

Table of Contents

1. Introduction	2
2. GHG Reduction Estimate Method and Models/Tools Used.....	2
3. Measure Implementation Assumptions.....	4
4. GHG Reduction Estimate Assumptions	5
5. Reference Case Scenario	6
6. Measure-Specific Activity Data	6
7. GHG Emissions Reduced	6

1. Introduction

The Windsor Water District (District) in California owns and operates a 2.2 million gallon per day (MGD) Water Reclamation Facility (WRF) that currently uses sludge ponds for storage and stabilization of the Waste Activated Sludge (WAS) and sludge generated by the Advanced Wastewater Treatment (AWT) clarifiers. The District established specific goals for their future solids management, including eliminating current reliance on outside contractors for biosolids disposal, increasing beneficial use of biosolids, reducing cost and carbon footprint associated with sludge disposal. To achieve these goals, the District completed a Feasibility Study (2021) and a Preliminary design (2022) that established the recommended project. The District selected thickening and dewatering, followed by biodryers and pyrolysis, as the recommended project. Surrounding Sonoma communities also rely on outside contractors for biosolids disposal. Accordingly, the District reached out to surrounding communities to inquire about potentially leveraging the new biosolids project as a regional facility.

The evaluation presented herein includes an operational greenhouse gas (GHG) assessment of current biosolids management for the District and five surrounding communities, including the City of Healdsburg, City of Cloverdale, City of Petaluma, Lytton Rancheria, and Sonoma County. This reference case scenario is compared with the operational GHG footprint of potential future biosolids management for the District and five surrounding communities with the implementation of a new regional biodrying and pyrolysis facility to produce biochar for local use. Overall, the District aims to eliminate current reliance on outside contractors for biosolids disposal, increase beneficial use of biosolids locally, reduce truck traffic associated with hauling, and improve regulatory certainty.

2. GHG Reduction Estimate Method and Models/Tools Used

The GHG Protocol¹ is a partnership of various entities including businesses, nongovernmental organizations, and governments which aims to develop an internationally accepted GHG accounting and reporting standard. The GHG Protocol classifies GHG emissions into three scopes, as defined below. For this study, this evaluation includes only scope 1 and scope 2 emissions because they are more directly under the control of District and Sonoma County communities, although the GHG analysis has been organized to accommodate the potential inclusion of scope 3 emissions in the future.

- Scope 1 emissions reflect direct emissions from sources that are owned or controlled by the District and surrounding Sonoma communities (e.g., carbon dioxide, methane, and nitrous oxide emissions from biological treatment), including on-site fossil fuel combustion, emissions from biological treatment processes, and transportation/hauling-related uses of fleet vehicles and fuel.
- Scope 2 emissions are those resulting from electricity, steam, heating, and cooling that is purchased and/or acquired by the District and surrounding Sonoma County communities.

¹ ghgprotocol.org

- Scope 3 emissions, or embodied GHG emissions, are all additional indirect emissions that occur in the value chain, including both upstream (e.g., manufacturing) and downstream (e.g., disposal) emissions. The Scope 3 emissions resulting from landfilling/land application as compared with biochar use are not included in the quantified GHG footprint of the two scenarios evaluated herein, but are discussed qualitatively in the conclusion.

A boundary must be established for consistent inclusion of inputs and outputs in the evaluation, and transparent communication of comparative results. The boundary of this evaluation includes biosolids-specific activities at the WRF, including onsite storage and treatment, and offsite hauling.

Two operational inventories were created for projected annual average conditions in 2025 through 2050, one assuming continuation of the existing practices (reference case scenario) and one assuming implementation of the proposed biodrying and pyrolysis process at the District WRF. The proposed biodrying and pyrolysis process at the District is assumed to receive biosolids from each of the surrounding Sonoma County communities, as described in Table 1.

Table 1: Current and Proposed Future Biosolids Management for the District and Surrounding Sonoma Communities

Community	Current Biosolids Management (Reference Case)	Proposed Future Biosolids Management
Town of Windsor	<ul style="list-style-type: none"> • Onsite sludge storage in unaerated ponds • Third party dredging, dewatering, and hauling for landfilling every year 	<ul style="list-style-type: none"> • Newly implemented thickening, dewatering, biodrying, and pyrolysis • Biochar production and local use
City of Healdsburg	<ul style="list-style-type: none"> • Dewatering with cationic polymer and centrifuge • Class B placed into contracted sludge hauling trailer for immediate delivery to landfill 	<ul style="list-style-type: none"> • Continued dewatering with cationic polymer and centrifuge • Biosolids hauled to District WRF for biodrying and pyrolysis instead of landfill
City of Cloverdale	<ul style="list-style-type: none"> • Onsite sludge storage in aerated ponds • Third party dredging, dewatering, and hauling for land application every four to six years 	<ul style="list-style-type: none"> • Continued onsite sludge storage in aerated ponds and dredging/dewatering/hauling as needed • Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application
City of Petaluma	<ul style="list-style-type: none"> • Thickening with belt thickener • Anaerobic digestion • Dewatering with screw press • Third party hauling of biosolids for land application and Lystek 	<ul style="list-style-type: none"> • Continued onsite thickening, anaerobic digestion, and dewatering • Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application
Lytton Rancheria	<ul style="list-style-type: none"> • Onsite aerated holding tank and dewatering with volute dewatering press • Facility commissioned on 3/13/2024 and 	<ul style="list-style-type: none"> • Continued onsite dewatering • Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application

Community	Current Biosolids Management (Reference Case)	Proposed Future Biosolids Management
	dewatered biosolids have not yet required hauling, but when needed, biosolids will be hauled to a landfill by a third party vendor	
Sonoma County – Russian River County Sanitation District (RRCSD)	<ul style="list-style-type: none"> Gravity belt thickener Third party hauling to landfill 	<ul style="list-style-type: none"> Continued gravity belt thickening Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application
Sonoma County – Airport/Larkfield/Wikiup (ALWSZ)	<ul style="list-style-type: none"> Sludge settling at bottom of secondary clarifiers Third party removal, dewatering, and hauling to land application 	<ul style="list-style-type: none"> Continued sludge settling, removal, and deatering Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application
Sonoma County – Sonoma Valley County Sanitation District (SVCSD)	<ul style="list-style-type: none"> Onsite gravity sludge thickening, sludge equalization tanks, and mechanical dewatering Third party hauling to Lystek 	<ul style="list-style-type: none"> Continued gravity sludge thickening, equalization, and mechanical dewatering Biosolids hauled to District WRF for biodrying and pyrolysis instead of land application

The operational inputs and outputs for current and proposed future biosolids management strategies were estimated using the following methods:

- Reference case information, including projected biosolids production, electricity use and/or equipment power ratings and run times, chemical use, and biosolids hauling frequencies/distances, were provided by each individual community,
- Methane emissions from the District’s unaerated onsite storage pounds were estimated using the Water Environment Federation’s BEAM*2022 model. BEAM*2022 is a spreadsheet modeling tool that calculates net greenhouse gas emissions from various biosolids management processes, and
- Electricity, natural gas, and chemical use estimates for thickening, dewatering, biodrying and pyrolysis at the District WRF were provided by the project design team and vendor (Bioforcetech Corporation) based on the water content of thickened/dewatered biosolids.

3. Measure Implementation Assumptions

Several key assumptions related to the implementation of the proposed regional biodrying and pyrolysis facility have been made for this GHG analysis. These assumptions include the following:

- Projected biosolids production rates in Table 2 were estimated based on information provided by the District and surrounding Sonoma County communities. Estimated biosolids production rates will be updated to reflect future projections by each community.

- Lytton Rancheria biosolids production rates were estimated using the published equivalent dwelling unit (EDU) value of 147 and typical biosolids production rates per EDU from surrounding communities.

Table 2: Assumed Biosolids Production Rates

Community	Biosolids Production Rate, dry tons/day					
	2025	2030	2035	2040	2045	2050
Town of Windsor	1.77	1.94	2.11	2.27	2.44	2.61
City of Healdsburg	0.99	0.99	0.99	0.99	0.99	0.99
City of Cloverdale	0.21	0.21	0.21	0.21	0.21	0.21
City of Petaluma	3.2	4.2	4.4	4.5	4.6	4.8
Lytton Rancheria	0.08	0.08	0.08	0.08	0.08	0.08
Sonoma County – Russian River County Sanitation District (RRCSD)	0.27	0.27	0.27	0.27	0.27	0.27
Sonoma County – Airport/Larkfield/Wikiup (ALWSZ)	0.55	0.55	0.55	0.55	0.55	0.55
Sonoma County – Sonoma Valley County Sanitation District (SVCSD)	1.4	1.5	1.5	1.6	1.6	1.7

- Current third party hauling distances and current onsite treatment of biosolids for landfilling and land application were assumed to remain constant in the reference case from 2025 to 2050.
- The regional biodrying and pyrolysis facility is assumed to come online in 2030 and all thickened/dewatered biosolids from the District and the surrounding Sonoma communities noted herein are assumed to be hauled to the regional facility instead of landfills and land application sites.
- Biochar produced at the regional biodrying and pyrolysis facility is assumed to be picked up by commercial and residential customers for local use, therefore eliminating the need for biochar hauling away from the District WRF.

4. GHG Reduction Estimate Assumptions

Several key assumptions were used as part of the method for estimating GHG emission reductions. These assumptions include the following:

- BEAM*2022 estimates of methane emissions from District storage ponds involved the following model inputs:

Technical Appendix

Town of Windsor

- 1,025 kg BOD5 per dry ton of biosolids to the storage lagoons (assumes all influent BOD5 is accumulated in the solids),
- Lagoons are not aerated,
- Lagoons have an average depth that is greater than 2 meters.
- The emissions factors in Table 3 were used to equate operational inputs and outputs to associated carbon dioxide equivalents (CO2e).

Table 3: Assumed Emissions Factors

Operational Input/Output	Emissions Factor	Unit	Reference
Electricity ¹	70	lbs CO2e/MWh	Sonoma Clean Power – EverGreen
	404	lbs CO2e/MWh	Healdsburg Electric – Standard Rate
Hauling	0.36	lbs CO2e/ton-mile	Average freight truck in the US, Environmental Defense Fund
Methane	28	units CO2e/unit CH4	2013 IPCC AR5 Fifth Assessment Report

¹ Electricity demand at the District WRF and at each surrounding Sonoma County community is assumed to be met with Sonoma Clean Power – EverGreen power based on agency input, except for the City of Healdsburg

5. Reference Case Scenario

The reference case scenario assumes that the District and each surrounding Sonoma County community continue the existing biosolids management practices (business as usual), which largely consist of minimal onsite treatment and third party hauling to either a landfill or land application site. The reference scenario is further described in Table 4. For cases in which multiple transport/hauling distances could be assumed, the average distance was assumed.

6. Measure-Specific Activity Data

The assumed measure-specific activity is that the regional biodrying and pyrolysis facility comes online in 2030 and that all participating communities direct all thickened/dewatered biosolids to these newly implemented processes. The District is assumed to cease all onsite storage in anaerobic ponds by 2030 and the surrounding communities are assumed to cease all landfill and land application hauling by 2030. Additionally, all biochar produced at the new biodrying and pyrolysis facility is assumed to be used locally with no third party hauling. Updated hauling distances from individual WRFs to the District WRF, as well as the operational inputs required for biodrying and pyrolysis, are provided in Table 5.

7. GHG Emissions Reduced

The proposed biodrying and pyrolysis facility is expected to result in an overall GHG reduction relative to the reference scenario due to the elimination of offsite biosolids hauling and the elimination of anaerobic storage ponds at the District WRF. Figure 1 shows the estimated annual GHG emission reductions of the regional facility relative to the reference scenario from 2025 to 2050 and Figure 2

shows cumulative GHG reductions. **Annual reductions range from 2,104 to 2,955 mtCO₂e per year. The cumulative GHG reduction from 2025 to 2050 is 53,169 mtCO₂e.** No GHG emissions reductions are estimated for the period of 2025 to 2029 because the new biodrying and pyrolysis facility is not expected to come online until 2030, therefore the cumulative GHG reduction from 2025 to 2030 is only that achieved in 2030 (2,104 mtCO₂e).

Table 4: Refence Scenario

	Electricity, kWh/dry ton	Electricity Provider	Chemical Use, lbs/dry ton	Chemical Hauling Distance, miles	Hauled Biosolids Solids Content, %	Hauled Biosolids, wet tons/dry ton	Hauled Biosolids Distance, miles
Town of Windsor ¹	37.85 (dewatering)	Sonoma Clean Power – Ever Green	NA	NA	15%	6.7	135
City of Healdsburg	1,461	Healdsburg Electric – Green Rate	69.4 (polymer)	445	16%	6.3	165
City of Cloverdale	37.85	Sonoma Clean Power – Ever Green	NA	NA	23%	4.3	154
City of Petaluma ²	66.7	Sonoma Clean Power – Ever Green	129 (polymer)	2,613	19%	5.3	65.3
Lytton Rancheria ³	51.4	Sonoma Clean Power – Ever Green	8.24 (polymer)	439	16%	6.3	108
Sonoma County – Russian River County Sanitation District (RRCSD)	57.3	Sonoma Clean Power – Ever Green	6.7 (polymer)	97	15%	6.7	44
Sonoma County – Airport/Larkfield/Wikiup (ALWSZ)	37.85	Sonoma Clean Power – Ever Green	NA	NA	20%	5.0	88
Sonoma County – Sonoma Valley County Sanitation District (SVCSD)	30.2	Sonoma Clean Power – Ever Green	11.4 (polymer)	52	16%	6.3	26

¹ The Town of Windsor has onsite anaerobic storage ponds, which produce methane emissions, as estimated by the BEAM*2022 model; model estimates are 8,480 lbs CO₂e/dry ton of biosolids based on BOD₅ load to storage ponds and pond depth (> 2 meters)

² The City of Petaluma also practices onsite anaerobic digestion of biosolids; this community's reference scenario includes 1% of flared methane being released as a fugitive emission, which equates to 52.1 lbs CO₂e/dry ton of biosolids

³ The Lytton Rancheria facility was commissioned on March 13, 2024. As such, the dewatering facility is not yet fully operational, and no actual electricity and chemical usage data is available. The facility's electricity and chemical usage is estimated based upon the electricity and chemical usage rates of neighboring entities.

Table 5: Measure-Specific Activity Data

	New Biosolids Hauling Distance, miles ¹	Electricity, kWh/dry ton	Electricity Provider	Thermal Energy, MMBTU/dry ton	Chemical Use, lbs/dry ton	Chemical Hauling Distance, miles
Town of Windsor ²	NA	1,297 (biodrying) 365 (pyrolysis)	Sonoma Clean Power - EverGreen	23 (total requirement for biodrying), 4 (recovered from pyrolysis), 19 (electric boiler)	31.1 (NaOH for pyrolysis) 21.0 (sulfuric acid for wet chemical scrubber)	100 (NaOH, and sulfuric acid)
City of Healdsburg	10					
City of Cloverdale	23					
City of Petaluma	29					
Lytton Rancheria	1					
Sonoma County – Russian River County Sanitation District (RRCSD)	18					
Sonoma County – Airport/Larkfield/Wikiup (ALWSZ)	3					
Sonoma County – Sonoma Valley County Sanitation District (SVCSD)	36					

¹ The surrounding Sonoma County community reference scenario inputs from Table 4 are maintained, except for the biosolids hauling distance, which now reflects the distance from the given WRF to the District WRF

² The Town of Windsor will have new thickening and dewatering to prepare its own biosolids for subsequent biodrying and pyrolysis; biosolids from other communities will go directly to biodrying

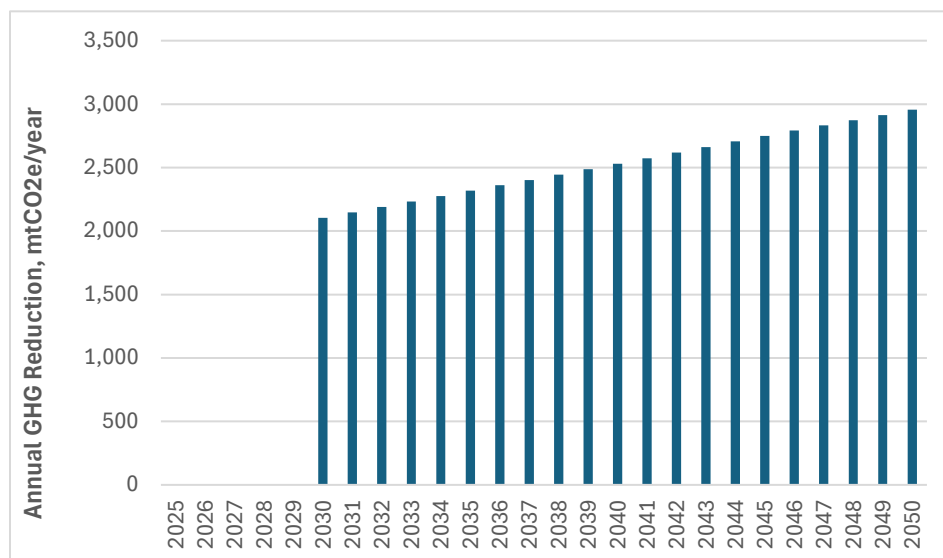


Figure 1: Estimated Annual GHG Reduction with the Regional Biodrying and Pyrolysis Facility Relative to the Reference Scenario

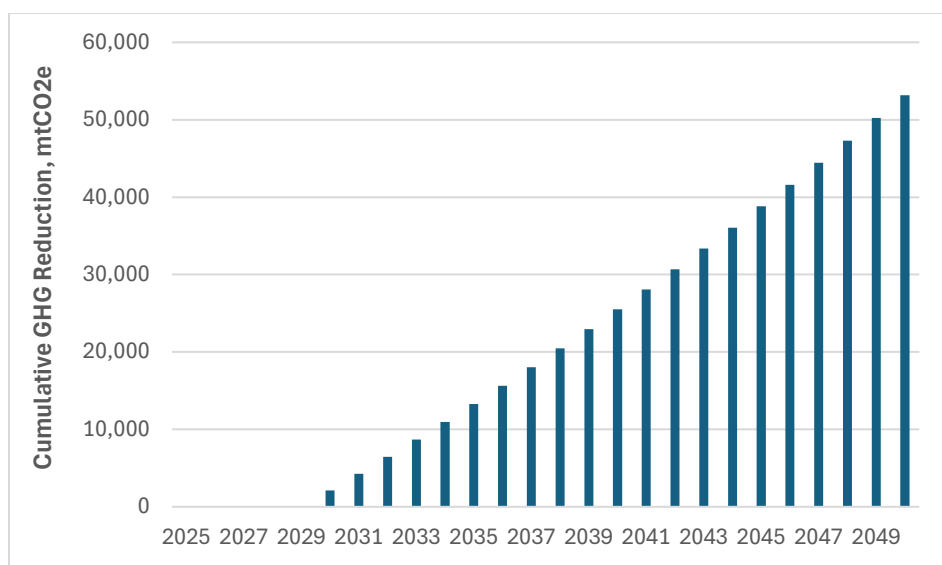


Figure 2: Estimated Cumulative GHG Reduction with the Regional Biodrying and Pyrolysis Facility Relative to the Reference Scenario

The assumptions listed below should be kept in mind when interpreting the GHG reductions estimated herein and when developing the monitoring plan:

- The electricity demand of new thickening, dewatering, biodrying, and pyrolysis processes is assumed to be met with Sonoma Clean Power EverGreen electricity; however, the District may opt to expand its onsite solar arrays. If solar arrays are expanded and purchased electricity needs are reduced, the estimated GHG reductions achieved by the alternative scenario relative to the reference scenario would increase.
- This evaluation assumes current onsite biosolids treatment and offsite hauling distances for the reference scenario will remain acceptable through 2050; however, future increased regulatory stringency may require additional biosolids treatment and/or longer hauling distances for land application and landfilling. If so, the estimated GHG reductions achieved by the alternative scenario relative to the reference scenario would increase. The alternative scenario, biodrying and pyrolysis, is less sensitive to regulatory changes because of the lack of reliance on third party vendors and the contaminant destruction achieved.
- The GHG emissions released from landfill/land application activities and the sequestration of GHG emissions provided by biochar are excluded from this evaluation due to the uncertainties associated with such estimates. If the boundary of the evaluation is expanded to include these operational outputs, the estimated GHG reductions achieved by the alternative scenario relative to the reference scenario would increase.
- The thermal energy required for biodrying is assumed to be partially met with recovered thermal energy from the pyrolysis process and partially met with energy imparted on water in an electric boiler. If additional engineering feasibility and cost analyses suggest the need for a natural gas boiler instead of an electric boiler, the emissions estimates presented herein will require an update.

Appendix A: GHG Emission Reduction Calculations

The attached calculations include a tab per community for the calculations and results of the reference scenario and alternative scenario. The reference scenario is shown on the left hand side of the community-specific tab and the alternative scenario is on the right hand side of the community-specific tab. Resultant annual and cumulative GHG reductions are calculated on the “Annual and Cumulative GHGs” tab.