

Energy Efficiency and Air Quality

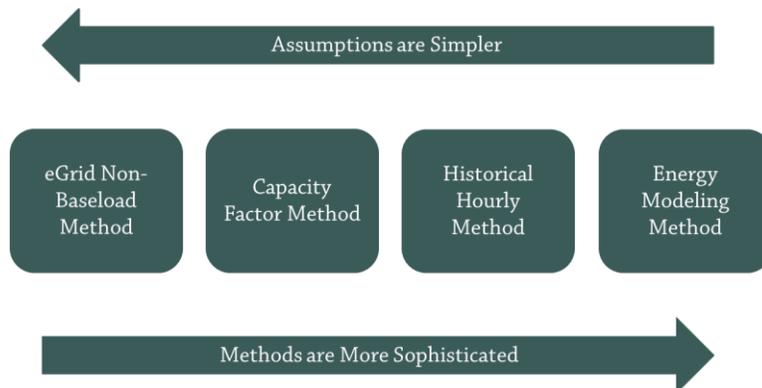
Background

States and local governments can have different motivations for being interested in air quality, from environmental sustainability to regulatory compliance, and can attain air quality standards from a variety of actions and programs. Air quality regulations are based on actual field measurements of certain pollutants in the atmosphere or on source emissions. The National Ambient Air Quality Standards (NAAQS), regulated by the U.S. Environmental Protection Agency (EPA), are standards that address NO_x, CO, SO₂, PM₁₀, PM 2.5, Pb, and Ozone. The Carolinas currently comply with EPA standards (known as being in attainment) for all NAAQS pollutants but have only recently reached this status for Ozone. Some metropolitan areas, such as Charlotte/Gastonia/Rock Hill and Raleigh/Durham/Chapel Hill, must continue plans to remain in attainment. Low level Ozone is formed by the reaction of sunlight, hydrocarbons, and nitrogen oxides (NO_x). Nitrogen oxides are produced by the combustion of fossil fuels, which occurs in electric power plants.

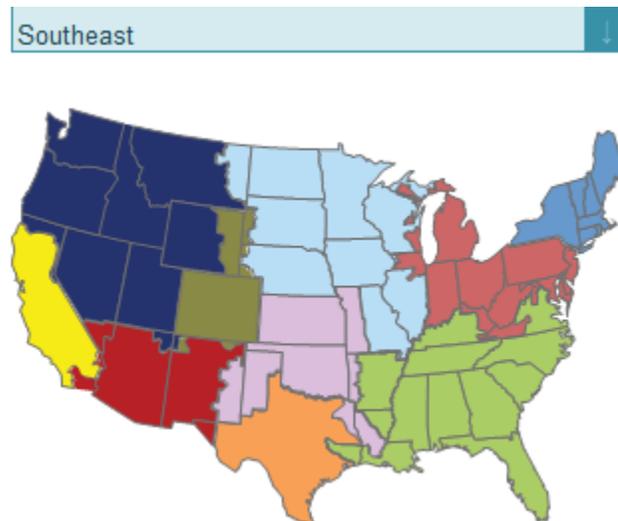
Numerous studies have shown that investing in energy efficiency for buildings is a cost-effective way to reduce air pollution. In the Carolinas, one of the most successful approaches has been programs led by electric utilities. Such programs have achieved a 0.64% (in North Carolina) and 0.53% (in South Carolina) reduction in electricity consumption in 2015, according to the American Council for an Energy Efficient Economy (ACEEE) 2015 State Energy Efficiency Scorecard. The challenge with counting energy efficiency programs toward air quality goals is that it is difficult to assess actual emission reductions, as this requires measuring the absence of such emissions.

Modeling for Air Quality Impacts and the AVERT – AVOIDed Emissions and generation Tool

The EPA has developed guidelines and acceptable methods to address this issue. Based on community air quality goals, various techniques can quantify the impacts of energy efficiency on air quality, some simple and some more sophisticated.



AVERT is intended to help states estimate emission reductions from energy efficiency/renewable energy (EE/RE). If AVERT's advanced features are used, it works as a **historic hourly method**. The tool uses historical hourly emissions rates based on recent EPA data reported by energy generating units. This data can then be combined with the hourly impact profiles of EE/RE resources to determine marginal emissions rates and emissions reductions. AVERT modeling is based on a large regional electricity market and is not recommended for estimating the emissions displaced by small local programs.¹



For North Carolina and South Carolina, the baseline emissions and reductions use the generation data for the entire Southeast grid region, including plants in Alabama, Arkansas, Georgia, Florida, Mississippi, Tennessee, Kentucky, South Carolina, North Carolina, and Virginia.

Research Methodology

Advanced Energy and its partners were interested in evaluating the impact of energy efficiency programs on local air quality in the Southeast and in the Carolinas, specifically. The research aimed to answer the following question: Do certain energy efficiency programs result in greater air emissions reductions per megawatt-hour (MWh) of energy saved based on hourly differences of air emissions factors? In other words, in the context of minimizing air emissions, does it matter when a kilowatt-hour (kWh) of energy is saved?

The main sources of data included evaluation, measurement, and verification (EM&V) results from Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) energy efficiency programs in North Carolina, load profiles for different end uses in residential and commercial buildings from the Electric Power Research Institute (EPRI), historical hourly emissions from AVERT, and future information specific to the Carolinas about power plant dispatch and emissions factors from Duke Energy.

While the results represent the best available information, there are limitations to the analysis. For example, operating the electric grid is complex, and dispatching resources to meet loads during peak times (marginal dispatch) varies year to year. These results are illustrative only, apply to the given service territory for the particular year, and should not be viewed as a forecast or exact representation of past performance.

¹ AVERT User Manual version 1.2. October 2014. Accessed at http://www3.epa.gov/statelocalclimate/documents/pdf/AVERT%20User%20Manual%2011-05-14_508.pdf

Actual emissions in any year will depend on numerous factors, such as weather, fuel price, plant maintenance downtime, customer electric load growth or decline, etc. For example, North Carolina has seen a significant growth of utility-scale solar generation that is not well represented in historical profiles, and the growth of this renewable energy has begun in South Carolina as well. The projections that were provided specific to the Carolinas are based on assumptions about what will happen in future years. Over the last few years, the price of coal and natural gas has affected utilities' dispatch strategies, and the timing of these price fluctuations could significantly impact actual emissions factors.

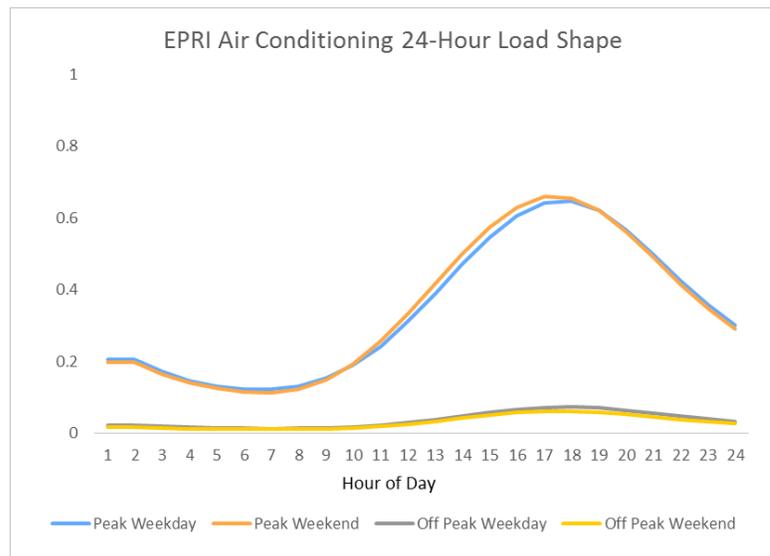
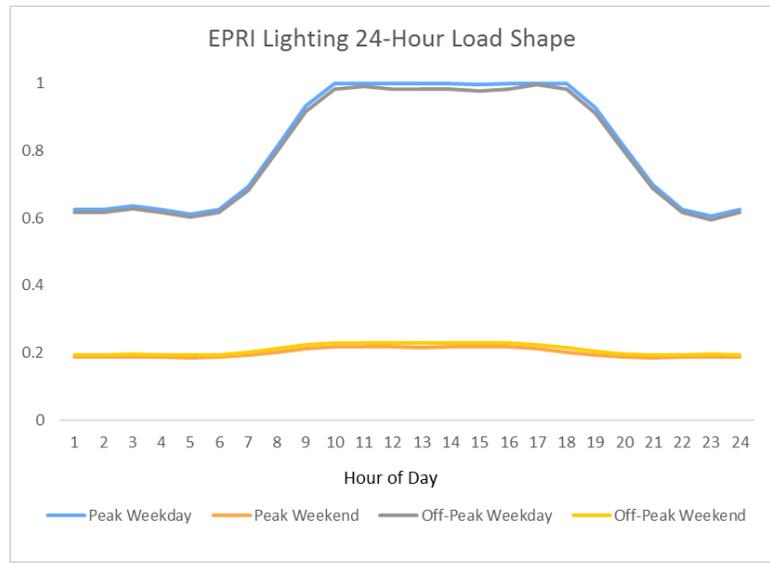
Carolinas Specific Electric Generating Information

This project was primarily focused on results specific to the Carolinas and not the Southeast region more generally. Upon further analysis, it was found that the Southeast regional generation mix and hourly dispatch in AVERT were quite different from those in the Carolinas. Therefore, the emissions factors for AVERT were scaled based on generation information from the largest electric utility in the Carolinas, Duke Energy. The generation for Duke Energy was divided by territory for Duke Energy Progress East and West and Duke Energy Carolinas. The table shows the difference between the AVERT emissions factor and the Duke Energy emissions factors overall.

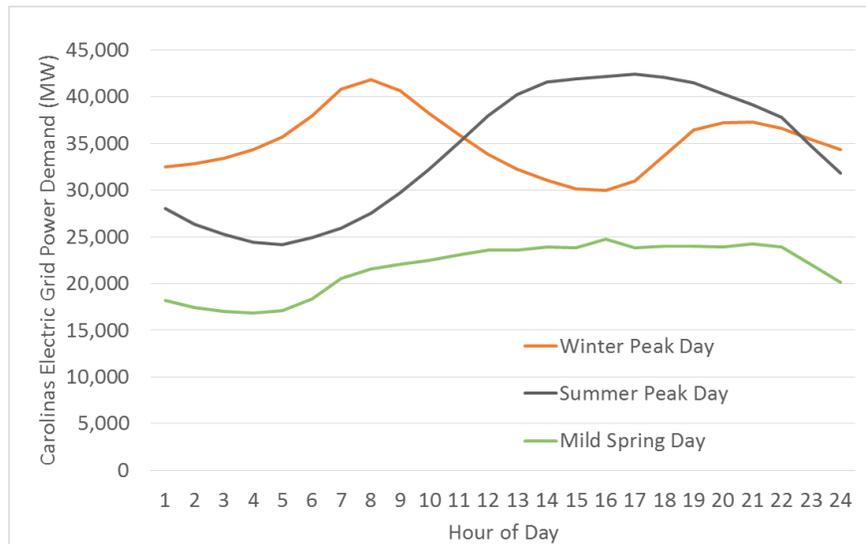
Territory	NO_x Emissions Factor (lb / MWh)	CO₂ Emissions Factor (ton / MWh)
Southeast (AVERT region)	0.889	0.712
DEP West	0.346	0.305
DEP East	0.189	0.225
DEC	0.583	0.312

Electric Load Profiles

The Electric Power Research Institute publishes profiles for different end-use loads that can be used for modeling impacts on the electric grid. Four typical-day load shapes are available — peak weekday, peak weekend, off-peak weekday, and off-peak weekend — for end-use loads including residential and commercial lighting, HVAC, and water heating. The terms peak and off-peak refer to times of the year when electricity demand is at its highest and lowest, respectively. Each profile is published for a 24-hour period and statistically represents the power drawn from that type of load throughout the day. Two example graphs of typical load are shown, one for residential lighting and the other for air conditioning. The lighting profile is similar for peak and off-peak weekdays and for peak and off-peak weekends, but the two parts of the week differ greatly. In contrast, the load for an air conditioner shows the most use from 12pm to 10pm on peak weekends and weekdays and little use in the off-peak season.



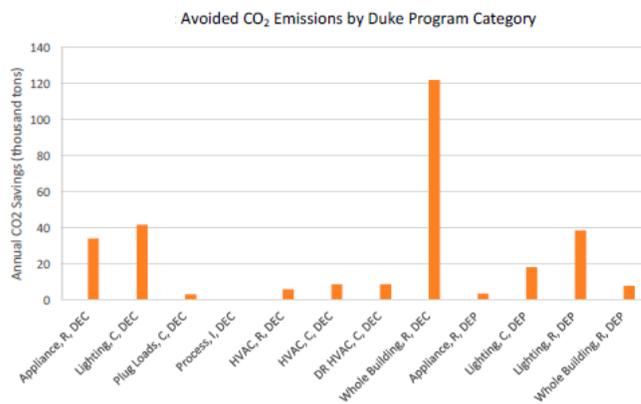
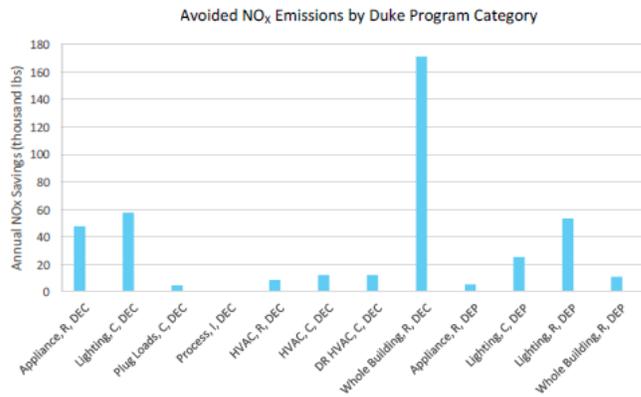
The actual demand on the electric grid is a compilation of all the different load types of an entire system. The graph below shows a representative daily demand profile for the Carolinas electric grid on a winter peak day, a summer peak day, and a mild weather day in the spring. There is a peak on the grid in the winter in the early morning between 7am and 9am and a smaller peak in the evening between 7pm and 10pm. The summer day has a much longer peak between 12pm and 10pm. There is relatively minimal variance in the load on the mild spring day but still a decrease in electrical demand at night.



Results

Two different scenarios were modeled in the AVERT/Carolinas generation model. The first scenario looked at the overall emissions reduction impacts scaled to actual participation in energy efficiency programs offered by Duke Energy Carolinas and Duke Energy Progress. The second scenario was designed such that program participation was scaled to have each program have the same MWh impact per year.

The results of the first scenario, scaled to actual participation, showed that numerous programs have enough energy reduction to avoid NO_x and CO₂ emissions. Residential whole building programs, which include energy measures such as weatherization and energy audits, had the most impact. Therefore, these programs had significant participation and overall energy savings.



The second scenario provides a better picture of the comparative air emissions if someone wanted to promote a program based on emissions reductions alone. The results showed that each program category achieved similar levels of air emissions reductions when the annual generation savings are held constant, despite each category having distinctly different load shapes.

To further investigate these findings, the NO_x and CO₂ avoided emissions rates used by the AVERT model for each hour of the year were evaluated. Although air emissions rates do vary throughout the day, there is no consistent or obvious trend about which hours are the "dirtiest." One trend was that summer afternoons had steadier NO_x and CO₂ avoided emissions rates; however, without a

more rigorous analysis, it is difficult to conclude if this pattern is statistically significant.

Conclusion

There are many benefits to supporting and participating in utility energy efficiency programs, one of which is improved air quality. North Carolina and South Carolina provide several programs with enough energy reduction to avoid NO_x and CO₂ emissions. Initially, it was believed that a program with the greatest impact on the generation peak during the year would have the greatest impact on air quality. However, this theory was not supported by the results in this research. There are limitations to the analysis, such as that it only applies to the given service territory for the particular year of data used. In spite of these limitations, the present findings show that different energy efficiency measures and programs have similar air emission reductions per MWh of energy saved. Furthermore, there is not a significant difference in air emissions based on the hour of the day that a kWh of energy is saved.