MEMORANDUM

To: Jennifer Brady, U.S. EPA

From: Chris Evans, Emily Rowan, Adam Brundage and Victoria Thompson, ICF

Date: January 16, 2009

Re: Updating WARM with regional electricity grid data

This memo explains the method used in the EPA's WAste Reduction Model (WARM) for calculating offsets associated with avoided electricity utility emissions from energy recovered at waste-to-energy (WTE) and landfill gas-to-energy (LFGTE) facilities. This memo provides justification for assuming that incremental increases in electricity generated by WTE and LFGTE offset GHG emissions from electricity generation at a *marginal* rate.

It also outlines an approach to improve the accuracy of these offset calculations by: (i) using data that more accurately estimates the avoided GHG emissions from electricity generation as a result of electricity produced from WTE and LFGTE and (ii) accounting for the regional variation in the carbon intensity of electricity produced across the U.S. electricity grid.

A. Key findings and recommendations

1. WARM assumes that energy captured by WTE and LFGTE offsets emissions from electricity generation at a marginal, fossil-fuel-only GHG emissions rate, rather than at the average rate. The rationale is that WARM is designed to model incremental changes in waste management practices that occur relative to a baseline scenario, and that changes in electricity generation from WTE and LFGTE will offset electricity generation on the margin.

2. The rationale for using a marginal emissions rate to calculate the electricity generation offset is supported by similar methodologies used by the UNFCCC, and the state of Massachusetts.

3. The calculation of electricity generation offsets in WARM can be further improved by taking into account more accurate estimates of the marginal emissions rate across geographic regions in the U.S., and by accounting for other uses of energy recovered from landfill gas. ICF recommends the following modifications to WARM:

    a. Use "non-baseload" emission factors that are calculated in the EPA's e-GRID database. These factors estimate the marginal emissions rate of electricity by weighting GHG emissions from plants that are more likely to respond to incremental changes in electricity supply and demand.

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b. Include regional versions of these non-baseload emission factors, to allow more user flexibility in WARM.

B. Current state: Electricity emissions offsets from WTE and LFGTE currently calculated in WARM

This section explains the rationale for estimating the benefits of energy recovery from WTE and LFGTE in WARM.

Currently, WARM assumes that energy recovered by WTE or LFGTE plants offsets electricity production at the weighted average emissions rate of all fossil-fuel power plants in the U.S. This emissions rate excludes sources of power such as nuclear power plants (which provide a steady level of baseload electricity) and renewables (which currently account for a small share of electricity production and are not considered a marginal source of electricity). As a result, the weighted average "fossil-fuel only" marginal emission factor is roughly 45% more carbon-intensive than the national average grid mix.[1]

The marginal GHG emissions rate assumption has a large impact on the benefit calculated for electricity offset by WTE and LFGTE. WARM is designed to estimate the GHG benefits from a change in waste management practices relative to a baseline scenario; it compares incremental changes that occur on the margin of what would have happened if practices stayed the same.

In the case of WTE or LFGTE, the model assumes that the energy recovered from these plants is used to produce electricity that offsets generation which would otherwise have been delivered by the national grid.[2] This represents an incremental change in the power supply which has not been taken into account in earlier decisions about the number, type, and operation characteristics of power plants built in the U.S.

As a result, existing power plants have to respond to an incremental increase in power from WTE or LFGTE by reducing their supply from what it would have been otherwise. In general, the type of plants that respond will be those with the highest operating cost; these tend to be plants which combust fuel, i.e., natural gas, oil, and coal power plants.

Since only a particular mix of plants respond to the incremental change, the emissions rate used to calculate the GHG benefit of offsetting electricity generated by power plants with WTE or LFGTE should be based on the mix of plants that actually respond to the incremental increase in supply, rather than the average emissions rate from all power plants. For simplicity, WARM currently takes this rate as the national weighted average of fossil-fuel plants.

C. Justification from other models and sources

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[1] "When estimating the GHG emission reductions attributable to utility emissions avoided, the electricity use displaced by waste management practices is assumed to be 100 percent fossil-derived, since fossil-based power plants typically operate at the margin, adjusting to conform to the demand for electricity." Source: EPA (2006) Solid Waste Management and Greenhouse Gases, p. ES-9.

[2] We also considered revisiting the existing WARM assumption that all gas recovery at landfills goes to electricity generation (instead of assuming that part is used in direct uses such as industrial boilers). However, an examinations of the logistical implications of changing this assumption convinced us that such a change would be very difficult and time consuming, and outside the level-of-effort of this task.

Using a marginal emissions rate to calculate the change in GHG emissions from incremental changes in electricity supply and demand is consistent with methodologies recommended by the United Nations and the state of Massachusetts.

The United Nations Framework Convention on Climate Change (UNFCCC) recommends using a "combined margin approach" to calculate energy savings from Clean Development Mechanism (CDM) projects that generate electricity from alternative energy sources. The combined margin incorporates both the short and long-term marginal impacts of a new source of electricity on the grid. WARM currently employs an "operating margin approach," which means that the predominant effect of an additional generation project is to impact the daily operation of other existing facilities in the grid.[3] Since the data requirements for a combined margin approach can be exhaustive, many other projects and organizations have followed a version of the operating margin methodology when calculating emissions reductions.[4] However, according to the CDM recommendations, accurate operating margins must exclude low-cost and must-run power plants in order to accurately assess the effect that additional power will have on the grid in the short term. In other words, this body of sophisticated literature recommends using a marginal rather than average rate when estimating displaced electricity under an operating margin approach.

Similarly, the state of Massachusetts uses marginal GHG emission rates to calculate the environmental impacts of electricity generation. The Massachusetts' Greenhouse Gas Emissions Policy and Protocol requires that projects take all feasible measures to avoid, minimize, or mitigate GHG emissions. This includes GHG emissions from purchased electricity usage. According the Protocol, GHG emissions from purchased electricity usage must be calculated based on the state's marginal electricity generation.[5]

A comprehensive review of other methodologies has not been conducted for this memo, but these two sources suggest that marginal GHG emissions rates are an acceptable assumption for calculating the impacts of additional changes in electricity generation relative to a baseline scenario.

D. Proposed improvements to calculating the marginal emissions rate of electricity generation

This section describes two improvements to the marginal GHG emission rate currently used by WARM for calculating WTE and LFGTE GHG offsets.

First, using a national average of only fossil-fuel plants to estimate the marginal emissions rate is a simplification that likely overestimates the actual marginal rate of emissions from electricity generation. While coal accounts for 50% of U.S. primary energy consumption—and 71% of fossil-fuel consumption—in the electricity sector[6], these plants may serve as baseload power with marginal changes in electricity supply met by natural gas plants in some areas. Natural gas plants have a much lower emissions rate than the coal-dominated national average of fossil-fuel plants.

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[3] Kartha, S., M. Lazarus, & M. Bosi (2002) Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector, OECD and IEA Information Paper. Pages 27-29..
[4] Ibid.
[5] Massachusetts Executive Office of Energy and Environmental Affairs (2007) MEPA Greenhouse Gas Emissions Policy and Protocol. Available at: http://www.mass.gov/envir/mepa/pdffiles/misc/GHG%20Policy%20FINAL.pdf.
[6] EIA (2008) Annual Energy Review 2007. Figure 5. Electricity Flow, 2007. Available at http://www.eia.doe.gov/aer/diagram5.html.

To improve on this simplifying assumption, WARM could be updated with "non-baseload" emission factors from the U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID). The "non-baseload" emission rates provide a more accurate estimate of the marginal emissions rate by scaling emissions from generating units based on their capacity factor. Plants that run at over 80% capacity are considered "baseload" generation and not included in the "non-baseload" emission factor; a share of generation from plants that run between 80% and 20% capacity is included in the emission factor based on a "linear relationship", and all plants with capacity factors below 20% are included.[7]

The effect of these improvements is shown in Figure 1. The left-most bar represents the marginal GHG emissions rate estimate from fossil-fuel electricity generation plants that is currently used in WARM. The middle bar shows the non-baseload GHG emissions rate from the e-GRID database for the U.S. The right-most bar shows the average GHG emissions rate of electricity generation in the U.S. The e-GRID estimate of the U.S. marginal GHG emission rate from electricity generation is 12% lower than the fossil-only assumption currently used in WARM for WTE and LFGTE.

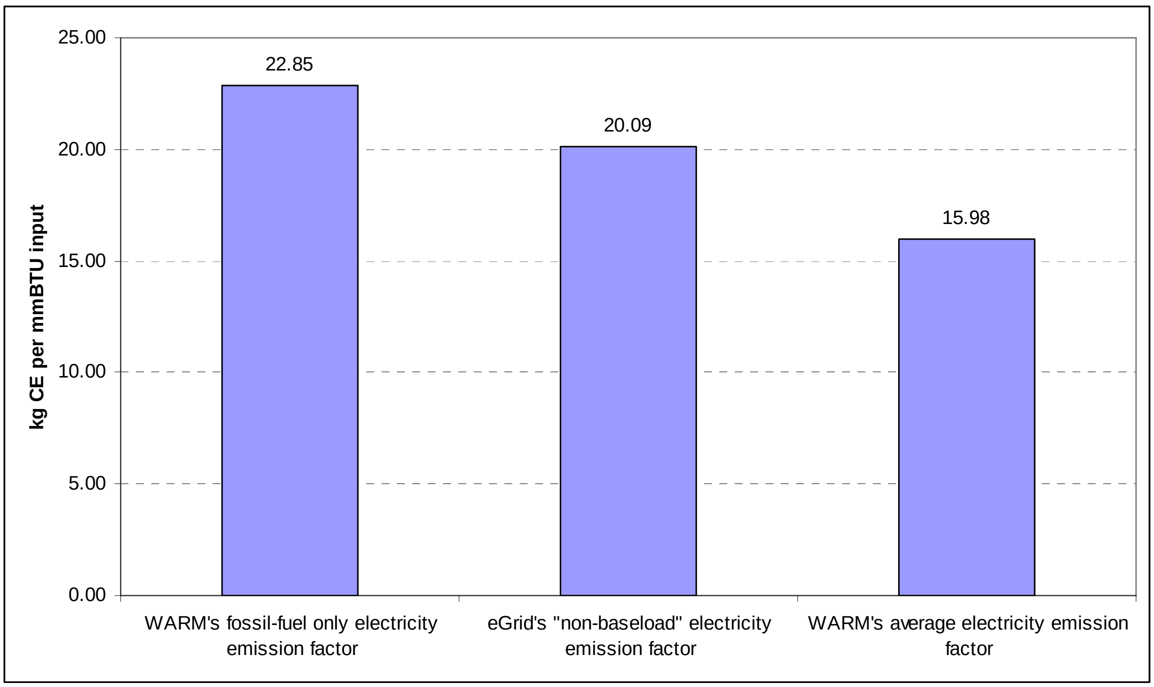

Figure 1: Effect of different assumptions on the national marginal GHG emissions rate of electricity generation in the U.S. Units are in kilograms of carbon-equivalent GHG emissions per million BTUs of fuel combusted.

Second, WARM currently use a national average to calculate the marginal GHG emissions rate of electricity generation. This assumption fails to capture regional differences in the emissions rate due to the variation in sources of electricity generation.

It is important to note the difference between eGRID NERC regions and sub-regions (which are based on the electricity transmission grid) and geographic regions based on state borders. ICF proposes using the state-level eGRID non-baseload emission factors and aggregating them by

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[7] E.H. Pechan & Associates (2006) The Emissions & Generation Resource Integrated Database for 2006 (eGRID2006) Technical Support Document. Prepared for the EPA, April 2007, p. 13.

geographic region similar to those in the Office Carbon Footprint Tool. The geographic regions are based on U.S. Census-Bureau designated areas.[8]

Programmatically and from a user perspective, it will be easier to consider the marginal offset emission rates based on the 9 geographic census regions (Pacific, East-North Central, East-South Central, Mid-Atlantic, Mountain, New England, South Atlantic, West-North Central, and West-South Central) rather than each individual state. However, since the regions will be based on state-level data from eGrid, a way will have to be found to create a weighted average of the non-baseload emission rates, which are in units of carbon equivalent per unit electricity output. To use an unweighted average of the states to create a regional emission factor would give an undue influence to states that produce much more or much less electricity compared to others. Ideally, a weighted average for a region would be created using the amount of non-baseload generation for each state. Unfortunately, this data is not publicly available from eGrid. Other options for weighting the state emission factors include (i) weighting based on a state's total electricity generation: this would assume that the ratio of non-baseload to total generation is the same for all states; (ii) weighting using a straight average, as described above; (iii) contacting eGrid for data on state-level non-baseload generation; however, this would leave future updates dependent on the availability of these data from eGrid; (iv) a weighted average based on state population. We recommend option (i).

E. Next steps

ICF recommends with the following next steps:

1. Update WARM and GHG MSTR with regional electricity generation data based on e-GRIDs "non-baseload" emission factors.
    a. Utilize state-level e-GRID data to aggregate into U.S. Census Bureau geographic regions similar to those listed in other EPA tools (i.e., The Office Carbon Footprint Tool), using total state generation numbers to create a weighted average of the state emission factors.
    b. Incorporate these factors into GHG_MSTR for the landfill and combustion pathways.
    c. Allow users of WARM to select a geographic region as a distinct user input. We would allow selection of a state which would automatically select the geographic region.

2. Use the rationale outlined in Section B to explain the use of marginal electricity generation GHG emission rates to stakeholders who may have questions or concerns about the sensitivity of WARM results to this assumption.

[8] U.S. Census Bureau, 2009. http://www.census.gov/geo/www/us_regdiv.pdf