Final Report

Can We Have Our Cake and Eat It, Too? Creating Distributed Generation Technology to Improve Air Quality

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Executive Summary

As a result of the deregulation of the utility industry, there is a growing potential for small, distributed sources of electrical power that may serve a single home, neighborhood, business, or business complex more efficiently than centrally located power plant, and at a lower cost. Indeed, the primary goal of electric power deregulation in California and elsewhere in the United States is to lower electricity costs through market competition and greater consumer choice. The challenge of achieving this goal through a movement toward more efficient energy generation that is simultaneously less harmful to the natural environment poses important questions: Exactly what kinds of DG should energy and environmental policy favor? What level of government is best-suited and/or most capable of governing DG? And what is the range of regulations that would most easily facilitate the competitive success of DG, in individual states as well as nationwide?

Motivated by questions such as these, this report recommends and rationalizes DG policy that is capable of improving air quality. More specifically, we: 1) determine the forms of DG that are most likely to improve environmental quality, and to reduce air pollution—in California, in particular; 2) determine the level of government that is best suited to govern the wide-scale introduction of DG into California and other states; and 3) recommend a set of regulatory actions designed to foster the growth of DG in a manner that is most likely to improve air quality and generally improve the natural environment. This research strategy entails a comparative analysis of the electricity generation process with heat recovery created to assess the level of polluting emissions associated with a range of technologies and fuel types. Then, given the results of this analysis, we evaluate the federal-state-regional-local governance structure responsible for regulating energy and environmental policy in California and a number of other states. From this, we determine a general policy and set of specific regulations for ensuring the use of the DG technologies and fuel sources that would be most beneficial to the environment and public health.

Our analysis suggests DG does have the potential to provide security to the U.S. electrical generation system along with competition that will insure the lowest cost electricity. Additionally, it is very reasonable to expect that DG will play a role in reducing local, regional, and even global air pollution, though this outcome is far from assured within the existing regulatory framework. *Yet only the lowest emitting DG with significant waste heat recovery is even marginally competitive with combined cycle power production when air pollution issues are considered*. Thus we advocate technology-forcing in the specific form of manufacturer-based regulation, which would require, over time, the reduction of emissions from DG units at the point of manufacture as a means of ensuring greater air quality.

I. Introduction

As a result of the deregulation of the utility industry, there is a growing potential for small, distributed sources of electrical power that may serve a single home, neighborhood, business, or business complex more efficiently than centrally located power plant, and at a lower cost. There are a variety of reasons for the interest in this distributed generation of electricity (DG). Central generating companies, often referred to as wire companies, see the potential for reduced loading on transmission equipment, local voltage support, and economics (Bartos, 2000; Carlson, 2000). Government utility regulators and energy agencies see the potential for increased competition, and thus price reductions, improved system reliability, more efficient resource use, and the need to address growing electricity demands (Silverstein, 2000). The United States Environmental Protection Agency (EPA), the developers of the Kyoto Protocol, and public interest groups have pointed out the potential value of DG for reducing air pollution and increasing energy efficiency (Grubb et al., 1999; MacCracken et al., 1999). Finally, DG equipment suppliers see the opportunity to increase market penetration and profits.

The position of each DG "interest group" is, of course, motivated by the type of DG that is envisioned by that group and who that DG "belongs" to (Vogel, 2000; Weisberg, 2000). In fact, there appears to be no clear definition of DG at this point in time other than at the extremes. At one extreme, large central-station electrical generating units that traditionally fall under environmental regulatory and public utility regulatory constraints are not considered DG. These units require extensive permitting, must offset emissions, and must meet strict production and connection requirements. This, at a minimum, captures generating units in excess of 100 megawatts capacity. Generating units that are sized to support a single home or moderate sized business are clearly at the other extreme. These typically less than 1 megawatt units fit within virtually all definitions of DG and in most cases are not included in present environmental regulatory structures. In the case of generating units greater than 1 megawatt and less than 100 megawatts, the designation as DG can vary from case to case. For purposes of this report the exact cut-point for DG is not critical and no attempt will be made to define a specific value.

In addition, DG may be distinguished by fuel type. Of course, DG has been developed in the form of renewable generation, such as photovoltaic conversion and wind energy conversion. These two forms of electrical generation may raise some environmental concerns in the broadest context such as visual blight, bird deaths (in the case of wind turbines), noise, or ultimate system disposal at the end of its life; however, they pose no direct air quality implications. Wind and solar energy should be subjected to a full cycle analysis and thus be fully evaluated in terms of environmental and energy penalties associated with the manufacture and disposal of this form of generation, but it is likely that they will pass with flying colors. For purposes of this report, they will be considered a net positive in all cases and will not be evaluated further. This report will thus evaluate DG derived from the oxidation[1] of fuels as the main point of consideration. DG fuels can be traditional fossil fuels, biomass, or waste combustibles from business, waste processing, home, or agricultural sources. This latter form of DG will be the focus of this report

[1] Oxidation includes the normal combustion of fuel in a boiler, turbine, or IC engine as well as the chemical "combustion" of fuel in a device such as a fuel cell.

since it has the potential to produce significant amounts of urban, regional, and global air pollution.

Of course, energy conservation may also fall under the rubric of DG, depending upon how this term is defined. To clarify this issue, the term distributed resources, DR, is often used in place of DG, and energy efficiency and energy conservation are viable forms of DR in the broader context. For purposes of this report, there is no need to address this decision either. Energy conservation carries with it no presently identified negative air quality implications and enjoys wide public support.

The centrality of energy conservation and environmental protection to public policy in the United States notwithstanding, policy concerns related to the growth of DG in this country emphasize the cost-effectiveness of these new sources of electricity (California Energy Commission, 1995). Indeed, the primary goal of electric power deregulation in California and elsewhere in the United States is to lower electricity costs through market competition and greater consumer choice. The challenge of achieving this goal through a movement toward more efficient energy generation that is simultaneously less harmful to the natural environment poses important questions: Exactly what kinds of DG should energy and environmental policy applicable to California favor? What level of government is best suited and/or most capable of governing DG in California? And what is the range of regulations that would most easily facilitate the competitive success of DG in this state?

Motivated by such questions, policy-makers, analysts, and the public at large increasingly realize that DG must address a number of critical issues, specifically:

1. Effective interconnection to the electricity grid.
2. Safety of DG operating in residential and commercial applications.
3. The economics of DG as an alternative to centrally generated electricity (CG).
4. Preserving the natural environment.

The interconnection and safety issue is being extensively addressed by the Institute of Electrical and Electronics Engineers, with support from the United States Department of Energy (DOE), through development of standards, as well as by individual state initiatives. We believe the question of cost issues likewise will be taken into account. The purpose of this review is to recommend and rationalize DG policy that is capable of improving air quality.

II. Air Quality

For purposes of this report, air pollution is any material that is introduced into the air in such quantities that it creates a significant local, regional, or global health, welfare, or ecological impact. In the United States, air pollution has been traditionally divided into four categories. These are: a) criteria pollutants[2], b) toxic compounds[3], c) ozone depleting compounds[4], and d)

[2] Criteria pollutants include carbon monoxide, nitrogen oxides, sulfur oxides, ozone, volatile organic compounds, and lead. Although the elimination of lead from gasoline has minimized the generalized nature of lead pollution.

global warming compounds[5]. DG can be a source of all such forms of air pollution except ozone depleting compounds. On a geographical basis, air pollution is typically discussed in the following three settings: a) urban air pollution, b) regional air pollution, and c) global air pollution. Each will be discussed independently.

A. Urban Air Pollution

The highest levels of air pollution typically occur in the densely populated urban areas. This is also where the greatest health problems are incurred due to the proximity of people and acute air pollution. In spite of thirty years of efforts, most American mega-cities continue to violate one or more air quality standards. Figure II.1 denotes non-attainment areas in the United States. Worldwide, most major cites also have severe and growing air pollution problems. In addition, the EPA promulgated tighter ambient air quality standards in 1997. While these standards are presently under judicial review, such tighter standards are likely to come into effect in the near future. This will demand even greater air pollution control efforts in U.S. cities to protect human health and welfare. It is into these urban settings that the highest concentrations of DG will likely develop. Thus, the impact of DG on urban air quality is a key issue that must be considered.

B. Regional Air Pollution

The concern over regional air pollution began in the late 1970s with the development of PSD[6] protection programs for national parks and wilderness areas. This concern has grown as the impacts of acid rain and the reduced visibility in the east and west has been recognized. More recently in the eastern United States, ozone has been recognized as a regionally transported pollutant. This problem is being addressed via a multi-state joint regulatory program. The long-range transport of acidic air pollution between the United States and Canada in the Northeast and between the United States and Mexico in the Southwest has long been noted, and is similarly the focus of binational air pollution abatement programs (Allison,1999; Ingram, 1988). More recently, transboundary air pollution moving from Asia to the West Coast has also been identified (Smil,1993). It is thus important to evaluate DG in the context of its regional implications.

[3] Toxic pollutants involve a wide range of compounds which have acute toxic properties or can cause cancer. Common toxic pollutants are mercury, benzene, 1,3 Butadiene, chromium, formaldehyde, and many others. More recently diesel particulate matter has joined this list in California.

[4] The chlorofluorocarbons are the predominate members of this class. These compounds are now generally banned all over the world.

[5] The key anthropogenic compounds in this class are carbon dioxide, methane, and nitrous oxide.

[6] PSD stands for prevention of significant deterioration. The concept of PSD is to prevent the air quality in clean areas from getting worse. Following the 1970 Clean Air Act amendments and a suit by the Sierra Club, a program was codified into the 1977 Clean Air Act amendments that sets special requirements for the protection of National Parks and wilderness areas and lessor levels of protection for other non-urban areas.

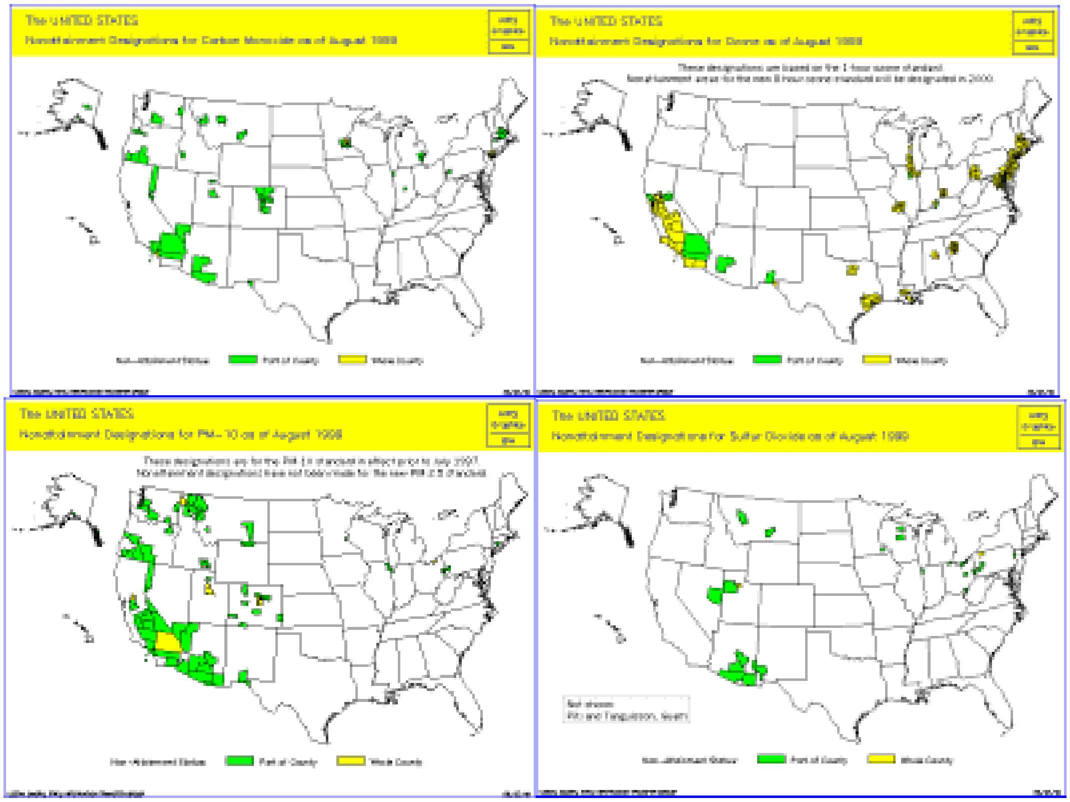


Figure II.1: US Non-Attainment Areas for CO, O_3, PM_{10} and SO_2 (EPA AIRS Website)

C. Global Air Pollution and Sustainability

Atmospheric levels of carbon dioxide have increased throughout the 20th Century in response to increased fossil fuel burning. Simultaneously, average temperatures worldwide appear to be increasing. Figures II.2a and b illustrate these changes.

a

b

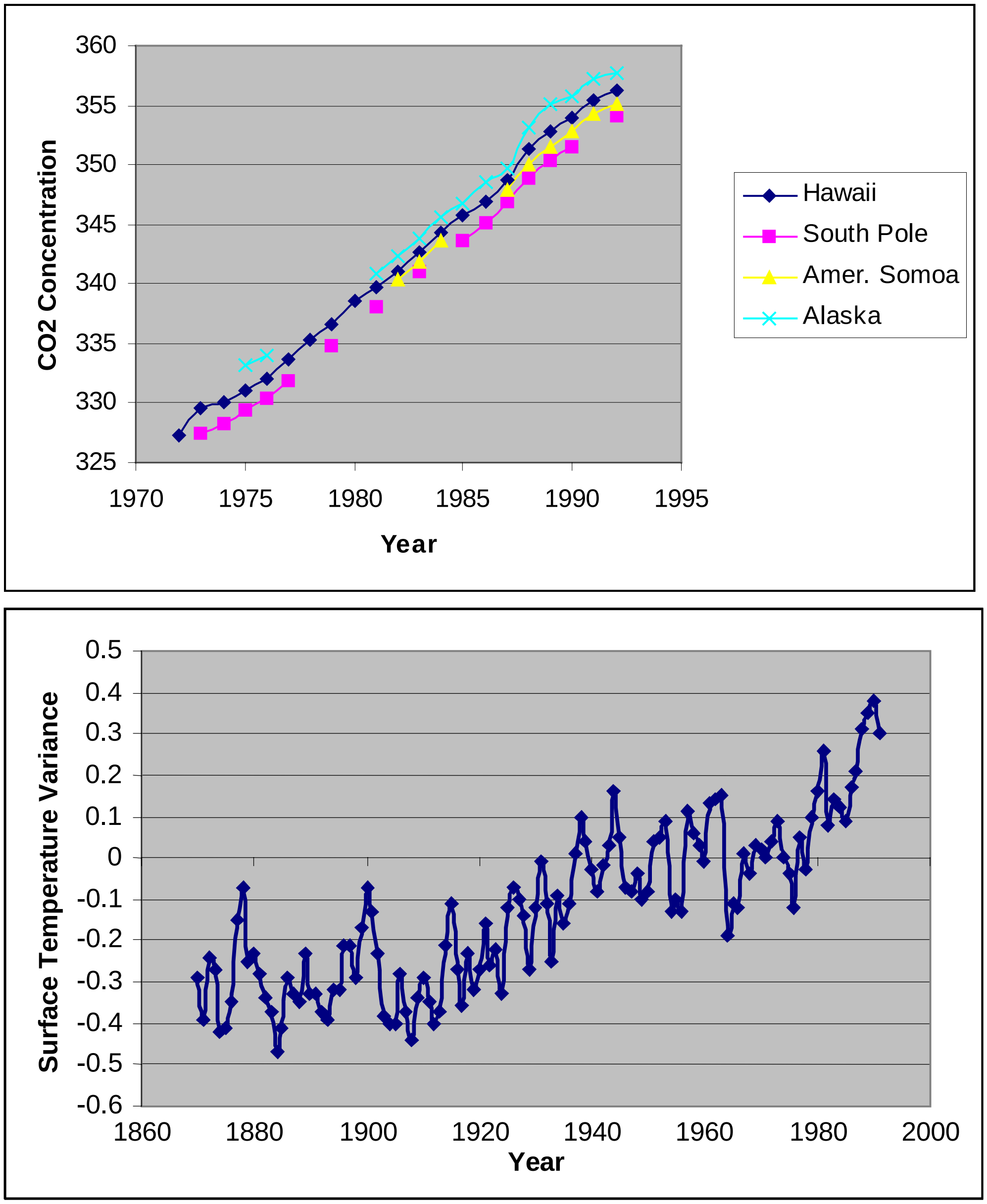


Figure II.2a: Atmospheric CO_2 Concentration 1970-1995. IIb: Surface Temperature Variance 1864-1991.

This has led to an intense debate about the impact of anthropogenic pollution on global climate. This debate has extended from discussions of CO_2 emissions to anthropogenic emissions of methane, CH_4, and nitrous oxide, N_2O. The causes of the CO_2 and N_2O emissions are overwhelmingly the combustion of fossil fuels. CH_4 can result from combustion processes, but also results from the decay of vegetation and waste and intestinal gases associated with human food production. Global warming gases are closely associated with human economic development and energy use and thus also relate closely to sustainability issues. DG can play an important positive or negative role in this issue.

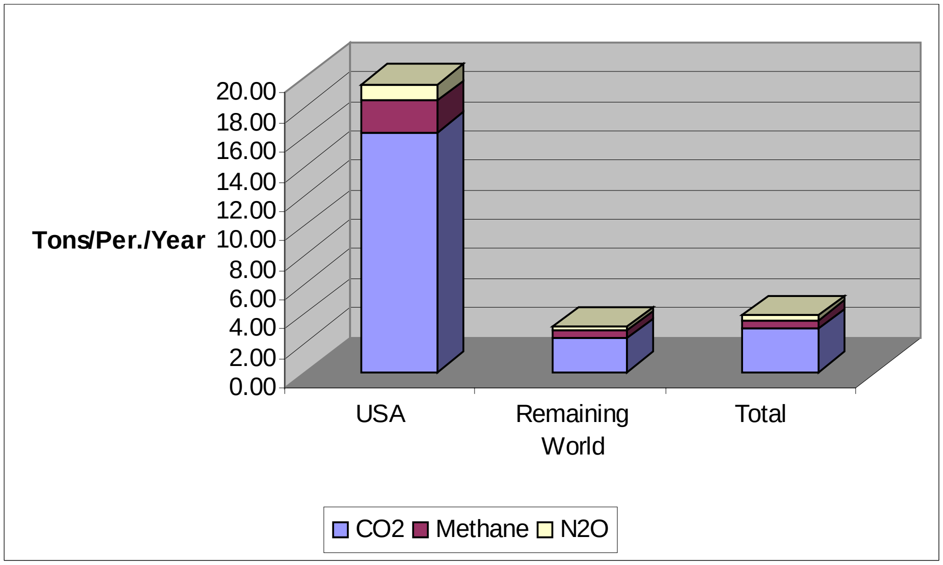
D. Growth and Future Air Pollution

Figures II.3a and b[7] illustrate the per capita emissions of global warming gases and criteria air pollutants in the United States compared with the rest of the world. Worldwide economic development that follows the U.S. pattern portends a considerable increase in global warming gases, criteria pollutants, and toxic emissions. Figure II.4a shows the growth of automobiles in developing countries compared to the United States, illustrating that these areas are adopting American lifestyles as their economy improves. Figure II.4b illustrates the population growth in the world since the beginning of civilization. The extreme rate of population growth in recent centuries combined with the recent growth of motor vehicle use and other energy demands in the developing world create significant implications for global sustainability and urban and regional air pollution problems in the 21st Century. Population growth rates are expected to slow considerably over the next 50 years, but by that time the world population will be over 9 billion.

Thus the consideration of DG must be taken in light of urban, regional, and global air pollution problems and the ability to provide adequate energy to support an economically developed world. At best, the goal for the application of DG should be to improve the environment. At worst, it should be developed in a way to avoid exacerbating environmental problems.

[7] The criteria pollutant graph represents the sum of VOC, NOx, SOx, and PM_{10} for each area.

a



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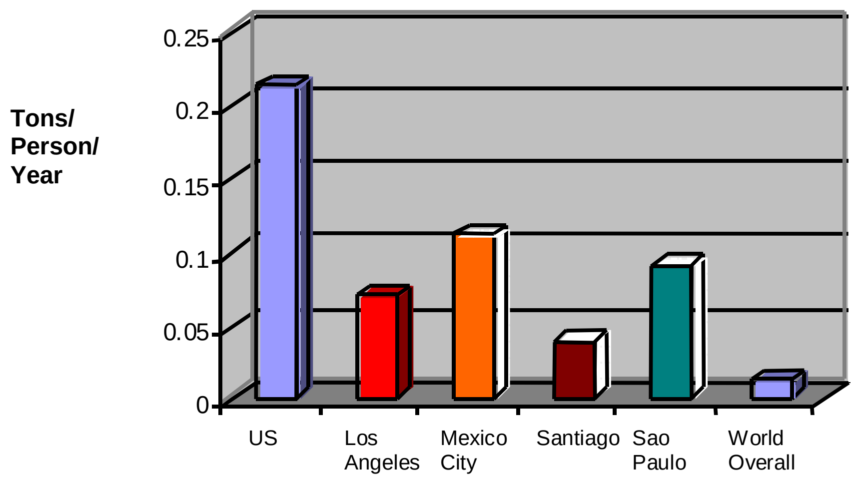


Figure II.3a: Per-Capital Global Warming Gases. II.3b: Per-Capital Criteria Pollutant Gases.

a

b

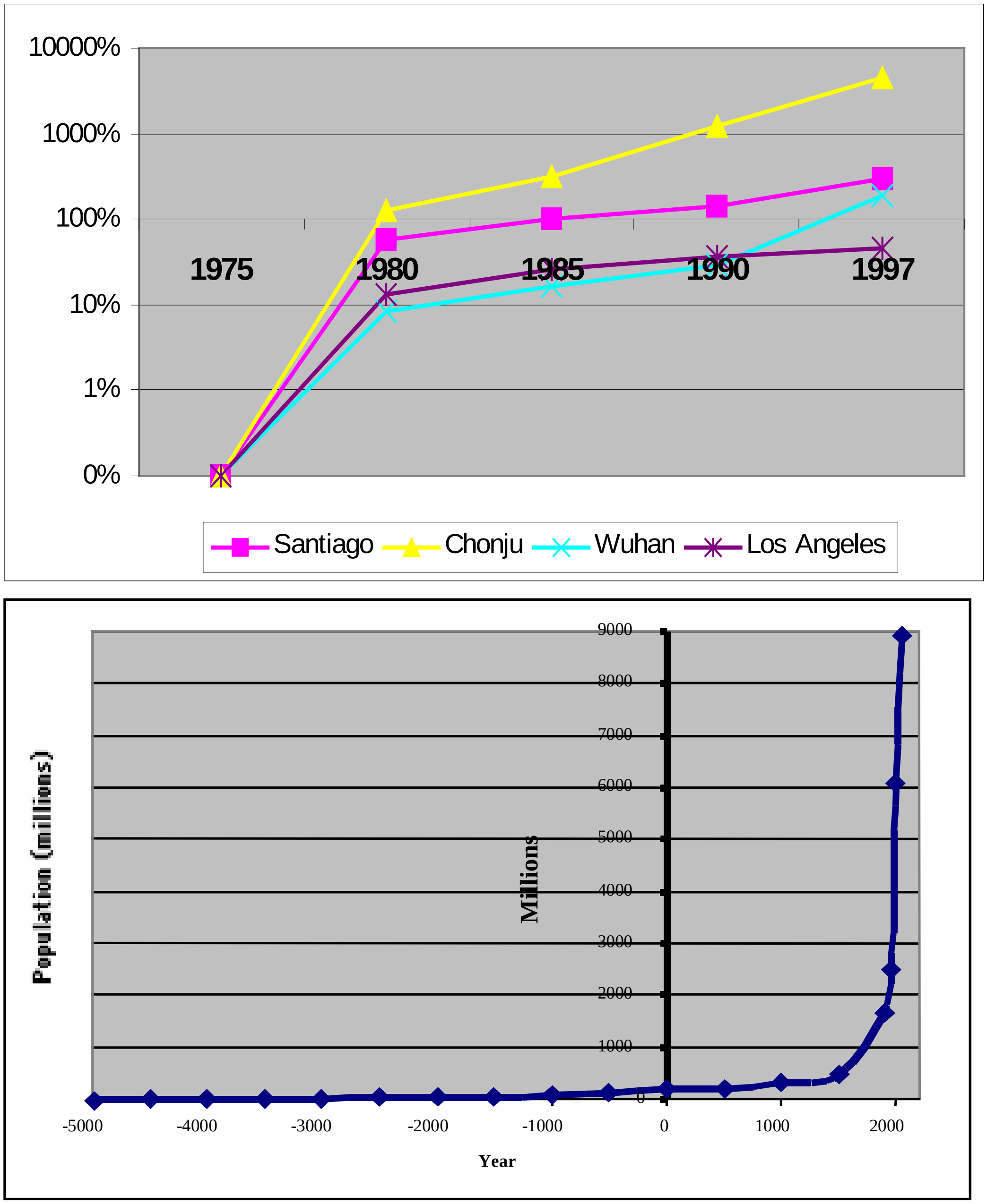
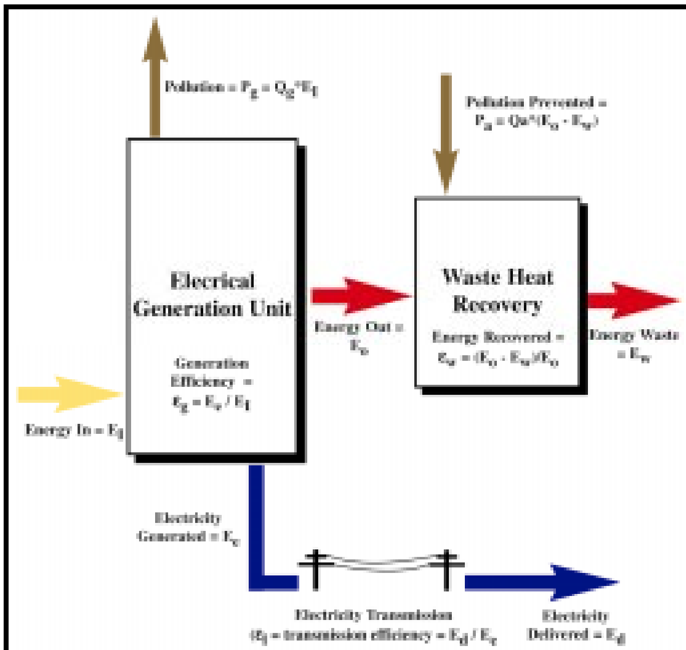


Figure II.4a: Vehicle Growth Rates in U.S. and Typical Developing Regions. II.4b: Worldwide Population Growth Rates since 5000 B.C.

III. Estimating the Air Quality Implications of Distributed Generation

The aforementioned goals for DG lead to an important and fundamental question for this analysis. To which power production technologies is DG compared when evaluating its air quality impacts? One might argue that the comparison should be to either no power production (and thus possibly austerity or more energy conservation) or to solar or wind energy. Austerity is not a likely or reasonable choice in the United States, and energy conservation can cover some of the needed demand but has not proved to be an adequate method for supplying all future power demands. Solar continues to be too expensive for general application and there are simply not enough good sites for wind energy to fill the demand for additional power generation cost-effectively. Therefore, an alternative response to this question would be to compare contending DG technologies with the central power plants that are currently being approved for construction and operation. At this time, all of the proposals for new power plants under review in California and Texas as well as in the Midwest and on the East Coast concern combined-cycle gas-fired power plants.[8] The most reasonable choice of a CG technology for comparison would be the gas fired combined cycle power generation. Figure III.1 illustrates the electricity generation process associated with fuel burning.



Where,
Q_g = generator pollutant emissions per kwhr of input energy.
P_g = generator pollutant emissions.
Q_a = avoided pollutant emissions per kwhr of input energy in waste heat recovery.
P_a = avoided pollutant emissions from waste heat recovery.
ε_g = generator efficiency (electricity generated per energy used).
ε_w = waste heat recovered.
ε_l = electricity transmission efficiency (energy transmitted per energy generated).

Figure III.1: Illustration of the Electrical Generation Process with Waste Heat Recovery

[8] Although coal-fired power plants are inexpensive to operate in areas such as the Midwest and East Coast, where coal is plentiful, they are increasingly costly to build. This is in part due to restrictions included in the CAA New Source Performance Standards (NSPS).

Figure III.1 can be used to represent either CG or DG. In the case of CG, waste heat is seldom recovered.[9] The emissions from the process in Figure III.1 can be written:

$$\mathbf{P_g = Q_g * E_I = Q_g * E_e / \varepsilon_g = Q_g * (E_d / \varepsilon_l) / \varepsilon_g = Q_g * E_d / (\varepsilon_g \varepsilon_l)} \qquad \textbf{Equation 1}$$

$$\mathbf{P_a = Q_a * (E_o - E_w) = Q_a * E_o * \varepsilon_w = Q_a * E_d * \varepsilon_w * (1 - \varepsilon_g) / (\varepsilon_g \varepsilon_l)} \qquad \textbf{Equation 2}$$

The net emissions from a generating system with heat recovery is thus,

$$\mathbf{P_N = P_g - P_a = [E_d / (\varepsilon_g \varepsilon_l)]* [Q_g - Q_a * \varepsilon_w (1 - \varepsilon_g)]} \qquad \textbf{Equation 3}$$

Equation 3 allows calculation of air pollution from a generating process with heat recovery based on the electricity to be supplied and the emission factors and efficiencies of the various processes.

Equation 4 compares the overall air quality impacts of a theoretical DG unit to the air quality impacts of a theoretical CSG unit. Thus,

$\mathbf{R_{DC}}$ **=** ratio of DG emissions to CSG emissions **=** $\mathbf{P_{NDG} / P_{NCSG}}$

Using Equation 3 and setting $\varepsilon_l = 1$ for DG and $\varepsilon_w = 0$ for CSG and introducing a new term f_C that corresponds to the fraction of CSG that is carried on in an urban area then,

$$\mathbf{R_{DC} = [(\varepsilon_{gC} * \varepsilon_{lC}) / \varepsilon_{gD}] * (Q_{gD} / Q_{gC}) * [1 - (Q_{aD} / Q_{gD}) * \varepsilon_{wD} * (1 - \varepsilon_{gD})]* (1 / f_C)} \qquad \textbf{Equation 4}$$

$\mathbf{f_C}$ is taken as 1 for regional and global pollution concerns since for these two cases the air pollution from CSG and DG are normally being introduced into the same air quality region.

IV. Analysis of DG Using Natural Gas or Diesel Fuel and Heat Recovery

A. Emission Factors for Generation and Heat Recovery

A likely application of DG is in the form of small turbines, internal combustion engines, or fuel cells in a small commercial or residential setting. In this case, any heat recovery will likely be in the form of hot water, space heating, and, more recently, space cooling. Equation 4 will be used to analyze this situation. Table IV.1 presents emissions and efficiency information for some potential DG units. The values presented were taken from a study for the California Air Resources Board (currently in draft form; see Greene and Hammerschlag, 2000). The emission

[9] One might consider that combined cycle generation recovers heat. However, this heat is used to generate more electricity, which is included within the context of the electrical generation unit. For purposes of this analysis the "heat recovery" in the combined cycle unit is captured as higher generation efficiency.

rates and efficiencies of many of the DG systems are continuing to change and the values in Table IV.1 will likely change over the next few years. The final row in Table IV.1 indicates the water heating emissions that we assume are replaced by any waste heat used for this analysis. Clearly, future experience will provide improved information on likely heat recovery applications.

Table IV.1: Emission Factors and Efficiencies Used for DG Analysis

Generation Type	Efficiency	CO	VOC	NOx	SOx	PM2.5	CO2*
	Elec.Out / EnergyIn	lbs / kwhr gen.	lbs / kwhr gen	lbs / kwhr gen	lbs / kwhr gen	lbs / kwhr gen	lbs / kwhr gen
Combined Cycle Gas	0.52	0.00017	0.00011	0.00013	0.00002	0.00002	0.62
Micro-Turbine	0.27	0.00285	0.00005	0.00140	0.00002	0.00009	1.25
ATS**	0.36	0.00260	0.00003	0.00109	0.00002	0.00007	0.95
Conventional Turbine	0.28	0.00151	0.00004	0.00124	0.00003	0.00009	1.20
Gas Powered ICE	0.35	0.00800	0.00170	0.00320	0.00001	0.00475	0.97
Diesel ICE	0.44	0.03000	0.00200	0.01700	0.00030	0.00300	1.70
PEM Fuel Cell	0.36	0.00000	0.00090	0.00002	0.00001	0.00000	0.95
Direct Fuel Cell	0.40	0.00000	0.00000	0.00000	0.00000	0.00000	0.85
Home/Commercial Water Heating	0.8	0.0542	0.009	0.2	0.0009	0.00774	155

*Emissions data for the other greenhouse gases N_2O and CH_4 were unavailable.
** Advanced turbine system

B. Ozone and Particulate Indices

To simplify the analysis that follows, pollutants have been grouped into two categories. The first category addresses ozone precursors. The second category addresses particulate precursors. Urban and regional ozone is the result of the interactions of VOC, NOx, and CO. CO acts like VOC but is only 2.1% as effective as typical VOC in forming ozone (California Air Resources Board (CARB), 1990). Urban and regional particulate matter, which contributes to visibility degradation and acid deposition, is the result of direct particulate matter emissions combined with NOx, SOx, and VOC, which is converted to particulate matter in the atmosphere. To simplify comparisons, an ozone and particulate matter index were created. The ozone index was created by adding VOC to NOx plus 0.02 times the CO. The particulate index was created by adding the PM2.5 emissions to 25% of VOC plus 50% SOx plus 50% of NOx to approximate the conversion rates.

C. Generation Location

An important consideration in carrying the analysis forward is the location of the various types of generation and the resulting impacts on urban airsheds. For example, by definition, all DG will be used within the local airshed. On the other hand, only a portion of central-station power generation typically occurs in the local airshed. Thus, from an urban airshed prospective some central-station power generation will contribute no emissions to that airshed. In the regional and global pictures, DG and central-station power will of course be emitting equally into these much broader airsheds.

It should also be considered that central-station power plants use much taller stacks than will typically be used for DG. These taller stacks disperse pollutants over a wider geographical range and reduce local impacts compared to DG. Thus, in the local urban situation, the impact of DG will be relatively greater than central-station power. This argument, of course, does not apply to the regional or global analysis. The great difficulty for the urban analysis will be the development of an appropriate factor to account for the central-station to DG location and stack height differences. In an exact analysis specific modeling studies would be necessary. However, this is beyond the scope of this study.

The issue discussed earlier of what DG will displace also becomes important in this context as well. As argued earlier, it is assumed that the most likely power source to be offset by DG is natural gas powered combined cycle electric generation. The central-station power plants being proposed for development at the present time tend to be very near or in urban areas.

For this analysis, it is assumed that 70% of central-station generation that would be displaced by DG will occur in the related urban airshed due to likely power plant location and stack height issues. This conservative assumption is closer to an educated guess than a scientifically derived estimate and arguments might be made in both directions. Considerable more effort is needed to understand the direct urban impacts of central-station power generation relative to DG generation.

D. Transmission Losses

One benefit of DG is its proximity to the point of use where central-station power generation can be located at a considerable distance for the point of use. For this general analysis, a simple assumption was made. Electricity generation outside of an urban area was assumed to result in a 15% transmission loss. Electricity generation inside of an urban area was assumed to result in no loss. Thus DG and central-station power in the urban airshed is assumed to have not loss.

Making the assumption that 70% of displaced central-station power would be located within the urban airshed results in an assumption that displaced central-station power has an overall transmission efficiency of 96%. If a 10% loss were assumed, the transmission efficiency would shift to 97% or if a 20% loss was assumed the transmission efficiency would shift to 94%. These tiny efficiency differences are extremely small in light of the present broad analysis.

V. Results of Analysis

A. Ozone Comparisons

Figure V.1a and b presents R_{DC} for the potential DG candidates compared to combined cycle centralized generation in an urban setting. The plots present relative net emissions verses heat recovered from the DG. Figure V.1a presents the full data set. Figure V.1b is an expanded version of Figure V.1a so that the cleaner technologies can be better viewed. A negative value in Figure V.1 indicates that the DG technology is actually reducing emissions from present levels while electrical generation is being increased.

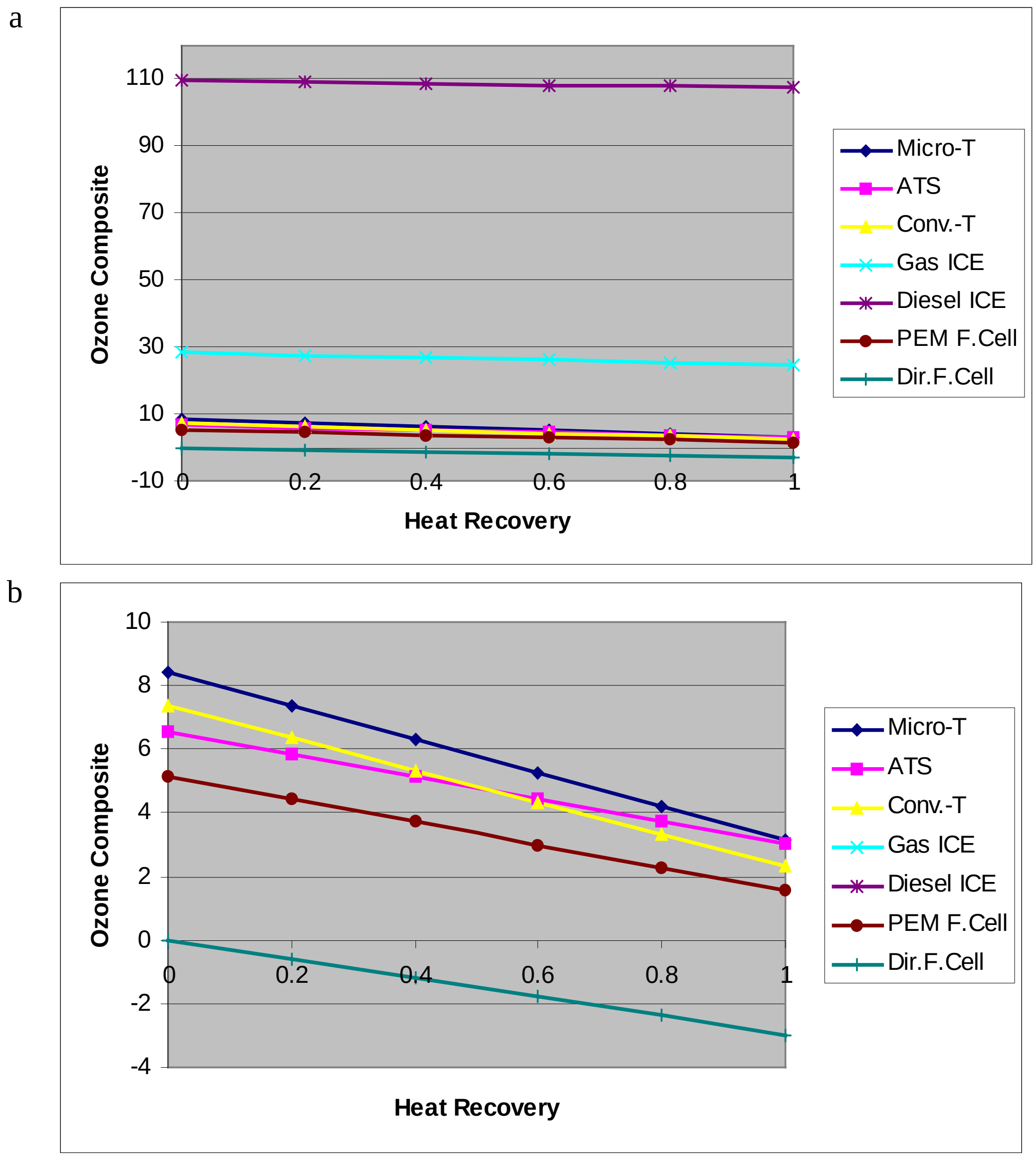


Figure V.1a/b: Relative Ozone Related Emissions of Candidate DG Units Compared to Combined Cycle for a Theoretical Urban Area

As can be seen in Figure V.1a/b, only the direct oxidation fuel cell, requiring no reforming, is competitive with combined cycle generation with no heat recovery. The diesel internal combustion unit has an ozone index 110 times that of combined cycle. The PEM fuel cell, conventional turbine, ATS, and micro-turbine are still more than twice the relative emissions rate at low heat recoveries. At very high heat recovery rates, the PEM fuel cell becomes somewhat competitive with combined cycle relative to ozone.

Figure V.2a and b present the ozone index in a regional context. In this case, the combined cycle and DG are assumed to produce their emissions into the same airshed. As would be expected, the direct conversion fuel cell continues to be better than combined cycle. The other likely forms of fuel burning DG still are not competitive with combined cycle even at very high heat recovery rates.

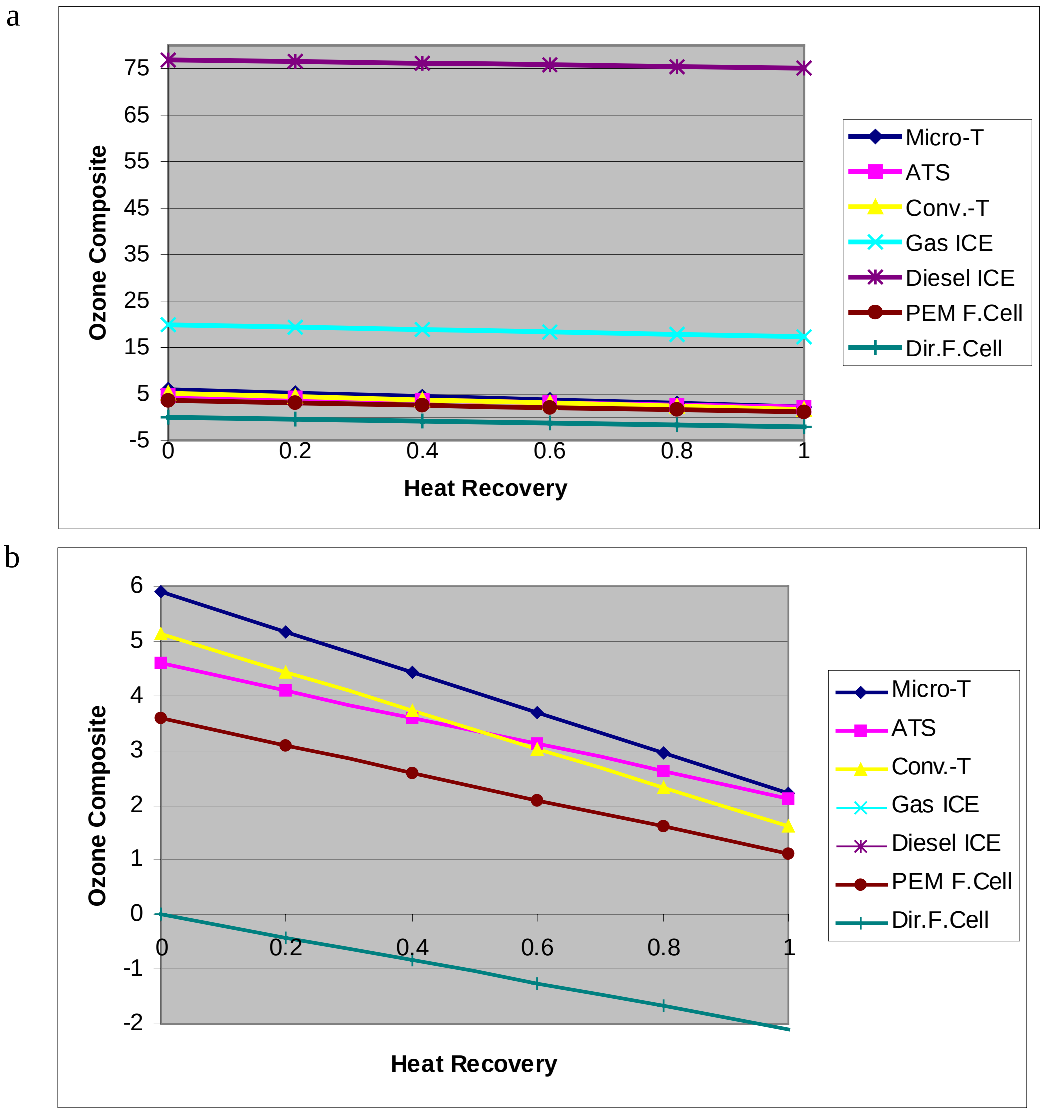


Figure V.2: Relative Ozone Related Emissions of Candidate DG Units Compared to Combined Cycle for a Theoretical Region

B. Particulate Comparisons

Figure V.3a and b and then Figure V.4a and b present the same comparisons as Figures V.1 and V.2 but for the particulate matter index.

a

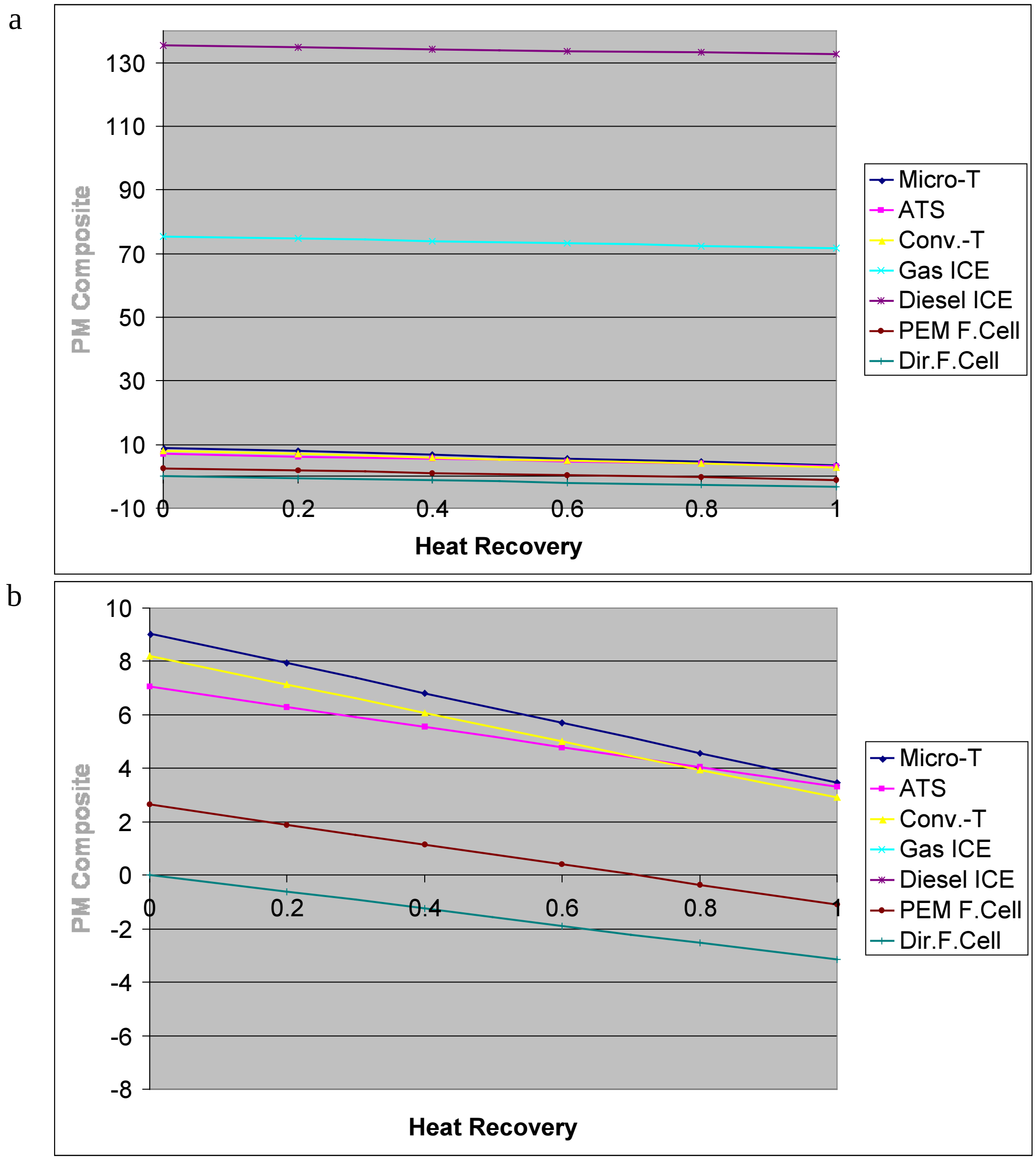
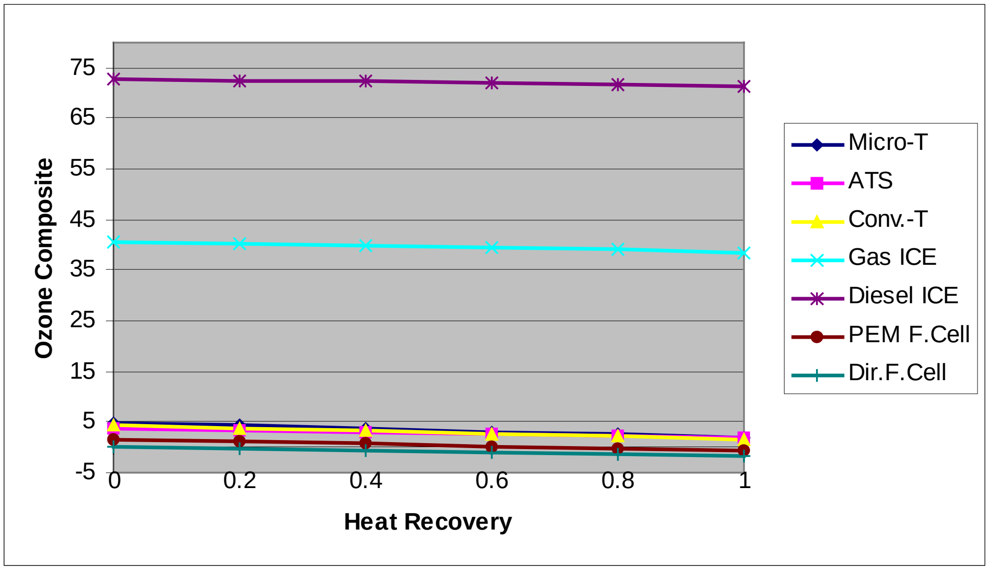


Figure V.3a/b: Relative Particulate Related Emissions of Candidate DG Units Compared to Combined Cycle for a Theoretical Urban Area

a



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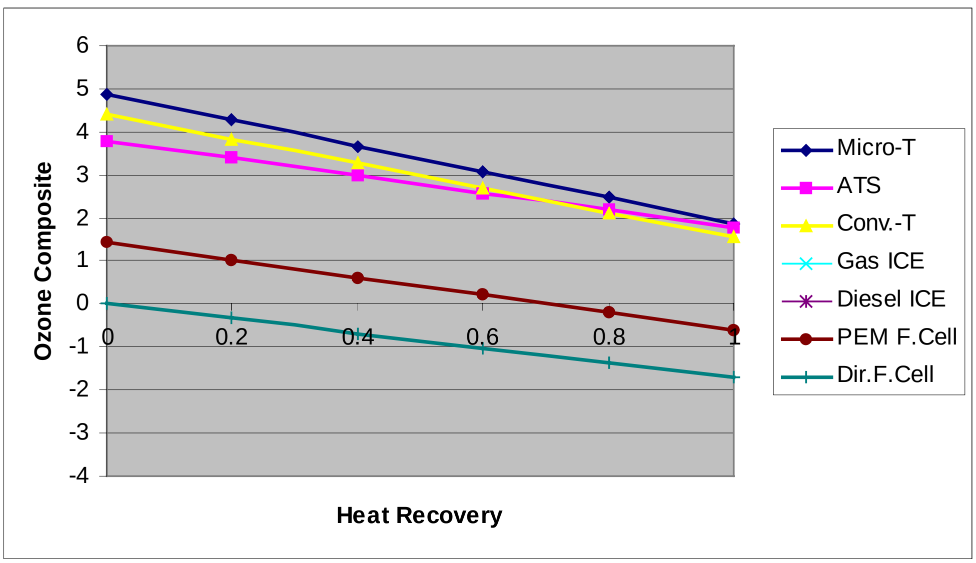

Figure V.4a/b: Relative Particulate Related Emissions of Candidate DG Units Compared to Combined Cycle for a Theoretical Region

With the exception of the Direct Conversion and the PEM fuel cells, present DG does not perform well relative to combined cycle even with high heat recoveries relative to fine particulate production.

C. CO_2 Comparisons

Figure V.5 presents the DG/Combined Cycle comparison for Carbon Dioxide, which is the main global climate change gas.

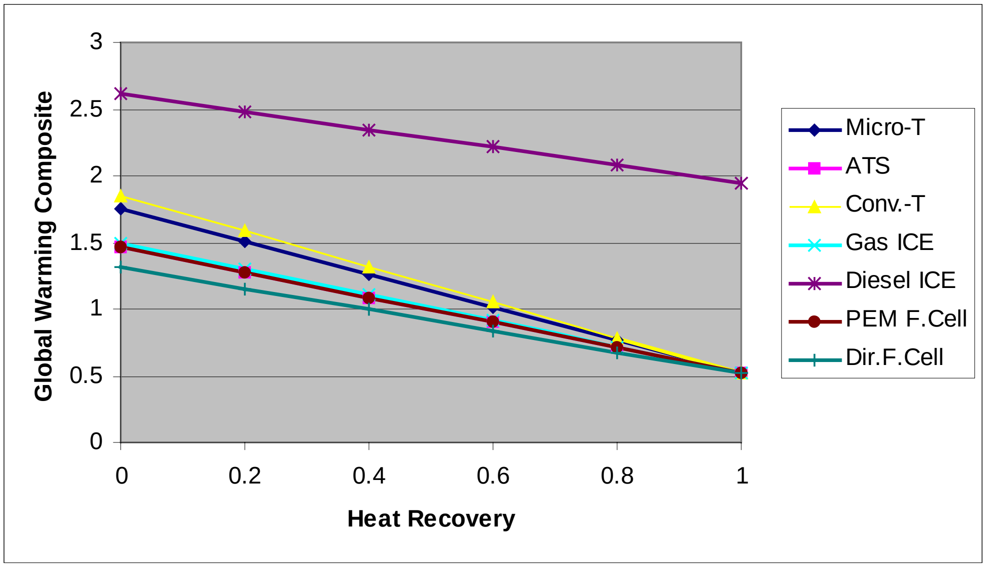

Figure V.5: Relative Carbon Dioxide Emissions for Candidate DG Units Compared to Combined Cycle

With the exception of the diesel internal combustion engine, DG units can be competitive with combined cycle with 50% or greater heat recovery. It should be repeated that heat recovery is necessary to achieve equivalency in this case.

D. Modifying DG to Achieve Equivalency

For this application of DG, it must be concluded that combined cycle central generation is the overall preferred alternative from an environmental viewpoint until significant heat recovery and a further reduction in emissions from the DG candidate units is achieved. Using equation 4, it is interesting to determine what type of DG unit would be competitive with combined cycle generation. There are infinite possibilities depending upon the rate of waste heat capture, generation efficiency, and emission rate; and clearly a DG type combined cycle unit would be competitive. Table V.2 presents potentially achievable factors that would make DG competitive with combined cycle for urban, regional, and global emissions due to the emissions offset from waste heat recovery.

Table V.2: Characteristics of an Ideal DG Unit

DG Unit	Generation Efficiency	Unit Emission Rate	Waste Heat Recovery
DG Unit to Prevent Air Quality Degradation Compared with Combined Cycle Generation	30% or greater	Less than 1.30 times combined cycle	60% or greater

Table V.3 presents an approximation of the emission reductions for candidate DG technologies to meet the Table V.2 goals.

Table V.3: Approximate Emission Reductions and Efficiency Improvements (assuming 60% heat recovery) to Provide Equivalent Performance to Combined Cycle

DG Unit	Overall Emission Reduction Needed	Generation Efficiency Improvement Needed
Micro-Turbine	80%	10%
Advanced Turbine	74%	0%
Conventional Turbine	77%	6%
Gas Fueled Internal Combustion Engine	96%	0%
Diesel Fueled Internal Combustion Engine	99%	0%
PEM Fuel Cell	49%	0%
Direct Conversion Fuel Cell	0%	0%

VI. Waste Gas Use in DG Units and Unique Heat Recovery Options

The previous section discusses the application of DG where natural gas or diesel fuel is used to power DG and the heat recovery is for typical small commercial and residential water and space heating. DG also has significant applications for using waste gases that would normally be flared for toxic or odor control or safety. There may also be unique industrial applications where more polluting processes might be displaced by the waste heat from a DG unit. Application of DG in these situations could be very environmentally beneficial.

Some key applications of DG are in solid waste dumps, oil fields, and possibly refineries where there are excess, often low-quality, gases that are being flared. Equation 4 can be modified for this situation. In this case, there would be a second subtraction term to account for emission savings from the elimination of the flare. Equation 4 becomes:

$$R_{DC} = [(\varepsilon_{gC} * \varepsilon_{lC}) / \varepsilon_{gD}] * (Q_{gD} / Q_{gC}) * [1 - (Q_{aD} / Q_{gD}) * \varepsilon_{wD} * (1 - \varepsilon_{gD}) - Q_f/Q_{gD}] * (1 / f_C) \qquad \textbf{Equation 5}$$

where Q_f represents the emissions produced by the flare being replaced and the other factors are as defined earlier. Table VI.1 presents emission factors used for flare emissions. These values are converted from EPA AP-42 factors for industrial flares. In actual fact, emissions from flares will vary considerably depending upon flare design and fuel. Thus, actual analysis will have to be on a case by case basis.

Table VI.1: Emission Factors for Industrial Flares

Source	CO	VOC	NOx	SOx	PM2.5	CO2
Units	lbs/kwhr input	lbs/kwhr input	lbs/kwhr input	lbs/kwhr input	lbs/kwhr input	lbs/kwhr input
Industrial Flare	.00126	.000478	.000232	unknown	0-.0001	154.7

Figure VI.1 presents data for the urban ozone case were DG units replace flares with emissions as shown in Table VI.1. All other assumptions are the same as for the earlier figures. The diesel IC engine has been dropped from the figure since it has little meaning in this context. Fuel cells were retained in the figure; although it is unlikely that a fuel cell could be used in this application due to the contamination associated with the waste gases used in the process.

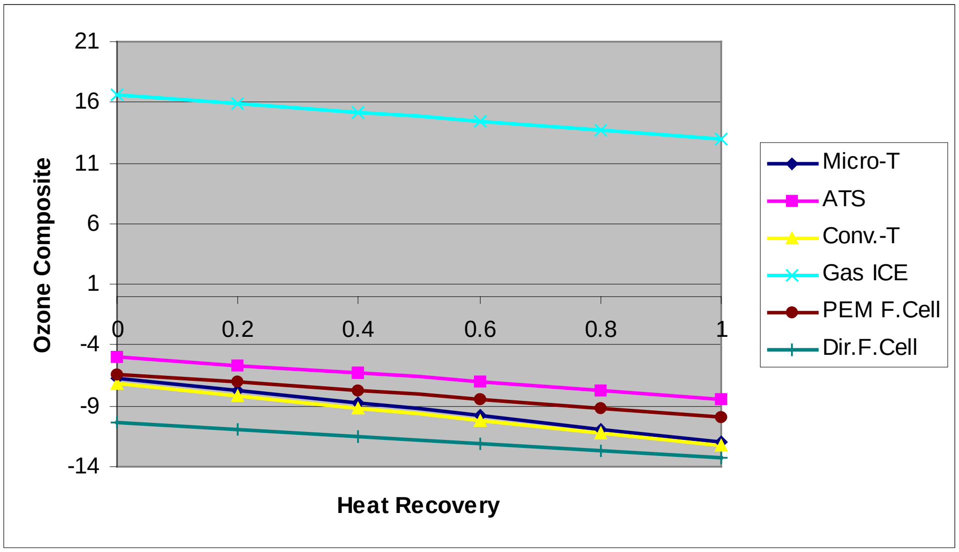

Figure VI.1a/b: Relative Ozone Related Emissions in an Urban Situation Compared with Combined Cycle

As can be seen, in this case, all likely DG units actually improve the environment over today with the exception of the waste gas powered internal combustion engine. Thus, non-internal combustion engine DG should be encouraged in place of flares if the DG units can perform close to the emission rates at the present levels of technological development, shown in Table IV.1, using waste gas. The regional case will not be repeated here since the results will look even better.

Figure VI.2 presents comparable data for the particulate index. As before, the internal combustion engine does not compare favorably, but the remaining DG candidates do very well and should be encouraged as an alternative to flares.

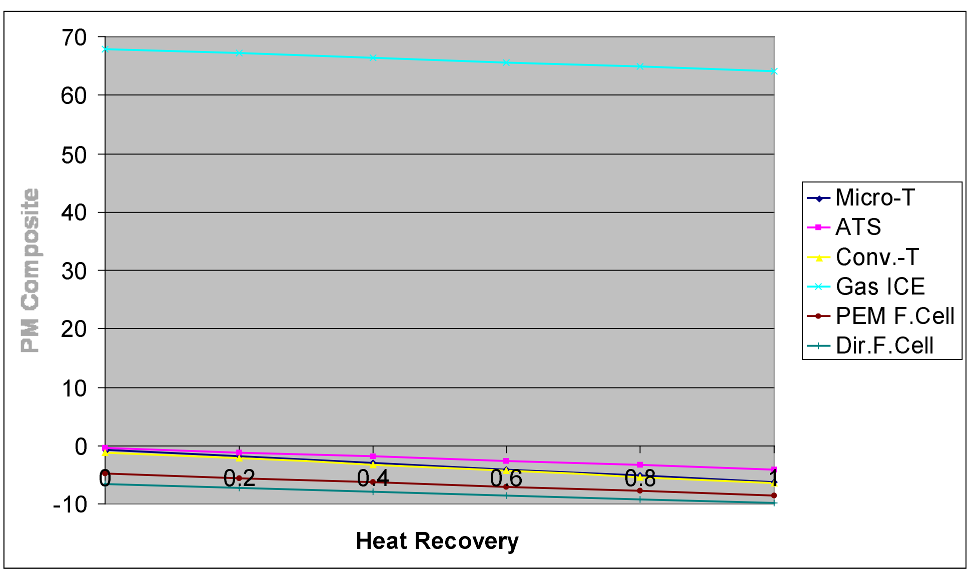

Figure VI.2: Relative Particulate Related Emissions in an Urban Setting Compared to Combined Cycle

No graphics are presented relative to CO_2 emissions since the fuel under consideration here is presently being flared and the new process would simply redirect the use of that fuel into electricity production. Thus, CO_2 emissions would not be increased and CO_2 emissions at a combined cycle plant would be simply offset. Thus, this application of DG is a global warming winner unless there are some unusual N_2O emissions from one of the DG processes that have not presently been identified.

VII. Distributed Generation Policy to Improve Air Quality

The previous discussions point out the importance of considering the impacts of all sources of air pollution emissions and the potential for air pollution problems to result from DG in certain circumstances. *The bottom line is that fossil fuel powered DG may or may not be environmentally beneficial relative to other alternatives for generating electricity, depending upon the specific application and the amount of heat recovery achieved*. An important issue to be resolved is how to encourage beneficial DG but discourage or prevent DG that does not represent an overall air pollution benefit.

An obvious place to look for the needed intervention is at current regulatory structures that exist at the federal, state, and local levels of government. It might also be possible to develop some semi-voluntary industry approach to facilitate the appropriate type of DG; however, this latter approach would be subject to competitive pressures vis-à-vis CG, not to mention the possibility that policy-makers and analysts might include coal-fired and other older means of electrical power production in their definition of CG.

That said, an important complication with respect to governmental intervention is that the emissions associated with DG on a unit by unit basis can often be smaller than the levels typically regulated by most government agencies. In this sense, DG resembles the situation that many regions face with respect to home and small commercial heat systems, or even automobiles, where the units on an individual basis pose little environmental threat, but in large quantities can result in significant air quality problems. This characteristic suggests the use of a manufacturer-based form regulatory approach. That is, the smaller DG units would be certified in the manner that appliances and cars are at the point of manufacture rather than at the point of use. There are some problems to this approach, which will be discussed later. Yet, at a minimum, some hybrid approach between manufacture regulation and point of use regulation may be the most viable way to achieve environmentally beneficial DG.

VIII. Overview of Air Quality Regulation in the U.S.

At the federal level, the EPA is authorized under the Clean Air Act to set limits on how much of a pollutant can be emitted, particularly for the larger sources. Yet permits to emit airborne pollutants are actually issued by Air Quality Management Districts (AQMDs), regional bodies that include all or parts of individual states. The permits themselves include information on which pollutants are being emitted, allowable emissions rates, and any efforts, such as air quality monitoring, that responsible individuals and corporations either already are taking or will be required to take. These documents are intended to ensure that air quality regulation at the state level meets federal air quality standards, though a number or states including California have established much more stringent standards. The procedures for issuing permits within a given state contribute to its State Implementation Plan (SIP), or the collection of all those rules and regulations the state has developed to improve air quality within its borders. SIPs are subject to approval by the EPA. In the event that a SIP is deemed unacceptable or an AQMD repeatedly fails to attain federal air quality standards, the EPA or other qualified administrative body can be empowered to enforce Clean Air Act as necessary.

In California, the California EPA, specifically the California Air Resources Board (CARB), essentially parallels the EPA's air pollution control efforts.[10] Like the EPA, it provides advice and guidance to California AQMDs on powerplant permitting and emissions regulations. There are, of course, clear differences between the federal approach to air quality regulation and California's, which are indicative of the differences that exist already or are likely to exist in other states. For example, while the local districts regulate small electricity generating units, authority to site larger units (greater than 50MW) has been vested in the California Energy Commission (CEC). Yet stationary sources are regulated primarily at the local level in California rather than at the state level as is the case in Texas and Colorado.

The diversity of regulatory approaches that exists among states, not to mention within each of them, highlights the overall importance of establishing minimum standards for DG at the federal level to improve air quality, particularly in non-attainment areas, regardless of how states decide to enforce them. This observation does not imply that the federal government must take the initiative with respect to regulating DG. Indeed, because states such as California and Colorado have served as laboratories for the development of new air quality regulations — mandatory introduction of low-emissions vehicles in California, for example, and caps on wood stove emissions in Colorado — it is reasonable to suggest that innovative DG policy at the state level now could lead to the desired national regulation over time.

Consider California, for example, a state that has taken some initiative in developing DG policy. Senate Bill 1298, which was recently signed into law, requires CARB to issue guidance to AQMDs regarding the adoption of a certification program and uniform emissions standards by January 2003 for electrical generation that is currently exempt from district permitting requirements. Notably, the bill requires that these standards reflect the best performance achievable by existing electricity generating technologies, which would imply gas-fired combined-cycle CG. As explained above, authority to regulate criteria air pollutants associated with the smaller, "unregulated" DG in California lies with the state and local air pollution control agencies. Interestingly, this specific state level approach is consistent with the position of the federal government. The EPA, in fact, has argued that the most appropriate level at which to

[10]Pursuant to the preceding paragraph, CARB takes responsibility for air quality control in non-compliant AQMDs within its jurisdiction, as well as for California's smaller AQMDs, which do not have the resources to regulate air quality themselves.

regulate criteria air pollutants is the state or local air pollution control agency. The EPA has, therefore, urged state utility and energy commissions to allow these agencies to manage the process of developing and implementing DG policy (Bryson, 2000). Hence, it is increasingly important that state and local agencies be made aware of the potential for a considerable influx of DG.[11]

In contrast to the regulation of criteria pollutants, emissions associated with global climate are rarely controlled by local agencies. Very few, if any, state or local air pollution control agencies have established authority to regulate global warming gases. Regulation of "greenhouse gases" (GHG) and energy efficiency, more generally, is currently and by default governed by the DOE as well as the EPA at the federal level, and by "energy commissions" at the state level. Consequently, GHG are practically unregulated. An added bonus of policies intended to foster DG that is capable of increasing energy efficiency *and* improving air quality would be the indirect regulation of GHG.

IX. The Manufacturer-Based Regulatory Approach

Given the dual necessity established in the preceding section to pair federal air quality standards with state and local regulations, we find a manufacturer-based regulatory approach like that used to improve the energy efficiency of appliances and automobiles would be highly desirable. If this approach could be modified to require or at least strongly encourage heat recovery, it is likely to be at least as successful as it has been for architectural paints and many appliances as well as for automobiles (Lents et al.,2000). Given the success of the automobile program, in particular, the manufacturer-based regulatory approach we advocate would consist of the following six elements:

A. Set meaningful air pollution emission standards to provide protection from inappropriate air quality degradation at the urban, regional, and global levels. In the past, automobile and architectural paint standards have had to be technology-forcing to provide the needed benefits. This may also be true for DG. Typically, in the case of technology-forcing regulations, a certain amount of time is allowed to reach the defined standards.

B. Develop an effective certification system to assure that the manufacturing process produces DG units that comply with emission standards at the point of sale and have a high probability of continuing to meet standards in use. This element has been problematic in the automobile industry, where historically cars have been found to pollute in use at two or three times the certification levels. However, in the case of water heaters and paints, units have remained closer to certification standards in actual use.

[11] Although the details of deregulation in California and elsewhere in the West lie outside the scope of this report, the rising cost and falling reliability of CG to rural residential consumers as well as industrial and commercial consumers has made DG an increasingly attractive option. It is the potential for DG in this respect that has, in part, fueled the initiative for DG policy in the state (Woolfolk,2000).

C. Mandate statistically valid in-use testing as part of an appropriate regulatory scheme. Not every DG unit needs to be tested, but enough testing needs to be included to find systematic failures or significant deterioration of emissions reduction approaches. In the automobile analogy, both the EPA and CARB test hundreds of in-use vehicles selected randomly to look for emission problems. This has allowed the identification of early failure of control components, emissions "cycle" cheating,[12] and user-control system modifications.

D. Establish adequate buy-in to the manufacturer-based approach by regulatory agencies to avoid duplicative permitting programs at the state and/or local level. It is inappropriate to create a complex DG certification and testing program and still have significant re-evaluation at the state or local level.

E. In the short-term, and potentially indefinitely, develop a credit system to encourage and support environmentally beneficial DG. This system should be designed to be easy to use and to encourage the use of waste fuel and recover waste heat out of the DG units and other beneficial options.

F. Revisit emission limits and efficiency levels on a regular basis to ensure the best available technology. Technologies can advance rapidly leaving existing standards outmoded and resulting in higher emissions.

A. Air Quality Emission Standards

As discussed in Section III, DG will ultimately compete primarily with gas-fired combined-cycle CG. Thus, to insure minimal air quality degradation, DG units should perform in a manner comparable to that means of electricity production. (The exceptions would be those cases that use waste gas that is not otherwise used productively, or that has significant heat recovery that replaces otherwise heavily polluting processes.) Unfortunately, the manufacturer-based regulatory approach has no ability to foresee the fuel source or waste heat recovery realized by a DG unit as it is being manufactured. One way to address this problem is to set DG standards to be ultimately equivalent to combined cycle, but allow the local permitting agency the ability to credit emission offsets from waste fuel and heat recovery such that non-complying DG can be used in these special cases.

Because, as we have demonstrated, it is not practical for any of the currently economically feasible DG technologies to perform at combined cycle efficiencies and emissions, there are two basic options available for regulating DG in accordance with the policy position advocated here and validated by SB 1298. One possibility would be to establish stricter standards comparable to combined cycle generation that would prevent a given DG technology from entering the market until it is able to meet them. The problem here is that DG manufacturers and potential electricity providers may not be willing to invest in cleaner yet not salable DG. A second approach would entail establishing future standards that are appropriately strict, but allowing some less efficient and more polluting DG to be marketed in the short term, so long as environmental quality and

[12] "Cycle" cheating refers to designing vehicle systems that operate such that they pass the requisite certification emission tests, but operate in a different higher polluting mode in use to provide the user with more power or better fuel mileage.

public health are not significantly impaired. The types of DG that are available now, for instance, with the exception of diesel and gasoline generator sets, are unlikely to be problematic until and unless sales increase markedly. Given this caveat, an important advantage of this approach would be a profit stream that could serve as the motivation for DG manufacturers and electrical power providers to invest in environmentally beneficial DG. Table IX.1 indicates the kilowatt-hours of DG generation that could be implemented with existing permissible emission rates, while keeping the emissions per day per square mile of particulate and ozone discussed in Section V, at 0.1%[13] of the present South Coast Air Basin emissions density.[14]

Table IX.1: Estimation of Kilowatt Hours per Day That Could be Produced in the South Coast Air Basin and Keep Emission Increases Less Than 0.1% of Year 2000 Basin Emissions

DG Unit	Electrical Generation Limit for Particulate Index (kilowatt hours/day/square mile)	Electrical Generation Limit for Ozone Index (kilowatt hours/day/square mile)
Micro-Turbine	308	363
ATS	395	467
Conventional Turbine	340	418
Gas Powered ICE	37	108
Diesel ICE	21	28
PEM Fuel Cell	1053	598
Direct Fuel Cell	Unlimited	Unlimited

As can be seen in Table IX.1, 300-400 kilowatt hours per day per square mile can be generated using existing DG emission rates without increasing emissions in the South Coast Air Basin by more than 0.1% in the case of micro-turbines, advanced turbines, and conventional turbines. Internal combustion engines using gas or diesel would have to be severely limited under this approach, while a PEM fuel cell could go as high as 1000 kilowatt hours per square mile per day. If 0.1% is considered too high, then the values in Table IX.1 can be proportionally reduced to reflect a lower level. If a decreasing emission limit over time is preferred, it should be recognized that significant technological advances have been realized in two- to five-year increments (Lents et al., 2000).

[13] 0.1% was selected as a level of air pollution impact that might be considered insignificant in the case of the introduction of an important technology that could, in the long run offer overall environmental improvement. In reality, many non-attainment areas must put considerable effort into adoption a rule or rules to gain a 0.1% reduction in overall emissions. Thus, it could easily be argued that the suggested increment is too large. As another point of comparison, Congress restricts the net increase in particulate levels from all sources combined in Class I areas to about 7% of national standards and the net increase of SO_2 levels of about 1% of national standards.

[14] The 1997 South Coast Air Quality Management Plan annualized daily emissions of CO, VOC, NOx, SOx, and $PM_{2.5}$ were used for this analysis. These emissions are presented in the plan on a daily basis over the whole Basin. To determine the average emissions density in the Basin, the plan emissions were divided by South Coast Basin size (6800 square miles) to produce average emissions per square mile per day in the South Coast Air Basin. Since the South Coast Air Basin has some of the nation's worse air quality, the emissions density for this region was thought to represent a level that should be avoided. DG units were compared to this value with the intent of keeping DG emissions from increasing emission densities by more that 0.1% of the South Coast emission density.

An important question related to Table IX.1 is the number of DG units that might be accommodated under such a limitation. This, of course, will depend upon the average size of the DG units that are installed and the hours that they are operated each day. Some DG will be used to supply general power, some for peak shaving to reduce costs, and some to increase power reliability. Table IX.2 provides a range of the number of DG units delivering 20 kilowatts while operating that might be accommodated in Los Angeles (the South Coast Air Basin) and meet the limits outlined in Table IX.1.

Table IX.2: Estimation of Number of DG Units That Could be Accommodated in Los Angeles and Keep Emissions Increases to De Minimis Levels

DG Unit	Used 24 Hours per Day	Used 3 Hours per Day
Micro-Turbine	4363	34907
ATS	5596	44767
Conventional Turbine	4817	38533
Gas Powered ICE	524	4193
Diesel ICE	298	2380
PEM Fuel Cell	8472	67773
Direct Fuel Cell	Unlimited	Unlimited

As can be seen in Table IX.2, the number of units that could be put into place in this scenario is quiet limited if they are to be used 24 hours per day. If they are used only for peak shaving or during times of stress on the electrical system, more units might be accommodated without exceeding the 0.1% guideline.

B. Certification of DG Units

Certification requires the establishment of a testing protocol for DG units including a way to test unit degradation over time. A process that has worked in the past involves bringing together a representative advisory group of manufacturers, potential regulators, and a research group. The research group assumes responsibility for developing the testing procedure under the direction of the advisory group. This approach was used with the regulation of restaurants in the South Coast Basin and worked well to establish an accepted testing protocol in a case where testing repeatability was a problem, and where there was substantial disagreement among parties on how testing should be conducted.

A second issue once a testing protocol is developed is the determination of how the protocol should be applied. In the automobile industry, prototype vehicles are certified including a deterioration analysis over 50,000 to 100,000 miles. Once the prototype testing is completed the vehicle is approved for production. In addition, a small number of vehicles are pulled from the assembly line to test the manufacturing process; however, in-use testing as described in the next step may eliminate the need for assembly line testing.

C. In-Use Testing of Certified DG Units

In the original days of setting standards for automobiles, regulators learned that automobiles in-use polluted above their certification levels. This was found to be due to component failure, poor maintenance, and tampering. Some of these problems have been solved with better, more durable automobile designs. The complication of the automobile has reduced tampering, and inspection and maintenance programs have resulted in better-educated mechanics and members of the public. In the case of DG, the problems are unlikely to be as acute as with automobiles. The in-use testing program will likely demonstrate this.

A potential approach is to test 10 to 20 units per type of DG after a year of operation. The variability in emissions from this group will provide some basic information on the number of tests that should be conducted to get statistically valid results. There are government programs such as the California Public Interest Energy Research (PIER) program that might provide the needed funding to collect the baseline testing information. The state or federal agency developing the standards would normally be the agency that would carry out the routine in-use testing program. The cost of such a program could be covered by some type of fee on the sales of DG units or could be absorbed into the normal regulatory budget.

D. Regulatory Agency Buy-In

It would do little good for a national certification program to be developed if state and local regulatory agencies do not accept the process. Local regulatory agencies could, in this case, include the air pollution, energy, and local building and safety programs. It is important that these agencies as well as state-level regulatory bodies are involved in the initial design of testing protocols to insure that all interests are adequately addressed.

E. Credit System for DG Using Waste Fuel and Heat Recovery

Many, if not most, state and local air pollution control agencies have some means available to track and transfer air pollution control credits for new construction. These programs are typically designed for major sources of air pollution, but the process is applicable to small sources. Thus, the concept should be familiar to the air pollution control agencies covering major urban areas. Two elements, in particular, would be well-suited to a credit program for DG. The first element involves the establishment of a standard credit for the use of waste gas or for heat recovery. This standard credit would of necessity be conservative to insure that any excess DG emissions are truly offset.[15] The second element of the program would allow the establishment of a specific credit for individual applications where the offset fuel or heat would have been higher polluting than the standard credit.

Of course, regulatory agencies would be encouraged to develop appropriate and automatic permitting processes in the case where standard credits are used. If non-standard credits are sought then the DG application would have to go through a normal permitting process.

F. Revisit Emission Limits

[15] That is, the credit will be established to cover cases in which the waste fuel replaced, or the energy displaced, in heat recovery is realistically set to reflect the heat-recovery capacities of cleaner types of DG. This will ensure that the credits are in fact real for the majority of all applications.

A final important issue is the progress of technology and the resulting ability to produce cleaner DG. Significant progress is being made in reducing DG emissions, increasing its efficiency, and reducing costs. As with any regulatory system, it is critical that the emission limits set for DG be revisited from time to time to consider technological progress and thus improved generation efficiency, reduced emissions, and lowered costs.

It is also important in reviewing DG emissions to recognize that it is not necessary to allow every form of DG into the market. A single standard that will allow adequate product competition at reasonable costs should be adequate to protect consumer interest.

X. Organizing Voluntary Standard Setting Among Manufacturers

A viable alternative to the manufacturer-based government regulation of DG outlined here would be the establishment of a voluntary standard setting organization for DG. This approach follows the example of the Underwriters Laboratory (UL) process established over 100 years ago in the electric appliance industry. UL is an independent, non-profit organization. According to its web site, UL completed 94,396 evaluations in 1999. To be credible, either a group such as UL should be used or an independent testing group would have to clearly establish itself as unbiased in its certifications.[16]

Clearly, if it is to work, this approach must inspire confidence in the regulatory community that it will work. This could involve the use of an existing process such as UL to provide the needed credibility or be set up as a combination government/manufacturer entity. The voluntary standard setting organization would have to develop the same set of testing processes and standards as would be the case with a state or federal agency setting up a certification process. The advantage of this approach is that it might be free of the complexity that often accompanies government bureaucracy. Still, the existence of voluntary standard setting organization is not likely to eliminate the need for a governmental process to develop a heat recovery credit mechanism

XI. Interim Regulation of DG

The default process will be the existing regulatory scheme. In the case of many states with smaller agencies and less severe air pollution problems, DG is not likely to be regulated at all in the short term due to its relatively low emissions and small numbers. This potentiality notwithstanding, states in the northeastern United States, California and Texas have all begun to consider and develop policy protocols for regulating DG within their borders. In these states, the typical process currently requires the development of standards for polluting units and the requirement that units undergo a permitting process whereby they are evaluated for likely compliance with standards, and then subjected to follow-up inspections to insure continued

[16] A good place to visit to get a sense of the viability and complexity of such a process can be found by visiting the UL web site at www.ul.com/welcome.html.

compliance. This evaluation and permitting process can take from a few weeks to years depending upon the situation. Despite the federal government's latent authority to regulate DG, it is unlikely, in the absence of a program to reduce GHG, to take significant action until there has been either extensive application of DG. Thus regulatory policy to cover DG will likely emerge and evolve within state and local air pollution control agencies over the next five years or so and, as explained above, these developments may well serve as templates for a national control strategy.

XII. Local Government Sensitivity to DG

Ironically, while the DOE and EPA (along with other federal and some larger state and local agencies) are aware of the potential implications of DG, this is not the case at the local level of government, nor among the many small air pollution control agencies. Yet it is these agencies that will be among the first to address DG in the form of building permits, fuel use inspections, and air pollution control activities. Therefore, there is a need to create a mechanism to provide these agencies with information and a mechanism for communicating about DG and its role in maintaining and improving air quality. This process may best be accomplished through the associations that represent these key regulatory processes. Many of these agencies hold annual, semiannual, and even monthly meetings at which DG could be discussed. In the case of air pollution control, the following organizations are recommended for interaction:

STAPPA/ALAPCO: The State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Organizations (ALAPCO) are national organizations that operate under the same management. Their membership includes all state air pollution control programs along with some interaction with U.S. territories and all major local air pollution control programs. They hold semiannual meetings, conduct conferences, and publish a newsletter. (www.4cleanair.org)

CAPCOA: The California Air Pollution Control Officers Association is made up of all local air pollution control programs in the state of California. This association holds semiannual meetings, produces a newsletter, and has monthly sub-group meetings. (www.capcoa.org)

NESCAUM: The Northeast States for Coordinated Air Use Management represent the state air pollution control programs in the states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. It holds meetings, carries out studies, and maintains a training academy in air pollution issues. It has recently completed a study of the deregulation of the power industry and impacts on air quality. This study is primarily addressed at major power plants but indicates a strong interest by the association in electric power production. (www.nescaum.org)

MARAMA: Mid Atlantic Regional Air Management Association represents state and local air pollution control agencies in the mid-Atlantic region of the eastern United States: Delaware, District of Columbia, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia, Philadelphia, and Allegheny County. MARAMA is primarily concerned about ozone, PM_{10} and $PM_{2.5}$ and long-range transport. All of these issues relate to DG. (www.marama.org)

WESTAR: The Western States Air Resources Council includes the air pollution control programs for Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. The purpose of the organization is to address western air quality issues. WESTAR holds meetings and distributes information similar to the other multi-state organizations. (www.westar.org)

There are other air pollution control groups, but those listed provide multiple access to almost all air pollution control agencies in the United States. STAPPA/ALAPCO is one of the better of these to focus on because it includes both state and local air pollution control agencies nationwide. Still some contact should be established with all of the listed groups.

With respect to building permits and safety inspections, the issues are handled by a variety of agencies. The Councils of Government (COG), often denoted Metropolitan Planning Organizations (MPO), are set up for each metropolitan area to bring coordinated planning between city and county governmental entities. The COGs include air quality planning, zoning, and safety as part of their interests. Thus, the COGs may be a good place to start. In addition, there are several other city/county organizations that might provide a valuable interface concerning DG issues. Some key groups are indicated below:

ICMA: The International City/County Management Association addresses many issues associated with city/county management. This association has interests in city/county safety issues and links with fire departments and other city safety agencies. (www.icma.org)

NARC: The National Association of Regional Councils provides an interface at the national level to COGs and MPOs. NARC is associated with the Association of Metropolitan Planning Organizations (AMPO). These groups include air quality as one of their major interest and thus may be a good starting point for an interface into local zoning and safety issues handled by city and county governments. (www.narc.org)

SSEB: The Southern States Energy Board addresses a number of concerns in the Southeastern United States that relate to energy and the environment. This group has existed since 1960. Interaction with this group might provide insight into issues outside of the air pollution regulatory perspective. (www.sseb.org)

PRIMA: The Public Risk Management Association addresses local safety issues which includes city/county organizations as members. (www.primacentral.org)

IAFC: The International Association of Fire Chiefs may provide a useful interface to city and county fire departments, which do much of the safety inspections for cites and counties. (www.iafc.org)

The preceding city/county associations provide an entryway into the issue of building, zoning, and safety permits associated with city governments.

XIII. Conclusion

As this report has made patently clear, DG does have the potential to provide security to the U.S. electrical generation system, along with the economic competition that will assure the lowest-cost electricity. Additionally, it is very reasonable to expect that DG will play a role in reducing local, regional, and even global air pollution, though this outcome is far from assured within the existing regulatory framework. Large-scale generating systems face stringent permitting requirements that are resulting in the implementation of gas-powered combined cycle generation with SCR or similar control technology for almost all new generation technology. DG will thus likely be replacing combined cycle generation rather than existing coal-fired power generation. Yet some of the most cost effective DG at the present time is diesel and gas powered internal combustion engines, and these units are highly polluting. *As established here, only the lowest emitting DG with significant waste heat recovery is even marginally competitive with combined cycle power production when air pollution issues are considered.* Thus, we advocate technology-forcing in the specific form of manufacturer-based regulation, which would require DG emissions to be reduced over time to ensure improved air quality. There is, of course, one present application of DG that should be encouraged immediately. That is the case where waste fuel is being flared and could be put to use in a DG generation unit. In this case, even with microturbines and advanced turbines now available, air pollution can be further reduced.

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