Date Submitted: October 12, 2023

Agresti Energy, LLC

Location of Headquarters: Fishers, Indiana, USA

PETITION TO ADD POTENTIAL BIOINTERMEDIATES TO THE REGULATORY DEFINITION

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Appendices

A.) Request and Background

Agresti Energy is kindly requesting that EPA add activated sludge, a potential biointermediate contained in a Municipal Wastewater Treatment Facility's (MWTF) produced biosolids, to the regulatory biointermediate definition. We are also requesting that digestate from a MWTF digester be added if the current definition, which does include digestate, is not covering it being produced by an MWTF digester. These requests are being made pursuant to Section 553(e) of the Administrative Procedure Act, and the Biointermediates Workshop Document provided in Appendix A of this petition.

The pathway for our Pressure Hydrolysis Process (PHP) was approved on March 15, 2022 but did not include MWTF sludge as a feedstock. An addendum to our pathway petition was submitted on April 23, 2020 requesting MWTF sludge feedstocks be included in our pathway and is still pending. This addendum is provided in Appendix D.

Sludge designations can vary in meaning and these designations are often used synonymously which can be confusing. For the purpose of this petition, we are more specifically differentiating some of these designations as follows:

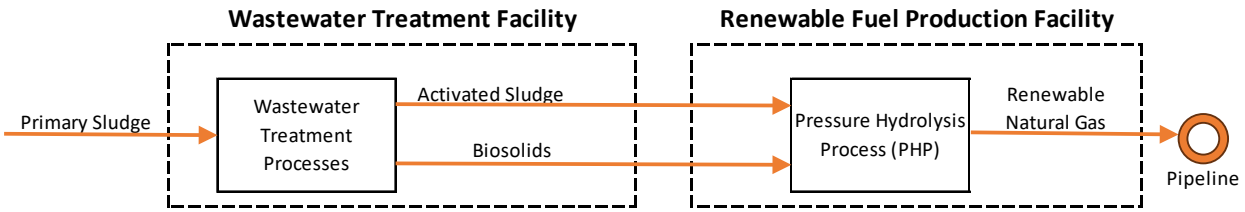
Primary Sludge: This is referring to the uncaptured sludge solids residing in the untreated wastewater, and is not to be confused with the sludge solids produced by the primary treatment process.

Biosolids: This is referring to the produced or captured sludge solids from the primary and secondary wastewater treatment process. When the secondary treatment solids are named separately as activated sludge or secondary sludge, this term represents the solids from the primary treatment process only. The term "MWTF Sludge" is also referring to the biosolids.

Activated Sludge: This is referring to the produced or captured sludge solids from the secondary wastewater treatment process which includes the aeration and aerobic biological treatment.

The following two feedstock flow diagrams illustrate how we plan on using activated sludge and digestate as biointermediates:

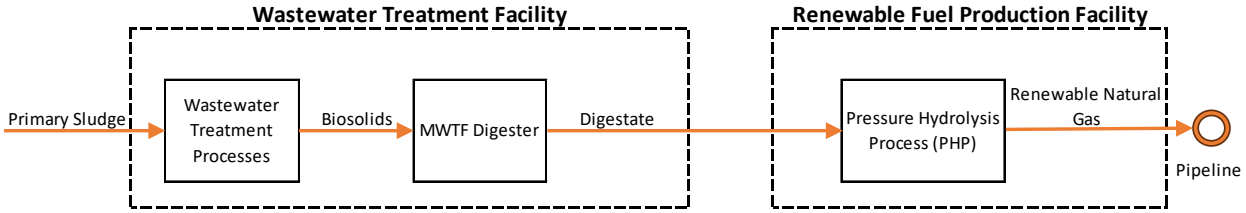
(continued on next page)



Fuel Type	Feedstock	Biointermediate Feedstock	Production Process	Requested RIN D-code
Renewable Compressed Natural Gas	Primary Sludge, Biosolids*	Activated Sludge*	Pressure Hydrolysis Proccess incl. Anaerobic Digestion (PHP)	Cellulosic Biofuel (D3)

*EPA has determined that biosolids & activated sludge are predominately cellulosic and could be used to generate renewable fuel with D3 RINs. See Appendix B & C.

Scenario 1: Typical feedstock flow without MWTF Digester



Fuel Type	Feedstock	Biointermediate Feedstock	Production Process	Requested RIN D-code
Renewable Compressed Natural Gas	Biosolids	Digestate	Pressure Hydrolysis Process incl. Anaerobic Digestion (PHP)	Cellulosic Biofuel (D3)

Scenario 2: Typical feedstock flow with MWTF Digester

The following sections are based on the requirements cited in the Biointermediate Workshop document included in Appendix A.

B.) An explanation of why a rulemaking is being requested

EPA has determined that activated sludge having undergone aeration/aerobic treatment is a substantially altered material, and is therefore considered a potential biointermediate. As a potential biointermediate it cannot be used by a renewable fuel producer as a feedstock at a separate facility than where the potential biointermediate was produced unless it is listed in the regulatory biointermediate definition. Likewise, digestate from a digester is considered substantially altered material. Digestate is currently included in the regulatory biointermediate definition, but as cited earlier, we are unsure if this inclusion also covers digestate from a MWTF digester or not.

Combining a municipal facility dealing in wastewater with a private facility dealing in fuel production into a single facility under single control has many legal and physical constraints. These constraints include insufficient feedstock quantity for our technology, operational and legal difficulties, insufficient land for a fuel production plant to coexist on treatment plant property, insufficient investor interest, and the inability to claim tax credits.

C.) A description of the potential biointermediate including:

1.) The feedstocks and production processes used to produce the potential biointermediate from those feedstocks

Biosolids are biproducts of the water treatment process that cleans wastewater before it is returned to rivers and streams. These solids themselves include the material removed from the wastewater for cleaning purposes. They are usually disposed of by land application, incineration or landfill disposal, with each way having its own environmental concerns to deal with. For instance, land applied biosolids can contain hazardous organic compounds like traces of medicine, polycyclic aromatic compounds, and PFAS; heavy metals; and pathogenic microorganisms. Our PHP's wet oxidation component can destroy chemicals, pathogens, and oxidize heavy metals to an inert non-leaching ash. Biosolids are generated nationwide from virtually every community and population center.

A primary purpose of wastewater secondary treatment (which includes biological aerobic treatment and produces activated sludge), is to remove dissolved organic (volatile) solids and further separate volatile and inorganic suspended solids (which includes the cellulosic fraction) from the water being treated/cleaned. The volatile organic solids are the reactive solids that can contribute to the production of biofuel. A digester utilizing an anaerobic biological process is also used to remove organic (volatile) solids from the water being treated, and has the further benefit of producing a biogas product. The digester also discharges digestate, that contains the altered and unconverted leftover feedstock solids from digestion.

The volatile solids removed by the aerobic and anaerobic processes are mostly the fats, carbohydrates, and proteins. The suspended lignocellulosic (cellulosic) volatile solids are largely unaffected by biological processing due to its lignin content being difficult to degrade. This removal of the volatile solids by biological treatment serves to increase the adjusted cellulosic content of the activated sludge or digestate above the originating feedstock values since it is calculated as a percent of the volatile solids.

Our interest in MWTF sludge including activated sludge and digestate is for its predominately cellulosic content. It is the lignocellulosic biomass fraction of the sludge that our PHP technology converts to a renewable energy product. It is our understanding that EPA has determined that biosolids and activated sludge are predominately cellulosic and could be used to generate renewable fuel with D3 RINs (Refer to Appendix B page 20, & Appendix C pages 32-34). Digestate as a biointermediate derived from biosolids would also have a predominately cellulosic content (i.e.: an adjusted cellulosic content ≥75%) as explained above.

2.) The renewable fuels that would be produced from the potential biointermediate and processes used to make the RF

Initially, we propose to produce renewable compressed natural gas, and is the fuel type of our approved pathway. Our PHP first produces C5/C6 sugars from lignocellulosic biomass. These sugars not only can be used to produce renewable natural gas, we can also produce other fuel types such as liquid natural gas (LNG), ethanol, biobutanol and methanol as well.

3.) Pathway considerations

We are working to get MWTF biosolids and its potential biointermediate derivatives approved for our pathway. We are not looking for any additional considerations at this time.

4.) The timeline for its development and ultimate production

We want a plant using MWTF biosolids for feedstock, up and running within two years. Constructing the plant is about a 15-month process, and would not start until our pathway provides for biosolids, and we have the feedstock and site secured.

D.) A discussion of whether the potential biointermediate could appropriately be produced, transferred, and used under the RFS biointermediates provisions

The potential biointermediates addressed herein are already being produced and transported from MWTFs nationwide. Agresti energy's renewable fuel facilities will be strategically located to provide short hauls or piping of the primary and biointermediate feedstocks from the MWTFs.

E.) A description of whether any unique considerations for the potential biointermediate are needed

The potential biointermediates we are requesting added to the biointermediate definition is for the regulatory purpose of allowing Agresti Energy to own and operate a facility separate from the MWTF providing the feedstock. Our PHP uses the chemically unaltered lignocellulosic biomass fraction, whether it's contained in an approved cellulosic feedstock or a regulatory listed cellulosic biointermediate, to produce its renewable fuel. In this case, activated sludge and digestate which are predominately cellulosic will perform exactly the same as cellulosic feedstock for our process.

Appendix A

Biointermediates Workshop Document (What is a Biointermediate?)

What is a Biointermediate?

Robert Anderson

Biointermediates workshop

Office of Transportation and Air Quality

September 29, 2022

About this Presentation

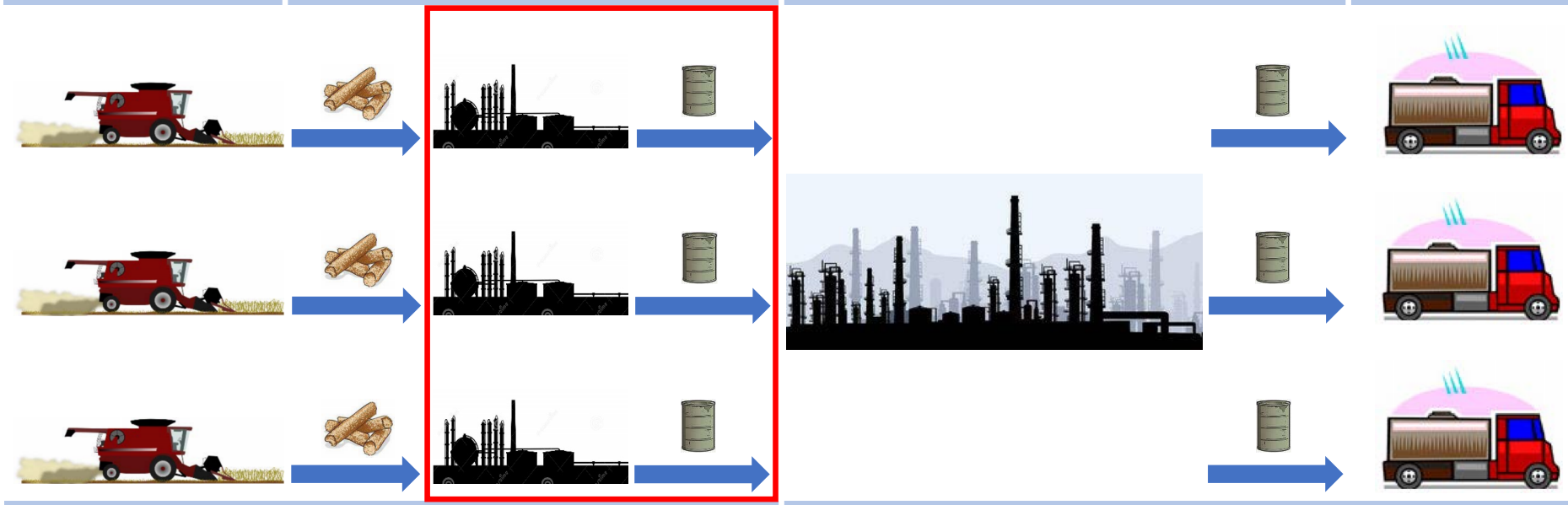
- This presentation is being given to assist stakeholders in complying with the regulations regarding biointermediates finalized in the 2020-2022 RVO final rule.
- The presentation is not intended to discuss the merits of the regulatory requirements but rather to assist stakeholders in implementing them.
- To the extent participants provide questions, advice, or materials during or after this meeting, they should do so in their individual capacity.
- This presentation is not intended to supplant the regulatory requirements. Parties must comply with the applicable regulatory requirements regardless of whether and how those requirements are discussed in these presentations.
- The topics in this presentation do not represent future EPA decisions or actions in any particular circumstance and do not bind EPA to any particular decision or action.

What is a Biointermediate (Conceptually)?

- In RFS2, we wrote our regulations to require renewable fuel to be produced from renewable biomass at a single facility (with limited exceptions).
- For years, we had heard that certain advanced and cellulosic biofuels require processing at more than one facility. The term 'biointermediate' refers to the partially-processed feedstock material that is transferred between facilities.
- To allow for these new advanced/cellulosic biofuels, we finalized provisions in the 2020-2022 RFS Standards rule to allow for certain biointermediates to be used.

Biointermediates: An Overview

Renewable biomass collected in multiple areas	Biomass is sent to local collection/pre-processing facility to produce a biointermediate	Biointermediates from multiple facilities are sent to a renewable fuel production facility	Renewable fuel is produced and distributed



e.g., A party gathers renewable biomass in numerous locations and converts it to biocrude

e.g., biocrude is shipped to a single refinery that converts the biocrude to cellulosic gasoline and diesel

Biointermediate is produced

What is a biointermediate (Regulatorily)?

- Under 40 CFR 80.1401, "*Biointermediate* means any feedstock material that is intended for use to produce renewable fuel and meets all of the following requirements:

  (1) It is produced from renewable biomass.

  (2) It has not previously had RINs generated for it.

  (3) It is produced at a facility registered with EPA that is different than the facility at which it is used as feedstock material to produce renewable fuel.

  (4) It is produced from the feedstock material identified in an approved pathway, will be used to produce the renewable fuel listed in that approved pathway, and is produced and processed in accordance with the process(es) listed in that approved pathway.

  (5) Is one of the following types of biointermediate: (i) Biocrude. (ii) Biodiesel distillate bottoms. (iii) Biomass-based sugars. (iv) Digestate. (v) Free fatty acid (FFA) feedstock. (vi) Glycerin. (vii) Soapstock. (viii) Undenatured ethanol.

  (6) It is not a feedstock material identified in an approved pathway that is used to produce the renewable fuel specified in that approved pathway."

What is Not a Biointermediate?

- Renewable fuels and renewable biomass that are not substantially altered are not biointermediates.

- The regulations at 40 CFR 80.1460(k)(2) state that no person shall: "[p]roduce a renewable fuel at more than one facility unless the person uses a biointermediate or *the renewable biomass is not substantially altered*. *Form changes of renewable biomass* such as bleaching through adsorption, rendering fats, chopping, crushing, grinding, pelletizing, filtering, compacting/compression, centrifuging, degumming, dewatering/drying, melting, triglycerides resulting from deodorizing, or the addition of water to produce a slurry *do not constitute substantial alteration*." (emphases added)

- The regulations at 40 CFR 80.1426(c)(6) address the situation where a renewable fuel is used as a feedstock.

Potential Biointermediates

- A potential biointermediate is a feedstock that is:
  - Renewable biomass that was substantially altered at a facility other than the renewable fuel production facility;
  - Not a renewable fuel; and
  - Not one of the types of biointermediates listed in the definition at 40 CFR 80.1401.
- Potential biointermediates cannot be used for RIN generation unless and until EPA amends its regulations to allow for such use.
- As noted in the final rule, "will likely continue to periodically issue rulemakings related to the RFS program to set volume requirements, promulgate new pathways, and technically amend the RFS regulatory provisions. These ongoing regulatory activities will provide ample opportunities to add new biointermediates to the program with any other necessary regulatory changes on a regular basis." See 87 FR 39638.

How to add a potential biointermediate

1. Submit a description of it to the support line
   - EPA will consider whether a potential biointermediate might actually be renewable biomass that was not substantially altered, or is a biointermediate that is already included in the regulations.

2. Consider submitting a petition for a rulemaking
   - Petition would request that EPA add the potential biointermediate to the regulations, thus allowing its use to produce RIN-generating renewable fuel

3. EPA will consider adding new biointermediates in future RFS-related rulemakings

What should a petition include?

- Petitions should contain the legal and technical justification for including a potential biointermediate in the program
- To help EPA consider your petition, include the following:
  - An explanation of why a rulemaking is being requested (because the potential biointermediate is not renewable biomass and EPA must revise the regulations to allow its use to produce RIN-generation renewable fuel)
  - A description of the potential biointermediate including:
    - The feedstocks and production processes used to produce the potential biointermediate from those feedstocks
    - The renewable fuels that would be produced from the potential biointermediate and processes used to make the RF
    - Pathway considerations
    - The timeline for its development and ultimate production
  - A discussion of whether the potential biointermediate could appropriately be produced, transferred, and used under the RFS biointermediates provisions
  - A description of whether any unique considerations for the potential biointermediate are needed

Potential Biointermediates Inquiries

- For the fuels support line e-mail: FuelsProgramSupport@epa.gov

Appendix B

EPA's 4/23/20 Response to Agresti Energy's Pathway Screening Tool (PST)

Dear Terry L Rainier:

We received and reviewed the pathway screening tool (PST) you submitted Feb 24, 2023, on behalf of Agresti Energy, LLC. This response to your PST includes the following:

- Summary of your proposed fuel pathway(s)
- Answers to PST Questions
- Contact for further questions

Summary of your proposed fuel pathway(s)

The table below reproduces the pathway summary table from your PST:

Fuel Type	**Feedstock**	**Production Process**	**Requested RIN D-code**
Renewable compressed natural gas	Municipal Wastewater Treatment Facility (MWTF) Sludge	Pressure Hydrolysis Process & Anaerobic Digestion (PHP)	Cellulosic biofuel (D3)

Answers to PST Questions

On a potential site using Municipal Wastewater Treatment Facility (MWTF) sludge as a feedstock, would it be acceptable to locate the PHP facility on adjacent contiguous land to the MWTF? In doing so, we would pipe the sludge to our facility from connection points where the sludge is currently being separated from the wastewater stream. We are aware that sludge was not added to the biointermediate definition as part of the 2022 rule changes. It is uncertain to us as to whether any action taken by the MWTF to pre-process the sludge prior to our biofuel production process would require sludge to be considered a biointermediate.

If the MWTF is located on contiguous land and the facility is owned and operated by the MWTF, there would not be biointermediate issues. This could include a situation where Agresti Energy's technology is used on-site of the MWTF, but the facility is owned and operated by the MWTF. If instead a facility was co-located with the MWTF but was owned or operated by Agresti Energy, there could be issues involving biointermediates or potential biointermediates.

A potential biointermediate is a product made from substantially altering a renewable biomass feedstock which will be used to produce a renewable fuel at a different facility than where the potential biointermediate was produced but is not listed in the definition of biointermediate. The regulations at 40 CFR 80.1460(k)(2) describes processes that do not constitute substantial alteration. Note that based on the information supplied in the PST, we believe that the aeration processes would constitute substantial alteration under 40 CFR 80.1460(k)(2). The MWTF sludge is not listed in the definition of biointermediate at 40 CFR 80.1401. If the MWTF has undergone an aeration process, it would have undergone substantial alteration under 40 CFR 80.1460(k)(2), and as such, a renewable fuel producer may not use the MWTF sludge as a feedstock.

In the Pathways II rule, EPA evaluated the cellulosic content of primary sludge, secondary sludge, and biosolids. EPA determined that secondary sludge and biosolids were predominantly cellulosic and could be used to generate renewable fuel with D3 RINs. EPA did not determine that primary sludge was predominantly cellulosic and without a determination by EPA, in order to generate cellulosic RINs for primary sludge used at another facility, Agresti would have to follow the regulatory requirements in 40 CFR 80.1450(b)(1)(xiii) and 40 CFR 80.1450(b)(1)(xiii).[1]

What are the requirements for transporting Sludge? Can sludge be trucked in from other remote MWTFs to be processed by our PHP facility? Is sewer pipe conveyance the only means by which sludge can be received by an MWTF?

There are not requirements for how sludge would need to be transported for the purposes of compliance with a pathway. Details about transportation method and distances would be required for the purposes of conducting an LCA as part of a pathway petition.

We understand that biomass-based sugars were added to the biointermediate definition as part of the 2022 rule changes. Our PHP as a first step produces sugars from the cellulosic fraction of the feedstock. Does this now allow (with proper approval) for these sugars to be further processed at a separate facility? Please elaborate.

On June 3, 2022, EPA finalized a package of actions referred to as the RFS Annual Rules that introduced regulatory changes intended to enhance the program's objectives, including a regulatory framework for biointermediates. Biointermediates are feedstocks that have been partially converted at one facility but are then sent to a separate facility for their final processing into a renewable fuel.

These regulatory provisions, which became effective August 30, 2022, specify which biointermediates are allowed under the program (40 CFR 80.1401) and what parties that produce, transfer, and use biointermediates must do to demonstrate compliance (40 CFR 80.1450, 80.1451, 80.1453, 80.1454). Pursuant to 40 CFR 80.1460(k)(2), no person may produce a renewable fuel at more than one facility unless the person uses a biointermediate or the renewable biomass feedstock is not substantially altered.[2]

Our understanding of Agresti Energy's PHP process from your PST and previously submitted pathway petition is that after processing renewable biomass, the PHP results in what would reasonably be described as biomass-based sugars. "Biomass-based sugars" are allowed to be used as they are listed as a biointermediate as defined in 40 CFR 80.1401, as long as all other regulatory requirements are met.[3]

It should be noted that only one biointermediate can be used in a pathway (e.g., if digestate from one facility was transported to a separate facility to use in Agresti Energy's PHP process, and then biomass-based sugars were generated from the digestate and transported to a third facility, this would constitute two biointermediate steps, and only one biointermediate is currently allowable under existing regulations).

[1] See Pathways II Rulemaking at: https://www.epa.gov/renewable-fuel-standard-program/renewable-fuel-pathways-ii-final-rule-identify-additional-fuel
[2] See 40 CFR 80.1401 "Biointermediate"
[3] The final rulemaking and related information are available at: https://www.regulations.gov/docket/EPA-HQ-OAR-2021-0324

Contact for further questions

Please submit further written questions and inquiries to the following email address: FuelsProgramSupport@epa.gov

Sincerely,
The EPA Petition Review Team

Appendix C

Air and Radiation Docket EPA-HQ-OAR-2012-0401 (Support for Classification of Biofuel Produced from Waste Derived Biogas as Cellulosic Biofuel and Summary of Lifecycle Analysis Assumptions and Calculations for Biofuel Produced from Waste Derived Biogas)

MEMORANDUM

TO: Air and Radiation Docket EPA-HQ-OAR-2012-0401

FROM: EPA Office of Transportation and Air Quality

DATE: July 1, 2014

SUBJECT: Support for Classification of Biofuel Produced from Waste Derived Biogas as Cellulosic Biofuel and Summary of Lifecycle Analysis Assumptions and Calculations for Biofuel Produced from Waste Derived Biogas

This memorandum provides additional support for EPA's determination that renewable fuel produced using biogas from landfills, separated MSW digesters, wastewater treatment facility digesters, and agricultural digesters should be classified as cellulosic biofuel. It also provides information on the key input assumptions used for the lifecycle analysis of renewable fuel produced from waste derived biogas. Data sources are presented to promote transparency for our lifecycle analysis. This memorandum also describes the calculations made for the lifecycle analysis of renewable fuel produced from waste derived biogas and discusses, in depth, the choice of baseline used in the lifecycle analysis.

I. Summary

In the June 14, 2013 Notice of Proposed Rulemaking (NPRM), EPA proposed to allow compressed natural gas (CNG), liquefied natural gas (LNG) and renewable electricity from landfill biogas to qualify for cellulosic renewable identification numbers (RINs), and requested comment on whether fuel derived from other sources of biogas should also be allowed to qualify for cellulosic RINs. The proposal to treat landfill biogas as a cellulosic biofuel feedstock was based on available data and was supported by a memo to the docket (EPA-HQ-2012-0401). This document expands upon the original memo to the docket and provides a summary of additional information provided through the public comment process or developed in response to comments received. Through the comment process, and additional EPA research, EPA has identified additional data that supports a finding that fuel derived from biogas from MSW digesters, municipal wastewater treatment facility digesters, and agricultural digesters is also predominantly derived from cellulosic components.

II. Determination of the Cellulosic Content of Waste Derived Biogas

A. Biogas from Landfills

For the purposes of this memorandum, the terms "cellulosic" or "cellulosic content" are intended to refer to the sum of the cellulose, hemicellulose, and lignin components of a feedstock.[a] However, when calculating the "adjusted cellulosic content" of a feedstock, which is a percentage value, the cellulosic content is divided by the volatile organic fraction because only this portion is reactive and can contribute to the production of biogas. For municipal solid waste (MSW) in landfills, the non-organic fraction is composed of metal, cement and other inorganic materials that will not yield methane in the landfill. Review and analysis of available data characterizing MSW landfill material and its associated biogas indicate that the organic fraction of MSW is predominately cellulosic and the biogas generated from MSW is predominantly derived from the cellulosic components.

The Barlaz research cited in the June 2013 NPRM most directly attempts to answer the question of what percent of the MSW landfill biogas is derived from the cellulosic components of the MSW. Results from this study are outlined in Table 1 and Figures 1 and 2, and show that methane does not appear until day 41, indicating that the initial decomposition was aerobic, involving loss of sugars to carbon dioxide and water. During this time period, about 20% of the MSW was lost, including fractions of cellulose and hemicellulose (Figure 1). Once the originally present oxygen was consumed, the reactors became anaerobic and methane production began (Figures 1 and 2). Large amounts of both cellulose and hemicellulose were converted during this period (Figure 1), and lignin accumulated in the residue (Figure 2). Overall, 71% of

[a] This is based on the definition of "cellulosic biofuel" *in Clean Air Act Section 211(o)(1)(E).*

the cellulose and 77% of the hemicellulose were converted during the reaction, roughly half aerobically and half anaerobically (Table 1). These data show that a substantial fraction of the cellulosic content of MSW is converted. In fact, based on the abundance of different biochemicals in the MSW and theoretical methane potentials for the different components (e.g., cellulose, proteins), the authors determined that 91% of the total methane in this sample was derived from cellulosic components. This research indicates that a predominant portion of the biogas from MSW landfills comes from anaerobic digestion of the cellulosic content of MSW, namely cellulose and hemicellulose.

Table 1 – Chemical composition of municipal solid waste (MSW) from different studies, the percent of each type of compound lost in a degradation experiment and the percent of total methane potential from the different components.

		Barlaz et al. (1989)[1]		
	% Composition (average of 14 studies)	% Composition	% Lost during decomposition	% of total methane potential
Cellulose	38 ± 14	51	71	74
Hemicellulose	8 ± 2	12	77	15
Lignin	16 ± 6	15	8	0*
Protein	3 ± 1	4	n.d.	8
Volatile Solids	69 ± 16	79	n.d.	100
Average % "Cellulosic"**	90 ± 30***	100****		91[b]

*The authors assumed that lignin had a methane potential of zero because lignin is known to react very slowly under anaerobic conditions.

**Calculated relative to the measured concentration of volatile solids.

***Standard error calculated by propagation of error.

****Note that this value is artificially high due to measurement uncertainties

[b] 91% represents the portion of the biogas derived from cellulose and hemicellulose, and is calculated by dividing the sum of their methane potential fractions by the total methane potential fraction for cellulose, hemicellulose, and protein. As calculated by Barlaz et al., there may be slight differences in numbers due to rounding.

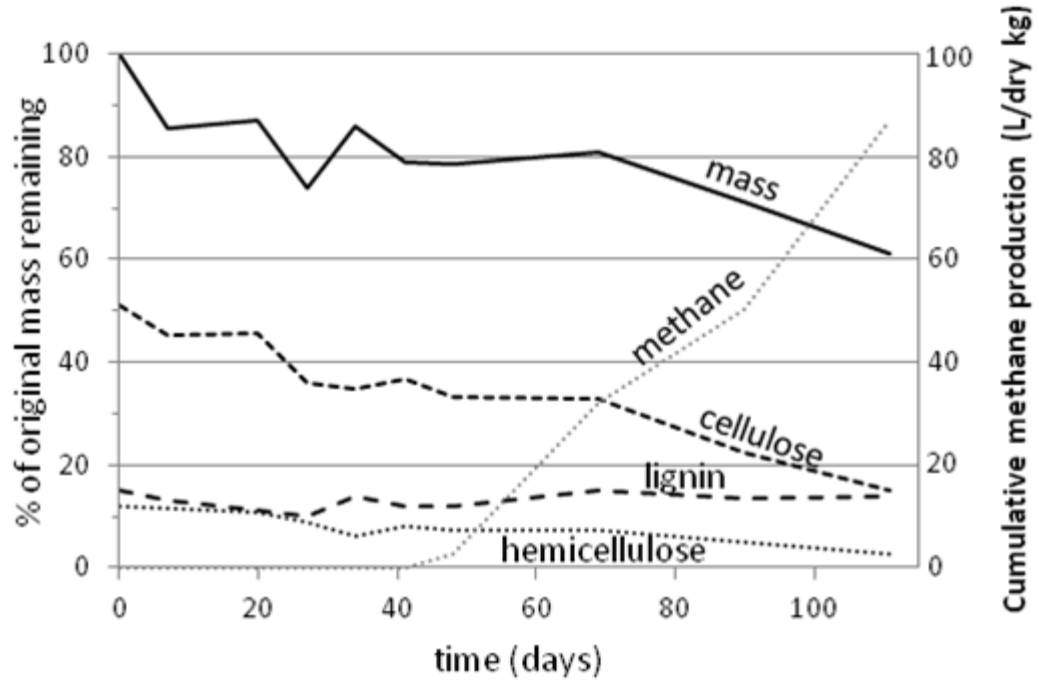


Figure 1 – Chemical Composition of degrading MSW versus time:[2] % of original mass remaining for total mass, cellulose, hemicelluloses and lignin, with cumulative methane yield plotted on the right axis. Methane first appeared (at very low concentration) on day 41.

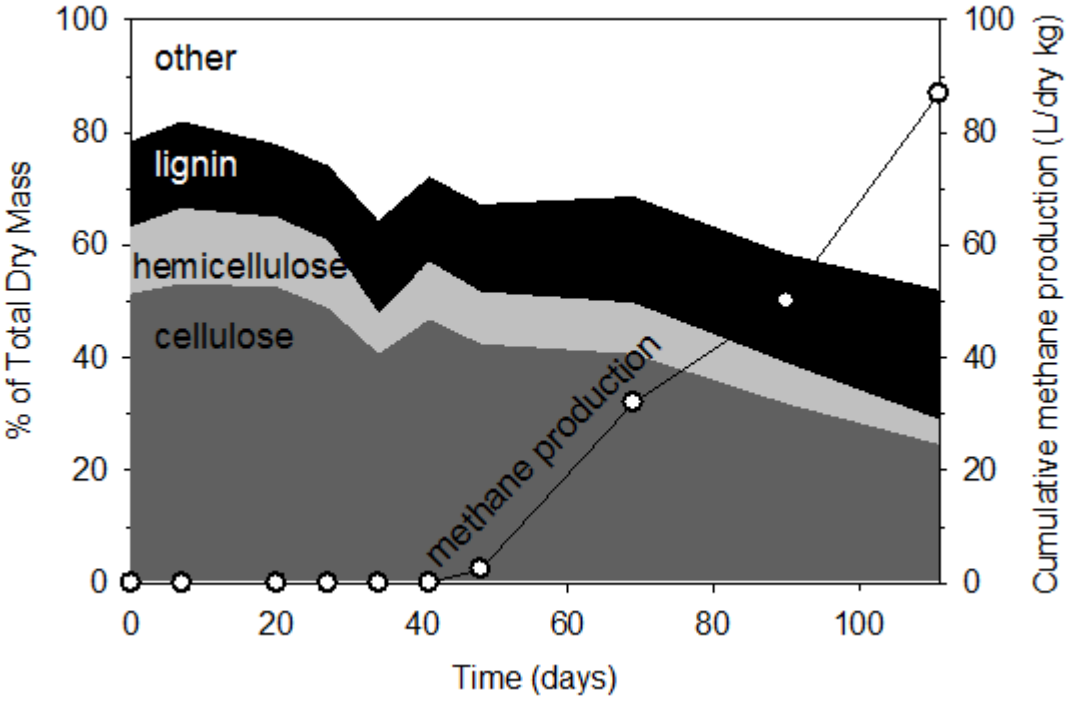


Figure 2 – Chemical Composition of degrading MSW versus time: percent composition of MSW over time, with the area between curves corresponding to the percent of total mass in that component. The "other" material (white) includes metals, plastics and cement, as well as organic materials such as proteins and starches. The circles show the cumulative production of methane in the reaction containers.

Recent studies have also confirmed that the organic fraction of MSW is still predominantly comprised of cellulose, hemicellulose, and lignin[2c]. Specifically, the organic fraction of MSW has been largely unaffected by changes in waste management trends such as increased recycling. Moreover, there is a strong and direct correlation between the amount of cellulosic materials present in the MSW and the amount of biogas that can be produced – demonstrating that anaerobic digestion is converting cellulosic biomass to biogas.[3] Based on the average of 14 studies, MSW contains 38% cellulose, 8% hemicellulose and 16% lignin, with smaller amounts of proteins, sugars and other organic materials (Table 1).[4] Since the average organic fraction of the MSW is 69%, the average adjusted cellulosic content of the landfill MSW is 90%.

MSW composition varies considerably depending on, for example, the amount of yard waste versus food waste versus metal waste deposited. It is worth noting that the studies examined were published over 27 years (1982 to 2009), during a time period in which recycling expanded considerably, leading to substantial changes in the types of materials deposited in landfills. Despite these changes, the cellulosic content of the organic fraction of MSW, the portion capable of contributing to biogas production, has not changed substantially during this time.[1] The data reviewed by EPA indicate that the vast majority of volatile solids in landfills are composed of cellulosic components[1].

Eleazer et al. (1997)[5] analyzed the decomposition of a variety of components of MSW, including leaves, paper, food and MSW itself. They found a correlation between the percent of cellulose and hemicellulose in the MSW and the yield of methane from the different samples, with methane yield increasing as the cellulose and hemicellulose increased. This study demonstrated that biogas yield is proportional to the cellulosic content of MSW, and supports the conclusion that landfill biogas is predominately derived from cellulosic components.

While the fraction of the biogas being generated from cellulosic components may vary slightly from location to location depending on the composition of the MSW, the volatile solids in MSW appear to always contain a large proportion of cellulosic materials[d], and a large proportion of the biogas generated will be derived from cellulose and hemicellulose. Therefore,

[c] This study compared data collected to other available data.
[d] Barlaz et. al. (1989) and Eleazer et. al. (1997)

we conclude that fuel derived from landfill biogas is predominantly cellulosic, and that all volumes of fuel made from landfill biogas qualify for cellulosic biofuel RINs.

B. Biogas from Separated MSW Digesters, Agricultural Digesters, and Municipal Wastewater Treatment Facility Digesters

For the reasons described below, EPA is extending its assessment that biogas derived from MSW landfills is predominantly cellulosic to include biogas from separated MSW digesters, municipal wastewater treatment facility digesters, and agricultural digesters.

Organic wastes in the United States that may be available for, and susceptible to, anaerobic decomposition to produce biogas can be generally characterized as falling into one of four categories. The first includes the organic fraction of municipal solid waste (OFMSW), the second is biosolids from municipal wastewater treatment facilities, the third is agriculture waste (including animal manure), and the fourth is wastes that do not fall into any of the first three categories. Almost all of the organic wastes anaerobically digested in the U.S. fall into one of the first three categories[e], and their adjusted cellulosic content is on average above 75%. (Table 4). Given our understanding of anaerobic digestion in MSW landfills, described above, we are confident that anaerobic digesters processing predominantly cellulosic materials, including materials from any of these first three general waste categories described above, would produce biogas that is predominantly cellulosic in origin. For our final rule we have identified three digester types that we believe will process wastes that are predominantly cellulosic: separated MSW digesters, municipal wastewater treatment facility digesters and agricultural digesters. Digesters processing the fourth category of organic wastes described above may accept large quantities of non-cellulosic materials, such as waste fats, oils and greases or industrial food wastes (e.g., food and beverage production wastes that are primarily composed of sugar or starch). While the materials comprising the fourth category may meet EPA's definition of renewable biomass, we do not have enough information at this time to determine that the biogas from these materials would be derived from predominantly cellulosic components. Therefore, biogas digesters primarily processing non-cellulosic materials such as those listed in the fourth category are considered non-cellulosic, and transportation fuels derived from biogas produced at these digesters may only qualify for cellulosic RINs for the cellulosic portions of the biogas and may produce advanced biofuel RINs for the non-cellulosic portions.

Finally, determinations regarding the cellulosic content of various types of organic wastes discussed in this memo apply only in the context of production of biogas through anaerobic digestion. Our determination that fuel derived from certain feedstocks that are anaerobically digested to produce biogas should be considered of cellulosic origin does not apply to fuels produced from the same organic wastes that are converted to fuel using a biomass conversion process other than anaerobic digestion. One of the reasons for this limitation is that the anaerobic

[e] "Municipal Solid Waste Generation, Recycle, and Disposal in the United States: Facts and Figures for 2012". U.S. Environmental Protection Agency: http://www.epa.gov/osw/nonhaz/municipal/msw99.htm

digestion process is known to convert cellulosic components of organic wastes to biogas, and this cannot be extended to all biomass treatments.

1. Separated MSW Digesters

Current regulations allow generation of cellulosic RINs for the entire biogenic fraction of separated MSW, and require testing to determine what portion of the finished fuel is made from the biogenic portion of separated MSW. The test prescribed is a carbon-14 radio dating test (ASTM Method D-6866). EPA determined in the March 2010 RFS rule that biogas is not formed from non-biogenic compounds in landfills, and thus it was unnecessary to require the ASTM method in the context of landfill biogas.

The biogenic portion of MSW may be processed in a separated MSW digester to produce biogas and biogas-derived transportation fuels. As discussed in the March 2010 rule, the organic fraction of MSW generally consists of yard waste and heterogeneous post-consumer food waste.[f] The biochemical conversion processes by which organic material is converted to biogas, known as anaerobic digestion, are thermodynamically identical in both landfills and anaerobic digesters. The only differences between the anaerobic conversion processes in these systems are kinetic (reaction rate). While the environmental conditions in landfill systems favor the anaerobic digestion of organic matter thermodynamically, the conversion process is not optimized kinetically. In fact, landfills can be viewed as anaerobic digesters that have not been optimized for efficient reaction kinetics capable only of passively generating biogas over long periods of time. Waste digesters, by contrast, actively perform the anaerobic biochemical processes that landfills allow passively because they are designed to optimize system kinetics. Therefore, waste digesters more rapidly and efficiently convert biomass to biogas. For example, while processing the same amount of identical biomass, a waste digester system would generate more useable biogas on a substantially shorter time-scale than a landfill system. However, despite kinetic differences, the bioconversion processes occurring in landfills and waste digesters are essentially identical. We considered – as we did for landfill biogas – whether to require biogas producers to use ASTM Method D–6866 to identify the biogenic versus non-biogenic fractions of the fuel. However, since landfill gas and digester biogas are produced in an identical fashion, and it is not formed from non-biogenic compounds in landfills or anaerobic digesters, no purpose would be served in using the ASTM method in the context of MSW digester biogas. Therefore, EPA finds that fuels made from biogas derived from digesters processing separated MSW are biogenic, and qualify for cellulosic biofuel RINs for the entire volume of fuel produced. .

EPA notes that the CAA requires that renewable fuel be produced from "renewable biomass" as that term is defined in CAA 211(o)(1)(I). MSW is not identified in the statute as renewable biomass. However, EPA determined that "separated MSW" as defined in 40 CFR

[f] U.S. EPA's waste characterization trends show that post-consumer food scraps and yard waste account for more than 86% of the OFMSW.

80.1426(f)(5)(i)(C), qualifies as renewable biomass for purposes of renewable fuel production provided that it is collected according to a plan submitted and approved by EPA pursuant to 40 CFR 80.1426(5)(ii). Material that could have been disposed of in a MSW landfill, but was diverted from it, does not automatically qualify on that basis as separated MSW. Rather, such waste must qualify as a different type of renewable biomass, such as animal waste, separated food waste, or separated yard waste to be an eligible feedstock for renewable fuel production. A "separated MSW digester" for purposes of today's rule is a digester processing separated MSW as defined in EPA regulations pursuant to an anaerobic digestion process.

2. Agricultural Digesters

There are approximately 250 agricultural digester projects in the U.S. Of these agricultural digesters about 40% are co-digesters processing a mixture of animal manure, on-farm crop residues, and small amounts of other biogenic wastes. There are no consistent data to portray the exact mixture of material being digested in individual digesters on a continuous basis because both the material composition and relative proportions of digested material varies over time. However, in aggregate, over 90% of the material processed in agricultural digesters is animal manure, and the remaining portion consists mainly of plant residues and other on-farm wastes that are predominately cellulosic in origin such as crop residues and separated yard waste.[g] This section provides information on both animal manure and on-farm crop residues – the main components processed in agricultural digesters.

Data used to estimate the aggregate composition of animal manure were obtained from a comprehensive review published by the Pacific Northwest National Laboratory covering four typically digested categories of animal manure (dairy, cattle, swine, and poultry)[6]. Although these studies reported the cellulose, hemicelluloses, and lignin on a total solids basis, they did not calculate an adjusted cellulosic content based on the fraction of the material that could be converted to biogas. To obtain an adjusted cellulosic content, we normalized the reported values based on the volatile organic fraction. When possible (e.g., if the studies analyzed the same categories of manure) and if comparable (e.g., provided the breakdown of cellulosic components in the same way), differing data were averaged. A weighted average based on the type and volume of animal manure digested, based on data from AgSTAR was used to estimate the cellulosic content for animal manure in aggregate. The adjusted cellulosic content was calculated by summing the cellulosic fractions (cellulose, hemicellulose, and lignin) and dividing by the volatile fraction capable of contributing to biogas production. The volatile fraction capable of contributing to biogas was assumed to be the volatile solids minus the organic nitrogen which would be converted to nitrogen gas or other inorganic nitrogen species rather than methane or carbon dioxide.

[g] U.S. EPA AgSTAR's digester project information, overall digester biogas data and a representative sample co-digester inputs were used to estimate the aggregate digester material. Some of these data are available at AgSTAR's online database: http://www.epa.gov/agstar/projects/index.html#database.

Table 2 – Data used to assess the cellulosic content of animal manure

	Animal Manure				
	Cattle (%)	Poultry (%)	Swine (%)	Animal Manure (Aggregate %)	Source[h]
Cellulose	25	22	22	25	(1)
Hemicellulose	23	12	14	21	
Lignin	19	7	7	17	
Volatile Solids	84	62	76	82	(2)
Organic Nitrogen	3	3	3	3	
Relative Volume	79	1	20	--	(3)
Adjusted Cellulosic %				80	

The aggregate cellulosic content of animal manure (highlighted in green in Table 2) was found to be 25% cellulose, 21% hemicellulose, and 17% lignin, which means the cellulosic components equal 63%. The volatile solids and organic nitrogen were found to be 82% and 3% respectively, which results in a volatile fraction of 79% capable of contributing to biogas production. Based on these values, the average adjusted cellulosic content of the biomass treated in animal manure digesters is estimated to be 80%. While this estimate assumes that the digester material would be exclusively animal manure, it is common practice to co-digest mixtures of animal wastes, farm/crop residues and other wastes. As described in a separate memo to the docket[i], materials that we have determined meet the RFS regulatory definition of "crop residue" have on average an adjusted cellulosic content of 84%. The addition of such crop residues would therefore typically increase the overall cellulosic content of the biomass being treated in manure digesters. Similarly, EPA has determined that "separated yard waste", as that term is defined in 40 CFR 80.1426(5)(i), should be deemed to be composed entirely of cellulosic materials. See 40 CFR 80.1426(5)(i)(A). Such materials may also be added to waste digesters in an agricultural setting, perhaps in combination with manure and/or crop residues. We have defined the term "agricultural waste digester" as those digesters processing animal manure, crop residue and separated yard waste, and we have specified in Table 1 to 80.1426 that fuel produced from biogas collected at such digesters qualifies as cellulosic biofuel for which cellulosic RINs may be generated for the entire volume. EPA understands that incidental *de minimis* quantities of materials that are not predominantly cellulosic, or materials that are not renewable biomass,

[h] (1) *Value added Chemicals from Animal Manure*. Chen et. al.. Pacific Northwest National Laboratory (2003): http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14495.pdf; (2)*[Animal] Manure Production and Nutrient Content*. Chastain et. al.. Clemson University, Swine – http://www.clemson.edu/extension/livestock/camm/camm_files/swine/sch3a_03.pdf, Dairy – https://www.clemson.edu/extension/livestock/camm/camm_files/dairy/dch3a_04.pdf, Poultry – http://www.clemson.edu/extension/livestock/camm/camm_files/poultry/pch3b_00.pdf; (3) AgSTAR Digester Database. U.S. Environmental Protection Agency: http://www.epa.gov/agstar/projects/

[i] See "Cellulosic Content of Various Feedstocks: 2014 Update" placed in docket EPA-HQ-OAR-2012-0401.

may be introduced into agricultural digesters. This practice would not disqualify the resulting fuel from qualifying as renewable fuel under the RFS program providing that such incidental de minimis feedstock contaminants are either impractical to remove or are related to customary feedstock production and transport. See 40 CFR 18.1426(f)(1).

3. Municipal Wastewater Treatment Facility Digesters

Municipal wastewater treatment facility (MWTF) digesters are anaerobic digesters that process the sludge, undissolved solids, and biosolids derived from municipal wastewater whether or not the facility is owned by a municipality. The composition of wastes processed in MWTF tend to be heterogeneous, but are generally composed of human wastes and highly fibrous tissue products. Wastes that are processed in municipal wastewater treatment facilities are often treated aerobically, but more and more are being configured to employ anaerobic digestion as part of the facility's primary treatment system, allowing biogas to be produced.

The data used to assess the cellulosic content of wastewater solids is presented in Table 3.

Table 3 – Data used to assess the cellulosic content of wastewater solids

	Characteristics of Wastewater Solids							
Wastewater Type[j]	% C	% H	% L	% Convertible Solids	% AC	% AH	% AL	Source
Primary	29.3			72.9	40.2			Champagne, 2009[7]
Primary	11.5		26.5	74.1	15.5		35.8	Cheung, 1997[8]
Primary	17		9	62.6	27.2		14.4	Wang, 2008[9]
AS	13.8			78.7	17.5			Champagne, 2009[4]
AS	9	16	13	49.3	18.3	32.5	26.4	Wang, 2008[6]
Biosolids	14	19	8	49.0	28.6	38.8	16.3	Wang, 2008[6]
	Averages							
					% AC	% AH	% AL	% ACC
Average of AS and Biosolids Data					22	36	21	79

[j] Primary sludge refers to the untreated wastewater solids whereas activated sludge (AS) and biosolids refer to solids separated from wastewater following treatment at the wastewater facility.

C =; cellulose; H = hemicellulose; L = Lignin; AC = adjusted cellulose; AH = adjusted hemicellulose; AL = adjusted lignin; AS =activated sludge; ACC = adjusted cellulosic content

While there are substantial data characterizing the solids composition of municipal wastewater, there are somewhat less data characterizing the composition of materials entering the digesters specifically. We chose to use the subset of peer-reviewed data (highlighted in green in Table 3) that analyzes the activated sludge and biosolids for the purposes of calculating the average adjusted cellulosic content of materials that would be expected to enter wastewater treatment facility digesters. This is because the broader data set did not include data for the fraction of hemicellulose in primary sludge and it does not adequately represent the material entering the digester. As will be discussed forthwith, the material entering a digester is better represented by activated sludge and biosolids.

The wastewater treatment process is designed to oxidize dissolved organics, remove nutrients such as aqueous nitrogen and phosphorus species, and separate suspended solids. A typical process will involve several steps as part of three broader systems: the primary treatment system (pretreatment, primary clarification and anaerobic digestion), the secondary treatment system (aeration, clarification, internal sludge recycle, and disinfection) and the tertiary treatment system (nutrient removal and solids handling). Anaerobic digestion at wastewater treatment facilities typically occurs as part of the process' primary treatment; however data characterizing primary sludge does not adequately represent the material entering the digesters because the primary sludge is separated from the wastewater and partially treated prior to entering the digester.

The material that enters the digester includes the undissolved solids that are recovered from the primary clarification tank and the solids that are allowed to settle out in a secondary clarification tank. Therefore, the data for activated sludge and biosolids are more likely to represent the material entering the wastewater facility digesters. In addition, the data related to activated sludge and biosolids is more consistent and comparable, and therefore provide a more robust estimate of the cellulosic content.

The data considered (highlighted in green in Table 3) offered consistent and comparable data, including values for cellulose, hemicellulose, and lignin individually, and the volatile solids representing the organic fraction of the wastewater solids that can be converted via anaerobic digestion was reported in each of these studies. The average adjusted cellulosic content was obtained by dividing the reported cellulosic fraction by the volatile organic fraction that can be converted to methane. Based on the data for activated sludge and biosolids, the material entering the digesters is determined to be on average composed of 13% cellulose, 22% hemicellulose, and 13% lignin, for a total of 48% cellulosic components. The volatile solids and organic nitrogen were found to be 64% and 3% respectively, which results in an organic fraction of 61%. When the cellulosic component is divided by the organic fraction that can be converted to methane, the average adjusted cellulosic content of the material used to generate the biogas

through anaerobic digestion from wastewater treatment facilities is, on average, 79% (Table 4). Therefore, we have determined that fuels made from biogas collected at MWTF digesters is predominantly cellulosic, such that the entire volume of fuel produced qualifies for cellulosic biofuel RINs.

Table 4 – Estimated average composition of anaerobically digested cellulosic biomass in the United States

	Aggregate Composition of Digested Biomass		
	% OFMSW	% wastewater biosolids	% animal manure
Cellulose	38	13	25
Hemicellulose	8	22	21
Lignin	16	13	17
Volatile Solids	69	64	82
Organic Nitrogen	--	3	3
Adjusted Cellulosic Content	90	79	80

Source: This table represents the aggregate data from Table 1, Table 2, and Table 3[k].

III. Lifecycle Analysis of Biogas-Derived Renewable Fuel Pathways

Under anaerobic conditions, organic wastes naturally decompose to produce biogas, and controlled management of organic waste digestion can reduce GHG emissions that would have occurred alternatively. The following sections describe the assumptions, analytical methods and conclusions regarding the lifecycle GHG emissions associated with renewable fuel produced from waste derived biogas.

A. Assumptions used in the Lifecycle Analysis

Table 5 outlines key assumptions used in determining the lifecycle GHG emissions associated with renewable fuel produced from waste derived biogas. EPA used these values in our lifecycle analysis as described in the subsequent sections.

[k] Table 1 – Barlaz et. al. (1989); Table 2 – see footnote *j*; Table 3 – Champagne et. al. (2009) and Wang (2008)

Table 5 –Key Assumptions for the Lifecycle Analysis of Renewable Fuel Produced from Waste Derived Biogas

Category	Assumption	Source	Notes
On-Site Emissions from Combustion of Biogas (considers CH_4 and N_2O only)			
Emissions from Flaring	1004 g CO_2-eq/ mmBtu biogas	GREET1_2011[10]	Value given is for Renewable Natural Gas
Emissions from Stationary Reciprocating Engines	9634 g CO_2-eq/ mmBtu biogas		Value given is for Biogas
Emissions from Turbines	554 g CO_2-eq/ mmBtu biogas		Value given is for Natural Gas; Emissions are assumed to be the same for Biogas
Emissions from Combined Cycle Gas Turbines	554 g CO_2-eq/ mmBtu biogas		Value given is for Natural Gas; Emissions are assumed to be the same for Biogas
% of Gas-to-Energy Projects using Reciprocating Engines	70.6% of total capacity (in MW)	EPA LMOP Database of Operational Projects[11]	Percentages exclude microturbines, which are used in 0.3% of projects
% of Gas-to-Energy Projects using Turbines	23.8% of total capacity (in MW)		Includes both gas and steam turbines; excludes microturbines
% of Gas-to-Energy Projects using Combined Cycle Gas Turbines	5.6% of total capacity (in MW)		
Weighted Average Emissions for Gas-to-Energy Projects	6965 g CO_2-eq/ mmBtu biogas	Calculated from data referenced in this table	
Upstream Emissions			
U.S. Average Electricity Production	219,823 g CO_2-eq/ mmBtu electricity	RFS Final Rule[12]	

Table 5, continued

Renewable Electricity Generation			
Efficiency of Electricity Generation from Biogas	11,700 Btu biogas/kWh	EPA LMOP LFGE Benefits Calculator[13]	Weighted average of gas-to-energy projects
Electricity-Ethanol Conversion	22.6 kW-h/gal ethanol	RFS Final Rule[6]	
Parasitic Loss Efficiencies for Reciprocating Engine-Generator Sets	93%	EPA LMOP Data[14]	
Parasitic Loss Efficiencies for Turbine-Generator Sets	88%		Use this value for Combined Cycle Gas Turbines as well
Electricity Demand for Biogas Collection Blowers	0.002 kWh/ft^3		For flaring and gas-to-energy projects
U.S. Average Transmission and Distribution Losses	6.6%	U.S. EIA State Electricity Profiles[15]	
CNG and LNG			
Energy Use for Gas Clean Up	0.030 MJe/MJ biomethane	GREET1_2011	
Energy Use for Compression	0.016 MJe/MJ biomethane		
Energy Use for Liquefaction	0.043 MJe/MJ biomethane		

B. Calculations for the Lifecycle Analysis of Renewable Electricity Produced from Waste Derived Biogas[l].

The lifecycle analysis of renewable electricity produced from waste derived biogas focused on emissions associated with production of the fuel. We did not consider any emissions associated with transportation of the renewable electricity (although losses are accounted for), and no tailpipe emissions, so the only significant GHG emissions are derived from fuel production.

The first step in determining the lifecycle GHG emissions associated with production of renewable electricity from waste derived biogas was to determine how much electricity (in

[l] The analysis was performed for biogas generated at a landfill offering a conservative estimate, as digester performance and biogas recovery is greater than landfill systems. Landfills lose approximately 20% of the total biomass to aerobic oxidation and as much as 30% to fugitive emissions.

mmBtu) could be produced from a given amount of biogas (in mmBtu) based on values for the efficiency of typical electricity generation at landfills or waste digesters provided by EPA's Landfill Methane Outreach Program (LMOP; Table 5) Table V.B.-1 in the Preamble outlines this calculation. We then apportioned the electricity generation proportionately according to the generation technology used (engines, turbines, combined cycle turbines) using the % of total capacity values given above. We used the parasitic loss efficiency values for engines and turbines (above) to determine the size of the parasitic losses for each category of electricity generation and subtracted these values from the generation values above. We then summed the amounts of electricity remaining after these losses to determine the net amount of electricity produced from the biogas after parasitic losses. We subtracted the amount of this energy that would be used to power the biogas collection system. We also calculated how much of the electricity leaving the facility would be lost during transmission and distribution using data from EIA (see Table 5) and subtracted this amount from the total electricity. In the end, we determined that 0.236 mmBtu electricity would be delivered to the consumer for each mmBtu biogas combusted.

There were two components of electricity production that figured in the lifecycle analysis: on-site emissions and upstream emissions (Table V.B.-2 in the Preamble). Based on the relationship between electricity production and biogas combustion, the emissions factor for flaring, and the weighted average emissions factor for gas-to-energy projects listed above (Table 5), we determined the amount by which on-site emissions at the biogas source would change. We used the value for the U.S. average GHG emissions from electricity production to calculate the amount of emissions in the flaring baseline scenario that are due to the grid electricity used to power the biogas collection system. This amount was assigned as a credit, since these emissions would be eliminated upon installation of a gas-to-energy project because renewable electricity would power the biogas collection system. Adding together the values for on-site and upstream emissions yields lifecycle GHG emissions of 12 kg CO_2-eq/mmBtu electricity, which is an 87% reduction in emissions from the petroleum gasoline baseline (Table V.B.-2 in the Preamble). Because the drivetrains of electric vehicles are roughly 3 times as efficient as those of traditional internal combustion cars, we also calculated GHG emissions taking this improved efficiency into account. For these calculations, we determined the GHG emissions for each lifecycle stage per mmBtu of a "fuel equivalent", assuming that it would take three times the energy of a liquid fuel to drive a car as far as a given amount of electricity. The lifecycle GHG emissions from electricity produced from waste derived biogas considering this factor are 4 kg CO_2-eq/mmBtu fuel equivalent, or a 96% reduction in GHG emissions from the petroleum baseline[m]. According to both of these calculations, renewable electricity produced from waste derived biogas could qualify as either cellulosic or advanced biofuel.

[m] The analysis was performed for biogas generated in a landfill system offering a conservative estimate, as digester performance and biogas recovery from digesters is greater than landfill systems.

C. Calculations for the Lifecycle Analysis of Renewable CNG and LNG Produced from Waste Derived Biogas.

As part of the March 2010 RFS final rule EPA determined that biogas produced from landfills, sewage waste treatment plants and manure digesters met the 50% lifecycle GHG requirements to be eligible to generate advanced RINs as part of the RFS program. In this rulemaking we indicate that CNG and LNG produced from biogas from landfills, MSW digesters, wastewater treatment facility digesters, and agricultural digesters should be classified as cellulosic biofuel if it meets the 60% lifecycle GHG requirements. Similar to renewable electricity, the only significant GHG emissions associated with the lifecycle analysis of CNG and LNG produced from waste derived biogas are derived from fuel production.

We considered the energy associated with cleaning the biogas and compressing it to either CNG or LNG based on the factors outlined in Table 5. We compared this to the flaring baseline as discussed above and determined that CNG and LNG produced from waste derived biogas would result in over an 80% reduction in GHG emissions compared to the petroleum baseline. According to these calculations, CNG and LNG produced from waste derived biogas could qualify as either cellulosic or advanced biofuel.

D. Choice of Baseline for Waste Derived Biogas Treatment

When conducting a lifecycle analysis of greenhouse gas emissions for biofuels produced from waste derived biogas, it is important to choose an appropriate baseline for comparison. The baseline assumption is important because, as per the approach outlined in the March 2010 RFS rule,[6] the lifecycle calculations are based on a scenario approach. The results are determined based on a comparison of the biogas-based biofuel scenario to a baseline scenario that would have happened if the biogas was not used to produce transportation fuels. There are two main components of the baseline to consider, how use of waste-derived biogas for transportation fuels would impact waste disposal, and how it would impact the current or alternative treatment of the biogas.

If waste management methods were impacted by use of biogas for transportation fuel, there could be indirect GHG emissions impacts. However, waste management policies are typically controlled by state and local governments, and there are many unique factors that influence these decisions. We have not seen any evidence or data to suggest that the RFS in general has had or will have a substantial impact on existing waste disposal practices across the U.S., and therefore we believe that there will not be significant GHG impacts associated with the biogas-based pathways adopted in this rule. Therefore no GHG impacts from waste disposal changes are included in the GHG analysis. This is consistent with the March 2010 RFS final rule which concluded that municipal solid waste has no agricultural or land use change GHG emissions associated with its production.

Biogas can be handled and/or processed in one of three primary ways: venting to the atmosphere, collection and flaring, and collection with use in a gas-to-energy or gas-to-fuel project. Theoretically, any of the above scenarios could serve as a baseline scenario for our lifecycle analysis since all three occur at biogas source sites in the U.S. We first examine how the prevalence of flaring and gas-to-energy projects at landfills has changed over time and what impacts this has had on total methane emissions from landfills. We then outline the implications of using other possible baselines and discuss why we propose to use flaring as the baseline.

Historical uses for landfill biogas

Figure 3, below, shows how the uses of landfill biogas in the U.S. changed over a 20-year period from 1990 to 2010 based on data from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.[16] During this time period, the amount of methane produced in landfills increased by 50%, however, the amount of methane released from these same landfills decreased by roughly 25% between 1990 and 2000 and has remained mostly constant since then. This large reduction in methane emissions is due primarily to the institution of EPA regulations, finalized in 1996, requiring large landfills to capture and treat their biogas.[17] In parallel, the Landfill Methane Outreach Program (LMOP) has facilitated the development of an array of projects to collect and beneficially use landfill biogas, particularly from smaller, unregulated landfills.[18] These emissions reductions were achieved via a 12-fold increase in the amount of methane that was flared from 1990 to 2010 and a 6-fold increase in the amount of methane used in gas-to-energy projects over the same time period (Figure 3). From 1990 to 2000, flaring and gas-to-energy projects increased more or less in tandem, but from about 2000 to 2005, gas-to-energy projects stabilized whereas flaring projects continued to increase. Leading up to 2010, the importance of flaring projects declined slightly whereas gas-to-energy projects increased substantially, such that in 2010, the amounts of methane destroyed by each type of project were almost equivalent. Today, most of the methane that is still emitted derives from small landfills that are not required to capture and treat their biogas. Smaller proportions derive from leakage at landfills that do capture their biogas; EPA's Compilation of Air Pollution Emission Factors (*AP-42*) estimates collection efficiencies at such landfills typically range from 60% to 85%, with an

average of 75% capture efficiency most commonly assumed.[19]

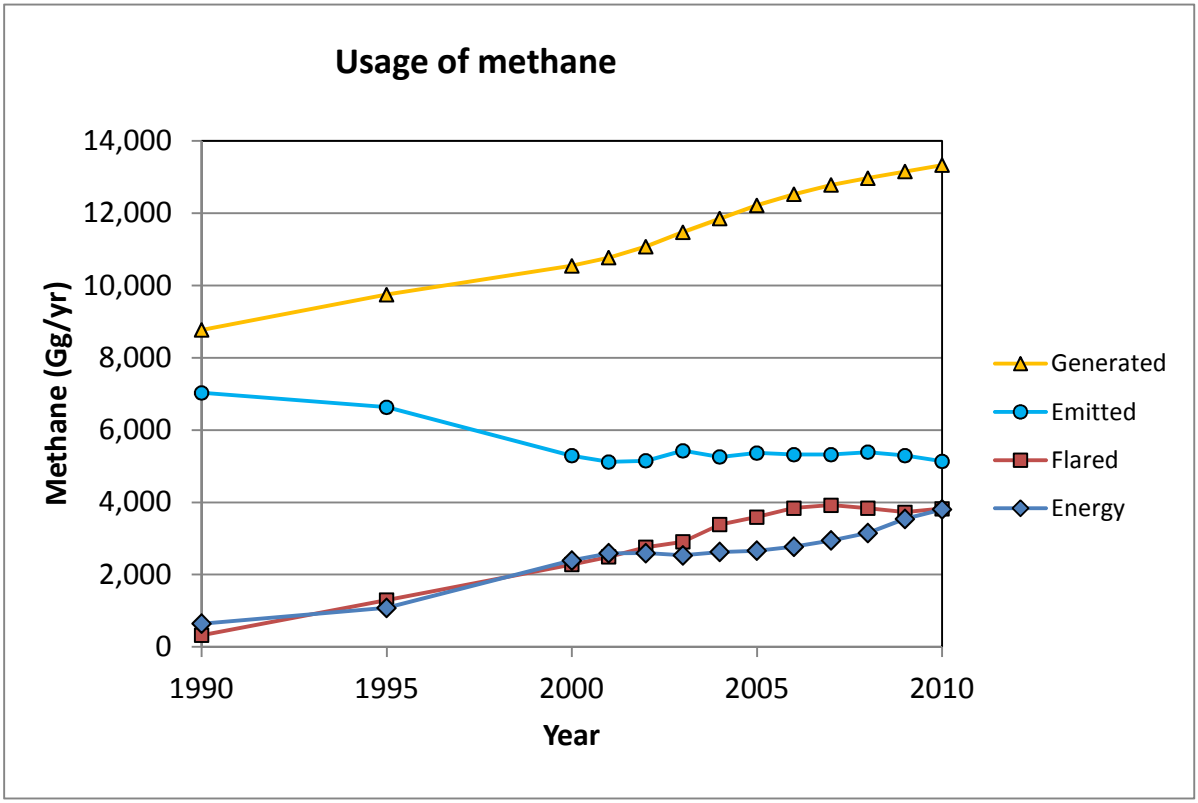


Figure 3 – Amounts of methane generated at, emitted from, flared at, and used in gas-to-energy projects at landfills in the U.S. from 1990-2010.[8]

Possible alternative baseline scenarios

The results of our landfill biogas lifecycle analysis would have been very different if, instead of landfills that flare their biogas, we had chosen as a baseline either landfills that do not capture and treat (e.g., that vent) their biogas or those with existing gas-to-electricity projects. Here, we examine in detail the possible use of these three baselines for the renewable electricity pathway.

Renewable Electricity Pathway. Table 5 below shows the results of lifecycle analyses for the renewable electricity pathway calculated using each of these three baseline scenarios. For the scenario involving conversion of a landfill that is venting its methane to a gas-to-energy project, the primary change is in the on-site emissions at the landfill. Under the venting scenario, the landfill would be releasing large amounts of methane, a potent greenhouse gas, to the atmosphere, so that collecting the methane to use in a gas-to-energy project would be accompanied by reductions in GHG emissions at the landfill of 1959 $kgCO_2$-eq/mmBtu electricity (Table 6). Another, smaller change relative to the flaring baseline is that because venting landfills do not collect their biogas, they would not have been using any electricity to power blowers for gas collection, so this is not a factor in this scenario. The large reduction in

methane emissions from the landfill results in a 2099% reduction in GHG emissions relative to the gasoline baseline upon conversion from a venting landfill to a landfill with a gas-to-electricity project. Consideration of the improved efficiency of electric vehicles results in a 765% reduction in GHG emissions relative to the baseline (Table 6). This demonstrates that renewable electricity would easily qualify as a cellulosic biofuel if we used landfills that vented (did not treat) their biogas as the baseline for comparison.

Table 6 – Comparison of total lifecycle greenhouse gas emissions (kg CO_2-eq/mmBtu electricity or gasoline) for renewable electricity produced from landfill biogas using three different baselines. Numbers in parentheses show values calculated per mmBtu fuel equivalent, which considers the greater efficiency of electric vehicles compared to gasoline vehicles.

Lifecycle Stage	From Landfills that Vented Biogas	From Landfills that Flared Biogas	From Landfills that Converted Biogas to Electricity	2005 Gasoline Baseline
On-site emissions	-1959 (-653)	25 (8)		
Upstream (electricity production for blowers)		-13 (-4)		
New electricity generation			220 (73)	
Total Emissions:	**-1959 (-653)**	**12 (4)**	**220 (73)**	**98**
% Change from Gasoline Baseline	**-2099% (-765%)**	**-87% (-96%)**	**124% (-25%)**	

The use of landfills that flare their biogas was discussed in the Preamble. Under this scenario, installation of electricity generators would result in increased on-site emissions due to less efficient combustion of generators versus flares. The other factor in this lifecycle analysis is reduced upstream emissions from grid electricity that was used to collect the biogas under a flaring scenario but would be replaced by renewable electricity upon installation of gas-to-electricity capability. Overall emissions using a flaring baseline were 12 kg CO_2/mmBtu electricity, corresponding to an 87% reduction in GHG emissions versus the gasoline baseline. These reductions increase to 96% upon consideration of the increased efficiency of electric vehicles.

In contrast, if our baseline is landfills that already capture their biogas and use it to generate electricity, there are no physical changes at the landfill, and the only change is that this renewable electricity is tracked to transportation uses. In this case, the lifecycle GHG emissions increase relative to gasoline, as shown in Table 6. Because there is no physical change at the

landfill, neither on-site emissions nor upstream electrical production to power gas collection blowers changes. However, this scenario could require additional electricity to be produced to replace that diverted for use in the transportation sector, and this new electricity, which we assume is derived from the grid, is accompanied by additional GHG emissions of 220 kg CO_2-eq/mmBtu electricity. The possible need for this additional electricity can be best understood by stepping through Figure 4 below. The left side of the figure shows the baseline situation in which combustion of biogas at a landfill generates electricity that is added to the shared electrical grid. Electricity from the grid is then withdrawn for a variety of uses. The transportation sector is completely separate from these sectors. However, if the electricity is directed to the transportation sector, as shown on the right side of the figure, all of these sectors are connected. EPA is required by the Energy Independence and Security Act of 2007 (EISA) to compare the GHG emissions of renewable fuels to those of the petroleum (gasoline or diesel) fuel baseline. One way of performing this analysis would be to compare electricity used in electrical vehicles (EVs) to baseline gasoline in gasoline vehicles. As shown in Figure 4, the net result is that additional electricity is withdrawn from the shared grid to power EVs (that replace gasoline vehicles). However, the demand for electricity for other uses would not change in this scenario (i.e., the balance of inputs and outputs from the grid box in Figure 4 must remain constant), which requires that the electricity diverted to transportation uses must be replaced with electricity from other sources. This electricity comes with additional GHG emissions of 220 kg CO_2-eq/mmBtu electricity (Table 6) and results in a 124% increase in GHG emissions compared with the gasoline baseline, such that renewable electricity using a gas-to-energy baseline would not qualify as a renewable fuel under the RFS program. Consideration of the increased efficiency of electric vehicles reduces these emissions to a 25% decrease versus the baseline, which would allow the electricity to qualify as a renewable fuel but not as an advanced or cellulosic biofuel.

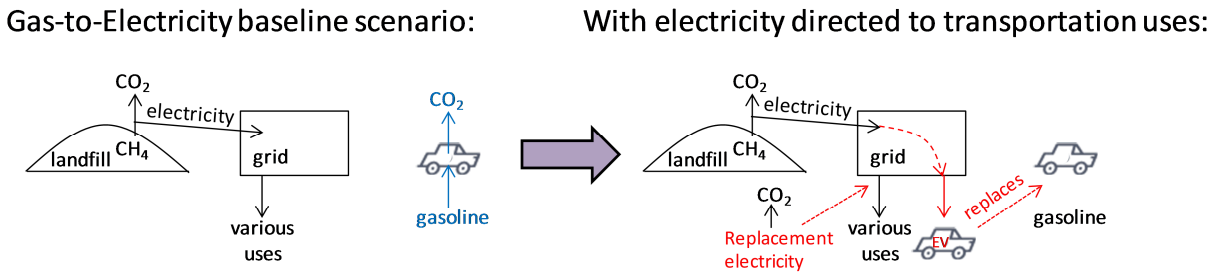


Figure 4 – Comparison of scenarios used for evaluating the renewable electricity pathway when using an existing gas-to-energy project as a baseline. Black arrows represent fluxes of greenhouse gases or electricity that are relevant under both scenarios, red arrows represent fluxes that are important only when electricity is directed to transportation use, and blue arrows are fluxes that decrease when electricity is directed to transportation uses.

However, in reality, the availability of additional renewable electricity would not have a direct impact on the numbers of EVs on the road and thus would not directly replace gasoline as

a fuel. Instead, the renewable electricity would replace other sources of electricity (e.g. from coal- or natural gas-fired power plants) as power for EVs. This scenario would represent a diversion of renewable electricity from general uses to EVs, and a diversion of grid electricity from general and EV uses to more general uses. This is effectively an exchange in the uses for the two types of electricity and would not result in any net change in GHG emissions from the baseline scenario. Thus, if we compare the GHG emissions of a gas-to-energy project used for transportation to one directed into the shared grid, there would be no change in GHG emissions. The electricity would not replace gasoline, there would be a 0% change from the petroleum baseline, and renewable electricity would still not qualify as a renewable fuel under the RFS program. As stated above, EPA is required by statute to compare to a petroleum fuel baseline, resulting in a very different lifecycle analysis for the resulting renewable electricity. However, renewable electricity does not qualify as a renewable fuel under either scenario using a gas-to-energy baseline, so these different ways of considering this question lead to the same end result.

Justification for the choice of a flaring baseline scenario

Of these three possible baseline scenarios, we believe a flaring baseline is the most logical for the renewable electricity pathway. First, flaring is a possible scenario at all waste digesters. Second, assuming that the biogas is flared generally provides a worst case baseline as compared to a venting baseline. If sources that are using flaring will achieve a 60% GHG reduction when converting to electricity production, sources that are venting their methane or portions of their methane will certainly do so as well. As discussed in the Preamble, we do not consider landfills that vent their biogas to be a realistic baseline for any of these pathways, and the flaring baseline is the more conservative baseline compared to venting. Moreover, venting landfills must be small in size and generate a relatively small amount of biogas, otherwise they would be required to capture and treat their biogas. Accordingly, we expect that these landfills would not typically generate enough electricity from their biogas to justify the capital costs to install generators, so we expect that few of these landfills would convert to gas-to-energy projects Therefore, these facilities are extremely unlikely to draw biogas from the small, unregulated landfills that currently vent their biogas. LMOP is currently working with some of the larger of these landfills to facilitate the installation of gas-to-energy projects, so such conversions are economically feasible for at least a subset of these landfills. However, use of venting landfills as a baseline would result in the same classification as would use of flaring landfills as a baseline. In both cases, the fuel produced from landfill biogas qualifies for the RFS program.

In contrast with the use of a venting baseline, if we used landfills with existing gas-to-electricity projects as a baseline, these landfill biogas-based biofuels would all fail to qualify for the RFS program. It is therefore especially important to consider which of these baselines is most appropriate. If we use a flaring baseline and qualify renewable electricity under the RFS program, it is possible that landfills with existing gas-to-energy projects may divert their

renewable electricity for use as a transportation fuel. In these cases, the renewable electricity would already be produced and added to the grid so there would be no actual change at the landfill. Additionally, Figure 3 shows that gas-to-energy projects have been expanding since 2003, which suggests that other incentives are already promoting installation of gas-to-energy projects at landfills. In contrast, if we used facilities with existing gas-to-energy projects as the baseline for comparison, no renewable electricity from landfill biogas would qualify for the RFS program. The use of this baseline would, therefore, exclude renewable electricity from facilities that converted from flaring (or even venting) from qualifying under RFS, even though these projects would be accompanied by real, large reductions in GHG emissions. Because of this result, we have determined that use of existing gas-to-energy projects as a baseline would not be appropriate. EPA believes that the Act should be interpreted and implemented to promote the growth in use of renewable fuels for transportation purposes, and to achieve GHG emissions reductions as a consequence. EPA believes that use of a flaring baseline best accomplishes these objectives.

One option to deal with the discrepancy in lifecycle results between facilities that used to flare their biogas and those with existing gas-to-energy projects would be to qualify electricity produced from these different types of facilities differently. In this case, renewable electricity produced from landfills that installed new gas-to-electricity projects would qualify as a cellulosic biofuel whereas renewable electricity produced from landfills with existing gas-to-electricity projects would not qualify as renewable fuel under the RFS program. One problem with such a tiered approach is that landfills with existing gas-to-energy projects previously made the decision to install the gas-to-energy equipment either to replace flaring or instead of installing flares and thus are already best-performers. Likewise, under such a system, electricity from all new gas-to-energy facilities would qualify as cellulosic biofuels, but electricity from existing facilities would not. However, many of the new facilities may have installed gas-to-energy projects regardless of the RFS program, driven by the same incentives that motivated the existing facilities. Given the existence of other incentives to install gas-to-energy capabilities, discriminating between existing and new gas-to-energy projects seems arbitrary in this light. Additionally, the RFS program does not discriminate against facilities that are already producing renewable fuels, and in fact, the program grandfathers many existing facilities into the program. It would therefore appear inconsistent with the RFS program to discriminate between facilities that are already creating renewable electricity and those that convert from flaring to gas-to-energy projects.

We considered all of these factors in deciding on a baseline and believe that a flaring baseline is most appropriate. The choice of a single baseline for all renewable fuels produced from waste-derived biogas does not discriminate based on prior use of the biogas and is thus consistent with the qualified pathways that have been approved to date under the RFS program. As discussed above, most venting landfills are unlikely to install gas-to-energy projects because of their small size, thus venting is an inappropriate baseline. Likewise, using existing gas-to-energy projects as a baseline is also inappropriate because this would exclude projects with

legitimate GHG emissions reductions (e.g., those that are currently venting or flaring) from qualifying. Use of landfills that flare their biogas as a baseline is appropriate because flaring is the main alternative to electricity generation or liquid fuel production at large landfills, and all existing and future gas-to-energy projects chose or will choose to generate electricity instead of simply flaring. Using this baseline, all renewable electricity generated from landfill biogas would qualify as cellulosic biofuel. Allowing renewable fuels produced from landfill biogas to generate RINs will provide an additional financial incentive for landfills to convert from flaring or venting to gas-to-energy projects and may thus help accelerate the adoption of this technology and lead to additional GHG emissions reductions.

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Appendix D

4/23/20 Addendum to Fuel Pathway Request to Include Municipal Wastewater Treatment Facility (MWTF) Sludge or its Digestate as Feedstocks

ADDENDUM REQUEST

DATE: 04/23/2020

RE: Addendum to Fuel Pathway Request to include Municipal Wastewater Treatment Facility (MWTF) Sludge or its Digestate as Feedstocks

FROM: Agresti Energy, LLC

Request Description and Type of Feedstock (No information claimed CBI)

Agresti Energy is kindly requesting an addendum to its previously submitted pathway petition to Include MWTF sludge, and MWTF sludge digestate as cellulosic feedstocks for its proposed Pressure Hydrolysis Process (PHP). All other aspects of the proposed pathways remain the same. Digestate would be considered the feedstock for the PHP when the primary sludge is first pretreated by anaerobic digestion. Otherwise, the primary sludge would be fed directly to the PHP. Digestate is the discharge material from an anaerobic digester containing the solid residue of the original injected feedstock. As illustrated in our petition application and associated responses, digestate contains practically all of the cellulosic solids of the original feedstock. Agresti Energy's PHP converts cellulosic biomass to biogas by weak acid hydrolysis and anaerobic digestion (refer to petition application for further details). The PHP facilities will be co-located with municipal wastewater treatment facilities and be an integral part of their operations.

MWTF sludge as a human and industrial waste derivative, requires special care in its treatment, processing, and residue disposal. Sludge contains varying concentrations of heavy metals, hazardous organic compounds, and pathogenic microorganisms. Conventional sludge treatment processes continue to come under increasing scrutiny as the hazards of sludge are being more completely understood and realized. Agresti Energy's PHP technology is a combination of subcritical wet oxidation, weak acid hydrolysis, and anaerobic digestion that can oxidatively destroy hazardous organic compounds like polycyclic aromatic compounds, oxidize heavy metals to an inert non-leaching ash, and destroy pathogenic microorganisms.

Biogas from wastewater treatment facility digesters is listed in Table 1 to 40 CFR 80.1426 with a D-Code of 3 (cellulosic biofuel) and indicating that EPA has previously evaluated MWTF sludge as a feedstock. Also, EPA-HQ-OAR-2012-0401 titled "Support for Classification of Biofuel Produced from Waste Derived Biogas as Cellulosic Biofuel and Summary of Lifecycle Analysis Assumptions and Calculations for Biofuel Produced from Waste Derived Biogas" summarizes the cellulosic content calculations and life cycle calculations from waste (including MWTF sludge waste) derived biogas. The category of renewable biomass per the definition of Part 80.1401 that MWTF sludge qualifies for is Animal (human) waste.

Information for New Feedstocks

N/A—EPA has previously evaluated

The following has been taken from an open access chapter (permitting unrestricted use, distribution, and reproduction in any medium) on the subject of Wastewater Sludge. It is well documented and provides detailed coverage on the various processing measures and disposal alternatives for sludge.

Chapter 6

Supercritical Water Gasification of Municipal Sludge: A Novel Approach to Waste Treatment and Energy Recovery

Jonathan Kamler and J. Andres Soria

1.1. Wastewater sludge

Sewer systems in the U.S. transport over 14.6 trillion gallons of municipal wastewater to ~17 thousand public wastewater facilities each year (CSS, 2011; Fytili & Zabaniotou, 2008). The facilities are designed to collect, remediate, and dispose of human and commercial wastes within an established regulatory framework (Chun et al., 2011; Demirbas, 2011b; Fytili & Zabaniotou, 2008; Svanström et al., 2004; USEPA, 2009). Sewage that enters wastewater treatment facilities gets processed and separated into two products. One is clean water, which is the primary objective of municipal facilities. The other is the leftover waste, generically known as sewage sludge (Abelleira et al., 2011).

Sludge is the most ubiquitous wet waste generated by humans (Abelleira et al., 2011). The U.S. Environmental Protection Agency (EPA) last estimated U.S. sewage-sludge production in 1998 at 6.9 million dry tons (USEPA, 1999b). Unconfirmed estimates dating back as far as 1982, however, put total U.S. sewage sludge volume much higher at nearly 20 million dry tons with an additional comparable amount of other industrial sludges (Gloyna & Li, 1993; Svanström et al., 2004).

All sewage sludge from modern wastewater treatment plants is potentially harmful to human health by design and is designated as a pollutant by the Clean Water Act (Harrison et al., 2006; Mathney, 2011; NASNRC, 1996, 2002; USEPA, 2009). When sewage undergoes treatment, the solids, along with a myriad of entrained hazardous and harmful pollutants and pathogens, are removed from the water and concentrated into sludge (Bernardi et al., 2010; Hong et al., 2009; Snyder, 2005; USEPA, 1999a, 2009). Consequently, the physical

properties and chemical constituents of sludges vary widely, depending on the source and treatment of the sewage. Generally, however, sewage sludge is treated as a homogenous, non-standardized slurry of materials, consisting mainly of human metabolic and food wastes as well as varying amounts of industrial, agricultural, and medical wastes (Harrison et al., 2006; Hong et al., 2009).

1.1.1. Sewage sludge composition & regulatory framework

All sewage sludge produced in the U.S. contains varying concentrations of three types of harmful pollutants: 1) heavy metals, 2) hazardous organic compounds, and 3) pathogenic microorganisms. Safely managing these hazardous compounds and pollutants has proven challenging (NASNRC, 2002; USEPA, 2009).

1.1.1.1. Heavy metals

Heavy metals ubiquitously entrained in sludge pose serious and well-documented public health and environmental risks (Babel & del Mundo Dacera, 2006; Bag et al., 1999; Beauchesne et al., 2007; Dimitriou et al., 2006; Fjällborg et al., 2005; Fytianos et al., 1998; Goyal et al., 2003; Hooda, 2003; Kidd et al., 2007; McBride, 2003; Pathak et al., 2009; Reddy et
al., 1985; Sánchez-Martín et al., 2007; USEPA, 2009). The EPA, however, limits sludge regulations to only ten (i.e., arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc) of the high-risk, hazardous, bioaccumulating, and leaching metals (Babel & del Mundo Dacera, 2006; Dean & Suess, 1985; Harrison et al., 1999; McBride, 2003; Pathak et al., 2009; Sánchez-Martín et al., 2007; USEPA, 2002b, 2009). Reviews
detailing heavy metal prevalence in sludge and related health concerns can be found elsewhere (Babel & del Mundo Dacera, 2006; Bag et al., 1999; Harrison et al., 1999; McBride, 2003; Pathak et al., 2009; Sánchez-Martín et al., 2007; Snyder, 2005).

1.1.1.2. Hazardous organic compounds

Hazardous organic compounds commonly found in sewage sludge matrices are many and varied, including endocrine disrupters, pharmaceuticals, polybrominated fire retardants, polychlorinated biphenyls, carcinogens, pesticides, household chemicals, solvents, and dioxins (Costello & Read, 1994; Gómez et al., 2007; Hale et al., 2001; McBride, 2003; NASNRC, 2002; Qi et al., 2010; Rulkens, 2008; Santos et al., 2010; Sipma et al., 2010; Snyder, 2005; Stasinakis et al., 2008; Zorita et al., 2009). Hazardous pollutants are ubiquitous in sewage sludge. The EPA studied sewage sludges from wastewater facilities across the U.S. and found large amounts of hazardous materials in all of the sludges (USEPA, 2009). Many organic compounds in sludge do not break down quickly in the environment and are often highly mobile, resulting in widespread harmful, organic-compound distribution (Guo et al., 2009; Kulkarni et al., 2008; Leiva et al., 2010; Rulkens, 2008). Consequently, human exposure to some harmful organic compounds from sewage sludge (e.g., dioxins) is considered pervasive and chronic (Kulkarni et al., 2008). Only about 110 organic chemicals (of fewer than 130 total chemicals) are on EPA's antiquated priority pollutant list, and there is no

regulatory requirement to monitor any of those in sewage sludge (Clarke & Smith, 2011; Deblonde et al., 2011; Eriksson et al., 2008; Harrison et al., 2006; Hospido et al., 2010; Petrovic´ et al., 2003; Verlicchi et al., 2010).

The proliferation of new pollutants in sewage sludge is also a growing concern. The number of organic chemicals is increasing rapidly, now well in excess of 100 thousand. Very few of the pollutants noted to be commonly present in sludge, including low-grade, radioactive residues in medical wastes, have been studied in detail either in terms of prevalence or harmful effects (Eriksson et al., 2008; Fytili & Zabaniotou, 2008). Even though their effects on environment and human health are largely unknown, these "emerging pollutants" fall outside EPA regulatory status (Deblonde et al., 2011; NASNRC, 2002; Tsai et al., 2009). Furthermore, there have been no major updates to the EPA's priority pollutant list in almost three decades (Harrison et al., 2006; Mathney, 2011; Snyder, 2005).

1.1.1.3. Pathogens

Pathogen loads in sewage sludge are almost universally high and pose a communicable disease hazard (NASNRC, 2002; Reilly, 2001; USEPA, 2009). The pathogens are a result of normal, human metabolic wastes as well as additional loading from medical effluents (Arthurson, 2008; Deblonde et al., 2011; Lewis et al., 2002; Mathney, 2011; Reilly, 2001; Straub et al., 1993; USEPA, 2009; Verlicchi et al., 2010). There are fewer than two dozen pathogens (e.g., fecal coliforms, Salmonella, enteric viruses, and parasites) monitored in sewage sludge (Mathney, 2011; NASNRC, 2002; Reilly, 2001; Snyder, 2005; USEPA, 2000, 2002b, 2003), and many dangerous pathogens (e.g., prions) are neither affected by sewage treatment nor detected by standard analytical methods (Gale & Stanield, 2001; NASNRC, 2002; Peterson et al., 2008b; Saunders et al., 2008; Smith et al., 2011; Snyder, 2005).

Despite considerable controversy surrounding potential sludge hazards, there has been disturbingly little critical inquiry into the environmental effects and human health risks of traditional sludge disposal methods (Deblonde et al., 2011; Mathney, 2011; Nature, 2008; Tollefson, 2008). Nonetheless, some EPA goals (albeit with no specified implementation horizon) indicate that very high destruction requirements (up to 99.9999%) may become standard for some compounds, along with totally enclosed treatment facilities (Lavric et al.,

2005; Veriansyah & Kim, 2007). If such regulatory standards are ever implemented, the feasibility and suitability of conventional sludge disposal techniques will be subject to increased scrutiny (Demirbas, 2011b; Veriansyah & Kim, 2007).

1.2. Sludge processing & disposal

Despite improvements in wastewater cleaning technology and expansion of centralized wastewater services to meet the needs of most of the U.S. population, sludge disposal has historically been, and continues to be, the weak link in the wastewater treatment process

(Demirbas et al., 2011; Fytili & Zabaniotou, 2008; Harrison et al., 2006; NASNRC, 1996, 2002).

Ocean dumping was a preferred sludge disposal method for the last couple of centuries (Chun et al., 2011; Snyder, 2005), but it was banned in the 1990s by both U.S. and international law due to the high level of harmful pollutants in the sludge and the adverse effect on marine organisms (Abbas et al., 1996; Costello & Read, 1994; Harrison et al., 2006; Snyder, 2005). The loss of ocean-dumping drove most municipalities to embrace either agricultural land application or thermal destruction (viz., incineration) as their primary sludge-disposal routes, with a small percentage using landfilling or composting (Lavric et al., 2006). Current sludge disposal methods, and associated regulations, are outgrowths of the need for municipalities to find a viable solution for treating or disposing large amounts of concentrated harmful pollutants resulting from wastewater treatment. Disposal choice is influenced by economics, public policy, and regional environmental conditions (Cappon, 1991; Rulkens, 2008).

1.2.1. Land application

Agricultural land application is the most commonly used and most controversial of the sludge disposal methods, but has gained favor due to the simple-bottom-line cost. Potential hazards of applying sludge to croplands were noted early on in the adoption of land-application practices.

Using material laden with harmful organic compounds in food and forage cultivation makes land application problematic both in terms of operational costs and, more importantly, public health concerns (Borán et al., 2010; CSS, 2011; Demirbas et al., 2011; Eriksson et al., 2008; Fytili & Zabaniotou, 2008; Harrison et al., 2006; NASNRC, 1996, 2002). Specifically, potential food-crop contaminant uptake and subsequent human-food-chain contamination are legitimate concerns (Cappon, 1991). Despite the well-documented, undesirable properties of sewage sludges for agricultural purposes, most communities continue to favor sludge land application over other disposal methods (Beauchesne et al., 2007; Beck et al., 1995; McBride, 2003). The proponents of sludge land application argue that harmful-organic-compound behavior in soils from sludge application is reasonably well understood and that there will be negligible detrimental health and environmental impacts (McBride, 2003).

1.2.2. Thermal destruction

Thermal destruction (i.e., incineration) offers a year-round, all-weather sludge disposal option, albeit an energy-intensive and thus increasingly expensive option. Many large cities

in the colder northern climates use incineration, with more than 200 sewage-sludge incinerators (fluidized-bed and multiple hearth configurations) in use nationwide (Sloan et al., 2008). High water content (along with associated high enthalpy demand) poses the main thermodynamic impediment to cost-effective thermal sludge destruction. During the destruction process, all of the energy released from the sludge, and essentially all of the incinerator fuel, is consumed to boil off water (Demirbas, 2011b; Dijkema et al., 2000; Fytili & Zabaniotou, 2008). Furthermore, sludge must initially be dewatered to a "sludge cake" consistency with moisture content below 85% prior to feeding into the incinerator. Once in the incinerator, the sludge cake must be further dewatered thermally to ~35 w/w% moisture before the material itself can actually begin to thermally combust (Abuadala et al., 2010). Dewatering is expensive, and as energy costs continue to rise, drying processes are becoming increasingly prohibitive (Weismantel, 2001).

Dry pyrolysis and gasification face similar thermoeconomic efficiency limitations to incineration, in that high-moisture levels in sludge cause ignition and combustion problems (Demirbas et al., 2011; Dogru et al., 2002). Specifically, traditional gasification technologies encounter operational air:fuel ratio and gas:ventilation mobility problems when the feedstocks exceed 30% moisture content, and sewage-sludge moisture content generally needs to start at less than 15% to serve as a proper feedstock for gasifiers (Dogru et al., 2002).

Plus, fuels produced require significant additional cleaning due to the presence of heavy metals and incomplete destruction of harmful organic compounds (Dogru et al., 2002). Indeed, traditional thermal technologies do destroy hazardous organic compounds, but only

up to a point. Incineration-derived slag, for example, still contains all of the heavy metals, up to 30% of the original hazardous organic compounds, and additional secondary combustion compounds (Dogru et al., 2002; Fytili & Zabaniotou, 2008). Most contemporary thermal options are prohibitively costly due to high capital investment and increasingly stringent, air-quality permitting and compliance standards (Chun et al., 2011; Fytili & Zabaniotou, 2008). Thermal destruction also meets with considerable, unfavorable public opinion due to the air-borne release of metal emissions and harmful gases (Abbas et al., 1996; Adegoroye et al., 2004; Lavric et al., 2006). Intense public protests of new permits alone

have derailed some incinerator permitting efforts (Sloan et al., 2008; Weismantel, 1996).

1.2.3. Landfill disposal

Landfilling (i.e., burial) of sludge is used as a disposal method by many municipalities, often

in an effort to avoid expensive regulatory incineration restrictions and to sidestep the

greater scrutiny of land application. Nonetheless, landfilling also has a host of problems, including decreased landfill life, increased landfill odor, and increased landfill leachate volume and toxicity. Leachate is a ubiquitous product of landfills, wherein excess water percolates through landfill waste layers, freeing organic compounds from the waste and carrying them away concentrated in leachate. The high water content of sewage sludge is known to escalate leachate volume from landfills (Demirbas et al., 2011). Furthermore, the degradation and conversion of organic compounds in landfilled sludge is usually

incomplete (Ejlertsson et al., 2003), and metabolites can be generated that are even more hazardous than their parent compounds, with the secondary organic pollutants also collecting in the leachate (Oleszczuk, 2008). The composition of leachate is complex, environmentally reactive (with very high COD values: above 60K mg/L), and difficult to treat via conventional methods (Wang et al., 2011). Landfill leachate is a noted health and environmental threat, and harmful compounds in sewage sludge exacerbate the problem (Demirbas et al., 2011). A rise in tipping fees, decreased availability of economic landfill sites, and a move toward sustainable solutions has begun to sour municipal fondness for landfilling (Abbas et al., 1996).

1.2.4. Composting

Non-industrial composting of agricultural wastes dates back thousands of years to ancient Rome, Greece, and Israel for agricultural recycling, and has now gained some recent traction
as a recycling method for modern organic wastes including sewage sludge (Epstein, 1997; Gajalakshmi & Abbasi, 2008; Hubbe et al., 2010; Kumar, 2011). Industrial composting processes are used to convert sewage sludge into "marketable fertilizer" products and ostensibly reduce sludge volume and organic pollutants (Oleszczuk, 2008). Nonetheless, under U.S. Department of Agriculture (USDA) branding regulations, sludge-derived compost
cannot legally be labeled as "Certified Organic", limiting its market potential (USDA, 2011). There are many composting methods. The simpler composting approaches of mixing sludge
with other organic wastes and letting them react with microorganisms are relatively lowtech,
inexpensive, slow, odorous, and invariably require large footprints and relatively dry and warm weather conditions for outdoor operations (USEPA, 2002a). More complex approaches often use thermally accelerated, composting processes, commonly known as invessel,
thermal drying, which produce agricultural "pellets" from sewage sludge at faster processing times in a reduced footprint (Gajalakshmi & Abbasi, 2008; Hubbe et al., 2010; Kumar, 2011; Turovskiy & Mathai, 2005; USEPA, 2002a). A number of municipalities use invessel,

thermal drying, but the high-temperature, pelletizing process generates secondary, hazardous organic metabolites similar to landfilling, but at a much accelerated rate (Farrell & Jones, 2009; Fytili & Zabaniotou, 2008; Kumar, 2011; Oleszczuk, 2008). High-temperature, in-vessel composting increases mobility and bioavailability of the metabolites, which by extension can significantly contaminate and toxify soil faster (Oleszczuk, 2008). Pellet production costs often exceed $400 per dry ton (and can approach $1,000 per dry ton), but many communities end up landfilling all or part of their pellets due to limited market demand (Sloan et al., 2008). Several reviews have evaluated the advantages and disadvantages of different composting technologies (Farrell & Jones, 2009; Gajalakshmi & Abbasi, 2008; Hubbe et al., 2010; Kumar, 2011; Phillips, 1998; USEPA, 2002a).

1.2.5. Carbonization

Carbonization of the sludge into a solid, fuel-like product is a competing energy recovery option that can be performed for considerably lower cost than compost-pellet production

due to elimination of the nuanced need to maintain a marketable fertilizer product. There are a number of competing carbonization conversion processes seeking commercialization that rely on drying and various woody-biomass or coal combinations (Chen et al., 2011; Roy et al., 2011). Some seek stand-alone fuel status, while others function on the expectation of using carbonized sludge as a co-firing fuel supplement with coal at concentrations less than 5 w/w% (Abbas et al., 1996; Roy et al., 2011; Rulkens, 2008). Reviews of sludge-derived, carbonized, solid fuels can be found elsewhere (Maier et al., 2011; Roy et al., 2011).

The PHP with MWTF Sludge as a Feedstock

When using sludge as a feedstock the objective is two-fold: 1. to recover the energy content of the sludge biomass to produce a renewable transportation fuel, and 2. to safely destroy the sludge leaving only biproducts that can safely be disposed. This is accomplished as follows:

- The PHP converts cellulosic organic solids contained in sludge to a natural gas product recovering the potential energy content of the hemicellulose, cellulose, and 60% of the lignin (lignin provides the endothermic heat energy for the conversion). Renewable Natural Gas (RNG) is the end primary product of this conversion, with CO_2 also being produced.

- To complete the safe destruction of the sludge, all remaining organic solids including the remaining lignin are oxidized. These are exothermic reactions that release the potential energy content of these solids as heat. In this case there will be excess heat which can be utilized to provide the mesophilic temperature requirements in the anaerobic digester, and to provide climatic indoor heating for the treatment plant facilities. To channel this heat for use, and to help control temperatures in the oxidation reaction zone, a water jacket (heat transfer fluid system) is fitted to the Vertical Reactor (VR). Due to oxidation, temperatures at the bottom of the VR will reach 464° F (240° C). This along with high gravity induced pressure at the bottom of

the VR provides subcritical water conditions that facilitate the sludge destruction process. Oxidation also produces CO_2.

The PHP system literally “plugs in” to the Municipal Wastewater Treatment Facility. The PHP replaces the solids processing. For instance, if the facility was disposing its sludge by incineration or land application, that would no longer be required. Preliminary treatment, Primary Treatment (including clarification functions and possibly anaerobic digestion), Secondary Treatment (including aeration, filtering, and disinfection) and Tertiary Treatment (nutrient/inorganic solids removal) continue to function independently with no reliance on the PHP. When anaerobic digestion is conducted as a Primary Treatment step, the PHP would utilize the resulting digestate as feedstock producing a similar quantity of RNG but less oxidative heat than what the primary sludge would produce as a feedstock.

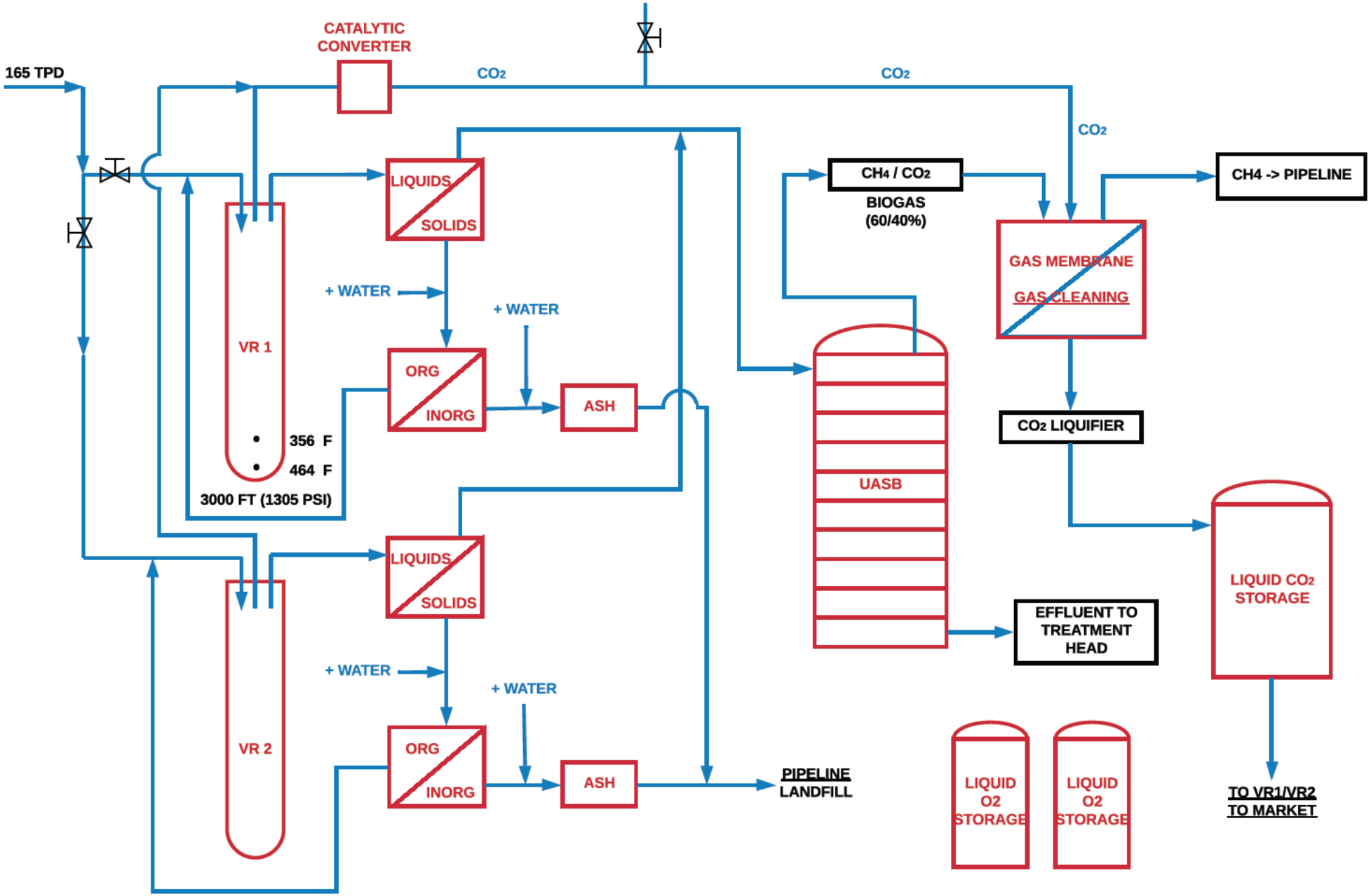
Attached is a Process Flow Diagram for the PHP at an MWTF. A two VR set-up is being illustrated for redundancy purposes. This provides for an individual VR to be taken out of service for maintenance without shutting down sludge processing and disposal. Also, attached are revised Mass and Energy spreadsheets reflecting sludge and sludge digestate as feedstocks. The spreadsheet values are based on an MWTF producing sludge containing 80 dry metric tons of cellulosic solids daily. If the sludge is pretreated by anaerobic digestion first, the produced digestate would provide 77 dry metric tons of cellulosic solids daily. These spreadsheets are also being provided in Microsoft Excel format.

Process Flow Diagram

Sludge Destruction & Energy Production

Process Flow Diagram
Sludge Destruction & Energy Production

AGRESTI ENERGY



Mass and Energy Spreadsheets

Sludge and Sludge Digestate Feedstocks

Data Submission Template for Petitions Involving Fuel Production Processes Not Previously Modeled

Requested Pathway

Fuel Produced	CNG, LNG
Feedstock	MWTF Sludge
Process	Pressure Hydrolysis Process (PHP) & UASB
D-Code Request (see Table V.C-7-D-Code Designations)	D3

Scenario: The presented data are daily values based upon Agresti Energy's PHP processing 80 dry metric tons of cellulosic solids from sludge per day. This sludge will be produced by a Municipal Wastewater Treament facility from sewage conveyed by sanitary sewers. Energy yields are based upon developmental lab testing and design of the PHP over a period of 5 years. Sludge is estimated to contain 79% fiber as a percent of the convertible solids, and 48%-67% of total solids. All mass units are in metric tons.

		Mass		Volume		Lower Heating Value (LHV)		Data Source	
Mass and Energy Balance Information		**Value**	**Units**	**Value**	**Units**	**Value**	**Units**	**Source (Required)**	**Year**
Mass									
Inputs	Feedstocks (specify)							(also list moisture content here)	
	Digestate and Crop Residue							12% solids (88% moisture)	
	Cellulose	22.000	Tons /day					Lab Testing & EPA Info	
	Hemicellulose	37.000	Tons / day					Lab Testing & EPA Info	
	Lignin	21.000	Tons / day					Lab Testing & EPA Info	
	Other convertible Solids	13.000	Tons/day						
	Chemicals (specify)								
	Oxygen (O2) for organic oxidation	76.900	Tons / day					PHP Mass Balance Model	
	Carbon Dioxide (CO2)	0.240	Tons / day					PHP Mass Balance Model	
	Caustic Soda (NaOH)	0.041	Tons / day					PHP Mass Balance Model	
	Others (specify)								
	Water (H2O)	7.200	Tons / day					PHP Mass Balance Model	
	Total	177.381	Tons / day						
Outputs	Fuels Produced (specify)								
	CNG, LNG (Methane)	17.100	Tons / day	25,600	NCM / day	826	Dth/day (LHV)	PHP Mass Balance Model	
	Co-Products (specify)								
	Carbon Dioxide (CO2)	132.300	Tons / day					PHP Mass Balance Model	
	Waste Materials (specify)								
	Water (H2O)	27.700	Tons / day					PHP Mass Balance Model	
	Others (specify)								
	VOC	0.281	Tons / day					PHP Mass Balance Model	
	Total	177.381	Tons / day						
Energy[1]									
Inputs [2]	Purchased Electricity	26,640	KWH/day					PHP Design Determination	
	Purchased Steam or Hot Water								
	Coal								
	Natural Gas								
	Diesel								
	CHP								
	Others (specify)								
Outputs [3]	Excess Electricity Generated								
	Others (specify)								
	Excess Heat generated	424	Dth/day						

[1]Energy balance information should include a list of any energy and process heat inputs and outputs used in the pathway, including such sources produced off site or by another entity.
[2]Energy input information should include fuels used by type, including purchased electricity. Indicate the source, type of fuel required, efficiency, and temperature/pressure for any steam or hot water purchased for the fuel production process.
[3]The extent to which excess electricity or other heat sources are generated and distributed outside the production facility should be described.

Data Submission Template for Petitions Involving Fuel Production Processes Not Previously Modeled

Requested Pathway

Fuel Produced	CNG, LNG
Feedstock	MWTF Sludge Digestate
Process	Pressure Hydrolysis Process (PHP) & UASB
D-Code Request (see Table V.C-7-D-Code Designations)	D3

Scenario: The presented data are daily values based upon Agresti Energy's PHP processing 77 dry metric tons of cellulosic solids from sludge digestate per day. This sludge digestate will be produced by anaerobic digestion of sewage sludge (containing 80 dry metric tons of cellulosic solids) from a Municipal Wastewater Treament facility's sewage conveyed by sanitary sewers. Energy yields are based upon developmental lab testing and design of the PHP over a period of 5 years. Digestate is estimated to contain 96% fiber as a percent of the convertible solids, and 53%-70% of total solids. All mass units are in metric tons.

		Mass		Volume		Lower Heating Value (LHV)		Data Source	
Mass and Energy Balance Information		**Value**	**Units**	**Value**	**Units**	**Value**	**Units**	**Source (Required)**	**Year**
Mass									
Inputs	Feedstocks (specify)							(also list moisture content here)	
	Digestate and Crop Residue							12% solids (88% moisture)	
	Cellulose	21.000	Tons /day					Lab Testing & EPA Info	
	Hemicellulose	36.000	Tons / day					Lab Testing & EPA Info	
	Lignin	20.000	Tons / day					Lab Testing & EPA Info	
	Other convertible Solids	3.000	Tons/day						
	Chemicals (specify)								
	Oxygen (O2) for organic oxidation	53.800	Tons / day					PHP Mass Balance Model	
	Carbon Dioxide (CO2)	0.240	Tons / day					PHP Mass Balance Model	
	Caustic Soda (NaOH)	0.041	Tons / day					PHP Mass Balance Model	
	Others (specify)								
	Water (H2O)	7.000	Tons / day					PHP Mass Balance Model	
	Total	141.081	Tons / day						
Outputs	Fuels Produced (specify)								
	CNG, LNG (Methane)	16.500	Tons / day	24,700	NCM / day	797	Dth/day (LHV)	PHP Mass Balance Model	
	Co-Products (specify)								
	Carbon Dioxide (CO2)	104.900	Tons / day					PHP Mass Balance Model	
	Waste Materials (specify)								
	Water (H2O)	19.400	Tons / day					PHP Mass Balance Model	
	Others (specify)								
	VOC	0.281	Tons / day					PHP Mass Balance Model	
	Total	141.081	Tons / day						
Energy[1]									
Inputs [2]	Purchased Electricity	26,640	KWH/day					PHP Design Determination	
	Purchased Steam or Hot Water								
	Coal								
	Natural Gas								
	Diesel								
	CHP								
	Others (specify)								
Outputs [3]	Excess Electricity Generated								
	Others (specify)								
	Excess Heat generated	254	Dth/day						

[1]Energy balance information should include a list of any energy and process heat inputs and outputs used in the pathway, including such sources produced off site or by another entity.
[2]Energy input information should include fuels used by type, including purchased electricity. Indicate the source, type of fuel required, efficiency, and temperature/pressure for any steam or hot water purchased for the fuel production process.
[3]The extent to which excess electricity or other heat sources are generated and distributed outside the production facility should be described.