Supplement Information for:

A Modular Methane Mapping Tool (M3T): Introduction to the *M3T* R package

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SI table S1. GEPA sectors used as is in M3T.

GEPA code	GEPA Sector	Thermogenic
1A	Combustion Mobile	yes
1B1a	Abandoned Coal	yes
1B1a	Surface Coal	yes
1B1a	Underground Coal	yes
1B2a	Petroleum Systems Exploration	yes
1B2a	Petroleum Systems Production	yes
1B2a	Petroleum Systems Refining	yes
1B2a	Petroleum Systems Transport	yes
1B2ab	Abandoned Oil Gas	yes
1B2b	Natural Gas Exploration	yes
1B2b	Natural Gas Processing	yes
1B2b	Natural Gas Production	yes
2B8	Industry Petrochemical	yes
2C2	Industry Ferroalloy	yes
3A	Enteric Fermentation	no
3B	Manure Management	no
3C	Rice Cultivation	no
3F	Field Burning	no
5A1	Landfills Industrial	no
5B1	Composting	no

S1. Datasets

The default configuration settings used in M3T are summarized below, as well as in the package documentation.

- Throughout
  - The source for all datasets is set to M3T other than those used as is from publicly available datasets
    - GEPA (Maasakkers et al., 2023; McDuffie et al., 2023) and Vulcan v4.0 (Gurney et al., 2025a, b) are set to download
  - M3T will use Vulcan v4.0 (Gurney et al., 2025a, b) by default rather than ACES v2.0 (Gately and Hutyra, 2022, 2017)
    - There is no strong reason to justify this. Vulcan covers a wider range of years (2010 to 2022) compared to ACES (2012 to 2017). Vulcan has also existed for longer and been updated more recently.
- Municipal Solid Waste
  - The residual between the GHGI and the GHGRP national total is evenly distributed to all LMOP facilities by default. A constant emission factor for each facility can instead be set.
  - The generation-first method (HH-6) is used by default over the collection-first (HH-8) method or reported data for GHGRP facilities
    - Stark et al. (2024) and Balasus et al. (2025) discussed that the generation-first (HH-6) method shows both emissions and trends that better match some top-down studies. However, other studies have discussed stronger correlations with the underlying data used to inform either method and this could be used to develop improved methods in the future (Howell et al., 2025; Krause et al., 2025; Srikanth et al., 2025).
- Natural Gas Distribution
  - Weller et al. (2020) emission factors are used for mains pipelines by default
  - The Fischer et al. (2018) emission factor in terms of residential gas consumption is used for residential post-meter by default
  - The commercial post-meter emissions are calculated equivalently to residential, but have an emission factor of 0 by default given the lack of data
  - GHGI emission factors are used for metering and regulating stations, maintenance events, meters, and services
  - The state-scale method is used by default as the LDC-scale method requires manual input and the domain-scale method is inappropriate for larger domains
- Natural Gas Transmission

  - GHGI emissions and activity data is used to calculate pipeline and transmission compressor emission factors by default
  - There are no method variations
- Stationary Combustion
  - Emission factors from the IPPC (Gómez et al., 2006) are used by default with the exception of natural gas for electric production which is based on Hajny et al. (2019)
  - The state-scale method is used by default as the domain-scale method is inappropriate for larger domains
- Wastewater
  - The Moore et al. (2023, 2025) log-log linear relationship between flow and emissions is the default rather than downscaling GHGI total emissions
    - Moore et al. (2023, 2025) used recent measurement campaigns with well-established and well-documented methods and demonstrated ~2x the emissions as currently estimated in the GHGI
  - GHGI non-septic emissions by year are used by default if set to use the GHGI downscaling method for municipal wastewater treatment plants
  - The DMR dataset is used as activity data for municipal wastewater treatment plants by default rather than the CWNS
    - The national total activity data is similar between the two, but there are differences at smaller spatial scales in both the activity data and facility locations. While the EPA is required to conduct the CWNS periodically in coordination with states, it is a voluntary survey that may include underreporting or nonreporting facilities/states (U.S. Code, 1972; Clean Watersheds Needs Survey (CWNS) – 2022 Report and Data, 2025). The DMR by comparison, are legally required (Electronic Code of Federal Regulations, 2015). The feedback below is from the ECHO help team regarding the differences between the CWNS and DMR (ECHO Support Team at ERG (EPA Contractor)).
    - "The Clean Water Needs Survey (CWNS) data and ECHO values may differ as these data are reported differently. The DMR Pollutant Loading Report on ECHO pulls water data from ICIS-NPDES, which contains discharge monitoring report data submitted by NPDES permitted facilities. The three flow values seen on this report are reported at either the time of permit application or is calculated using flow data reported in ICIS-NPDES. The Average Facility Flow (DMR) value is the average flow from all external discharge points (outfalls) at the facility during the selected reporting year, calculated in the Loading Tool from flow data reported on DMRs. For more information about the data, please see the DMR Pollutant Loading Report Help (https://echo.epa.gov/help/loading-tool/reports/pollutant-loading-report-help-dmr)... The CWNS data is based on a comprehensive survey conducted by EPA every four years to get a comprehensive assessment of the capital costs (or needs) to meet the water quality goals of the CWA and address

what quality and water quality related public health concerns. We recommend reviewing the CWNS 2012 Data Dictionary (https://www.epa.gov/sites/default/files/2016-01/documents/cwns-2012-data_dictionary2.pdf)..."

- GHGI septic emissions by year are used by default for the national septic method
- The national septic method is used by default rather than the state level method
  - There is no strong reason to justify this choice. It was selected as it relies on fewer datasets, just the NLCD and GHGI. The state method relies on census population and septic fraction data, the NLCD, and a GHGI per capita septic EF.
- The GHGI septic per capita EF is used by default if set to use the state septic method
  - U.S. Census national and state septic fractions are used by default for the state septic method
- The national total "Developed, Open" and "Developed, Low Intensity" is calculated directly using NLCD data for CONUS and a linear regression using the limited AK NLCD data available by default

- Wetlands and Inland Waters
  - Rosentreter et al. (2021) emission factors are used by default for freshwater emissions
  - SOCCR1 and 2 EFs are used by default for the SOCCR methods, but other EFs could be used by changing these EFs and using the SOCCR methods. SOCCR1 does not vary by watershed while SOCCR2 does.
  - WetCHARTs is used by default
    - There is no strong reason to justify this choice. WetCHARTs is composed of numerous model runs and is, to our knowledge, more commonly used to represent wetland emissions in the literature
- Combine Sectors
  - The default is to only produce the min, mean, and max value across the variations chosen. Separating into thermogenic and non-thermogenic totals and calculating all possible combinations across variations will not be relevant for all users and will considerably increase processing time.

S2. Aligning GHGRP and HIFLD Transmission Compressor Datasets

The GHGRP and HIFLD do not have common identification codes. To define matching facilities, the nearest HIFLD facility was calculated for each GHGRP facility, including all years of GHGRP data. All years were considered as names and locations can change over time, and some facilities may not report every year as emissions may be low enough some years and not others. This was taken as an initial match and was then checked by comparing facility names manually. Though exact name matches were uncommon, reasonable matches (e.g., MGT Potomac 2118 and #2118 Potomac or EPNG Belen Compressor Station and Belen) were common. Facilities that were within 1 km were considered a match even if there was no clear name match. Across facilities with a match, 481 (82%) GHGRP facilities had a HIFLD facility within 1 km, 75 (13%) had a HIFLD facility between 1 and 10 km away, and 29 (5%) had a HIFLD facility >10 km away, up to a maximum of 55.5

km. For context, GHGRP facility locations can also be updated over time. Across all facilities that had at least 2 years of reported data 728 (93%) had updated locations within 1 km, 37 (5%) had updated locations between 1 and 10 km away, and 20 (3%) had updated locations > 10 km away, up to a maximum of 289 km for GHGRP ID 1002979.

S3. Per Area and Per Capita Analysis

We investigated the ten urban areas with the largest emissions per capita and per area in addition to those with the largest emissions. These are different sets of urban areas than those with the largest emissions, though many of those with significant per capita emissions also have significant per area emissions. Those with the largest total emissions are all large, dense urban environments with areas of at least 3,000 km^2 and populations of at least 3.5 million while those with the largest per capita or per area emissions are all small urban areas under 160 km^2 and populations under 65 thousand, many under 10 thousand. Figures S1 and S2 show that these urban areas with large per capita or per area emissions are also each dominated by one type of point source such as landfills, natural gas transmission compressors, or wastewater treatment plants unlike the urban areas with large emissions discussed in the main text that each had a range of significant sources.

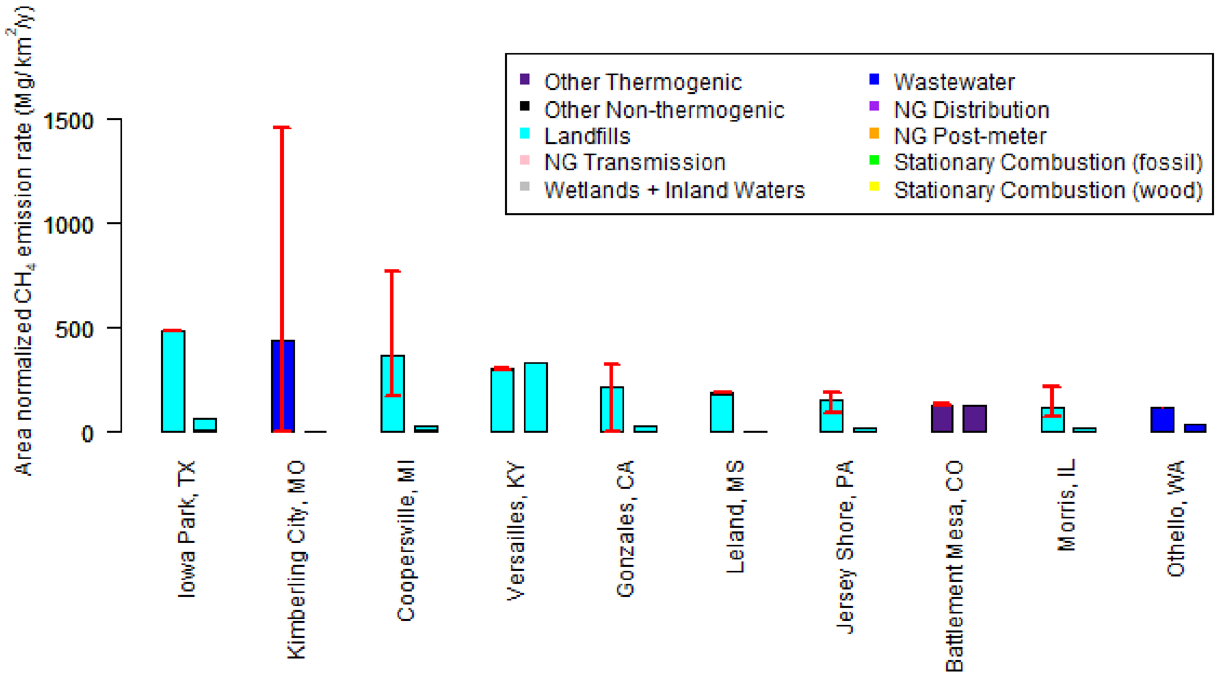


Figure S1: Bar plot equivalent to main text Figure 8 for the ten urban areas with the largest emissions per area. Bars on the left for each sector represent the average M3T output across all variations with error bars representing the range across variations. Bars on the right represent GEPA emissions.

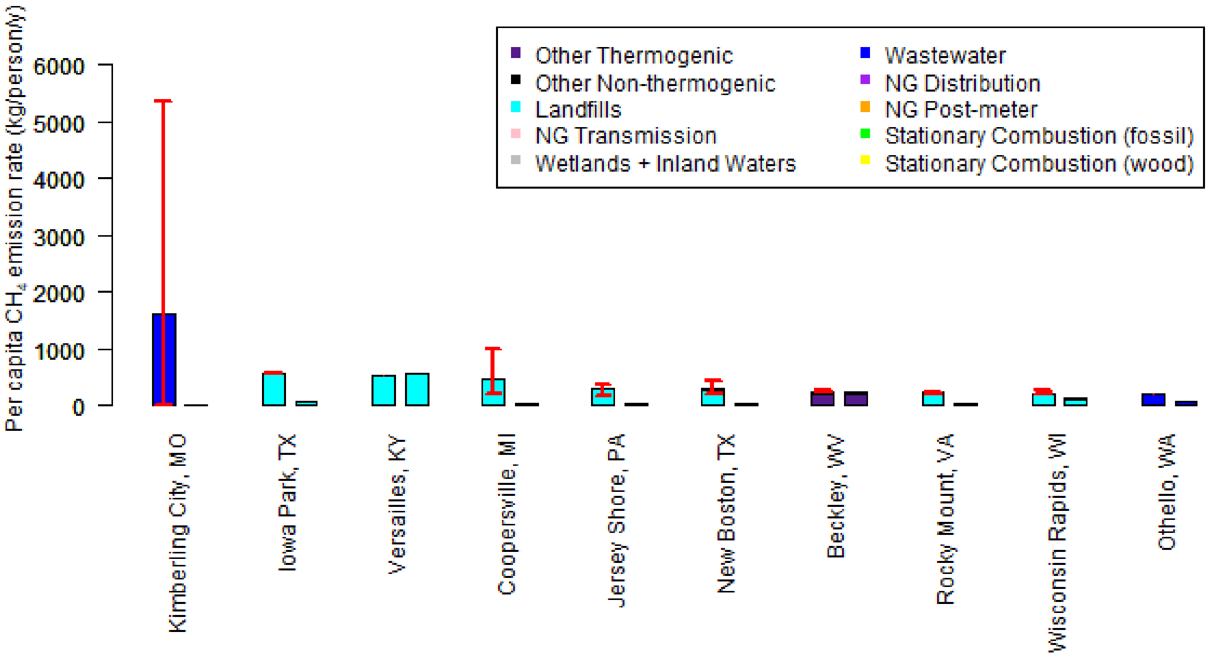
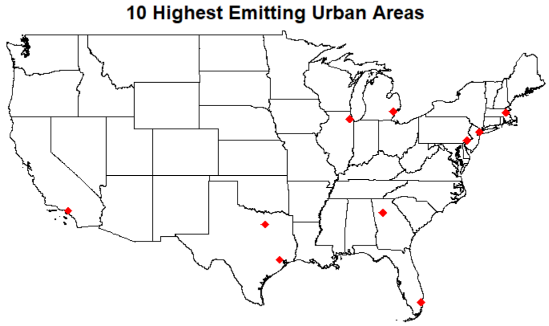
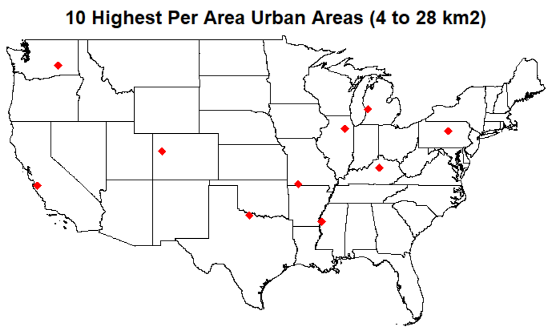


Figure S2: Bar plot equivalent to main text Figure 8 for the ten urban areas with the largest emissions per capita. Bars on the left for each sector represent the average M3T output across all variations with error bars representing the range across variations. Bars on the right represent GEPA emissions.





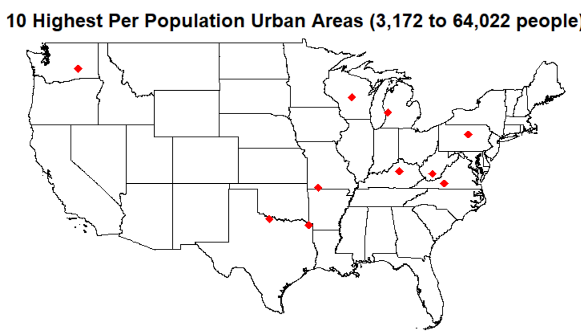


Figure S3: CONUS maps with red diamonds showing the urban areas with the largest emissions or largest emissions per population or area as per their titles. Data for all 30 urban areas are provided in Tables S1 - S3.

SI table S2. Emissions data for the ten urban areas with the largest emissions

Urban Area	State(s)	Mean Emissions (Gg/year)	Area (km^2)	Emissions Per Area ($Mg/km^2/year$)	Population	Emissions Per Capita (kg/person/year)
New York–Newark	NY--NJ–CT	226.699	8,936	25	18,351,295	12
Chicago	IL–IN	149.111	6,327	24	8,608,208	17
Los Angeles--Long Beach--Anaheim	CA	146.765	4,496	33	12,150,996	12
Dallas--Fort Worth--Arlington	TX	108.193	4,608	23	5,121,892	21
Houston	TX	94.634	4,299	22	4,944,332	19
Philadelphia	PA–NJ–DE–MD	82.884	5,132	16	5,441,567	15
Detroit	MI	75.766	3,463	22	3,734,090	20
Atlanta	GA	75.495	6,851	11	4,515,419	17
Miami	FL	67.012	3,208	21	5,502,379	12
Boston	MA–NH–RI	61.494	4,852	13	4,181,019	15

SI table S3. Emissions data for the ten urban areas with the largest emissions per area. Those in bold are urban areas that are also in SI Table S4.

Urban Area	State(s)	Mean Emissions (Gg/year)	Area (km^2)	Emissions Per Area ($Mg/km^2/year$)	Population	Emissions Per Capita (kg/person/year)
Iowa Park	**TX**	**3.632**	**7**	**485**	**6,285**	**578**
Kimberling City	**MO**	**5.152**	**12**	**441**	**3,172**	**1,624**
Coopersville	**MI**	**1.877**	**5**	**370**	**3,951**	**475**
Versailles	**KY**	**8.349**	**28**	**301**	**15,907**	**525**
Gonzales	CA	0.880	4	216	8,174	108
Leland	MS	0.927	5	190	4,539	204
Jersey Shore	**PA**	**2.858**	**18**	**158**	**9,606**	**298**
Battlement Mesa	CO	0.989	8	130	5,071	195
Morris	IL	3.177	26	122	15,668	203
Othello	**WA**	**2.450**	**20**	**120**	**11,207**	**219**

SI table S4. Emissions data for the ten urban areas with the largest emissions per capita. Those in bold are urban areas that are also in SI Table S3.

Urban Area	State(s)	Mean Emissions (Gg/year)	Area (km^2)	Emissions Per Area ($Mg/km^2/year$)	Population	Emissions Per Capita (kg/person/year)
Kimberling City	**MO**	**5.152**	**12**	**441**	**3,172**	**1,624**
Iowa Park	**TX**	**3.632**	**7**	**485**	**6,285**	**578**
Versailles	**KY**	**8.349**	**28**	**301**	**15,907**	**525**
Coopersville	**MI**	**1.877**	**5**	**370**	**3,951**	**475**
Jersey Shore	**PA**	**2.858**	**18**	**158**	**9,606**	**298**
New Boston	TX	1.367	12	117	4,707	290
Beckley	WV	15.948	158	101	64,022	249
Rocky Mount	VA	1.361	19	72	6,048	225
Wisconsin Rapids	WI	6.396	56	115	29,169	219
Othello	**WA**	**2.450**	**20**	**120**	**11,207**	**219**

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