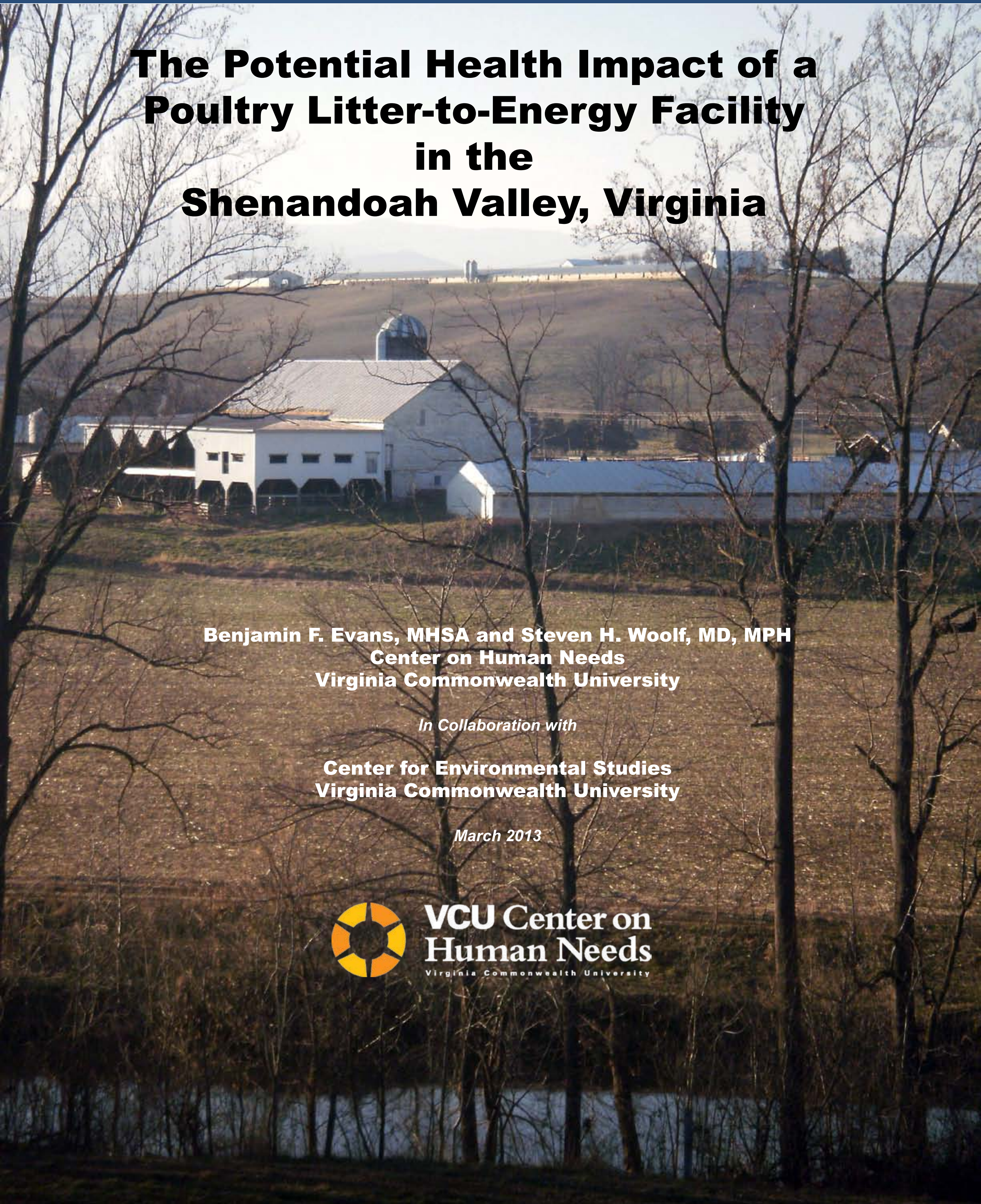

The Potential Health Impact of a Poultry Litter-to-Energy Facility in the Shenandoah Valley, Virginia

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Acronyms

$\mu g/m^3$	Micrograms per Cubic Meter
µg/L	Micrograms per Liter
AQI	Air Quality Index
BRFSS	Behavioral Risk Factor Surveillance System
CAA	Clean Air Act
CAFO	Confined Animal Feeding Operation
CDC	Centers for Disease Control and Prevention
CES	VCU Center for Environmental Studies
CHN	VCU Center on Human Needs
CO	Carbon Monoxide
CO2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disorder
CVD	Cardiovascular Disease
DCR	Virginia Department of Conservation and Recreation
dB	Decibel
DEQ	Virginia Department of Environmental Quality
E. Coli	Escherichia Coli
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ER	Emergency Room
ED	Emergency Department
HA	Hospital Admission
HAP	Hazardous Air Pollutant
HCl	Hydrogen Chloride
HIA	Health Impact Assessment
HRA	Health Risk Assessment
HuIP	Human Impact Partners
IEN	University of Virginia's Institute for Environmental Negotiation
lb/MMBtu	Pounds per Million British Thermal Unit
mg/L	Milligrams per Liter
N	Nitrogen
NAAQS	National Ambient Air Quality Standards

NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHTSA	National Highway Transportation Safety Administration
NO2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
NRC	National Research Council
SNP	Shenandoah National Park
SO2	Sulfur Dioxide
SOx	Oxides of Sulfur
O3	Ozone
OR	Odds Ratio
OSHA	Occupational Safety and Health Administration
RR	Risk Ratio
Pb	Lead
PM	Particulate Matter
PM2.5	Particulate Matter 2.5 Micrometers in Diameter
PM10	Particulate Matter 10 Micrometers in Diameter
ppb	Parts per Billion
ppm	Parts per Million
RfD	Reference Dose
TAN	Total Ammoniacal Nitrogen
TEF	Toxic Equivalency Factor
TEQ	Toxicity Equivalence
TMDL	Total Maximum Daily Load
UAN	Urea Ammonium Nitrate
USDA	United States Department of Agriculture
VCU	Virginia Commonwealth University
VDH	Virginia Department of Health
VHI	Virginia Health Information
VDACS	Virginia Department of Agriculture and Consumer Services
VOC	Volatile Organic Compounds
WHO	World Health Organization
WIP	Watershed Implementation Plan

Introduction

Funding for the HIA is provided by the Health Impact Project, a collaboration of the Robert Wood Johnson Foundation and The Pew Charitable Trusts.

Disclaimer: The views expressed are those of the author(s) and do not necessarily reflect the views of the Health Impact Project, The Pew Charitable Trusts, or the Robert Wood Johnson Foundation.

Under mandate from the U.S. Environmental Protection Agency's (EPA) Total Maximum Daily Load (TMDL) program, the Commonwealth of Virginia is required to reduce the amount of pollutant entering impaired water bodies and tributaries of the Chesapeake Bay. The Chesapeake Bay watershed encompasses approximately 64,000 square miles and 11,684 miles of shoreline.[1] The watershed includes parts of six states, Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia.[1] It is the first estuary[a] in the nation to be targeted for restoration as an integrated watershed and ecosystem.[1]

As of 2011, the water quality of the Bay suffered from numerous impairments: [2]

- 66% of the combined open water, deep water, and deep channel water volume failed to meet dissolved oxygen standards during the summer;[2]
- 95% of the tidal waters failed to meet the water clarity goal;[2]
- 82% of the tidal waters had chlorophyll a concentrations that failed to achieve goals;[2]
- 72% of analyzed tidal waterways had impairment from chemical contaminants.[2]

The health of the Chesapeake Bay and its ecosystems is dependent on the concentrations of many different chemicals, including the concentration of nutrients. Nutrients are necessary for plant and animal growth and survival, but elevated concentrations may contribute to ecological shifts that endanger aquatic life integral to the Bay's health. The nutrients that are the primary contributor to the Bay's poor health are nitrogen and phosphorus. Potential routes of entry for these nutrients are from wastewater, air pollution, and water runoff from the land. According to the EPA, the largest single source of nutrient loading into the Chesapeake Bay is agricultural practices, including fertilizer application.[3] Of the six states and the District of Columbia that make up the Chesapeake Bay watershed, Virginia contributes the second largest burden of nitrogen and the most phosphorus pollution.[3] The Chesapeake Bay TMDL for Virginia calls for a reduction of 53.7 million pounds of nitrogen and 5.7 million pounds of phosphorus by 2025.[3]

Almost one-quarter of the land area in the watershed is used for agriculture.[4] This includes both livestock and crop production. Over the past several decades, livestock production—and in particular poultry production—has become increasingly geographically concentrated.[5] Since 1978, the amount of poultry produced in the United States has increased 191%, while the amount of farms dedicated to raising poultry has decreased 15%.[5] In 1950, the United States produced just over 580 million chickens in total; by 2007, some states produced an even larger number of chickens by themselves.[5] One of the driving factors behind this concentration pattern has been economies of scale that have lowered costs in poultry producing regions. Lower production costs keep retail costs lower for consumers.

Poultry production in the watershed potentially affects water bodies through the management of manure. Poultry litter, a mixture of the bedding material that line the houses for the birds, manure, feathers, spilled water, and waste feed, contains high levels of nutrients, specifically nitrogen, phosphorus, and potassium. The high nutrient content makes poultry litter an excellent organic fertilizer for crops. Due to the relative scarcity of phosphorus in agricultural areas that lack livestock production, demand for poultry litter outside of the watershed is high. However, poultry litter is very dense and heavy, making

a An estuary is a water body were fresh and salt water mix transport over long distances costly. As a result, poultry litter is an ineffective commodity for wide geographic distribution, resulting in high quantities of nutrients to remain in areas of concentrated poultry production. If these nutrients are land applied and the nutrient content exceeds the nutrient demand of local crop, the risk of polluting local water bodies increases.

The Shenandoah Valley

The Shenandoah Valley[b] (heretofore referred to as "the Valley") is located in northwestern Virginia. In 2007, 720,000 acres—about 43% of land use— were dedicated to agriculture.[5] The Valley's poultry industry produced more than 86 million broilers[c] and turkeys, approximately one-third of the total state production.[5] In 2011, the Valley produced approximately 345,000 tons of poultry litter, virtually all of which was used to fertilize local crops.[6] This potential nonpoint source[d] of nutrients to the Chesapeake Bay tributaries has been identified by state environmental agencies as a potential intervention point to meet the TMDL reduction goals.

The success of the Valley's poultry industry is important not only to the region's economy, but also to the preferred lifestyle of its residents. Maintaining the rural character of the area is an explicit priority in the development plans of all four counties.[7-10] Using available land for crop production protects large areas of the region from other development uses that could alter the nature of life in the Valley. Livestock production also supplements crop production by providing a low-cost organic fertilizer. In order to meet the twin goals of attaining the nutrient reduction goals of the TMDL and continuing the success of the poultry industry in the Valley, alternative nutrient management practices need to be developed.

Poultry Litter Use as a Fuel

A substantial portion of the composition and weight of poultry litter is the woody biomass that lines the houses where the birds are grown. This component of the litter is a potential fuel source for energy and technologies that convert poultry litter into energy through a variety of thermal and non-thermal reactions are currently available for individual farmers or a co-operative of farmers. Large-scale, poultry litter-to-energy facilities also exist in the United Kingdom as well as in Benson, Minnesota. The combustion of poultry litter typically releases nitrogen into the atmosphere and leaves phosphorus in the ash byproduct. This byproduct is significantly reduced in weight and can be transported out of the watershed, thereby reducing the concentration of unnecessary nutrients and their threat to the watershed.

Although use of technologies that convert poultry litter into energy could potentially limit the amount of nutrient pollution in the Chesapeake Bay watershed, it could also introduce a new air pollution source. Both small- and large-scale combustion processes increase ambient air concentrations of potentially harmful substances such as oxides of nitrogen (NOx), oxides of sulfur (SOx), particulate matter (PM), volatile organic compounds (VOC), dioxins/furans, and other substances. In addition to harming air quality, the alternate use of poultry litter to generate energy could also potentially affect current poultry litter management practices—such as its transport and the income and employment that its use generates — which could subsequently affect the health of the population in the Valley. The purpose of this health impact assessment (HIA) is to inform decision-makers of the health tradeoffs related to a shift in poultry litter management from land application to use as a fuel source.

Description of the Decision That Will Be Informed By the HIA

Although there is no formal proposal for a poultry litter-to-energy facility in the Valley, the Virginia Watershed Implementation Plan (WIP) includes mention of such a facility:

"The Commonwealth is in the exploratory stages

b For purposes of this report, the Shenandoah Valley constitutes Augusta, Page, Rockingham, and Shenandoah Counties

c Broilers refers to chickens bread for consumption of meat

d A nonpoint source refers to a pollution source that is diffuse such as runoff from agriculture as compared with a concentrated source such as emissions from a smoke stack.

with a major energy firm to determine the impact and feasibility of a potential poultry litter to energy project in the Shenandoah Valley which would burn litter and export or landfill the residual materials. By 2025, this practice would impact 75,000 tons annually provided the residual materials are landfilled or exported outside the watershed."[11]

The findings and recommendations of this HIA will inform the following decision-makers:

- Fibrowatt, the technology company that would develop the proposal for the facility and, if approved, construct it.
- The local board of supervisors of the potential hosting county (Augusta, Rockingham, or Shenandoah County).
- The Virginia Department of Environmental Quality (DEQ), the agency responsible for attaining the goals of the TMDL and issuing an air permit for a potential facility.
- Local residents of the affected counties.

The decision by the local board of supervisors will likely take place in one of three counties: Augusta, Rockingham, or Shenandoah County. The Page County Board of Supervisors has already issued a ruling denying any future request to construct a facility and it is unlikely that this will change in the near future. The air permitting decision-making process will begin once a site is selected, a proposal is made, and the local board has approved its construction. The DEQ will be responsible for the decision and will allow for public comment during the process.

This HIA will focus its analysis on two alternative poultry litter management practices:

- Land application for use as fertilizer
- Combustion in a large-scale facility for use in energy production

Screening

The National Research Council (NRC) describes the screening process of HIA as:

"determin(ing) whether a proposal is likely to have health effects and whether the HIA will provide information useful to the stakeholders and decision-makers."[12]

The screening step in an HIA explores whether a particular policy or project decision could potentially have an impact on health, whether heath impacts are being considered in the decision-making process, and concludes whether or not an HIA would be beneficial to the process. Other important considerations include the distribution of impacts among the population (such as disproportionate impacts on vulnerable populations), the potential for an HIA to provide timely information to a decision, and the availability of data and resources to conduct an analysis. The screening for this HIA was conducted by the research team (defined below) in consultation with local stakeholders—including DEQ officers; the technology company that constructed the biomass facilities in the United States and the United Kingdom that are currently burning poultry litter; and environmental advocacy groups in the Valley.

The proposal to build a large-scale, poultry litter-to-energy facility has generated some opposition among the public. In a public meeting held in Page County in March 2010, residents expressed a wide range of concerns, including apprehension about the potential health impact (Box 1). If constructed, the facility would emit pollutants that have an established association with increased risk of poor health. Without an HIA, it would be unclear whether these emissions would exceed thresholds at which health would be compromised or the degree to which health would be compromised. Conversely, the facility could benefit health by reducing nutrient pollution of the Chesapeake Bay and thereby reduce contamination of drinking water and exposure to impaired water bodies during recreational activities. Lastly, household income and employment are determinants of health, and these could be affected by the opening of the facility. These preliminary considerations persuaded the research team that the decision about constructing a poultry litter-to-energy facility could potentially impact health.

Because nutrient pollution in local water bodies can impact downstream areas, any decision that reduces nutrient pollution can benefit residents throughout the watershed but detrimental effects on air quality, truck traffic, employment, and income are more likely to have local impacts. Virginia communities

Box 1 – Comments from the public meeting of the Page County Board of Supervisors on a potential large-scale poultry litter-to-energy facility in the Valley: 3/16/2010

"For God's sake, does EDA committee and the board, whoever is in charge, if you'd just take a look at the last few decisions that they've made on our behalf, they buy land in Luray, assessed at $48,000 and pay $648 for it, they pay $7 million for a million dollar project here, and the very same people is coming to us now to put a smoke stack in Page County that provides dioxin to eventually kill the population, do these people have any credibility?"

"There was a letter to the editor recently by the VFW. It was a good letter that cited the effects of Agent Orange and the NOx that would be produced by this plant. And I think there are a lot of other ways to bring business to our community without bringing something that's going to hurt us overall and be a long-term problem. Once it's here, once it pollutes, it's never going to leave."

"Mainly what I do now is environmental allergies, illnesses caused by things in the environment…In this suitcase I have vials from all, I've done everything, a good many things are in our environment that people react to. And I think I got vials from most of the things, that is byproducts of this operation. I have a dioxin vial, CO2, CO, acid, I've got stuff for lungs, I can see a lot of sickness coming with this. I really can. And I treat this type of sickness, it's all I do anymore. So if this is introduced into our environment, you're going to make me rich."

"Everybody wants jobs to be available. But the Fibrowatt company, upon easy research, had glaring, objectionable, health-destroying deficiencies that should have quickly and easily excluded it from talks with Page County, long before it got to this point."

in the Chesapeake Bay watershed include urban communities near Washington, D.C., the more affluent suburbs of Northern Virginia, and the rural areas of the Valley. The distribution of health effects across these different populations is also an important consideration in the decision.

Although health is an obvious concern of the public and the decision-makers, evaluating the health impacts typically does not occur until late in the process. Before a facility can be constructed, the decision-making process will go through three distinct phases:

Proposal Development – Currently, the development of the proposal is solely in the hands of the technology company proposing the facility. This group will independently determine the location of the facility, establish the process for supplying fuel, and determine the characteristics of the operations such as the emissions control technology. Health is a likely consideration for this group so as to avoid denial for health reasons, but an analysis by the developer involves an entity with a vested interest in construction of the facility, and its findings are not required to be reported.

Local Approval – Once a proposal is made, the facility will be approved or denied by local elected officials in the hosting county in a process that involves public hearings and discussion but no systematic investigation of the health impacts. Without a formal HIA, elected representatives with concerns about the health impacts of the facility can only base their decision on comments from the technology company and any other interested party (such as residents, environmental groups, and agricultural groups).

Air Permit – If approved by local officials, the technology provider must then apply to DEQ for an air permit. At this stage, a comprehensive air modeling effort is conducted in order to determine if the facility would violate federal and state air standards and if emissions controls and operations of the facility would exceed a minimum impact on health. However, only health impacts associated with air quality are considered in this permitting process; impacts on other health determinants are not components of this analysis.

Residents have concerns about the environmental effects of the facility and how they would impact human health. As already noted, in a public meeting in Page County, VA, a number of the attendees voiced concern about the health impacts related to air quality (Box 1). Although residents do not specifically mention concern about *health impacts* related to economic and social impacts of the facility in the publically available statements, they do express concern about certain economic and social consequences of the facility:

> *"We live in one of the most upscale neighborhoods in Page County, directly across the street from the property that we're talking about putting Fibrowatt on. I just want to know if any of you have given any consideration to what it's going to do to the property value around that neighborhood."*

> *"It's potentially gonna present a lot of negative externalities that no one, as far as I know, has even tried to quantify. Do a cost benefit analysis and do it fairly and diligently. How much more will it cost for example to repair the roads due to the higher traffic from heavy trucks rolling down the roads. Has anyone quantified that? Opportunity costs, if we put that here, what do we lose that might have come here instead? That is such a critical question to ask. I don't hear anyone asking it yet."*

In preparation for a proposal by a technology vendor to construct a poultry litter-to-energy facility, the DEQ prepared a scope of work for an analysis to determine the environmental impacts of such a facility. It formed the Poultry Litter-to-Energy Advisory Group composed of local stakeholder who stressed the importance of including an analysis of health impacts. Transcripts of meetings of the group and public comments illustrated a deep concern over the health impact of the proposed facility and disappointment that concerns about potential health impacts would not be considered until the air permitting process. Despite these requests, the DEQ did not include an analysis of health impacts from the facility, arguing that any facility would have to address health impacts from changes in air emissions when it applied for an air permit.

In subsequent public statements after the scope of work was issued, stakeholder organizations have cautioned that postponing consideration of health impacts until the air permitting process may be too late. By then, important decisions about the proposed facility, such as its location, must already be determined precluding consideration of other locations that might be better for health. In addition, the local board of supervisors will have to make its approval decision without an unbiased, rigorous analysis of the full health impacts.

The research team therefore determined that conducting an HIA on the proposal in question would add value and serve to increase the consideration of health in the decision making process. We began the HIA at an early stage, before the vendor had made a formal proposal to construct a large-scale, poultry litter-to-energy facility in the Valley. The technology company was evaluating locations and had not made any potential sites public. We began the HIA at this early stage in an effort to help inform the proposal development and to allow ample time to engage stakeholders, conduct analysis, and disseminate results before a final decision was made.

Research Team

The primary entity responsible for the production of this report was the Virginia Commonwealth University (VCU) Center on Human Needs (CHN), an academic research unit that studies issues related to health equity and the social determinants of health. The CHN team at VCU managed the project, organized stakeholder involvement, formed the analytic plan, conducted literature reviews, and wrote the report. CHN collaborated with the VCU Center on Environmental Studies (CES), which was primarily responsible for conducting the air models associated with the assessment phase and providing guidance on environmental issues. We formed an advisory panel composed of 10 stakeholders[e] who provided periodic feedback throughout the project. Technical assistance and HIA training was provided by the Human Impact Partners (HuIP).

Summary

Transcripts of public meetings and written comments from members of the DEQ Poultry Litter-to-Energy Advisory Group illustrated a deep concern over the health impact of the proposed facility and disappointment that concerns about potential health impacts would not be considered until the air permitting process. Without advanced analysis, county board of supervisors will be uninformed of the magnitude and location of air impacts from a poultry litter-to-energy facility. Public comments reveal a concern over the economic and social impacts of such a facility; however, these issues are not being evaluated for their impact on health. Conducting an HIA on this issue will provide information to decision-makers on the magnitude of the health impact from changes in air quality and other potential impacts that have not been addressed during the early public deliberation.

e For more details on the advisory panel, see the scoping section of the report.

Scoping

The NRC describes the scoping process of HIA as:

"establish(ing) the scope of the health effects that will be included in the HIA, the population affected, the HIA team, sources of data, methods to be used, and alternatives to be considered"[12]

The scoping step in an HIA is used to identify the areas of focus for the analysis. The proposed policy can affect a range of health determinants but limited time and resources prevent examination of every issue and require parsimony and a priority-setting process to focus on key issues.

Stakeholder Engagement

A key component of scoping is identifying and engaging stakeholders that could be impacted by the decision or could influence the outcome, either as advocates or policymakers. As noted early, the DEQ established an advisory group on poultry litter-to-energy matters in 2011. The panel was composed of members of national and state government agencies, advocacy groups, the major power company of Virginia, a technology company that constructs such facilities, universities, and other stakeholders. They were notified at the beginning of our project that the decision about constructing a poultry litter-to-energy facility was to be the subject of an HIA.

The members of the advisory group were invited to a training session on conducting HIAs that was led by HuIP. The DEQ poultry litter-to-energy advisory group received the invitation by email and was encouraged to forward the invitation to other groups that might also have an interest in the topic. Ten people[f] attended the two-day session which included HIA training and planning sessions directed specifically at the proposed poultry litter-to-energy facility. The group included members of:

- Virginia Department of Environmental Quality
- Virginia Department of Agriculture and Consumer Services
- Chesapeake Bay Commission
- Virginia Cooperative Extension

In order to get feedback from a wider audience, a four-hour public meeting was held in New Market, Virginia on March 30th, 2012 to hear from concerned community members and organizations about the most important health impacts of a large-scale, poultry litter-to-energy facility. Prior to the meeting, diagrams that illustrate the different pathways through which health could be impacted by the facility were prepared by the research team. These pathway diagrams are included below.

Pathways

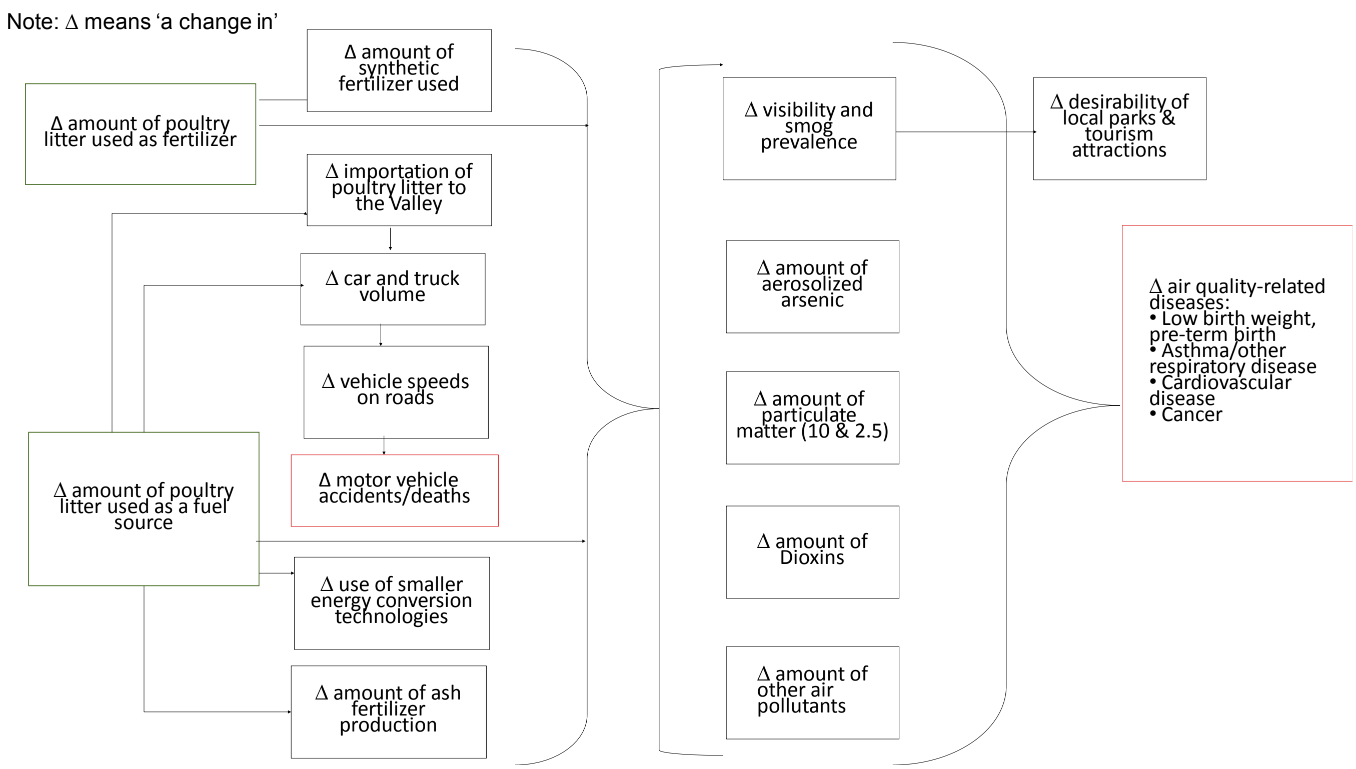
- Air Quality
- Water Quality
- Economic Effects
- Employment
- Other Community Factors

f The ten people that attended this training session do not directly correspond with the ten people in the HIA's advisory panel mentioned later in the report. Some attendees of the training session did participate in the advisory panel and others did not.

Air Quality

Because the facility would use a combustion process in the conversion of poultry litter into energy, a large-scale facility would result in an increased concentration of Hazardous Air Pollutants (HAPs). These emissions may be associated with increased risks of asthma, chronic obstructive pulmonary disease, heart disease, and cancer. Changes in heavy truck traffic to serve the facility could also affect air quality. Finally, the effect on air emissions associated with the transfer, storage, and land application of poultry litter as fertilizer must be compared with the air impacts of using litter as a fuel source.

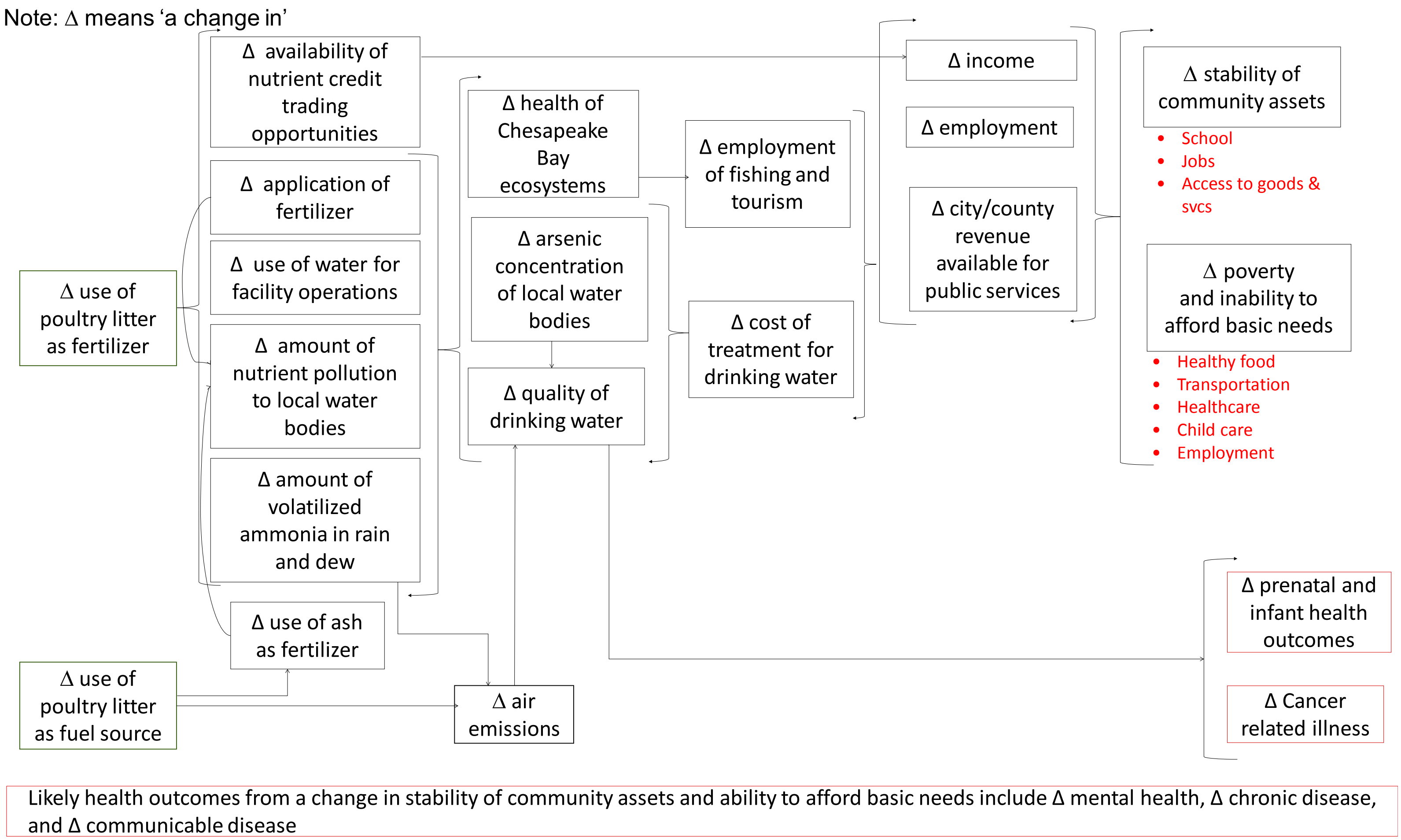
Figure 1: Air Quality Pathway Diagram



Water Quality

Land application of poultry litter has the potential to result in nutrient runoff and groundwater leaching of pollutants to local water bodies. Use of poultry litter as a fuel source is an alternative to land application that allows poultry farmers to use a valuable byproduct without harming local water bodies. However, the emissions from the energy conversion process could cause pollutants to accumulate in rain and dew, which could also lead to pollution of local streams in the Valley. In addition, the use of commercial fertilizers, which is likely to increase if poultry litter is removed as a viable option, could affect soil health and ultimately water health.

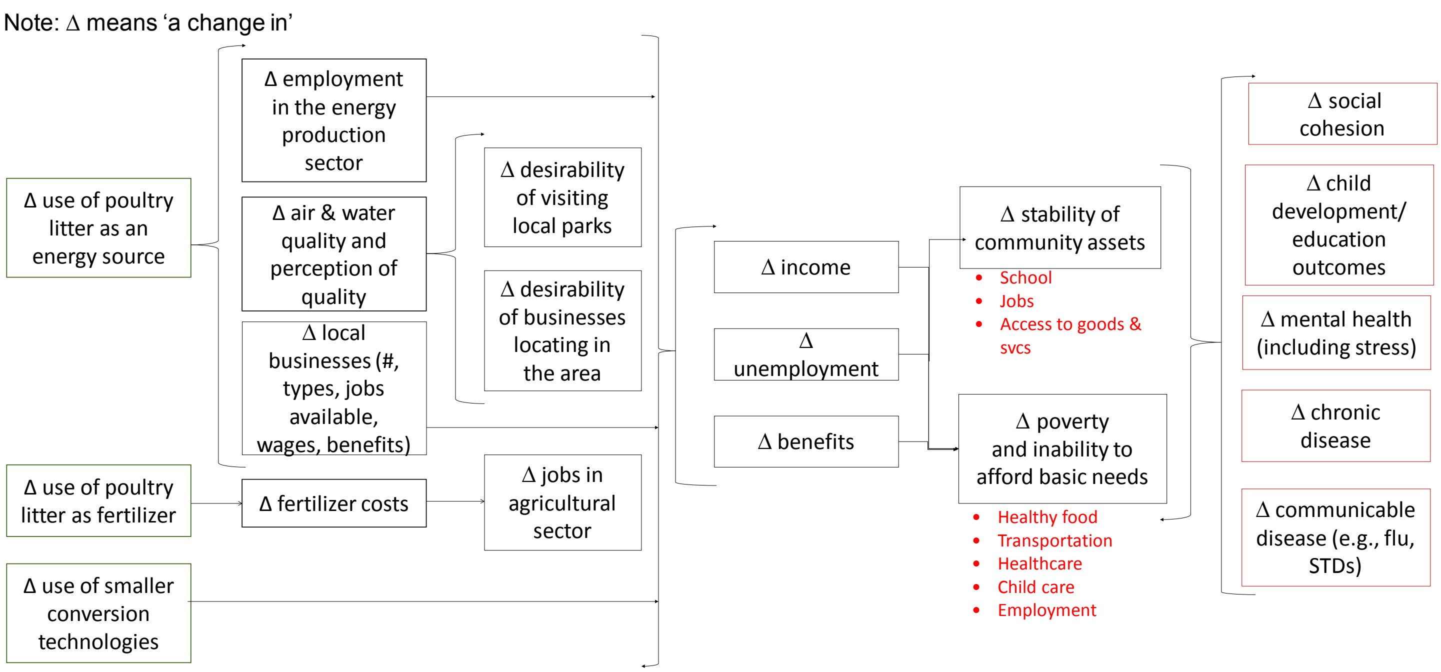
Figure 2: Water Quality Pathway Diagram



Employment

The proposed facility would introduce a new job source to the area as well as an increased demand for supplemental services such as truck driving. By adding a new revenue stream for poultry farmers, it would also offer a potential economic benefit to poultry farmers, brokers, and applicators. Conversely, a large facility would remove other revenue opportunities from poultry litter, such as fertilizer use, compost, or conversion via smaller, on-farm technology. Moreover, impaired air or water quality might diminish tourism, particularly in the region's national park, and its related sources of revenue, such as cabin rentals.

Figure 3: Employment Pathway Diagram



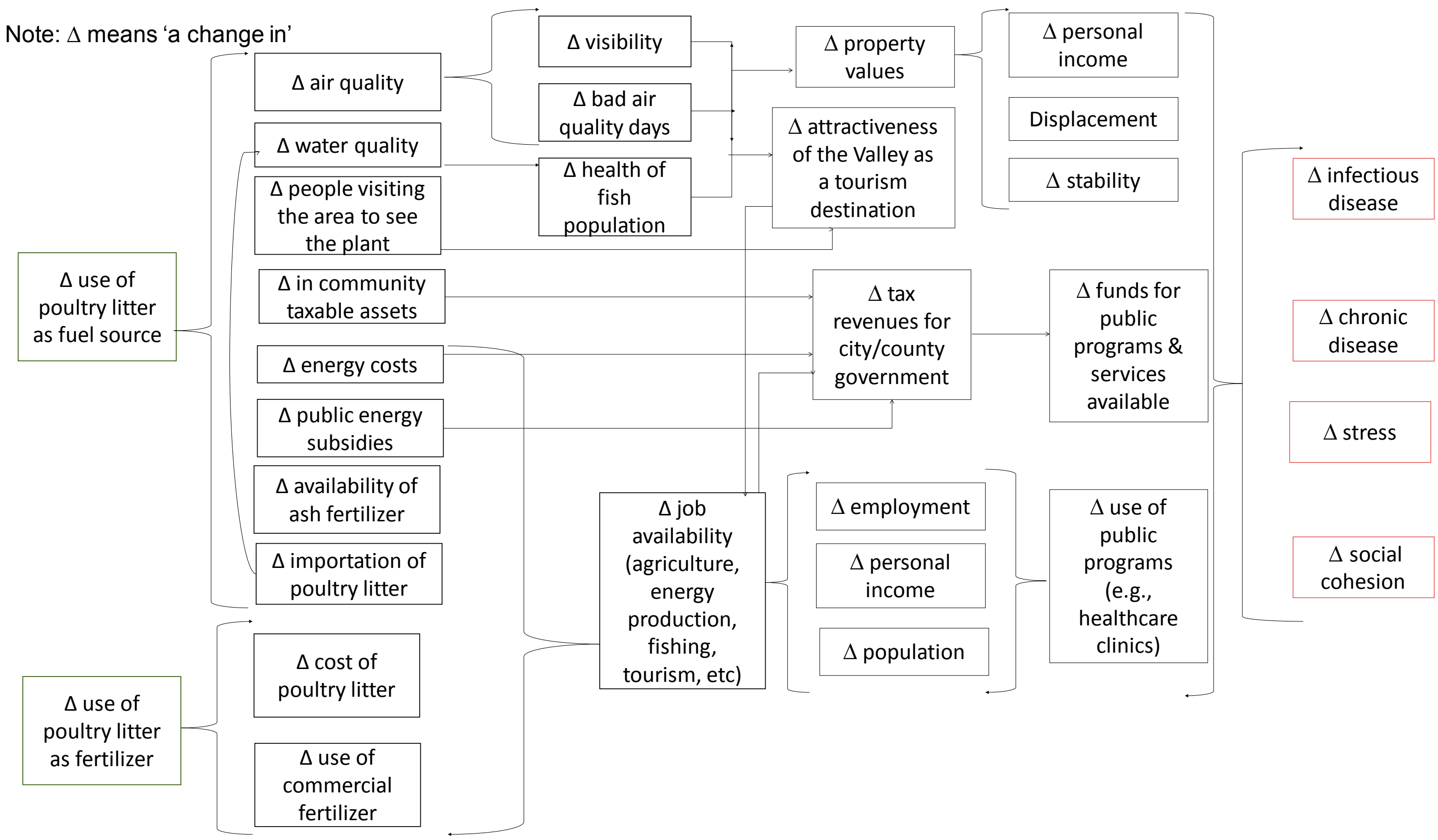
- Health impacts of mental health include: stress-related illness, substance abuse, decrease in lifespan
- Health impacts of chronic disease include: heart disease, diabetes, hypertension,

Local Economy

Apart from its effects on jobs, the proposed facility could have other important impacts on economic interests in the area, which might also impact health. Energy production might lower utility costs, and using poultry litter as fuel and the ash byproduct as fertilizer could benefit farmers financially. Conversely, detrimental effects on real or perceived air quality could lower property values in the community.

using poultry litter as fuel and the ash byproduct as fertilizer could benefit farmers financially. Conversely, detrimental effects on real or perceived air quality could lower property values in the community.

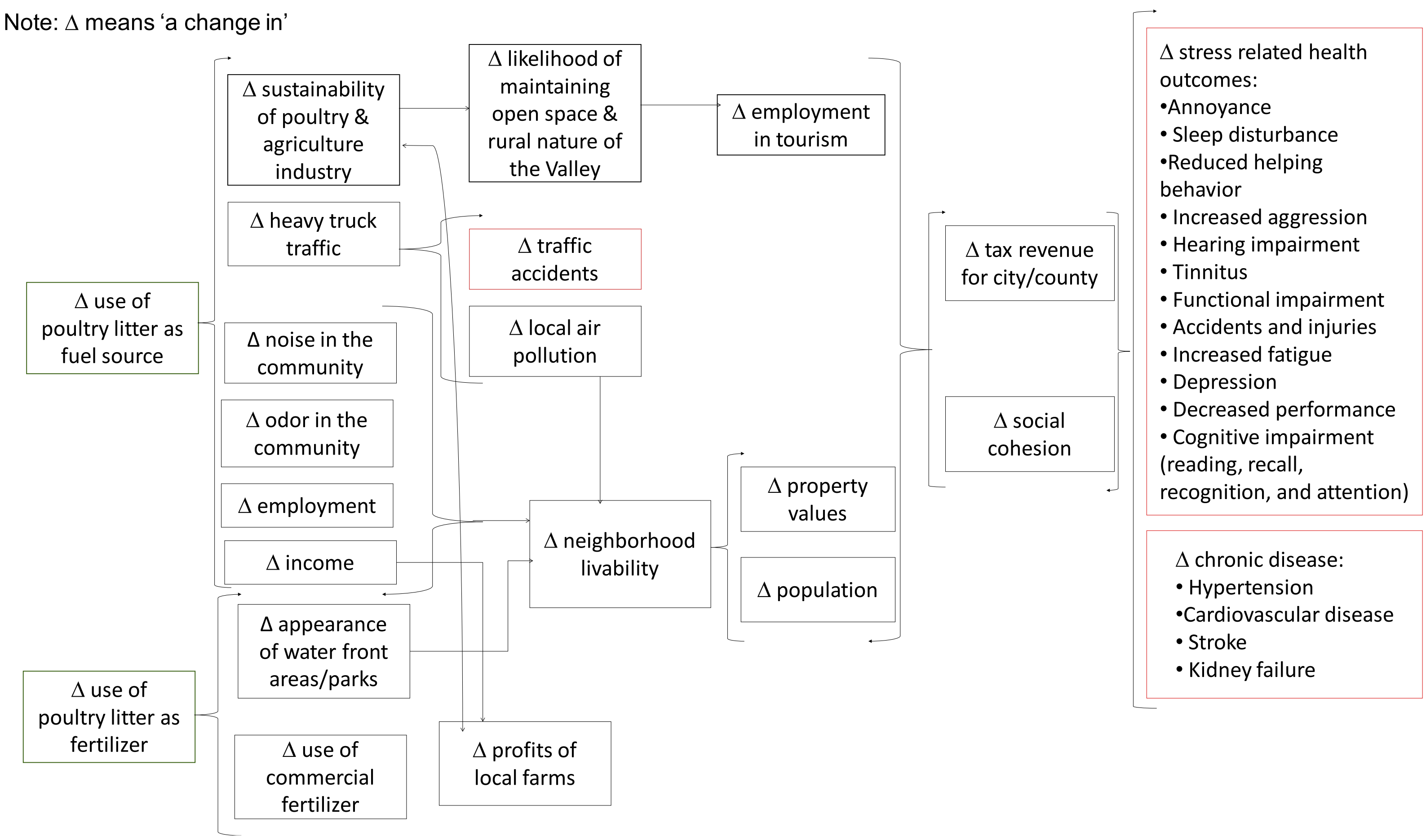
Figure 4: Local Economy Pathway Diagram



Other Community Factors

An increase in heavy truck traffic on the Valley's highways resulting from the establishment of a new facility could affect noise and odor levels. The facility's tall smoke stack, although necessary to disperse emissions for better air quality, could interfere with existing view sheds. As already noted, the long range planning reports for all four counties highlight the importance of maintaining the historic rural nature of the Valley, which is rotted in agriculture and the presence and viability of the local national parks.

Figure 5: Other Community Factors Pathway Diagram



How research questions were determined

Questions of Importance to Community

Appendix A provides a full report on the feedback from the community meeting in March 2012. Research questions were identified to explore the hypothesized links in the pathway diagrams and to identify the strength and direction of putative associations with health outcomes. Guided by community input, the research team identified the following 23 research questions:

Air Quality

1. How would the operations of the facility impact air quality in the region?
2. How would the transition from land application of poultry litter to commercial fertilizer impact ambient air concentrations of ammonia and PM?

Water Quality

3. How would the transition from land application of poultry litter to commercial fertilizer impact the introduction of nutrient runoff to local water bodies?
4. How would atmospheric deposition of air emissions of nutrients from a new energy facility impact local water bodies?
5. How would the use of water in the industrial process of energy production impact local water quality?

Employment

6. How would employment in the energy production sector be impacted by a new poultry litter-to-energy facility?
7. How would employment in the poultry/agriculture industry be impacted by a new poultry litter-to-energy facility?
8. How would employment in the fishing industry be impacted by a new poultry litter-to-energy facility?
9. How would employment in the tourism industry be impacted by a new poultry litter-to-energy facility?

Local Economy

10. How much additional community revenue would result from additional taxes and jobs provided by the facility?
11. How would a transition from the use of poultry litter as fertilizer to commercial fertilizer impact the costs associated with managing crop land?
12. How would a change in soil quality as a result of changes in fertilizer management impact the costs associated with managing crop land?
13. How would a new poultry litter-to-energy facility impact energy/utility costs among residents?
14. How would a new poultry litter-to-energy facility impact the economic benefit of nutrient credit trading?
15. How much support from state subsidies would a new poultry litter-to-energy facility require?

Other Community Factors

16. Will the facility assist in maintaining the rural/agricultural nature of the Valley?
17. Will the facility create an eye sore that decreases neighborhood livability?
18. How will the level of community noise change as a result of the new facility?
19. How will the level of community malodors change as a result of the new facility?
20. How will the facility impact the perception of the Valley as a place for economic development in the eyes of outside businesses?

Common Questions

21. How would a large-scale, poultry litter-to-energy facility impact the adoption of alternative litter management techniques and technologies?
22. How would a large-scale, poultry litter-to-energy facility impact the amount of heavy truck traffic in the community?
23. How would a large-scale, poultry litter-to-energy facility impact the National Parks in the Valley and how would that impact the economic and employment benefits that the Parks provide?

Initial Questions Excluded from Analysis

The following questions were considered by the research team during preparation for the community meeting but were ultimately excluded from analysis:

- The impact on greenhouse gases and climate change.
  Rationale: This was not mentioned as a priority among community members and the research team was skeptical as to whether it would be able to address this question.
- The impact that impaired air quality would have on physical activity among Valley residents.
  Rationale: This was not mentioned as a priority by the community and the research team questioned the availability of data and research necessary to establish this link and make appropriate prediction of its impact.
- The impact of meeting the TMDL requirements on housing and property values for shoreline communities of the Chesapeake Bay.
  Rationale: A majority of the population impacted by this research question live outside of the study area. In addition, the biomass facility is only one component of the TMDL project and pollution reductions would likely be addressed via other approaches even if the facility were not constructed. Thus, there would likely be little difference in this health effect regardless of whether or not the facility was constructed.
- The impact on the diversification and expansion of extant businesses in the Valley as a result of constructing the facility.
  Rationale: The research team felt that it would be labor intensive to address this question and the community did not mention it as a priority.

Advisory Panel

- In an effort to receive more periodic feedback and meaningfully incorporate a diversity of perspectives from local stakeholders, we formed a 10-member advisory panel. We circulated a monthly newsletter—*The HIA Chronicle*— that gave the panel an update on the analysis and held monthly conference calls to discuss progress in the steps of the HIA process. In addition to community residents, panel members included representatives of the following groups[g]:
- The Virginia Department of Environmental Quality
- The Virginia Department of Agricultural and Consumer Services
- The Chesapeake Bay Commission
- The Shenandoah Valley Network
- The National Park Service
- The Shenandoah Riverkeeper

In order to identify the research questions of most importance to the decision-making process as well as limit the analysis to a reasonable number of questions, the advisory panel was asked to identify priorities among the 23 research questions posed by the attendees of the community meeting. The group identified the following six priorities:

- **Air Quality**: an analysis of how air quality might be affected by the operations of the facility and by changes to the type and methods of fertilizer application.
- **Water Quality:** an analysis of how water quality might be affected by a change in the type of fertilizer applied, the deposition of air pollutants into water bodies as a result of the facility's operations, and pollutants introduced by the release of water from the facility after its use in the industrial process.
- **Truck Traffic:** an analysis of the impact of trucking on air quality, automobile and pedestrian collisions, and noise levels.
- **Poultry/Agricultural Employment:** an analysis of the effect on job opportunities among poultry growers, litter brokers, and crop farmers.
- **Alternative Technologies:** an analysis of smaller, on-farm poultry litter-to-energy technologies[h].
- **National Park:** an analysis of the economic impact on the Shenandoah National Park.

g Participation in the advisory panel by members of these organizations should not be viewed as explicit endorsement of the project's findings by the individuals or the groups they represent.

h Other litter management strategies also have the potential to reduce nutrient concentrations in the area.

Appendix B provides a complete list of research questions, along with data sources and methods.

Summary

The research questions that form the basis of this HIA emerged from a preliminary understanding of the potential impacts of a proposed poultry litter-to-energy facility and the feedback received by community members and interested parties in the Valley. The research team held a two-day training on HIA methods and practices, and many of those who attended that meeting remained engaged throughout the HIA process as members of an advisory panel. The initial list of research questions was created based on feedback from a community meeting where members of the public articulated their health concerns about the facility. The resulting list was prioritized by the advisory panel. It focused on air quality, water quality, employment in the poultry/agriculture industry, truck traffic, alternative technologies, and the national park.

Assessment

The NRC describes the assessment process of HIA as:

"involve(ing) a two-step process that first describes the baseline health status of the affected population and then assesses potential impacts"[12]

The assessment phase of an HIA describes the existing health conditions in the study area and attempts to predict the potential beneficial and adverse health impacts of a poultry litter-to-energy facility. The methods used to predict impacts include:

- A review of the literature;
- Focus group and key interviews;
- Quantitative modeling of truck traffic; and
- Air modeling

A further description of the methods is included in the narrative below as well as in Appendix C.

Current demographics in the Valley

The Valley is located in the northwestern portion of Virginia, about 130 miles from Washington, D.C. With the exception of a few urban areas such Harrisonburg and Staunton, the area is largely rural with agriculture playing a large role in the culture of the community. The presence of the Shenandoah National Park makes the area a popular tourist attraction. A clean, healthy environment is a key asset to both the economic success of the region and the population's perceived identity as a group.According to the U.S. Census Bureau, there was an average of 215,411 residents in the Shenandoah Valley during 2006-2010.[13] The proportion of the population that is non-Hispanic White is significantly larger than that found in either Virginia or the United States as a whole (Table 1).

Table 1: Race/Ethnicity in the Shenandoah Valley, Virginia, and the United States

	Shenandoah Valley	Virginia	United States
White Non-Hispanic	92.2%	65.7%	64.7%
Black Non-Hispanic	2.7%	19.3%	12.2%
Hispanic	3.7%	7.3%	15.7%
Other	1.4%	7.7%	7.4%

Source: U.S. Census Bureau, American Community Survey, 5 Year Estimates. 2006-2010

Racial and Ethnic Integration

The vast majority of the population is non-Hispanic White, a majority that is far larger than the one seen in either Virginia or the United States (Table 1). Standard metrics of residential segregation by racial and ethnic class indicate the Valley has a comparatively high level of integration. The *Index of Dissimilarity*[i] (a measure of the evenness in the distribution of classes) was 0.49 for the White/Black distribution and 0.43 for the White/Hispanic distribution.

Population Age and Income

The Valley is home to a larger senior population (age 65 and up) as well as a larger group between the ages of 45 and 64 than either Virginia or the United States (Table 2).

Table 2: Gender and Age Distribution in the Shenandoah Valley, Virginia, and the United States

	Shenandoah Valley	Virginia	United States
Male	50.0%	49.1%	49.1%
Female	50.0%	50.9%	50.9%
Under 18	22.6%	23.5%	24.4%
18 - 44	32.6%	38.1%	37.0%
45 - 64	28.9%	26.6%	25.9%
65 and older	15.9%	11.8%	12.7%

Source: U.S. Census Bureau, American Community Survey 5 Year Estimates. 2006-2010

Median income among Valley residents is slightly less than that of the United States and significantly less than that of Virginia (Table 3). Among the counties in the Shenandoah Valley, Page County has the lowest

i The *Index* describes how the racial and ethnic makeup of smaller areas within the Valley compares to the racial/ethnic distribution of the area as a whole. It ranges from 0 to 1 with higher numbers indicating spatial isolation of minority populations from the majority race/group. The interpretation of the value is the percentage of the minority population that would have to relocate in order to attain a completely integrated population.[14] In comparison to the top 100 largest metro areas in the United States, the Valley's *Index* scores would rank 82nd and 66th for White/Black and White/Hispanic comparisons, respectively.[15] However, rural areas often have lower scores than urban areas so this comparison should be interpreted cautiously. The largest Black population in the Valley is found in southwestern Augusta County while the largest Hispanic population is in southeastern Rockingham County.

Table 3: Income-to-Poverty Ratio and Median Income in the Shenandoah Valley, Virginia and the United States

	Shenandoah Valley	Virginia	United States
Median Income	$41,617 to $50,612	$ 61,406	$51,914
	Income to Poverty Ratio		
<50%	2.6%	2.9%	4.0%
50% - 99%	4.5%	4.3%	6.0%
100% - 199%	16.4%	12.6%	15.6%
200% - 400%	37.6%	28.6%	30.6%
400% and up	38.9%	51.6%	43.7%

Source: U.S. Census Bureau, American Community Survey, 5 Year Estimates. 2006 - 2010

median income ($41,617) while the highest median income ($50,612) is found in Augusta County. Families in the Valley have a slightly higher rate of near poverty[j] than either Virginia or the United States, but have a lower poverty rate. Among individual counties, the highest poverty rate was in Page County with the lowest in Shenandoah County.

Education

Almost two-fifths of adults age 25 and older in the Valley have high school graduation as their highest level of educational attainment, a rate significantly higher than either Virginia or the United States (Table 4). In addition, a relatively small proportion of the adult population has attained a Bachelor's degree or higher. Page County has the highest percentage of adults without a high school education (27.5%) and the lowest percentage of adults with at least a Bachelor's degree (11.1%).

Air Quality

The proposed facility could affect air quality because of the emission of pollutants related to its operations, notably ***NOx***, ***SOx***, and—of particular concern—***PM***, as well as the contribution of ***ammonia-nitrogen*** to the Valley atmosphere related to fertilization practices.

j Near poverty is defined here as household income that falls between 100% and 200% of the federal poverty limit.

Table 4: Educational Attainment for Adults 25 and over for the Shenandoah Valley, Virginia, and the United States

	Shenandoah Valley	Virginia	United States
Less than high school	19.7%	13.9%	15.0%
High school only	39.8%	26.0%	29.0%
Some college	21.6%	26.3%	28.1%
Bachelor's or higher	18.8%	33.8%	27.9%

Source: U.S. Census Bureau, American Community Survey, 5 Year Estimates. 2006 - 2010

An estimated 16% of total atmospheric ammonia emissions in the United States originate from poultry production and research in the Valley links atmospheric ammonia-nitrogen levels to the poultry industry.[16] Ammonia volatilization occurs from litter on the floor of poultry houses, during storage, and during land application. Airborne ammonia-nitrogen can travel great distances and deposit in rainwater, resulting in increased nitrogen runoff into local water bodies. Finally, although ***arsenic*** is no longer commonly used in poultry feed, the proposed energy facility raises continuing concerns about potential emissions for multiple reasons (Box 2).

Unfortunately, the resources available for this project were not sufficient to conduct an air model of all the compounds noted as important by the community and our advisory team.[k] Therefore, although a much longer list of emissions are regulated by governmental authorities, we focused on four air pollutants identified by the community and our advisory panel:

- Nitrogen oxides
- Sulfur oxides
- Particulate matter

k Because VOCs and dioxins/furans represent a large class of compounds with different physical properties that would impact the air model, these classes were much more resource-dependent than the other four of interest: NOx, SOx, PM2.5, and arsenic. Modeling either VOCs or dioxins/furans would exhaust the resources of the project without allowing for modeling of any other compound. For this reason, the decision was made to model the four compounds completely and describe the potential impacts of VOCs and dioxins/furans in the narrative below.

- Arsenic[1]

Why Air Quality Matters to Health

According to a variety of studies, human exposure to NOx, SOx, and PM2.5—all potential products of litter combustion—has been linked with an increased risk of respiratory and cardiovascular symptoms and with higher mortality rates.[17-19] People exposed to NOx are 4-75% more likely to report respiratory symptoms such as cough, shortness of breath, and wheezing.[20-23] They also have higher rates of admissions to emergency departments (EDs) and hospital admissions (HAs) for asthma[24-39] and other respiratory diseases.[26, 37, 40-49] This association has been reported in the general population[25, 26, 34-38, 40-43, 50] as well as specifically among children,[26, 37, 45-50] adults,[25, 29, 31, 33, 45] and older adults.[28, 39, 45, 46, 51] The reported increase in risks is 2-40% for all ages,[40, 52] 3-35% for children,[28, 45] 3-30% for adults,[32, 33] and 7-10% in older adults.[29, 53] Lastly, some studies have claimed a 1-10% increase in respiratory mortality among people exposed to NOx.[54-58]

Similar complications are reported in studies of exposure to SOx, another potential pollutant from litter combustion. Short-term exposure is associated with a 4-31% increase in respiratory morbidity[59-63] and a 7-20% increase in ED visits and HAs for respiratory distress.[64-71] Research has also linked short-term SOx exposure to cardiovascular morbidity[72-78] and ED and hospital visits for cardiovascular symptoms.[77, 78] Studies that looked at the association with respiratory morbidity found odds ratios that ranged from a 15% to 30%.[72, 77] Short-term SOx exposure is also associated with a 2.6-6.9% increase in all-cause mortality rates.[79-87] Long-term exposure to SOx may also have health consequences, even at lower concentrations, including respiratory morbidity,[88] cancer incidence and mortality,[89-91] prenatal and neonatal outcomes,[92, 93] and all-cause mortality.[91, 94-96]

Box 2 – Arsenic in Poultry Litter

Community concern about arsenic is related to the common poultry industry practice of using feed additives or medications that contain arsenic. The primary concern was the commercial feed additive, Roxarsone, which contains arsenic to inhibit bacterial growth in the poultry gut. Data reported in 2008 by the CES and the DEQ documented the presence of arsenic in litter produced in the Valley. In July 2011, Alpharma, the manufacturer of Roxarsone, voluntarily removed the product from the market.[179] Poultry farmers were allowed to use inventories of Roxarsone that were still on hand. Although it is possible that some farmers could have this product stockpiled, it is unlikely that Roxarsone would still be used by the time the proposed facility would be constructed.

That said, there is no legal barrier to the return of arsenic in poultry feed if a demand existed. The permit issued by the U.S. Food and Drug Administration is still valid. Arsenic may persist as an issue for other reasons. It is a naturally occurring metal that often contaminates the wood shavings that line poultry houses, which could mix with the feces and be emitted on combustion. Other arsenicals are used by poultry farmers, such as Nitarsone, an arsenic-based medication, which is used in outbreaks of blackhead disease in turkeys. Arsenic concentrations similar to those found when Roxarsone was available are unlikely for a medication, which is used in smaller quantities than a feed additive, but litter produced by turkey flocks that experienced blackhead disease would be expected to harbor higher arsenic levels.

The risk due to exposure to PM is typically distinguished based on the size of the particles that are suspended in the air. Coarse PM is distinguished as particles that are between 2.5 and 10 µm in diameter (PM10). Fine PM is considered anything that is less than 2.5 µm in diameter (PM2.5). The health con-

1 In addition to arsenic, previous measurements of poultry litter also indicate concentrations of selenium and cadmium. Selenium's EPA-established RfD for non-carcinogenic health effects through oral exposure is 5e-3 mg/kg/day.[180] Cadmium is not listed in EPA's Integrated Risk Information System but has been shown to be associated with the inhibition of cancer fighting cells in mice.181 EPA's 2008 National Emissions Inventory Data lists selenium emissions in the Valley at 29.6 lbs for a daily average of 8.1E-2 lbs/day.[157] Cadmium emissions in the Valley for the same year were 10.3 lbs for a daily average of 2.8E-2 lbs/day.[157] Rockingham County had the largest level of emissions for both selenium and cadmium among Valley counties.[157]

Table 5: Disease-Specific Mortality and Mortality Rates for the Shenandoah Valley

	Augusta		Page		Rockingham		Shenandoah	
	#	Rate	#	Rate	#	Rate	#	Rate
Chronic Lower Respiratory Disease	31	31.7	16	49.1	36	37.4	23	36.7
Cancer	137	146.2	59	187.8	147	151.9	96	164.1
Heart Disease	148	170.4	78	247.2	128	134.0	84	135.0

Source: Virginia Department of Health, County Health Profile. 2010
Rates are per 100,000 persons and are age adjusted

sequences of exposure to PM are well documented. Although long-term exposure[m] to PM10, even at lower concentrations, has been shown to be associated with a 16-34% increase in cardiovascular mortality,[97, 98] exposure to PM2.5 may be of greater importance because smaller particles can diffuse to smaller airways and possibly enter the circulatory system. Short-term exposure of PM2.5 has been linked with increased ED visits and HAs for respiratory illnesses (a 2.8-4.5% risk increase),[99, 100] asthma (a 10.1% risk increase),[101, 102] and chronic obstructive pulmonary disorder (a 1.5%-17.1% risk increase).[71, 81, 82, 103-105] It also contributes to ED visits and HAs for cardiovascular disease (a 1.5-5.0% risk increase),[106, 107] congestive heart failure (a 1.3-13.1% risk increase),[107-109] and cerebrovascular disease (a 0.8-5.0% risk increase).[107, 109] PM 2.5 exposure is associated with a 0.6-1.2% increase in all-cause mortality.[110-115] Long-term exposure at lower concentrations have been shown to increase the risk of cardiovascular mortality by 11.0-12.0%[116-119] and respiratory mortality by 27%.[116, 117]

Ammonia emissions can have multiple health effects. Exposure to high concentrations of ammonia, a corrosive substance, can induce airway irritation and cough.[120-129] Such concentrated ammonia levels are atypical of ambient air but can exist in a poultry house.[130] High atmospheric concentrations may also result in environmental problems such as soil acidification and nitrogen deposition into aquatic ecosystems that can impact employment in agriculture and fishing industries. Finally, ammonia can react with atmospheric NOx and SOx to form PM2.5 in the atmosphere.[131]

Arsenic is a known carcinogen when inhaled at high concentrations[132-137] and is associated with a higher risk of cancer mortality.[138-143] At least one study suggests that arsenic concentration exhibits a linear relationship with health impacts.[136] This suggests that health consequences may exist even without exceeding certain thresholds of arsenic concentration.

Current Conditions

Current Health Conditions

The respiratory conditions that could be affected by litter combustion are already common in the Valley. For example, as of 2010, 12.9% of adults in Virginia reported having had asthma at some time in the past.[144] The corresponding percentages in the Valley are difficult to quantify, but proxies of respiratory illness can be examined. For example, the 15 acute and critical care hospitals that serve Valley residents reported that pulmonary diagnoses accounted for 9.5% of the nearly 150,000 outpatient and inpatient admissions in 2010.[145] More than one-quarter of the cases treated at Page Memorial Hospital were for pulmonary symptoms.[145] In addition, pulmonary care accounted for 7.7% of the costliest admissions (exceeding diagnosis-related cost expectations) to hospitals in the northwest region in 2010.[145]

Cardiovascular disease—another condition potentially affected by airborne emissions—is also already prevalent in the Valley. In 2010, 4.1% of adults in

m Short-term exposure to PM10 has been associated with a modestly increased risk of emergency department and hospital admissions for cardiovascular disease[104, 348] and an increased risk of congestive heart failure,[349-353] respiratory disease,[119, 354- 356] asthma,[41] and all-cause mortality.[357-364]

Table 6: Percentage of Days in which AQI Scores Indicated a Moderate Risk to Health for Augusta, Page, Rockingham, and Shenandoah County (2006-2008)

	Augusta	Page	Rockingham	Shenandoah
Percentage of days in which AQI score was above 50	17.8%	40.0%	17.8%	28.9%
Distribution of criteria pollutant that exceeded emissions standards for moderate risk days				
Ozone	57.8%	70.0%	57.8%	86.7%
Particulate Matter 2.5	8.9%	30.0%	8.9%	13.3%
Particulate Matter 10	5.6%	0.0%	5.6%	0.0%
Sulfur Dioxide	27.8%	0.0%	27.8%	0.0%
Nitrogen Oxide	0.0%	0.0%	0.0%	0.0%
Carbon Monoxide	0.0%	0.0%	0.0%	0.0%

Source: U.S. Environmental Protection Agency. *MyAir*. 2006-2008/ In an effort to describe health risk due to air quality on a universal scale, the EPA converts the concentrations of the six criteria pollutants into an Air Quality Index (AQI). An AQI score under 50 for any of the criteria pollutants represents good air conditions; a score above 50 represents moderate to severe risk to health.

Virginia had angina or coronary heart disease.[144] As is true throughout the country, cardiovascular disease and cancer are the leading causes of death in the Valley (Table 5).

Current Air Quality Conditions

The Clean Air Act requires the EPA to establish National Ambient Air Quality Standards (NAAQS) for certain air pollutants—including Nitrogen Dioxide (NO2), Sulfur Dioxide (SO2) and PM2.5—that protect public health. This standard represents the EPA's interpretation of available research as to the concentration of each pollutant that is safe for human exposure. Table 6 presents EPA data for 2006-2008 on the percentage of days in which each Shenandoah county experienced at least a moderate risk to health. The most common contributor was ozone (O3) emissions.[n] Table 7 presents EPA-calculated cancer risks associated with air emissions by county, calculated in 2002. The largest cancer risk rates in the Valley were in Bridgewater, just south of Harrisonburg, where air emissions were estimated to cause 42 additional cancer cases per one million persons.[146]

Although ambient air concentrations in the Valley can vary by location and are based off the nearest available air monitor, current levels of NO2[o] (Table 8) and SO2 (Table 9) appear to be well below the levels that the EPA considers a threat to health. However, ambient concentrations of PM2.5 in the Valley are a greater concern.

As shown in Table 10, monitoring data for PM2.5 over the most recent three years from Harrisonburg, VA averaged 10.2 micrograms per meters cubed ($\mu g/m^3$). The highest over the past four years was 11.5 $\mu g/m^3$ in 2008. The margin between background concentrations and the current NAAQS annual average (15$\mu g/m^3$)[147] is smaller for PM2.5 than it is for the other pollutants we modeled. Recently, the EPA issued a new rule that lowers the standard for the annual average of PM2.5 to 12 $\mu g/m^3$, a ruling that converts a number of areas from attainment to non-attainment.[148] Documents from the Clean Air Scientific Advisory Committee (CASAC) recommend consideration of lowering the standard to as low as 11 $\mu g/m^3$ to protect health.[149] Non-attainment status discourages development because new emitting permits are unlikely to be

n Ground-level O3 comes from chemical reactions in the atmosphere among O3 precursors. These precursors can come from fuel combustion in transport vehicles (cars, trucks, aircraft, trains, etc.), from other power plants or factories, from the operation of heavy machinery such as in the agricultural industry, and from the evaporation of organic compounds such as paint, cleaners, and solvents.

o The NAAQS covers all of the compounds included in NOx in addition to NO2 but NO2 is the substance of most concern.

Table 7: 2002 National Air Toxic Assessment Values by County

Risk Type		Augusta	Page	Rockingham	Shenandoah
Cancer	Total	21	17	24	20
	Arsenic	1.8	2.4	3.9	1.8
	Cadmium	0.13	0.097	0.25	0.11
	Dioxins/Furans	0	0	0	0

Source: U.S. Environmental Protection Agency. *Technical Transfer Network 2002 National-Scale Air Toxics Assessment.* Note: Assessment values are interpreted as the number of expected additional cases of cancer per 1,000,000 persons exposed to the present air concentrations in the Valley over a lifetime

granted. A permit to emit PM2.5 in the Valley should be issued with the understanding that it could not only impact health but future development projects as well.

The EPA's National Emissions Inventory estimated Valley air contained 16,549 tons of ammonia in 2008, with approximately 3,782 tons (or 23%) coming from fertilizer application (Appendix C, Table C9).[150] The amount of ammonia released during the land application phase of litter management is dependent on a number of factors such as the type of crop, wind or precipitation while the litter is on the ground, the pH level of the litter, temperature, moisture content, air exchange rates, and the application method (surface applied versus incorporated[p]).[151] In general, application methods that reduce the amount of time litter is exposed to the soil surface are the best strategy for limiting ammonia losses. Watershed areas with the highest density of poultry houses also have the highest ammonium ion concentration in rain water.[152] In addition, the ammonium ion concentration of rainwater in the Valley varies throughout the year with the highest concentrations occurring during seasons where litter is typically being spread on fields.[152]

The EPA does not have a NAAQS for arsenic but they do provide estimates of the cancer risk to the exposed population at certain concentrations of ambient arsenic (Table 11). Arsenic concentrations in the Valley air are available from 2002 estimates released by the EPA. The average concentration in Augusta, Rockingham, Nelson, and Rockbridge Counties (four counties potentially affected by the proposed facility) was approximately 1.9e-3 μg/m^3, just below the level recognized by the EPA as sufficient to result in one additional cancer case for every 100,000 persons exposed to it over a period of lifetime. The estimates ranged from a low of 2.3e-4 μg/m^3 in southwestern Augusta County to a high of 1.7e-2 μg/m^3 in Waynesboro. The arsenic concentration in Waynesboro is nearly enough to reach EPA's threshold for an additional cancer case per 10,000 residents exposed over a lifetime. The area in Rockingham County that surrounds Interstate 81 and is immediately south of Harrisonburg, including the Bridgewater area, had arsenic concentrations that exceeded the E5[q] risk level, along with areas of Buena Vista in Rockbridge County and Waynesboro in Augusta County.

Projected Impact

We developed an air model based on the most currently available emissions data from stack tests of existing poultry litter-to-energy facilities. Details of the methodology and the meteorological assumptions for the six projected locations for the facility are provided in Appendix C. There are few currently operating, large-scale, poultry litter-to-energy facilities in the United States or the European Union for which

p Estimates of ammonia emissions associated with land application of poultry litter vary. Studies in the United Kingdom estimate that between 43% and 57% of ammonia released from poultry production occur during the land application stage.[154, 155] These rates probably overestimate the importance of this stage in the United States, where it is common practice to keep litter in the poultry houses for a longer period of time resulting in a higher percentage of ammonia being released before it is land-applied.[156] Moore et al. (2010) found that 7.91 grams of ammonia per bird was released during broadcast application or approximately 15% of the applied nitrogen.[156]

q The risk levels are named after the e-notation of the population when written in scientific notation. For example: 1,000,000 written in scientific notation is 1 x 10^6 or 1E6. The EPA labels this as E6.

stack tests addressing our substances of interest were available. The most current data involve emissions control technology that may now be considered obsolete. Under Virginia regulation, an air permit issuance requires the use of the best emissions control technology available at the time of the proposal. Emission controls are continually improving and technologies that were approved even a few years ago may not be adequate proxies for the required emissions controls for a permit to be issued today. The most recent air permit for a large-scale, poultry litter-to-energy facility was issued in 2003 for the facility in Minnesota. The permit for a United Kingdom facility was issued in the 1990's. Results from these facilities are likely to be biased towards larger air emissions than would be expected for a new facility in the Valley.

Reliance on stack tests from these facilities also assumes that the fuel stock used at these sites would be similar to that used in the proposed facility, but poultry management practices vary from place to place, especially between countries. Feed practices and the frequency of litter 'clean-out' have significant impacts on the contents of litter. Although practices that optimize the health of poultry are nearly universal, regional variation could influence the characteristics of poultry litter. The stack test for the British facility on which we base our arsenic model was conducted before 1999, when the European Union banned the use of *Roxarsone* for poultry production. If the litter came from birds fed *Roxarsone*, as we suspect, the model is likely to overestimate the arsenic levels that would be produced in the Valley.

Our air model also assumes that the primary fuel stock for the poultry litter-to-energy facility would be poultry litter, but it is also likely that wood biomass could comprise 50-80% of the fuel used by a facility in the Valley because poultry litter is less available. A report released in April 2012 indicated that the poultry industry produces less litter annually than was previously expected.[6] It is not entirely clear how a shift towards wood biomass as a fuel mixture will impact emissions. Preliminary research by the North Carolina Division of Air Quality comparing the emissions rates of the poultry litter-to-energy facility in Benson, MN with facilities that burn new wood, new coal, existing coal, and existing biomass suggest new wood would have slightly greater levels of PM, NOx, and carbon monoxide (CO) than a facility that burned mostly poultry litter.[153,154] During the spring, farmers typically clear litter out of poultry houses less frequently which may result in the facility using wood biomass as its primary fuel stock. This may result in altered levels of PM, NOx, and CO than during the rest of the year.

No official proposal for the poultry litter-to-energy facility currently exists so our analysis lacks some of the project specifics that would be necessary in order to most-accurately predict air quality impacts and subsequent health impacts. In an effort to be as informative as possible given these restrictions, we have run air models at a variety of locations in Augusta County. The locations are shown in Map 1 and will be referred to as follows:

- **Northern-most** – At the northern portion of Augusta County near the intersection of Interstate 81 and Route 11
- **2nd northern-most** – Off of Interstate 81 in Verona
- **3rd northern-most** – Off of Interstate 81 just south of Mint Spring
- **4th northern-most** – Near the intersection of Interstate 81 and Route 340
- **Southern-most** – Off of Interstate 81 in Spottswood
- **Eastern-most** – Off of Route 340 in Stuarts Draft

Map 1: Six Locations Used to Model Air Emissions

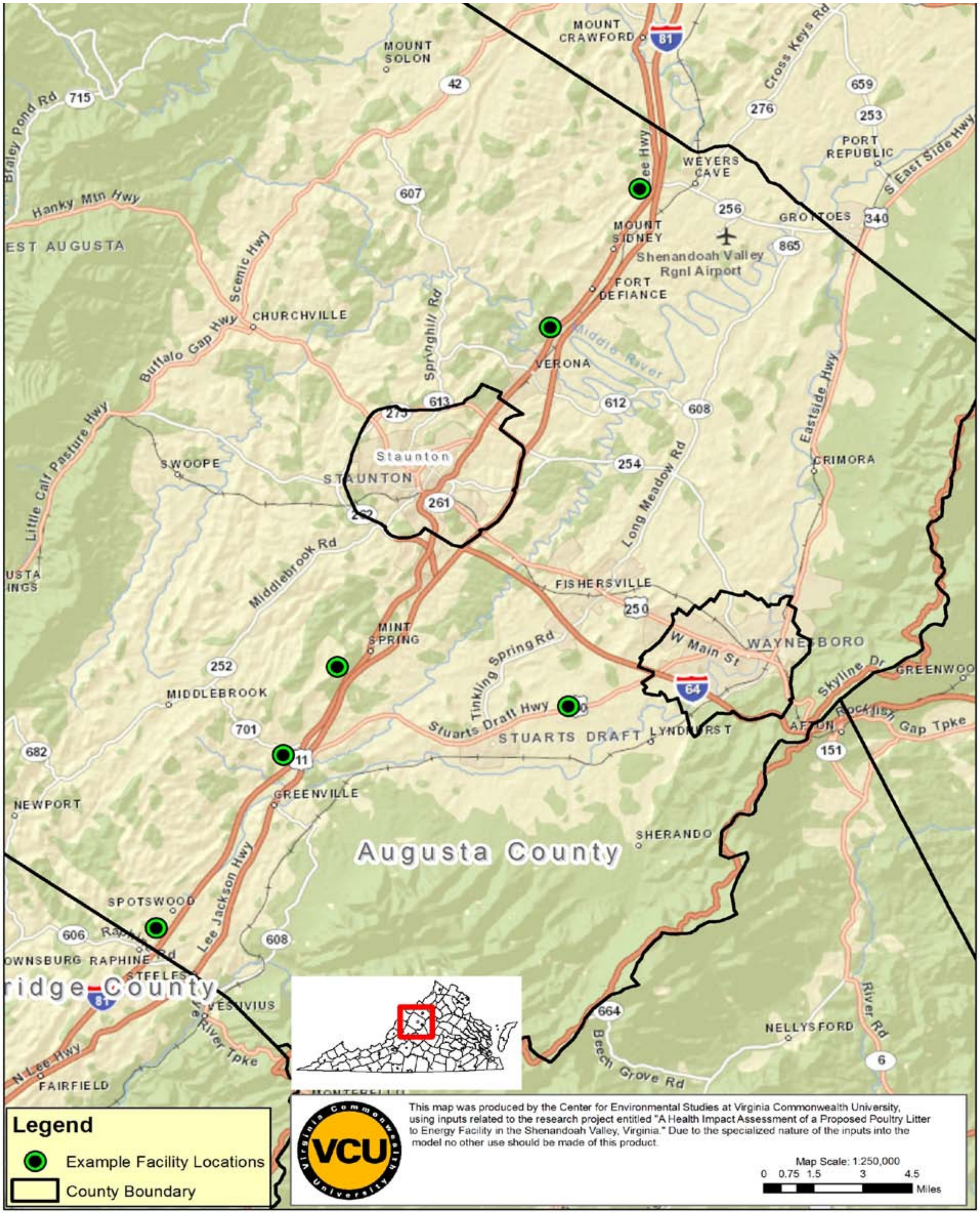


Table 8: Ambient Air Concentrations and Standards for Nitrogen Dioxide					
Annual Averages from Harrisonburg, Virginia					
	2008	2009	2010	2011	3-Year Average
Annual Average	20.7 μg/m³	16.9 μg/m³	18.8 μg/m³	16.9 μg/m³	17.5 μg/m³
98th Percentile 1-Hour Daily Maximum	75.2 μg/m³	75.2 μg/m³	82.7 μg/m³	67.7 μg/m³	75.2 μg/m³
National Ambient Air Quality Standards					
		1-hour			Annual
NO_2		188 μg/m³			99.6 μg/m³

Note: Standards are issued for time periods of varying length in order to regulate long-term and short-term exposure. Some research has found an association with hospitalization for NO2 concentrations as low as 3.4 parts per billion (ppb) which is approximately 6.4 μg/m³. However, research into health effects at levels this low is thus far conflicting. The EPA maintains the standard at a concentration where the majority of evidence suggests a clear cut point at which health would be impacted. The current NAAQS for NO2 is 100 ppb (≈188 μg/m³) for a one-hour average and 53 ppb (≈99.6 μg/m³) for an annual average.[155]

With these caveats in mind, we now review the results of the model's predictions of the impact of the proposed facility on levels of NOx, SOx, and PM2.5. The model predicts that locating the plant at the northern-most location would produce the highest ambient air concentrations for all these pollutants due to the unique topography of the Shenandoah Valley.

Oxides of Nitrogen

The results of the air model for NOx are shown for all six locations in Appendix C maps C1 – C6. A total of 13 census tracts would be exposed (Tables C1 and C2). However, the concentrations will not realistically result in breaching the standards for NO2, although the concentrations will vary considerably depending on the location of the facility. Daily and even hourly fluctuations of NO2 and NOx concentrations can impact health. Linn et al. (2000) suggest that even small increases can result in a slight increase in emergency room visits and hospitalizations.[32]

Projected levels would be highest (1.80 μg/m3) for a facility in the northern-most location: census tract 703 of Augusta County but also reaching into tracts 116, 117, and 118 in Rockingham County. The Shenandoah National Park does not appear to be at risk. Because of the low emissions suggested by the model and the significant gap between current ambient NO2 background and the NAAQS, it is unlikely that the facility would result in a non-attainment status or a threat to public health. However, daily averages from the plant during certain times of the year are likely to exceed the emissions rates suggested in this model.

Lower levels of NOx are projected to the south of this area. The maximum concentration for a facility at the **2nd northern-most location** is projected to be less than half of that predicted in the northern-most location. In this area, census tract 703 is predicted to have the highest concentration, with tracts 707 and 708 impacted as well.

The maximum concentration at the **3rd northern-most location** would be significantly lower than at either of the two sites to the north. The emissions would track as far north as Fishersville (tract 706) and tracts 709, 711.01, 711.02, and 710. Although the emissions are low in comparison with the more northern locations, the model suggests that emissions could potentially impact a wider cross section of the population. Maximum concentrations at the **4th northern-most location** are predicted to be slightly higher than those seen at the 3rd northern-most location, but the cross section of the population exposed to the emissions would be smaller. Tracts 709 and 710 would have the greatest exposure.

Table 9: Ambient Air Concentrations and Standards for Sulfur Dioxide

99th Percentile 1-Hour Daily Maximum from Harrisonburg					
	2008	2009	2010	2011	3-Year Average
SO2	28.8 μg/m³	34.1 μg/m³	21.0 μg/m³	15.7 μg/m³	23.6 μg/m³
National Ambient Air Quality Standards					
					1-hour
SO_2					196.5 μg/m³

Note: Initially, the EPA set the NAAQS for SO2 at 140 ppb (≈366.8 μg.m³) for a 24-hour maximum and 30 ppb (≈78.6 μg.m³) for an annual average.[156] In 2010, the 1-hour standard was set at 75 ppb (≈196.5 μg.m³) and the two prior standards were revoked as they did not provide additional public health protection.[156]

The **southern-most location** poses the least risk, with one tenth the emissions predicted for the northern-most location. Tract 710 is the only area in Augusta County that would be affected. However, emissions in this area could spread outside the county into neighboring Rockingham and Rockbridge Counties (Tables C1 and C2). A small portion of the population in the north of tract 9302 in Rockbridge would be impacted, along with some higher plumes in tract 9301.

Maximum emissions concentrations at the **eastern-most location** would be higher than those predicted at the southern-most location but still considerably lower than the levels predicted at the northern-most location. In the eastern area, the highest exposure would be in tract 711.01 and 709, with lesser concentrations in tracts 710 and 711.02, north of Interstate 64 in tract 706 (Fishersville), and in Waynesboro. The eastern most location is the only location in which the Shenandoah National Park may potentially be exposed.

As mentioned earlier, greater use of wood biomass as a fuel in place of poultry litter could change the NOx emissions from a facility in the Valley. Based off of the preliminary results from the North Carolina Division of Air Quality and the large margin between the NAAQS for NO2 and the current ambient background, it is unlikely that any additional NOx that would be released should the facility use a higher ratio of wood biomass to poultry litter would result in concentrations that would impact health.

Oxides of Sulfur

The model's predicted annual average concentrations of SOx at the six hypothetical locations are shown in Appendix C, maps C7 – C12. Augusta, Rockingham, and Rockbridge Counties could be potentially exposed (Tables C3 and C4). A total of 14 census tracts and Waynesboro could potentially be exposed. The model predicts annual average concentrations whereas the NAAQS are given in hourly averages, but the wide margin between concentrations and standards makes it unlikely that emissions from the facility would exceed the standard.

As with NOx, a facility in the **northern-most location** would produce the highest levels of SOx. The model predicts that SOx emissions from a facility constructed in this region would add an additional 2.68 μg/m³ in a small area of northern Augusta County. Census tracts 703 and 704 of Augusta County are the location of the highest concentrations, with smaller values in tracts 116, 117, and 118 of Rockingham County. Even this concentration is unlikely to exceed the one-hour NAAQS or to threaten public health.

The maximum concentration at the **2nd northern-most location** would be significantly lower and the emissions would not threaten the Shenandoah National Park. The highest concentrations would be in census tracts 707 and 703, with smaller concentrations in

Table 10: Ambient Air Concentrations and Standards for Particulate Matter 2.5 μg

Concentrations of Particulate Matter 2.5 μg from Harrisonburg, VA					
	2008	2009	2010	2011	3-Year Average
24-hour average 98th percentile	24.7 μg/m³	21.7 μg/m³	25.2 μg/m³	22.8 μg/m³	23.2 μg/m³
Weighted Annual Arithmetic Mean	11.5 μg/m³	9.8 μg/m³	11.2 μg/m³	9.6 μg/m³	10.2 μg/m³

National Ambient Air Quality Standards		
	Annual	24-hour
PM2.5	12 μg/m³ *	35 μg/m³

Note: Current 24-hour maximum average NAAQS are set at 35 μg/m³ for PM2.5 and 150 μg/m³ for PM10. [147]
Current standard is 15 μg/m³ but the standard is to be lowered to 12 μg/m³ by the year 2020.

tract 704. The **3rd northern-most location** mainly impacts census tract 709 with minor concentrations in tract 711.01 and 706. Census tract 710 has the highest concentrations of SOx in the model from the **4th northern-most location** with lower concentrations in tract 709, 711.01, and 711.02.

The **southern-most location** poses the least risk, with maximum SOx concentrations predicted to be more than 11.5 times lower than that predicted for the northern-most location. Census tract 710 in southern Augusta County would be primarily impacted, along with smaller areas of exposure in census tract 9301 of Rockbridge County. The maximum concentration in the **eastern-most location** would be slightly less than 0.9 μg/m³ and could potentially impact the southern portion of the Shenandoah National Park. The most affected areas would be census tracts 706, 709, 711.01, 711.02, 712, and Waynesboro. Staunton is most likely to be exposed if the facility is sited near the eastern-most location but it could also be impacted if sited at the 2nd or 3rd northern-most location.

Particulate Matter

Of the three criteria pollutants in the model, PM2.5 is the most concerning, mainly because of the current ambient air concentrations in the Valley and less because of the amount the proposed facility would produce. Even with the new, reduced NAAQS for PM2.5 of 12 μg/m³, our models suggest that the emissions produced by a new facility are unlikely to exceed air standards, at least for annual measurements; however the narrow margin would leave little room for further development. A shift towards a wood biomass-based fuel stock without advanced emissions controls could increase the release of PM by 16-25% as compared with poultry litter.[19]

The predicted concentrations of PM2.5 at the six hypothetical locations are shown in Appendix C, maps C13 - C18. The maps present annual concentrations. Daily and hourly concentrations will fluctuate; higher short-term concentrations could have health consequences even if the annual standard is not exceeded. The EPA considers the NAAQS for the annual average to be the most protective of health.

A total of 15 census tracts would potentially be exposed to higher PM emissions. Depending on the location of the facility, Augusta County along with Rockingham and/or Rockbridge Counties could be impacted (Table C5 and C6). Once again, the highest maximum concentration would result from a facility in the **northern-most location**. The model predicts a maximum concentration of 0.143 μg/m³ in this area, a level that does not result in exceeding the NAAQS based on the most recent monitoring data. The census tracts in Augusta County that would be impacted by this emission would be 703, 704, and 708. Census tracts 116, 117, and 118 in southern Rockingham

County would also be impacted.

Lower PM levels are predicted if the facility was in the **2nd northern-most location**. The census tracts that would be impacted in Augusta County are 703, 704, and 707. Far lower levels are predicted for the **3rd northern-most location**; affected Augusta census tracts would include 709, 711.01, and 711.02. Similar levels would exist if the facility was in the **4th northern-most location,** but PM would spread to a wider geographic area. Augusta County census tracts that would be impacted include 709, 710, 711.01, and 711.02.

Although the maximum concentration at the **southern-most location** is the lowest of the six locations measured, the difference between this location at the 3rd and 4th northern-most locations is only about 0.01 $\mu g/m^3$. The maximum concentration at the northern-most location, however, is close to seven times higher. Census tract 710 is the most impacted tract in Augusta County. In Rockbridge County, census tract 9301 is the area with the highest concentrations but tract 9302 also has small concentrations as well. Augusta County census tracts affected by PM2.5 emissions from the **eastern-most location** include 706, 709, 711.01, 711.01, 712, and Waynesboro. The Shenandoah National Park would only likely be impacted from the eastern-most location.

Ammonia Volatilization

It is beyond the scope of this report to rigorously quantify the impact on ammonia emissions that would result from a different fertilizer type or the impact of ammonia emissions on the formation of PM2.5. However, published research and data on characteristics of the Shenandoah Valley region can inform expectations about the potential impact of changing fertilizer practices.

Based on preliminary proposals, the facility would displace 86,000-200,000 tons (25-58% of the total produced by Valley poultry growers[6]) of the litter that is currently used for land application in favor of other nitrogen sources such as other forms of livestock manure or commercial fertilizer. Not all of the litter that would be displaced is currently applied within the Valley; therefore the area may not realize some of the ammonia reductions associated with a change in fertilizer.

Another factor impacting ammonia emissions is the form of nitrogen in the fertilizer that would replace the litter. This is discussed in detail in Appendix C3. A reduction in ammonia-nitrogen volatilization would be less likely if urea nitrogen was the primary form of nitrogen fertilizer that replaces poultry litter. Urea nitrogen can produce ammonia emissions comparable to situations where poultry litter is broadcast but incorporated within a few days. Urea nitrogen emissions would be expected to be greater when compared with poultry litter that is immediately incorporated, and lower when compared with losses from poultry litter that is not incorporated within seven days of surface application or not at all. If poultry litter nitrogen were replaced by Urea Ammonium Nitrate (UAN), it is more likely that ammonia emissions would be reduced, except when compared with instances where poultry litter is immediately incorporated. It is difficult to conclusively determine whether the use of dairy manure to replace poultry litter nitrogen would reduce ammonia emissions. However, since dairy manure is land applied regardless of whether the facility is constructed, it is plausible that increasing the acreage to which dairy manure is applied would result in a reduction in ammonia emissions as compared with poultry litter.

Because atmospheric ammonia is a precursor for PM2.5, it is worth considering whether a reduction in ammonia emissions would also lower PM2.5 levels. If the facility can reduce PM2.5 concentrations by reducing the emission of PM2.5 precursors, it could have a net benefit for air quality. However, a reduction of ammonia emissions does not always yield a reduction in PM2.5. As discussed in Appendix C3, findings from the San Joaquin Valley suggest that ambient concentrations of NOx, not ammonia, may be the limiting factor in PM2.5 production. Based on our review of available data and literature, we are not able to determine whether reducing ammonia emissions would reduce PM2.5 formation (Appendix C3). Formation of PM2.5 from precursor compounds is complex and highly variable regionally and seasonally due to differences in atmospheric chemistry. An analysis of the role and contributions of ammonia emissions to PM2.5 formation in the Shenandoah Valley has not been conducted. As such, it is currently not clear whether PM2.5 concentrations in the Valley would be impacted by reductions in ammonia emissions that could result from reducing poultry litter land application or by changing the type of fertilizer.

Arsenic

Results of the air modeling for arsenic concentrations are shown in Appendix C, maps C19 – C24. The model predicts that the facility could expose 23 census tracts to higher arsenic emissions: one in Albemarle County, 12 in Augusta County, two in Nelson County, three in Rockbridge County, and five in Rockingham County. All of these tracts had arsenic concentrations in 2002 that exceeded the E6 risk (Table 11).

Table 11: Risk Level at Specified Ambient Arsenic Concentrations

Concentration	Risk Level
2e-2 μg/m^3	1 additional cancer case in a population of 10,000 a.k.a. **E4**
2e-3 μg/m^3	1 additional cancer case in a population of 100,000 a.k.a. **E5**
2e-4 μg/m^3	1 additional cancer case in a population of 1,000,000 a.k.a. **E6**

Note: The risk levels are named after the e-notation of the population when written in scientific notation. For example: 1,000,000 written in scientific notation is 1 x 10^6 or 1E6. The EPA labels this as E6

Once again, a facility in the **northern-most location** would produce the highest arsenic concentrations, although these levels would be far below the EPA risk standard. The largest concentration would be in the Weyers Cave area and in Northern Augusta County, just west of Interstate 81 (census tract 703). According to estimates from the EPA in 2002, this tract had a background arsenic concentration just below the E5 risk level suggested by the EPA (Table 11). Higher levels would also reach the Bridgewater area in southern Rockingham County, which had an arsenic level in 2002 that was more than triple that necessary to cause an addition cancer case for every 100,000 persons. Southern Rockingham County has four total census tracts with a background arsenic risk of E5.

If the facility were located in the **2nd northern-most location**, the highest arsenic concentration would be in census tract 707, which had a background arsenic concentration just under the E5 risk level in 2002. However, emissions from the facility would not be high enough to push the concentration beyond its current risk level. The concentration of arsenic at this location also extends into the northern portion of Augusta County; the southern tracts of Rockingham County, where 2002 arsenic concentrations were higher; and the northeastern portion of Staunton. A facility in the **3rd northern-most location** would produce the highest arsenic levels in the northeastern portion of census tract 710 and the southeastern portion of tract 709, where the 2002 arsenic concentration was slightly above the E6 level. A small portion of Nelson County would also be exposed to arsenic emissions. Similar levels of arsenic would be produced if the facility were in the **4th northern-most location**, but the plume would spread faster into nearby Nelson County than if the facility was in any other location.

The **southern-most location** for the facility had the lowest concentrations of the locations that were tested. The highest concentration at the northern-most location was five times greater than the highest concentration at the southern-most location. Census tract 710 received the highest concentration and had a background arsenic concentration of 3e-4 μg/m^3, a rate above the E6 rate based on EPA estimates indicating an increased risk of one additional cancer case per one million residents. Nelson and Rockbridge Counties were also impacted by a facility at this location. The risk level in Rockbridge County is slightly above the E6 level. Concentrations at the **eastern-most location** are slightly higher than at either the 4th or 5th northern-most locations. In addition, areas in nearby Albemarle and Nelson Counties as well as a small portion of Staunton are impacted.

Deposition models were not run for arsenic but it could have an impact on health as well. We are unable to answer whether soils located near the facility would accumulate additional concentrations of arsenic that would be sufficient to affect health

Volatile Organic Compounds

Volatile Organic Compounds[r] represents a large class of compounds with varying impacts on health. The health effects associated with VOCs and the population that is most vulnerable to them varies greatly depending on the individual compound. Potential risks include eye, nose, and throat irritation; headaches; loss of coordination; nausea; damage to the liver; kidney; and central nervous system.[157] Most importantly, VOCs in the atmosphere can react with NOx or SOx to create ground-level O3, a criteria pollutant with known health effects.[158] The 8-hour maximum NAAQS for O3 is 0.075 ppm (≈150 $\mu g/m^3$).[159] According to data from the air monitoring station in Rockingham County, there was one day in 2010 in which the background O3 concentration exceeded this level. Despite this, the Valley is not deemed to be a non-attainment area for O3 concentration and thus is not considered a danger to health[s]. The concentrations as measured by the nearest air monitoring sites along with how many individual days exceeded the O3 NAAQS are shown in Table 12 below. The highest average (only 0.002 ppm from the O3 NAAQS) is found at the Big Meadow station in the Shenandoah National Park.[160]

The types and quantity of VOCs in the Valley and for Augusta County alone are included in the Appendix C, table C10 and C11 of this report. The poultry litter-to-energy facility that is currently operating in Benson, Minnesota is permitted to emit 69 tons of VOCs per year.[161, 162] The EPA estimates that there are currently more than 3,500 tons of VOCs in the Valley atmosphere and more than 1,100 tons in Augusta County. It is important to note that for purposes of estimating health risk, the actual quantity of VOCs is not as explanatory as a measure of concentration, data that is unfortunately not available for this project. The EPA does not have an ambient air standard for VOCs; however the U.S. Occupational Safety and Health Administration (OSHA) has standard of 0.75 ppm (≈1,500 $\mu g/m^3$) for formaldehyde exposure in work place settings. Ambient concentrations are unlikely to reach that level.[157]

The biggest health concern would be the contribution of these emissions to O3 formation. As highlighted above, the Valley has a background standard of O3 that is very close to the NAAQS. Ozone is also responsible for visible haze in the Valley, which can impact tourism industries. Along with PM, VOCs are some of the most important considerations in the impact on air quality.

However, as with PM2.5, it is not clear what the impact of reducing VOC formation would have on O3 concentrations in the Valley. Ozone formation occurs via a complex set of reactions that depends on VOC and NOx concentrations and atmospheric conditions. Concentrations of either VOCs or NOx can limit O3 formation.

Dioxins/Furans

Dioxins/Furans are a byproduct of the combustion of organic materials. Forest fires, automobiles, and combustion from industrial practices are a source of diox

r Volatile Organic Compounds are distinguishable as an organic compound that have a high vapor pressure under normal room temperatures resulting in a high rate of evaporation or sublimation from the liquid or solid form into a gaseous form. These vapors can come from combustion activities but also from common household products such as paint, lacquers, cleaning supplies, and pesticides. Under normal circumstances, VOCs are much higher indoors than they are outdoors.[157]

s Attainment of O3 concentration is measured by taking the average of the fourth highest daily maximum 8-hour average for each of the three most recent years.

Table 12: Fourth-Highest Daily Maximum 8-Hour Ozone Average from Air Monitoring Sites near Augusta County, Virginia (2008 – 2010)					
8-Hour Maximum Standard			0.075 ppm		
	2008	2009	2010	3-Year Average	Days Exceeded 0.075 ppm
Rockingham	0.069 ppm	0.063 ppm	0.068 ppm	0.066 ppm	1
Albermarle	0.073 ppm	0.065 ppm	0.071 ppm	0.069 ppm	3
Big Meadow	0.078 ppm	0.069 ppm	0.074 ppm	0.073 ppm	
Source: Virginia Department of Environmental Quality, Virginia Ambient Air Monitoring 2010 Data Report					

ins/furans, but the largest contributor to atmospheric deposition is the household burning of trash, 35.1% or 498.5 g Toxicity Equivalence (TEQ)[t] in total in 2000.[163] More than two million tons of solid waste (12.3% of the total) in Virginia was incinerated in 2011 according to the DEQ.[164]

Exposure to dioxins is associated with cancer incidence.[165-169] Boers et al. (2008) found an increase in hazard ratio for non-Hodgkin's lymphoma of 54% for workers in a herbicide manufacturing factory.[165] Hu et al. (2009) found the excess cancer risk was twice as high in a population exposed to burning incense in a temple in comparison to the rest of a local population.[169] There is some evidence to suggest that the risk is higher for those over 65 years of age.[166] In addition to the cancer link, there is also evidence to suggest an association between exposure to dioxins and disruption of neurological development in infants[170-179], lowered birth weight[180], impairment of both male[181-184] and female[185-189] reproductive systems, impairment of the immune system[190, 191], diabetes[192], and increased all-cause mortality rate.[168, 193, 194]

Estimates from the World Health Organization (WHO) suggest that 90% of human exposure to dioxins is through food.[195] This is mainly through meat and dairy products as dioxins are fat soluble and can accumulate through the food chain.[195] The EPA-established reference dose (RfD) for non-carcinogenic effects from TCDD is 7e-10 mg/kg-day.[196] The FDA recommends not eating fish and shell fish with more than 50 parts per trillion (50 ppt) of TCDD.[197] The EPA has yet to establish a carcinogenic RfD or risk assessment for TCDD exposure through inhalation, but the WHO suggests that levels found in air are typically very low.[195]

The ambient concentration of dioxins/furans in the Valley for both air and soil is unknown. The facility in Benson, Minnesota releases 3.64e-07 tons (0.0007 lbs or 0.012 oz) of total dioxins/furans per year with a toxic equivalency of 7.14e-08 tons (0.000143 lbs or 0.0023 oz) per year.[198] The amount of dioxins expected to be emitted by the proposed facility in the Shenandoah Valley would likely be less as the facility is expected to produce less energy and have more advance emissions control technology.

Water Quality

Agricultural practices such as fertilizer application—both manure and commercial fertilizers—are the largest single source of nitrogen and phosphorus loading into the Chesapeake Bay watershed.[3] Virginia contributes the second most total nitrogen and the most phosphorus loading of the six Chesapeake Bay states and the District of Columbia.[3] The Chesapeake Bay watershed includes four smaller watersheds in the Shenandoah Valley: the South Branch Potomac, the

t Dioxins/Furans represent a class of 17 chemicals that share certain structures and biological characteristics, each with varying levels of toxicity.[197, 365] The most toxic is 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). This substance serves as a reference point for the toxicity of the combined exposure of all dioxin/furan compounds. The total risk is expressed in terms of toxicity equivalence (TEQ) which is translated as the amount of TCDD that would be equivalent to the risk due to exposure of the total amount of dioxins in an area.[365] The 17 compounds that are described as dioxins and dioxin-like compounds by the EPA's Toxic Release Inventory Program and their TEQ factors are listed in the Appendix C, Table C12 page 113.

North Fork Shenandoah, the South Fork Shenandoah, and the Upper James River watersheds. The Potomac River Basin, which drains a portion of the Shenandoah Valley, contributes 22% of the total nitrogen load to the Chesapeake Bay watershed (the second greatest single basin contributor of nitrogen) and 27% of the phosphorus (the greatest single basin contributor of phosphorus).[3] According to the U.S. Department of Agriculture (USDA), areas that are fertilized with manure have a much higher rate of loss of nitrogen and phosphorus compared to areas that do not.[199]

Nitrogen pollution of water bodies can also occur through atmospheric deposition of nitrogen in the form of NOx or ammonia. Ammonia-nitrogen, predominantly from agricultural practices, makes up approximately one-third of the atmospheric emissions that end up in the Bay.[3] Land application of arsenic-containing fertilizers could create arsenic runoff into local streams and contaminate drinking water sources.

Why Water Quality Matters to Health

The consumption of nitrite/nitrates in drinking water by pregnant women has been linked with methemoglobinemia in infants,[200-205] a disorder that reduces the circulation of oxygenated blood and causes cyanosis. Although the presence of phosphorus in drinking water has no direct link with health effects, it can contribute to harmful algal blooms and reduce the availability of clean water. Arsenic in drinking water has been linked with a rare form of gangrene called Blackfoot disease,[206-208] skin lesions,[207, 209-214] cancer,[207, 208, 211-226] and mortality.[214, 221, 222]

Manure application could also infect water supplies with harmful microscopic flora, such as fecal coliform, *Escherichia coli* (E. coli), and other fecal organisms such as enterococci, coliphage and cryptosporidium.[227] Drinking water with heavy contamination of these organisms can produce gastrointestinal illnesses and infectious diseases.[227] The EPA has set a standard concentration of zero for total coliforms, fecal coliforms, E. coli, and other fecal indicators in municipal drinking water.[227] Exposure to fecal coliform bacteria in surface waters can increase the risk of skin infections. The local health departments routinely tests beaches in the Chesapeake Bay region for the presence of fecal coliform bacterium and beach closures and no-swimming advisories due to the presence of fecal coliforms are not uncommon.

Although not related to surface or ground water quality, the large water cooling towers used by energy facilities are associated with an increased risk of infection with *Legionella*, the bacterium responsible for Legionnaires' disease, which is a particular risk to the elderly and others with compromised immune systems.[228-231, 231-239] Between 5% and 30% of cases are fatal.[239] The Virginia Department of Health reports that 96% of cases in 2006 required hospitalization.[240] Besides the population over 50 years of age and those with compromised immune systems, Legionnaires' disease occurs more frequently among current or former smokers and those with chronic lung diseases like emphysema. According to the Centers for Disease Control and Prevention (CDC):

> *"Cooling towers contain large amounts of water and are potential breeding grounds for Legionella bacteria if they are not properly disinfected and maintained. Water within cooling towers is heated via heat exchange, which is an ideal environment for Legionella heat-loving bacteria to grow. Legionnaires' disease can be acquired when an individual breathes in water droplets containing Legionella bacteria."*[241]

Research has also documented *Legionella* aerosols in the community near a cooling tower that match the biological fingerprint of the colony in the tower, supporting the claim of the mobility of bacteria from cooling towers to the surrounding community.[242] Legionellosis outbreaks in the United States that have been linked to cooling towers have most affected those living in close proximity to the towers and those visiting the building.[228, 230] However, the population at risk of infection could be as far as two miles away from the towers.[237]

Current Conditions

Current Health Conditions

Methemoglobinemia from non-congenital causes is very rare; there were eighteen total deaths attributable to it in the United States between 1999 and 2010.[243] There is no reliable estimate of the prevalence currently available, although evidence suggests that it is higher in rural areas.[244] The CDC reported 214 hospitalizations associated with outbreaks of E. coli in the United States for 2008.[245]

Legionnaires' disease is also rare; in 2010, there were 3,346 total cases natiownide.[246] In Virginia, there were a total of 775 cases between 1997 and 2010.[247] The five-year average between 2005 and 2010 was 63.4 cases per year with the highest annual total number being 110 cases in 2003.[247] During that same time period, there were a total of 18 cases of legionellosis in the Valley, a rate of 3.2 cases per 100,000 residents. Reported cases of legionellosis by health planning region[u] show an increased incidence in the last several years, but this may reflect increased reporting rather than true increase in cases.

Current Water Quality Conditions

In 2010, there were 1,585 reports of impairment in water bodies of the Chesapeake Bay within Virginia.[248] The most common problems were related to pH levels, temperature, dissolved oxygen, E. coli, fecal coliform, and mercury or polychlorinated byphenols in fish.[248] There were no impairments in the Valley caused by nutrients with a total of eight nutrient impairments in the Commonwealth.[248] Nutrient pollution in the Valley watershed drains downstream and contributes to pollution levels elsewhere in Virginia or potentially another state in the Bay watershed. A water body that is not considered impaired based on nutrient content can still impact water quality by promoting growth of noxious aquatic plants or depleting oxygen. Virginia does not currently have nutrient or algal standards to identify rivers and streams as impaired but first person accounts in the area have verified that there is heavy algal and excessive rooted grass growth which impacts the public's use and enjoyment of the river.

Although most Virginia households rely on municipal drinking water, 1.5 million households use private water.[249] In 2009, more than half of the Augusta County population drank from private wells.[250] The EPA public water supply standard for nitrate-nitrogen is 10 milligrams per liter (mg/L).[251] A concentration of 3-5 mg/L or higher is an indication of contamination from fertilizers or organic wastes.[249] A sample of private wells in Augusta County taken in 2009 found that 1.3% had a nitrate concentration that exceeded the EPA's standard of 10 mg/L.[249] The average nitrate concentration among the sample was 1.8 mg/L.[249] In Rockingham County, 18.9% of wells sampled had nitrate levels that were high enough to impact health and the average concentration (4.273 mg/L) was within range to suggest contamination.[252]

In addition to contributing to nitrate concentrations in drinking water, land application of livestock manure can contribute to *Escherichia coli* (E. coli) and coliform bacteria contamination of drinking water. However, not all contaminated drinking sources can be traced back to agricultural practices as private wells can also be contaminated from septic systems. Almost half of those sampled in Augusta County (45.7%) had coliform bacteria present and nearly one of every ten (9.0%) had E. coli bacteria present.[227] In Rockingham County, 27.0% of those sampled contained coliform bacteria and 2.7% contained E. coli. Evidence of excessive levels of dissolved solids, another potential result of land application, was present in 16.5% of those sampled in Augusta County and 29.7% in Rockingham County.[249, 252]

In a separate study conducted in 2004, the Virginia Department of Public Health tested two water sources in the Valley, including one in Augusta County, to test for differences in arsenic concentration depending on proximity to confined animal feeding operations. Arsenic concentrations at both locations were below testable levels (less than 5 µg/L).[253]

u The Valley counties are in the Northwest Health Planning District which includes Rockbridge and Bath Counties and all the counties north of them except for Loudon, Fairfax, and Prince William and the counties west of Hanover, Goochland, and Buckingham.

Projected Impact

Changes in Fertilizer Application

Evidence from the USDA suggests that replacing livestock manure with commercial fertilizer would decrease nutrient runoff and both the EPA and the DEQ assume that harmful nutrient runoff into water bodies would be reduced by replacing poultry litter with other types of fertilizer.[199] The magnitude to which this would occur is unclear as application of commercial fertilizers will also result in nutrient runoff. The nutrient runoff reduction resulting from a shift from poultry litter to commercial fertilizer is clearer for phosphorus than for nitrogen. The ratio of nitrogen to phosphorus content in poultry litter ranges from 1:1 to 1.5:1 and varies greatly from broiler to turkey litter.[6, 254] The nutrient needs of crops vary as well, but they usually require a higher ratio of nitrogen to phosphorus.[254] As a result, the application of litter based on the nitrogen needs for crop growth tends to cause over-application of phosphorus and greater phosphorus runoff.[254-259]

A shift from poultry litter to commercial fertilizer may result in a reduction in ammonia emissions that would lower atmospheric deposits of nitrogen into local water bodies.[v] This could also have a salutary effect on nitrate exposure in drinking water that Valley residents currently consume. Under current estimates, the percentage of private well water that exceeds the nitrate/nitrite standard is not very high, but reducing the amount of litter that is land applied could reduce it even further.[249]

A shift from poultry litter to other types of fertilizer is unlikely to affect arsenic exposure. The arsenic content in Valley water sources was well below the EPA's standard of 0.010 mg/L near confined animal feeding operations (CAFOs) even before arsenic was removed from the feed.[253, 260]

A significant portion of private well water in the Valley is contaminated by coliform bacteria and/or E. coli. The extent to which this would be alleviated by the proposed facility would depend on how much litter would be used by the facility and how much that litter would be replaced by commercial sources rather than other livestock manure. The health effects associated with exposure to these pollutants are usually not serious; therefore the net impact is likely to be minor.

Changes in Industrial Use of Water

According to permit applications for the facility in Benson, Minnesota, that facility used approximately 300,000 gallons of water per day.[161] Part of that supply comes from treated effluent, which presumably could also occur with the facility in the Valley.[161] The proposed facility in the Valley would likely be smaller, and therefore require less water, than the Minnesota plant. The Minnesota facility uses "several water recycle and reuse processes"[161] that greatly limit the release of contaminated water back into the community. Similar processes could presumably be used by the facility constructed in the Valley.

Cooling towers and growth of legionella

The risk of legionellosis introduced by the proposed facility's cooling towers is difficult to quantify. Not all cooling towers contain *Legionella*, and standard cleaning practices can inhibit growth within the towers. Studies of water samples taken randomly from cooling towers in Istanbul, Turkey found that 44% contained *Legionella* strains.[234] Another study in Shanghai, China found strains in 59% of sampled cooling towers.[261] A similar study in Greece identified colonies in 49% of tested cooling towers.[231] A sampling of cooling towers in the United States showed 54% of them had some *Legionella* present, but only 10% had a significant colony.[262, 263] Nonetheless, the probability of a *Legionella* outbreak caused by the cooling towers of the proposed facility is low given the rare nature of the disease and that most infections are solitary cases and not community-level outbreaks. The population most at risk would be those employed by the facility. The CDC provides standard guidelines for cleaning cooling towers that protect the community and plant workers from infection.

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v For more information on this topic, see the section titled "Review of Research on Ammonia Emissions from Fertilizer Application" in Appendix C, Section C3 on page 104.

Heavy Truck Traffic

The California Air Resources Board (2000) estimated that heavy-duty diesel vehicles accounted for only 2% of on-road vehicle traffic but approximately 30% of the NOx and 65% of the PM released by motor vehicles in California.[264] Sathaye et al. (2009) hypothesize that heavy truck traffic may also contribute to air pollution through increased pavement maintenance.[265] Such maintenance is more necessary on roadways frequented by heavy trucks and heavy loads.

Poultry litter that is not used on the farm where it was generated is shipped by a heavy truck to either another farm that requires fertilization or to a storage area managed by a broker (Box 3). The broker then ships the litter for application as fertilizer elsewhere in the county or to other areas. According to Pease et al. (2012), 51,740 to 68,987 (15%-20%) of the 344,936 tons of litter produced in the Valley in 2011 were used as fertilizer on the farm in which the litter originated.[6] Currently, between 170,000 to 200,000 tons of litter (50-60% of the total amount produced) is exported out of the county of origin and is potentially available for purchase by the proposed facility.

Box 3: The Role of Brokers

Using litter as fertilizer involves entities other than poultry producers and crop farmers. Because the litter supply chain involves multiple suppliers (poultry growers) and consumers (crop farmers), direct transfer would be inefficient without a middle entity. Litter brokers fill this role by picking up the litter from poultry growers and selling it to crop farmers as fertilizer. This process involves storage of the litter as well as trucking, which is occasionally performed by the broker. Virginia Cooperative Extension lists 46 individuals and businesses that serve as litter brokers in Augusta, Page, Rockingham, and Shenandoah Counties and another six that are located outside the Valley but can supply litter to the area.

Why Truck Traffic Matters to Health

Patel et al. (2010) found an association between pulmonary symptoms—such as wheezing, shortness of breath, chest tightness—and exposure to traffic-related PM and diesel exhaust particles, with a stronger association among residents of urban than suburban areas and among people with asthma than non-asthmatics.[266] Kim et al. (2004) and McConnell et al. (2006) also found that traffic-related pollution was associated with a higher prevalence of asthma and chronic respiratory symptoms.[267, 268] Gauderman et al (2004) found deficits in pulmonary function in groups exposed to elemental carbon, nitrogen dioxide, acid vapor, and fine PM.[269] Studies have also demonstrated that short-term increases in ambient traffic-related particles exacerbate asthma and increase airway inflammation in children with asthma.[270-273]

Heavy truck traffic also increases the risk of traffic fatalities. Although large trucks constituted only 4% of all registered vehicles and 7% of total vehicle miles traveled, they accounted for 8% of vehicles involved in fatal crashes.[274] According to Lyman et al. (2003) the involvement of large trucks in fatal crashes per vehicle-mile traveled decreased between 1975 and 1999, but a concurrent increase in truck travel has resulted in a stable rate of involvement per unit population.[275] According to the National Highway Traffic Safety Association, in 2010 large trucks were involved in 541 injury crashes and 32.4 fatal crashes per 100,000 registered vehicles.[276] This represents 20 injury crashes per 100 million vehicle-miles travelled, of which 1.2 crashes involved fatal injuries.[276] In 2008, 74% of the fatalities and 71% of the injuries involved occupants of the other vehicle involved in a crash with a large truck.[277] Large trucks were more likely to be involved in fatal multiple-vehicle crashes than were passenger vehicles.[277] In Virginia, 71 (6.5%) of the 1,097 vehicles involved in fatal accidents in 2008 were large trucks.[277] Fully 1.7% of all U.S. fatal crashes involving heavy trucks occurred in Virginia that year.[277]

Traffic accidents disproportionately impact young adults[278] and females.[279] Significant factors that are associated with the severity and incidence of an accident with a heavy truck include speed, weather conditions, and the level of alertness of the driver. [279-284]

Exposure to road traffic noise has been associated with annoyance, sleep disturbance, cognitive functioning in children, physiological stress reactions, hypertension, and cardiovascular problems.[285-288] Kluizenaar et al. (2009) found an association between long-term exposure to road traffic noise and fatigue.[289] Among three large cohorts, Botteldooren et al. (2011) found that traffic noise was the strongest factor affecting perceived quality of life.[290] Dratva et al. (2009) found that a high level of noise annoyance was inversely associated with health-related quality of life.[291] Ndrepepa et al. (2011) reported an association between hypertension and traffic noise.[292] van Kempen et al. (2012) found that every five decibel (dB) increase in traffic noise corresponded with a 3.4% increase in the odds of hypertension.[288] An eight-hour average of at least 55 dB was associated with a higher risk of cardiovascular disease.[288] The World Health Organization (WHO) reports an association with heart disease at levels above 65 dB.[286] Sorensen (2011) found a significant association between traffic noise and stroke; each 10 dB increase in noise exposure resulted in a 14% increase in stroke risk for people age 50 and older and 27% higher risk for those age 65 years and older.[293]

Current Conditions

Current Truck Traffic Conditions

In 2010, the Virginia Department of Transportation estimated that heavy trucks[w] accounted for 4.7 % of Shenandoah Valley traffic: 4.2% in Augusta County,[294] 2.4% in Page County,[295] 4.5% in Rockingham County,[296] and 5.9% in Shenandoah County.[297] Heavy truck traffic was greatest in Augusta County, along a 13.5-mile segment of Interstate 81 northbound between Interstate 64 and the Rockingham County line. Almost one in four vehicle trips on this road was made by a heavy truck.[294] In Page County, heavy truck traffic was greatest on US 211 (also known as Lee Highway) between the Shenandoah County line and US 340; almost one in 10 vehicle trips on this road involved a heavy truck.[295] In Rockingham County, heavy truck traffic was greatest on the Valley's major highway (Interstate 81), with a slightly higher rate in northbound (24%) than south bound (21%) lanes.[296] In Shenandoah County, heavy truck traffic was greatest on Oranda Road and Conicville Road between US 11 (Old Valley Pike) and US 11 (Main Street). On this two-lane road, approximately one in three vehicle trips are made by a heavy truck.[297]

w Heavy trucks were defined as two-axle or more single-unit trucks, not including pick-ups or buses, and any truck with a trailer.

Projected Impact

Sophisticated modeling of projected effects on truck traffic was not possible for this project given resource and time constraints, but some general estimations can be made. The operation of a poultry litter-to-energy facility would entail truck trips to the facility, which is likely to be located in Augusta County. Those shipments would not likely involve a broker but would go directly to the facility. The farmland that would otherwise be fertilized by poultry litter would require truck shipments of commercial fertilizer or other livestock manure to substitute for the litter. The hypothetical facility would require between 86,000 and 200,000 tons of poultry litter per year as well as between 200,000 and 314,000 tons of wood biomass. Although it is more economical for the plant to truck the litter from nearby locations to minimize transportation costs, the large quantity of litter required by the facility may necessitate shipments in greater volume from suppliers at greater distances than is currently required. According to estimates by Pease et al. (2012), the litter needs of the facility could be met by the amount of litter that is currently exported from the county of origin (Table 13).[x] However, if the facility needs as much as 200,000 tons, essentially all of the litter that is currently exported from the county of origin would need to be trucked to the new facility. Otherwise, the fuel stock would need to come either from litter that would otherwise remain in county for local use or from truck shipments of litter from counties outside the Valley.

x By current estimate, 170,000-200,000 tons of litter leave its county of origin and the maximum amount of litter for which the technology providers of the facility have proposed is 200,000.

Table 13: Litter Availability by County			
County	Total Litter Produced (tons)	Amount of Litter that is Currently Exported to Surrounding Counties	Miles from Augusta
Augusta	69,829	34,415 to 41,897	-
Page	66,679	33,340 to 40,007	53
Rockingham	168,202	84,101 to 100,921	29
Shenandoah	32,744	16,387 to 19,664	59
Total	337,484	168,742 to 202,490	

All data comes from Pease et al. (2012). Miles are based on distance from county seat to county seat.

Given the cost savings of trucking over shorter distances, it is unlikely that even litter that leaves the county of origin travels very far, and adjacent counties are likely to be the chief suppliers, especially for farms near the county line. Although it is unknown how much litter from Page or Shenandoah County is currently trucked to Augusta County for use as fertilizer, Rockingham County is a more likely source. At a minimum, the poultry litter-to-energy facility based in Augusta County would require trucking of some portion of the litter from both Augusta and Rockingham Counties as Augusta County litter alone cannot supply even the most conservative estimates of necessary fuel for the facility.

Based on assumptions in Appendix D[y], the following approximations can be used to quantify the change in truck mileage: Every truck that delivers Augusta-based litter to the new facility would decrease truck travel by 66 miles round trip if the litter would otherwise be exported elsewhere, but it would increase travel by 22 miles round trip if the litter would otherwise be used within the county. Thus, by replacing truck trips that export litter from Augusta County, the facility could reduce the need for heavy truck traffic. The corresponding values for Rockingham-based litter would be a decrease of 41 miles and an increase of 44, respectively. Page and Shenandoah Counties are both far enough away from Augusta County that replacing truck trips for land application with truck deliveries to the facility would result in a net increase of truck miles regardless of whether they are replacing a truck trip within the county or one that exports litter. However, a truck trip to the facility that displaces a trip that exports litter will result in a lower net impact on total truck mileage as compared with one that displaces a truck trip within the county. The net impact on truck mileage for Page-based litter would be 43 miles for exported litter and 106 miles for litter moved within county. The corresponding values for Shenandoah-based litter would be 42 miles and 118 miles, respectively.

Another consideration is truck travel to deliver wood biomass to supplement litter as feedstock. According to the technology provider, the majority of this material would come from Harrisonburg and Staunton. The distance is relatively short: Harrisonburg is approximately 25 miles from Staunton traveling by Interstate 81. The average of these distances suggests that a truck delivering wood biomass would travel approximately 13 miles to reach the facility.

In summary, truck trips to the proposed facility that replace export shipments would result in less heavy truck traffic than those that replace shipments that would otherwise occur within county. Scenarios that enable the facility to meet its litter demand using only supply from Augusta and Rockingham Counties and replacing as many truck trips as possible that currently export the litter out of these counties with truck trips to the facility are the most likely to reduce total truck mileage in the entire Valley area. Based on our model, the largest decrease in truck traffic (300,000 miles) would occur if (1) all poultry farmers sold their litter to the facility, (2) truck carrying capacity was limited

y The change in the amount of heavy truck traffic on the highways in the Valley is contingent on a number of variables. This analysis used the following factors as independent variables in quantifying mileage in order to estimate the sensitivity of the quantity to each individual factor: the amount of litter available for purchase (this will include both the total amount of litter available and the amount of litter that is currently exported), the amount of litter that the facility will require for fuel needs, the amount of litter each individual truck will carry, and the percentage of litter in each county that poultry farmers will be willing to sell to the facility (note: we will also presume that this percentage will be the same across all four counties).

to 10 tons[z], (3) 60% of litter would otherwise be exported, and (4) the facility required 172,468 tons of litter for feedstock. Conversely, the largest increase in truck traffic (483,000 miles) would occur if (1) only 70% of the farmers sold litter to the facility, (2) truck carrying capacity was limited to 10 tons, (3) 50% of litter was slated to be exported, and (4) the facility required 200,000 tons of litter for feedstock.

As compared with a litter distribution system that transfers litter from farm to farm, a centralized destination for transporting litter could have a salutary effect on air pollutions and traffic accidents and fatalities. Reducing PM2.5 concentrations might help offset concerns about the PM consequences of issuing a point source permit for the proposed facility. However, as noted above, our air model predicts that locating the facility in more southern locations would curb air pollution levels from stack emissions, but doing so would increase the distance from litter-producing counties and increase emissions from truck traffic. Data are lacking to identify the optimal location to offset these competing concerns.

It is also difficult to forecast how the reduction in truck mileage would affect traffic noise. At a distance of about 50 feet or less, a heavy truck typically produces about 90 dB of noise.[298] This is above the World Health Organization's 65 dB threshold for an association with heart disease,[286] but the health risks from noise are related to continuous exposure, not isolated truck trips to ship litter. A centralized location for litter delivery would increase traffic congestion of heavy trucks especially in the area surrounding the facility and possibly in other areas along the route. Local residents would be at increased risk of adverse health from traffic noise.

Employment in the Poultry/Agricultural Industry

An advantage to poultry growers of using poultry litter as an energy source is that it provides a potential new market for litter. Poultry production has increased in the United States over several decades but decreased slightly in the recent term.[299] A resurgence in the industry would result in more litter which, given the increasing regulation of land application, accentuates the importance of alternative management practices to the local economy. Poultry producers have small profit margins, high capital costs,[300] and limited flexibility

z Note that the carrying capacity of trucks also refers to the amount of litter carried by trucks currently exporting litter from the county of origin. Changing truck carrying capacity is only a viable option to reduce overall truck traffic if the carrying capacity is increased over the amount that it is currently being used.

Box 4: Comments from Poultry Farmers Regarding the Current Economics of Poultry Farming

"We built our houses in 93, what was it 100 feet from the property line. Now it would be 500 feet from residence? Some counties are worse than others."

"You once stuck a house on 5 or 10 acres a few years ago. Today you would probably need 20 – 25. So that adds into the cost."

"The thing we are talking about and this is just from my memory. (I)Built them in 93, propane that winter was 58 cents a gallon. We have paid as high as two or two and a quarter (dollars)…But we have paid that. A load of shavings delivered to my farm was $525. Today, I haven't bought shavings in a couple years what $1800, $2000?"

"The ammonia treatment will be $1,000. We're paying in ammonia treatment to deal with it what we were paying in peanut shells"

"The cost of equipment. You used to be able to [get] a tractor for $15,000 - $20,000. Today, I mean go price them. It's nothing for someone to be asking $60,000.. $80,000…$100,000."

"My two houses are both 42 by 504 which is roughly 41,000 – 42,000 square feet. I smoothed off the flat spot, built two chicken houses, put the equipment in, put in an automatic generator, and drilled a well: $280,000. A new house today, a 63 by 624, roughly the same capacity, within a couple thousand birds, that house will cost you $400,000 at least. Or half a million, it would be closer to half a million. So you've doubled the cost of the facilities in twenty years. And you've still got the same gross!"

in maintaining profit if variable costs—such as litter management costs—increase (Box 4). Increased regulations aimed at protecting environmental quality or public health such as the increasing the lot size for a new poultry house or setting a greater set back distance from vulnerable areas, have increased the cost of poultry growing operations or expansion. Without alternative management practices, regulatory restrictions on land application of litter could threaten the financial viability of the poultry industry. Protecting the poultry and agriculture industry is important for farm jobs but also preserves the rural landscape of the Valley that is vital to the economy of all four counties.[7-10]

Why Employment Matters to Health

Employment is important to stable income, and a vast amount of research documents the strong link between income and health. Economic well-being increases access to health-promoting assets (such as medical care) and activities that contribute to healthier lifestyles, enables people to live in healthier neighborhoods and communities, and reduces stress.[301-303] Financial distress during periods of unemployment is also associated with impaired health outcomes, even when compared with employed individuals with lower net worth.[304, 305] Cross-sectional correlational studies suggest that people who work for pay report better well-being than those who are unemployed, retired, or "keeping house".[306-308] Benavides et al. (2000) found that precarious employment was associated with fatigue, backache, and muscular pain.[309] Ross et al. (1994) found significantly slower declines in perceived health and physical functioning for those that were employed full-time.[308] Other studies have shown an association between employment and decreased symptoms or impairments, rates of series disease, hospitalization, and death.[307, 310-315] Lund et al. (2011) found that employment was associated with improved health-related quality of life of the morbidly obese population, independent of other health factors such as diabetes, hypertension, obstructive sleep apnea, and treatment.[316] Many studies demonstrate a link between employment and mental health.[317,318-322] Reemployment significantly increases mental health after a period of unemployment;[323] although this may be limited to those employed in satisfying jobs.[324, 325] The adverse relationship between unemployment and health has been documented in men[306, 307] and women,[314, 315, 326-332] and the effects are worsened with longer periods of unemployment.[322, 323]

The largest employment sectors in the Valley are educational services, health care, and social assistance, with just over one-fifth of employed residents over 16 years of age (Table 14). Manufacturing, transportation and warehousing, and construction are also majoremployers in the area, significantly more so than in Virginia or the United States. The percentage of residents employed in the agriculture sector is approximately double that of Virginia and the United States.

Poultry farming is a major employer in the area. According to the Virginia Poultry Federation, poultry farming in 2010 supported 1,100 Virginia farm families and contributed $984.7 million to the state's economy.[333] That same year, the Valley alone operated approximately 550 chicken farms and 280 turkey farms that earned approximately $80 million. Six poultry processing companies employed 6,000 workers[aa], and five poultry company feed mills produced more than 1.5 million tons of feed annually. Across the Valley, The poultry industry indirectly supports approximately 43,200 jobs in other sectors.[333] The average wages for these industries are provided in Table 15.

Projected Impact

The technology vendor that is proposing the facility estimates that it would create 32 jobs related to plant operation, five jobs related to operating the ash fertilizer plant, and more than 100 jobs for trucking. Jobs created for truck drivers must be offset by trucking

aa According to U.S. Bureau of Labor Statistics, in 2011 the average hourly wage for farming, fishing, and forestry occupations in Virginia was $14.48 (Table 16). Those employed in transportation and material moving occupations had a median hourly wage of $13.91. For a typical family of four, the hourly rate for self-sufficiency in 2006 for Valley residents ranged from around $16 an hour in Page County to as high as $20 in Harrisonburg and Staunton.[366] This rate is not inflation-adjusted.

Table 14: Employment by Industry for Shenandoah Valley, Virginia, and the United States

	Shenandoah Valley	Virginia	United States
Agriculture, forestry, fishing and hunting, and mining	3.7%	1.1%	1.9%
Construction	10.5%	7.5%	7.1%
Manufacturing	16.6%	8.2%	11.0%
Wholesale trade	3.1%	2.2%	3.1%
Retail trade	13.3%	10.8%	11.5%
Transportation and warehousing, and utilities	4.7%	4.2%	5.1%
Information	2.0%	2.5%	2.4%
Finance and insurance, and real estate and rental and leasing	4.1%	6.7%	7.0%
Professional, scientific, and management, and administrative and waste management services	5.7%	14.2%	10.4%
Educational services, and health care and social assistance	20.2%	20.3%	22.1%
Arts, entertainment, and recreation, and accommodation and food services	6.7%	8.0%	8.9%
Other services, except public administration	5.2%	5.2%	4.9%
Public administration	4.3%	9.0%	4.8%

Source: U.S. Census Bureau, American Community Survey, 5 Year Estimates. 2006 - 2010

Table 15: Average Wage by Occupation in Virginia for Industries Impacted by the Biomass Facility (May, 2011)

Position	Average Hourly Wage
Farming, Fishing, and Forestry Occupation	$14.48
First-Line Supervisors	$23.44
Agricultural Inspectors	$20.25
Graders and Sorters, Agricultural Products	$11.10
Agricultural Equipment Operators	$14.34
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	$11.21
Farmworkers, Farm, Ranch, And Aquacultural Animals	$11.58
Agricultural Workers, All Other	$10.69
Transportation and Material Moving Occupations	$16.04
First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	$22.62
First-Line Supervisors of Transportation and Material-Moving Machine and Vehicle Operators	$26.60
Heavy and Tractor-Trailer Truck Drivers	$17.81
Cleaners of Vehicles Equipment	$10.41
Laborers and Freight, Stock, and Material Movers, Hand	$12.11
Material Moving Workers, Other	$18.78

Source: U.S. Bureau of Labor Statistics. *State Occupational Employment and Wage Estimates: Virginia*. May 2011

positions that will be lost due to the removal of litter shipments for fertilizer. It is uncertain if truck drivers in the Valley who currently transport litter would be able to assume jobs to deliver litter to the facility. Due to the lack of empirical data, we sought input from poultry farmers. We conducted interviews and a focus group with poultry farmers to elicit their perspective about the facility. The farmers expressed concerns about the economic health of poultry farming, specifically rising costs, primarily for farming equipment and propane, and stagnant revenues (Box 4). Between 2000 and 2010, the cost of utilities as a proportion of variable costs grew from 40% to 60%.300 They also mentioned zoning restrictions and set back requirements as examples of regulations that would prevent construction of new poultry houses necessary to increase production.

Based on the conversations that we had with poultry growers in the Valley, changes in these costs are the greatest concern to the poultry industry, as opposed to increasing regulations on land application of litter. Growers expressed confidence that selling litter to brokers will remain a valid option; programs to export litter out of the watershed—such as the joint partnership between the Virginia Department of Conservation and Recreation (DCR) and the Virginia

Poultry Federation—are encouraging to poultry farmers and give them reason to believe they will be able to continue that management practice for the foreseeable future.

"You've got brokers who are begging for litter. We don't have a litter problem; we might have a distribution problem."

Growers did reiterate, however, that if land application were to no longer be an option, they would be far more open to all alternatives, including a large-scale facility.

"Well, if we couldn't use it [as fertilizer], [using it as a fuel source] would definitely be an option. I mean you have to do something with it."

"If it wouldn't be for brokers, I don't know what I'd do."

Farmers were hesitant about entering a partnership with a large-scale facility to manage their litter. They expressed concern about getting what they consider a fair price for their litter and about being responsible for litter that is deemed to have too much moisture for energy production.

"When you talk about [a large-scale, poultry litter-to-energy facility] and the tonnage, I went to several meetings. I was just curious. And the one that night and they were offering us two, three dollars a ton for the litter…It was basically a joke."

Some farmers were open to hearing more about the technology and the benefits a litter-to-energy facility could provide, particularly if it would pay a fair price.

"I kind of like the idea, cause it would make the litter go up, and we could sell it to other people higher."

However, a larger number of farmers were completely opposed to the facility and suggested that they would not do business with the facility if it were constructed. As mentioned earlier, their unwillingness to sell their litter to the facility would lead to an increase in heavy truck traffic mileage. However, even skeptical farmers emphasized that they are businessmen and they would support the facility if selling litter to the plant would be in their economic interest. As of now, a consensus of approval was lacking among the farmers with whom we spoke.

"I have zero interest in something like that."

"As poultry farmers, we're looking for something that would increase the value of litter, as in using it to heat the houses or whatever. Rather than decrease the value of litter, which is what [a large-scale facility] would do."

Lastly, some farmers expressed the concern that the economic benefits and stability that a poultry litter-to-energy facility might bring to poultry growers were not worth the health risk to Valley residents associated with air pollution.

"I breathe it in the chicken house; I don't want to breathe it outside."

"I guess one of the things, just from me personally, I mean I've worked in poultry, I wouldn't have had my farm if I didn't build the poultry houses. I want you to understand that I do appreciate where I come from. But we've worked in the ammonia, we've worked in this ammonia treatment in the chicken houses, okay. And I'm hoarse tonight from breathing chicken dust all day, okay. So, in all fairness I'm not totally opposed to [a large-scale, poultry litter-to-energy facility], but I'm thinking, I breathe it in the chicken house all day. I work in it most of the year. And you're going to send it up the stack? I mean, that's just a mental thing, a hurdle for me to get over. That you're going to burn it and send it up into the air for everybody else? You know I want to feed the country. I want to grow a good bird. I want to do it right. Sometimes you tell yourself 'I'm sacrificing for the greater good'. I don't want to put that on them."

Impact on Litter Brokers

Early proposals for the facility required a quantity of litter that would exhaust the Valley's entire supply, removing the need for brokers and thereby threatening revenue and employment except for brokers who were also truck drivers. Following the release of Pease et al. (2012) (noted above), which downsized the estimated quantity of available litter, the vendor has now reduced expectations to between 25% and 58% of the total litter produced in the Valley. These scenarios would allow for litter to continue to be used as fertilizer, which would offer some job protection to brokers, but would still cut their revenue stream significantly. Because transportation costs limit the affordable litter sources to farms in the immediate vicinity, the supply is relatively scarce, and a drastic decrease in the amount of litter available for fertilizer may result in a per unit price increase that brokers could charge. There is, however, some uncertainty whether this price increase would occur, as there is some evidence that demand for litter exceeds supply, and thus price elasticity is limited.

Impact on Crop Farmers

One of the reasons poultry litter is a desirable fertilizer is that it is typically less expensive than alternative fertilizers. Removing litter from the market place for crop farmers would increase fertilizer cost and reduce income, which would impact employment and subsequent health. The magnitude by which costs would increase is unclear. As part of their report, Pease et al. (2012) estimated the market value of the nutrient content of nitrogen, phosphorus, and potassium that would be contained in the amount of litter a large-scale facility would need for its operations. Their estimate was that if the nutrients present in poultry litter could be separated and sold as it is for commercial nutrients, their value would be as much as \$13.3 million.[6] It is important to distinguish that this value likely over-estimates the actual costs to crop farmers.[ab]

"And the other thing is, as you go up and down the Valley, you're looking at all poultry growers here [referring to the people in the room]. The guys that are next door that don't raise poultry that do get the litter, they sure don't want [a large-scale facility] to cause the price to go up. They have a genuine interest in not having it there because they can't compete."

Alternative Poultry Litter-To-Energy Technologies

Large power plants are not the only option for converting litter to fuel. At least three technology vendors[ac] have on-farm technologies in development that can be used by individual farms or farm cooperatives to generate energy for poultry operations, and other vendors may join the market as well. Poultry houses typically use propane to heat the houses during cold weather and to cycle the air in the houses so that ammonia and carbon dioxide concentrations do not accumulate to levels that harm the flock. Energy produced by these units that is unneeded for poultry house heating could potentially be converted to electricity and either sold to utility companies or used to off-set on-farm electricity use via net metering programs.

Farmers would need to invest significant upfront costs for on-farm technologies with the expectation that the cost will be recouped by reducing heating costs and/or selling energy back to the grid. Several technology vendors propose generating revenue from sale of the phosphorus- and potassium-dense ash byproduct. Depending on the arrangement between the technology vendor or the grower, the

ab Commercially available nitrogen, phosphorus, and potassium can be customized to meet the specific needs of crops. This usually means higher concentrations of nitrogen than phosphorus or potassium. By comparison, poultry litter is not customizable. If a crop farmer wanted to purchase enough poultry litter to meet the nitrogen needs of his or her crops, he or she would also be purchasing more phosphorus than would be necessary for crop growth. The market for poultry litter has already priced these excess nutrients into the price; therefore poultry litter can be purchased at a lesser cost than if the nutrients were purchased individually. Crop farmers who are replacing litter with commercially available nutrients would not be purchasing the same amount of nutrients as they would be if they were getting them from litter; therefore, the cost would not be as high as it would be if you valued litter as the value of the nutrients on the open market. In addition, research conducted by the Water Stewardship, Inc. suggests that the amount of nutrients available from other livestock manure in the Valley—such as cattle and swine—may be able to replace the nutrients displaced from poultry litter being used as a fuel source, negating the need to purchase commercial fertilizers.[338]

ac *Biomass Heating Solutions (BHSL)* located in Ireland, *Global Refuel* located in Indiana, and *Enginuity Energy, LLC* located in Pennsylvania ash could constitute a new source of revenue for the farmer. Because it is lighter and more dense in nutrients than the original poultry litter, ash can be transported longer distances cost-effectively, thereby expanding end-user markets. Nitrogen content of the ash is generally greatly reduced, if not completely eliminated. However, in contrast to a centralized facility, farmers would be responsible for oversight of the technology, including operations and maintenance, regulatory obligations, and marketing the nutrient-dense byproduct.

One advantage of this type of technology for air quality is that litter would be burned in smaller quantities and in multiple locations rather than burning a large amount of litter and releasing it from a single point source such as the power plant, which produces a higher concentration of air pollutants. However, there is currently little data available on emissions from on-farm systems; smaller technologies may lack advanced emissions controls that would be employed in a large facility, which could negate the advantages to air quality.

With respect to reducing phosphorus pollution in the Shenandoah River and the Chesapeake Bay, it is important that the ash be used on fields that are deficient in phosphorus or transported outside of the Chesapeake Bay region. Tracking the fate of poultry litter nutrients concentrated in ash would be easier with a large-scale facility as compared with multiple smaller facilities.

Projected Impact

Research on the air quality, economics, and health impacts associated with smaller, on-farm units is still evolving and the impacts in comparison with a large-scale facility are not entirely clear. We could not identify objective research that compares large-scale facilities with smaller, on-farm units in terms of air emissions and pollution levels. Evaluation of these technologies is ongoing and is expected to yield more evidence about the air impact and economic benefit.

For this report, we sought qualitative information on demand for the technology by interviewing poultry farmers in the region. Their biggest reservation with the technology is how quickly costs can be recouped and how future revenue would be affected. A dairy farmer who had previously used one of these units on his farm told us that the technology is not ready for widespread use by the livestock production community and that large litter volumes would be necessary to produce enough energy to offset the upfront cost. This farmer said he would need manure from 1,000 cows to produce enough energy to make the unit worthwhile, but the average farm has approximately 100 cows. He was concerned that burning enough manure to make the unit profitable would exceed the DEQ standards that would allow the unit to operate without a point source permit. Obtaining a permit adds costs and reduces the profitability of the unit. Despite these reservations, the farmer was optimistic about the potential benefits of such technology. Other farmers were also very optimistic (Box 5).

Apart from the economics, there was also some concern about the workload the units would impose on the farmer. They estimated that it takes 1.0-1.5 days to clean the litter out of houses to be picked up by a broker, but were concerned that processing the litter would take more time, including for maintenance of the units (Box 6).

Farmers would also be responsible for adhering to applicable regulations. One farmer said,

"If DEQ, or whoever it is that is going to come in and inspect that thing there, that's just one more government regulation I got to deal with."

Farmers said they might consider the units even if a large-scale facility were already in the area, especially if they thought the facility would not give them a fair price or set onerous requirements on acceptable litter composition. In the end, however, the economics of these units would have to be well established. Some poultry farmers said the units would have to do more

Box 5: Comments from Poultry Farmers on Small, On-Farm, Poultry Litter-to-Energy Units

"There's a number of technologies out there that are right on the edge of becoming economically successful. The pyrolysis thing, if it ever gets out of the government, it might go somewhere. But the guys in Ireland, they're the ones building the small, on-farm sized ones. And burning is one step below pyrolysis. It's about as clean as pyrolysis. But the guys who are doing that are putting systems in, on farms, in Ireland, that looks extremely promising."

"If it will pay for itself, people will come. We're businessmen enough, everybody is businessman enough to know you don't mind spending $10 if you spend it towards something that…to get a return on it."

"If you can get it to the point where it gives an economic return, people will do it."

"I can assure you that if any of them are extremely successful and economically feasible, people will find out about them."

"The other thing that's happening is energy costs, whether its propane or electricity, whatever, as these costs continually rise at some point you're going to intersect where these technologies will pay for themselves."

Box 6: Comments from Poultry Farmers about the Work Burden of Alternative Litter Management Options

"Someone at a West Virginia company a couple of years ago…the ones I've seen have gotten rid of it up till now. The mechanics, it don't work all that well, getting the litter into the thing, it becomes a labor nightmare. You'll mess with that thing all night long rather than doing your chores."

"It's got to be user friendly."

"One thing I was thinking about from a stand point of what we are doing now. We're getting a reasonable price for the litter. And we talked about the broker and especially the guy that we sell for, we're handling that litter one time. We're shoving it to the end door, and he comes in with a telescopic boom loader and he loads it. We shove it to the door and we're done. We go do something else. When you start loading it and hauling it over here and unloading it and loading it back up, all this aggravation you have. For what we're getting for litter now, if I can shove it to the door and he scoops it up and loads it. Good deal for me."

"The other thing with this alternative, I don't care if it's a methane digester whether you're burning your litter. It becomes a labor issue…Pretty soon if you're not careful you have to have a sole man that all he does is fiddle with that thing.

than just 'pay for themselves' to justify the additional work and the regulatory burden.

National Parks

The Shenandoah National Park, located in the Valley, is important to the local economy. According to the National Park Service, in 2010 it received almost 1.3 million visitors[334] and accommodated more than 300,000 overnight stays, generating more than $71 million in revenue—more than $63 million from non-local visitors. As of 2010, the Shenandoah National Park had 234 employees, resulting in over $10 million in salaries and over $4 million in benefits to the surrounding population.[334] In 2010, spending by tourists on entrance fees, overnight stays, food, merchandise, and other expenses supported 968 local jobs and more than $25 million in labor income, bringing more than $41 million in value added to the economy.[334] The impact of the park payroll on the rest of the economy was 314 additional jobs, over $16 million additional in salary, and over $18 million in value added.[334]

Why National Parks Matter to Health

Interest in the national park as a tourism destination is, in part, dependent on the actual air and water quality in the area as well as the public's perception of each. If air quality in the area deteriorates or the presence of a poultry litter incinerator creates the perception that air quality is deteriorating, it may impact the amount of business and the amount of revenue the park can generate. If this deterioration results in a loss of the employment and income that the park currently provides, the risks of poor health associated with unemployment and financial difficulties that were detailed in the employment section of this report may be increased among the people for whom their livelihood depend on the park. In addition, the presence and the environmental and economic health of the park promote the objective of all four Valley county governments of sustaining a rural and agricultural nature into the region and its development.[7-10, 335, 336] If the air quality around the park were to significantly deteriorate and tourism were to be impacted, it would have an impact on the development plans of the region.

Current Conditions

Shenandoah National Park already faces important environmental challenges. It has among the highest concentrations of airborne sulfate particles, acidic deposition, and ground-level ozone of all national parks.[337]

- Between 1990 and 2000, the mean and maximum ozone exposures at Big Meadows, a location in the park, were 47 ppm-hr and 87 ppm-hr, respectively. Experts believe vegetation begins to show effects at 25 ppm.
- The park's air quality from 1997 to 2001 did not meet EPA's 8-hour ground-level ozone standards.
- The long-term trend of concentrations of sulfur in wet deposition was decreasing in 2003. Some areas have seen a decreasing trend in nitrogen deposition but not as steep as the trend in sulfur reduction.
- Annual average haziness is about three times the natural haziness of the park. The annual average visibility is approximately 20% of the park's estimated natural visual range of 115 miles.
- As of 2003, the park's forest vegetation had absorbed approximately 80% of its nutrient capacity, thus limiting its ability to absorb acid rain and prevent its accumulation in local water bodies. In a 1992 survey, half of the park's siliciclastic streams were chronically acidic, which can have lethal effects on brook trout.

Projected Impact

Visibility is important to the Shenandoah National Park, and emissions from the facility that would most likely affect visibility would be VOCs, NOx, and SOx along with the rate of formation of O3. The poultry litter-to-energy facility that currently operates in Benson, Minnesota is permitted to emit 69 tons of VOCs per year[161] and emitted 0.00050 lbs/MMbtu in its stack test,[198] but the facility in the Valley is likely to burn less fuel and thus emit fewer VOCs. As discussed above, our air model for dissemination of NOx, SOx, PM2.5 from the facility indicated that the park would not be affected unless the facility was located in the eastern-most location; the first- and second-more northern locations could potentially raise arsenic levels at the park. We did not model VOCs and cannot predict how increasing VOCs in the Valley would impact air quality in the park, the perception of the air, and the tourism industry. The best option for the park would be to site the facility a great distance from the park, but the effect of those locations on local populations, as discussed above must also be considered.

Characterization of Effects

	Direction	Intensity	Magnitude	Distribution	Timing & Duration	Likelihood	Confidence or Certainty	Notes
Air Quality								
NOx	Adverse	Low	Low	Widespread, persistent, impacting children, elderly and respiratory impaired	Immediate, long-term	Low	High	
SOx	Adverse	Low	Low	Widespread, persistent, impacting children, elderly and respiratory impaired	Immediate, long-term	Low	High	
PM2.5	Adverse	High	Medium – High	Widespread, persistent, impacting children, elderly and respiratory impaired	Immediate, long-term	High	High	The magnitude of the impact is dependent on the prevalence of respiratory and cardiac illness in the area and the location of the facility
Ammonia	Beneficial	High	Medium – High	Widespread, persistent	Slow development	Low	Low	Likelihood is dependent on the speciation of NOx in the Valley
Arsenic	Adverse	Low	Low	Widespread, persistent	Immediate, long-term	Low	Medium	Impact from Air concentration is low but impact from deposition may be higher
VOCs	Adverse	Medium	Medium – High	Widespread, persistent, impacting children, elderly and respiratory impaired	Immediate, long-term	High	High	
Dioxins/ Furans	Adverse	Low	Low	Widespread, persistent	Immediate, long-term	Low	High	Magnitude is unclear because there is no safe standard guidelines from the EPA
Water Quality								
Drinking Water	Beneficial	High	Low	Widespread, persistent, impacting infants and pregnant women	Slow development, long-term	High	High	The intensity would be high for infants and their families but low for adults
Recreational Activities	Beneficial		Low	Widespread, persistent	Slow development, long-term	High	High	
Legionella	Adverse	Low	Low	Narrow impact, persistent	Slow development, long-term	Low	Low	Extremely unlikely but a high magnitude and intensity if it were to happen

Truck Traffic								
Air Quality	Adverse	High	Medium – High	Widespread, persistent, impacting children, elderly and respiratory impaired	Immediate, long-term	High	High	The magnitude would be dependent on the location
Traffic Safety	Adverse	High	Low	Widespread, persistent, impacting young adults and women	Immediate, long-term	High	High	
Traffic Noise	Adverse	High	Medium	Narrow impact, impacting the elderly	Immediate, long-term	Medium	High	Likelihood is dependent on the location of the facility and the route of transportation
Employment								
Poultry Farmers	Beneficial	Low	Low	Widespread, persistent	Slow development, long-term	Medium	High	
Litter Brokers	Adverse	Low	High	Narrow impact, transitory	Immediate, long-term	High	High	
Crop Farmers	Adverse	Low	Medium	Narrow impact, transitory	Immediate, short-term	High	High	
Alternative Technologies	Conflicting	Low – Medium	Low	Narrow impact	Immediate, short-term	High	Low	
National Parks	Adverse	Low	Medium	Narrow impact, long-term	Slow development, short-term	Low	High	

Direction – indicates whether the effect is adverse or beneficial

Intensity – indicates the severity of the effect
High: Fatal
Medium: Disabling
Low: No disabilities

Magnitude – refers to the expected size of the effect and can be described by the number of people affected or by expected changes in the frequency or prevalence of symptoms, illness, or inquiry
High: Positive or negative health effects would accrue across the entire population
Medium: Positive or negative health effects could result in more changes in health for some households
Low: Positive or negative health effects would not be perceptible and these changes would impact few people

Distribution – delineates the spatial and temporal boundaries of the effect; identifies various groups or communities that are likely to bear differential effects

Timing & Duration – indicates at what point of the proposed activity the effect will occur, how long it will last, and how rapidly the changes will occur, also discusses whether effects are reversible or permanent

Confidence or Certainty – characterizes the effect according to level of confidence or certainty in the prediction

Definitions are taken from: *National Research Council, Committee on Health Impact Assessment. Improving Health in the United States: The Role of Health Impact Assessment. Washington, DC: National Academies Press; 2011.*

Recommendations

The NRC describes the recommendation process of HIA as:

"suggest(ing) design alternatives that could be implemented to improve health or actions that could be taken to manage the health effects, if any, that are identified"[12]

In view of the HIA findings, we offer the following recommendations should the decision-makers decide to construct a large-scale, poultry litter-to-energy facility:

1. **Early Involvement:** The findings of this analysis suggest that characteristics of the facility such as its location, the litter supply chain from local farms, and the composition of fuel it would use could have significant impacts on health. As it is, the decision-making process currently cedes control over these decisions entirely to the technology vendor. Elected officials and government agencies only have control over approving or denying the facility based on the characteristics supplied by the vender. Early involvement by local and state entities as well as local communities who could be impacted, will contribute to a well-designed, strategically placed facility that maximizes health. *Stakeholder groups in the Valley related to health, the environment, and agriculture should be involved in the process during the proposal development phase so that their concerns are addressed and input included before the decision reaches local officials. This group should include the Central Shenandoah Health District of the Virginia Department of Health, the Virginia Department of Environmental Quality, the Virginia Department of Agriculture and Consumer Services, the Virginia Cooperative Extension program, and the Virginia Department of Conservation and Recreation. Consideration should be given to projected versus current health risks and accumulative versus immediate health risks.*

2. **TMDL Requirements**: The report details several instances in which health risk to the population in the Valley would be reduced if the TMDL requirements were met. It would reduce exposure to harmful contaminants in drinking water and impaired streams, rivers, and other water bodies. It would also improve employment and income prospects for industries dependent on water conditions such as tourism and fishing. Although a large-scale, poultry litter-to-energy facility could contribute to meeting these regulations, it is not the only potential solution. *Regardless of the decision to construct or not to construct a large-scale, poultry litter-to-energy facility, the Commonwealth of Virginia should meet the requirements of the TMDL. If an alternative to a large-scale, poultry litter-to-energy facility is proposed, a Health Impact Assessment or Health Risk Assessment should be conducted before its implementation to assure that health risks are minimized and benefits are maximized. This analysis should be a joint effort of the Central Shenandoah Health District of the Virginia Department of Health, the Virginia Department of Environmental Quality, the Virginia Department of Agriculture and Consumer Services, the Virginia Cooperative Extension program, and the Virginia Department of Conservation and Recreation.*

3. **Arsenic Deposition:** This HIA modeled expected air concentrations of arsenic and the associated health risks that could result. We did not, however, model the expected deposition of arsenic through air emissions of the facility, which could eventually impact the concentrations in soil and locally grown crops. *During the air permitting process for a proposed poultry litter-to-energy facility, the Virginia Department of Environmental Quality should model deposition of arsenic in addition to the required air concentrations.*

4. **Pre-Existing Risk from Ambient Air Concentration of Arsenic:** Current ambient air concentration of arsenic in the portion of the Valley where the facility is expected is highest in Waynesboro and in southern Rockingham County. *The Technology Vendor should locate the facility in an area that does not impact these regions. Locating the facility no further north or east than the city of Staunton is a sufficient benchmark to achieve this objective. This recommendation should also be enforced by the local board of supervisors as a condition of approval for construction.*

5. **Assuring Fuel-Mix Ratio:** The fuel used by the

proposed facility would likely be a mixture of poultry litter and woody biomass. Using litter as fuel decreases the concentration of nutrients in the Valley and supports local poultry growers by increasing the demand for their products. Using woody biomass as a fuel source does not contribute to a reduction in nutrient concentration and potentially increases the emissions of fine particulates, a significant concern of health. *The Technology Vendor should ensure that the size of the facility is designed so that poultry litter constitutes the vast majority of the fuel source. This recommendation should also be enforced by the local board of supervisors as a condition of approval for construction.*

6. **Control of Fine Particulate Matter:** The annual concentration of PM2.5 in the Valley is much closer to the NAAQS than the other pollutants that we modeled. In addition, the recommendations from the CASAC suggest that PM2.5 concentration below the NAAQS could contribute to adverse health impacts. *The Virginia Department of Environmental Quality should use a standard of 11 μg/m^3 for fine particulate matter and should not issue a permit unless the facility can keep annual concentrations below this standard.*

7. **Precursors to Fine Particulate Matter:** Displacing poultry litter as a fertilizer may contribute to a reduction in the emissions of ammonia related to fertilizer application. Whether this reduction would contribute to a reduction in PM2.5 formation is dependent upon how much ammonia contributes to current PM2.5 concentrations. *The Virginia Department of Environmental Quality should evaluate how ammonia emissions in the Valley might contribute toward PM2.5 formation. This should be done during the proposal development stage and before any decision is made by local officials or on the air permit.*

8. **Reduction in Ammonia Emissions:** Loss of ammonia-nitrogen to volatilization impacts air quality and the operation costs of crop farmers in the Valley. Application practices that prevent this loss can be beneficial regardless of whether the facility is constructed. *Farmers in the Valley should use immediate fertilizer incorporation or injection methods. The Virginia Department of Conservation and Recreation should continue to establish nutrient management guidelines that include standards for applying appropriate rates and the timing of application to maximize crop uptake. If the facility is constructed and a portion of poultry litter is lost for fertilizer purposes, replacement fertilizer should either be other livestock manure or urea ammonium nitrate in order to minimize ammonia volatilization.*

9. **Negotiation of Litter Payment:** The sale of litter is the domain of each individual poultry grower and that should not be changed. However, a likely outcome of an iterative negotiation process between the technology vendor and individual growers is that a poultry litter-to-energy facility is more likely to be built with minimal support from the poultry grower community. The result of this would likely include a higher amount of woody biomass being burned instead of poultry litter and an increase in truck traffic as the litter would come from a wider geographic space, increasing the amount of truck traffic. *Before negotiating with each individual grower, the Technology Vendor should negotiate for endorsement from a group that represents the interest of poultry growers. This can be a group (or several groups) formed particularly for this process or a pre-existing group such as the Contract Grower's Association. Individual growers should still retain the right to refuse the deal negotiating for them for their supply of liter. This action will more thoroughly establish a relationship between the operators of the facility and the poultry grower community in the Valley which would have a salutary impact on health.*

10. **Dioxins/Furans:** Concern over the emissions of dioxins/furans from a poultry litter to energy facility were commonly expressed among commu-

nity members. Based on the emissions rate for the facility in Minnesota, it is not expected that a new facility in the Valley would significantly contribute to the concentration of dioxins/furans in the environment. However, dioxins/furans are very mobile once they are in the environment and the most likely exposure for humans is through ingestion of contaminated food. The most likely contributor to dioxins/furans in the environment is the burning of household trash. *The Virginia Department of Environmental Quality should require state-of-the-art emissions controls to reduce the potential emissions of dioxins/furans. Additionally, the local board of supervisors in Augusta County should broaden the pick-up of trash form households within the Valley.*

11. **Legionella Exposure:** Cooling towers, such as those that would be needed for the proposed facility, are a common source of community outbreaks of Legionnaire's Disease. In the United States, more than half of large cooling towers have growth of some legionella bacteria within them. The risk of exposure is highest among workers at the facility. *The Technology Company and the operators of the facility should follow the guidelines of the U.S. Centers for Disease Control and Prevention for the cleaning of cooling towers, including the requirement of protective equipment for workers.*

12. **Traffic Volume in the Valley:** Because a large proportion of poultry litter is already being trucked throughout the Valley for use as fertilizer, a shift towards the use of poultry litter as a fuel source—depending on the characteristics of the supply chain—could increase or decrease the total truck volume in the Valley. Decreasing volume would reduce the risk currently seen from the impact of trucking on air quality, traffic safety, and community noise. *The Technology Vendor should only use litter supplied by growers who are near the facility. The specifics of what growers would be included as suppliers are dependent on the exact location of the facility. The supply chain should be explicitly detailed as part of the initial proposal to local officials.*

13. **Traffic Noise:** Even if the fuel supply chain for the facility is crafted so as to reduce the total amount of truck traffic in the Valley, a centralized location for delivery of litter would result in an increase in traffic congestion in some areas of the Valley. One of the impacts of traffic congestion is an increase in community noise, which can impact the health of the population, particularly those over 50 years of age. *The Technology Company and the local board of supervisors should ensure that the location of the facility is not only in an area of low population, but also in one with few older adults. In addition to the area around the facility, the route of litter delivery should be examined to ensure that it does not create a traffic congestion problem in areas other than near the facility.*

14. **Traffic Accidents:** Fatalities from traffic accidents are more likely when a heavy truck is involved and increasing the heavy truck traffic or congestion will increase the risk of traffic accidents involving heavy trucks. The likelihood of traffic accidents are increased by factors such as road conditions, weather, and speed. *The local board of supervisors and the Virginia Department of Transportation should limit the speed of heavy trucks to no more than 55 miles per hour. The Technology Company should schedule deliveries only during daylight hours and have contingency plans for litter supply and storage on bad weather days. Routes should be developed that avoid schools and other high pedestrian areas.*

15. **Employment:** The facility would result in an increase in the number of jobs available for its facility operations and production of phosphorus fertilizer. *A committee of local residents and stakeholders should be created to provide input on strategies to increase local hiring. This group should include representatives from the local Chamber of Commerce and the Shenandoah Valley Partnership. For positions at the facility that require specialized training, the Technology*

Company should provide job training so that local residents can remain competitive.

16. **Alternative Technologies:** Small, on-farm, litter-to-energy technologies are potentially more beneficial to health than large-scale facilities because they would burn less litter and spread the emissions of air pollutants into a wider geographic space, diminishing their concentration. However, they are also less likely to have advanced emission controls such as a full-time monitoring staff or large smoke stacks; therefore, it is unclear if the smaller-scale technologies would actually be better for overall air quality. *The Virginia Department of Environmental Quality and/or universities with an interest in this topic should systematically evaluate the health impacts of small, on-farm, poultry litter-to-energy technologies.*

17. **Future Decisions**: At the time of the completion of this report, no proposal of a large-scale, poultry litter-to-energy facility was actively being developed in the Valley. If a proposal for the facility were to be submitted in the future, the projections of this report could be outdated. *The Virginia Department of Health and the Virginia Department of Environmental Quality should update the findings and recommendations of this report if the decision is to be made several years after its release.*

Conclusions

Management of geographically concentrated nutrients associated with modern livestock production practices is an issue faced by many regions. The Chesapeake Bay TMDL serves as the impetus for the development of alternative strategies in the Valley but other agricultural areas, particularly those with water bodies exhibiting signs of impairment, are likely to be faced with similar questions in the future. Current livestock production methods produce a high quality product in demand by American households at the lowest price possible. Solutions that address environmental needs while maintaining competitive economics for poultry growers are key to a successful litter management strategy.

HIA is meant to inform a decision and one of the greatest contributions this HIA can make is to frame the question as one of a comparison of risks. Concern over the potential air quality effects of this decision were evident in the highly vocal opposition to the proposed facility in early public meetings, but the health effects of using litter as a fertilizer—from the impact on water quality, economics of poultry growers, and transportation of litter throughout the Valley—was not as widely voiced. Large-scale, poultry litter-to-energy facilities have many beneficial characteristics that can contribute to a successful litter management strategy. Large-scale power production calls for a large supply of poultry litter to be consumed by the facility. Using litter as fuel instead of a fertilizer eliminates a major mechanism of excess nutrients being introduced to local water bodies—runoff, groundwater leaching, and deposition from volatilized ammonia—and because such a large quantity of litter is necessary, a large-scale facility by itself is an almost immediate solution to nutrient concentration issues.

However, because of the scale of the project and the large footprint it could leave on the area, a large-scale, poultry litter-to-energy facility has to be a good fit with the environmental, economic, and social characteristics of the community in order to avoid health impacts. Areas with poor air quality could be trading one health risk for another. The air quality of the Valley should not be categorically classified as poor but there are concerning trends, foremost among them being the concentration of PM2.5. There are not a high number of point source emissions within the Valley to explain the higher concentration of PM2.5 and unless the majority is coming from a distant point source—such as a power plant in another state—the most likely contributor is from mobile sources. Although most of the Valley is very rural with little traffic congestion compared to more urban areas, Interstate 81, which runs directly through Augusta, Rockingham, and Shenandoah Counties is a common route for supply trucks moving goods across the Commonwealth. Demand in the larger economy of the region likely impacts the amount of truck travel through this stretch of highway, causing fluctuations in the annual concentrations of air pollutants. This may explain why the concentration of PM2.5 has had such variance over the past four years, as emissions would depend on how much trucks come through the Valley.

An understanding of the air pollutant concentrations at geographic areas smaller than what is publically available would be useful in identifying the most appropriate location for the facility. However, presuming mobile sources are the biggest contributor, it would probably be most beneficial to locate the facility far away from the main highways. Unfortunately, this location would also likely result in an increased interaction between the operations of the facility and local communities, increasing risk of both traffic accidents and community noise.

A vital consideration in any litter management strategy is the support it would receive from poultry growers. Among poultry growers with whom we spoke, there does not appear to be a consensus agreement as to the benefit of a large-scale, poultry litter-to-energy facility. Preliminary proposals indicate that a facility could operate with as little as one-quarter of available litter in the Valley committed to its operations with the rest of the fuel supplemented by woody biomass. Such a scenario reduces the contribution the facility would make to the core issue of nutrient concentration and impacts the composition of air emissions. Other strategies for litter management are also unlikely to be successful unless they will be adopted by a majority of individual growers.

The poultry industry provides a lot of benefit to the Valley and the desire of its residents to maintain its rural heritage. In addition to providing employment opportunities, poultry growing operations make use of and preserve large sections of the rural landscape. The litter produced as a result of poultry production also supports local agriculture which also serves to preserve the land from further development. As regulation on litter application increases, it is important for the Valley to develop alternative litter management strategies that support the industry. Although a large-scale, poultry litter-to-energy facility can contribute to that effort, a thoughtful and informed approach to the development of such a facility is critical to avoid introducing unnecessary health risks.

Appendix A: Report of Feedback from Initial Community Meeting

Health Impact Assessment for a proposed Poultry Litter-to-Energy Facility Community Meeting

March 30, 2012, 1:00 – 5:00 pm

Quality Inn, New Market, Virginia

Meeting Summary

Facilitated by UVa's Institute for Environmental Negotiation

Convened by VCU's Center for Human Needs along with support from Human Impact Partners

Meeting Summary Overview

Twenty-five people gathered at the Quality Inn in New Market, Virginia on March 30th for a meeting regarding the potential health impacts of a proposed poultry litter-to-energy facility in the Shenandoah Valley, Virginia. The meeting was convened by VCU's Center on Human Needs (CHN) and facilitated by UVa's Institute for Environmental Negotiation (IEN), with presentations and training support from Human Impact Partners (HIP).

The goals of the meeting were to introduce participants to what a Health Impact Assessment (HIA) is, to describe the poultry litter-to-energy HIA, and to gain input and provide feedback on the HIA scope. CHN is leading the HIA for the proposed facility, which is believed to be the first HIA conducted in Virginia. The HIA will be publically available on the CHN website after it is completed and the results will be disseminated to local and state decision makers and community members that express interest. Funding for the HIA is provided by the Health Impact Project, a collaboration between the Robert Wood Johnson Foundation and The Pew Charitable Trusts. Potential health concerns were discussed with respect to five main topic areas at the meeting: air quality, water quality, local economy, employment, and social cohesion. Future community engagement will follow in the summer and fall of 2012, and Ben Evans of CHN may be contacted for additional information for upcoming meetings (see the end of the meeting summary for contact information).

Meeting Opening

Ben Evans from the Center on Human Needs at Virginia Commonwealth University welcomed participants to the meeting and introduced the project, the purpose of the meeting, project partners, and funding for the HIA. Christine Gyovai, an IEN facilitator, solicited and reviewed meeting guidelines, and gave an overview of the agenda that included a presentation on the proposed poultry litter-to-energy facility and an overview of the HIA process followed by a review of the main elements of the HIA. After the presentations, group discussions revolved round the five study topics: air quality, water quality, local economy, employment, and social cohesion.

Before the presentation began, several participants had questions regarding the overall project as well as questions around the proposed poultry litter-to-energy facility. Three main questions were asked from meeting participants before the presentation started:

1. What are other options for addressing poultry litter in the valley?

2. Why aren't there more farmers at the meeting?

3. What other alternative energy technologies can be used with poultry litter in the region?

Ben Evans described that the poultry litter-to-energy facility is being explored partially in light of the need for Virginia to meet Total Daily Maximum Load (TMDL) water quality requirements for the Chesapeake Bay. The Commonwealth of Virginia recently submitted a Watershed Implementation Plan (WIP) that stated that Virginia would look into establishing poultry litter-to-energy facilities (as well as other options) in order to reduce sediment and nutrient runoff into waterways that eventually enter the Chesapeake Bay watershed.

In response to a participant's question and comment about the lack of farmers present at the meeting, one participant suggested that daytime meetings during the spring are a difficult time for farmers to participate as it is a busy time of the year. Another participant, who had previously attended public meetings in Page County about a proposed poultry litter-to-energy facility (which was not constructed), said that the lack of farmers at the meeting might be attributed to the status of the proposed facility. In other words, more farmers may have attended the meeting if the proposed facility had already applied for a permit, instead of being a proposed facility.

Another participant pointed to the general frustration that many farmers have toward increased regulations at the state and federal level around the increasing responsibility placed on farmers to meet these regulations, particularly around the Chesapeake Bay TMDL. The participant added that farmers care about the health of their families and land as well, but that proposed regulations were onerous to farmers. Another participant suggested that Friday afternoons were not convenient times to hold public meetings, and other methods to get the word out about the meeting would be helpful (such as conducting outreach through the Farm Bureau). A meeting attendee participant noted that future meetings should be held closer to where farmers live and, and suggested that meeting organizers reach out to meet with farmers at places like a Farm Bureau meeting or a "over the fence" – going out to speak with farmers at their farms. After this discussion, the HIA team thanked participants for their comments and presentations followed.

<u>Presentation on the Proposed Poultry Litter-to-Energy Facility and Overview of the Health Impact Assessment</u>

Ben Evans of VCU's Center for Human Needs and Jennifer Lucky and Casey Tsui of Human Impact Partners gave a presentation on the proposed Poultry Litter-to-Energy Facility and an overview of the Health Impact Assessment process. The presentation outlined the project description for the HIA as well as the potential location for the proposed facility in Augusta County, Virginia.

The steps for this HIA involve the following:

- Screening: determines the need and value of a HIA
- Scoping: determines which health impacts to evaluate, methods for analysis, and a work plan
- Assessment: provides a profile of existing health conditions and evaluation of potential health impacts.
- Recommendations: provide strategies to manage identified adverse health impacts and maximize beneficial health impacts
- Reporting: includes development of the HIA report and communication of findings & recommendations
- Monitoring: tracks the impact of the HIA on the decision-making process, the implementation of the decision, and the impacts of the decision on health determinants.

The specific goals for this HIA process are to: identify the potential public health impacts and benefits of the proposed poultry litter-to-energy facility; to develop recommendations to improve the plans to site this facility such that the decision serves to improve health; and increase awareness about HIA as a tool for identifying health impacts of decision-making.

The scope for the HIA would involve studying five specific topic areas: air quality, water quality, employment, social networks/social cohesion, and the local economy. Research questions that involve these topic areas may include the following examples of potential impacts:

- Traffic on local roads, and traffic safety
- Exposure of residents to facility emissions
- Pollutant concentration in groundwater, drinking water and surface waters
- Jobs available to local residents
- Changes in property values and municipal budgets
- Neighborhood livability

Feedback from participants, especially in regard to concerns of local community members, is crucial in the Health Impact Assessment process. The HIA team sought to gain input from meeting participants around these key themes:

- Are there other issues that the HIA should evaluate?
- What is missing from the questions posed in the presentation?
- How should these issues be prioritized?
- Are there any specific locations or vulnerable populations that the HIA team should pay special attention to?

A few questions were asked during the presentation. One question was about the price per ton that Fibrowatt, potential owners and operators of the poultry litter-to-energy facility, would pay farmers for their poultry litter. After some time for verification, a representative of Fibrowatt who was present at the meeting, stated that the company would pay the going fair market price for the poultry litter. In response to a question about the potential health outcomes of the proposed facility, the HIA team stated that the HIA will explore that question and will be completed by the end of 2012.

Group Discussion of Health Concerns

After the presentation, participants were asked to relate the health concerns they had about the proposed poultry litter-to-energy facility around five specific topic areas: air quality, water quality, employment, social networks/social cohesion, and the local economy. Below is a summary of the input and questions from participants regarding areas for consideration in the HIA articulated by meeting participants, grouped by topic area (although there is overlap between topics):

Air Quality

- Arsenic, which has historically been used in poultry feed and ends up in poultry litter, was noted as a primary concern from meeting participants.
    - One participant asked where does it go when combusted?
    - Where are the US Geological Survey arsenic hot spots in the area? (Another participant noted that none of them are currently on farms.)
- Is arsenic currently added to the poultry feed used in the Shenandoah Valley? Some participants noted that it is being phased out of poultry food currently and may no longer be a concern.
- What data is there on the emissions from existing facility in Benson, Minnesota (a poultry litter-to-energy facility by Fibrowatt currently is operating in Minnesota)? This information would be helpful to consider in the HIA.
    - Visibility and air quality:
    - What impact could there be on air quality in Shenandoah National Park? For what distances around the proposed facility and in which directions?
    - What effects would reduced visibility and potential smog have on tourism to the region?
    - How will an increase in truck traffic concentrating in the area around the plant affect air quality?

- ○ Will the emissions be trapped in the valley by the mountains? Where will the emissions go, and what are they?
- The HIA should look at the effects of particulate matter, (specifically particulate matter (PM) 10 and PM 2.5), and precursors to ozone.
  - ○ How much is formed? From the proposed plant, and from ash applied to land?
  - ○ From ground application?
  - ○ What are the thresholds for health impacts? What are the health impacts?
- It would be helpful to compare emissions of the proposed facility with existing emissions in the area. It would also be helpful to consider the emissions of litter as fertilizer and of ash (which is a byproduct of the poultry litter combustion process) as a fertilizer, as well as emissions of the ash plant as part of the Fibrowatt facility.
- What are the effects of bringing in poultry litter from other places to the centralized plant? There were concerns at the meeting around trucking and emissions.
- What are dioxin concerns? Participants noted that this needs to be addressed in depth in the HIA.
- The HIA should note tradeoffs between poultry litter as fertilizer versus farmers using synthetic fertilizers, and associated economic and environmental costs and benefits of each.

Local Economy

- How will the air quality changes impact the Shenandoah National Park (SNP)? Potential changes can include:
  - ○ Reduced visibility (and potential reduction in tourists and income from tourists).
  - ○ Will there be a potential increase in bad air quality days in the SNP?
  - ○ Water quality changes that may affect the number of Brook Trout and other trout in the water; also changes to the overall water quality of area waterways. This could impact the number of people who come to fish in the region and associated economic benefits from fishing.
- Ash, poultry litter, and fertilizer issues:
  - ○ The availability of ash fertilizer needs to be considered around the potential benefits and availability to farmers, as well as potential concerns from the ash.
  - ○ Effects of potentially bringing in poultry litter from out-of-area sources (but also potential health concerns of the ash) needs to be considered (including prices and concerns around water and air quality).
  - ○ The potential increase in the need to purchase commercial fertilizer and increasing cost of fertilizer needs to be considered, particularly if poultry litter will not be as readily available to area farmers.
  - ○ More information is needed on how will the size of the plant affect the cost of poultry litter and availability (how much litter would be available to farmers if the plant uses a significant amount of poultry litter)? Several participants noted this potential concern.
- Cost and availability of poultry litter:
  - ○ How will this affect the viability of the poultry industry in the region? Will this increase or decrease the need for poultry litter in the region?
  - ○ What will be the exact purchase price for poultry litter be for Fibrowatt?
  - ○ Who will it be purchased from? Farmers? Anyone?
  - ○ How will cost of poultry litter versus other fertilizers be affected by the proposed facility? What are the potential effects on other growers who use litter as fertilizer?
- Other issues and concerns to the local economy include:
  - ○ How will the cost of utilities/electricity affect local homes? Will the price increase or decrease as a result of the proposed facility?
  - ○ There is a need for more information about potential nutrient trading credits, and how they would work around nitrogen and phosphorous.
  - ○ Will centralized facility require public funds and subsidy?
  - ○ How will this affect local power bills/property taxes? How might it impact those on limited incomes?

- Distribution of benefits and negative impacts
  - What would be the tax benefits to host community?
  - Effects to surrounding counties around these areas (potential economic gains, water and air quality concerns, etc.)?
- Other effects to tourism that should be taken into account in the HIA include:
  - Fishing impacts
  - Viewshed and visibility considerations (and distance around each)
  - Community health (around many of the topic areas)
  - People visiting the plant (could the plant be a draw to scientists and researchers)?
  - Secondary impacts to tourism should be considered as well including a potential decrease in cabin rentals, dining opportunities, etc. in regard to potential pollution from the facility. Several participants commented on this point.
- Several participants noted the need to preserved farmland and promote agricultural viability in the Shenandoah Valley, as well as the character of the land use that is part of the tourist draw to the region.

Employment

- What type and how many jobs will be created with the proposed facility?
  - Will they be open to local or nonlocal as well?
  - How many transportation and construction jobs will be created?
  - How many will be full time, high quality jobs?
    - (According to Fibrowatt representative, 30 to 40 jobs will be created)
- Effects on existing employment
  - Could it help keep the local industry viable?
  - How can the Shenandoah Valley poultry industry remain competitive?
    - Poultry industry currently employs about 6,000 people and is very important to the local economy.
- Compare effect of different scales for manure to energy facilities (including different types of facilities) in the HIA.
  - Consider one larger facility in one location (such as the proposed Fibrowatt facility) versus many smaller facilities using different technologies in different regions, and potential advantages and disadvantages of each.
- One question was asked from a researcher from CHN around how many people currently have health insurance (as one indicator of the economic health of the region). Other participants asked what the potential effects might be on health insurance from the proposed facility in the region, including considerations around would it be more difficult to get insured, and will the price for insurance increase/decrease?

Water Quality

- What would be the potential impacts on brook trout and fishing in general be from the proposed facility? How would water quality be impacted, and are there any polluted streams near the location of the proposed facility?
- What would the plant water use be? How much water would be used, and what would the water quality be before it enters the facility and after it exits?
- How does the ash behave in soil/water? Is it soil or water borne? How would it potentially impact waterways, and water are the potential health outcomes of the ash?
- How much of an impact will removing litter have on the watershed, both in increasing water quality and potential increase in use synthetic fertilizers?
- How will application of fertilizer change?
- Potential nitrogen and phosphorous nutrient credit trading opportunities need to be available to growers as well as others.

Social Cohesion

- What effect will the proposed facility have on local jobs and families?
- Will the proposed facility help maintain the open space and agricultural nature of the Shenandoah

Valley? Or be a detriment to it? Will some growers not be able to afford synthetic fertilizer, for example, and go out of business thus increasing potential development? Currently the poultry industry helps maintains farmland in the Valley.
- Will the proposed facility use all the excess (not used for land application) poultry litter and therefore discourage other entrepreneurial, farm-based alternatives, such as composting, bailing, gasification, and pyrolysis? If so, will this have a destabilizing effect on the diverse solutions/options for the poultry industry?
- What will be the potential impact of truck traffic and noise, and how will that affect local communities? What route would trucks take? What would the effect of diesel be on surrounding homes and communities?
- How will the size of the plant affect the attractiveness of the area; how will this effect neighbors? For example, will it be a large facility near a residential neighborhood, or would it be located in an industrial area?
- The HIA should consider the overall nature that the proposed facility could use a regionally available fuel, and that could be attractive from a sustainability standpoint.
- Participants noted whether the perception of the proposed facility would be "clean" or "polluting" by residents and visitors, and this should be considered in regard to social cohesion and quality of life.
- Odor concerns
  - Will the poultry litter have an odor?
  - Will odor be concentrated where it is stored?
  - Will there be an odor from trucks?
  - At the facility and during combustion?

Based on these participant responses, a few **cross-cutting themes** emerged, as well as other areas for consideration, including:

- Maintaining farmland and patterns of land use was important to meeting participants.
  - The proposed facility maintains a compatibility with the poultry industry, which is important in the Shenandoah Valley.
  - Maintaining economic viability of agricultural activities, as well as maintaining viewsheds and land use patterns are important for both residents and visitors to the Shenandoah Valley.
- Effects on tourism are an important concern for community members.
  - Perception of impacts may be just as important as actual negative impacts (around tourism, jobs, and livability) for one-time and repeat visitors.
- What infrastructure would be associated with the plant, including power lines that might affect views, and other infrastructure considerations?
- How would the change in poultry litter use affect soil health, especially around a potential decrease in applying poultry litter to the soil for agriculture?
  - Would there be a change in organic versus inorganic matter in the soil over time?
  - What would long-term agricultural residue in soils be from a change in fertilizer use?
- What are the additional impacts of all the biomass required by the plant? A significant amount of biomass could be required by the proposed facility and should be considered in the HIA as well.
- What would the price per ton of poultry litter be paid by Fibrowatt?
  - Will litter be bought on contract? Potentially a 10-year contract?
  - How does this compare to potential benefits to growers from diverse, farm-scale alternatives?
- How much poultry litter is currently available in the Shenandoah Valley? How will this determine the size of the plant?
- What specific impacts will the facility have on farmers?

Next Steps

After the large group discussion, the last part of the meeting was dedicated toward discussing the next steps in the HIA process. Another HIA follow up meeting will likely be planned for the fall of 2012, however the venue for the meeting would likely change. Participants were asked for ways to get more stakeholders involved, and other helpful ideas to keep in mind for the next meeting. Participants suggested the following:

- Outreach specifically in Augusta County, where the facility is being proposed.
- More information on how poultry litter can be used beyond only the proposed Fibrowatt facility.
- Conducting more outreach to local farmers, and having representatives from the Farm Bureau present would be helpful.
- Tractor Supply – use both to get the word out, invite people to future meetings.

Participants were encouraged to continue communication with CHN, including the possibility of forming a committee to continue to provide input for the Health Impact Assessment. This could allow CHN and community members to stay up-to-date on the progression of the HIA for the proposed poultry litter-to-energy facility.

If anyone would like additional information about the meeting, or have any questions with regard to the HIA process for the proposed Fibrowatt facility, please contact CHN's Ben Evans at (804) 828-4573 or bfevans@vcu.edu.

Appendix B: Research Questions

Table B1: Air Quality Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicators	Data Sources	Methods
Proximate Effects				
What are existing levels of air pollution? Specifically, NOx, SOx, PM, arsenic, dioxins/furans, ammonia?	How would the concentrations of these air pollutants change as a result of a new point-source permit?	Concentration of NOx, SOx, PM, ammonia, dioxins/ furans, arsenic	EPA's National Emissions Inventory, EPA's National-Scale Air Toxics Assessment, Stack test results from facilities in Minnesota and the United Kingdom	Air modeling
	How will the concentrations of ammonia and PM change as a result of the change of fertilizer types?			Literature review
Health Outcomes				
What is the current rate of pulmonary illness among residents of the Valley	How would changes in air quality resulting from the project be expected to impact pulmonary illness?	Prevalence of asthma, chronic obstructive pulmonary disorder (COPD), other pulmonary-related illness; Utilization of pulmonary-related health care services	Virginia Health Information (VHI), Virginia Department of Health (VDH), Behavioral Risk Factor Surveillance System (BRFSS), National Center for Health Statistics (NCHS)	Air modeling, literature review
What is the current rate of respiratory-related mortality among residents of the Valley?	How would changes in air quality resulting from the project be expected to impact respiratory-related mortality?	Respiratory disease-specific mortality rate	CDC Wonder, VDH	
What is the current rate of heart disease among residents of the Valley?	How would changes in air quality resulting from the project be expected to impact heart disease?	Prevalence of heart disease, hypertension, brachycardia	VDH, BRFSS	
What is the current rate of heart disease mortality among residents of the Valley?	How would changes in air quality resulting from the project be expected to impact heart disease-mortality?	Heart disease-related mortality rate	CDC Wonder, VDH	
Vulnerable populations				
How do demographics of populations living near air pollution sources compare to characteristics of people living elsewhere?	Will projected changes in air pollution exposure adversely impact people with social, economic, or education-related vulnerabilities?	Income, ethnicity/ race, age data	U.S. Census Bureau	Qualitative description (lit review and review of available stats)
What is current air quality at the sites at which sensitive receptors live, work, play, or go to school?	How will the proposed project impact air quality for sensitive receptors at those sites?	Air quality measurements at various sites	EPA's National Emissions Inventory, EPA's National-Scale Air Toxics Assessment	Qualitative description (lit review and review of available stats)

Table B3: Employment Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicators	Data Sources	Methods
Proximate Effects				
How many people are currently employed in the agriculture industry in the Valley? How sound is the long-term future of the industry in the Valley?	How will employment among poultry farmers change as a result of the project?	Number of people employed in poultry farming, average wage, prevalence of benefits	Census Bureau, Bureau of Labor Statistics, Virginia Poultry Growers Federation, Farm Bureau, focus group	Qualitative description, literature review, focus group
	How will employment among litter brokers and applicators change as a result of the project?	Number of people employed as litter brokers/applicators, average wage, prevalence of benefits		
	How will employment among crop farmers change as a result of the project?	Number of people employed in crop farming, average wage, prevalence of benefits		
Health Outcomes				
What are the current rates of fair/poor health status? Hospitalization rate? Mental health impairment?	How would changes in employment impact the prevalence of fair/poor health status, hospitalization, mental health impairment?	Self-reported health status, hospitalization rate, measurements of mental health	VDH, BRFSS	Qualitative description, literature review

Table B4: Alternative Technologies Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicators	Data Sources	Methods
Proximate Effects				
How much demand is there currently for alternative litter management strategies such as on-farm, litter-to-energy conversion units, composting, baling, pellitization?	How would this demand change as a result of the project?	Number of farmers willing to invest in alternative strategies	Focus groups	Qualitative description

Table B2: Water Quality Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicators	Data Sources	Methods
Proximate Effects				
What is the current status of rivers, streams, lakes, and other water bodies in the Valley?	How will the level of impairment among water bodies in the Valley change as a result of atmospheric deposition/acidification from the new point source?	Number of streams, rivers, lakes, or water bodies that are listed as impaired	DEQ's 2010 Water Quality Assessment; EPA's MyWater Quality Assessment	Air modeling
	How will the level of impairment among water bodies in the Valley change as a result of changes in fertilizer types and application methods?			Qualitative description, literature review
	How will the level of impairment among water bodies in the Valley change as a result of water being used in the industrial process?			Qualitative description, literature review
Health Outcomes				
What is the current risk of methemoglobinemia in infants?	How would that risk change as a result of the new project?	Level of nitrate in the ground water	Virginia Cooperative Extension	Qualitative description, literature review
What is the current risk of arsenic exposure in drinking water?	How would that risk change as a result of the new project?	Level of arsenic in the ground water	Virginia Cooperative Extension	Qualitative description, literature review
Vulnerable Populations				
How do demographics of populations with well water sources differ from populations with municipal sources?	Will projected changes in water quality benefit people with social, economic, or education-related vulnerabilities?	Income, ethnicity/race, age data	Census Bureau	Qualitative description, literature review

Table B6: National Park Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicators	Data Sources	Methods
Proximate Effects				
How much community revenue and employment are generated from the Shenandoah National Park? How integral to the rural/agricultural perception of the Valley is the National Park?	How would revenue and employment related to the park change as a result of the project?	Income and jobs related to tourism and visiting the National park	National Park Service	Qualitative description, literature review
Health Outcomes				
What are the current rates of fair/poor health status? Hospitalization rate? Mental health impairment?	How would changes in employment impact the prevalence of fair/poor health status, hospitalization, mental health impairment?	Self-reported health status, hospitalization rate, measurements of mental health	VDH, BRFSS	Qualitative description, literature review
Vulnerable populations				
How do the demographics of those employed by the park or have some financial attachment to the park differ from those who do not?	Will changes to the national park be disproportionately impact people with social, economic, or education-related vulnerabilities?	Income, ethnicity/race, age data	Census bureau	Qualitative description, Literature review

Table B5: Heavy Truck Traffic Research Questions

Existing Conditions Research Questions	Impact Research Questions	Indicator	Data Source	Methods
Common Questions				
What percentage of the traffic in the Shenandoah Valley currently comes from heavy trucks?	How would that percentage change as a result of the new project?	Percentage of traffic that is heavy trucks, percentage on community roads, percentage on highways	Virginia Department of Transportation	Modeling, qualitative description, literature review
Health Outcomes				
How many traffic accidents currently occur in the Valley? How many fatalities?	How would the number of injuries and fatalities from traffic accidents change as a result of the project?	Injuries and fatalities from traffic accidents	National Highway Transportation Safety Administration, Virginia Department of Transportation	Qualitative description
What is the rate of respiratory and pulmonary illness in the Valley?	How would that rate change as a result of changes in air quality related to heavy truck traffic?	Concentrations of particulate matter, ozone, NOx, SOx, heavy metals	EPA's National Emissions Inventory, EPA's National-Scale Air Toxics Assessment	Qualitative description, literature review
What is the current rate of stroke and hypertension in the Valley?	How would that rate change as a result of increased traffic-related noise in the Valley?	Prevalence of stroke and hypertension	VDH, BRFSS, CDC Wonder	Modified risk ratio from national and state estimates
Vulnerable populations				
How do demographics of populations living near the location of the facility compare to characteristics of people living elsewhere?	Will projected changes in air pollution and noise exposure adversely impact people with social, economic, or education-related vulnerabilities?	Income, ethnicity/race, age data	Census	Qualitative description (lit review and review of available stats)

Appendix C: Air Quality

Section C1: Air Model Methods

Introduction

A model was used as a quantitative tool to correlate the source (proposed stack) and effect of air quality constituents found in an area. The EPA has proposed a number of models to simulate air quality under different scenarios. One of the most recent models is AERMOD model for industrial sources. AERMOD has become the EPA preferred regulatory model and was the model used in this study.

What is AERMOD?

Pollutants are continuously released from numerous sources into the atmosphere. The pollution sources could be point sources (e.g., stacks or vents), area sources (e.g., landfills, ponds, storage piles), or volume sources, (e.g., conveyers, structures with multiple vents). The source in this study was a point source (proposed stack). The dispersion of the pollutants in the atmosphere emitted from these sources depends on various factors. These factors can be classified into two main categories.

Source characteristics:

- Emission rate of pollutant
- Stack height
- Exit velocity of the gas
- Exit temperature of the gas
- Stack diameter

As well as:

- Meteorological Conditions:
- Wind velocity
- Wind direction
- Ambient temperature
- Atmospheric stability
- Mixing height

AERMOD Model and Its Characteristics

AERMOD uses a Gaussian and a bi-Gaussian approach in its dispersion models. It generates daily, monthly, as well as annual concentrations of pollutants in ambient air. The model handles a variety of pollutant sources in a wide variety of settings such as rural and urban as well as flat and complex terrain. It is an updated version of the Industrial Source Complex (ISCST3) model that had been used by the USEPA for assessing air quality impact from industrial sources.

AERMOD is actually a modeling system with three separate components: AERMOD, AERMAP (AERMOD Terrain Preprocessor), and AERMET (AERMOD Meteorological Preprocessor). The features of the AERMOD model are: i) concept of plume penetration, ii) estimation of dispersion coefficients, iii) estimation of plume rise, iv) concentrations predictions in convective layer, v) concentration predictions in stable layer, vi) handling of downwash, and vii) treatment of simple terrain and complex terrain.

The model is applicable to primary pollutants and continuous releases of toxic and hazardous waste pollutants. Chemical transformation is treated by simple exponential decay.

The information for the AERMOD model can be downloaded from the USEPA's web site (http://www.epa.gov/scram001/tt26.htm#aermod)

Input Data Requirements

The site information source as well as meteorological data is used as inputs for AERMOD. Receptor data are also specified as well.

A typical AERMOD interface uses the five pathways to develop an input file. These pathways are Control pathway, Source pathway, Receptor pathway, Meteorological pathway, and Output pathway.

The Control pathway is used to specify the modeling scenario, and the overall control of the modeling run. Source pathway is used to define the sources of pollutant emissions. Receptor pathway is used to determine the air quality impact at specific locations. Meteorology pathway is used to define the atmospheric conditions of the area being modeled, which will be useful to determine the distribution of air pollution impacts for the area. The Output pathway allows the user to define the type of output results necessary to meet the needs of air quality modeling analyses.

Control pathway is a collective term used to specify the overall job control options including titles, dispersion options, terrain options, and pollutant/ average time options.

Source pathway feature enables the handling of multiple sources, including point, volume, and area source types. Several source groups may be specified in a single run, with the source contributions combined for each group. It also has various features such as building downwash, urban sources, and hourly emission file.

Receptor pathway in the software allows for the flexibility in the specification of receptor locations. The user can specify multiple receptor networks in a single run. A Cartesian grid receptor network was used in this analysis.

In the meteorology pathway the model uses a file of surface boundary layer parameters and a file of profile variables including wind speed, wind direction, and turbulence parameters. These meteorological inputs are generated by the meteorological preprocessor AERMET.

The Output pathway allows for the processing of several averaging periods using the emissions data.

AERMET and AERMAP

The module AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters such as mixing height and friction velocity, needed by AERMOD. Data used were representative of the meteorology in the modeling domain. Specifically, National Weather Service (NWS) hourly surface observations, and NWS twice-daily upper air soundings and data were employed and processed using AERMET.

The module AERMAP was used as a gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location. AERMAP was run utilizing site-specific Digital Elevation Model (DEM) data obtained from the United States Geological Survey (USGS).

Coordinate Systems

The modeling was performed using the Universal Transverse Mercator (UTM) system. UTM is more precise than latitude and longitude in defining a location of the proposed facility and uses meters as its basic unit of measurement.

Terrain

Terrain elevation was defined as the elevation relative to the facility base elevation. The results of the air quality modeling were impacted by terrain elevations. The terrain used in the model was "Complex Terrain". In this case, the terrain elevations for the surrounding area, defined as anywhere within 50 km from the stack, are above the top of the stack being evaluated. AERMAP is the digital terrain pre-processor for the AERMOD model. It analyzes and prepares digital terrain data for use by AERMOD. AERMAP requires that the digital terrain data files be in native 7.5-minute DEM format, which were used in the modeling.

Model Inputs

Meteorology plays an important role in the dispersion of effluents. Various meteorological factors affect the dispersion of emissions into the atmosphere in a variety of ways. One of the most important meteorological variables responsible for high ground level concentrations is the height of convective boundary layer (or mixing height).

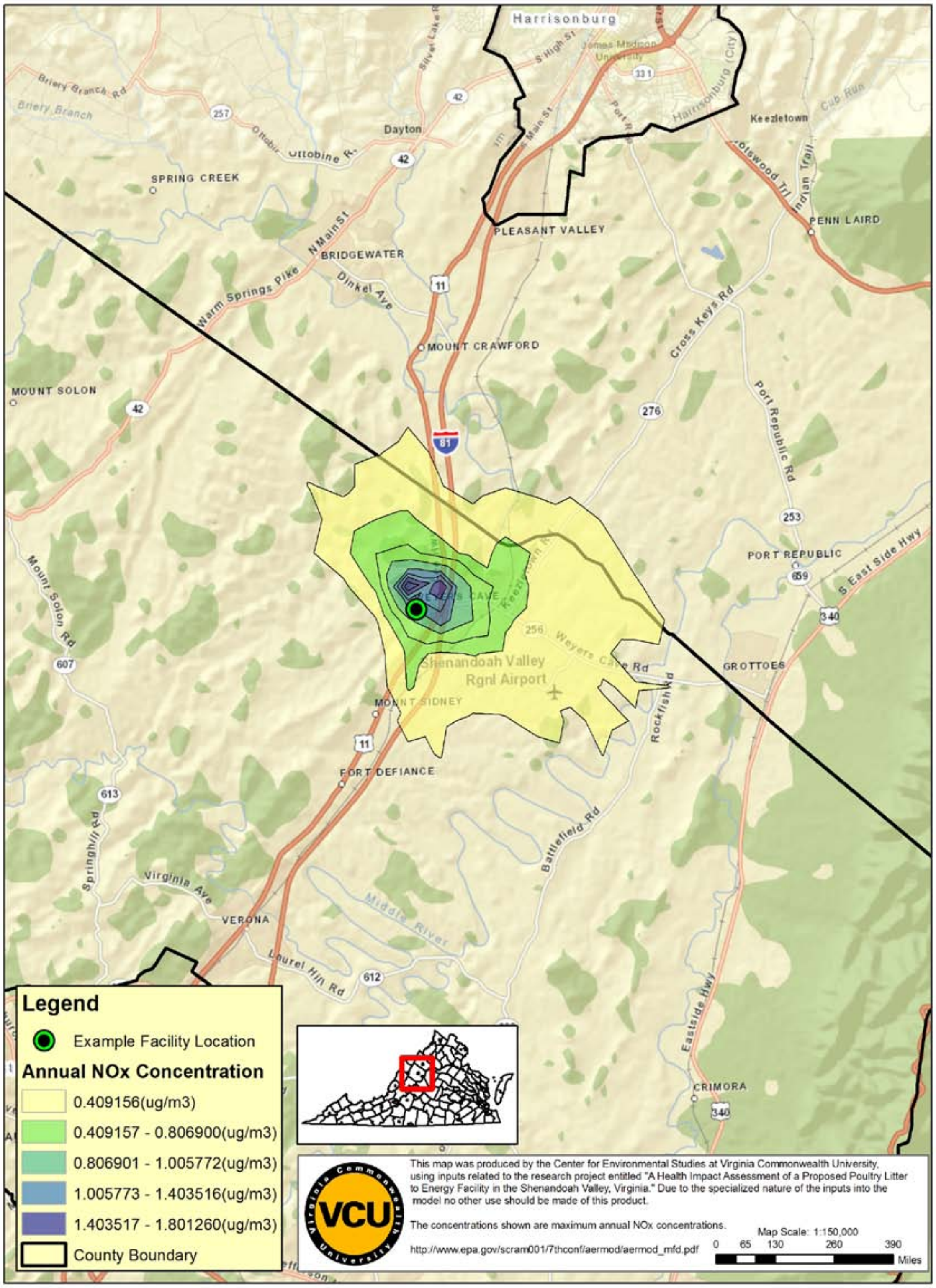
Model inputs were as follows:

- Surface data and mixing height files (employing the AERMET processor) were taken from SCRAM for the year 1990 at the Roanoke/Woodrum Airport (surface station #13741).

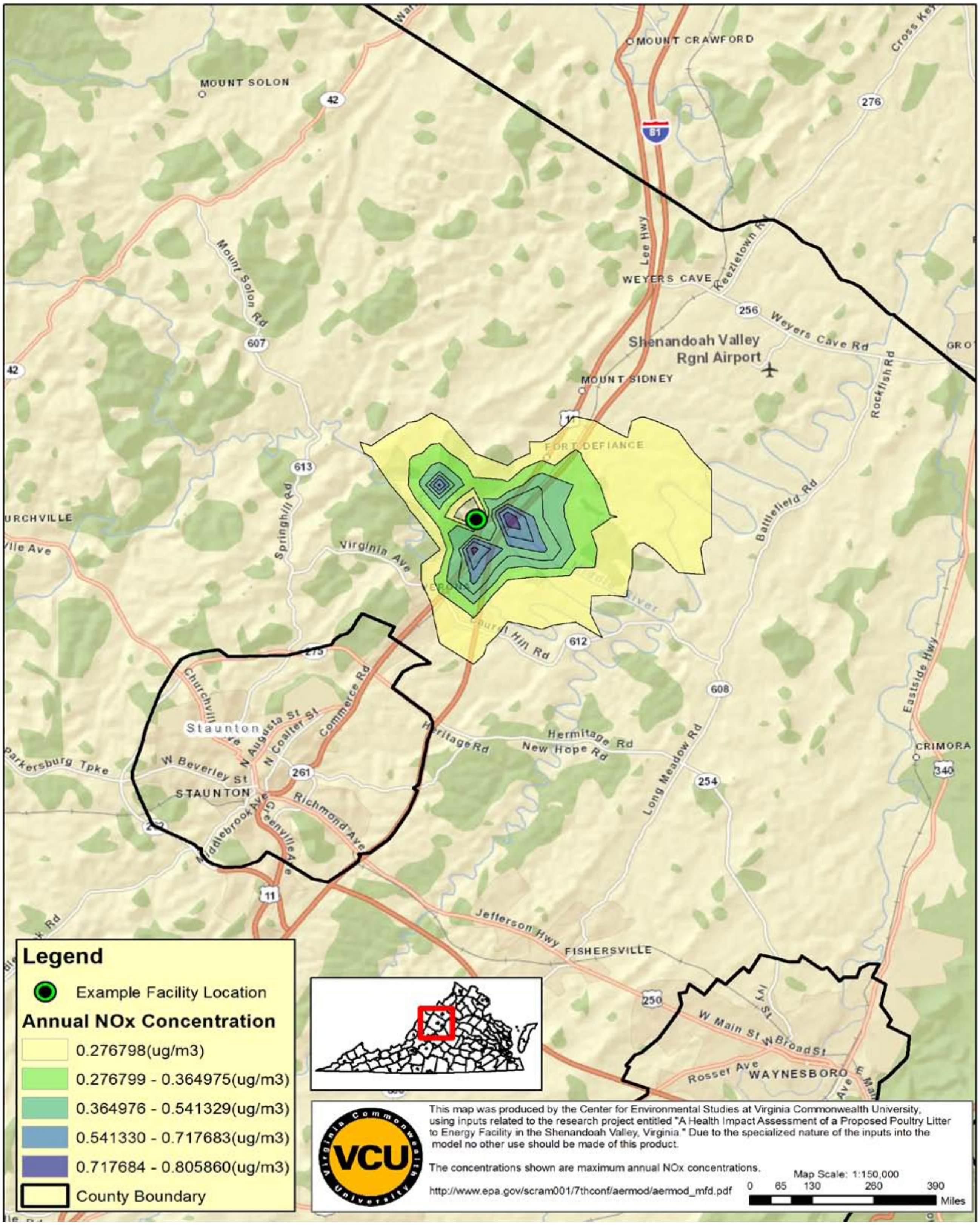
- Upper atmospheric data were also taken from 1990, but from the Sterling meteorological station (surface station #93734).
- The proposed stack was modeled as a point source at a release height of 180 meters.
- The source emission rates used for the various constituents (As, NOx, PM2.5 and SOx) were taken from Fibrominn, an operating poultry litter-to-energy facility in Minnesota. Specifically, the maximum emission rates at 100% load were taken from Table 5-1 on Page 5-3 of the "Application for a PSD Permit to Construct and a Federal Permit to Operate for the Fibrominn Biomass Plan, Benson, Minnesota". This application was prepared by Alternative Resources Inc., and was dated August 28, 2001. The document "Updated Air Quality Impacts Analysis for Minor Design Changes of the Fibrominn Biomass Plant, Benson, Minnesota", prepared by ARI and dated September 24, 2004 was also utilized.
- Gas exit temperature was 500K.
- Stack inside diameter was 2.5 meters.
- Gas exit velocity was 25.0 meters/second.
- Gas exit flow rate was 260,025.95 cubic feet per minute.
- Receptors were modeled as a uniform Cartesian grid with 225 discrete receptors.
- The AERMAP terrain processor was used to model the terrain utilizing actual topographic data from the Shenandoah Valley.

Section C2: Results of the Air Modeling

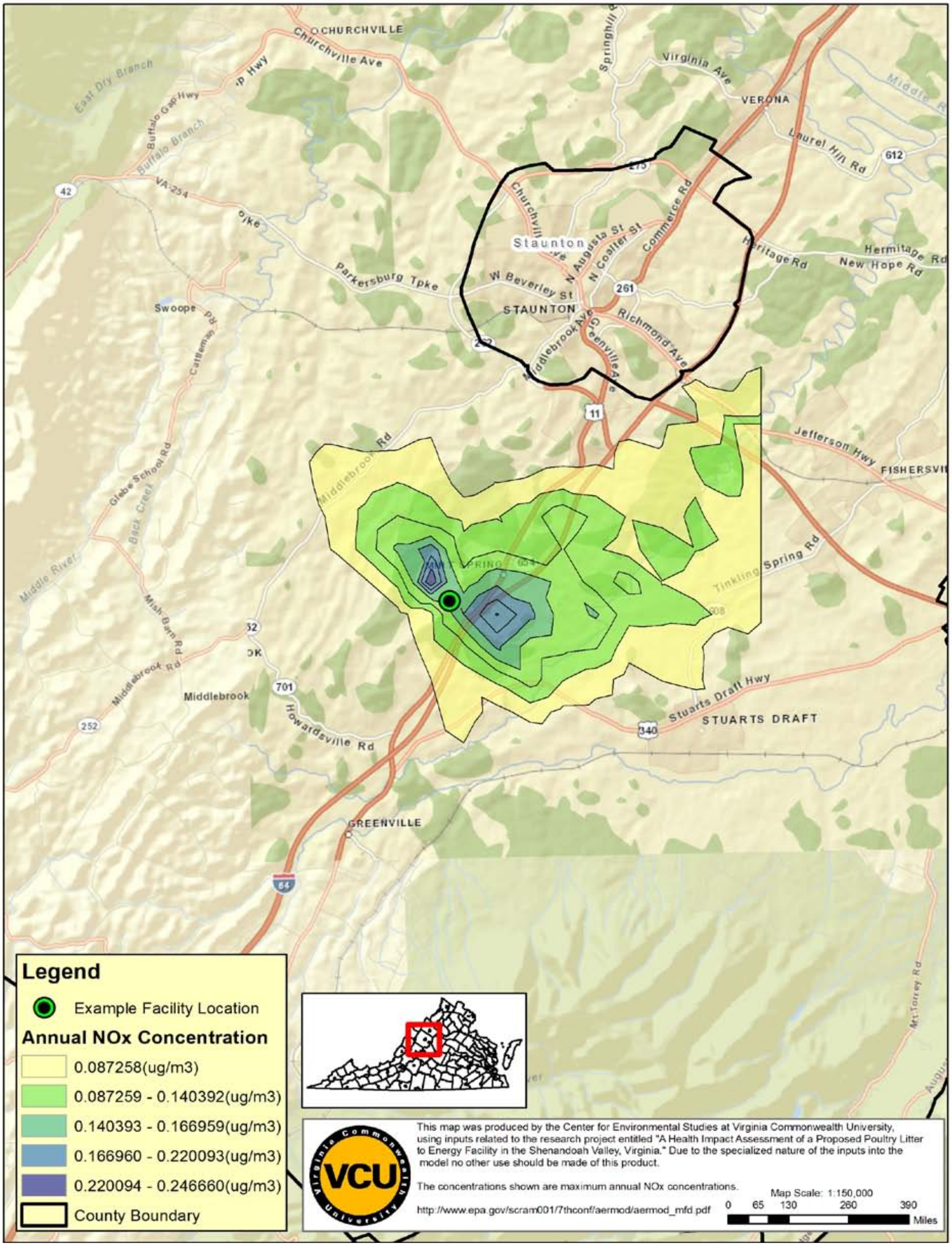
Map C1: Estimated Emissions of Nitrogen Oxides from the Northern-Most Location



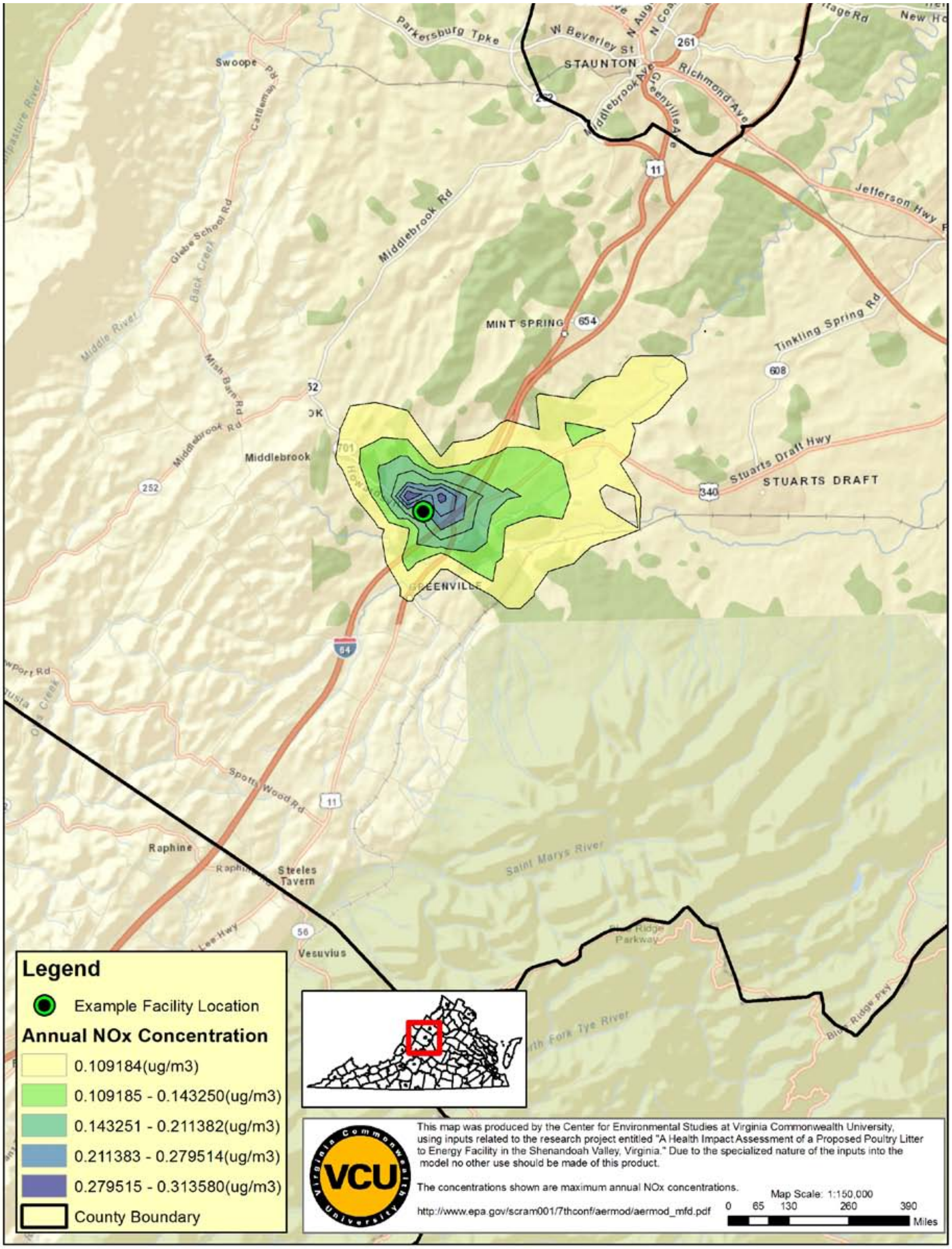
Map C2: Estimated Emissions of Nitrogen Oxides from the 2nd Northern-Most Location



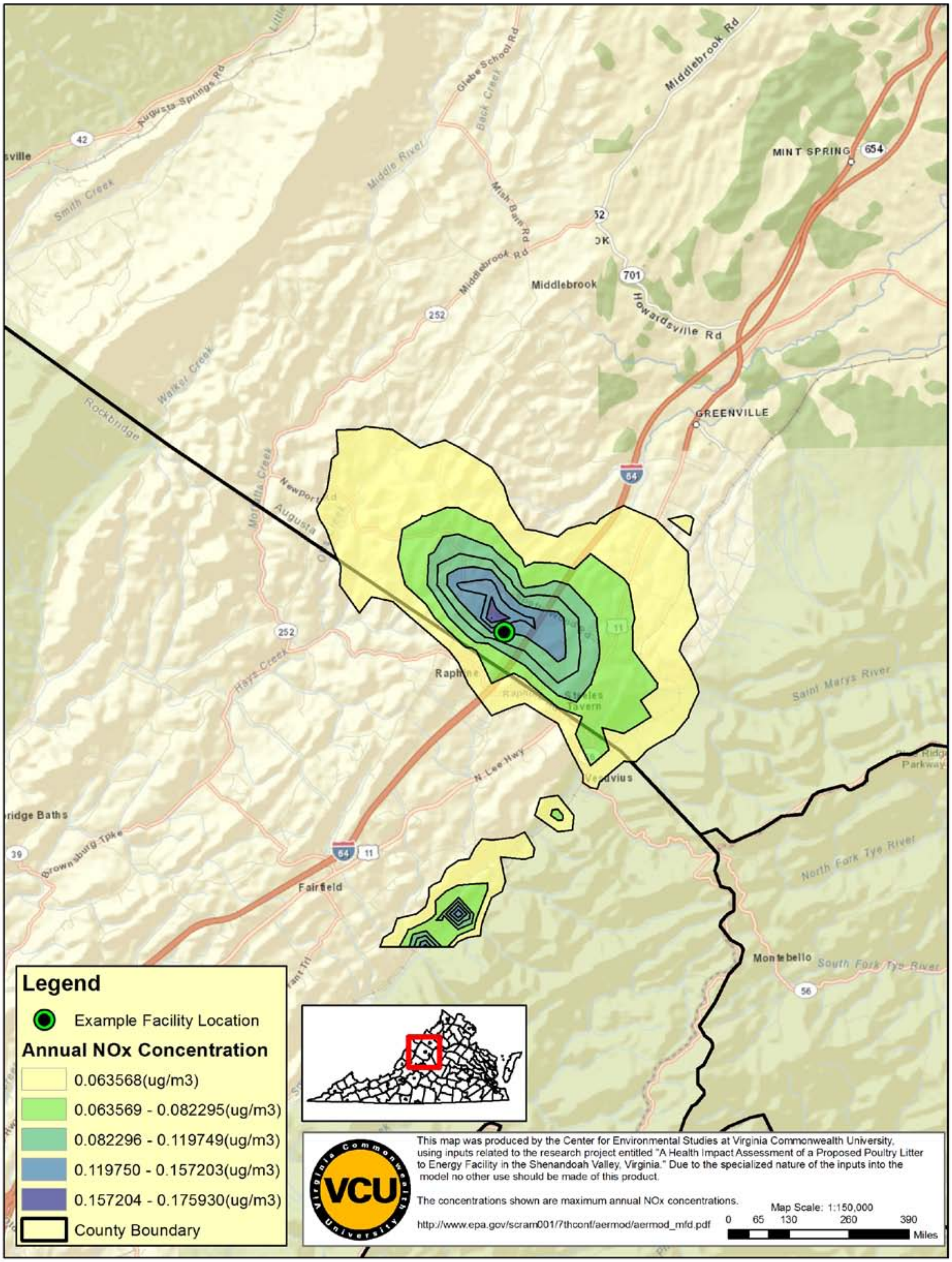
Map C3: Estimated Emissions of Nitrogen Oxides from the 3rd Northern-Most Location



Map C4: Estimated Emissions of Nitrogen Oxides from the 4th Northern-Most Location



Map C5: Estimated Emissions of Nitrogen Oxides from the Southern-Most Location



Map C6: Estimated Emissions of Nitrogen Oxides from the Eastern-Most Location

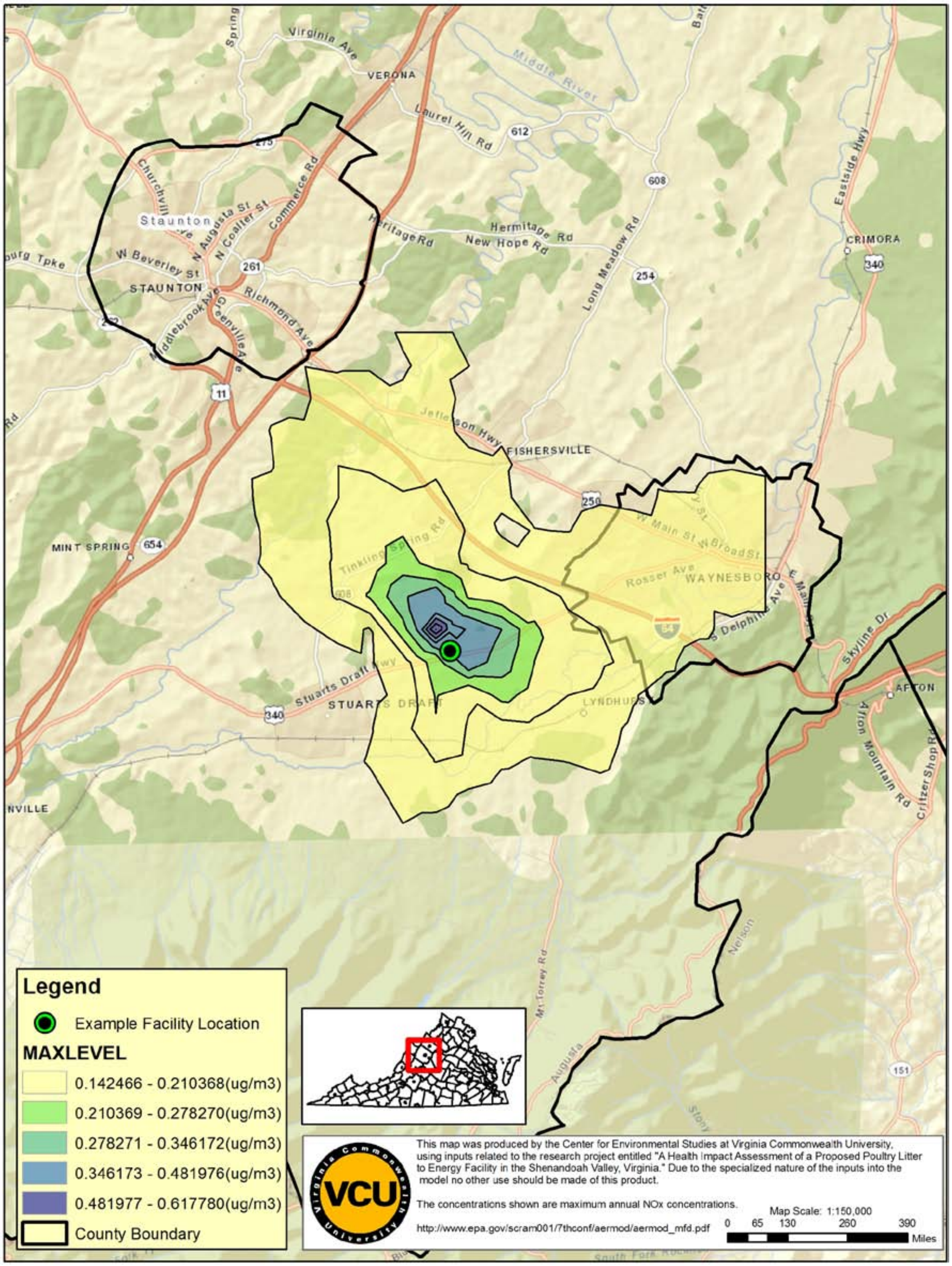


Table C1: Characteristics of Tracts Impacted by Potential NOx Emissions

Place	Unemployment Rate	Median Income	Percent in Poverty
Augusta 703	1.7%	$54,254	7.5%
Augusta 706	1.1%	$58,991	9.2%
Augusta 707	4.6%	$43,152	12.1%
Augusta 708	3.8%	$45,000	8.8%
Augusta 709	4.6%	$46,757	9.8%
Augusta 710	2.5%	$52,857	13.3%
Augusta 711.01	5.9%	$45,821	***4.9%***
Augusta 711.02	8.0%	$54,115	10.9%
Waynesboro	**10.8%**	$40,977	**19.4%**
Rockbridge 9301	5.3%	***$39,283***	13.9%
Rockbridge 9302	4.3%	$40,122	10.6%
Rockingham 116	3.0%	$57,734	***4.9%***
Rockingham 117	1.3%	$45,292	13.7%
Rockingham 118	4.3%	**$63,192**	6.6%

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey, 5-Year Estimates

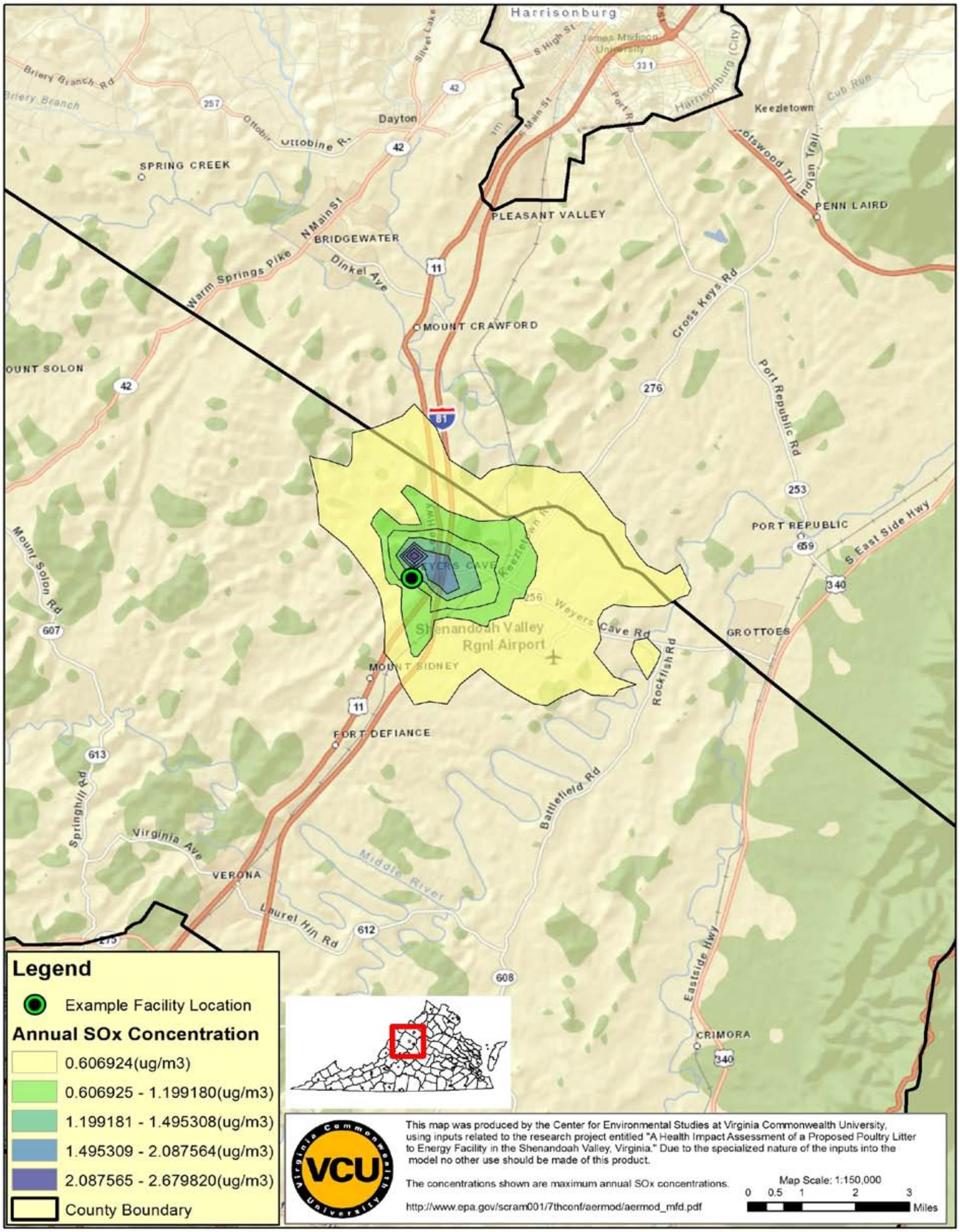
Table C2: Characteristics of the Population Exposed to Potential NOx Emissions by Location of the Facility

Location	Counties Impacted	Census Tracts Impacted	Population	Age Distribution				Shenandoah National Park Impacted (Y/N)
				< 18	18 – 44	45 – 64	>65	
Northern Most	Augusta, Rockingham	116; 117; 118; 703	17,609	23.1%	30.5%	28.6%	17.7%	N
2nd Northern Most	Augusta	703; 707; 708	17,747	23.5%	30.3%	30.7%	15.5%	N
3rd Northern Most	Augusta	709; 710	10,353	19.6%	29.2%	32.2%	19.0%	N
4th Northern Most	Augusta	709; 710	10,353	19.6%	29.2%	32.2%	19.0%	N
Southern Most	Augusta, Rockbridge	710; 9301; 9302	17,229	20.7%	30.6%	30.8%	17.9%	N
Eastern Most	Augusta, Waynesboro	706; 709; 710; 711.01; 711.02	28,581	22.5%	30.9%	29.6%	17.1%	Y

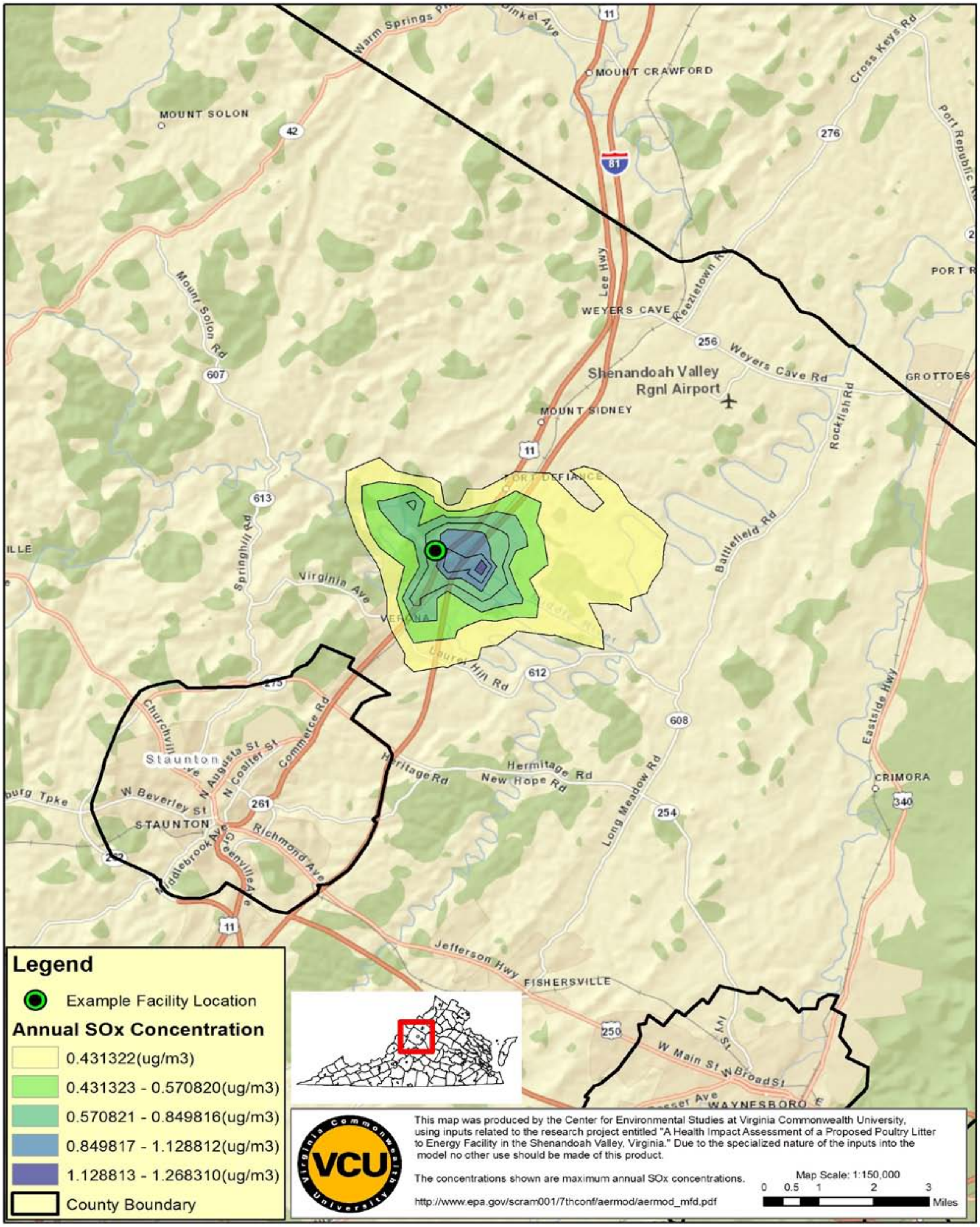
Note: The population estimates are of the census tracts and places which are the approximate site of the NOx emissions. They do not represent estimates of the population that would be exposed.

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey 5-Year Estimates

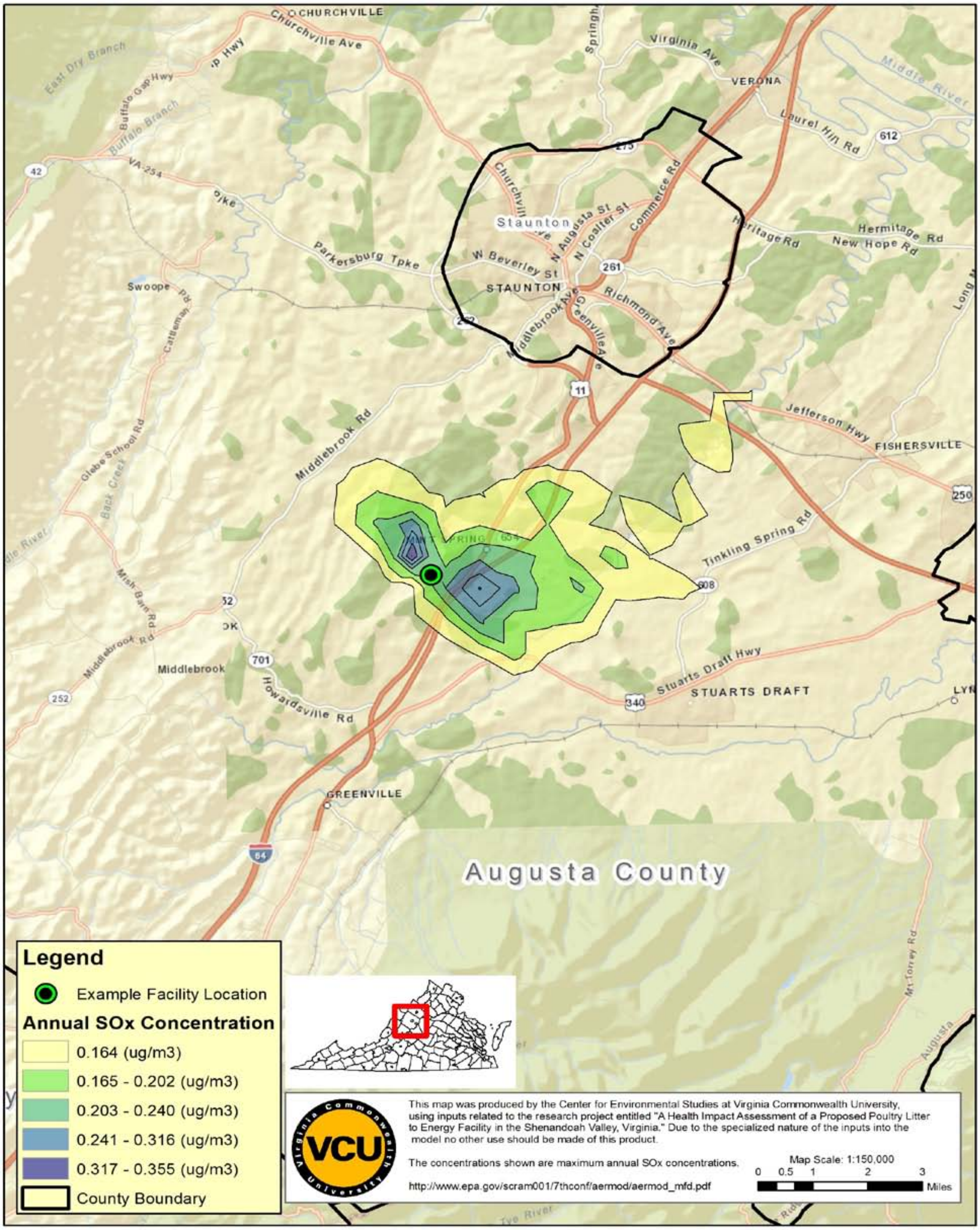
Map C7: Estimated Emissions of Sulfur Oxides from the Northern-Most Location



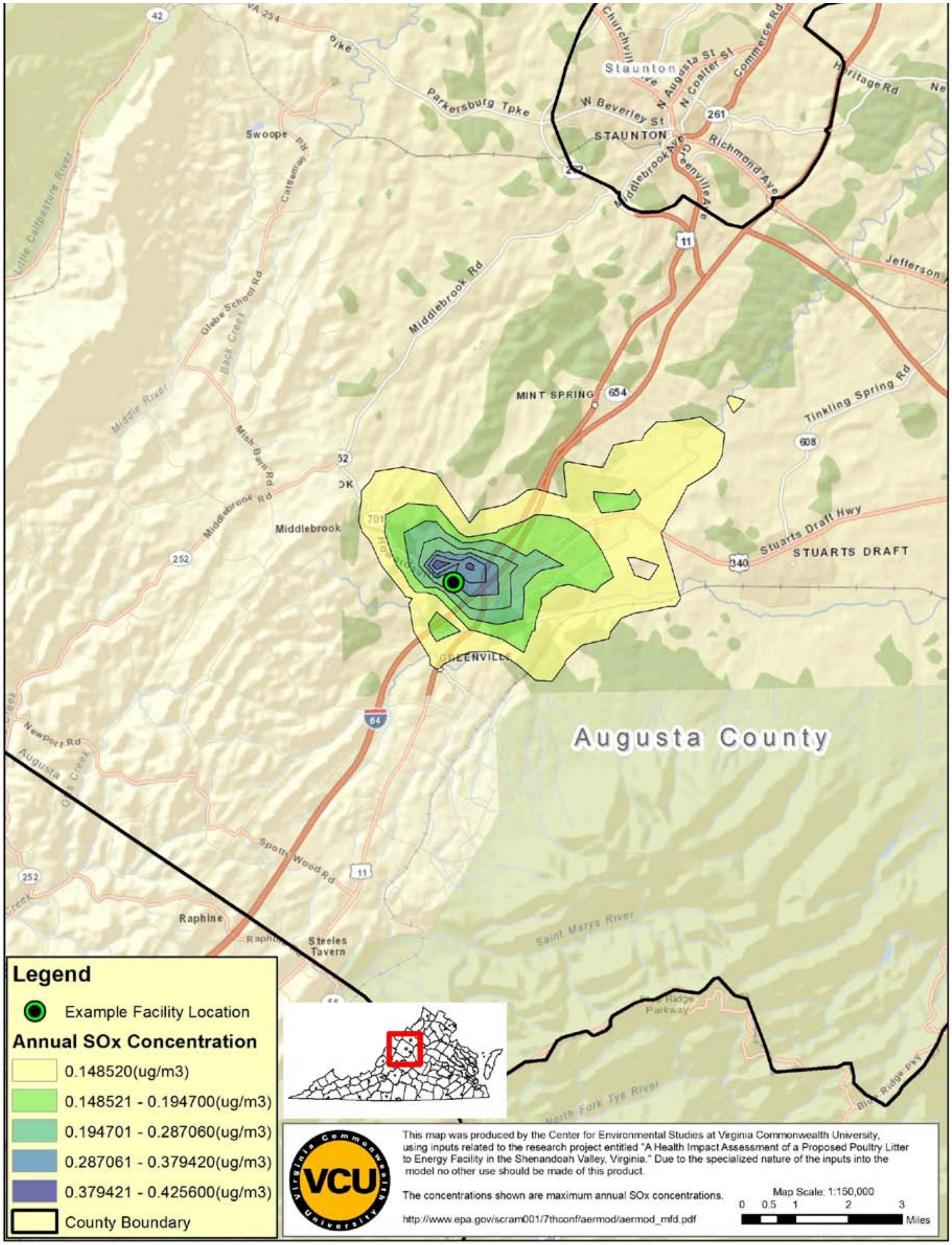
Map C8: Estimated Emissions of Sulfur Oxides from the 2nd Northern-Most Location



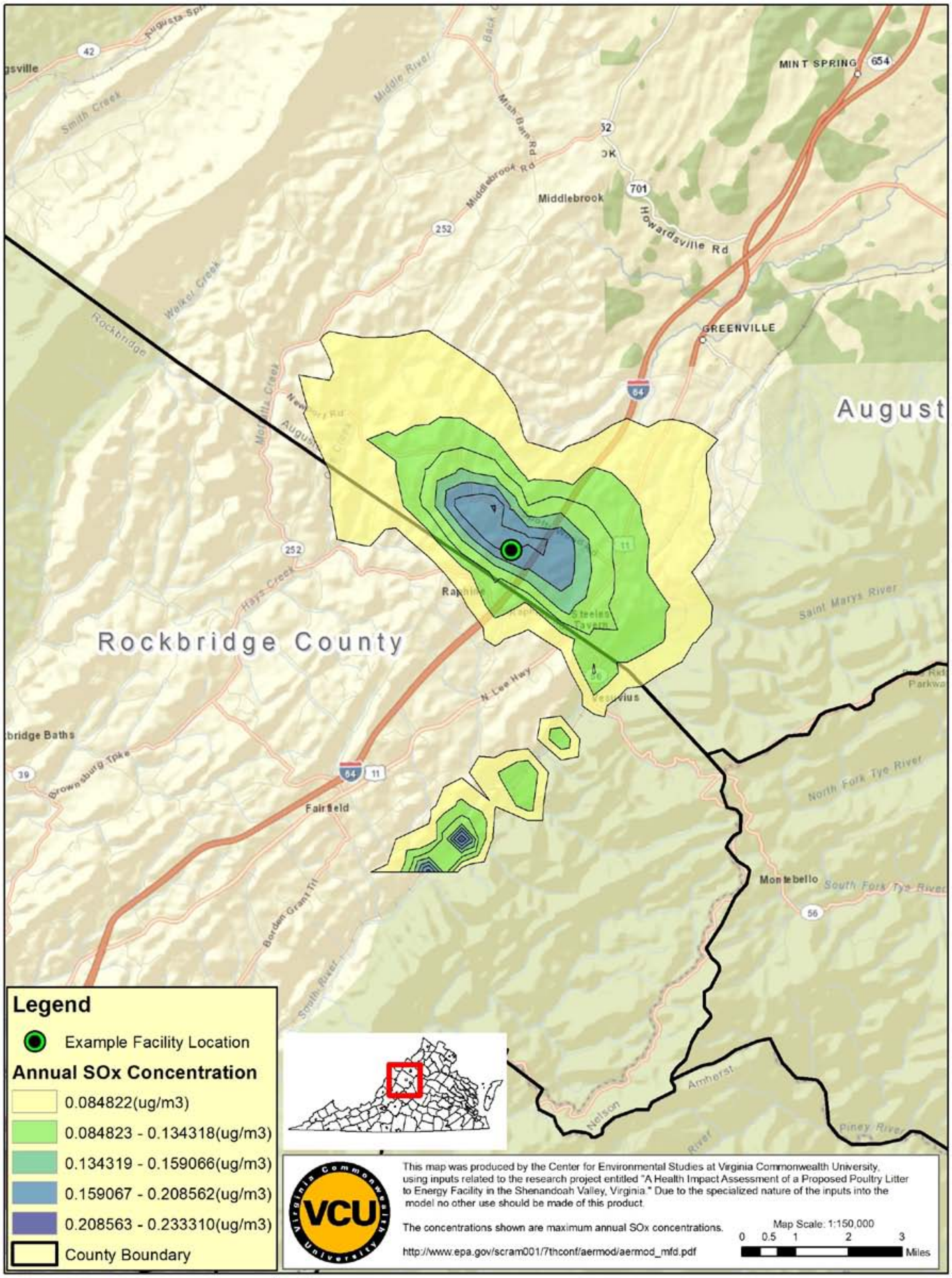
Map C9: Estimated Emissions of Sulfur Oxides from the 3rd Northern-Most Location



Map C10: Estimated Emissions of Sulfur Oxides from the 4th Northern-Most Location



Map C11: Estimated Emissions of Sulfur Oxides from the Southern-Most Location



Map C12: Estimated Emissions of Sulfur Oxides from the Eastern-Most Location

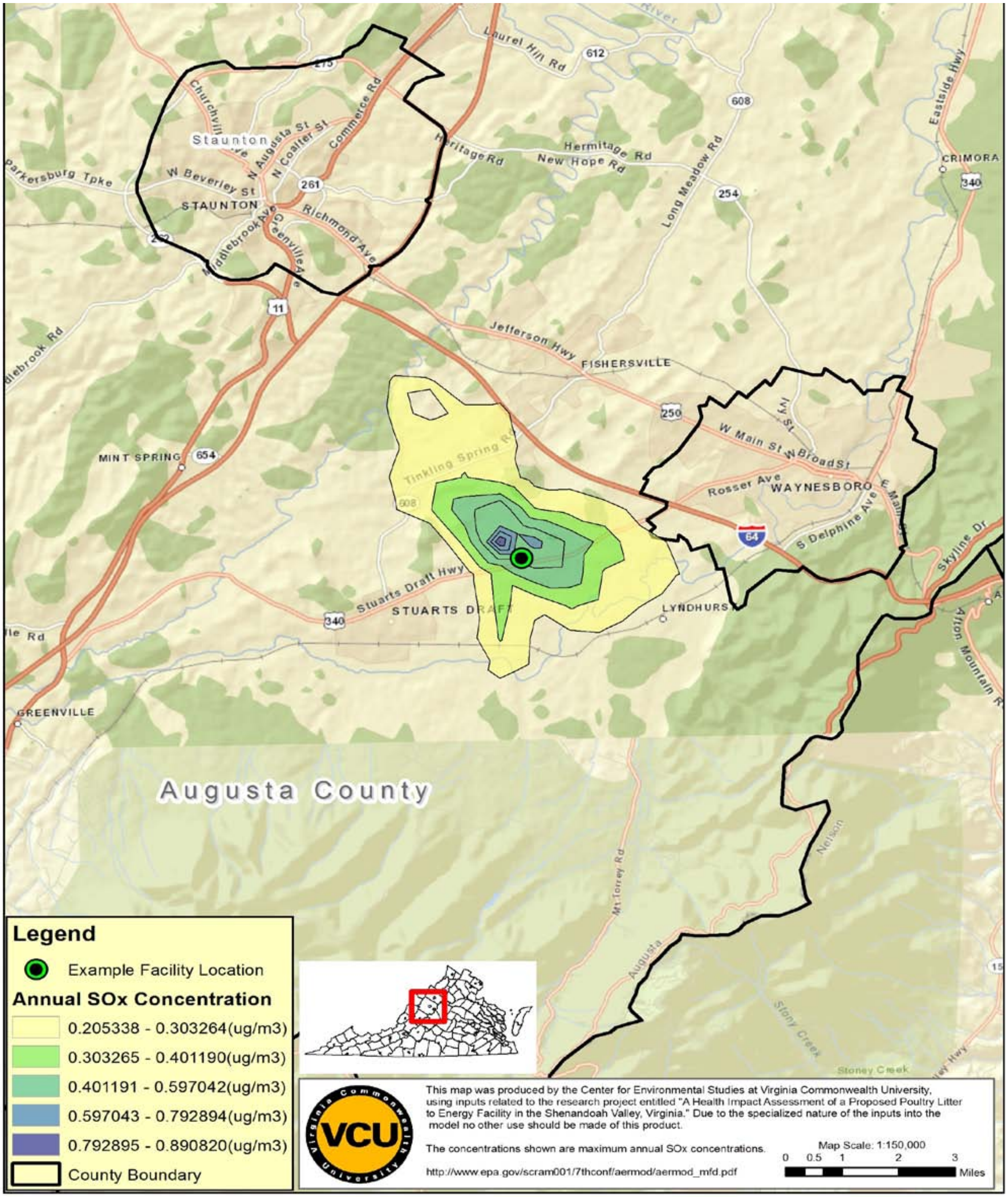


Table C3: Characteristics of Tracts Impacted by Potential SOx Emissions

Place	Unemployment Rate	Median Income	Percent in Poverty
Augusta 703	1.7%	$54,254	7.5%
Augusta 704	5.4%	$39,857	10.6%
Augusta 706	1.1%	$58,991	9.2%
Augusta 707	4.6%	$43,152	12.1%
Augusta 709	4.6%	$46,757	9.8%
Augusta 710	2.5%	$52,857	13.3%
Augusta 711.01	5.9%	$45,821	4.9%
Augusta 711.02	8.0%	$54,115	10.9%
Augusta 712	6.4%	**$63,849**	4.4%
Waynesboro	**10.8%**	$40,977	**19.4%**
Rockbridge 9301	5.3%	***$39,283***	13.9%
Rockingham 116	3.0%	$57,734	4.9%
Rockingham 117	1.3%	$45,292	13.7%
Rockingham 118	4.3%	$63,192	6.6%

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey, 5-Year Estimates

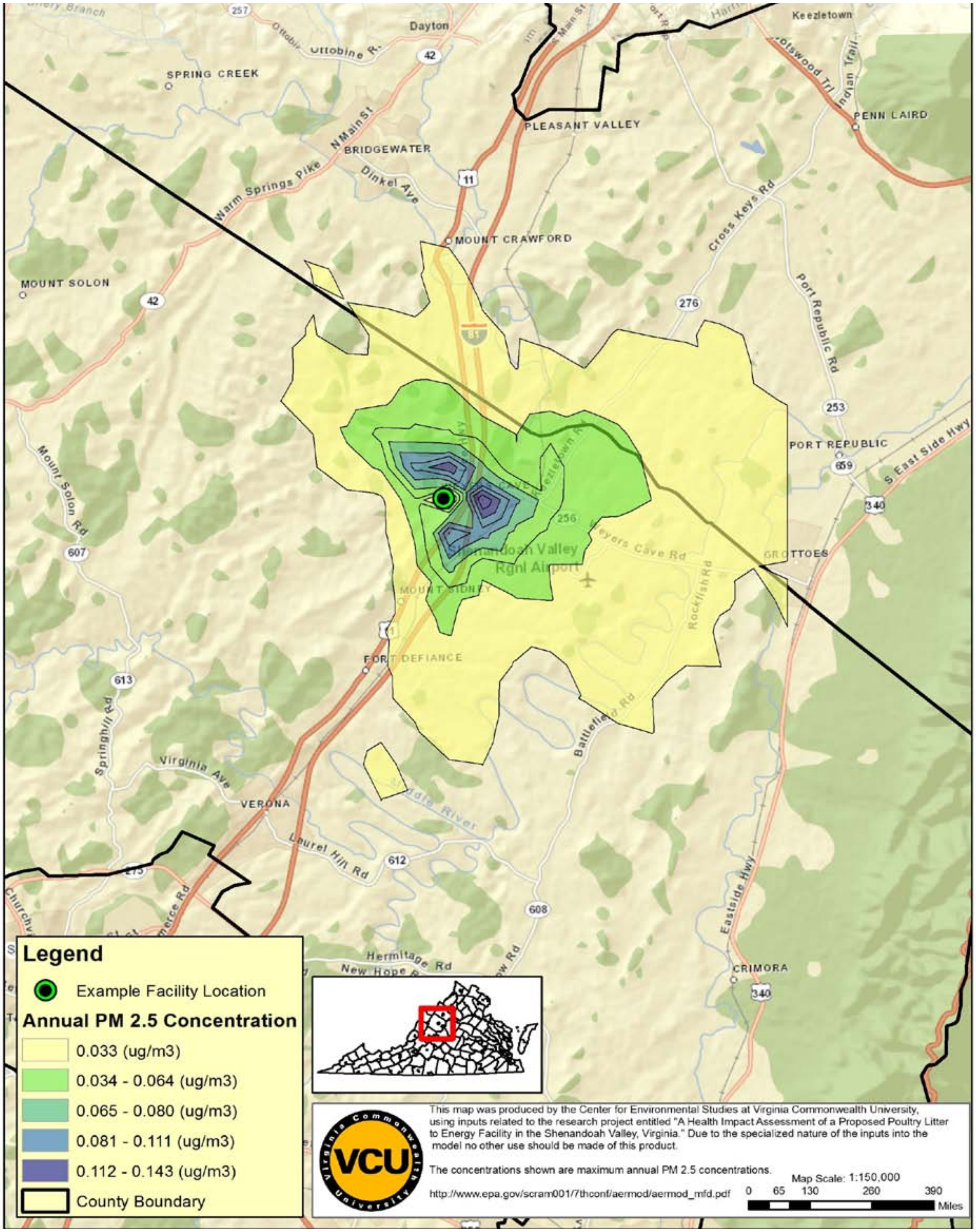
Table C4: Characteristics of the Population Exposed to Potential SOx Emissions by Location of the Facility

Location	Counties Impacted	Census Tracts Impacted	Population	Age Distribution				Shenandoah National Park Impacted (Y/N)
				< 18	18 – 44	45 – 64	>65	
Northern-Most	Augusta, Rockingham	116; 117; 118; 703; 704	23,576	24.1%	31.6%	28.0%	16.4%	N
2nd Northern-Most	Augusta	703; 704; 707	17,628	25.5%	32.2%	28.3%	14.0%	N
3rd Northern-Most	Augusta	706; 709; 711.1	17,566	21.7%	31.2%	29.7%	17.4%	N
4th Northern-Most	Augusta	709; 710; 711.01; 711.02	20,045	21.9%	31.3%	30.3%	16.5%	N
Southern-Most	Augusta, Rockbridge	710; 9301	12,772	21.4%	31.8%	29.8%	17.0%	N
Eastern-Most	Augusta, Waynesboro	706; 709; 711.01; 711.02; 712	29,412	22.6%	31.6%	29.9%	15.9%	Y

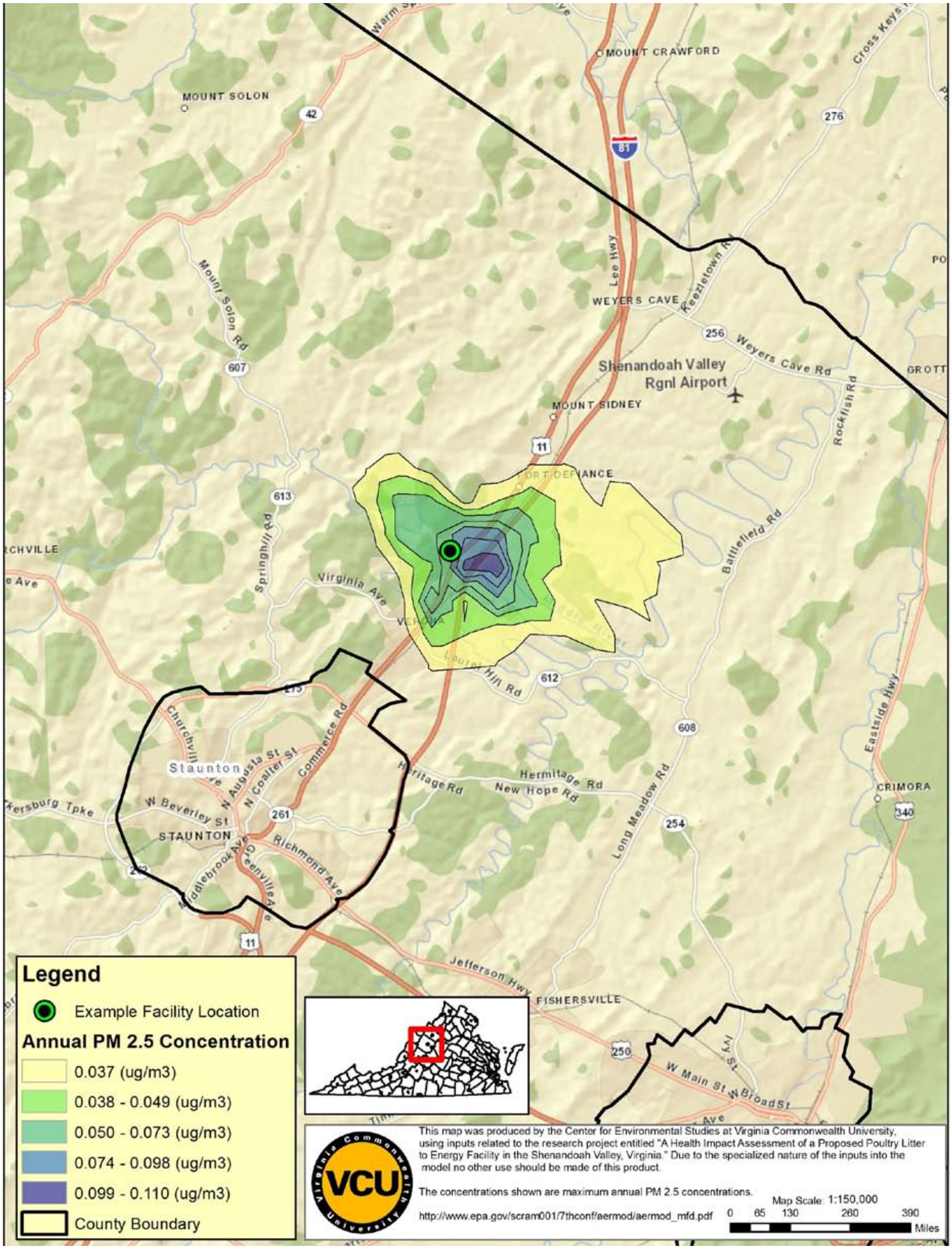
Note: The population estimates are for the census tracts and places that are the approximate sites of the SOx emissions. They do not represent estimates of the population that would be exposed.

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey 5-Year Estimates

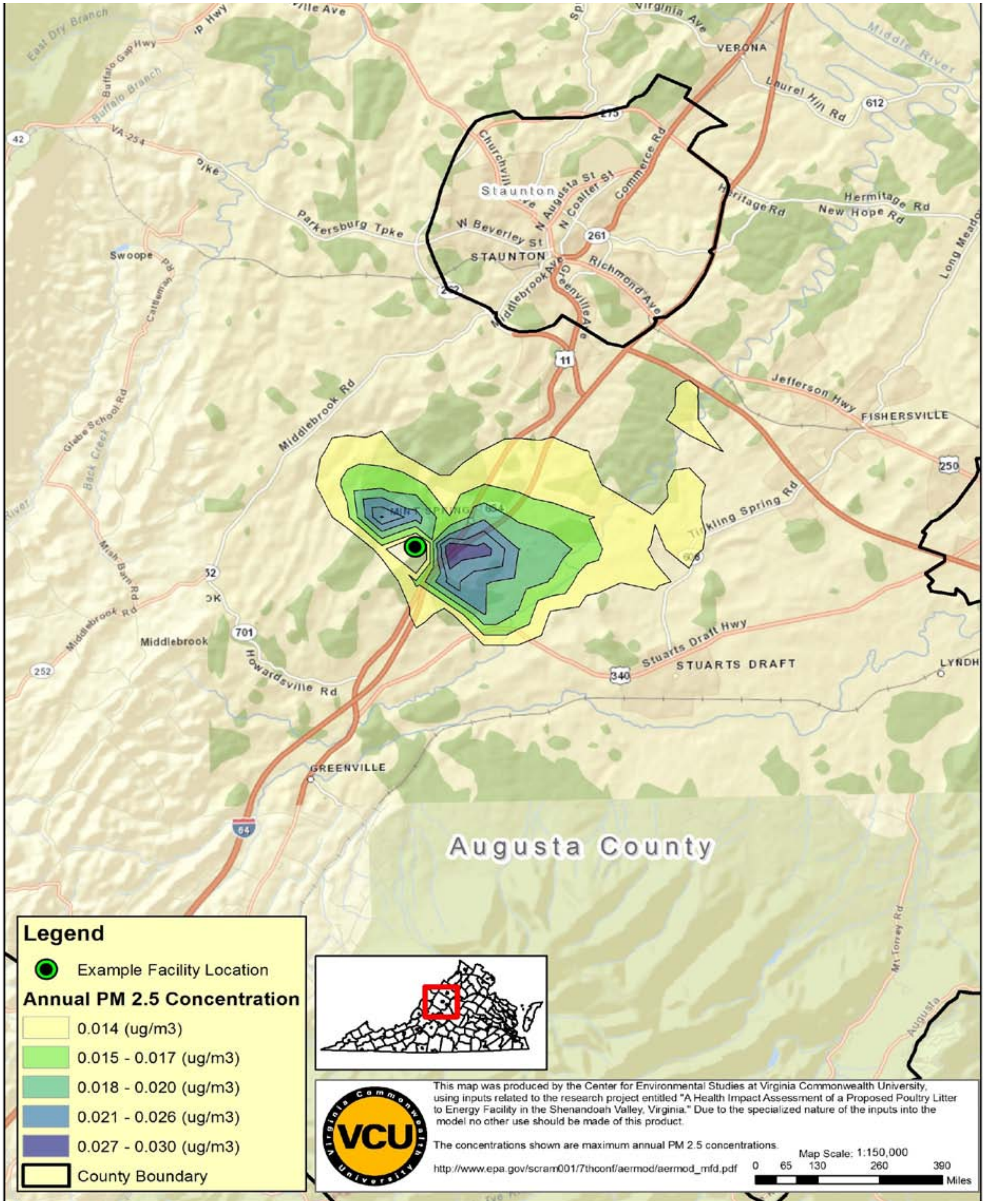
Map C13: Estimated Emissions of Particulate Matter 2.5 from the Northern-Most Location



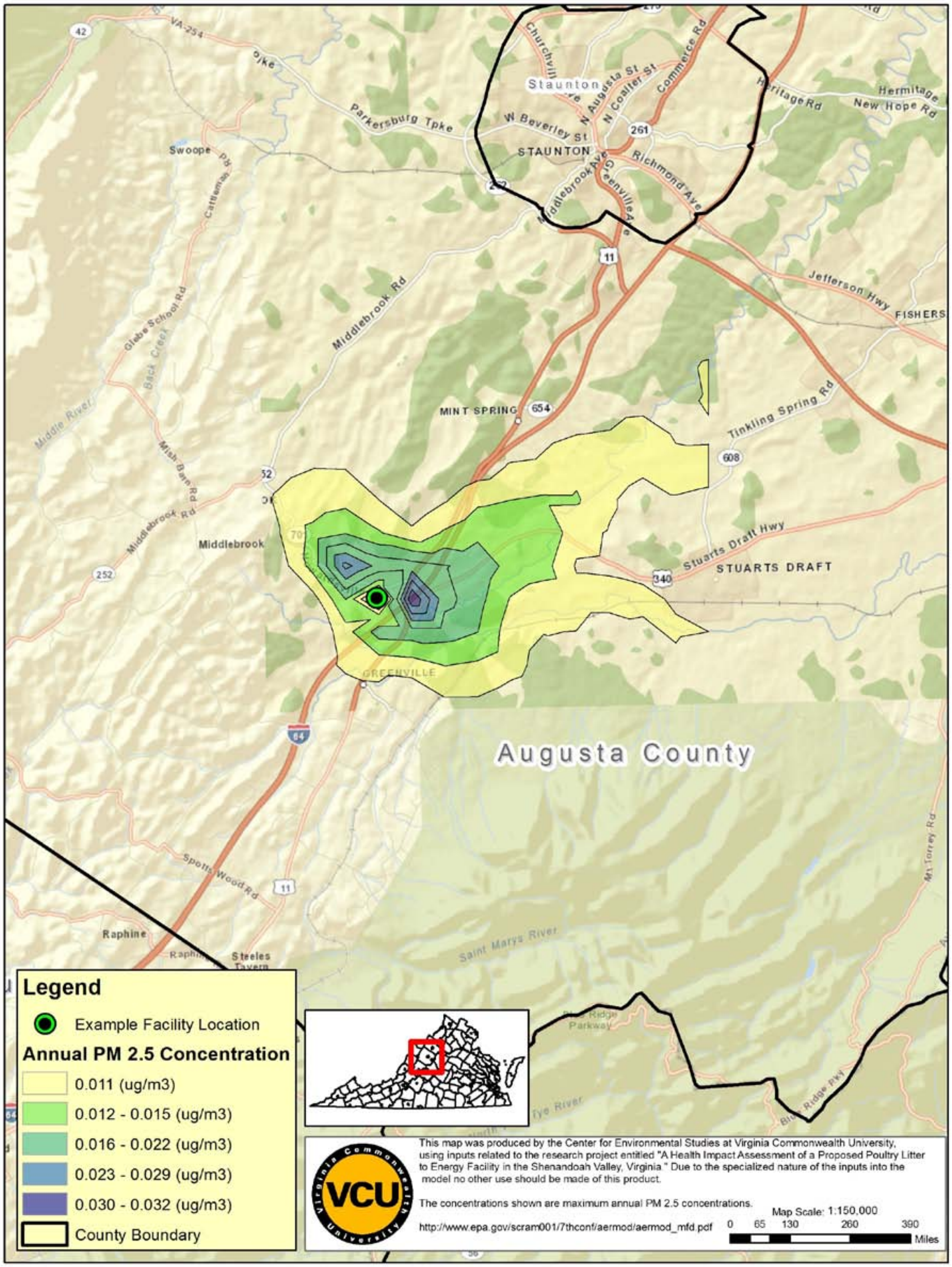
Map C14: Estimated Emissions of Particulate Matter 2.5 from the 2nd Northern-Most Location



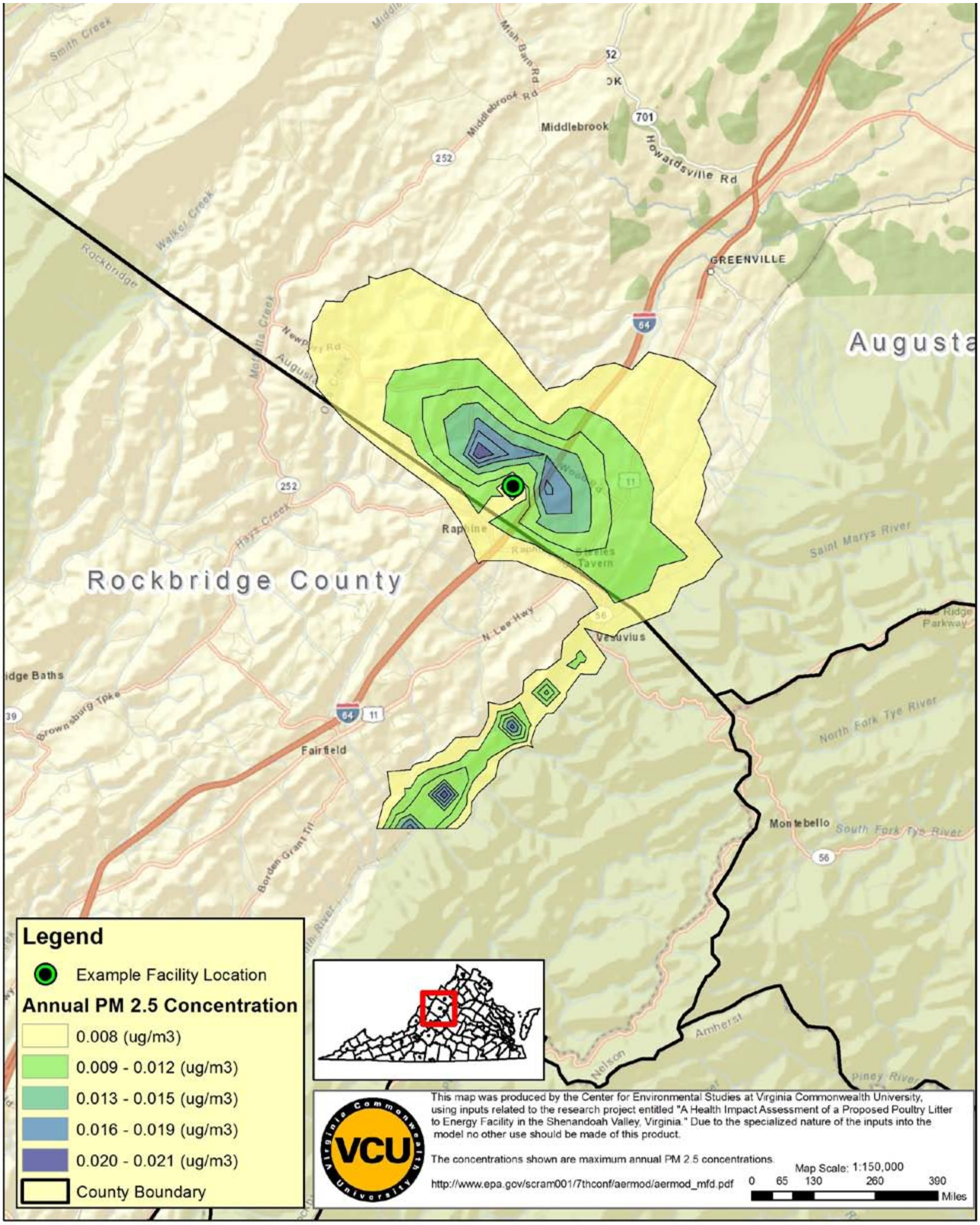
Map C15: Estimated Emissions of Particulate Matter 2.5 from the 3rd Northern-Most Location



Map C16: Estimated Emissions of Particulate Matter 2.5 from the 4th Northern-Most Location



Map C17: Estimated Emissions of Particulate Matter 2.5 from the Southern-Most Location



Map C18: Estimated Emissions of Particulate Matter 2.5 from the Eastern-Most Location

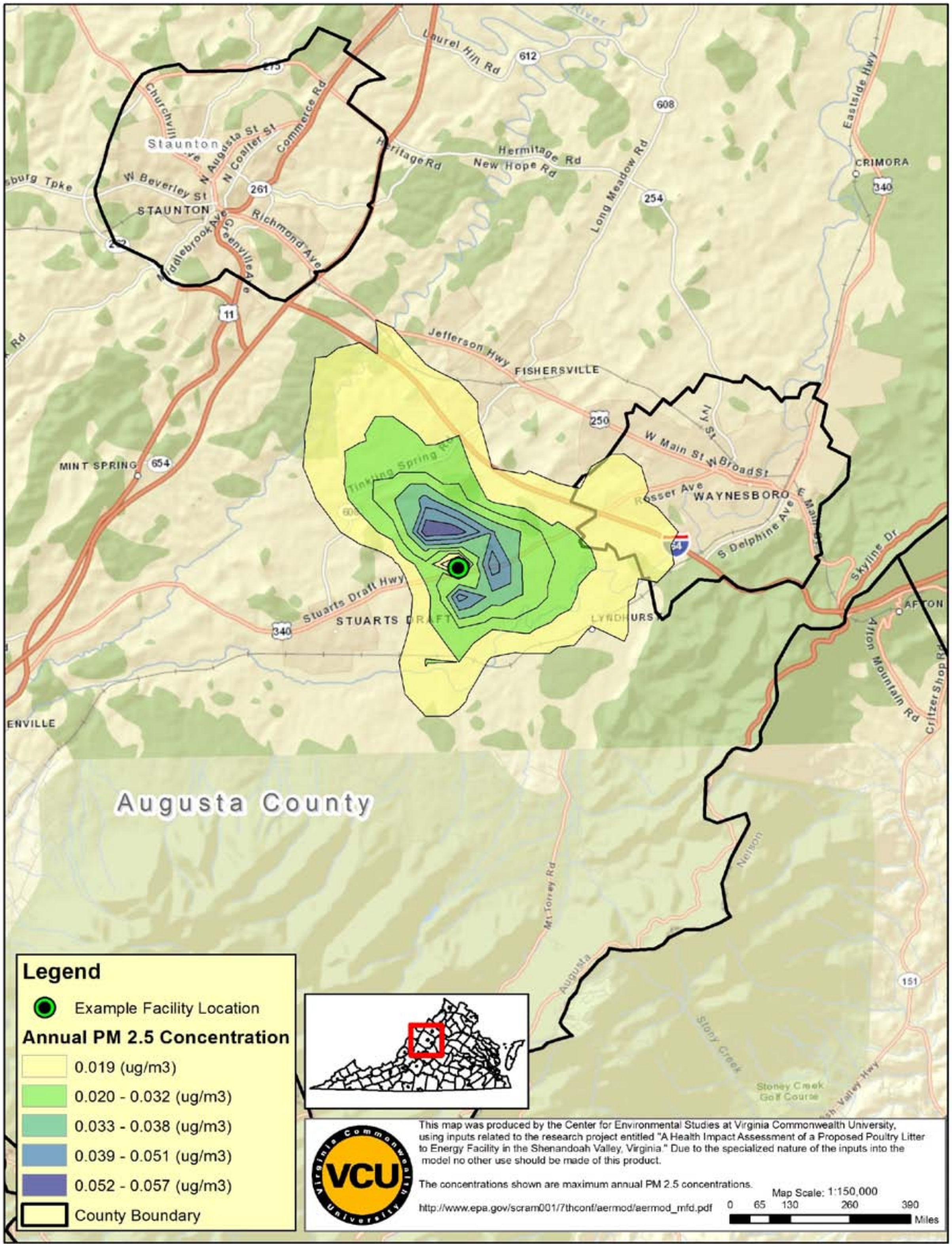


Table C5: Characteristics of Tracts Impacted by Potential PM2.5 Emissions

Place	Unemployment Rate	Median Income	Percent in Poverty
Augusta 703	1.7%	$54,254	7.5%
Augusta 704	5.4%	$39,857	10.6%
Augusta 706	1.1%	$58,991	9.2%
Augusta 707	4.6%	$43,152	12.1%
Augusta 708	3.8%	$45,000	8.8%
Augusta 709	4.6%	$46,757	9.8%
Augusta 710	2.5%	$52,857	13.3%
Augusta 711.01	5.9%	$45,821	***4.9%***
Augusta 711.02	8.0%	$54,115	10.9%
Waynesboro	**10.8%**	$40,977	19.4%
Rockbridge 9301	5.3%	***$39,283***	13.9%
Rockbridge 9302	4.3%	$40,122	10.6%
Rockingham 116	3.0%	$57,734	***4.9%***
Rockingham 117	1.3%	$45,292	**13.7%**
Rockingham 118	4.3%	**$63,192**	6.6%

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey, 5-Year Estimates

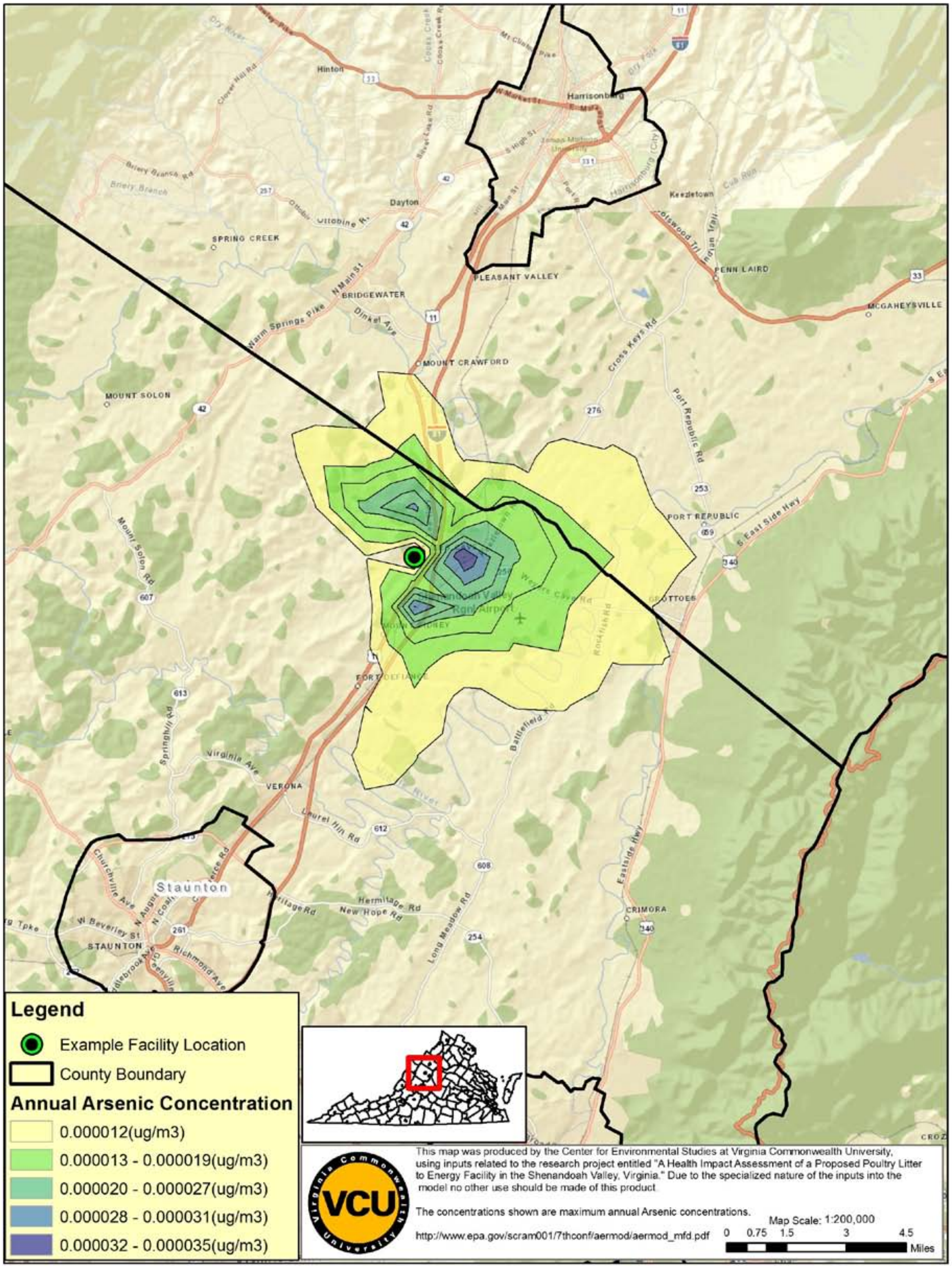
Table C6: Characteristics of the Population Exposed to Potential PM2.5 Emissions by Location of the Facility

Location	Counties Impacted	Census Tracts Impacted	Population	Age Distribution < 18	18 – 44	45 – 64	>65	Shenandoah National Park Impacted (Y/N)
Northern Most	Augusta, Rockingham	116; 117; 118; 703; 704; 708	29,662	23.4%	31.1%	29.0%	16.5%	N
2nd Northern-Most	Augusta	703; 704; 707	17,628	25.5%	32.2%	28.3%	14.0%	N
3rd Northern-Most	Augusta	709; 711.01; 711.02	14,748	22.5%	31.9%	30.3%	15.3%	N
4th Northern-Most	Augusta	709; 710; 711.01; 711.02	20,045	21.9%	31.3%	30.3%	16.5%	N
Southern-Most	Augusta, Rockbridge	710; 9301; 9302	17,229	20.7%	30.6%	30.8%	17.9%	N
Eastern-Most	Augusta, Waynesboro	706; 709; 711.01; 711.02; 712	29,412	22.6%	31.6%	29.9%	15.9%	Y

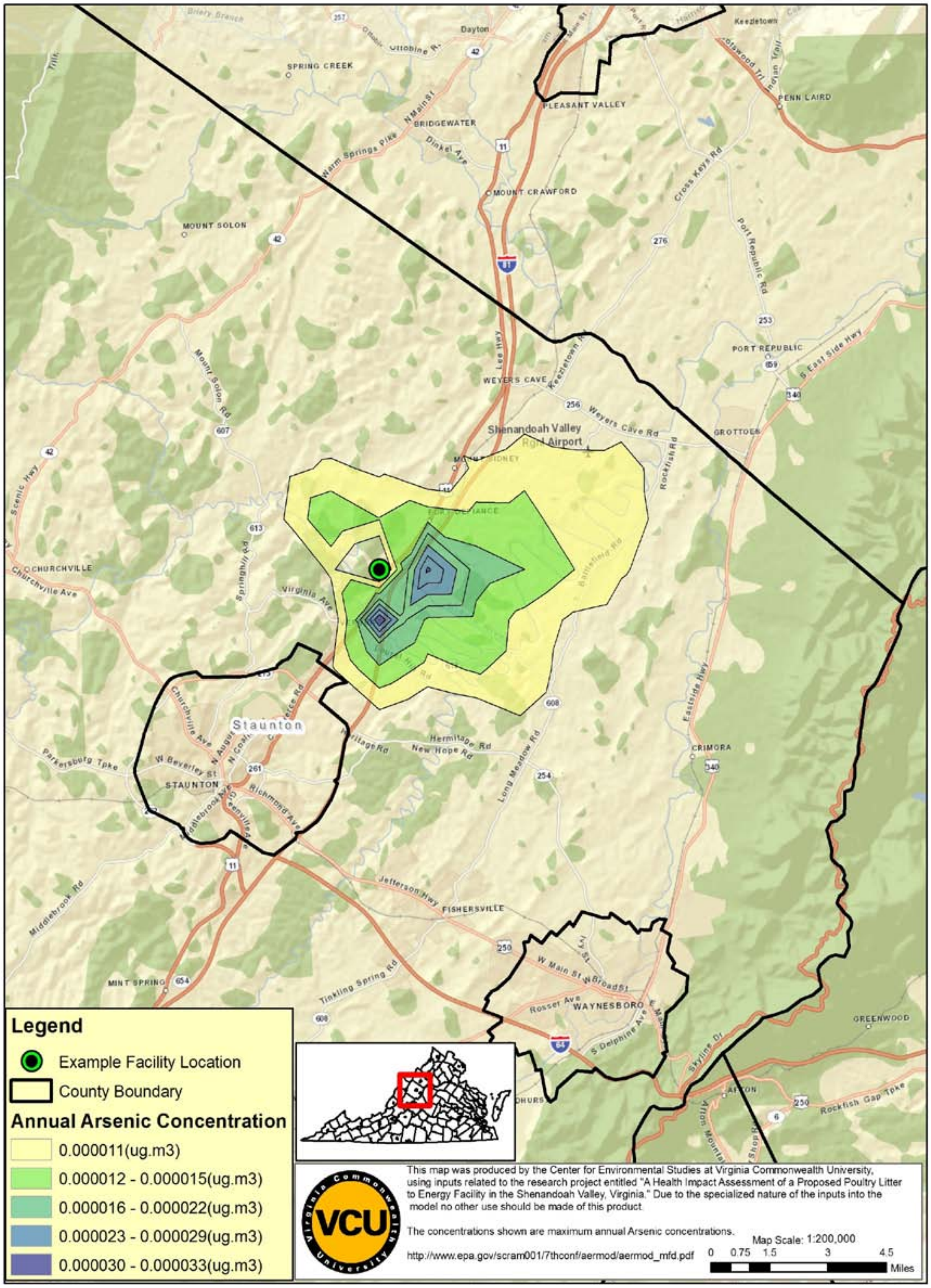
Note: The population estimates are for the census tracts and places that are the approximate sites of the PM2.5 emissions. They do not represent estimates of the population that would be exposed.

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey 5-Year Estimates

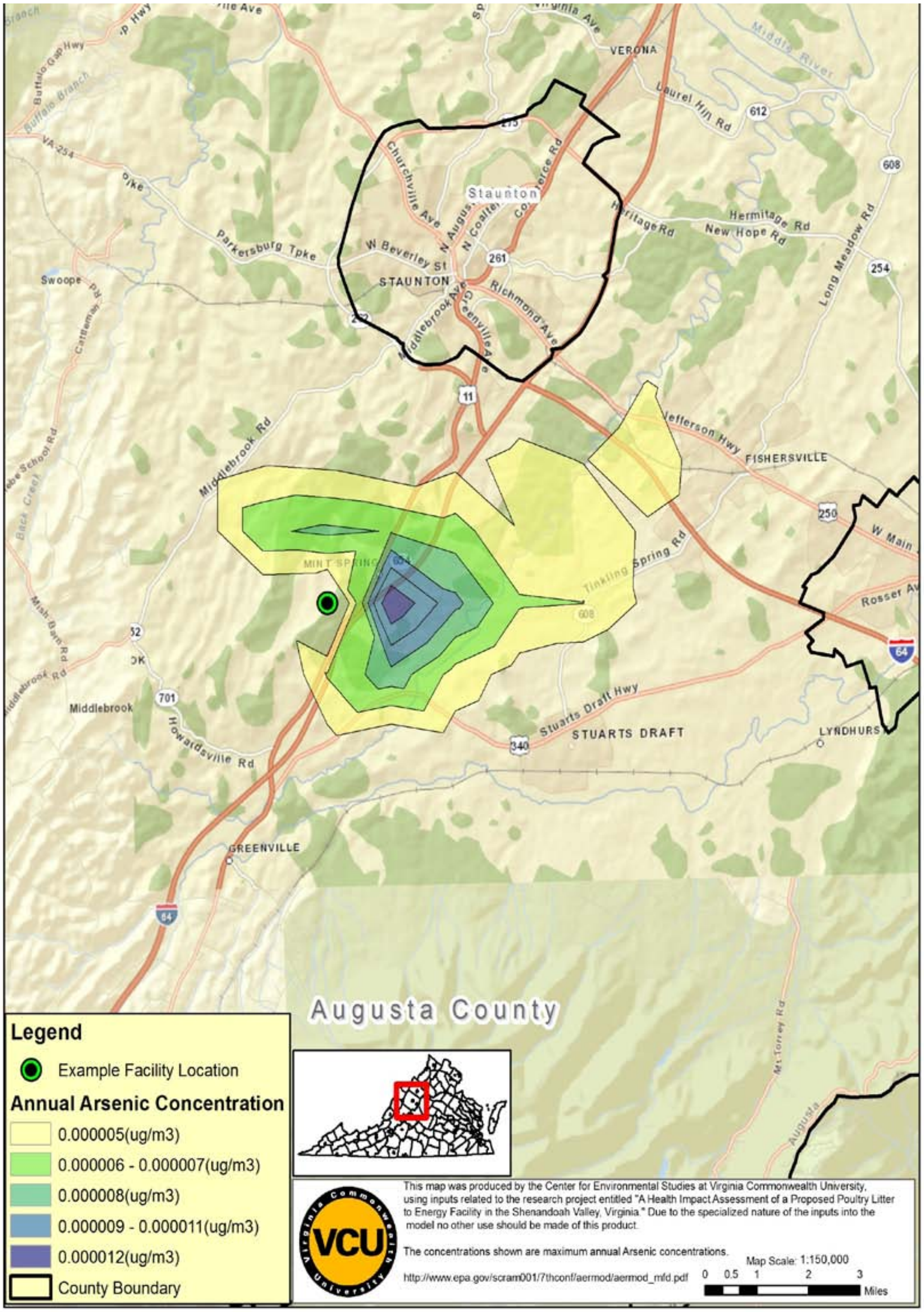
Map C19: Estimated Emissions of Arsenic from the Northern-Most Location



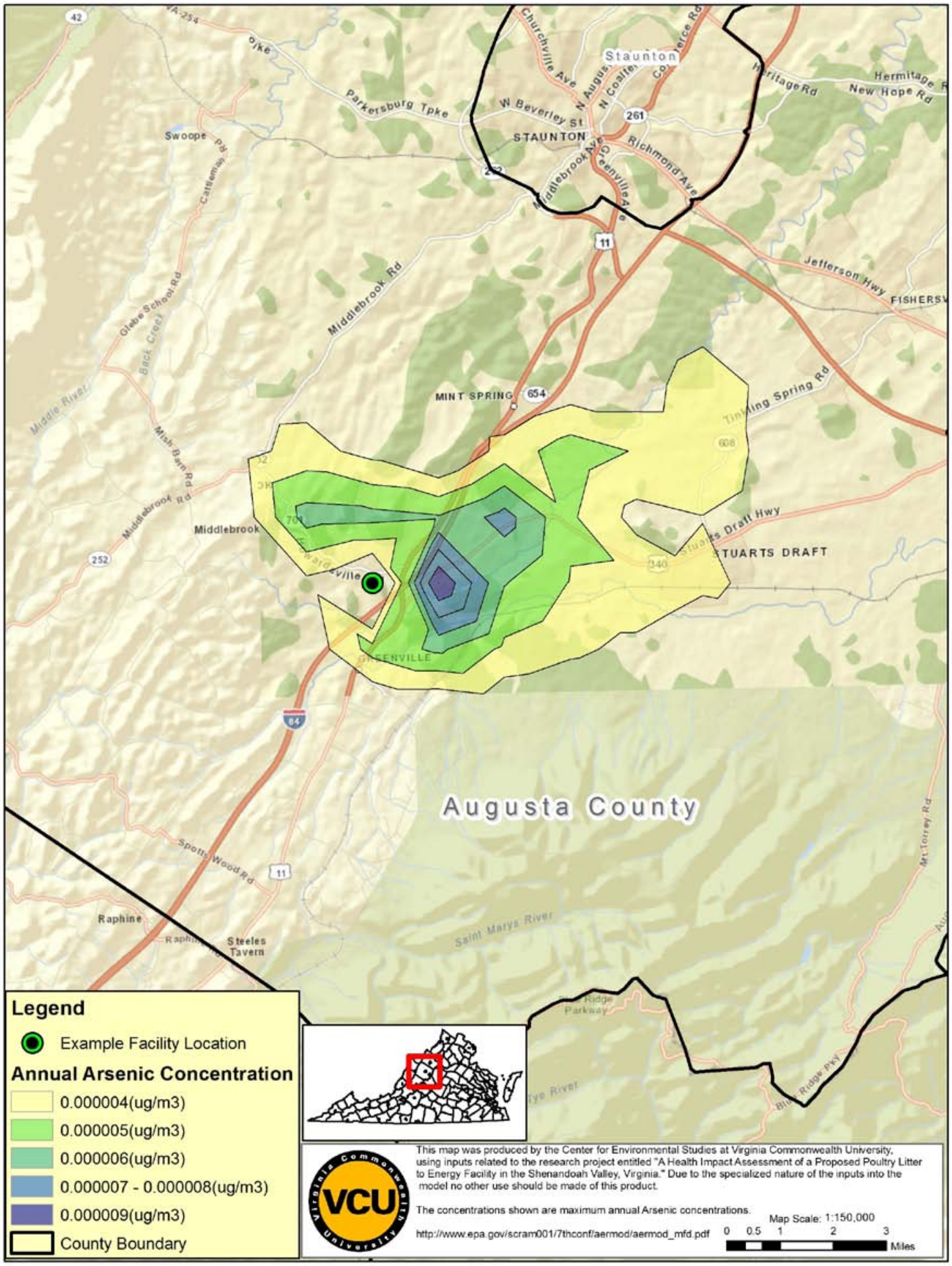
Map C20: Estimated Emissions of Arsenic from the 2nd Northern-Most Location



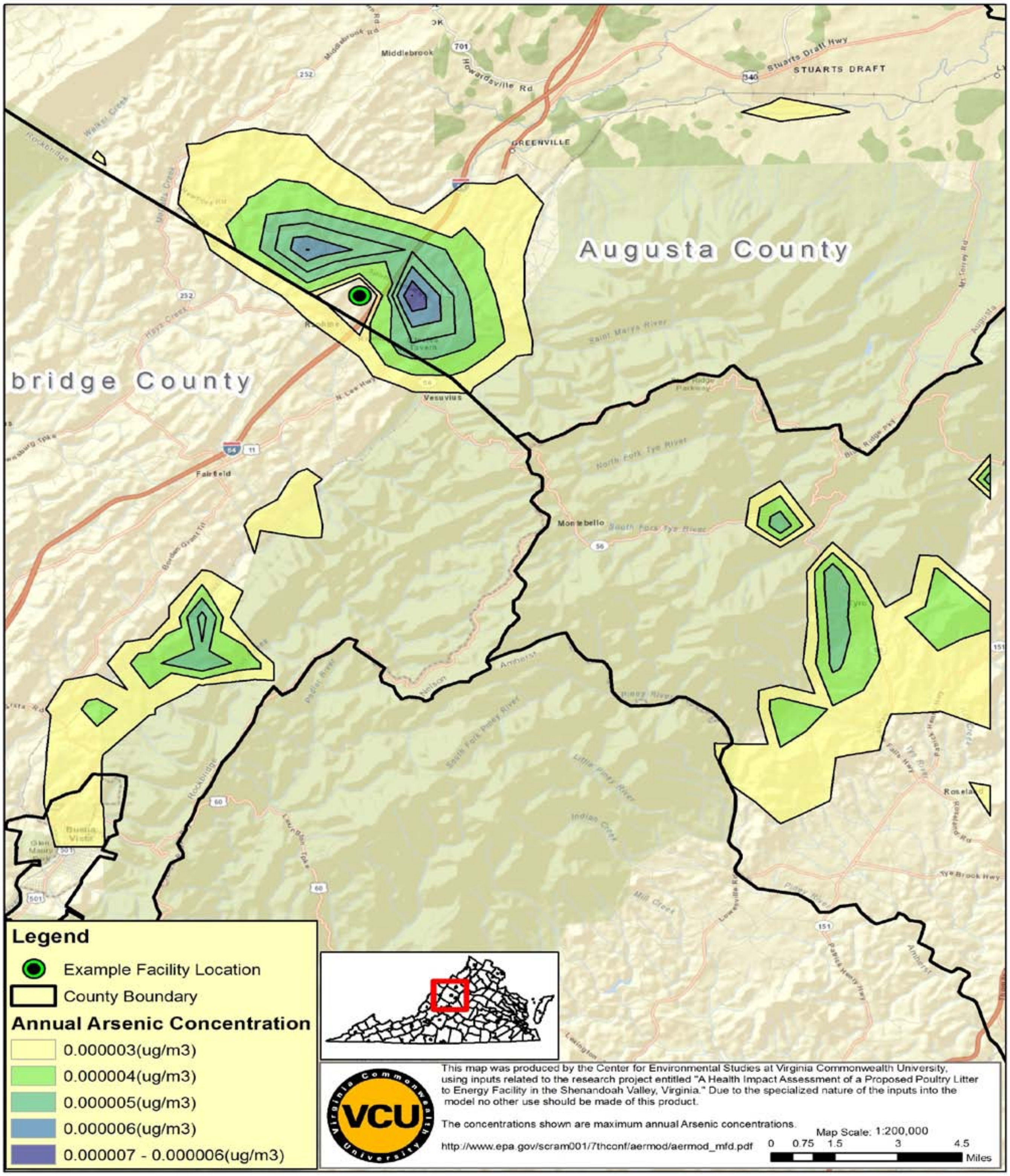
Map C21: Estimated Emissions of Arsenic from the 3rd Northern-Most Location



Map C22: Estimated Emissions of Arsenic from the 4th Northern-Most Location



Map C23: Estimated Emissions of Arsenic from the Southern-Most Location



Map C24: Estimated Emissions of Arsenic from the Eastern-Most Location

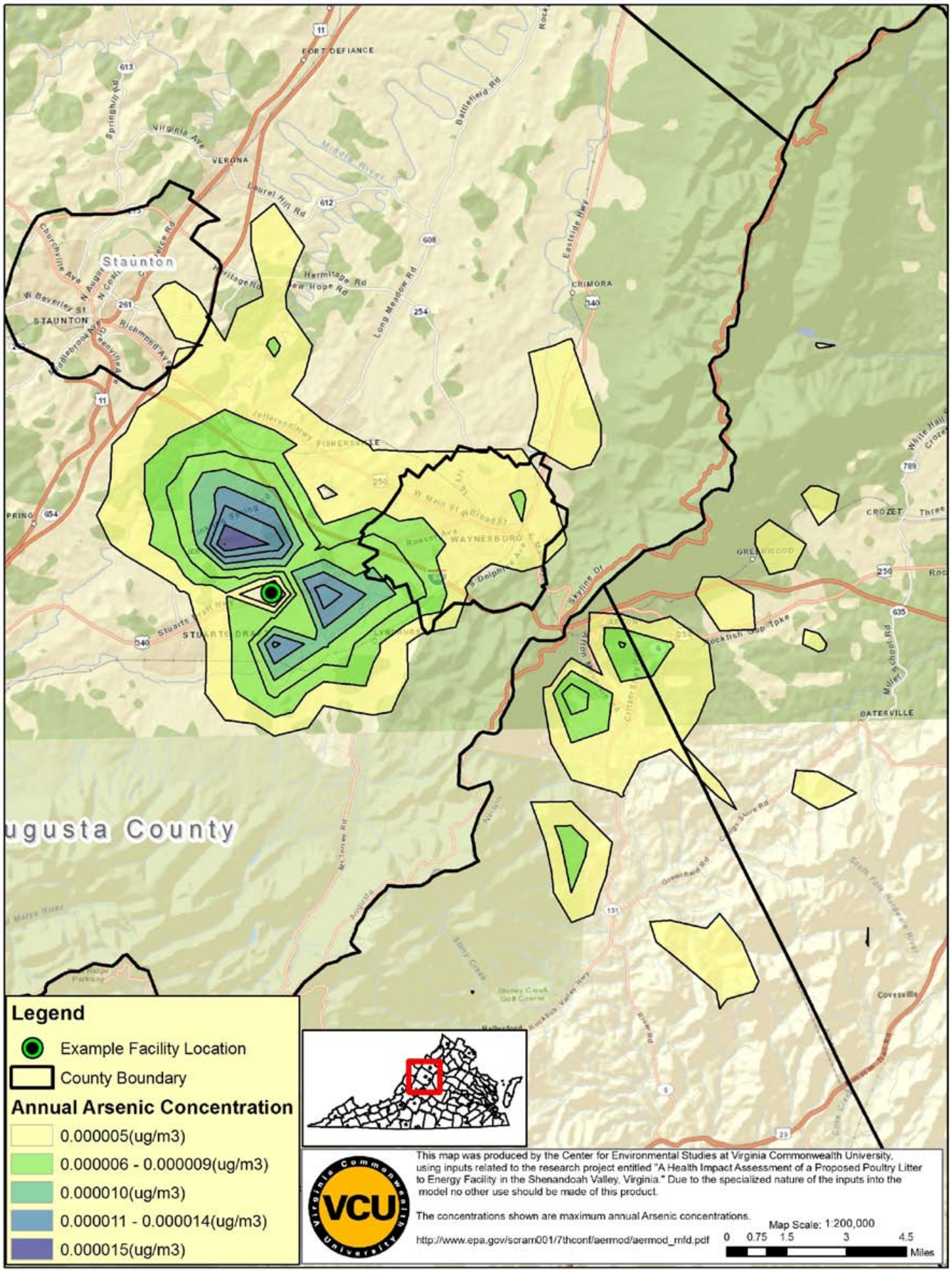


Table C7: Characteristics of Tracts Impacted by Potential Arsenic Emissions				
Place	Background Arsenic Concentration (μg/m³)[a]	Unemployment Rate[b]	Median Income[b]	Percent in Poverty[b]
Albemarle 112.01	4.8e-4	1.8%	$60,559	4.6%
Augusta 703	1.5e-3	1.7%	$54,254	7.5%
Augusta 704	8.6e-4	5.4%	$39,857	7.1%
Augusta 705	8.0e-4	5.8%	$51,171	***0.9%***
Augusta 706	1.4e-3	1.1%	$58,991	6.3%
Augusta 707	1.4e-3	4.6%	$43,152	8.1%
Augusta 709	3.9e-4	4.6%	$46,757	7.7%
Augusta 710	2.9e-4	2.5%	$52,857	9.7%
Augusta 711.01	1.4e-3	5.9%	$45,821	1.3%
Augusta 711.02	1.4e-3	8.0%	$54,115	10.6%
Augusta 712	9.2e-4	6.4%	$63,849	2.2%
Staunton	ranges from 6.6e-4 to 2.8e-3	5.3%	$42,724	9.3%
Waynesboro	ranges from 8.7e-4 to **1.7e-2**	**10.8%**	$40,977	16.3%
Nelson 9502	5.7e-4	6.1%	$55,629	4.7%
Nelson 9503	3.2e-4	4.9%	$45,417	10.3%
Rockbridge 9301	3.6e-4	5.3%	$39,283	6.2%
Rockbridge 9304	7.7e-4	5.2%	$36,432	13.2%
Buena Vista	2.2e-3	8.1%	$39,955	**17.5%**
Rockingham 115	7.0e-3	4.8%	$49,903	9.1%
Rockingham 116	3.6e-3	3.0%	$57,734	0%
Rockingham 117	2.1e-3	1.3%	$45,292	8.3%
Rockingham 118	1.5e-3	4.3%	**$63,192**	3.9%
Rockingham 120	1.3e-3	5.0%	$43,775	12.8%
U.S. Environmental Protection Agency, 2002 National-Scale Air Toxics Assessment				
U.S. Census Bureau, 2006 – 2010 American Community Survey, 5-Year Estimates				

Table C8: Characteristics of the Population Exposed to Potential Arsenic Emissions by Location of the Facility

Location	Counties Impacted	Census Tracts Impacted	Population	Age Distribution < 18	18 – 44	45 – 64	>65	Shenandoah National Park Impacted (Y/N)
Northern Most	Augusta, Rockingham	115; 116; 117; 118; 120; 703; 704; 707	40,302	23.2%	34.4%	26.6%	15.7%	Y
2nd Northern-Most	Augusta, Rockingham, Staunton	118; 120; 703; 704; 705; 707;	58,356	21.6%	32.7%	28.8%	16.9%	Y
3rd Northern-Most	Augusta, Nelson	705; 706; 707; 709; 710; 711.01; 711.02; 9502	45,097	21.7%	30.8%	31.1%	16.4%	N
4th Northern-Most	Augusta, Nelson, Rockbridge, Waynesboro	705; 706; 707; 709; 710; 711.01; 712; 9502; 9503; 9301	78,291	21.7%	32.1%	29.5%	16.7%	N
Southern-Most	Augusta, Buena Vista, Nelson, Rockbridge	710; 9503; 9301; 9304	27,684	21.4%	32.3%	28.6%	17.7%	N
Eastern-Most	Albemarle, Augusta, Nelson, Staunton, Waynesboro	705; 706; 709; 711.01; 712; 9502; 112.01	82,384	20.7%	32.9%	29.2%	17.2%	Y

Note: The population estimates are for the census tracts and places that are the approximate sites of the arsenic emissions. They do not represent estimates of the population that would be exposed.

Source: U.S. Census Bureau, 2006 – 2010 American Community Survey 5-Year Estimates

Section C3: Review of Research on Ammonia Emissions from Fertilizer Application

There are several forms of nitrogen present in both organic and inorganic sources of nitrogen fertilizer. The forms of nitrogen most susceptible to volatilization are ammonia (NH_3) and ammonium (NH_4^+). Atmospheric losses of nitrogen from fertilizer are usually expressed as a percentage of the total ammoniacal nitrogen (TAN), the sum of the N in ammonium form and ammonia form. Although ammonium is not volatile, in higher pH environments (> pH 7) where there is more competition for hydrogen, it can become NH_3, which is volatile. Thus higher pH environments facilitate ammonia volatilization.

Organic manures also contain organic nitrogen – a broad term for nitrogen contained in organic material. A portion of organic nitrogen in manure and poultry litter is subject to microbial degradation, or mineralization, whereby microbes consume organic material and excrete ammoniacal nitrogen as a byproduct. Through this process, organic nitrogen may also be lost to the atmosphere via volatilization.

Poultry litter consists of both organic and ammoniacal nitrogen. According to the Virginia Nutrient Management Standards and Criteria (2005), dry broiler litter in Virginia contains an average of 65 pounds of total nitrogen per ton (organic plus ammoniacal), of which 18% (or 11.5 pounds per ton) is in the form of ammoniacal nitrogen.[123] Availability of ammoniacal nitrogen in broiler litter ranges from 90% for poultry litter that is incorporated immediately after application, to 50% if litter is land applied without incorporation.[123]

There are a number of potential nitrogen fertilizer options for crop farmers in the Valley to replace poultry litter. These include both inorganic and organic sources. With respect to organic sources, a report from Water Stewardship, Inc. in 2010 estimated that nutrients from dairy manure currently produced in the Valley exceeds the nutrient requirements of phosphorus-based soil tests which suggests that if poultry litter were no longer available for purchase, there would be additional livestock manure available to replace it.[338] Dairy manure is currently land-applied close to the point of origin, as transporting dairy manure—which is mostly water and has less nitrogen per ton than poultry litter—more than a few miles is generally not economically competitive with the cost of commercial nitrogen sources.

Despite transportation distance limitations, nearly all of the dairy manure produced in the region is land-applied. Therefore, the impact of the facility may be to increase the acreage to which dairy manure produced in the Valley is land-applied. This may result in a reduction of the amount of ammonia emissions associated with land application of dairy manure in the region, as it would reduce the rate at which nitrogen is applied and increase the likelihood that manure nitrogen is taken up by plants, versus being lost to the atmosphere or water resources. However, the benefit of lower rates of application varies according to the timing and method of application, as well as local conditions. For example, injection of dairy manure has the lowest TAN loss while broadcast application to the surface with no incorporation has the highest rate of TAN loss. Although manure injection systems are not common in the Valley, they have been used regionally by a few farmers.

Studies in Europe suggest that ammonia losses from volatilization associated with poultry litter application are between 15% and 45% of TAN.[339-341] Research conducted in the southeastern United States of ammonia volatilization from fescue pastures ranged from 28% to 46% of TAN.[342] By comparison, ammonia lost from land-applied cattle slurry ranged from 40% to 70% TAN and between 61% and 99% for solid dairy manure.[343, 344]

In addition to other livestock manure, commercial fertilizer is also a possibility for crop farmers in the Valley. Commercial fertilizers come in two broad categories: urea nitrogen and urea ammonium nitrate (UAN). In urea nitrogen, all the N is in the form of urea $CO(NH_2)_2$, a very reactive form of N. Urea in the presence of water molecules and urease, an enzyme that is ubiquitous in the environment, reacts very quickly to form ammonia gas (NH_3) and carbon dioxide. Ammonia gas readily speciates between NH_3 and NH_4^+ when in contact with water, depending on the pH level.[151] According to the Virginia Cooperative Extension, all of the N present in urea is subject to potential loss as ammonia, though it is unlikely that even in the worst of conditions, all of the urea-N would be lost as ammonia emissions.[345]

Alternatively, UAN is a mixture of N in the form of both urea and ammonium nitrate. Only the N in urea is immediately available to volatilize. The ratio of urea to ammonium nitrate is variable; however, one of the more common mixtures is 35% urea and 45% ammonium nitrate. Because only the N in urea is subject to volatilization, ammonia volatilization is less likely with UAN as compared with urea nitrogen fertilizers. Although all of the urea-N in both urea and UAN could potentially be volatilized, in practice, a maximum of 25% - 35% of the urea-N would be expected to be lost as ammonia emissions, and only in the most severe conditions.[345]

Based on the potential for ammonia volatilization, the alternative fertilizer that behaves the most similarly with poultry litter is UAN. In both UAN and poultry litter, a significant portion of the total nitrogen content is in a non-volatile form, although this non-volatile form can be transformed into ammonia and ammonium over time.

The atmospheric chemistry involved in the formation of fine PM from ammonia and NOx or SOx is complex and difficult to model. Ammonia in the presence of NOx or SOx does not necessarily react to form PM; and when it does, the size of the particles are not always fine (less than 2.5 µm in diameter).

Areas that exceed the NAAQS for any criteria pollutant are required to establish an attainment plan that addresses point source emissions of the pollutant in question as well as any logical precursors that would impact the ultimate concentration. Looking at precedents of how the EPA has handled non-attainment in the past can illustrate how criteria pollutant-precursors should be handled. The San Joaquin Valley of central California is a non-attainment area for PM and also has a large agriculture industry. In that situation, the EPA ruled that any plan to achieve attainment had to address emissions of sulfur dioxide and NOx but not ammonia.[346] This is due in part to NOx being the limiting-agent of the reaction in the area.[346]

The chemical reaction of ammonia and NOx or SOx creating PM, is modeled by the following equations:

$$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$$

$$NH_3 + H_2SO_4 \rightarrow NH_4HSO_4$$

In each scenario, the ratio of ammonia to NOx or SOx is 1:1. Thus, in a situation where a chemical reaction was completely substance-limited, the limiting factor to the reaction would be the substance of greatest scarcity between ammonia and NOx plus SOx. The quantity of PM precursors in the Valley's atmosphere is listed in Table C9. Comparisons of mass should not be considered a substitute for ratios at the molecular level because the molecular weight of each compound is different.

Any ammonia molecule could potentially react with NOx or SO_2, but for purposes of evaluating the impact the facility would have on changes in PM concentrations, only the ammonia attributed to fertilizer use would theoretically be potentially reduced. Ammonia reacts preferentially with SO_2 but in its absence will also react with NOx.[346] Whether ammonia or NOx plus SOx is the limiting agent in the Valley atmosphere is dependent upon the speciation of NOx in the Valley. Using nitrogen dioxide as the baseline for the molecular weight of NOx (Table C9) would suggest that NOx and SOx is the limiting agent; however, using nitrogen monoxide as the baseline for molecular weight would suggest that ammonia is the limiting agent. We are unaware of any previous research that establishes the speciation of NOx in the Valley atmosphere.

Table C9: Ammonia, Nitrogen Oxides, Sulfur Dioxide Emissions in the Shenandoah Valley, 2008

	Tons	Molecular Weight (g/mol)	Tons/Molecular Weight
Ammonia	16,548.7	45	367.8
Ammonia attributed to fertilizer use	3,781.6	45	84.0
Nitrogen Oxides	12,321.7	48*	256.7
Sulfur Dioxide	1,124.6	64	17.6

Source: U.S. Environmental Protection Agency, National Emissions Inventory, 2008
Note: Nitrogen oxides and sulfur oxides represent separate classes of individual compounds thus the molecular weights can vary from 30 to 180 g/mol
* molecular weight for nitrogen dioxide (NO_2)

Table C10: Amount of Volatile Organic Compounds in the Shenandoah Valley Atmosphere (2008)

Chemical	Total Weight (lbs)	Percentage of Total Weight
1,1,2,2-Tetrachloroethane	0.02	0.0%
1,1,2-Trichloroethane	0.01	0.0%
1,2,4-Trichlorobenzene	3.89	0.0%
1,3-Butadiene	85,696.95	1.0%
1,4-Dichlorobenzene	3.08	0.0%
2,2,4-Trimethylpentane	211,237.80	2.4%
2,4-Dinitrophenol	0.22	0.0%
2,4-Toluene Diisocyanate	10.15	0.0%
2-Nitropropane	0.00	0.0%
4,4’-Methylenediphenyl Diisocyanate	71.05	0.0%
4-Nitrophenol	16.37	0.0%
Acetaldehyde	150,003.50	1.7%
Acetonitrile	2,253.24	0.0%
Acetophenone	7.90	0.0%
Acrolein	54,869.11	0.6%
Acrylonitrile	3.63	0.0%
Allyl Chloride	0.18	0.0%
Benzene	479,058.55	5.4%
Benzyl Chloride	0.08	0.0%
Biphenyl	28.61	0.0%
Bis(2-Ethylhexyl)Phthalate	15.25	0.0%
Carbon Disulfide	40.61	0.0%
Carbon Tetrachloride	10.53	0.0%
Carbonyl Sulfide	51.39	0.0%
Chlorobenzene	32.26	0.0%
Chloroform	94.91	0.0%
Chloroprene	0.22	0.0%
Cresol/Cresylic Acid (Mixed Isomers)	4,540.56	0.1%
Cumene	1,055.04	0.0%
Dibenzofuran	238.95	0.0%
Dibutyl Phthalate	16.10	0.0%
Dimethyl Phthalate	5.08	0.0%
Dimethyl Sulfate	0.01	0.0%
Epichlorohydrin	0.04	0.0%
Ethyl Acrylate	0.02	0.0%

Table C10: Amount of Volatile Organic Compounds in the Shenandoah Valley Atmosphere (2008)		
Ethyl Benzene	201,067.49	2.3%
Ethylene Dichloride	77.27	0.0%
Ethylene Glycol	25,624.17	0.3%
Ethylene Oxide	2.09	0.0%
Formaldehyde	1,501,424.62	17.0%
Hexachlorobenzene	0.69	0.0%
Hexachlorobutadiene	0.01	0.0%
Hexachlorocyclopentadiene	0.01	0.0%
Hexane	179,430.11	2.0%
Hydrazine	2.70	0.0%
Isophorone	0.02	0.0%
Methanol	3,934,326.76	44.6%
Methyl Bromide	6.52	0.0%
Methyl Chloroform	13,531.30	0.2%
Methyl Isobutyl Ketone	8,578.23	0.1%
Methyl Methacrylate	63.82	0.0%
Methyl Tert-Butyl Ether	0.60	0.0%
Methylene Chloride	3,471.41	0.0%
m-Xylene	21,891.33	0.2%
N,N-Dimethylaniline	3.03	0.0%
Nitrobenzene	0.06	0.0%
o-Cresol	5.18	0.0%
o-Toluidine	0.02	0.0%
o-Xylene	23,505.30	0.3%
p-Cresol	10.35	0.0%
p-Dioxane	10.32	0.0%
Pentachlorophenol	1.70	0.0%
Phenol	15,121.30	0.2%
Propionaldehyde	11,409.82	0.1%
Propylene Dichloride	14.43	0.0%
Propylene Oxide	6.88	0.0%
p-Xylene	21,880.00	0.2%
Styrene	38,078.94	0.4%
Tetrachloroethylene	117.24	0.0%
Toluene	948,842.51	10.7%
Trichloroethylene	158,039.71	1.8%
Triethylamine	410.45	0.0%
Vinyl Acetate	61.62	0.0%

Table C10: Amount of Volatile Organic Compounds in the Shenandoah Valley Atmosphere (2008)

Vinyl Chloride	7.88	0.0%
Vinylidene Chloride	3.98	0.0%
Xylenes (Mixed Isomers)	715,174.89	8.1%
Total Weight	8,827,708.66	

Source: U.S. Environmental Protection Agency, National Emissions Inventory, 2008

Table C11: Amount of Volatile Organic Compounds in the Augusta County Atmosphere (2008)

Chemical	Total Weight (lbs)	Percentage of Total Weight
1,1,2,2-Tetrachloroethane	0.01	0.0%
1,1,2-Trichloroethane	0.00	0.0%
1,2,4-Trichlorobenzene	1.37	0.0%
1,3-Butadiene	37,257.35	1.2%
1,4-Dichlorobenzene	1.06	0.0%
2,2,4-Trimethylpentane	72,465.06	2.4%
2,4-Dinitrophenol	0.14	0.0%
2,4-Toluene Diisocyanate	3.43	0.0%
2-Nitropropane	0.00	0.0%
4,4’-Methylenediphenyl Diisocyanate	24.04	0.0%
4-Nitrophenol	5.58	0.0%
Acetaldehyde	62,997.04	2.1%
Acetonitrile	1.10	0.0%
Acetophenone	2.67	0.0%
Acrolein	27,189.80	0.9%
Acrylonitrile	1.23	0.0%
Allyl Chloride	0.06	0.0%
Benzene	194,054.05	6.4%
Benzyl Chloride	0.03	0.0%
Biphenyl	9.65	0.0%
Bis(2-Ethylhexyl)Phthalate	5.15	0.0%
Carbon Disulfide	13.74	0.0%
Carbon Tetrachloride	3.56	0.0%
Carbonyl Sulfide	24.92	0.0%
Chlorobenzene	6.31	0.0%
Chloroform	42.70	0.0%
Chloroprene	0.08	0.0%
Cresol/Cresylic Acid (Mixed Isomers)	1,528.47	0.1%

Table C11: Amount of Volatile Organic Compounds in the Augusta County Atmosphere (2008)

Cumene	194.47	0.0%
Dibenzofuran	48.58	0.0%
Dibutyl Phthalate	5.45	0.0%
Dimethyl Phthalate	1.72	0.0%
Dimethyl Sulfate	0.00	0.0%
Epichlorohydrin	0.01	0.0%
Ethyl Acrylate	0.01	0.0%
Ethyl Benzene	67,847.16	2.2%
Ethylene Dichloride	21.66	0.0%
Ethylene Glycol	8,669.76	0.3%
Ethylene Oxide	0.71	0.0%
Formaldehyde	522,819.97	17.2%
Hexachlorobenzene	0.25	0.0%
Hexachlorobutadiene	0.00	0.0%
Hexachlorocyclopentadiene	0.00	0.0%
Hexane	67,004.16	2.2%
Hydrazine	-	0.0%
Isophorone	0.00	0.0%
Methanol	1,172,480.87	38.5%
Methyl Bromide	0.00	0.0%
Methyl Chloroform	4,716.32	0.2%
Methyl Isobutyl Ketone	2,672.20	0.1%
Methyl Methacrylate	21.59	0.0%
Methyl Tert-Butyl Ether	0.20	0.0%
Methylene Chloride	1,284.22	0.0%
m-Xylene	10.97	0.0%
N,N-Dimethylaniline	1.02	0.0%
Nitrobenzene	0.02	0.0%
o-Cresol	1.75	0.0%
o-Toluidine	0.01	0.0%
o-Xylene	564.91	0.0%
p-Cresol	3.50	0.0%
p-Dioxane	3.49	0.0%
Pentachlorophenol	0.60	0.0%
Phenol	4,663.78	0.2%
Propionaldehyde	4,478.72	0.1%
Propylene Dichloride	0.04	0.0%

Table C11: Amount of Volatile Organic Compounds in the Augusta County Atmosphere (2008)		
Propylene Oxide	2.33	0.0%
p-Xylene	-	0.0%
Styrene	14,015.17	0.5%
Tetrachloroethylene	54.04	0.0%
Toluene	352,327.09	11.6%
Trichloroethylene	158,024.78	5.2%
Triethylamine	10.30	0.0%
Vinyl Acetate	20.85	0.0%
Vinyl Chloride	0.02	0.0%
Vinylidene Chloride	1.35	0.0%
Xylenes (Mixed Isomers)	258,903.24	8.5%
Total Weight	3,042,521.72	

Source: U.S. Environmental Protection Agency, National Emissions Inventory, 2008

Table C12: Dioxin and Dioxin-Like Compounds Listed in the Toxic Release Inventory Program and their Toxic Equivalency Factors

Compound	Toxic Equivalency Factor
2,3,7,8-tetrachlorodibenzo-p-dioxin	1.0
1,2,3,7,8-pentachlorodibenzo-p-dioxin	1.0
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	0.1
1,2,3,6,7,8-hexachlorodibenzo-p-dixon	0.1
1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	0.1
1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	0.01
1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	0.0001
2,3,7,8-tetrachlorodibenzofuran	0.1
1,2,3,7,8-pentachlorodibenzofuran	0.05
2,3,4,7,8-pentachlorodibenzofuran	0.5
1,2,3,4,7,8-hexachlorodibenzofuran	0.1
1,2,3,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,4,6,7,8-heptochlorodibenzofuran	0.01
1,2,3,4,7,8,9-heptochlorodibenzofuran	0.01
1,2,3,4,6,7,8,9-octachlorodibenzofuran	0.0001

Source: U.S. Environmental Protection Agency, Federal Register: 40 CFR Parts 9 and 372 Vol 72, No 90

Appendix D: Heavy Truck Mileage

Assumptions

The area surrounding the site of the facility would predictably experience a large increase in the amount of truck traffic as a result of hosting the facility. The impact on the rest of the Valley is unclear and dependent on a number of different factors. In order to estimate the change in the amount of truck trips, the following assumptions were made:

- **The litter-to-energy facility will first prioritize sources of litter that are nearest to the plant** – Depending on where the facility is constructed, litter sources within Augusta County will almost always be the closest options. In the instance where the facility is constructed in northern Augusta, there may be a small sub-section of farms in southern Rockingham County that would be closer than farms in southern Augusta County; however, for our purposes we will assume that litter from Augusta would be the first choice of the facility. Our assumption would be that the order of preference in source of the litter would be Augusta, Rockingham, Page, and Shenandoah Counties.
- **The facility will second prioritize litter that is already being exported from the county of origin over litter that is currently land-applied within the source county** – This assumes that unless the amount of litter that is currently being exported is insufficient to meet fuel demands of the facility, no additional litter that is currently used within county will be sent to the facility.
- **The mileage necessary to carry litter from Page, Rockingham, or Shenandoah Counties to the facility in Augusta County will be equal to the distance between each county seat** – – In reality, the distance from any given farm in either Page, Rockingham, or Shenandoah Counties to the facility in Augusta County will vary greatly. Some farms in southern Rockingham will be closer to the facility than farms in northern Rockingham, which would also be the case in Page or Shenandoah Counties. Because variance from the county seat-to-county seat distance for each individual farm will include both distances that are greater and distances that are less, the tendency of the average of all of these distances will be to skew towards a more moderate value. A model of each individual trip from farm to facility would provide the most accurate mileage measurement; however, this project does not have the capacity to create individual trip models. At the very least, making the above assumption will provide a reasonable approximation of the miles traveled in order to base predictions of the health impacts.
- **The mileage necessary to carry litter between counties will be entirely highway miles** – When making an assumption as to the position of the facility, priority was given to locations with highway access—five of the six locations were just off of Interstate 81 with another just off of US Route 340. Because of the position of the facility, it is unlikely there are any more direct routes to Augusta County from Page or Shenandoah Counties than the one provided by Interstate 81. Some routes from Rockingham County may be shorter using residential streets, particularly if the facility is located in northern Augusta, but the best route from a majority of farms in Rockingham would also be Interstate 81.
- **The mileage attributable to litter that is currently exported was assumed to be equal to the mean distance from county seat-to-county seat of each adjacent litter-demanding county** – Pease et al. (2012) does not quantify the amount of miles that are currently being traveled as a result of exported litter; in order to gauge the approximate distance between counties, the authors provide a chart of the distance from county seat-to-county seat. Because the preference for litter delivery is to minimize the distance traveled, it is presumed that when litter leaves its county of origin, its destination is farmland of a nearby county. In an instance in which an adjacent county does not have any farmland, that county was excluded from the calculation. The estimated mileage from each county is shown in Table D1.

County	Estimate of Average Distance (in miles) Traveled (Round Trip)	Amount of Litter Exported (in tons)		Estimated Total Mileage with Average Tuck Capacity of 15 Tons		Estimated Total Mileage with Average Truck Capacity of 10 Tons	
		Min	Max	Min	Max	Min	Max
Augusta	88	34,915	41,897	204,832	245,798	307,248	368,697
Page	64	33,340	40,007	142,249	170,698	213,373	256,047
Rockingham	86	84,101	100,921	482,179	578,615	723,269	867,922
Shenandoah	76	16,387	19,664	83,027	99,633	124,541	149,449

Table D1: Estimation of Current Heavy Truck Mileage from Exported Litter (Round Trip)

Note: Total litter and exported litter uses estimates from Pease et al (2012). Average distances are calculated from county seat-to-county seat.

- **Litter that is currently remaining on the farm in which it originated will not be available for purchase by the facility** – Pease et al. (2012) estimates that 15% to 20% of litter produced remains on the farm in which it originated. This analysis assumes that 85% of the litter produced by each county will be available for purchase and that this rate is consistent across all four counties.

In order to approximate the distance litter from Augusta County would have to travel to be used as a feedstock at a facility within Augusta County, we attempted to quantify an average driving distance from within Augusta to a centralized location. The U.S. Census Bureau estimates Augusta to be 967.0 square miles[347] with approximately 31 driving miles separating the northern border from the southern border down Interstate 81 and 31 miles separating the west from the east border. Because Augusta's geographic shape is an approximate square, we can estimate that the diagonal distance is approximately 44 miles.[ad] Based on these estimates, a location perfectly centralized within the county would be approximately 22 miles from each corner. Litter created in Augusta could travel a minimum of approximately zero miles—in the instance where the farm is immediately adjacent to the facility—and a maximum of 22 miles—in the instance the farm is in the far corner of Augusta. The average between these possibilities would be 11 miles. Our analysis uses this approximation as an estimate for the amount of heavy truck mileage that would be created from litter originating in Augusta being trucked to the poultry litter-to-energy facility.

Impact of Farmer's Preference for Selling to the Facility

No variable in the model had more of an impact on the amount of truck traffic that resulted than did the amount of litter that was available to the facility for purchase. All of the models that were run assuming that all of the litter was available resulted in a reduction in truck miles except in the case of limiting the amount of litter as feedstock to just over 86,000 tons. None of the models we ran in which less than 70% of the farmers were willing to sell to the facility resulted in a net reduction in truck miles.

The relationship between farmer's preference and change in truck miles was not necessarily linear; reducing farmer's preference while holding other factors constant did not necessarily result in an increase in truck miles. The largest increase in truck miles occurred when farmer preference was set at 70%. This is because, at this rate, the higher litter feedstock scenarios such as when the facility would burn 172,000 or 200,000 tons of litter are still possible but only if all of the truck trips that currently occur in Page and Shenandoah Counties (from farms that are further away than those in Augusta or Rockingham Coun-

ad The Pythagorean Theorem explains that the diagonal of a triangle is the square root of the sum of the squares of the opposing sides. For the diagonal across Augusta County, that would be approximately $\sqrt{(31^2 + 31^2)} \approx 44$ miles ties) and all of the truck trips that currently move litter within the originating county are replaced with truck trips to the facility. In a scenario where less than 70% of the farmers are willing to sell to the facility, it is not possible to use 172,000 or 200,000 tons of litter as the feedstock estimate unless you assume the importation of litter from other counties or the exportation of litter from poultry farms that use the litter themselves. Both of these possibilities would result in an increase in truck miles.

Impact of Amount of Litter that is Currently Exported

Pease et al. (2012) estimated that between 50% and 60% of the total litter produced in the Valley is currently exported outside of its originating county.[6] This is the difference of approximately 35,000 tons of litter being exported or between 2,300 and 3,500 truck trips, depending on the assumed carrying capacity of the truck. Replacing current exporting truck trips with trips to the facility would result in a lower impact and, in the instance of trips originating in Augusta and Rockingham Counties, a net negative impact on truck mileage—assuming a higher rate of export results in lower truck miles. The more litter the facility uses as feedstock, the greater the impact the amount of litter that is currently exported has on net mileage.

When the amount of litter that is currently exported is presumed to be 60%, a net reduction in truck mileage can occur when farmer preference is as low as 70%. If the amount of litter exported is presumed to be 50%, no net reduction in truck mileage occurs if farmer preference is any lower than 90%.

Impact of the Amount of Litter Used as Fuel

A reduction in the amount of litter used as fuel increases the amount of wood biomass necessary for the operation of the facility. Because the biomass would most likely come from Staunton or Harrisonburg, replacing trucks carrying litter from distant counties like Page or Shenandoah with trucks carrying biomass results in a net reduction of truck miles. Replacing trips from Rockingham Counties with trucks carrying biomass, however, can result in an increase in total mileage if it is replacing trips that typically exported litter.

The quantity of fuel most likely to result in a net reduction in heavy truck mileage was 137,974 tons of litter. Exactly half of the model runs at this quantity resulted in a net reduction. For the most part, this occurred when a high percentage of farmers were agreeable to sell to the facility and a greater percentage of the litter was assumed to be currently exported. All scenarios in which the feedstock was assumed to be 86,234 tons of litter resulted in an increase in heavy truck miles ranging from 38,000 miles to almost 326,000 miles. At this low level of feedstock, not enough truck trips from Rockingham to the facility would displace exported litter from Rockingham to make up for the large increase necessary for the additional biomass needs.

Impact of the Carrying Capacity of Heavy Trucks

This model assumes that both trucks carrying litter to the facility and trucks that currently export litter would carry the same average amount of litter. If that assumption is not met—for example if trucks currently exporting litter carried more than trucks that would take litter to the facility, or the reverse of that scenario—it would likely change the expected mileage.

In no scenario that we ran did the average carrying capacity of a truck change the direction of the impact on net mileage. That is, if a scenario in which the trucks were assumed to have a carrying capacity of fifteen tons resulted in a negative net impact on heavy truck mileage, the scenario in which every other variable was held constant but the carrying capacity was reduced to 10 tons also resulted in a net negative mileage impact. This was also the case if the net mileage impact was found to be positive. Regardless of the truck carrying capacity, all other things being held constant, we would expect the impact on the net heavy truck miles to remain positive.

In all instances in which the net mileage impact was found to be negative, assuming a carrying capacity of 10 tons resulted in a 50% decrease in the number of truck miles as compared with trucks with the average carrying capacity of 15 tons. This is due to the assumption that a truck that currently exports litter would require more trips to completely export the litter if it could only do so 10 tons at a time. If these truck trips were replaced by truck trips carrying 15 tons of litter to the facility, each truck trip would result in a net decrease in truck miles for each individual trip. Conversely, if the net mileage impact was found to be positive, (i.e. the Valley would see more truck traffic as a result of constructing a facility) the increase in mileage was 50% greater assuming a carrying capacity of 10 tons compared to 15 tons. In scenarios where carrying capacity is assumed to be higher—25 tons for instance—the relationship between carrying capacity and net change in truck miles persists. In scenarios where the net impact in truck miles is negative, a carrying capacity of 25 tons results in mileage that is 40% higher than if 15 tons is presumed, and 60% higher than if 10 tons is presumed. In scenarios where the net impact in truck miles is positive, a carrying capacity of 25 tons results in mileage that is 40% lower than if 15 tons is presumed and 60% lower than if 10 tons is presumed.

Interpretation of these results should be viewed with caution as manipulating the carrying capacity of future truck trips from the litter-originating farm to the facility would follow the patterns seen here only if they match the average carrying capacity of the trucks that are currently exporting litter.

Table D2: Estimation of Impact on Heavy Truck Mileage Assuming 100% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
						50% Currently Exported		60% Currently Exported	
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			15 tons	10 tons	15 tons	10 tons
59,355	-	140,645	-	200,000	200,000	-8,458	-12,686	-144,734	-217,101
59,355	-	113,113	-	172,468	227,532	-65,360	-98,041	-201,633	-302,450
59,355	-	78,619	-	137,974	262,026	-105,583	-158,375	-146,549	-219,823
59,355	-	26,879	-	86,243	313,766	80,681	121,021	39,715	59,573

Table D3: Estimation of Impact on Heavy Truck Mileage Assuming 90% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
						50% Currently Exported		60% Currently Exported	
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			15 tons	10 tons	15 tons	10 tons
53,420	17,905	128,675	-	200,000	200,000	67,187	100,781	-55,454	-83,181
53,420	-	119,048	-	172,468	227,532	11,481	17,222	-111,164	-166,746
53,420	-	85,554	-	137,974	262,026	-59,806	-89,709	-146,894	-220,342
53,420	-	32814	-	86,243	313,766	76,234	114,351	39,370	59,055

Table D4: Estimation of Impact on Heavy Truck Mileage Assuming 80% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
						50% Currently Exported		60% Currently Exported	
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			15 tons	10 tons	15 tons	10 tons
47,484	38,138	114,378	-	200,000	200,000	190,845	286,267	59,420	89,130
47,484	10,606	114,378	-	172,468	227,532	87,624	131,435	-21,398	-32,098
47,484		90,490	-	137,974	262,026	17,043	25,564	-91,979	-137,968
47,484		38,750	-	86,243	313,766	71,789	107,684	39,018	58,527

Table D5: Estimation of Impact on Heavy Truck Mileage Assuming 70% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			50% Currently Exported		60% Currently Exported	
						15 tons	10 tons	15 tons	10 tons
41,549	39,674	100,080	18,697	200,000	200,000	322,157	483,236	195,549	293,324
41,549	30,839	100,080	-	172,468	227,532	194,621	291,931	79,635	119,453
41,549	-	96,425	-	137,974	262,026	93,301	139,952	-1,503	-2,255
41,549	-	44,685	-	86,243	313,766	67,343	101,014	38,668	58,002

Table D6: Estimation of Impact on Heavy Truck Mileage Assuming 60% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			50% Currently Exported		60% Currently Exported	
						15 tons	10 tons	15 tons	10 tons
There is not enough litter in the Valley to supply 200,000 tons to the facility when only 60% of farmers will sell litter as fuel									
There is not enough litter in the Valley to supply 172,468 tons to the facility when only 60% of farmers will sell litter as fuel									
35,613	16,578	85,783	-	137,974	262,026	169,629	254,443	87,865	131,798
35,613		50,621	-	86,243	313,766	63,805	95,707	38,323	57,484

Table D7: Estimation of Impact on Heavy Truck Mileage Assuming 50% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			50% Currently Exported		60% Currently Exported	
						15 tons	10 tons	15 tons	10 tons
There is not enough litter in the Valley to supply 200,000 tons to the facility when only 50% of farmers will sell litter as fuel									
There is not enough litter in the Valley to supply 172,468 tons to the facility when only 50% of farmers will sell litter as fuel									
29,678	28,339	71,486	8,471	137,974	262,026	294,970	442,456	227,089	340,634
29,678	-	56,556	-	86,243	313,766	140,647	210,970	72,509	108,764

Table D8: Estimation of Impact on Heavy Truck Mileage Assuming 40% of Poultry Farmers Are Willing to Sell Litter to the Facility

County in which Litter Originated				Total Litter (in tons)	Total Wood Biomass (in tons)	Total Miles			
						50% Currently Exported		60% Currently Exported	
Augusta (in tons)	Page (in tons)	Rockingham (in tons)	Shenandoah (in tons)			15 tons	10 tons	15 tons	10 tons
There is not enough litter in the Valley to supply 200,000 tons to the facility when only 40% of farmers will sell litter as fuel									
There is not enough litter in the Valley to supply 172,468 tons to the facility when only 40% of farmers will sell litter as fuel									
There is not enough litter in the Valley to supply 137,974 tons to the facility when only 40% of farmers will sell litter as fuel									
23,742	5,304	57,188	-	86,243	313,766	217,148	325,722	162,637	243,955

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Center on Human Needs:
www.humanneeds.vcu.edu

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Human Impact Partners:
http://www.humanimpact.org/

Institute for Environmental Negotiation:
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