Attachment G

Summary of 2025 Updates to the Montgomery County Climate Assessment Quantification Tool

23 May 2025, prepared by ICF staff Hazelle Tomlin, Blake Walkowiak and Bella Scornaienchi

The purpose of this document is to summarize all updates and key decisions made during the 2025 updates to the 2022 Montgomery County Climate Assessment Quantification Tool.

1. Background

On July 25, 2022, the Montgomery County Council signed Bill 3-22, "Climate Assessments" into law. The bill requires assessments of climate impacts for County bills, zoning text amendments and master plans and master plan amendments (collectively referred to as master plans). As a result of the bill, the Montgomery County Planning Department (Montgomery Planning) is responsible for conducting climate assessments for Zoning Text Amendments (ZTAs) and master plans, and the Office of Legislative Oversight will be responsible for conducting climate assessments for County bills. Montgomery Planning hired ICF to conduct research and recommend an approach to conducting climate assessments. In January 2023, ICF delivered the Montgomery County Climate Assessment Quantification Tool. In February 2025, a new task order was established with ICF to update the Montgomery County Climate Assessment Quantification Tool. The intention is to periodically update the tool to ensure that methods and underlying activity data that feed emission factors reflect the latest practices and trends.

2. Key Results of 2025 Update

1. ICF made several changes to the Montgomery County Climate Assessment Quantification Tool in the 2025 update, including a full data refresh wherever new data were available, changes to parameters and assumptions based on new reports or literature, and changes to the representation of carbon stock changes between the Baseline and Master Plan results in visualizations and summary tables to clarify enhanced carbon stocks.
2. The overall impact on total emissions estimates using a realistic test case was a 19.4% reduction in ***estimated*** emissions.

3. The decreasing energy use intensity for residential buildings had the greatest overall impact on the change in emissions estimates between the 2022 (unedited) and 2025 (updated) tools.

3. Summary of Updates

To demonstrate the difference the 2025 updates have made on GHG estimates, ICF developed a representative "test case" and input test case values into both the 2022 tool and the 2025 (updated) tool. Table 1 shows the test case inputs and Table 2 shows the Master Plan lifetime GHG results of the test case using the 2022 and 2025 tool. Table 2 shows the Master Plan percentage difference between the 2022 tool lifetime GHG estimate and the 2025 tool lifetime GHG estimate.

Building lifetime energy emissions was affected most significantly by the 2025 tool updates, showing a reduction of -24.5% in ***estimated*** emissions. The change in building lifetime energy emissions is driven by a marked decrease in building energy use intensity (EUI) values for 2023 which represent the average building consumption of electricity and natural gas per unit of building square footage in units of thousand British Thermal Units per square foot (kBTU/sq.ft.).

Building waste, and, lifetime transportation emissions showed a minor increase and decrease in ***estimated*** emissions, of 3.6% and -0.9% respectively. Building waste emissions are driven by an increase in the total population of Montgomery County updated value for 2023 from the 2016 population, and updated waste emission factors. Lifetime transportation emissions decreased, despite adjusted electric vehicle (EV) penetration rate to a decreased value. This is due to lower observed population change and thus projected annual population, compared to previous higher modeled population projections leading to lower estimated drivers on the road.

Lifetime building embodied emissions and lifetime carbon stocks show a minor increase of 2.8% and 1.7% in ***estimated*** emissions, respectively, due to emission factors based on newer and more accurate sources.

Table 1: Test case tool inputs to demonstrate impacts of updates on GHG estimates. NOTE: GFA = gross floor area.

Building Type / Other Input	**Test Case**	**Unit**
Single-family detached	100	No. units
Single-family attached	300	No. units
Apartments in buildings with 2-4 units	1000	No. units
Apartments in buildings with 5 or more units	3000	No. units
Mobile Home	-	No. units
Warehouse and storage	1000	GFA
Office	1000	GFA
Service	10	GFA

Mercantile Retail (other than mall)	10	GFA
Mercantile Enclosed and strip malls	100	GFA
Public assembly	100	GFA
Religious worship	1	GFA
Education - College or university	100	GFA
Education - K-12 School	10	GFA
Food services	1	GFA
Lodging	1	GFA
Food sales	10	GFA
Health care inpatient	10	GFA
Health Care Outpatient	1	GFA
Public order and safety	10	GFA
Other	1000	GFA
Vacant	-	GFA
Pavement	100	Thousand GFA
VMT Calculation Method	Specified VMT	N/A
Total Annual Projected VMT for Projection Year	200,000,000	VMT
VMT Projection Year	2045	Year
Projected Population in VMT Projection Year	20	Thousand
Value set equal for all land use types and for area added and area removed	100	hectares
Baseline (all other inputs for MP) value set equal for all land use types and for acreage of land cover type	100	hectares

Table 2: Difference in GHG emissions using "test case" tool inputs.

Lifetime Emissions Source	2022 Tool (MT CO2e)	2025 Tool (MT CO2e)	Difference (%)
Total Lifetime Embodied Building GHG Emissions	272,176	279,824	2.8%
Lifetime Residential Emissions per residential unit	26	28	7.0%
Lifetime Commercial Emissions per commercial square foot	0	0	0.0%
Lifetime Total Pavement Embodied Emissions	3,144	2,826	-10.1%
Total Lifetime Building Energy GHG Emissions	2,083,551	1,572,138	-24.5%
Lifetime Residential Emissions per residential unit	272	165	-39.4%
Lifetime Commercial Emissions per commercial square foot	0.263	0.251	-4.5%
Total Lifetime Building Waste GHG Emissions	394,260	408,366	3.6%
Annual Total Building Waste Emissions	4,231	4,617	9.1%
Lifetime Residential Emissions per residential unit	90	93	3.6%
Lifetime Commercial Emissions per commercial square foot	0	0	6.4%
Total Lifetime Transportation GHG Emissions	775,347	768,342	-0.9%
Land Cover & Management Ecosystem Carbon Stock (CO2 Sequestration)	234,359	238,257	1.7%
Total GHG Emissions	3,759,694	3,028,669	-19.4%

3.1. Data Refresh

Wherever possible, ICF updated tool data where newer data were available. The data refresh included:

- Update of kg $CO2e/ft^2$ for office buildings, commercial buildings and residential homes from EC3 and GREET 2022 Building Module data.
- Update of **average building square footage** for residential building use types from the 2020 Residential Energy Consumption Survey (2022 tool used the 2015 Survey). Commercial buildings average building square footage were not updated as the 2018 CBECS remains current.
- Update of **average building energy consumption** for:
  - Residential buildings using the 2020 Residential Energy Consumption Survey data.
  - Commercial buildings using underlying data for the Building Energy Performance Standards Technical Report, supplied to ICF by Emily Curley (DEP).
- Update to the **average building life span** for single family homes based on data from the Census New Housing Construction report for 2020 and RECS Existing Housing Stock data for 2020. The average building life span for multi-family units was considered for an update but the new data would change the estimated lifespan from 71 years to 38 years, potentially due to incomplete data, and so ICF recommended, and MC Planning agreed to maintain an average lifespan of 71 years for multi-family units.
- Updated Montgomery county **population data**[1] and updated **total waste generated, recycling and compostables data** based on the Maryland Department of the Environment Resource Management Program Annual Report 2022 data.[2]
- Updated **waste emission factor values** for landfilled mixed municipal solid waste (MSW) and composted mixed organic waste.[3]
- Updated **people per unit** for estimating transportation emissions using 2023 MWCOG Cooperative Forecasts data on populations and households.[4]

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[1] ACS Demographic and Housing Estimates (Table DP05). US Census Bureau. 2023. https://data.census.gov/table?q=Population+Montgomery+County+in+2023.

[2] Maryland Department of the Environment Resource Management Program Annual Report (CY 2022 Data). Resource Management Program of the Maryland Department of the Environment. 2023. https://mde.maryland.gov/programs/land/RMP/Documents/Maryland%20Solid%20Waste%20Management%20and%20Diversion%20Report.pdf.

[3] EPA Emission Factors for GHG Inventories, Table 9. April 2021. https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

[4] Cooperative Forecasts: Employment, Population, and Household Forecasts by Transportation Analysis Zone. Montgomery Planning's Research and Special Project's Division. November 2023. Personal communication with James Lee, Montgomery County Planning Department on 04/07/2025.

- **Annual VMT values and on road vehicle stocks** were not updated in the 2025 update due to personal communication with David Anspacher (Montgomery County Planning Department) noting that the most current available values were already implemented in the 2022 tool.
- **EV energy economy** was updated using AFLEET data[5] on the kWh / mile for passenger cars and passenger trucks.
- **Forest above-, below- and soil organic carbon stock values** in tonnes carbon/hectare using USDA 2022 data.[6] The most current default values from IPCC are used for grassland, green roofs, non-forest tree cover, and wetlands/meadows. Default carbon values for turfgrass were explored for updates as detailed in the following section.

3.2. Literature reviews

Land Cover and Management Literature Reviews

A limited literature review was conducted to assess whether the **green roof carbon stock** values used in the 2022 tool should be updated. A key finding of ICF research was that the 2009 study[7] used was most appropriate, as other research was not as regionally relevant. Additionally, a limited literature review was conducted to assess whether the **turf grass or non-forest tree carbon stock values** should be updated. Key findings of this assessment were i) that the 2022 tool values are in the middle of the range of relevant literature and ICF do not recommend any updates at this time and ii) more recent values of non-forest tree cover carbon stocks are still appropriate (the 2022 tool used 2022 values). Key literature for turf is included below. Table 3 shows 2022 tool turf carbon stock values, recommended for use in 2025 updated tool, and Table 4 shows the range of carbon stock values for turf soil organic carbon that were found from the review, justifying continued use of the 2022 tool value.

Table 3: Summary of 2022 tool carbon stock values, recommended for use in 2025 updated tool.

Land Cover Type	Carbon Pool	C Stock (T C/hectare)	Source	Source Year
Turf	Above-ground biomass	0.82	https://www.sciencedirect.com/science/article/pii/S030147978570062X	1995
Turf	Below-ground biomass	1.39	https://www.sciencedirect.com/science/article/pii/S030147978570062X	1995
Turf	Soil organic carbon	71.10	https://www.fs.usda.gov/research/treesearch/19590	2009

[5] AFLEET Tool. Argonne National Laboratory. 2024. https://greet.es.anl.gov/afleet.
[6] Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2022. USDA USFS. 2024. https://www.fs.usda.gov/rds/archive/catalog/RDS-2024-0065.
[7] Carbon Sequestration Potential of Extensive Green Roofs. Getter, Kristin L., et al. 2009. https://pubs.acs.org/doi/pdf/10.1021/es901539x.

Aboveground Biomass Carbon Stocks

- **0.5–2.1 Mg C ha^{-1}** in residential lawns (Phoenix, AZ, and other arid regions) https://pmc.ncbi.nlm.nih.gov/articles/PMC9571228/
- **16.5 Mg C ha^{-1} yr^{-1}** in Maryland lawns and **10.2 Mg C ha^{-1} yr^{-1}** in California lawns, though these higher values may reflect intensive management or measurement methodologies https://www.uvm.edu/~pbierman/classes/critwrite/2009/Holland_Carbon_turf_draft.pdf
- Newly established turfgrass can store **1.8–3.4 Mg C ha^{-1}** within three years of establishment https://pmc.ncbi.nlm.nih.gov/articles/PMC9571228/
    - **0.5–2.1 Mg C ha^{-1}** for mature turfgrass systems

Belowground Biomass Carbon Stocks

- **1.0–2.2 Mg C ha^{-1}** in root biomass three years after turfgrass establishment https://pmc.ncbi.nlm.nih.gov/articles/PMC9571228/

Soil Organic Carbon Stocks

Table 4: Summary of more recent soil organic carbon stock values from literature review.

SOC Stock (Mg C/ha)	Region / Notes	Year	Link
64.75	Average SOC in residential turfgrass systems globally	2022	Link
127	Residential turfgrass soils in Denver, CO (arid climate with intensive management)	2022	Link
45.8	various cities in the USA, ranging from 20.8 to 96.3 Mg C ha−1	2012	Link
12.6–48.9	Total SOC stocks in established turfgrass systems	2022	Link

Building Embodied Emissions Literature Review

The 2022 tool relied on dated lifecycle emission factor for **pavement embodied emissions** estimates from concrete and asphalt pavement based on Hanson et al. (2012)[8]. Updated emission factors were estimated based on data sourced from the latest peer-reviewed literature from Hoxha et al. (2021)[9] and U.S. Department of Energy

[8] Hanson, C. S., Noland, R. B., & Cavale, K. R. (2012). Life-Cycle Greenhouse Gas Emissions of Materials Used in Road Construction. Transportation Research Record, 2287(1), 174–181. https://doi.org/10.3141/2287-21
[9] Hoxha, Endrit, et al. "Life cycle assessment of roads: Exploring research trends and harmonization challenges." Science of the total environment 759 (2021): 143506.

(DOE) reporting[10]. The data from these sources was used to derive emissions estimates for laying one 30-year lane mile of pavement of 821.6 MT CO_2e for concrete (15% cement, 5% water) and 195.8 MT CO_2e for hot mix asphalt (5% binder). These updated emission factors represent a decrease of -8.1 percent and an increase of 1.1 percent for these factors, respectively.

3.3. Building Embodied Emissions

Updates described in the data refresh and literature reviews section above.

3.4. Building Energy Emissions

Building Use Types

Building use types serve as important building groupings to which energy use intensity data should be aggregated. The energy use intensity (EUI) determines emissions per square foot of each building type and has three key components; i) electricity EUI and ii) gas EUI, which sum to the iii) site EUI. Data on electricity and gas components of the EUI were sourced from an Excel workbook provided by Emily Curley, Building Energy Performance Programs Manager for Montgomery County Department of Environmental Protection, on April 7th, 2025 , and available for 65 unique building uses, and aggregated to 18 grouped building use types. In the 2025 update, ICF explored whether the building use groups could be simplified to facilitate the resources required to develop and enter input data when using the tool. Given the current (2022 tool) building use groups already resulted in a spread of site EUI in any given group, ICF determined that if building uses were further aggregated, the carbon dioxide per square foot (CO_2e/SF) would further trend towards a mean and impair emissions estimated for building uses at either the higher or lower end of the site EUI range. The options presented to MC Planning are included below and after internal discussion, MC Planning agreed with ICF's recommendation that the building use type groups should not be changed, and no change was implemented.

- **<u>OPTION 1:</u>** Keep level of aggregation of building use types the same, per Steven Winter Associates (SWA) classification
- **<u>OPTION 2:</u>** Aggregate building use types based on groups per range of site energy use intensity (EUI) which is based on electricity and gas EUI, and directly determines the emissions per square foot of building in the tool
    - JUSTIFICATION: This would result in the most accurate weighted emission factor per square foot of building

[10] Iyer, Rakesh, et al. "Greenhouse Gas Emissions for Annual Construction and Maintenance of US Roadways." (2024). https://www.energy.gov/sites/default/files/2024-08/DOE_Program_Record_for_Road_Infrastructure_GHG_Emissions_08.14.2024.pdf

    - CONSIDERATIONS: Would result in additional time demands from GIS team for generating input data on total square footage and will be different to the historical grouping in the tool and used in previous climate analyses.
- **<u>OPTION 3:</u>** Aggregate building use types further to simplify needs from GIS team.
    - CONSIDERATIONS: Will result in CO2e/SF trending towards a mean and will not accurately estimate emissions for higher and lower EUI building types.

Average Building Life Span

Average building life span is a key assumption for estimating lifetime GHG emissions. The national average building life span was estimated in the 2022 tool by dividing all new privately owned housing units (completed and under construction) by the existing housing stock. In addition to the update to the average building life span for single family homes detailed in the first section of this report, the average building life span for multi-family units was considered for an update in 2025. Updating the underlying data for multi-family units would change the estimated lifespan from 71 years to 38 years, due to incomplete updated data on existing housing stocks, and so ICF recommended, and MC Planning agreed to maintain an average lifespan of 71 years for multi-family units as previously estimated in the 2022 tool. The average lifespan for all residential units was estimated using 2025 updated data for single family homes and 2022 tool data for multi-family units, resulting in an average lifetime of 88 years.

Electricity Fuel Mix and Emission Factor Assumptions

The electricity fuel mix and emission factor assumptions were not update as the 2022 tool used the most current data source.[11]

3.5. Building Waste Emissions

Updates described in the data refresh section above.

3.6. Transportation Emissions

EV Penetration

Montgomery County Department of Environmental Protection (DEP) data on electric vehicle ("EV") penetration shows an EV penetration of 4.54% in 2024[12]. The 2022 tool

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[11] 2030 GGRA Plan Modeling Data. Maryland DEP. 2023 https://mde.maryland.gov/programs/air/ClimateChange/Pages/Greenhouse-Gas-Emissions-Reduction-Act-(GGRA)-Plan.aspx.

[12] Year-End EV Report for Montgomery County. personal communication with *Montgomery County Maryland on 12/13/2024 02:24 PM EST.* Year-End EV Report for Montgomery County.

value had EV penetration at 1% starting in 2018 with an annual increase of 1%, estimating an EV penetration of 6% in 2024. ICF updated the starting EV penetration rate to reflect historical EV adoption rates as reported by DEP, which resulted in adjustment of annual increment from 1% to 0.59%.

The 2022 tool predicted 2060 will be the year that 42% of the on-road vehicles will be EVs. If the new updates are implemented (0.59% EV penetration rate) the EV penetration in 2060 would be 28%.

There are no Montgomery County updates to the BEPS EE and ZNC targets per the latest BEPS report and personal communication with Emily Curley (DEP).

3.7. Land Cover and Management Carbon Stocks

Land Carbon Stocks and Visualization

ICF updated the MP Calcs and EF's and Dashboard tabs to ensure that the difference between baseline carbon stocks and MP carbon stocks is clearly communicated. ICF added notes, and used the terms gross and net where relevant, updated the existing bar graph and generated a new figure for the Dashboard.

- Existing bar graph updates: Additional carbon stocks (Baseline Carbon Stocks – Master Plan Carbon Stocks) are now shown as a below zero value. All emissions are shown as above zero values but a new net emissions bar was included to illustrate how much of the emissions would be offset by the additional carbon stocks.
- New graph: A waterfall graph was developed to show each individual source of emissions and the comparative net and gross emissions.

A new table was included on the master plan calculations tab, to show the difference in lifetime carbon stocks in the master plan, relative to the baseline. Carbon flux estimates are not currently included in the tool.

3.8. Methodological Updates

No methodological updates were made in the 2025 tool update, methods were considered current and the data refresh updated information that feeds into emission factors. Possible future updates to the tool's methods are included in the subsequent section.

4. Recommended future improvements

Include Annual Carbon Flux from Land Use Methods and Factors

ICF reviewed the July 2020 report[13] Examining the Role of Forests and Trees in Montgomery County's Greenhouse Gas Inventory to assess whether any values could be implemented in the 2025 updates. The report covers carbon flux values, but the tool currently only has capacity to estimate the lifetime difference in carbon stocks based purely on the area of land allocated to each land use type. ICF recommend that inclusion of a method for estimating annual and lifetime cumulative carbon flux and stocks is included in a future tool update. The method should be aligned with IPCC guidance and the U.S. national inventory methods. This could include the flux values developed in the 2020 report, Examining the Role of Forests and Trees in Montgomery County's Greenhouse Gas Inventory. Estimating land use emissions is complex, and ICF estimate development of this method would take approximately 50 hours, but a better estimate could be provided when the scope of this proposed improvement is discussed.

Include Agriculture Emissions

Citizen groups that MC Planning are working with expressed interest in including emissions estimates from agricultural activities. Agriculture emissions sources include livestock emissions from digestive processes and breakdown of manure methane and nitrogen, and crop emissions from nitrogen and organic based fertilizers, crop residues, and other soil amendments such as limestone and urea. Controlled burning also generates GHG emissions however this may not be a common agricultural activity in Montgomery County's jurisdiction and generally contributes a very small amount to total agriculture emissions so a decision could be made as to whether this source should be included. Agriculture emissions are reported in MWCOG inventories.

Data Center Emissions

MC Planning also expressed interest in exploring the extent to which data centers contribute to MC emissions as it is understood data centers contribute significantly to energy related GHG emissions. In a future update ICF could explore whether data centers are likely to contribute significantly to Montgomery County emissions and provide a recommendation as to whether parameters and methods should be included to estimate their emissions. Emissions from energy use of data centers are reported in MWCOG inventories.

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[13] Examining the Role of Forests and Trees in Montgomery County's Greenhouse Gas Inventory. Montgomery County, Maryland. July 2020. https://www.montgomerycountymd.gov/climate/Resources/Files/climate/workgroup-recommendations/Examining%20the%20Role%20of%20Forests%20and%20Trees%20in%20Montgomery%20Countys%20Greenhouse%20Gas%20Inventory%20(July%202020).pdf.

5. Appendix: Recommended Updates Memo

MEMORANDUM

To:	Khalid Azfal, Mark Symborski, Steve Findlay, Clark, Larson, Tina Schneider
From:	Hazelle Tomlin, Blake Walkowiak, Bella Scornaienchi, Deb Harris
Date:	03.11.2025
Subject:	Recommended Updates for Montgomery County Climate Assessment Quantification Tool

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Background

On July 25, 2022, the Montgomery County Council signed Bill 3-22, "Climate Assessments" into law. The bill requires assessments of climate impacts for County bills, zoning text amendments and master plans and master plan amendments (collectively referred to as master plans). As a result of the bill, the Montgomery County Planning Department (Montgomery Planning) is responsible for conducting climate assessments for Zoning Text Amendments (ZTAs) and master plans, and the Office of Legislative Oversight will be responsible for conducting climate assessments for County bills.

Montgomery Planning hired ICF to conduct research and recommend an approach to conducting climate assessments. In January 2023, ICF delivered the Montgomery County Climate Assessment Quantification Tool. In February 2025, a new task order was established with ICF to update the Montgomery County Climate Assessment Quantification Tool. A draft tool model is presented in Figure 1**Error! Reference source not found.** of the appendix. This memo documents ICF's draft recommended climate assessment tool updates.

Key Recommendations

1. <u>ICF recommends an update to hardcoded data</u> (yellow cells) where more recent data are available since the tool's development and release to Montgomery Planning in January 2023. Input data sources that have already been identified for update and the nature of the proposed update or revision are described in detail in Table 5. The following tool components have proposed data revisions:
    a. Average building embodied emissions,
    b. Average building square footage,
    c. Pavement embodied emissions,
    d. Average building energy consumption,
    e. Average building life span,
    f. Electricity fuel mix and related emissions factor assumptions,

g. Building energy efficiency assumptions,
h. Population data for waste generation per person, number of people per unit or building and building life-span transportation emissions,
i. Annual VMT by jurisdiction, and
j. EV energy economy.

2. ICF is not recommending any methodological updates to the tool at this time.

Table 6 and Table 7 in the appendix detail methodology, emission factor and data updated that were proposed in the 2022 Climate Assessment Recommendations for Master Plans and Zoning Text Amendments in Montgomery County.

Table 5: Proposed data, emission factor or assumption updates.

Current Emission Factors and Assumptions	Recommended Revisions
Embodied Emissions	

• Building materials and amenity assumptions (i.e., embodied emissions): GREET 2022
• Residential floorspace per unit and building types: EIA Residential Buildings Energy Consumption Survey (RBECS) 2018
• Commercial building type definitions: Commercial Buildings Energy Consumption Survey (CBECS) 2018
• Floorspace per building: EIA 2003 CBECS
• Average window size: EIA 1993
• Pavement embodied emissions: based on four older life cycle assessments[19]
	Average Building Embodied Emissions (MTCO2e / square foot):
	• Update Dec 2022 GREET Building Life-Cycle Analysis module to Jan 2024 release:
	   ◦ UPDATE: Sample Residential Home average embodied emissions XX kg CO_2e/ft^2
	   ◦ Consider adding: Multi-Family Residential Building emission factor XX kg CO_2e/ft^2 (available in 2024 version)
	• Update Dec 2022 Building Transparency EC3 model studies/reports to latest release post-Jan 2024:
	   ◦ UPDATE: Office building average embodied emissions XX kg CO_2e/ft^2
	   ◦ UPDATE: Commercial building average embodied emissions XX kg CO_2e/ft^2
	• Consider updating average building lifespan as estimated by MC according to the time to replacement; was previously only available for residential buildings – need to check with MC for updates.
	• Revise groups of building type, e.g., combine retail, health care and or education into more aggregated group(s) to decrease burden on staff inputting data and GIS staff analyzing square footage
	• Enable Montgomery Planning to update zoning data (unlock for Montgomery Planning Commission)
	• Review assumptions related to upstream emissions associated with building materials (can see Roadway Construction Emissions Model, or Asphalt Pavement Embodied Carbon Tool - asPECT).
	
	Revise Pavement Embodied and Paving Emission Factor:
	• Update Pavement embodied emissions from Hanson et al., 2012 to reflect more current literature: ICF intend to develop this production to construction emission

Current Emission Factors and Assumptions	Recommended Revisions
	factor using EC3, GREET, literature (e.g., DOE reports), and reasonable input assumptions. • DOE Program Record - Greenhouse Gas Emissions for Annual Construction and Maintenance of U.S. Roadways • NAPA-SIP109-TheCarbonFootprintOfAsphaltPavements-March2024.pdf • MDOT_LCTMGrant_Application_6102024.pdf **Revise Average Building Square Footage:** • Building materials and amenity assumptions: 2018 CBECS is latest version; update from 2015 RECS to RECS 2020 • Residential floorspace per unit and building types: update from RECS 2015 to RECS 2020 • *No update recommended for commercial building type definitions as 2018 CBECS is latest version* • *No update recommended for floorspace per building as 2018 CBECS is latest version* • Recommend updating the number of people per unit or building, in the current tool, this comes from Montgomery Planning's Research and Special Project's Division; 2016-2020 ACS. Recommend updating population forecasts.
Energy Emissions	
• Energy consumption for residential buildings: IEA, RECS, CE2.2. Annual Household site fuel consumption in the Northeast, 2015 • Energy consumption and floorspace per building for	**Average Building Energy Consumption:** • Revise energy consumption for residential buildings from 2015 to 2020 RECS • *No update recommended for energy consumption and floorspace per building for commercial buildings as 2018 CBECS is latest version* • Revise average non-residential building energy consumption from performance standards from 2019 BEPS report by building type (site kBTU/ SF) to updated BEPS Technical Report (2023) – Table 3 MD BEPS Building Energy Performance Standards

Current Emission Factors and Assumptions	Recommended Revisions
commercial buildings: BEPS Technical Report, Table 9.; Using 2019 benchmarking data provided by DEP • Carbon Coefficient for buildings: Buildings Energy Data Book 2005 • Residential floorspace per unit: EIA 2015 (RECS), and EIA 2018 (CBECS) • Average life span of residential buildings (also used for commercial buildings)[20]: Census 2001, Residential Energy Consumption Survey 2001	• Revise carbon co-efficient for buildings: Building Performance Database (lbl.gov) (has emissions intensities based on building types) • Revise residential floorspace per unit from RECS 2015 to RECS 2020 • Recalculate the average life span of residential buildings using more recent housing data from New Residential Construction (census.gov) or undercust.xls (live.com), newresconst.xls (live.com) (new housing stock), and 2020 RECS (existing housing stock). • Revise Future Grid Resource Mix using the 2030 GGRA Plan Modeling Data, refer to the Electricity Emissions – GGRA tab, row 88. **Average Building Lifespan:** • Update average building lifespan per average building energy consumption • Consider development of an average life span of commercial buildings that is separate from residential buildings (i.e., avoid using the same assumption for both residential and commercial buildings). **Electricity Fuel Mix and Emission Factor Assumptions:** • Consider updating electricity fuel mix and emission factor assumptions based on Maryland's Climate Pathway (2023) report supplement Greenhouse Gas Emissions Reduction Planning **Building Energy Efficiency Assumptions:** • Update building energy efficiency assumptions from 2019 BEPS to 2023 BEPS, as described for average building energy consumption
Transportation Emissions	
• Number of people per unit: Montgomery Planning's Research	**Building Life-Span Transportation Emissions:**

Current Emission Factors and Assumptions	Recommended Revisions
and Special Project's Division; 2016-2020 ACS; email from Caroline McCarthy of Planning on 12/5/22 • Residential Floorspace per unit: 2018 CBECS • Number of employees per thousand square feet: CBECS 2018 • Vehicle-related GHG emissions estimates: • Current and future VMT: MWCOG Table B1. Annual VMT by Jurisdiction for Climate Action Planning Activities • MWCOG Summary of Population Forecasts • EV Energy Economy: AFLEET Tool 2020 • Life-cycle fuel-related emission factors, RENew Northfield 2006	• Number of people per unit: update from 2015 to 2020 RECS, Montgomery Planning's Research and Special Project's Division may also have information on this. Update from Montgomery Planning's Research and Special Project's Division; 2016-2020 ACS; ask MWCOG planning for data • No update necessary for employees per square foot: 2018 CBECS is latest version, however, Montgomery Planning's Research and Special Project's Division may also have information on this; ask MWCOG planning for data • Revise current and future Annual VMT by jurisdiction (miles) if update is available and align population forecasts as with other population data updates • Revise On road vehicle stocks by updating VMT by vehicle type for the Transportation Behavior Plan (TBP) planning areas if new data is available • Revise EV Energy Economy by updating AFLEET 2020 data to AFLEET 2024 version • Revise assumptions for Future EV Penetration Rates using the 2030 GGRA Plan Modeling Data, refer to the ZEB LDVs Stock by Scenario tab, which conveys different penetration curves for types of vehicles.
Land Cover and Management Emissions	

• Land Cover Type: Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2019	• **Land Cover Type:** Consider updating land cover and management emissions data
	  ○ Forest – update carbon stock factors for Maryland from 2019 to 2020. Compare against US GHG inventory calculated carbon stock factors to validate data
	  ○ *No update recommended: Grassland – IPCC 2006 Guidelines for National Greenhouse Gas Inventories Chapter 6 - Table 6.4*

Current Emission Factors and Assumptions	Recommended Revisions
	○ Green Roof – dated literature from Getter et al., 2009; review whether more recent source available ○ Non-Forest Tree Cover – Update OurTrees Tool output to latest year or consider a new source Turf – dated study by Jo and McPherson (1995); review whether more recent source available Wetland/Meadow – dated publication specific to Maryland (1996); review whether more recent source available • Review presentation of carbon stocks to ensure visualizations represent emissions and stocks or sequestration clearly • Add comments to carbon stock rows to ensure that it is clear carbon stocks are not emissions, ensure clarity around carbon stocks and annual sequestration values • Examining the Role of Forests and Trees in Montgomery Countys Greenhouse Gas Inventory (July 2020).pdf
Building Waste Emissions	
• Maryland Solid Waste Management and Diversion Report, 2017 • National Average Waste Production EPA, Facts and Figures on Materials, Waste, and Recycling (2018) • Waste emission factor from EPA's Emission Factors for GHG Inventories, Table 9	**Building waste management**: • Reference the most recent building code for this information. • Update waste data per 2023 Report: Maryland Solid Waste Management and Diversion Report.pdf; EPA national annual MSW values extend only to 2018. **Waste Generation per Person** • Update Montgomery County population from 2016 census to latest census (2023); note that changes are minimal. **Waste Emission Factor Values** • Update waste emission factor to 2022 value from 2021.

Appendix

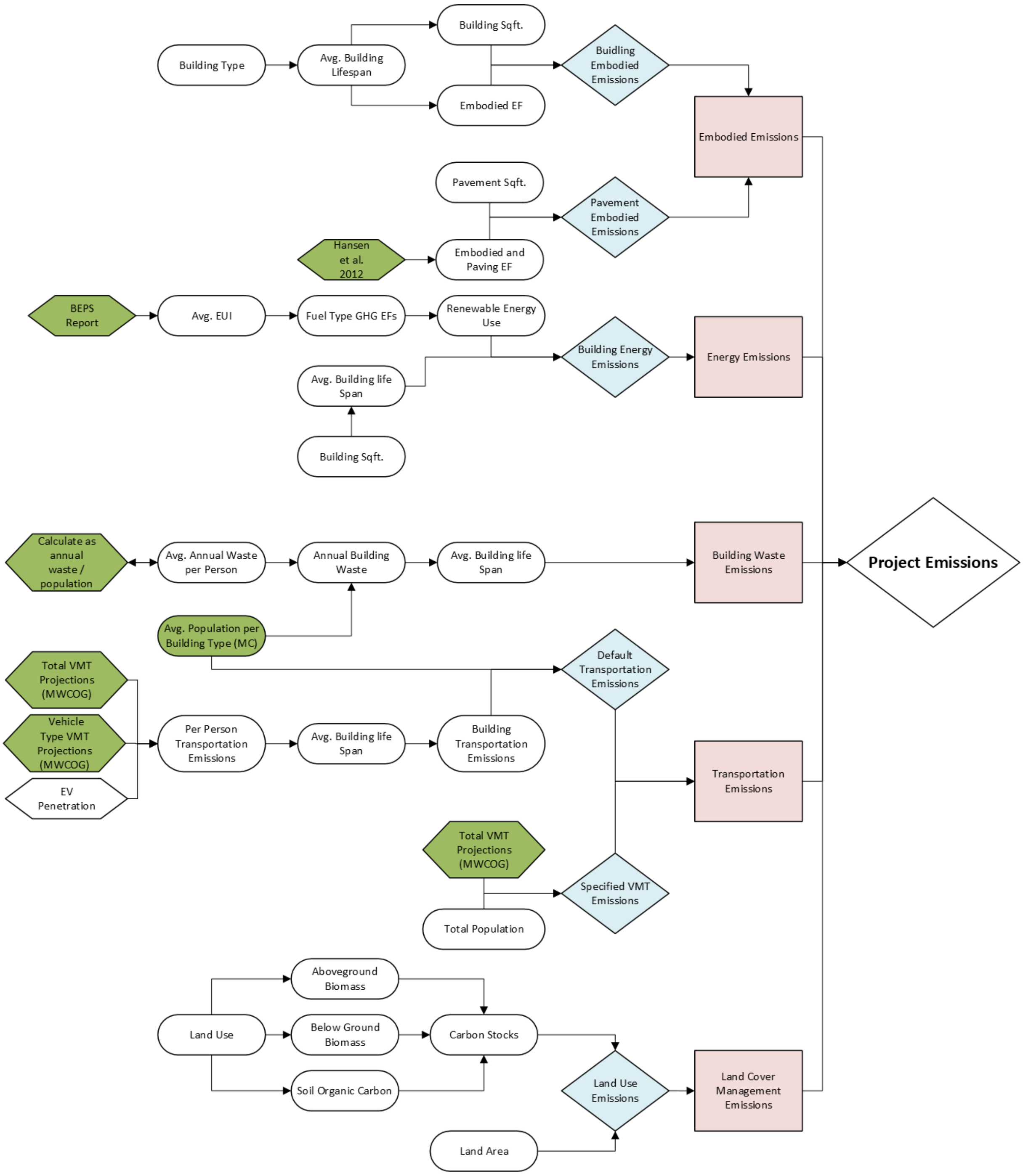

Figure 1: DRAFT Model of Montgomery County Climate Assessment Tool.

Table 6: 2022 Memo Methodology / calculation revisions or additions

Sector	Current Calculations	Recommended Calculation Revisions / Additions
Embodied Emissions	• Based on building type, square footage (commercial) or number of units (residential), building life span, and life span related embodied GHG emissions. • Also include the embodied emissions associated with pavement (for the entire assumed lifetime of the building).	• Add the upstream and end of life emissions associated with embodied emissions (i.e., production, transportation, and disposal of different types of materials used for construction).
Energy Emissions	• Based on the building type identified, the tool assumes the average floorspace, carbon coefficient, energy consumption, and lifespan to develop a lifespan energy related emissions per thousand square foot estimate.	• Montgomery Planning may optionally enter the projected floorspace that will be affected by the master plan if known. • Montgomery Planning may optionally enter the projected energy consumption if known, or the energy use intensity based on the building code vintage the building will comply with. • Montgomery Planning may enter data associated with the IGCC or other energy efficiency credentials of the building which would result in emission reductions, embodied energy, etc.

Transportation Emissions	• Calculates combustion emissions associated with transportation based on building type, assumed people in the unit or building, square footage, life span of the building, and Maryland state vehicle related GHG emissions.[17]	• Include life cycle/ upstream emissions associated with the fuel combusted (i.e., fossil fuel production and transportation). • Allow Montgomery Planning to enter an estimated total number of estimated building residents or daily occupants (i.e., employees). • Breakout emissions by transportation mode and vehicle type. Allow for Montgomery Planning to enter the vehicle types that are most likely to be impacted. • Include assumptions of future EV penetration and fuel mix rates.

Table 7: Recommended emission factor or assumption revisions

Sector	Current Emission Factors and Assumptions	Recommended Revisions	Recommended Additions
Embodied Emissions	• Building materials and amenity assumptions (i.e., number of walls, windows roofs etc.): Buildings Energy Data Book 2001	• Building materials and amenity assumptions: 2018 CBECS; 2020 RECS • Residential floorspace per unit and building types: RECS 2015	• Assumptions related to upstream emissions associated with building materials (can see Roadway Construction Emissions Model, or Asphalt Pavement

	• Residential floorspace per unit and building types: EIA Residential Buildings Energy Consumption Survey (RBECS) 2001 • Commercial building type definitions: Commercial Buildings Energy Consumption Survey (CBECS) • Floorspace per building: EIA 2003 CBECS • Average window size: EIA 1993 • Pavement embodied emissions: based on four older life cycle assessments[19]	• Commercial building type definitions: 2018 CBECS • Embodied emission factors of average materials in buildings: EC3 - Find & Compare Materials (buildingtransparency.org) (includes average materials and average window size). • Floorspace per building: 2018 CBECS • Pavement embodied emissions: can develop this emission factor using GREET and reasonable input assumptions. • Building energy efficiency, renewable energy, and waste management: reference the most recent building code for this information.	Embodied Carbon Tool - asPECT).
Energy Emissions	• Energy consumption for residential buildings: Building Energy Data Book 2007	• Energy consumption for residential buildings: 2020 RECS	• Develop an average life span of commercial buildings that is separate from residential buildings (i.e., avoid using the same

	• Energy consumption and floorspace per building for commercial buildings: EIA 2003 • Carbon Coefficient for buildings: Buildings Energy Data Book 2005 • Residential floorspace per unit: EIA 2001 • Average life span of residential buildings (also used for commercial buildings)[20]: Census 2001, Residential Energy Consumption Survey 2001	• Energy consumption and floorspace per building for commercial buildings: 2018 CBECS • Carbon co-efficient for buildings: Building Performance Database (lbl.gov) (has emissions intensities based on building types) • Residential floorspace per unit: RECS 2015 • Recalculate the average life span of residential buildings using more recent housing data from New Residential Construction (census.gov) or under_cust.xls (live.com), newresconst.xls (live.com) (new housing stock), and 2020 RECS (existing housing stock). • Future Grid Resource Mix: use the 2030 GGRA Plan Modeling Data, refer to the Electricity Emissions – GGRA tab, row 88.	assumption for both residential and commercial buildings).
Transportation Emissions	• Number of people per unit: Washington State Estimates 2007 • Residential Floorspace per unit: Residential	• Number of people per unit: 2020 RBECS2020 RBECS, Montgomery Planning's Research and Special Project's Division may also have information on this.	• Use VMT breakdown estimates based on vehicle type developed by NREL to distribute emissions

	Energy Consumption Survey 2001 • Number of employees per thousand square feet: Commercial Building Energy Consumption Survey 2003 • Vehicle-related GHG emissions estimates: • 2006 Washington State Annual VMT • 2006 Washington State Population • 2006 Transportation Energy Book - National Average Fuel Efficiency • Life-cycle fuel-related emission factors, RENew Northfield 2006	• Employees per thousand square feet: 2018 CBECS, Montgomery Planning's Research and Special Project's Division may also have information on this. • Use more accurate and recent fuel efficiency and fuel emission factors from NREL (average annual fuel use by vehicle type, fuel efficiency by vehicle type) • Use the most recent MWCOG transportation data to source annual VMT (from the MOVES model) and vehicle type distribution. • Use the most recent census for the Maryland population, or MWCOG data for Montgomery County population. • Include life cycle/ upstream emissions associated with the fuel combusted (i.e., fossil fuel production and transportation): GREET tool and reasonable fuel mix / vehicle assumptions • Future EV Penetration Rates: use the 2030 GGRA Plan Modeling Data, refer to the ZEB LDVs Stock by Scenario tab, which conveys	across more vehicle types and fuel types.

	different penetration curves for types of vehicles.	