Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Water Systems
Virtual INPLT Training & Assessment

Session 3

Tuesday – March 17th, 2021

10 am – 12:30 pm

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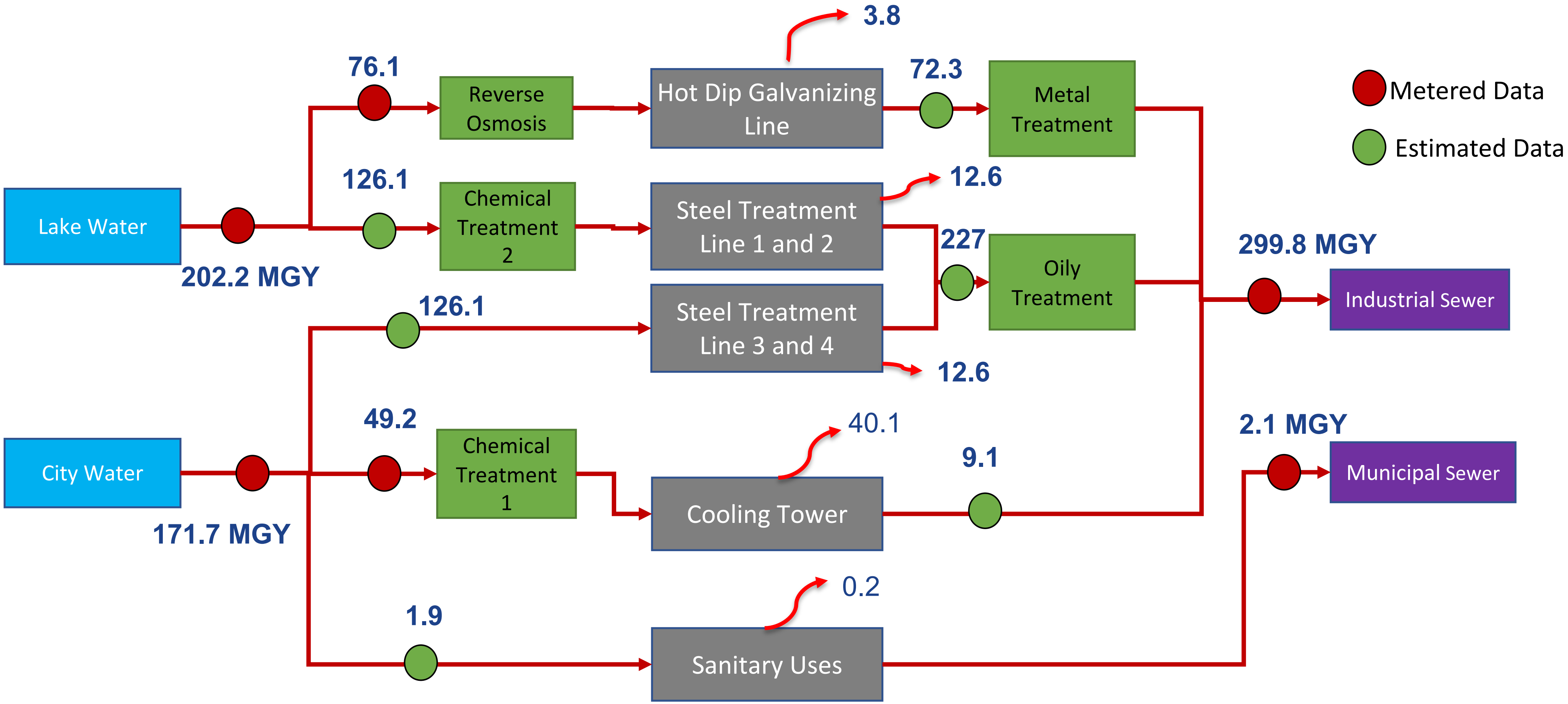
Water Virtual INPLT Agenda

- Week 1 (March 3rd) – Introduction to Industrial Water Assessment and Plant Water Profiler
- Week 2 (March 10th) – Understanding System Level Water use
- Week 3 (March 17th) – True Cost of Water
- Week 4 (March 24th) – Plant Water Profiler Working Session
- Week 5 (March 31st) – Identifying Water Savings Opportunity
- Week 6 (April 7th) – Virtual Treasure Hunt
- Week 7 (April 14th) – Estimating Water Savings Opportunities
- Week 8 (April 21st) – Industrial Water System VINPLT Wrap-up Presentations

Review – Day 1 and 2

- Water Risks
- Industrial Water Assessment
  - Step 1 - Water Baselining
  - Step 2 - True Cost of Water
  - Step 3 - Identifying water savings opportunities
- Water Baselining
  - Plant Water Flow diagram
  - Data Collection (system level and facility level)

Example Facility – Water Baseline



Agenda – Session THREE

- Today's Content:
  - True Cost of Water
  - What is true cost of water, why
  - Typical True Cost Components
  - Data to collect
  - True cost exercise
- Roundtable - review of assignment
- Kahoot Quiz Game
- Q&A

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Day 3 – True Cost of Water

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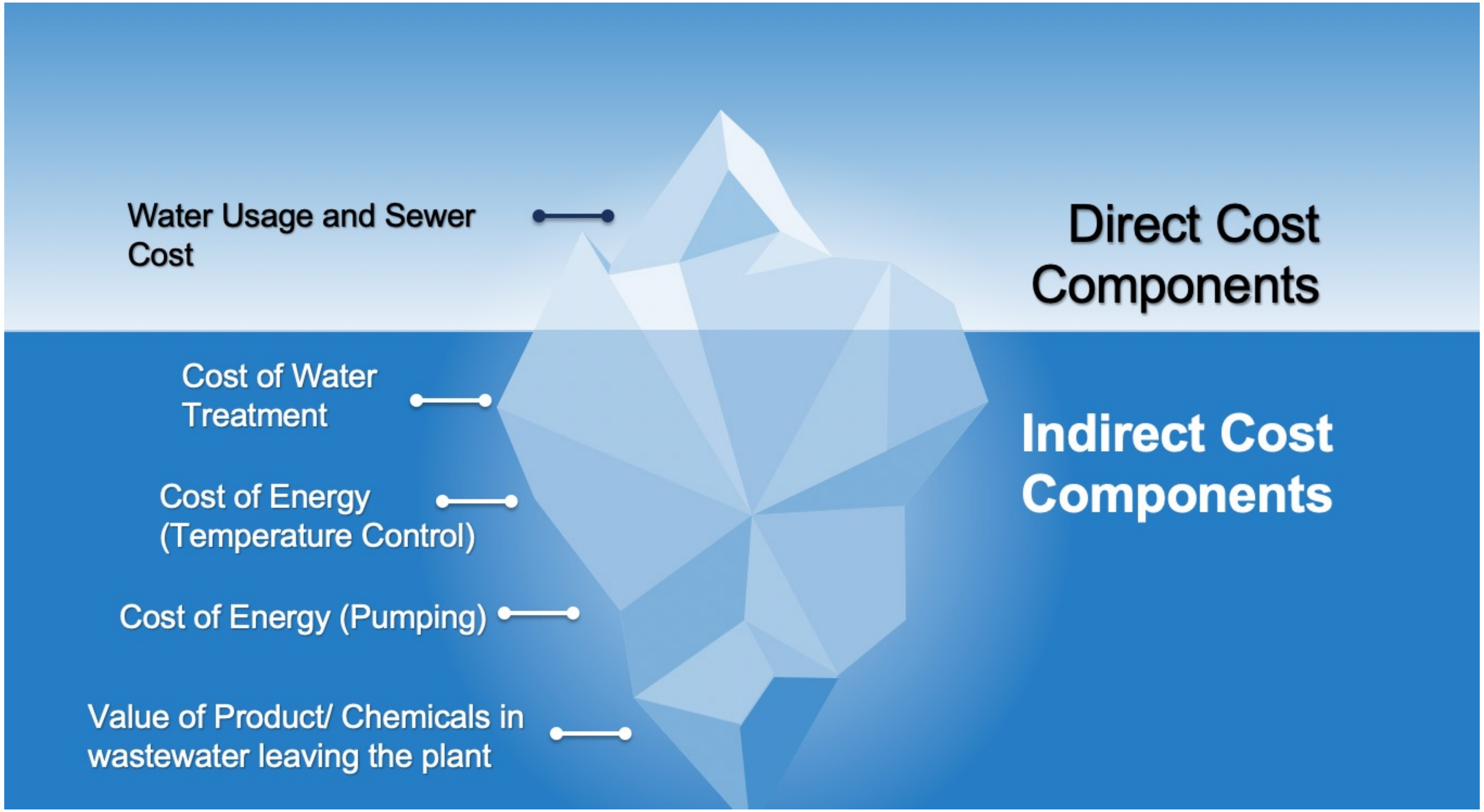
What is true cost of water?



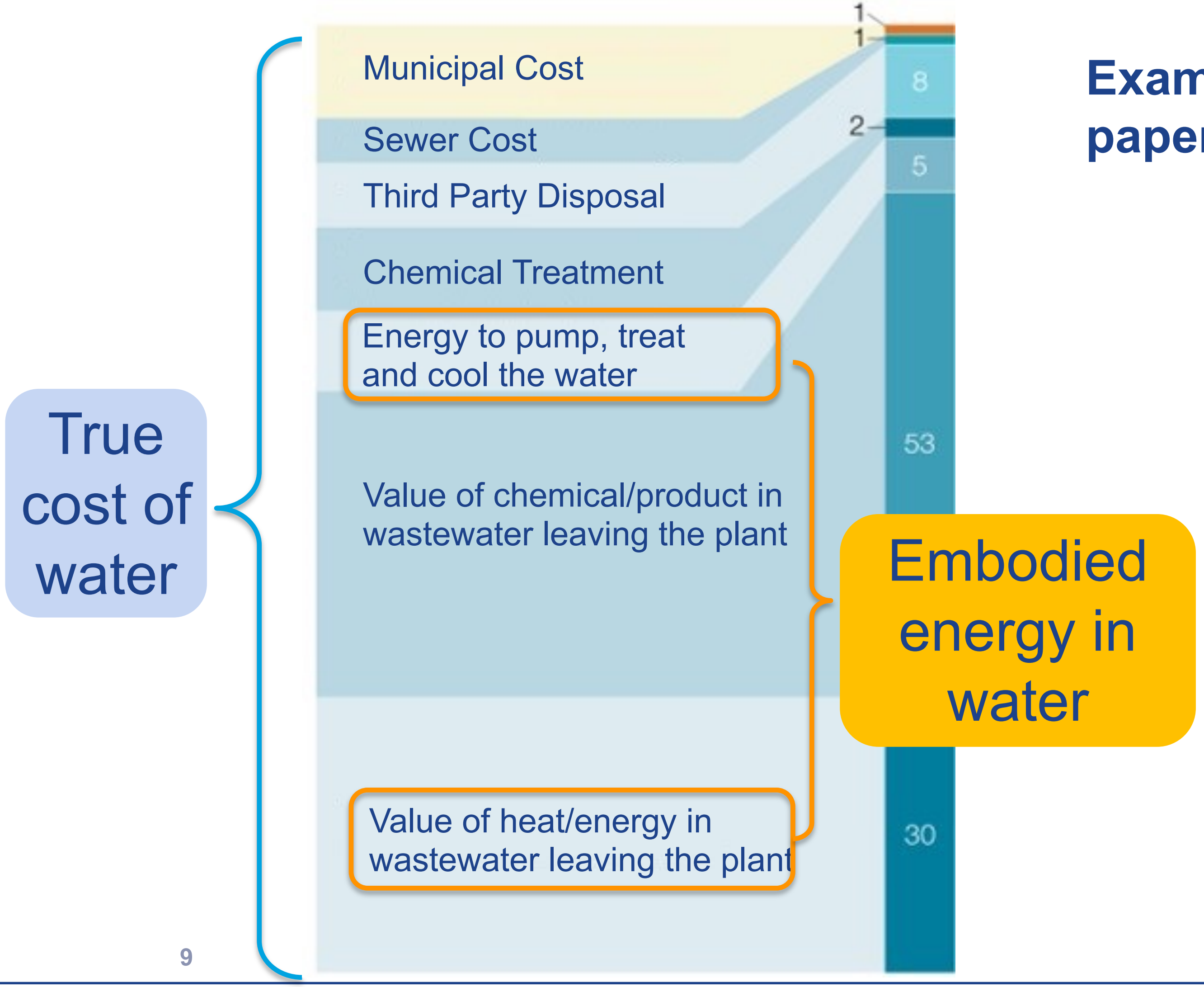
True Cost of Water – Example

True cost of water

Example from a Pulp and paper manufacturer

Source: Henderson et al. 2013. Measuring the Real Cost of Water.

True Cost of Water – Example



Example from a Pulp and paper manufacturer

Source: Henderson et al. 2013. Measuring the Real Cost of Water.

True Cost of Water – Example

True cost of water

Example from a Pulp and paper manufacturer

Measures implemented

- recaptured heat from condensation
- reduced steam consumption
- reduced chemical use

Savings realized

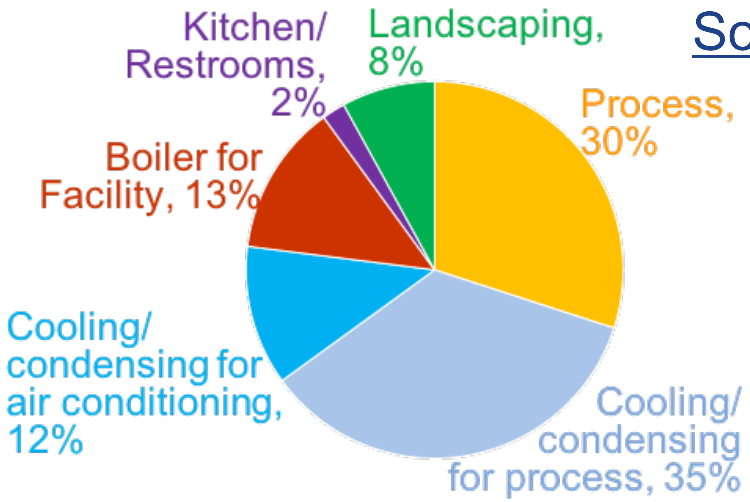
- 5% water savings
- 10% true cost savings

Source: Henderson et al. 2013. Measuring the Real Cost of Water.

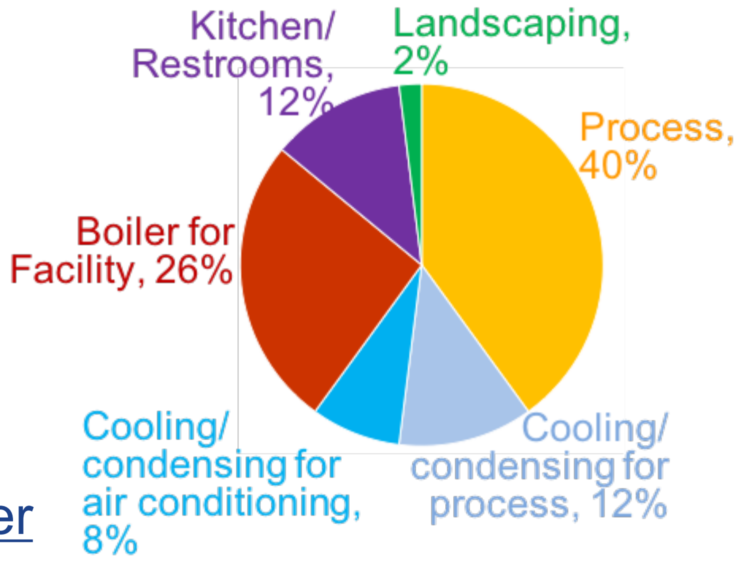
Why true cost of water?

Significance to the facility

- Reveals hidden costs of using water
- Identifies water use-intensive versus cost-intensive systems to help prioritize measures
- Helps estimate the actual cost savings from water efficiency projects, thereby prioritize and justify them



Source water intake



True cost of water

Typical True Cost Components

1. Direct costs (Municipal water intake and Wastewater disposal)
2. Cost of pumping (and other motor energy)
3. Cost of water and wastewater treatment
4. Cost of heat energy in wastewater

Direct Costs (Municipal Water Intake and Wastewater Disposal)

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Direct Costs

1. Municipal water intake
   - Potable
   - Non-potable
2. Wastewater disposal
   - Domestic sewer
   - Industrial sewer
   - Stormwater sewer
3. Third-party wastewater disposal services
   - Transportation, treatment and disposal.

Municipal Water and Wastewater Cost : Utility Bills

The municipal water intake and sewer can be separate or combined bills

Typically, includes two components:

1. Usage charge: based on the amount of water use and wastewater discharge
   - **Typically, different rates for residential and commercial/industrial customers**

2. Fixed charge
   - **Meter Fees -** capacity charge based on the meter size
     - Industrial: 2”, 3”, 4”, 6”, 8”, 10”, 12”, 16”
   - **Storm Drain Fees -** standard fixed cost or based on the area of impervious ground surface
   - **Fire Line Fees -** for customers with private fire protection lines

*Industrial sewer rate structure can have additional components that are discussed later

Municipal Water and Wastewater Rate Structure: Example

Customer Charge (by Water MeterSize)	Water Service Charge	Wastewater Service Charge
2"	$70.80	$113.00
3"	$141.60	$229.00
4"	$221.25	$362.00
6"	$442.50	$720.00
8"	$708.00	$1,160.00

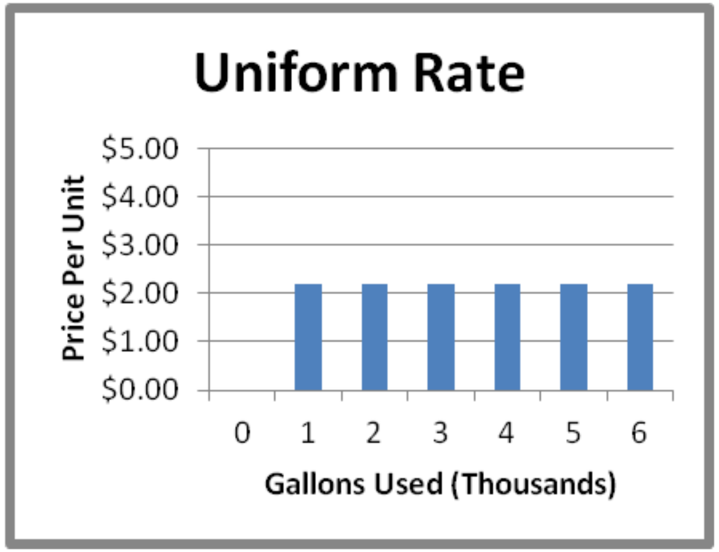
Industrial

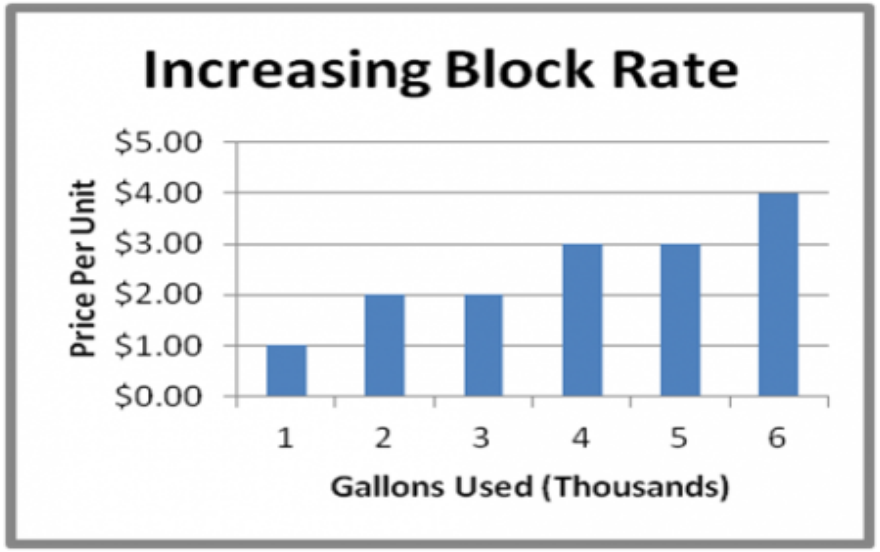
Consumption Charge	Water (in dollars)	Wastewater (in dollars)	Water & Wastewater (dollar total)
(per 100cubic feet of metered water)	$2.60	$2.38	$4.98

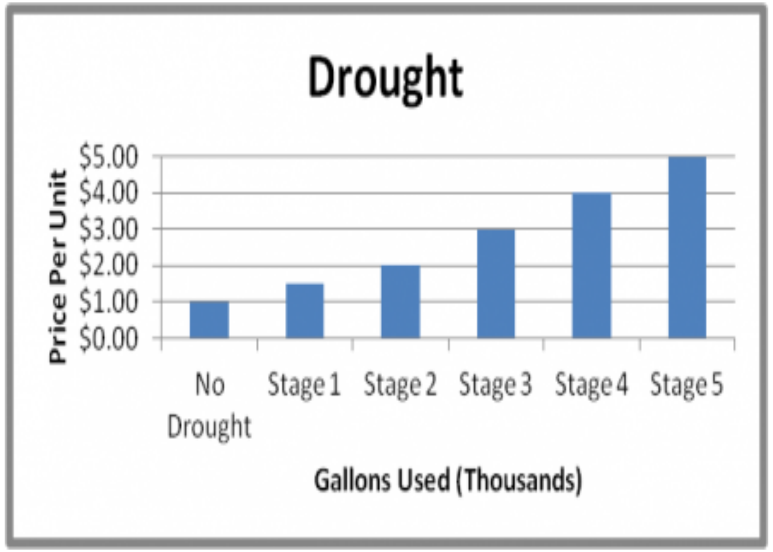
Note: Here wastewater is not metered separately; wastewater charges are based on the water usage

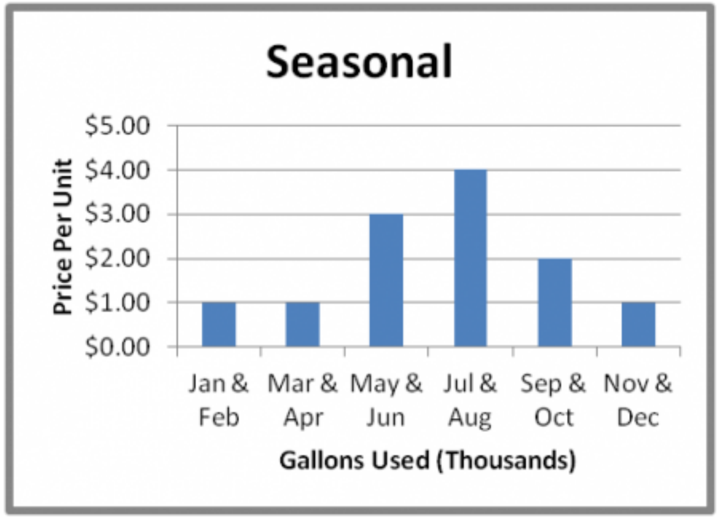
https://danvilleutilities.com/water/water-rates/industrial-water-rates.html

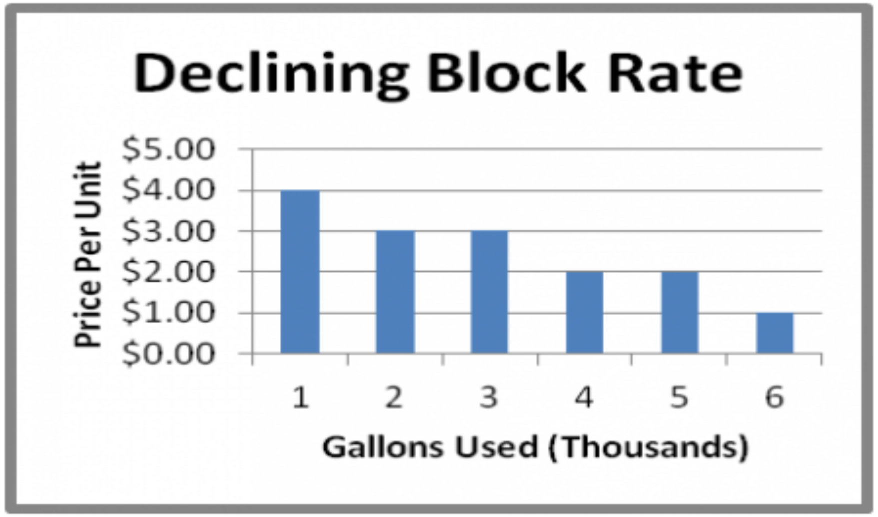
Municipal Water Rates: Usage Rate Types

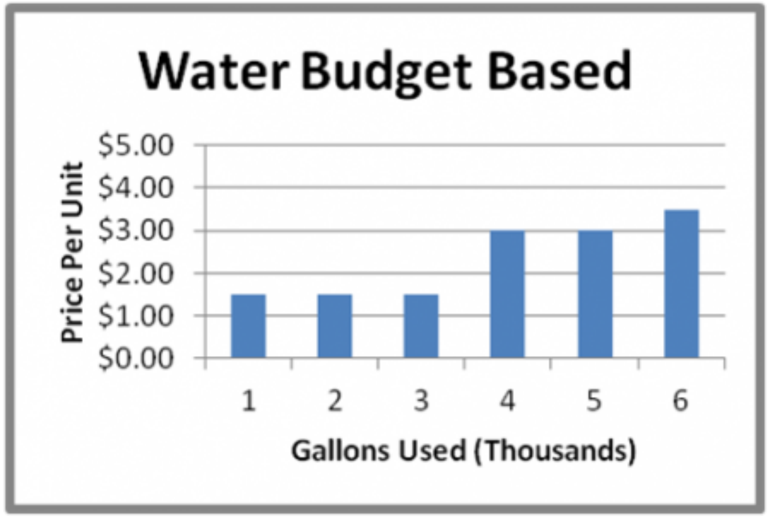












Industrial Sewer – Rate Structure

Industries with Metered Water Supplies

- Estimated wastewater (= water demand times % of water collected/ treated)
- Collection and treatment cost in $/million gallon

Industries with Unmetered Water Supplies

A **flat monthly sewer rate** based upon

- Type of industrial process
- Annualized cost of sewerage facilities in $/million gallon, derived from
  - Capital cost
  - Annual operation and maintenance cost

Surcharging based on wastewater constituent

Contaminant	Surcharge Rate
Flow	$6.50 per 1,000 gal.
BOD	$0.42 per pound
Suspended Solids	$0.50 per pound
Total Nitrogen	$1.37 per pound
Fats, Oils and Grease (FOG)	$0.50 per pound
Silver	Non-Compatible
Zinc	Non-Compatible
Phthalates	Non-Compatible
Phosphorous	$6.87 per pound

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https://www.codepublishing.com/CA/Holtville/html/Holtville13/Holtville1316.html

https://www.aub.org/for-my-business/commercial-customer-service/commercialindustrial-rate-information/commercialindustrial-wastewater-rates

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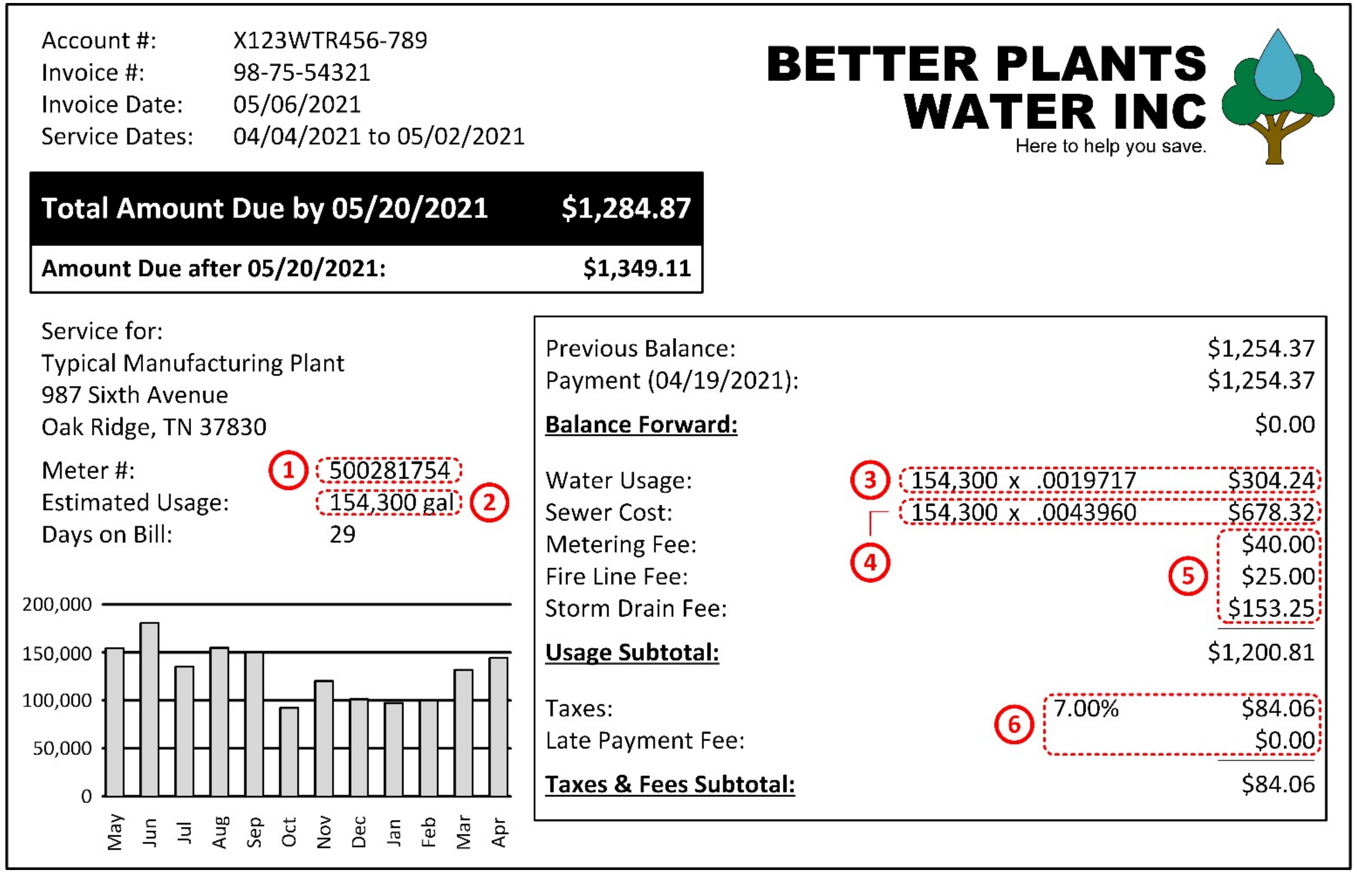
Utility Bill Example

Example utility bill with key information highlighted,
(1) Meter number,
(2) Meter reading,
(3) Usage charge,
(4) Sewer Charge,
(5) Fixed charge Miscellaneous Fees,
(6) Taxes and Late Fee

Note: the water usage and sewer cost are different given different rate structures



Account #: X123WTR456-789
Invoice #: 98-75-54321
Invoice Date: 05/06/2021
Service Dates: 04/04/2021 to 05/02/2021

BETTER PLANTS WATER INC
Here to help you save.

Total Amount Due by 05/20/2021	**$1,284.87**
Amount Due after 05/20/2021:	**$1,349.11**

Service for:
Typical Manufacturing Plant
987 Sixth Avenue
Oak Ridge, TN 37830

Meter #:	(1)	500281754
Estimated Usage:	(2)	154,300 gal
Days on Bill:		29

Previous Balance:			$1,254.37
Payment (04/19/2021):			$1,254.37
Balance Forward:			$0.00
Water Usage:	(3)	154,300 x .0019717	$304.24
Sewer Cost:	(4)	154,300 x .0043960	$678.32
Metering Fee:	(5)		$40.00
Fire Line Fee:			$25.00
Storm Drain Fee:			$153.25
Usage Subtotal:			$1,200.81
Taxes:	(6)	7.00%	$84.06
Late Payment Fee:			$0.00
Taxes & Fees Subtotal:			$84.06

Municipal Water and Wastewater Rates: Multiple Rates

If multiple water meters in the facility, water rates may be different depending on

- Utility provider
- Meter size
- Usage
- Quality of supplied water
  - Potable water
  - Non-potable water
  - Reclaimed or recycled water

Within a facility, wastewater rates and rate structure may be different for

- sanitary sewer,
- stormwater sewer,
- industrial sewer

*City may require **stormwater be discharged to an industrial sewer** if possibility to pick up industrial pollutants.*

It is important to consider the water intakes/discharges separately in the water baseline if they cost significantly different

http://www.cvwd.org/385/Nonpotable-Water-Rates

Third-party Wastewater Disposal

Typically seen in facilities that produce specialized contaminates that cannot be sent to local municipal

Examples:

- Water with hazardous materials
- Battery wash water,
- Tank cleaning wastewater,
- Specialized industrial process wastewater

The direct cost component will include the **treatment cost** as well as the **cost to transport** the wastewater to the receiving/processing facility

A holding tank stores wastewater from various sources until it is pumped out and hauled to a receiving/processing facility.

https://www.wrijax.com/Services/Transportation-Services/
https://www.iec-nj.com/wastewater-hauling/

PWP Tool and Utility Cost

Part 5.1 - Utility Cost

Please select all utilities that are relevant to your plant and enter the unit cost. For utilities that have fixed costs associated, determine the unit cost by dividing the total cost incurred in a year by the quantity of water, wastewater or fuel it was charged for.

Utility		Cost ($)	Unit	Comments
Municipal Water - Potable	☐		per kGal	
Municipal Water - Nonpotable	☐		per kGal	
Municipal Water - Other	☐		per kGal	
Municipal Wastewater Disposal	☐		per kGal	
Third-Party Disposal	☐		per kGal	
Stormwater Charge	☐		per kGal	
Electricity	☐		per kWh	
Natural Gas	☐		per MMBtu	

PWP uses a blended cost to calculate results - only the annual average cost of utility is needed per kgal for water.

While, the seasonal variations and other nuances of cost structure is not considered in PWP, knowing how the facility is billed is still important to know.

Polling Question 1

What is the blended usage cost for intake water?

1.) $5.3 per kgal
2.) $6.8 per kgal
3.) $14.6 per kgal
4.) $4.1 per kgal

Water Supply Services
Your water, our priority.

Billing Summary			
Billing Date:	9/04/2020	Amount Due:	$7,688.26
Due Date:	9/18/2020	After Due Date:	$8,072.67

Account Information	
Account Number:	AB123W987-654
Invoice Number:	29-08-789321
Customer Name:	Fine Factories Inc.
Service Address:	123 Four Street Huntington, WV 25701
Current Meter Reading:	648,844
Previous Meter Reading:	124,544
Usage:	524,300 gal
Meter Read Date:	8/31/2020
Days on Bill:	31

Account Summary		
Previous Amount:		$7,153.58
Payment 08/12/2020:		-$7,153.58
Balance Forward:		$0.00
Meter Fee:		$760.76
Fire Line Fee:		$37.25
Storm Drain Fee:		$57.32
Usage Cost:	524,300 gal	$3,582.64
Sewer Cost:	524,300 gal	$2,815.11
Sales Tax (6.00%):		$435.18
Current Charges:		$7,688.26
Amount Due:		**$7,688.26**

Questions or comments? We're available 24/7 at:
betterbuildingssolutioncenter.energy.gov/better-plants/program-information

Indirect Cost
(Pumping, water and wastewater treatment, heat energy)

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Pumps and Fans – Motor driven Systems

- Source water intake:
  - Pumping Groundwater
  - Pumping Surface water
- Process
  - Booster Pressure pump
  - Recirculation pumps
- Cooling and condensing system
  - Make-up water pumps
  - Water recirculation pumps
  - Cooling Tower Fans
- Boiler/Steam system
  - Make-up water pumps
  - Boiler Feedwater pumps
  - Condensate Return pumps
  - Other auxiliary services

Outside of these stand alone motors, there is energy considered as part of water treatment as well

Pumps and Fans: Cooling Tower

- Cooling tower recirculation pumps
- Cooling Tower fan
- Make-up water pumps

Pumps and Fans: Boiler/Steam Systems

- Boiler Feedwater pumps
- Condensate Return pumps
- Make-up water pumps
- Auxiliary fans

Costs for pumping and motor energy

Total Energy Use(kwh/year) = $kW_{full\ load}$ * Load Factor * Hours of Operation per Year

1. Motor nameplate data

   Calculation using rated horsepower

   - *$kW_{full\ load}$ = 0.746 * Horsepower / Efficiency*

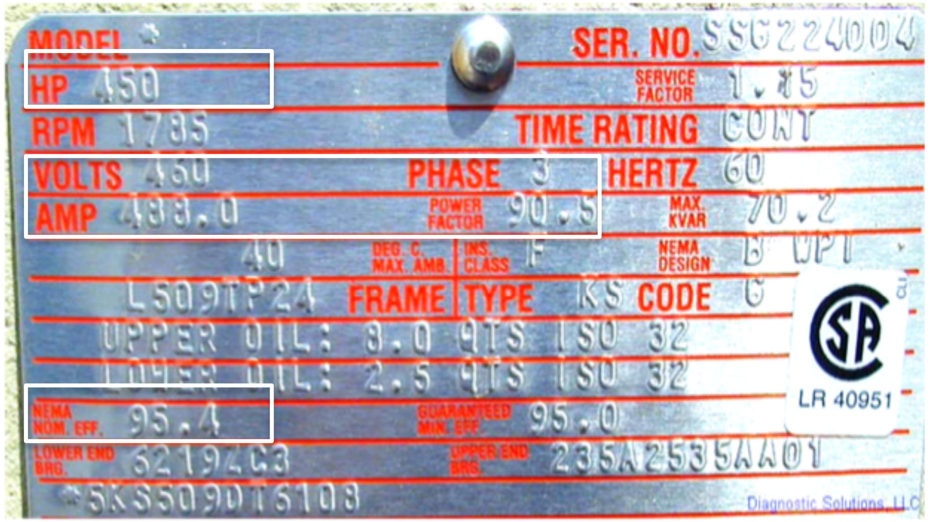
   Calculation using rated full load amps

   If single-phase motor

   - *kW = Volts x Amps x Power Factor / 1000*

   If 3-phase motor

   - *kW = Volts x Amps x Power Factor x √3 / 1000*



2. Operational details
   - Hours of Operation per Year
   - Load Factor (i.e., average load/peak load)

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Digital Multimeters

- Multimeters can be used to get the instantaneous current, energy and power
- Limited logging capability and used primarily for spot measurements
- Load factor can be estimated accurately

Run time Loggers

- Used to collect the run time of a motor system over a period
- Simple to setup and use and provides the operating hours of a system

Pumps and Motor Energy in PWP Tool

Part 8.2 - Pump, Fan and Motor Energy

This table calculates the electricity use associated with pump, fan and other motor-driven equipment to use water in your plant. Please select the water-using system from the drop-down lists and enter data in the highlighted cells.

Water-Using System	Description	Number	Hours of Operation per Year	Load Factor	Horsepower	Efficiency (%)	Energy Use (kWh)
Process: Process 1	Service Water Pump	1	8,760	0.7	25.0	91.0%	125,672
Cooling Tower for: Process 1	Hot Well Pumps	2	8,760	0.7	100.0	91.0%	1,005,378
Cooling Tower for: Process 1	Cold Well Pumps	2	8,760	0.7	50.0	91.0%	502,689
Cooling Tower for: Process 1	Fans	2	4,800	0.7	25.0	91.0%	137,723
Cooling Tower for: Air Conditioning	Hot Well Pumps	1	5,600	0.7	25.0	91.0%	80,338
Cooling Tower for: Air Conditioning	Cold Well Pumps	1	5,600	0.7	10.0	91.0%	32,135
Cooling Tower for: Air Conditioning	Fans	1	3,200	0.7	10.0	91.0%	18,363
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Plant-wide Source Water Intake and Circulation
Plant-wide Wastewater Discharge
Process: Process 1
-
-
Cooling Tower for: Process 1
Cooling Tower for: Air Conditioning
-
Boiler for: Facility Needs
-
Kitchen and Restrooms
Landscaping and Irrigation

Select the system the electric energy applies to and enter power, load factor and hours of operation to calculate energy - Whole facility or individual systems can be chosen

A small fraction of the motor population is responsible for most of the energy consumption

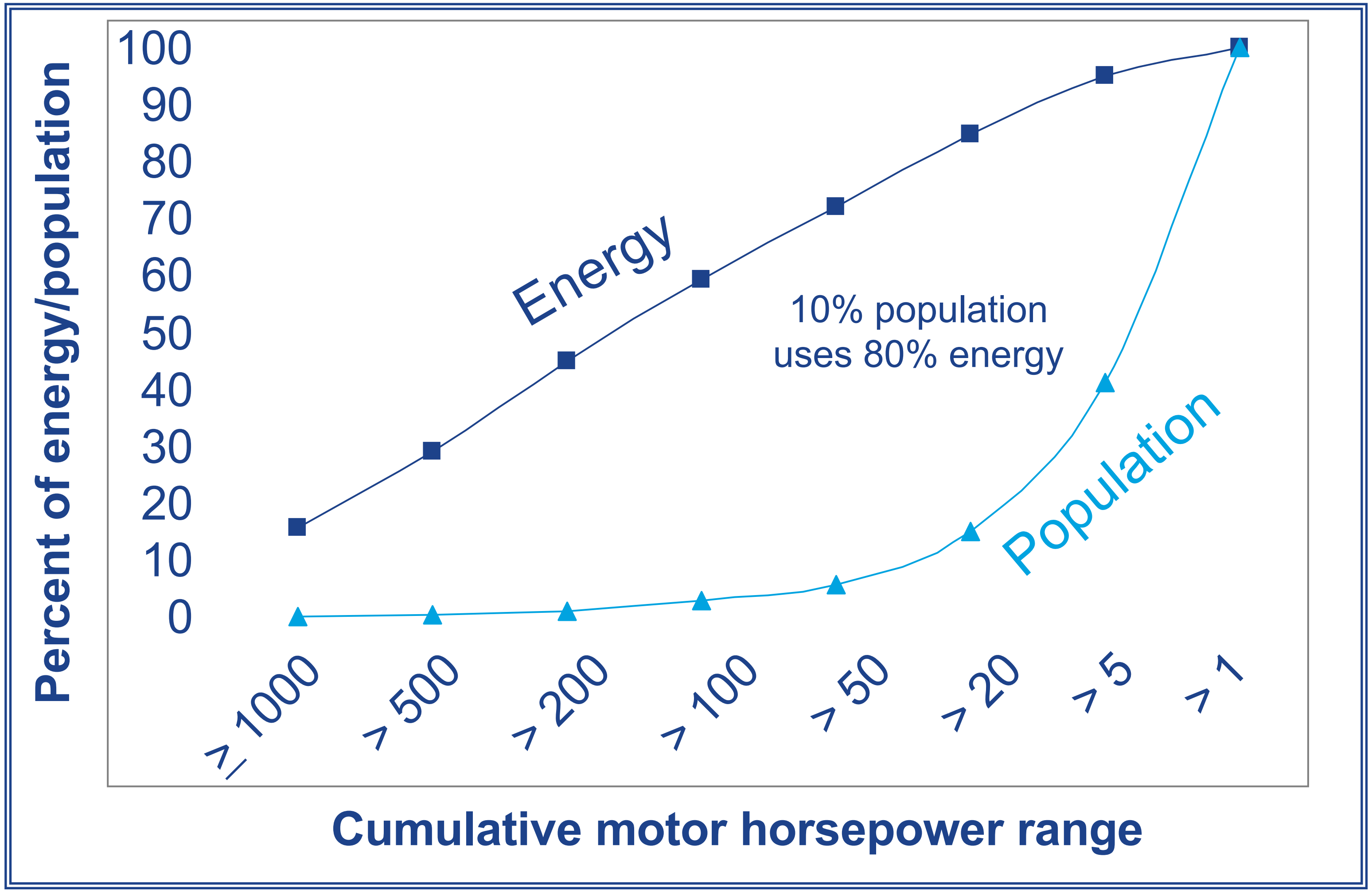
Focus on the relatively big stuff that runs a lot.

These are typically
- Intake pump station
- Cooling tower recirculation systems
- Plant wide circulation pumps

Facilities inventory can be used if kept updated

System drawing might not have the most updated and accurate information

Secondary pumps can be ignored



Note the descending order (left to right)

Cost of Water and Wastewater Treatment

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Water and Wastewater Treatment

- Water Treatment: Treatment done to intake water prior to use in facility
  - Treatment method is driven by **process needs** and **quality of makeup water**
  - Surface water intakes can be of varying hardness and contain dissolved solids not appropriate for use
  - Typically done by chemicals and/or membrane filtrations systems

- Wastewater Treatment: Treatment done after being used in facility operations
  - Treatment method is driven by **process contaminates** and **discharge requirements.**
  - The water can pick up various contaminates (depending on the product) which need to be removed before discharge or being recycles for other operation.
  - Can be multiple different treatment steps in succession

Water Treatment: for Cooling Tower

Make-up to boilers and cooling tower is treated to ensure efficiency, maximize equipment life, reduce maintenance costs and maintain levels of operational performance.

Cooling tower contaminants can include chlorides, hardness, iron, biological materials, silica, sulfates, TDS, and or TSS.

Makeup water:

- **Pre-treatments,** such as **water softeners** and **dealkalizers**
- **Scale and corrosion inhibitors** – to reduce or eliminate contaminants, such as minerals, in makeup water supply that can result in blockages and deterioration in your system's piping

Water in the cooling tower reservoir

- **Biocides** –to control the development of potentially harmful microorganisms.
- **Organic dispersants** – to prevent fouling and the accumulation of biofilms
- **Chlorine dioxide** – as a disinfectant to destroy microorganisms and prevent recurring growth.

https://www.r2j.com/cooling-tower-water-treatment-chemicals/

Water Treatment: for Boiler/Steam System

Boiler makeup feeds can include dissolved, suspended solids and inorganic matter such as iron, copper, calcium, magnesium, aluminum and dissolved gases.

Level of treatment depends on the boiler operation pressure. Common methods and technologies used to treat boiler feedwater include

Makeup water:

- **Water Softening** - Removal of calcium, magnesium, and certain other metal ions
  - Softening chemicals like sodium phosphate and soda ash
  - ion exchange and reverse osmosis
- **Oxygen Scavengers** - to reduce the amount of dissolved oxygen and oxides in the water to reduce oxygen-related metallic corrosion
- **Alkalinity Builders** - to raise the pH level of the water
- **Amines (neutralizing chemicals)** - to keep the condensate pipe on a boiler from corroding
- **Anti-Scaling Agents** (a blend of polymers and phosphates)

https://sensorex.com/blog/2019/12/03/common-chemicals-in-boiler-water-treatment/

Water Treatment: for Process

Process water can be Direct (contact) or Indirect (non-contact).

Indirect Water – Doesn't need much treatment except to avoid scaling/corrosion in pipes

Direct Contact Water - Different degrees of treatment might be needed based on process needs and the raw water quality.

Purified deionized/demineralized (DM) water with its mineral ions removed is an important utility for a lot of direct process water

Purified water used in industries are typically divided into five based on their quality

- **Deionized Water** – critical manufacturing steps , food processing, medium pressure boiler feed, battery top-up;
- **Purified Water** – cosmetics, chemical manufacturing
- **Apyrogenic Water** – pharmaceuticals, medicinal preparation , tissue culture, water for injections;
- **High Purity Water** – laboratories, high pressure boilers
- **Ultrapure water** – manufacturing of precise and sensitive products like micro electronics

Note: These are broad high-level classifications and water quality will vary even within the sector

Industrial Wastewater: Contaminants by Industry

Food industries:

- Organic particulate and waste matter.
- Synthetic compounds like antibiotics and growth hormones (animal slaughter)

Metals Processing Industry:

- Metal contaminates from surface treatments
- Waste products like ammonia and cyanide in cooling water
- Oil and grease contaminates in processes require water as a coolant and lubricant

Pharmaceutical:

- Residual and nonresidue drug waste

Pulp & Paper:

- Acids, chlorine, chloroform, dioxins, hydrocarbons and phenols in wastewater from bleaching
- Presence of lignin and lignin derivates

Textiles:

- Chemical products like bleach and dyes.

Automotive:

- Grease, paints and solvent in wastewater are common

Industrial Wastewater Discharge

Wastewater treatment steps are according to the quality of wastewater and discharge limitations

Established by

- National Pollutant Discharge Elimination System (NPDES) permit
- Effluent Limitations Guidelines and Standards
- National Pretreatment Program
- Cooling Water Intake Structures
- Stormwater runoff control

NPDES required for direct discharge to surface water sources

The permit may require

- **pretreatment** before discharge,
- restriction of peak flow discharges
- discharge of certain wastewaters only to specified sewers of the city
- relocation of point of discharge
- prohibition of discharge of certain wastewater components
- restriction of discharge to certain hours of the day

Water and Wastewater Treatment: Example Processes

Chemical Treatment

- Oil/Water Separation
- Neutralization
- Chemical Treatment of Cooling Tower Makeup Water
- Lime Softening
- Chlorination, Ozonation

Physical Treatment

- Screening and Grit Removal
- Flotation, Dissolved Air Flotation
- Sand Filtration, Bag Filtration, Cartridge Filtration
- Granular Activated Carbon Adsorption (GAC)
- UV Filtration
- Ion Exchange Softening
- Membrane Filtration

Physio-Chemical Water Treatment

- Coagulation – Flocculation – Sedimentation
- Clarification (Settling, Sedimentation)

Biological treatment

- Membrane Bioreactor (MBR)
- Activated Sludge / Aerobic Lagoon
- Anaerobic Lagoon
- Biological Nutrient Removal (BNR)

Thermal treatment

- Evaporation
- Distillation/rectification

Common Wastewater Systems – Examples

Aeration System

Settling/Separation tanks (chemical treatment)

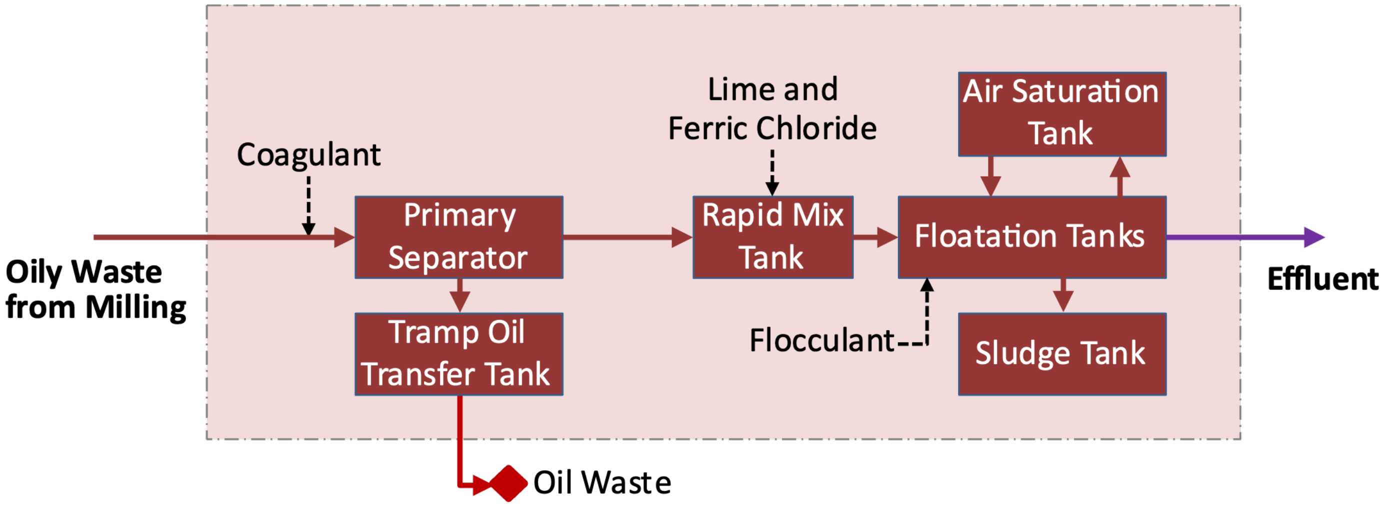

Clarifiers


PH Neutralization Systems

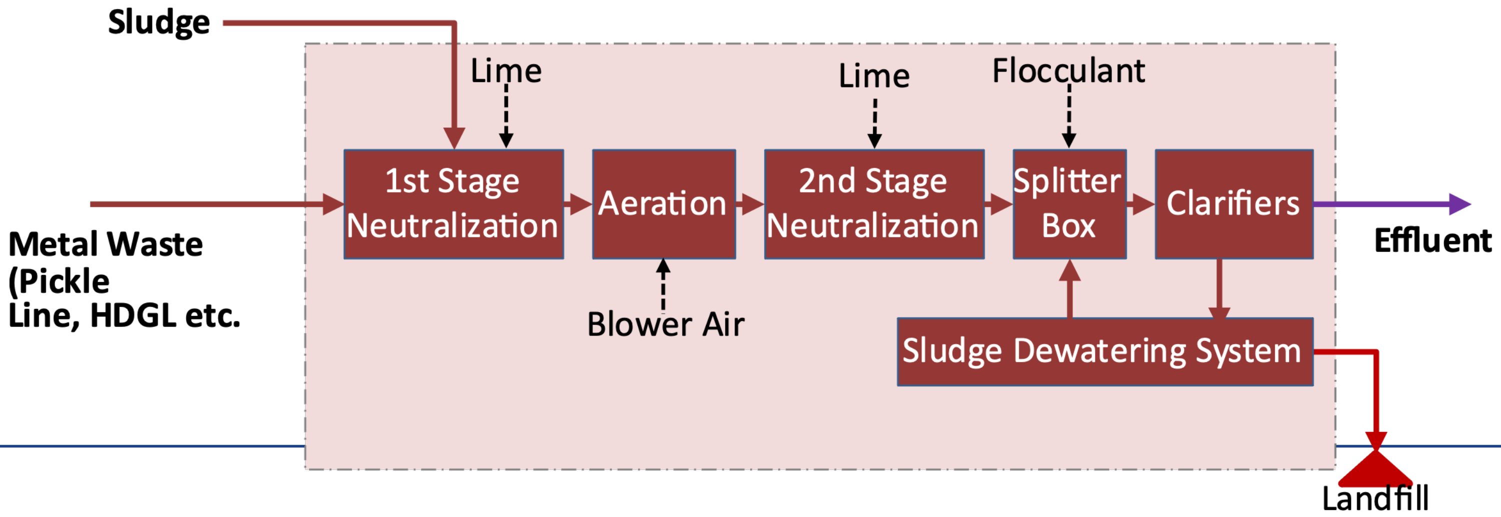
Source: BP Summit 2021 , Suncombe

Wastewater Treatment Trains in Iron and Steel

Typical Oily Waste Treatment



Typical Metal Waste Treatment



Chemical treatment

Most used in industries and can be used to treat for various contaminates.

Typical Water Treatment

- Scale and corrosion inhibitors – Boiler and cooling tower makeup

Typical Wastewater Treatment

- Neutralizing – Ph control
- Precipitating out heavy metals - Treatment of metals and toxic materials

Typical cost components:

- Cost of chemicals
- Cost of electricity use
  - Feeder pumps
  - Water circulation
- Labor cost for testing chemical levels
- Maintenance of equipment

Chemical treatment with automated monitoring and control

Physical treatment

Suited for removing solids contaminants via clarifiers , oils and grease with separators or deionization with filtration

Example treatment processes
- Screening, skimming
- Filtration
- Clarifiers/ Sedimentation

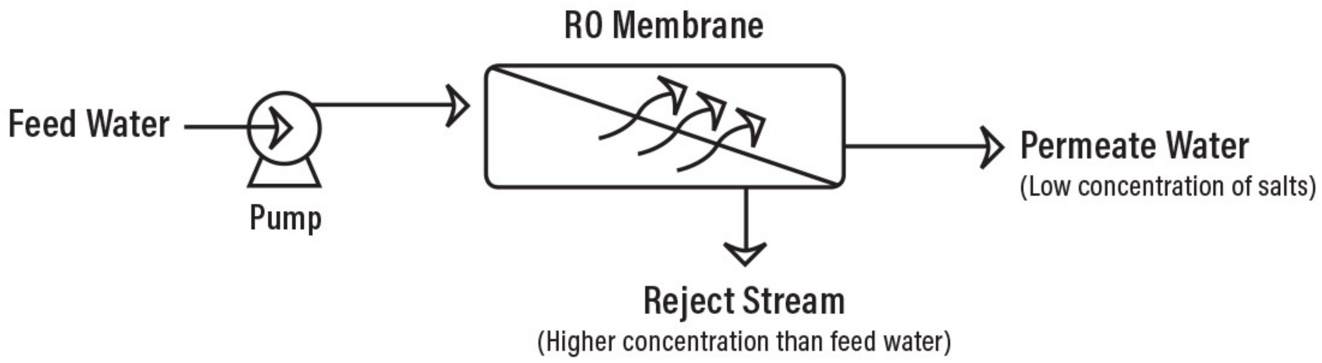
Typical Cost Components:
- Electricity to operate mechanical equipment
- Pumping energy
- Maintenance (membrane cleaning)
- Recuring replacement cost

Clarifiers - Example of Physical Treatment

Settling tanks built with mechanical means for continuous removal of solids being deposited by sedimentation

Physical treatment: RO System (Membrane filtration)

Water is demineralized or deionized by pushing it under pressure through a semi-permeable Reverse Osmosis Membrane.



Typical cost components:

- Electricity to operate pumps
- Chemicals for pretreatment and membrane cleaning
- Media replacement

Deionization to remove unwanted ions

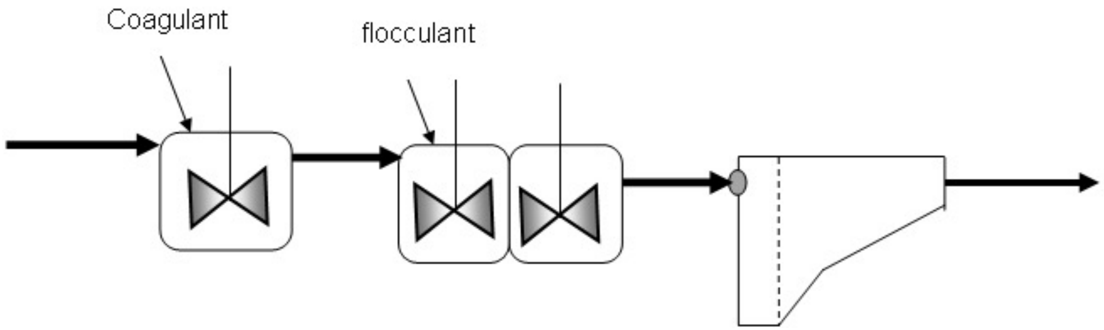
Physio-chemical treatment: Coagulation with Sedimentation

Involves using chemicals which can modify physical state of colloidal particles making them more stable and coagulable for further treatment or filtration purposes.

- Coagulation (Coagulant + rapid mixing)
- Flocculation (Flocculant + slow-mixing)

Typical cost components::

- Cost of chemicals
- Cost of Pumping
- Cost of motor energy for mixing
- Maintenance and replacement cost



Coagulation – Flocculation -- Sedimentation

Aerobic treatment

Air is added into wastewater to allow aerobic bio-degradation of the pollutant components.

Typical cost components:

- Electricity for air blowers/ compressed air/ mechanical agitators
- Pumping
- Operations and maintenance

https://gsps-eng.com/aerators-wastewater.html

Thermal treatment of wastewater

Thermal separation process are any technology that involves high temperatures in its treatment.
E.g. Evaporation, distillation/rectification etc.

Its best suited when,

- Wastewater ingredients, dry substance contents, pH value or particle size changes frequently
- Wastewater is highly concentrated

Example manufacturing processes

- Wastewater from Industrial Laundries
- Toxic wastewater from Chemical Production Process
- Wastewater from the production of wood fiber boards

Multi effect Evaporation Plant

True Cost Components

- Heat input (electricity or fossil-fuel)
- Mechanical energy input
- Other (maintenance)

https://www.gea.com/en/binaries/wastewater-industry-concentration-membrane-filtration-gea_tcm11-34902.pdf

Estimating Cost of water and wastewater treatment

For each water and wastewater treatment process:

If maintained by the facility

- Cost of water (or wastewater) treatment ($/year) = Sum of unit cost of treatment process ($/kGal)
    - Cost of chemicals
    - Cost of energy
    - Cost of operation (replacements, maintenance)
    - Annualized cost of equipment installation (if appropriate)

If maintained through a third-party service

- Cost of water (or wastewater) treatment ($/year) = Annual total amount paid to the third-party

Unit Cost data for PWP Tool

Part 5.2 - Water Treatment Cost

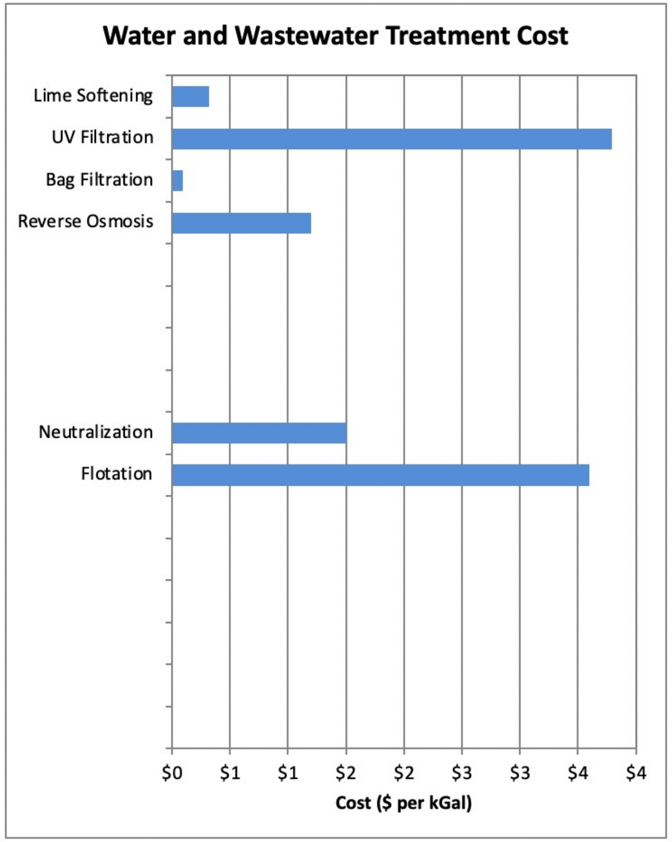
Please indicate all water treatment processes that are used in your plant. Select from the dropdown menu and enter cost in the highlighed cell. You may select Other and type the name if not listed as a dropdown option. For determining the cost in $ per kGal, you may divide the sum of all costs incurred in a year for a water treatment process by the quantity of water that was treated. Include the costs of chemicals, energy input (e.g., heating, cooling, pumping), operation and maintenance, and otherwise.

Water Treatment Process	Typical Range	Cost ($ per kGal)	Comments
Lime Softening	Not Available	0.32	
UV Filtration	$0.23–$1.84	3.79	
Bag Filtration	$0.07–$0.17	0.09	
Reverse Osmosis	$0.75–$6.50	1.20	

Part 5.3 - Wastewater Treatment Cost

Please indicate all wastewater treatment processes that are used in your plant. Select from the dropdown menu and enter cost in the highlighed cell. You may select Other and type the name if not listed as a dropdown option. For determining the cost in $ per kGal, you may divide the sum of all costs incurred in a year for a wastewater treatment process divided by the quantity of wastewater that was treated. Include the costs of chemicals, energy input (e.g., heating, cooling, pumping), operation and maintenance, and otherwise.

Wastewater Treatment Process	Typical Range	Cost ($ per kGal)	Comments
Neutralization	Not Available	1.50	
Flotation	Not Available	3.60	



- Volume of water and wastewater treated
- Unit costs of water & wastewater treatment (To be calculated)

True Cost Components
4. Cost of Heat Energy in Wastewater Leaving the Plant

U.S. DEPARTMENT OF ENERGY

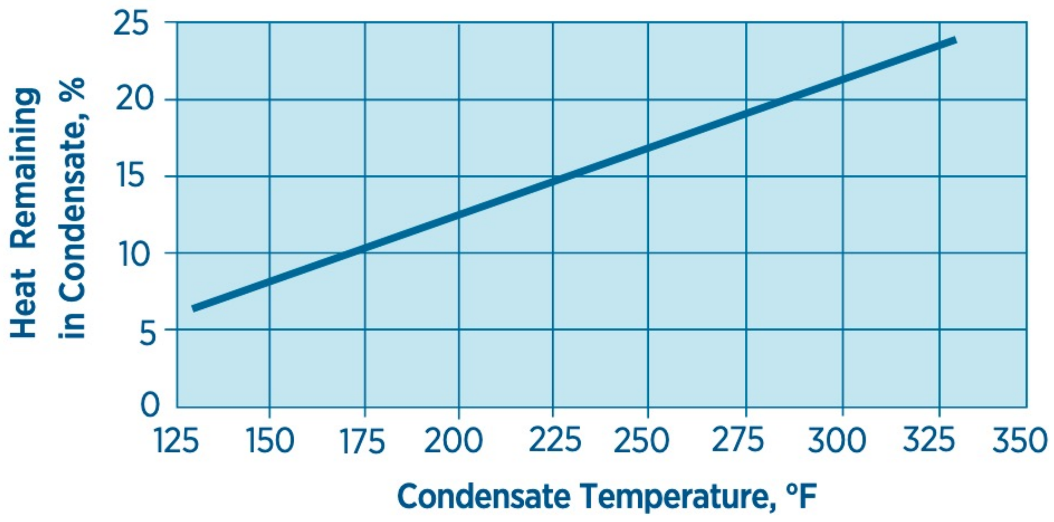
High Temperature Wastewater Sources

Energy lost in the form of heat in the discharge stream can add to the true cost

Typical steam of heat loss

- Boiler blowdown (212 ºF at atmospheric pressure)
- Condensate (130-225 ºF)
- Processes cleaning/sanitizing

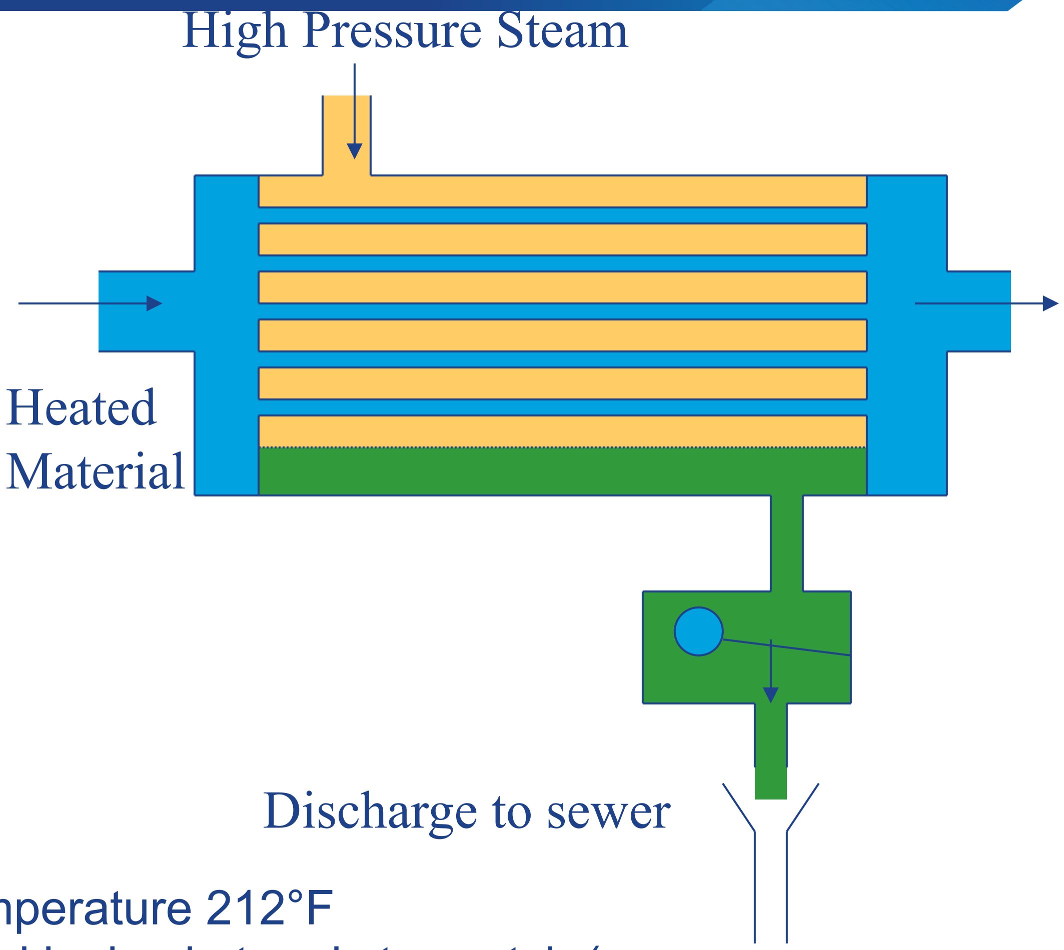
If lesser water is used, the energy (and cost) associated with heating it can be reduced



https://www.energy.gov/sites/prod/files/2014/05/f16/steam8_boiler.pdf

High Temperature Wastewater Sources: Condensate

- Condensate exits a process heat exchanger as a saturated liquid
- The condensate temperature provides an indication of the energy loss associated with the condensate return system



Measured condensate temperature 212°F
Condensate flow measured by bucket and stopwatch (mass and energy balance is also a common method)

Estimating cost of heat energy in wastewater

Data to collect

- For high temperature wastewater leaving the facility:
  - Quantity (MGal/year)
  - Temperature of wastewater
- Temperature of source water intake
- Water heating efficiency (e.g., ~0.78 for typical combustion system)
- Cost of heating fuel ($/MMBtu);

$$\text{Cost of Heat Energy in Wastewater (\$/year)} = \frac{\text{Volume * Density * Specific Heat * Temperature rise}}{\text{Water Heating Efficiency}} \times \text{Cost of Heating Fuel}$$

Part 8.1 - Heat Energy in Wastewater Leaving the Plant

This table calculates the heat energy in wastewater leaving the plant. For each water-using system, please provide the average temperature of incoming source water and outgoing wastewater.					Heating Efficiency:	0.78
Water-Using System	Water Temperature (°F)		Temperature Rise (°F)	Quantity of Wastewater Discharge (Million Gallon)	Heat Energy in Wastewater (MMBtu)	
	Incoming Source Water	Outgoing Wastewater				
Process: Process 1	75.0	95.0	20.0	4.7	1,006	
-			-	-	-	
-			-	-	-	
Cooling Tower for: Process 1			-	-	-	
Cooling Tower for: Air Conditioning			-	-	-	
-			-	-	-	
Boiler for: Facility Needs	75.0	110.0	35.0	0.4	150	
-			-	-	-	
Kitchen and Restrooms			-	1.4	-	
Landscaping and Irrigation			-	-	-	
-			-	-	-	
TOTAL					1,156	

- Volume of high temperature wastewater leaving the facility
- Temperature of incoming water and high temperature wastewater leaving the facility
- Unit cost of water heating fuel

True Cost of Water: Wrap Up

Cost of municipal water intake and wastewater disposal

- **Volume** of purchased water, sewer discharge and third-party disposal
- Unit costs of municipal water, sewer and third-party disposal

Costs for pumping and motor energy

- Pump and motor specifications and operation
- Unit cost of electricity

Cost of water and wastewater treatment

- Volume of water and wastewater treated
- Unit costs of water & wastewater treatment (To be calculated)

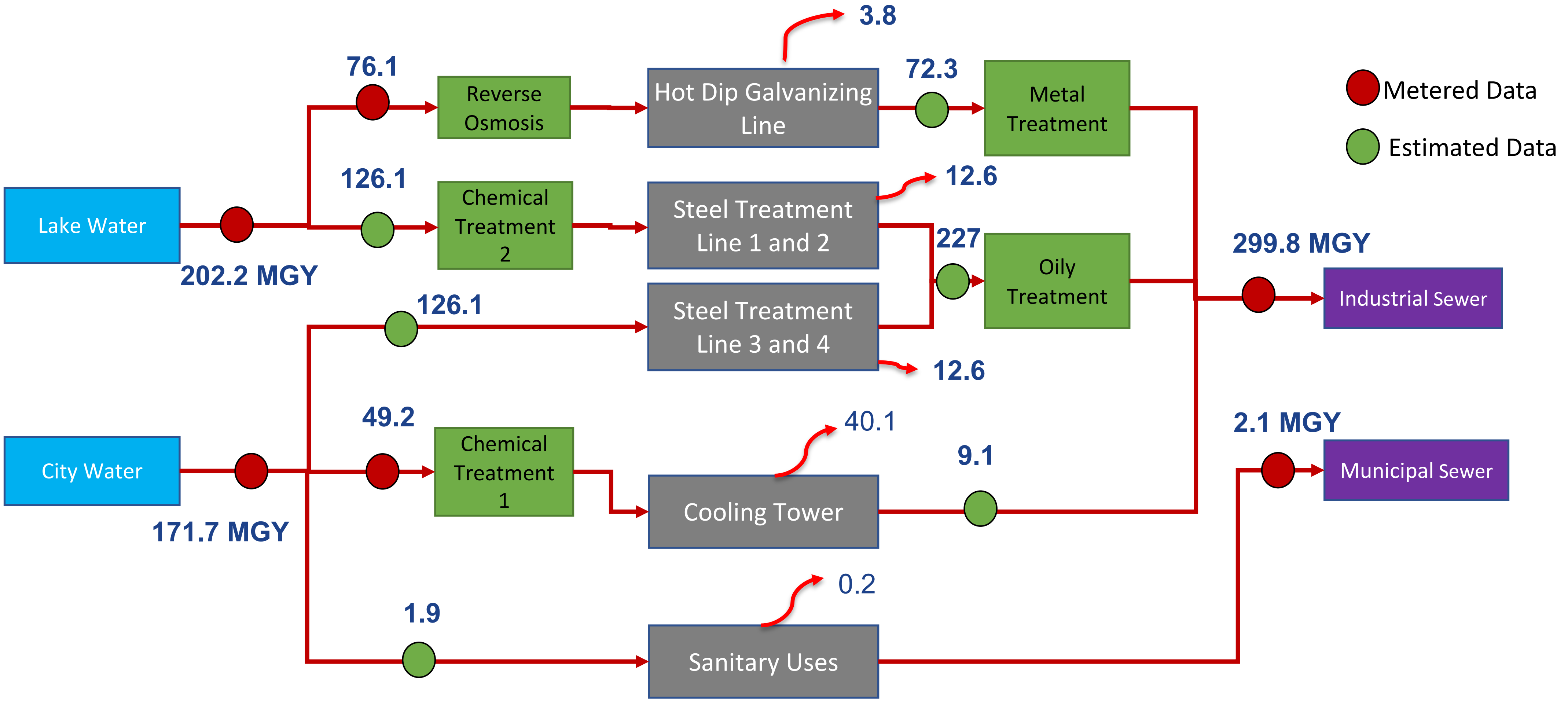
Cost of unused heat energy in wastewater

- Volume of high temperature wastewater leaving the facility
- Temperature of incoming water and high temperature wastewater leaving the facility
- Unit cost of water heating fuel

True Cost of Water – Exercise

U.S. DEPARTMENT OF ENERGY

Example Facility – With Data (Session 2)

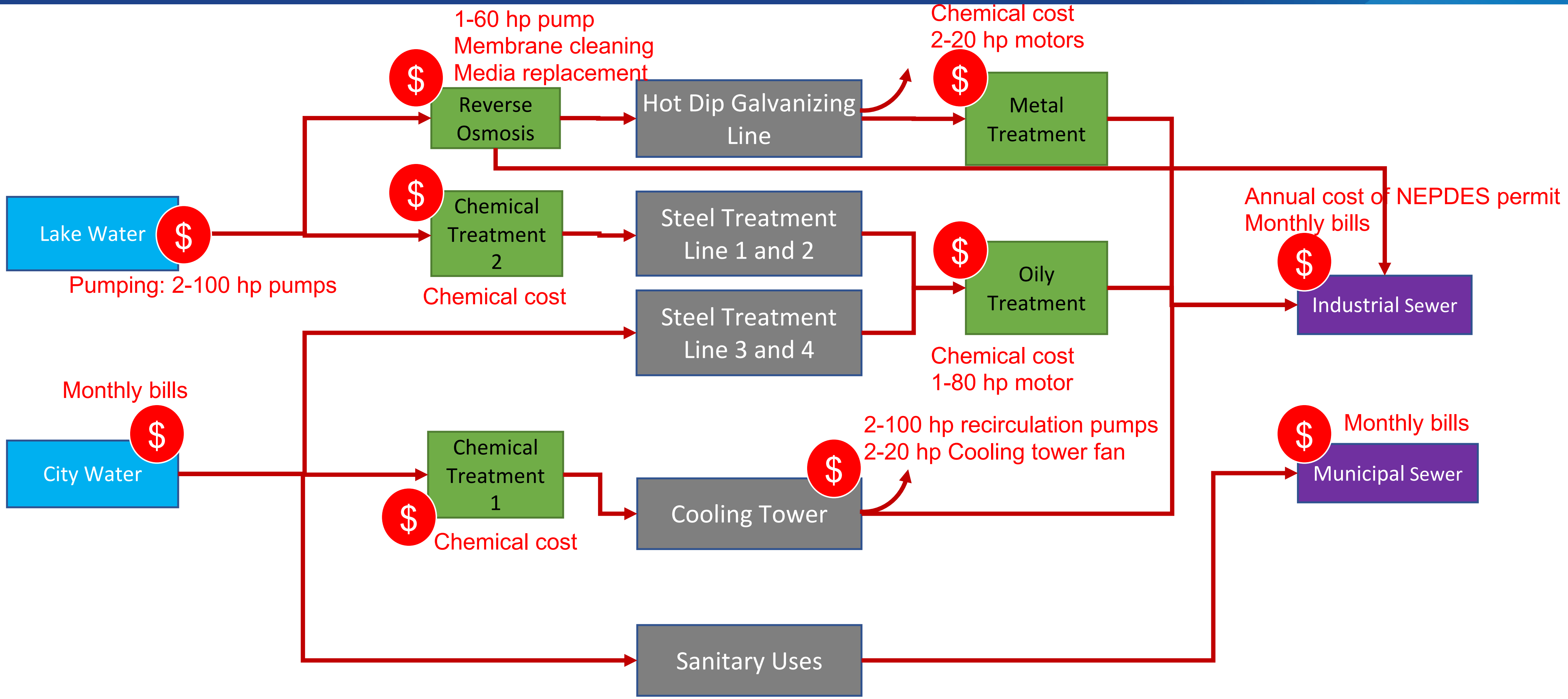


True Cost Exercise: Plant information

Following information has been collected from our example facility

- Utility bills for city water, sewer and electricity.
- Chemicals added from vendor
  - Cooling tower
  - RO system
  - Oily Waste
  - Metal Removal
- Nameplate data and run hours
  - Main Lake water Pump station
  - Cooling Tower System – Fans and pumps
  - RO System
  - Equipment's in Metal and Oily Removal

Identify True Cost Components



Utility Costs

- City water cost: $104.65/month fixed charge and $1.71/kGal usage charge

  City Water cost = (104.65*12) /(171.7*1000) + 1.71 = 1.72/kGal

- Domestic sewer cost: $18.22/month fixed charge and $1.14/kGal volume charge

  Domestic Sewer cost = (18.22*12) /(2.1*1000) + 1.14 = 1.24/kGal

- Industrial sewer cost: Variable monthly charge based on peak flow rate; sum of monthly bills = $588,000

  Industrial Sewer cost = 598000/(299.8*1000) = $2/kGal

- **Electricity cost: $0.05/kWh**

Polling Question 2

What is the cost of operating 2 recirculation pumps (100 hp, 80% efficiency, load factor = 0.7) 24hours a day throughout the year? Note: 1 hp is 0.746 kw ; Average electricity cost is $0.05/kWh

1.) $57,181/year
2.) $45,744/year
3.) $75,181/year
4.) Need more information

Total Energy Use(kwh/year) = kW * Load Factor * Hours of Operation per Year

kW = hp *0.746/ efficiency ; Cost/year = kwh/year * $/kwh

Pump energy use = (0.746*2*100*0.7/0.8)*8760 = 1,143,618 kWh/year

Pump electricity cost = $0.05/kWh * 1,143,618 kWh/year = $57,181/year

Pumping cost

Lake water:

- 2 recirculation pumps (100 hp, 80% efficiency, load factor = 0.7)
  - Pump energy use = (0.746*2*100*0.7/0.8)*8760 = 1,143,618 kWh/year
  - Pump electricity cost = $0.05/kWh * 1,143,618 kWh/year = $57,181/year

Cooling tower:

- 2 recirculation pumps (100 hp, 80% efficiency, load factor = 0.7)
  - Pump energy use = (0.746*2*100*0.7/0.8)*8760 = 1,143,618 kWh/year
  - Pump electricity cost = $0.05/kWh * 1,143,618 kWh/year = $57,181/year
- 2 cooling tower fans (20 hp, 80% efficiency, load factor = 0.7)
  - Motor energy use = (0.746*2*20*0.7/0.8)*8760 = 228,724 kWh/year
  - Motor electricity cost = $0.05/kWh * 228,724 kWh/year = $11,436/year
- Total electricity cost: $68,617

Polling Question 3

For the cooling tower that has a makeup of 49.2 MGY, the vendor charges a fixed cost of $800 a month for providing the chemicals and maintaining its proper operation. The feeder pumps are automated and operate sparingly, its energy use is negligible.

What is the unit cost of chemically treating the cooling tower makeup?

1.) $0.19 /kgal
2.) $0.29 /kgal
3.) $0.09 /kgal
4.) Need more information

Chemical cost ($800/month) = 12*800 = $9600; Unit cost = 9600/(49.2*1000) = $0.195/kGal

Water Treatment Cost

- **Chemical Treatment 1 for cooling tower**
  - Volume of water to be treated = 49.2 MGY
  - Chemical cost ($800/month) = 12*800 = $9600
  - Unit cost = 9600/(49.2*1000) = $0.195/kGal

- **Chemical Treatment 2 for steel treatment lines 1&2**
  - Volume of water to be treated = 126.1 MGY
  - Chemical cost ($1200/month) = 12*1200 = $14,400
  - Unit cost = 14400/(126.1*1000) = $0.114/kGal

Water Treatment Cost – RO System

- **RO System (Vantage® M84R036) operates throughout the year and has a pump motor that is 60 HP, 80% efficiency, load factor = 0.9**
  - Pump energy use = (0.746*60*0.9/0.8)*8760 = 441,110 kWh/year
  - Pump electricity cost = $0.05/kWh * 441,110 kWh/year = $22,056/year
- **Membrane cleaning costs $200 and is done 4 times a year)**
  - 200 x 4 = $800/year
- **The media is replaced semiannually and costs $1,000**
  - 2 x 1000 = $2,000/year
- Total cost = $24,856/year
- Unit cost = 24856/(76.1*1000) = $0.33/kGal

System Cutsheets can be used along with nameplate data as appropriate

Operating hours can be estimated or metered using runtime loggers

Membrane replacements and other operational cost can be got from Logs

SPECIFICATIONS

Model No**	Flow Rate Specifications GPM Nominal (m³/hr) Product*	Feed	Reject	Vessel Staging	Membrane Vessel	Membrane Quantity	Customer Connection Specifications Feed	Product	Reject	Utility Requirements*** High Voltage Service	High Voltage FLA	Pump HP	Approx Shipping Weight lb (kg)
M84R024	107 (24.3)	143 (32.5)	36 (8.7)	3:2:1	4	24	3"	3"	2"	480 VAC 3ph	67	50	5576 (2529)
M84R036	160 (36.3)	215 (48.8)	53 (12.0)	4:3:2	4	36	4"	4"	2"	480 VAC 3ph	79	60	6115 (2774)
M84R048	214 (48.6)	285 (64.7)	71 (16.1)	6:4:2	4	48	4"	4"	2"	480 VAC 3ph	79	60	6465 (2932)

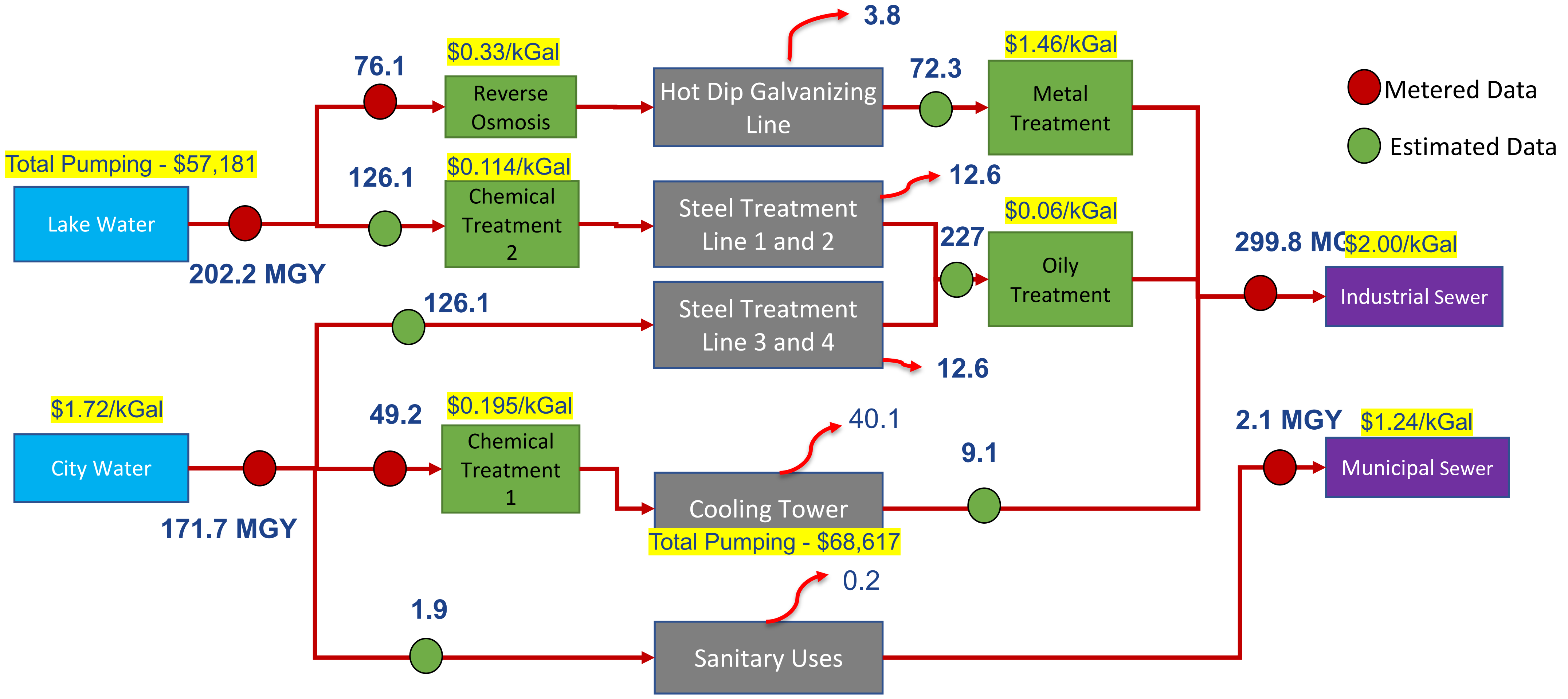
* Product flow rates are based on a flux rate of 16 GFD and equipment design parameters listed below. Product flow rates may not be appropriate for other feed waters.
** The 8 designates 8" housing, the 4 designates 4 elements in length, and the -R0XX designates the number of membranes.
*** Additional voltage options are available. Refer to equipment specifications.

Wastewater Treatment Cost

- **Metal wastewater treatment -** 2 motors (20 hp, 80% efficiency, load factor = 0.70)
  - Chemical cost = $15,000 annual
  - Motor energy use = (0.746*2*20*0.7/0.8)*8760 = 228,724 kWh/year
  - Pump electricity cost = $0.05/kWh * 228,724 kWh/year = $11,436/year
  - Total cost = $26,436
  - Unit cost = 26436/(18.1*1000) = $1.46/kGal

- **Oily wastewater treatment -** 1 motors (80 hp, 80% efficiency, load factor = 0.7)
  - Chemical cost = $8,000 annual
  - Motor energy use = (0.746*80*0.7/0.8)*8760 = 114,362 kWh/year
  - Pump electricity cost = $0.05/kWh * 228,724 kWh/year = $5,718/year
  - Total cost = $13718
  - Unit cost = 13718/(227*1000) = $0.06/kGal

Example Facility – With Data (Session 2)



True cost of water: facility wide

	Unit cost $/kGal	MGY	Total
City water	$ 1.72	171.7	$ 295,324
RO system	$ 0.33	19	$ 6,270
	$ 0.20	49.2	$ 9,594
	$ 0.11	126.1	$ 14,375
	$ 1.46	18.1	$ 26,426
	$ 0.06	227	$ 13,620
Cooling tower pumps and fans			$ 68,617
Lake water			$ 57181
Industrial sewer	$ 2.00	299.8	$ 599,600
Sanitary sewer	$ 4.24	2.1	$ 8,904
True cost of water			**$ 1,099,911**
Direct costs			**$ 903,828**
Ratio			**1.22**

Roundtable Discussions

Data Collection Sheet

Helps collect all the necessary data to complete the Plant Water Profiler Tool

Oak Ridge National Laboratory

Better Plants U.S. Department of Energy

Water In-Plant Training
Data Collection Sheet

Required Information Prior to Plant Visit

Company: Example Facility

Location: Knoxville, TN

Table of Contents

Homework #3

1. Collect the necessary facility level and system data needed to determine true cost for the facility
   - Complete sections 7 *to 9* in the data collection sheet provided.

Plant Water Profiler (PWP) Tool

The Plant Water Profiler (PWP) tool is a comprehensive excel-based tool designed for use by manufacturing plants to help perform a facility level water assessment

https://www.energy.gov/eere/amo/plant-water-profiler-tool-excel-beta-version-pwpex-v01

Plant Water Profiler Tool

Language:	English
Water Measurement Unit:	Million Gallons
Currency:	USD

Note: The Plant Water Profiler Tool is currently available in the English language only. It uses only Million Gallons for water use calculations and USD for cost calculations.

Disclaimer

This tool was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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