FINAL

TM 4.6 – R2E2 DEBOTTLENECKING AND FUTURE RESOURCE RECOVERY

NEW Water Facility Plan

B&V PROJECT NO. 402658

PREPARED FOR

NEW Water
The brand of the Green Bay Metropolitan Sewerage District

Green Bay Metropolitan Sewage District

1 JULY 2021

BLACK & VEATCH

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction and Purpose

The Green Bay Metropolitan Sewerage District, operated under the brand name of NEW Water, collects and treats wastewater from 15 communities in a service area encompassing over 285 square miles with an estimated population of approximately 237,000 in 2019. The NEW Water facilities are comprised of the Green Bay Facility (GBF) and the De Pere Facility (DPF). The NEW Water treatment facilities receive domestic, commercial, and industrial wastewater as well as hauled-in waste (HW)/high strength waste (HSW). NEW Water administers an industrial pretreatment program that regulates industrial contributors.

The GBF treated an average of 36.6 mgd of total wastewater in 2019 with a liquid treatment train consisting of influent pumping, screening, primary clarification, primary sludge grit removal, activated sludge configured for enhanced biological phosphorus removal (EBPR), secondary clarification, and disinfection with sodium hypochlorite and dechlorinated with sodium bisulfite. The solids handling treatment train includes sludge thickening with gravity thickeners, gravity belt thickeners, a thickening centrifuge followed by anaerobic digestion with co-digestion of HSW, and centrifuge dewatering followed by solids drying and incineration. The digestion and incineration processes were installed under the Resource Recovery and Electrical Energy Project (R2E2) and have been in operation since 2018.

The DPF treated an average of 8.8 mgd in 2019 of wastewater with a treatment train consisting of screening, influent pumping, grit removal, activated sludge configured for enhanced biological phosphorus removal (EBPR), intermediate clarification, final clarification, tertiary sand filters, and disinfection with UV. An industrial forcemain pumps waste from the Fox River Fiber industrial customer downstream of grit removal. Waste activated sludge (WAS) from the DPF is pumped to the GBF for biosolids processing via a forcemain.

As part of a full-plant facility plan, determining how to manage solids is critical to ensuring the adequate treatment of wastewater. NEW Water recently made a major investment in its solid treatment facilities through R2E2. As with many large infrastructure projects, there were several operational limitations and bottlenecks that would have been difficult to foresee during design. Chemical processing facilities often go through a “debottlenecking” effort after building new facilities, identifying operational limitations and holdups after facilities are operational to improve the overall application. The purpose of Technical Memorandum 4.6 (TM 4.6) is to evaluate and summarize the current capacity of the R2E2 facilities to treat projected flows and loads described in TM – 2.1 and develop alternatives to debottleneck the R2E2 facilities based on current operational experience. In addition to this debottlenecking effort, an evaluation of most feasible alternatives for NEW Water for additional energy and resource recovery to meet future goals was completed. The specific objectives of TM 4.6 are:

1. Assess the future solids processing capacity needs of the GBF based on the projected future flow and loads. If existing installed capacity is not sufficient, describe what projects need to be considered in the future to address the capacity needs.
2. Currently, solids occasionally need to be stored in the liquid part of the GBF when adequate solids processing is not available. Evaluate how much more biosolids storage is needed to limit impacts on the liquid side of the plant.
3. Consider opportunities for energy savings. When solids cannot be processed in R2E2, they are hauled to a landfill and the plant cannot produce energy from those solids. Therefore, the energy benefits of storage with subsequent processing will be considered.

4. Identify potential technologies to explore future resource recovery.

As the R2E2 project is relatively new, a full condition assessment was not part of the scope of this project.

2.0 Biosolids and Energy Production Gap Analysis

The R2E2 project replaced the aging solids facilities at the GBF. The facility processes thickened primary sludge (TPS) and thickened waste activated sludge (TWAS) in anaerobic digesters followed by dewatering and incineration. The incineration process is equipped with a partial dryer, utilizing waste heat recovered from the incinerator. These processes also generate and recover energy for the plant's use. Biogas from anaerobic digestion is utilized in combined heat and power (CHP) engines to generate electricity. Heat is recovered from the engines and incineration, then used to dry digested biosolids cake, heat plant buildings, and heat the digester process.

2.1 Capacity

A process flow diagram is presented Figure 2-1Primary Sludge (PS) and Waste Activated Sludge (WAS) are thickened in gravity thickeners and gravity belt thickeners (GBTs). Previous evaluations identified capacity limitations at the thickening process and TM 4.2 evaluated alternatives for NEW Water. Therefore, the thickening process is not further evaluated in this TM. The capacity of R2E2 facilities downstream of thickening requires evaluation due to the increased industrial loading anticipated in 2025, which was not projected during the R2E2 planning and design processes.

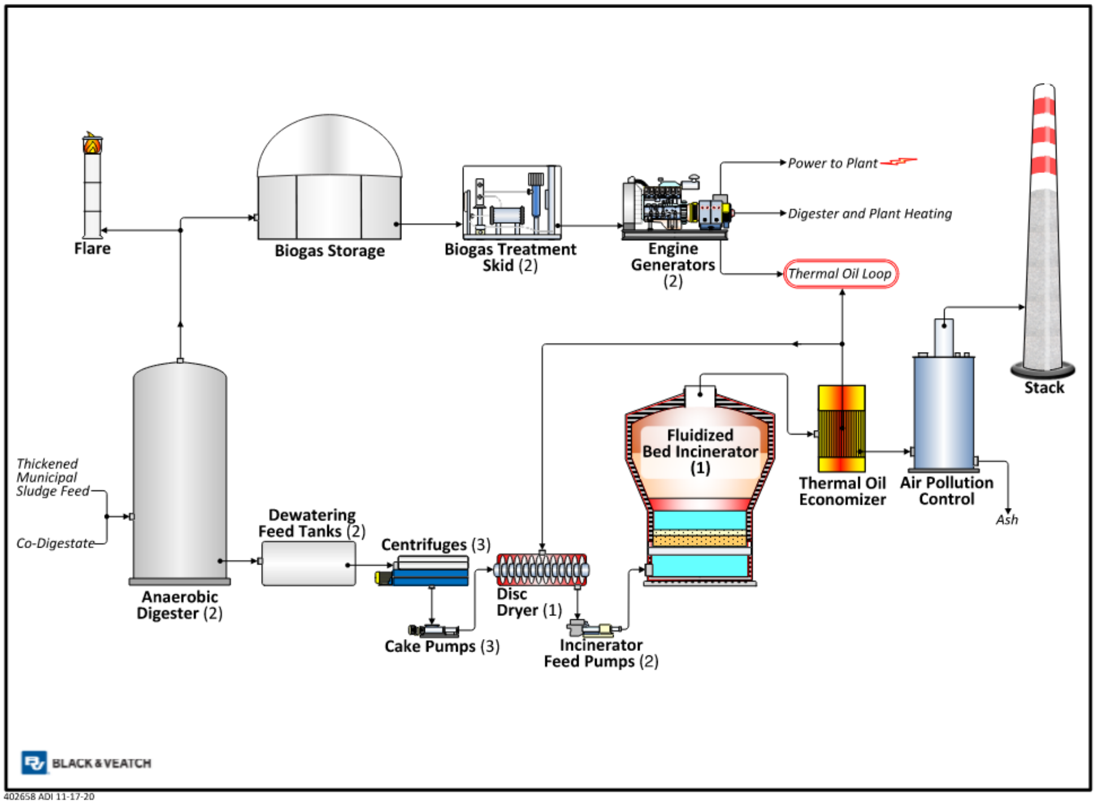

Figure 2-1 R2E2 Process Flow Diagram

2.1.1 Anaerobic Digestion

Thickened sludge is fed to two anaerobic digesters that are 2.25 million gallons (Mgal) each. HSW is also introduced to the digesters to increase biogas production. Table 2-1 summarizes the 2035 design conditions, current conditions, and projected future conditions for anaerobic digestion feed parameters. The values for the design conditions were obtained from conformed documents for

Resource Recovery and Electrical Energy (R2E2) Project Digestion and Solids Facilities Contract No.34 Volume V of VIII Drawings dated July 2015. Historical data between January 2019 and July 2019 shows that the digester feed total solids (TS) concentration ranged between 3.5 and 6.4 percent, averaging approximately 4.9 percent, which is lower than the design target of 6 percent.

For future conditions, the design solids throughputs from TM 4.2 (May 2020) were used to estimate the projected performance criteria; therefore, the future solids throughputs were based on the 2025 50th percentile, 2040 50th percentile, and 2040 90th percentile as presented in TM 4.2. Based on the values presented in the referenced TM, the GBF PS was 39,000, 41,000, and 52,000 pounds per day (lb/d), respectively. Further, the combined WAS from the GBF and DPF were 55,000, 60,000, and 76,000 lb/d, respectively. It was assumed that all sludges would be co-thickened to 6 percent TS with a capture rate of 95 percent as recommended in TM 4.2. The values shown in Table 2-1 include a polymer dosage of eight pounds of active polymer per dry ton of solids.

Table 2-1 Anaerobic Digestion Influent Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025 AA)	Projected Future Conditions (2040)
Influent Thickened Sludge Flow, gpm	202 (AA) 234 (MM)	169.3	204	213 (AA) 250 (MM)
Thickened Sludge Feed Concentration, % TS	6.0%	4.9%**	6.0%	6.0%
Thickened Sludge Loading, lb TS/d	88,907 (AA) 112,000 (MM)	100,170	89,660	96,340 (AA) 122,090 (MM)
Thickened Sludge VS Content, % VS/TS	75-76%	78.7%	78%	78%
Influent HSW Flow, gpm	79	19.2	0***	0***
HSW Feed Concentration, % TS	N/A	4.9%**	N/A	N/A
HSW Loading, lb TS/d	N/A	11,350	N/A	N/A
HSW VS Content, % VS/TS****	74%	74%	N/A	N/A

N/A: Not Applicable
* Based on 7 days per week operation.
** Sludge and HSW were not reported separately so it was assumed that TS concentration of HSW is equal to TS of thickened sludge.
*** For future conditions, HSW flow was assumed as zero to determine if there is capacity surplus or deficit.
**** This value was not reported. It was assumed based on Burrowes et al. (2015).

AA is Annual Average

MM is Maximum Month

Table 2-2 presents the digested sludge parameters for the R2E2 digesters. Historical data shows that the range for digested sludge TS concentration was between 2.9 percent and 3.4 percent, averaging approximately 3.2 percent. The average volatile solids (VS) content of the digested sludge was approximately 67 percent. These values are higher than design estimates. For the projected future conditions, the volatile solids reduction (VSR) was assumed to be equal to the historical rate of 45 percent for calculating the digested sludge parameters as presented in Table 2-2. The average historical biogas production was calculated as 649,530 cf/d. For projected future conditions, it was assumed that the biogas yield would be equal to the current conditions at 16.5 standard cubic feet of biogas per pounds of removed volatile solids (scf/lb VSR).

Table 2-2 Anaerobic Digestion Effluent Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025 AA)**	Projected Future Conditions (2040)**
Digested Sludge Concentration, % TS	2.6 (AA) 2.8 (MM)	3.2	3.9	3.9
Digested Sludge, lb TS/d	64,185 (AA) 79,443 (MM)	71,545	58,250	62,580 (AA) 79,300 (MM)
Digested Sludge VS Content, % VS/TS	59.5-60.5%	67%	65.9%	65.9%
Biogas Production, cf/d	842,152 (AA) 962,483 (MM)	649,530	518,050	556,750(AA) 705,580 (MM)

* Based on 7 days per week operation.
** Projected future conditions exclude HSW flows and loads.

Table 2-3 presents anaerobic digestion performance parameters for R2E2 digesters. The typical target for solids retention time (SRT) in an anaerobic digestion process is to maintain SRT for at least 15 days or more because one method for demonstrating compliance with the federal rules for pathogen reduction prior to land application (40 CFR Part 503) is maintaining SRT for 15 days at a temperature of 95 degrees Fahrenheit (°F). Current digestion operation at R2E2 is averaging 16.6 days of maintaining SRT.

Based on the projected future solids throughput to the anaerobic digesters shown in Table 2-1, the lowest SRT would be 18.5 days under 2040 MM loading conditions; therefore, the existing digestion system will have adequate capacity due to both improved thickening and excluding HSW flow. HWS was excluded so that the capacity of the digesters could be better understood. Presumably NEW Water would accept HSW to use up the unused capacity. Further discussion on HSW co-digestion capacity is provided at the end of this section.

Table 2-3 Anaerobic Digestion Process Performance Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025)**	Projected Future Conditions (2040)**
SRT, d	15.5 (AA) 13.3 (MM)	16.6	25.1	23.4 (AA) 18.5 (MM)
Organic Loading Rate, lb VS/cf-d	0.163 (AA) 0.192 (MM)	0.145	0.116	0.125 (AA) 0.158 (MM)
VSR, %	61% (AA) 58.5% (MM)	45%	45%	45%
Biogas Yield, scf/lb VSR	14-15	16.5	16.5	16.5

* Based on 7 days per week operation.
** Projected future conditions exclude HSW flows and loads.

Organic loading rate, measured as pounds of volatile solids per cubic feet of digesters per day (lb VS/cf-d), is one process parameter that can be used to assess the loading to the digesters. WEF Manual of Practice No.8 (MOP No.8) recommends a typical average loading basis of design for sludge-only digestion as approximately 0.160 lb VS/cf-d. For a maximum month loading rate, a reasonable target would be 0.180 lb VS/cf-day; however, the addition of high strength organic wastes to anaerobic digestion has been shown to create a more diverse biological system that can accommodate higher organic loading rates than with sludge only. The acceptable increase in loading is dependent on the sludge and other feedstock characteristics, and it is difficult to identify specific loading rates that accommodate all types of wastes; however, Black & Veatch (B&V) recommends not to exceed 0.200 lb VS/cf-d unless the digestion system is tested and shows healthy operation under higher loading rates.

As shown on Table 2-3, the current organic loading rate at R2E2 is approximately 0.145 lb VS/cf-d, including HSW feed. The projected loading rate under 2025 conditions is 0.116 lb VS/cf-d. Under 2040 conditions, the organic loading rate is projected to increase to 0.125 lb VS/cf-d for AA and 0.158 lb VS/cf-d for MM loadings, which are below the loading criteria discussed above for sludge only digestion. It should be noted that these projected loading rates do not include HSW co-digestion which is discussed later in this section.

VSR is a measure of digester performance and is also a parameter that can be used to demonstrate compliance with the federal biosolids land application rules. Calculating the VSR can be performed using a mass balance across the digestion process or by use of the VS concentrations of the feed and effluent from the digesters (Van Kleek equation). If VSR is used for demonstrating compliance with the Part 503 requirements for vector attraction reduction, then the VSR must be 38 percent or greater. At R2E2, the current VSR is averaging approximately 45 percent. For a well-functioning digestion system, 50 to 60 percent VSR represents a good performance. Although the current VSR of 45 percent falls outside this range, it is within acceptable values and indicates a healthy process. It should be noted that this VSR is below the design target of 55-57 percent, which results in a greater amount of solids out of digestion and a higher percentage of solids in digested solids.

Biogas yield, calculated as standard cubic feet of digester gas per pound of volatile solids reduced (scf/lb VSR), is another process parameter that can be used to assess the performance of the digesters. Typically, the biogas yield should be between 12 and 18 scf/lb VSR for a healthy digester. The overall average for the R2E2 anaerobic digestion process was calculated as 16.5 scf/lb VSR, which further demonstrates the digesters are performing well.

2.1.2 Dewatering

Digested sludge is stored in two dewatering feed tanks upstream of the dewatering centrifuges. Table 2-4 shows design, current operation and projected future conditions for dewatering feed tanks. Historical data shows that there is currently approximately 2.4 days of storage capacity in these tanks; however, the storage capacity will improve to more than 3 days under AA conditions after the recommended thickening improvements are put into operation.

Table 2-4 Dewatering Feed Tanks Process Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025 AA)**	Projected Future Conditions (2040)**
Influent Flow, gpm	202 (AA) 234 (MM)	189	125	134 (AA) 170 (MM)
Number of Tanks	2			
Capacity (each), gal	329,600			
Total Capacity, gal	659,200			
Holding Time, d	2.3 (AA) 2.0 (MM)	2.4	3.7	3.4 (AA) 2.7 (MM)

* Based on 7 days per week operation
** Projected future conditions exclude HSW flows and loads.

Table 2-5 presents the parameters for dewatering centrifuges. There are three centrifuges operating as two duty and one standby. The design documents noted that dewatering and downstream processes would operate on a five day a week schedule under AA conditions and seven day a week schedule under MM conditions.

Table 2-5 Dewatering Centrifuge Process Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025)**	Projected Future Conditions (2040)**
Feed flow, gpm	282 (AA) 234 (MM)	264 (AA)	175 (AA)	187 (AA) 170 (MM)
Number of equipment	2+1			
Capacity (each), gpm	130			
Total processing capacity, gpm	260			
Solids Throughput, lb/hr/centrifuge	1,890 (AA) 1,655 (MM)	2,090 (AA)	1,700 (AA)	1,830 (AA) 1,660 (MM)
Estimated Solids Throughput Capacity, lb/hr/centrifuge	1,860			
Cake Solids Concentration, % TS	21	19-20	21	21

* AA is based on 5 days per week operation. MM is based on 7 days per week operation.

** Projected future conditions exclude HSW flows and loads.

In terms of hydraulic loading, the existing centrifuges can process 130 gpm each and a maximum solids throughput of 2,190 lb/hr (based on a manufacturer published 175 gpm maximum feed rate and at 2.5 percent TS). The design maximum solids throughput was established as 1,890 lb/hr under AA conditions, which is 85 percent of the machine's estimated maximum capacity. Under current loading conditions, the dewatering process is meeting the design hydraulic loading criteria for the centrifuges while operating five days per week. Based on current loading estimate of 2,090 lb/hr/unit, the centrifuges seem to be overloaded in terms of the solids throughput. Existing centrifuges have enough capacity to handle future projected hydraulic and solids loadings without HSW co-digestion.

Another performance criterion for the centrifuge operation is the solids concentration of the final cake product. The design estimated that the dewatering process will produce a cake at minimum 21 percent TS. Based on the discussions with NEW Water staff during the Workshop on September 22, 2020, the cake solids concentration ranges between 19 and 20 percent. It is critical for the dewatering process to achieve a minimum 21 percent TS because the performance of the downstream drying process will be adversely affected from higher moisture content as the loadings increase. If the dryer cannot meet its performance goal of 38 to 40 percent TS, then more energy would be required in the incinerator to evaporate that extra moisture. For future projected conditions, it was estimated that the centrifuges would operate at their specified performance to produce 21 percent cake TS.

2.1.3 Drying

A scalping dryer is used to increase solids concentration upstream of the incineration process. This allows the incinerator to operate with a cold windbox. The recovered heat from the incineration system is directed to the dryer to evaporate water in the sludge cake. This results in an increase of TS concentration from 21 percent to 38 to 40 percent. Table 2-6 presents the drying process parameters for design, current operation, and projected future conditions. Similar to the dewatering process, the design assumed that the drying process would be operated on a five day per week schedule under AA conditions and seven day per week schedule under MM conditions.

Table 2-6 Drying Process Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025)**	Projected Future Conditions (2040)**
Dryer feed, dry lb/hr	3,601 (AA) 3,208 (MM)	4,014 (AA)	3,268 (AA)	3,511 (AA) 3,178 (MM)
Feed TS, %	21	20	21	21
Dried Solids TS, %	38	38	38	38
Amount of H_2O to evaporate, lb/hr	7,670 (AA) 6,833 (MM)	9,510 (AA)	6,960 (AA)	7,480 (AA) 6,770 (MM)
Evaporation rate, lb H_20/hr		9,340		
Thermal Energy Requirement, Btu/lb H_2O			1,290	
Thermal Energy Required, MMBtu/h	9.90 (AA) 8.81 (MM)	12.26 (AA)	8.98 (AA)	9.65 (AA) 8.73 (MM)
Dryer Thermal Capacity, MMBtu/hr			11.5	

* AA is based on 5 days per week operation. MM is based on 7 days per week operation.
** Projected future conditions exclude HSW flows and loads.

The scalping dryer's capacity was analyzed based on the moisture evaporation rate and thermal capacity. The moisture evaporation rate is defined as pounds of water to evaporate in an hour (lb H_2O/hr) to increase solids content from 19 to 21 percent up to the 38 to 40 percent range. Thermal capacity is defined as British thermal units (Btu) of heat required to evaporate that water (Btu/hr). Under current operation, both the moisture evaporation demand and thermal capacity seem to be slightly above the dryer's capacity. Therefore, it is expected that the dried solids content is close to 37-38 percent instead of 39-40 percent. For projected future conditions, it was assumed that the centrifuges will improve their performance to meet 21 percent TS in the cake sludge. If the centrifuges can operate at the specified cake solids concentration and other sludge conveyance issues can be addressed that deal with the “sticky sludge”, , then the dryer has enough evaporative and thermal capacity to produce dried biosolids at 38 percent TS or higher.

2.1.4 Incineration

Downstream of the dryer, the partially dried solids are incinerated in a fluidized bed incinerator (FBI). The FBI reactor uses a cold windbox to burn the solids. A hot oil economizer was installed downstream of the reactor to recover the heat via thermal oil, which is heated to 392°F. Downstream of the economizer, a wet scrubber equipped with a quench section, cooling tray, and a multiple venturi section was installed to remove particulate and acid gas from the flue gas. A wet electrostatic precipitator (WESP) was installed after the scrubber to polish clean flue gas before it enters the demister. Downstream of moisture removal, a hot oil heat exchanger increases flue gas temperature above the dew point. Clean flue gas from the hot oil heat exchanger is passed through a fixed carbon bed adsorber. Ash from the air pollution control system is collected in ash collection tanks, dewatered, and disposed of in a landfill. There is one scalping dryer and one FBI at the R2E2 to process maximum of 51 dry tons per day of solids (dtpd). It was assumed that digested solids would be dewatered and disposed to a landfill during any maintenance of these equipment trains. Potential storage alternatives will be addressed as a solution to this limitation. Table 2-7 summarizes FBI operational parameters for design, current operation, and projected future conditions.

Table 2-7 Incinerator Train Parameters*

Parameter	Design Conditions (2035)	Current Operation (1/2019-7/2019)	Projected Future Conditions (2025)**	Projected Future Conditions (2040)**
Feed rate, dtpd	43.2 (AA) 38.5 (MM)	48.2 (AA)	39.2 (AA)	42.1 (AA) 38.1 (MM)
Incinerator Capacity, dtpd	51			
Moisture Loading, lb H_2O/hr (Based on 38% TS in the feed)	5,876 (AA) 5,233 (MM)	6,550 (AA)	5,332 (AA)	5,728 (AA) 5,186 (MM)
Incinerator Moisture Capacity, lb H_20/hr	5,309			

* AA is based on 5 days per week operation. MM is based on 7 days per week operation.
** Projected future conditions exclude HSW flows and loads.

The FBI has a dry solids capacity of 51 tons per day. The current solids feed rate is below the dry solids loading capacity, but the moisture loading is above the specified capacity of the FBI. For the projected future conditions, the dry solids loading rates to the FBI are projected to be below the system’s capacity when there is no HSW co-digestion.

The heat from the flue gas is recovered in a thermal oil economizer to be used in the thermal oil loop. The loop provides heat to the scalping dryer and buildings at the plant. The economizer has a capacity of 15.2 MMBtu/hr to increase thermal oil temperature from 320 to 392°F. Since the thermal oil loop provides heat to the scalping dryer and the buildings, no process or operational change is expected under projected future conditions.

2.1.5 Combined Heat and Power (CHP)

There are two CHP engines at the R2E2 facility. The engines utilize biogas or a blend of biogas and natural gas to produce power. The jacket water cooling system provides heat to the anaerobic digesters. Heat from the exhaust is recovered to be used in the thermal oil loop described before. Table 2-8 summarizes CHP operational parameters for design, current operation, and projected future conditions.

Table 2-8 CHP Parameters

Parameter	Design Conditions (2035)	Current Operation (1/2019-3/2020)	Projected Future Conditions (2025 AA)*	Projected Future Conditions (2040)*
Biogas production, scf/d	842,152 (AA) 962,483 (MM)	649,600	518,050	556,750(AA) 705,580 (MM)
Lower Heating Value, Btu/scf	645 (AA) 639 (MM)	550 (assumed)	550	550
Total Power Generation from Biogas, kW	2,700 (AA) 3,000 (MM)	1,530 (biogas only) 1,952 (biogas+NG)	1,320	1,420 (AA) 1,800 (MM)
Electrical Generation Efficiency, %	39.8%	37.9% (P-21) 35.8% (P-22)	37.9%	37.9%
Power Generation Capacity, kW	1,994 (one engine) 3,984 (two engines)			
* Projected future conditions exclude HSW flows and loads.				

Historical data from January 2019 till March 2020 shows that average total power generation from biogas was 1,530 kW, assuming a lower heating value for the biogas was 550 Btu/scf. The total power generation was 1,952 kW when natural gas was blended with biogas, and a lower heating value of 1,000 Btu/scf was assumed for natural gas. Hence, approximately 78.5 percent of power generation was from biogas. Evaluating each engine separately showed that each engine was generating approximately 1,820 kW power, which is 91 percent of the design capacity. Figure 2-2 shows electrical generation efficiency for the two CHP engines at R2E2. Between January 2019 and March 2020, Co-Generation Unit No.3 (P-21) averaged approximately 37.9 percent efficiency whereas Co-Generation Unit No.4 (P-22) averaged approximately 35.8 percent. For the future projections, it was assumed that the lower heating value of the biogas and natural gas would be the same as current conditions. It was also assumed that both engines would operate at the electrical generation efficiency of 37.9 percent. Based on these assumptions and assuming no HSW co-digestion, the capacity of the two engines will be sufficient to meet the future projected biogas production.

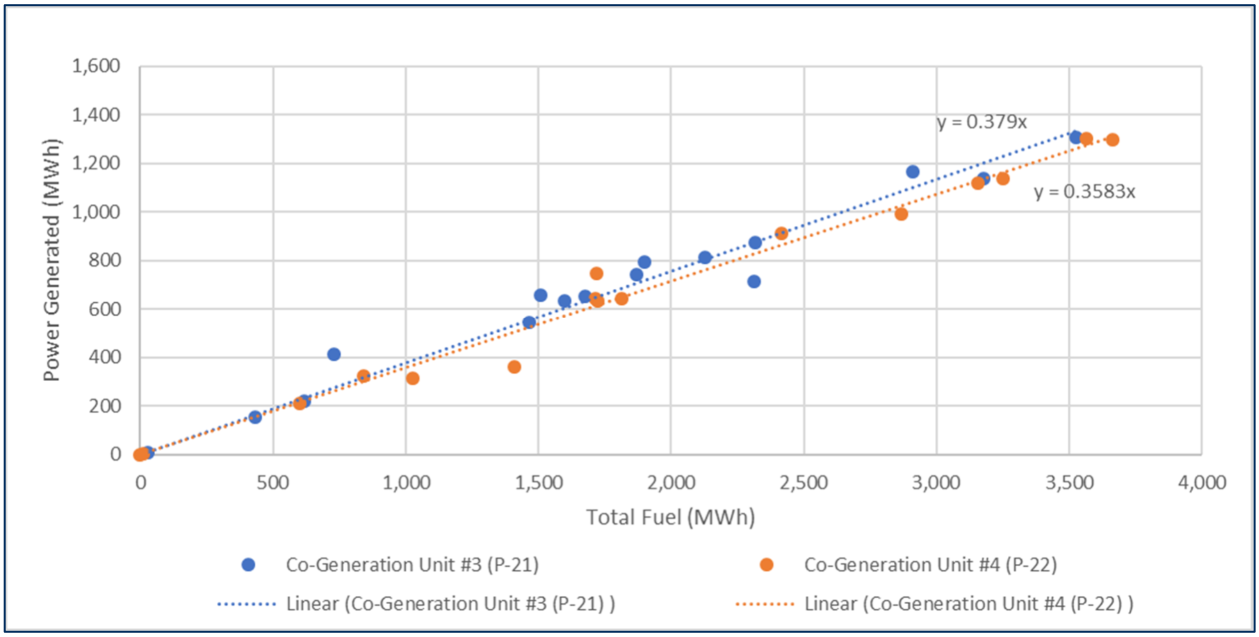

Figure 2-2 **Power Generation Efficiency**

The existing two biogas compressors on biogas treatment skids have a capacity of 560 scfm per compressor. The maximum gas production in 2040 was estimated to be approximately 490 scfm; therefore, the biogas treatment process and the compressors have adequate capacity.

2.1.6 HSW Co-Digestion

The previous sections evaluated the capacity of anaerobic digestion, dewatering centrifuges, dryer, incinerator, and CHP units within the R2E2 scheme to process the sludge produced at the GBF and DPF. As presented in Table 2-7, the FBI has capacity to process additional solids under 2025 AA and 2040 AA conditions; however, the projected hydraulic loading may require auxiliary fuel for incinerator to thermally oxidize solids if the dryer is producing 38 percent TS or lower.

During planning and design phases, one of R2E2's goal was to produce enough biogas to generate 50percent of the GBF's electrical demand. The biogas needed to generate this energy is not available from sludges produced at GBF and DPF. Supplementing digester feed with HSW will produce more biogas and, hence, generate more power for the plant. Based on the preliminary evaluation, the incinerator capacity was more limiting than the digestion capacity. Therefore, the future HSW capacity was projected based on capacity available in the FBI system. For these calculations, it was assumed that the HSW has 4.9 percent TS with 74 percent VS content.

As presented in Table 2-9, HSW feed flow will be limited to 44.6 and 33.6 gpm under future projected loads in 2025 and 2040, respectively, in order not to exceed the maximum solids throughput of the FBI. It should be noted that these flow rates are below the design criteria of 79 gpm. Historical data between May 2019 and March 2020 shows that NEW Water fed HSW to the digesters at a rate of 32 to 42 gpm. This is an acceptable range in order to not impact solids throughput of the incineration process.

Table 2-9 HSW Co-Digestion Effects on R2E2 Processes

Parameter	2035 AA Design Criteria or Industry Standard	Projected Future Conditions (2025 AA)	Projected Future Conditions (2040 AA)	Projected Future Conditions (2040 MM)
HSW Feed Flow, gpm	79	44.6	33.6	33.6
HSW TS Concentration, %	N/A	4.9%		
HSW TS Loading, lb/d	N/A	26,240	19,750	19,750
HSW VS Content, %	N/A	74%		
Effects on Anaerobic Digestion Process				
SRT, d	>15	18.5	18.7	15.4
Organic Loading Rate, lb VS/cf-d	<0.180	0.148	0.149	0.182
Biogas Production, scfd	842,152	662,140	665,190	814,030
% of Biogas from HSW	N/A	22%	16%	13%
Power Generation from Biogas, kW	2,700	1,685	1,693	2,072
Effects on Dewatering Process				
Dewatering Feed Tank Storage Time, d	N/A	2.7	2.7	2.3
Centrifuge Feed Flow, gpm	<260	236.6	234.1	203.0
Centrifuge Solids Throughput, lb TS/hr	<1,890	2,210	2,210	1,930
Effects on Drying				
Evaporation Rate, lb H_2O/hr	<9,340	9,054	9,054	7,895
Required Thermal Energy, MMBtu/hr	<11.5	11.68	11.68	10.18
Effects on Incineration				
Solids Throughput, dtpd	<51	51	51	44.5
Moisture Loading, lb/hr	<5,310	6,940	6,940	6,050

Adding HSW will increase the organic loading rate to the digesters by approximately 30 percent in 2025 and 20 percent in 2040. Therefore, the overall organic loading rate from both sludge and HSW will be approximately 0.150 lb VS/cf-d under AA conditions, which is below the criteria of 0.160 lb

VS/cf-d noted above. Under 2040 MM conditions, the organic loading rate will be approximately 0.182 lb/cf-d, which is acceptable since HSW will be co-digested with municipal sludge.

If the HSW flow rate is controlled based on incinerator capacity, then the SRT of the digestion process will be above 15 days. A minimum average SRT of 15 days is typical for land application of biosolids as Class B per EPA 503 regulations as noted above. Even if the SRT drops below 15 days due to a change in HSW characteristics (i.e. lower TS concentration), this low SRT may be acceptable since NEW Water does not currently apply biosolids to land as Class B; however, an SRT that dips too low may result in microorganisms being washed out from the digesters, so it is not recommended to lower SRT below 12 days.

The HSW addition may affect the performance of the dewatering process (as presented in Table 2-9). The solids throughput of centrifuges will increase above design conditions while hydraulic loading will be below. Therefore, the centrifuges will be solids limited at the expected feed concentrations. Dryer and FBI processes will have adequate capacity since the evaluations were based on maximum throughput of the incineration process.

2.1.7 Capacity Summary

From a capacity standpoint, the R2E2 facilities are all within design values, assuming that thickening is implemented to increase the solids concentration being fed to the digesters. If the solids concentration into the digestion is not maintained at 6 percent solids, capacity limitations would occur in the centrifuge processes because the hydraulic loading would increase above design conditions. This would result in poorer dewatering performance, which would affect the performance of drying and incineration. In fact, at the current thickened solids concentration of 4.9 percent solids, most of these facilities are already operating at near design capacity. From a debottlenecking perspective, any improvements to R2E2 would be driven by needs identified from operations and maintenance over the past two years, not capacity limitations driven by the increased flows and loads from the new industry. The only improvements needed for capacity, operations, and maintenance would be associated with the thickening process, as discussed in TM 4.2.

2.2 Operations and Maintenance Gaps

NEW Water staff and B&V had a workshop on September 22, 2020 to discuss the objectives of the study presented herein. The team also discussed current operation of R2E2 processes. The primary goal of this project was to address the future biosolids capacity need of the GBF, and the objective of this TM is to assess the limits of solids processes, so they do not impact the liquid treatment. Therefore, current operational issues are summarized herein to provide a background for possible recommendations for future studies or evaluations. The intent of this TM is not to provide resolutions to these operations and maintenance issues.

NEW Water staff noted during the workshop that the R2E2 system can meet its design objectives when it is operating. The overall challenge is that there is a lack of redundancy in many of the R2E2 components, which results in increased downtime when an individual component or system fails. Having a single train is an issue throughout R2E2. It takes more operational effort than had been planned even when the single train is running well, thus adding demands for maintenance staff. Originally, the FBI was supposed to be offline during the weekends for regular maintenance; however, in practice, the system is commonly down during the week for maintenance, so maintenance staff does not have to work over the weekend. Overall, the weekly maintenance on solids processes is increased from what was expected. There are several ongoing projects and efforts to address the challenges noted during the workshop.

Biogas cleaning and compression system has a lack of redundancy. There are two engines. When both engines run, 100 percent of the gas cleaning system (two skids of 600 scfm each) needs to be available. There are iron sponges for H_2S treatment, but H_2S levels are very low in the biogas due to metals in the sludge. There are also carbon adsorption units for siloxane removal that operate without an issue.

Engine Generators have had multiple warranty issues since the startup. There are two engines that can run on biogas or a blend of biogas and natural gas. There are also two diesel emergency generators. Recovered heat from exhaust of biogas engines is used to supplement the digester heating loop. NEW Water had to do top-end repairs for the second time on one of the engines. Staff observed excessive wear on cylinder heads. The manufacturer has done a design change to address that issue. NEW Water has experienced only one month with both engines online since R2E2 was commissioned.

Dewatering centrifuges shut down on vibrations and are subject to plugging. Staff also mentioned that their cake solids have 18 to 20 percent TS, which is below the design target of 21 percent. Staff also noted that the cake is "sticky." Staff mentioned that it is a challenge to convey 20 percent TS sludge cake to either the sludge drying and then incineration processes or for loading to a truck to haul it to the landfill.

Regarding the FBI, NEW Water had an issue with the granular activated carbon (GAC) that caused the FBI to be offline for two months in late 2019. There is currently a potential future issue with a failing expansion joint. Staff mentioned issues with the primary heat exchanger (HEX) and the thermal oil economizer a few times during the workshop. Further, feed pumps to the FBI also require attention.

The FBI has not been able to achieve autogenous combustion since the startup. The ultimate analysis of the feed sludge showed that the high heating value (HHV) of the feed is below the design estimates.

NEW Water adjusts HSW received to maximize one engine on biogas. HSW receiving station has two square tanks with pumped mixing. HSW supply is a single source from a side-stream waste from a dairy. Overall, no issues with HSW, but the tanks have not been inspected since startup. They receive inquiries from other utilities in the area for hauling their sludge to this facility, but they currently do not accept any.

Biogas storage is designed for approximately 20 minutes of storage (35,000 cubic feet). Existing storage is intended to simply be a “wide spot” in the line.

Landfilling of biosolids is a challenge because few landfills accept the biosolids. The landfills prefer 18 to 20 percent solids out of the centrifuges because the 40 percent solids out of the dryer are too hard to work with. Dried cake at 40 percent solids also has odor issues.

2.3 Existing Biosolids and Energy Systems Conclusions

Based on the evaluations presented above, the following conclusions were provided.

First, based on the projected conditions in 2025 AA, 2040 AA and 2040 MM, Figure 2-3 presents a summary of estimated solids process capacities downstream of the anaerobic digesters for the sludge produced at the GBF and DPF. These estimates assumed that the anaerobic digesters will have 45 percent VSR and dewatering centrifuges will produce cake at 21 percent solids. The dewatering, drying and incineration processes have enough capacity to handle sludges from GBF and DPF under 2025 AA and 2040 AA conditions operating five days a week as shown on Figure 2-3. Under 2040 MM conditions, however, the system may need to be operated seven days a week for the FBI to handle the solids throughput. It should be noted that the evaluations showed that there will also be some capacity available to process HSW within the R2E2 system as the FBI will be at approximately 80 percent of its solids throughput capacity or below.

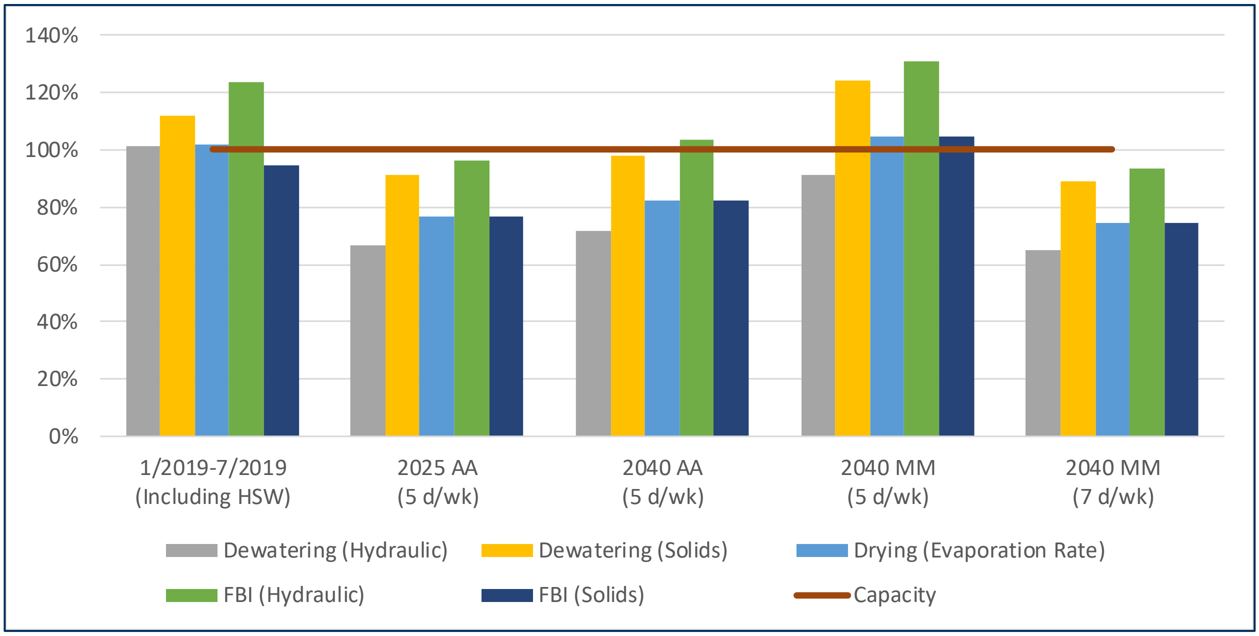

Figure 2-3 Capacity evaluation of existing solids processes assuming thickened sludge at 6 percent TS and dewatered cake at 21 percent TS.

Second, if dewatering process cannot get to the design performance requirement of 21 percent TS because of material handling issues then the dryer will be the bottleneck for the R2E2 system. When the dryer feed is between 19 to 20 percent solids, the evaporation capacity of the dryer will be exhausted to remove additional water from the digested sludge cake. Therefore, the FBI will have to be operated at a lower solids throughput than design conditions. As shown on Figure 2-4, the system will be limited by the dryer capacity under all future projected conditions unless system is operated longer than five days a week. Further, there will not be any additional capacity available for HSW co-digestion. Therefore, understanding and finding a resolution to the current material handling issues related to the digested sludge cake is important to determine future capacity constraints.

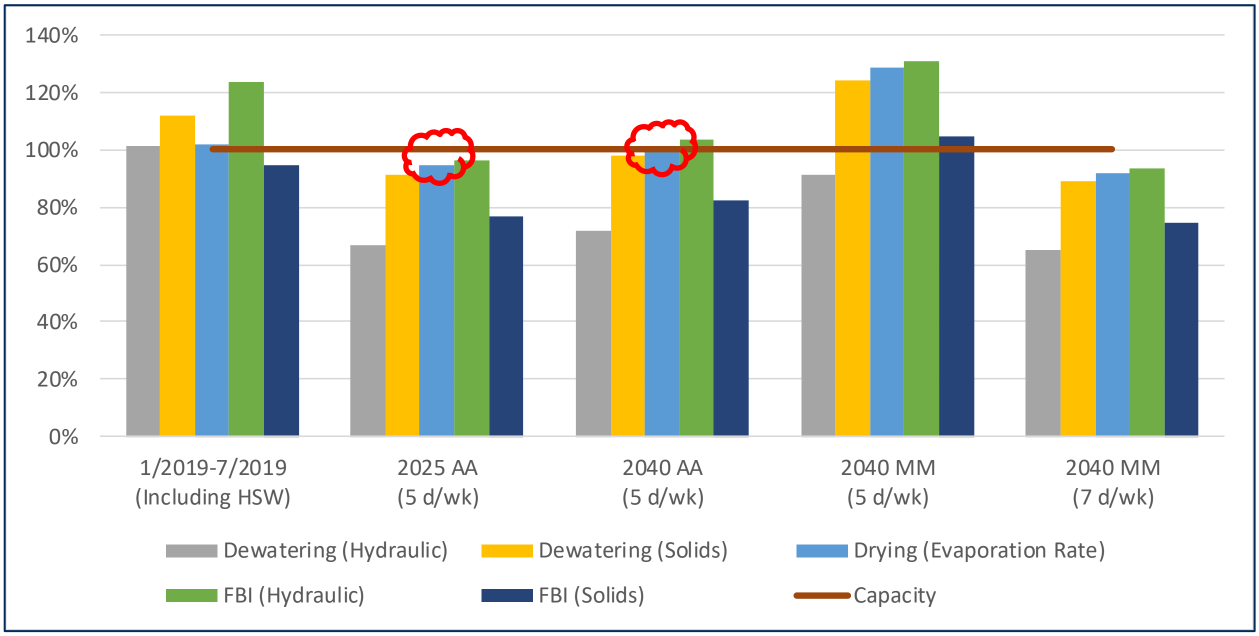

Figure 2-4 Capacity evaluation of existing solids processes assuming thickened sludge at 6 percent TS and dewatered cake at 19 percent TS.

There is a limit at how much HSW the facility can accept. Under current operational conditions, the R2E2 cannot achieve design basis HSW loads. The processes downstream of anaerobic digestion would be solids limited because of lower VSR in the digesters.

Third, current operation is to control HSW addition based on engine availability; however, NEW Water should also track centrifuge and FBI solids capacity as the sludge loads to the incinerator increases in the future.

3.0 R2E2 Debottlenecking with Biosolids Storage

There are no raw sludge storage tanks at the GBF. Therefore, the solids produced at the NEW Water facilities are fed to the digesters continuously. There are two Dewatering Feed Tanks that are located downstream of the digesters, and they provide two to three days' storage for digested sludge before the sludge is dewatered and incinerated. As shown in Table 2-4, the storage time in these tanks will drop below two days under the projected 2040 conditions.

This limited sludge storage upstream of incineration necessitates NEW Water to store solids in the activated sludge process by minimizing sludge withdrawal when the incinerator is down for maintenance. This inconsistent wasting leads to large fluctuations in the mixed liquor suspended solids (MLSS) concentration in the aeration basins, impacting sludge settleability, nutrient removal performance, and wet weather treatment. Details concerning the impacts on aeration basin operation are included in TM 4.3.

3.1 Storage Sizing Evaluation

In order to minimize the effect of solids processes on liquid treatment and the number of hauling events to landfill, extra storage capacity upstream and downstream of the digestion process was evaluated. There are limited options for storing liquid sludge upstream of the digestion. One option is to use the currently unused two decant tanks and unused equalization tank. Based on the tanks total volume and average day WAS production rates, these tanks could provide 1.3 days of WAS storage. Based on the limited amount of additional storage this option provides, NEW Water concluded that the associated operational challenges of using the tanks did not justify the relatively small incremental benefit and liquid storage was not considered further.

For the purposes of projecting benefits and cost of additional solids storage after digestion, a representative shutdown condition was assessed. Based on a 5 day per week operation schedule for centrifuge dewatering and incineration including scalping dryer, Figure 3-1 presents 2040 AA digested sludge cake production of 42.1 dtpd during a five-day shut down. During this period, a cake storage capacity of 211 dry tons would be needed, and it would take approximately 13 days for the FBI to catch up with the daily solids production. As shown in Table 3-1, this storage need equates to 1,700 cubic yards (cy) of storage capacity to be provided.

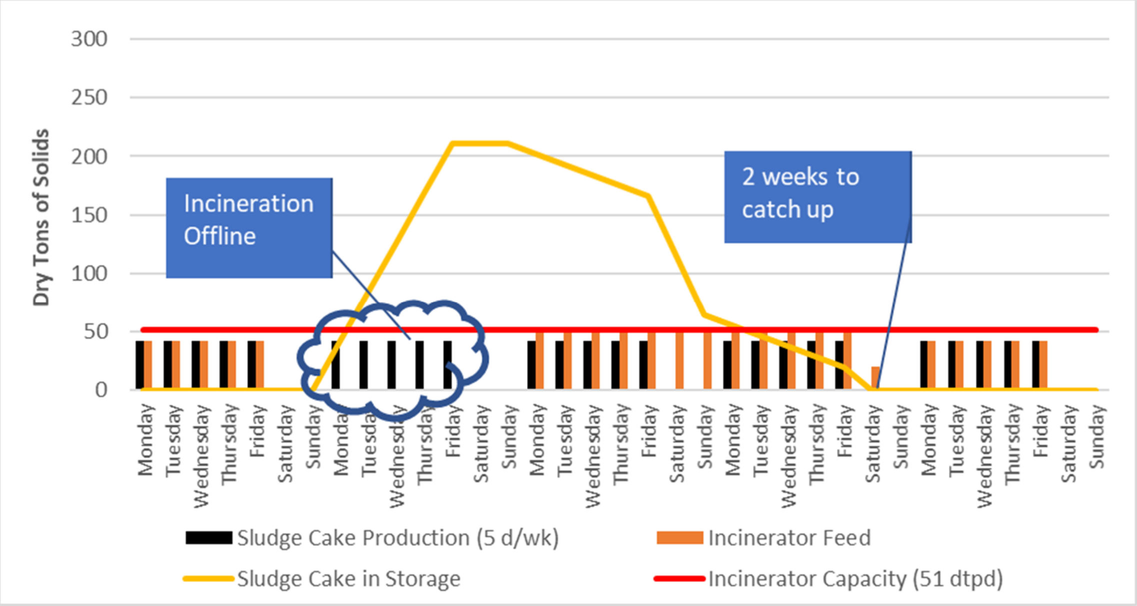

Figure 3-1 Digested Sludge Storage Requirement in 2040

Table 3-1 Digested Sludge Cake Storage Requirements

Parameter	Projected Future Conditions (2025)	Projected Future Conditions (2040)
Normal Incineration Operation, d/wk	5	5
Average Day Incinerator Feed, dtpd	39.2	42.1
Sludge Cake Storage Required, dt	196	211
Sludge Cake TS, %	21	21
Sludge Cake Density, lb/cf	55	55
Sludge Cake Storage Required, wet ton	934	1,000
Storage Capacity Required, cy	1,260	1,351
Filling Efficiency, %	80	80
Storage Volume, cy	1,600	1,700

A sliding frame silo type cake storage was assumed for this evaluation. At a volume of 425 cy per silo, a total of 4 silos would be needed. The cylinder section of each silo would be 25 feet high with an inner diameter of 25 feet. These silos would be located north of the Solids Facility so the existing cake pumps could be utilized to convey dewatered digested sludge to a silo. There would be one cake pump installed under each silo to feed sludge cake back into the scalping dryer when the incinerator is put back online. Figure 3-2 shows the proposed location for 4 sludge cake silos with 25 feet diameters. It is expected that the foul air from these silos will be exhausted to an odor control system when the silos are storing cake.

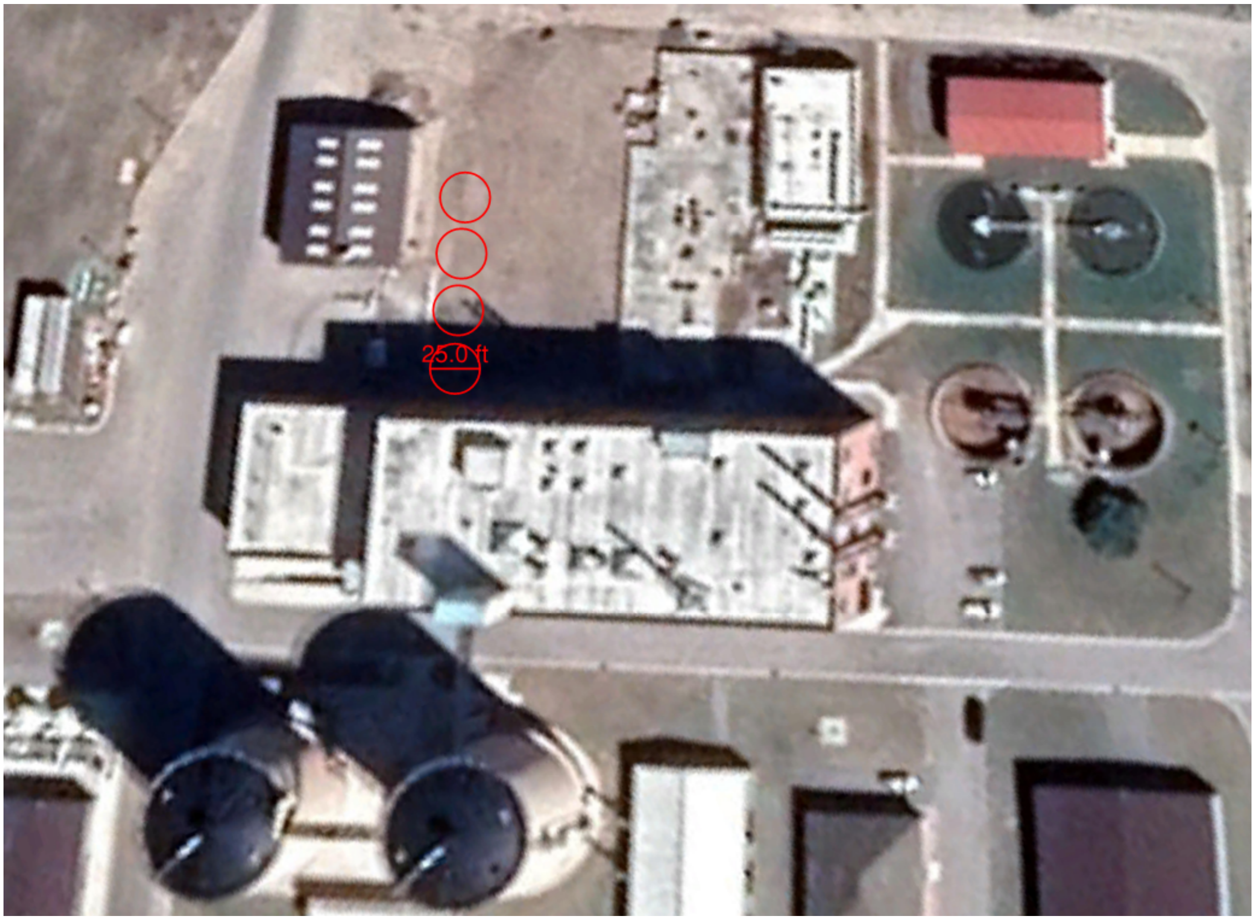

Figure 3-2 Proposed Location for Dewatered Sludge Cake Silos

A conceptual level (Class 5) opinion of probable construction cost estimate (OPCC) is provide in Appendix A. The construction cost of installing 4 dewatered cake storage silos was estimated at $15 Million.

3.2 Storage Recommendations

Currently, NEW Water hauls digested sludge cake to landfill or backs up the solids in the liquids treatment system every time the incineration process is shut down for maintenance. Based on the evaluations presented herein, a five-day capacity cake storage system can be installed to minimize the amount of solids landfilled each year.

During the Workshop, NEW Water staff noted that the current pipe layout to transfer sludge cake from centrifuges to hauling trucks is not adequate and it limits staff's ability to quickly haul cake out of the plant when transferring to a landfill. If cake silos are installed, they can also be utilized to fill trucks more conveniently and efficiently to haul cake out of the plant quickly.

B&V recommends NEW Water further evaluate the cake storage concept based on the criteria presented in this TM and develop a feasibility study to determine if this concept should be implemented at the GBF.

4.0 Energy Savings and Capacity Flexibility

Section 2 presented an evaluation of the capacity of the existing processes in R2E2 process scheme. It was concluded that there is currently enough capacity to process municipal solids from the GBF and DPF for the projected future loading conditions; however, there are operational limits that prevent NEW Water from achieving its R2E2 targets. One of these targets is to thermally oxidize all solids in the FBI to produce heat and minimize landfilling biosolids. As discussed above, NEW Water staff noted several challenges with the existing incineration process to achieve this goal. One alternative is to install a second FBI unit to provide full redundancy; however, this option is cost prohibitive. As an alternative, Section 3 provided a high-level evaluation of installing a dewatered digested sludge cake storage facility to minimize hauling solids to a landfill when the FBI is down.

This section presents potential technologies for NEW Water to consider in order to achieve R2E2's target of generating 50percent of the GBF's power demand from biogas and further reducing the solids load to incineration.

4.1 Digestion Enhancements

Although the digesters have the capacity to process HSW and generate more biogas, the overall capacity is limited due to lower than projected VSR. Improving VSR in digestion will increase biogas production to be used in the existing CHP engines and reduce solids going into the downstream processes. The following section provides a high-level discussion of digestion enhancement technologies that are currently available in the market to achieve better VSR in the digestion process and may improve dewaterability of digested sludge.

4.1.1 All Sludge Thermal Hydrolysis

A thermal hydrolysis process (THP) could hydrolyze solids prior to digestion and produce a digester feed that is easier to degrade. The use of THP would allow for a significant increase in throughput of the existing digesters (around double the current throughput). With the THP, digesters could be fed at around 10 to 11 percent TS as compared to the current feed concentration of around 5 to 6 percent TS. Due to the increase in throughput, this option would potentially allow the NEW Water to process a significant additional quantity of HSW and even consider receiving solids from other facilities in the region.

The use of THP would also allow NEW Water to produce a Class A cake product that is relatively low in odor. Having a Class A product may allow NEW Water to evaluate the potential for land application when the incinerator is down for maintenance; however, land application may be difficult to implement on an interim basis without a substantial storage capacity to develop a suitable inventory. This could also require a significant increase in staff obligations, arranging for sites, coordinating and managing application, and permit reporting. Contract land application operations could alleviate some of that burden, but storage would be needed to provide the interface between daily production and land application operations. Other factors to consider include effects of emerging contaminants on the regulatory side as well as public acceptance issues. Given these considerations and the fact that land application is unlikely given existing NEW Water investments and the soil conditions around Brown County, this section will focus on the energy benefits of CHP.

The THP would require a new pre-dewatering system that would dewater thickened sludge. The cake from pre-dewatering would be fed into a cake bin upstream of the THP system. The cake bin would also receive trucked HSW and potentially dewatered sludge from participating regional facilities.

One THP is the Cambi Process, where dewatered cake at 16 to 20 percent total solids is fed into a preheating tank, where heat recovered from the process is used to heat the solids. The preheated solids are fed to a second tank where high pressure steam is added to achieve temperatures of 300 to 320°F and pressures of about 115 to 130 pounds per square inch (psi). After approximately 30 minutes of reaction time, the pressure is released (flashed) and the steam is recirculated to the first tank for preheating of the incoming raw solids. The treated solids are cooled to 95°F and fed to anaerobic digesters. Since the process provides a 30-minute retention at around 300°F, final biosolids meet the time and temperature requirements for pathogen reduction per EPA 503 to achieve a Class AA product. Figure 4-1 illustrates the THP process. Table 4-1 presents advantages and disadvantages of THP implementation at R2E2.

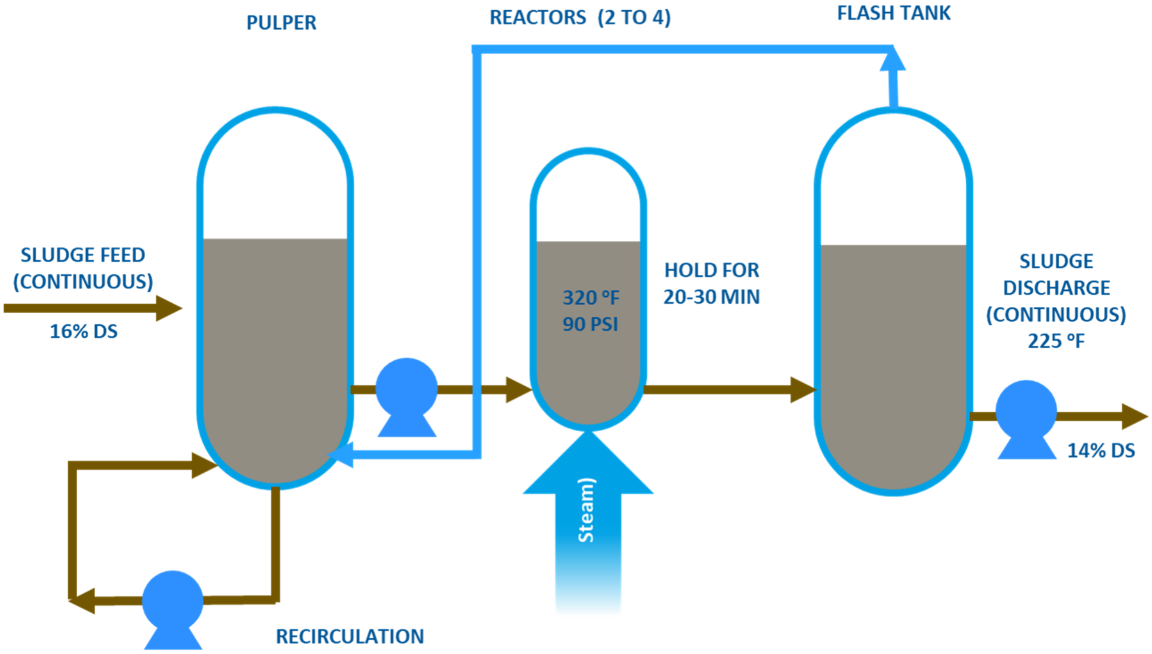

Figure 4-1 THP Process Schematic (Source: Cambi)

Table 4-1 Advantages and Disadvantages of THP Implementation.

ADVANTAGES	DISADVANTAGES
THP is a proven technology.	Significant capital investment would be required for the new THP system and ancillary equipment.
Installation of THP would double the throughput of existing digesters providing flexibility for receiving HSW and regional biosolids.	Operation of a medium pressure steam boiler system required which is a concern for some utilities.
The system is energy efficient and would be a net energy producer.	Limited experience with thermal drying of THP conditioned solids. Potential effects would need to be considered.
Typically achieves better VSR than conventional mesophilic digestion (55-60% VSR expected).	Increase in sidestream nitrogen and phosphorus loading (including recalcitrant components).
High loading rates and better VSR would generate more biogas and reduce downstream solids for processing.	Polymer consumption for pre-dewatering.
Final digested sludge cake can achieve 30 to 33% solids with centrifuge.	

4.1.2 WAS Only Thermal Hydrolysis

The WAS is the portion that is most difficult to digest and benefits the most from being hydrolyzed. There are several systems that could be used for WAS-only hydrolysis. One would be the use of a THP system as previously described. In this scenario, the primary sludge (which is readily digestible by nature) would be thickened and sent straight to the digester. Due to hydrolysis of only part of the feed material, the cake solids for this process would be expected to be somewhere between the concentration achieved with conventional digestion and that achieved with full THP.

Another hydrolysis process would be to use a thermochemical hydrolysis process (TCHP). TCHP uses heat and sodium hydroxide (caustic) to hydrolyze WAS prior to digestion. The process would result in improved digestibility and volatile solids conversion, but would produce a Class B rather than a Class A product since the primary sludge is typically bypassed to the digesters and the process does not provide a batch hold at suitable times and temperatures to achieve Class A. Thermochemical hydrolysis is available from CNP, who have a single installation in the U.S. at Kenosha, WI.

Advantages and disadvantages of a WAS-only THP solution for NEW Water are summarized in Table 4-2.

Table 4-2 Advantages and Disadvantages of WAS Only THP

ADVANTAGES	DISADVANTAGES
The process would result in greater volatile solids conversion in the digesters and less dry solids sent to the scalping dryer.	The throughput of the system will still be limited by dryer capacity. There may be some overall capacity increase due to additional VS conversion freeing up dryer capacity.
The cake solids concentration sent to the dryer and FBI would be expected to be higher than the current operation, leading to savings in natural gas consumption.	Additional capital investment would be required for the THP system and ancillary equipment.
The process would generate more biogas than the current digestion process.	Operation of a medium pressure steam boiler system is required, which is a concern for some utilities.
TCHP would not require a predewatering step.	The system would add complexity to the already complex process scheme.

4.1.3 Post-Digestion Thermal Hydrolysis

Thermal hydrolysis can be introduced downstream of anaerobic digestion in order to degrade extracellular polymeric substances (EPS) that are still present after anaerobic digestion. Cambi is marketing this process as ‘SolidStream’.EPS consists of long chain carbohydrates and proteins and it forms the bulk of the biological floc. EPS can bind up to 80 percent of the water and, in turn, affect the dewaterability of the digested solids. Thermal hydrolysis degrades EPS by using high temperature and pressure, combined with pressure drop disintegration. Following heating and a pressure drop, the solids are dewatered using a centrifuge without polymer. The degraded EPS and other cellular material are returned to the anaerobic digestion system as solubilized along with particulate material in the dewatering centrate. The final product is projected to be 40 to 60 percent TS. Therefore, this process could potentially eliminate the scalping dryer and the dewatered cake could be directly fed to the FBI. The process is depicted in Figure 4-2. The advantages and disadvantages of post-digestion THP are presented in Table 4-3.

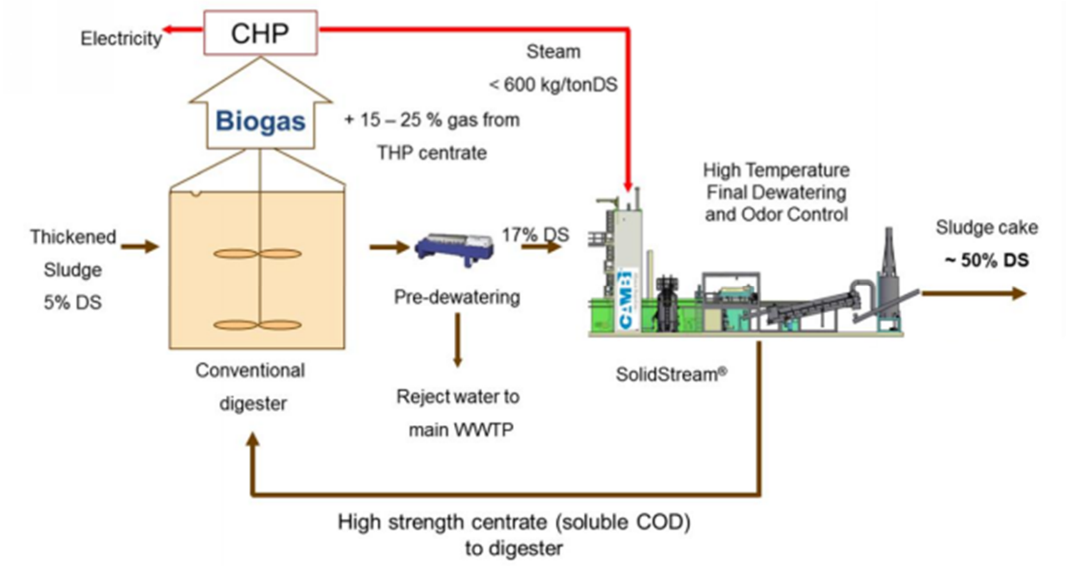

Figure 4-2 Cambi SolidStreamTM Process Schematic (Source: Cambi)

Table 4-3 Cambi SolidStreamTM Process – Advantages and Disadvantages

Advantages	Disadvantages
More gas production.	No operating systems in the US. Only one in the world in Germany.
Improved dewatering.	Requires steam boiler or heat recovery steam generator for hydrolysis.
Low polymer requirement for dewatering.	Not Class A per EPA 503 regulations.
No pumps within thermal hydrolysis process.	
Eliminate scalping dryer.	

4.2 Improving Dewatering Performance

Section 2 noted that the existing dewatering centrifuges have solids throughput limitations when HSW is co-digested to produce more biogas as well as sludge conveyance issues downstream because of the stickiness of the sludge. When the solids throughput gets too high for the centrifuge, the performance of the machine may be adversely impacted, producing sludge cake that has a lower TS concentration than the specified 21 percent. Moreover, higher sludge cake TS would also improve the capacity of the downstream dryer because the moisture loading would be lower.

The Orege SLG system would pre-condition sludge to improve dewaterability and reduce odors. The system would consist of a compressor, skid-mounted reactor, and deaerator. The system would be installed upstream of polymer introduction into the sludge feed (see Figure 4-3). Current units active in the US typically treat 80-110 gpm of sludge, although larger units are available.

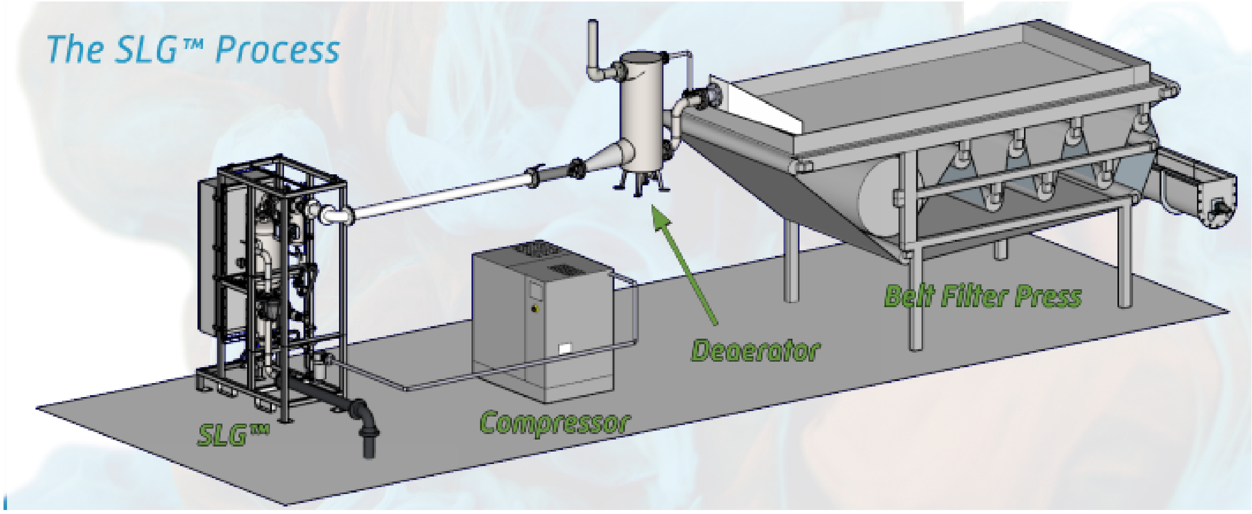

Figure 4-3 Orege Process Flow Diagram (Source: Orege)

Other than the equipment shown on Figure 4-3, the only additional equipment required would be odor control for the very small airflow from the deaerator. Recent testing indicates that this airstream could be highly odorous because the process would be volatilizing sulfide in the sludge; however, these exhausts could be treated with a small biotrickling filter.

There are approximately six installations in the US that show 1.4 to 3 percent point improvements in the sludge cake TS (WEF Fact Sheet 2019). The impact of this process on stored sludge cake odors has been studied in Europe but not as extensively in the US.

The relative advantages and disadvantages for this approach are summarized in Table 4-4.

Table 4-4 Orege SLG Pretreatment Advantages and Disadvantages

ADVANTAGE	DISADVANTAGE
Potential increases in cake solids.	Unproven for improving dewatering performance or odor reduction in U.S.
Potential decreases in transport, landfilling, and polymer costs.	Proprietary system.
Apparent odor reduction during extended storage (based on European data).	
Low O&M costs.	
Small footprint.	

4.3 Potential Energy Savings and Capacity Limitation Projects

There are several potential technologies that could be part of the long-term facilities at NEW Water and the cost of these facilities would range from $50 million to $70 million . While they bring improvements to energy management and capacity flexibility, many of these technologies will add complexity and additional assets to operate. The overall impacts should be considered as part of a large biosolids management planning project.

5.0 Resource Recovery

In addition to energy and heat recovery from R2E2 facilities, there are other resource recovery options. This section provides a high-level presentation of potential technologies for NEW Water to consider for further evaluation.

5.1 Resource Recovery from Ash

The end product of incineration is ash, which is an inert material. Interest in beneficial reuse of ash is increasing. Historically, the most common way to dispose of ash is to a landfill, which involves tipping fees. Ash produced at R2E2 is disposed at a landfill.

For the past three decades, facilities have been exploring potential for reusing ash to avoid landfill tipping fees. Some of the reuse applications include the following:

Fill material — Ash can be used as fill material for excavations. One utility, for example, has a contractor using the material to fill old sludge lagoons. The material can also be used as a flowable fill.

Soil amendment — In some specific areas (particularly areas with high clay soils), incinerator ash may be used as a soil amendment through an additive process, which produces a soil that handles more easily, allows better drainage and airflow, and includes some valuable minerals.

Landscaping material — Ash may be blended with topsoil to improve the concentration of available phosphorus.

Brick — Ash has been used in brick manufacturing by various utilities quite successfully. The brick manufacturers normally require large quantities of ash at a time. Such quantities could be obtained from a lagoon that needs to be emptied.

Concrete fly ash — Ash has been used as a fly ash substitute in concrete mixes.

Asphalt additive — Ash has been used as a mineral filler and fine aggregate in asphalt mixes.

Some emergent technologies that aim to recover phosphorus from incinerator ash are being tested in Europe, where regulations are driving the change. These technologies release unavailable phosphorus in the ash to the bioavailable form and maximize phosphorus content in the ash that can be used for plant nutritional purposes. Additionally, some of these technologies are able to remove contaminants — such as iron, chlorine, and heavy metals — that may be detrimental to agricultural production.

Since several of these technologies are still in early stages of development, the associated capital costs are quite high, ranging from $17 to $28 million for a facility designed to process 20,000 tons of ash per year. The different technologies and their associated stages of development are summarized in Table 5-1.

Table 5-1 Phosphorus Recovery Technologies (Hoener and Kappe, 2020)

TECHNOLOGY	LOCATION	PROCESS	PRODUCT	DEVELOPMENT STAGE
TetraPhos® / Remondis Aqua	Germany	Wet chemical extraction, filtration, ion-exchange, and evaporation.	High-grade phosphoric acid.	Pilot, full-scale in construction.
Ash2®Phos / Easy Mining	Sweden	Acid leaching, alkaline precipitation of phosphorus, and additional dissolution/ precipitation.	Calcium phosphate, additional products with more stages.	Pilot tested, full-scale in preparation.
Metawater	Japan	Alkaline leaching, membrane separation, precipitation, drying, and granulation.	Calcium hydroxyapatite (HAP).	2 full-scale facilities in operation since 2010 and 2013.
AshDec® / Outotec	Finland	Thermochemical calcination using sodium sulfate, a reducing agent, and heat.	Phosphorus pentoxide (20-35%) in ash matrix.	Pilot tested, full-scale in preparation.
PHOS4green / Glatt Seraplant	Germany	Suspension with phosphoric acid, water, and nutrients; granulation; drying; and cooling.	Various phosphate and complex fertilizers based on added nutrients.	Pilot tested, full-scale in construction.

A large portion of the phosphorus contained in incinerator ash is not bioavailable without additional treatment and a mature phosphorus recovery technology is still not available, as described above. In addition, the cost of phosphorus recovery technologies currently available is orders of magnitude higher than other potential reuse methods, such as construction material or soil amendment. Therefore, phosphorus recovery is not recommended as part of this project.

Reuse of incinerator ash has not generated a revenue source for utilities to-date; however, there has been a large cost savings in landfill tipping fees.

Based on the review of the latest established technologies and experience of existing facilities in North America, the following industries may be explored for reuse of ash from the R2E2:

- Construction material — Bricks, concrete, aggregates, tiles.
- Soil application — Fertilizer, landscaping.
- The utilities listed in

- Table 5-2 have engaged in the process of providing ash to various industries to be reused.

Table 5-2 Utilities Applying Reuse of Ash

UTILITY	LOCATION	DISPOSAL USE	PROCEDURE
Northeast Ohio Regional Sewer District (NEORSD)	Cleveland, Ohio	Additive in soil product.	Utility pays to haul the incinerator ash to a local soil manufacturer, who uses the ash to improve the nutrient content of one of their soil products.
Central Contra Costa District (CCCD)	Martinez, California	Additive to improve nutrient content in fertilizer product.	Utility pays to haul the incinerator ash to a local fertilizer manufacturer, who uses the ash to improve the nutrient content of their fertilizer product.
Little Blue Valley Sewer District (LBVSD)	Independence, Missouri	Fertilizer in tree farms.	Incinerator ash has been licensed by the utility as a fertilizer by the Missouri Fertilizer Board. LBVSD has periodically supplied ash for use on a tree farm to reduce landfill tipping fees.
Metropolitan Council of Environmental Services	St. Paul, Minneapolis	Study to assess nutrient value.	Utility partnered with the University of Minnesota to run a full-scale test at the University's Rosemount Research and Outreach Center. The university is applying incinerator ash to corn and soybean cropland to study the nutrient value of phosphorus in incinerator ash over a three-year period. Study in its final stage.

Among these utilities, The Metropolitan Council of Environmental Services in Minneapolis was not ready to share the outcome of the study. LBVSD advised that their experience had not been successful and that it would not add value to this assessment. NEORSD introduced the initiative in 2008, and, after several studies and trials, it is very satisfied with the current operation.

5.2 Nutrient Harvesting From Centrate

NEW Water invested in nutrient harvesting as part of the R2E2 project in the form of struvite harvesting. The main nutrient harvested is phosphorus, and the recovery is predicated on achieving enhanced biological phosphorus removal (EBPR) in the activated sludge process. As discussed in TM 4.3, a significant portion phosphorus removal is achieved via influent metals in the form of iron and aluminum. These metals not only bind influent phosphorus but have a lingering impact on the recoverable soluble phosphorus in the digesters. To understand the impacts of influent metals on recoverable phosphorus, a simulation was completed using the whole plant model developed in TM 2.4. In simulations, when influent metals were added to the influent ("turned on"), the soluble phosphorus concentration quickly dropped and came to a steady-state after approximately 10 days of addition. When the influent metals were removed from the simulation, however, stable digester soluble phosphorus did not stabilize for over 100 days (results in Figure 5-1). This is an important note as it would indicate that struvite harvesting would not be feasible until no influent aluminum or ferric was present for at least 100 consecutive days. Given the history of chemical addition in the NEW Water collection system from industrial users, struvite harvesting is not a likely option for NEW Water in the near term.

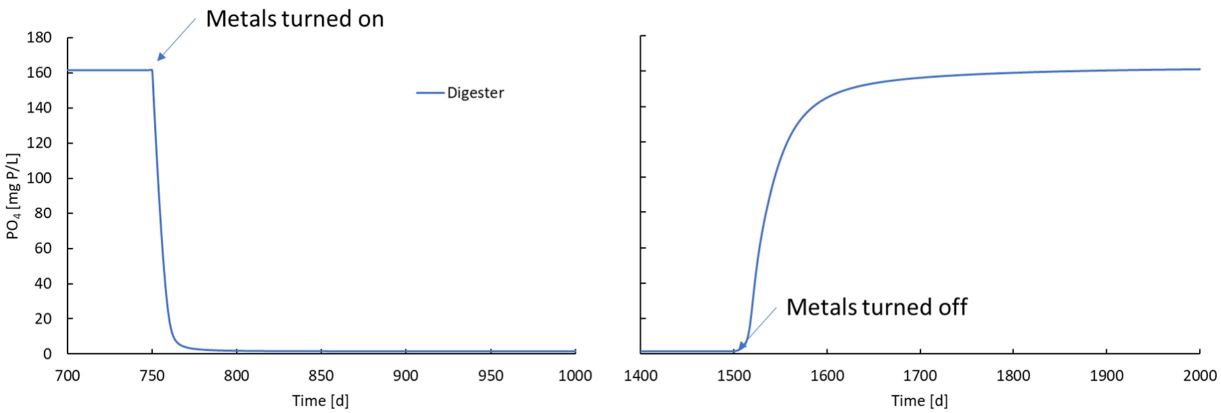

Figure 5-1 Dynamic Simulations Showing the Impact of Influent Metals on Digester Soluble Phosphorus

An emerging area for nutrient harvesting is recovery of iron on phosphorus from vivianite. A new technology for iron on phosphorus from vivianite recovery is currently being developed by research groups at Delf University (shown schematically in Figure 5-2). Phosphorus bound with iron is separated from digested sludge via a magnetic process, and a caustic compound is used to strip the phosphorus from the iron. The phosphorus is available for fertilizer, while the recovered iron can be recycled for phosphorus removal. This process is in the beginning of research and development but should be monitored by NEW Water as a potential solution in the future.

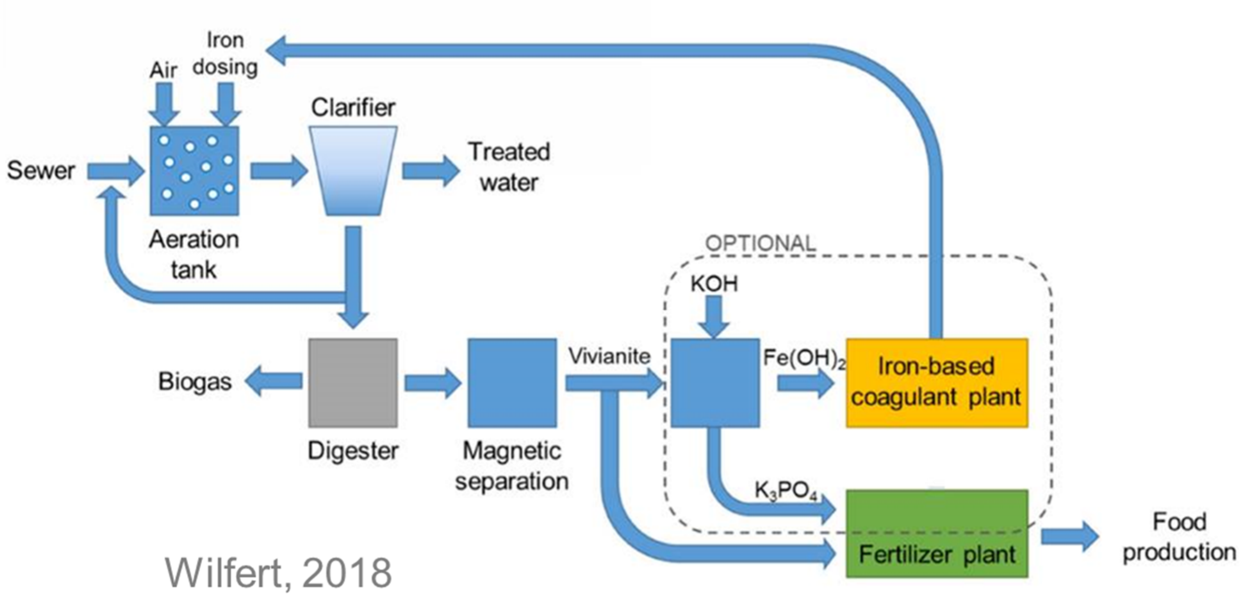

Figure 5-2 Potential Configuration for Vivianite Based Phosphorus Recovery

5.3 Resource Recovery from Liquid Stream

There are appreciable precious metals in the liquid influent to DPF and GBF. For example, there is a total of about $4.6 million/year in gold in the combined influent. About 45% of the gold is captured in the ash from the biosolids. Currently, cost effective technologies do not exist to extract gold from the influent or ash. However, if such technologies are developed in the future, they will enable much greater resource recovery.

5.4 Future Approach

Resource recovery is a part of the long-term strategic plan for NEW Water. Energy has been a focus in previous projects and should continue to be a key target. No imminent projects would warrant investment in the near-term CIPs; however, recovery of nutrient from ash or centrate should be considered as part of the long-term applied research efforts by NEW Water.

6.0 Conclusions and Recommendations

The focus of TM 4.6 was to:

- Assess the capacity of the biosolids facilities under its current actual operating conditions and desired design operating conditions to handle future loading rates. The TM concluded that after 2025 when additional loadings are expected, the biosolids facilities will be increasingly capacity limited and less HSW could be accepted so that there will be adequate available processing capacity handle municipal loads.
- Consider the feasibility and cost of biosolids storage to provide more flexibility in handling biosolids. Liquid storage of biosolids was evaluated and not considered feasible. It would be feasible to add additional solids storage for a cost of approximately $15 million. However, the sludge handling characteristics of the sludge would need to be improved before this option is feasible.
- Consider longer term options for additional energy recovery such as advanced digestion technologies. Such options would cost $50 million to $70 million and should only be considered in the context of a long-term biosolids plan.
- Consider longer term options for resource recovery. There are no options for additional liquid or solids resource recovery, but the technologies should be tracked as they develop.

In view of these conclusions, the following is recommended:

1) The thickening improvements outlined in TM 4.2 are implemented would alleviate many of the critical limitations of the R2E2 infrastructure by increasing SRT in the digesters and, potentially, improving VSR. Better VSR and lower digested sludge flow rate would lower the hydraulic and solids throughput to the centrifuges, essentially lowering the loads to the dryer and incinerator.

2) The greatest short-term biosolids processing challenge is the overall sludge handling characteristics. The "stickiness" of the sludge limits R2E2 capacity and creates operational challenges. B&V recommends NEW Water complete an optimization study for the R2E2 processes to evaluate the following:

    a. Digester Performance — Since the anaerobic digestion process does not achieve the design VSR values, more solids are being processed by the downstream equipment. For example, the dewatering centrifuges appear to be overloaded with solids when co-digesting HSW under current and projected future loads although hydraulic throughput is below design values. It should be noted that the latter is contingent on implementing the improvements identified in TM 4.2. NEW Water should consider assessing current digester performance with and without HSW and evaluating applicability of any of the digestion enhancement technologies presented in this TM to increase VSR.

    b. Centrifuge Performance — In order to increase the solids content in the sludge cake and address the "sticky" sludge noted by the staff, a dewatering performance optimization study should be undertaken to evaluate and identify operational and process parameters (including polymer type and dose) that could be implemented.

Increasing solids content will reduce the load on the dryer and lower the number of trucks to landfill when incineration is not operational.

c. FBI Performance — The incineration system including the dryer should be assessed in detail to address the current operational issues with the thermal oil system. It is also recommended to evaluate options to achieve autogenous combustion of solids. This evaluation may include separate ultimate analysis of digester feed sludge to identify if any of the sludges or HSW has lower than expected HHV, improving dryer performance to achieve 40 percent solids on a consistent basis, and considering options to install a system that will preheat the fluidization air. It should be noted that increasing cake solids out of the dryer also depends on the dewatering centrifuge performance to increase cake solids.

d. Overall R2E2 Asset Evaluation — Many of the R2E2 components have a lack of redundancy which results in increased downtime when an individual component or system fails. Some of these components are relatively easy to address. For example, biogas treatment skids may need a redundant blower to feed biogas to the CHP engines when one of the duty engines fail. Other components, such as the thermal oil system, is more complicated. Therefore, it is recommended that NEW Water evaluate the assets on the R2E2 scheme between the digesters and the ash ponds and develop a strategy to increase the uptime of the system through processes such as Criticality Path Analysis and Failure Modes Effects and Criticality Analysis.

The cost to perform a study to address items a to d is estimated to be approximately $1M.

3) Assuming the study described above can improve the sludge handling characteristics, B&V recommends further evaluation and implementation of the biosolids storage system for providing a wide-spot between the centrifuges and incinerator. An illustrative example of a biosolids storage facility was presented in Section 3. Other improvements to the R2E2 system will be longer term. Additional sludge storage will provide a needed shorter-term option to manage sludge during R2E2 maintenance down times so the sludge does not need to be landfilled.

4) If a solution cannot be found for the sludge handling characteristics, then it is likely that NEW Water will either need to achieve future required capacity through consideration of advanced digestion processes as described in Section 3 or through adding capacity to its existing R2E2 processes.

Figure 6-1 summarizes the sequences of these recommendations.

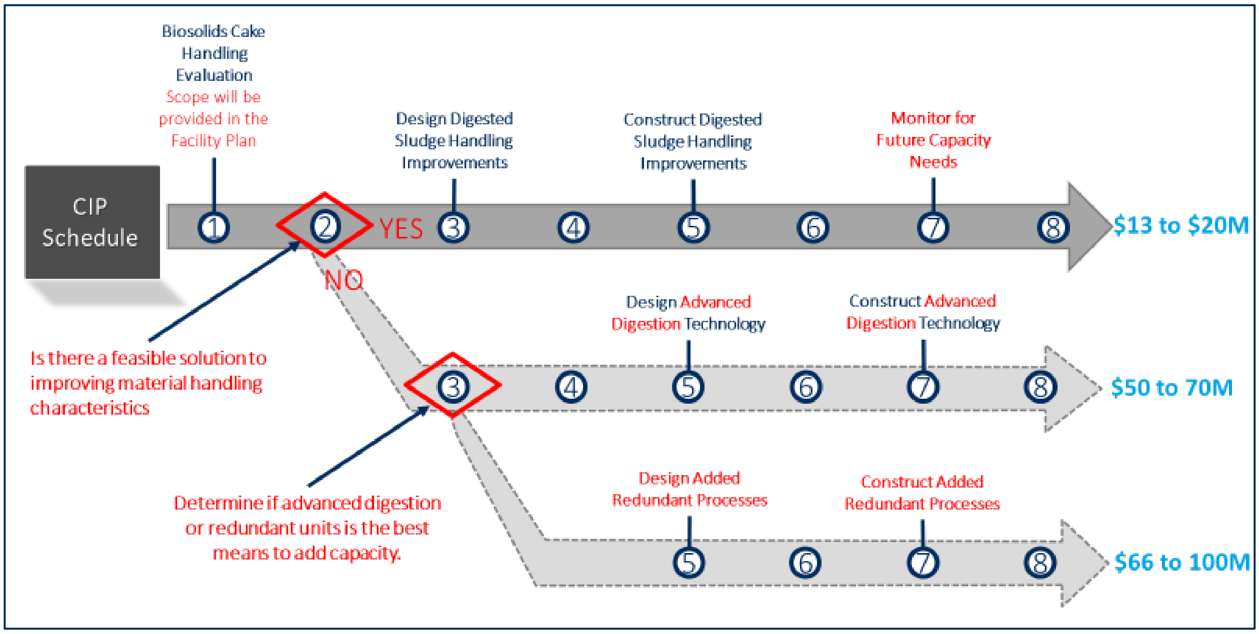

Figure 6-1 **Roadmap for R2E2 debottlenecking.**

It typically takes multiple years to plan, design, and construct a new process such as digestion enhancements, however, so NEW Water should consider planning for these studies within the next five years.

7.0 References

Hoener, Webster; Kabbe, Christian. (2020). Incineration of Biosolids Provides a Pathway for Maximum Phosphorous Recovery from Water Reclamation Facilities: A German Approach. Proceedings of the WEF Residuals and Biosolids Conference. 310-323

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