Better Plants
U.S. DEPARTMENT OF ENERGY

Primer on Energy Efficiency for Water and Wastewater Treatment

Quarterly Webinar # 3

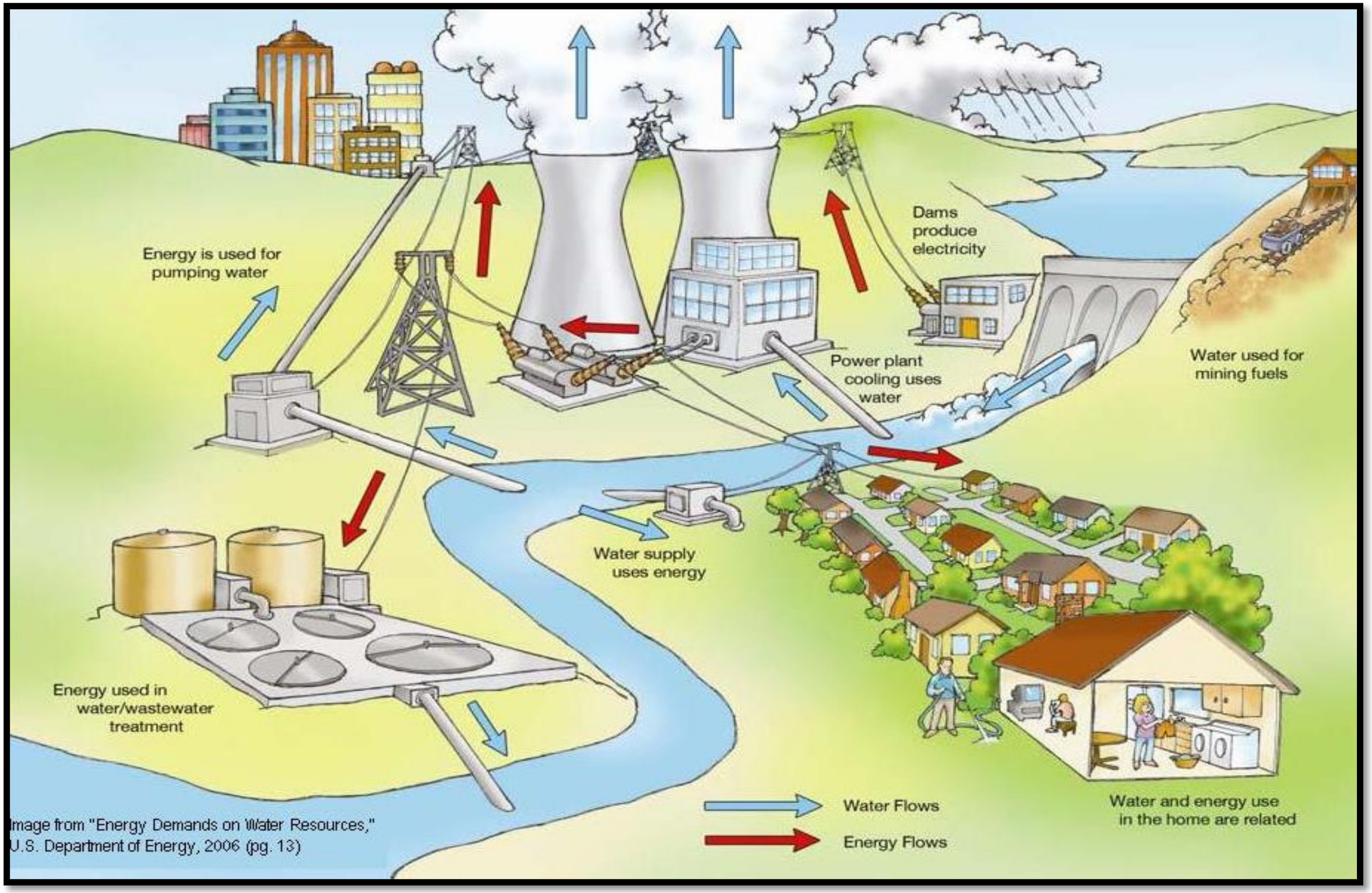
March 24, 2016

U.S. DEPARTMENT OF ENERGY

Agenda

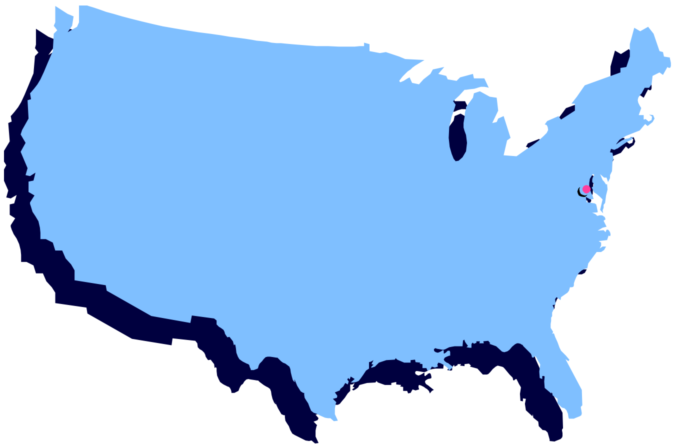
- Welcome/Introductions
- Water-Energy Nexus/Current State of Industry
- Energy Intensity
  - Potable Water Sector
  - Wastewater Treatment
- Performance Opportunities
- Case studies
- Conclusion

Water-Energy Nexus



Water/Wastewater Treatment - Energy Significance!

- Small fraction of National Electrical Use:



~4%

- Large fraction of Municipal Electrical Use:

Up to 50%

Why Water & Energy Efficiency

1. **Resource uncertainty**
   - Increasing variability of energy costs
   - Drought conditions in different parts of the U.S.

2. **Water / wastewater industry developments**
   - Vintageness & condition of water/wastewater infrastructure
   - Population & economic growth adds to demand
   - More stringent water quality regulations

3. **Sustainability**
   - Viability of infrastructure
   - Keep operating costs under control
   - Be ready for more stringent regulations

4. **Benefits**
   - Prevent/forestall rate hikes
   - Improve public image
   - Use energy cost savings internally

Barriers to Energy Efficiency

Water/Wastewater Sector

- Culture of focusing on primary mission (water quality, service)
- Skepticism of energy savings, permit jeopardy, lack of EE knowledge
- Funding for EE assessment/training services

Technologies

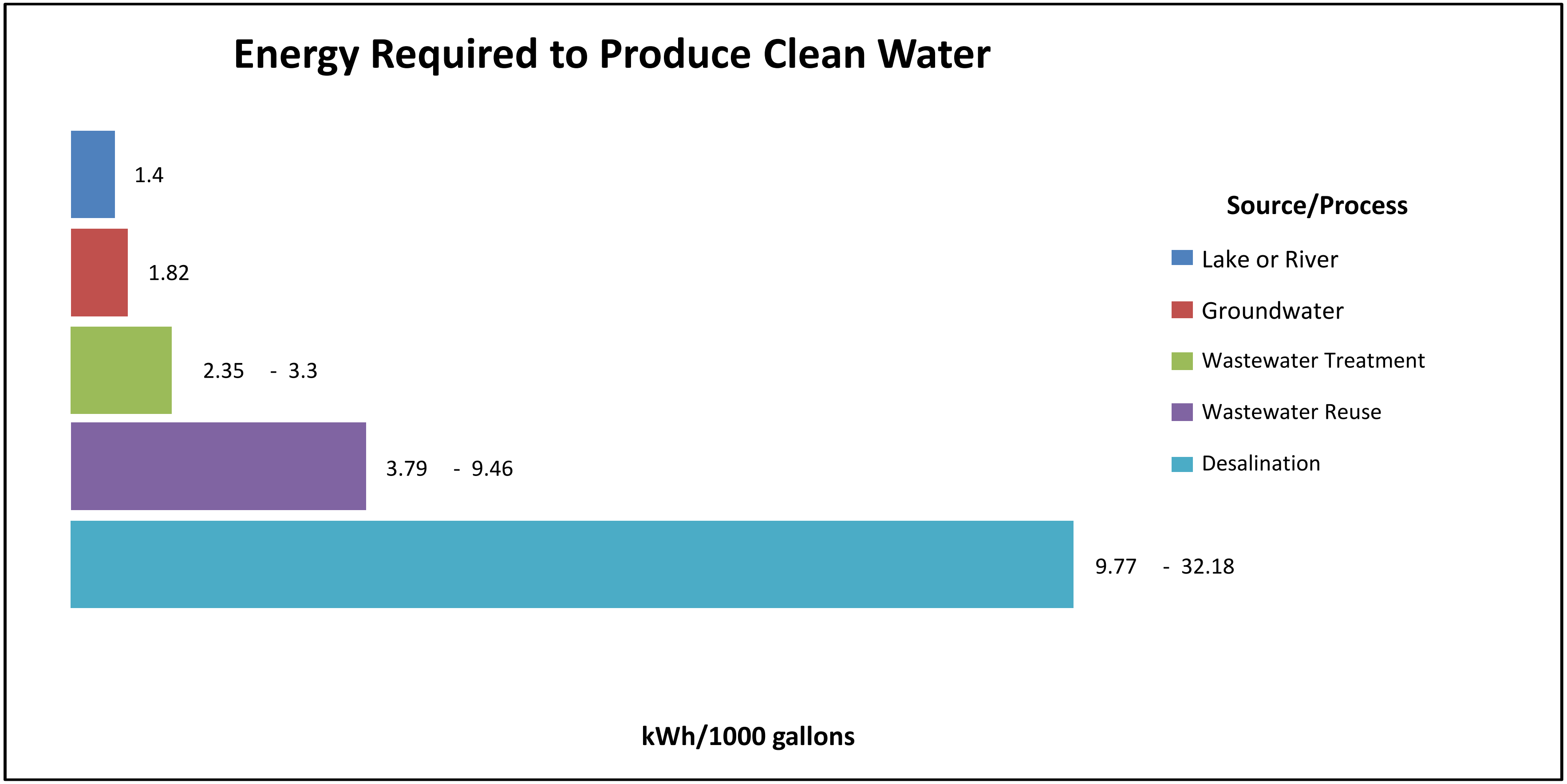
- Existing technologies have uneven adoption rates
- New/advanced technologies not always accepted by regulators
- Difficulty assessing energy consumption/performance

Financing

- Many energy utility incentives do not apply to water/wastewater agencies
- Water/wastewater agencies not always aware of funding sources

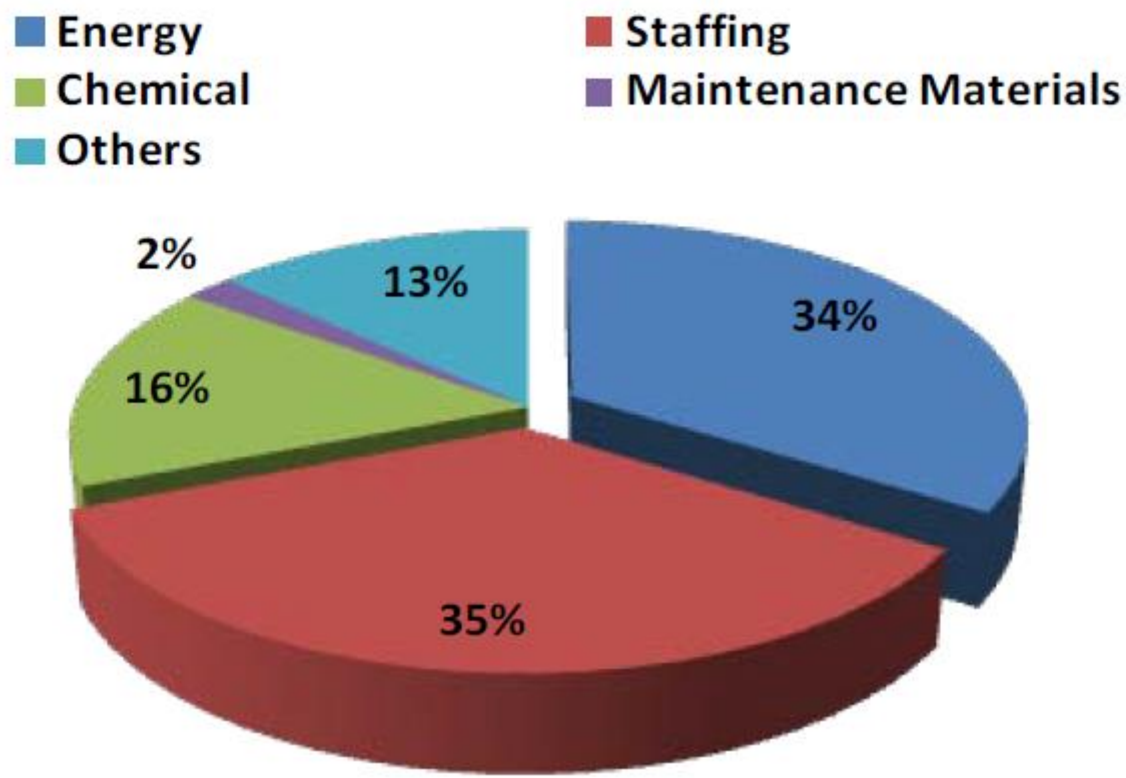
Energy Intensity

- Energy among top 3 costs of water/wastewater treatment agencies (around 35% of municipal energy use)



[1] Electric Power Research Institute (EPRI). *Water & Sustainability (Volume 4): U.S. Electricity Consumption for the Water Supply & Treatment–The Next Half Century*. Topical Report1006787. Palo Alto, CA: EPRI, March 2002.

Typical Potable Water Treatment Plant Costs

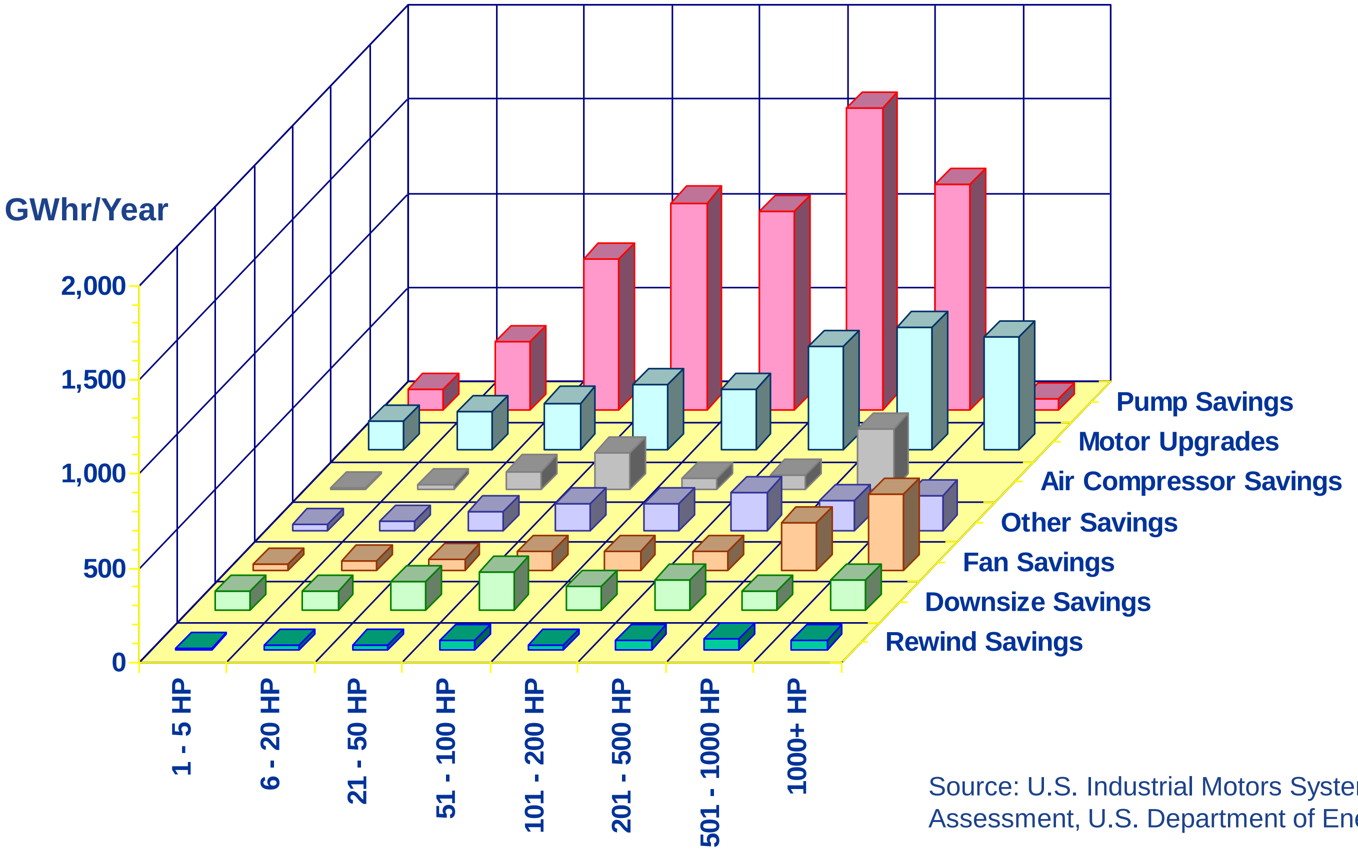


Example: Leaks in Water Delivery System

- Whenever water is lost to leaks, the energy and cost of energy embodied in that water is also lost
- Many distribution systems around the world are leaky
  - Industrialized countries: Where infrastructure is old
  - In the U.S. 35 water utilities had 15% leakage rate in 2003
  - In developing countries leakage rates can be as much as 50%
- Often water conservation focuses on end-users (homes, businesses)
- Water and energy efficiency in the water supply infrastructure can yield important water and energy savings

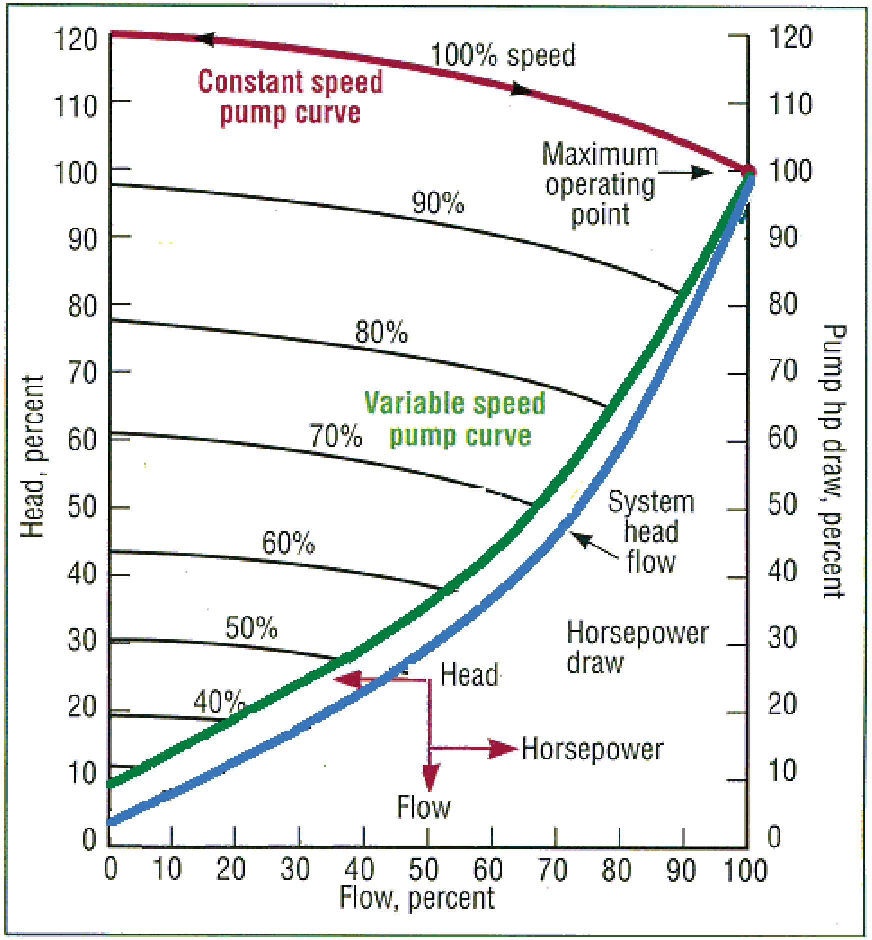
Energy Intensive Systems in Water/Wastewater treatment – Pumping

Pumping systems are a major opportunity for energy efficiency improvements in water/wastewater industry



Source: U.S. Industrial Motors Systems, Market Opportunities Assessment, U.S. Department of Energy

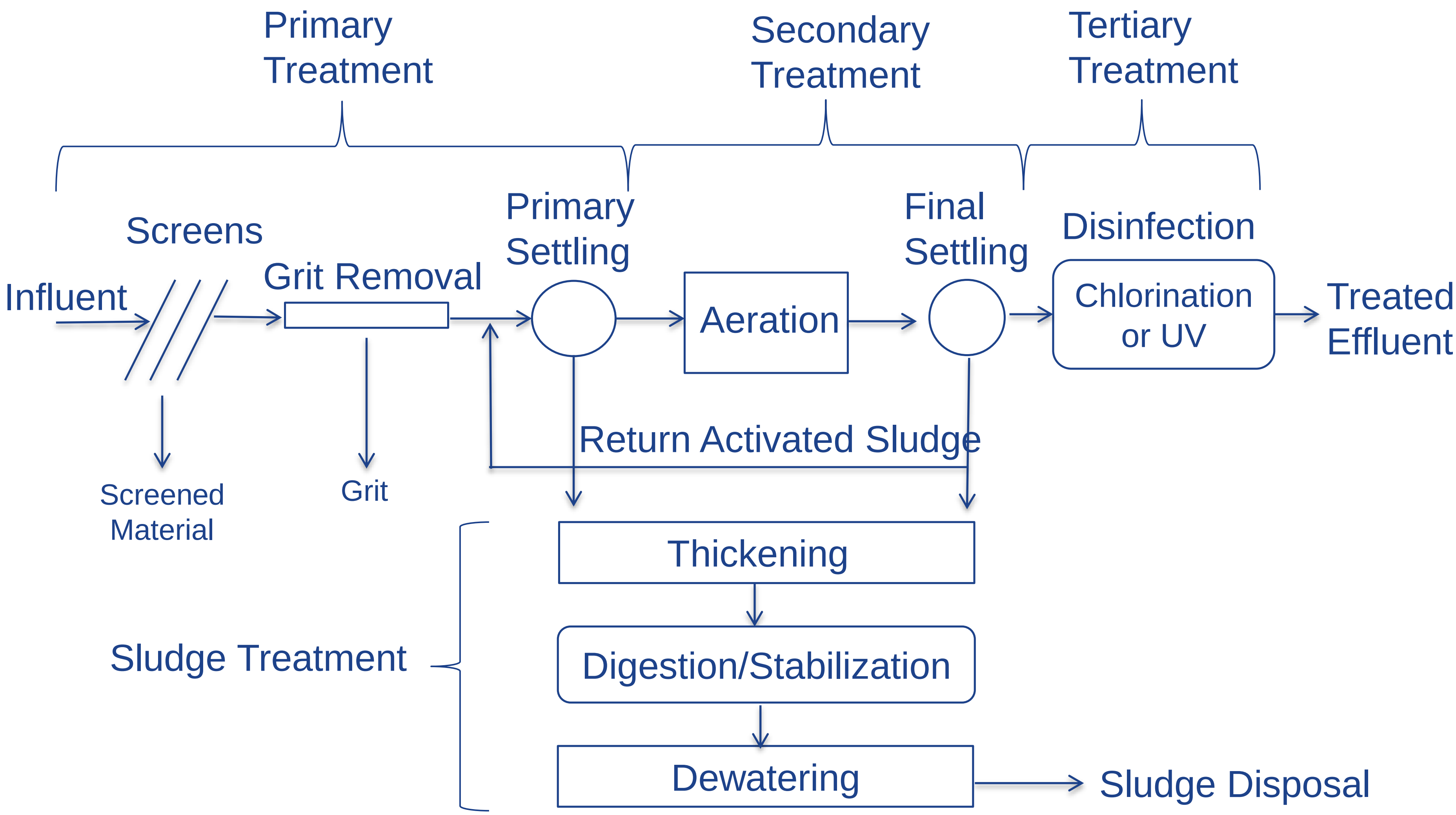
Power varies with the cube of the speed - Affinity Laws for Pumps and Fans



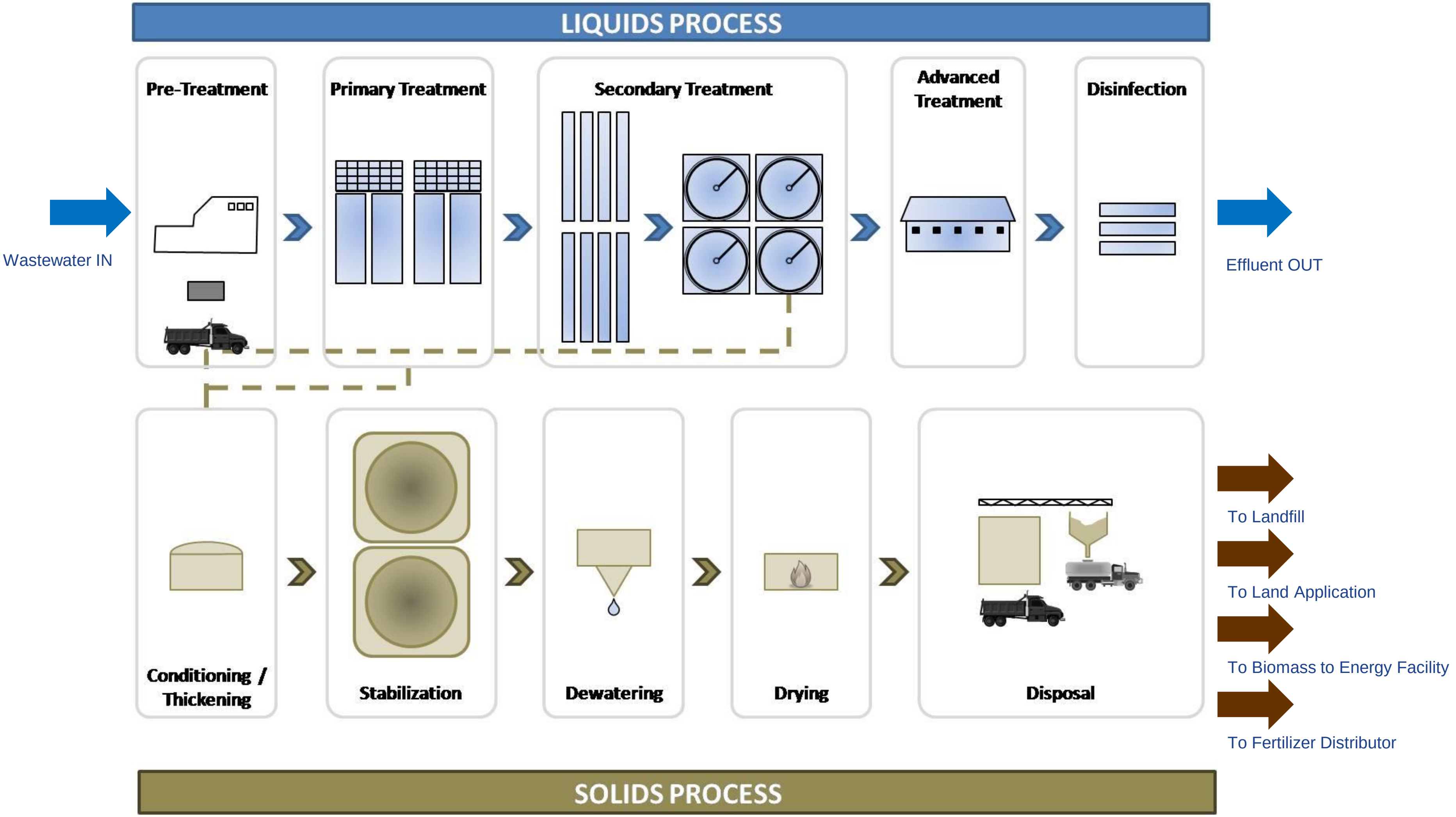
- Flow ∝ RPM
- Head ∝ RPM^2
- Power ∝ RPM^3

RPM	FLOW	HEAD	POWER
100%	100%	100%	100%
90%	90%	81%	73%
80%	80%	64%	51%
70%	70%	49%	34%
60%	60%	36%	22%
50%	50%	25%	13%
40%	40%	16%	6%

Municipal WWT Process Overview

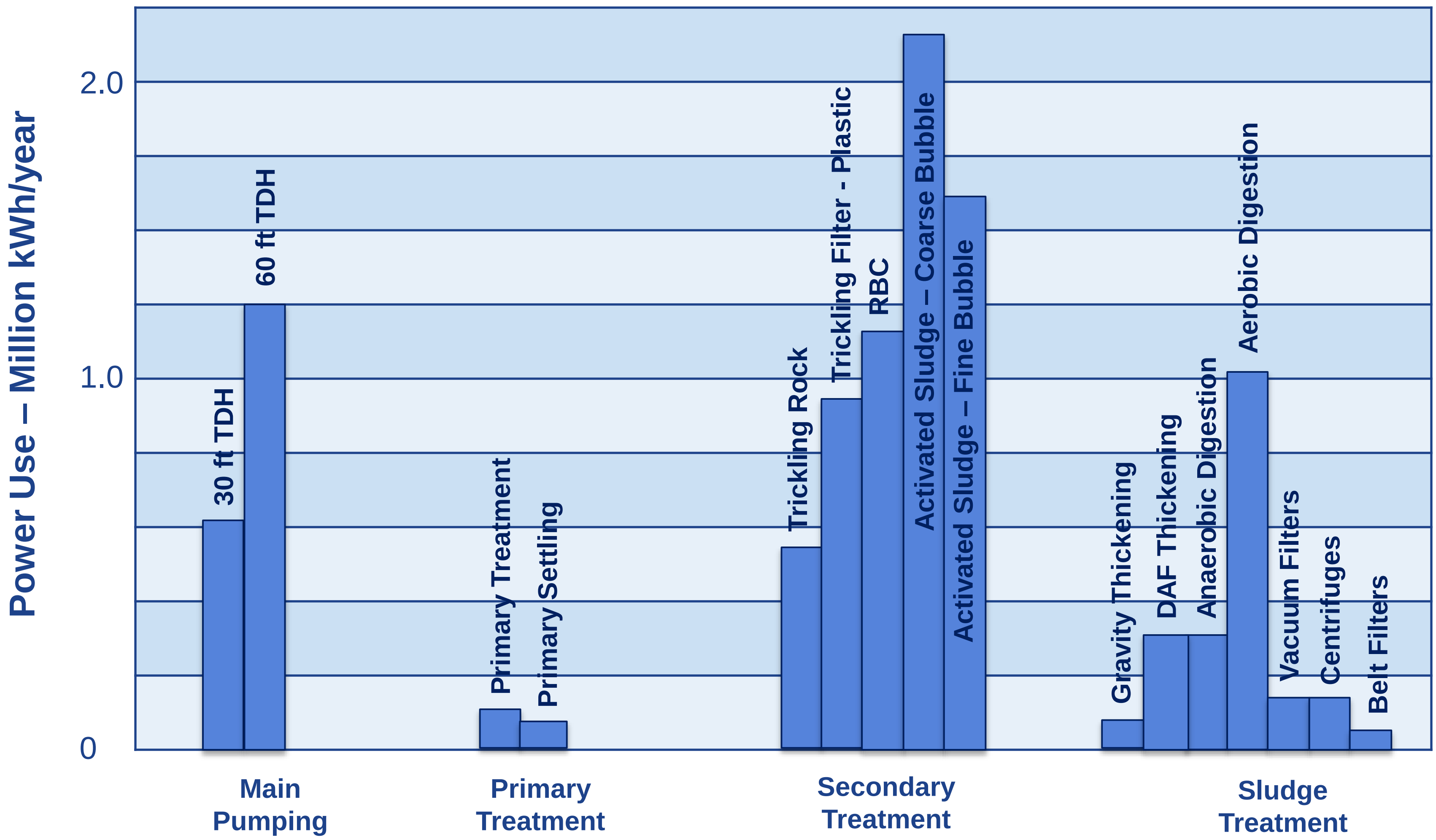


Municipal WWT Process Overview



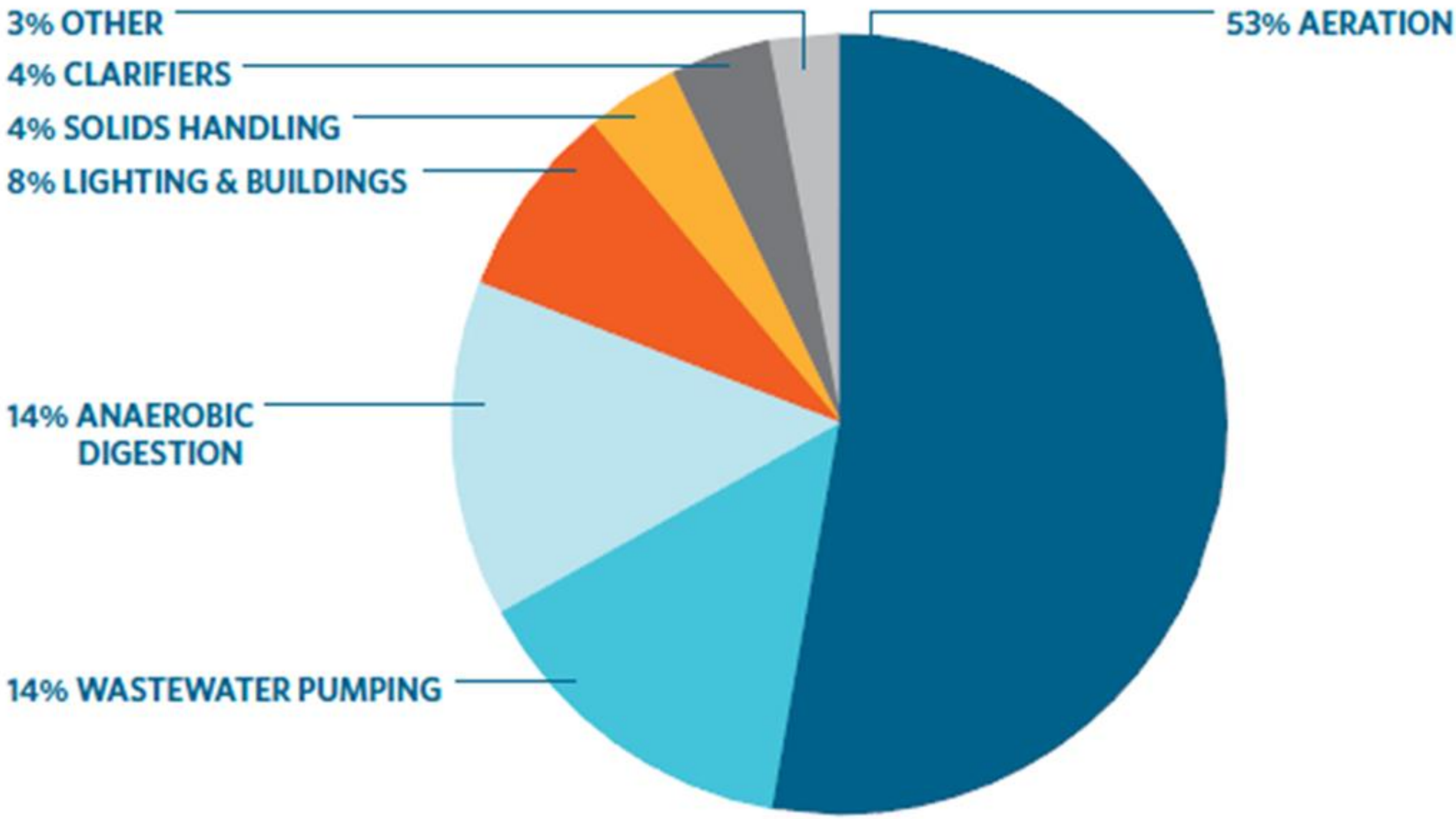
Typical Energy Use Profile

(for 10-mgd secondary treatment processes)



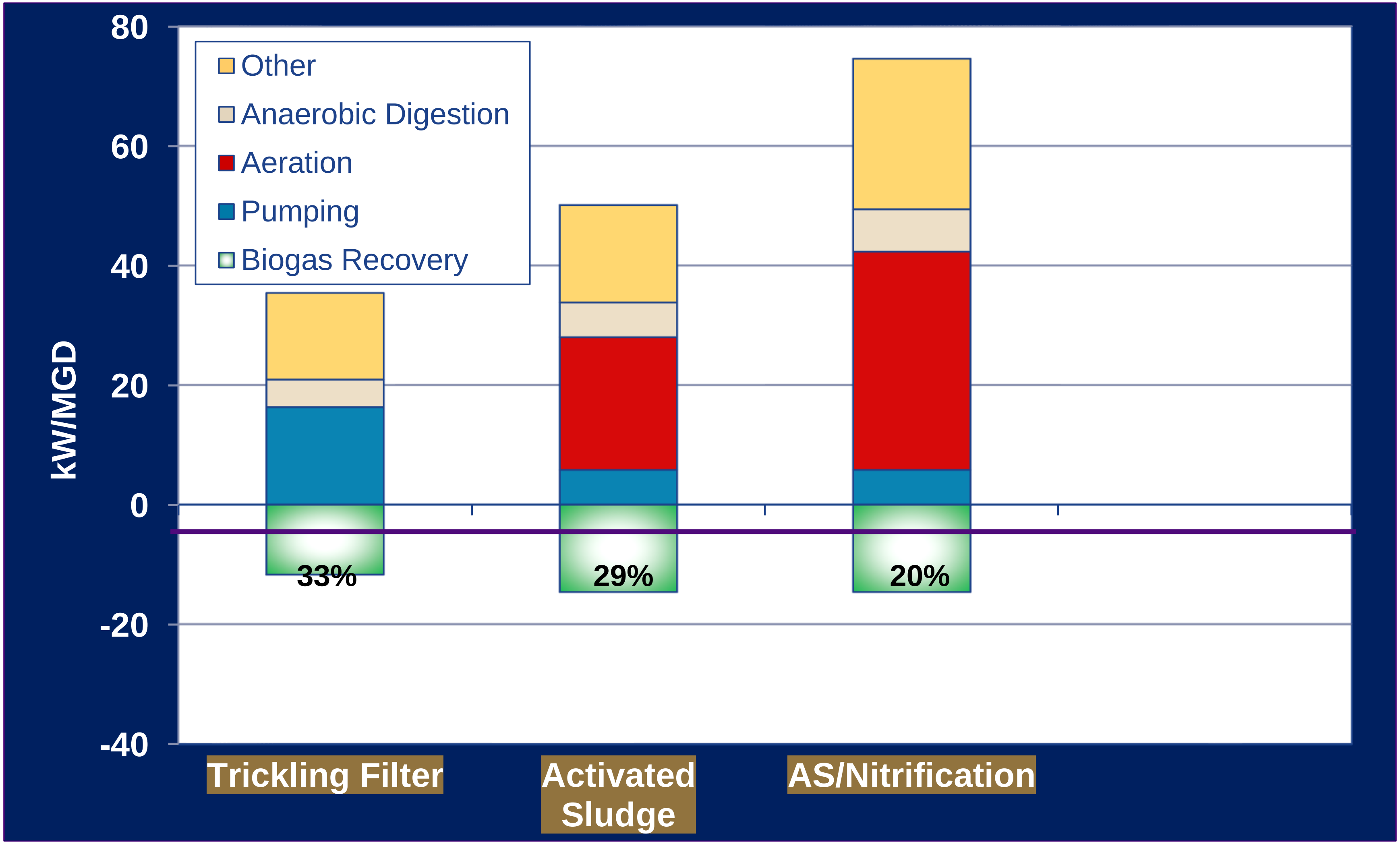
Source: Energy Conservation in Water and Wastewater Facilities - Manual of Practice. McGraw-Hill Professional, 2009.

Typical WWTP Energy Use Distribution



Source: Wastewater Treatment Energy Savings Guide: Energy Trust of Oregon

Historical Wastewater Process Electrical Demand



Source: WEF MOP MFD-2 (1997)

Energy Intensive Systems - Aeration

Aeration introduces air into waste water, providing an aerobic environment for microbial degradation of organic matter.

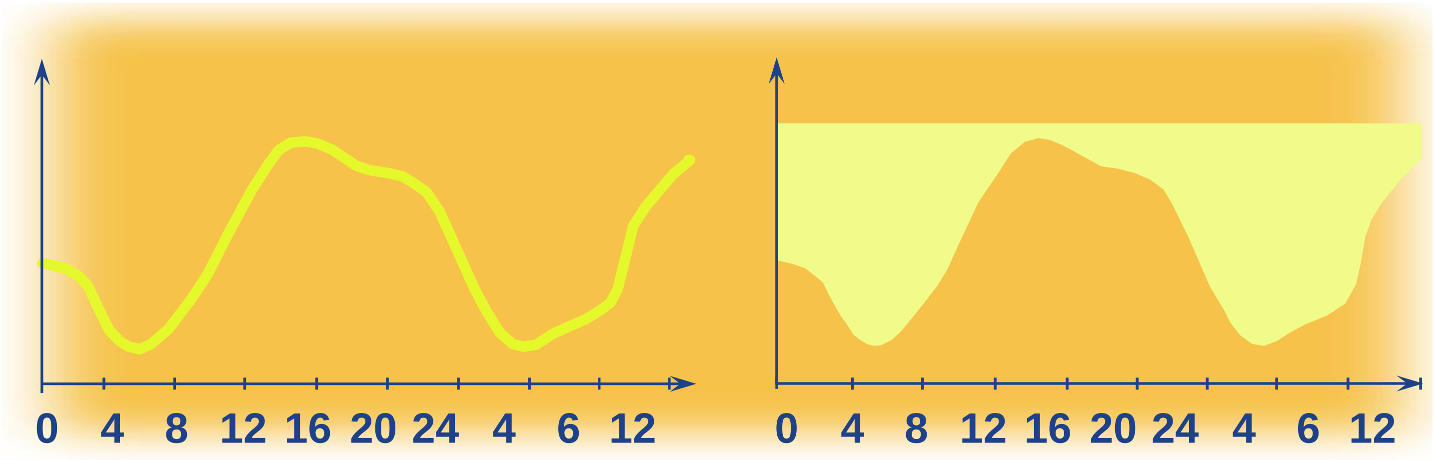
- Supply the required oxygen to the metabolizing microorganisms
- Provide mixing so that the microorganisms come into intimate contact with the dissolved and suspended organic matter.

Surface/Mechanical Aeration

Sub Surface Aeration

Aeration Control: Fluctuations in Biological Load

- A typical WWTP can experience load fluctuations by as much as a factor of 5 over a 24-hour period
- Manual or poor control of aeration can cause excess energy consumption by as much as 50-65%



Energy Intensive Systems - Sludge Treatment / Solids Handling

Alternative to Landfill

Anaerobic Digester
- Breaks down biodegradable material in the absence of oxygen.
- Anaerobic digestion provides biogas and fertilizer.

Incinerator
- Burns Waste material at high temperature.
- Reduces Volume and Landfill Cost
- Heat can be recovered to generate electricity and provide space heating.
- Air emissions concerns
- Requires supplemental fuel

Composting
- Compost provides large quantities of organic matter and nutrients (such as nitrogen and potassium) to the soil.
- Bulking agents must be added.
- Turning, monitoring, or process control is necessary

Best Alternative Depends on
- Time perspective
- Local conditions
- Alternative electricity and heat generation
- Waste transports

Energy Efficiency Opportunities – Fans/Blowers

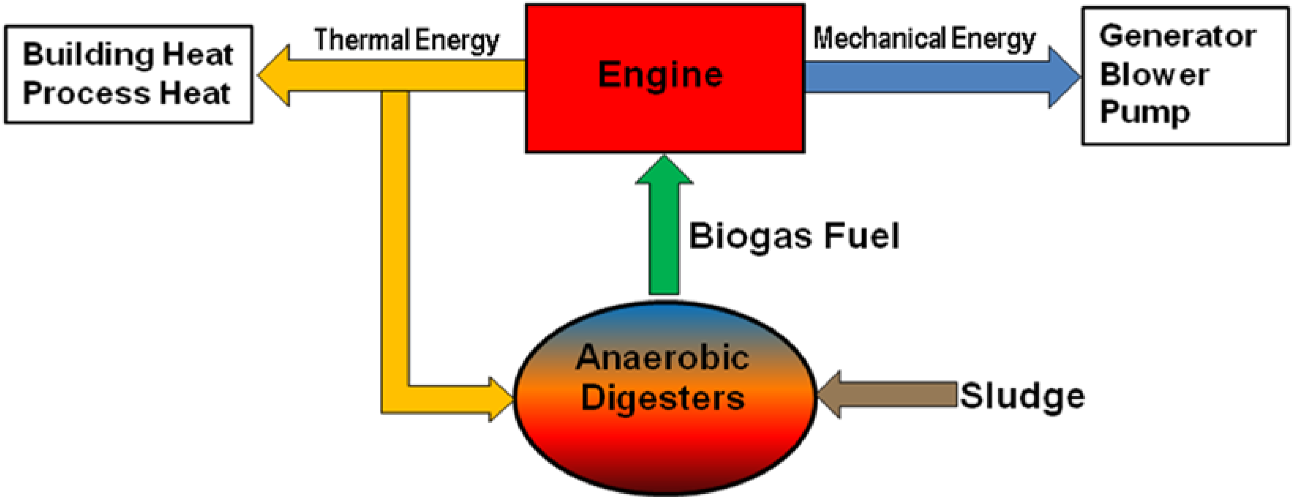
- Proper application of variable speed drives
- Retrofit diffusers with fine bubble type diffusers
- System control strategy - SCADA System, feedback loops & ERP systems
- Automated DO control system and DO sensor technology, optical sensor technology
- Ammonia Derived DO Control
- Improve oxygen transfer efficiency
- Premium efficiency equipment (motors, single stage vs. turbo blowers)
- Apply synchronous Drive Belts

Energy Efficiency - Sludge Treatment / Solids Handling

- Use the Biogas/Methane formed in the anaerobic digestion of sludge
  - As a source of process, space, and water heating through on-site boilers.
  - Treat the gas and use this gas in an internal-combustion engine, in gas turbines.
  - As feedstock for fuel cells.
- Maximize methane production (e.g. the use of fats, oils and greases [FOG])
- Potential for variable speed drive technology
- System monitoring and control
- Reuse of other solid waste
- Conversion from vacuum filters to more efficient technologies
- Solar sludge drying

CHP Opportunity With Anaerobic Digesters

- Over 3,100 WWTPs in the U.S. (with influent flow rates > 1 mgd)
- 1,351 WWTPs use Anaerobic Digestion
- 104 WWTPs with CHP, representing 190 megawatts (MW) of capacity
- CHP technically feasible at 1 MGD, economically feasible at 5 MGD
- Potential Electric Generation: nearly 400 MW
- Approximately 38,000 MMBtu/day of thermal energy

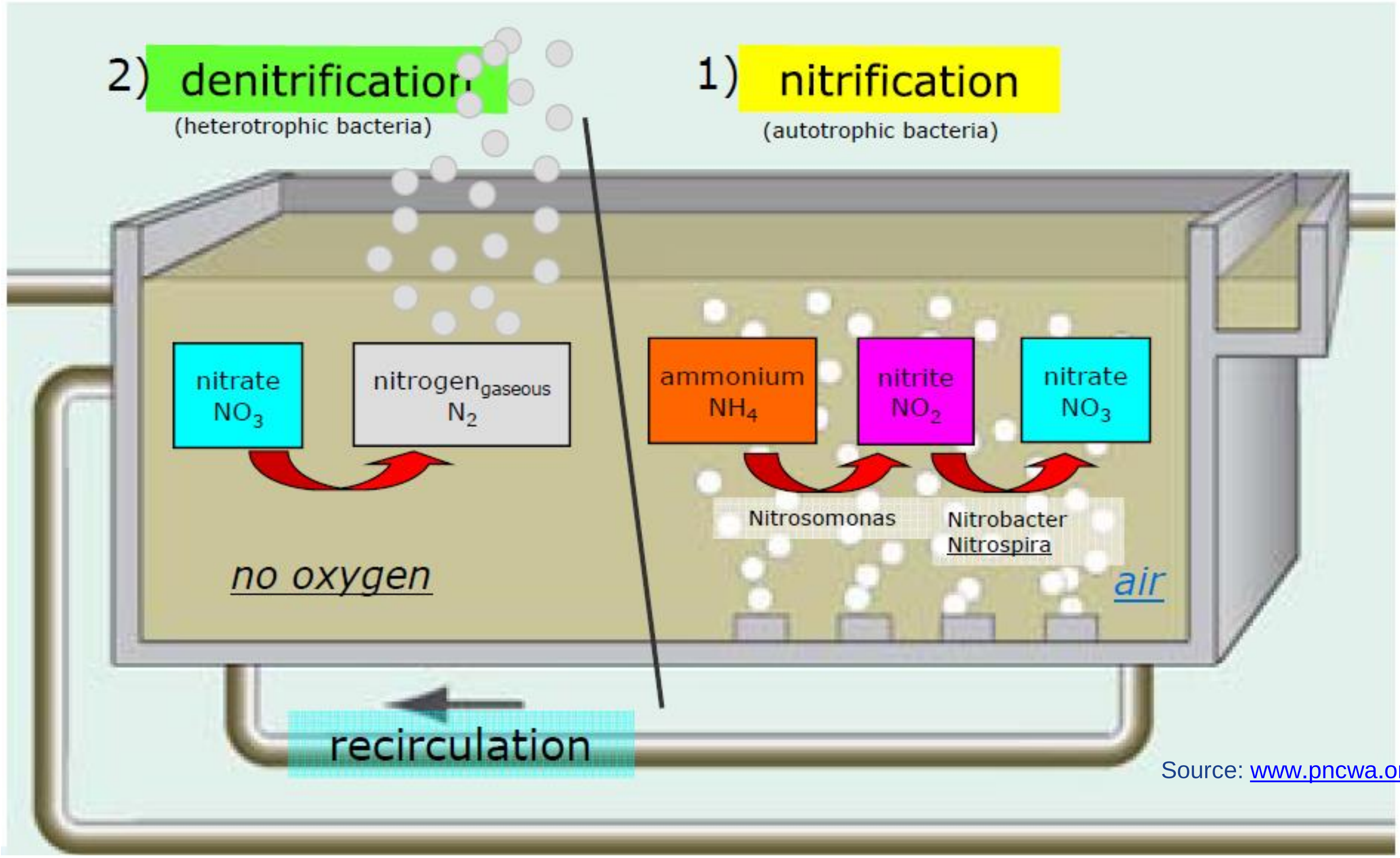


Source: http://www3.epa.gov/chp/documents/wwtf_opportunities.pdf

Energy Efficiency Opportunities – Pumping

- Proper application of variable speed control and multi-stage pumping strategies
- Optimize pump operation – match pump type and size (hp) to task
- Intelligent pump control & strategy - SCADA System, feedback loops & ERP systems
- Premium efficiency equipment (after system issues are resolved)
- Clog Free Pumping technologies/Blockage removal Practices
- Reduce system head (proper design of pipe system) and strategic placement of storage to take maximum advantage of gravity flow

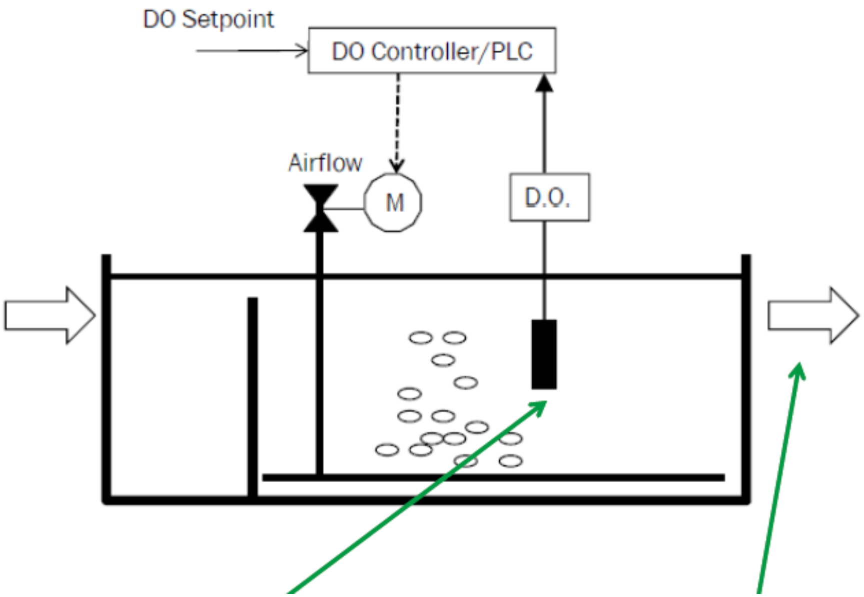
Energy intensive systems – Biological Nitrogen Removal



Source: www.pncwa.org

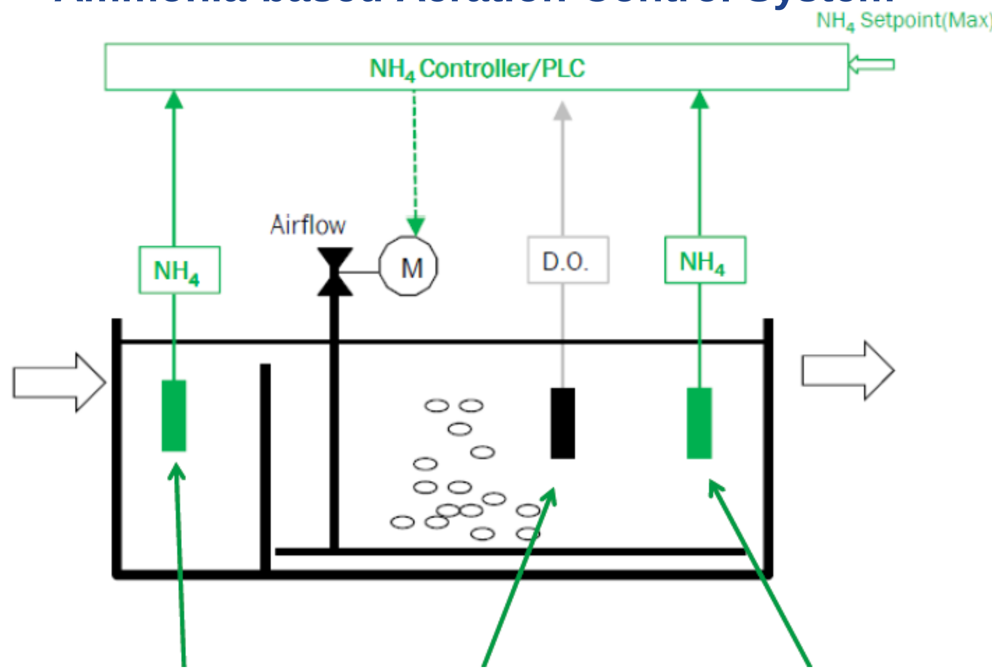
Ammonia-based Aeration Control System

Typical Aeration Basin Control Strategy



DO set point chosen to minimize historical NH4 breakthrough

Ammonia-based Aeration Control System



Upstream NH3. Min & Max limiting DO. Downstream NH4

Source: www.pncwa.org

Energy Intensive Systems – Disinfection

- Most common method of disinfection - Chlorination/ Dechlorination
- Concerns over the handling of chlorine gas and formation of disinfection byproducts
- Ultraviolet (UV) radiation is becoming more common
- UV disinfection requires considerably greater quantities of primary energy than chlorination

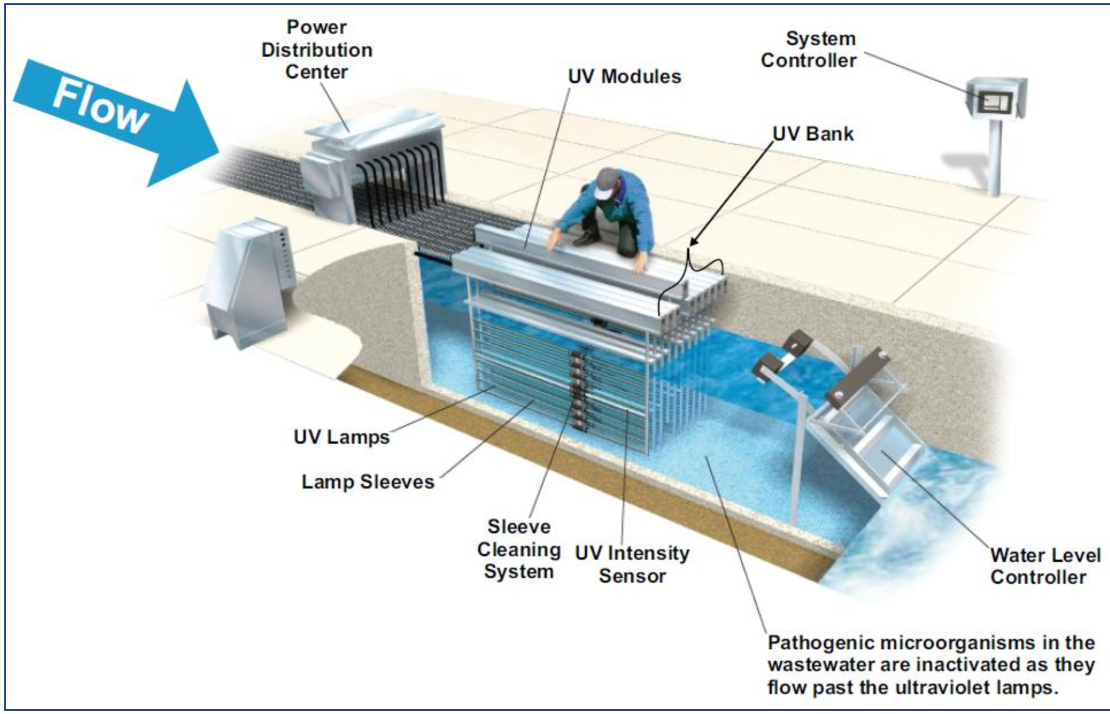
Estimated power consumption for disinfection (200 fecal coliform units/mL) alternatives for 18-mgd WWTP in the NYSERDA study (URS Corporation, 2004)

Disinfection Process	Chlorination/ Dechlorination	UV – Low Pressure	UV – Low Pressure High-Output*	UV – Medium Pressure
Power Consumption (kWh/d)	144	1,440	1,080	4,560

Energy Intensive Systems – Disinfection

Ways to save energy

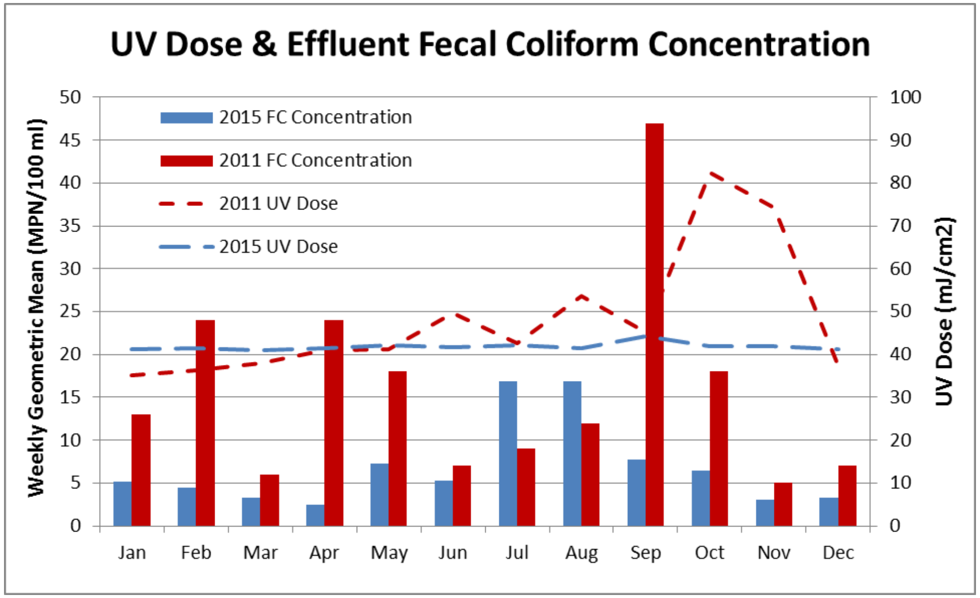
- Modulate UV system output to the level required for disinfection (dose-pacing control) and system turndown (number of operating lamps and lamp output)
- Properly sizing disinfection stage pumps and UV lamps
- Use electronic ballasts instead of electromagnetic ballasts. Electronic ballasts are ~10% more energy efficient than electromagnetic ballasts.
- LED UV emerging



Source: City of Riverside

Case Study NBC Bucklin Point Wastewater Treatment

- UV disinfection retrofit study & improvements
- Average Flow– 20 million gallons/day

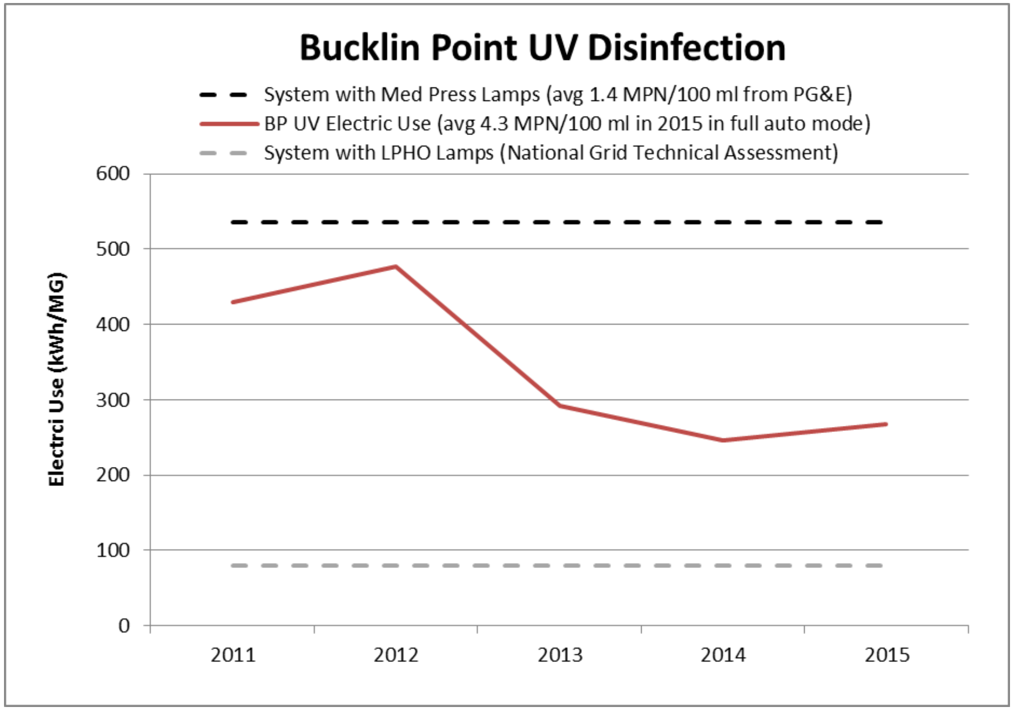


- Existing Condition
  - 10 yr old disinfection system
  - 20 yr useful life
  - Med press lamps
  - Paced w/ %T, Flow & TSS
  - Uses 40 mJ/cm2 dose (200 MPN/100 ml monthly limit)
  - Elevated Fecal Coliform (FC) at low summer flow

- Problem
  - Algae & floc solids shield FC from UV radiation
  - High dose with 2 banks didn't fix problem

Case Study – Bucklin Point (Continued)

- Solution
  - Clean UV Channel monthly if needed to remove solids
  - Ensure All 100 Lamps in Bank are replaced at same time
  - Upgraded Final Clarifiers as part of BNR Upgrade
  - NBC Now Operates System in full automatic mode
  - LPHO Retrofit is Breakeven Option for Future
- Impacts:
  - Compliance to Effluent FC Limits Maintained
  - Normalized Electric Use Reduced 48% in 3 years
  - Potential Future Savings with LPHO UV Lamps



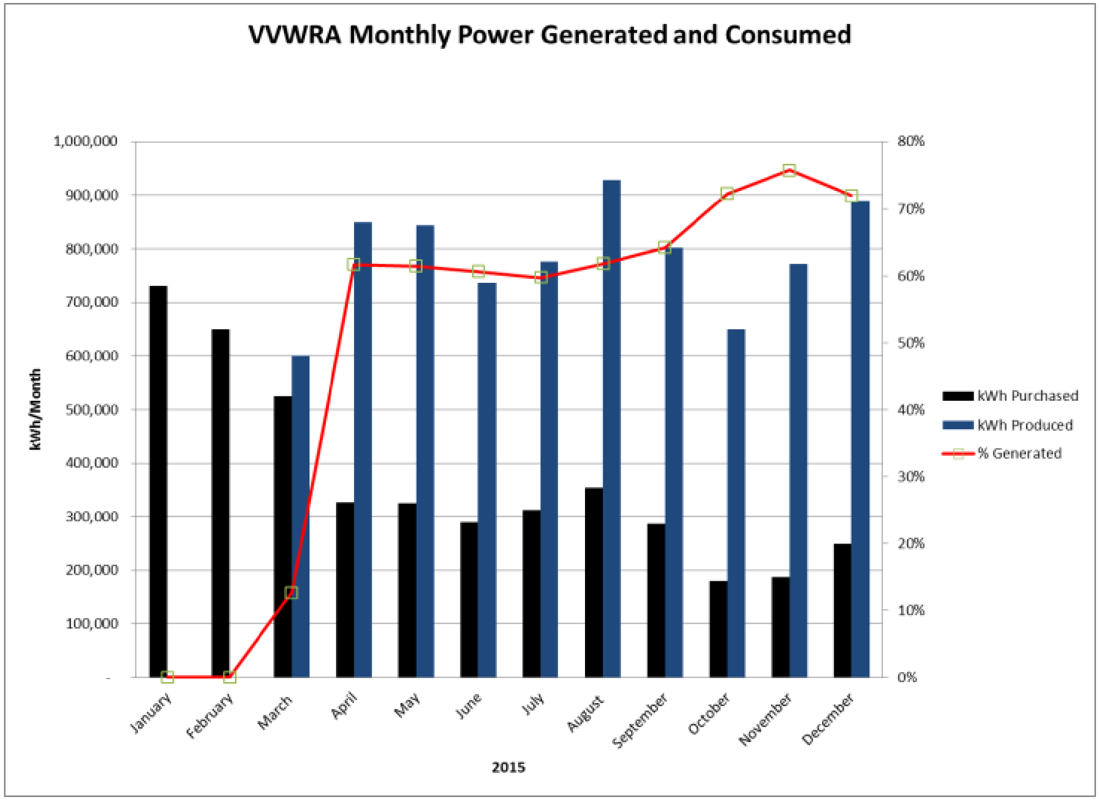
Case Study – Victor Valley Wastewater Reclamation Authority Pathway to Energy Neutrality

- Average Flow– 12.2 MGD
- Existing Condition
  - Activated sludge MLE (Modified Ludzack-Ettinger) process
  - Chlorination/Dechlorination
  - Anaerobic digester
- Problem
  - Increasing electrical cost and demand due to regulatory nitrogen limitations and trihalomethanes
  - Need for nutrient removal and UV disinfection system
  - Not enough biogas
- Solution
  - Optimize conventional activated sludge process for Biological Nutrient Removal (BNR)
  - Replaced gas chlorination disinfection system with Ultraviolet Disinfection (UV)
  - Update and re-design the hauled waste and digestion facility to accept high strength waste, to come from local industries
  - Installed CHP System (2 – 800kW IC engines)

[2] WERF: Barriers to Biogas Use for Renewable Energy.

Case Study - Victor Valley (Continued)

- Impacts
  - Significantly reduced nutrient discharge by implementing low cost alternatives
  - Optimized UV system operations reduced UV system electrical demand by 50%
  - Increased biogas production 300%
  - Increase revenue $252,000 from tipping fees
  - Able to operate two 800kW IC engines
  - Heat reclaimed used for digester
  - In many cases, energy efficiency increased, operational costs were reduced and process stability improved



Discussion

- **Content**
  - Was anything new?
  - How useful was the content?
  - Are any partners considering the emerging technologies?

- **Next Steps**
  - Survey results – top 4 topics
    1) Emerging Technologies for wastewater treatment plants and trends in regulatory requirements
    2) Beneficial use of biogas
    3) Existing and emerging technologies for potable water treatment plants
    4) CHP and interconnection issues
  - Schedule of webinars for 2016
    - June
    - September
    - December

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Glossary of Common Terms

- Activated Sludge - Sludge that has undergone flocculation forming a bacterial culture typically carried out in tanks.
- Advanced Primary Treatment - The use of special additives to raw wastewater to cause flocculation or clumping to help settling before the primary treatment.
- Aerobic Wastewater Treatment - Oxygen dependent wastewater treatment requiring the presence of oxygen for aerobic bacterial breakdown of waste.
- Biosolids - Rich organic material leftover from aerobic wastewater treatment, essentially dewatered sludge that can be re-used.
- BOD - Biological Oxygen Demand - Since oxygen is required in the breakdown or decomposition process of wastewater, its "demand" or BOD, is a measure of the concentration of organics in the wastewater
- Clarifier - A piece of wastewater treatment equipment used to "clarify" the wastewater, usually some sort of holding tank that allows settling.
- Combined Sewer Flows - Municipal sewer systems that combine sewer flows with storm drainage.
- Digestion - The breaking down of sludge and other waste biologically by microorganisms.
- DO - Dissolved Oxygen - The amount of oxygen dissolved in the water..
- Effluent - The final output flow of a wastewater treatment plant.
- Influent The untreated wastewater or raw sewage coming into a wastewater treatment plant
- MGD - Million Gallons per Day - 694.4 gallons per minute.
- TDS - Total Dissolved Solids Total Dissolved Solids (TDS) is the combined total of all dissolved solids in wastewater