NATIONAL ENERGY TECHNOLOGY LABORATORY

DRAFT-DELIBERATIVE-PREDECISIONAL

To: [redacted]
From: [redacted]
CC:
Date: October 20, 2023
RE: Synthesis of Thoughts on Interpreting the Market Adjustment Factors in the FECM LNG Export Study

INTRODUCTION

The LNG Analysis project is a collaborative effort between NETL (specifically the LCA competency), On-Location (specifically the National Energy Modeling System (NEMS) modeling team), and Pacific Northwest National Laboratory (PNNL, specifically the Global Change Assessment, or GCAM, modeling team). This project seeks to quantitatively assess the expected global effects of different quantities of US LNG exports.

Past studies done by NETL on LNG have largely been techno-economic analyses focused on expected costs per unit delivered (landed) or attributional life cycle analyses that only estimate the emissions and other impacts associated with units of LNG delivered. These LCA studies are limited in that they have not, to date, considered the consequences of delivering LNG, such as how domestic or foreign energy markets may be affected by increasing the supply of natural gas (e.g., whether, given additional supply, natural gas-fired power plants in Europe might take market share from other types of electric plants). Such market-based effects could lead to increases or decreases in GHG emissions.

In this project, the LCA component seeks to determine the consequences of additional exported volumes of US LNG, such as how additional available quantities of natural gas led to changes in the energy sectors of countries that purchase the LNG. These consequential effects are estimated by tracking differences in global CO_2 emissions and quantities of US LNG exported from the GCAM model scenarios. The result is a market adjustment factor (MAF) using the following equation, and would be considered a value to be combined with usual upstream LCA results for production of natural gas (currently -5.3 on an IPCC AR6-100 year basis).

$$MAF_{scenario\ n} = \frac{Global\ Emissions_{scenario\ n} - Global\ Emissions_{scenario\ 1}}{US\ LNG\ Exports_{scenario\ n} - US\ LNG\ Exports_{scenario\ 1}}$$

In this memo, we seek to provide additional background context on the data and methods that lead to the currently drafted MAF results (which may not appear in the final report), to ensure internal stakeholders are aware of them and to attempt to converge on appropriate text that frames these contextual issues.

ADDITIONAL ANALYSIS

Application of the MAF equation leverages GCAM results (and uses past NETL reports to harmonize them) that are meant to quantify the effect on global CO_2e emissions from increased US LNG exports. This global MAF is *calculated annually*, including interpolation of GHG and LNG scenario results between the 5-year GCAM timesteps, and is *reported cumulatively* over the 35-year time horizon of the study. In the recently reviewed version of the report, the global MAFs on an IPCC AR6-100 basis for Scenario 2 (vs. Scenario 1) was estimated at -5 g CO_2e/MJ and for Scenario 7 (vs. Scenario 6) was estimated at -3 g CO_2e/MJ. These results suggest that export of US NG leads to lower global emissions.

Such a result might be applied to support US LNG export authorization decisions. While these export authorizations are not contingent on knowing where the LNG might go, the reality is the LNG will go to a specific region and not to "the world" (and as discussed throughout the project, GCAM has a global LNG pool from which regions import it, and does not model explicit trades of LNG to or from any region).

We elected to attempt to look at the GCAM results *regionally* to attempt to quantify similar MAF values for all regions, but especially for expected future importers of LNG (e.g., China, India, Europe, Japan, and South Korea). As such, we developed a slightly different MAF equation of "delta CO2e for each region" divided by "delta ***imported*** LNG" for that region. We note that this creates several issues:

- This was not the focus of the original model, which was set up to focus on changes of exporting US LNG (as the control variable)
- GCAM has a global pool and thus we can not associate their reductions with US LNG
- By focusing on delta imported LNG, rather than "delta NG consumption" overall, we miss potential differences that exist from how regional markets choose local, pipeline, or LNG in its consumption mix, and such interactions are a feature of GCAM that is lost

In these hypothetical results, some are positive and some are negative. Table 1 summarizes these regional MAFs for a subset of GCAM regions From Table 1, China, Japan and EU-15 regions have slightly positive regional MAFs (suggesting emissions would increase), and the South Korea and India regions are slightly negative (decreasing emissions). Not obvious in the table is that if all four European GCAM regions are aggregated, its result is -4 g CO_2e/MJ. Some regions with large absolute values of MAFs are an order of magnitude higher, but they are small importers in the GCAM results.

An overall takeaway from this analysis is that the "regional MAFs" in the most prominent importers are generally bounded to a range of approximately -5 to +10 g CO_2e/MJ of gas imported. And it might be more appropriate to refer to this range of values in the main report.

Commented [ST1]: Are you recommending this range as the study results on MAF values to replace the single -5 value?

If yes, what do recommend as a the expected value? Asusming -5 and +10 braket the likley range (not sure what the correct statistical terms should be).

Table 1: Hypothetical Regional Market Adjustment Factors for GCAM Regions (S2)

Region	Cumulative MAF
USA	45.74
Australia_NZ	45.50
Africa_Eastern	16.40
Pakistan	9.40
Japan	**9.21**
EU-15	**7.94**
Southeast Asia	4.46
Taiwan	3.63
Mexico	2.53
China	**2.30**
South Korea	**-0.81**
Europe_Non_EU	-1.93
Africa_Southern	-2.02
South Africa	-2.57
India	**-4.36**
Brazil	-4.94
Colombia	-6.04
European Free Trade Association	-6.59
Argentina	-9.58
Africa_Western	-17.36
Middle East	-19.24
Europe_Eastern	-25.47
South America_Northern	-26.29
Russia	-29.71
Indonesia	-32.31
Central Asia	-33.27
Canada	-50.11
EU-12	-54.76
Africa_Northern	-64.61
South America_Southern	-66.75
Central America and Caribbean	-87.06

Note: (note that USA and Australia do import a small amount of LNG, which is why the large MAFs –net imports were not modeled, but it would not affect the main regions of interest).

Another underlying dynamic to synthesize is the issue of calculating and reporting the MAF annually vs. cumulatively. Figures 1 and 2 show the annual (red lines) and cumulative MAF values (blue lines) for the same subset of regions and also a zoom in on just the selected regions highlighted above. The value of the blue line at 2050 in these figures is the value in the table above.

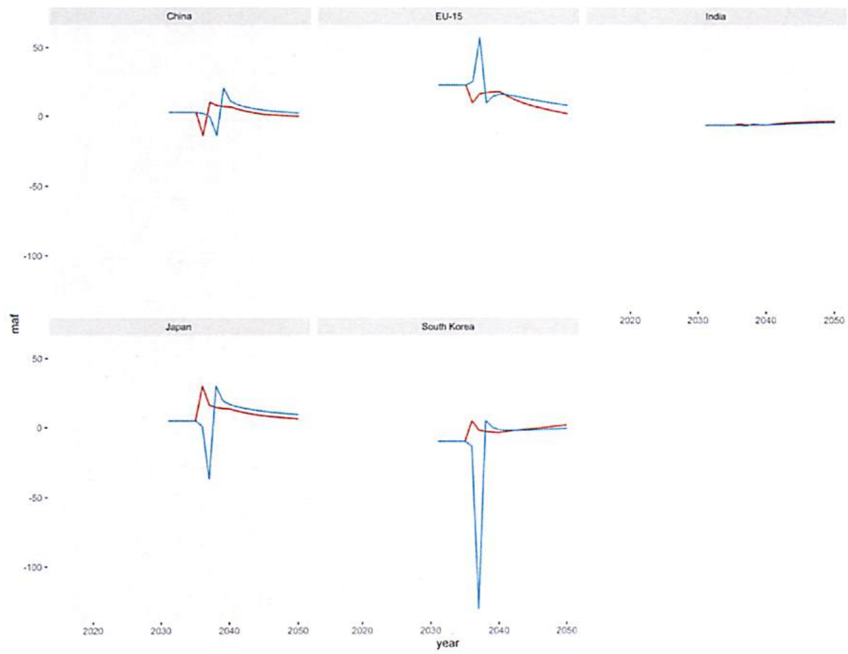

Figure 1: Hypothetical Regional MAFs for Expected Top Import Partners for US LNG in the Future

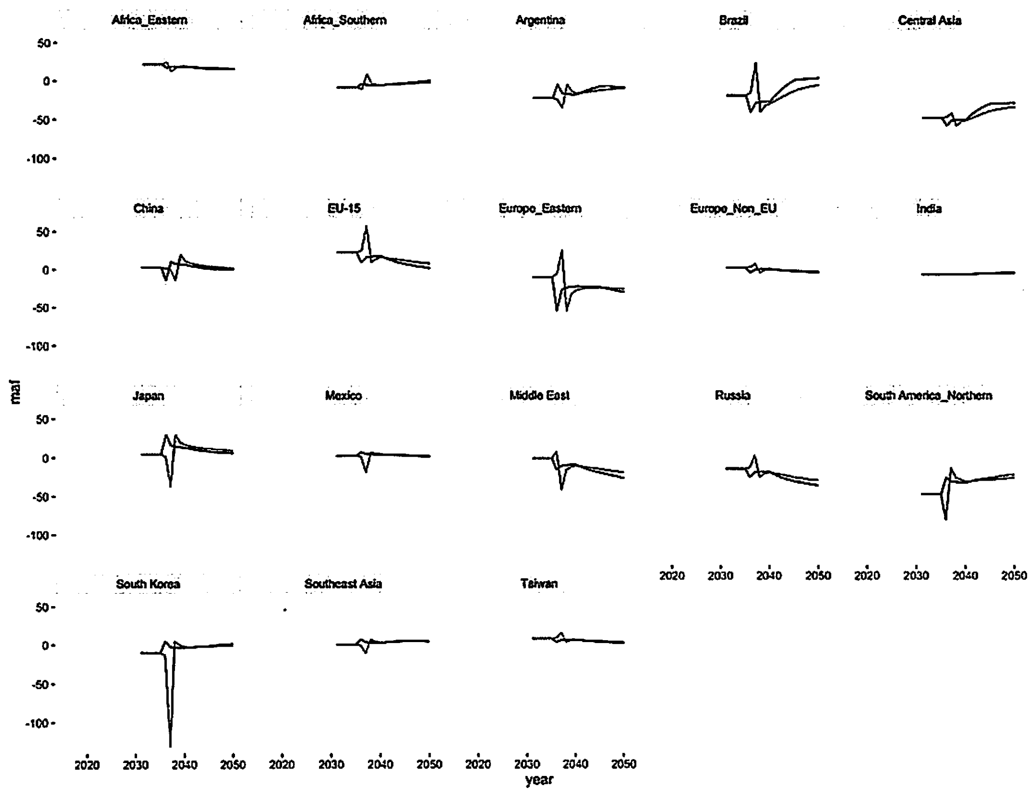

Figure 2: Hypothetical Regional Results for Expected Top Import Partners for US LNG in the Future

Figure 3 shows the not previously shown time series of annual and *global* MAF values that have been previously summarized in the report (and memo, above).

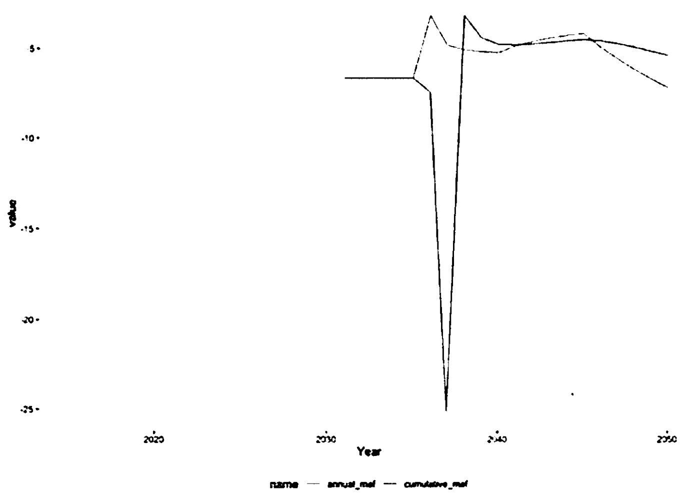

Figure 3: Global Annual and Cumulative MAFs

These results show that there are some negative-positive spikes of annual MAF values in the period 2035-2040, which happen due to a few reasons:

(1) The scenario results for CO_2e and LNG finally start to differ in that time period (but recalling that S1 and S2 separately depend on GCAM or NEMS for the underlying LNG export values)

(2) As they only differ in this time period by a small amount in this time period, small and less than 1 values in the (delta LNG) denominator can lead to visible (swings in) MAF results.

(3) There are changes in the sign of the CO2e and LNG deltas or the MAF (e.g., initially negative/negative = positive and then a slight change in one value and its then -/+ = negative), and vice versa

(4) Interpolating the underlying values (CO_2 emissions, LNG exports) between 5-year model timesteps separately before dividing them, rather than interpolating the every 5 year MAF results.

Finally, additional care may be needed in describing the presentation and application of the cumulative MAF values as the default metric in the study. While LNG is going to be exported in a particular year into the global market (e.g., 2025), which would lead to a specific set of emissions (if we believed the model, it would be the specific value shown for that year in the graph), the *cumulative* MAF (blue line value at 2050) is what is summarized in the study.

While the decisions or authorizations are connected to these annual emission and MAF results, there are biases that could be introduced if only the annual (or 5-year cumulative period) MAFs were used (for example, a five year period with a positive or negative value when the cumulative is the opposite). It thus seems appropriate given the results in hand to assume that exports would continue for the foreseeable future into the global market, and while the graphical results show how they might vary year to year, the cumulative result over the entire 35 year period of the GCAM model results is ~~an~~ the appropriate metric.

Commented [ST2]: At what time step interval? 15, 20, 30, 35, 50 years? How do we determine the correct cumulative time period? Basing it on the export authorization time period for consistency? Or a point with greater market certainty?