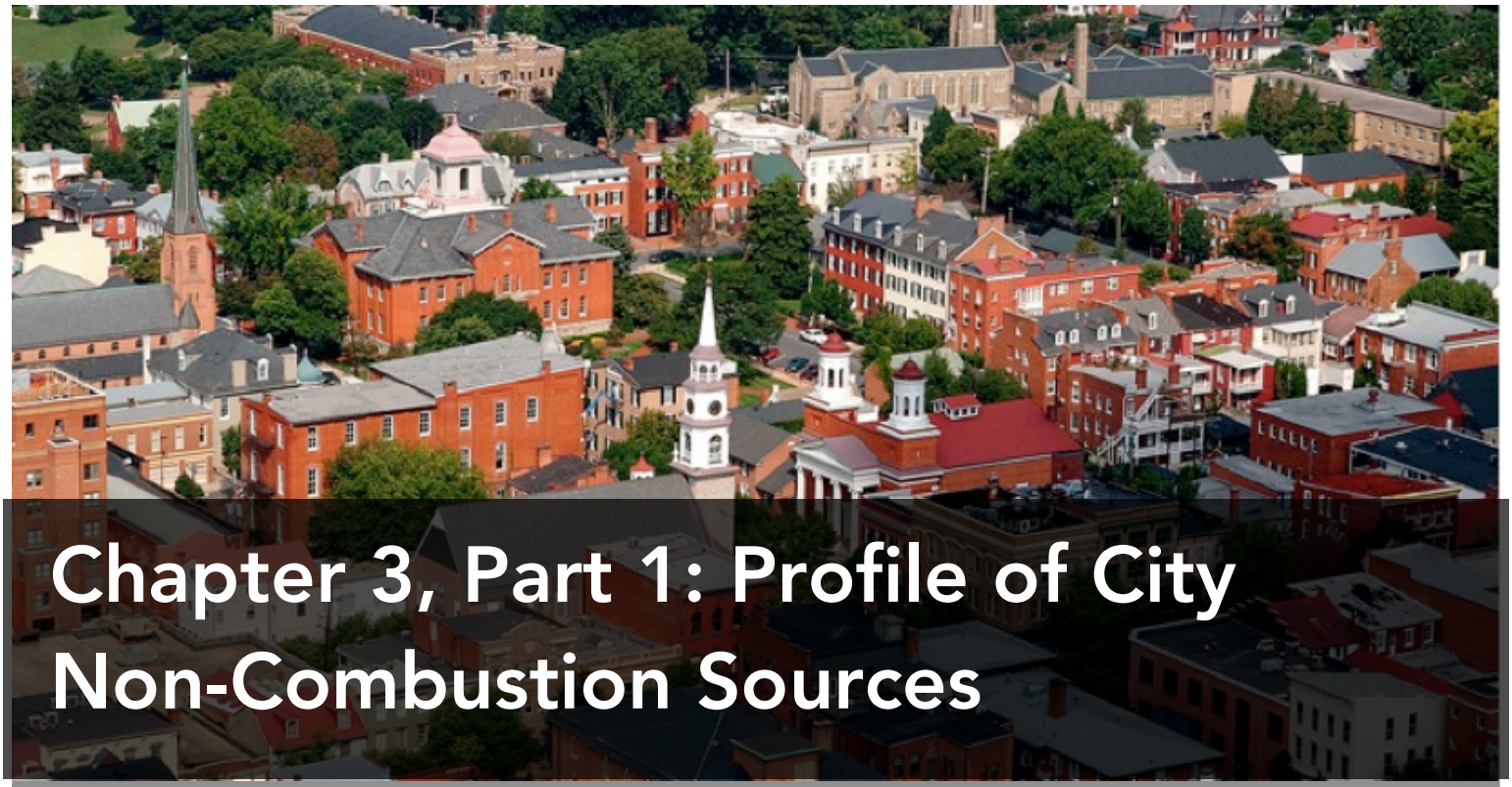

Chapter 3, Part 1: Profile of City Non-Combustion Sources

A Local Government Greenhouse Gas (GHG) Emissions Inventory

A collaborative partnership between

PALS

The City of Frederick Maryland

Authors: Christine Dunham, Albert Engel

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Executive Summary

Non-combustion emissions are the smallest source of greenhouse gas (GHG) emissions in the City of Frederick (Figure 1) at 18% of the total emissions. Within that sector, the largest source at 93%, is the City's solid waste emissions (Figure 2A). The City's urban tree canopy is a sizable source of carbon sequestration overall for the City and stores approximately 6,583 metric tonnes of carbon dioxide equivalent (a metric tonne equals 1.1 ton). However, the City will need to consider how and where it grows and evaluate all aspects of its operations to fully track, account for and mitigate emissions.

Two data issues in this profile illustrate the difficulty of GHG inventories, specifically in calculating emissions from wastewater treatment plants. While the Local Government Greenhouse Gas Inventory Tool (LGGIT) was used to calculate emissions with information obtained from the City's Department of Public Works, that data and the LGGIT model's results contradicted information supplied by the assistant superintendent of the City's wastewater treatment plant. These challenges apply to all wastewater treatment facilities due to the sophisticated nature of each plant and the difficulty in estimating GHGs from a generalized tool. Thus all results should be viewed cautiously and an effort made to do a more in-depth analysis. The two main points of difference were whether there are emissions from the plant's aeration basins and whether Frederick County processed a portion of the City's wastewater. This report reflects the most current data, with notations where the data differed. However, all final emissions from the wastewater treatment plant should be reviewed by technical experts to provide more accurate results.

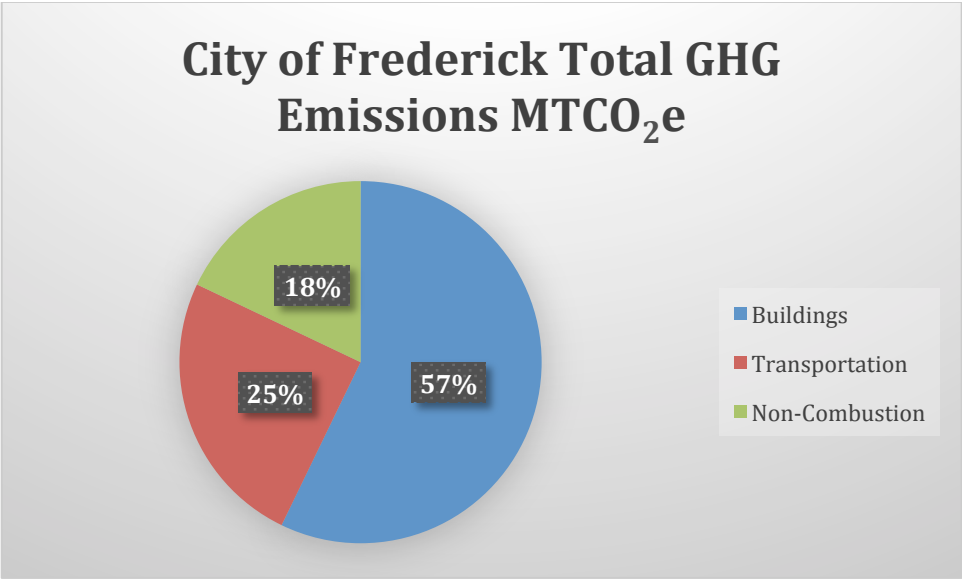


Figure 1: City of Frederick GHG Emissions by Sector

Non-Combustion Emissions Sources

Non-combustion sources of greenhouse gas emissions comprise the smallest component of the City's emissions, at 18% of the total. Figure 1 illustrates the distribution of greenhouse gas emissions based on a City-wide inventory. Because the City controls these sources, they are considered "scope 1" sources. The survey only counts those sources that the City is responsible for and is different from a community-wide survey that tracks emissions from all sources, including businesses and residents. The City's total non-combustion GHG emissions for 2013 were 3660 metric tonnes of Carbon Dioxide Equivalent ($MTCO_2e$). This equates to approximately 4.4 $MTCO_2e$ for each of the 830 City employees and approximately .05 $MTCO_2e$ for each of the 67,000 residents.

Figure 2 illustrates the percentages of emissions and sources that comprise the non-combustion contribution to overall GHG emissions and Figure 3 illustrates the totals within the categories of wastewater treatment, solid waste emissions and fertilizer application. Emissions have been normalized to reflect their carbon dioxide equivalent in metric tonnes, or $MTCO_2e$. Solid waste emissions, including those related to its transportation, are the largest non-combustion source of greenhouse gas emissions, producing 3,406 CO_2e in the year 2013, however, a breakdown of the individual gases is not available. Emissions associated with wastewater treatment amounted to 220 CO_2e in that year, and a small amount—34.32 CO_2e—was emitted as a result of fertilizer application. Within wastewater treatment GHG emissions, approximately 134 $MTCO_2e$ was nitrous oxide, with approximately 86 MT of methane. Fertilizer application emissions consisted solely of nitrous oxide. Due to the variety of factors associated with wastewater emissions, a large portion of the analysis addressed this sector.

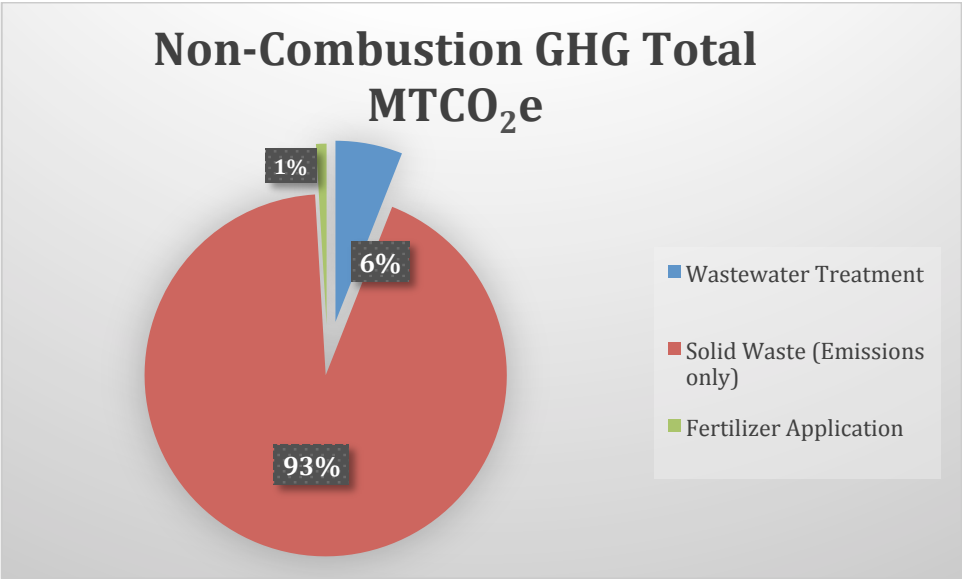


Figure 2: Non-Combustion GHG Percentages by Source

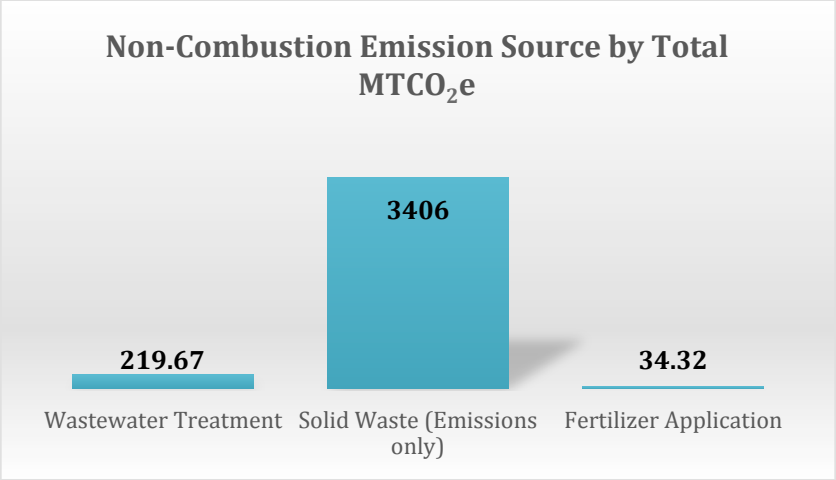


Figure 3: Non-Combustion Sources and Total Emissions

Wastewater

Measuring wastewater emissions presented some challenges. The data about methane emissions, plant processes, percentage of City residents served by the plant, and the roles of the County and City plants was contradictory. Also, the beta LGGIT model produced results inconsistent with City expectations and the model did not account for aeration basins. Finally, wastewater treatment plant emissions are difficult to account for using a generalized model. These uncertainties affected key components of the emissions profile. This profile is based on the most current data, with indications where differences exist.

Current and Future Capacity

The City wastewater treatment plant processes up to 8,000,000 gallons of wastewater per day, or about 120 gallons per City resident per day. However, the daily average throughput of wastewater is around 6,000,000 gallons per day, or about 90 gallons per resident per day. While the system is not a combined sewer overflow (CSO) system, weather events do affect throughput when stormwater infiltrates the sewer system via open manhole covers.

In 1990, the City entered into the Monocacy Interceptor Sewer Capital Funding Agreement with Frederick County. The City's growth is limited by its water and sewer capacity, but the plant has enough capacity to meet expected population growth until the year 2035, and the City's agreement with the County allows for future allocations up to 250 gallons per resident per day. Both the City and County plants were permitted increases for the resulting loadings into the local water body, the Monocacy River.

Loadings into local water bodies affect water quality and are permitted by State and federal law. Wastewater treatment plants are crucial components of water quality efforts under the Chesapeake Bay clean-up efforts, including the Chesapeake Bay Total Maximum Daily Load, which sets pollution limits on inputs to local waters and ultimately the Bay, including limits on nitrogen (N), which is major source of water quality impairment.

The City's 2010 Comprehensive Plan Background Data report indicates that the County's Ballenger/McKinney Wastewater Treatment Plant serves a portion of City properties. It also notes that the 1990 agreement "provides for up to 3.0 MGD of capacity for use by the City at

the Ballenger/McKinney WWTP (17)." In order to accommodate growth, the report notes that an additional 1,000,000 will still be needed in plant capacity. However, according to plant assistant superintendent Tara Fiery, the City "currently uses 0% of the 1.36 [million gallons] average daily flow or 3.4 [million gallons] maximum daily flow allowed in the City and County agreement, meaning that the County does not treat any City wastewater on a regular basis." She noted that the City's plant receives an average of 8,000,000 gallons of wastewater per day, of which approximately 2,000,000 gallons are Frederick County flow, which is redirected to the County treatment plant.

Emissions from Treatment Plant Operations

Original results from the LGGIT model showed that the majority of the plant's greenhouse gas emissions were in the form of methane gas, the climate-change effects of which are 20 times more potent than carbon dioxide over a 100-year time scale (EPA, Overview of Greenhouse Gases). The two most important drivers of wastewater treatment plant greenhouse gas emissions are biochemical oxygen demand, or BOD, and total throughput, which is the amount of water treated by the plant (CH2MHILL). BOD is an indicator of the amount of organic material in water (United Nations Department of Economic and Social Affairs). It measures the amount of oxygen needed for oxidation of the organic material within the water, and in the context of wastewater treatment plants, BOD represents the amount of "work" that must be done to treat the water.

The treatment process releases nitrous oxide due to nitrification and denitrifitication, which occur during the removal of nitrogen from the wastewater. Methane is released as a result of anaerobic decomposition of organic material, which occurs during the activated sludge portion of wastewater treatment (Daelman, Voorthuizen and Dongen). As the treatment process releases methane, this means that higher-BOD water input results in higher methane production. However, the plant attempts to mitigate this by maintaining a stable BOD level.

While BOD level exerts a large influence on methane production, the drivers of BOD are in the environment within the treatment plant and are not human-controlled. Therefore, while macro-trends such as climate change may affect BOD level, BOD is not correlated with population growth. Throughput, on the other hand, is strongly correlated with population growth; absent major water-conservation measures, an increase in population will result in a corresponding increase in wastewater production.

The initial results of the LGGIT calculator, which was set-up to receive values specific to the City of Frederick, estimated high levels of emissions from the liquid stage of treatment, but Fiery points out that the plant does not have lagoons—which the LGGIT calculator assumes are the major source of emissions—and that the aerated basins in the City's plant "do not produce methane; the environment is not suited for methane formers." She added that "methane can only be captured by the digesters."

The LGGIT calculator offers two options for estimating wastewater treatment plant emissions. The first uses City-specific data obtained from the Department of Public Works, and the second uses default numbers provided by the calculator that reflect the U.S. average and includes data assumptions. For the City of Frederick, the first method produced significantly higher emissions than the second and the results were very sensitive to the BOD annual loading estimate. This calculation assumed a throughput of 8,000,000 gallons per day, and included

emission of methane (CH_4) from anaerobic and facultative wastewater treatment lagoons, which resulted in emissions of 1,097 metric tonnes of CH_4/year or 23,044 $MTCO_2e$. In addition, incomplete combustion or flaring of the digester gas resulted in 3.88 metric tonnes of CH_4/year, or about 219 $MTCO_2e$. For scale, a result of 23,044 MTCO2e would account for more than half of the total MTCO2e emissions calculated as part of the City's 2013 GHG inventory.

According to the second method, the wastewater treatment plant produces 656 metric tonnes of CH_4/year or 13,784 $MTCO_2e$. This method focused exclusively on CH_4 from assumed anaerobic and facultative wastewater treatment lagoons and assumed significantly lower BOD, which would equate to lower amounts of methane produced. However, the fact that the plant does not have lagoons and only produces methane in the digesters from the biosolids negated both of these methods' validity for determining emissions.

While this report includes three different estimates, the results from the LGGIT calculator are not consistent with the expectations of City staff, which raised doubts about the LGGIT calculator and its methods. As a result, this report discounts the calculator's results for liquid-based emissions. Therefore, GHG emissions from the treatment plant are considered simply to be 3.88 $MTCH_4$ (81.53 $MTCO_2e$) from non-flared methane out of the biosolids digester and a somewhat larger amount of nitrous oxide from the denitrification process, or 134 $MTCO_2e$, along with 4.14 $MTCO_2e$ from a small number of septic systems within the City. The result is 219.67 $MTCO_2e$ in plant and septic emissions. The plant's methane emissions result from the incomplete combustion of the digester methane gas that is currently flared. Even once the cogeneration unit is operating, there will likely not be 100% combustion and thus methane emissions would remain. According to the *Discussion Paper for a Wastewater Treatment Plant Sector Greenhouse Gas Emissions Reporting Protocol*, "small amounts of direct CH4 emissions may also be released as a result of incomplete combustion of digester gas (2-3)." Based on this estimate, this report will assume a 99% destruction efficiency rate and estimate an incomplete combustion rate of 1%. Additional technical expertise is needed to review all final emissions from the wastewater treatment plant to accurately reflect the totals.

One way to understand the individual contribution to greenhouse gases is to consider the GHG or CO_2 equivalent per flush. The plant treats approximately about 6,000,000 gallons per day, and, according to the accounting used in this report produced approximately 220 $MTCO_2e$ in the year 2013. Assuming a standard flush of 1.6 gallons, each flush would therefore produce approximately 1.6×10^{-7} pounds of CO_2e through its treatment at the plant.

To develop a range of potential future greenhouse gas emission levels, four scenarios were tested: BOD-decrease and BOD-increase scenarios for both 10% and 25% population increases. These scenario estimates were made using the LGGIT tool and by inputting and adjusting factors. Table 1 shows the expected greenhouse gas emissions in CO_2e for each scenario. The scenario analysis shows methane emissions are highly sensitive to BOD levels, but that nitrous oxide is related to population and throughput. Also, if the population increases by a large enough proportion, a decrease in BOD is not enough to offset emissions.

Table 1: BOD and Growth Scenarios

		Scenario 1 Low Growth (10%) 20% increase in BOD	Scenario 2 20% decrease in BOD	Scenario 3 High Growth (25%) 20% increase in BOD	Scenario 4 20% decrease in BOD
Emissions:	**CH_4:**	102.6184887	68.69759416	102.6184887	68.69759416
	N_2O:	147.1043	147.1043	167.16595	167.16595
	Total:	249.7227887	215.8018942	269.7844387	235.8635442
	Change:	35.86%	-3.73%	59.28%	19.68%

Emissions from Treatment Plant Energy Consumption

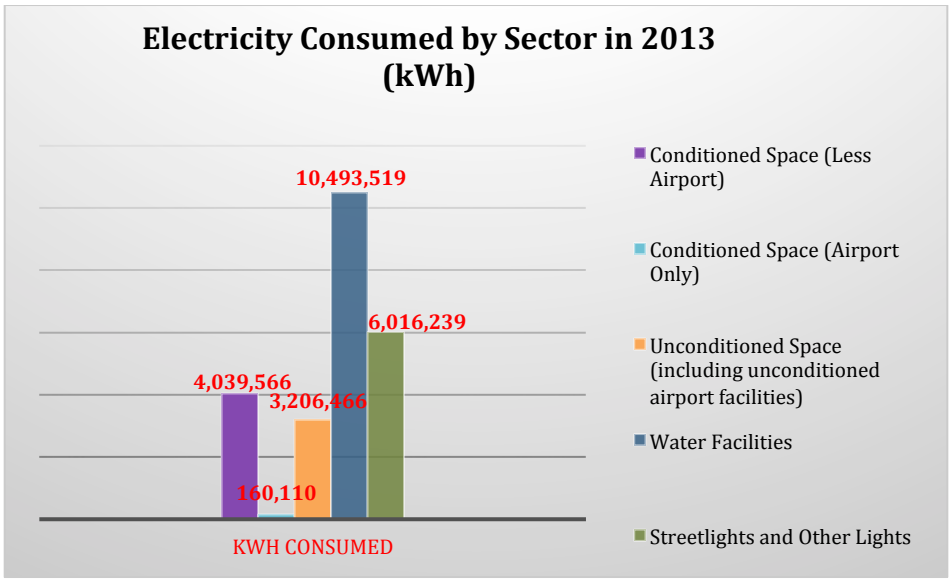


Figure 4: Electricity Consumed by Sector

As shown in Figure 4, water facilities are the City buildings with the largest electricity consumption. The wastewater treatment plant, which consumed 5,280,738 kWh in 2013, is the largest among them. This equates to 10,924 $MTCO_2e$. At a City population of 67,000, the per person energy consumption from the wastewater treatment plant is 31,383 kWh.

The treatment plant is due for several technology upgrades, some of which will affect energy usage. This includes replacing older equipment with appropriately-sized equipment, which will result in a reduction of energy consumed. However, given the uncertainty in assessing the potential energy effects of the plant's technological upgrades, as well as the variable nature of the power produced by the planned cogeneration system, it is difficult to determine the overall effect of these changes on the plant's total energy use.

In accordance with Chesapeake Bay Watershed-wide goals to reduce nitrogen (N) pollution entering the Bay, the plant is required to upgrade to Enhanced Nutrient Removal (ENR). The ENR technology upgrades are not expected to use more electricity. One of the equipment upgrades is the switch from chlorine to UV lights in the final disinfection stage to kill bacteria and pathogens. The UV lights are expected to increase electricity usage, as the EPA estimates that a typical UV disinfection system as used at a wastewater treatment plant costs approximately $25,448 per year in operations and maintenance (Wastewater Innovations). The assumption is that energy costs account for most of this.

At the time of this writing, the plant expects to start operating a cogeneration unit on November 24, 2014. Cogeneration is "the simultaneous production of electricity and heat from a single fuel source (United States Environmental Protection Agency)." In this case, the fuel source is biogas, or methane that is recovered from two anaerobic digesters into which biosolids, or the post-treatment remains of human solid waste, have been deposited. Within the digesters, the biosolids are heated to "[promote] the growth of bacteria that breaks down (digests) a large portion of the sludge which pathogenically helps stabilize the sludge while reducing the volume of sludge that needs to be disposed of (Wastewater Treatment Plant Congeneration System Project Description 1)."

Combusting the 3,837 to 4,796 ft3/hr of methane gas produced from the digestion process will provide 250 kW of electricity generating power (Wastewater Treatment Plant Congeneration System Project Description 1-2). This will power the generator, which will in turn run the heat exchangers for the digesters, reducing natural gas usage. However, because the level of methane produced will vary, the cogeneration system will not be reliable enough to power all components of the plant. Electricity will be sold back to the grid and shortfalls will be made up with purchases from the grid. All electricity generated from the cogeneration facility is eligible for renewable energy credits as part of the Renewable Energy Credit Program.

The cogeneration system is expected to save approximately 1,850,000 kWh per year, a 36.5% reduction in current levels. At the plant's current energy cost rate of $0.822 per kWh, this equates to savings of over $150,000 per year. That number rises to nearly $170,000 per year when accounting for reductions in monthly demand charges.

Solid Waste

Other non-combustion activities that contribute to the City's emissions total include landfill use, recycling and composting. These are considered "scope 3," or limited-City-control activities. This includes 19,318 short tons of solid waste and 460 short tons of yard waste generated by City activities that is later composted; it does not include residential or commercial waste. This is the largest sector of non-combustion emissions at 3,406 $MTCO_2e$ or 93% of the total. The majority of these emissions would be in the form of methane due to organic material decomposition of the portion of the City's waste at the County landfill**.** The solid waste emissions figure also includes the emissions from transporting the waste to the County landfill, where methane gas is recovered for energy.

The WARM model was used to estimate solid waste emissions. Despite the City's lack of control over the landfill and emissions occurring there, the more it can increase recycling rates, the less material will be diverted to the landfill. Going forward, data collection could include the

amount of trash and percentage being recycled, the portion that could be recycled and the costs of servicing trash versus recycling.

Compost is also transported and those emissions are factored into the waste transportation emissions. However, compost is also one of the "sinks" that absorb carbon. The more emphasis placed on recycling and composting throughout the City, by businesses, government, residents and institutional properties, the less waste is transported to the landfill and the greater the reduction in GHG from this sector.

Fertilizer

The City applies 24,400 pounds of fertilizer consisting of 8,174 pounds of nitrogen at the City-owned golf course. Nitrification and denitrification both occur due to bacteria in the soil reacting with the added nitrogen (Snyder, Bruulsema and Jensen). Both of these processes release nitrous oxide, which in the case of Frederick for the year 2013 equated to 34.32 $MTCO_2e$. To reduce the amounts of N running into the local watershed and in keeping with Chesapeake Bay-wide efforts to reduce N pollution, the City should consider fertilizing the course less frequently. Although this is a small amount of emissions, it could be viewed as a simple first step to manage "low hanging fruit."

Similarly, creating a percentage goal for City recycling and composting would be another relatively easy first step.

Carbon Sequestration

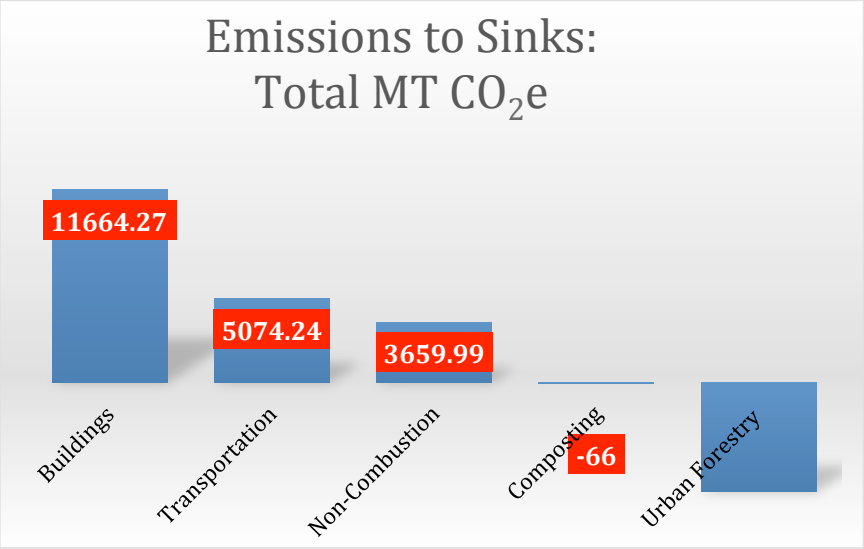
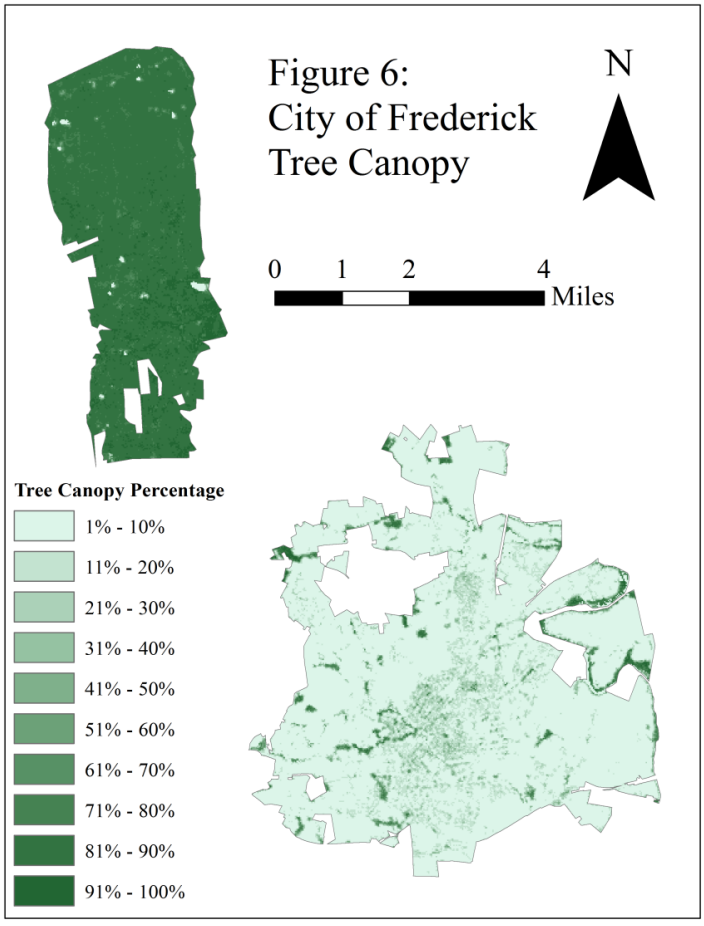


Figure 5: Non-Combustion Emissions and Sinks (Sources of Carbon Sequestration)



Urban Tree Canopy

Urban tree canopy sequesters carbon because the amount of CO_2 returned to the atmosphere as a result of organic respiration in trees and forest habitat is slightly less than the amount of CO_2 absorbed by trees in the photosynthesis process, and therefore carbon accumulates over time in trees (Lorenz and Lal). Urban tree canopy is the largest carbon sink in the City, with the LGGIT model estimating that the City's trees sequestered 5,969 $MTCO_2e$ in 2013. This estimate is based on the 1,804-acre canopy cover estimate contained in the City's 2009 study (A Report on the City of Frederick's Existing and Possible Urban Tree Canopy). There are several caveats associated with this estimate, but it illustrates that there are also

opportunities to greatly improve the City's tree canopy cover.

The City owns a large forested parcel to its northwest known as the Frederick Municipal Forest. Although it is not urban forest per se, it is a large area of trees that provides sequestration benefits in the immediate vicinity of the City. Because it is owned and maintained by the City for drinking water, for the purposes of a greenhouse gas inventory, the municipal forest should be considered a scope 1 sink. The City did not include the municipal forest in the 2009 urban tree canopy study because it is not contiguous with the City and has no direct air or water quality benefits within the City. When its 6,241 acres are added to the 1,804 acres identified in the Urban Tree Canopy Study, the amount of forest sequestration jumps to 26,719 CO_2e. Figure 6 shows the tree canopy—both urban and forested—within the City's municipal boundaries and within the Frederick Municipal Forest.

Looking toward the future, the study estimates that an additional 69% of the City's area (or 67%, if the areas of Fort Detrick and Frederick Municipal Airport are excluded) could theoretically be covered by urban tree canopy. However, the City has no control over Fort Detrick as a federal facility and the FAA and MAA dictate the airport landscape and discourage trees. While it is not feasible to plant trees on the entire 67%, if the City achieved the State urban tree canopy goal of 40% coverage, it would dramatically increase the amount of forest sequestration occurring, as shown in Table 2. Although, there is much uncertainty in estimating sequestration amounts and methods used.

Table 2: Urban Tree Canopy Scenarios (Sequestration in $MTCO_2e$)

Tree Canopy	2009 Urban Tree Canopy Study, scaled to 2013	including Frederick Municipal Forest	40% Urban Tree Canopy	all possible Urban Tree Canopy areas
Acres	1,804	8,045	12,114	18,280
Percent	12%*	55%	83%	125%
Sequestration	5,969	26,719	40,322	60,726

* The 2009 study stated the urban tree canopy was 14% (see explanation below)

The 2009 urban tree canopy study indicated 14% urban tree canopy cover based on 12,886 acres of total land within the City boundaries. The 12% figure above is adjusted for the addition of land (2,147 acres) between 2009 and 2013 as the result of annexation. To stay consistent with the temporal boundaries defined at the outset of this inventory exercise (e.g., a CY 2013 boundary), we apply the 12% figure, which accounts for the addition of land. Because the annexed properties were non-forested farmland, the assumption is that the overall acreage remained the same, but the percentage of urban tree canopy decreased.

In addition to carbon sequestration effects, there are a number of co-benefits associated with increasing tree canopy. These include water quality benefits such as slower runoff of stormwater and infiltration, air quality benefits such as the reduction of the urban heat island effect and uptake of particulates, and increased habitat and green infrastructure.

Other Sequestration Sources

Application of compost to farm fields stores carbon, although the mechanical turning and transport of compost from yard waste produces greenhouse gas emissions. This sequestration is modeled in the WARM model, which for the year 2013 estimates sequestration of 66 CO_2e for composting. This estimate accounts for storage of carbon and emissions of CO_2, but at present does not consider N_2O or CH_4 emissions that may result from the various stages of the composting process (EPA).

Conclusion

There is significant complexity in assessing accurate emissions from wastewater treatment plants, due to changing equipment, processes, number of users and differences in methodologies in counting emissions from the source. For example, future emissions are uncertain based on unknowns about population growth and the effect of a larger developed land use base on the wastewater treatment plant, the amount of future recycling and composting and the amounts of transportation emissions from servicing a greater area. Increased population growth will lead to increased throughput of wastewater and possible increased emissions. While the wastewater treatment plant is the greatest user of energy, it is unclear how much the technology upgrades will reduce electricity usage, and despite the savings from the cogeneration facility, certain processes will still require purchased electricity.

We also know that the City expects to grow to approximately 98,000 people by 2030, per the Planning Department, and that the City's growth is limited by the ability to obtain sewer and water (Adkins).

The City's urban tree canopy is low and will remain so, if farmland continues to be annexed without a concerted effort to ramp up canopy cover. With increasing population and expanded developed land base, all emissions sources could continue to increase and larger sinks such as increased urban tree canopy will not be able to keep up with the increase of emissions. Smaller sinks, e.g. composting and efforts to divert recycling from waste streams, while important, will not be enough to significantly impact any increases in emissions. For example, the 2013 net remaining emissions were 13,749.68 $MTCO_2e$. However, these emissions are based solely on City operations and do not include community emissions from residential, commercial and other operations. If those sources were included, emissions would significantly increase from the small scope of activities examined here.

The differences in data illustrate the difficulty in calculating emissions, particularly from wastewater treatment plants, where varied data and methods can yield very different results. This proves the axiom that results are only as good as the data. The differences between the Department of Public Works and Planning Department supplied data and the information supplied by the wastewater treatment plant suggest that the various City departments and the sustainability coordinator will need to collaborate closely moving forward. Also, additional technical assistance will be needed to review the wastewater treatment plant contributions as the City attempts to make meaningful progress in reducing its GHG emissions.

References

A Report on the City of Frederick's Existing and Possible Urban Tree Canopy. Frederick, MD: University of Vermont Spatial Analysis Laboratory and USDA Forest Service's Northern Research Station, 2009.

Adkins, Joe. “Email communication, Department of Planning 11/12/14.” n.d.

CH2MHILL. *Discussion Paper for a Wastewater Treatment Plant Sector Greenhouse Gas Emissions Reporting Protocol*. Report prepared for the California Wastewater Climate Change Group and Bay Area Clean Water Agencies. Oakland, CA, 2007.

City of Frederick. «Background Data.» April 2010. *2010 Comprehensive Plan.* <https://www.cityoffrederick.com/DocumentCenter/Home/View/1526>.

—. “Wastewater Treatment Plant Congeneration System Project Description.” n.d.

Daelman, M.R.J., et al. "Methane and nitrous oxide emissions from municipal wastewater treatment – results from a long-term study." *Water Science and Technology* 67.10 (2013): 2350-2355.

EPA. “Composting.” 2010 йил 28-October. *United States Environmental Protection Agency.* <http://www.epa.gov/climatechange/wycd/waste/downloads/composting-chapter10-28-10.pdf>.

—. *http://epa.gov/climatechange/ghgemissions/gases/ch4.html*. n.d.

—. *Overview of Greenhouse Gases*. n.d. http://epa.gov/climatechange/ghgemissions/gases/ch4.html. 2014 йил 11-11.

Fiery. “Email communication with Tara Fiery.” 11/20/14 and 11/21/14.

Lorenz, Klaus and Rattan Lal. *Carbon Sequestration in Forest Ecosystems*. Dordrecht: Springer, 2010.

Snyder, C.S., et al. "Review of greenhouse gas emissions from crop production systems and fertilizer management effects." *Agriculture, Ecosystems & Environment* 133.3-4 (2009): 247-266.

United Nations Department of Economic and Social Affairs. 2007 йил October. *Indicators of Sustainable Development: Guidelines and Methodologies.* <http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets.pdf>.

United States Environmental Protection Agency. *Combined Heat and Power Partnership*. 10 April 2013. 24 November 2014. <http://www.epa.gov/chp/basic/>.

Wastewater Innovations. “Technology: Ultraviolet (UV) Disinfection.” 2014 йил January. <http://www.wastewaterinfo.asia/sites/default/files/tech-sheets/uv-disinfection.pdf>.

Chapter 3, Part 2: Tree Planting on Residential Properties

December 12, 2014

University of Maryland
School of Architecture, Planning and Preservation
URSP688R The Carbon and Energy Economy for Planners
Fall 2014

Christine Dunham and Albert Engel

Sponsored by PALS—Partnership for Action Learning in Sustainability
A National Center for Smart Growth initiative
Gerrit Knapp, Executive Director
Uri Avin, PALS Director

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Project Description and Characteristics

A tree planting coupon program should be a signature component of the City's Sustainability Program to engage and involve the community in these efforts. The program will help the City increase its tree canopy from 14%, as reported in the City's 2009 Urban Tree Canopy Study.

Urban tree canopy (UTC) sequesters carbon because the amount of CO_2 returned to the atmosphere as a result of organic respiration in trees and forest habitat is slightly less than the amount of CO_2 absorbed by trees in the photosynthesis process, and therefore carbon accumulates over time in trees (Lorenz and Lal). UTC is the largest carbon sink in the City, with the LGGIT model estimating that the City's trees sequestered 6,583 MT CO_2e in 2013. This estimate is based on the 1,804-acre canopy cover estimate contained in the 2009 study. There are several caveats associated with this estimate, but it also illustrates opportunities.

The 2009 study estimates that an additional 69% of the City's area (or 67%, if the areas of Fort Detrick and the Frederick Municipal Airport are excluded) could theoretically be covered by urban tree canopy. While it is not feasible to plant trees on that entire area, if the City were to reach the statewide and its UTC goal of 40% coverage, it would dramatically increase the amount of forest sequestration occurring. In the Environmental Element of the City's 2010 Comprehensive Plan, Policy 1 states that the City should "preserve and increase the tree canopy within the developed areas of the City (p. 104)." Yet the specific goal of the stated implementation strategy is to "reduce the amount of impervious cover and tree loss in development projects (p. 171)." This goal may stem losses in tree canopy but, as it doesn't call for any programs to increase canopy, it is inconsistent with the policy it was designed to address. Therefore, the conclusion of this workgroup is that the City of Frederick should implement a new program to increase urban tree canopy in existing developed areas. While additional programs will be needed for other land types, this program will focus exclusively on residential land. Residents control the largest percentage of the city's canopy and moderate density residential land is the largest land use available for planting.

The proposed tree planting coupon program will build off the State of Maryland's tree coupon program, "Marylanders Plant Trees." The State program is funded by a settlement for violations of the Clean Air Act, and offers Marylanders $25 off the price of an eligible native tree costing at least $50. This workgroup recommends enacting a similar coupon program that would offer a further $25 off the price of a $50 tree. Trees would be purchased at the nurseries within Fredrick that participate in the State program and the additional incentive created by the prospect of free or reduced price trees would lead more residents to take advantage of the coupon and direct funds to local businesses.

Project Benefits

Beyond serving as a vehicle for implementing the City's UTC goal and increasing the carbon sinks, the program involves numerous co-benefits. Among these are infiltration and reduction of stormwater volume, absorption of airborne chemicals and particulate matter and a reduction of the urban heat island effect. If the City can increase and maintain its green infrastructure, traditional stormwater infrastructure costs can be reduced.

Increased tree canopy is also a best management practice that can be used to meet the goals of the local Watershed Implementation Plan. If just one percent of the current population planted a single tree (e.g., a two-inch caliper oak), the resulting 670 trees would yield $34,840 of quantifiable environmental, energy and property benefits. If scaled up to 18,000 trees, this would result in almost $1 million in environmental benefits in the first year, which would significantly increase as the trees mature. The greatest value to homeowners would be increased property values, $44 for each two-inch caliper oak, and reduced energy costs that would equate to between 15-35% for cooling and 10-20% for heating.

Project Costs: Financing and Implementation

The project costs fall into two categories: staff time and the coupon costs for the trees. Up to one-half of the Sustainability Manager's time will be needed to launch the pilot program. Once the program moves beyond the pilot stage, a half-time (or full-time) coordinator should be added, with salary costs to be determined at a later date. The pilot project's goal for the first year would be to plant the number of trees that equal half of one percent of the City's population. At a population of about 67,000, 335 trees would meet the first year goal, and the coupon costs would be $8,375. After that, the project's goal would be one percent of residents planting per year, or $16,750 in tree expenses.

As the City's population grows to an eventual 98,000 residents, the program should seek to increase its planting rate to 1,000 trees per year or $25,000. Over 20 years, the total City investment for residential trees would be $450,000 (calculations included in worksheet). Connecting the goal to population growth creates a clear link between a growing city, the number of residents and a method to reduce GHG emissions. A small amount of advertising at $500-$1,000 would be also be necessary, with a goal of reaching new partners for additional no-cost promotions.

Community and Employee Engagement: Marketing

To build neighborhood capacity, reduce the staff burden and involve the community, the program will include a volunteer component. Modeled after Tree Baltimore's "Tree Keepers" and other programs, volunteers will provide assistance and guidance to homeowners. A small initial effort could be scaled to include neighborhood teams and team trainings and would build on prior outreach efforts by the Sustainability Manager. The program would be marketed through community organizations, schools and local media, as well as through local property tax bills and program partners.

Another key partnership could be with Potomac Edison Power, which could assist with funding and promotions, while benefiting from reduced power demand due to increased canopy. A friendly local competition promoted within the neighborhoods and through public announcement of the goal would aid program visibility. The coupon would include instructions and graphics for planting and residents would be encouraged to map their tree through the State's online program.

Case Studies

While a number of tree-planting programs exist, especially for street trees and public property, this program would specifically target private residential property and would invest in larger trees to ensure a higher rate of survival. The State of Maryland's program is a model and a partnership would leverage efforts for a 50% cost match. This program has planted approximately 116,000 trees across the State. Another example of a private property coupon program was Baltimore County's Growing Home program, which offered $10 tree coupons. It expanded to Harford County and Baltimore City and in six years planted approximately 7,000 trees.

Sensitivity Analysis and Potential Barriers

This project is most sensitive to the amount of staff time and funding levels, which will determine its level of success. Due to the Sustainability Manager's many other duties, it is recommended that the City create a separate position to manage and continue to grow this program. The program is highly sensitive to yearly funding levels. To reach its goals, the program will need to be an annual item in the City's budget. If funds and staff time are not budgeted yearly, City efforts to address increased emissions from a growing population will fail. The pilot will take at least a year to develop, allowing time to complete a tree inventory.

APPENDIX A:
REVIEW OF LOCAL GOVERNMENT RESIDENTIAL TREE INCENTIVE PROGRAMS

Portland, OR (https://www.portlandoregon.gov/bes/article/314187)
The City of Portland offers the "Treebate" program, which offers $15, $25, or $50 rebates on water/sewer bills (depending on tree size and stormwater benefits) to homeowners who plant eligible trees on their property between 9/1/2014 and 4/30/2015. To be eligible, trees must be "planted in Portland residential yards," "at least 1 inch in diameter 6 inches above the soil line that are at least 6 feet tall if broadleaf and 4 feet tall if coniferous (has needles) at time of planting," and "planted with enough space to reach full canopy spread." Trees whose mature height will be less than 15 feet, which were purchased, planted and submitted from May to August, which received other kinds of City subsidies, or were "planted to satisfy a condition of development or mitigation," or are considered nuisance trees are automatically ineligible.https://www.portlandoregon.gov/bes/article/314187

Erie, CO (https://www.erieco.gov/185/Tree-Incentive-Programs)
The City of Erie offers two tree incentive programs that apply to residential areas: the "HOA Cost Share Program" and the "Residential Cost Share Program." The "HOA Cost Share Program" offers homeowner's associations a 50% cost share for the planting of trees in "Town or HOA owned and HOA-maintained parks, open space, and arterial right-of ways." Each year, $12,000 is made available through that program. The "Residential Cost Share Program" offers up to $150 for a tree planted on private residential property. The City has a comprehensive table of tree types (https://www.erieco.gov/DocumentCenter/View/3469), grading them on an A-D scale, designating which species are most recommended for planting under the program. In addition, the City designates specific nurseries for the program.

Anaheim, CA (http://www.anaheim.net/article.asp?id=4150)
In partnership with the local public utility, the City of Anaheim offers the "TreePower Program," which has three different options. The first option arranges a visit from a TreePower representative, who:
i. recommends different types of trees that will maximize shading and require minimal pruning
ii. helps site the best location for resident's/')tree(s)
iii. provides residents with planting and maintenance tips
iv. asks residents to sign a planting agreement
v. discusses delivery arrangements

The program will then deliver up to six trees to single-family residences (or more to multi-family residences depending on "property size and needs") for free. The second option offers $20 rebates for up to three trees (which may be in addition to six free trees received under the first option) that homeowners purchases on their own. The City recommends eight types of trees for planting, and requires that trees receiving rebates under this program must be at least five gallons when purchased with a mature height of less than 25 feet, and must be planted at least eight feet from the east, south, or west sides of the house. The homeowner must then submit a receipt and a rebate coupon, and a TreePower representative will inspect the plantings for program compliance to approve the rebate.

Valley Center, KS
(http://www.valleycenterks.org/DocumentCenter/Home/View/84)http://www.valleycenterks.org/DocumentCenter/Home/View/84
The City of Valley Center offers the "Tree Incentive Program," which offers 50% reimbursement for up to two approved trees per household planted per year (and a maximum of six trees in five years) according to program guidelines, which are contained in the "Trees for Valley Center"pamphlet (http://www.valleycenterks.org/DocumentCenter/Home/View/89). There are spring (2/1 to 4/30) and fall (9/1 to 11/30) program windows, with program funds split equally between the two windows. Reimbursements are granted after an inspection from the Valley Center Tree Board or Park Superintendent.

Oconomowoc, WI (http://www.oconomowoc-wi.gov/DocumentCenter/View/1659)
Oconomowoc offers an incentive program through its public utility, Oconomowoc Utilities. The utility will credit account holders up to 50% or $50 of the purchase price of up to three trees, with the following conditions: it must be deciduous, nursery stock, expected to achieve a mature height of at least 25 feet, planted in a location that will "[provide] significant shading of an air conditioning unit or the south or west exposure of a home upon tree maturity," and "away from underground and overhead utility lines."

Middletown, RI (http://www.middletownri.com/government/46/451/Tree-Planting-Incentive-Program-and-Tree-Planting)
The Town of Middletown Tree Commission gives $50 credits to Town residents who purchase trees at one of three nurseries in Middletown and plant them within the Town, with the nurseries themselves deducting the credit from the purchase price of the tree.

Washington, DC (http://ddoe.dc.gov/service/riversmart-homes-shade-tree-planting)
The District Department of the Environment subsidizes the planting of trees on residential property through the RiverSmart Homes program, reducing the price to $50 per tree. The program does not limit the number of trees planted per property, but the City has a list of four medium-sized deciduous trees, eight large-sized deciduous trees, and three evergreen trees that are eligible for the program. After a homeowner submits a request, DDOE sends an auditor to conduct a home consultation. The program requires that the trees have a mature height of at least 25 feet. Separately, DDOE funds the Casey Trees rebate program (http://caseytrees.org/programs/planting/rebate/), which has a much larger list of eligible trees, and which offers up to $100 per large tree and up to $50 per small or medium size tree (having a mature height of at least 15 feet) as a post-purchase rebate.

Calgary, AB, Canada (http://www.calgary.ca/CSPS/Parks/Pages/Programs/Tree-planting/Planting-Incentive-Program.aspx)
Calgary's "Planting Incentive Program" subsidizes 50% of the cost of trees planted on city-owned property in residential areas. Homeowners, organizations, and neighborhood associations can pledge $190 per tree for the planting of trees in public areas and the City will make up the difference and plant the tree. Trees are officially City property after their planting.

Pasadena, CA (http://cityofpasadena.net/waterandpower/CoolTrees/)
Residential customers of Pasadena Water and Power are eligible for rebates on the purchase of eligible "cool trees," from a list provided by the utility

(http://ww2.cityofpasadena.net/waterandpower/cooltrees/Cool%20Trees%20Catalog.pdf). PWP offers rebates of up to $40 if the trees are purchased from a vendor outside of the City of Pasadena or $50 if the trees are purchased from a vendor within the City. The utility also offers a $10 bonus for customers that participate in the "Greening Pasadena Rewards Program," which is a more comprehensive residential sustainability program, and includes a 120-day commitment to purchasing green power through PWP.

Lancaster, PA (http://cityoflancasterpa.com/tree-planting)
The City of Lancaster offers residents the option to purchase trees through the City. While the City's "Street Tree Planting Program" doesn't subsidize the cost of the trees, it connects residents with the City arborist and arranges for the arborist to provide free advice and recommendations, site preparations such as stump or sidewalk removal, and delivery and planting of the tree.

Baltimore County, MD
The Growing Home program offered a $10 coupon toward the purchase of a minimum $25 native tree at participating nurseries for residential plantings. A signature program of the then Department of Environmental Protection and Resource Management, it later expanded to Harford County and Baltimore City. In six years, it planted approximately 7,000 trees in the region. BGE was a partner in the program. The program was later subsumed by other forestry efforts and the state's program.
http://www.avenuenews.com/news/article_bf6d9a1f-2dab-5e2c-9311-7ac79edf73b6.html?mode=jqm
http://www.bayjournal.com/article/dollars_and_sense_growing_home_banking_on_increasing_tree_canopy
http://www.harfordcountymd.gov/dpw/engineering/download/2125-1204.pdf
http://weblogs.baltimoresun.com/features/gardening/2011/04/discount_coupons_for_tree_plan.html
http://www.greenfieldsnursery.com/Growing-Home-Campaign.html

State of Maryland
The Marylanders Plant Tree Program is a $25 coupon program for residential plantings of trees valued at $50 or more. It has planted approximately 116,000 native trees across the state. Due to its close connection with Governor O'Malley, the future of the program is unknown.
http://trees.maryland.gov/

Tree Baltimore
This is the umbrella organization for City agencies and multiple partner organizations working to increase the City's tree canopy.
http://www.treebaltimore.org/

Numerous jurisdictions in Maryland have tree and/or Green Infrastructure programs, or even "Rain Check Rebate" programs (Prince George's County). Montgomery County's Planning Department also runs a $25 tree coupon program.

Volunteer Models:
Prominent models would include the following, although there are numerous examples.
- Tree Baltimore "Tree Keepers"
- Tree People (LA)

- Other programs and non-profits: TreeMendous MD, Co. Forestry Boards, Chesapeake Bay Foundation, Chesapeake Bay Alliance, Potomac Conservancy, etc.

APPENDIX B: COST CALCULATION

Tree goals per year:

Year 1:	335 trees
Year 2-5:	670 trees
Years 6-20:	1,000 trees
Total:	18,015 trees

Cost to City: $25/tree

Total Cost Year 1:	$8375.00
Total Cost Year 2:	$16,750.00
Total Cost for all 20 years:	$450,375

The City should also simultaneously create separate programs for street trees and increasing canopy on institutional/governmental and commercial properties, which were also noted as important opportunities in the 2009 report. These efforts could be wrapped in together as a four-pronged approach to reach the 40% UTC goal.

APPENDIX C: EXPLANATION OF BENEFITS OF TREE PLANTING

Increasing tree canopy is a key component in reducing the City's GHG emissions. There are also a number of co-benefits, including air and water quality benefits. For example, in terms of stormwater benefits and the broader implications of green infrastructure, the EPA considers the implementation of certain green infrastructure as a strategy to meet MS4 permit requirements. Green Infrastructure is a best management practice that can help to meet local watershed implementation plans. http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/WIPPhaseIICountyDocuments.aspx

Outside the realm of regulatory requirements, one of the largest benefits of planting trees is their positive effect on property values, and trees can also lower energy bills during both the summer and the winter. During the summer, trees planted to the east or west of a house can reduce energy use by 15% to 35% by providing shade. During the winter, trees planted to serve as a windbreak can reduce heating bills by 10% to 20% (Marylanders Plant Trees).

The Maryland Tree Benefit Calculator (http://trees.maryland.gov/calculate-your-benefits/) is a tool that shows the monetary benefits of tree planting. For example, planting one oak (as suggested by the Maryland Forest Service's "Tree-Mendous Maryland" Program) with a two-inch diameter would result in $52 in quantifiable benefits in its first year. During that time, the tree would intercept 159 gallons of stormwater runoff, raise property values by $44 and reduce CO_2 by 40 pounds. If 18,000 of those trees were planted, there would be almost one million dollars in environmental benefits within their first year. 720,600 pounds of carbon would be removed from the atmosphere, which according to the EPA's Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/cleanenergy/energy-resources/calculator.html) would equate to removing 252 cars from the road.These benefits would significantly increase as the trees mature.

According to the Baltimore Tree Trust (http://baltimoretreetrust.org/), every dollar spent on trees yields five to six dollars in benefits. Tree People also lists 22 benefits of trees, including those mentioned above and in the proposal. http://www.treepeople.org/top-22-benefits-trees

APPENDIX D: DEFINITIONS

Carbon Sequestration
"Any process (natural or artificial) by which carbon dioxide is removed from the atmosphere and held in solid or liquid form, e.g. in forests, oceans, or geological strata."
(Oxford English Dictionary)

Carbon Sink
"A sink for carbon; *spec.* a part of the biosphere (such as a forest or ocean) that causes carbon dioxide to be removed from the atmosphere."
(Oxford English Dictionary)

Green Infrastructure
The use of "vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water."
(US EPA: http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm)

MS4
A municipal separate storm sewer; a conveyance or system of conveyances that is "owned by a state, city, town, village, or other public entity that discharges to waters of the U.S, designed or used to collect or convey stormwater (including storm drains, pipes, ditches, etc.), not a combined sewer; and not part of a Publicly Owned Treatment Works (sewage treatment plant)."
(US EPA: http://water.epa.gov/polwaste/npdes/stormwater/Municipal-Separate-Storm-Sewer-System-MS4-Main-Page.cfm)

MS4 Permit
A document issued under the National Pollutant Discharge Elimination System (NPDES) to an operator of an MS4, requiring that it "develop, implement, and enforce a stormwater management program designed to reduce the discharge of pollutants from their MS4 to the 'maximum extent practicable,' to protect water quality, and to satisfy the appropriate water quality requirements of the CWA."
(US EPA: http://water.epa.gov/polwaste/npdes/stormwater/upload/fact1-0.pdf)

Organic Respiration
The exchange of oxygen and carbon dioxide between an organism or cell and the environment; the process by which this occurs; (also) the process by which oxygen is distributed to the tissues of an organism.
(OED)

Photosynthesis
The process (or series of processes) by which the energy of light absorbed by chlorophyll is utilized by plants for the synthesis of complex organic compounds from carbon dioxide, with the accompanying oxidation of water to form oxygen.
(OED)

Urban Tree Canopy
The layer of leaves, branches, and stems of trees that cover the ground when viewed from above.
(MD Forest Service: http://www.dnr.state.md.us/forests/programs/urban/urbantreecanopygoals.asp)