plant efficiency by five to eight percent and reduce emissions by the same amount.

Operating Efficiency Improvement

Emissions from boilers can be sharply decreased by improving operating efficiency, and this is best accomplished by reducing the need for steam and, thus cutting operating costs and air pollution as well. Examples of such measures include reducing steam leaks, insulating steam pipes, maximizing condensate return and heat recovery of process operations. Measures like these can boost system efficiency by a low of 5 to 40 percent, recovery costs typically inless than two years and in many cases less than one year.

System Operation Improvements

Increasing the load control of boilers and decentralizing steam supply can sharply raise efficiency. Variable loads can decrease it, so a installing decices such as topping or bottoming cycle turbines that allow a boiler to run at a consistent load reduces fuel consumption and pollution. Decentralizing steam production eliminates the loss of energy by eliminating long steam and condensate pipe runs in large facilities.

Fuel Switching

Replacing carbon rich fuels such as coal and oil with fuels that result in lower emissions, is an option at many industrial and manufacturing facilities. Typically, coal and oil are replaced by natural gas or renewables (e.g., biofuels). Operating and maintenance costs when burning gas generally decrease due to longer life of associated boiler hardware such as the tube walls and feedwater heat exchangers.

Emissions will typically be cut 30 to 45 percent when converting to gas from oil and coal respectively, while capital and installation costs are typically low enough to justify the fuel switch.

Cogeneration of Heat and Power

In addition to increasing the efficiency with which steam is generated and used, boiler emissions can be curbed through the adoption of cogeneration, in which fuels are burned and the heat produced is used both for generating electricity and for process heat.

Cogeneration facilities can generally convert to heat and energy as much as 80 to 85 percent of the heat content of the fuel, significantly reducing the air pollution produced compared to facilities where electricity and heat are produced separately. A variety of technologies now are employed that continue to improve the overall efficiency of cogeneration. Conventional steam turbines that recover a portion of waste heat are being displaced by higher-efficiency and less costly gas-turbine cogeneration systems and combined-cycle cogeneration systems that use some of the heat from the gas turbine to run a lower-temperature steam turbine as well as to provide process steam.

Cogeneration systems operate at an overall system efficiency of 80 to 85 percent compared to 33 percent efficiency for the typical coal fired electric generating plant. While an industrial steam plant can be 80 percent efficient, the addition of a gas turbine or a topping cycle steam turbine to a steam heating plant can generally increase the plant efficiency. Because the electricity generation cycle is added in front of, or on the "top" of the steam heating cycle, electricity is generally produced at very high efficiencies. When this electricity generation displaces utility generation, carbon emissions are reduced considerably.

Electric Motor Systems

Indirect emissions attributable to motors and drives can be reduced through a variety of measures. In the case of motors, the indirect savings will depend on the type of fuel used by the electric generating facility and its efficiency.

Some of these opportunities lie in improving the efficiency with which the output of a motor is used, not in the motor itself. Standard motors operate with an efficiency of 70 percent for small devices of a few kilowatts, to 92 percent for large motors of 100 or more kilowatts. High-efficiency motors operate in the range of 83 to more than 95 percent.

One analysis of an industrial pumping system showed that only 49 percent of the energy output of the electric motor was actually converted into work to move the liquid. Optimizing system design rather than simply choosing components can lead to improvements of 60 percent using existing technology. One study found that replacing traditional power-transmission “V” belts with modern flat belts could improve efficiency from 85 to 98 percent. Adjustable-speed electronic drives that better match mechanical load reduce electricity demand.

Policy Options

Policy options for achieving these objectives include output based emissions standards, simplified environmental permitting procedures, accelerated depreciation of investment instruments in specific technologies, procurement guidelines, subsidies for innovative technologies, and voluntary agreements. More specific measures are discussed below:

General Strategies

Adopt output based emission standards.

Encourage operational changes that increase efficiency through subsidies and incentives.

Promote the adoption of technologies that provide harmonized reductions in GHG and criteria pollutant emissions. These technologies should be examined as best available control technology and reasonably available control technology.

Encourage or require large industrial energy consumers to appoint an energy manager within the company to identify energy efficiency measures and monitor energy use. This approach has been used in Italy with support provided by regional energy centers.

Promote participation in the multitude of government programs designed to encourage energy efficiency (e.g., Industries of the Future, Motor Challenge, Waste Wi$e, Climate Wi$e and Green Lights).

Negotiate voluntary agreements to cost-effectively reduce industry's impacts on GHG and criteria pollutant emission inventories. These voluntary agreements have been widely used in Denmark, Germany and the Netherlands.

Iron and Steel

Provide incentives or other support for the development of smelt reduction pilot projects.

Provide incentives or other support for feasibility studies of cogeneration projects.

Cement

Expedite the permitting process to help increase the use of alternative fuels.

Find joint solutions between the state authorities, companies and local waste management systems.

States should set clear re-use ruling for fly-ash and blast furnace slag in cement kilns.

DOTs can be stimulated to take a more active role in the use and prescription of blended cements in building and construction codes to generate a "market-pull" effect for blended cements.

POWER GENERATION UTILIZING FOSSIL FUELS

Electric power generators are the largest source of carbon dioxide in the United States (U.S.), responsible for roughly 35 percent of the nation's total emissions. Most of this CO_2 comes from the burning of fossil fuels, particularly coal: power plants consume 87 percent of the coal burned in the U.S. This sector is also a major source of non-CO2 pollutants, including those that cause global warming.

Thus, the electric industry is one of the most effective points of leverage in reducing both greenhouse gases (GHGs) and other pollutants. Electrical power plants area also responsible for a significant amount of fine particulate matter (PM) as the SO_2 and NO_x emissions react to form the sulfates and nitrates.

Conventional pollutants from powerplants can be controlled in a relatively straightforward fashion. Baghouses or electrostatic precipitators can be installed to capture particulate matter, including black carbon; and, selective catalytic reduction or other technologies can lower emissions of oxides of nitrogen. Unfortunately, use of these types of emission control systems require additional energy, resulting in an increase in total CO_2 emissions. However, there are technologies and practices that will simultaneously reduce emissions of all pollutants. And, powerplants can also switch to lower carbon fuels, such as natural gas, or zero-emitting ways of generating electricity, such as solar and wind.

California

Virtually all electricity generated within California is with natural gas. Thus fuel switching to reduce emissions of carbon dioxide is not, in most cases, an option. Now technologies and practices, however, are quite feasible. So is, especially, moving away from fossil-fueled electricity generation altogether, toward non-fossil sources such as wind and solar.

Quite a lot of California's electricity, while generated with natural gas, is by either "simple cycle" gas turbines or boilers, the two most inefficient means of producing power. Pollution and costs can be sharply reduced by extracting as much useful energy as possible from the fuel.

Boilers are essentially tea kettles: the gas is burned to generate steam, which is then used to spin the blades of a turbine to make electricity. In a "gas" turbine--so called because it uses combustion gases to spin turbine blades, not necessarily because it burns natural gas--efficiency is greater. The newest versions can approximate 40 percent. Turbines that generate electricity only by burning fuel are "simple" cycle, and their efficiency can be increased by using their waste heat to generate steam, which is then also used to make electricity. These are "combined cycle" plants, because they couple steam and gas together.

Even after producing steam for a combined cycle, eneough energy remains in the waste gases to be put to use to, for example, heat or cool buildings. Thus, total efficiency can be increased to 65 to 85 percent, with emissions cut proportionately.

In addition, most processes using fossil fuels to produce energy have residual energy waste streams that can be "recycled" into other productive uses. Recycling thus captures energy that otherwise would be unused, convert it to electricity or productive thermal energy. Recycled energy produces no or little increase in fossil fuel consumption or pollution emissions. Examples of energy recycling methods include industrial gasification technologies to increase energy recovery, as well as less traditional CHP technologies, and the use of energy that is typically discarded from pressure release vents or from the burning and flaring of waste streams. These energy recovery technologies have the ability to reduce both costs for power generation and air pollution.

But air pollution can be eliminated altogether by using non-fossil fuels to generate electricity. Electricity and thermal energy production from renewable resources (except biomass) produces no incremental increase in air pollutants such as nitrogen oxides, black carbon, and carbon monoxide.

Outside California

The most cost-effective method of achieving large scale CO_2 reductions from coal-fired powerplants is to “repower” the plant to burn natural gas. New gas turbines reduce CO_2 emissions by more than 50 percent. However; there are also technologies that allow plants to continue using coal as a fuel and achieve very substantial reductions at a cost competitive with a new coal fired plant.

Listed below are the recommended options for reducing GHG emissions from fossil-fired electric generators. Most of these options provide substantial reductions in criteria pollutant emissions as well.

- New turbine technologies
- Combined cycle
- Integrated gasification combined cycle
- "Recycled" energy
- Fuel cells
- Fluidized Bed Combustion
- Combined heat and power production

Turbine Technologies

Traditionally, electricity has been generated at fossil-fueled plants in a “simple cycle.” Water is turned to steam with the heat of fossil-fuel combustion, and the steam provides the mechanical energy needed to generate power. However, over the past decade great advances have been made in combined-cycle systems, in which fossil fuel combustion is used to drive a gas turbine and waste heat from this process is captured to drive a conventional steam generator. The two cycles together capture more of the energy content of the fuel.

Combined-cycle systems require clean gaseous fuels, and this historically has dictated the use of natural gas, but advances in other areas have made it possible to use coal as a fuel, by first converting it to a gas. However, as a carbon reduction strategy, coal gasification itself is only valuable in that it allows a coal-based fuel to be burned more efficiently. The gasification process removes little carbon from the fuel.

Gas-Fired Combined Cycle

The Gas-Fired Combined Cycle (GFCC) turbine has changed the electricity generating more than any other technology during the past two decades. In GFCC systems, a heat recovery steam generator extracts exhaust heat from the gas turbine to produce steam for electricity generation in an adjacent steam turbine. By running two systems rather than one, another 1/6 of the fuel energy is extracted. The combined cycle system can thus obtain roughly one-third of the energy from the gas turbine generator, and one-sixth from the steam turbine generator to achieve a total thermal efficiency over 50 percent.

Integrated Gasification/Combined-Cycle

Integrated Gasification/Combined-Cycle (IGCC) systems replace the traditional coal combustor with a gasifier and gas turbine. Over 99 percent of the coal's sulfur can be removed before the gas is burned in the gas turbine. Exhaust heat from the gas turbine is used to produce steam for a conventional steam turbine. The gas and steam turbines operate together as a combined cycle. Thus, the IGCC system uses the same combustion technology as the GFCC, but gasified coal is used as a fuel.

The primary environmental advantage of the IGCC system, compared to conventional coal plants, is low SO_2, CO, NO_x, and PM emissions. The gasification process can remove as much as 99 percent of sulfur in coal and vastly reduce particulate, including black carbon, emissions during combustion. Also, because combustion temperatures are lower, NO_x emissions are reduced by 90 percent or more compared to a conventional pulverized coal plant.

"Recycled" Energy

A 2005 analysis by researchers at the Lawrence Berkeley Laboratory[2] concluded that there are at least 19 different technological approaches to extracting energy that are largely unused or under-used in the United States. The purpose of the analysis was to determine whether such less traditional technologies have sufficient market potential to warrant the development of a clean energy technology initiative on the energy supply-side that might complement the energy efficiency programs offered on the demand side.

The study identified 19 diverse technologies, ranging from small,distributed power systems on farms to large integrated gasifiers at petroleum refineries. The characteristics of the technologies and potential users vary widely, and so do the barriers to and opportunities for implementation.

The preliminary results of the analysis concluded that there is a technical potential of nearly 100,000megawatts (MW) of untapped electrical capacity, capable of producing 742 terawatt-hours (TWh) of electricity, saving roughly 19 percent of current U.S. electricity consumption. The energy savings would reduce carbon dioxide emissions (CO2) by nearly 400 million metric tons, as well as 630,000 metric tons of nitrogen oxides (NOx), 1.8 million metric tons of sulfur dioxide (SO2), and 9 metric tons of mercury (Hg).

Fuel Cells

Fuel cells are devices that convert fuel into electricity chemically. Fuel cell power systems are extremely efficient, and they emit air pollution at negligible rates. Unlike turbines and combined-cycle systems, which must generate electricity or steam on a relatively large scale, fuel cells can do so in much smaller applications. Thus, fuel-cell systems offer the possibility of small-scale as well as large-scale electricity production at a conversion efficiency ranging from 40 to 70 percent (and more than 80 percent when waste heat is fully utilized).

[2] Owen Bailey and Ernst Worrell, "Clean Energy Technologies A Preliminary Inventory of the Potential for Electricity Generation," LBL, 2005.

Fuel cells operating on natural gas emit very small amounts of NO_x and Carbon Monoxide (CO). Emissions of NO_x are in the range of 0.02 lb/mmBtu, and CO emissions are in the range of 0.2 lb/mmBtu.

Fluidized Bed Combustion

Fluidized bed combustion is very efficient, reducing CO_2 emissions by and reducing emissions of both NO_x and SO_2 by 80 to 95 percent as compared to conventional generators. There are two basic types of fluidized combustors: atmospheric fluidized-bed combustors (AFBC) and pressurized fluidized-bed combustors (PFBC). Both types offer advantages compared to conventional pulverized coal boilers. A fluidized-bed is a mass or "bed" of small particles – solid fuel, ash and sorbents used for sulfur removal – through which flow large volumes of air and combustion gases. The gases move through the bed at velocities sufficient to cause the mass of particles to behave like a fluid; hence the term "fluidized-bed."

Atmospheric Fluidized Bed Combustion

In the AFBC, one or more fluidized-beds are used to perform two key functions: combustion of the fuel and capture of sulfur carried in the fuel. Unburned solid fuel is fed back into the bed and mixed with the bed's hot particles, increasing efficiency and reducing particulate emissions. Thermal energy is removed from the bed by heat transfer to water carried in tubes passing through the bed. The resulting steam can be used indirectly for space or process heat, to drive a steam turbine, or both.

Pressurized Fluidized Bed Combustion

Pressurized Fluidized Bed Combustion (PFBC) systems are composed of a fluidized bed combustor operating under elevated pressure, which drives a gas turbine. The electrical output of the gas turbine can increase the efficiency of the system to 43 percent under optimal conditions. Second generation units are expected to have efficiencies of 45 to 55 percent. Typical unit size is 200 to 400 MW, larger sized plants can be developed by integrating multiple units.

The Värtan PFBC plant in Stockholm is probbably the cleanest coal plants in the world. Owned and operated by Stockholm Energy, the plant is located near the center of the city. It can produce 135 MW of electricity and more than 225 MW heat, which is supplied to the district heating grid. The plant burns low-sulfur and low ash, imported coal. The plant is equipped with systems for SNCR and mini-SCR NO_x reduction, high efficiency bag filters, fuel and sulfur sorbent storage, handling and preparation facilities, and auxiliary equipment. Its operating efficiency is 93 percent, compared to the average efficiency of existing U.S. plants of about 33 percent.

Combined Heat and Power Production

Combined-cycle generators, which use waste heat to generate electricity, are described above. The term, Combined Heat and Power (CHP), describes any system in which waste heat is used for purposes such as industrial processes or space heating or cooling. In the typical U.S. powerplant, roughly one-third of the fuel is converted to electricity, while two-thirds is vented into the air through cooling towers or other ways of releasing the waste heat. The use of waste heat can bring overall efficiencies of electric generators up to 90 percent. There are two types of CHP systems commonly in use: cogeneration systems and district heating systems.

Cogeneration facilities are electric generating plants sited at an industrial "host". The process and space heating demands of the industrial site are met by utilizing steam heat from the electric generating plant that would normally be rejected to the atmosphere as waste. This saturated steam has significant heat content but the moisture content of saturated steam prevents it from being utilized in a steam turbine. District heating is basically the same as cogeneration except the host is a residential or commercial location.

A variety of cogeneration technologies now are employed that continue to improve the overall efficiency of combined heat and power generation. Conventional steam turbines that recover a portion of waste heat are being displaced by higher-efficiency and less costly gas-turbine combined-cycle cogeneration systems that use heat from the gas turbine to run a lower-temperature steam turbine as well as to provide process steam. This system configuration results in higher electric power production per unit of heat production allowing units to either be scaled up or sited at a smaller "host."

Cogeneration systems operate at an overall system clean natural gas fired efficiency of 80 to 85 percent compared to 33 percent efficiency for the typical coal fired electric generating plant. Emission reductions will depend on (1) the efficiency of the generator, and (2) the kind of combustion displaced by the waste heat from the generator. In a "low-reduction" scenario, a simple-cycle turbine might capture enough waste heat to make it as efficient as a combined-cycle turbine, and the displaced combustion might have a relatively low emission rate. In a "high-reduction" scenario, enough waste heat could be captured to bring total system efficiency up to 90 percent and waste heat might reduce the use of a unit with high emissions.

Policy Options

To have the greatest influence on the emissions of fossil-fueled electric generators, state and local air agencies must work with power generation companies and utility regulators to increase the efficiency of power plants and switch to lower carbon fuels. These goals can be achieved by a number of regulatory and market-based mechanisms. Note that the policy approaches discussed here, focusing on fossil-fired generation, must be considered along with those discussed in the section on renewable energy technologies.

Change the Form of Emission Standards. To promote plant efficiency, air regulators should adopt emission standards expressed in terms of energy output (lb/MWH) not heat input (lb/mmBtu). This simple change would result in considerable carbon reductions, as plant owners increased efficiencies in order to comply with emission standards at lower cost.

Incentivize Plant Retirement. Government agencies should seek to provide companies with incentives such as tax credits to convert older coal- and oil-fired plants to gas, clean coal or carbon-free technologies. If competition puts pressure on companies to extend the life of the older equipment, government agencies should attempt to offset these pressures with other incentives.

Support Clean Technologies. To stimulate advanced fossil-fueled technologies in the market, state and local agencies can increase their support of demonstration projects utilizing low-emission technologies. State and federal funds are often available for such projects, and the support of state regulators increases the chances of obtaining these funds. Regulators should also seek to facilitate innovative partnerships between project developers and other stakeholders in the climate change debate.

Permitting Exemptions. Very-low emitting fossil technologies, such as fuel cells, should be exempted from air permitting requirements. This would attract developers to these technologies and lower the administrative costs of projects. Fuel cells are exempted from the air permitting process in Massachusetts and areas of California.

Impose Taxes or Feebates. By taxing CO_2, Sweden and Denmark have stimulated significant movement toward non-carbon fuels, ranging from biomass to wind power. In Sweden, this incentive effect is bolstered by taxes on other pollutants, including CO_2 and volatile organic compounds.

Level the playing field. Currently, disparate emission standards applied to power plants of different vintages provide an environmental subsidy to older plants by allowing them to pollute at higher rates. Removing this inequity in emission regulation would make the new technologies discussed above more competitive with older power plants. The most efficient way to "level the environmental playing field" is with GPSs. These standards would cap emissions of a given pollutant within a region and allocate emission allowances based on a generator's portion of total generation in the region. Thus, companies are rewarded for efficient generation, tradable allowances facilitate efficient compliance, and allowances are not allocated based on historical emissions but on actual activity levels.

Regulate In-state Electricity Sales. Governments could, as California has with respect of long-term sales of coal-fired electricity, require the power to meet minimum emission standards.

Pulp and Paper

Implement recycled product specifications.

Consideration should be given to establishing cogeneration as Best Available Control Technology or Reasonably Available Control Technology

Develop guidelines for procurement of recycled and unbleached paper products by state and local agencies.

Large paper consumers can also be encouraged to use paper products following the same guidelines, following the example of L.L. Bean (Maine) and many other companies.

Petroleum Refineries

Consideration should be given to establishing combined heat and power as Best Available Control Technology or Reasonably Available Control Technology at refineries.

Consideration should also be given to requiring pinch analysis and optimized process management as Reasonably Available Control Technology.

Promote participation in the Department of Energy's "Industry for the Future" project. Various research projects are being undertaken to reduce energy consumption, increase resource recovery and reduce emissions.

11.

1. FRIEDMAN, M.S., POWELL, K.E., HUTWAGNER, L., GRAHAM, L.M., & TEAGUE, W.G. Impact of changes in transportation and Commuting behaviors during the 1996 Summer Olympic Games in Atlanta on Air Quality and Childhood Asthma
JAMA 2001: 285; 897-905
Comparison of the 17 days of the Olympic Games (July 19-Aug 4) to a baseline period consisting of the 4 weeks before and 4 weeks after the Olympic Games. Peak one hour level of O3 fell to 50-100 ppb during the games from a predicted value of about 70-120 in the comparison periods. PM10 (24 hour level) was 20-45, compared to levels of 30-70; NO2 was only slightly lower running at about 30 ppb peak one hour level compared to values between 20-65. CO also slightly lower. Traffic density measurements showed decreases of 22% in weekday 1-hour morning peak traffic counts during the Olympic Games. Ozone levels fell slightly over the same period in three different places 60 km to 100 km from Atlanta; but these changes were only about one fifth of the drop in Atlanta.
Citywide acute care visits and hospitalizations for asthma were logged. Results showed no changes in nonasthma diagnoses; decreases of 41% in Medicaid claims file, 44% decreases in HMO database; 11% decreases in two emergency pediatric departments; and decreases of 19% in Georgia Hospital Discharge Database. Lack of change in other diagnostic categories indicates that children did not leave Atlanta over the period of the Olympic Games.

2. One of the study's authors, Michael S. Friedman viewed it important because "it provides evidence that decreasing automobile use can reduce the burden of asthma in our cities and that citywide efforts to reduce rush-hour automobile traffic through the use of public transportation and altered work schedules is possible in America." Centers for Disease Control, "CDC study links improved air quality with decreased emergency visits for asthma," Press Release, Feb. 21, 2001, http://www.cdc.gov/od/oc/media/pressrel/r010221.htm.

3. BURNETT, R.T., SMITH-DORION, M., STIEB, D., RAIZENNE, M.E., BROOK, J.R., DALES, R.E., LEECH, J.A., CAKMAK, S., & KREWSKI, D.
Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age
Am J Epidemiol 2001: 153; 444-452
15 year period 1980-1994 in Toronto (including 6 cities of Toronto, North York, East York, Etobicoke, Scarborough & York). Daily number of emergency or urgent hospital admissions for croup, pneumonia, asthma and acute bronchitis/bronchiolitis. Gastroentieritis used as control (second leading cause of hospitalization). Prediction equations, previously validated, used to predict PM2.5 from TSP, and sulfates also used in the summer. LOESS nonparametric smoothing method. Adjustemnt for weather descrivbed, and temporal trednds and day of the week effects taken oput. Mean values for ozone 45.2 ppb; PM2.5 18 micrograms/m3; PM10-2.5 16.2; NO2 ppb 44.1; SO2 ppb 11.8; CO ppm 1.9. Mean admissions/day for respiratory problems 2.9; mean GI admissions 1.2:
Percentage increase in daily admissions in May-August period was 14.2% associated with a 45.2 ppb increase in O3. (daily one hour maximum.) if lag of one day used. If lag of 2 days, was 13.2% increase. Based on five day average, 45.2 ppb increase in ozone associated with 34.8% increase. This became 29.4% after adjustment for either PM10-2.5 or NO2. Correlation of O3 withPM2.5 was0.58 and with NO2 was 0.52; with CO was 0.24.
Increases for asthma were 31.3%; croup 45.3%; acute bronchitis/bronchiolitis 45.7%; and 23.3% for pneumonia. Note of CO relationship since this showed strongest relationship after adjustment for ozone.

4. PETROESCHEVSKY, A., SIMPSON, R.W., THALIB, L., & RUTHERFORD, S.
Associations between outdoor air pollution and hospital admissions in Brisbane, Australia
Arch Environ Health 56; 37-52; 2001
Period of study was 1987-1994. Total of 41,127 emergency admissions for cardiovascular disease, and 33,710 respiratory admissions which included 13,246 for asthma (constituting 39% of all respiratory admissions). All public hospitals in Brisbane area included. Air pollution data from 7 stations, measuring ambient levels every half-hour. 24 hour averages and maximal 1 hour concentrations used in analysis, but an 8 hour average used for ozone. Statistical analytical methods exactly followed the APHEA protocol, which is described in some detail. This is an iterative model-building process after correction for more than 60 day temporal cycles. Abstract notes: "Ozone was consistently associated with admissions for asthma and respiratory disease – with little evidence of a threshold. In two pollutant models, the ozone effect was relatively unaffected by the control for high levels of other pollutants. Particulate pollution (measured by nephelometry) was associated positively with admissions for respiratory disease and admissions for asthma in summer, whereas a negative association was observed for cardiovascular admissions". SO2 was associated with admissions for the control diagnosis of digestive disorders.

Note that ozone levels were similarly elevated throughout the year, with mean 8 hour levels being 1.99; 1.67; 1.61; and 2.23 pphm in summer; autumn; winter and spring respectively. Mean 24 hour NO2 levels were 0.97; 1.29; 1.79; and 1.53 pphm in the same seasons. NO2 was not associated with hospital admissions. Risk ratios for asthma admissions in age groups 0-14; 15-64; and for total asthma were 1.064; 1.084; and 1.090 for a unit increase (pphm) in 8 hour ozone. This represents a 9% increase in asthma admissions per 1 pphm increase in ozone. Figure of RR for asthma all ages versus average 8 hour O3 lagged 2 days is linear from 1.0 to 3.0 pphm with no evidence of a lower threshold.

5. BAG, R., FROLOV, AQ., KEYS, J., ZIMMERMAN, J.L., & HANANIA, N.A.
Association between ambient ozone levels and emergency department (ED) visits for asthma in Houston, TX, USA
Am J Respir Crit Care Med 161: A308; 2000
Adult visits for asthma (> 17 years) recorded. 7982 asthma visits with 4214 during the ozone high months. Mean age 41.6 years; 61% were women. In ozone months, mean values were 36.8 ppb as 8 hour average and 50.8 for 1 hour maximum levels. 71 days with 8 hour average above 0.08 ppm. Significant association between ozone levels and ED visits in the ozone months.

6.SUNYER, J., BASAGANA, X., BELMONTE, J., & ANTO, J.M.
Effect of nitrogen dioxide and ozone on the risk of dying in patients with severe asthma
Thorax 2002: 57; 687-693

Patients over the age of 14 who died during the period 1985-1995 in Barcelona who had visited the emergency department of one of the four largest hospitals in the city. for asthma during 1985-1989. Total of 467 men and 611 women. “Air pollution was measured at the city monitoring stations which provide a mean for the entire city”. Daily values of PM10 - appears to have a mean value of 61.2 micrograms/m3; Black smoke 40.0; 1 hour NO289.7 micrograms/m3; 24 hour NO2 52.3 micrograms/m3; 1 hour ozone 69.3 micrograms/m3; 8 hour ozone 54.4 micrograms/m3; SO2 18.8 micrograms/m3; Pollen and spores recorded weekly and measured by ‘the Cour method’. Thought to be accurate for pollen grains, but fungal spores get damaged and are underestimates.

For cases with more than one admission always for asthma, the odds ratio for interquartile change was as follows:

> NO2 1.688 (1.074 to 2.652): Ozone 1.755 (0.984 to 3.133) with 95% confidence limits in brackets. These values were not much changed by correction for total pollen and for spore counts. “Patients with severe asthma – that is, those with more than one admission to the emergency department for an asthma exacerbation – had a higher risk of dying on days with higher levels of NO2 regardless of the season, and O3 in the warm season. These associations were not confounded by the weekly levels of pollen and fungal spores”

7.DESQUEYROUX, H., PUJET, J-C., PROSPER, M., SQUINAZI, F., & MOMAS, I.
Short-Term effects of low-level air pollution on respiratory health of adults suffering from moderate to severe asthma
Environmental Research Section A; 89;29-37 (2002)
60 severe asthmatics mean age 55 studied over 13 month period. Criteria included attendance at Center for Treatment of Respiratory Diseases in Paris, and included more than 15% increase in FEV1 after beta2 agonist inhalation; more than 20% FEV1 fall after provocative dose of methacholine; recurrent wheezing and physician certified moderate to severe asthma. Daily values of SO_2 from 28 sites; for PM_{10} from 7 sites; for NO_2 from 15 sites; and from 6 sites for O_3. Each subject seen by a physician at each consultation whether scheduled or emergency. An Asthma attack was defined as the need to increase twofold the dose of inhaled beta2 agonist and confirmed by clinical examination.
Odds ratio for risk of an asthmatic attack per 10 microgram/m^3 increase in PM_{10} was 1.41. An increase of 10 microgram/m^3 (5 ppb) of Ozone was associated with an OR of 1.20. 3-5 day delay for PM_{10} but 2 day delay for O_3. No association with NO_2 nor with SO_2. Convincing and clinically thorough panel study.

8. **THURSTON, G.,** LIPPMANN, M., BARTOSZEK, M., & FINE, J.
Summer haze associations with asthma exacerbations, peak flow changes, and respiratory symptoms in children at a summer asthma camp
In: Program Abstracts of the Sixth Conference of the International Society for Environmental Epidemiology: Research Triangle Park, NC September 18-21, 1994.
Abstract 227:
Daily air pollution and health data collected for a week in June 1991, 1992, and 1993 at a camp for asthmatic children. Highest O3 was 160 ppb in 1991, and in 1992 was 63 ppb. Children aged 7-13 had to go to on-site physician for medication. Medication requests monotonically related to ozone levels. Decrements in PEFR also noted. Conclude that there was "a strong association between summertime haze air pollution and asthma exacerbations". Upper respiratory symptoms of sore throat, runny nose, and eye irritation were related to pollen counts in 1992 when pollution levels were low.

9. California Air Resources Board, *The Land Use-Air Quality Linkage*, 1997.

10. Rebecca Carr, “GRTA request for funds well received; Area fights image as sprawl ‘poster child,’” *The Atlanta Journal*, C9, Feb.11, 2000.

11. Please note this table relies on data collected by other researchers from the metropolitan areas themselves. The numbers differ slightly from those available at publicly accessible data sources, such as the Bureau of the Census, presumably because of varying assumptions in predictive models. Other tables in this paper rely on Census and comparable official data.

12. Jim Motavalli, “Chattanooga on a roll: from America's dirtiest city to one of its greenest,” *E-Magazine*, p. 13, March 13. 1998.

13. Torres, Nelson - Translator, *Curitiba, The Ecological Revolution,*Pallotti, Av. Plinio Brasil Milano.

14. Municipal Secretariat for the Environment, City of Curitiba, *Curitiba: Toward an Environmentally Correct City*, p. 3, (Curitiba, Brazil, undated).

15. Municipal Secretariat for the Environment, City of Curitiba, *Curitiba: Toward an Environmentally Correct City*, p. 3, (Curitiba, Brazil, undated).

16. Torres, Nelson - Translator, *Curitiba, The Ecological Revolution,*Pallotti, Av. Plinio Brasil Milano.

[2] See Appendix B

18. Types of digesters include the following:

Complete-mix: These are more common in warmer climates, where manure is flushed out of bams or pens with water. lowering the solids' concentration to a level generally between 3 percent and 10 percent. Often there is a mixing tank where the manure accumulates before entering the digester. These digesters make use of gravity and pumps to move the manure through the system. They are often in the shape of a vertical cylinder and made of steel or concrete with a gas-tight cover. These digesters are typically heated to maintain a constant temperature and constant gas flow.

Plug-flow digesters: These consist of long and relatively narrow heated tanks, often built below ground level, with gas-tight covers. Plug-flowdigesters are only used for dairy manure because they require higher manure solids' content, around 11 percent to 13 percent. As with complete-mix digesters. they are maintained at constant temperatures throughout the year to maintain consistent gas production.

Fixed-film digester: These work where concentrations of solids are very low, such as in manure management situations where manure is very diluted with water. Fixed-film digesters consist of atank packed with inert media on which bacteria grow as a biofilm.

Covered lagoon: Covered earthen lagoons are the simplest systems used in large-scale operations in developed countries and generally the least expensive. Used with solids' concentration of less than 3 (e.g with swine or dairy cattle) methane is captured by covering the manure lagoon with a floating cover and piping the gas to its point of use. Because these digesters are not generally heated, the available gas flow varies significantly over the course of the year.

Dome digesters: These small-scale. unheated digesters are used in developing nations to provide cooking fuel. A typical dome digester is a brick-lined cylinder sunk in the ground with a wall dividing the cylinder into inlet and outlet ports connected to the bottom of the tank. Biogas is typically used by the household for cooking and other household energy needs.

Polyethylene bag: A small-scale, unheated digester used in developing nations that also provides fuel for cooking, this digester is a hole dug in the ground covered with a plastic bag, with an area for input of manure and a pipe with a valve for gas produced.

Covered lagoon: a smaller-scale and much cheaper version of the covered lagoon small-scale lagoons generate bicgas for household use, although some can produce enough energy for shaft power for, for example, irrigation.

Flexible-bag: another relatively simple and low-cost unheated digester, used principally in developing countries for fuel and light, the gas is generated and collected in a plastic bag.