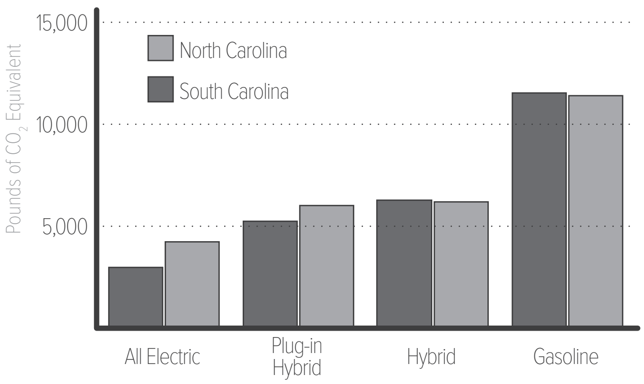
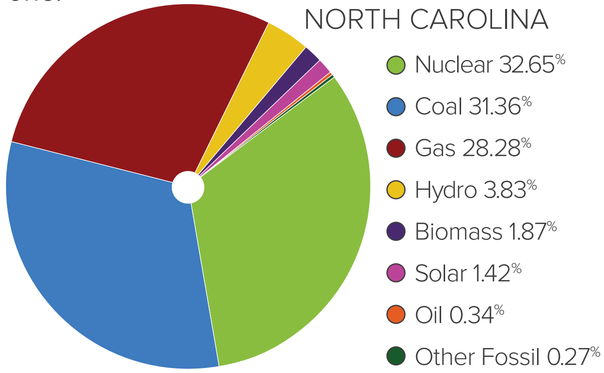
ELECTRIC VEHICLES AND AIR QUALITY

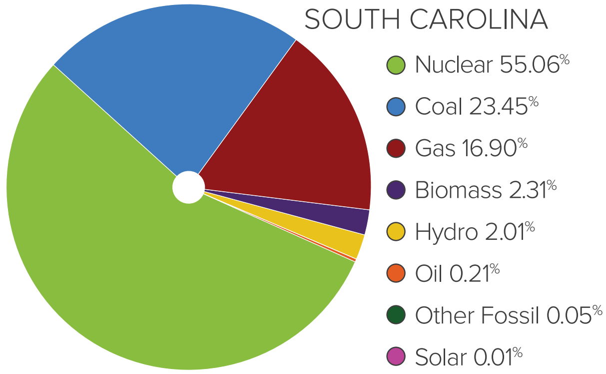


According to data from the U.S. Energy Information Administration (EIA), for the first time since 1979 America's cars, trucks, and airplanes now emit more carbon dioxide (CO_2) than its power plants do. This shift has occurred because the electric grid is becoming more efficient and cleaner due to the growth of renewable energy and non- or low-emitting generation sources. Transportation emissions are now seen as a large problem for air quality. Electric vehicles, though, can benefit air quality. Studies have shown that these vehicles can greatly decrease local air pollution, and if they are largely adopted, the local impact can expand to a national one.

The National Renewable Energy Laboratory (NREL) conducted a study on emissions associated with charging electric vehicles. The study found that the potential emissions reduction depends on when and where drivers charge, because emissions rely on the percentage of fossil fuels in the electricity mix at the charging location. However, the study also showed that electric vehicles charged on high-carbon grids still produced fewer carbon emissions than conventional gasoline vehicles.

Locally in the Carolinas, data shows that emissions are lower for all-electric and plug-in hybrid electric vehicles than for gasoline vehicles. This result stems from our diverse mix of electricity sources. Electric vehicles also benefit the environment because there is little run-off from gasoline spills and leaks, and there are no emissions coming directly from the tailpipe, so it is safe to be around a vehicle when it is running. These features are extremely helpful in decreasing pollution in situations in which there is a lot of idling, such as in school pick-up lines and traffic.





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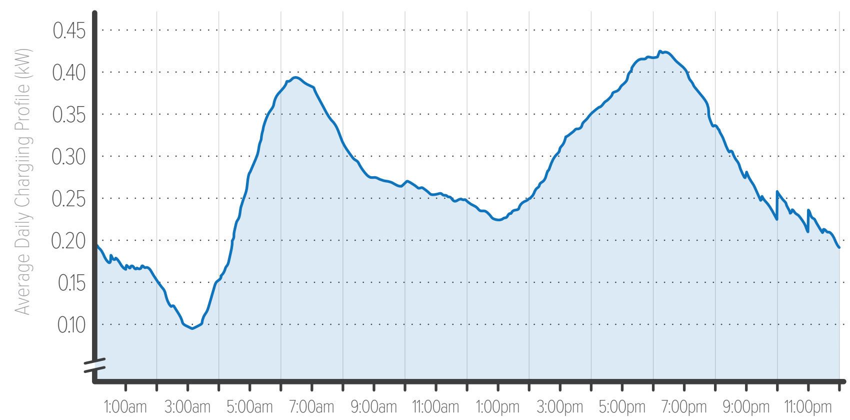
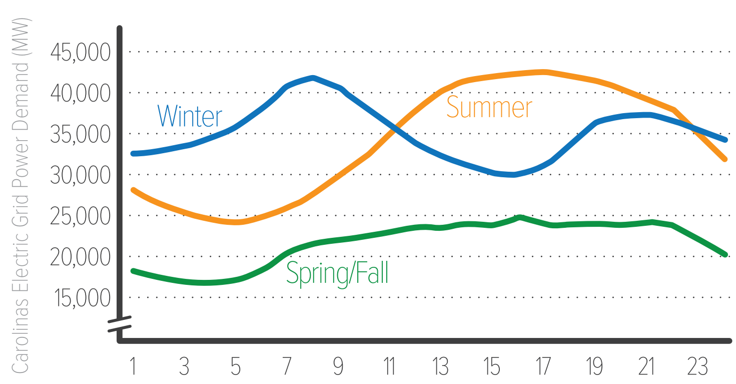
Carolinas Electric Vehicle Analysis
The Carolinas Energy Planning for the Future project partners were interested in extending the analysis from other organizations to reflect local data from the Southeast and the Carolinas, specifically. The primary sources of information included a plug-in electric vehicle (PEV) Usage Study in North Carolina, projected PEV adoption in the Southeast and the Carolinas, and historical hourly emissions from a tool called AVERT (AVoided Emissions and geneRation Tool) from the U.S. Environmental Protection Agency (EPA).

The analysis quantified the effect of grid resource allocation changes in the Southeast associated with emerging renewable and transportation technologies on regional air quality metrics, such as the reduction in CO_2, SO_2 (sulfur dioxide), and NO_x (nitrogen oxides) emissions. The analysis sought to answer the question, "would air quality metrics adjust as the relative levels of renewables and vehicle charging change based on projections for adoption over the next 10 years?"

PEV Usage Study and Vehicle Adoption
The analysis consisted of leveraging data collected by Advanced Energy on a fleet of 40 electric vehicles over the course of the PEV Usage Study from 2012 to 2014. All participants were Nissan Leaf owners, and their driving and charging habits were continuously monitored throughout the study. The participants lived at varied distances from work and had different types of access to workplace charging, from no access to Level 2 charging stations. The charging data collected for each vehicle was combined into a "typical" charging profile throughout the day and year.



Interestingly, the typical charging demand tends to be greatest when existing grid peaks are already expected to occur and when solar generation (by far the dominant form of renewable generation in the Southeast) tends to be less influential. In the analysis, it is assumed that the general shape and magnitude of the individual charging profile remains the same, which is a caveat of the results. Driving range, battery size, and instantaneous demand required for electric vehicles are all factors that may change as technology develops.



The actual demand on the electric grid is a compilation of all the different load types of an entire system. 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 a decrease in demand still occurs at night.

The charging information was aggregated and combined with statistics estimating projected electric vehicle adoption rates in the Southeast to estimate the increase in electrical energy generation required to support vehicle charging. Southeast regional vehicle adoption rates projections were based on a Florida Solar Energy center report (FSEC-CR-1998-15) and the EIA's Annual Energy Outlook 2016 report (DOE/EIA-0383). In addition, data on projected increases in regional wind and solar renewable energy generation was obtained from the EIA's Annual Energy Outlook 2016 report (DOE/EIA-0383).

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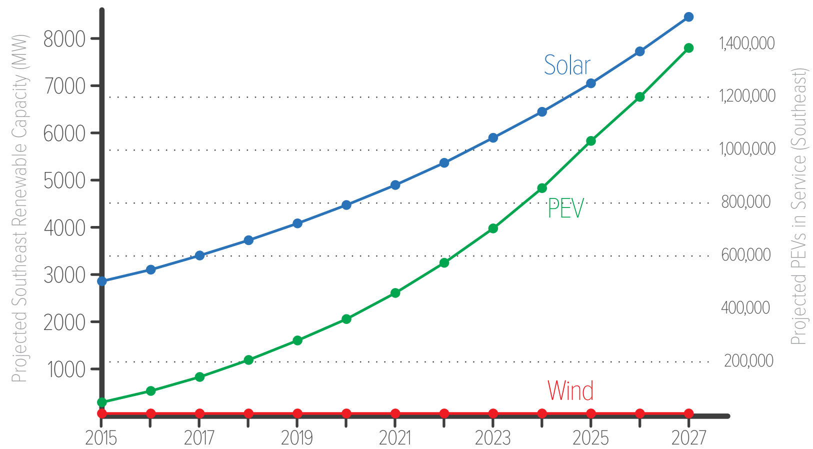
Calculating Emissions



The data was entered into the EPA's AVERT platform to analyze the effect of changes in regional utility dispatch associated with various scenarios of interest. AVERT is intended to help states estimate air pollutant emission reductions for CO_2, NOx, and SO_2 from energy efficiency and renewable energy (EE/RE) programs. If the tool's advanced features are used, it is categorized as a historic hourly methodology based on electric generating units' hourly generation and emissions reported through the EPA's Acid Rain Program. The generation emissions data is combined with the hourly impact profiles of EE/RE resources to determine hourly marginal emissions rates and emissions reductions. Additional load of electric vehicles was entered into the modeling tool instead of EE/RE resource profiles (typically entered to simulate decreased loads).

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

Electric Generation Analysis Limitations

While the results represent the best available information, there are limitations to the analysis. An evaluation of the emissions for the Southeast showed that the Carolinas are significantly cleaner for CO_2, NO_x, and SO_2 than the region more generally. Therefore, the results will tend to overstate the emissions for electric vehicles. Also, operating the electric grid is complex, and dispatching resources to meet loads during peak times (marginal dispatch) varies year-to-year. The results are illustrative only, as actual emissions in any given year will depend on numerous factors, such as weather, fuel price, plant maintenance downtime, customer electric load growth or decline, etc. Furthermore, the projections are based on assumptions about what will happen in future years for renewables, but do not include other new generation.

Scenarios Investigated

Four scenarios were investigated to examine effects on air quality metrics: the effect of charging time, the effect of regional projected electric vehicle adoption in the absence of renewable generation deployment, the effect of projected increases in renewable generation in the absence of electric vehicle adoption, and the interactive effect of projected electric vehicle adoption and renewable generation. The analysis assumed constant 2015 levels of regional energy generation and resource dispatch while varying renewable generation and electric vehicle adoption as projected for each year through 2027.

Results

The effect of charging time on air quality metrics was evaluated by comparing the actual charging profile to one in which vehicles were only charged at night (off-peak) from 10pm to 6am. Changing the time during which charging occurs produced no significant effect on air quality metrics.

For the effects of vehicle only, renewables only, and the two combined on air quality, the changes in metrics take into account changes in pollutants produced by regional power generation and also by any associated reduction in the use of conventional vehicles resulting from the adoption of PEVs.

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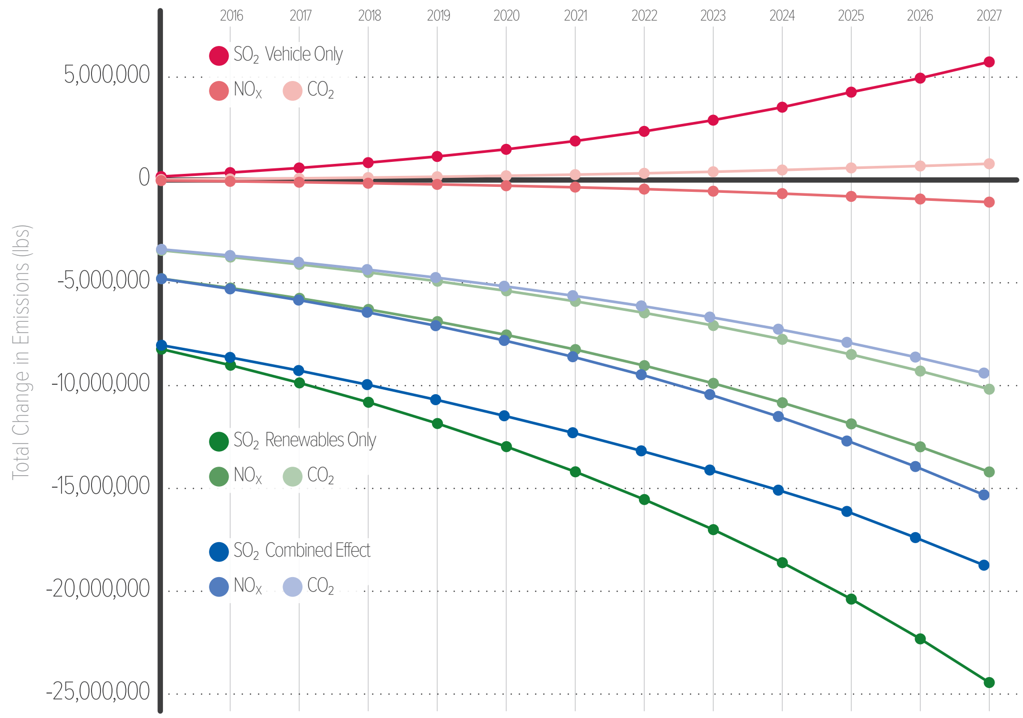
It was hypothesized that PEV adoption would offset air pollutant production based on the reduction in tailpipe emissions. Although this result was found for NO_x pollutants (which are important when considering regional Ozone production), it was not obtained for SO_x or CO_2 pollutants when using data from Argonne National Lab. One explanation for these latter findings is that the Southeast power production may be less clean than the Carolinas specifically. Another possible explanation is the fact that the analysis does not take into account future changes in traditional generation. Also, the prior research conducted for this study reported differing emissions projections for traditional gasoline vehicles. New conventional vehicles entering the market are more efficient and produce less emissions. This complicates the research because it is difficult to estimate if plug-in electric vehicles will replace older (more emissions producing) or newer vehicles. The baseline emissions for gasoline vehicles presented in this analysis came from Argonne National Lab, which were more conservative than the baseline emissions from other sources.



No synergistic effect was found between renewable energy deployment and PEV adoption. It was assumed that these two trends would reinforce each other with regard to overall reductions in air pollutants, however, the results do not support this hypothesis. One potential contributor to the lack of a combined benefit could be that there is some misalignment between vehicle charging peak demand and solar generation.

Conclusions and Future Work

Across the country and in the Carolinas, the electric grid is becoming cleaner. This development is making electric vehicles more attractive from an air quality standpoint. The results from the investigation suggest that large projected solar deployments in the Southeast will play a major role in reducing future regional air pollutants, but that PEV adoption may only be beneficial with respect to NO_x reductions. Generation in the Carolinas is cleaner than in the Southeast overall, and therefore electric vehicles may have more air quality benefits than are reported in this analysis. The AVERT tool was used because it can look at hourly demand changes; however, the hourly analysis did not show a significant difference for emissions reductions based on varying the charging profiles of electric vehicles.

Future research could help refine this analysis by:

1. Including modeling of future generation resource retirement and changes to utility dispatch patterns
2. Scaling the results to be more specific to the Carolinas
3. Evaluating assumptions on emissions data for traditional vehicles to be more specific to local purchasing and driving patterns.

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