# Diesel/Black Carbon Technical Assessment and Feasibility Study

CONNECT Our Future

Vibrant Communities – Robust Region


**The 14-county bi-state region includes:** Anson, Cabarrus, Cleveland, Gaston, Iredell, Lincoln, Mecklenburg, Rowan, Stanly and Union Counties in North Carolina, and Chester, Lancaster, Union and York Counties in South Carolina.

# Air Quality and Climate Change

## Diesel/Black Carbon Technical Assessment and Feasibility Study

The Air Quality and Climate Change Work Group investigated the diesel engine exhaust and black carbon emissions that are by products of construction projects in the CONNECT Our Future 14-county region. This study assessed major construction projects in five primary activity sectors expected to occur over a five year planning horizon (2013 – 2018). The assessment yielded new tools and resources for municipalities and other stakeholders as well as recommendations that can help mitigate the environmental and human health impacts of these emissions.

"CONNECT Our Future" is a process in which communities, counties, businesses, educators, non-profits, and other organizations work together to grow jobs and the economy, improve quality of life and control the cost of government. This project will create a regional growth framework developed through extensive community engagement and built on what communities identify as existing conditions, future plans and needs, and potential strategies.

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ERG

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# 1. Executive Summary

The authors of this report hope that readers will consider the following steps to ensure that air quality, public health, and the stability of our climate are considered in balance with the many other factors that inform and shape planning for major construction projects. We urge readers to:

- Learn about black carbon's connection to climate change and how mitigating black carbon emissions offers relatively quick, inexpensive, and localized climate change benefits.
- Gain a deeper understanding of the health effects of diesel engine exhaust, including emissions of fine particulate matter and black carbon, and how mitigating those emissions can impact health (cancer and non-cancerous) outcomes in the long term.
- Review the technical approach and data sources used by ERG to quantify anticipated construction activity in the region and estimate emissions generated by diesel construction equipment (DCE) used to carry out that activity. Consider the findings in terms of mass emissions quantified by the DCE Emissions Assessment Tool.
- With an understanding of emissions modeled to reflect planned activity, become better acquainted with diesel emissions reduction strategies, including retrofit technologies, operational changes, policy measures, voluntary partnerships and incentives, and deployment of alternative fuels.
- Learn to use the DCE Emissions Assessment Tool to compare emissions reductions that various emissions control scenarios could deliver to the 14-county region and, perhaps more importantly, to assess emissions reductions that could be achieved at an individual construction project.
- Learn about external funding opportunities that can help municipal as well as private-sector fleet and equipment owners make the business case for using newer and/or cleaner construction equipment.
- Consider how supporting clean diesel equipment purchases and programs can deliver economic benefits and support job growth in the region and nationally.
- Most importantly, apply the findings and approaches mentioned above to the framework presented in Section 9 of this report to evaluate and rank future construction projects and their relative impacts on public health and the environment. Use the framework's relative score to help guide decisions around construction projects in most need of diesel emissions controls.

With our collective efforts, the CONNECT Our Future 14-county region can grow in a cleaner, greener fashion, benefiting the air and climate systems upon which we all depend.

# 2. Introduction

## Background

Nearly every modern building, road, port, and public space in the United States was built by machines operating on diesel fuel, and nearly every product in our society is shipped, trucked, stored, and delivered by diesel engines. In short, it is not an exaggeration to state that diesel fuel, and the engines and trucks that use it, literally built and sustain our modern lifestyles. Yet the past and ongoing accomplishments of the diesel engine have come with a price: air pollution that poses serious hazards to public health, the environment, and our climate.

While federal, state, and local agencies have acknowledged, researched, and worked to mitigate the health and environmental impacts of diesel emissions by mandating cleaner engines and more stringent fuel standards, a huge challenge remains: legacy diesel engines. Millions of older, dirtier diesel engines are still in use throughout the country. They will remain in use for a long time, up to 20 to 30 more years depending on their age, thanks to their longevity and durability, and the expense of replacing them. In fact, of the estimated two million diesel engines currently powering construction equipment across the nation, 31 percent of them were manufactured before the introduction of emissions regulations.[1]

The construction sector not only relies on many older, dirtier engines, but activity in the sector is expanding rapidly too, especially in the Metrolina region. With our region's population expected to double by 2050, we can expect the demand for further investments in infrastructure to continue. That means we will need to build new roads and bridges, add new homes, expand commercial space, and install utility pipes and lines. Diesel engines will be an important contributor to meeting each of these needs—and to expected air pollution and its harmful effects.

## About This Study

In 2013, with federal funding from a Sustainable Communities Regional Planning Grant, the CONNECT Our Future Air Quality and Climate Change work group decided to conduct targeted research to forecast and assess major construction activity, estimate the amount of black carbon and criteria pollutant emissions that would be a byproduct of this activity, identify mitigation strategies, and create tools to help bring those strategies to those who could use them. The Diesel/Black Carbon Technical Assessment and Feasibility Study is the outcome of that decision.

This study describes diesel pollution and its characteristics, provides information about black carbon, and details why diesel pollution and its components are harmful to the environment and human health. Of direct relevance to the CONNECT region and its leaders and planners, this report goes into significant detail about the region's current and forecasted construction-related diesel emissions footprint. It provides planners and municipal leaders with information on tools and strategies to measure and mitigate diesel emissions, resources to help procure and implement those tools and strategies, and a look at the positive economic impact of doing so.

Lastly, and perhaps most importantly, this study yielded the Diesel Construction Equipment (DCE) Emissions Assessment Tool and a framework to help regional planners and municipal leaders assess how new construction projects are likely to impact local communities and how emissions control strategies might benefit them. We hope this tool and framework will serve both the region and the nation as a model that will deliver cleaner air, healthier communities, and contribute to a more stable climate.

[1] http://northeastdiesel.org/construction.html. Accessed May 2014.

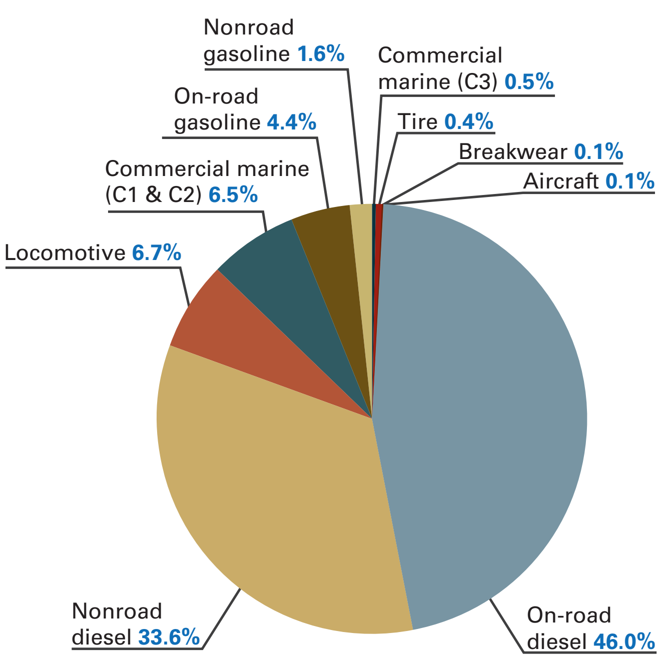
# 3. Black Carbon: An Overview

## What is Black Carbon?

The U.S. Environmental Protection Agency's (EPA) 2012 *Report to Congress on Black Carbon* describes black carbon as "the most strongly light-absorbing component of particulate matter (PM)." Unlike many other pollutants, black carbon is relatively easy to see, smell, and touch. At the lay level, black carbon is a major part of the dark smoke coming from tailpipes, smokestacks, chimneys, and other sources that burn fossil fuels and biomass. It is a product of incomplete combustion and a major component of soot.

At the technical level, black carbon is the solid portion of fine particulate matter ($PM_{2.5}$). $PM_{2.5}$ also contains organic carbon, but the proportions of the two elements vary by source. Diesel emissions have more black carbon than organic carbon (approximately 70-80 percent to 20-30 percent) compared to emissions from burning biomass. This is important to bear in mind when developing strategies to reduce black carbon emissions: reductions in diesel emissions will yield more reductions in black carbon than reductions in emissions from biomass emissions.

Figure 3-1. U.S. Black Carbon Emissions from all Mobile Source Categories (2005)




The primary sources of black carbon emissions vary in ranking by geographic region but generally include diesel engines, cook stoves, burning wood, and forest fires. In 2005, the total emissions of black carbon from United States sources represented about 8 percent of the global total black carbon emissions. In the United States, more than 50 percent of black carbon emissions were produced by mobile sources and within U.S. mobile sources, the vast majority (about 90 percent) were related to diesel combustion.[2]

## Why is Black Carbon so Important? Climate Change and Public Health Perspectives

Black carbon is a particularly important pollutant. Not only does it have a direct impact on human health (as a component of $PM_{2.5}$), but is also associated with climate change. And while many pollutants share these two characteristics, black carbon is relatively cheap and easy to control, and its control can have an immediate climate benefit, essentially buying more time for society to deploy other more costly and long-term strategies to mitigate climate change impacts and adapt to new climate realities.

## Black Carbon's Connection to Climate Change

In recent years, climate scientists have developed a keener understanding of black carbon and its role in climate change. As a result, we now know that black carbon, when emitted directly into the atmosphere as $PM_{2.5}$, influences climate change in three ways:

- It directly absorbs incoming and outgoing light energy, which is then converted to heat.
- When deposited on snow and ice, it reduces these surfaces' natural reflectivity and accelerates melting.
- By interacting with clouds in the atmosphere, it may cause changes to precipitation patterns.

Because of these influences, black carbon is now commonly considered either the second or third most powerful climate forcer after $CO_2$ and, depending on the assessment, $CH_4$ (methane). In fact, since the Intergovernmental Panel on

[2] U.S. Environmental Protection Agency. Report to Congress on Black Carbon. 2012.

Climate Change's (IPCC) *Fourth Assessment on Climate Change* was released in 2007, several panel authors have concluded that the assessment underestimated black carbon's contribution to global climate change by a factor of two. Even more recently, a 2014 report sponsored by the World Bank also indicated that black carbon is second only to $CO_2$ in terms of its climate forcing and 3,200 times more effective on a mass-equivalent basis than $CO_2$ in causing climate impacts within a 20 year period.[3]

Like other particulates, black carbon has a short lifespan. In a period of days or weeks, it is naturally removed from the atmosphere through precipitation and deposition, generally landing in fairly close proximity to the emissions source (though dispersion can be as far as 1,000 miles). Black carbon is therefore primarily a regional pollutant. In contrast, long-lived climate forcers like carbon dioxide ($CO_2$), as well as some other greenhouse gases, are global pollutants and exist in fairly even concentrations around the world. Long-lived climate forcers can remain in the atmosphere for decades or longer interacting with other gases.

Because of these two considerations —black carbon's strong global warming potential and short atmospheric life— reductions in black carbon emissions can provide nearly immediate benefits. And as new emissions are reduced or eliminated, atmospheric concentrations of black carbon would be reduced quickly and slow the rate of climate change.[4]

## Black Carbon and Public Health

Diesel emissions, which include black carbon, are associated with and cause numerous health problems. These human health impacts are well documented by many state and federal agencies, including EPA, the National Toxicology Program, the International Agency for Research on Cancer (IARC), the Health Effects Institute, the World Health Organization (WHO), and the National Institute for Occupational Safety and Health (NIOSH). Following is a brief discussion of impacts from several pollutants commonly linked to emissions from diesel vehicles and equipment: fine particulate matter, diesel engine exhaust, black carbon, and elemental carbon.

This report divides the impacts of these pollutants into cancer and non-cancer outcomes. It further divides non-cancer outcomes into those resulting from acute and chronic exposures. Lastly, for each pollutant, this report presents a short summary of the available information on populations susceptible to exposure-related health effects. For further reference, Appendix A includes links to major assessments published by widely recognized authorities on pollution-related health effects.

### Health Effects of Fine Particulate Matter

***What is fine particulate matter and where does it come from?*** Fine particulate matter, or $PM_{2.5}$, are airborne particles with diameters less than or equal to 2.5 microns. Some fine particles (primary particles) are emitted directly into the air, and others (secondary particles) are formed in the air by chemical reactions involving precursor chemicals. Primary $PM_{2.5}$ emissions sources include fossil fuel combustion in industry, on-road mobile sources, nonroad vehicles and engines, other industrial processes, fugitive dust, and natural sources. Because many of these sources do not involve diesel engines, it is difficult to attribute how much $PM_{2.5}$ is coming from diesel engines and how much is coming from other sources in a given air quality measurement. This in turn has implications on calculating the health benefits associated with reducing $PM_{2.5}$ from diesel sources.

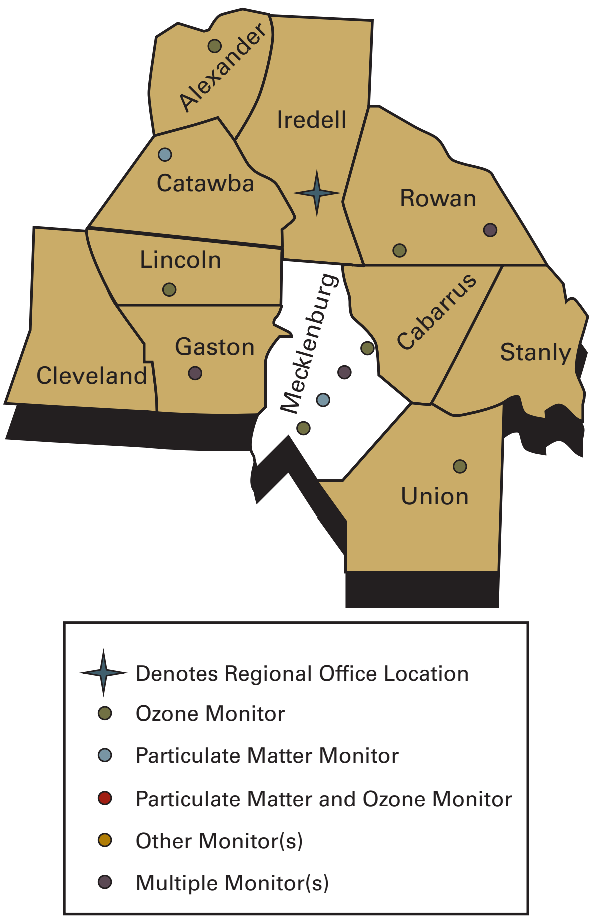
Because there are many non diesel sources of $PM_{2.5}$, the contribution of diesel emissions to primary $PM_{2.5}$ emissions obviously varies with location. In the 14-county CONNECT region, according to EPA's 2011 National Emissions Inventory (NEI), diesel-related emissions sources (e.g., light-duty diesel vehicles, heavy-duty diesel vehicles, diesel-powered equipment) account for between 3 and 18 percent of county-wide primary $PM_{2.5}$ emissions. At these levels, all counties in the region meet EPA's $PM_{2.5}$ air quality standards, indicating that PM levels measured at fixed monitoring stations throughout the region are below health-based standards. However, the monitoring network does not cover all populated areas (See Figure 3-2).[5]

[3] Reducing Black Carbon from Diesel Vehicles: Impacts, Control Strategies, and Cost-Benefit Analysis. International Council for Clean Transportation. 2014.

[4] Bounding the role of black carbon in the climate system: A Scientific Assessment. Journal of Geophysical Research: Atmospheres. 2013.

[5] http://daq.state.nc.us/ambient/monitors/Mooresville.shtml

Figure 3-2. Locations of Air Quality Monitoring Stations




**Links between acute $PM_{2.5}$ exposure and non-cancer effects.** EPA's most recent Integrated Science Assessment for Particulate Matter, which synthesized hundreds of peer-reviewed publications, concluded:

- A "causal relationship exists" between short-term exposures to $PM_{2.5}$ and ***cardiovascular effects***, such as emergency department visits and hospital admissions for coronary heart disease, congestive heart failure, and other cardiovascular outcomes.[6] This conclusion was based on consistent findings observed across multiple large-scale epidemiological studies, and supported by cardiovascular changes observed in controlled human exposure studies.
- A "causal relationship exists" between short-term exposures to $PM_{2.5}$ and ***mortality*** from all causes combined, excluding accidents.[7] This conclusion was based on consistent positive associations between short-term $PM_{2.5}$ exposures, typically on the order of 24 hours, and different mortality metrics.
- For ***respiratory*** effects, EPA concluded that a "causal relationship likely exists"—as opposed to saying a causal relationship exists—between short-term $PM_{2.5}$ exposure and respiratory effects.[8] This weaker conclusion was selected due to inconsistencies among underlying studies. Observed acute respiratory effects include increased emergency department visits and hospital admissions for chronic obstructive pulmonary disease and respiratory infections and increased pulmonary inflammation in asthmatic children.

**Links between *chronic* $PM_{2.5}$ exposure and *non-cancer* effects.** Similar to the findings for acute exposures, EPA's review of the scientific literature concludes:

- A "causal relationship exists" between long-term inhalation exposure to $PM_{2.5}$—typically characterized by annual average concentrations—and ***cardiovascular*** effects and increased ***mortality*** risks from all causes combined, excluding accidents.[9]
- A "causal relationship likely exists" between elevated long-term inhalation exposure to fine particulate matter and non-cancer ***respiratory*** effects, including impaired lung function growth, increased respiratory systems, and development of asthma.
- Available evidence is "suggestive of a causal relationship" between elevated long-term $PM_{2.5}$ exposures and various ***reproductive*** and ***developmental*** effects (e.g., decreased birth rate, increased infant mortality). The weaker conclusion was assigned to this final category because limited insights are available on underlying mechanisms and biological plausibility, even though epidemiological studies support associations between exposures and these effects.

**Links between chronic $PM_{2.5}$ exposure and cancer effects.** EPA's scientific review indicates that available evidence is "suggestive of a causal relationship" between

[6] EPA's "Integrated Science Assessment for Particulate Matter," EPA/600/R-08/139F, December 2009.

[7] Ibid

[8] Ibid

[9] Ibid

**Elevated short-term and long-term exposures to $PM_{2.5}$ have been associated with many non-cancer and cancer health outcomes, with non-cancer cardiovascular effects and mortality having the strongest evidence for causality.**

long-term $PM_{2.5}$ exposures and cancer. This finding is based on multiple epidemiological studies that reported positive associations between fine particulate matter exposures and lung cancer mortality. Consistent with EPA's finding, IARC recently classified PM into a category of pollutants known to be "carcinogenic to humans."

Health effects assessments for $PM_{2.5}$ are inevitably confounded by the fact that fine particulate matter is not a single substance and its composition, particle size distribution, and other characteristics can vary considerably with emissions source, location, and time. Nonetheless, the literature has identified several populations susceptible to particle-related health effects, such as the elderly (primarily for cardiovascular effects), children (primarily for respiratory effects), and people with pre-existing cardiovascular and respiratory conditions (e.g., asthma). The available literature provides extensive additional insight on the significance of particle composition, ultrafine particles, lag times between exposure and effect, and other factors affecting the relationship between airborne PM and health effects. Further information on the toxicity of $PM_{2.5}$ emitted specifically from diesel engines is presented below.

## Health Effects from Diesel Engine Exhaust

Diesel engines release a complex mixture of particles and gases, which EPA collectively refers to as "diesel engine exhaust" (DEE). The composition of DEE varies considerably across engine types, fuel characteristics, engine operating conditions, and the presence of pollution controls (e.g., diesel particulate filters, diesel oxidation catalysts). Particles in DEE are predominantly in the $PM_{2.5}$ size range and have a core of elemental carbon onto which many other organic compounds and inorganic compounds adsorb. The most significant gases and particle-bound chemicals in DEE from a health perspective include benzene, 1,3-butadiene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), and nitroarenes. The following information focuses on health effects information published on DEE as a whole, and not that of the individual substances.

Insights on DEE health effects largely come from controlled dosing studies of healthy human volunteers, epidemiological studies of highly exposed workers (e.g., locomotive repair technicians, miners, bus garage workers), epidemiological studies of residents and schoolchildren in high-traffic areas, and laboratory animal studies. The exposure levels in these various studies—particularly the occupational epidemiological studies—are typically far higher than the environmental exposures that most people experience. Consequently, the full range of DEE-related health effects documented among the highest exposed individuals will not necessarily occur among those exposed at lower concentrations.

Like the previous section, this review focuses largely on a major EPA health effects assessment. That assessment was published in 2002 and characterizes health effects associated with exhaust from engines built through the mid-1990s. Other agencies have reported that diesel exhaust emissions from "new technology engines" have decreased considerably, but the newer generation emissions still contain a similar profile of toxic constituents, just in smaller quantities.[10]

**Links between acute DEE exposure and non-cancer effects.** Several agencies findings underscore health impacts of DEE:

- EPA's 2002 assessment found that both animal studies and human studies indicate that acute exposure to DEE can cause various reversible health effects, including eye, nose, and throat irritation and inflammatory responses in the lung. However, the studies available at the time did not provide evidence for significant impairment of lung function among workers or animals following elevated acute exposures to DEE.
- California's Office of Environmental Health Hazard Assessment (OEHHA) and the American Lung Association of California later reported additional reversible symptoms linked to elevated acute exposure

[10] Available literature reviews use different terminology when referring to the complex mix of pollutants released by diesel engines (e.g., diesel engine exhaust, diesel exhaust particulate, and diesel emissions). This summary cites the same terminology used in the underlying publications.

to diesel exhaust, such as light-headedness, nausea, headaches, and exacerbated responses to allergens.

- A 2012 Health Effects Institute publication confirmed associations between non-specific symptoms (e.g., headaches, nausea) and acute exposures to diesel exhaust particulates among human volunteers, but the study found no statistically significant evidence of allergic inflammatory responses in the lower respiratory tract at the exposure levels tested (up to 100 µg/m³ of diesel exhaust particulate), even among individuals who are mildly asthmatic. The authors noted that inflammatory and allergic responses in the lower respiratory tract could occur at exposure levels higher than those that were tested. However, those higher exposure levels might not be relevant for typical environmental or ambient exposures.

In 2012, IARC added DEE to its list of known carcinogens based on historical studies of occupational exposure.

**Links between *chronic* DEE exposure and *non-cancer* effects.** Although some studies of humans highly exposed to DEE over longer time frames have shown evidence of impaired pulmonary function, the findings are not robust because they are not consistently observed across studies and due to methodological limitations in the underlying research. Nonetheless, studies of chronically exposed laboratory animals have demonstrated that DEE exposure causes airway inflammation and damages lung tissues—effects that are observed across multiple species tested and therefore can be expected to occur in humans, provided exposures are high enough. The Clean Air Task Force has indicated that exposure to DEE can lead to other chronic health effects (e.g., chronic bronchitis), but that assessment appears to be based on PM toxicity and not on specific evaluations of DEE toxicity.

**Links between *chronic* DEE exposure and *cancer* effects.** Extensive information has been published on links between DEE and cancer in humans. The publication dates for the major assessment reports are important to consider because confidence in the carcinogenicity assessments and calculations of cancer risks has increased over the years as more epidemiological studies find increased cancer risks among highly-exposed human occupational cohorts. The following list chronicles the different conclusions regarding DEE carcinogenicity over the years:

- In 2002, citing consistent findings across multiple epidemiological studies, EPA's health effects assessment concluded that DEE is "likely to be carcinogenic to humans by inhalation from environmental exposures." At the time, EPA did not select the more definitive "carcinogenic to humans" classification due to uncertainties in the weight of evidence for carcinogenicity. EPA also concluded that the studies' exposure data were not adequate for deriving inhalation cancer risk estimates. Without a published cancer unit risk factor, future EPA analyses—such as the agency's National-Scale Air Toxics Assessment—do not calculate cancer risks for DEE, despite the evidence for carcinogenicity.
- Since 2002, additional studies with less uncertain exposure estimates provided further evidence for carcinogenicity, culminating in a 2012 NIOSH study that evaluated cancer risks among a cohort of more than 12,000 workers occupationally exposed to diesel exhaust. The NIOSH study found statistically significant excess risk for developing lung cancer and esophageal cancer, with greatest risk among workers with highest exposures. By controlling for many confounding factors that contributed to the uncertainty documented in EPA's 2002 assessment, this study and others have led other authorities to develop quantitative cancer risk estimates for DEE.
- The more recent cancer classifications and risk estimates reflect the growing knowledge base for DEE carcinogenicity. For example, IARC's 2013 assessment classifies DEE as "carcinogenic to humans" (i.e., a "Group 1" carcinogen) based on sufficient evidence in humans (both for lung cancer and bladder cancer) and in laboratory animals. This classification is not surprising, given that DEE contains numerous individual substances that are also known carcinogens, such as arsenic, benzene, and certain polycyclic aromatic compounds.
- Based on the emerging state of the science, other entities have derived quantitative cancer risk estimates for DEE, and the recently estimated DEE cancer risks far outweigh the cancer risks for most other air toxics. According to California OEHHA, for example, DEE poses the greatest cancer risk to the population out of all air toxics—DEE accounts for approximately 70 percent of the estimated cancer risk among Californians that is attributable to outdoor air pollution. Similarly, the Clean Air Task Force (CATF) has estimated that the cancer risk attributable to

**Mecklenburg County residents have an estimated lifetime cancer risk associated with diesel engine exhaust exposure of approximately 1 in 7,000; this is the highest countywide risk level in all of North Carolina.**

DEE is 7.5 times greater than the cancer risk estimated for all other air toxics combined. According to a CATF online search tool, Mecklenburg County residents have an estimated lifetime cancer risk associated with DEE exposure of approximately 1 in 7,000; this is the highest countywide risk level in all of North Carolina.[11]

As with $PM_{2.5}$, elevated short-term and long-term exposures to DEE have been associated with both acute and chronic health effects. The likelihood of anyone developing these effects depends on actual pollution levels, exposure duration, and other factors. Publications have identified several subpopulations believed to be susceptible to DEE health effects, but these findings appear to be based on susceptibilities identified for $PM_{2.5}$ exposures. Susceptible subpopulations cited in the literature include people with respiratory diseases (e.g., asthma, chronic obstructive pulmonary disease), the elderly, and children.

Concerns have also been expressed about links between DEE and cancer, and elevated cancer risks have been calculated based on lifelong exposures to diesel exhaust. These cancer risk findings are based on theoretical calculations that infer cancer rates for lowly-exposed populations based on observations among highly-exposed cohorts. The calculations are based on well established risk assessment science, but the cancer risk estimates have inherent uncertainties and the exact number of cancer cases actually attributable to DEE exposure (and to most other risk factors, for that matter) is not known. Nonetheless, several recent publications indicate that the cancer risk attributed to DEE likely far outweighs the cancer risks associated with many other carcinogenic substances typically found in urban air.

## Health Effects of Black Carbon and Elemental Carbon

As noted previously, diesel exhaust includes fine particles that have a core of elemental carbon onto which many other chemicals adsorb. Elemental carbon (EC) refers to carbon that is not chemically bonded to other elements, like hydrogen or oxygen. EC is measured using thermal techniques. Black carbon is defined based on its light absorbing properties, and is typically measured using optical methods. EC and black carbon represent different components of fine particulate matter and diesel exhaust, but the values are often highly correlated and are typically used as indicators of DEE in PM samples.

While health effects caused by exposures to $PM_{2.5}$ and DEE have been studied extensively, the literature examining black carbon and EC toxicity is far more limited. Based on its 2012 health effects assessment, WHO has concluded that black carbon "may not be a major directly toxic component" of $PM_{2.5}$. However, WHO notes that black carbon may still be an important health concern due to both the presence of toxic chemicals adsorbed to its surface (e.g., black carbon acts as a carrier of these other toxic chemicals from ambient air into the lung) and the fact that black carbon is a component of $PM_{2.5}$, which is known to cause adverse health effects. The distinction is a subtle one: black carbon pollution levels have been associated with certain adverse health effects, but the studies do not demonstrate that black carbon exposure (as opposed to exposures to other substances found in $PM_{2.5}$) *caused* the observed effects.

Reviews of recent studies provide further perspective on this issue. For example, a 2013 publication documents a study that found associations between black carbon exposure levels and subtle neurotoxic effects in children.[12] However, the authors considered black carbon as "a marker of traffic-related particles from gasoline-and especially diesel-powered motor vehicles" and did not attribute the observed attention deficits specifically to black carbon toxicity. Similarly, a recent study observed associations between black carbon exposure levels and changes in blood pressure, but the authors again explained that black carbon was selected as a metric of "traffic pollution."[13]

Information on the inherent toxicity of black carbon is

[11] http://www.catf.us/diesel/dieselhealth/. Accessed March 2014.

[12] YM Chiu, DC Bellinger, BA Coull, S Anderson, R Barber, RO Wright, and RJ Wright. "Associations between Traffic-Related Black Carbon Exposure and Attention in a Prospective Birth Cohort of Urban Children." Environmental Health Perspectives 121(7):859-864. 2013.

[13] EH Wilker, A Baccarelli, H Suh, P Vokonas, RO Wright, and J Schwartz. "Black Carbon Exposures, Blood Pressure, and Interactions with Single Nucleotide Polymorphisms in MicroRNA Processing Genes." Environmental Health Perspectives 118:943-948. 2010.

extremely limited: exposure to black carbon—and the other chemicals whose concentrations correlate with black carbon levels—has been found to be associated with certain adverse health effects, but one cannot attribute the observed effects to any single component of diesel-related particulates.

## 4. Construction Activity Assessment

As a component of diesel pollution, black carbon is closely linked to construction activity. Because the CONNECT region is expected to experience significant population and economic growth in the next 40 years, the region is preparing for a major uptick in construction activity, over and above its "business as usual" activity. As part of this preparation and in recognition of the importance of black carbon emissions and anticipated increases, stakeholders across the region are seeking a better understanding of black carbon's impact and effective policies, programs, and strategies to mitigate it, especially those that focus on diesel pollution from the construction sector.

One of this project's primary objectives is to create a useful tool that can help municipal leaders and planners estimate black carbon and other criteria pollutant emissions generated by diesel construction equipment (DCE) operating at major construction projects. To develop such a tool, ERG followed a "bottom up" emissions inventory methodology, which offers two key benefits:

- Project-level activity data can be expanded upon or updated in the future to account for new/improved project information.
- The detailed equipment use profiles allow users to modify inputs to integrate alternative DCE fleet information and generate more precise, project-specific emissions estimates.

To integrate the information necessary to ultimately produce a DCE Emissions Assessment Tool, ERG prepared equipment use profiles, researched and collected activity surrogates, and calculated emission factors. Each of these components is described in detail below.


Equipment use profiles represent the expected range of DCE commonly used to perform a construction activity, including the expected DCE mix, engine horsepower, and annual operating hours by engine model year. ERG identified five common construction project types or "sectors" responsible for the substantial portion of DCE activity and produced equipment use profiles specifically for these sectors. ERG's selections were based on our previous nonroad emission inventory experience and the sectors' relevance to municipalities, planners, and local leaders responsible for managing the growth in the CONNECT region.[14] They include:

**Top Down or Bottom Up? Two Approaches to Compiling DCE Emissions Inventories**

A "top down" inventory uses highly aggregated information, such as total annual sales of nonroad diesel fuel for a given region, and associates it to the assumed equipment population in a given area to estimate equipment use total emissions.

A "bottom up" inventory attempts to account for all of the specific activities that use diesel equipment (e.g., road construction projects, housing developments, etc.), then quantifies the equipment, its horsepower, its hours in use, and other factors, which are summed up to calculate the total emission inventory for a specific area and analysis period (e.g., Mecklenburg County for 2014).

For information on the relative advantages and disadvantages of each approach, see Appendix D.

[14] These sectors do not account for 100 percent of all DCE use in a given region. For example, backhoes and excavators are used to some degree outside of the construction sector, in commercial landscaping and agricultural sectors, among others. Such activities were excluded from this analysis to focus resources on the sectors responsible for the greatest portion of DCE emissions.

1. **Road construction and maintenance.** This sector is further broken down into five subcategories:
   - New road construction - Projects involving road construction along a new route, or complete replacement of a previous roadway.
   - Bridgework - Projects primarily involving bridge construction or replacement.
   - Widening/turn lane additions - Projects widening existing roadways for safety purposes or to otherwise expand capacity.
   - Repair and maintenance - Projects involving resurfacing, rehabilitation, and basic maintenance such as sealing, etc.
   - Miscellaneous - Other projects involving significant amounts of heavy construction equipment (e.g., structures, grading for flood control, etc.). We excluded projects with low/minimal equipment use (e.g., signage work, guardrail repair, etc.)
2. **Utility work** - Projects involving major trenching for laying lines (sewer, water, electrical).
3. **Residential** - Projects involving construction of single family homes.
4. **Commercial** - Projects involving construction of commercial buildings including offices, retail facilities, and warehouses.
5. **Landfill activity** - Equipment use related to the day-to-day operation of municipal solid and construction waste landfills.

ERG prepared equipment use profiles for each of these sectors based on findings from prior studies the ERG completed in Texas.[15] Each profile is expressed in terms that correlate as closely as possible with actual engine work (and therefore emissions), while also allowing for each profile to "link up" directly with the available surrogate data. For example, in the Road Construction and Maintenance profile, the amount of equipment work required for new road construction projects is generally proportional to the total surface area of the new road. Further, the number of lane-miles[16] for new road projects (the surrogate data) is readily available in State Transportation Improvement Program (STIP) plans. Unfortunately, not all sectors are quite so straightforward. For example, the utility sector's equipment use corresponds most closely to trench excavation volume or at least linear feet of installation. However, surrogate data for utility work is often only available in terms of total project value ($), which is less closely correlated. The number of pieces of equipment and activity levels (hours of use per piece of equipment, per year) for each of the above sectors' equipment use profiles are summarized in Appendix B.


Activity surrogates, or surrogate data, are the amount of activity anticipated to occur within each construction sector. ERG collected construction activity surrogates for each sector from a variety of sources which are introduced below and supplemented by data tables presented in Appendix C.

## Sources for Heavy-Highway Construction and Maintenance Activity

ERG contacted the North and South Carolina Departments of Transportation (NC DOT and SC DOT) to obtain information regarding current and planned project work for the 2013 - 2018 timeframe. ERG received STIP data from the DOTs containing basic project descriptions, estimated start and end dates, project length (where applicable), and yearly construction budgets covering the 14-county region out to 2019 and beyond.

ERG screened the STIP data sets to eliminate projects that were not likely to require significant DCE use. This resulted in approximately 220 projects to assess further. By reviewing project descriptions and through consultation with DOT staff, ERG assigned each of the approximately 220 projects to one of the five Road Construction and Maintenance subcategories (i.e., new construction, bridgework, etc.). For multiyear projects that use lane-mile surrogates, ERG assumed that the lane-mile construction for a given year was proportional to the fraction of total construction expenditures for that year. For example, if a 20 lane-mile project was scheduled to expend 25 percent of its total construction budget in year one, then ERG assumed five lane-miles would be completed in that year. The NCDOT and SCDOT STIP project summaries are available in Appendix E, along with the associated surrogate values used in the tool (Appendix C).

[15] Studies were based on historical project records for the different sectors, characterizing emissions for DCE greater than 25 hp.

[16] Lane-miles = centerline miles x number of lanes.

## Sources for City/County Roadwork Activity

Roadwork projects performed by city and county agencies are not substantively different in terms of equipment requirements than work performed with DOT funding. However, the surrogate data sources are different for these projects. ERG separated city/county roadwork surrogates from the heavy-highway construction surrogates in the DCE Emissions Assessment Tool; however, both data sets are applied to the same roadwork equipment use profiles. After consulting with Centralina COG and other local agencies, ERG selected three primary data sources for city/county roadwork activity, including:

- County-level repair/maintenance budgets (Powell bill funding for NC, and "C" Program funding for SC)
- Capital Improvement Program (CIP) budgets for the City of Charlotte, NC
- Pennies for Progress projects for York County, SC

For Powell bill and C Program construction activity, ERG obtained county-level repair and maintenance budgets for fiscal year 2013 and then projected these budgets through 2018, assuming that funding levels would grow at the same rate as the county populations.[17] For York County, SC, ERG collected project descriptions, endpoint locations, dollar value, and project status (e.g., design, under construction) from the Pennies for Progress program website.[18] We then estimated project lengths using designated endpoints and Google Maps. Although precise project durations and start/end dates were not made available for these projects, ERG was informed that most of these projects last 12 to 24 months. In the absence of a detailed schedule, ERG assumed all construction work would last two full years and randomly assigned start dates for approved projects to dates in 2015 through 2017 (the end of the currently authorized spending cycle).

## Sources of Residential Construction Activity

ERG obtained the estimated number of single family dwelling units for each county in the CONNECT region for 2010 from Seven Hills Planning Group. These base year values, which are presented in Table 4-1, are the same baseline data used by other CONNECT Our Future technical assessments.

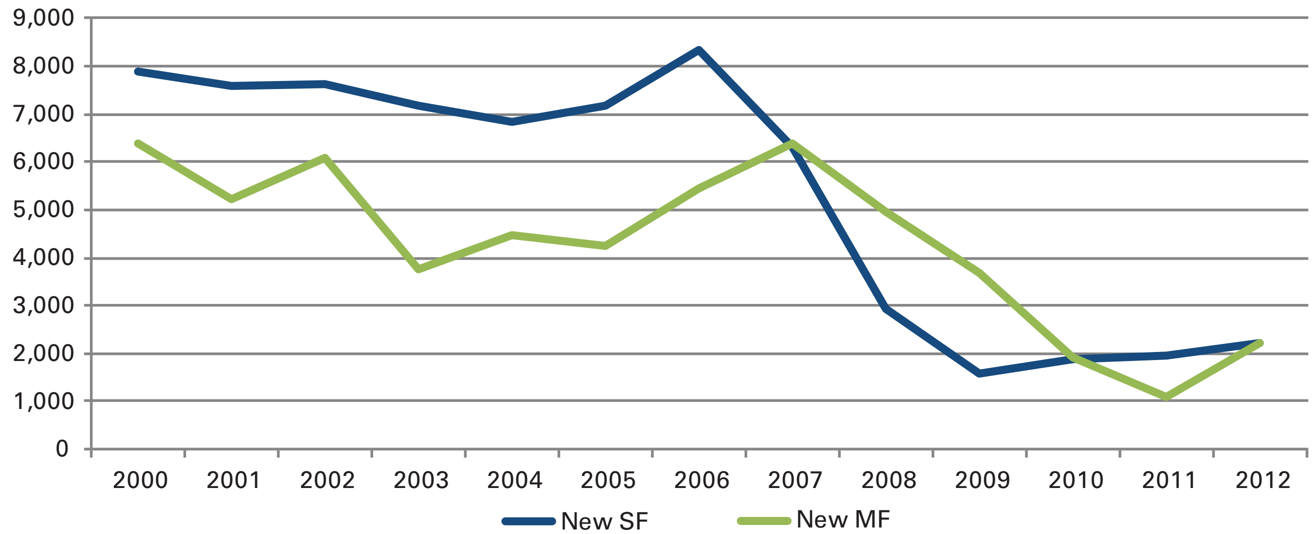
**Table 4-1. 2010 Base Year Single Family Dwelling Units by County**

| County | # of Units |
|---|---|
| **North Carolina** | |
| Anson | 2,629 |
| Cabarrus | 81,120 |
| Cleveland | 15,347 |
| Gaston | 32,593 |
| Iredell | 44,348 |
| Lincoln | 23,272 |
| Mecklenburg | 207,480 |
| Rowan | 17,400 |
| Stanly | 9,855 |
| Union | 60,863 |
| **South Carolina** | |
| Chester | 3,619 |
| Lancaster | 16,762 |
| Union | 911 |
| York | 61,506 |
| **Total** | **577,705** |

[17] http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/demog/countytotals_2010_2019.html; http://www.sccommunityprofiles.org/census/proj_c2010.php. Accessed March 2014.

[18] http://www.penniesforprogress.net/Projects. Accessed March 2014.

Figure 4-2. Mecklenburg Single-family (SF) vs. Multi-family (MF) Differential Growth Rates[19]




Staff from the City of Charlotte's Regional Modeling Section provided ERG with data indicating the differential construction rates for single and multi-family homes in Mecklenburg County (NC) from 2000 through 2012 (see Figure 4-1). The data show a relatively clear split between 2006 and 2007, indicating a distinct movement from single-family (SF) to multi-family (MF) dwellings in more recent years. Accordingly, ERG calculated the average percentage difference between new single and multi-family construction for these two time periods (14.2 percent) and used this differential to adjust the projected residential construction growth rate downward accordingly.

### Sources of Landfill Activity

Mecklenburg County compiled estimates for 2012 disposal tonnages for all permitted municipal solid waste and construction waste landfills operating in North Carolina (18 facilities total). Tonnage estimates for eight facilities in South Carolina were provided by the South Carolina Department of Health and Environmental Control (SCDHEC) for 2012 as well. Tonnage projections were also provided based on per capita disposal rates, from the associated Solid Waste Management Plans. However, since waste generated in one county is frequently disposed of in a different county, ERG estimated annual growth rates for disposal tonnage based on the region-wide census population growth rate of 1.5 percent per annum.

### Sources of Utility Construction Activity

ERG's utility category profile estimates equipment requirements for trenching that is associated with pipe laying projects. While some utility project work involves laying communications and electricity cables, the vast majority of work involves installation of water and sewer lines. To estimate the amount of utility project work for this study, ERG purchased forecast data from Reed Construction Data (Reed). Reed's data set contains dollar value information on civil projects expected to take place in the CONNECT region between 2013 and 2017.[20] Reed's "Other Civil" category includes the "Water and Sewer Piping" subcategory, as well as a variety of other project work that does not involve significant DCE use (e.g., fencing, electrical, machinery and supply purchases). ERG used the Reed data with detailed subcategory listings for Mecklenburg County to estimate the fraction of total "Other Civil" project valuation associated with the target "Water and Sewer Piping" category (44 percent). We then applied this fraction (44 percent) to Reed's projected "Other Civil" dollar values for all other counties in the CONNECT region to obtain the final surrogates for the utility category.

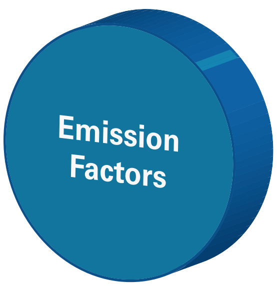
### Sources of Commercial Activity

ERG and CCOG attempted to locate aggregated surrogate data for commercial building construction in the CONNECT

[19] Mecklenburg County Tax Parcel Data

[20] Reed data projections do not extend beyond five years. Therefore ERG assumed civil project activity in 2018 would equal that projected for 2017 for the purposes of this analysis.

region. Building permit data was only available in highly disaggregate form, from the numerous permitting agencies in the region. In addition, data sources available for purchase (e.g., from Dodge-McGraw Hill Construction) could not be acquired within the project budget. However, ERG has included blank surrogate tables for commercial sector construction within the DCE Emissions Assessment Tool. This will allow users to input their own estimates (in thousands of square feet of commercial building installation) for any county and year combination and generate the DCE emissions estimates.



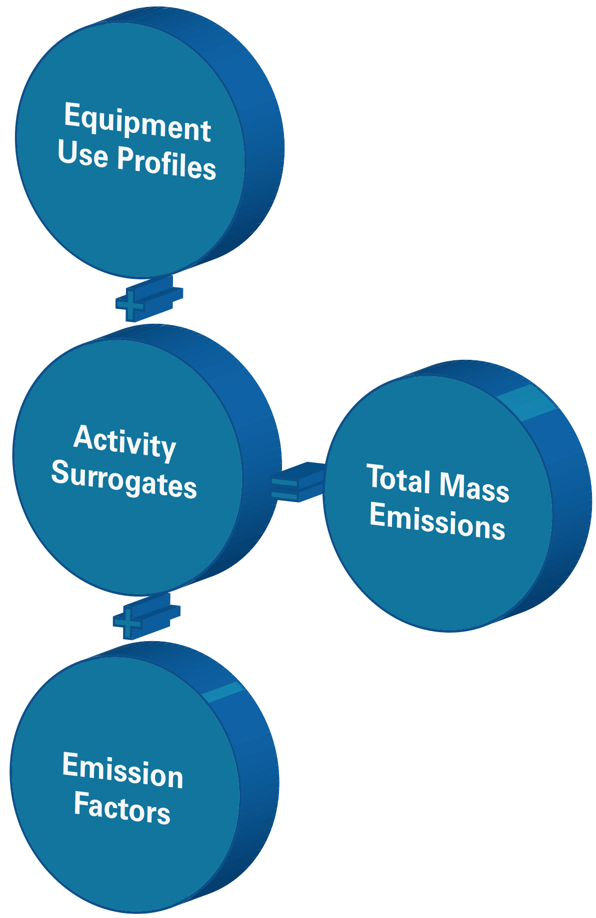

ERG obtained emission factors from EPA's NONROAD2008a model, which is the model most commonly used by professional mobile source modelers, such as state air quality officials and consultants, for estimating $PM_{2.5}$[21] $NO_x$, VOC, and other air pollutant inventories. NONROAD calculates emission factors based on engine horsepower, hours of use, and model year/emission standard for most nonroad equipment categories, including DCE. The model also allows the user to select from a range of past and future calendar years, accounting for the impacts of progressively tighter emission standards as well as engine deterioration over time.

To estimate the emission rates for DCE operating in the different activity sectors, ERG modified NONROAD's reference files to reflect the annual activity hours per year associated with each equipment type and construction sector (see Appendix B). ERG ran NONROAD for each sector and calendar year combination and divided the mass emissions (computed by NONROAD) by the estimated equipment counts. This calculation yielded emission factors expressed as tons of each pollutant produced per year, per piece of equipment, which ERG incorporated in the DCE Emissions Assessment Tool.

## DCE Emissions Assessment Tool

As introduced above, ERG developed the DCE Emissions Assessment Tool to estimate mass emissions for DCE

Figure 4-2. DCE Emissions Assessment Tool




operating in the 14-county CONNECT region between 2013 and 2018. The tool estimates emissions at the county (or project) level in tons per year for black carbon, $PM_{2.5}$, $NO_x$, VOC, and $CO_2$.

The tool uses lookup tables to combine the equipment use profiles, activity surrogates, and emission factors to calculate total mass emissions for each equipment type, sector, county, and calendar year (see Figure 4-2). Users can calculate DCE mass emissions for any county, activity sector, and calendar year included in this study. Users can rely on the default values in the tool to calculate "business as usual" emissions inventories or modify the tool with project-specific activity surrogates (e.g., number of lane-miles) and/or equipment use profile details (e.g., DCE working at a specific new road

[21] The NONROAD model does not estimate black carbon emissions. ERG applied a factor of 0.75 to all PM2.5 emissions from the model in order to estimate black carbon emissions for DCE, based on the speciation factor obtained from EPA's Report to Congress on Black Carbon. http://www.epa.gov/blackcarbon/2012report/fullreport.pdf.

construction project) when such project-specific inputs are available. The tool also allows the user to perform "what if" scenarios to estimate the impact of several emissions control options (see Section 6). A short User Guide will be provided with the final version of the DCE Emissions Assessment Tool that will help demonstrate tool input, functionality and outputs.

## DCE Emissions in the CONNECT Region

This section presents a subset of results calculated by ERG using the DCE Emissions Assessment Tool. The total mass emissions summarized in Figures 4-3 through 4-7 represent the cumulative annual emissions of each pollutant during the study's time horizon (2013 – 2018) using all the available activity surrogates which reflect construction activity across sectors and in all 14 counties.

Figure 4-3. Black Carbon Emissions from DCE (cumulative tons, all sectors, 2013 – 2018)

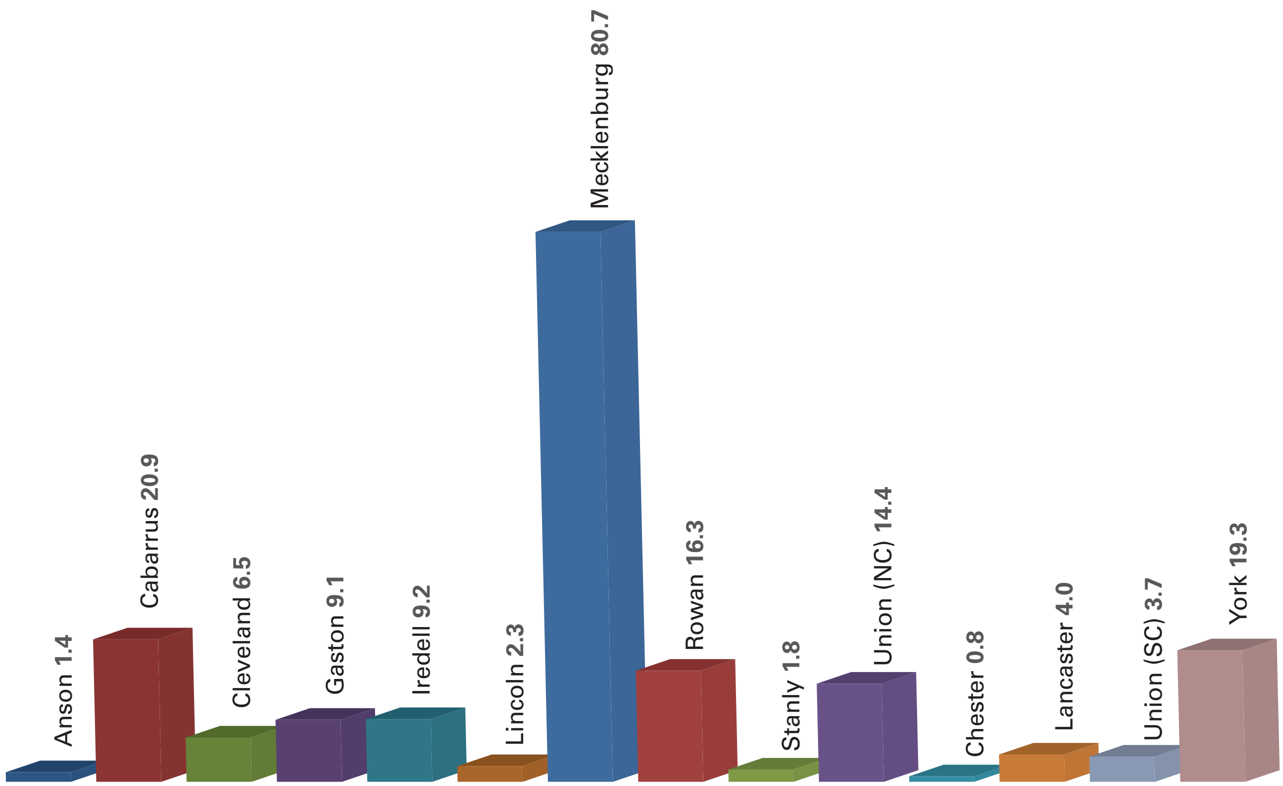


Figure 4-4. $PM_{2.5}$ Emissions from DCE (cumulative tons, all sectors, 2013 - 2018)

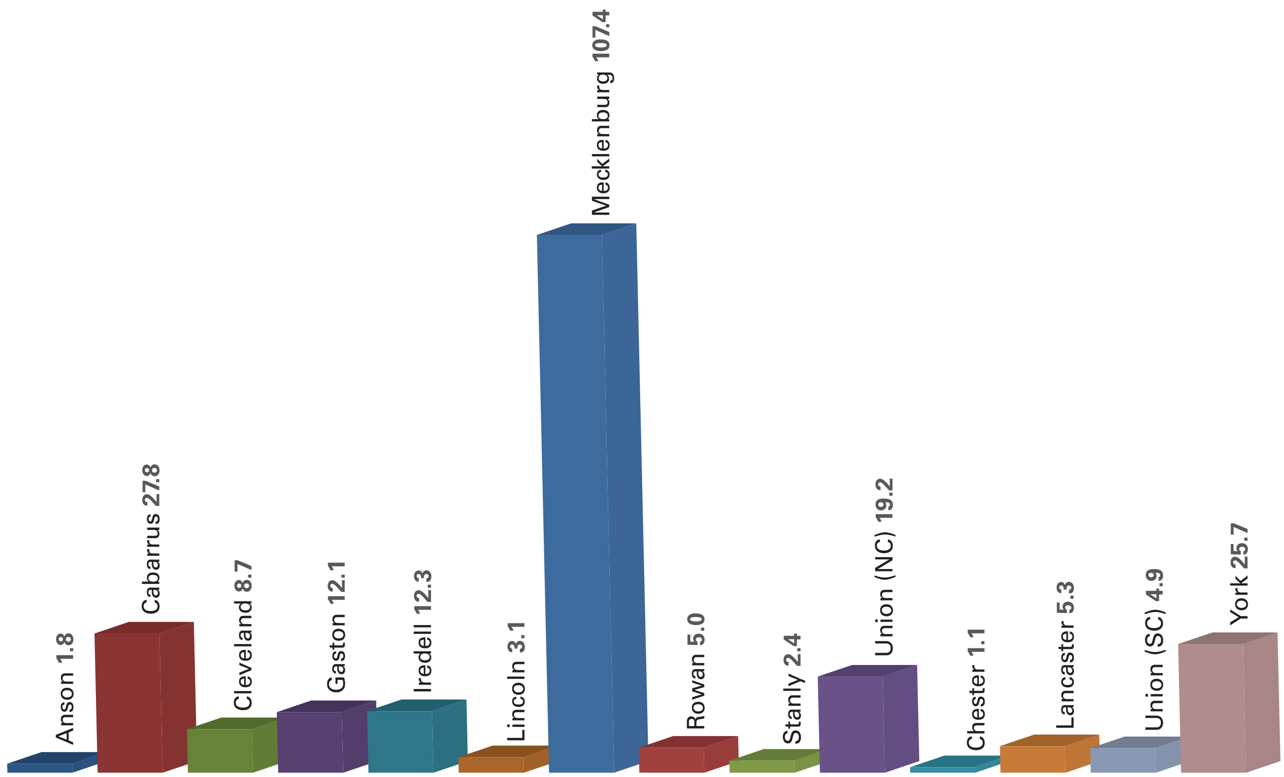



Figure 4-5. $CO_2$ Emissions from DCE (cumulative tons, all sectors, 2013 - 2018)

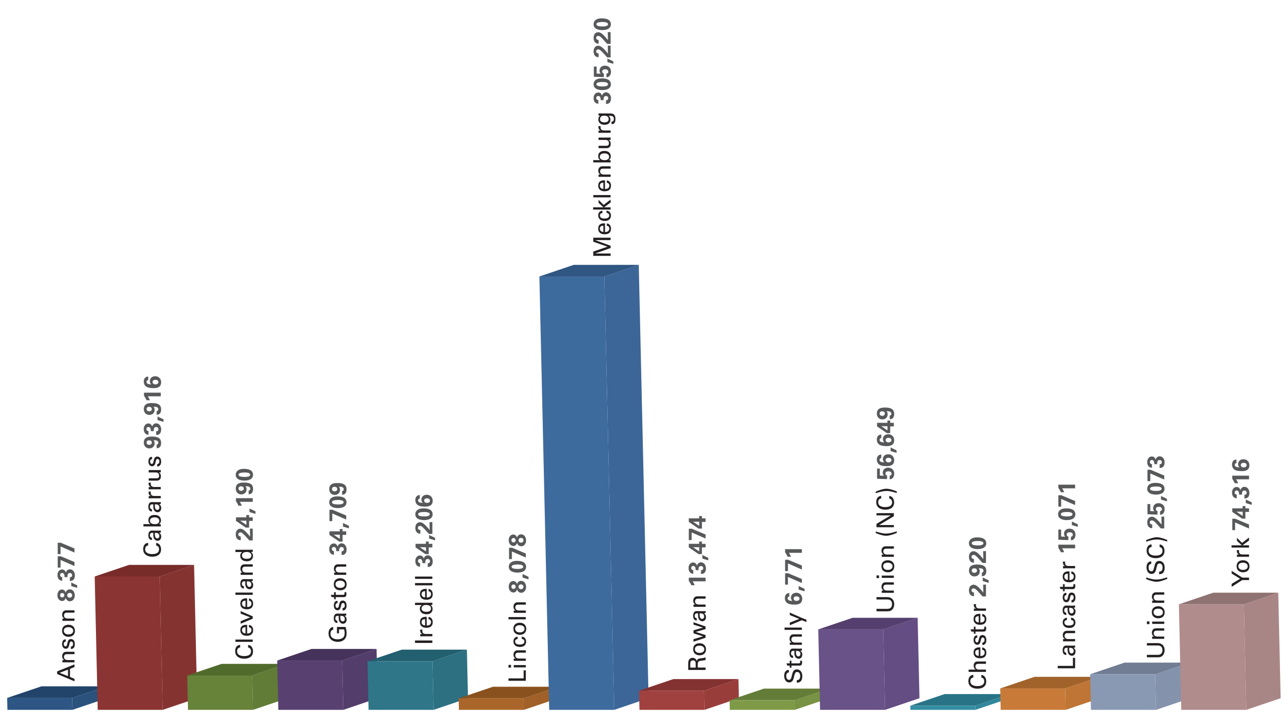


Figure 4-6. $NO_x$ Emissions from DCE (cumulative tons, all sectors, 2013 - 2018)

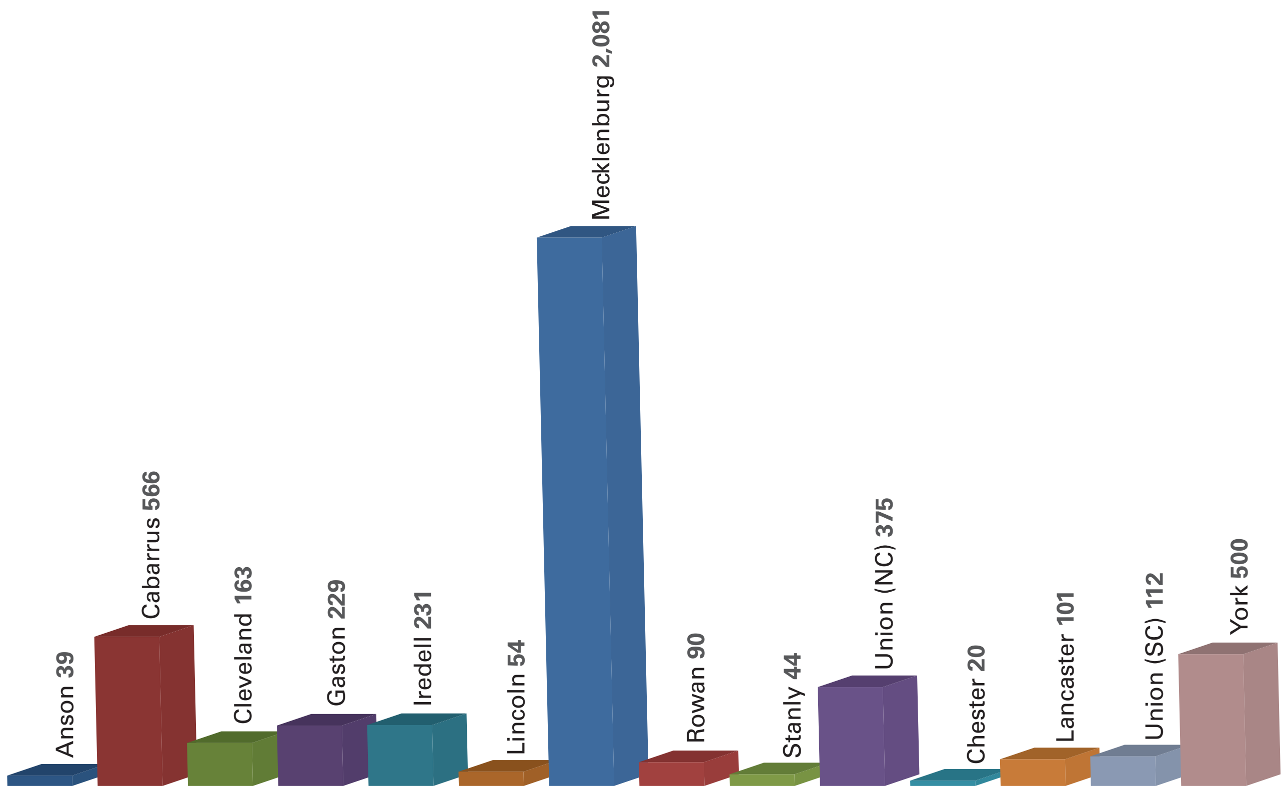
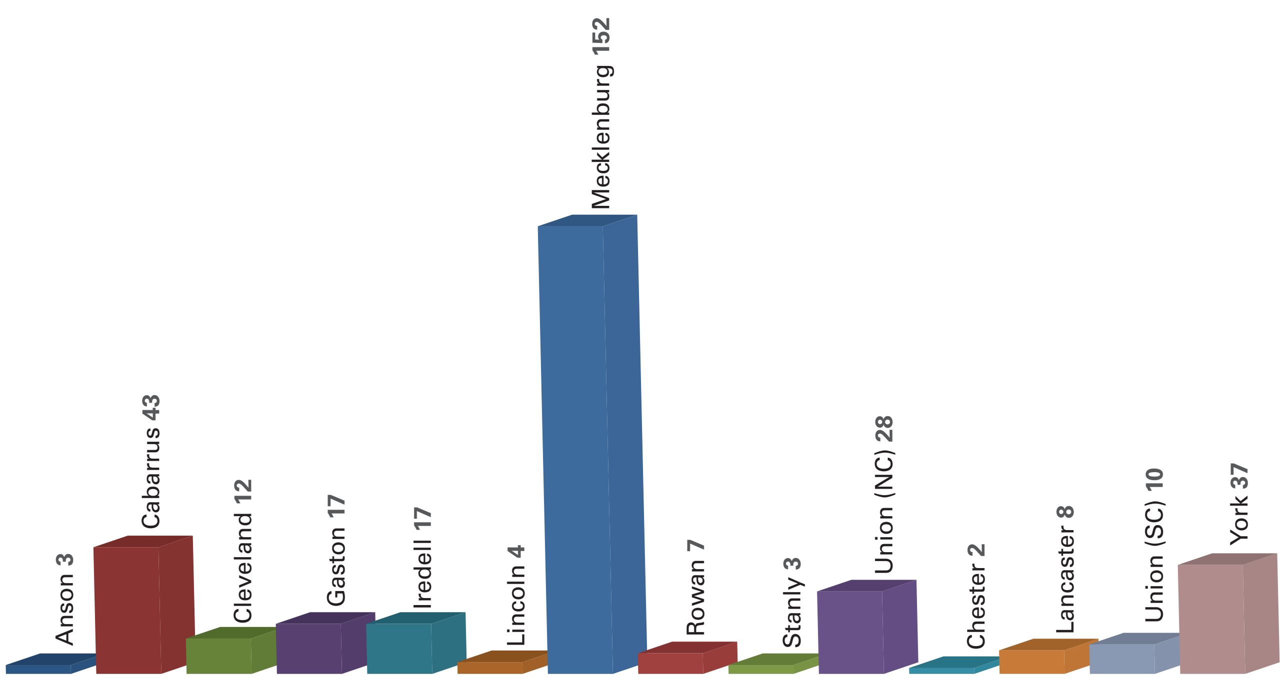



Figure 4-7. VOC Emissions from DCE (cumulative tons, all sectors, 2013 - 2018)



# 5. Mitigating Diesel Emissions

EPA defines and regulates PM, oxides of nitrogen ($NO_x$), ozone, lead, sulfur oxides, and carbon monoxide as primary or "criteria" pollutants. Because of federal regulations, state and local air quality agencies throughout the country monitor criteria pollutant concentrations. Regions with criteria pollutant levels that exceed the National Ambient Air Quality Standards (NAAQS) are described as being in "nonattainment" for those pollutants. Regions that are in nonattainment have three years to develop implementation plans outlining how they will attain and maintain the standards by reducing the criteria pollutant emissions. As noted above, all 14 counties within the CONNECT region are currently in attainment for PM. However, as of July 2014, Mecklenburg county, as well as portions of Cabarrus, Gaston, Iredell, Lincoln, Rowan, Union (NC), and York (SC) counties, all had nonattainment designations for ozone.

There are several ways to address and mitigate black carbon and criteria pollutant emissions from DCE. Regions with success in reducing DCE emissions often rely upon incentives or regulations to encourage or compel contractors to invest in cleaner DCE. Ideally, the public sector builds upon incentives and/or regulations aimed at the private sector and invests in repowers, retrofits, or accelerated retirement programs for its publicly owned DCE fleet. PM and $NO_x$ emissions control technologies are widely available and many have been evaluated and certified by EPA and/or the California Air Resources Board (CARB) for use with nonroad equipment. In addition, operational improvements and alternate fuel use can help lower emissions.

## Voluntary Measures and Incentives

Contractual incentives are a powerful tool for spurring action within the construction industry, but they should be carefully designed. Small businesses make up a large percentage of the construction industry, but they lack the capital to invest in new DCE.[22] Therefore, incentives that reward companies that use newer, cleaner DCE should be designed to help small businesses by providing them access to funding to offset costs of new equipment (see Section 7). Some incentive programs and voluntary measures in place today include:

- **Pilot Credit for Clean Construction.** Projects seeking to earn a LEED certification from the U.S. Green Building Council can earn a clean construction pilot credit by using clean DCE during the project's construction phase. More information can be found at http://www.epa.gov/cleandiesel/sector-programs/construct-overview.htm.[23]
- **Green Roads.** Operated by the Greenroads Foundation in Washington, the Green Roads Rating System allows roadway design and construction projects to earn recognition for demonstrating sustainability leadership and deploying clean construction technologies and practices. The program provides resources and incentives, such as earning the use of a designated logo, to participating projects. More information can be found at www.greenroads.us.
- **Clean Construction Contract Specifications.** The CONNECT Region's Air Quality and Climate Change work group's Clean Construction Toolkit contains sample clean construction contract specifications, which projects can voluntarily adhere to in order to deliver fewer emissions.
- **Best Practices for Clean Diesel Construction: Successful Implementation of Equipment Specifications to Minimize Diesel Pollution.** In addition to specifications, the Clean Construction Toolkit also contains this Best Practices document, which outlines how to improve communication and engagement by all parties associated with a construction project. The resource also provides sample checklists for the project owner/sponsor, construction manager, and contractor.

## Operations

There are operational practices that can deliver cleaner construction projects without the expense of investing in new technology. The challenge with these practices is that they require behavior changes. Fortunately, information, prompts, training, and other measures can help people learn how and why changing their behavior on the jobsite is important. Other operational measures simply require policy-type

[22] http://www.epa.gov/cleandiesel/documents/caaac-apr06.pdf. Accessed May 2014.

[23] http://www.epa.gov/cleandiesel/documents/caaac-apr06.pdf. Accessed May 2014.

changes that can be easily executed once decisions are made. A few of the more effective operational changes include:

- **Idle reduction.** Idling engines waste fuel and contribute to noise and air pollution at the worksite and beyond. Idling also damages engine performance and shortens engine life. Reducing the frequency and length of time that equipment idles unnecessarily can be an effective way to reduce emissions. Fleet managers can train and encourage equipment operators to shut down their engines rather than idling. However, idle reduction tends to yield only marginal emission reductions in the nonroad sector, including DCE, because the fraction of time nonroad engines run at idle speed is generally quite low. In contrast, idle reduction policies in the on-road sector (e.g., long haul tractor-trailers) where engines would otherwise idle for many hours every day, have produced significant emissions reductions and saved operators a great deal of fuel (visit the SmartWay Transport Partnership's website to learn more).
- **Preventive Maintenance.** A preventive maintenance program keeps engines operating at their original level of performance and includes inspection, detection, and correction of potential equipment failures. Routine maintenance can catch and repair engine and exhaust system problems before they lead to excessive pollution.
- **Operator Training.** Many construction companies train their DCE operators to safely and efficiently operate their heavy-duty equipment. Proper training can help reduce fuel consumption and therefore also reduce unnecessary emissions.

## Controlling Emissions with Retrofits

The most common and available diesel engine retrofit technologies include:

- **Diesel Particulate Filters (DPF) and Catalyzed DPFs.** DPFs physically trap PM and remove it from the exhaust stream. They can be installed on any equipment and are used with ultra-low sulfur diesel, which presented a barrier prior to implementation of more recent fuel standards. DPF's effectiveness at reducing emissions is determined by the equipment type, usage, and age and can result in a slight increase in fuel consumption, thus slightly increasing $CO_2$ emissions. Regeneration of the catalyst in Catalyzed DPFs (CDPFs) requires high exhaust temperatures, making CDPFs poor candidates for equipment that operates for long hours at low loads.
- **Diesel Oxidation Catalyst (DOC).** DOCs consist of a flow-through honeycomb structure that is coated with a precious metal catalyst and surrounded by a stainless steel housing. As hot diesel exhaust flows through the honeycomb (or substrate), the precious metal coating causes a catalytic reaction that breaks down the pollutants. Like DPFs, DOCs' effectiveness depends upon the type, usage, and age of the equipment on which they are installed.
- **Accelerated Retirement/Repower.** Older diesel vehicles or machines can be retired and replaced with newer, cleaner models, or older equipment can even be repowered by retrofitting the chassis with a newer diesel engine. In both cases, the original equipment or

**Table 5-1. Relative Emissions Impacts for Diesel Engine Retrofits*,[24]**

| Control Technology | Cost Range (per unit) | Control Effectiveness | | | | |
|---|---|---|---|---|---|---|
| | | VOC | CO | $NO_x$ | PM | $CO_2$ |
| DPF | $8,000-$50,000 | Decrease 60%-90% | Decrease 60%-90% | – | Decrease 90% | Increase 2%-4% |
| CDPF | | Decrease 20%-90% | Decrease 20%-90% | Decrease 0%-5% | Decrease 90% | Increase 1%-4% |
| DOC | $600-$4,000 | Decrease 20%-90% | Decrease 20%-90% | – | Decrease Up to 50% | Increase Up to 2% |
| Repower | Varies | | | | | |

** Percentage of decrease/increase presented where that information was available.*

[24] Cambridge Systematics, Inc. and Eastern Research Group, Inc. Evaluate the Interactions Between Transportation-Related Particulate Matter, Ozone, Air Toxics, Climate Change, and Other Air-Pollutant Control Strategies. NCHRP 25-25. AASHTO. 2010.

engine must be taken out of service and scrapped so it is not sold and placed in service elsewhere. Replacing or repowering older equipment is a highly effective mitigation strategy that completely removes older diesel engines from service. However, capital costs for purchasing new equipment and installing new engines varies considerably and can be quite high. Programs that couple strong financial incentives in areas with much older fleets may have the greatest success.

### Alternative Fuels

Alternative fuels may also achieve emissions reductions; however some fuels, while lowering emissions for some pollutants, increase emissions for others. For example, using compressed natural gas (CNG) lowers VOC, $NO_x$, PM, and CO emissions, but can increase methane emissions. One of the most well-known alternative fuels is biodiesel. Biodiesel is produced from animal fats, soybean oil, and cooking oils and then mixed with petroleum diesel. Using biodiesel lowers VOC, CO, PM, and toxic emissions, but may increase $NO_x$ emissions. The potential for increased $NO_x$ emissions increases with the biodiesel blend percentage. Biodiesel blends consisting of up to 20 percent biodiesel may be used without significant engine or fuel system modifications.

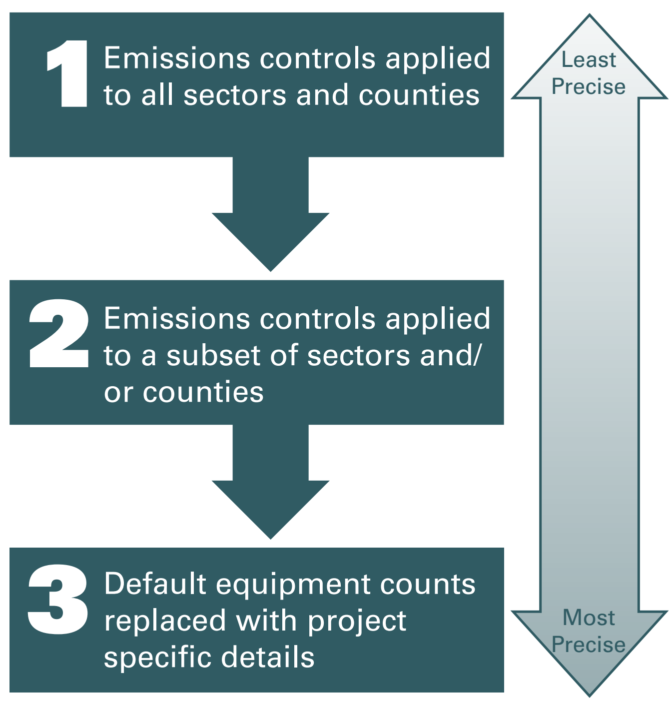
The following section (Section 6) describes how the DCE Emissions Assessment Tool can be used to assess the relative impact of employing these different emissions controls on DCE operating at major construction projects in the CONNECT region.

## 6. What Could Emissions Controls Achieve in the CONNECT Region?

The DCE Emissions Assessment Tool is able to broadly assess the relative effectiveness of several emissions control options, including the use of alternative fuels, retrofits, and accelerated retirement/repower/rebuild programs. These emissions control options first introduced in Section 5 and explained further below were selected by the work group for evaluation because they are generally effective at reducing black carbon emissions, can be applicable to the nonroad sector, and because several of the control options have been used by work group members to address air pollution within the CONNECT region.

The DCE Emissions Assessment Tool can assess control effectiveness in three ways. First, the user can apply any of the control measures below to all construction activity sectors across all 14 counties for a given calendar year. This analysis yields the broadest, most general assessment of an emissions control strategy. Second, the user can apply any of the control measures below to a subset of construction sectors and/or subset of counties in the CONNECT region by simply changing selections (checkboxes) on the Scenario Selection input screen. Finally, if the user has a detailed inventory of the DCE in use at a specific project site, the tool's default equipment counts can be replaced by entering new values in the appropriate sector worksheet (e.g., for assessing a new highway construction project, the user would modify equipment counts on the "Highway-New Construction" worksheet). Since these changes will most accurately reflect the project-specific equipment use profile, the tool will generate the most precise evaluation (see Figure 6-1).

Figure 6-1. Evaluating Scenarios with the DCE Emissions Assessment Tool




[25] Ibid

The following section describes how the DCE Emissions Assessment Tool applies each emission control option in an evaluation, the emissions reduction factors used in the tool, and presents several theoretical emission control scenarios that demonstrate sample results.

**Biodiesel.** The DCE Emissions Assessment Tool allows the user to specify both a biodiesel blend level (between 0 and 100 percent) as well as an anticipated penetration rate (i.e., the percentage of the DCE fleet that will use biodiesel during project work). The tool applies the emission reductions for B20 and B100[26] as described in Table 6-1. Positive numbers indicate an increase in emissions when compared to standard diesel use. Net $CO_2$ emissions are assumed to decrease by the biodiesel blend percentage (i.e., biodiesel is assumed to be carbon-neutral).[27]

**CNG.** ERG ran the NONROAD model to estimate per engine emissions for PM, $NO_x$, and VOC for comparable CNG and diesel units.[28] The resulting emission reductions for CNG are presented in Table 6-1. ERG also estimated $CO_2$ reductions associated with replacement of diesel engines with CNG units based on the relative gram per gallon values of the two fuels, and the different fuel consumption rates for these engines.[29] Since many types of construction equipment are not available in CNG models, it is reasonable to expect a relatively low penetration rate for this control option.

**PM Retrofits.** PM and black carbon emissions from DCE can be significantly reduced with diesel DPF and DOC retrofits. ERG obtained estimates for DPF and DOC effectiveness from EPA[30] and, as with the other control strategies, ERG assumed that black carbon reductions will be proportional to overall PM reductions. Nonroad diesel equipment meeting Tier 3 and later emission standards already use some form of PM exhaust control technology so the tool assumes that DPF and DOC retrofits will only be applied to pre-Tier 3 engines (approximately pre-2006 model year DCE).[31] In addition, these retrofit technologies are not applicable to all DCE. For example, low horsepower equipment and equipment with significant idling may not achieve the necessary exhaust temperatures to allow the retrofits to work efficiently. Therefore it is reasonable to expect the penetration rates to be significantly below 100 percent for these strategies.

**Accelerated Retirement/Repower/Rebuild.** Although the process and costs are very different, retiring an old diesel engine and replacing it with a new engine has

**Table 6-1. Summary of Emissions Control Effectiveness in the DCE Emissions Assessment Tool**

| Pollutant | Percent Change in Emissions for Each Control Strategy | | | | |
|---|---|---|---|---|---|
| | Biodiesel (B20)* | Biodiesel (B100)* | CNG | DPF | DOC |
| PM/Black carbon change [32] | -12.0% | -47.2% | -93.3% | -90.0% | -20.0% |
| $NO_x$ change | 2.0% | 10.3% | -35.8% | 0.0% | 0.0% |
| VOC change | -20.1% | -67.4% | -71.7% | -20.0% | -20.0% |
| $CO_2$ change | -20.0% | -100.0% | -13.4% | 2.0%** | 0.0% |

**Biodiesel/diesel blend. For example, B20 is 20 percent biodiesel and 80 percent diesel.*

[26] See http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

[27] The DCE Emissions Assessment Tool does not account for minor efficiency penalties associated with using biodiesel compared to petroleum diesel.

[28] NONROAD's "other construction equipment" category, 175 hp bin.

[29] 10,180 g/gal $CO_2$ for diesel vs. 8,053 g/gal for CNG (US EPA SmartWay); 0.371 gal/hp-hr fuel consumption for diesel vs. 0.406 gal/hp-hr for CNG (EPA NONROAD model).

[30] http://www.epa.gov/cleandiesel/documents/420r07005.pdf

[31] Since more and more pre-Tier 3 engines are retired each year and are replaced with new, cleaner engines, retrofit strategies are applicable to a smaller and smaller proportion of the DCE fleet each year.

[32] EPA's report did not include the change in black carbon emissions. Therefore ERG assumed a 1:1 correlation between percent changes in PM and black carbon.

the same emission benefits as repowering or rebuilding the old engine to meet new emission standards. The DCE Emissions Assessment Tool allows the user to model the emission reductions associated with effectively replacing on old engine with a brand new engine, with the user specifying the model year prior to which the engine is replaced (any model year between 1995 and 2013).

In the following scenarios, each emission reduction factor from Table 6-1 is multiplied by the penetration factor specified by the user and then multiplied by the baseline emissions estimates. This calculation yields the emissions reductions achieved by each control strategy in a single year. Reductions of each pollutant are presented in tons per year. ERG used the 2014 activity surrogates from all activity sectors and all counties for the hypothetical scenarios in Table 6-2. Note that Table 6-2 does not include a hypothetical scenario for an accelerated retirement/repower/rebuild program. The very high implementation costs for this type of scenario make a high-level, region-wide evaluation impractical. However,

**Table 6-2. Hypothetical Emissions Reductions Achieved Through Five Scenarios**

| Pollutant Reduced (Increased) | Scenarios* | | | | |
|---|---|---|---|---|---|
| | B20 50% penetration | B100 10% penetration | CNG 20% penetration | DPF 50% penetration | DOC 50% penetration |
| Black carbon (tons) | 2.1 | 1.7 | 6.6 | 9.1 | 2.0 |
| $PM_{2.5}$ (tons) | 2.8 | 2.2 | 8.7 | 12.0 | 2.7 |
| $NO_x$ (tons) | (8.5) | (8.9) | 62.0 | - | - |
| VOC (tons) | 6.4 | 4.3 | 9.2 | 3.0 | 3.0 |
| $CO_2$ (tons) | 11,895.6 | 11,895.6 | 3,195.9 | (374.6) | - |

**Calendar year 2014 surrogates for all sectors and all counties.*

the DCE Emissions Assessment Tool can be used to evaluate the impact of a county or project-level program.

To illustrate the potential impact of each control strategy, Figures 6-2, 6-3, and 6-4 compare total base case (uncontrolled) emissions of black carbon, $PM_{2.5}$, and $NO_x$ respectively, to the total emissions produced in each of the control scenarios. These figures show that among the retrofit and alternative fuel options described in this study, DPFs are the most effective option for reducing black carbon and $PM_{2.5}$ emissions.

## Figure 6-2. Tons of Black Carbon Emitted (per year)

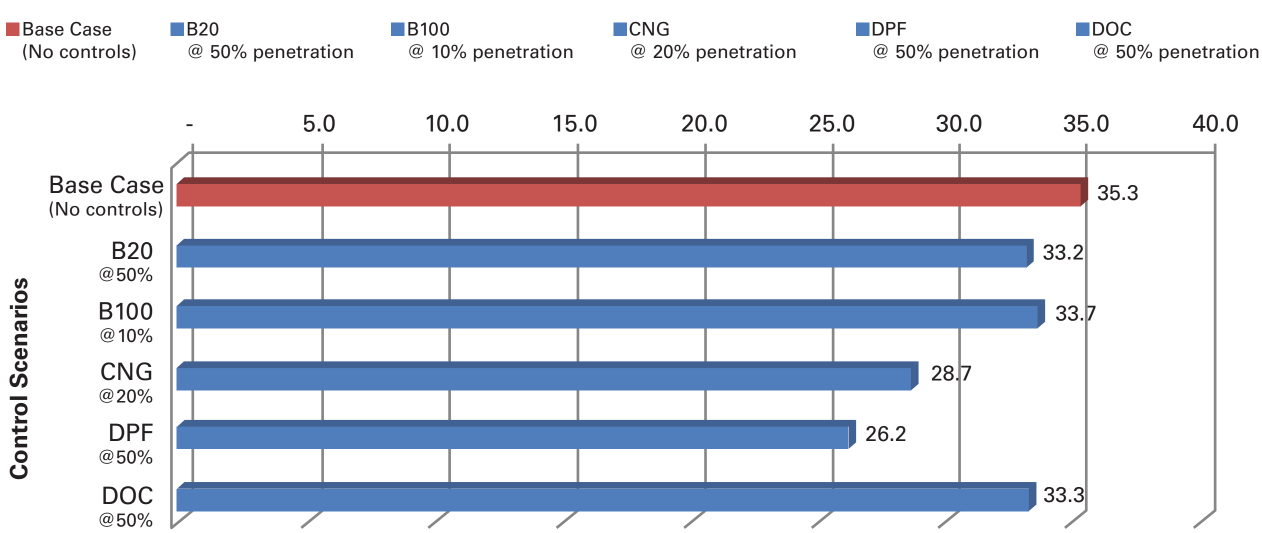


Figure 6-3. Tons of $NO_x$ Emitted (per year)

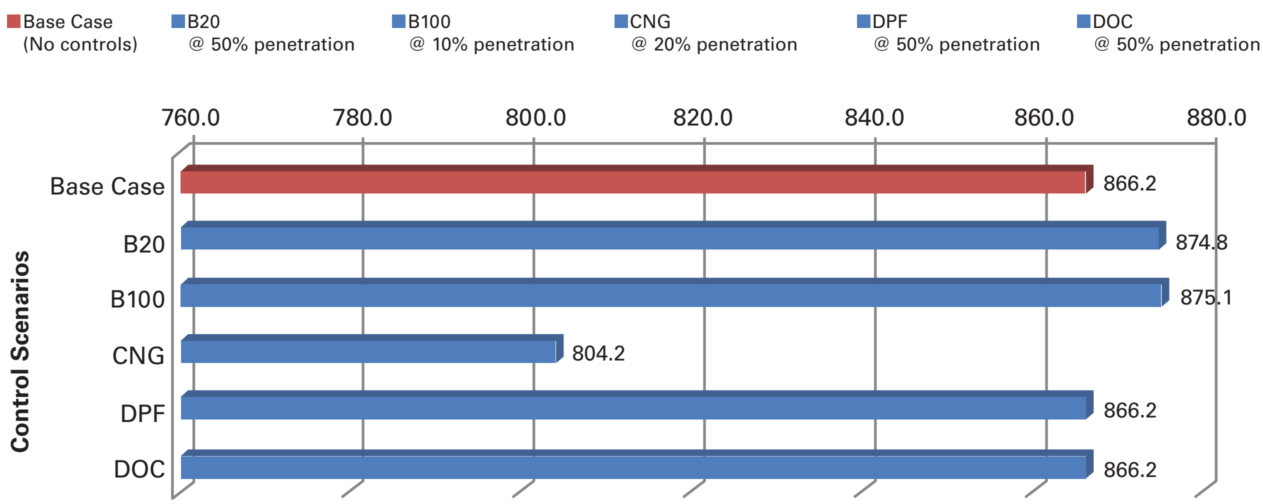
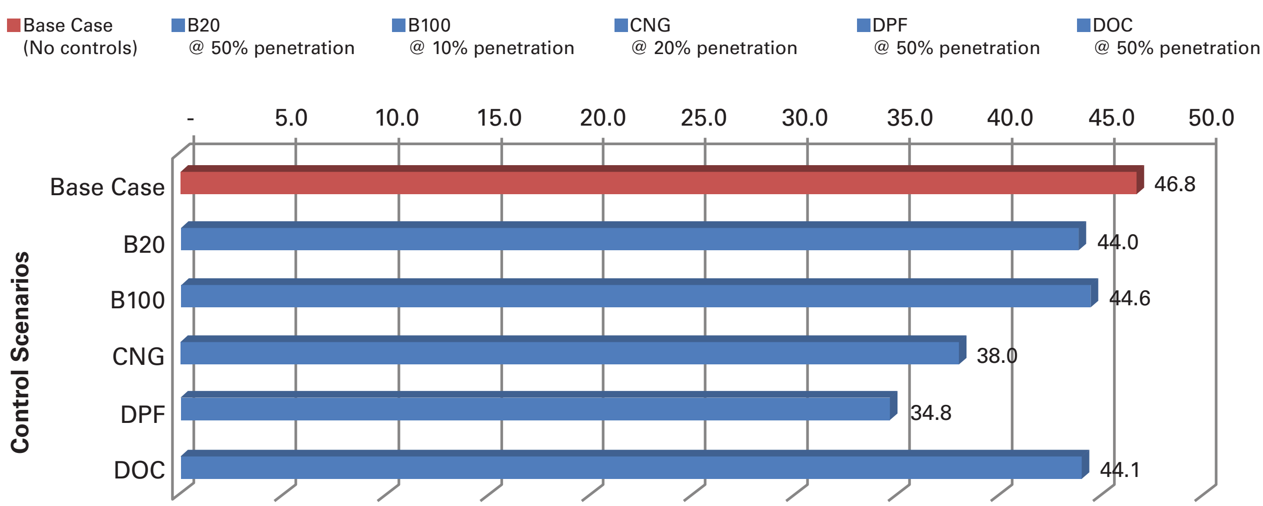



Figure 6-4. Tons of $PM_{2.5}$ Emitted (per year)



# 7. Funding Opportunities

Mitigating emissions of PM, black carbon, $NO_x$, and other air pollutants produced by construction equipment can represent a significant capital investment for private and public fleet owners. DCE retrofit, repower, and accelerated retirement programs generally require fleet managers to pay an upfront cost for implementation. The following section introduces several well established funding opportunities that have already proven effective at helping offset these costs both locally in North and South Carolina as well as nationwide.

## National Clean Diesel Campaign

EPA's National Clean Diesel Campaign (NCDC) promotes a range of clean air strategies by collaborating with stakeholders to voluntarily reduce diesel emissions. NCDC includes sector-specific funding programs that are focused on reducing diesel emissions from freight transportation (The SmartWay Transport Partnership), school buses (Clean School Bus USA), and the construction sector, among others. NCDC is primarily funded through the Diesel Emissions Reduction Act (DERA)[33] program of EPAct. It was expanded with appropriations from the American Recovery and Reinvestment Recovery Act (ARRA). Together, DERA and ARRA funds have been used to clean up both private and public sector diesel equipment and have saved hundreds of millions of gallons of fuel and reduced tons of mobile source emissions. According to EPA's *Second Report to Congress on DERA*, DERA and ARRA have provided for nearly 60,000 diesel vehicles being retrofitted, replaced, repowered, or equipped with idling reduction technologies.

With $800,000 in 2011 DERA funds, Mecklenburg County helped repower or replace 126 pieces of diesel cargo handling equipment used at Charlotte Douglas International Airport with cleaner diesel or electric equipment.

In 2013, EPA announced a Construction Equipment Funding Opportunity to reduce diesel emissions from existing fleets of nonroad construction equipment that operate in areas with poor air quality. Roadmark Corporation, a highway construction company based in Durham, NC, was selected to receive funding assistance for engine replacements or retrofits.

EPA established four complementary funding programs to allocate DERA resources. The following two have been used to mitigate nonroad sector diesel emissions:

- The **National Clean Diesel Funding Assistance Program** offers grant funding for projects that implement EPA- or Air Resources Board (ARB)-verified and certified diesel emission reduction technologies.
- The **State Clean Diesel Grant Program** allocates funds to participating states to implement their own grant and loan programs for clean diesel projects.

Most recently, EPA announced a $5.67 million funding opportunity for the 2014 State Clean Diesel Program[34] (applications were due June 6, 2014) and a $9 million funding opportunity for the 2014 National Clean Diesel Funding Assistance Program[35] (applications were due June 17, 2014). In 2014, for the first time EPA issued a standalone Tribal Competition request for proposals[36] backed by DERA funding of up to $1 million. This targeted funding opportunity is in response to feedback from Tribal communities and was announced on June 5, 2014, with applications due by August 14, 2014. More information about NCDC and each of its funding programs can be found at: www.epa.gov/cleandiesel.

## Congestion Mitigation and Air Quality Improvement Program

The Congestion Mitigation and Air Quality Improvement (CMAQ) program is administered by the Federal Highway

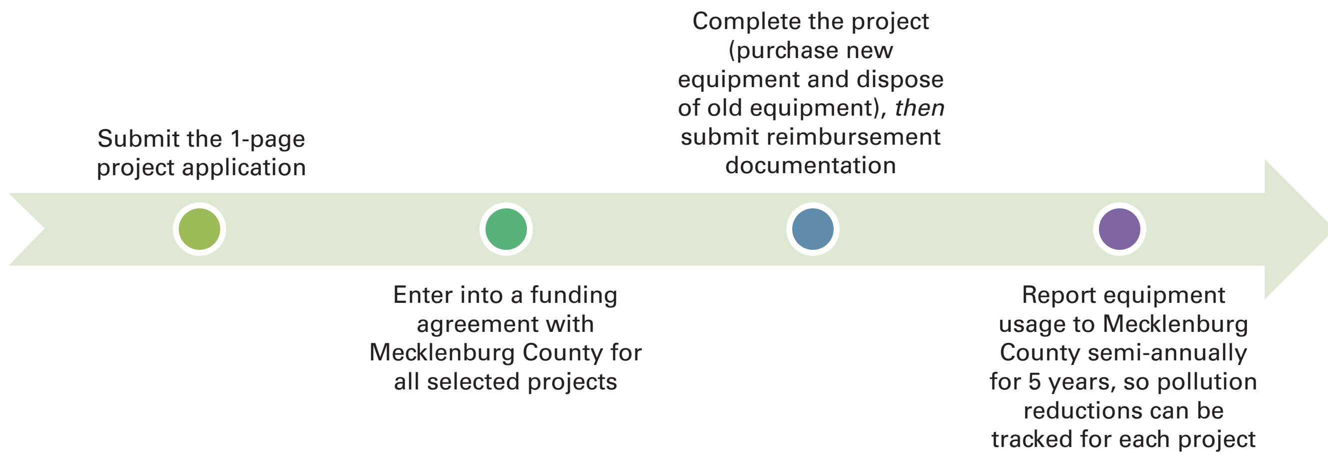
[33] DERA was created under the Energy Policy Act of 2005 (EPAct), Title VII, Subtitle G (Sections 791 to 797).

[34] http://www.epa.gov/cleandiesel/prgstate.htm

[35] http://www.epa.gov/cleandiesel/prgnational.htm

[36] http://www.epa.gov/cleandiesel/prgtribal.htm

Figure 7-1. How GRADE Works




Administration and the Federal Transit Administration. CMAQ provides funding to state departments of transportation (DOTs); State DOTs distribute funds to metropolitan planning organizations (MPOs) and transit agencies for surface transportation and other related projects that improve air quality and reduce congestion. CMAQ funding is largely reserved for areas that do not meet the air quality standards for one or more criteria pollutant, as well as maintenance areas that were previously in nonattainment.

In 2012, CMAQ was reauthorized under legislation titled *Moving Ahead for Progress in the 21st Century Act*, or more commonly referred to as MAP-21. Like earlier iterations of this legislation, MAP-21 gives priority to eligible entities in nonattainment regions. However, three considerations are worth specific mention for their relevance to black carbon:

- MAP-21 requires that states with designated nonattainment or maintenance areas $PM_{2.5}$ use a portion of their CMAQ funds for projects to specifically reduce black carbon.
- MAP-21 emphasizes diesel engine retrofits and other efforts that prioritize reducing $PM_{2.5}$.
- States without nonattainment or maintenance areas still receive a minimum amount of CMAQ funding to be used either for air quality projects or other elements of flexible spending.

More information on CMAQ can be found at: www.fhwa.dot.gov/environment/air_quality/cmaq/.

## Grants to Replace Aging Diesel Engines

GRADE, or Grants to Replace Aging Diesel Engines, is a regional air quality program administered by Mecklenburg County, Division of Air Quality. GRADE provides grants that help diesel equipment owners purchase newer, cleaner, less-polluting equipment or engines. GRADE emphasizes reducing emissions of $NO_x$, a precursor to ground-level ozone pollution. Ground-level ozone is a pollutant of concern throughout much of the CONNECT region. GRADE has focused on different categories of diesel equipment, depending on funding cycles, but the program's approach has stayed consistent: helping offset the capital costs of replacing or repowering aging nonroad diesel equipment.

Since 2007, the GRADE program has completed 233 projects and reduced more than 314 tons of $NO_x$. More information about GRADE is available at www.GRADEplus.net and several program materials are also included in the Clean Construction Toolkit.

## Mobile Source/NC Diesel Emission Reduction Grants

In 2009, North Carolina Department of Environment and Natural Resources (NC DENR), Division of Air Quality received ARRA funding and subsequently awarded $1.1 million in NC Diesel Emissions-Economic Recovery (DEER) grants primarily for diesel engine retrofits, repowers, and buying down the cost of biodiesel. NC DENR may have funds available again in fall 2014. More information can be found at: http://daq.state.nc.us/motor/ms_grants/.

# 8. Costs and Opportunities of Clean Diesel Programs

Implementing clean diesel programs that reduce PM, black carbon, $NO_x$, and other harmful emissions will incur economic costs and deliver benefits to projects, construction contractors, diesel retrofit equipment manufacturers, equipment service providers, the region and state, and possibly health care facilities and the housing market. It is beyond the scope of this study to precisely quantify this wide range of economic costs and benefits. However, with knowledge of the cost of technologies and their market penetration, we can project some economic considerations that are especially relevant to CONNECT Our Future's planning objectives.

## How much does it cost to reduce PM and $NO_x$?

Different technologies reduce PM and $NO_x$ at different costs, so there is a large range of price points for reducing these pollutants. In 2007, EPA's Office of Transportation and Air Quality issued its evaluation of the cost effectiveness—or the cost per ton of emissions reduced—of retrofitting heavy-duty nonroad diesel equipment with DOCs and DPFs as well as with selective catalytic reduction (SCR) systems and engine upgrade kits for $NO_x$ reduction. EPA's study found that:[37]

- Standard DOCs and DPFs can reduce PM for $18,700 to $87,600 per ton.
- Selective catalytic reduction systems and engine upgrade kits can reduce $NO_x$ for $1,900 to $19,000 per ton.

Diesel reduction technologies and strategies that target on-road vehicles deliver PM and $NO_x$ emissions reductions for a cost comparable to the nonroad sector. For comparison, EPA's study reports the following cost effectiveness findings:[38]

- PM retrofits for school busses and class 6-8b trucks range from $11,100 to $69,900 per ton of PM reduced.
- Inspection and maintenance programs reduce $NO_x$ for $2,100 to $6,800 per ton.
- Vanpool programs reduce $NO_x$ for $6,100 to $104,200 per ton.

EPA also estimated the cost-effectiveness of the Nonroad Tier 4 emissions standard to be $11,200 per ton of PM reduced and $1,000 per ton of $NO_x$ reduced. For comparison, EPA calculated the cost-effectiveness of the 2007 Heavy-Duty Highway (on-road) emission standard to be $14,200 per ton of PM reduced and $2,100 per ton of $NO_x$ reduced.

It is important to note that another EPA study[39] warns decision-makers against making direct comparisons between the cost-effectiveness of reducing different pollutants, specifically PM and $NO_x$. The cost-effectiveness of reductions in these two pollutants is not comparable because the health effects, emissions inventories, and control options for the two pollutants are very different. For example, while reducing a ton of PM often costs more than reducing a ton of $NO_x$, the health effects of PM are greater (per ton) than for $NO_x$, so a little PM reduction may actually be more effective than a larger $NO_x$ reduction from a public health perspective.

## An Unexpected Cost of Reducing Diesel Emissions: Labor Shortages

While retrofit technologies and new federal standards for cleaner DCE are shown to be relatively cost-effective strategies for reducing diesel and black carbon emissions, they have introduced another possibly unexpected concern: an unmet need for more highly specialized and trained service and support. In the past, diesel engine mechanics were able to service diesel engines with little formal classroom training. However, today's heavy duty diesel equipment, which operates with sophisticated computer-operated systems (called ECMs), demands that technicians and mechanics complete specialized training before they are qualified to service and repair the newest engines. Dealerships that sell, lease, and service heavy duty

[37] EPA, 2007. "Diesel Retrofit Technology: An Analysis of the Cost-Effectiveness of Reducing Particulate Matter and Nitrogen Oxides Emissions from Heavy-Duty Nonroad Diesel Engines Through Retrofits." http://www.epa.gov/cleandiesel/documents/420r07005.pdf. Accessed 4/16/2014.

[38] EPA, 2007. "The Cost-Effectiveness of Heavy-Duty Diesel Retrofits and Other Mobile Source Emission Reduction Projects and Programs." http://www.epa.gov/cleandiesel/documents/420b07006.pdf. Accessed 4/16/2014.

[39] EPA, 2007. "The Cost-Effectiveness of Heavy-Duty Diesel Retrofits and Other Mobile Source Emission Reduction Projects and Programs." http://www.epa.gov/cleandiesel/documents/420b07006.pdf. Accessed 4/16/2014.

equipment have encountered a shortage of qualified service technicians and this shortage introduces a "hidden" cost of clean construction programs and broad deployment of retrofit technologies.

Notably, some equipment dealers in the CONNECT region have struggled to find job candidates with the training necessary to properly service and repair "Tier 4" engines, exhaust systems, and other advanced technologies used in today's DCE equipment.[40,41,42] Additionally, these employers are finding that the existing workforce of service technicians is aging, which suggests that a shortage of service technicians could be intensified unless more students enroll in and complete training programs.

Several dealers in the CONNECT region have responded to this challenge by partnering with local community colleges to offer both certificate and degree education programs. By forming these partnerships, the community college programs can offer students real world, hands-on training at the equipment manufacturer's facilities.[43,44,45] Several programs currently serving the CONNECT region are described in the following sections.

## Green Jobs and the Construction Industry

In the CONNECT region, as with the nation at large, newer and cleaner DCE is becoming a source of "green" jobs.[46,47] EPA's increasingly protective emissions requirements and growing public awareness about the hazards of diesel pollution are spurring demand for more sustainable construction practices and equipment. Among private sector industries, construction had the largest employment rate increase in "green goods and services" jobs, increasing from seven to almost nine percentage points between 2010 and 2011.[48] The CONNECT region could also see an increase in green manufacturing jobs. If demand for retrofit technologies grows, investment in manufacturing of the components for these retrofit technologies could draw additional business—and jobs—to the CONNECT region.[49]

This trend is expected to continue nationally, with growth driven by federal attention on the nation's aging infrastructure and electricity delivery systems, and in the CONNECT region where demand for new roads, utility service, homes, and office buildings matches the upward trend in population growth.

### Top 5 States With Jobs in the Emissions Control Manufacturing Industry (2009)

1. Texas
2. Michigan
3. New York
4. New Jersey
5. North Carolina

[40] Joe Thornton, employee development manager at Carolina Tractor. Presentation at the March 19, 2014, CONNECT Air Quality/Climate Change Working Group Meeting at the Carolina Tractor facility in Statesville, NC.

[41] Wernle, Bradford. 2012. High Demand for Diesel Techs. *Automotive News*, November 5. http://www.autonews.com/article/20121105/RETAIL07/311059989/high-demand-for-diesel-techs. Accessed 3/19/14.

[42] Nohr, Emily. 2013. Omaha Company Invests in Training Diesel Mechanics to Combat Shortage. *Omaha World Herald*, August 21. http://www.omaha.com/apps/pbcs.dll/article?AID=2013130829826. Accessed 3/19/14.

[43] Central Piedmont Community College. 2014. Carolina CAT Service Technician Program. http://www.cpcc.edu/transport_systems/cat-program-1. Accessed 3/17/14.

[44] Blanchard CAT. 2014. Think Big Program Details. http://www.blanchardmachinery.com/Company/Careers/Student-Recruitment/Think-Big-Program-Details.aspx. Accessed 3/17/14.

[45] Wake Technical Community College. 2014. Diesel and Heavy Equipment Technology. http://www.waketech.edu/programs-courses/credit/diesel-and-heavy-equipment-technology. Accessed 3/19/14.

[46] Note that ERG did not include jobs for heavy duty equipment operators in this analysis because the qualifications and employment outlook for operators of newer, cleaner DCE is the same as for operators of older DCE.

[47] http://dieselcleanup.org/downloads/Jobs%20table.2.1.09.pdf. Accessed 5/8/2014.

[48] U.S. Department of Labor. (2013, March 19). Bureau of Labor Statistics News Release. Employment in Green Goods and Services: http://www.bls.gov/news.release/pdf/ggqcew.pdf. Accessed 3/16/2014

[49] http://dieselcleanup.org/jobs.html. Accessed 5/7/2014.

According to the BLS, "employment growth of mobile heavy equipment mechanics will be spurred by increased construction activity. Population and business growth will result in the construction of more houses, office buildings, roads, bridges, and other structures."

The Bureau of Labor Statistics (BLS) Occupational Outlook Handbook projects a 9 percent growth rate from 2012 to 2022 for heavy vehicle and mobile equipment service technicians as well as diesel service technicians and mechanics, a rate that is comparable to that of all U.S. employment. In addition, the job outlook noted that "those with certificates from vocational schools or two-year degrees from community colleges should have very good job opportunities, as employers strongly prefer these candidates." In contrast, the Handbook also reports that "those without formal training will have difficulty finding jobs."[50]

## Where are the Training Opportunities?

As noted previously, clean diesel equipment and technologies are driving demand for trained service technicians. To meet this demand in the CONNECT region, service technicians are receiving specialized training through programs that are the result of public/private partnerships between manufacturers and institutions of higher education. For example, Central Piedmont Community College (CPCC) and Florence-Darlington Technical College (FDTC) now operate programs in concert with some of CAT's North and South Carolina dealership network. These and other service technician training programs within or close to the CONNECT region are discussed below.

***CPCC/Carolina CAT***: Since 2010, Carolina CAT has partnered with CPCC's Heavy Equipment and Transport Technology (HEATT) program to offer the Carolina CAT Service Technician Program.[51] This program's curriculum incorporates 40 weeks of a full-time course load that is completed in the classroom at CPCC's campus. Classroom study is followed by a two-month, 40-hour per week unpaid internship. Students gain real world work experience at CAT facilities by completing the internship.

The Carolina CAT Service Technician Program is designed to produce graduates with the knowledge and skills to work as technicians on medium and heavy-duty diesel powered equipment, focused especially on equipment manufactured by CAT. CAT offers some scholarships to students accepted to the program and graduates of this program have successfully found work in the field. So far, the graduating classes have produced 10-15 students per year, and Carolina CAT has hired about 90 percent of these students.[39]

*2012 Graduates of CPCC's Carolina CAT Service Technician Program*

***ThinkBIG at FDTC***: Three CAT dealerships in North Carolina and South Carolina—Blanchard Machinery, Carolina Tractor, and Gregory Poole—all partner with FDTC to offer the CAT's "Think-Big" program.[52] During the first year of the program, students take classes over five, eight-week sessions at FDTC with technical instruction in diesel engines, hydraulic systems, fuel systems, electrical systems, and other highly relevant topics. Concurrently,

[50] Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2014-15 Edition, Heavy Vehicle and Mobile Equipment Service Technicians. http://www.bls.gov/ooh/installation-maintenance-and-repair/heavy-vehicle-and-mobile-equipment-service-technicians.htm. Accessed 4/16/ 2014.

[51] Central Piedmont Community College. 2014. Carolina CAT Service Technician Program. http://www.cpcc.edu/transport_systems/cat-program-1. Accessed 3/17/14.

[52] Blanchard CAT. 2014. Think Big Program Details. http://www.blanchardmachinery.com/Company/Careers/Student-Recruitment/Think-Big-Program-Details.aspx. Accessed 3/17/14.

students also work as a paid intern at one of Blanchard's 14 locations. Through classroom and on-the-job experience, students learn how to repair tractors, trucks, graders, excavators, and many other machines in the CAT line-up, and the training involves working with the latest diagnostic tools, current machines, and components. After completing the two-year program, graduates receive an Associate of Applied Science degree and work as entry level technicians with Blanchard for the following three years.[53] This program is accredited by the Association of Equipment Distributors (AED) and approximately 10 students each year have been readily hired from this program.

> "[ThinkBIG] graduates also learn how to make these massive machines run as cleanly as possible. Stricter emissions standards for heavy equipment...means new systems will come online and incentive grants will encourage machinery owners to upgrade their older equipment to new national standards."

***Wake Tech Community College/John Deere***: R.W. Moore Equipment Company (Raleigh, NC), Van Lott Inc. (Columbia, SC), and other John Deere equipment dealers in surrounding states sponsor students who wish to earn an Associates of Applied Science in Heavy Equipment and Transport Technology at Wake Tech Community College.[54] This program is located outside the CONNECT region but could be a useful recruiting spot for employers that operate within the region. Wake Tech's program is AED accredited and offers a general track in Heavy Equipment and Transport as well as a Construction and Forestry Equipment track for students who are sponsored by a John Deere dealer. These programs prepare students to repair, service, and maintain diesel engines. Instruction includes engines, hydraulics, electrical, electronic and power train systems, and other topics. Similar to CAT's programs, Co-Op opportunities are offered. Graduates are ready for entry-level employment opportunities at businesses that repair truck and construction equipment. Certificate and diploma programs are also available but are not sponsored by John Deere and do not involve internships at nearby dealers.

***Iredell-Statesville Schools Career Academy and Technical School (CATS)***: CATS is a vocational school that offers a new heavy equipment and diesel technology program for students who want to get a head start in the field.[55] Classroom instruction focuses on air brake systems, hydraulic systems, electrical systems, and diesel engines. The CATS heavy equipment curriculum is not comprehensive like those at CPCC and FDTC; rather it is offered to complement other general courses that are also required at the vocational school. However, these courses do give students an introduction to and better understanding of the field.

Training programs for operators of diesel construction equipment tend to be much shorter than those for service technicians. Also, operator training has limited correlation to the cleaner performance of newer or retrofitted construction equipment and most of this instruction is provided through on-the-job training. Some operator training programs, like one offered by John Deere University,[56] use web-based technologies and training methods. Another seemingly more comprehensive operator training program is a result of a partnership between Stanly Community College in Albemarle, NC, and Carolina CAT. This two semester program includes eight classes covering general job skills, specific operator skills, and equipment and simulator training for a variety of heavy construction equipment. The program helps prepare students for various equipment operator certifications.[57]

[53] Lyles, Samantha. 2011. A Hard Job is Good to Find: Diesel Mechanics. News and Press Online, August 3. http://newsandpressonline.com/story_0803Hardjob.htm. Accessed 3/19/14.

[54] Wake Technical Community College. 2014. Diesel and Heavy Equipment Technology. http://www.waketech.edu/programs-courses/credit/diesel-and-heavy-equipment-technology. Accessed 3/19/14.

[55] Iredell-Statesville Schools Career Academy and Technical School (CATS) Heavy Equipment and Diesel Technology Program. http://iss.schoolwires.com/Page/43427. Accessed 4/30/14.

[56] John Deere University. 2014. Instructor-Led Training for Operators. http://www.deere.com/wps/dcom/en_US/services_and_support/training_and_safety/instructor_led_training.page?. Accessed 3/17/14.

[57] Stanly Community College, 2014. Heavy Equipment Operations Program. http://www.stanly.edu/continuing-education/industrial-occupations/heavy-equipment-operations/624. Accessed 4/20/14.

# 9. Applying the Research

Well planned growth is paramount to the economic development of the CONNECT region. However, construction projects generate environmental impacts that potentially affect the health and wellbeing of people living and working nearby. To best balance the benefits and impacts of new construction projects, municipal leaders, planners, and the public need the right information, tools, and analysis to understand and take into account project-generated environmental and health impacts so that they can be modeled, mitigated, and possibly avoided.

In consultation with Centralina COG and air quality and climate change work group members, ERG developed the following framework to help municipal leaders and land use planners assess new construction projects. The framework focuses on four key considerations:

- Estimated diesel exhaust emissions for a given project
- Baseline air quality for the project vicinity
- Proximity of the project to sensitive populations
- Proximity of the project to environmental justice communities

Municipal leaders and planners can use these four considerations to determine which construction projects are of greatest concern for their potential to impact the environment and human health. The framework generates a simple project score, which is illustrated and described in more detail at the end of this section. Although the scoring system cannot be used to determine if adverse health impacts will occur or to specify which effects might be observed, it can be used to rank various projects on a relative scale and identify the best candidates for emissions reduction strategies or further study. A more detailed discussion of each consideration is presented below, followed by application to two sample construction projects selected by the work group.

## Total Estimated Emissions Profile of a Project

Every new construction project will generate emissions from diesel engines. The emissions will include black carbon, PM, nitrogen oxides, and other pollutants. Project site emissions will be carried by prevailing winds and impact air quality in the immediate vicinity and in the region. Construction site workers, nearby residents, and passersby in surrounding areas may be exposed to the various pollutants released into the air. By using the DCE Emissions Assessment Tool it is now possible to quantify these emissions.

Two factors should be considered when evaluating the significance of a project's diesel particulate emissions:

1. Municipal leaders or planners are encouraged to compare estimates of a project's annual or cumulative $PM_{2.5}$ emissions to countywide estimates from all diesel sources combined, which are provided by the National Emissions Inventory and listed in Table 9-1. This comparison gives some sense of the relative magnitude of a given project in the context of other local sources—an issue that the following section discusses in further detail.

2. The project's emissions provide an indicator of diesel exhaust air quality impacts, which ultimately determine human exposures to diesel pollution and the likelihood of adverse health effects occurring. Predicting offsite air quality impacts is a complicated task because every project differs in terms of intensity, duration, proximity to residents, and many other factors important to a complete public health evaluation. Nonetheless, screening models can provide some insights into the magnitude of emissions that might warrant further evaluation. For instance, ERG conducted a dispersion modeling analysis for a hypothetical project source[58], and that analysis indicates:

- For projects with DCE operating at ground level, the greatest air quality impacts will occur at the project boundaries. The modeling shows that the first 100 meters

[58] The modeling analysis estimated air quality impacts from a ground-level source, for which diesel emissions were assumed to occur over an area of 100 meters by 100 meters. Modeling was conducted using AERSCREEN—an EPA recommended screening model. Inputs were based on recommended values for summertime conditions in urban settings (e.g., for albedo, surface roughness) and standard default assumptions (e.g., for temperature, minimum wind speed). Air quality impacts were predicted at regular intervals from the site boundary to locations 5 miles downwind from the source.

from the project boundaries will have demonstrably higher impacts than those observed further downwind—a finding consistent with the scientific literature on near-roadway air quality monitoring[59].

- For the scenario considered in the hypothetical project, modeled air quality impacts at 100 meters from the project boundary decrease by roughly an order of magnitude over the next ¼ mile from the site boundary and they decrease by roughly a factor of 50 at locations approximately one mile from the site boundary. These observations form the basis of spatial analyses considered later in this section—namely, that selected scorecard evaluations should focus on populations living within ¼ mile of a project.
- Based on the modeling results, projects with estimated emissions greater than 1.5 tons of $PM_{2.5}$ per year should rank highest in terms of concerns over potential health effects.[60] This finding is based on the estimated air quality impacts for such projects and published health benchmarks for diesel exhaust PM. This cutoff is only used for purposes of ranking projects and setting priorities. One should not infer that projects with emissions greater than 1.5 tons per year will necessarily cause health effects among neighboring communities. Rather, such projects would be good candidates for diesel emissions controls or closer examination of public health impacts (e.g., via health impacts assessments).

## Baseline Health Risks from Outdoor Air Quality

Air quality varies across the CONNECT region. Some areas have relatively cleaner air in comparison to others. The picture becomes quickly nuanced when considering emissions associated with diesel engines. While the region meets federal air quality standards established for PM, it fails to meet federal air quality standards for ozone. Cancer risks, which correlate to air quality, are also high in some areas, and relatively lower in others. When planning a new construction project, one consideration is thus the background levels of air quality for the project site. If the air quality is relatively good, then the project will not place an undue health and environmental burden on a population already exposed to poor air quality and thus higher cancer risks. If the air quality is relatively poor, then the project would be a strong candidate for diesel emission mitigation and other measures.

Information on baseline health risks from outdoor air quality in the CONNECT region were gleaned from an EPA nationwide modeling study, the National-scale Air Toxics Assessment (NATA). Two key findings from NATA are used in the scoring system presented later in this section:

- **Estimated cancer risks from all air toxics.** The map in Figure 9-1 shows how estimated cancer risks attributed to air toxics vary from one location to the next in the CONNECT region. The map displays estimated cancer risks resulting from exposures to dozens of known or suspected carcinogens found in the air. However, diesel exhaust is not reflected in the cancer risk maps due to limitations in the quantification methodologies employed by EPA at the time. Consistent with expectations, the map shows highest estimated cancer risks near the most densely populated areas and industrial areas.
- **Estimated non-cancer hazard from diesel particulate emissions.** In addition to presenting cancer risks, outdoor air pollution can cause various health effects other than cancer. These include respiratory effects, developmental effects, neurological problems, and damage to the immune system (see Section 3 for a complete discussion of known health effects). Whether health effects occur depends on the amount and composition of air pollution at a given location. The map in Figure 9-2 shows the areas within the CONNECT region where diesel exhaust is believed to pose the greatest non-cancer health risks. As one would expect, risk is greatest for the most densely populated areas and locations in close proximity to major thoroughfares.

[59] http://www.epa.gov/ttnamti1/files/2009conference/4_Baldauf.pdf. Accessed March 2014.

[60] No guidance is available for establishing cutoffs to rank diesel emissions from construction projects. This evaluation used a 1 in 10,000 estimated cancer risk at locations 1/2-mile from site boundaries to determine the cutoff (1.5 tons per year) to use in the scoring system. Calculations were based on the modeling results and the diesel exhaust cancer unit risk factor published by California's Office of Environmental Health Hazard Assessment. The proposed cutoff is based on modeling of a hypothetical source and should be viewed as a general indicator of projects to evaluate more closely. The cutoff should not be used to infer actual health risks, which are best derived from other forms of study (e.g., risk assessments based on actual site conditions, health impact assessments to study changes in key indicators related to important public health outcomes).

## Proximity of Construction Projects to Sensitive Populations

Construction projects, specifically the air pollution that they generate, affect different people in different ways. In general, those with respiratory conditions like asthma, young people (whose respiratory systems are still developing), and the elderly are more susceptible to health effects from airborne particulate matter than healthy adults. As a result, these groups are often referred to as "sensitive populations" in risk assessments, health impact assessments, and other studies that evaluate the public health significance of environmental contamination.

In the context of this assessment, the closer a construction project is to daycare centers, elementary and high schools, after school activity facilities and camps, hospitals, senior living facilities, nursing homes, and the like, the stronger candidate it would be for diesel emissions mitigation technologies and policies, further health study, or even replanning. As one example of an evaluation of sensitive populations, the maps in Figures 9-3a and 9-3b show where schools and day care centers are located in proximity to the Interstate 485 extension construction project and the Carolina Ridge residential development project. Section 9.5 presents a scoring system for considering the locations and numbers of sensitive populations when evaluating the significance of construction projects.

Note that other data sources for sensitive populations were also considered for the scoring system but ultimately rejected for various reasons. As one example, data sources were accessed that presented spatially resolved indicators of asthma conditions (e.g., emergency department visits with a primary diagnosis of asthma and hospital discharges with a primary diagnosis of asthma). However, the finest spatial resolution offered by these data sources was at the county level, which is too coarse for assessing localized impacts from construction projects.

## Proximity of Construction Projects to Environmental Justice Communities

The federal government and most state government agencies acknowledge that some communities—known as environmental justice (EJ) communities—bear a disproportionately high human health and environmental burden in comparison to others. These communities are often home to minority, tribal, low-income, and otherwise underserved and overburdened Americans who have been denied full and fair participation in the decisions that affect their communities. Accordingly, municipal leaders and planners are encouraged to consider whether new construction projects are in or near (within one mile) an EJ community. If yes, the project is a good candidate for mitigation and other measures to ensure that the project's environmental and health impacts neither pose an additional burden on the community nor an obstacle to economic growth.

For the CONNECT region specifically, EJ communities are indicated in green in the map shown in Figure 9-4. These locations were determined based on two criteria recommended by HUD, and they represent approximately 10 percent of the overall population in the CONNECT region. The first HUD criterion is that a given area's median gross income must be less than 60 percent of the median gross income for the broader geographic area. The second criterion is that a given area must have an "appreciably higher" minority population than the broader geographic area. For purposes of this analysis, a Census tract had to contain at least 50 percent minorities to meet the second criterion.

## Proposed Project Scoring System

To help municipal leaders and planners establish priorities for construction projects, ERG developed a scoring system that ranks projects based on the various indicators identified earlier in this section. The scoring system was based on a review of all relevant data sources specific to the CONNECT region. The system, which offers just one possible method for determining which projects are of greatest interest from a public health perspective, is meant to rank projects on a relative scale. A relative scale means that scores can be compared across projects to determine priorities, but the score itself should not be viewed as a metric for whether project-related health impacts will occur. Additional options for priority projects may include requirements for emission controls, further evaluation of health impacts (e.g., through a health impact assessment), ambient air monitoring to quantify air quality impacts, and so on.

Table 9-2 presents the complete scoring system, in which most factors are assigned a numerical ranking between 1 and 4. However, greater weight is given to the magnitude of diesel emissions because this factor has the greatest bearing on $PM_{2.5}$ exposure levels, which is arguably the strongest indicator for potential health effects. The table also applies the scoring system to a sample highway project (the Interstate 485 extension) and a sample residential project (the Carolina Ridge development). As Table 9-2 shows, the composite score for the Interstate 485 project (14) is considerably higher than the score for the Carolina Ridge project (5). This difference suggests that the Interstate 485 project would be a higher priority site from a public health perspective—a potentially useful insight for municipal leaders and planners, who often times must make difficult decisions when deciding which, if any, projects are the best candidates for emission controls and/or further study.

Municipal leaders and planners are encouraged to use the DCE Emissions Assessment Tool and scoring system developed for this project to examine environmental implications from a much wider range of construction projects, such that they can determine which subset of these projects are best candidates for emissions controls, more detailed health evaluations, and other potential follow-up activity.

**Table 9-1. Total Estimated Annual $PM_{2.5}$ Emissions from All Diesel Sources in the CONNECT Region**

| County | $PM_{2.5}$ Emissions From All Diesel Sources (tons/year) |
|---|---|
| **North Carolina** | |
| Anson | 20 |
| Cabarrus | 116 |
| Cleveland | 60 |
| Gaston | 117 |
| Iredell | 136 |
| Lincoln | 49 |
| Mecklenburg | 724 |
| Rowan | 95 |
| Stanly | 34 |
| Union | 152 |
| **South Carolina** | |
| Chester | 38 |
| Lancaster | 50 |
| Union | 19 |
| York | 206 |

**Emissions data are from EPA's 2011 National Emissions Inventory—a nationwide compilation of emissions data for different sources.*[60]

[60] http://www.epa.gov/ttnchie1/net/2011inventory.html. Accessed April 2014.

**Table 9-2. Proposed Scoring System for Evaluating the Public Health Significance of Construction Projects**

| Factor | Scoring Scale | Sample Highway Project (I-485 extension) | Sample Residential Project (Carolina Ridge) |
|---|---|---|---|
| Project-specific $PM_{2.5}$ emissions from diesel construction equipment (2014) | • Greater than 1.5 tons per year (Score = 8)<br>• Between 1 and 1.5 tons per year (Score = 6)<br>• Between .75 and 1 tons per year (Score = 4)<br>• Between .25 and .75 tons per year (Score = 2)<br>• Less than .25 ton per year (Score = 0) | 6 | 2 |
| Baseline cancer health risks from outdoor air quality, averaged over area within ¼ mile of site boundary | • Cancer risk greater than 70 in 1,000,000 (Score = 4)<br>• Cancer risk between 60 and 70 in 1,000,000 (Score = 3)<br>• Cancer risk between 50 and 60 in 1,000,000 (Score = 2)<br>• Cancer risk between 40 and 50 in 1,000,000 (Score = 1)<br>• Cancer risk less than 40 in 1,000,000 (Score = 0) | 2 | 1 |
| Baseline non-cancer hazard from other diesel emissions sources, averaged over area within ¼ mile of site boundary | • Hazard index greater than 0.125 (Score = 4)<br>• Hazard index between 0.075 and 0.125 (Score = 3)<br>• Hazard index between 0.050 and 0.075 (Score = 2)<br>• Hazard index between 0.025 and 0.050 (Score = 1)<br>• Hazard index less than 0.025 (Score = 0) | 3 | 1 |
| Proximity of project site to sensitive popula-tions | • More than five sensitive populations are located within ¼ mile of the site boundary (Score = 4)<br>• Between two and five sensitive populations are located within ¼ mile of the site boundary (Score = 3)<br>• More than ten sensitive populations are located within 1 mile of the site boundary (Score = 2)<br>• Fewer than ten sensitive populations are located within 1 mile of the site boundary (Score = 1)<br>• No sensitive populations are located within 1 mile of the site boundary (Score = 0) | 3 | 1 |
| Proximity of project site to environmental justice communities | • 4 – More than half of the population within ¼ mile of the site boundary lives in an EJ community (Score = 4)<br>• EJ communities are located within ¼ mile of the site boundary but they account for less than half of the population (Score = 3)<br>• More than half of the population within 1 mile of the site boundary lives in an EJ community (Score = 2)<br>• EJ communities are located within 1 mile of the site boundary but they account for less than half of the population (Score = 1)<br>• No EJ communities are located within 1 mile of the site boundary (Score = 0) | 0 | 0 |
| | Composite Scores | 14 | 5 |

ERG calculated project-specific $PM_{2.5}$ emissions (Table 9-3) using the DCE Emissions Assessment Tool with inputs collected from publicly available surrogate data sources (NC DOT's website, news articles) supplemented by consultations with NC DOT project engineers and planning department staff in Lincoln County.

ERG has provided Centralina COG with all supplemental spatially-resolved data (e.g., cancer risk data, non-cancer hazard data, and locations of EJ communities) one would need to score other individual projects.

**Table 9-3. Estimated Emissions for Two Sample Projects**

**Scenario Summary - I-485**

| | |
|---|---|
| Year | 2014 |
| County | Mecklenburg - NC |
| Construction Sectors | Highway - New Construction |

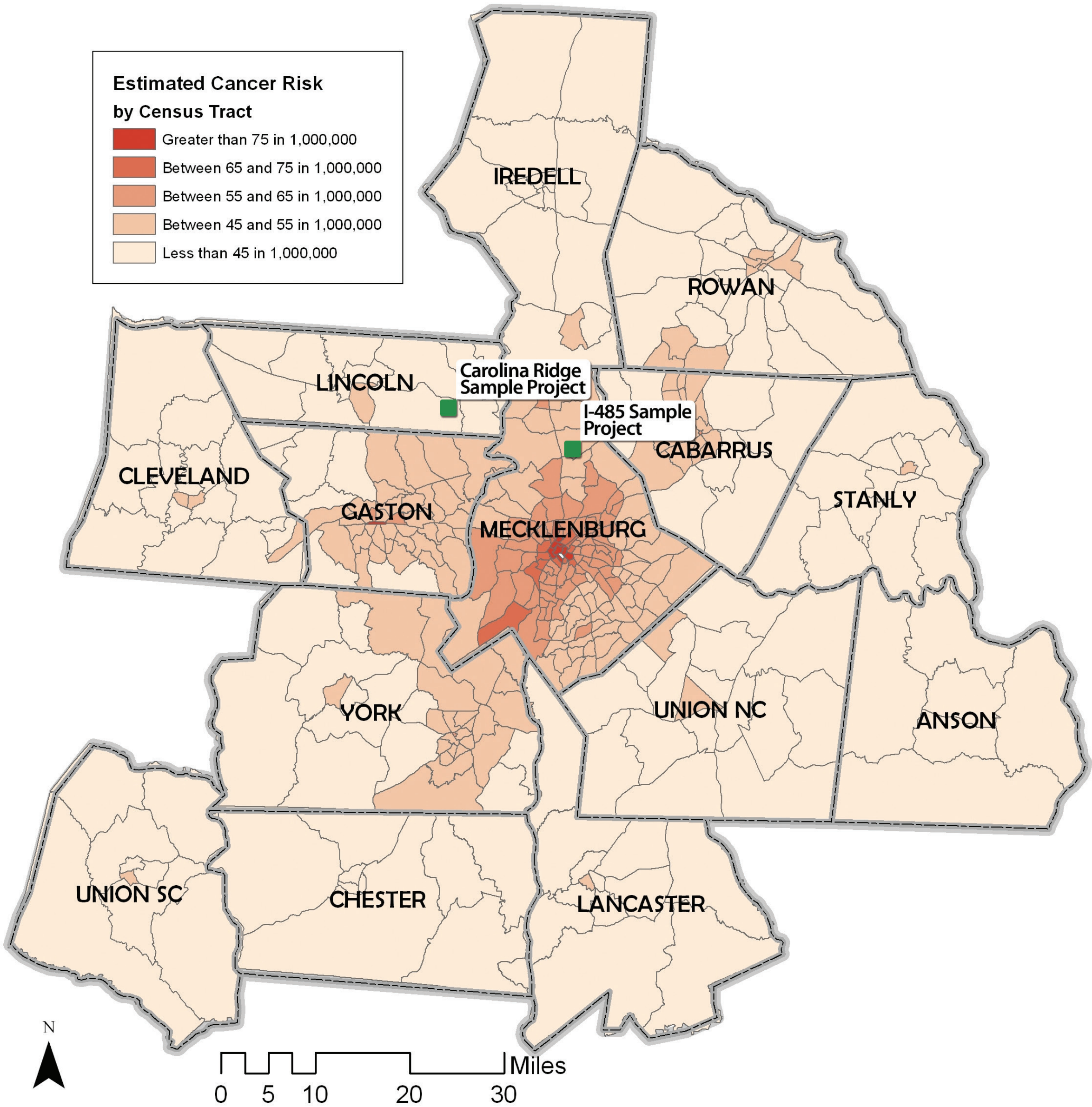
| Base Case (Uncontrolled) Emissions | | |
|---|---|---|
| Pollutant | Unit | Total Emissions |
| Black Carbon | tons/yr | 0.8 |
| $PM_{2.5}$ | tons/yr | 1.1 |
| $NO_x$ | tons/yr | 21.1 |
| VOC | tons/yr | 1.5 |
| $CO_2$ | tons/yr | 2,950 |

**Scenario Summary - Carolina Ridge**

| | |
|---|---|
| Year | 2014 |
| County | Lincoln - NC |
| Construction Sectors | Residential |

| Base Case (Uncontrolled) Emissions | | |
|---|---|---|
| Pollutant | Unit | Total Emissions |
| Black Carbon | tons/yr | 0.2 |
| $PM_{2.5}$ | tons/yr | 0.3 |
| $NO_x$ | tons/yr | 5.0 |
| VOC | tons/yr | 0.4 |
| $CO_2$ | tons/yr | 668 |

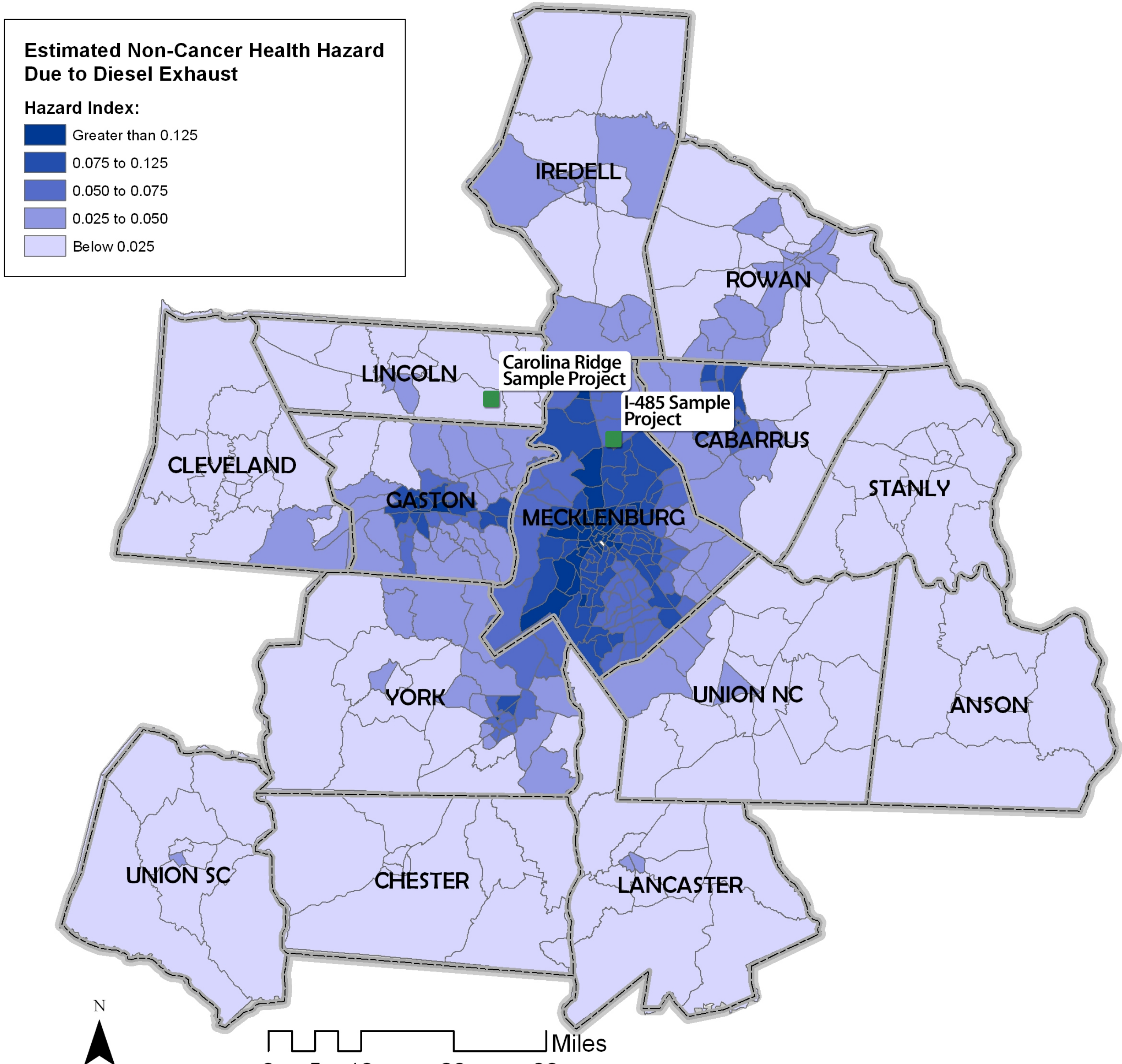
Figure 9-1. Estimated Cancer Risks Attributed to Outdoor Air Quality, by Census Tract




*Data are from EPA's most recent (2005) National-scale Air Toxics Assessment, which assesses health risks associated with exposures to air toxics[61].*

[61] http://www.epa.gov/ttn/atw/natamain. Accessed September 2013.

Figure 9-2. Estimated Non-Cancer Health Hazard Attributed to Diesel Exhaust, by Census Tract




*Data are from EPA's most recent (2005) National-scale Air Toxics Assessment, which assesses health risks associated with exposures to air toxics.*[62]

[62] http://www.epa.gov/ttn/atw/natamain. Accessed September 2013.

Figure 9-3. Locations of Sensitive Populations near Two Sample Construction Projects

Figure 9-3a. Example Highway Project - I-485 Extension

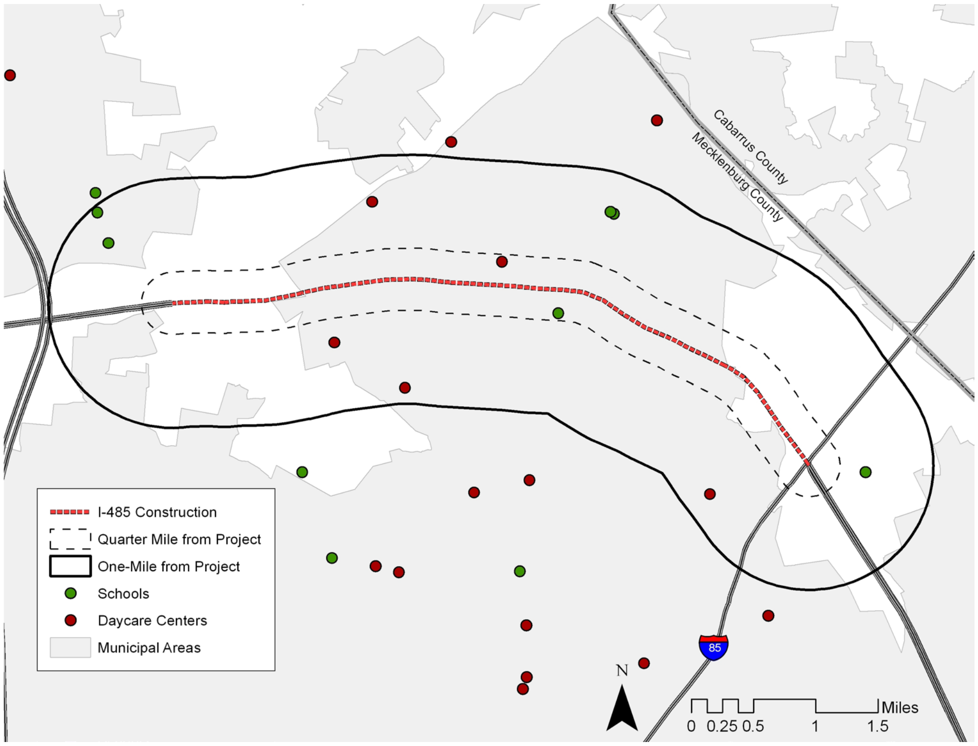
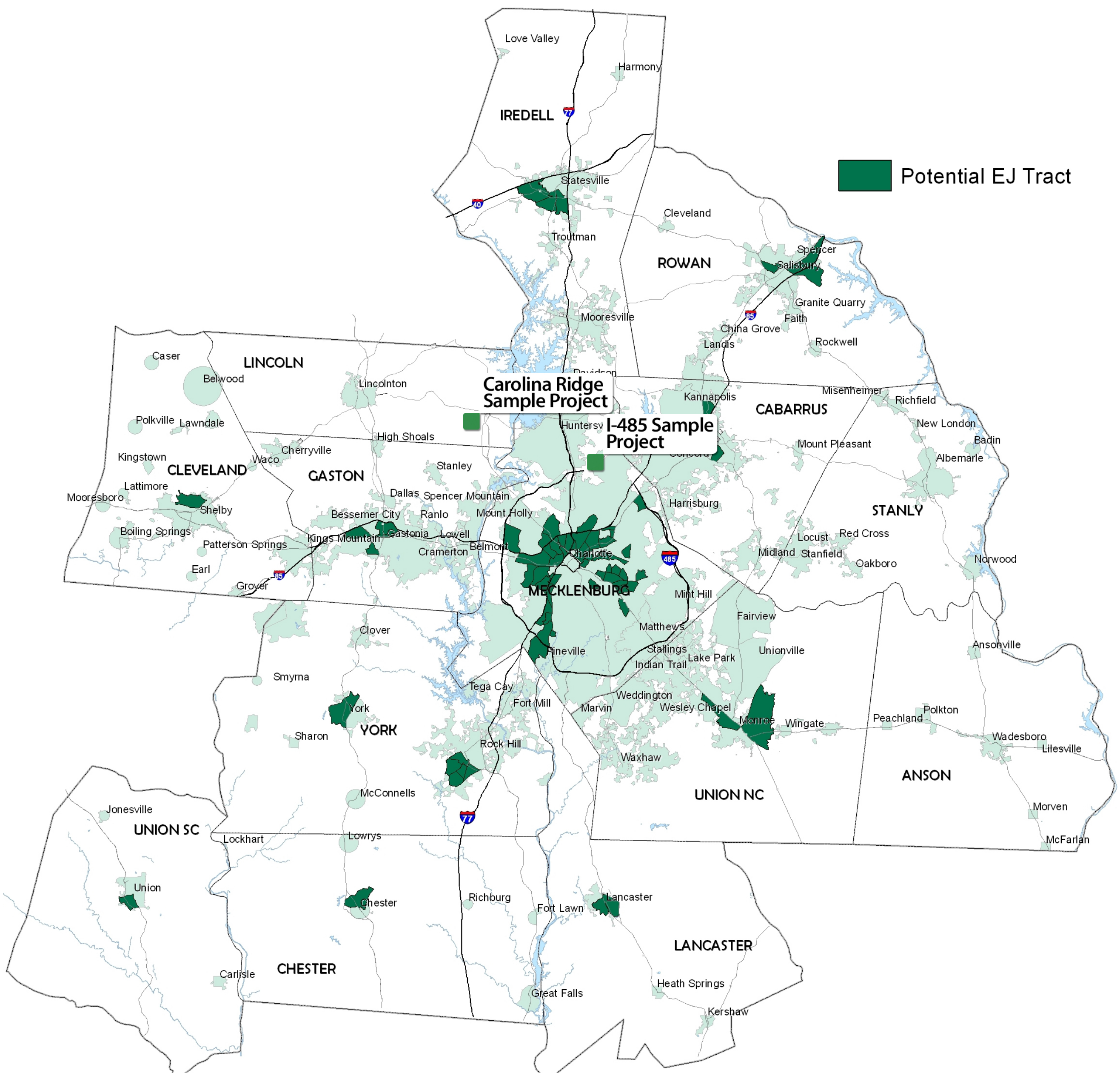



Figure 9-3b. Example Residential Project (Carolina Ridge)

Centralina COG provided ERG with the locations of schools and daycare centers surrounding these two example construction projects. Centralina COG as well as the MPOs and RPOs operating in the CONNECT region can produce similar GIS-based maps using readily available data sources.

Different government agencies have published various guidelines for identifying EJ communities. This map displays EJ communities based on an application of HUD guidelines.

Figure 9-4. Environmental Justice Communities in the CONNECT Region



# Appendix A. Primary References for Health Effects of Diesel Exhaust and Black Carbon

## Health effects of fine particulate matter ($PM_{2.5}$)

### *Selected major scientific assessments and reviews*

- EPA's "Integrated Science Assessment for Particulate Matter," EPA/600/R-08/139F, December 2009. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546.
- HEI's "Assessment of the Health Impacts of Particulate Matter Characteristics," Research Report 161, 2012. Available at: http://pubs.healtheffects.org/getfile.php?u=685.

### *Less technical assessments and plain language information on health effects*

- EPA's "Particle Pollution and Your Health" fact sheet (2003). Available at: http://www.epa.gov/oar/oaqps/particlepollution/pdfs/pm-color.pdf.
- WHO "Air Quality Guidelines for Particulate Matter, Ozone, and Sulfur Dioxide," 2005. Available at: http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf.

## Health effects from diesel engine exhaust (DEE)

### *Selected major scientific assessments and publications*

- EPA's "Health Assessment Document for Diesel Engine Exhaust," EPA/600/8-90/057F, May 2002. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060.
- IARC's "Monograph on Diesel and Gasoline Engine Exhausts and Some Nitroarenes." Volume 105, 2013. Available at: http://monographs.iarc.fr/ENG/Monographs/vol105/mono105.pdf.
- HEI's "Allergic Inflammation in the Human Lower Respiratory Tract Affected by Exposure to Diesel Exhaust." February 2012. Available at: http://pubs.healtheffects.org/getfile.php?u=693.

### *Less technical assessments and plain language information on health effects*

- CATF's "Diesel and Health in America—The Lingering Threat," 2005. Available at: http://www.catf.us/resources/publications/files/Diesel_Health_in_America.pdf.
- California OEHHA and the American Lung Association's co-authored fact sheet on "Health Effects of Diesel Exhaust." See: http://oehha.ca.gov/public_info/facts/pdf/diesel4-02.pdf.

## Health Effects of black carbon and elemental carbon

### *Selected major scientific assessments and publications*

- EPA's "Report to Congress on Black Carbon," EPA-450/R-12-001, March 2012. Available at: http://www.epa.gov/blackcarbon/2012report/fullreport.pdf.
- WHO's "Health Effects of Black Carbon." 2012. Available at: http://www.euro.who.int/__data/assets/pdf_file/0004/162535/e96541.pdf.

### *Selected health effects studies*

- YM Chiu, DC Bellinger, BA Coull, S Anderson, R Barber, RO Wright, and RJ Wright. "Associations between Traffic-Related Black Carbon Exposure and Attention in a Prospective Birth Cohort of Urban Children." Environmental Health Perspectives 121(7):859-864. 2013. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3701996.
- EH Wilker, A Baccarelli, H Suh, P Vokonas, RO Wright, and J Schwartz. "Black Carbon Exposures, Blood Pressure, and Interactions with Single Nucleotide Polymorphisms in MicroRNA Processing Genes." Environmental Health Perspectives 118:943-948. 2010. Available at: http://ehp.niehs.nih.gov/0901440.

# Appendix B. Equipment Use Profiles for Selected Construction Activity Sectors

| | | ***Equipment Type*** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sector/ Subsector | Units (annual^) | Pavers | Rollers/ Compactors | Scrapers | Other Paving | Surfacing | Excavators | Graders |
| Roadwork | | | | | | | | |
| New Road | # pcs/lane-mile | 0.03 | 0.30 | 0.13 | 0.06 | 0.01 | 0.32 | 0.24 |
| Bridgework | # pcs/M$ | 0.01 | 0.22 | N/A | 0.01 | 0.04 | 0.14 | 0.12 |
| Repair/Maint | # pcs/ M$ | 0.01 | 0.29 | N/A | N/A | 0.04 | 0.05 | 0.13 |
| Widening | # pcs/lane-mile | 0.01 | 0.15 | N/A | 0.02 | 0.01 | 0.09 | 0.08 |
| Other | # pcs/M$ | 0.05 | 0.35 | 0.02 | N/A | 0.04 | 0.12 | 0.27 |
| Residential | # pcs/1,000 unit | 2.7 | 7.1 | N/A | N/A | 2.3 | 13.1 | 4.3 |
| Utility | # pcs/M$ | 0.63 | 0.63 | N/A | N/A | N/A | 0.65 | N/A |
| Landfills* | #pcs/Mtons | N/A | 6.80 | 2.32 | N/A | N/A | 2.14 | 2.99 |
| Commercial | # pcs/1,000 sqft | 0.006 | 0.007 | N/A | N/A | N/A | 0.002 | 0.004 |
| [redacted] | | | | | | | | |
| Roadwork | | 488 | 387 | 914 | 518 | 512 | 945 | 1,157 |
| Residential | | 821 | 745 | N/A | N/A | 561 | 859 | 821 |
| Utility | Hours/pc/year | 57 | 92 | N/A | N/A | N/A | 500 | N/A |
| Landfills | | N/A | 2,951 | 663 | N/A | N/A | 2,249 | 1,345 |
| Commercial | | 821 | 760 | N/A | N/A | N/A | 1,092 | 962 |

| | | Equipment Type | | | |
|---|---|---|---|---|---|
| Sector/ Subsector | Units (annual^) | Wheeled Loaders | Backhoes | Dozers | Cranes |
| Roadwork | | | | | |
| New Road | # pcs/lane-mile | 0.28 | 0.22 | 0.32 | 0.08 |
| Bridgework | # pcs/M$ | 0.20 | 0.19 | 0.12 | 0.10 |
| Repair/Maint | # pcs/ M$ | 0.10 | 0.09 | 0.03 | N/A |
| Widening | # pcs/lane-mile | 0.09 | 0.08 | 0.06 | 0.08 |
| Other | # pcs/M$ | 0.28 | 0.27 | 0.10 | 0.03 |
| Residential | # pcs/1,000 unit | 10.5 | ** | 16.5 | N/A |
| Utility | # pcs/M$ | N/A | 0.65 | 0.63 | N/A |
| Landfills* | #pcs/Mtons | 1.38 | N/A | 4.27 | N/A |
| Commercial | # pcs/1,000 sqft | N/A | ** | 0.037 | N/A |
| | | | | | |
| Roadwork | Hours/pc/year | 844 | 467 | 858 | 990 |
| Residential | | 761 | ** | 936 | N/A |
| Utility | | N/A | 38 | 643 | N/A |
| Landfills | | 1,641 | N/A | 2,588 | N/A |
| Commercial | | N/A | ** | 936 | N/A |

**Activity Profile Data on tub-grinders not available* *^Assumes 260 working days/year* **** Residential and commercial profile surveys did not include backhoes*

# Appendix C. Construction Activity Surrogates

**Table C-1a. Heavy Highway Surrogates: New Construction (lane-miles)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | *North Carolina* | | | |
| **Anson** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Cabarrus** | 10.1 | 4.8 | 9.5 | 4.6 | 0.6 | 0.6 |
| **Cleveland** | 35.7 | 24.7 | 1.5 | 0.0 | 12.5 | 0.0 |
| **Gaston** | 15.6 | 18.3 | 20.2 | 14.5 | 1.0 | 0.0 |
| **Iredell** | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | 0.0 |
| **Lincoln** | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 |
| **Mecklenburg** | 26.5 | 30.0 | 37.4 | 1.9 | 24.0 | 7.7 |
| **Rowan** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| **Stanly** | 0.0 | 0.0 | 0.0 | 2.3 | 2.3 | 2.3 |
| **Union** | 0.0 | 0.0 | 19.1 | 23.6 | 23.6 | 20.3 |
| | | | *South Carolina* | | | |
| **Chester** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Lancaster** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Union** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **York** | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 |

**Table C-1b. Heavy Highway Surrogates: Bridgework ($M)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | *North Carolina* | | | |
| Anson | $ 0.09 | $ 0.03 | $ 0.03 | $ 0.81 | $ 0.11 | $ 0.11 |
| Cabarrus | $ 0.68 | $ 2.09 | $ 8.27 | $ 6.16 | $ 1.71 | $ 1.91 |
| Cleveland | $ 0.26 | $ 0.03 | $ 0.03 | $ 0.06 | $ 0.11 | $ 5.79 |
| Gaston | $ 0.53 | $ 1.75 | $ 0.03 | $ 1.11 | $ 0.11 | $ 0.11 |
| Iredell | $ 0.03 | $ 0.04 | $ 0.04 | $ 2.32 | $ 5.62 | $ 0.12 |
| Lincoln | $ 0.03 | $ 0.64 | $ 0.03 | $ 0.06 | $ 0.11 | $ 0.11 |
| Mecklenburg | $ 8.54 | $ 1.82 | $ 5.10 | $ 3.58 | $ 2.96 | $ 5.61 |
| Rowan | $ 8.94 | $ 1.95 | $ 5.94 | $ 4.50 | $ 1.02 | $ 3.55 |
| Stanly | $ 0.03 | $ 0.93 | $ 0.03 | $ 5.19 | $ 5.24 | $ 0.71 |
| Union | $ 0.03 | $ 2.86 | $ 0.03 | $ 0.64 | $ 0.11 | $ 3.46 |
| | | | *South Carolina* | | | |
| Chester | $ - | $ 5.50 | $ - | $ - | $ - | $ - |
| Lancaster | $ - | $ - | $ 2.20 | $ - | $ - | $ - |
| Union | $ - | $ 4.86 | $ - | $ 17.00 | $ - | $ - |
| York | $ - | $ 6.53 | $ 14.49 | $ - | $ 4.36 | $ 7.99 |

**Table C-1c. Heavy Highway Surrogates: Repair & Maintenance (M$)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | ***North Carolina*** | | | |
| Anson | $ - | $ - | $ - | $ - | $ - | $ - |
| Cabarrus | $ 2.80 | $ 2.80 | $ 2.80 | $ 2.80 | $ 2.80 | $ 8.67 |
| Cleveland | $ 0.80 | $ 0.80 | $ 0.80 | $ 11.75 | $ 0.80 | $ 0.80 |
| Gaston | $ 0.99 | $ 0.99 | $ 0.99 | $ 0.99 | $ 6.20 | $ 0.99 |
| Iredell | $ 2.52 | $ 2.52 | $ 9.20 | $ 2.52 | $ 2.52 | $ 6.60 |
| Lincoln | $ - | $ - | $ - | $ - | $ - | $ - |
| Mecklenburg | $ 5.02 | $ 5.02 | $ 15.71 | $ 12.60 | $ 17.95 | $ 36.82 |
| Rowan | $ 1.09 | $ 1.09 | $ 1.09 | $ 7.77 | $ 1.09 | $ 1.09 |
| Stanly | $ - | $ - | $ - | $ - | $ - | $ - |
| Union | $ - | $ - | $ - | $ - | $ - | $ - |
| | | | ***South Carolina*** | | | |
| Chester | $ - | $ 1.10 | $ - | $ - | $ - | $ - |
| Lancaster | $ - | $ 2.07 | $ - | $ - | $ - | $ - |
| Union | $ - | $ 1.20 | $ - | $ - | $ - | $ - |
| York | $ - | $ 3.37 | $ - | $ - | $ - | $ - |

**Table C-1d. Heavy Highway Surrogates: Widen/Turn Lanes (lane-miles)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | ***North Carolina*** | | | |
| Anson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cabarrus | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cleveland | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaston | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Iredell | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| Lincoln | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mecklenburg | 0.2 | 0.2 | 0.6 | 0.1 | 0.0 | 0.0 |
| Rowan | 0.0 | 0.2 | 15.0 | 0.0 | 0.0 | 0.0 |
| Stanly | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Union | 0.2 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | ***South Carolina*** | | | |
| Chester | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lancaster | 0.0 | 0.0 | 9.2 | 0.1 | 0.0 | 0.0 |
| Union | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| York | 0.0 | 1.0 | 8.9 | 0.0 | 0.0 | 0.0 |

**Table C-1e. Heavy Highway Surrogates: Other ($M)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| ***North Carolina*** | | | | | | |
| Anson | $ - | $ - | $ - | $ - | $ - | $ - |
| Cabarrus | $ - | $ 1.00 | $ 2.79 | $ - | $ - | $ - |
| Cleveland | $ - | $ - | $ - | $ - | $ - | $ - |
| Gaston | $ 1.99 | $ 11.58 | $ - | $ 0.30 | $ 0.88 | $ 1.09 |
| Iredell | $ - | $ 2.25 | $ 4.16 | $ 3.59 | $ - | $ - |
| Lincoln | $ - | $ 0.47 | $ - | $ - | $ - | $ - |
| Mecklenburg | $ 2.75 | $ 5.41 | $ 13.15 | $ 1.08 | $ 1.13 | $ 1.13 |
| Rowan | $ 0.12 | $ 2.30 | $ 0.02 | $ - | $ - | $ - |
| Stanly | $ - | $ - | $ - | $ 0.22 | $ - | $ 0.49 |
| Union | $ 0.73 | $ 0.00 | $ 1.42 | $ 1.08 | $ 1.13 | $ 1.13 |
| ***South Carolina*** | | | | | | |
| Chester | $ - | $ - | $ - | $ - | $ - | $ - |
| Lancaster | $ - | $ - | $ - | $ - | $ - | $ - |
| Union | $ - | $ - | $ - | $ - | $ - | $ - |
| York | $ - | $ - | $ - | $ - | $ - | $ - |

**Table C-2. County Roadwork Surrogates: Repair and Maintenance Estimates (M$/year)**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| ***North Carolina*** | | | | | | |
| **Anson** | $ 0.36 | $ 0.36 | $ 0.36 | $ 0.36 | $ 0.36 | $ 0.36 |
| **Cabarrus** | $ 3.34 | $ 3.40 | $ 3.45 | $ 3.50 | $ 3.55 | $ 3.61 |
| **Cleveland** | $ 1.03 | $ 1.03 | $ 1.02 | $ 1.02 | $ 1.02 | $ 1.02 |
| **Gaston** | $ 3.82 | $ 3.80 | $ 3.79 | $ 3.78 | $ 3.77 | $ 3.76 |
| **Iredell** | $ 1.92 | $ 1.93 | $ 1.94 | $ 1.95 | $ 1.96 | $ 1.97 |
| **Lincoln** | $ 0.38 | $ 0.38 | $ 0.39 | $ 0.39 | $ 0.40 | $ 0.40 |
| **Mecklenburg** | $ 23.57 | $ 23.87 | $ 24.16 | $ 24.46 | $ 24.76 | $ 25.05 |
| **Rowan** | $ 2.18 | $ 2.19 | $ 2.20 | $ 2.21 | $ 2.22 | $ 2.23 |
| **Stanly** | $ 0.96 | $ 0.98 | $ 1.00 | $ 1.02 | $ 1.04 | $ 1.06 |
| **Union** | $ 2.79 | $ 2.79 | $ 2.79 | $ 2.79 | $ 2.79 | $ 2.79 |
| ***South Carolina*** | | | | | | |
| **Chester** | $ 0.99 | $ 0.98 | $ 0.98 | $ 0.98 | $ 0.98 | $ 0.98 |
| **Lancaster** | $ 1.26 | $ 1.27 | $ 1.29 | $ 1.30 | $ 1.32 | $ 1.33 |
| **Union** | $ 0.84 | $ 0.84 | $ 0.84 | $ 0.84 | $ 0.84 | $ 0.84 |
| **York** | $ 2.24 | $ 2.29 | $ 2.33 | $ 2.37 | $ 2.41 | $ 2.45 |

**Table C-3. County Roadwork Surrogates: Approved CIP Project Totals for the City of Charlotte, North Carolina**

| Project Categories | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| **New/Rebuild Total** (lane-miles) | 1.73 | 2.73 | 2.73 | 4.50 | 4.50 | 5.17 |
| **Widening Total** (lane-miles) | 1.64 | 2.23 | 2.05 | 2.89 | 1.71 | 1.33 |
| **Bridgework Total** ($M) | $0.00 | $0.00 | $0.00 | $5.03 | $5.03 | $5.03 |

**Table C-4. County Roadwork Surrogates: Pennies for Progress Project Totals for York County, South Carolina**

| Project Categories | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| **New/Rebuild Total** (lane-miles) | 1.25 | 2.75 | 1.5 | 0 | 0.5 | 0.5 |
| **Widening Total** (lane-miles) | 1.5 | 8.35 | 9.85 | 5.65 | 7.7 | 5.05 |
| **Bridgework Total** ($M) | $0.00 | $0.00 | $5.82 | $5.82 | $0.00 | $0.00 |
| **Misc Total** ($M) | $1.50 | $1.50 | $6.74 | $9.66 | $10.03 | $7.10 |

**Table C-5. Residential Construction Surrogates: Single-family vs. Multi-family Differential Growth Rates in Mecklenburg County, North Carolina[1]**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|
| **New SF** | 7,900 | 7,588 | 7,605 | 7,183 | 6,831 | 7,169 | 8,348 |
| **New MF** | 6,371 | 5,210 | 6,093 | 3,773 | 4,484 | 4,252 | 5,462 |
| **Total** | **14,271** | **12,798** | **13,698** | **10,956** | **11,315** | **11,421** | **13,810** |
| **SF %** | 55.4% | 59.3% | 55.5% | 65.6% | 60.4% | 62.8% | 60.4% |
| **MF %** | 44.6% | 40.7% | 44.5% | 34.4% | 39.6% | 37.2% | 39.6% |
| | | | | | | | |
| **New SF** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | |
| **New MF** | 6,320 | 2,929 | 1,563 | 1,882 | 1,956 | 2,229 | |
| **Total** | 6,378 | 4,961 | 3,691 | 1,907 | 1,090 | 2,226 | |
| **SF %** | **12,698** | **7,890** | **5,254** | **3,789** | **3,046** | **4,455** | |
| **MF %** | 49.8% | 37.1% | 29.7% | 49.7% | 64.2% | 50.0% | |
| | 50.2% | 62.9% | 70.3% | 50.3% | 35.8% | 50.0% | |
| | | | | | | | |
| Average SF % - pre-2007 | | 59.6% | | | | | |
| Average SF % - 2007-2012 | | 45.5% | | | | | |
| | **Delta** | **14.2%** | | | | | |

[1] *Mecklenburg County Tax Parcel Data*

**Table C-6. Residential Construction Surrogates: New Single-family Units**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | ***North Carolina*** | | | |
| **Anson** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Cabarrus** | 1,200 | 1,217 | 1,235 | 1,254 | 1,272 | 1,291 |
| **Cleveland** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Gaston** | 136 | 136 | 137 | 138 | 138 | 139 |
| **Iredell** | 443 | 447 | 452 | 456 | 461 | 466 |
| **Lincoln** | 24 | 24 | 24 | 24 | 24 | 24 |
| **Mecklenburg** | 4,611 | 5,384 | 5,616 | 5,774 | 5,926 | 6,079 |
| **Rowan** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Stanly** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Union** | 752 | 761 | 770 | 780 | 790 | 799 |
| | | | ***South Carolina*** | | | |
| Chester | 0 | 0 | 0 | 0 | 0 | 0 |
| Lancaster | 221 | 224 | 227 | 230 | 233 | 236 |
| Union | 0 | 0 | 0 | 0 | 0 | 0 |
| York | 1,237 | 1,261 | 1,287 | 1,313 | 1,339 | 1,366 |
| Total | **8,623** | **9,456** | **9,748** | **9,969** | **10,183** | **10,400** |

**Table C-7. Landfill Activity Surrogates: Projected Disposal Rates by County**

| Growth Projections | | | | Millions of Tons/Year | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **County** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| | | | | ***North Carolina*** | | | |
| **Anson** | 0.267 | 0.271 | 0.275 | 0.279 | 0.283 | 0.287 | 0.291 |
| **Cabarrus** | 1.032 | 1.048 | 1.063 | 1.079 | 1.095 | 1.111 | 1.127 |
| **Cleveland** | 0.165 | 0.167 | 0.169 | 0.172 | 0.174 | 0.177 | 0.18 |
| **Gaston** | 0.228 | 0.231 | 0.235 | 0.238 | 0.242 | 0.245 | 0.249 |
| **Iredell** | 0.159 | 0.162 | 0.164 | 0.166 | 0.169 | 0.171 | 0.174 |
| **Lincoln** | 0.107 | 0.109 | 0.111 | 0.112 | 0.114 | 0.116 | 0.117 |
| **Mecklenburg** | 0.171 | 0.174 | 0.177 | 0.179 | 0.182 | 0.184 | 0.187 |
| **Rowan** | 0.132 | 0.134 | 0.136 | 0.138 | 0.14 | 0.142 | 0.145 |
| **Stanly** | 0.048 | 0.048 | 0.049 | 0.05 | 0.051 | 0.051 | 0.052 |
| **Union** | 0.011 | 0.011 | 0.011 | 0.011 | 0.011 | 0.012 | 0.012 |
| | | | | ***South Carolina*** | | | |
| **Chester** | 0.032 | 0.032 | 0.032 | 0.033 | 0.033 | 0.034 | 0.034 |
| **Lancaster** | 0.065 | 0.066 | 0.067 | 0.068 | 0.069 | 0.07 | 0.071 |
| **Union** | 0.793 | 0.805 | 0.817 | 0.829 | 0.841 | 0.853 | 0.866 |
| **York** | 0.143 | 0.146 | 0.148 | 0.15 | 0.152 | 0.154 | 0.157 |

**Table C-8. Utility Construction Surrogates: Projected Valuation ($M/year)[2]**

| County | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | | *North Carolina* | | | |
| **Anson** | $2.92 | $1.00 | $0.64 | $1.22 | $0.88 | $0.88 |
| **Cabarrus** | $7.31 | $7.04 | $6.75 | $6.40 | $8.25 | $8.25 |
| **Cleveland** | $3.80 | $4.76 | $4.30 | $4.21 | $5.79 | $5.79 |
| **Gaston** | $3.85 | $7.96 | $7.57 | $4.81 | $9.24 | $9.24 |
| **Iredell** | $13.21 | $11.03 | $7.25 | $9.87 | $6.94 | $6.94 |
| **Lincoln** | $7.85 | $5.37 | $4.90 | $3.43 | $2.69 | $2.69 |
| **Mecklenburg** | $65.36 | $49.36 | $47.17 | $22.40 | $21.72 | $21.72 |
| **Rowan** | $4.20 | $9.32 | $6.10 | $8.34 | $4.69 | $4.69 |
| **Stanly** | $3.76 | $2.27 | $3.74 | $2.62 | $3.61 | $3.61 |
| **Union** | $4.38 | $7.98 | $7.65 | $9.70 | $9.31 | $9.31 |
| | | | *South Carolina* | | | |
| **Chester** | $1.90 | $0.59 | $1.43 | $1.40 | $1.93 | $1.93 |
| **Lancaster** | $1.56 | $5.39 | $4.93 | $4.82 | $3.39 | $3.39 |
| **Union** | $1.64 | $1.37 | $0.75 | $1.69 | $1.66 | $1.66 |
| **York** | $19.29 | $2.93 | $11.43 | $10.92 | $10.49 | $10.49 |
| **ALL** | **$141.03** | **$116.37** | **$114.61** | **$91.85** | **$90.60** | **$90.60** |

[2] *Data is from Reed Construction Data. Reed's data set contains dollar value information on civil projects including a "Water and Sewer Piping" subcategory.*

# Appendix D. Emissions Inventory Methodologies

There are two basic approaches to compiling mobile source emissions inventories and, specifically, inventories pertaining to DCE. A "bottom up" inventory attempts to account for all of the specific activities utilizing diesel equipment, such as road construction projects, housing developments, utility line installation, etc. Given adequate detail regarding these activities, inventory specialists can estimate the specific types of equipment that are likely to be used, as well as their approximate power rating (horsepower) and number of hours of use, based on previous project experience. Hours of use and engine power (along with assumptions regarding other factors such as engine model year distribution) also contribute to project-level emissions estimates. Emissions estimates developed for each of these activities are then summed up to provide the total emission inventory for a specific area and analysis period (e.g., Mecklenburg County for 2014).

A "top down" emission inventory utilizes highly aggregated information that can be correlated with total equipment use, such as total annual sales of nonroad diesel fuel for a given region. Total fuel consumption is then allocated to the assumed equipment population in a given area to estimate equipment use total emissions. Since nonroad diesel engines are not registered (like cars and trucks), the total population in a given area has to be estimated based on a number of assumptions, such as national level equipment sales, assumed equipment scrappage rates, and the like.

Both of these approaches to emission inventory development have strengths and weaknesses. Bottom-up methodologies allow for greater precision as specific equipment types, engine sizes and hours of use may be estimated at a granular level. Since many emissions, such as PM, black carbon, and NOx, vary substantially depending upon equipment type and engine size, the bottom up approach has the potential to provide more precise emissions estimates. However, to the extent that certain equipment activities are not accounted for, it may underestimate total emissions. Some amount of underestimation of emissions is inevitable with a bottom-up approach since DCE use is not monitored directly, or even indirectly.[1] In addition, project listings for activities that involve these equipment are often incomplete or non-existent. For example, there is no centrally-compiled source of information regarding all commercial construction projects (e.g., office space, warehouses, etc.) in the CONNECT region. Therefore one goal of bottom-up inventories is to be as comprehensive as possible when developing project activity lists, given time and resource constraints.

Top-down emission inventory methodologies are typically easier to develop than bottom-up approaches, relying on single aggregated factors, such as fuel consumption which is allocated to pre-existing equipment distributions and use profiles (e.g., based on EPA's NONROAD emissions model). These inventories are also likely to be more comprehensive than bottom-up approaches, as total fuel sales should account for a very high fraction of total fuel consumption in a given region.[2] However, top-down approaches can generate imprecise emissions inventories since they do not account for the type of engine consuming the fuel (e.g., bulldozers versus forklifts, tractors versus generators).

[1] As a counter-example, on-road vehicle activity is monitored indirectly through tube counter and capacity observations, which are used to extrapolate to total vehicle miles travelled using travel demand models.

[2] Some amount of diesel equipment use in a region may consume fuel purchased in a different region. On the other hand, some amount of fuel purchased in the same region will likely be consumed outside the region. If the net flux of nonroad diesel fuel in and out of the region is relatively small then the error introduced in estimating emissions should be small as well.

# Appendix E. NCDOT and SCDOT State Transportation Improvement Plan (STIP) Project Descriptions

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLEVELAND | B-1135 | BEAVERDAM CREEK. REPLACE BRIDGE NO. 139 | Bridgework | | | | $ 295 | | | | | |
| ANSON | B-2506 | BROWN CREEK. REPLACE BRIDGE NO. 8 | Bridgework | | | | | | | $ 750 | | |
| ROWAN | B-4628 | BACK CREEK. REPLACE BRIDGE NO. 6 | Bridgework | | | | | | | | | $ 1,185 |
| UNION | B-4651 | SOUTH FORK CROOKED CREEK. REPLACE BRIDGE NO. 251 | Bridgework | | | | | $ 1,375 | | | | |
| CABARRUS | B-4720 | DUTCH BUFFALO CREEK. REPLACE BRIDGE NO. 113 | Bridgework | | | | | $ 700 | | | | |
| GASTON | B-4751 | STANLEY CREEK. REPLACE BRIDGE NO. 203 | Bridgework | | | | | | | $ 1,050 | | |
| IREDELL | B-4766 | ROCKY CREEK. REPLACE BRIDGE NO. 69 | Bridgework | | | | | | | | $ 2,500 | |
| MECKLENBURG | B-4779 | MALLARD CREEK. REPLACE BRIDGE NO. 147 (SBL) AND BRIDGE NO. 140 (NBL) | Bridgework | | | | | $ 2,800 | | | | |
| ROWAN | B-4808 | REPLACE BRIDGE NO. 141 OVER SOUTH SECOND CREEK. | Bridgework | | | | | | | $ 3,075 | | |
| ROWAN | B-4809 | LAKE FISHER. REPLACE BRIDGE NO. 221 | Bridgework | | | | $ 2,000 | | | | | |
| ROWAN | B-4810 | BACK CREEK. REPLACE BRIDGE NO. 12 | Bridgework | | | | $ 750 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STANLY | B-4818 | ISLAND CREEK. REPLACE BRIDGE NO. 138 | Bridgework | | | | | $ 600 | | | | |
| CABARRUS | B-4972 | ROCKY RIVER. REPLACE BRIDGE NO. 227 | Bridgework | | | | | | $ 1,100 | | | |
| CABARRUS | B-4973 | IRISH BUFFALO CREEK. RE-PLACE BRIDGE NO. 271 | Bridgework | | | | | $ 1,800 | | | | |
| STANLY | B-4974 | PEE DEE RIVER. REPLACE BRIDGE NO. 51 (COORDINATE WITH R-2530). | Bridgework | | | | | | | $ 10,250 | $ 10,250 | |
| IREDELL | B-4982 | THIRD CREEK. REPLACE BRIDGE NO. 38 | Bridgework | | | | | | | | $ 3,000 | |
| CABARRUS | B-5000 | BURRAGE ROAD. RE-PLACE BRIDGE NO. 151 OVER THREE MILE BRANCH. | Bridgework | | | | $ 900 | | | | | |
| MECKLENBURG | B-5105 | LITTLE SUGAR CREEK. RE-PLACE BRIDGE NO. 49 | Bridgework | | | | | $ 52 | | | | |
| MECKLENBURG | B-5105 | LITTLE SUGAR CREEK. RE-PLACE BRIDGE NO. 49 | Bridgework | | | | | | $ 1,950 | | | |
| UNION | B-5109 | GOOSE CREEK. REPLACE BRIDGE NO. 29 | Bridgework | | | | | $ 1,275 | | | | |
| CABARRUS | B-5123 | ROCKY RIVER AND ACCESS ROAD. RE-PLACE BRIDGE NO. 14 AND BRIDGE NO. 19 | Bridgework | | | | | | $ 155 | | | |
| CABARRUS | B-5123 | ROCKY RIVER AND ACCESS ROAD. RE-PLACE BRIDGE NO. 14 AND BRIDGE NO. 19 | Bridgework | | | | | | | $ 6,100 | | |
| UNION | B-5134 | CHINKAPIN CREEK. RE-PLACE BRIDGE NO. 72 | Bridgework | | | | | $ 575 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CABARRUS | B-5136 | SOUTHERN RAILROAD. REPLACE BRIDGE NO. 66 AND BRIDGE NO. 69 | Bridgework | | | | | | $ 8,500 | | | |
| STANLY | B-5137 | LITTLE MOUNTAIN CREEK. REPLACE BRIDGE NO. 215 | Bridgework | | | | | $ 550 | | | | |
| IREDELL | B-5142 | CORNELIUS CREEK. REPLACE BRIDGE NO. 57 | Bridgework | | | | | | | $ 2,250 | | |
| LINCOLN | B-5155 | HOYLE CREEK. REPLACE BRIDGE NO. 37 | Bridgework | | | | | $ 750 | | | | |
| ROWAN | B-5160 | NAILS BRANCH. REPLACE BRIDGE NO. 50 | Bridgework | | | | | | | $ 450 | | |
| ANSON | B-5169 | REMOVE BRIDGE NO. 309 OVER NORTH FORK JONES CREEK. | Bridgework | | | | $ 60 | | | | | |
| UNION | B-5243 | SOUTH FORK CROOKED CREEK. REPLACE BRIDGE NO. 258. | Bridgework | | | | | | | $ 575 | | |
| ROWAN | B-5366 | SLOANS CREEK. REPLACE BRIDGE NO. 19 | Bridgework | | | | | | | | | $ 1,350 |
| CABARRUS | B-5369 | COLD WATER CREEK. REPLACE BRIDGE NO. 53 | Bridgework | | | | | | | | | $ 1,800 |
| UNION | B-5370 | EAST FORK STEWARTS CREEK. REPLACE BRIDGE NO. 444 | Bridgework | | | | | | | | | $ 450 |
| UNION | B-5371 | CLEAR CREEK. REPLACE BRIDGE NO. 71 | Bridgework | | | | | | | | | $ 2,300 |
| STANLY | B-5373 | LONG CREEK. REPLACE BRIDGE NO. 44 | Bridgework | | | | | | | | | $ 600 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | B-5374 | BUFFALO CREEK. RE-PLACE BRIDGE NO. 448 | Bridgework | | | | | | | | | $ 600 |
| CLEVELAND | B-5390 | MUDDY FORK CREEK. RE-PLACE BRIDGE NO. 31 | Bridgework | | | | | | | | | $ 1,975 |
| CLEVELAND | B-5392 | KNOB CREEK. REPLACE BRIDGE NO. 201 | Bridgework | | | | | | | | | $ 2,400 |
| CLEVELAND | B-5393 | MAPLE CREEK. REPLACE BRIDGE NO. 192 | Bridgework | | | | | | | | | $ 1,300 |
| CABARRUS | B-5548 | REPLACE BRIDGE NO. 103 OVER DUTCH BUF-FALO CREEK. | Bridgework | | | | | | | | $ 1,600 | |
| MECKLENBURG | B-5792 | REPLACE BRIDGE NO. 342 OVER AN-DRILL TERRACE STREET AND IRWIN CREEK. | Bridgework | | | | | | | | | $ 5,500 |
| ROWAN | BD-5109 | DIVISION 9 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| ANSON | BD-5110 | DIVISION 10 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| CABARRUS | BD-5110 | DIVISION 10 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | BD-5110 | DIVISION 10 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| STANLY | BD-5110 | DIVISION 10 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| UNION | BD-5110 | DIVISION 10 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| CLEVELAND | BD-5112 | DIVISION 12 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| GASTON | BD-5112 | DIVISION 12 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| IREDELL | BD-5112 | DIVISION 12 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LINCOLN | BD-5112 | DIVISION 12 PURCHASE ORDER CON-TRACT BRIDGE REPLACEMENT PROJECTS AT SELECTED LOCATIONS. | Bridgework | | | | $ 360 | $ 360 | $ 360 | $ 540 | $ 720 | $ 720 |
| GASTON | BK-5120 | CREEK. RE-PLACE BRIDGE NO. 170 | Bridgework | | | | $ 500 | | | | | |
| ROWAN | C-4908 | CONSTRUCT SIDEWALKS AT SELECTED LOCATIONS. | Miscella-neous | | | | $ 373 | $ 299 | $ 134 | | | |
| ROWAN | C-4916 | CONSTRUCT SIDEWALKS AT SELECTED LOCATIONS. | Miscella-neous | | | | | $ 561 | | | | |
| GASTON | C-4934 | NC 279 (NEW HOPE ROAD), BURTON-WOOD DRIVE TO SR 2466 (GARRISON BOULEVARD) IN GASTONIA. WIDEN TO MULTI-LANES. | New/rebuild | 0.5 | 2 | 1.1 | $ 1,400 | $ 3,050 | | | | |
| MECKLENBURG | C-4956 | INTERSECTION IMPROVE-MENTS AT SELECTED LOCATIONS IN CORNELIUS. | Turn lane additions | 0.1 | 1 | 0.1 | $ 200 | | | | | |
| UNION | C-5128 | CONSTRUCT SIDEWALKS IN MARSHVILLE. | Miscella-neous | | | | $ 184 | | | | | |
| GASTON | C-5148 | SIDEWALKS ALONG MOUN-TAIN STREET IN CHER-RYVILLE. | Miscella-neous | | | | $ 455 | | | | | |
| CABARRUS | C-5157 | CONSTRUCT SIDEWALKS ON TOM QUERY ROAD, ROBINSON CHURCH ROAD AND STALL-INGS ROAD IN HARRISBURG. | Miscella-neous | | | | | $ 473 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROWAN | C-5158 | CONSTRUCT SIDEWALKS ON KERNS STREET, SALISBURY AVENUE AND CHURCH STREET. | Miscellaneous | | | | | $ 406 | | | | |
| CABARRUS | C-5159 | ROXIE STREET, NC 3 AND DALE EARNHARDT BOULEVARD IN KANNAPOLIS. STREET IMPROVEMENTS. | Miscellaneous | | | | | | $ 540 | | | |
| ROWAN | C-5160 | NEWSOME ROAD. CONSTRUCT BIKE LANES. | Miscellaneous | | | | | $ 1,256 | | | | |
| CABARRUS | C-5161 | IRISH BUFFALO CREEK GREENWAY IN KANNAPOLIS. CONSTRUCT GREENWAY. | Miscellaneous | | | | | | $ 1,944 | | | |
| GASTON | C-5185 | GASTON MALL-FRANKLIN SQUARE AREA AND BELMONT AREA. CONSTRUCT PARK AND RIDE LOTS. | Miscellaneous | | | | | $ 100 | | | | |
| IREDELL | C-5200 | NC 115 AND NC 150 IN MOORESVILLE. CONSTRUCT DEDICATED RIGHT TURN LANE AT NC 115 SOUTHBOUND AND NC 150 AND MAKE SIGNAL MODIFICATIONS. | Turn lane additions | 0.1 | 1 | 0.1 | $ 231 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IREDELL | C-5201 | NC 115 IN MOORESVILLE, MECKLENBURG COUNTY LINE TO NORMAN AVENUE. CONSTRUCT FOUR FOOT BIKE LANES ALONG BOTH SIDES. | Miscellaneous | | | | | $ 2,250 | | | | |
| MECKLENBURG | C-5225 | TOBY CREEK GREENWAY (PHASE II). CONNECT UNCC TO NEARBY RETAIL AND RESIDENTIAL DEVELOPMENT. | Miscellaneous | 1.3 | | | $ 1,593 | | | | | |
| MECKLENBURG | C-5227 | UNIVERSITY CITY BOULEVARD IN CHARLOTTE. CONSTRUCT A 10 FOOT WIDE MULTI-USE PATH ON THE NORTH SIDE OF UNIVERSITY CITY BOULEVARD BETWEEN MALLARD CREEK CHURCH ROAD AND BROADRICK BOULEVARD. | Miscellaneous | | | | $ 500 | | | | | |
| MECKLENBURG | C-5228 | DAVID COX ROAD-NC 115 IN CHARLOTTE. INTERSECTION IMPROVEMENTS. ADD LEFT TURN LANES ON ALL FOUR APPROACHES. | Turn lane additions | 0.1 | 4 | 0.4 | | | $ 1,614 | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | C-5229 | HARBURN FOREST CONNECTIVITY IMPROVEMENTS IN CHARLOTTE. EXTEND HARBURN FOREST DRIVE TO CONNECT TO RIDGE ROAD TO PROVIDE A THIRD ACCESS FOR HIGHLAND CREEK. | New/rebuild | 0.1 | 2 | 0.2 | $ 960 | | | | | |
| CABARRUS | C-5502 | LITTLE TEXAS ROAD IN KANNAPOLIS, FOREST PARK DRIVE TO EXISTING SIDEWALK SOUTH OF MISSION TRIPP STREET. CONSTRUCT 800 FEET OF SIDEWALK. | Miscellaneous | | | | | | $ 176 | | | |
| CABARRUS | C-5503 | US 601 AND NC 24/NC 27 IN MIDLAND. CONSTRUCT SIDEWALKS. | Miscellaneous | | | | | | $ 126 | | | |
| GASTON | C-5505 | RAIL TRAIL, WOODLAWN AVENUE TO BELMONT ABBEY COLLEGE AND DOWNTOWN. CONVERT ABANDONED NCDOT RAILROAD LINE TO A PEDESTRIAN TRAIL. | Miscellaneous | | | | $ 1,300 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GASTON | C-5508 | DALLAS-HIGH SHOALS ROAD (OLD US 321), DALLAS CHERRYVILLE HIGHWAY TO PARK ROAD AND EAST ON PARK ROAD TO SAM RHYME COURT. CONSTRUCT SIDEWALKS. | Miscellaneous | | | | $ 237 | | | | | |
| IREDELL | C-5528 | INTERSECTION OF NC 150 AND TALBERT ROAD IN MOORESVILLE. CONSTRUCT RIGHT TURN LANE ON SOUTHBOUND APPROACH. | Turn lane additions | 0.1 | 1 | 0.1 | | | $ 350 | | | |
| IREDELL | C-5529 | INTERSECTION OF NC 115 AND FAITH ROAD-CAMPUS LANE IN MOORESVILLE. CONSTRUCT A LEFT TURN LANE ON SOUTHBOUND APPROACH. | Turn lane additions | 0.1 | 1 | 0.1 | | | $ 350 | | | |
| IREDELL | C-5531 | KISTLER FARM-BRIARCLIFF-BELLINGHAM-WHITE OAK SIDEWALK NETWORK IN MOORESVILLE. CONSTRUCT SIDEWALKS IN VARIOUS LOCATIONS. | Miscellaneous | | | | | | $ 429 | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LINCOLN | C-5532 | GENERAL BOULEVARD-MAIN STREET PEDESTRIAN IMPROVEMENTS IN LINCOLNTON. CONSTRUCT HIGH VISIBILITY CROSSWALKS, PEDESTRIAN REFUGE ISLANDS AND INSTALL COUNTDOWN TIMERS. | Miscellaneous | | | | | $ 469 | | | | |
| MECKLENBURG | C-5533 | SR 5469 (SHOPTON ROAD) AND SR 1156 (BEAM ROAD) IN CHARLOTTE. CONSTRUCT A SINGLE LANE ROUNDABOUT. | Turn lane additions | 0.1 | 1 | 0.1 | | | | $ 995 | | |
| MECKLENBURG | C-5534 | SR 4979 (BALLANTYNE COMMONS PARKWAY-MCKEE ROAD) AND NC 16 (PROVIDENCE ROAD) IN CHARLOTTE. CONSTRUCT AN ADDITIONAL LEFT TURN LANE ON SR 4979 AND A SECOND LEFT TURN LANE ON SOUTHBOUND NC 16. | Turn lane additions | 0.1 | 2 | 0.2 | $ 498 | $ 498 | $ 498 | | | |
| MECKLENBURG | C-5535 | NC 16 (BROOKSHIRE BOULEVARD) AND LAWTON ROAD IN CHARLOTTE. CONSTRUCT AN ADDITIONAL RIGHT TURN LANE ONTO NORTHBOUND LAWTON ROAD. | Turn lane additions | 0.1 | 1 | 0.1 | | $ 1,491 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | C-5537 | BARTON CREEK GREENWAY IN CHARLOTTE. CONSTRUCT A CONNECTOR BETWEEN CLARK'S CREEK AND MALLARD CREEK GREENWAYS. | Miscellaneous | | | | $ 910 | | | | | |
| MECKLENBURG | C-5538 | INTERSECTION OF TUCKASEEGEE-BERRYHILL-THRIFT ROADS IN CHARLOTTE. CONSTRUCT A TRAFFIC CIRCLE. | Miscellaneous | | | | | | $ 2,410 | | | |
| MECKLENBURG | C-5540 | NAVIN ROAD, ALPINE DRIVE TO GIBBON ROAD. CONSTRUCT SIDEWALK ON NORTH SIDE. GIBBON ROAD, NEVIN ROAD TO SUGAR CREEK ROAD. CONSTRUCT SIDEWALK ON SOUTH SIDE. WEST SUGAR ROAD, BISANER STREET AND MALLARD CREEK ROAD. FILL GAPS IN SIDEWALK NETWORK ON EAST SIDE | Miscellaneous | | | | | | $ 752 | | | |
| MECKLENBURG | C-5541 | PROVIDENCE ROAD IN CHARLOTTE. CONSTRUCT A SIDEWALK ON SOUTHWEST SIDE. | Miscellaneous | | | | | $ 1,075 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | C-5542 | SOUTH TRYON STREET, QUEEN ANNE DRIVE TO NATIONS FORD ROAD IN CHARLOTTE. CONSTRUCT SIDEWALK ON SOUTHEAST SIDE. | Miscella-neous | | | | | | $ 1,490 | | | |
| MECKLENBURG | C-5543 | SUNSET ROAD, I-77 TO STATESVILLE ROAD IN CHARLOTTE. CONSTRUCT SIDEWALKS ON SOUTH SIDE AND INSTALL SIDEWALK ON THE I-77 OVERPASS. | Miscella-neous | | | | | $ 1,431 | | | | |
| CABARRUS | C-5557 | CITY OF CONCORD'S NE SUBSET SIDEWALKS. INSTALL SIDEWALKS AT VARIOUS LOCATIONS. | Miscella-neous | | | | | $ 525 | | | | |
| MECKLENBURG | EB-4714 | IRWIN CREEK BIKEWAY: IRWIN AVENUE ELEMENTARY SCHOOL TO CEDAR YARD (NEAR BANK OF AMERICA STADIUM) IN CHARLOTTE. | Miscella-neous | 1.0 | | | | $ 600 | | | | |
| MECKLENBURG | EB-4715 | LITTLE SUGAR CREEK GREEN-WAY. | Miscella-neous | | | | | $ 1,000 | | | | |
| MECKLENBURG | EB-5010 | CORNELIUS GREENWAY TRAIL. COR-NELIUS OPEN SPACE TO BAILEY ROAD PARK. | Miscella-neous | | | | | $ 2,150 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | EB-5011 | BEARSKIN CREEK GREEN-WAY, SKYWAY DRIVE TO ICE MORLLE STREET IN MONROE. | Miscella-neous | | | | | | $ 1,420 | | | |
| GASTON | EB-5114 | MOUNT HOLLY RIVERFRONT GREENWAY. | Miscella-neous | | | | | $ 800 | | | | |
| MECKLENBURG | EB-5524 | TOBY CREEK GREENWAY, NC 49 TO WEST ROCK RIVER ROAD IN CHARLOTTE. | Miscella-neous | | | | | | $ 1,500 | | | |
| STANLY | EB-5525 | US 52 BUSI-NESS, SOUTH STREET TO ROCK CREEK PARK IN ALBEMARLE. CONSTRUCT SIDEWALK. | Miscella-neous | | | | | | | $ 220 | | |
| STANLY | EB-5526 | LEONARD AVENUE, MAIN STREET TO NC 24/NC 27 IN ALBEMARLE. INSTALL SIDE-WALK ALONG ONE SIDE. | Miscella-neous | | | | | | | | | $ 493 |
| IREDELL | EB-5530 | OLD MOUN-TAIN ROAD, NORTH MAIN STREET TO SOUTH IREDELL HIGH SCHOOL IN TROUTMAN. CONSTRUCT SIDEWALK ON SOUTH SIDE OF ROAD. | Miscella-neous | | | | | | $ 480 | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GASTON | EB-5531 | 12TH STREET, CHADWICK COURT TO KAISER ROAD AND YELLOW JACKET LANE/ BESS TOWN ROAD, 12TH STREET TO 14TH STREET (NC 274) IN BESSEMER CITY. CON-STRUCT SIDEWALKS. | Miscella-neous | | | | | | | $ 300 | | |
| IREDELL | EB-5532 | NORTH MAIN STREET GREEWAY EXTENSION, OLD MURDOCK ROAD TO SR 1005 (OLD MOUNTAIN ROAD) IN TROUTMAN. CONSTRUCT NEW GREE-WAY/SIDE-WALK. | Miscella-neous | | | | | | | $ 340 | | |
| GASTON | EB-5533 | CAROLINA THREAD TRAIL, POSTON PARK TO SOUTH FORK RIVER IN GASTONIA. CONSTRUCT TRAIL. | Miscella-neous | | | | | | | | $ 875 | |
| GASTON | EB-5534 | CATAWBA CREEK GREENWAY EXTENSION IN MOUNT HOLLY, FERGUSON PARK TO DOWNTOWN. CONSTRUCT GREENWAY. | Miscella-neous | | | | | | | | | $ 410 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GASTON | EB-5535 | LAKEWOOD PARK TRAIL, LAKEWOOD PARK TO US 29/US 74 IN CRAMERTON. CONSTRUCT 10 FEET WIDE TRAIL. | Miscellaneous | | | | | | | | | $ 680 |
| ROWAN | I-2304 | I-85, NORTH OF SR 2120 (EXIT 81) IN ROWAN COUNTY TO US 29-52-70/I-85 BUSINESS (EXIT 87). ADDITIONAL LANES AND YADKIN RIVER BRIDGE RECONSTRUCTION. (PROJECT INCLUDES B-3833) | Bridgework | | | | $ 21,403 | $ 13,646 | $ 12,246 | $ 12,246 | $ 12,246 | $12,246 |
| IREDELL | I-3302 | I-40, SR 1717 (EXIT 138) IN CATAWBA COUNTY TO WEST OF SR 1512 (EXIT 146) IN IREDELL COUNTY. PAVEMENT AND BRIDGE REHABILITATION. | Repair/resurfacing | 6.1 | 4 | 24.4 | | | | | | $21,800 |
| CABARRUS | I-3802 | I-85, NC 73 IN CABARRUS COUNTY (EXIT 55) TO US 29/ US 601 CONNECTOR (EXIT 68) IN ROWAN COUNTY. ADD ADDITIONAL LANES. | New/rebuild | 8.3 | 2 | 16.6 | $ 27,075 | $ 25,075 | $ 25,075 | $ 25,075 | | |
| ROWAN | I-3802 | I-85, NC 73 IN CABARRUS COUNTY (EXIT 55) TO US 29/ US 601 CONNECTOR (EXIT 68) IN ROWAN COUNTY. ADD ADDITIONAL LANES. | New/rebuild | 5.3 | 2 | 10.6 | | | | | | $ 2,000 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | I-3803 | I-85, US 29/NC 49 CONNECTOR, MECKLENBURG COUNTY TO NC 73 IN CABARRUS COUNTY. ADD ADDITIONAL LANES. (COORDINATE WITH U-3415) | New/rebuild | 5.2 | 2 | 10.4 | $ 8,778 | $ 4,586 | $ 4,586 | $ 4,586 | $ 4,586 | $ 4,586 |
| CABARRUS | I-3803 | I-85, US 29/NC 49 CONNECTOR, MECKLENBURG COUNTY TO NC 73 IN CABARRUS COUNTY. ADD ADDITIONAL LANES. (COORDINATE WITH U-3415) | New/rebuild | 7.6 | 2 | 15.2 | $ 12,843 | $ 6,710 | $ 6,710 | $ 6,710 | $ 6,710 | $ 6,710 |
| IREDELL | I-3819 | STATESVILLE, MODIFICATION OF I-40/I-77 INTERCHANGE AREA. | Bridgework | | | | | $ 1,097 | $ 1,097 | $ 1,097 | $ 1,097 | $ 1,097 |
| ROWAN | I-4718 | I-85, CABARRUS COUNTY LINE TO NC 152. REPAIR PAVEMENT AND OVERLAY. | Repair/resurfacing | 5.0 | 4 | 20.0 | $ 331 | $ 331 | $ 331 | $ 331 | $ 331 | $ 331 |
| MECKLENBURG | I-4720 | I-77, I-277 (EXIT 9) TO THE SOUTH CAROLINA STATE LINE. RESURFACE WITH NOVACHIP. | Repair/resurfacing | 9.3 | 4 | 37.2 | $ 276 | $ 276 | $ 276 | $ 276 | $ 276 | $ 276 |
| IREDELL | I-4723 | I-77, MECKLENBURG COUNTY LINE TO EXIT 45. MILL AND RESURFACE. | Repair/resurfacing | 15.1 | 4 | 60.4 | $ 1,070 | $ 1,070 | $ 1,070 | $ 1,070 | $ 1,070 | $ 1,070 |
| MECKLENBURG | I-4733 | I-77/SR 5544 (WEST CATAWBA AVENUE) IN CORNELIUS. MODIFY INTERCHANGE. | New/rebuild | 0.1 | 4 | 0.4 | $ 5,375 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GASTON | I-4928 | CONSTRUCT NEW WEIGH STATION ALONG I-85. | Miscella-neous | | | | | $ 12,000 | | | | |
| GASTON | I-5000 | I-85/US 321. GEOMETRIC SAFETY IM-PROVEMENTS TO INTER-CHANGE. | New/rebuild | 0.5 | 4 | 2.0 | | | | $ 9,950 | $ 9,950 | |
| MECKLENBURG | I-5006 | I-85, GASTON COUNTY LINE TO CONCRETE PAVEMENT IN MECKLEN-BURG COUNTY NEAR SR 1601. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 0.7 | 4 | 2.8 | $ 114 | $ 114 | $ 114 | $ 114 | $ 114 | $ 114 |
| GASTON | I-5007 | I-85, SOUTH FORK RIVER BRIDGE TO EXIT 27. PAVE-MENT REHA-BILITATION. | Repair/re-surfacing | 3.1 | 4 | 12.4 | $ 334 | $ 334 | $ 334 | $ 334 | $ 334 | $ 334 |
| IREDELL | I-5106 | I-77, MILE MARKER 57.83 TO MILE POST 61.74. PAVE-MENT REHA-BILITATION. | Repair/re-surfacing | 3.9 | 4 | 15.6 | $ 439 | $ 439 | $ 439 | $ 439 | $ 439 | $ 439 |
| ROWAN | I-5209 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 9. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 200 | $ 200 | $ 200 | $ 200 | $ 200 | $ 200 |
| MECKLENBURG | I-5210 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 10. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 699 | $ 699 | $ 699 | $ 699 | $ 699 | $ 699 |
| CABARRUS | I-5210 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 10. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 699 | $ 699 | $ 699 | $ 699 | $ 699 | $ 699 |
| IREDELL | I-5212 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 12. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLEVELAND | I-5212 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 12. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 |
| GASTON | I-5212 | INTERSTATE MAINTENANCE PRESERVATION FOR DIVISION 12. | Repair/re-surfacing | #REF! | 4 | #REF! | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 | $ 222 |
| ROWAN | I-5316 | I-85, NORTH OF NC 152 TO SOUTH OF US 601 (JAKE ALEXANDER BOULEVARD). PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 5.0 | 4 | 20.0 | | | | $ 4,925 | | |
| MECKLENBURG | I-5317 | I-77, MILE MARKER 10.4 TO MILE MARKER 13. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 1.6 | 4 | 6.4 | | | | $ 1,800 | | |
| MECKLENBURG | I-5318 | I-485, MILE MARKER 51 TO MILE MARKER 61. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 8.0 | 4 | 32.0 | | | $ 8,000 | | | |
| IREDELL | I-5320 | I-40, MILE MARKER 146 TO MILE MARKER 151. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 5.0 | 4 | 20.0 | | | $ 2,800 | | | |
| MECKLENBURG | I-5343 | I-485, MILE MARKER 37 TO MILE MARKER 40. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 3.0 | 4 | 12.0 | | | | | $ 4,500 | |
| MECKLENBURG | I-5344 | I-485, MILE MARKER 31 TO MILE MARKER 33. PAVEMENT REHABILITA-TION. | Repair/re-surfacing | 2.0 | 4 | 8.0 | | | | $ 2,900 | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | I-5345 | I-77, SOUTH CAROLINA LINE TO MILE MARKER 10. PAVEMENT REHABILITATION ON RAMPS ONLY. | Repair/re-surfacing | 9.9 | 4 | #REF! | | | | | $ 500 | |
| MECKLENBURG | I-5346 | I-85, MILE MARKER 29.8 TO MILE MARKER 36. PAVEMENT REHABILITATION. | Repair/re-surfacing | 6.3 | 4 | 25.2 | | | | | $ 6,600 | |
| MECKLENBURG | I-5347 | I-85, MILE MARKER 36 TO MILE MARKER 42. PAVEMENT REHABILITATION ON RAMPS ONLY. | Repair/re-surfacing | 6.0 | 4 | #REF! | | | | $ 100 | | |
| MECKLENBURG | I-5348 | I-277, US I-77/ US 74 TO MILE MARKER 2. PAVEMENT REHABILITATION. | Repair/re-surfacing | 2.0 | 4 | 8.0 | | | | $ 1,100 | | |
| CLEVELAND | I-5350 | I-85, SOUTH CAROLINA LINE TO GASTON COUNTY LINE. PAVEMENT REHABILITATION. | Repair/re-surfacing | 8.2 | 4 | 32.8 | | | | $ 7,800 | | |
| CABARRUS | I-5367 | I-85, MILE MARKER 58.5 TO ROWAN COUNTY LINE. PAVEMENT REHABILITATION. | Repair/re-surfacing | 4.4 | 4 | 17.6 | | | | | | $ 1,600 |
| MECKLENBURG | I-5369 | I-85, MILE MARKER 36 TO MILE MARKER 42. PAVEMENT REHABILITATION. | Repair/re-surfacing | 6.0 | 4 | 24.0 | | | | | | $ 8,900 |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | I-5370 | I-277, MILE MARKER 2.6 (BEGINNING OF ASPHALT) TO NC 16/I-77. PAVEMENT REHABILITATION. | Repair/resurfacing | 1.9 | 4 | 7.6 | | | | | | $ 1,000 |
| GASTON | I-5374 | I-85, CLEVELAND COUNTY LINE TO MILE MARKER 12. PAVEMENT REHABILITATION. | Repair/resurfacing | 3.9 | 4 | 15.6 | | | | | $ 2,100 | |
| MECKLENBURG | I-5381 | I-77, SOUTH CAROLINA LINE TO MILE MARKER 9.9 (BEGINNING OF CONCRETE). PAVEMENT REHABILITATION. | Repair/resurfacing | 9.9 | 4 | 39.6 | | | | | | $ 6,300 |
| MECKLENBURG | I-5383 | I-485, I-77 TO MILE MARKER 3. PAVEMENT REHABILITATION. | Repair/resurfacing | 6.0 | 4 | 24.0 | | | | | | $ 3,200 |
| MECKLENBURG | I-5405 | I-77, I-277 (BROOKSHIRE FREEWAY) TO WEST CATAWBA AVENUE (EXIT 28). CONSTRUCT HIGH OCCUPANCY TOLL (HOT) LANES AND CONVERT EXISTING HIGH OCCUPANCY VEHICLE (HOV) LANES TO HIGH OCCUPANCY TOLL (HOT) LANES. | New/rebuild | 17.0 | 2 | 34.0 | | | $ 64,000 | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | I-5507 | I-485, I-77 SOUTH OF CHARLOTTE TO US 74 (INDEPENDENCE BOULEVARD). ADD ONE EXPRESS LANE IN EACH DIRECTION. | New/rebuild | 16.6 | 2 | 33.2 | | | | | $156,100 | $21,600 |
| IREDELL | K-4908 | I-77, NEW REST AREA PAIR ON NEW LOCATION TO REPLACE TWO EXISTING PAIRS. ONE IN IREDELL COUNTY (LAKE NORMAN) AND THE OTHER AT THE IREDELL-YADKIN COUNTY LINE. TO IMPROVE SPACING AND REDUCE MAINTENANCE COST. | Miscellaneous | | | | | | $ 6,500 | $ 6,500 | | |
| MECKLENBURG | R-2123 | I-485 (CHARLOTTE EASTERN OUTER LOOP), US 74 EAST (INDEPENDENCE BOULEVARD) TO I-85 NORTH. CONSTRUCT FREEWAY ON NEW LOCATION. | Bridgework | | | 0.0 | $ 31 | $ 31 | | | | |
| MECKLENBURG | R-2248 | I-485 (CHARLOTTE WESTERN OUTER LOOP), WEST OF I-77 TO I-85 NORTH. FREEWAY ON NEW LOCATION. | New/rebuild | 5.7 | 8 | 45.6 | $ 46,500 | $ 46,500 | | | | |
| LINCOLN | R-2307 | RELOCATED NC 16 (TIP PROJECT R-2206) TO I-77. WIDEN TO MULTI-LANES. | New/rebuild | 8.7 | 2 | 17.4 | | | | | $ 5,500 | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IREDELL | R-2307 | RELOCATED NC 16 (TIP PROJECT R-2206) TO I-77. WIDEN TO MULTI-LANES. | New/rebuild | 12.1 | 2 | 24.2 | | | | | $ 5,500 | |
| STANLY | R-2530 | NC 24/NC 27, SR 1963 (ST. MARTIN ROAD) IN ALBEMARLE TO NC 73. WIDEN TO MULTI- LANES. (COORDINATE WITH B-4974). | New/rebuild | 8.9 | 2 | 17.8 | | | | $ 6,950 | $ 6,950 | $ 6,950 |
| MECKLENBURG | R-2555 | SR 5544 (WEST CATAWBA AVENUE), NC 73 (SAM FURR ROAD) TO EAST OF SR 2195 (TORRENCE CHAPEL ROAD). WIDEN TO MULTI-LANES. | New/rebuild | 3.4 | 2 | 6.8 | | | | | | $ 3,750 |
| CLEVELAND | R-2707 | US 74 SHELBY BYPASS. FOUR LANE DIVIDED FREEWAY ON NEW LOCATION. | New/rebuild | 18.6 | 4 | 74.4 | $ 45,200 | $ 31,300 | $ 1,900 | | $ 15,900 | |
| UNION | R-3329 | US 74 BYPASS, I-485 (CHARLOTTE OUTER LOOP) TO PROJECT R-2559 (US 74 MONROE BYPASS). MULTI-LANE FREEWAY ON NEW LOCATION. (COORDINATE WITH U-3825). | New/rebuild | 19.7 | 6 | 80.0 | | | $ 76,000 | $ 94,000 | $ 94,000 | $55,000 |
| MECKLENBURG | R-4902 | I-485, I-77 SOUTH OF CHARLOTTE TO REA ROAD. WIDEN TO SIX-LANES. | New/rebuild | 6.6 | 2 | 13.2 | $ 31,833 | $ 31,833 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STANLY | R-5302 | US 52, SOUTH CITY LIMIT OF NORWOOD TO SOUTH CITY LIMIT OF ALBEMARLE. CONSTRUCT SAFETY IMPROVEMENTS. | Turn lane additions | 0.1 | 4 | 0.4 | | | | | | $ 2,000 |
| MECKLENBURG | U-0209 | US 74 (INDEPENDENCE BOULEVARD), BROOKSHIRE FREEWAY TO IDLEWILD ROAD IN CHARLOTTE. ADD ADDITIONAL LANES AND CONSTRUCT INTERCHANGES WITH SHARON AMITY ROAD AND IDLEWILD ROAD AND SAFETY IMPROVEMENTS. | New/rebuild | 1.4 | 2 | 2.8 | $ 24,006 | $ 4,606 | $ 4,606 | $ 4,606 | $ 4,606 | $ 4,606 |
| MECKLENBURG | U-2507 | SR 2467 (MALLARD CREEK ROAD), SR 2480 (SUGAR CREEK ROAD) TO SR 2472 (MALLARD CREEK CHURCH ROAD) IN CHARLOTTE. WIDEN TO MULTI-LANES, PART ON NEW LOCATION. | New/rebuild | 4.1 | 2 | 8.2 | | $ 26,500 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GASTON | U-3321 | GARDEN PARKWAY, I-85 IN GASTON COUNTY TO I-485/NC 160 NEAR THE CHARLOTTE DOUGLAS INTERNATIONAL AIRPORT IN MECKLENBURG COUNTY. FOUR LANES ON NEW LOCATION. | New/rebuild | 17.1 | 4 | 68.4 | $146,349 | $166,347 | $ 171,256 | $ 129,896 | | |
| MECKLENBURG | U-3321 | GARDEN PARKWAY, I-85 IN GASTON COUNTY TO I-485/NC 160 NEAR THE CHARLOTTE DOUGLAS INTERNATIONAL AIRPORT IN MECKLENBURG COUNTY. FOUR LANES ON NEW LOCATION. | New/rebuild | 1.7 | 4 | 6.8 | $ 14,651 | $ 16,653 | $ 17,144 | $ 13,004 | | |
| CABARRUS | U-3440 | NC 3, PROPOSED WEST SIDE BYPASS (U-2009) TO SR 1691 (LOOP ROAD) IN KANNAPOLIS. WIDEN TO MULTI-LANES. | New/rebuild | 2.5 | 2 | 5.0 | | $ 420 | $ 17,800 | | | |
| ROWAN | U-3459 | SR 2541 (KLUMAC ROAD) IN SALISBURY. CONSTRUCT A GRADE SEPARATION WITH THE NORTH CAROLINA RAILROAD. | Bridgework | | | | $ 5,000 | $ 2,426 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | U-3467 | SR 1316 (REA ROAD) EXTENSION, NC 16 TO SR 1008 (INDIAN TRAIL-WAXHAW ROAD) IN WEDDINGTON. MULTI-LANES, PART ON NEW LOCATION. | New/rebuild | 3.8 | 2 | 7.6 | | | | | | $ 7,000 |
| GASTON | U-3633 | TUCKASEEGEE ROAD (AT BEATTY DRIVE) TO HIGHLAND STREET (AT A & E DRIVE) IN MOUNT HOLLY. WIDEN TO MULTI-LANES. | New/rebuild | 1.3 | 2 | 2.6 | | $ 1,350 | $ 12,400 | | | |
| MECKLENBURG | U-3850 | I-277 (JOHN BELK FREEWAY) AT I-77. ADD WESTBOUND LANE THROUGH I-77 INTERCHANGE IN CHARLOTTE. | New/rebuild | 0.5 | 1 | 0.5 | | | | | | $ 3,550 |
| MECKLENBURG | U-4713 | SR 3440 (MCKEE ROAD) EXTENSION, SR 3457 (CAMPUS RIDGE ROAD) TO SR 3448 (PLEASANT PLAINS ROAD) IN MATTHEWS. TWO LANES ON MULTI-LANE RIGHT OF WAY ON NEW LOCATION. | New/rebuild | 1.1 | 2 | 2.2 | $ 2,000 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | U-4714 | SR 1009 (JOHN STREET-OLD MONROE ROAD), SR 3448-SR 3474 (TRADE STREET) TO SR 1377 (WESLEY CHAPEL-STOUTS ROAD). WIDEN TO MULTI-LANES. | New/rebuild | 4.2 | 2 | 8.4 | | | | | | $16,900 |
| MECKLENBURG | U-4714 | SR 1009 (JOHN STREET-OLD MONROE ROAD), SR 3448-SR 3474 (TRADE STREET) TO SR 1377 (WESLEY CHAPEL-STOUTS ROAD). WIDEN TO MULTI-LANES. | New/rebuild | 2.3 | 2 | 4.6 | | | | | | $16,900 |
| MECKLENBURG | U-4744 | STP-DA IN MECKLENBURG-UNION METROPOLITAN PLANNING ORGANIZATION (MUMPO). | Miscellaneous | | | | $ 1,500 | $ 175 | $ 38 | $ 6,100 | $ 6,250 | $ 6,250 |
| UNION | U-4744 | STP-DA IN MECKLENBURG-UNION METROPOLITAN PLANNING ORGANIZATION (MUMPO). | Miscellaneous | | | | $ 1,500 | $ 175 | $ 38 | $ 6,100 | $ 6,250 | $ 6,250 |
| CABARRUS | U-4910 | SR 1445 (DERITA ROAD), SR 1394 (POPLAR TENT ROAD) TO SR 2894 (CONCORD MILLS BOULEVARD) IN CONCORD. WIDEN TO MULTI-LANES. | New/rebuild | 2.6 | 2 | 5.2 | $ 10,566 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | U-4913 | SR 3174-SR 1501 (IDLEWILD ROAD), I-485 TO SR 1524 (STEVENS MILL ROAD). WIDEN TO MULTI-LANES. | New/rebuild | 0.6 | 2 | 1.2 | | | | | | $ 3,000 |
| MECKLENBURG | U-4913 | SR 3174-SR 1501 (IDLEWILD ROAD), I-485 TO SR 1524 (STEVENS MILL ROAD). WIDEN TO MULTI-LANES. | New/rebuild | 0.2 | 2 | 0.4 | | | | | | $ 3,000 |
| MECKLENBURG | U-5008 | CONSTRUCT SR 2975 (SUGAR CREEK ROAD) GRADE SEPARATION OF NORTH CAROLINA RAILROAD CROSSING 715 352H IN CHARLOTTE. | Bridgework | | | | | | $ 9,420 | $ 10,000 | $ 9,000 | |
| MECKLENBURG | U-5108 | NORTHCROSS DRIVE EXTENSION, END OF NORTHCROSS DRIVE TO WESTMORELAND ROAD IN CORNELIUS. CONSTRUCT ROAD ON NEW LOCATION. | New/rebuild | 0.2 | 2 | 0.4 | | $ 4,500 | | | | |
| MECKLENBURG | U-5110 | US 74 TO STEVENS MILL ROAD IN MATTHEWS. CONSTRUCT NEW 2-LANE ROAD. | New/rebuild | 0.5 | 2 | 1.0 | | $ 2,000 | | | | |
| MECKLENBURG | U-5111 | WILGROVE-MINT HILL ROAD, NC 51 TO NELSON ROAD IN MINT HILL. WIDEN ROADWAY. | New/rebuild | 0.2 | 2 | 0.4 | | $ 650 | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNION | U-5112 | INTERSECTION IMPROVEMENTS AT POTTER ROAD AND PLEASANT PLAINS ROAD IN STALLINGS. | Turn lane additions | 0.1 | 4 | 0.4 | | $ 2,000 | | | | |
| MECKLENBURG | U-5113 | CONSTRUCT MULTI-USE PARKING DECK IN DAVIDSON. JOINT PROJECT WITH CATS. | Miscellaneous | | | | | | $ 2,500 | | | |
| MECKLENBURG | U-5114 | INTERSECTION OF US 21 AND GILEAD ROAD IN HUNTERSVILLE. CONSTRUCT INTERSECTION IMPROVEMENTS, INCLUDING BICYCLE AND PEDESTRIAN ACCOMMODATIONS. | Miscellaneous | | | | | | $ 4,500 | | | |
| MECKLENBURG | U-5115 | INTERSECTION OF NC 51 AND IDLEWILD ROAD. CONSTRUCT INTERSECTION IMPROVEMENTS. | Turn lane additions | 0.1 | 1 | 0.1 | | | $ 500 | | | |
| UNION | U-5325 | INTERSECTION OF NC 84 AND SR 1344 (MATTHEWS-WEDDINGTON ROAD). CONSTRUCT A ROUNDABOUT. INTERSECTION OF NC 16 AND SR 1317 (WEDDINGTON CHURCH ROAD). RELOCATE INTERSECTION. | Miscellaneous | | | | $ 900 | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MECKLENBURG | U-5507 | CONSTRUCT NORTHWEST ARC OF THE I-485/ PROSPERITY CHURCH ROAD INTERCHANGE IN CHARLOTTE. | New/rebuild | 0.5 | 2 | 1.0 | | | $ 10,500 | | | |
| MECKLENBURG | U-5519 | NORTH COMMUNITY HOUSE ROAD EXTENSION AND BRIDGE ACROSS I-485. | Bridgework | | | | $ 8,500 | | | | | |
| GASTON | W-5311 | AT SR 2416 (ROBINSON RD), AND US 321 JUST N. OF SR 2416. REPLACE OVERHEAD RR BRIDGE TO CONSTRUCT TWO-LANE, TWO-WAY ROAD FOR SR 2416, CON-STRUCT RIGHT TURN LANE FOR US 321 N.BOUND AP-PROACH AND CONSTRUCT TWO LIMITED MOVEMENT CROSSOVERS AND REVISE FLASHERS. | Bridgework | | | | | $ 1,900 | | | | |
| ROWAN | W-5313 | SR 2335 (LOWER STONE CHURCH ROAD) TO SR 1337 (LENTZ ROAD). WIDEN AND INSTALL RUMBLE STRIPS. | Turn lane additions | 7.4 | 2 | 14.8 | | | $ 5,600 | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROWAN | W-5314 | NC 801 AT SR 2048 (COOL SPRINGS ROAD/WOOD-LEAF ROAD), SR 1951 (PARKS ROAD) AT SR 2048 (WOODLEAF ROAD) AND NC 801 AT SR 2004 (WOOD-LEAF BARBER ROAD/QUARRY ROAD). WIDENING, INTERSECTION REALIGNMENT, TURN LANES AND GEOMET-RIC IMPROVE-MENTS. | Turn lane additions | 0.1 | 2 | 0.2 | | | $ 800 | | | |
| ROWAN | W-5316 | US 52, SR 2342 (GOLD KNOB ROAD), SR 2319 (CRESCENT ROAD), AND SR 2382 (AN-THONY ROAD). INTERSECTION IMPROVE-MENTS. | Turn lane additions | 0.1 | 2 | 0.2 | | $ 690 | | | | |
| UNION | W-5502 | SR 1364 (PLEASANT PLAINS ROAD) AT SR 1357 (POTTERS ROAD) IN STALLINGS. INSTALL LEFT TURN LANES AND REVISE TRAFFIC SIG-NAL. | Turn lane additions | 0.1 | 2 | 0.2 | $ 500 | | | | | |
| ROWAN | W-5516 | SR 1210 (OLD BEATTY FORD ROAD) / SR | | | | | | | | | | |
| 1221 (BOSTIAN ROAD) TO SR 1337 (LENTZ ROAD). RELO-CATE EXISTING | | | | | | | | | | | | |

| COUNTIES | ID | DESCRIPTION | Project Category | LENGTH | # Lane | Lane Miles | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROAD WITH GRADE SEPA-RATION OVER I-85. | Bridge-work | | | | | | $ 5,000 | | | | | |

| | | | | | | Thousands of Dollars Per Year Allocated | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| County | Description | Length | # lanes | lane mile | Project Category | 2014 | 2015 | 2016 | 2017 | 2018 | > 2018 |
| Union | SC-9 Misc | | | | Bridge | | | 17000 | | | |
| Union | S-22 Enoree River | | | | Bridge | 4860 | | | | | |
| Union | Union County Pavement Resurfacing | | | | Repair_ Maint | 1189 | | | | | |
| Chester | SC 97 Rocky Creek | | | | Bridge | 5500 | | | | | |
| Chester | Pavement Resurfacing | | | | Repair_ Maint | 1093 | | | | | |
| Lancaster | S 770 Hanging Rock Creek | | | | Bridge | | 1980 | | | | |
| Lancaster | S 770 Hanging Rock Creek | | | | Bridge | | 195 | | | | |
| Lancaster | Pavement Resurfacing | | | | Repair_ Maint | 2085 | | | | | |
| Lancaster | SC 160 Phase II | 2.29 | 4 | 9.16 | Widening | | 7000 | | | | |
| Lancaster | US 521 at Marvin Rd | 0.1 | 1 | 0.1 | Widening | | | 756 | | | |
| York | S 22 Steel Creek; S 64 Allison Creek; S 103 Fishing Creek; S 732 Calabash Branch; S 347 Stony Fork Creek | | | | Bridge | 4820 | | | | | |
| York | S 81 / S5 Tools Fork Creek | | | | Bridge | | 11252 | | | | |
| York | S 101 Wildcat Creek | | | | Bridge | 1710 | | | | | |
| York | S 50 Man-chester Creek | | | | Bridge | | 3240 | | | | |
| York | SC 274 Mill Creek | | | | Bridge | | | | | 1825 | |
| York | US 321 Allison Creek | | | | Bridge | | | | | 4378 | |
| York | S 654 Burgis Creek | | | | Bridge | | | | | 1788 | |

| | | | | | | Thousands of Dollars Per Year Allocated | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| York | S 655 Fishing Creek | | | | Bridge | | | | 4364 | | |
| York | SC 160 / Gold Hill Road Project | | | 1 | Widening | 4066 | | | | | |
| | | | | | | | | | | | |
| York | East White Street / SC 72 | 0.1 | 1 | 0.1 | Widening | | 950 | | | | |
| York | Springhill Farm Road | | | 0 | Widening | 0 | | | | | |
| York | Dave Lyle Blvd / I 77 Exit Ramp Cham-berside Dr | 0.1 | 2 | 0.2 | Widening | | 1619 | | | | |
| York | Pavement Resurfacing | | | | Repair_ Maint | 3388 | | | | | |
| York | Cel River Rd S-50 Phase I | 2.5 | 3 | 7.5 | Widening | | 6000 | | | | |
| York | Riverview/ Riverchase | | | 1.14 | Widening | | 3406 | | | | |
| York | Riverview Road Exten-sion | 1 | 3 | 3 | New_Re-build | | 4250 | | | | |

| | lane-mi/yr | | | | | |
|---|---|---|---|---|---|---|
| County | 2014 | 2015 | 2016 | 2017 | 2018 | Comments |
| Union | | | | | | |
| Union | | | | | | |
| Union | 3.6 | | | | | SC 49 (S-425 (T. Wesley Dr.) to 0.21 Mi. S of S-291 (Fincher Rd.)) |
| Chester | | | | | | |
| Chester | 3.3 | | | | | SC 9 (0.26 Mi. S of S-259 (Melton St.) to SC 9 Bus. (Lan-caster Hwy.)) |
| Lancaster | | | | | | |
| Lancaster | | | | | | |
| Lancaster | 6.2 | | | | | S-50 (0.07 Mi. E of S-280 (Victoria St. ) to SC 9 (Pageland Hwy.)) |
| Lancaster | | | | | | |
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| | lane-mi/yr | | | | | |
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| York | | | | | | http://www.dot.state.sc.us/inside/pdfs/PublicHearings/SC160_handout.pdf |
| | | | | | | |
| York | | | | | | RFATS - dedicated left turn lane |
| York | | | | | | Phase II - SC 51 @ S-641 & S-328 @ S-48; US 21 Median Improvements & US 21 @ SC 51 |
| York | | | | | | RFATS - dual turn lanes |
| York | 10.1 | | | | | SC 49 (0.18 Mi. N of S-80 (Campbell Rd.) to SC 274 (Hands Mill Hwy.)) S-31 (S-710 (Firetower Rd.) to S-161 (Harmony Rd.)) S-697 (0.67 Mi. E of S-832 (Rowells Rd.) to SC 5) |
| York | | | | | | (US 21 to North of S-645) |
| York | | | | | | Intersection Improvements |
| York | | | | | | New 3 lane facility - Eden Terrace to Mt Gallant |

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