University of Virginia
Environmental Footprint Reduction Plan
Part 2 - Nitrogen

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Introduction

The Nitrogen Footprint Reduction Plan is part two of the four-part Environmental Footprint Reduction Plan (EFRP) being developed by the University of Virginia (UVA) through the Office of the Architect in concert with the University Committee on Sustainability. The goal of this and other phases of the EFRP is to enhance the sustainability of the University through specific environmental impact reductions. The plan for nitrogen develops a framework to reduce the amount of reactive nitrogen lost to the environment as a result of University activities and recommends a formal reduction target for the University. In 2009, the UVA Board of Visitors approved Part 1 of the EFRP, the Carbon Footprint Reduction Plan. To our knowledge, the plan presented in this paper contains the first institution-level nitrogen footprint model ever constructed.

The overall objectives of this plan are to:

- Quantify the amount of reactive nitrogen lost to the environment as a result of University activities,
- Propose a goal for reductions of UVA's Nitrogen Footprint, and,
- Suggest strategies to achieve this goal.

The above objectives were met through the following specific activities:

- A nitrogen footprint model was developed to calculate UVA's Nitrogen Footprint and an inventory of UVA's nitrogen-releasing activities was completed.
- Projections of UVA's Nitrogen Footprint from 2010-2025 were modeled.
- Strategies to reduce UVA's Nitrogen Footprint were identified: Implementation of the Carbon Footprint Reduction Goal adopted by the Board of Visitors in June 2011, changes in food purchasing and food waste practices, and denitrification of sewage.
- Based on the above, an aggressive, but realistic, nitrogen footprint reduction goal for adoption by UVA is recommended.
- A mechanism is proposed to monitor progress and to implement new, refined, and/or more cost-effective practices as they become available.

What is Reactive Nitrogen and Why is it Important?

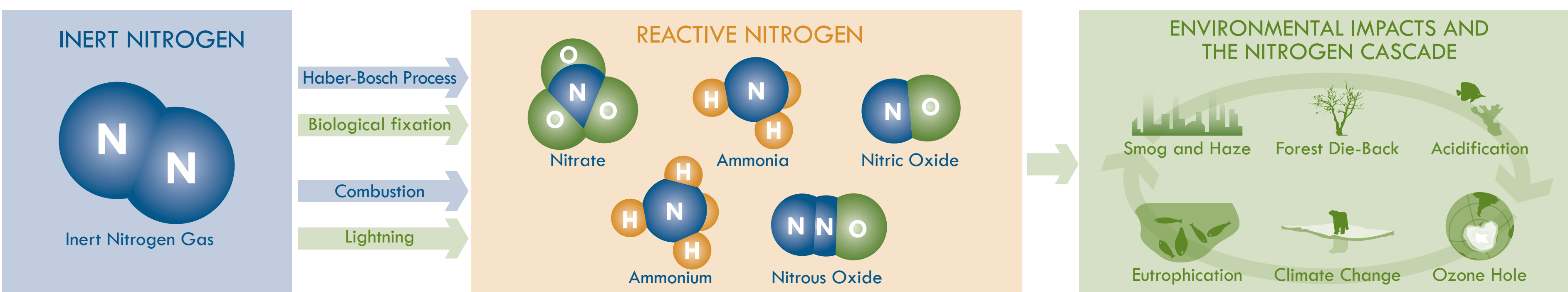
Reactive nitrogen is defined as any nitrogen that is biologically, photochemically, or radiatively active.[1] Reactive nitrogen includes all forms of nitrogen except the unreactive N_2, which accounts for about 78% of N in Earth's atmosphere. Examples of reactive nitrogen include nitrogen oxides ($NO_x = NO + NO_2$), nitric acid (HNO_3), nitrous oxide (N_2O, a greenhouse gas), ammonia (NH_3), and N-containing particles in the atmosphere. Unless otherwise stated, reference to nitrogen in this paper means reactive nitrogen.

Humans create nitrogen by the Haber-Bosch process, cultivation of legumes and the combustion of fossil fuels (**Figure 1**). The first two support food production, the third produces energy. The Haber-Bosch process also supplies NH_3 for industrial processes. Anthropogenic sources of nitrogen are twice as large as natural terrestrial sources.[2] This dominance is so great that human interference with the nitrogen cycle was recently identified as one of three global issues where the rate of change cannot continue without significantly impacting Earth-system functioning.[3]

During agricultural production, nitrogen is applied as fertilizer or created by the cultivation of legumes. Some of that nitrogen is then lost to the environment during each step of the production process. Loss pathways include fertilizer not taken up by a crop, crop processing waste, livestock manure, and consumer-level food waste. Only about 20%of the nitrogen used in food production is actually contained in food products that are consumed; the rest is lost to the environment.[4] When nitrogen is consumed as protein in food, it is ultimately released to the environment as human waste, with the exception of sewage that is treated in a sewage treatment facility with nitrogen removal technology.

Once in the environment, nitrogen causes a cascade of negative impacts.[5] For example, NO_x emitted from fossil-fuel combustion drives production of photochemical smog and together with NH_3 emitted from agricultural processes leads to the production of pollutant aerosol. Both processes have negative consequences for the health of biota including humans. Deposition of atmospheric HNO_3 and acidic N-containing particles contribute to acidification of soils and fresh waters. Together with N in surface runoff, this leads to eutrophication of fresh and coastal water bodies, with associated losses of biodiversity. The declining health of the Chesapeake Bay and associated mitigation efforts by surrounding states illustrates the importance of these processes regionally. N_2O is an important greenhouse gas that contributes to global warming. These and other wider-ranging impacts are significantly degrading the quality of both our environment and health; thus, they warrant concerted efforts to mitigate emissions.

FIGURE 1 INERT NITROGEN VS REACTIVE NITROGEN - AND WHY IT MATTERS



Section 1 - The Challenge

The extensive and detrimental effects of reactive nitrogen indicate the importance of managing nitrogen efficiently to reduce its loss to and impact on the environment. A first step in managing nitrogen at UVA is assessing the current contribution from the University. **To our knowledge, the plan presented in this paper contains the first institution-level nitrogen footprint model ever constructed.** The use of this tool will allow the University to assess and reduce its nitrogen footprint and can serve as a starting point for other institutions who wish to decrease their impact on the environment.

A nitrogen footprint provides a metric for measuring the University's environmental impact that is distinct from a carbon footprint. This is particularly important in the area of dining services and food purchasing, because the environmental impact of food production and consumption is largely absent from carbon footprint measures. The overlap between C and N footprints in the energy sector also provides further support for energy conservation strategies.

Section 2 – UVA Nitrogen Footprint

2.1 Defining System Boundaries

The University houses a diverse population of faculty members, students and staff of various disciplines and lifestyles. In 2010, the UVA full-time population included 18,019 full-time degree seeking students, 4,571 part-time or non-degree seeking students, 12,189 full-time employees, and 1,550 part-time employees.[6] Each member of the UVA community contributes to the system's overall nitrogen footprint in distinct ways. A student living on the University Grounds is likely to contribute a large portion of their personal footprint to the overall UVA nitrogen footprint because much of their energy use and food consumption will take place in UVA-owned facilities. In contrast, a student living off-Grounds may not have a meal plan and much of their personal energy use will occur in privately-owned facilities. For employees, the UVA nitrogen footprint will include their commutes to the university and energy use associated with their activities on-Grounds.

In an effort to fairly account for all nitrogen lost to the environment as a result of the UVA community's activities, the system lines for the UVA nitrogen footprint are bounded by the University's geographical presence as well as the "upstream" consequences of University activities.

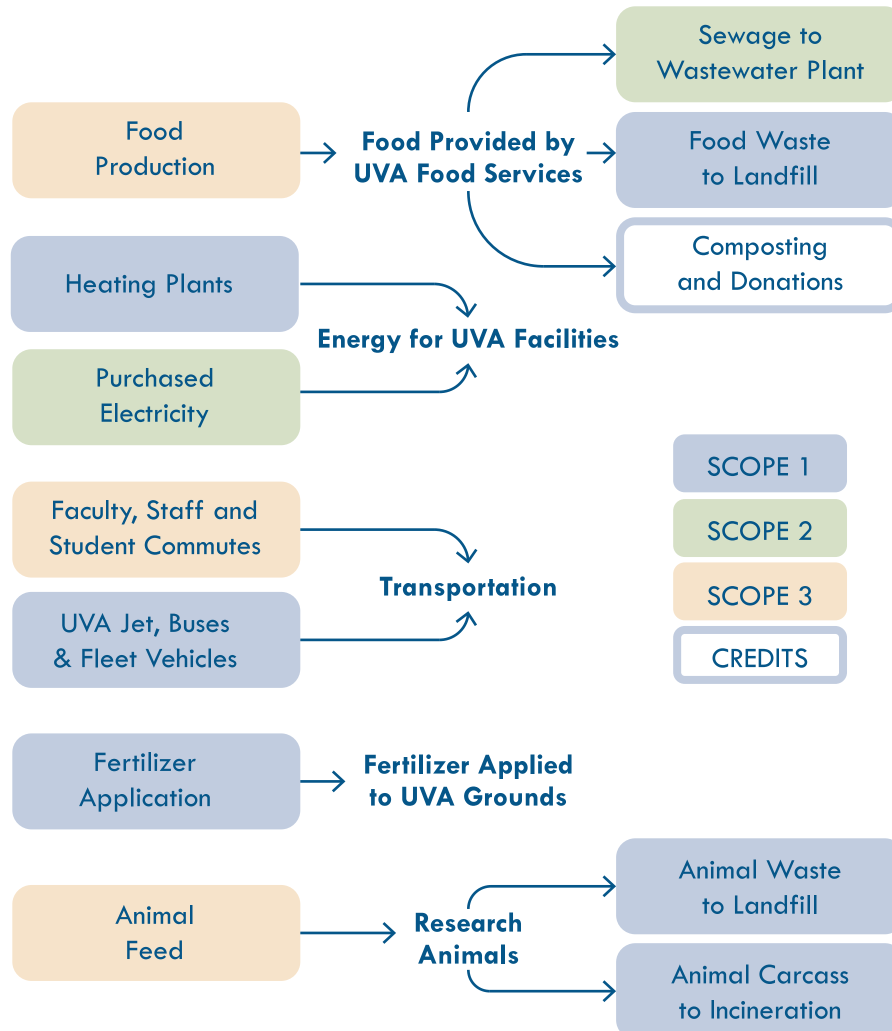
The model surveys UVA's main campus in Charlottesville, Virginia, divided among the University's Central Grounds, Health System, and North Grounds. This model takes into account the nitrogen lost to the environment due to food consumed in the UVA dining venues, energy used at UVA, animals used in research facilities, fuel used by the University's fleet, and on-Grounds fertilizer application (**Figure 2**). Any nitrogen losses due to food or energy consumption that occur in off-Grounds housing units not provisioned by the university are not included in this model.

The upstream nitrogen losses include a) the nitrogen released in the production and transportation of food ordered and served in university dining venues, b) the nitrogen released to the environment due to electricity production off-Grounds, and c) the nitrogen released in the transportation of commuters to and from UVA. Despite the consideration of food production, upstream production losses associated with other goods ordered by the university, including paper, furniture, and research supplies, are not included in this model at this time.

Additionally, the model recognizes that UVA fits into the larger system of Charlottesville and operates within the city framework. Thus, nitrogen removal in the Rivanna Water and Sewer Authority (RWSA) sewage treatment is factored into the UVA nitrogen model. However, nitrogen recycled back into the Charlottesville community that leaves the university system, such as through food waste donations and composting, is subtracted from the overall footprint because it has left the UVA system and is then re-used.

As data and reporting methodologies improve in coming years, it is likely that total emissions figures will vary as a result of better data (as opposed to actual changes in emissions). The numbers cited in this report are based on best available methodology, but should not be compared with future results without first accounting for variations caused by inventory methodology. Future UVA documents will evaluate differences in methodology and provide the relevant context for cross-referencing information and reports over time.

FIGURE 2 SCHEMATIC OF THE UVA NITROGEN FOOTPRINT

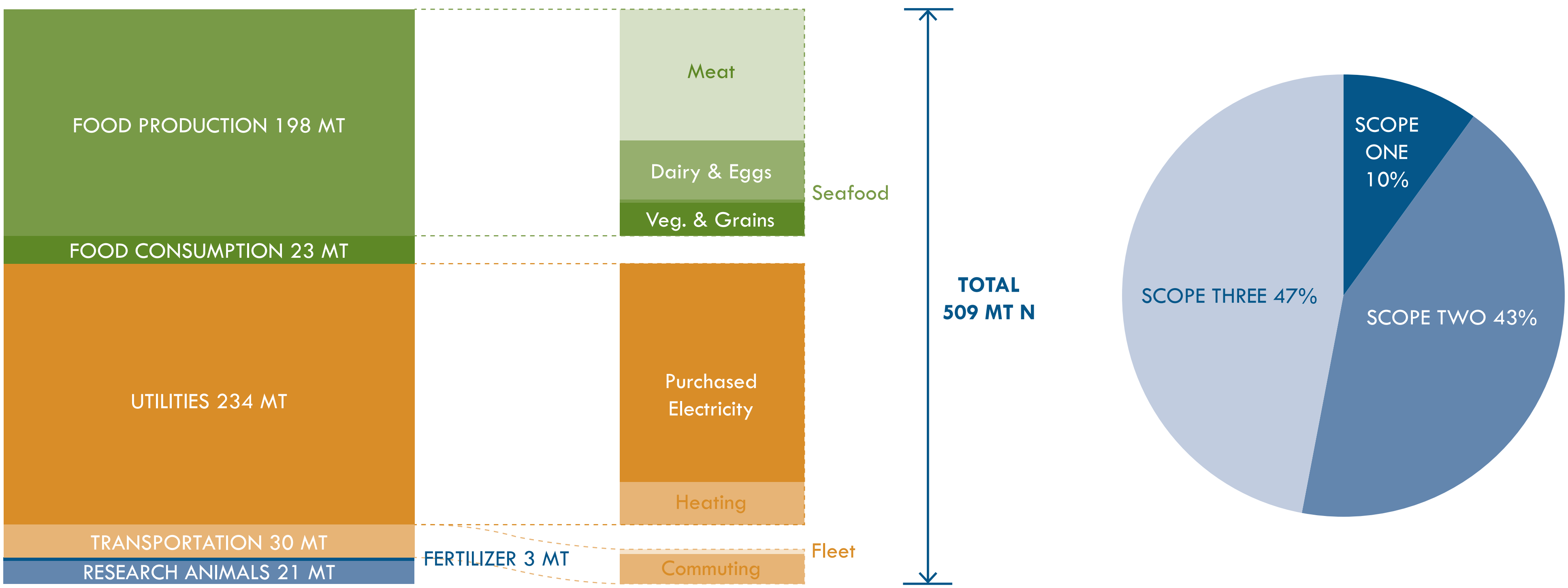


2.2 UVA Nitrogen Footprint

The total nitrogen footprint of the University in 2010 (**Figure 3**) was found to be 509 metric tons of reactive nitrogen (MT N). Utilities usage at the University, including electricity and heating, contributes the most to the University footprint at 46% of the total footprint. Food production was the second biggest contributor to the footprint at 39%. The remaining sectors (food consumption, fertilizer usage, and research animals) make up the remaining 15% of UVA's nitrogen footprint.

Accounting for the nitrogen footprint by scopes shows that 53 MT of nitrogen released to the environment is classified as scope 1, meaning that it enters the environment directly from UVA owned-facilities. 220 MT of nitrogen are released to the environment as a result of UVA use of purchased electricity and wastewater disposal (Scope 2). Scope 3 measured Indirect releases of nitrogen, which amounts to 235 MT. Nitrogen lost to the environment as a result of food production is the main component of scope 3.

FIGURE 3 2010 UVA NITROGEN FOOTPRINT BY SECTOR/SUBSECTOR & SCOPE



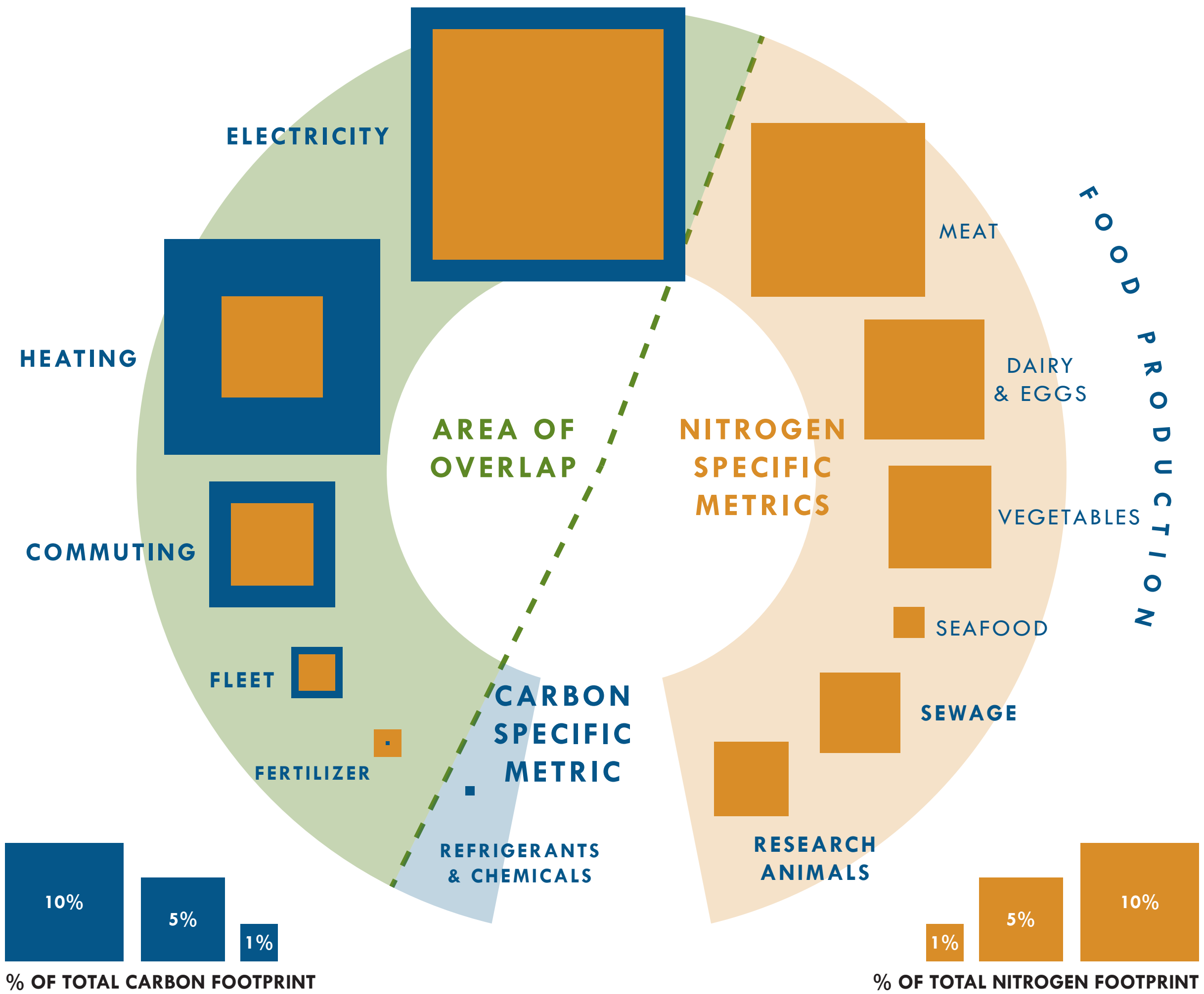
2.3 Alignment with Carbon Footprint

The sources of carbon emissions at UVA are also, in nearly all cases, sources of nitrogen. **Figure 4** presents the major sectors of each footprint and illustrates the overlap between carbon and nitrogen footprints. Blue squares in the figure indicate sources of carbon emissions, sized by the percentage contribution of each source to the total. Orange squares represent the amount of nitrogen lost to the environment for each source. UVA's use of purchased electricity is the largest source of both carbon and nitrogen.

As a result of the alignment between carbon and nitrogen, actions to reduce the University's carbon footprint will generally decrease the nitrogen footprint. This relationship is not perfectly correlated. For instance, substitution of biomass for fossil fuels will decrease carbon emissions but may not decrease the amount of nitrogen lost to the environment. However, most carbon reduction strategies, including conservation, efficiency, and co-generation, will benefit UVA's nitrogen footprint to a similar magnitude.

But nitrogen and carbon footprints are not synonymous. Almost half of UVA's nitrogen footprint comes from sources specific to the nitrogen footprint. The nitrogen footprint methodology allows UVA to quantify and reduce the environmental impact of food production, sewage disposal, and use of research animals.

FIGURE 4 COMPARING UVA's CARBON & NITROGEN FOOTPRINTS BY SECTOR



Section 3 – Growth Projections

Growth in UVA's nitrogen footprint is driven primarily through two trends: population growth that leads to an increase in the amount of food served and building growth that leads to an increase in energy usage. The model projected growth in UVA's nitrogen footprint based on expected increases in population and new construction projects listed in the University's capital plan.

Future projections are complicated by the variety of ongoing and planned activities that will affect the size of the nitrogen footprint in future years. Significant uncertainty remains about the feasibility, timing, and scale of both actions that will increase UVA's nitrogen footprint and strategies that will be undertaken to reduce it. The Nitrogen Footprint Reduction Plan presents four projections for future changes in the University's nitrogen footprint (**Figure 5**).

PROJECTION 0

Projection zero is the 2010 baseline forecast of UVA's nitrogen footprint through 2025. Under this scenario, the University will continue the practices in place as of 2010, such as limited composting and transportation demand management. This scenario also assumes that the University will meet its goal to reduce UVA carbon emissions by 25% below 2009 levels by 2025. The activities implemented to meet the carbon reduction goal are assumed to be relatively nitrogen-efficient. In this projection, UVA's nitrogen footprint in 2025 is expected to be 507 MT (-0.4%).

PROJECTION -1

Projection negative one is a hypothetical scenario that keeps current actions in place, but removes all future actions designed to reduce UVA carbon emissions. Without accounting for actions to reduce the University's carbon footprint, UVA's nitrogen footprint is expected to grow to 585 MT in 2025 (+13%). The 76 MT difference between this projection and the previous scenario reflects the impact of the planned carbon reductions on UVA's nitrogen footprint.

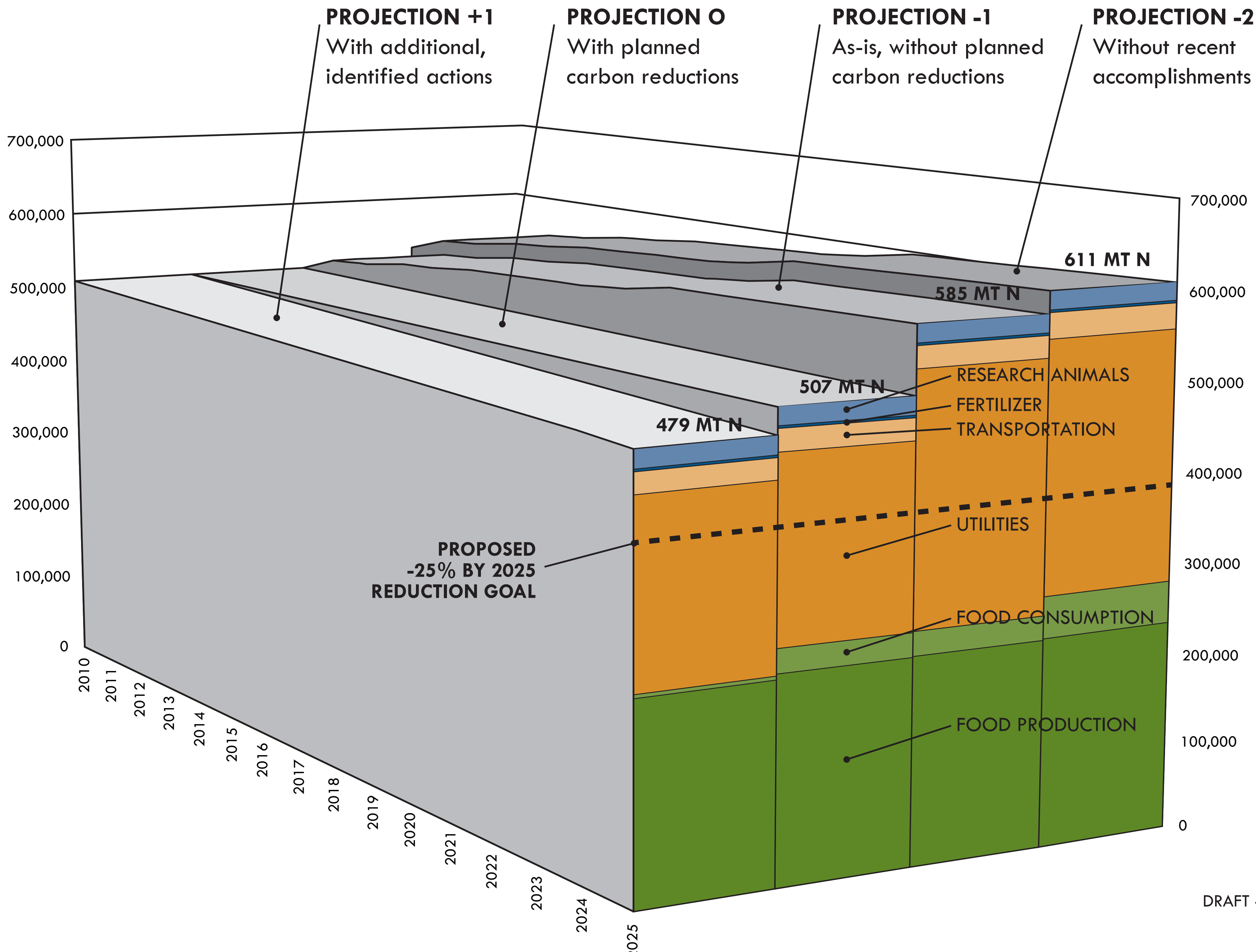
PROJECTION -2

Projection negative two is a worst-case scenario that assumes that UVA does not pursue its carbon reduction goal and that certain nitrogen-lowering actions, such as composting, that were practiced in 2010 will cease to be practiced in the future. While this is an unlikely scenario, this projection approximates the nitrogen savings that have resulted from previously implemented actions. Under this projection UVA's nitrogen footprint would grow to 611 MT (+20%).

PROJECTION +1

Projection positive one builds on projection zero by including additional activities that lower UVA's nitrogen footprint. The largest reduction comes as a result of tertiary treatment upgrades to the Moore's Creek Waste Water Treatment Plant, which is operated by the Rivanna Water and Sewer Authority. Upgrades to the plant were completed in 2011 and samples records indicate a 91% nitrogen removal factor. This scenario also models nitrogen reductions resulting from additional composting of food waste at all dining locations and an increase in donations of unused food. All of the new activities included in projection positive one are considered either in process of implementation or relatively feasible. Under this scenario, UVA's nitrogen footprint would be 479 MT in 2025, a 6% reduction below the 2010 level.

FIGURE 5 2010 to 2025 PROJECTIONS FOR UVA NITROGEN FOOTPRINT



Section 4 - Reduction Strategies

4.1 Planned Carbon Footprint Reduction Strategies

This section describes reductions in the nitrogen footprint due to the energy reductions suggested by the Carbon Footprint Reduction Plan and the June 2011 Board of Visitors Sustainability Commitment.

ENERGY REDUCTIONS

The utilities reductions scenario involves five different actions towards renewable energy usage and energy reduction – 1) the Virginia Renewable Portfolio Standard (RPS) 2025 goal, 2) cogeneration of electricity and heat by natural gas, 3) energy conservation efforts, 4) biomass co-burn, and 5) renewable energy generation at the University. Projections 0 and +1 reflect these actions.

TRANSPORTATION DEMAND MANAGEMENT STRATEGIES

To simulate the better management of transportation demand in 2025, Projections 0 and +1 forecast a decrease in the percentage of commuters that drive alone to UVA and an increase in the percentage of commuters that use alternative modes of transportation such as carpooling, transit, telecommuting, bicycling, and walking. The decrease in the percentage of commuters who drive alone reduces the amount of fuel consumed by employees and students commuting to UVA.

4.2 Reduction Strategies Implemented After 2010

SEWAGE TREATMENT

Projection +1 includes estimated reductions in nitrogen from food consumption due to the incorporation of a tertiary treatment process in the local wastewater treatment facility. Tertiary treatment technology involves the denitrification of sewage (i.e., converting reactive nitrogen to its inert form, N_2) and the removal of sludge. The Rivanna Water and Sewer Authority installed a tertiary treatment system in 2011, and sewage sample records show a 91% nitrogen removal factor. This factor includes all nitrogen in the sludge removed and repurposed from sewage and the nitrogen denitrified in the tertiary treatment.

4.3 Additional Reduction Strategies

Projection +1 models a 6% reduction of the 2010 UVA nitrogen footprint by 2025 based on currently implemented, planned, or likely actions. To understand what actions might further reduce UVA's nitrogen footprint, multiple strategies were analyzed to determine the impact of both different consumption patterns and production methods on a food nitrogen footprint.

COMPOSTING FOOD WASTE

The composting food waste scenario projects reductions in nitrogen due to food production in the event that all dining halls send their food waste to composting facilities. The model allows for adjustments of the proportion of food waste composted and the number of participating dining halls to test the impacts of graded scenario implementation. Projection +1 models composting rates of 75% at O-Hill and Newcomb Dining Halls and 50% at all other dining facilities. 100% Composting at all dining facilities would further reduce the nitrogen footprint by 4 MT.

FOOD DONATION

The food donation scenario tests for the reduction of nitrogen losses associated with food donation programs. The two dining halls that donated food in 2010 gave 0.1% of their total food orders to community shelters. This proportion was applied to the total food orders at all other dining halls for Projection +1. Increasing donations to 0.2% would further reduce the nitrogen footprint by 0.3 MT.

MEAT FREE MONDAYS

The Meat Free Mondays scenario estimates the reductions in nitrogen due to food consumption and food production with increased student participation in the Meat Free Mondays program at the University's three leading dining halls. Meat Free Mondays involves the replacement of a meat-serving food station at a dining hall for a vegetarian station every Monday that the dining hall is in service. Projection +1 models participation of 10% of diners choosing a meat-free option at lunch and dinner for the twenty-eight Meat Free Mondays that occur during the year. The nitrogen footprints, including food consumption and production, of an average meat-free meal and an average meal with meat were calculated. The amount of nitrogen from the meals with meat that were replaced due to Meat Free Mondays was subtracted from the total footprint, and the nitrogen due to all meat-free meals was added to the footprint for the scenario calculation. 100% participation would further reduce the nitrogen footprint by 19 MT.

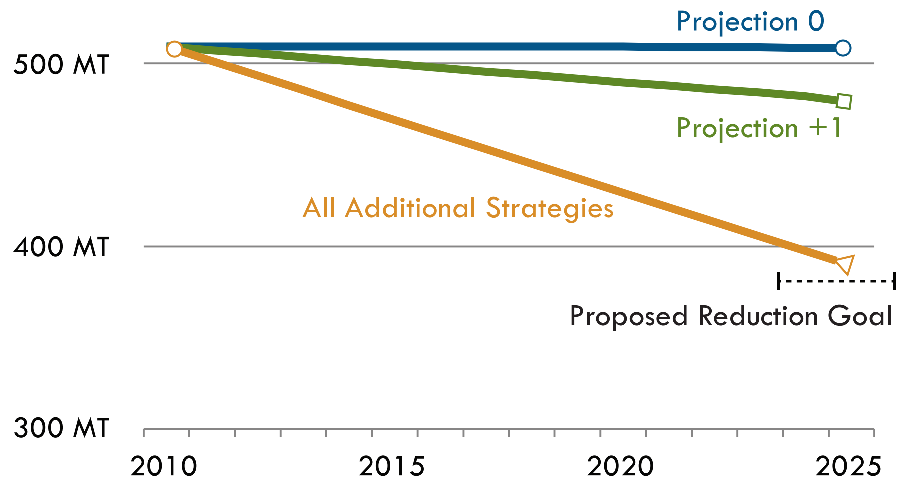
REPLACE BEEF WITH CHICKEN

The beef replacements scenario estimates the reductions in nitrogen due to food production and consumption when the University's total beef purchases are replaced with poultry. By shifting meat orders from a low-efficiency meat (beef) to high-efficiency meat (chicken), the University can decrease its nitrogen footprint while maintaining meat options. Replacing 20% of beef served with chicken would reduce the nitrogen footprint by 9 MT. 100% replacement would lead to an additional 36 MT reduction. Full replacement of beef with chicken is not expected to be feasible.

SUSTAINABLE FARMING METHODS

This scenario replaces current food production practices with the recommended nitrogen management strategies suggested by a 2011 EPA Science Advisory Board report.[7] The following three recommendations were utilized in the calculations: 1) Total artificial applied nitrogen can be decreased by up to 20%; 2) Livestock-derived NH_3 emissions can be decreased by 30%; and 3) NH_3 from fertilizer applications can be decreased by 20%. The report states that these recommended

FIGURE 6 ALL REDUCTION STRATEGIES VS. GOAL



reductions can be achieved through the implementation of available technologies and best management practices. A 60 MT reduction to the food production nitrogen footprint that would occur if all food purchases at the University were subject to these sustainable farming methods. Unfortunately, no straightforward mechanism exists to identify food producers who practice sustainable farming methods and implementation of this strategy is not currently feasible. It is likely that some food purchased by UVA in 2010 was produced using these methods, but it is not possible to quantify the impact of those purchases on UVA's nitrogen footprint.

ALL LOCAL FOOD

The local food scenario tests for decreases in nitrogen due to food production, specifically due to food transportation, if the University were to limit all food orders to a 100-mile distance. This scenario would result in a 0.4 MT reduction in the nitrogen footprint.

ALL ADDITIONAL REDUCTION STRATEGIES

If all of the above reduction strategies were implemented concurrently and to the fullest degree (**Figure 6**), UVA's nitrogen footprint would decrease by a further 118 MT by 2025; 24% below the 2010 UVA nitrogen footprint.

Section 5 - Nitrogen Reduction Goal

At the November 29, 2012 meeting of the University Committee on Sustainability, the Committee unanimously recommended that the University adopt a commitment to reduce its nitrogen footprint by 25% below 2009 levels by 2025. This goal is informed by N-FRP projections of reduction potential (Section 4), published recommendations from scientists and policy makers, and the first-mover opportunity for leadership.

5.1 Goal Discussion

In its deliberations to adopt UVA's greenhouse gas reduction target, the Committee balanced three inputs to determine an appropriate reduction target: in-house analysis of greenhouse gas reduction potential, recommendations of scientists and policy makers, including President Obama and Governor Kaine, and the declared reduction targets of other universities and institutions.

The Committee followed a similar approach to select a nitrogen reduction target. However, as this is the first institutional-level nitrogen footprint, nitrogen reduction targets for comparable institutions were not available.

The reduction strategies described in Section 4 formed the starting point in the deliberations of the Committee on Sustainability to select a nitrogen reduction target. Projection positive one suggests that the University is on track to reduce UVA's nitrogen footprint to 479 MT (-6%) by 2025.

In the science and policy sphere, there are estimates of what is possible to do using best-available technology at the national and global scale. For the former, the recently published Integrated Nitrogen Management Strategy report from the EPA Science Advisory Board recommends a 25% reduction in the formation of reactive nitrogen.[8] This percentage was recommended not because it would solve the problem, but rather because it is what could be done with current technology. For the global scale, the Galloway et al. (2008) *Science* paper also suggests that there could be a 25% decrease in the formation rate of reactive nitrogen.[9]

5.2 Footprint Accounting

A significant amount of time and effort was necessary to complete the University's first nitrogen footprint. Although the amount of effort necessary to complete future footprint calculations will be substantially less than the original, the University must still commit the resources necessary for annual nitrogen footprint updates. The key to simplifying annual nitrogen footprint updates will be to automate data collection for food purchases in a similar way as the collection of energy consumption data has been automated to create annual carbon footprint reports.

5.3 Next Steps

The University Committee on Sustainability is actively seeking support of the nitrogen reduction goal from University stakeholders, including the University of Virginia Faculty Senate, the Student Council, and the Employee Communication Councils. Endorsement from University stakeholders will demonstrate the UVA community's support for and commitment to the nitrogen goal. Ultimately, the goal will be recommended to the UVA Board of Visitors for approval.

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Acknowledgments

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