Link Foundation Fellowship Report

Prepared by: Elisabeth A. Gilmore
Advisors: Dr. Lester Lave and Dr. Peter Adams
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Narrative of work completed

Introduction

Peak hour electricity demand is associated with wholesale electricity prices that are sometimes more than 10 times higher than in off-peak periods. During these high-demand periods congested transmission lines and insufficient generation capacity can lead to brownouts and blackouts. This problem can be especially acute in urban centers. One way to alleviate this problem is to build new peaking plants. We investigated the costs and benefits, including expenditures and adverse health effects, of using existing backup generators and battery based electrical storage facilities to meet peak load demands rather than investing in a new power plant. Using small-scale generation located close to the point of use, rather than a centralized power plant with transmission lines to ship the electricity to where it is needed, is referred to as distributed electricity generation. We found that distributed generation in the form of existing generators installed for backup during blackouts could meet these peak demands cost-effectively. Small electrical storage facilities could also be used. To avoid the transfer of adverse health effects from urban centers to outlying areas, clean power generators must be used to charge the battery.

Results

The costs, air quality and human health effects of using installed backup generators for meeting peak electricity demand

We found that on a private cost basis, properly controlled backup generators are more cost-effective for meeting peak electricity demand than building new peaking plants. Since the generators have already been bought to address blackout concerns, the cost of using generators at peak demand periods would be only their incremental operational cost, mostly fuel costs.[1] Although this strategy would lower costs, many of these generators are diesel fueled internal combustion engines that have significant air emissions unless fitted with emission controls such as filters. The emissions are primarily fine particulate matter and nitrogen oxides (that lead to the creation of ozone), both of which have been shown to damage human health. Thus, locating the generators close to areas where the power will be used, for example, city centers, has a large potential to harm human health. Deciding whether to implement these strategies therefore requires a careful examination of the costs and benefits.[2]

We studied New York City and then extended the work to include Atlanta, Chicago and Dallas. We examined the effects of emissions from 1,000 megawatts of operation of generators for 12 hours over six days for diesel generators with and without emission controls. To quantify the cost from changes in air quality, first, we convert the air emissions to ambient concentrations using an air quality chemical transport model. This allows us to observe pollutants, such as ozone and a portion of the fine particulate matter, that are not released from a source but are formed chemically from emitted precursors. This modeling also allows us to estimate exposure. We transform these ambient concentrations and exposure to their equivalent human health effects and translate the ill health into dollars. Adding the cost from air quality and human health to the cost savings from using these generations, we find that uncontrolled diesel generators have a full social cost that is greater than the cost of new peaking plant. Emission control technologies, specifically a diesel particulate matter filter and exhaust gas recirculation, are available to mitigate these concerns. Thus, properly controlled backup generators are clearly cost-effective for meeting peak electricity demand[3].

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[1] Meyer, J.F., J.; Troester, D., *Standby Generation: A New Proposition.* Public Utilities Forthnightly, 2002. **140**.
[2] Matthews, H.S. and L.B. Lave, *Applications of environmental valuation for determining externality costs.* Environmental Science & Technology, 2000. **34**(8): p. 1390-1395.
[3] Gilmore, E.A., L.B. Lave, and P.J. Adams, *The costs, air quality, and human health effects of meeting peak electricity demand with installed backup generators.* Environmental Science & Technology, 2006. **40**(22): p. 6887-6893.

The costs, benefits and distribution of the air quality and human health effects of introducing electric energy storage into the electricity grid

We also examined the costs and benefits of using energy storage facilities to meet peak hour electricity demands. Electrical energy storage comprises a range of technologies that have the ability to charge during one time period and release the electricity during another period when it is needed and is more valuable. In a previous market analysis, Walawalkar et al. (2007) showed that there are significant profits in installing a sodium sulfur (NaS) battery facility in New York City, NY area.[4] Such an electrical storage facility could supply power during the afternoon hours using power acquired from cheaper generation available at off peak hours from the rest of the state. The difference between on peak and off peak prices would create a profit for owners and provide less expensive power to the city when it is needed.

While there are benefits to New York City, this approach may involve the production, in the short term, of more emissions in upstate locations. Using the same approach as above to convert the emissions into a cost from changes in human health, we found that there is a net statewide social benefit from the storage facility. This is due to the large population in New York City that benefits from the displacing the emissions from either natural gas or distillate fuel oil peaking plants. However, clearly, in the short term, the upstate population does not benefit from the electricity stored in the batteries and may be adversely affected from the additional emissions from the charging plant. The issue can be addressed by obtaining the electricity to charge the batteries from intermittent cleaner alternative power generation such as night time wind power thus benefiting both local and statewide power users.

Implications

Distributed electricity generation and electrical storage facilities have the potential to produce significant social benefits. In particular, distributed generation can reduce the cost of generation,

[4] Walawalkar, R., J. Apt, and R. Mancini, *Economics of electric energy storage for energy arbitrage and regulation in New York.* Energy Policy, 2007. **35**(4): p. 2558-2568.

improve grid reliability and support the feasibility of generation by renewable technologies such as wind power. However, unless consideration is given to air quality emissions, the costs from adverse human health can outweigh any savings. Fortunately, the low cost of retrofitting generators to reduce emissions to acceptable levels makes them a more cost-effective way, in terms of both expenditures and adverse effects on human health, to produce electricity to meet peak hour demand than building a new peak hour demand plant. Using storage facilities to meet peak hour demand is also feasible, but the initial net transfer of emissions to areas where the source of the charging electricity is located raises ethical and political concerns. These concerns could be addressed by building cleaner new power generation technologies to charge the batteries.

Journal papers

Published:

Gilmore, E.A, Lave, L.B. and Adams, P.J. (2006). The costs, air quality, and human health effects of meeting peak electricity demand with installed backup generators. Environmental Science and Technology 40 (22): 6887 – 6893

Expected:

Gilmore, E.A., Lave, L.B., and Adams, P.J. "A sensitivity analysis of using backup generators to meet peak electricity demand"

Gilmore, E.A., Adams, P.J., Apt, J., Lave, L.B., and Walawalkar, R. "The Air Quality and Health Effects of Emerging Electricity Storage Technologies in New York"

Discretionary funds

The discretionary funds were used to purchase a desktop computer capable of supporting regional air quality models and supporting programs. The conference funds were used to offset some of the costs of attending conferences at which this work was presented, including the Air and Waste Management Association Annual Meeting (2007) and the Society for Risk Analysis (2007).

Fellowship support

The Link Energy Fellowship played an important role during my doctoral degree studies. Having an independent source of stipend support gave me significant freedom in pursuing my work. The discretionary funds that accompany the fellowship were also instrumental in allowing me to complete this work. Since specialized computers are required for complex regional air quality modeling, having my own custom designed computer allowed me to explore promising directions that would have been difficult to pursue sharing available computer resources. Finally, the conference funding was especially valuable as it allowed me to present this work in the relevant engineering policy forums. Part of this work was awarded first place in pollution prevention/sustainable development student paper/poster competition and second place in the doctoral student paper/poster competition at Air and Waste Management Association Conference 2007.