Making a Splash
Targeting Water Measures for Maximum Impact
Cutting Water Waste

DOE Began Working with Partners on Water Goals in 2015

• Saving water saves energy
• Cuts costs
• Improves resiliency
• Demonstrates environmental stewardship
Better Buildings Water Savings Initiative

- More than 40 Partners
- 9 Goal Achievers
- More than 6 billion gallons cumulative water savings
- 30+ solutions to common barriers, such as:
  - Making the business case for water savings
  - Tracking and managing water data

betterbuildingssolutioncenter.energy.gov/challenge/water-savings
Speakers

- Sachin Nimbalkar, Oak Ridge National Laboratory
- Hakon Mattson, Anthem Inc.
- Otto Van Geet, National Renewable Energy Laboratory
Plant Water Profiler (PWP) Tool for Industry

Sachin Nimbalkar
Mini Malhotra
Kristina Armstrong
Asha Shibu
Oak Ridge National Laboratory

Rochelle Samuel
Saint Gobain

T20-S8a - Making a Splash Targeting Water Saving Measures for Maximum Impact

Better Buildings Summit 2018
August 23, 2018 - 8:30 to 10:00 am
Cleveland, OH
Outline

• Need for Water Conservation/Efficiency in Industry
• Benefits of Water Conservation/Efficiency in Industry
• Plant Water Profiler (PWP) Tool Overview
• PWP Tool Methodology
• Significance of PWP Results for a Facility
• PWP Tool Demo
• Case Study – Beta Testing
• Summary
• Limitations and Future Work
Need for Water Conservation/Efficiency in Industry

## Benefits of Water Conservation/Efficiency in Industry

<table>
<thead>
<tr>
<th>Cost savings and operational improvements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of purchasing water for facility</td>
<td></td>
</tr>
<tr>
<td>Cost of material for water treatment</td>
<td></td>
</tr>
<tr>
<td>Cost of discharge water treatment</td>
<td></td>
</tr>
<tr>
<td>Cost of energy for heating and cooling water</td>
<td></td>
</tr>
<tr>
<td>Cost of energy for pumping water</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduce business risks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Interruption— Risk of disruption of water supply in supply chain</td>
<td></td>
</tr>
<tr>
<td>Regulatory- Risk of increased government regulation on water use</td>
<td></td>
</tr>
<tr>
<td>Access to capital- Risk of financial institution adopting stricter lending and investment based on water uncertainties</td>
<td></td>
</tr>
</tbody>
</table>
Plant Water Profiler (PWP) Tool Overview

• The Plant Water Profiler (PWP) tool (US Department of Energy, 2018) is a comprehensive tool designed for use by manufacturing plants to help their sustainability teams:

1. Understand the procurement, use, and disposal of water in their plants;
2. Be cognizant of the true cost of water, including the costs associated with water procurement, treatment, and consumption and wastewater disposal; and
3. Identify opportunities to reduce water use and achieve associated cost savings.
<table>
<thead>
<tr>
<th>Name</th>
<th>Sector/Spatial Scale</th>
<th>Purpose</th>
<th>Inputs</th>
<th>Output</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cummins Water Tool</td>
<td>Industrial facility (engine and power systems)</td>
<td>True cost of water</td>
<td>Facility water and energy use data, costs</td>
<td>True cost by system and cost category</td>
<td>(Dhennin, Personal Communication, 2017)</td>
</tr>
<tr>
<td>Colgate-Palmolive True Cost of Water Toolkit</td>
<td>Industrial facility</td>
<td>True cost of water</td>
<td>Facility water data, costs</td>
<td>True cost of water</td>
<td>(Colgate-Palmolive, 2014)</td>
</tr>
<tr>
<td>Veolia True Cost of Water tool</td>
<td>Industrial facility</td>
<td>True cost of water, water risk analysis</td>
<td>Facility water data, costs</td>
<td>Probability versus potential economic impact of each risk</td>
<td>(Veolia, 2014)</td>
</tr>
<tr>
<td>BIER True Cost of Water toolkit</td>
<td>Industrial facility (beverage industry)</td>
<td>True cost of water</td>
<td>Facility water data, costs</td>
<td>True cost by system and cost category</td>
<td>(BIER, 2015)</td>
</tr>
<tr>
<td>PepsiCo ReCon Tool</td>
<td>Industrial facility</td>
<td>True cost of water</td>
<td>Facility water data, costs</td>
<td>True cost of water</td>
<td>(Dallbauman, 2012)</td>
</tr>
<tr>
<td>Water Footprint Assessment Tool</td>
<td>Agricultural, industrial; global, country or basin level</td>
<td>Water footprint of processes and products</td>
<td>Water use and production data</td>
<td>Water footprint impact index, possible water footprint reduction targets and water footprint component</td>
<td>(Water Footprint Network, n.d.)</td>
</tr>
<tr>
<td>WBCSD Global Water Tool (GWT)</td>
<td>Country level (GWT–WRI)</td>
<td>Water risk analysis</td>
<td>Facility GPS location, facility water data</td>
<td>Water inventory, reporting indicators, global map of facilities overlaid with water-related map layers</td>
<td>(WBCSD, 2015)</td>
</tr>
<tr>
<td>WRI India Water Tool</td>
<td>Watershed level (GWT-University of New Hampshire); No distinction between industries</td>
<td>Water risk analysis</td>
<td>Facility GPS location, facility water data</td>
<td>Map showing areas of greatest groundwater availability and quality risks, reporting indicators, Ramsar-designated sites</td>
<td>(WRI, 2015)</td>
</tr>
<tr>
<td>GEMI Collecting the Drops: A Water Sustainability Planner tool</td>
<td>Industry, community, natural resource (facility-wide)</td>
<td>Develop water sustainability strategies</td>
<td>Facility water use, impact of operations on the regional water supply</td>
<td>Potential water reduction; water risk level</td>
<td>(GEMI, 2007)</td>
</tr>
<tr>
<td>GEMI Connecting the Drops Toward Creative Water Strategies</td>
<td>Industrial</td>
<td>Water risk analysis; develop water strategy</td>
<td>Facility water use data, business operation</td>
<td>Guide for developing and implementing water strategies</td>
<td>(GEMI, 2002)</td>
</tr>
<tr>
<td>GEMI Local Water Tool</td>
<td>Industrial (site and operation-specific)</td>
<td>Water risk analysis</td>
<td>Facility water use and discharge data</td>
<td>Water use metrics, external impact and risk levels</td>
<td>(GEMI, 2015)</td>
</tr>
<tr>
<td>WWF Water Risk Filter</td>
<td>Country or basin level; 35 industry sectors</td>
<td>Water risk analysis</td>
<td>Facility GPS location, type of industry, 30-question survey on physical, regulatory, and reputational data</td>
<td>Global map of facilities overlaid with water-related map layers: Physical, regulatory, and reputational risk at the basin and company level</td>
<td>(WWF, 2012)</td>
</tr>
<tr>
<td>Ecolab Water Risk Monetizer</td>
<td>Industrial</td>
<td>Water risk analysis</td>
<td>Facility water data, business information</td>
<td>Various metrics for incoming and outgoing water risks</td>
<td>(Ecolab, 2017)</td>
</tr>
<tr>
<td>WRI Aqueduct Tool</td>
<td>Administrative district or subdistrict level; No distinction among industries</td>
<td>Water risk analysis</td>
<td>Facility GPS location</td>
<td>Global map of facilities overlaid with a combination of 12 global water risk indicators</td>
<td>(WRI, 2014)</td>
</tr>
</tbody>
</table>
Plant Water Profiler (PWP) Tool: Methodology

1. Baseline Water Use and Water Balance
2. Determine True Cost of Water
3. Identify Water Efficiency Opportunities
Step 1 - Water Flow Model and Water Balance

Water Flow Model

System Water Balance

Plant Water Balance

Source, \( s \)

\( I_s \)

Evaporative Loss

Unknown Loss

Facility Boundary

System x

System y

System z

Wastewater Discharge Outlet, \( a \)

\( f_s(R_{in,s}) \)

\( f_x(R_{in,x}) \)

\( f_y(R_{in,y}) \)

\( f_z(R_{in,z}) \)

Products

\( f_s(W_{out,s}) \)

\( f_x(W_{out,x}) \)

\( f_y(W_{out,y}) \)

\( f_z(W_{out,z}) \)

Water Flow Model

System Water Balance

Water Flow Model

System Water Balance

Plant Water Balance

Source Water

Incoming Water

Water Used in Products

Wastewater Discharge

Recycled to Other Systems

Source Water

WATER USING SYSTEM
SYSTEM WATER BALANCE
Incoming Water – Outgoing Water = Unknown Losses

PLANT
PLANT WATER BALANCE
Source Water – Outgoing Water = Unknown Losses

Conservative Loss
(Evaporation/Irrigation)

Water Used in Products

Wastewater Discharge

Recycled to Other Systems

Unknown Water Losses

Unknown Water Losses
Step 2 - Water Flow Diagram with True Cost Components
Step 3 - Identify Water Efficiency Opportunities

- User answers system-specific questions to evaluate water efficiency status on system-level and to identify potential opportunities.

<table>
<thead>
<tr>
<th>Water Saving Opportunity Level</th>
<th>Scorecard</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling/condensing for process</td>
<td>Has once-through cooling water been eliminated with the use of chillers, cooling towers, or air-cooled equipment?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Has blow-down/bleed-off control on cooling towers been optimized?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Is treated wastewater (or other sources of water for cooling tower make-up) reused where possible?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Are cycles of concentration for cooling towers maximized through efficient water treatment?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Is a conductivity controller installed on each cooling tower?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Have cooling towers been equipped with overflow alarms?</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Are high-efficiency drift eliminators in use?</td>
<td>No</td>
</tr>
<tr>
<td>Cooling/condensing for air conditioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler for Facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchen and Restrooms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaping</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Significance of Results for a Facility

**Water Use Intensity**
- Establishes baseline to track water use and savings over the years
- Allows comparison with industry average (motivation to conserve/save)

**Plant & System Water Balance**
- Quantifies unknown water losses to be eliminated (low-cost/no-cost measure)

**True Cost of Water**
- Reveals hidden costs of using water
- Identifies cost-intensive systems to help prioritize measures, accordingly

**Savings from eliminating losses and maximizing recirculation**
- Provides realizable saving estimates from low-cost/no-cost measures

**Recommendations**
- Steps to follow to save water and associated costs
Case Study - Beta Testing
Facility Description & PWP Tool Results*

Manufacturing Facility
• CertainTeed – Saint Gobain North America’s (SGNA) siding products manufacturing facility
• Produces millions of sqft of polymer siding using injection molding process.

Plant’s water consuming systems
• Cooling and condensing for process operation
• Kitchens and restrooms
• Landscaping and irrigation
• Fire sprinkler system

Plant’s water intake and discharge
• Potable municipal water intake; metered
• Discharged to municipal sewer; unmetered*
  *Sewer charges based on % of water intake

Existing submeters
• For cooling system incoming water and blowdown; however, metered data was not recorded ⇒ Data collection challenge

*Provided by Saint Gobain North America
Comparison with Industry Average

Source Water Intake Benchmark using EIO-LCA data

- CertainTeed facility NAICS code 32619: Other Plastics Product Manufacturing
- There is not a specific industry code for polypropylene siding products

Comparison with Industry Average

- As per our initial findings, the facility performed below average with its peers for the amount of water used in its cooling/condensing processes
- Performed well for using no water in its manufacturing process, and for low amounts of water used in the sanitary and domestic processes
- Scored well for its low wastewater discharge.
- Sub-metered data is essential to get more reliable results
Case Study – Beta Testing
Takeaways/Lessons Learned*

Recommendations for the plant

- **Short-term:** Continuously monitor and record all cooling system meters and use this info to check water/sewer bills
- **Long-term:** Connect meters to network so data is uploaded continuously

- Borrow/rent/buy a flow meter to determine non-metered flows such as sewer (DOE Better Plants Equipment Loan program)

- Consider capturing and treating blowdown for other purposes

*Provided by Saint Gobain North America
Case Study – Beta Testing
Takeaways/Lessons Learned*

Recommended process for water audit

<table>
<thead>
<tr>
<th>PRE AUDIT (Company's Water Audit Team)</th>
<th>AUDIT (Water Audit Team &amp; Plant Manager)</th>
<th>POSTAUDIT (Plant Manager)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact sites with pre-audit questionnaire</td>
<td>Kickoff webinar with selected site(s) on audit process</td>
<td>Visit site &amp; review data collected</td>
</tr>
<tr>
<td>Screen sites based on metering/data collection ability</td>
<td>PWP Tool sent to site for completion</td>
<td>Review results with site, resolve issues, make recommendations</td>
</tr>
<tr>
<td></td>
<td>3-4 WEEKS (6-8 MONTHS W/O METERS)</td>
<td>1-2 WEEKS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 DAYS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site implements recommendations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site conducts annual audits &amp; tracks water use</td>
</tr>
</tbody>
</table>

*Provided by Saint Gobain North America
Plant Water Profiler (PWP) Tool: Summary

• Benchmarking functionality allows comparison with industry averages, which serves as a motivation to save water.

• The water balance steps quantify the unknown water losses to be eliminated, which are usually low-cost/no-cost measures.

• The true cost of water reveals the hidden costs of using water and identifies cost-intensive systems to help prioritize measures, accordingly.

• The estimate of savings from eliminating losses and maximizing recirculation provides realizable saving estimates from low-cost/no-cost measures.

• The water-efficiency recommendations provide a facility a list of steps to follow to save water and associated costs.
Limitations and Future Work

• The scope of PWP is the facility boundary.

• Good understanding of water flows in the plant needed, especially if submetering is not done on system level.

• PWP doesn’t factor in equipment-related costs, indirect costs, and economic factors (discount rate, inflation).

• It doesn’t account for a company’s water-related business risks or impacts because there is no context for the facility’s water use within the watershed.

• It doesn’t account for the indirect embodied energy — i.e., energy used indirectly and offsite during different life stages of water/wastewater systems.

• PWP doesn’t quantify savings from or conduct a cost-benefit analysis of installing water-saving devices and implementing specific measures; it only estimates potential savings associated with reducing water use by eliminating quantified losses and increasing recirculation.
Download PWPEx Tool - Beta Version

Questions

Sachin Nimbalkar, nimbalkarsu@ornl.gov
Unmetered Facility - Water Use Calculations

**Cooling Tower System**

- **Evaporation**
  - Water Sprayed Downwards
  - Water with Concentrated Mineral Salts
- **Recirculated Water**
- **Heat Exchanger**
- **Chiller**
- **Cooling Load**
- **Evaporation**
- **Recirculated Water**

**Rules of Thumb**

- **Load as a Fraction of Chiller Tonnage**, the typical range is 0.5 - 0.8
- **For “Evaporation Rate per 10°F Temp. Drop,” 0.85% is a typical value**, and the typical range is 0.65% for moist climate to 1.0-1.2% for very dry climate.
- **For “Temp. Drop Across Cooling Tower,” typical range 10-15°F**

**Boiler System**

- **Recirculated Water (Condensate Return)**
- **Evaporation Loss (Steam Lost)**
- **Heating Load**
- **Steam**
- **Makeup Water (From Source or Other Systems)**
- **Pump**
- **Feedwater**
- **Blowdown (To Wastewater Discharge or Other Systems)**
- **Desorber**
- **Boiler**

**Rules of Thumb**

- **“Steam Generation Rate per Horsepower” is 34.5 lb/h at 212°F.**
- The total annual water use associated with your boiler system(s) can be estimated by knowing either of the following:
  - Softener Performance
  - Steam Generation Rate


Better Buildings Summit - Making A Splash

How Anthem Reduced Water Usage by 30% in less than 4 years!
Leadership Commitment  
Benchmark Locations  
Set Goal  
Identify & Prioritize Projects  
Dedicated Budget  
Measure & Report
2013 Anthem Real Estate Footprint
~9 million ft²
- California: 74%
- Richmond: 15%
- Other: 11%

2013 Anthem Water Footprint
131,000 Kgal
- California: 41%
- Richmond: 35%
- Other: 24%
June 2014
5,353 Kgal

August 2017
2,810 Kgal
Otto Van Geet, PE - NREL

NREL

ESIF Data Center Water Use Reductions
NREL Data Center

Showcase Facility

• ESIF 182,000 ft.$^2$ research facility
• 10,000 ft.$^2$ data center
• 10-MW at full buildout
• LEED Platinum Facility, PUE ≤ 1.06
• NO mechanical cooling (eliminates expensive and inefficient chillers)

Data Center Features

• Direct, component-level liquid cooling, 24ºC (75ºF) cooling water supply
• 35-40ºC (95-104ºF) return water (waste heat), captured and used to heat offices and lab space
• Pumps more efficient than fans
• High voltage 480-VAC power distribution directly to high power density 60-80-kW compute racks

Compared to a Typical Data Center

• Lower CapEx—costs less to build
• Lower OpEx—efficiencies save

Utilize the bytes and the BTUs!
Metrics

\[
PUE = \frac{\text{"Facility energy"} + \text{"IT energy"}}{\text{"IT energy"}}
\]

\[
ERE = \frac{\text{"Facility energy"} + \text{"IT energy"} - \text{"Reuse energy"}}{\text{"IT energy"}}
\]

Assume ~20MW HPC system & $1M per MW year utility cost.
Metrics

WUE = \frac{“Annual Site Water Usage”}{“IT energy”}

the units of WUE are liters/kWh

WUESOURCE = \frac{“Annual Site Water Usage” + “Annual Source Energy Water Usage”}{“IT energy”}

WUESOURCE = \frac{“Annual Site Water Usage”}{“IT energy”} + [EWIF \times PUE]

where EWIF is energy water intensity factor
Air- and Water-Cooled System Options

Air-Cooled System
• Design day is based on DRY BULB temperature
• Consumes no water (no evaporative cooling)
• Large footprint/requires very large airflow rates

Water-Cooled System
• Design day is based on the lower WET BULB temperature
• Evaporative cooling process uses water to improve cooling efficiency
  o 80% LESS AIRFLOW \(\rightarrow\) lower fan energy
  o Lower cost and smaller footprint.
• Colder heat rejection temperatures improve system efficiency

However, water-cooled systems depend on a reliable, continuous source of low-cost water.
Traditional Wet Cooling System

- **Process Loop**
  - Heat In
  - Condenser
  - Condenser Water Pump
  - Wet Loop
    - Sized for Design Day Thermal Duty
  - Moist Heat Out
  - 95°F (35.0°C)
  - 75°F (23.9°C)

Temperatures:
- **95°F (35.0°C)**
- **75°F (23.9°C)**
Basic Hybrid System Concept

- **95°F (35.0°C)** (Dry Heat Out)
- **85°F (29.4°C)**
- **75°F (23.9°C)**
- **75°F (23.9°C)** (Moist Heat Out)

**Dry Loop**
- Sized for Design Day Thermal Duty
- Dry Sensible Cooler

**Wet Loop**
- Sized for Water Savings
- Condenser Water Pump

**Process Loop**
- "Wet" when it’s hot, “dry” when it’s not.
Improved WUE—Thermosyphon
Applications

Any application using an open cooling tower is a potential application for a hybrid cooling system, but certain characteristics will increase the potential for success.

**Favorable Application Characteristics**

- Year-round heat rejection load (24/7, 365 days is best)
- Higher loop temperatures relative to average ambient temperatures
- High water and wastewater rates or actual water restrictions
- Owner’s desire to mitigate risk of future lack of continuous water availability (water resiliency)
- Owner’s desire to reduce water footprint to meet water conservation targets
Sample Data: Typical Loads and Heat Sinks
First year of TSC operation (9/1/2016–8/31/2017)

- **Hourly average IT Load**: 888 kW
- **PUE**: 1.034
- **ERE**: 0.929

**WUE** = 0.7 liters/kWh

(with only cooling towers, **WUE** = 1.42 liters/kWh)

**Annual Heat Rejection**

- **WUE_{SOURCE}** = 5.4 liters/kWh
- **WUE_{SOURCE}** = 4.9 liters/kWh if energy from 720 kW PV (10.5%) is included
  - using EWIF 4.542 liters/kWh for Colorado
Otto Van Geet, PE
Principal Engineer, NREL
Otto.vangeet@nrel.gov