United States Environmental Protection Agency

Docket No. EPA-HQ-OLEM-2023-0451

Prepared by: Joshua R. Castigliego, Applied Economics Clinic

Date: February 9, 2024

Re: Comments on Avoided Emissions from Energy Recovery in EPA's Waste Reduction Model (WARM) v16

Table of Contents

I. Introduction

Many U.S. states and municipalities are assessing their waste management systems to inform better strategies and management practices promoting waste diversion and minimizing the impact of waste on public health and the environment. Differences in waste management impacts across various kinds of systems can be informed by a life cycle assessment of waste materials (e.g., paper, plastics, metals, glass, food waste, etc.) and their corresponding waste management practices (e.g., source reduction, recycling, anaerobic digestion, composting, combustion, and landfilling). A life cycle assessment allows for the evaluation of various environmental impacts, including the quantification of life cycle greenhouse gas emissions.

The U.S. Environmental Protection Agency (EPA) developed its Waste Reduction Model (WARM)[1] to assess the net greenhouse gas emissions impact of different waste material types across various management practices. EPA built WARM to be a "streamlined" life cycle assessment tool to evaluate greenhouse gas emissions across three main factors:

- life-cycle emissions of a waste material (including the pre-consumer stages of raw material extraction and manufacturing as well as the post-consumer stage end-of-life management);
- carbon sinks affected by manufacturing, recycling, and disposing of the waste material; and
- avoided emissions from energy recovery that could displace other electric generation on the grid.

Greenhouse gas emissions from the waste sector can be split into two categories: (1) *direct emissions* from waste decomposition and combustion, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O); and (2) *avoided emissions* that could be realized through waste management activities that result in

[1] See: https://www.epa.gov/warm

energy recovery, material recovery, and carbon storage.[2] Compared to direct emissions, avoided emissions are more uncertain and challenging to estimate since they generally vary by location and change significantly over time. As a result of this greater level of uncertainty in avoided emissions estimates, most emission accounting methodologies report avoided emissions separately from direct emissions.[3]

In December 2023, EPA opened a 45-day comment period on the recently released WARM Version 16 and its supporting documentation. EPA seeks public comment on questions related to improving the usability, integrity, and functionality of WARM. The comments provided herein focus on WARM's methodology and assumptions regarding avoided emissions from the displacement of grid electricity through energy recovery at waste incineration facilities. Of critical importance is WARM's failure to consider the sales of renewable energy credits (RECs), particularly as it relates to state renewable portfolio standards (RPS), in its estimation of emissions displaced by electric generation from waste incinerators, explained in detail in Section II. In Section III, a more general explanation of modeling avoided emissions in electric grid operations provides the context in which WARM's errors related to renewables policies can be understood, along with raising concerns about WARM's methods related to the electric grid. These related deficiencies in WARM tend to overestimate net emission reductions from waste incinerators. The last section of these comments provides key takeaways and recommendations for how the U.S. EPA can improve WARM going forward.

II. WARM ignores state renewable portfolio standards (RPS) resulting in overestimation of net emission reductions from waste incinerators

EPA's WARM uses flawed emission factors to calculate avoided emissions from grid displacement (discussed further in Section III below), but in addition, WARM makes another, perhaps more critical, error by ignoring state renewable portfolio standards (RPS) and their corresponding market for renewable energy credits (RECs) in its estimation of avoided electric sector emissions. Although RPS policies incentivize the development of renewable energy resources and displace fossil fuel-fired generation on the grid, the inclusion of emitting resources, like waste incinerators, as RPS-eligible resources creates a dynamic where cleaner, renewable resources can be displaced within a REC market itself.

Many U.S. states have implemented RPS policies, or similar voluntary goals, to increase the share of electricity generated from renewable energy resources. The requirements, structure, and eligible resources of RPS policies vary widely from state to state with no two states having the exact same policy.[4] In general, RPS-eligible resources include: wind, solar, geothermal, biomass, and certain types of hydropower, but can also include landfill gas and municipal solid waste.[5] Electric distribution companies are required to purchase a number of RECs equivalent to a given share of customer sales; that share of sales increases each year. Utilities may purchase (or generate) electricity that itself qualifies for RECs through RPS eligibility or it may purchase energy and RECs separately. In either case, sufficient RECs and renewables must be generated each year to supply utilities' RPS requirements.

---

[2] Castigliego, J.R., A. Pollack, C.J. Cleveland, M.J. Walsh. 2021. "Evaluating Emissions Reductions from Zero Waste Strategies under Dynamic Conditions: A Case Study from Boston." Waste Management, 126, 170-179. Available at: https://doi.org/10.1016/j.wasman.2021.02.026

[3] Entreprises pour l'Environnement, 2013. *Protocol for the quantification of greenhouse gases emissions from waste management activities - Version 5.* Available at: https://ghgprotocol.org/sites/default/files/2023-03/Waste%20Sector%20GHG%20Protocol_Version%205_October%202013_1_0.pdf

[4] U.S. Energy Information Administration. Nd. "Renewable energy explained: Portfolio standards." Available at: https://www.eia.gov/energyexplained/renewable-sources/portfolio-standards.php

[5] *Ibid.*

A total of 30 U.S. states (including the District of Columbia) have enforceable RPS policies with an additional seven states having voluntary renewable goals; about half of these states include waste incinerators as an RPS-eligible resource. With 65 electric generating waste incinerators currently operating throughout the United States and two-thirds of these facilities located in or able to sell RECs to a state with an RPS policy, it is important to consider the impact of these resources in the context of generation from waste incinerators displacing non-emitting renewable resources. Twenty-seven state RPS policies have a single set of RPS-eligible resources (i.e., Class I) all of which are options for meeting the state's renewable energy targets. The remaining ten states, however, have multiple classes assigning specific targets to different sets of resources—seven of these states include waste incinerators as an RPS-eligible resource, typically as a "Class II" resource, that may include anything from older renewables (primarily certain categories of hydroelectric dams) to black liquor (paper mill waste burning) and waste coal burning power plants. The dynamics of REC purchases add another layer of complexity to the identification of which resources waste incinerators are potentially capable of displacing.

When evaluating the avoided emissions from waste incinerators, the emissions of the marginal grid resource is only the right answer when there is *not* an RPS policy that includes the burning of municipal solid waste. RPS policies that allow participation of waste incinerators provide another energy market for these facilities—one that buys and sells RECs. Electric distribution companies only need the number of RECs required by the state RPS each year; if they can buy RECs from waste incinerators then they do not need RECs from other RPS-eligible generation. Under these circumstances, waste incinerators displace other RPS-eligible generation, not marginal grid resources like gas-fired combined cycle power plants.

WARM does not take into consideration waste incinerators' RPS eligibility or their potential for within-RPS-program displacement of other RPS-eligible resources. The effect of this oversight is an overestimation of the emission rates of generating resources displaced by waste incinerators and, in consequence, an overestimate of net emission reductions possible from waste incinerators. Correcting the omission of state RPS policies in WARM's assumptions would improve the accuracy of estimates of net emission reductions from waste incinerators.

III. WARM's simplistic electric sector emission factors tend to overestimate net emission reductions from waste incinerators

EPA's WARM estimates avoided emissions from the electric sector due to energy recovery at waste incinerators, anaerobic digesters, and landfills.[6] Waste incinerators (sometimes referred to as "waste-to-energy" combustion facilities) generate electricity by burning waste materials, while anaerobic digesters and landfills (if equipped with gas recovery systems) produce methane biogas that can be used to generate electricity or injected into gas distribution networks. Individual energy resources like waste incinerators, anaerobic digesters, and landfills are small in comparison to total grid energy flow. The electricity generated by these resources displaces generation that would have been produced by the grid's "marginal resource" (that is, the last, and most expensive, generating resource selected for operation to meet customer demand). (If waste incinerators generate electricity, then some other generator does not run as much and does not create as many emissions.)

[6] U.S. EPA Office of Resource Conservation and Recovery. December 2023. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*. "Background Chapters." Available at: https://www.epa.gov/system/files/documents/2023-12/warm-background_v16_dec.pdf p.1-6

To estimate the avoided emissions from displacing grid electricity, EPA's WARM utilizes "non-baseload" emission factors from EPA's Emissions and Generation Resource Integrated Database (eGRID) as a proxy for marginal emission factors.[7] EPA defines "non-baseload" electric generation as "power plants that are 'demand-following' and adjust to marginal changes in the supply and demand of electricity."[8] EPA's non-baseload emission factors are calculated as the average emissions rate from emitting generators (e.g., biomass, fossil fuels, etc.) weighted by their assigned non-baseload factor, which is equal to 1 for power plants with capacity factors below 20 percent and a between 0 and 1 (based on a linear relationship) for power plants with capacity factors between 20 and 80 percent.[9] EPA's WARM provides a choice between national and regional avoided emission factors to capture regional variations in the mix of power plants on the grid. EPA estimates emission factors for nine regions (as defined by U.S. Census Bureau-designated areas) by averaging state-level eGRID non-baseload emission factors weighted by each state's fossil fuel-fired electric generation.[10]

WARM's static nature (that is, a model that does not look at changes over time) only allows for an analysis of waste management practices under current conditions, ignoring year-to-year changes in the composition of electric supply driven both by economics and policy. As a model commonly used to evaluate forward-looking public policy decisions (e.g., long-term contracts, building new waste management infrastructure, etc.), it is problematic that WARM does not account for expected changes in the electric grid over the next few decades as the share of clean energy resources continues to grow and the emissions intensity of the grid shrinks along with potential avoided emissions from waste incinerators.

EPA's non-baseload emission factors tend to overestimate the avoided emissions from grid displacement and are not an ideal proxy for marginal emission factors. The concept of "baseload" and "non-baseload" resources has been used historically in the electric sector to categorize electric generating resources; however, the resource mix of the electric grid has changed dramatically over time—increasing in complexity—which has introduced a variety of different resource types and characteristics that no longer fit into a binary categorization. In fact, a peer reviewer of WARM's draft methodology made the same observation about how the grid's resource mix has changed in recent years: "the grid make up has changed significantly over the past decade and it is not clear what grid generation profile WARM uses."[11] With that, WARM's methodology and assumptions to estimate avoided emissions from energy recovery are subject to the following critiques:

1. **EPA's definition of "non-baseload" is a poor proxy for the marginal resource.** EPA's eGRID calculates non-baseload emission factors for emitting resources (including natural gas, oil, coal, and biomass), which are used as a proxy for marginal emission factors within EPA's WARM to estimate

---

[7] U.S. EPA Office of Resource Conservation and Recovery. December 2023. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*. "Management Practices Chapters." Available at: https://www.epa.gov/system/files/documents/2024-01/warm_management_practices_v16_dec.pdf p.5-8

[8] U.S. EPA Office of Resource Conservation and Recovery. December 2023. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*. "Management Practices Chapters." p.6-16

[9] Abt Associates. January 2024. *eGRID Technical Guide with Year 2022 Data*. Prepared for the Clean Air Markets Division of the U.S. EPA Office of Atmospheric Programs. Available at: https://www.epa.gov/system/files/documents/2024-01/egrid2022_technical_guide.pdf pp.20-21

[10] U.S. EPA Office of Resource Conservation and Recovery. December 2023. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*. "Management Practices Chapters." p.5-9

[11] Eastern Research Group, Inc. December 2022. *External Peer Review of EPA's Draft Waste Reduction Model (WARM) Methodology: Final Peer Review Report.* Available at: https://www.epa.gov/system/files/documents/2023-12/final_warm_peer_review_report_508.pdf p.19

avoided emissions from the electric grid. The vast majority of U.S. electric sector "dispatch" decisions (that is, what generator runs when) are made based on economics: The first unit chosen to run has the lowest operating costs, then the unit with the next lowest costs, and so on. The last unit chosen to run (called the "marginal unit") has the most expensive running costs and it is also the first unit to be turned off when customer demand falls, or another cheaper unit becomes available.

EPA's eGRID uses plant-level capacity factors (the share of hours that a generator runs in a year out of total possible hours) as a proxy for determining "dispatch order" (what units run first, last and so on) and categorizing power plants as "baseload" or "non-baseload."[12] Power plants with a capacity factor less than 20 percent are assigned a non-baseload factor of 1: These generators are likely "peakers," run only at times of the greatest customer demand, and are given full weight in eGRID's non-baseload emission factor averages. In contrast, power plants with a capacity factor greater than 80 percent are given no weight in the non-baseload average.[13] Power plants with a capacity factor between 20 and 80 percent are assigned a weight between 1 and 0 (based on a linear relationship) that purports to estimate the percentage of generation and emissions that is non-baseload.[14]

Waste incinerators in the United States typically run around the clock to process the waste materials received. In calculating the marginal emissions displaced by waste incinerators, it is important to consider how the daily operating hours of the waste incinerators align with what resources are on the margin at a given time. As an example, peaker plants sit idle at most times so that they can be available to run if needed during a period of peak demand; these plants guarantee their availability to the grid operator and suffer monetary consequences if they fail to run when called upon. Waste incinerator operations, in contrast, are determined by the availability of waste to burn and are likely not good candidates for peaker operations. The assumptions employed by EPA's WARM do not currently consider this nuance, which may result in inflated avoided emissions levels from energy recovery and cause waste incinerators to appear more favorable than other waste management options in terms of net emission reduction.

Capacity factors, however, are an imperfect guide to identifying the marginal resource. EPA's methodological approach for categorizing "baseload" and "non-baseload" power plants is an oversimplification of how resources are dispatched. The electric industry uses more precise methods for identifying marginal resources in modeling and decision making as discussed in detail below.

2. **Avoided electric emissions are best estimated based on the displacement of the marginal resource.** Much of the U.S. electric sector is organized into wholesale markets including: ISO-New England (ISO-NE), New York ISO (NYISO), PJM Interconnection (PJM), Midcontinent ISO (MISO), Southwest Power Pool (SPP), California ISO (CAISO), and Electric Reliability Council of Texas (ERCOT).[15] These marketplaces rely on a comparison of operating costs to determine the order in which generators are dispatched. Outside of these marketplaces, individual utilities make dispatch decisions for their own generators. Most so-called "vertically integrated" utilities are regulated by state utility commissions that expect them to make resource decisions on a cost-basis (although

[12] Abt Associates. January 2024. *eGRID Technical Guide with Year 2022 Data*. Prepared for the Clean Air Markets Division of the U.S. EPA Office of Atmospheric Programs. p.20
[13] *Ibid.*
[14] *Ibid.* pp.20-21
[15] See: https://www.ferc.gov/sites/default/files/2020-05/elec-ovr-rto-map.pdf

other, non-economic factors may play a role in a utility choosing to operate a specific resource).

In any case, the concept of the most expensive resources being "on the margin" and subject to displacement is commonly accepted and utilized throughout the electric industry. Estimating emissions from avoided generation by assuming that the emissions of the marginal unit would be displaced is a practice used frequently in electric sector decision making. As discussed below in more detail, several tools and datasets are regularly used within the electric industry to evaluate the avoided emissions from displacing the electric grid's marginal resource.

3. **Sometimes wind is on the margin.** Although fossil fuel-fired power plants, such as gas-fired combined cycle plants, are frequently the marginal resource, this is not always the case for every hour, day, or season of the year. Other resources, such as wind, regularly serve as the marginal resource in some regions of the United States.[16]

   For instance, wind resources in SPP accounted for nearly 20 percent of resources on the margin in summer months for 2022 and 2023 and often 40 percent or more of marginal resources in other seasons.[17,18,19] Wind resources have also grown as a marginal resource in PJM, accounting for over 11 percent of resources on the margin in 2022 (up from roughly 2.5 percent in 2018).[20] In ISO-NE gas-fired generation accounts for a majority of marginal resources (95.5 percent in 2022); however, wind was the next most frequent marginal resource, accounting for nearly 2.5 percent of marginal generation.[21] As the share of renewable energy on the electric grid continues to grow in the future, the mix of resources on the margin can be expected to shift away from fossil fuel-fired power plants.

   The non-baseload emission factors from EPA's eGRID—which are used as a proxy for estimating marginal emissions in EPA's WARM—are limited exclusively to fossil-fuel resources, effectively assuming that non-emitting resources like wind are never on the margin. This assumption likely leads to overestimation of the electric grid's marginal emissions, and as a consequence, overestimation of the net emission reduction provided by waste incinerators.

4. **EPA's regions are not the regions that organize the electric grid.** EPA's WARM aggregates its non-baseload emission factors into nine U.S. Census Bureau-designated areas (see Figure 1 below) using eGRID's state-level data.[22] WARM's geographic regions do not align with the regions defined by real-world electric sector operations and dispatch decisions: ISOs, RTOs and utility service territories (see Figure 2 below). In fact, WARM's electric utility regions split up highly integrated territories for ISOs and RTOs like PJM, MISO, and SPP, which all have wholesale energy markets with known marginal

---

[16] Note that wind can be and is a marginal resource in several electric regions. Wind generation can be "curtailed" or "shed" to not deliver energy when not needed.

[17] Southwest Power Pool (SPP) Market Monitoring Unit. October 2023. *Summer 2023 Quarterly Report (June-August 2023).* Available at: https://www.spp.org/documents/70433/summer%202023%20quarterly%20presentation.pdf p.8.

[18] Southwest Power Pool (SPP) Market Monitoring Unit. August 2023. *Spring 2023 Quarterly Report (March-May 2023).* Available at: https://www.spp.org/documents/69890/spring%202023%20quarterly%20presentation.pdf p.7.

[19] Southwest Power Pool (SPP) Market Monitoring Unit. May 2023. *Winter 2023 Quarterly Report (December 2022-February 2023).* Available at: https://www.spp.org/documents/69272/winter%202023%20quarterly%20presentation.pdf p.7.

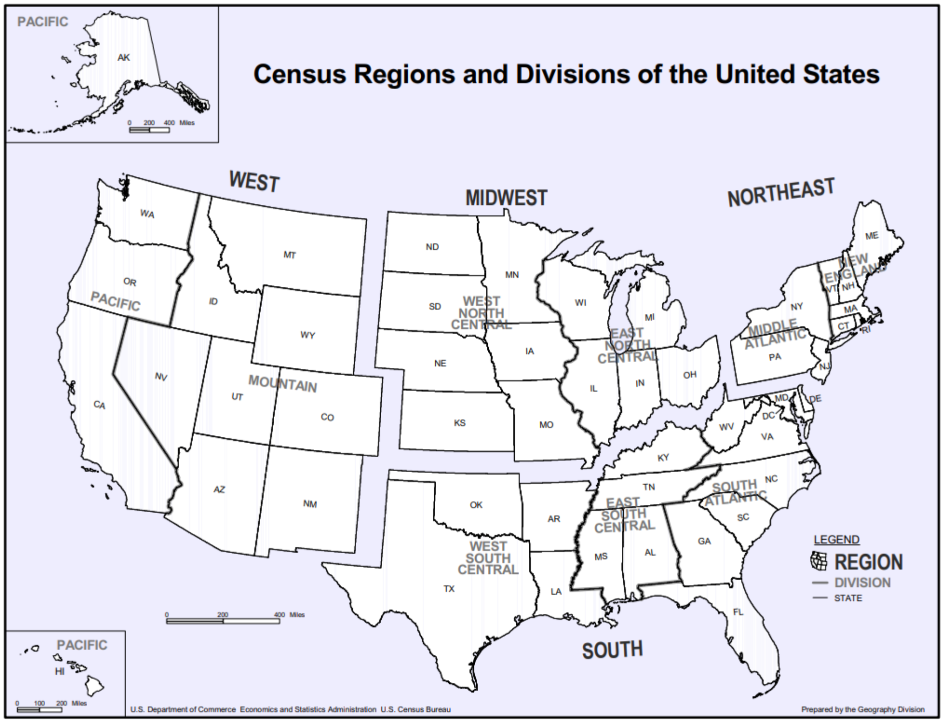
[20] PJM Interconnection. April 27, 2023. *2018-2022 CO_2, SO_2 and NO_x Emission Rates.* Available at: https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/2022-emissions-report.ashx

[21] ISO-New England. 2022. *Operations Reports: Dispatch Fuel Mix*. Available at: https://www.iso-ne.com/isoexpress/web/reports/operations/-/tree/gen-fuel-mix

[22] U.S. EPA Office of Resource Conservation and Recovery. December 2023. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*. "Management Practices Chapters." p.5-9

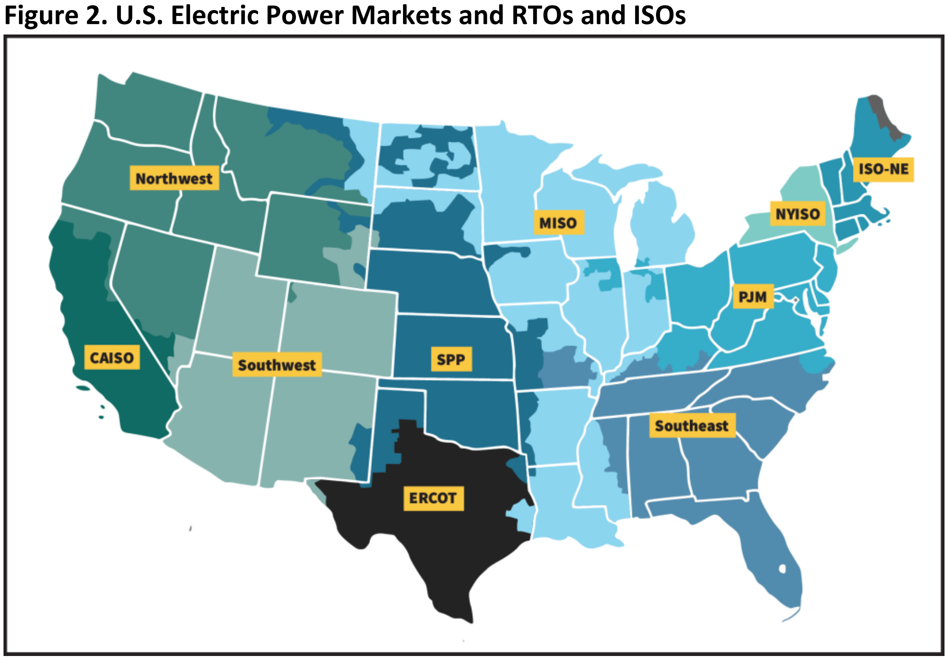
resources. WARM's use of regional territories unrelated to the electric sector's operational boundaries is an additional obstacle to producing accurate avoided emission estimates.

Figure 1. U.S. Census Regions Used in EPA's WARM for Electric Sector Emission Factors



Reproduced from: U.S. Census Bureau. Nd. "Census Regions and Divisions of the United States." Available at: https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

Figure 2. U.S. Electric Power Markets and RTOs and ISOs



Reproduced from: Federal Energy Regulatory Commission. Nd. "Electric Power Markets." Available at: https://www.ferc.gov/electric-power-markets

The critiques discussed here (oversimplification of electric grid emissions displacement, inclusion of peakers and exclusion of wind among assumed marginal resources, and incorrect assignment of electric sector regions) suggest that EPA would benefit from refining WARM's methodology and assumptions relating to avoided emissions from electric generation. In the electric sector, wholesale energy markets directly track data on how resources are dispatched; some ISOs and RTOs provide estimates for marginal emissions rates by time period. For example, PJM makes its real-time marginal emission rates available at 5-minute intervals[23] and prepares annual reports summarizing emission rates.[24] Similarly, ISO-NE makes available real-time data on its dispatch fuel mix[25] and prepares an annual Electric Generator Air Emissions Report, which includes emission rates for marginal units.[26]

In addition to data and reporting provided by grid operators, several methods for estimating avoided emissions are commonly used in electric industry modeling and related public decision making. Detailed electric sector planning models evaluate the dispatch of generating resources under multiple scenarios to meet system needs such as satisfying electric demand while minimizing customer costs. Dispatch models are commonly used to identify marginal resources on the electric grid based on model inputs such as generator characteristics and system constraints. Some common dispatch models used in the electric sector include: EnCompass, Plexos, ProMod, and Aurora.[27] As one example, Otter Tail Power Company in Minnesota uses the EnCompass model in the development of its recent integrated resource planning process including estimates of emissions from electric generation.[28] ICF's Integrated Planning Model (IPM)[29] is a similar tool with the capability to estimate avoided emissions from the electric grid that is often used by U.S. federal agencies; IPM integrates least-cost capacity expansion and electricity dispatch with emission control strategies and other environmental constraints. The EPA used IPM in the development of its Power Sector Modeling Platform to evaluate impacts of proposed policies, such as the Inflation Reduction Act of 2022, to limit utility air emissions from the electric sector.[30] EPA's AVoided Emissions and geneRation Tool (AVERT) is another model developed to evaluate "regional changes in emissions from electric power plants and displaced fuel-burning vehicles resulting from energy policies and programs such as energy efficiency, renewable energy, and electric vehicles"[31]—which could be used to estimate avoided emissions from electricity generated by waste incinerators. A 2016 study conducted by the Lawrence Berkeley National Laboratory (LBNL) and the National Renewable Energy Laboratory (NREL) utilized EPA's AVERT to estimate fossil fuel-fired generation (and associated greenhouse gas emissions) displaced by increased renewable generation resulting from state RPS policies.[32]

---

[23] PJM Interconnection. Nd. "Emissions." Available at: https://www.pjm.com/markets-and-operations/m/emissions

[24] PJM Interconnection. April 27, 2023. *2018-2022 CO_2, SO_2 and NO_x Emission Rates.*

[25] ISO-New England. Nd. *Operations Reports: Dispatch Fuel Mix*.

[26] ISO-New England. December 21, 2023. *2022 ISO New England Electric Generator Air Emissions Report.* Available at: https://www.iso-ne.com/static-assets/documents/100006/final_2022_air_emissions_report.pdf p.5

[27] EnCompass: https://anchor-power.com/encompass-power-planning-software/
Plexos: https://www.energyexemplar.com/plexos
ProMod: https://www.hitachienergy.com/us/en/products-and-solutions/energy-portfolio-management/enterprise/promod
Aurora**:** https://auroraer.com/company/models/

[28] Otter Tail Power Company. Nd. "Integrated Resource Plan." Available at: https://www.otpco.com/about-us/energy-generation/resource-plan/

[29] See: https://www.icf.com/technology/ipm

[30] See: https://www.epa.gov/power-sector-modeling/post-ira-2022-reference-case

[31] See: https://www.epa.gov/avert/avert-overview-0

[32] Wiser, R., G. Barbose, J. Heeter, T. Mai, L. Bird, M. Bolinger, A. Carpenter, G. Heath, D. Keyser, J. Macknick, A. Mills, and D. Millstein. 2016. *A Retrospective Analysis of the Benefits and Impacts of U.S. Renewable Portfolio Standards*. Lawrence Berkeley

NREL has created a tool purpose-built for estimating electric sector emissions today and in the future. NREL's electric sector dataset (called "Cambium") provides publicly available data modeling hourly emissions, costs, and electric generation for a variety of future scenarios out to 2050.[33] Cambium includes an estimation of both short-run and long-run marginal emission rates, where the latter is defined as "emission rate of the generation that would either be induced or avoided by a marginal change in electric load, including both the operational and structural (e.g., building new generation or transmission capacity) consequences of the marginal change."[34] A long-run marginal emission rates account for changes over time in electric infrastructure (storage and generation capacity), whereas short-run marginal emissions rates do not.[35] In December 2023, the Public Service Commission of the District of Columbia released an order that adopts the use of NREL's long-run marginal emission rates as part of electric utility benefit-cost analyses for forecasted greenhouse gas emissions and confirmed with actual dispatch data from PJM for historical emissions.[36]

These methodologies and data sources are commonly used within the electric sector to estimate the avoided emissions attributable to electric generation displaced on the grid; several of these methods are used by EPA in other contexts. EPA's WARM does not necessarily need to employ these methodologies, but its methodology should be informed by best practices within the electric sector to better capture the emissions impact associated with energy recovery at waste incineration facilities.

IV. Conclusions and Recommendations

As decision makers weigh the pros and cons of different waste management pathways to best align with state and local climate goals, accurate estimation of the relative emissions impact of waste management practices is critical. EPA's WARM aims to facilitate this comparison by providing a tool that compares the emissions impacts of various waste materials and management practices. Regrettably, WARM's current methodology and assumptions are flawed and include errors that together appear to result in an overestimation of net emission reductions from waste incineration facilities.

A critical error in WARM's assumptions is its exclusion of state RPS policies and the impact that waste incinerators may have on displacing other resources within the context of a REC market. EPA must recognize that REC sales from a landfill or waste incinerator mean that displacement must be measured by what other renewable resources would be used to meet that demand, and not on displacement of fossil fuels on the electric grid generally. This failure to account for displacement within a REC market can lead to an overestimation of avoided emissions resulting from energy recovery at waste incinerators.

In addition, our assessment has identified additional critiques of WARM's current methodology for estimating electric sector emission factors:

National Laboratory and National Renewable Energy Laboratory. NREL/TP-6A20-65005. Available at: http://www.nrel.gov/docs/fy16osti/65005.pdf

[33] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. 2023. *Cambium 2022 Scenario Descriptions and Documentation.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-84916. Available at: https://www.nrel.gov/docs/fy23osti/84916.pdf

[34] *Ibid.*, p.44.

[35] *Ibid.*, p.44.

[36] Public Service Commission of the District of Columbia. 2023. *GENERAL DOCKET NO. 2019-04-M, IN THE MATTER OF THE IMPLEMENTATION OF THE 2019 CLEAN ENERGY DC OMNIBUS ACT COMPLIANCE REQUIREMENTS.* Order No. 21398. Case No. GD-2019-04-M. Available at: https://edocket.dcpsc.org/apis/api/Filing/download?attachId=196851&guidFileName=8d6e3aa5-43e7-4e9d-8197-d2d36c1fb7bd.pdf p.11.

- WARM's emission factors for the electric sector are too simplistic and a poor proxy for marginal emissions.
- Avoided electric emissions are best estimated using the displacement of the marginal resource.
- Wind regularly serves as the marginal resource in some regions, meaning that emitting resources are not the only ones displaced.
- WARM's regions do not align with the regions that correspond to electric sector operations and dispatch decisions.

A majority of the flaws in WARM's grid displacement assumptions center around the misalignment with how these emissions are addressed within the electric sector. To improve the accuracy of estimating avoided emissions from energy recovery in the waste management sector, EPA must better approximate what resources are most likely to be displaced by waste incinerators based on the characteristics of these facilities compared to other resources on the grid. WARM's assumptions should be constructed with insight from best practices and other methodologies commonly utilized within the electric sector (and by EPA in other contexts) to ensure that its emission factors are representative of electric grid operations.

Outside of these main points, EPA's WARM does not fully serve its purpose of informing decision makers due to the following shortfalls:

- As a static model (that is, a model that does not look at changes over time), WARM is restricted to evaluating the emissions impact of waste management practices under current conditions, which does not account for the year-to-year evolution of electric generating resources associated with policy and program development. WARM should, at a minimum, assume that existing RPS laws are complied with when projecting the (declining) carbon intensity of displaced electricity over the time period that WARM's results are being referred to for future policy-making decisions. In other words, if WARM is used to make a decision on a 30-year investment in waste infrastructure, or in choosing between a 10-year waste disposal contract with a landfill versus an incinerator, WARM's results should be based on the understanding that fossil fuel displacement will not be the same over those time periods, and that any displacement credits given are expected to shrink over time, possibly altering the conclusion of which disposal method is preferable.
- WARM adds together direct and avoided emissions without reporting each type of emissions source or sink individually, making it impossible to compare the amount of greenhouse gases emitted into the atmosphere versus those avoided through energy recovery, material recovery, and/or carbon storage.
- WARM's spreadsheet-based model contains locked/fixed values, hidden tabs, and external links, which prevent third-party review or proper evaluation of model results.

Without addressing these issues, EPA's WARM cannot adequately inform forward-looking decision making within the waste management sector.