ReNEW RESOURCE RECOVERY ROADMAP

ReNEW Water Project: Resource Recovery to Fuel and Grow a Circular Economy

ReNEW

WATER PROJECT

H_2O Water	E Energy	14 N Nitrogen	31 P Phosphorus	Bio Biosolids

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1 Overview

The concept of a circular economy has steadily been gaining traction in recent years, especially in the water sector, the idea of which is to reduce the amount of waste produced by creating valuable products out of traditional waste streams. Water resource recovery facilities (WRRFs) can directly contribute to a circular economy by producing clean water, nutrients, renewable energy, and other valuable bio-based materials from wastewater. The WEF ReNEW Water Project seeks to create a bold, aspirational, and public call to action to accelerate resource recovery at WRRFs in order to fuel and grow a circular economy.

ReNEW has two components:

- **Call to Action** – Encourage utilities to pursue resource recovery as a way to improve operations, manage risk, and enhance sustainability. WEF seeks to catalyze the recovery of high-value products from wastewater by helping utilities develop business cases for resource recovery and alignment and integration of other related industry efforts including:
  - Utility of the Future Today Awards
  - US Department of Energy Water Security Grand Challenge to double resource recovery from wastewater by 2030
  - UN Sustainable Development Goals
- **Progress and Impact Reports** – will be developed on a periodic basis to determine progress towards the US DOE goal, as well as to report on the impact of those utilities creating value from former waste streams. The first Report was the resource recovery baseline released at WEFTEC 2018.

1.1 Resource Recovery Contributions to a Circular Economy

For nearly a decade, WEF has been promoting resource recovery. WEF's 2011 Renewable Energy Position Statement posits:

"Wastewater treatment plants are not waste disposal facilities but are Water Resource Recovery Facilities that produce clean water, recover nutrients (such as phosphorus and nitrogen), and have the potential to reduce the world's dependence on fossil fuels through the production and use of renewable energy."

WRRFs can recover many resources to create valuable bio-based products. The examples listed below represent just a few of the many products that can be recovered from wastewater. WEF encourages the development of other innovative ways to recover different bio-based materials from wastewater.

Water

Fresh water is a valuable resource necessary for all living things, and its use must be carefully managed. WRRFs can produce water of different qualities fit for a variety of purposes:

- Indirect Potable Reuse
- Direct Potable Reuse
- Land Subsidence
- Groundwater Replenishment
- Irrigation
- Habitat for Aquatic Life
- Wetland Restoration
- Other nonpotable uses, such as for cooling towers and boiler feed water

Phosphorus

Phosphorus is a non-renewable resource in limited supply that is necessary for life. WRRFs can recover phosphorus, producing a number of valuable products in a more sustainable way compared to phosphate mining. Phosphorus recovery options include:

- Struvite Recovery (and other phosphate minerals) to produce fertilizer while reducing struvite formation in pipes
- Land Application of Biosolids
- Recycled Water used for Irrigation
- Urine Separation – collects nutrient-rich urine separately to be treated and used as fertilizer
- Recovery from Incinerator Ash – phosphorus can be extracted from incinerator ash and used as fertilizer

Carbon

Some WRRFs use carbon from wastewater to generate the energy needed for operation, and there is a growing trend to view WRRFs as biorefineries. Whether for energy or nutrient removal, carbon can be utilized in a variety of valuable ways:

- Biogas production
- Other biofuels, such as compressed natural gas (CNG) and biocrude oil
- Carbon source for nutrient removal and recovery

Nitrogen

Unlike phosphorus, nitrogen is an element in abundant supply. However, high nitrogen concentrations in effluent can be harmful to receiving water bodies and aquatic life. Some options for recovering and reusing nitrogen include:

- Land Application of Biosolids
- Recycled Water used for Irrigation
- Ammonia Recovery
- Urine Separation – collects nutrient-rich urine separately to be treated and used as fertilizer

Other High Value Product Potential

There is potential to recover a variety of other resources that are not listed above. As our understanding matures, we are hopeful to see additional products produced from wastewater treatment, including:

- Metals
- Algae – can be used to treat wastewater and then harvested to produce animal feed, biofuels, nutraceuticals, proteins, and other bio-based materials
- Structural materials can be obtained from carbonates and phosphorus compounds
- Proteins and other chemicals can be recovered
- Solids can be stored for future mining

1.2 Alignment with Relevant Global Programs

There are a number of other programs currently in the water sector that align nicely with the mission of the WEF ReNEW Water Project. The goal is not to duplicate efforts, but instead to jointly support the overarching effort to promote resource recovery and the concept of a circular economy.

Utility of the Future Today Recognition Program

Utility of the Future Today is a recognition program launched by the WEF, the National Association of Clean Water Agencies (NACWA), The Water Research Foundation (WRF), and the WateReuse Association (WRA) to celebrate the achievements of forward-thinking, innovative water utilities that are providing resilient value-added service to communities, particularly in community engagement, watershed stewardship, and recovery of resources such as water, energy, and nutrients.

U.S. Department of Energy's Water Security Grand Challenge

The Water Security Grand Challenge is a White House initiated, U.S. Department of Energy led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. Using a coordinated suite of prizes, competitions, early-stage research and development, and other programs, the Grand Challenge has set the following goals for the United States to reach by 2030, including doubling resource recovery from municipal wastewater by 2030.

United Nation's Sustainable Development Goals

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.

The 17 SDGs cover a variety of topics, a number of which relate to the water sector:

SUSTAINABLE DEVELOPMENT GOAL 6

Ensure availability and sustainable management of water and sanitation for all

- Goal 6 – Ensure availability and sustainable management of water and sanitation for all
  - Target 6.3 – By 2030, Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
  - Target 6.4 – By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
  - Target 6.5 – By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
  - Target 6.6 – By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

SUSTAINABLE DEVELOPMENT GOAL 7

Ensure access to affordable, reliable, sustainable and modern energy for all

- Goal 7 – Ensure access to affordable, reliable, sustainable and modern energy for all
  - Target 7.2 – By 2030, increase substantially the share of renewable energy in the global energy mix
  - Target 7.3 – By 2030, double the global rate of improvement in energy efficiency
  - Target 7.a – By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

SUSTAINABLE DEVELOPMENT GOAL 12

Ensure sustainable consumption and production patterns

- Goal 12 – Ensure sustainable consumption and production patterns
  - Target 12.4 – By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
  - Target 12.5 – By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

SUSTAINABLE DEVELOPMENT GOAL 14

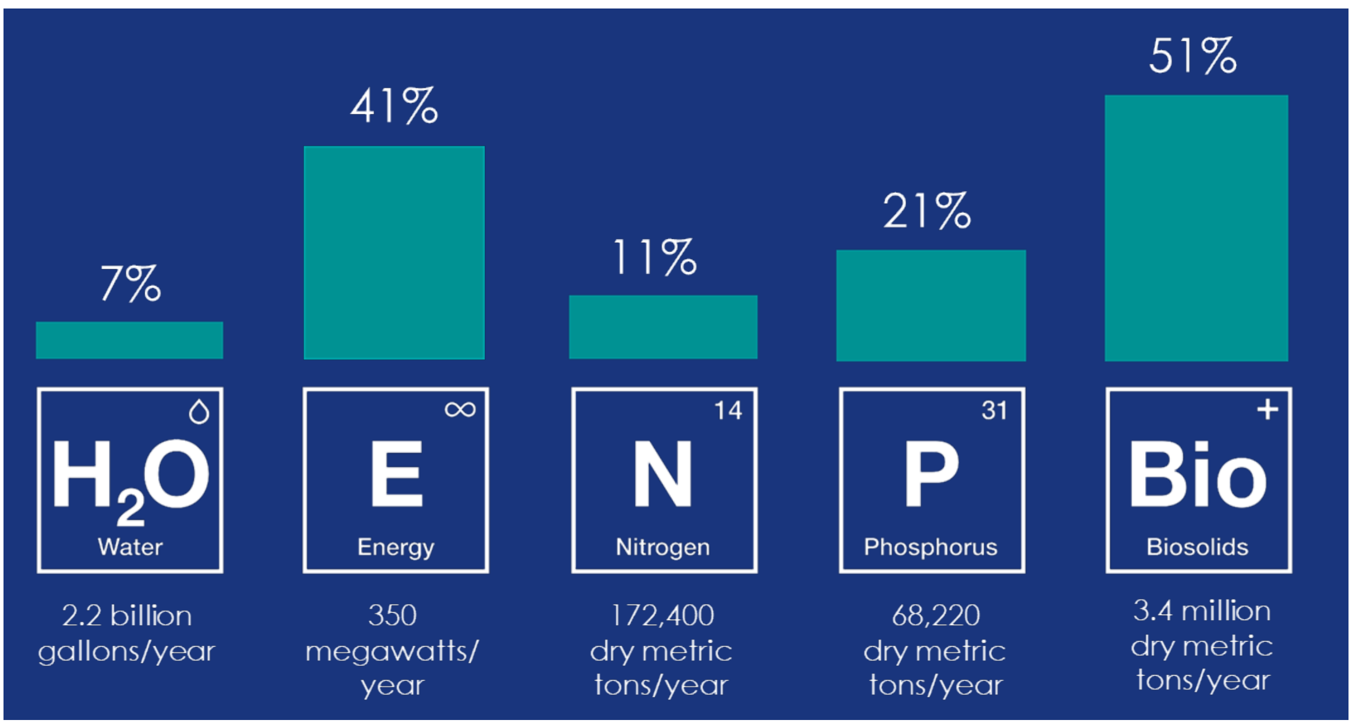
Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Goal 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development
  - Target 14.1 – By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

1.3 Progress Reports

WEF will produce progress reports for the ReNEW Water Project on a bi-annual basis to track the progress towards increasing resource recovery to support a circular economy. The first progress report was released at WEFTEC 2018 (Baseline Data to Establish The Current Amount Of Resource Recovery from WRRFs, WEF Technical Report WSEC-2018-TR-003) with the baseline recovery rates for water, energy, nitrogen, phosphorus, and biosolids. The rates from the 2018 baseline shown below are calculated using a mass-balance approach.

In addition to the updated recovery rates, the bi-annual progress report will include case studies documenting how WRRFs are producing a variety of high value products from wastewater.



2 Nutrient Recovery: Part of the Solution

Nutrients — commonly nitrogen and phosphorus — are found in agricultural and home fertilizers and also are generated by livestock, industrial, and municipal systems Specific sources include confined animal feeding operations, row crop farming, industrial pre-treatment facilities, septic systems, municipal and industrial stormwater, and WRRFs According to the U S Environmental Protection Agency (EPA), more than 100,000 miles of rivers and streams, close to 2 5 million acres of lakes and ponds, and more than 800 square miles of bays and estuaries are affected by nitrogen and phosphorus pollution

In excess, nutrients can be harmful water pollutants excess nutrients can lead to algal blooms, which cost the tourism industry some $1 billion annually, according to the EPA algae also can result in hypoxic zones and can turn to harmful algal blooms (HAB), which produce toxins HABs received national attention in summer 2014 after a cyanobacteria bloom in Lake Erie caused Toledo, Ohio, to issue notices to nearly half a million people not to drink, cook, or bathe with city water.

However, WRRFs also are part of the solution With advanced biological and chemical methods, facilities already can achieve significant nutrient reductions This roadmap lays out a strategy for facilities to achieve zero net impacts from nutrient discharges by 2040 WRRFs also can reclaim nutrients Biosolids are one such supply of nitrogen and phosphorus Fertilizers can be energy-intensive to manufacture, and the supply of some nutrients, such as phosphorus, is limited Recovery not only prevents nutrients from entering waterbodies as point source discharges but provides a supply of these essential resources.

This image, taken in 2011, shows one of Lake Erie's worst algae blooms in decades. Image by NASA.

2.1 Nutrient Treatment Technologies

A number of treatment technologies are available for both mainstream and sidestream treatment for nitrogen and phosphorus The details of these can be found in WEF manuals of practice 8, 11, and 34 or Design of Municipal Wastewater Treatment Plants, Operation of Municipal Wastewater Treatment Plants, and Nutrient Removal, respectively Below is a chart of some of the most common nutrient removal and recovery technologies:

- ● Strong Positive Impact
- ↑ Positive
- ↓ Negative
- ● Strong Negative Impact

	Nitrogen Removal	Phosphorus Removal	Energy Usage	Supplemental Carbon Requirements	Dewatering	Biogas Production
MAINSTREAM TREATMENT TECHNOLOGIES						
Conventional Nitrification-Denitrification *(e.g., Modified Luszack Ettinger, Bardenpho, etc.)*	Strong Positive Impact	Negative		Strong Negative Impact		Negative
Nitritation-Denitritation = "Nitrite Shunt"	Strong Positive Impact	Negative	Positive	Negative		Positive
Partial Nitritation-Anammox = "Deammonification"	Strong Positive Impact	Positive / Negative	Strong Positive Impact	Positive		Strong Positive Impact
Chemical Phosphorus Removal *(e.g. iron (Fe) & aluminum (Al) addition)*	Negative	Strong Positive Impact			Positive	Positive
Biological Phosphorus Removal *(e.g. Virginia Initiative Plant, University of Cape Town, and Anaerobic/Oxic processes)*	Negative	Strong Positive Impact		Negative	Strong Negative Impact *	Negative
SIDESTREAM TREATMENT TECHNOLOGIES						
Sidestream Deammonification			Positive	Positive		
Struvite Precipitation & Recovery		Strong Positive Impact		Positive	Negative	

2.2 Introduction to Nutrient Removal

WRRFs can achieve very low nutrient discharges through a variety of processes, primarily biological nutrient removal (BNR), physical separation, and chemical methods However, economic and environmental trade-offs exist, such as greenhouse gas production in the form of nitrous oxide (N2O) and increased energy demands due to aeration in BNR Nutrient removal techniques also can affect biogas production and dewatering.

Most technologies capable of removing both nitrogen and phosphorus utilize BNR, which relies on bacteria to transform nutrients present in wastewater Select species of bacteria can accumulate phosphorus, others can transform nitrogen, and a few can do both Achieving significant reductions in both nitrogen and phosphorus requires careful design, analysis, and process control to optimize the environment of nutrient- removing organisms The uptake of nutrients and growth of microorganisms could be inhibited by a limiting nutrient, available carbon, or other factors, including oxygen levels The selection of a BNR process should be based on influent flow and loadings, such as biological oxygen demand, nutrient concentrations, and other constituents as well as target effluent requirements

Some nutrient removal systems rely on two separate processes for nitrogen and phosphorus In some cases BNR is used to remove the majority of nitrogen and phosphorus, and then chemical methods are used to further reduce phosphorus concentrations Mainstream nutrient treatment takes place within the typical process flow However, sidestream treatment refers to liquid resulting from biosolids processing that is intercepted with the additional goal of removing nutrients from a concentrated stream Like mainstream nutrient treatment processes, sidestream treatment also can vary from biological to physical and chemical removal methods

2.2.1 Nitrogen Removal

Nitrogen can be removed from wastewater through physiochemical methods, such as air-stripping at high pH, but it is more cost efficient to use BNR conventionally, this method utilizes the natural nitrogen cycle, which relies on ammonia oxidizing bacteria (AOB) to transform ammonia into nitrites ($NO2–$) after which nitrite oxidizing bacteria (NOB) form nitrates ($NO3$ –) — a process called nitrification Other species of bacteria can transform these compounds into nitrogen gas ($N2$) — a process called denitrification

Biological nitrogen removal requires anaerobic, anoxic, and aerobic conditions in the proper sequence as both nitrification reactions require aerobic conditions while denitrification requires anaerobic conditions Though optimal conditions differ for nitrification and denitrification, both can be carried out simultaneously in the same unit if anaerobic zones exist Most processes combine nitrification and denitrification, either in one basin or as two separate stages, and can be broken down into two categories based on whether bacteria are suspended within the waste stream or fixed to a film or filter. As denitrification occurs, nitrogen gas is produced and released safely into the atmosphere, where nitrogen gas is more abundant than oxygen.

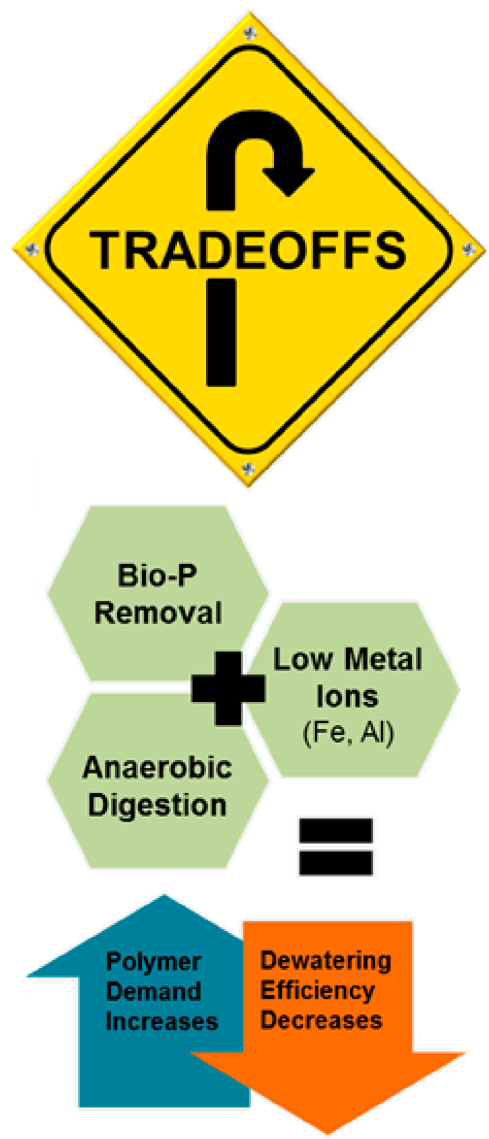
When performing biological nitrogen removal, it is important that the activated sludge has enough available carbon, which bacteria use to build new cells The nitrogen removal rate also depends on the amount of time sludge spends in the reactor (solids retention time), the reactor temperature, dissolved oxygen, pH, and inhibitory compounds.

2.2.2 Phosphorus Removal

Unlike nitrogen, phosphorus cannot be removed from wastewater as a gas Instead, it must be removed in particulate form through chemical, biological, hybrid chemical–biological processes, or nano processes Nano methods involve membranes and include reverse osmosis, nanofiltration and electrodialysis reversal Chemical methods (chem-P) typically involve metal ions, such as alum or ferric chloride These compounds bind with the phosphorus and cause it to precipitate It can then be removed by sedimentation and filtration Chemical methods are influenced by a number of factors including the phosphorus species, choice of chemical, chemical to phosphorus ratio, the location and number of feed points, mixing, and pH.

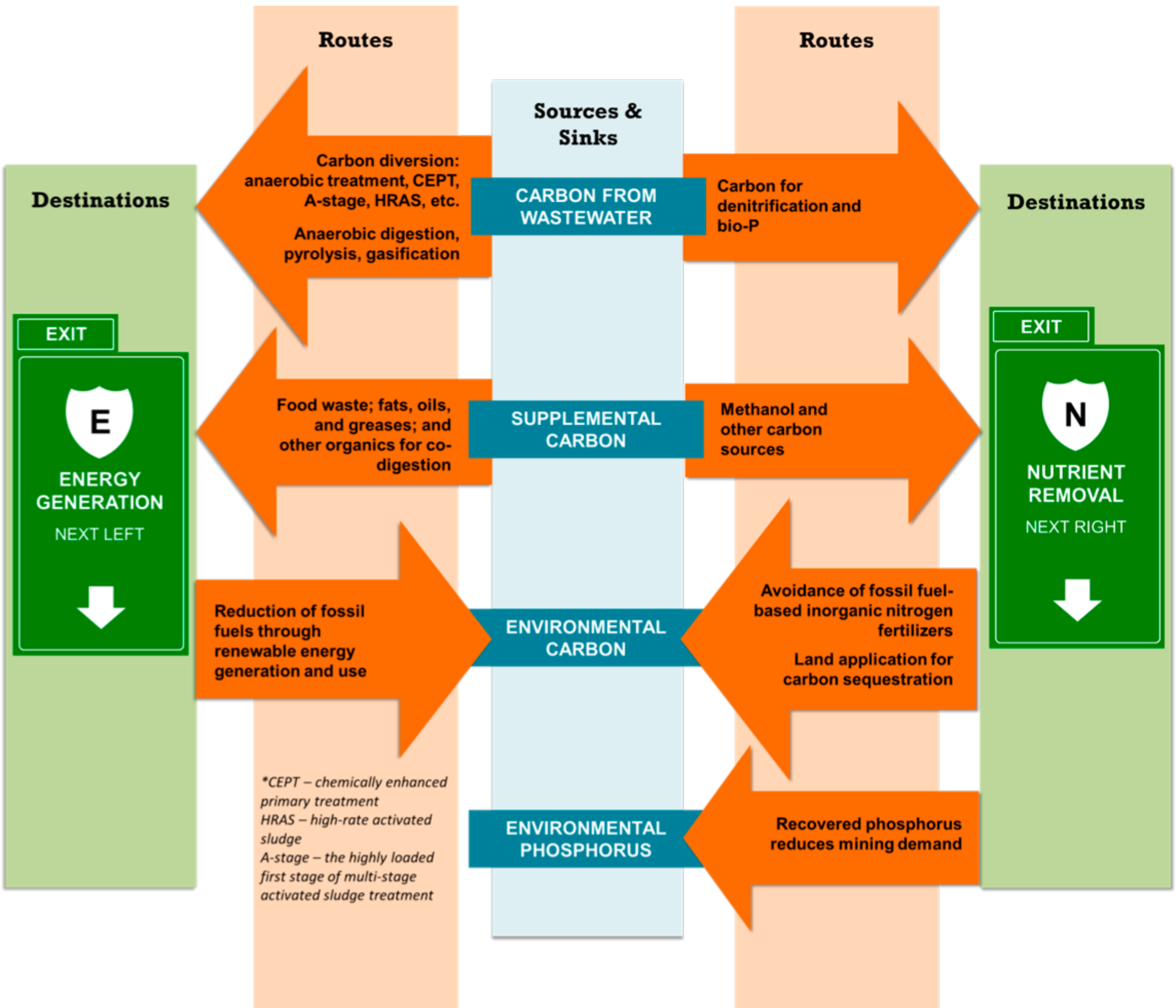
Biological phosphorus removal (bio-P) is a two- step process First, phosphorus is converted to a soluble form, and secondly, it is assimilated by phosphorus accumulating organisms (PAOs) Many biological nitrogen removal processes can be modified to remove phosphorus as well Similar to biological nitrogen removal, bio-P also requires the proper sequence of anaerobic, anoxic, and aerobic conditions Additionally, as with biological nitrogen removal, oxygen levels, solids retention time, and temperature play an important role in bio-P The ability of PAOs to uptake phosphorus is highly dependent on the availability of volatile fatty acids, which serve as a carbon source for the bacteria. Further, nitrates in return streams can negatively affect bio-P — an important factor to consider in combined nutrient removal systems.

This figure shows in more detail how the dewatering process is negatively affected by bio-P. During anaerobic digestion, flow from the bio-P process can decrease the efficiency of dewatering and require additional polymer as a coagulant, particularly when there are fewer metal ions, such as iron (Fe) and aluminum (AL), present.



2.3 Interrelationships

In upgrading facilities for better nutrient management, WRRFs must make decisions about the amount of carbon used for nutrient recovery and removal and carbon used for energy generation The following graphic gives a high-level overview of the interrelationships to consider when planning for nutrient management. The WRRF exemplified here must remove nutrients but also wants to generate energy "Energy Generation" and "Nutrient Removal" are destinations or goals in the roadmap allegory There are various "routes" WRRFs can take to reach these two outcomes using various carbon sources Carbon can come from wastewater and other supplemental sources to achieve nutrient removal and energy generation goals The WRRF also should consider new products — energy and fertilizer — that are generated as a result of nutrient removal and energy generation.



2.4 Greenlighting Nutrient Recovery

Phosphorus is a finite resource, with some estimating that demand will outpace supply within the next century For this and other reasons, interest in recovering nutrients from wastewater has increased over the last decade The "utility of the future" is shifting toward recovering nutrients and other marketable resources, including energy, electricity, and vehicle fuels However, the maturity of nutrient recovery technologies varies and each has its advantages and disadvantages

EPA estimates that the approximately 16,000 WRRFs in the U S generate about 7 million tons of biosolids About 60% of these biosolids are beneficially applied to agricultural land, with only 1% of crops actually fertilized with biosolids However, generating solid fertilizer from biosolids is the most common method of nutrient recovery from wastewater treatment

Currently some WRRFs are having success with struvite recovery, which allows for the precipitation and recovery of both nitrogen and phosphorus Other methods of phosphate precipitation also are becoming more common Sidestream treatment of sludge and sludge liquor, where the nutrients are more concentrated, is generally the preferable target for nutrient recovery.

2.5 Key Nutrient Treatment Terms

Nitrification-Denitrification: A biological nitrogen removal process where ammonia is oxidized to nitrate through biological nitrification The process of denitrification follows where nitrate is reduced to nitrogen gas

Nitritation-Denitritation: Another biological nitrogen removal process Here ammonia is oxidized to nitrite and then biologically reduced to nitrogen gas The term nitrite shunt is often used to describe this process

Partial Nitritation-Anammox: Often referred to as "deammonification," it is a two-step process that includes partial nitration Aerobic ammonia oxidation to nitrite occurs in the first phase then nitrogen gas is produced by anaerobic ammonia oxidation Anammox refers to anaerobic ammonia oxidation, a biological process carried out by specialized bacteria in which ammonia is oxidized using nitrite as an electron acceptor under anaerobic conditions

Struvite Precipitation and Recovery: By this method, both phosphorus and ammonium can be simultaneously recovered and used as a fertilizer

3 Major Themes in Water

Water reuse is an element of a diverse and resilient water management strategy.

Water reuse is a multifaceted issue and two important terms are used to describe how recycled water is an integral part of the water cycle. Recycled Water generally refers to treated domestic wastewater that is used more than once before it passes back into the water cycle The terms reused, reclaimed, and recycled are often used interchangeably depending on where you are geographically. Two primary themes are present in successful water reuse efforts: Fit for Purpose and Legitimacy.

3.1 Fit for Purpose

Fit for purpose means matching water of a specific quality to a use appropriate for that quality For example, a water with quality suitable for irrigation might not be suitable for industrial use as boiler feedwater Because water can be treated to varying qualities depending on the need, water resource recovery facilities (WRRFs) should be aware of the end use of the product water they treat This focus on treating to the appropriate use (fit for purpose) ensures both sufficient treatment for public health, environmental, or product needs while also minimizing the cost of overtreating water to a quality level much different than is actually required by the end use The following three examples show how water reuse can be used for environmental quality and irrigation, industrial, and even for drinking

3.1.1 Habitat Restoration and Public Recreation at Tres Rios Wetlands

In 1990, the Arizona Department of Environmental Quality released new water quality standards for wastewater discharges into Arizona waterways The solution that was selected by the City of Phoenix was the construction of the Tres Rios wetland project, meeting water quality requirements while providing habitat for threatened and endangered species, as well as public

recreation space After passing through the wetlands, the water is then used for crop irrigation Phoenix reuses 100 percent of their effluent, as the water that does not go to the wetland is provided as cooling water for the nearby power plant.

3.1.2 West Basin's Designer Water

In the early 1990s, the West Basin Municipal Water District in Los Angeles, California, added recycled water to its portfolio to serve a population of a million people To meet the unique needs of their commercial and industrial customers, the utility produces "designer water," or amended tertiary water for industrial and irrigation use The types of designer water the district produces include the following:

- Irrigation Water: Filtered and disinfected for industrial and irrigation use
- Cooling Tower Water: Tertiary treated water with ammonia removal
- Seawater Barrier and Groundwater Replenishment Water: Secondary water, with either lime clarification or microfiltration and reverse osmosis (RO)
- Low-Pressure Boiler Feed Water: microfiltration and reverse osmosis membranes for pure RO water
- High-Pressure Boiler Feed Water:
- Ultra-pure RO water treated by microfiltration membranes and passed through RO membranes twice

The designer water strategy enables the use of recycled water far beyond the potential of common irrigation applications for street medians, parks, and golf courses West Basin also helps ensure the economic production in the area by supplying a critical resource to several local refineries and a power generation company

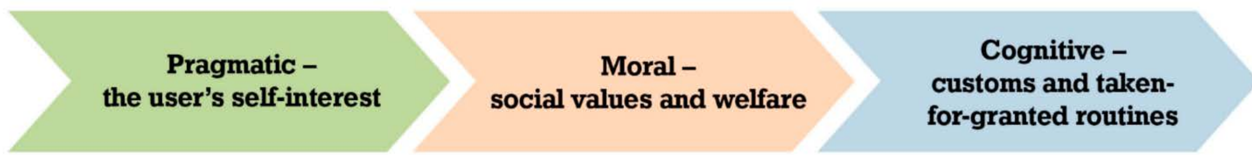
3.1.3 Clean Water Services' Pure Water Brew Challenge

In order to demonstrate that water should be judged by its quality, not its history, Clean Water Services (Portland, OR) began partnering with Oregon brewers in 2014 with the goal of raising awareness and starting conversations about the reusable nature of all water The Pure Water Brew Challenge advances the understanding of how high-purity water can be used for product manufacturing by highlighting one particular product: beer The utility produced a batch of high-purity water that far exceeds safe drinking water standards and provided it to local brewers to make beer. These beers have been featured at WEFTEC® since 2014 and can be found at the

Pure Water Brewing Alliance Beer Garden next to the Innovation Pavilion at WEFTEC. In fact, the Pure Water Brewing Alliance members have brewed beers in Arizona, Wisconsin, Idaho, Kentucky, Tennessee, Singapore, California, Colorado, and the list keeps growing. The Pure Water Brew Challenge is engaging industry professionals, public leaders, and people everywhere in this conversation about water The hope is that conversations inspired by Pure Water Brew will broaden understanding about the potential of reused water as a source of clean water.

3.2 Legitimacy

Three Levels of Legitimacy



Innovative potable reuse projects have often been met with public opposition, despite having proven technology and water quality meeting or exceeding drinking water standards. Technical professionals such as engineers and scientists often mistakenly is assume that the public will accept new technologies when provided with information through marketing and public education activities. A study at Orange County (CA) Water District (OCWD) and Orange County Sanitation District (OCSD) about the success of their indirect potable reuse program showed that the success of their program was due to the legitimacy of their effort. In order to have a successful project, the concerns of the user must be addressed by answering questions at three levels of legitimacy:

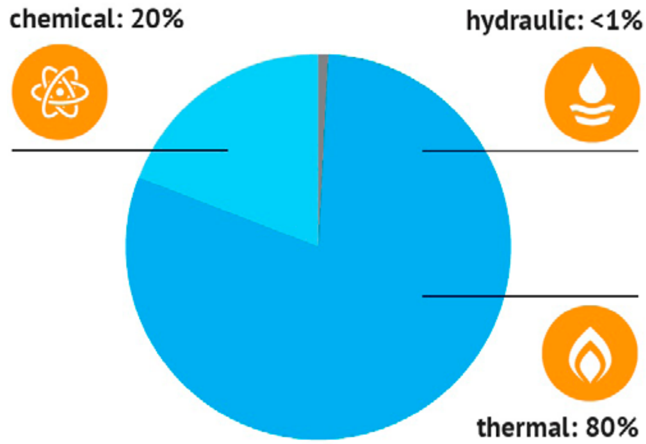
- **Pragmatic** – How do I benefit? How am I involved in decision-making?
- **Moral** – How are safety and quality guaranteed? How has the organization performed in the past?
- **Cognitive** – How essential is the technology, given any alternatives? How does the technology fit with my daily life?

The OCWD/OCSD exampled showed the benefits of having utility managers become recognized as trustworthy and competent experts through their dedication to the outreach efforts and have been well documented in the following papers:

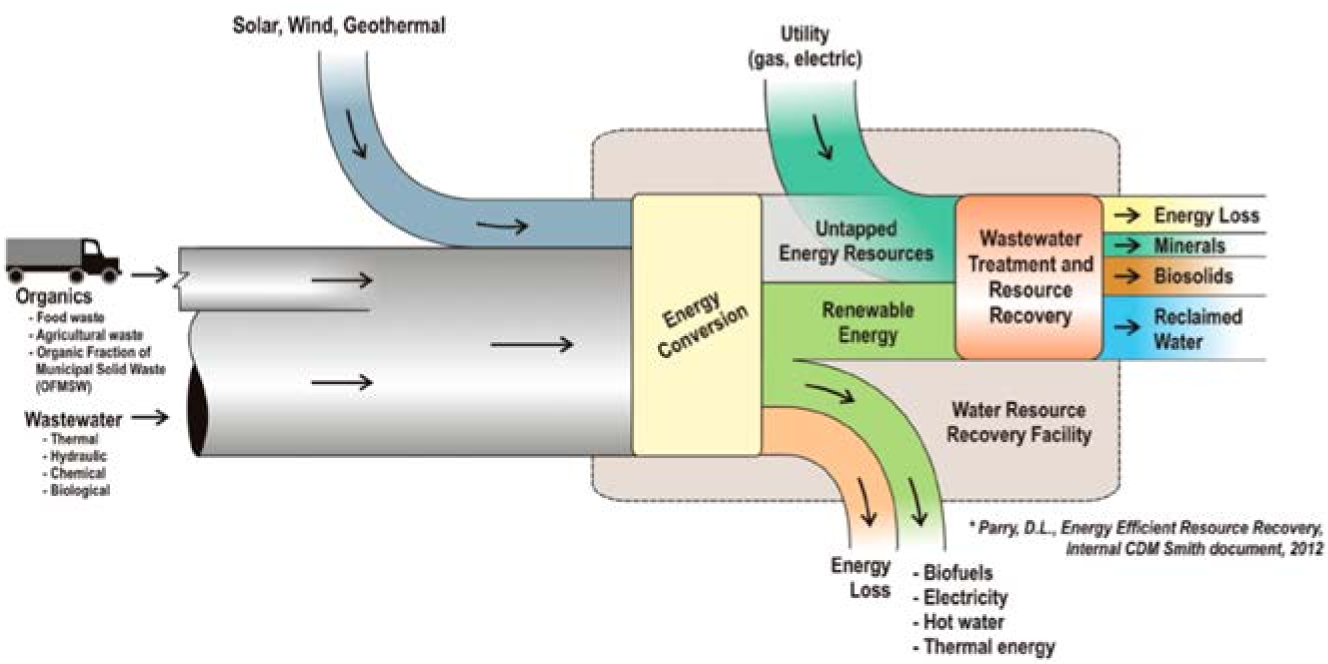
- Binz, C , S Harris-Lovett, M Kiparsky, D L Sedlak, and B Truffer (2016) "The thorny road to technology legitimation— Institutional work for potable water reuse in California " Technological Forecasting and Social Change 103: 249–263
- Jordi, A (2015) "Legitimacy – the key to successful implementation " Eawag Aquatic Research News, October 2015 www.eawagch/fileadmin/Domain1/News/User_Acceptance_englisch pdf
- Harris-Lovett, S R , C Binz, D L Sedlak, M Kiparsky, and B Truffer (2015) "Beyond user acceptance: a legitimacy framework for potable water reuse in California " Environmental Science & Technology 49(13): 7552–7561

4 Energy

Energy is critical in resource recovery from wastewater because, wastewater contains nearly five times the amount of energy needed for the wastewater treatment process—the majority in the untapped area of thermal energy. The wastewater sector has the potential to generate enough energy and eliminate its net-consumption, generating excess energy for other uses at a competitive price.



The balance between energy efficiency and resource recovery involves tradeoffs and can best be achieved through holistic process planning. The more resources that are recovered, the less energy is available for generation or the more energy that is consumed. These tradeoffs must be understood and managed to achieve your utility's particular sustainability goals. A generalized view of energy flows at a WRRF is shown below:



5 The ReNEW Resource Recovery Roadmap

Knowing that resource recovery is a good thing and possible is one thing, but taking actionable steps on the journey can seem overwhelming given the opportunities and complexities. Through extensive research with the expertise within the WEF membership, WEF has developed high level sets of best practices to help utilities begin the journey to resource recovery. These roadmaps started with the Energy Roadmap in 2013, followed by the Nutrients roadmap in 2015 and Water Reuse in 2017. While the 3 roadmaps continue to stand on their own, the ReNEW Resource Recovery Roadmap integrates all three domains into one set of best practices by simplifying the common elements shared by the three domains.

The goal of the ReNEW Roadmap is to present a high-level approach to help guide utilities and industry decision-makers in issues to address when considering resource recovery, be it focused on energy, nutrients, or water reuse. Like the individual roadmaps, the ReNEW roadmap is brief and high level to be accessible to all types of stakeholders, including public officials, utility managers, operators, engineers, and regulators. The roadmap will not "reinvent the wheel," with all of the great technical resources available. Rather, the focus will be to help decision-makers to quickly understand the strategic issues inherent in a resource recovery effort. A total of 19 practice areas are grouped into 7 themes. Each practice area describes a set of general best practices to guide utilities on their paths to supporting the circular economy through resource recovery.

- Culture of Innovation
  - Innovating for the Future
  - Implementing Technologies
- Resource Recovery
  - Water Reuse
  - Nutrients
  - Energy Management
  - Energy Generation
- Monitoring and Controlling
  - Monitoring
  - Modeling and Analysis
  - Source Control
- Marketing and Communication
  - Product Development
  - Message Development
  - Communication and Outreach
- Strategic Management
  - Circular Economy Vision
  - Human Resources
  - Financial Sustainability
- One Water Management Framework
  - Regulatory Environment
  - Integrated Water Resources Management
- Risk and Resiliency
  - Risk Management and Communication
  - Resiliency

5.1 Culture of Innovation

5.1.1 Innovating for the Future

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Research and Development (R&D)	**Prepare for R&D** • Collaboration with research organizations as WRF drives innovation and understanding and adoption • Staff well-versed in existing technologies • Opportunities are identified by survey of emerging technologies • Reduce risk through collaborative research and information sharing • Have WRRF leadership/managers recognize and reward innovative approaches	**Preform R&D** • Utility budget includes R&D funding to demonstrate culture of embracing innovation • Leadership group recognizes and rewards innovative approaches • Utility actively participates in water innovation partnerships (e g, Water Innovation Centers, research foundations, university partnerships, etc)	**Expand R&D** • Site visits to facilities utilizing innovative technologies occur regularly • Completed trials and research projects provide the foundation for further advancement within the industry • Utility serves as a demonstration facility for public education and collaboration with research organizations like WRF • Patents are obtained to protect utility and water sector
Test Beds	**Evaluate Technologies** • Technologies that reduce energy use or increase generation are identified • Test beds are identified to enhance collaboration with universities, R&D of the equipment supplies and agencies and other stakeholders • Validation and data requirements for new/ alternative technologies are identified	**Initiate Trials** • Treatment technologies are demonstrated • Standard validation protocols developed to evaluate technologies for effectiveness and sustainability • Develop mobile treatment testing for field testing • Plans are made to leverage test beds and communicate results with data base of results • Institutional resistance is overcome by demonstration facility, pilot projects, specificity of design and technology options, and goals of the reuse project	**Implement Full-Scale Solution** • Flexible and effective technologies are implemented to meet the needs of the various quality levels of recycled waters

Alternative Management Approaches	**Identify Alternatives**
	• Decentralized treatment options are considered
	  • Package plants and technologies
	  • Scalping plants
	  • On-site reuse
	  • Green infrastructure
	• Planning is performed on a watershed basis and includes consideration of robustness of satellite nodal structure of decentralized infrastructure
		Implement Alternatives
		• Green Infrastructure technologies such as treatment wetlands and riparian buffers are implemented where appropriate as part of multiple barriers approach
		• Enhanced regionalization (e g , biosolids processing) has been considered and implemented where appropriate
			Expand Integration
			• Alternative management approaches (e g , decentralization, regionalization, etc.) are used, where appropriate, to maximize overall, regionwide benefit

5.1.2 Implementing Technologies

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Technology Evaluation	**Identify Treatment Levels**
	• Determine level of treatment available
	• Determine level of treatment required or desired
	• Define operational/process changes required to provide water quality, nutrient recovery or energy recovery
	• Identify available technologies to provide appropriate multi-barrier protection
	  • Where used/experience with technology
	  • Maturity of technology
	  • Alternative analysis
	  • Waste stream (brine, other) implications
	  • Regulatory issues
		Identify Opportunities
		• Ensure adequate treatment vs overtreating to meet regulatory requirements with minimum concentrate generation
		• Consider storage
		  • Emergency
		  • Process upsets
		  • Demand variability
		  • Equalization
		  • Monitoring
		  • Attenuation
		• Identify additional opportunities requiring more time or capital to implement, and develop a plan to finance/implement
		• Assess liquid vs solid recovery (water reuse vs land application/struvite recovery)
		• Ensure biosolids nutrients are considered a resource
			Evaluate and Implement
			• Multi-barrier approach using cost-effective
			• and low carbon footprint technology to provide right quality reuse
			• Unintended consequences are evaluated through scenario planning or other means, such as
			  • No return flows
			  • Collection system issues from scalping
			  • Aggressive water
			• Identify research and development needs to drive innovations
			• Identify water quality trading and greenhouse gas offset credit opportunities

Process Control Framework	**Get the Big Picture**
	• Baseline performance (water quality, energy use, etc) and benchmarks are determined
	• Supervisory control and data acquisition (SCADA) and other control system capabilities and needs are identified
		Understand Key Processes
		• Proactive maintenance is in place through computerized maintenance management system
		• Technologies for remote monitoring system are in place (e g , wide integration including satellite systems)
		• Real-time monitoring and control strategy in place
		• Developed mass balances
		  • Water
		  • Organics (energy)
		  • Nutrients (nitrogen and phosphorus)
		  • Salts
		  • Metals
			Monitor for Real-Time Control and Optimization
			• Real-time control is in place (e g , SCADA) to optimize water quality, chemical use, energy use, and efficiency
			• System learning algorithms (data driven) that incorporate dynamic supply–demand challenges are in place

5.2 Resource Recovery

5.2.1 Water Reuse

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Treatment Management for Water Reuse	**Plan for the Future**
	• Identify unit operations/basins for use in future iterations of designer water production
	• Long-term planning such as leaving space in the facility hydraulic profile to accommodate future processes
	• Develop scenario analysis in master planning
	  • Future regulations
	  • Water supply/demand
	  • Treatment resiliency and failsafe planning
		Mitigate Risks
		• Design for current requirements with an eye toward future requirements
		• Validate technologies
		  • Reliability
		  • Long-term prospects
		  • Path dependency
		  • Public support
		  • Intellectual property issues
		  • Operational efficiency
		  • Scalability
		  • Monitoring requirements
		  • Byproducts and coproducts
			Manage Tradeoffs
			• Understand tradeoffs
			  • Reliability vs advanced technology
			  • Regulatory requirements vs business needs
			  • Resource recovery vs treatment

Fit for Purpose	**Identify Level of Treatment**
	• Determine levels of treatment required to meet needs of customers and environment
	  • Is reuse desirable, given source
	  • water constraints, environmental needs?
	  • Is nutrient removal necessary
	  • or are nutrients desirable for irrigation?
	  • What levels of constituents (metals, total dissolved solids, etc) are needed by end use?
	• What are the seasonal, diurnal, or daily variations in source water and product water demands?
		Identify Opportunities
		• Produce products for market needs, such as:
		  • Irrigation (agriculture, municipal, residential)
		  • Cooling
		  • Fire protection
		  • Boiler makeup
		  • Wash water
		• Dual treatment or flexible treatment options available to produce varying quality of water for intended purposes
		• Consider decentralized infrastructure to optimize recovery (for example, sewer scalping)
			Prioritize and Implement
			• Technical solutions design/tailored to fit- for-purpose water demands
			• Water allocation are prioritized among various users based on water supply needs and business considerations
			• Designer water approach provides operational flexibility to supply "flavors" of water

5.2.2 Nutrients

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Nitrogen Removal Evaluation	**Identify Low-Cost Options**
	• Determine whether the facility currently has capacity (tankage, blowers, etc) for nitrification and denitrification
	• Evaluate the energy cost of various technologies and sustainable nitrogen removal for various effluent concentrations
	• Evaluate opportunities for high-nitrogen sidestreams
		Optimize Facility
		• Reuse existing tankage to get immediate nitrogen removal to ~10-15 mg/L at low cost
		• Consider N2O emissions from nitrification and denitrification when designing the system
			Evaluate Long-Term Improvements
			• Study impact of low dissolved oxygen and ammonia-based aeration control on:
			  • PAO uptake of phosphorus
			  • Competition between PAOs and glycogen-accumulating organisms (GAOs)
			  • Increases in N2O emissions

Phosphorus Removal Evaluation	**Evaluate Short-Term Improvements**
	• Modifying existing facilities to get low-hanging fruit
	  • Phosphorus to ~1 mg/L at no/low cost
	  • Switch off mixers for low-tech phosphorus removal
	  • More carbon for fermentation of mixed liquor
	• Recognize emerging information to minimize cost of chem-P
	  • Good mixing at the point of application
	  • Ferric/Magnesium addition
		Optimize Facility
		• Recognize phosphorus-removal techniques vary for meeting different objectives, such as developing a product vs minimizing negative impacts on receiving waterbodies
			Observe Regulatory Landscape
			• Assess phosphorus limitations on land application of biosolids in areas with phosphorus saturated soils
			• Based on Natural Resources Conservation Service code 590, land application may not be applicable for phosphorus recovery/ reuse, depending on local conditions

Carbon	**Identify Low-Cost Options**
	• Determine if facility can denitrify simply and at low cost (excess capacity, sufficient carbon), and what effluent concentrations/mass could be achieved
		Investigate Potential Problems
		• Explore supplemental carbon issues
		  • Procurement policy and pricing
		  • Demonstration and testing
		  • Waste products
			Evaluate Nutrient Recovery
			• Evaluate how simultaneous nitrification and denitrification can lower carbon requirements
			• Evaluate whole facility nutrient recovery

5.2.3 Energy Management

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Electricity costs and billing	**Get Organized** • Historical electric bills are analyzed (2-plus years of data are preferred).	**Understand The Details** • Rate structure and billing details are understood • Demand charges • Energy charges, unit costs, and time of use • Billing period	**Implement Changes** • Modifications are made to billing and/or operations to reduce costs • New rate structure is selected and • Loads are shifted to reduce on-peak demand charges or unit costs.
Power Management and Control	**Initiate Audit** • Energy team performs energy audit. • Goals are set for reducing energy use and costs. • Energy use by each significant unit process area is determined. • Energy use is benchmarked against similar size/type plants to identify target areas for energy reductions. • Electricity use and process data are analyzed together.	**Implement Recommendations** • Cost-effective recommendations from audit are implemented. • Energy team tracks actual vs planned results. • Load management (shedding/switching) is in place.	**Plan For The Future** • Energy savings are incorporated to the design of all future capital projects and new operating strategies. • Utility Implements ISO 50001 Standard
Alternative Energy treatment technologies	**Evaluate Technologies** • Technologies that reduce energy use or increase generation are identified.	**Initiate Trials** • Advanced low-energy treatment technologies and energy production technologies are demonstrated.	**Implement Full-Scale Solution** • Lower energy-consuming processes replace energy- intensive secondary treatment. • Excess power generation is wheeled to other assets or entity.

5.2.4 Energy Generation

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Strategy	**Set Production Goal** • Measurable energy generation goal is established. • Energy generation plan is coordinated with utility strategic plan. • Energy team understands regulatory and permit limitations (e.g., air emissions) with regard to generation.	**Obtain Support** • Governing body approves capital budget for energy generation projects. • Regulatory issues have been addressed and satisfactorily resolved.	**Grow Program** • Infrastructure for energy generation is proactively maintained, renewed, and upgraded. • Holistic evaluation methodologies (e.g., triple bottom line) are used to evaluate energy generation opportunities.

Energy from water	**Evaluate Integral Energy Sources**
	• Available energy resources are quantified, such as
	  • Biogas,
	  • Hydropower, and
	  • Heat.
		Implement Generation Systems
		• Energy generation facilities are operating and producing power/heat for utility use
		• Electricity/heat and
		• Fuel (natural gas, pellets, etc.).
			Optimize Production
			• Energy production is optimized to maximize the value of generation (e.g., biogas storage to offset power purchases during on-peak hours).

Supplemental energy sources	**Identify Supplemental Energy Sources**
	• Available non-water- derived energy sources are quantified, including
	  • Co-digestion,
	  • Solar, and
	  • Wind.
	• Feedstock market evaluation is performed.
		Implement Generation Systems
		• Energy generation facilities are operating and producing power/heat or fuel.
		• Quantity and quality of feedstock meets capacity.
			Maximize Production
			• On-site electricity generation from all sources approaches or exceeds
			• on-site electricity demand.
			• High-strength organic waste (e.g., food; fats, oils, and grease; etc.) is integrated into feedstock supply to increase generation potential.

Renewable energy certificates (RECs)	**Plan For RECs** • Staff gain understanding of state regulations • for renewable portfolio standard and production and sales of RECs.	**Use RECs** • Utility produces, sells, and/ or purchases RECs, as appropriate.	**Maximize Value Of RECs** • Sales and purchases of RECs are optimized to maximize value of resources, potentially using automation.

5.3 Monitoring and Controlling

5.3.1 Monitoring

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Monitoring Plan	**Collect Information** • Develop plan for parameter monitoring for decision-making (nitrogen species, carbon, greenhouse gas emissions, etc),	**Analyze Data** • Model the treatment process to understand its constraints and opportunities, and ensure redundancy in design • Data analytics management plan developed • Assess current facility performance for varying water quality needs of customers • Assess current facility performance for nutrient removal • Understand current removal of nitrogen species (incidental/intentional) • Assess receiving-water impacts/needs • Water quality degradation because of nutrient discharges • Understand greenhouse gas emissions	**Proactively Use Data** • Use data to improve • Facility operations • Trading programs • Source control • Next design upgrade • Continual improvement of monitoring program
Sampling	**Define Sampling Protocol** • Sampling locations may include: • Upstream • Collection system • Industrial dischargers • At treatment facility • Influent, in-facility, and effluent • End Use • Customer (agriculture, industrial) • Environment (receiving body, aquifer) • WRRF considers frequency of sampling to account for diurnal and seasonal variations	**Process Sample Data** • Process information to understand options. examples include: • Carbon to nitrogen ratio • Carbon to phosphorus ratio • Rate of accumulation and control of salts and metals • Technical resiliency (e g, dynamic response time to spike loading)	**Continually Advance Program** • Sensor and monitoring advances for reporting are tracked • Unregulated water quality parameters are considered
Lab Capacity	• Laboratory capacity at facility and throughout region analyzed for analytical, biological services for cation-exchange capacity, CCL3, and unregulated contaminant monitoring rule	• Bioassay tools for process monitoring are developed • Reliable online/early warning monitoring systems are in place for water quality (both source water and effluent)	• Well-developed laboratory capabilities and/or partnerships for performance and compliance • UCMR • CCL3 • LEC

5.3.2 Modeling and Analysis

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Innovation (MOVE AND SPREAD OUT)	**Reward Innovation**
	• Reduce risk through collaborative research and information sharing
	• Have WRRF leadership/managers recognize and reward innovative approaches
	• Characterize discharge impacts by conducting research on how receiving waters react to different effluent concentrations
		Improve Models
		• Develop better modeling tools
		  • Multiple populations of AOB and NOB
		  • Kinetics for anammox bacteria (AMX)
		  • Bioaugmentation speed
		  • Biofilms and granules
		• Develop better stoichiometry and kinetics for chem-P models
		• Improve simulation models for GAOs and the benefit to bio-P from internal carbon fermentation
		• Model the digester for sidestream returns
			Pilot Test
			• Test model recommendations

Modeling	**Select Model**
	• Ensure that data gathered is useful for modeling efforts
		Modeling for Design
		• Use water quality modeling to identify/quantify receiving water response to nutrients
		  • How do nutrient effluent concentrations change and affect receiving waters?
		  • Decision making support for appropriate technology for various performance levels
		• Model the treatment process to understand its constraints and opportunities
		  • Redundancy in design
		• Determine whether nitrogen removal technology will require major capital investment
		• Understand effects on greenhouse gas emissions
			Modeling for Operations
			• Utilize molecular tools
			• Use modeling in decision-making
			  • Determine carbon tradeoffs with nitrogen removal
			  • Nitrogen removal requires more supplemental carbon if using bio-P
			  • Max denitrifying PAOs
			• Develop digester phosphorus precipitation models focusing on critical chemistry
			• Understand settling characteristics –must not compromise settleability or dewaterability
			• Model to understand diffusion and mass transfer to facilitate control schemes
			• Implement online control
			• Control N2O

5.3.3 Source Control

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Upstream Management	**Understand Upstream**
	• Reduce inflow and infiltration
	• Evaluate water efficiency and conservation
	• Evaluate water efficiency and conservation
	• Separate combined systems
	• Pretreat to minimize nitrification inhibition
	• Identify sewer scalping and stream separation opportunities
	• Integrate resource management – include outside wastes and broaden markets
		Create Balanced Framework
		• Pretreatment policy
		  • Charge for Total Kjeldahl Nitrogen (TKN), total phosphorus, and low alkalinity
		  • Reward for readily biodegradable chemical oxygen demand and high alkalinity
		• Put a water efficiency program in place
		• Decentralize infrastructure to optimize recovery
		• Treatment (sewer scalping)
		• Stream separation
			Balance Source Control with Resource Recovery
			• Seek partnerships for animal waste and other waste streams
			• Implement sewer scalping and urine diversion
			• Recover proteins, and remove nitrogen and phosphorus before treatment (industrial waste)
			• Separate ecological sanitation streams

Source control	**Understand Influent** • Loads (industrial, water use, I&I) are understood and evaluated for energy treatment requirements and energy production potential.	**Manage Loading** • Methods are in place to manage influent loading to reduce energy use (e.g., industrial surcharge optimization, I&I reduction program, etc.). • Methods to reduce flows are investigated.	**Enhance Environment** • Sources are managed to reduce energy use and maximize • Energy production potential (e.g., appropriate incentives for trucking high-strength waste).

5.4 Marketing and Communication

5.4.1 Product Development

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Marketing	**Data Collection**
	• Collect data to understand the market
	  • Identify stakeholders and potential customers in the market for water reuse and other recovered resources
	  • Assess competition for product (alternative sources of supply)
	• Identify anchor customers and distribution system
	• Determine end uses, quality requirements, and variability (seasonal, daily) for customers or end use:
	  • Agriculture
	  • Environment/Habitat
	  • IPR
	  • DPR
	  • Industrial uses (cooling, washing, etc)
	• Evaluate potential for greenhouse gas reduction credits
		Develop Marketing Strategy
		• Create a value-cost proposition
		  • Identify value of various water quality levels for product
		  • Evaluate sales potential with respect to treatment, monitoring, and distribution costs
		• Develop marketing, sales, and branding strategy
		• Communicate benefits and advantages of water reuse, nutrient recovery, and energy recovery.
		• Use market-driven standards (ex U S Department of Agriculture partnership for phosphorus products
			Sell Recovered Resources
			• Brand and sell recycled water, nutrients,energy, and other recovered resources
			• Sell greenhouse gas offset credits
			• View customers as partners in efforts to meet customer needs through sustainable water management
			• Utility uses partnerships to maximize energy sales revenues and/or reduce demand (e.g., selling power or biogas to adjacent facility, working with a feedstock provider for co-digestion).

Quality Control	**Product Development**
	• Develop a quality assurance program and process for products
	• Implement adaptive management techniques
		Product Production
		• Quality assurance processes in place
		  • Water quality (including chemical addition)
		  • Water quantity (to avoid supply disruptions)
			Quality Verification
			• Utility has adopted a quality standard (HACCP, Six Sigma, ISO 9001)
			• Permit and compliance program exists with established water analysis protocol
			• Active partnership with agriculture exists to ensure downstream product quality

5.4.2 Message Development

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Legitimacy	**Identify Resources** • A transparent planning process is developed to establish legitimacy of project owner • Independent advisory group or expert panel considered • Success stories and best practices from relevant organizations are identified	**Collaborative Communication** • Appraisal conducted of public perception of: utility competence legitimacy, public health issues, water supply, risks • Plans in place to address Pragmatic, Moral, and Cognitive Legitimacy	**Ongoing Leadership** • Legitimacy of project and project owner established to meet the region's water needs • Organizational commitment to public health protection is accepted by public • Utility is the trusted source of quality
Stakeholder	**Identify Stakeholder Values** • Identify values of community and utility board of trustees • Shift cultural mindset from "meeting the permit" to recovering resources • Identify environmental, social, and economic incentives for water reuse • Identify visible agency champion	**Public Outreach & Intake** • Develop public understanding of the new purpose of a WRRF • Gather input from all stakeholder categories	**Shared Experience** • Share best practices with other utilities and the sector • Identified stakeholder groups vested in each benefit/service
Message Framing	**Develop Message** • Understand local cultural values • Positive messaging (NOT "do not drink from purple pipe") developed for reuse • Themes to include • Resiliency • Water independence • Drought proofing • Sustainable • Safety • "All water is reused" – de facto reuse • "Water should be judged by its quality, not its history" • "One Water" – reuse is just another part of the portfolio • Value of water • Water as a valuable service which enhances health and wealth of community • Water as critical product for agriculture, industry, commercial uses and the associated economic development	**Enhance Message** • Consistent terminology used • Counter-argument developed to counter false information • Message uses easy-to-understand common terminology for reuse technologies and presents them in exciting and enticing ways	**Continually Evaluate Message** • All utility members know the "elevator speech" of the reuse mission and can clearly articulate the message whether at work or in the community • Partner agencies are consistent in messaging on reuse • "Flavors" of water used to demonstrate fit for purpose • Measures of public opinion are used on a periodic basis to evaluate program and update messaging to ensure public acceptance • Ongoing engagement with opponents with respect • Educational activities are engaging for appropriate audiences (e g , field trips focusing on environment and technology for students, reuse beer tasting for adults)

5.4.3 Communication and Outreach

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Customers and Community	• Community education on fit for purpose water, the urban water cycle, and is continuously updated Education precedes customer outreach and education strategy on specific project needs
	• Community groups are identified for outreach to develop understanding
	• Early education and outreach to the public avoids opposition based on yuck factor for all reuse sources but particular drinking water
	• Agency obligation to initiate discussion with the public
	• Ensure that "Community" leaders are involved in the decision process
	• Speakers Bureau trained for effective communication with the public (educated volunteers)
	• Public volunteers representing different interests are essential to serve as community ambassadors
		• Proactive customer education and outreach program (e g , bill inserts, tours, fact sheets, website) that focuses on public health, economic growth, environmental benefits, and
		• cost-effectiveness is established
		• Community opinion leaders are engaged
		  • Politicians
		  • Reporters
		  • Environmental interests
		  • Clergy
		  • Physicians and other medical professionals
		  • Farmers
		  • Teachers
		  • Service groups
		• Early adopters are identified and encouraged to educate those with questions (doubters)
			• Utility engages customers in helping to achieve sustainable water resources management
			• Utility and public employees are ambassadors to community
			• Transparent process for community-driven decision-making is in place to demonstrate respect for community
			• "Hands on" engagement opportunities exist
			• Demonstration and visitor center
			• Interactive and static displays and exhibits
			• Water tastings
			• Beer tasting
			• Technology tours
			• Utilitize information that already exists through the WateReuse Association and others
			  • "Downstream"
			  • "The Global Connections Map
			  • "The Ways of Water" video
			• Water: Think & Drink animations

Media	• Media outlets are identified and strategies are developed	• Media kit is developed (e g , video, • sound-bites, pictures, and press releases) • Deal proactively with national water crisis in news (Flint, food contamination, floods, droughts, etc)	• Dedicated utility staff work on messaging with media, both news and social • Media champions are nurtured to inform public of factual benefits and issues with respect to reuse, especially potable applications

Water Sector	• Key energy staff network at local/regional industry events and information sharing groups supporting
	  • National goal supporting reuse and conservation
	  • Uniform criteria for IPR/DPR projects
	  • Risk-based reuse guidelines for agriculture, industrial, and commercial projects
		• Successes, failures, and lessons learned are shared at industry events
		• Staff contributes to development of guidelines for design and operation of relatively newer treatment and monitoring technology
			• Staff leads industry initiatives to support sector advancements in water reuse, specifically
			  • National reuse framework
			  • National regulatory standards

Environmental advocacy groups	• Outreach strategy is developed to support resource recovery projects. • Appropriate partnerships are identified.	• Utility shares resource recovery program activities (e.g., tours, fact sheets, etc.).	• Joint programs and outreach that support the goals of both organizations are implemented.

5.5 Strategic Management

5.5.1 Circular Economy Vision

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Vision	**Develop Vision**
	• Leadership Group develops Water Reuse Vision
	  • Long-term 5 years to 50 years
	  • Resilience and drought-proofing
	  • Water independence
	  • Flexibility
	  • Utility financial sustainability
	  • Economic development
	  • Environmental enhancement
	  • Resource recovery
	  • Health and ecological
	• Become climate-ready
	  • Reduce direct and indirect emissions
	  • Improve resilience — address water scarcity and diversify water sources
	  • Improve efficiency of water supply
		Communicate Internally
		• WRRF leadership/managers link the vision to staff performance plans
		• WRRF leadership/managers incorporate sustainability goals and key performance indicators into strategic plan
			Communicate Externally
			• Utility shares vision with external stakeholders and the industry
			• Long-term, yet flexible, plans are in place to embrace external market changes
			  • Future regulations
			  • Political outlooks
			  • Changing demand
			  • Changing public acceptance
			• Robust asset and risk management in place
			• Review performance against goals
			• Reassess long-term goals

Nutrient Vision	**Develop Vision**
	• Evaluate goals and current drivers
	  • Regulatory requirements
	  • Watershed water quality and total maximum daily loads
	  • Effects of nutrient management beyond the watershed (long distance aquatic connections, atmospheric)
	• Establish aspirational goals and sub-goals
	  • Nitrogen and phosphorus recovery
	  • Energy and water recovery
	• Reduce direct and indirect emissions		

5.5.2 Human Resources

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE
Strategic Direction	**Set Goals** • Goals and key performance indicators are established for both water conservation and water reuse to encourage efficient use of integrated water resources • Investigation conducted of organizational capacity (technical, managerial, and financial) • to handle interdependencies of a reuse program	**Gather Support** • Utility incorporates goals and key performance indicators into strategic plan • Adequate organizational capacity exists to ensure effective practices can be developed and adopted to meet demands of reuse programs	**Prioritize & Implement** • Program initiatives are prioritized using tools such as Strategic Business Planning • Utility utilizes triple bottom line approach for sustainability project decision-making • Interdisciplinary collaboration exists to ensure thorough understanding of timescale and resources required for reuse programs

Staff Development and Alignment	**Set Training Plan**
	• Utility fulfills training needs for all relevant positions: management, engineering, and operations
	• Current practices are evaluated for training needs with respect to potential impact of water reuse/ resource recovery activities
	  • Technology complexities
	  • Flexibility to meet multiple objectives
		Train and Support Staff
		• Relevant staff are trained according to current and future knowledge requirements, including
		  • Technology operations
		  • Potable applications constraints
		  • Predictive analytics
		  • Safety
		• Staffing and institutional knowledge issues, including recruitment, enhancement, and succession are planned for
			Empower Staff
			• Standard operating procedures and SCADA system are suitable for new processes and technologies
			• Operations staff are certified in both wastewater and drinking water operations
			• WRRFs mentor and guide other local and regional utilities to advance reuse goals
			• Team connects to other organizations to maintain currency of knowledge

Action teams	**Form Team** • Utility establishes cross- functional resource recovery (or specific focus, such as an energy team). • Leadership group establishes clear charge and authority for team with defined roles for members.	**Take Action And Track** • Team drives implementation of recommendations. • Team systematically reports on progress and future actions.	**Empower Team** • Team provided significant budget authority to implement improvements. • Team interfaces directly with governing body to get direction from and report on resource recovery program status.

5.5.3 Financial Sustainability

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Benefit Identification	**Identify Benefits**
	• Benefits of water available through reuse are identified and associated with specific beneficiaries
	• Benefits are quantified
	• Long-term view is undertaken to represent future generations
		Analyze Benefits
		• Benefits are expressed in monetary terms to demonstrate the inherent value in wastewater
		• Benefits are evaluated on triple bottom line for sustainability
		• Deferred capital and other opportunity costs related benefits are identified and quantified
			Obtain Benefits
			• Benefits are internalized through reduced costs and revenue enhancement
			  • Reward incentives are created for operations staff
			  • Energy efficiency
			  • Water resource management
			  • Inorganic salt management
			• Carbon management resource recovery

Cost Identification	**Identify Costs**
	• Costs of service for reuse are identified
	  • Treatment, distribution, marketing, customer service
	  • Capital, operations and maintenance
	  • Absolute and marginal
		Allocate Costs
		• Costs are allocated to functions and organizations (water, wastewater, customer)
		• Ancillary benefits to water reuse are included in cost analysis with respect to other water sources to ensure consistent calculation and comparison between alternatives
			Ensure Fairness
			• Environmental justice/water as a basic human right is recognized and accommodated in the cost model to ensure affordability

Financial Viability	**Identify Funding Options**
	• Develop financial strategy to support resource recovery projects
	• Sources of potential funding are identified
	  • State Revolving Fund (SRF), federal, and state grants
	• Consider alternate financing methods
	  • Public–private partnerships (P3) and joint ventures
	• Alternative project delivery (design-build-operate, build-own-operate-transfer, etc)
	• Recovery of costs from ratepayers is evaluated to ensure full understanding of legal framework (including regulatory and tax reform laws)
	• Incentives and tax credits for new/innovative or available technologies are investigated
	• Sale of greenhouse gas credits for N2O-emission reduction and renewable energy generation
		Budget for Success
		• Use lifecycle analysis for project decision-making
		• Water reuse is considered on all capital project designs, in operating budget decisions, and standard operating practices
		• Sustainable revenue model is in place to address
		  • Equitable cost allocation
		  • Variability of demand (seasonality, drought, abundance)
		  • Diversification of financial portfolio
			Invest in the Future
			• Effective utilization of available sources of funding (public, private, bonds, SRF, grants)
			• Full value of water is recovered in reuse rates, including variable costs based on “flavor” of water used and incentives for upstream reuse and recycling
			• Local industry and NGOs are engaged to ensure continuous support for funding
			• WRRF’s recovered resource revenues generate sufficient funding to invest in other priorities and reduce upward pressure on rates

5.6 One Water Management Framework

5.6.1 Regulatory Environment

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Regulatory and Legislative	**Identify Regulations**
	• Key regulators are identified and effective working relationships are established prior to project development
	• Legislative strategy is developed to enhance opportunities and minimize hurdles for
	• water reuse
	• Regulatory framework and gaps are identified
	• As part of an ongoing relationship, key regulators are educated on potable and nonpotable
	• reuse issues
		Seek to Unify Regulations
		• Utility advocates for unified regulations that
		  • Are science based
		  • Protect health and environment while maintaining flexibility for types of technologies
		  • Incentivize collaboration across district borders and across disciplines
		  • Are flexible for small systems
		  • Encourage innovation
		  • Are clear and consistent, without conflicts (such as between National Pollution Discharge Elimination System and recycled water permits, or water vs air, groundwater vs watershed)
		• Regional collaboration with other agencies occurs (e g , for funding or policy changes)
			Resolve Differences
			• Utility works with industry associations to influence regulators/legislature to create incentives to encourage reuse, where appropriate
			• Utility influences funding agencies to prioritize water sector projects
			• Regulators and utility work together to resolve cross-media issues
			• Mechanism exists for resolving differences in conflicting regulations, dealing with externalities, and creating the space for innovation

Regulatory Risk Management	**Identify and Prioritize Risks**
	• Evaluate legal/regulatory implications of voluntary action
	• Identify early technology adoption risks
	• State-of-the-art technology vs new technology vs technology specified by regulation
	• Evaluate costs of overtreatment or regulations that are not practicably implementable
		Mitigate Risks
		• Develop strategy for risk mitigation and/or sharing
		  • "Creating the Space for Innovation"
		  • "Safe Harbor"
		• Encourage policies that enable rapid new technology evaluation and adoption
			Leverage Innovation
			• Organization successfully implements innovative projects and is adaptable to emerging opportunities
			• Anticipate future regulations and impacts
			• Organization supports integrated, systems-thinking approach to regulations, such as
			  • Reuse as crop irrigation source and other Food Energy Water Nexus issues
			  • Public–private partnerships

Water Rights	**Evaluate Legal Framework**
	• Evaluate positive and negative implications of policies such as
	  • Conservation mandates
	  • Water rights (agriculture, urban)
		Manage Permits
		• Permitting reuse projects address legal risks of water rights
			Source Ownership
			• Ownership of source (wastewater) and the product (recycled water) is well-defined

5.6.2 Integrated Water Resources Management

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Local Drivers	**Identify Drivers**
	• Key drivers are considered, including
	  • Economic development
	  • Water scarcity
	  • Climate change
	  • Regulatory requirements
	  • Urbanization
	  • Diversification of water sources
	  • Reduced dependency on external sources
		Evaluate Impacts
		• Evaluation of impacts to local needs developed
		• Project boundaries are identified
		• Economic impacts quantified (gross domestic product growth, job creation)
		• Natural resources, impacts are identified (land subsidence, wildlife habitats, water sources)
			Maintain Vigilance
			• Plans are in place to adapt to changes of drivers

Integrated Water Resources Management for "One Water"	**Evaluate Opportunities**
	• Explore and analyze opportunities for collaboration on water resources between water, wastewater, and stormwater utilities, as well
	• as other water stakeholders such as those in industry and agriculture
	• All available sources of water are identified, including reuse, surface water, groundwater, seawater, stormwater
	• Potential partners and neighboring agencies are involved in watershed-based planning
	  • Utilities
	  • Agriculture
	  • Industry
	  • Power plants
	  • All relevant sectors
		Establish Connections
		• Utility planning efforts are integrated with other agencies regarding multiple resources (e g , water, stormwater, etc)
		• Implement contracts with partners to facilitate data exchange and planning
		• Regulatory issues have been addressed and satisfactorily resolved
		• Consider embedded resources in water such as nutrients and energy in water resource planning
		• Consider accumulative constituents (salts, metals) and develop long-term management strategy
		• Partners understand relationships between treatment, discharge, and reuse
		• Framework for future potable reuse developed, even if initial reuse is nonpotable
			Leverage Resources
			• Holistic evaluation methodologies (e g , triple bottom line) are used to regional (watershed) water supply plan
			• Mature protects participate in dialogue to promote water valuation that is consistent with regional/watershed sustainability
			  • Return to river
			  • Local issues (desalination plant next to flood farming)
			• Optimized supply demand model exists of future growth and resiliency plans
			• Opportunities exist for water trade between community and regional users
			• Water resources managed in an integrated manner (integrated water resources utility with water/wastewater or multi-agency approach with embedded leadership at all levels of organization

Collaborative Partnerships for "One Water"	**Evaluate Opportunities** Identify markets/opportunities for reuse water, as well as applicable water quality and treatment requirements Source water and treatment objectives are identified according to market and water quality needs	**Establish Connections** Connect with customers and potential customers to ensure they understand opportunities for diverse, sustainable sources of water	**Leverage Resources** Utility uses partnerships to maximize water reuse sales revenues and/or reduce demand for water and energy, and optimize the need for advanced and costly levels of treatment Systems thinking integration of systems – water, energy, food – is in place

5.7 Risk and Resiliency

5.7.1 Risk Management and Communication

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Public Health	**Identify Public Health Issues**
	• Engage public health tracking networks including Center for Disease Control and Prevention's National Environmental Public Health Tracking Network
	• Project plans consider public health and environmental risk for both new and established riparian projects
		Mitigate Public Health Risks
		• Systems approach is used for reliability analysis mitigating risks of
		  • Contaminating potable water source IPR
		  • Recontamination of groundwater
			Enhance Public Health Network
			• Multiple barriers are in place to reduce health and environmental risks
			  • Robust/redundant treatment
			  • Cross-connection control
			• Real-time pathogen monitoring and risk management throughout treatment and distribution

Risk Management	**Identify and Prioritize Risks** • Risk of high consequence of a single dramatic failure is understood • Strategy for risk mitigation is developed • Planning includes consideration of • Measures for climate change adaptation (e g , extreme events) • Overtreatment vs public safety • Water shortage • Not recovering reclaimed water in GWR/augmentation projects • Treatment technology • Cyber technology • Unintended consequences • Health, environmental, social	**Mitigate Risks** • Risk is reduced through water source diversification • Risk allocation ensures each party takes the risk that they can manage/control • Cyber-security capabilities and contingency plans are in place	**Leverage Innovation** • Have contingencies to deal with uncertainties • Technology risk level set so that no single failure of an active component shall result in health risk • Organization can successfully trial and implement innovative projects and is adaptable to emerging opportunities and changing environments

Risk Communication	**Define Risk Message**
	• Agency, community, regulatory risk tolerances identified
	• Risk concepts include
	  • Opportunities instead of challenges
	  • Uncertainty instead of risk
	  • Cost vs risk
	  • Risk of status quo
	  • Risk vs benefits, without overselling
	  • Testing and monitoring framework and controls in place
	  • Needs vs risk
	  • Meeting regulations vs cost of over-treating
	  • Zero risk does not exist, and safety is what the public wants
		Refine Risk Communications
		• Risk information on CECs, toxicology, and other probabilistic statements are crafted in plain English
		• Communication efforts learn from other sectors (HACCP, etc)
			Validate Approach
			• Independent expert panel in place to evaluate and provide oversight for risk management

Infrastructure Risk Management	**Plan for the Future** • Identify unit operations/basins for use in future iterations of nutrient reduction • Leave space in the facility hydraulic profile to accommodate future processes	**Mitigate Risks** • Evaluate future reduction targets • Design for current requirements with an eye toward future requirements	**Evaluate Options** • Assess resource recovery versus treatment/reduction

5.7.2 Resiliency

	PLAN	PREPARE & IMPLEMENT	EVALUATE & IMPROVE

Resiliency	**Evaluate Water Resources**
	• Available water resources are quantified to evaluate resiliency of current supply and the current systems ability to meet future demands based on growth and supply shortage
	• Importance of diverse water supply portfolio is understood, including
	  • Reuse
	  • Surface water
	  • Groundwater
	  • Seawater
	  • Stormwater
	  • Conservation
		Implement Water Supply Plan
		• Methods developed to define value for long-term sustainability through diversification
		  • Water portfolio and resiliency and sustainability
		  • Climate change, urbanization, etc
			Optimize Supply
			• No stranded assets as full utilization of reuse as a new water supply
			• Diverse water resource portfolio is resilient and adaptable to changes in demand, water quality

Continuity of Operations	**Prepare Plans**
	• Integrated continuity of operations plan is developed
	  • Natural disasters (hurricane, earthquake, flooding, fires, etc)
	  • System integration risk
	  • Water quality dynamics impacting customer agreements
	  • Public safety
	• Worker safety (gas, chemical spills, etc)
		Test, Implement, Improve
		• Plan is tested and reviewed for currency on annual basis
			Continuous Monitoring
			• Proactive controls and monitoring analytics manage process risk

Toward carbon neutrality	**Plan Carbon Footprint Analysis** • Approach to carbon footprint analysis/GHG inventory is established.	**Inventory GHG* Emissions** • Carbon footprint/GHG inventory is developed.	**Recover Resources** • Additional resources are recovered or realized (e.g., carbon credits) as utility moves toward carbon neutrality. • Comprehensive carbon footprint/GHG inventory is maintained, including fugitive emissions and embodied energy of significant inputs (e.g., chemicals).

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