Lehigh Valley Green Transportation Infrastructure Project

Technical Appendix

Lehigh Valley Planning Commission

pennsylvania DEPARTMENT OF TRANSPORTATION

Technical Appendix and Optional GHG Emission Reduction Calculations Spreadsheet

This attachment provides additional details describing the methods proposed for reducing GHG emissions from Lehigh Valley's major transportation corridors prioritizing urban greening practices within available rights-of-way, retrofitting and enhancing existing stormwater control measures, adding efficient lighting fixtures and improving multi-modal connections. This project aligns with Goal 5 of the Lehigh Valley Priority Climate Action Plan for Transportation Decarbonization (February 2024).

Methodology and Assumptions

Site Selection: Major transportation corridor rights-of-way within the Lehigh Valley were reviewed for potential opportunities to retrofit with enhanced landscaping features to directly reduce GHG emissions. Initial review began with identification of major state and interstate corridors including State Routes 22, 33 and 378 and Interstates 78 and 476 and 309. Roadway corridors and interchanges were reviewed for potential greening opportunities along with stormwater control measures and existing parking lots. The four main drivers for site selection criteria included the following considerations:

- **Land Availability and Use** – The availability of suitable publicly-owned and controlled land within right of way without conflicting land uses.
- **Carbon Sequestration Potential** – Sites that can maximize the absorption of CO_2 including areas that are able to support forests, grasslands or similar ecosystems
- **Environmental Justice** – Sites in proximity to sensitive user groups such as Justice 40 communities, Schools, hospitals and playgrounds.
- **Safety Improvement** -- Sites near high crash corridors where improvements can minimize hazard and maximize carbon absorption.

Potential Co-Benefits– Sites were evaluated for potential co-benefits of proposed improvements including:

- **Biodiversity Consideration** – Sites that offer the opportunity to protect, restore, or enhance biodiversity.
- **Access and Infrastructure** – Accessibility considerations and availability of infrastructure to support project implementation and monitoring.
- **Health Improvements** – Sites adjacent to sensitive populations where improvements can reduce heat island effects, improve air quality to assist populations with high levels of respiratory illnesses.

These considerations were discussed among project partners to determine appropriate areas for potential improvements. In total, 19 “enhancement sites” are proposed for retrofitting. Sites include 17 interchanges, including nine within State Route 22, six within State Route 33, plus 2 linear areas along State Route 33 and State Route 378 for pollinator corridor establishment. Within these sites are nine existing stormwater basins that will be redesigned to enhance their water quality features, increase resiliency to more frequent and intense storms and manage stormwater volume and velocity. The project team identified nearly 30 million square feet, or 683 acres, of right-of-way areas for potential enhancement opportunities within public right-of-way. A detailed site analysis was conducted which considered PennDOT highway clearances and limitations, resulting in proposed enhancements of nearly 76% of existing right-of-way or 20.6 million square feet (522 acres). The team evaluated current conditions of these areas, documenting land areas and determining suitability for a suite of enhancement measures such as lawn to meadow conversions, tree canopy additions, bioretention and bioswale additions, stormwater basin retrofits and addition of energy efficient lighting. Opportunity areas included land within interchanges, corridor lands and parking lots. Each site was analyzed for its existing GHG emission profile to determine existing conditions. They were then evaluated for net reduction of GHG emissions with completion of proposed improvements.

GHG Reduction Estimate Methods and Outcomes

Direct GHG Reduction Measures

In the Lehigh Valley, direct GHG capturing strategies can be implemented to transform land use and vegetation. These include converting turf grass to diverse vegetation that captures more GHGs, introducing low-maintenance lawn alternatives to enhance biodiversity and reduce emissions, and modernizing stormwater management with native plants to improve resilience against climate change impacts. Together, these measures aim to create a sustainable landscape that supports local ecosystems while adhering to safety standards.

- **Land Conversion --** Vegetative cover within the implementation corridors primarily consists of turf grass species maintained as lawn, some shrublands, unmown lawn or meadows, vacant land (compacted soil, gravel) as well as existing stormwater detention basins with concrete low flow channels. A primary GHG impact strategy is the conversion of lawn areas, primarily rye and bluegrass. Such areas require scheduled mowing for view corridors and have limited impact to heat island effect as well as pollinator benefits. Replacement cover-types will include a suite of higher GHG-capturing planting typologies more indicative of the Lehigh Valley including hardwood forest, meadow, dry meadow, and no/low-mow grasses. The suite of vegetative cover typologies has distinct characteristics that will be utilized in accordance with PennDOT safety/design standards.
- **Lawn Alternatives --** The proposal recognizes the need for low vegetation within view corridors at turns add a 30-foot offset from the roadway. Within these zones, lawn-alternative plant species will replace mown lawn. No/low-mow plantings will have higher biodiversity and may consist of grasses, low shrubs, and perennials that eliminates the use of regular mowing which produces GHG and disturbs beneficial pollinators. Select plant species will differ based on micro-climactic conditions.
- **Stormwater Basins/Management Areas --** The role of stormwater management within transit corridors is essential for safety and emergency access. Direct GHG benefits are sourced from additions of native vegetation and water management. Increased water uptake in vegetation aids in reducing subsurface karst degradation, which is a major growing maintenance burden. Indirect GHG benefits from modernizing stormwater management areas include improving regional emergency vehicle access during severe weather. Failing and overflowing basins are not keeping up with larger storm events fueled by climate change. Updated resiliency infrastructure, including native long-rooted vegetation and removing low flow concrete channels will slow and filter pollutants while accommodating more extreme rainfall events, thus maintaining emergency access to address damage and health needs in the region.

Indirect Reduction Measures

Indirect Reduction Measures are defined as GHG reduction/capture strategies that currently do not have known associated methodologies to supply quantifications. These strategies target secondary impacts including excess net GHG production as a result of pollinator decline, the heat island effect, road safety and emergency access, and impacts of roadside pollution to communities. While some items are also listed as co-benefits, it is important to acknowledge a correlation to additional GHG reductions through environmental improvements. These specific relationships are further described below:

- **Pollination Improvements --** While pollinator loss correlates to increased GHGs, lack of pollinators can further produce GHGs and lower current rates of GHG sequestration. A historically agricultural region, the Lehigh Valley's farming industry depends on pollinators. Decreased numbers of pollinators can lead to reduced agricultural yields. Similarly, reduced pollination of native vegetation can cause plant populations to decline, leading to the reduction of GHG capture from established areas. Natural habitats serve as carbon storage areas, thus maintaining regionally healthy pollination levels is a critical indirect GHG capture strategy.
- **Heat Island Reduction --** Mitigating local heat islands is an indirect GHG reduction strategy and a unique impact opportunity for roadway infrastructure in the Lehigh Valley and across the United States. In the United States, the majority of roadways (approximately 59%) are paved, mostly surfaced in asphalt which have low albedo that does not reflect light well and holds heat. Within the Lehigh Valley, many low-income and disadvantaged communities (LIDAC) are concentrated in more developed areas with a high proportion of grayscape, such as in cities and boroughs. Center City Allentown and Southside Bethlehem are at the 90th percentile nationwide for share of land area covered by impervious surface. Routes 22 and 378 bisect these communities. LIDAC neighborhoods in urban areas are susceptible to extreme heat and urban island effects as temperatures rise, and heat islands are made worse by vehicle exhaust in areas with high proximity to traffic. Converting impervious areas to natural areas combined with reducing traffic in these areas can significantly improve temperature conditions for the region's LIDAC communities.

<u>Existing Conditions</u>

Existing land cover within highway corridor opportunity areas were identified for landscape enhancements, supplemental native plantings, lawn to meadow conversions, increased tree canopy and improved stormwater management. Carbon dioxide (CO2) emissions and/or sequestration were calculated for each land cover type (Lawn, naturalized grassland and meadows, shrubs, tree canopy and stormwater) to establish baseline conditions to compare with proposed interventions at each site. Existing areas of available right-of-way were derived via Geographic Information Systems (GIS) analysis of existing land cover and converted to both square feet and acres. Carbon sequestration is expressed in pounds or metric tons of CO_2e. Existing Conditions included the following land cover types:

- **Lawn** - An area of turf grass adjacent to a road that is regularly cut and maintained to keep a neat and uniform appearance, which typically consists of Bermuda and ryegrass. Lawn along roadways often have an unhealthy proportion of invasive to native species, providing little habitat value. These degraded landscapes can often be net emitters of CO_2.

- **Naturalized Grasslands** – Grassy areas with instances of meadow planting at establishment. Some plants along the right-of-way include switchgrass, goldenrods, & little bluestem.
- **Shrub** – Areas alongside roads that are dominated by shrubs, small trees and herbaceous plants.
- **Parking Lots** – Designated paved area for parking vehicles.
- **Tree Canopy** – Area that is covered by the upper layer or habitat zone formed by the crowns of mature trees in forest or wooded area.
- **Stormwater Feature** – Infrastructure designed to convey and manage stormwater runoff from roadways and specific adjacent areas.
- **Vacant Lots** - Areas that are not intentionally planted or maintained, with a layer of loose material consisting of gravel, crushed stone, slag, or uncovered soil.

Measurement Tools/ Resources Used to Calculate GHG Emissions or Sequestered

Each land cover type was assigned either a CO_2 emissions value or CO_2 sequestration value based on data and conversion factors provided by several models including **Greenhouse Gases Equivalencies Calculator - Calculations and References | US EPA**, Carbon Conscience tool and values obtained via literature reviews. Conversion factors used to calculate carbon emissions or carbon sequestration values are indicated below along with specific sources and citations of studies consulted. The selection of Carbon Conscience tool was made due to its significant research on many different landscape typologies, allowing more precise estimates based on local conditions. A full version of this table is included in the GHG calculations worksheet.

Land Cover Conversion Factors and Sources		
Land Cover Type	**Net lbs. CO2 Sequestered /acre/year**	**Source**
Deciduous Broadleaf Woodland (Temperate Continental Forest)	13227	Carbon Conscience Resource: Plug Planting+50mm Mulch+1 cm Whip/Bareroot Tree Planting (1 Tree/5 SM) + Restored Temperate Mixed Tree, Shrub and Forb Landscape ("Garden") UN FAO. (2001). STATE OF THE WORLD'S FORESTS 2001. https://www.fao.org/3/Y0900E/y0900e04.htm
Meadow	8222	Carbon Conscience Resource: Hydroseed Planting (Wild Collected Seed Mix) + Plug planting (24/SM) + 150mm Compost Restored Prairie Grassland Kumar, B. M., & Nair, P. K. R. (Eds.). (2011). Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges (Vol. 8). Springer Netherlands. https://doi.org/10.1007/978-94-007-1630-8
Low-mow Lawn	3108	Carbon Conscience Resource: Hydroseed Planting (turf)+ 150mm Compost+ 100mm Sand Amendment+ Restored Turf Lawn Selhorst, A., & Lal, R. (2013). Net carbon sequestration potential and emissions in home lawn turfgrasses of the United States. Environmental Management, 51(1), 198–208. https://doi.org/10.1007/s00267-012-9967-6
Lawn	-1543 (emitted, not sequestered)	Carbon Conscience Resource: Sod Planting+ 150mm Compost+ 100mm Sand Amendment+ 100mm deep drain rock + Restored Turf Lawn Selhorst, A., & Lal, R. (2013). Net carbon sequestration potential and emissions in home lawn turfgrasses of the United States. Environmental Management, 51(1), 198–208. https://doi.org/10.1007/s00267-012-9967-6
Bioretention	10117	Kavehei, E., Jenkins, G.A., Adame, M.F., & Lemckert, C.J. (2018). Carbon sequestration potential for mitigating the carbon footprint of green stormwater infrastructure. Renewable and Sustainable Energy Reviews. https://doi.org/10.1016/j.rser.2018.07.002 Kavehei, E., Jenkins, G.A., Lemckert, C.J., & Adame, M.F. (2019). Carbon stocks and sequestration of stormwater bioretention/biofiltration basins. Ecological Engineering. https://doi.org/10.1016/j.ecoleng.2019.07.006
Rain Garden	8399	
Bio-swale	3174	
Stormwater Pond	2611	

Additional reference links:

1. Carbon Conscience White Paper
   https://issuu.com/sasakiassociates/docs/cc_white_paper_2023_-_hardy
2. Plug Planting
   Kendall, A., & McPherson, E. G. (2012). A life cycle greenhouse gas inventory of a tree production system. The International Journal of Life Cycle Assessment, 17(4), 444–452. https://doi.org/10.1007/s11367-011-0339-x
3. Hydroseed Planting
   Smetana, S. M., & Crittenden, J. C. (2014). Sustainable plants in urban parks: A life cycle analysis of traditional and alternative lawns in Georgia, USA. Landscape and Urban Planning, 122, 140–151. https://doi.org/10.1016/j.landurbplan.2013.11.011
4. Compost
   Saer, A., Lansing, S., Davitt, N. H., & Graves, R. E. (2013). Life cycle assessment of a food waste composting system: Environmental impact hotspots. Journal of Cleaner Production, 52, 234–244. https://doi.org/10.1016/j.jclepro.2013.03.022
5. Sand Amendment
   Antti, R. (2013). Carbon footprint for building products. ECO2 data for materials and products with the focus on wooden building products. UTGIVARE, VTT Technical Research Center of Finland.

A full excel worksheet with embedded formulas is included with this appendix. Images below are drawn from the full table.

		Existing Conditions								
Site No.	Location	Lawn	Naturalized Grassland+ Meadow	Shrub	Parking lot	Tree Canopy	Stormwater	Vecant lot	CO2 emitted	CO2 sequestered
1	SR22-SR309	1,098,072	65,880	43,074	-	441,218	-	-	38,969	155,007
2	SR22-CEDAR CREST	255,248	27,629	-	-	49,078	3,001	-	9,058	20,336
3	SR22-15TH ST	314,651	271,751	9,100	-	107,953	126,483	24,037	25,244	93,585
4	SR22WB-GOLDEN CORRAL	521,835	78,189	121,581	-	31,016	41,962	13,341	26,333	50,228
5	SR22-SR987&SR378	3,381,488	236,279	284,342	-	634,871	-	-	120,006	292,751
6	SR22-SR512	209,869	90,279	30,640	-	124,010	25,305	3,671	9,598	62,237
7	SR22-SR191	164,589	-	-	-	381,254	-	22,760	19,170	115,985
8	SR22-SR33	4,108,908	75,536	42,262	-	1,187,464	-	76,966	190,896	383,700
9	SR22-WOOD AVE	104,894	7,546	30,057		161,046	-	6,424	7,485	56,227
10	SR33-WILLIAM PENN HWY	626,023	98961	374489	43787	229178	-	-	88,145	160,778
11	SR378-8TH AVE	390,406	30,961	-	-	595,873	22,376	-	13,855	188,476
12	SR33-HECKTOWN RD	1,340,072	40,745	68,755	-	364,709	-		47,558	131,939
13	SR33-SR248	984,932	-	-	-	387,227	-	-	34,954	117,803
14	SR33-SR191	887,795	-	33,228	-	670,586	-	-	31,507	210,425
15	SR33-HENRY RD	448,536	21,981	-	-	404,897	-	22,824	29,285	127,335
16	SR33-SR512	345,474	113,033	12,223	-	65,557	19,999	5,793	15,653	44,881
17	William Penn Park and Ride Lot	137,938			450322		-	-	682,922	-
18	SR33 Pollinator Corridor	4,991,770	-	-	-	-	-	-	177,153	-
19	SR378 Pollinator Corridor	429,240	-	-	-	-	-	-	15,233	-
Total(sqft) (lbs)		20,741,740	1,158,770	1,049,751	494,109	5,835,937	239,126	175,816	1,583,025	2,211,693
Total(acre)(m t/year)		477	27	24	11	134	5	4	712	995

Analysis of the net carbon emissions within the existing right-of-way available areas using factors noted in the previous table indicate that 602,699 lbs. of CO_2 (273 metric tons) are being sequestered by the existing landscaping including trees and various landscape features. (2211793 – 1583025)/2000 x .90407185 = 273 $MTCO_2e$). This figure excludes emissions generated by the existing highway infrastructure (roadway surfaces, bridges, ramps) and mobile sources using the highway.

Impact on GHG emissions resulting from proposed green infrastructure enhancements

Definitions

Bioretention – are shallow depressions filled with a layered soil mix that supports growth of native vegetation and is designed to temporarily hold stormwater runoff, allowing it to slowly infiltrate into the ground or be taken up by vegetation.

Bioswale - are primarily linear features that use vegetation or mulch to slow and filter stormwater runoff. They are similar in design to a rain garden (smaller version of a bioretention practice), with the main difference being that they infiltrate and convey stormwater runoff rather than solely infiltrating.

Low Mow Lawn – are areas planted with native grasses which are adapted to local climate and soil conditions. Species require minimal mowing and irrigation compared to traditional turf lawn.

Proposed areas for enhancement were derived based on GIS analysis and netting out areas within PennDOT ROW restrictions enhancements including viewshed maintenance and offset requirements. This reduced available land from the initial right-of-way of 709 acres to about 522 acres.

The table below summarizes the proposed improvements at the 19 sites and estimated GHG reductions. This is drawn from GHG calculations worksheet included as an attachment to this Appendix.

Site Locations	Proposed Landscape Improvements								
Site No.	Proposed Low-mow Lawn*	Meadow (Pollinator)*	Tree Canopy*	Bioretention#	Bioswale#	Parking Lot (Improved)#	Conversion Area	CO2 emitted (lbCO2e/year)	CO2 sequestered (lbCO2e/year)	CO2 Improvement (lbCO2e/Year)
1	785,424	81,539	781,281	-	-	-	1,141,146	-	309,247	193,209
2	152,813	5,255	140,659	30,552	5,677	-	258,249	-	62,232	50,955
3	368,311	1,799	339,186	140,580	4,099	-	474,271	-	162,867	94,526
4	309,934	96,853	359,655	13,292	28,190	-	698,719	-	155,036	131,140
5	2,251,327	202,306	2,012,492	-	70,855	-	3,665,830	-	816,606	643,860
6	207,891	13,340	171,843	90,700	-	-	269,485	-	90,767	38,128
7	186,351	6,357	319,769	56,126	-	-	187,349	-	124,864	28,049
8	1,684,207	612,330	3,121,854	72,745	-	-	4,228,136	-	1,202,850	1,010,046
9	134,733	-	175,234	-	-	-	141,375	-	62,941	14,199
10	475,712	166,331	402,518	315,227	-		1,031,649	-	261,265	188,632
11	345,381	148,327	545,908	-	-	-	412,782	-	218,815	44,195
12	625,273	320,564	868,444	-	-	-	1,408,827	-	369,516	285,135
13	476,086	296,526	599,547	-	-	-	984,932	-	272,502	189,654
14	561,065	360,625	669,919	-	-	-	921,023	-	312,107	133,189
15	245,377	203,787	449,074	-	-	-	471,360	-	192,696	94,646
16	268,735	22,735	246,356	24,253	-	-	383,489	-	104,100	74,872
17			150,588	-	-	437,672	588,260	658,980	45,812	69,754
18	-	4,991,770	-	-	-	-	4,991,770	-	943,974	1,121,127
19	-	429,240	-	-	-	-	429,240	-	81,172	96,405
Total(sqft) (lbs)	9,078,620	7,959,684	11,354,327	743,475	108,821	437,672	22,687,892	658,980	5,789,369	4,501,720
Total(acre)(m t/year)	209	183	261	17	3	10	522	297	2,625	2,042

Additional GHG Measures

Impacts from higher efficiency lighting

PennDOT will replace its existing ballast light fixtures with 578 new high efficiency luminaires. PennDOT reports that its current fixtures include Conventional Light Poles along mainline segments (400-Watt lamp + 85-Watt for high pressure sodium ballast = 485 Watts) and those along ramps (250-watt lamp + 50-Watt for high pressure sodium ballast = 300 watts). Assuming even split between these two types of fixtures, monthly kWh figures were generated for both types and then entered into EPA's power profile calculator tool to generate pounds of CO2 emitted per year (466,654). Re calculated based on reported energy efficiency factor of 70%, which resulted in reduction to 139,999 pounds of C02 emitted per year, a difference of 326,655 pounds of CO2 or 148 metric tons of CO2 annually.

Mainline and Ramp Lighting Upgrades to Energy Efficient Luminaries.

485 Watts x 8 hours per day = 3,880 watt-hours per day

(3,880 watt-hours per day x 365 days per year) / 1000 = 1,416 kWh per year/12 = 118 kWh per month

118 kWh per month x 289 luminaries = 34,102 kWh per month

300 Watts x 8 hours per day = 2400 watt-hours per day

(2400 watt-hours per day x 365 days per year)/1000 =876 kWh per year/12 = 73 kWh per month

73 kWh per month x 289 luminaries = 21,097 kWh per month

34102 + 21,097 =55,199 kWh per month (662,388 per year)

Using EPA's Power Profiler | US EPA calculated CO_2 emissions based on the monthly kWh figure:

*Using the eGRID subregion **RFCE** (**RFC East**) emission rates and **4.5%** line loss, your estimated annual use of **662,388 kWh** of electricity results in **466,654** pounds **CO_2**, **233.7** pounds **SO_2**, and **205.3** pounds **NO_x** emitted in one year from the power plants in your area.*

Assuming 70% efficiency improvement with new lights:

*Using the eGRID subregion **RFCE** (**RFC East**) emission rates and **4.5%** line loss, your estimated annual use of **198,720 kWh** of electricity results in **139,999** pounds **CO_2**, **70.1** pounds **SO_2**, and **61.6** pounds **NO_x** emitted in one year from the power plants in your area.*

Difference in CO2 = 466,654 – 139,999 = 326,655 pounds of CO2/2000= 163.3 tons * .907185 **= 148** metric tons of CO2 reduced annually.

Magnitude of GHG Reductions from 2025 through 2030

The estimated sum of landscape GHG reductions is shown below, assuming a phase-in rate of 50% starting in year3 (2027). The estimated lighting GHG reductions assume full implementation in 2025

Measure/Year	2025	2026	2027	2028	2029	2030	Sum
Landscape $MTCO_2e$ reduction			1021	2042	2042	2042	**7147**
Energy Efficient Lighting ($MTCO_2e$)	148	148	148	148	148	148	**888**
Summary of all Measures	658	1169	1679	2190	2190	2190	**8035 $MTCO_2$ e**

Magnitude of GHG Reductions from 2025 through 2050 – Please see attached calculations worksheet for cumulative analysis.

Measure/year	2025 - 2050
Landscape emissions reductions	47,987 $MTCO_2e$
Lighting emissions reductions	3,848 $MTCO_2e$
Summary all measures emissions reductions	**51,835 $MTCO_2e$**

Measure Implementation Assumption

It is assumed that implementation of the measures will be phased in during the grant period, focusing on areas that are more easily accessible for preparation, planting and/or retrofitting. Starting with sites along Route 22 has been the priority to pilot the ideas and provide testing ground for species survival and establishment. It is assumed that some improvements will require more advanced design and permitting such as the stormwater basins, which are part of PennDOT's regulatory regime. Replacement of highway lighting is expected to commence within the first year of grant implementation. The project team recognizes that part of the implementation phase of converting lawns to native meadows and woodlands is establishment. Native habitats need several years to grow and out-compete non-native and invasive weeds. These costs are included in the project's budget to ensure that these habitats survive and flourish. Once established, maintenance needs are less intensive, with just annual mowing and selective treatment for weeds. The team envisions specific workforce development opportunities/educational opportunities to care for these sites both during establishment and post establishment years.

GHG Reduction Estimate Assumptions

GHG reduction estimates, similar to implementation, are assumed to be realized in stages, concurrent with completion of the enhancement site improvements. Therefore, initial reductions will be smaller in the first three to four years of the grant period as sites are planted and built towards full establishment. We expect modest improvements with the replacement of lighting and reduced mowing will be realized by before the end of the grant period and increase in future years.