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To: Rachel Schmeltz, U.S. EPA/CCD

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Subject: Methodological refinements as applied in the 1990-2016 estimates of U.S. greenhouse gas emissions from MSW landfills to account for emissions from facilities not reporting to the Greenhouse Gas Reporting Program

1. Background

For the 1990-2015 Inventory of U.S. Greenhouse Gas Emissions and Sinks (the Inventory), EPA made methodological changes to begin using the net methane emissions for municipal solid waste (MSW) landfills as directly reported to the Greenhouse Gas Reporting Program (GHGRP). However, because the GHGRP does not require emissions reporting from all MSW landfills in the United States, EPA developed a scale-up factor as a proxy to account for emissions from MSW landfills that do not report to the program. The scale-up factor was applied to the total GHGRP net emissions each year in the time series that the GHGRP data were used. Details on the methodology applied for the 1990-2015 Inventory can be found in the memorandum entitled, "Methodological changes to the methane emissions from municipal solid waste landfills as reflected in the public review draft of the 1990–2015 GHG Inventory" (RTI 2017), and in the Waste Chapter of the 1990-2015 Inventory[1]. A conservative scale-up factor (12.5 percent) was applied in the 1990-2015 Inventory, based on the average percent difference in net emissions between the 1990-2014 Inventory and the GHGRP net emissions, with the intention of performing a more in-depth analysis of the quantities of waste landfilled at facilities that do not report to the GHGRP for the 1990-2016 Inventory.

In preparation for the 1990-2016 Inventory, EPA sought to revise the scale-up factor of 12.5 percent from the 1990-2015 Inventory after receiving multiple comments that the value was too high. To begin addressing these comments, EPA worked to compile a list of landfills which do not report to the GHGRP. Using information from these non-reporting landfills, EPA could compare data between the non-reporting landfills and landfills reporting to the GHGRP to develop a more accurate scale-up factor. In an August 2017 stakeholder webinar, EPA presented its work in compiling a non-reporting landfills database and outlined four alternative scale-up factors: 1) 11 percent based on total waste-in-place; 2) 9 percent based on waste-in-place adjusted for 23 percent construction and demolition and inert waste disposed; 3) 34 percent based on estimated emissions from total waste-in-place; and 4) 26 percent based on estimated emissions from waste-in-place adjusted for 23 percent construction and demolition and inert waste disposed. Based on feedback from stakeholders, EPA pursued alternative 2 and developed a scale-up factor based on waste-in-place adjusted for 23 percent construction and demolition and inert waste.

This memorandum documents the methodology used and the findings from this in-depth analysis, as well as the revisions made to the scale-up factor (from 12.5 percent to 9 percent) to account for emissions from non-reporting landfills in the 1990-2016 Inventory.

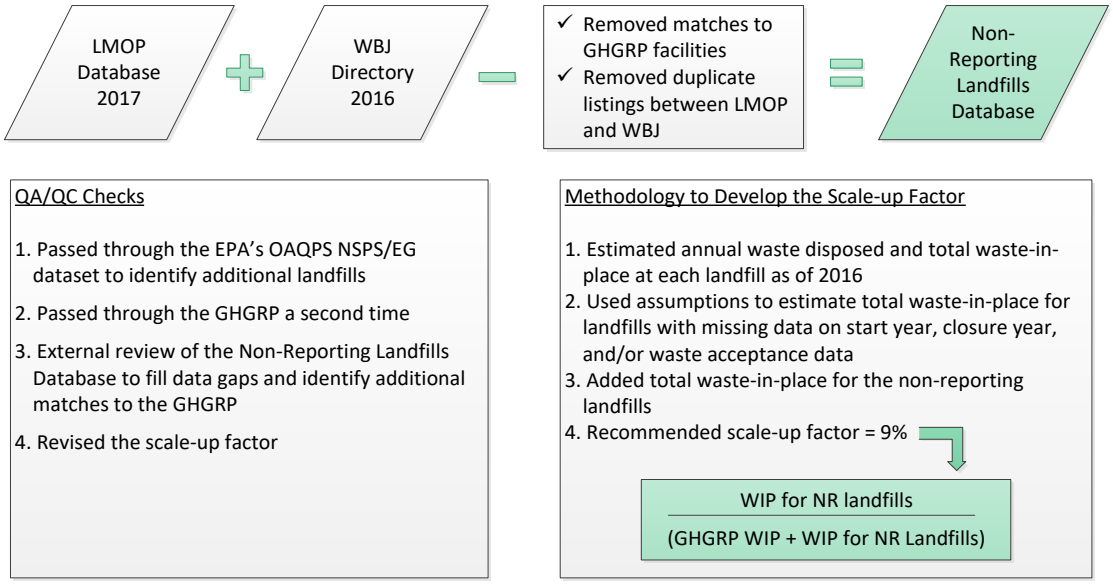
[1] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

2. Methodology Used to Develop the Scale-up Factor for the 1990-2016 Inventory

In theory, nationwide MSW landfill methane emissions should equal the net emissions reported to the GHGRP plus net methane emissions from landfills that do not report to the GHGRP. One way to estimate net methane emissions from landfills that do not report to the GHGRP is to determine the annual quantity of waste landfilled for this community, identify facilities with landfill gas collection and control systems using the Inventory recovery databases to account for recovery, and then estimate emissions via the Inventory Waste Model. As documented in the 1990-2016 Inventory Waste Chapter, there are several uncertainties associated with the activity data itself (i.e., estimates of MSW landfilled) and the various emission factors used in the Waste Model to estimate methane generation and emissions. Therefore, as an alternative we also investigated developing a scale-up factor based on total waste-in-place (i.e., the cumulative total waste disposed in MSW landfills), in order to minimize the uncertainty added with the use of the scale-up factor.

Figure 1 shows the main steps used to develop the scale-up factor for the 1990-2016 Inventory. The Inventory compilers developed a database (referred to as the Non-Reporting (NR) Landfills Database) from two secondary sources – the Landfill Methane Outreach Program (LMOP) Database 2017 (EPA 2017a) and the Waste Business Journal Directory (WBJ) Database 2016 (WBJ 2016); extracted landfills matched to GHGRP reporting facilities and duplicate facilities between LMOP and WBJ; and estimated total waste in-place (WIP) and methane emissions for the non-reporting community.

Figure 1. Methodology used to develop the scale-up factor



The resulting scale-up factor was applied to the net emissions reported to the GHGRP as follows:

Total MSW landfill emissions = (Net emissions reported to GHGRP) * (1 + scale-up factor)

Section 2.1 describes steps taken to identify MSW landfills that did not report to the GHGRP in 2016.

Section 2.2 describes how total WIP and methane emissions were estimated for the non-reporting landfills.

2.1 Identification of Non-Reporting Landfills

Two databases, the LMOP Database 2017 (EPA 2017a) and the Waste Business Journal (WBJ) Directory 2016 (WBJ 2016), were used as the main sources of information to identify non-reporting landfills and the total waste-in-place (WIP) at these facilities.

Data contained within the LMOP database are voluntarily gathered and compiled into an annually published database available at https://www.epa.gov/lmop/landfill-gas-energy-project-data-and-landfill-technical-data. The LMOP Database does not contain records on every landfill in the U.S. It focuses on landfills that either have landfill gas-to-energy projects or are candidates for such projects. While the Database is published annually, the data are updated periodically and the year the record was last updated is included. Industry stakeholders and waste officials opt to share information regarding their landfill, including permitted waste capacity, landfill open and closure years, total WIP, and data pertaining to the landfill gas collection and control projects at the landfill.

The LMOP Database 2017 contains records on 2,450 unique MSW landfills that are either accepting waste or have closed. 1,203 (49 percent) of the landfills in LMOP are not associated with a GHGRP identification number. WIP data are not presented for 434 of the 2,450 landfills (17.7 percent). WIP can be estimated using landfill design capacity and the first year or waste acceptance and year of closure or estimated closure however. 108 of the 434 landfills have landfill design capacity data and a start year such that WIP could be estimated. Landfill design capacity and WIP data are not available for 323 of these 434 landfills, leaving no way to estimate WIP.

The WBJ Directory contains data collected from waste facility owners and operators as collected by a telephone survey (see **Table 1**). This proprietary Directory is published annually; however, the date each record was last updated is not included. Of the more than 9,000 facilities listed in the WBJ Directory, only 1,782 are indicated to be landfills. In addition to geographical descriptors such as physical address and coordinates, the Directory contains information on a facility's total waste volume, operating hours and days per year, waste types accepted, remaining landfill capacity (in tons), and ownership information. There is no indication as to whether a landfill is open or closed, or whether it is permitted/classified as an MSW, industrial waste, or other type of landfill.

Like the LMOP Database, the WBJ Directory contains incomplete data for some facilities due to the voluntary nature of the data collection. For example, data on total waste acceptance and/or start/closure years of the landfill are critical factors required to estimate WIP and one or more of these data elements are not available for 374 of the 1,782 landfills listed in the database (21 percent).

Table 1. Number of Facilities by Type in the Waste Business Journal Directory 2017

Facility Type	Count
Composting	570
Demolition Landfill	1174
Incinerator	18

Facility Type	Count
Landfill	1782
Materials Recovery	1171
Materials Recovery & Transfer	682
Rail Transload Facility	14
Refuse Derived Plant	11
Transfer Station	3641
Waste-to-Energy Plant	94

To identify the non-reporting landfills, facilities across the two databases were compared to facilities reporting to the GHGRP to identify and remove matches with the GHGRP (EPA 2017b), and then compared to each other to match the same landfills across one or more databases. To accomplish this, the following steps were taken:

1. **Data preening**: We started with the WBJ Directory because it contained the largest number of facilities across the databases. The WBJ Directory was filtered on those facilities categorized as 'landfills' in the Database to exclude all other waste facility types. The WBJ Directory includes a column that indicates principal waste type acceptance; only those with a principal waste type acceptance of MSW were included (for 227 landfills MSW was not indicated as their principal waste, so they were filtered out). Next, all landfills within the LMOP database were pulled and included in an intermediary database. The initial list included 4,005 facilities (1,555 WBJ facilities + 2,450 LMOP facilities).

2. **Exact name and state matching**: The first round of matching was conducted by comparing the facility names in the LMOP database and WBJ Directory to those included in the GHGRP database. If an exact name match was found, an additional pass was made to match the associated states within the GHGRP and WBJ and/or LMOP to confirm the match. If these two identifiers aligned, the facilities were considered matches and were removed from the non-reporting landfill analysis. However, during this matching process, we found that the same landfill can have different names across the databases and in other sources of information; therefore, this step was not completely effective in identifying all matches across the databases.

3. **Location-based matching**: The second round of matching compared the reported latitudinal and longitudinal coordinates of facilities across the databases. If a facility in the LMOP and/or WBJ had coordinates that were either a) an exact match, or b) an approximate match (approximate for this analysis being a difference of 0.02 or less) to coordinates of a facility within the GHGRP, these facilities were considered a match. Information from the LMOP and/or WBJ facility that matched with a GHGRP facility was removed from the non-reporting landfill analysis. This exercise was also completed for the facilities already matched in Step 2 as a quality control check; no changes were made to those facilities as the matches in Step 2 were found to be accurate based on location. However, during this step we found that coordinates for the same landfill were different across the databases (by more than a 0.02 difference), making this comparison of coordinates unreliable as well. Plotting the coordinates and visualizing the

facilities in Google Maps, for example, is effective in identifying possible matches of the same landfill, but requires a significant amount of effort for several thousand facilities, therefore we did not undertake this additional step for all facilities, only for those with similar (but not identical) names located within the same county.

4. **Matching between LMOP and WBJ**: Steps 2 and 3 matched LMOP and WBJ facilities to the GHGRP facilities. This next step was needed to match LMOP and WBJ facilities remaining in the non-reporting landfills dataset to each other to avoid duplication. To eliminate duplicates, Steps 2 and 3 were repeated for the LMOP and WBJ by using an Excel formula to identify exact name/state combinations, and manually to identify similar name and same state matches. When matches were identified, the duplicate was removed. This step yielded several hundred matches between the WBJ and LMOP databases, most with slightly different name variations.

5. **GHGRP QC Check**: After completing the previous steps, there were still GHGRP facilities that had not been matched to a landfill in either the LMOP or WBJ databases. Since the GHGRP program ideally represents the largest emitters within the United States and the LMOP and WBJ databases contain a larger number of GHGRP facilities, we expected the number of unmatched GHGRP facilities to be fairly low, ideally zero, as they would likely be found in one of the two other databases. A total of 37 unmatched GHGRP landfills were initially found. Each of these 37 landfills were manually compared against facilities within the non-reporting landfill database. We also conducted Internet searches to find alternative names to attempt to match them to a facility in the LMOP or WBJ databases. Two of the 37 landfills were matched during this exercise, leaving 35 unmatched GHGRP facilities within the dataset. Additional passes were made to match these facilities after the External Expert Review (see Section 3 of this memorandum).

6. **Comparison to OAQPS database**: The list of non-reporting landfills was then compared (by facility name + state) to those included in EPA's Office of Air Quality Planning and Standards dataset (OAQPS) (EPA 2016), which consists of 1,986 facilities. This database was developed in 2015 for the revisions to the New Source Performance Standards (NSPS) and Emissions Guidelines (EG) for MSW landfills and consists of certain facilities that reported to the GHGRP up to Reporting Year 2014, certain facilities included in the LMOP database up to 2014, some NSPS/EG model landfills, and state permitting agency information on landfills expected to be modified in the next 5 years. The OAQPS database includes more facilities than the GHGRP, but it is not a comprehensive list as stated in its accompanying memorandum:

> "The landfill databases used in the July 2014 NSPS proposal and ANPRM were updated using data from the GHGRP, select web searches, and input from EPA Regions and state and local regulatory agencies on landfills expected to undergo a modification in the next 5 years. Landfills that stopped accepting waste on or before November 8, 1987 are not affected by the EG. To accommodate this rule applicability criterion for the purposes of the dataset, any landfill closing before 1988 was removed from the consolidated dataset." (ERG memo to H. Ward, July 2015).

After comparing the list of non-reporting landfills to the OAQPS database, we found:

- 5 landfills that were not included in the initial combined list of LMOP and WBJ facilities (the combined databases included up to 4,005 facilities); and

- 22 facilities in the WBJ Directory that were removed from our list during the "data preening" exercise, because they were not coded as a landfill in the WBJ Directory, were added back in.

After these steps, the NR Landfills Database consisted of 1,773 facilities.

2.2 Estimated Scale-up Factors: Waste-In-Place and Methane Emissions

After the matching exercise was completed, we exported data on landfill open and closure years, waste acceptance and WIP, and other relevant data from both the LMOP and WBJ databases. A total of 1,069 landfills from the NR Landfills Database contained all the information necessary to estimate WIP; however, hundreds of landfills were still missing data needed to calculate WIP values:

- 267 landfills did not have any data needed to estimate WIP and therefore, WIP could not be estimated. These facilities did not have WIP data from LMOP or a waste acceptance rate from WBJ and did not have a start year and closure year. These landfills remained in the NR Landfills Database, but additional data gathering would be necessary.
- 437 landfills had one or more missing data elements, so that the WIP could be estimated with some assumptions. These assumptions included (1) "forced" start year 30 years prior to the landfill closure year if a closure date was included; or (2) forced closure year of 2016 if the landfill was indicated as closed and a closure year was not included in the source database.
- An additional assumption was made for some landfills included in both LMOP and WBJ where both databases had enough data to estimate WIP (n=178 landfills). For these 178 landfills, the total WIP differed greatly, many by an order of magnitude and we averaged the WIP between the two databases and assigned an average WIP to each facility.

After applying the above assumptions, the total WIP across the non-reporting facilities was approximately 2,489 million metric tons, or 22 percent of the total estimated WIP in the universe of landfills (as presented in **Table 2**). Using this method, the scale-up factor of 22 percent would be applied to the directly reported GHGRP emissions to generate a complete Inventory estimate.

Table 2. Waste-in-Place (WIP) for GHGRP Reporting and Non-Reporting Landfills in 2016

Category	WIP (million metric tons)	Percentage of Total
Non-reporting landfills	2,489	22 percent
Reporting landfills	9,082	78 percent
Total	11,571	100 percent

We also used the EPA's Waste Model to estimate the methane emissions from the non-reporting landfills. First, we summed annual waste disposal by year across all landfills and then entered the data into the Waste Model using the same assumptions for the methane generation equation as used in the Inventory for years 1990-2004. As presented in **Table 3**, the estimated net methane emissions for the non-reporting landfills is approximately 1.90 million metric tons. Using this method, the scale-up factor of 34 percent

would need to be applied to the directly reported GHGRP emissions in order to generate a complete national Inventory.

Table 3. Net Methane Emissions for GHGRP Reporting and Non-reporting Landfills (as estimated) in 2016

Category	Net Methane Emissions (million metric tons)	Percentage of Total
Non-reporting landfills	1.90	34 percent
Reporting landfills	3.64	66 percent
Total	5.54	100 percent

There is a large amount of uncertainty in the estimated scale-up factors of 22 percent (based on WIP) and 34 percent (based on net methane missions) given the number of landfills with incomplete data and inconsistency in the year of the data for each landfill

3. Expert Review and Revisions to the NR Landfills Database

As an attempt to fill the data gaps, EPA shared the NR Landfills Database (consisting of 1,773 landfills with data including, but not limited to, geographical location, start year, closure year, waste acceptance, and total WIP) with several external organizations[2] to voluntarily solicit their expert opinions on the data used and steps taken to estimate the scale-up factor. The objective of the external review was also to identify additional matches from the NR Landfills Database to the GHGRP database and across the LMOP and WBJ Databases, and to provide missing data on WIP, years of operation, etc.

The reviewers were asked to provide data in a consistent format. Given the number of facilities in the database, no constraints were placed on how they reviewed the database. In general, the list was sorted by highest value of WIP, by state, or by owning/operating organization. A variety of methods were used to identify missing data, including internal database and Internet searches. The quality of data identified through the Internet searches was not assessed, but ranged from state published reports, lists of permitted facilities, and municipal waste management Web sites. The data provided were from inconsistent years, which further increased the uncertainty. For example, a WIP data point may have been provided for 2009 for one landfill and 2000 for another. These uncertainties and data quality issues are represented by the uncertainty factor applied to the scale-up factor when estimating landfill emissions (see Section 5 of this memorandum).

During this review, an additional 229 facilities were removed from the NR Landfills Database for the following reasons:

[2] The reviewers consisted of those in the waste industry (Waste Management, Inc.; Republic Services; representatives from SWANA, and SCS Engineers), and LMOP. An EPA intern also participated in this review to find matched landfills and fill in data that was missing. During this time, RTI staff conducted a second pass at the landfills to fill in missing data, where possible.

- 7 were removed because they were identified as being duplicates (i.e., they were in both LMOP and WBJ and were not previously identified because of name variations)
- 57 were removed because the reviewers provided information confirming or indicating they were not MSW landfills
- 165 were removed because the reviewers provided information confirming matches with GHGRP facilities based on a name variation and/or location match.

A total of 1,207 unique landfills were reviewed by the external expert reviewers, LMOP, the EPA intern, and additional RTI staff. The remaining 566 landfills were not reviewed given time constraints of the Inventory development cycle and the difficulty in finding additional data; however, these 566 landfills are considered the smallest in terms of estimated WIP and therefore, are expected to have a smaller impact on estimated methane emissions.

Table 4 presents a high-level summary of the expert review. Most importantly, the total number of landfills in the NR Landfills Database decreased from 1,773 to 1,544 due to the additional landfills that were matched to those reporting to the GHGRP, those identified as duplicates between LMOP and WBJ or those that were not MSW landfills. In addition, reviewer-provided data were received for 829 landfills, half of which were updated or new data (n = 403 landfills) pertaining to WIP that could be used to estimate a revised scale-up factor.

Table 4. Summary of Reviewer Input Provided on the Non-reporting Landfills Database

Category	Number	Comments
Initial Number	1,773	
Reviewed	**1,207**	279 of the total landfills were reviewed by more than one reviewer
Matches to GHGRP facilities	*165*	*Matched by landfill name aliases, geographical plotting*
Non-MSW landfills	*57*	*Mostly transfer stations, limited information found online*
Duplicates	*7*	*Similar names between LMOP and WBJ databases*
Total removed	*229*	
Not reviewed	**566**	37 percent of 1,544
New Total Number	**1,544**	
New information provided for	829*	*Less than half of the input was related to WIP (n=403) and 33 percent of that data was for 1 year only
Unmatched GHGRP facilities	29	Indicates that the NR Landfills Database does not provide complete coverage

Despite this additional review, there is still a significant amount of missing data in the NR Landfills Database:

- 234 landfills did not have any data required to estimate WIP (down from 267) and therefore, WIP could not be estimated. These facilities did not have WIP data from LMOP or a waste acceptance rate from WBJ and did not have a start year and closure year. These landfills remained in the NR Landfills Database, but additional data gathering would be necessary.
- 341 landfills had one or more missing data element (down from 437 in the initial version of the database), and the WIP could be calculated with some assumptions. These assumptions included (1) "forced" start year 30 years prior if a closure date was included; or (2) forced closure year of 2016 if a closure year was not included in the source database and the landfill was noted as closed.

Nearly 63 percent of the facilities in the NR Landfills Database have enough information to estimate total WIP; however, we must note that most of this information is coming from LMOP or WBJ versus directly verified reviewer feedback.

Additionally, 29 GHGRP landfills still cannot be matched to those in the NR Landfills Database. This reveals that the NR Landfills Database is not complete and that the scale-up factor may possibly be overestimating the contribution of non-reporting landfills to the total emissions, since if those 29 landfills can be matched to those in the NR Landfill database, then the WIP of those landfills could be removed from the scale-up factor. Next steps to investigate this gap include searching the WBJ Directory and LMOP database again for matches to these 29 GHGRP facilities.

In addition to the reviewer-provided data, we received other comments during the expert review of the Waste Chapter of 1990-2016 Inventory. These comments were in response to 'charge questions' distributed with the expert review material in order to focus the review on the following:

- There are no other datasets to use (aside from LMOP and WBJ).
- A scale-up factor of 12.5 percent is too high.
- Base the scale-up factor on WIP, not first order decay estimated emissions
- It is not necessary to make special account of GHGRP facilities that have legitimately stopped reporting to the program via the off-ramp provisions
- Do not overcomplicate the methodology by applying different scale-up factors for different years, or blocks of years over the time series.

After reviewing all the input, we compiled the various sets of comments and data inputs on specific landfills in the NR Landfills database and revised the total WIP to 0.922 million metric tons as presented in **Table 5**.

Table 5. Revised Waste-in-Place (WIP) for Non-reporting Landfills in 2016

Category	Estimated WIP (million metric tons)
Landfills with all required data to estimate WIP	0.510
Landfills with 1 or more missing data element (forced assumptions to estimate start year or closure year)	0.412
Total	0.922

Note: forcing data refers to the assumptions made for the start and closure years.

4. Results and Impact on the 1990-2016 Inventory

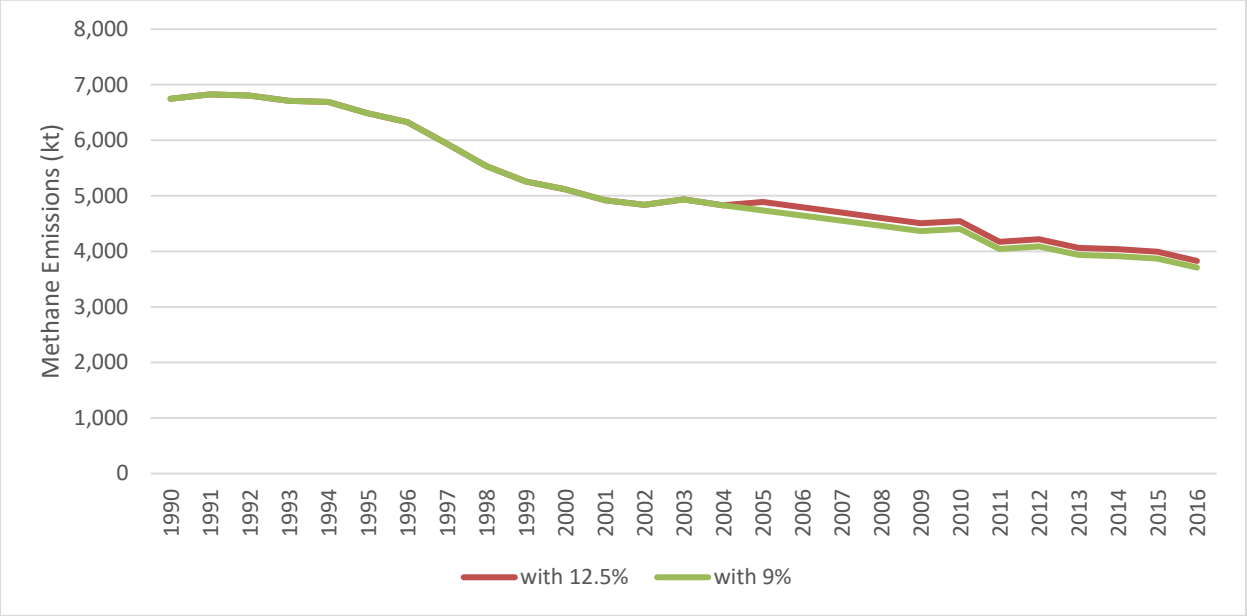
The recommended scale-up factor based on the non-reporting landfill WIP estimates of 0.92 million metric tons is 9 percent (see **Table 6**).

Table 6. Revised Waste-in-Place (WIP) for GHGRP Reporting and Non-reporting Landfills in 2016

Category	Estimated WIP (million metric tons)	Percentage
Non-reporting facilities	0.92	9 percent
GHGRP facilities	9.08	91 percent
Total	10.0	100 percent

The scale-up factor used in the 1990-2015 Inventory was 12.5 percent and a lower scale-up factor reduces overall emissions over the time series by an average of approximately 3 percent as shown in **Figure 2**. The same 9 percent scale-up factor will be applied each year the GHGRP reported emissions are used in the Inventory (2005 to date). Prior to 2005, the Inventory uses the FOD model exclusively to estimate emissions from all landfills, therefore the scale-up factor is not needed for those years in the time series. Emissions for the years 2005 to 2009 are estimated by back-casting of net CH_4 emissions that are reported by landfill facilities under the GHGRP for 2010 to 2016. The 9 percent scale-up factor is applied to the GHGRP emissions during these years for completeness. For 2010 to 2016, directly reported net methane emissions to the GHGRP are used with a 9 percent scale-up factor again applied to account for landfills that are not required to report to the GHGRP. It is important to note that the GHGRP reported emissions may be subject to change annually because the reporting facilities may re-submit revised GHG reports for any reporting year to correct any errors that they or EPA identify. These report resubmissions would impact the total GHGRP emissions and back-casted emissions from 2005 to 2009. However, EPA does not intend to revise the scale-up factor from one Inventory year to the next.

Figure 2. Impact of Two Scale-up Factors (12.5 percent and 9 percent) over the Time Series of the 1990-2016 Inventory



5. Recommended Uncertainty Factor

Limited information is available for landfills that do not report to the GHGRP. RTI developed the list of landfills that do not report to the GHGRP with the intent of quantifying the total WIP for these landfills such that the percentage of the total would equal the scale-up factor. Many gaps still exist in the NR Landfills Database, and assumptions were made for many landfills in order to estimate the scale-up factor. Additionally, a simple methodology was used to back-cast emissions for 2005 to 2009 using the GHGRP emissions from 2010 to 2016. This methodology does not factor in annual landfill to landfill changes that may occur in CH_4 generation and recovery.

The UNFCCC requires Annex I parties to quantitatively estimate the uncertainty of the data used for all source and sink categories using either a propagation of error approach, or a Monte Carlo simulation. EPA opts to use a Monte Carlo simulation for estimating uncertainty in the Waste chapter, defined as the 2.5 and 97.5 percentile bounds around a 95 percent confidence interval (IPCC 2006). Because of this, an uncertainty factor of 25 percent is recommended for the estimated emissions from 2005 to 2016 due to the application of the scale-up factor to the GHGRP data.

6. Discussion and Next Steps

Using a scale-up factor was deemed by the Inventory compilers and expert reviewers as the best way to augment the GHGRP data to develop a more complete and accurate national emissions inventory. We recommend using a scale-up factor based on total WIP because it avoids the additional uncertainties surrounding the methane generation equation, including that of the composition of waste disposed and other emission factors (fraction of degradable organic carbon, decay rate, landfill methane oxidation

factor, etc.). Because a comprehensive database of all active and closed MSW landfills in the United States does not exist, the Inventory compilers used resources that were available. There are several limitations with the approach used. First, the databases used to compile the NR Landfills Database most likely do not include the universe of MSW landfills given that there are 29 GHGRP facilities that could not be matched and that solid waste disposed in the U.S. territories is not comprehensively addressed. LMOP reviewers of the NR Landfills Database also identified a few more landfills that were not originally in the WBJ and LMOP databases. Second, the GHGRP data were incorporated into the Inventory to use an existing program and to reduce overall uncertainty, however the data gaps and data quality issues in the NR Landfills Database used to develop the scale-up factor instead introduced uncertainty, which impacts the benefits gained from using the GHGRP data.

We have identified several additional steps to further refine the scale-up factor and reduce the uncertainty in the Inventory calculations for the subsequent Inventory cycle. First, we will collect information about solid waste management in the U.S. territories and investigate the additional landfills identified by the LMOP reviewers. Any newly identified non-reporting landfills will be added to the NR Landfills Database and the scale-up factor will be re-estimated, as appropriate. Second, EPA will perform limited Google Maps searching for a certain number of landfills within the NR Landfills Database which may further eliminate duplication within the dataset. Third, EPA will continue communicating with other EPA divisions, researchers, and industry stakeholders to enhance the NR Landfills Database and attempt to fill in existing data gaps to make a more comprehensive database.

7. References

EPA (2017a) Landfill Methane Outreach Program (LMOP). 2017 Landfill and Project Level Data. June 2017. Available online at: < https://www.epa.gov/lmop/landfill-technical-data>.

EPA (2017b) Greenhouse Gas Reporting Program (GHGRP). 2017 Envirofacts. Subpart HH: Municipal Solid Waste Landfills. Available online at: <http://www.epa.gov/enviro/facts/ghg/search.html>.

EPA (2016). 2016 Municipal Solid Waste New Source Performance Standards (NSPS) and Emission Guidelines (EG) Data Files. Available online at: <https://www.epa.gov/stationary-sources-air-pollution/2016-municipal-solid-waste-new-source-performance-standards-nsps>.

ERG (2015). *Summary of Updated Landfill Dataset Used in the Cost and Emission Impacts Analysis of Landfill Regulations*. Memorandum prepared by ERG for H. Ward (EPA). July 2015.

IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. Chapter 3: Uncertainties. [C. Frey, J. Penman, L. Hanle, S. Monni, and S. Ogle].

RTI (2017). *Methodological changes to the methane emissions from municipal solid waste landfills as reflected in the public review draft of the 1990-2015 GHG Inventory*. Memorandum prepared by K. Bronstein and M. McGrath for R. Schmeltz (EPA). March 31, 2017.

Waste Business Journal (WBJ) (2016) Directory of Waste Processing & Disposal Sites 2016.