WRF 4973 Fact Sheet: ID 1701

Strategy: Energy Savings

Reduce Energy Consumption Overview

Pumping is One of the Key Power-Consuming Processes.
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Maintain Efficient Aeration to Reduce Energy Use.
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Power use constitutes one of the major operational cost centers at a water resource recovery facility (WRRF). Aeration (blowers) and pumping are two key power-consuming processes at a nutrient removal WRRF. Disinfection and solids treatment can also be significant power consumers. The magnitude and rank of the WRRF power consumption very much depends on the treatment requirements, technology selection, and environment. In addition, WRRF layout could contribute significantly to power demand if intermediate pumping is required to transport liquid to the downstream treatment unit.

Key performance indicators (KPIs) can help WRRF staff track and manage energy use. It is best to establish WRRF-specific target KPIs and, based on those, set a target for energy consumption. An operator can then see the progress toward the energy use goals at a WRRF by tracking its KPIs.

This fact sheet focuses on practices to optimize a nutrient removal WRRF for energy (power) use. Opportunities to reduce energy use are found in operational strategies, installed equipment that does not match the flow variations at the WRRF, and inefficiencies of aged facilities. Optimization strategies include equipment adjustments or changes in equipment, such as replacing inefficient or aged facilities, old and fouled diffusers, and oversized blowers or pumps that lose efficiency when operating at the edge.

Many WRRFs strive to reach an energy-neutral operation status by generating power on site to offset power use at the WRRF. Energy neutrality has been demonstrated at a handful of WRRFs, in most cases with the aid of solar, wind, or imported organics to maximize on-site power generation. This topic is not covered in these fact sheets.

Fact Sheet Application Checklist

R = fact sheet relevant to item
PR = fact sheet is potentially relevant to item depending on application, existing conditions, etc.

Category		
		Intensification
		Chemical addition
		Carbon management
	R	I&C strategies
		Sidestream mgmt.
	R	Energy savings
		Chemical savings
	R	Operational savings
		Other means of NutRem

Nutrient		
	R	Ammonia
	R	NOx
	R	TN
	R	Ortho-P
	R	TP

Scale (Design flow)		
	R	Small (<1 mgd)
	R	Medium (1–10 mgd)
	R	Large (>10 mgd)

Goal		
		Improve reliability
		Reduce nutrient
	R	Reduce O&M cost

Group		
	R	Optimize existing CNR
	R	Optimize existing TNR
		NutRem in secondary plant

Process		
		Small
		Pond
	R	Fixed film (secondary)
	R	Conventional act. sludge (CAS)
	R	Nitrifying act. sludge (NAS)
	R	Conventional NutRem (CNR)
	R	Tertiary NutRem (TNR)
		Other

CAS = conventional activated sludge (BOD only)
NAS = nitrifying activated sludge (without denitrification)
CNR = conventional nutrient removal no chemical/no filter, etc.
TNR = tertiary nutrient removal with chemical, filter, etc.

Technology Summary Evaluation

Footprint	3	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	4–5	Technology ranking based (LIFT) see below*
Energy use	1	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M cost	2	Scale 1–5: 1 = cost much less; 3 = cost similar to conventional; 5 = cost much more
Material/consumables	1	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	1	Scale 1–3: minimal/none = 1; some = 2; significant = 3 (e.g., chemical process)

* Technology ranking based on Leaders Innovation Forum for Technology (LIFT) Water Research Foundation (WRF) Technology Development Level (TDL) definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional

Descriptions/Evaluation

Strategy	Reduce energy consumption at a nutrient removal WRRF
Description	Strategies to reduce energy (power) consumption at the WRRF through changes in operation strategy, modifying installed equipment, or addressing the inefficiencies of aged facilities
Application	The major power-consuming processes at a WRRF are the following: • Aeration blowers • Pumps • Filtration pumps and blowers • Ultraviolet (UV) disinfection • Solids processing equipment
Constituents removed	None: these energy-saving strategies should maintain treatment performance.
Development status*	The energy optimization strategies generally fall in LIFT TDLs 4–5.
O&M considerations	Implementing a new strategy will require some additional training for staff.
Benefits	Reduce cost and power consumption. Reducing energy or generating power from digester gas provides a more sustainable, green treatment process.
Limitations	None
Design considerations	Depends on strategy, but generally some minor design is required.
Potential fatal flaws	None
Footprint requirements	None
Residuals	No change in residuals
Cost considerations	Some investment may be required for equipment refurbishing and replacement. A life-cycle cost analysis is recommended to determine if the return on investment is acceptable.
Past experience	City of Henderson, Nevada: biological process, operations and maintenance (O&M) Hampton Roads Sanitation District (HRSD), Virginia: energy, process, chemical, O&M, automation Clean Water Services, Oregon: energy, process, automation Central Contra Costa Sanitary District, Martinez, California: energy Pima County Regional Wastewater Reclamation, Arizona: energy, process, O&M, automation
Publications	Menniti, A. and K. Eberhardt. 2017. “Optimizing aeration system performance and efficiency at the Durham Advanced Wastewater Treatment Facility.” Annual Conference: PNCWA. Reardon, D. 1998. “Energy Usage Wastewater treatment plants.” Waterworld, August 31. U.S. Department of Energy. 2019. “Energy Data Management Manual Wastewater Treatment.” DOE/EE-1700 Better Buildings, U.S. Department of Energy, December 2017.
Related fact sheets	1710: Optimize Available Equipment 1740: Reduce Process Power Demand 1901: Optimize Operation and Maintenance
Date updated	9/10/2022
Contributors	Mario Benisch, Mike Falk, JB Neethling, James Barnard, Anand Patel, Jeff Prevatt

Note

* Technology ranking based on LIFT WRF TDL definitions:

1 = bench research and development

2 = small-scale pilot

3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional (https://www.waterrf.org/sites/default/files/file/2019-07/LIFT%20Scan%20Application-LIFT%20Link%2BHub_0.pdf : accessed September 2020)

Additional Information

Power Use at WRRFs

Power use constitutes one of the major operational cost centers at a WRRF. Aeration (blowers) and pumping are two key power-consuming processes at a nutrient removal WRRF. Disinfection and solids treatment can also be significant power consumers. The magnitude and rank of the WRRF power consumption depends very much on the treatment requirements, technology selection, and environment. In addition, WRRF layout could contribute significantly to power demand if intermediate pumping is required to transport liquid to the downstream treatment unit. These factors make it challenging to assign an expected energy demand to a WRRF.

The following figures are included to provide a range of the energy usage by unit process from various sources. Figure 1 contains the distribution of various unit processes in a WRRF. Distribution of energy demand at two WRRFs is shown; the one on the left shows that aeration dominates the cost for secondary treatment and disinfection. The second WRRF includes more cost centers (essentially complete treatment process) with aeration still the main cost center.

Energy demand versus WRRF capacity for different WRRF processes from Gu et al. (2017) is shown in Figure 2. Curves for trickling filters, activated sludge, and advanced treatment processes are shown in terms of kilowatt-hours (kWh) per million gallons (MG) treated.

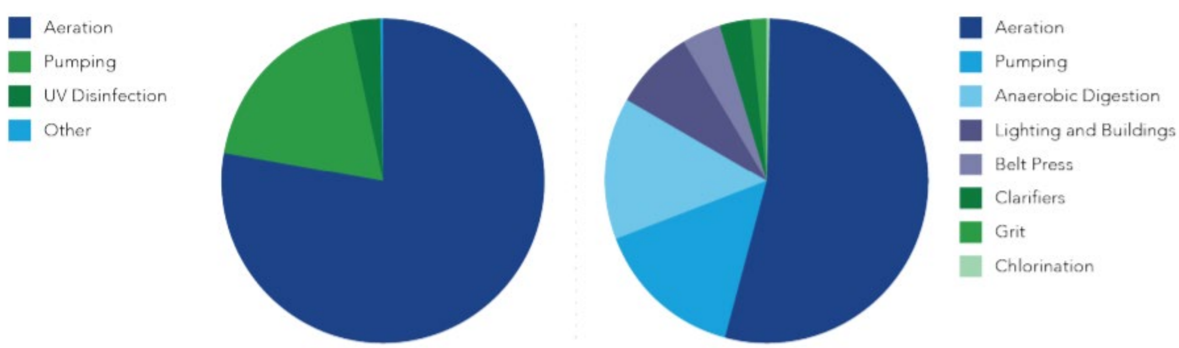

Figure 1. Typical Wastewater Treatment Energy Demand at Unit Processes.
Source: U.S. DOE 2017.

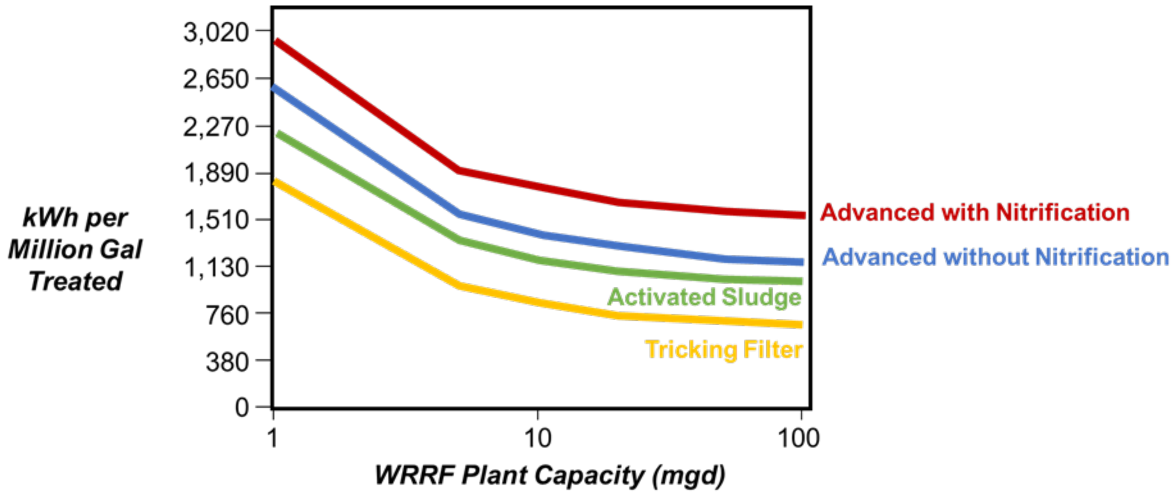

Figure 2. Energy Demand vs. WRRF Capacity for Different WRRF Processes.
Source: Reprinted from Gu et al. (2017) with permission from Elsevier.

Power Saving Strategies

Identifying the power demand of the individual unit processes at a WRRF can help identify the key areas where the most energy is being used and where process/operational changes can make the biggest difference in terms of energy savings. At most WRRFs, these key areas include aeration, pumping, solids handling, and/or other processes. Under other processes, UV disinfection is commonly a high energy consumption process. Strategies to reduce energy use at these unit processes can be classified as follows:

- Change the unit process operation to reduce the energy demand at the unit process
- Optimize the available equipment to enable efficient performance under all operating conditions
- Modify operating conditions at the equipment to reduce power demand

This approach includes strategies that reduce the energy demand from unit processes by making process changes. The process changes could modify the treatment process performance or change conditions that make the process more efficient. Strategies can include items such as:

- Reduce the dissolved oxygen (DO) set point in the bioreactor to increase oxygen transfer efficiency (see Fact Sheet 1740).
- Implement online DO control (see Fact Sheets 1501 and 1740).
- Reduce recycle pumping (see Fact Sheet 1740).
- Reduce mixing energy in unaerated zones by pre-mixing influent streams, then reduce mixing energy to less than 0.08 horsepower (hp) per 1,000 cubic feet (kcf) for slow-speed top entry-mixers. For the same mixing, thrust high-speed submersible mixers use three to four times more power.
- Reduce pump head and use axial flow pumps for recycling mixed liquor.

KPIs and Metrics

See report Chapter 4, Section 4.1.4.

KPIs can help WRRF staff track and manage energy use. It is best to establish WRRF-specific target KPIs and, based on those, set a target for energy consumption. Direct comparison metrics with other WRRFs are rarely useful, because WRRFs are operated under different permit conditions, environments, site constraints, and other factors. However, comparing current KPIs with the past performance of the same WRRF (as a whole or in individual power consuming centers) provides a more appropriate measure and comparison of operational energy efficiency. Figure 3 shows energy usage at WRRFs.

Figure 3. Energy Usage at WRRFs.
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Abbreviations

BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
DO	Dissolved oxygen
hp	Horsepower
HRSD	Hampton Roads Sanitation District
I&C	Instrumentation and controls
kcf	1,000 cubic feet
KPI	Key performance indicator
kWh	kilowatt-hour(s)
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
MG	Million gallons
mgd	Million gallons per day
NAS	Nitrifying activated sludge
NO_x	Oxidized nitrogen (nitrate + nitrite)
NutRem	Nutrient removal
O&M	Operations and maintenance
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
TDL	Technology Development Level
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
UV	Ultraviolet
WRF	The Water Research Foundation
WRRF	Water resource recovery facility