

POWER GENERATION EMISSIONS AND DISTRIBUTED ENERGY

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Summary

Electricity power generation emissions represent a significant contribution to nitrogen oxides, sulfur oxides, and mercury emissions in the United States. This paper explores the role of Distributed Energy in reducing power generation emissions. The results indicate that on-peak Distributed Energy and other demand side management solutions provide significant opportunity for reducing the reliance on older, less efficient, higher emitting intermediate and peak power plants.

As many regulators are seeking to facilitate the development and siting of distributed energy through emissions standards, this research indicates that implementing DE technologies can reduce power generation emissions. The impact of Distributed Energy on power generation is dependent upon the region and time of use, as illustrated in Table 1.



Table 1 – Average Central Power Generation Emissions, 1998

State	Baseload NO _x Emission Rate >3500 hrs (lbs/MWh)	On-Peak NO _x Emission Rate ≤3500 hrs (lbs/MWh)
California	0.25	0.75
Connecticut	2.67	1.94
Texas	2.61	2.94
New York	1.34	2.10
Massachusetts	1.91	3.74
Illinois	3.20	8.60

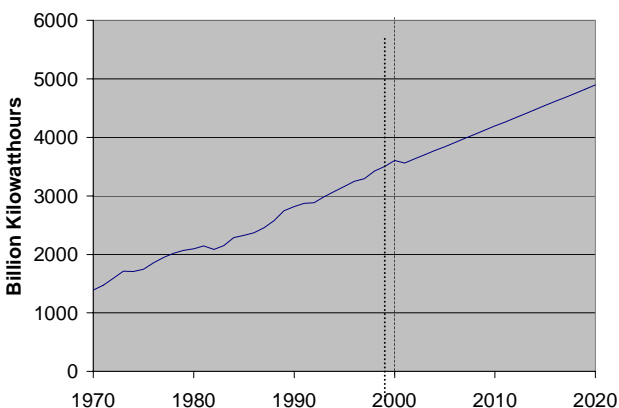
Source: EPA EGRID

A second major finding is that Distributed Energy will not generally displace combined cycle combustion turbines. Instead, DE and CCCT both reduce reliance on older fossil-fueled (coal, gas and oil) simple cycle generation.

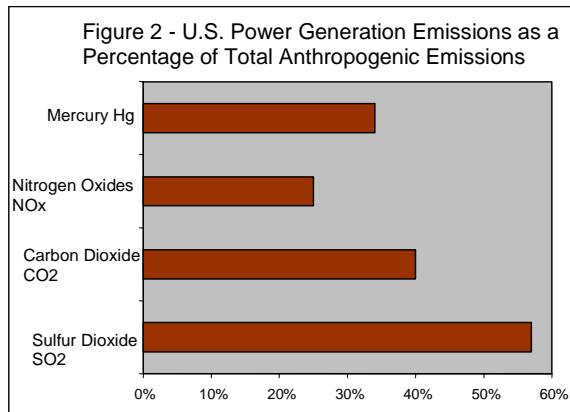
Background

In homes throughout America lights are shining and refrigerators are humming. Air conditioners are cooling businesses, and computerized machinery is running in factories. Every portion of our society is using electricity at an ever-increasing rate. Electricity end use has risen more than 1200% in the past fifty years, and shows no sign of slowing. This continued growth is illustrated in Figure 1.

Figure 1 - Electricity End Use, 1970-2020



One side effect of our country's insatiable appetite for electricity is the large quantity of emissions from power generation. Despite advances in renewable energy and low emissions power generation, the production of electricity is still responsible for a large percentage of the pollution released every year in the United States. In fact, the power industry alone produces over one-third of all air pollution emissions in the country. Figure 2 shows the contribution of power generation to national emissions of four of the principal pollutants.



Problem Statement

According to the Energy Information Administration's Annual Energy Outlook 2002, 355 GW of new generating capability is required to keep up with increasing electricity demand and replace retiring units through 2020. Natural gas fired technologies (such as simple and combined cycle combustion turbines) offer a low emissions option for meeting some of this new demand. Nuclear and coal plant power uprates and life extensions, as well as new coal plants, are also emerging to meet this new demand. Existing

power plants will be pushed to their limits to keep up with this new demand. In Illinois, for example, **coal generation is only operating at approximately 50% utilization and is poised to meet much of this new demand.** In 2000, the national average utilization of all coal plants was 72%. Increasing this to 85% would supply an additional 479 billion kWh per year, which is nearly 1/3 of the projected growth through 2020.

As a result, emissions from central power generation will continue to be substantial. This article will demonstrate that **“on-peak” Distributed Energy and Combined Heat and Power, with emissions from 1 to 4 lbs of NO_x per MWh, can lower power generation emissions** in most states.

Distributed Energy is electricity generation at or near the point of use, rather than at a central generating plant. The paper examines the impact of natural gas fueled DE technologies on power generation emissions. Currently, reciprocating engines and turbines are the primary technologies supplying this market, with ongoing efforts to develop microturbines and fuel cells. Many, though not all, applications of DE are combine heat and power (CHP) systems. In addition to generating electricity, CHP systems convert the waste heat from the generator into useful energy and offer a significant opportunity for reducing emissions.

Generation Segments

Electric utilities typically classify electricity generation into two categories for pricing purposes. One category is “on-peak” generation, which some utilities, such as ComEd in Chicago, define as 9 a.m. to 10 p.m., Monday through Friday. This equates to approximately 3500 hours per year of on-peak generation. The other classification is “off-peak” which refers typically to electricity consumption during the nighttime and weekends. Most utilities have developed rate structures that reflect the higher cost of supplying on-peak electricity due to ancillary services and increased generation costs. These rate structures require that consumers pay higher costs for using on-peak electricity. Some utilities have further separated the “on-peak” period, but this paper only differentiates between on-peak (e.g. <3500 hours) operation and baseload (>3500 hours) operation.

Baseload generators are the plants in a region that operate nearly all the time. They produce the base amount of electricity required during on and off-peak periods. Plants operating in this segment are generally the most economical generators in the region. This segment is primarily made up of nuclear plants, as well as combined cycle gas, hydro and coal. Plants operating more that 3500 hours per year will be considered to be in the baseload segment.

Utilization, also called capacity factor, is defined as the ratio of actual generation to the theoretical maximum generation from a particular plant. A utilization of 40% represents 3500 hours of operation per

year, at maximum capacity. This cutoff was chosen to differentiate baseload generators from on-peak generators.

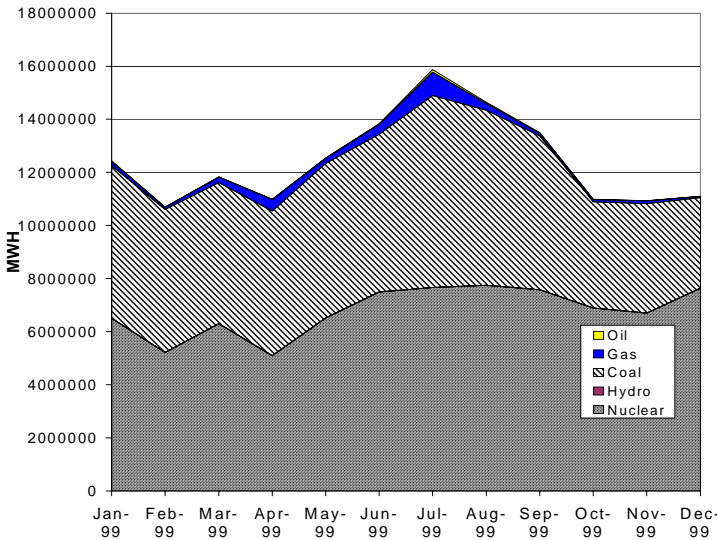
Marginal Costs - Key to Power Generation Emissions

Power plant marginal costs are key to determining which central power plants operate and when. In a deregulated electricity market, an Independent System Operator (ISO) determines which plants operate in a given day, and for how long. Over the course of a day, electricity demand fluctuates. As demand increases, the ISO “dispatches” more and more generating plants in order to increase supply (see Figure 5). Conversely, the ISO “deselects” plants as demand decreases. In other words, the ISO dispatches generating plants to balance electricity supply with demand.

The order in which the ISO selects plants for operation is determined primarily by the marginal operating cost of the generators selected in a given hour. The ISO will normally select the plants with lower marginal price per kWh first. As demand increases, the ISO will have to dispatch plants bidding increasingly higher prices. However, as soon as demand decreases, these higher cost plants can be deselected.

Therefore, the lower the marginal price, the longer a central generating plant will operate in a given day. Additionally, the longer a plant operates, the greater its effect on emissions. For example, if a particular plant has very low emissions per MWh, but is very expensive to operate, it is unlikely to be selected to run for very long. Therefore, the potential emissions benefits of such a plant would not be realized.

**Figure 3 - Electricity Generation Disposition
Illinois 1999, Utility Only**



**Figure 4 - Electricity Generation Disposition
Texas 1999**

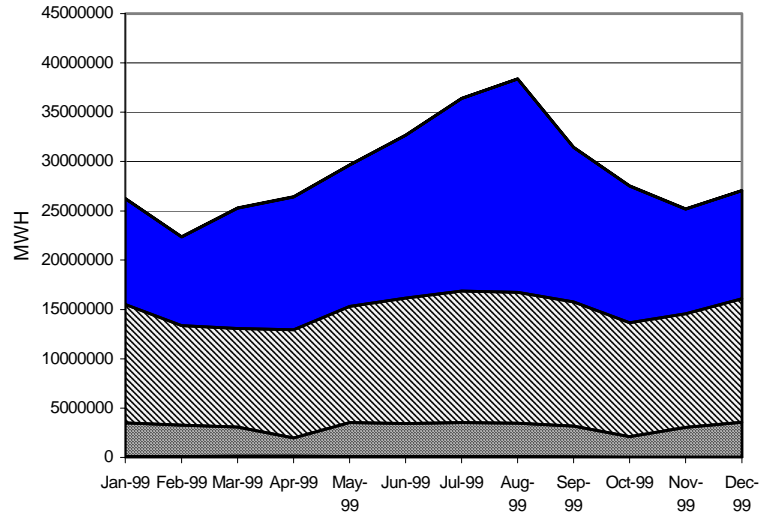


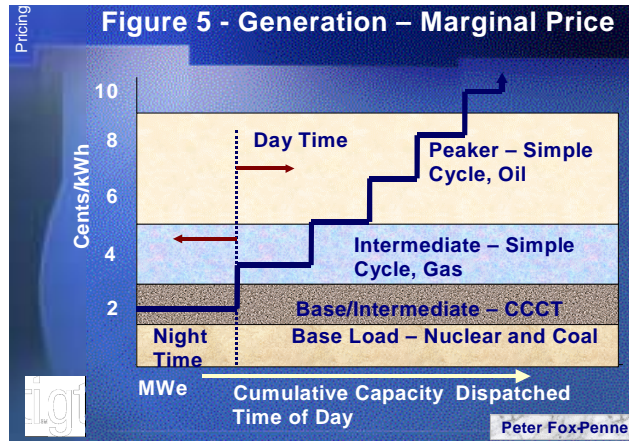
Figure 3 is the actual generation disposition for the electric utilities in Illinois. This graph shows that zero emitting nuclear plants supply the majority of the baseload, while coal supplies virtually all of the intermediate power and some of the baseload. It can be clearly seen that gas is used primarily for peaking. This is verified by the data in Table 2 on page 5.

Distributed Energy resources, however, are not dispatched by the ISO. Instead, they typically operate when their marginal cost to operate is lower than grid costs. Therefore, the owner will operate the DE technology whenever it is economical versus the grid. In many states, off-peak electricity prices are lower than the DE marginal costs (e.g. ~4-6 cents/kWh). Therefore, it is generally cheaper to buy electricity from a utility than to operate a DE unit during off-peak times. This provides an opportunity to utilize on-peak only DE to offset intermediate power from central generation and relieve grid congestion.

Distributed Energy as a Demand Side Management Tool

When evaluating the benefits of Distributed Energy, it is important for regulators to recognize on-peak DE as a demand side management (DSM) tool. This has several important implications.

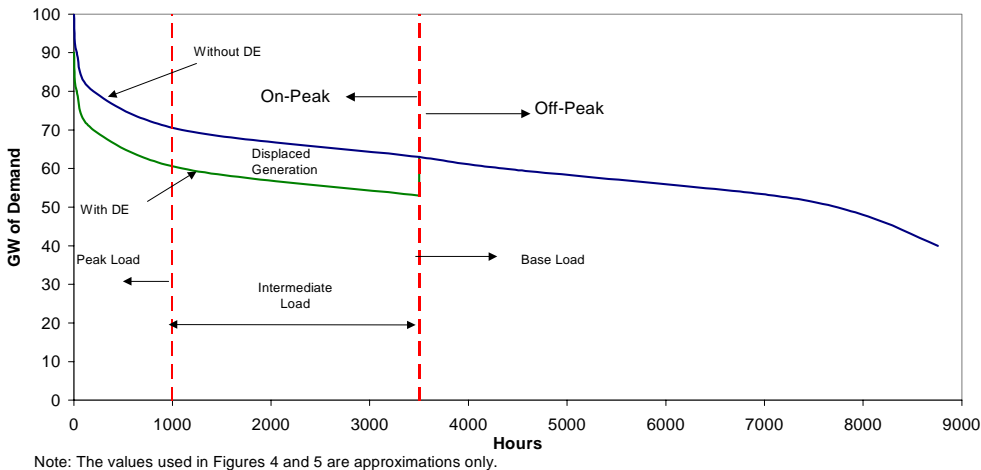
Distributed Energy has the effect of decreasing the demand on the grid whenever it is operating. As a result, the output of the highest cost generator at any given hour will be reduced when DE is operating. The typical order of displacement is shown in Figure 5. The first plants to be displaced are typically the simple cycle oil and gas, then CCCT, then Coal, then Nuclear, then Hydro (See Figure 5).



Another way of visually representing the effect of DE on electricity demand is through a load duration curve. This is a graph of electricity demand vs. hours in a year. It shows demand on the vertical axis, and hours on the horizontal axis. Demand is plotted for each of the 8760 hours in a year, and arranged from highest to lowest demand. So, the first point on the graph is the most electricity used in any single hour that year. The next point on the graph is the second most electricity used in any single hour, which may have been on a different day, or month than the first hour. Figure 6 shows a load duration curve for a typical region, before and after the addition of 10 gigawatts of on-peak Distributed Energy. The area between the two curves represents the generation displaced by DE.

The effect of the 10 GW of Distributed Energy can be clearly seen in Figure 6. With the addition of DE, the load drops by 10 GW from 0 to 3500 hours (when the DE is operating). It can also be seen that this displacement lies in the peak and intermediate segments.

Figure 6 - Load Duration Curve w/ 10 GW of On-Peak Distributed Energy



Note: The values used in Figures 4 and 5 are approximations only.

What this Means to Regional Emissions

It is important to recognize that the grid cannot effectively store electricity. This means that each kWh consumed at a point in time must have a generator online to supply that kWh, or the grid will fail. Therefore, when a customer reduces electricity consumption (via EE, CHP, solar, etc.) a central power plant must reduce its output by a proportional amount.

The emissions benefits from on-peak Distributed Energy will depend on the central power generating technology being displaced each hour it is reducing grid demand. The mix of generation technologies and their utilization varies by region and time of day, and therefore the effect of DE also varies.

Table 2 presents generation and emissions data for the state of Illinois that will be used to illustrate the potential emissions reduction of “on-peak” Distributed Energy. The reductions in other states will vary, but the model used would be the same. This data was obtained from the United States Environmental Protection Agency (EPA).

Table 2 – Illinois 1998 Electricity Generation

Generation Segment	Net Capacity (MW)	Net Generation (MWh)	Net NO _x Emissions (tons)	Average NO _x Emissions Rate (lbs/MWh)	Net SO _x Emissions (tons)	Average SO _x Emissions Rate (lbs/MWh)
On-Peak						
<1000 hours	2,162	344,170	1,523	8.85	57	0.33
<3500 hours	12,981	29,171,845	125,341	8.59	209,543	14.37
Baseload	19,860	109,155,898	174,651	3.20	616,740	11.30

Source: The values in Table 2 were calculated using data from the EPA EGRID.

Generation segments are based on the definitions given in the Generation Segments section of this article.

From the above information, we can draw some conclusions about the generation mix in Illinois. First, the relatively high NO_x rate coupled with the extremely low SO_x rate for plants operating less than 1000 hours indicates that these generators are primarily older, simple cycle natural gas plants. The emissions characteristics for plants operating less than 3500 hours (“on-peak”) suggests that the majority of these plants are coal fired. Finally, the baseload emissions characteristics imply a mix of coal and nuclear generation. These conclusions have been verified using the EPA EGRID, which confirms that the generation stack shown in Figure 3 is an accurate representation of the selection order in Illinois.

The average on-peak generator emits 8.59 lbs/MWh. Assuming Illinois promoted the installation of on-peak DE technology with NO_x emissions less than 3.5 lbs/MWh, power generation emissions would be greatly reduced.

In Chicago, large commercial “off-peak” power prices are just over 2 cents/kWh whereas “on-peak” electricity costs over 11 cents. DE system operating costs, assuming \$3/mmbtu gas, 32% efficiency and 1.5 cent O&M cost, are less than 5 cents per kWh. This in effect ensures that DE will only operate “on-peak”. Therefore, operating a 1MWe DE system during on-peak hours would displace 9 tons of NO_x and 25 tons of SO_x annually.

It should be noted that this analysis is not intended to be an exact prediction of the effect of DE on emissions. What it is intended to do is present a model for representing the potential emissions offset from Distributed Energy.

Conclusions

Power generation emissions differ significantly from state to state. **Regional emissions variation should not be overlooked when considering emissions standards for Distributed Energy that are intended to improve air quality.**

Furthermore, natural gas fueled Distributed Energy technology operating during on-peak periods has the potential to displace a large quantity of older, higher emitting generation operating in the on-peak segment in some states. This could equate to considerable reductions in power generation emissions. This potential reduction, however, can only be realized if emissions standards for Distributed Energy consider the emissions characteristics of the generators being displaced.

The data that led to many of the conclusions presented in this article came from the EPA's EGRID. The EPA is currently in the process of updating this data. More current data may provide additional insight into the impact of Distributed Energy on power generation emissions and the technologies it will displace. GTI will be conducting an in-depth analysis of regional emissions to verify the preliminary results presented in this article.

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