CIFAR Water Energy Nexus
Technical Support Services

Background

The California Institute of Food and Agricultural Research (CIFAR) at the University of California Davis (UCD), provides technical expertise to food and beverage processing facilities to conduct Water-Energy Nexus (WEN) Assessments. To provide these services, CIFAR integrates knowledge from UC Davis professors and field specialist along with the experience of senior engineer sub-contractors who are ASME Certified Practitioners in industrial process system evaluations[1].

CIFAR's Relevant Capabilities

CIFAR's staff, associates and sub-contractors offer field experience working in the operations and management of food and beverage processing facilities. Moreover, they uniquely couple this experience with an ability to assess efficiency in industrial water and energy systems. CIFAR has leveraged these capabilities to design and implement resource conservation demonstration projects and perform economic assessments of existing and emerging technology investments. CIFAR also conducts measurement and verification activities.

CIFAR is housed at the UCD Department of Food Science and Technology with access to research and implementation facilities at the California Processing Tomato Industry Pilot Plant, the August A. Busch III Brewing and Food Science Laboratory and the Milk Processing Laboratory. CIFAR is also associated to the Viticulture and Enology Department and the Robert Mondavi Institute. CIFAR's work with wineries is supported by the Jess Jackson Sustainability Winery. "This facility opened on May 2013, to fulfill a vision of sustainability that allows UC Davis and the wine and food industries to reach a new level in conservation of water, energy and natural resources."[2]

Views of the Robert Mondavi and the Jess Jackson Sustainability Winery Facilities at UC Davis

CIFAR utilizes the data collection protocols and software tools developed by the ASME's Industrial Best Practices (BP) program.[3] These tools are used to model the performance of the

[1] American Society Mechanical Engineers, http://www1.eere.energy.gov/energymanagement/assistance.html
[2] Professor Roger Bolton, director The Jess Jackson Sustainability Winery. http://rmi.ucdavis.edu/news/news-items/the-jess-jackson-sustainable-winery-building-is-now-open
[3] Energy Resource center, Advanced Manufacturing Office, US DOE http://www1.eere.energy.gov/manufacturing/tech_assistance/ecenter.html

steam, pumping and fan systems used in industrial facilities to process fresh water and wastewater. Using these tools, CIFAR has developed a Water-Energy Nexus (WEN) Assessment methodology to identify and evaluate potential industrial water conservation opportunities and energy efficiency measures.

The WEN Assessment incorporates a systems approach to account for the interdependence and differentiation that exists in both the supply-side and the demand-side of the water-energy nexus. The WEN Assessment evaluates the fresh water and wastewater systems at food and beverage processing facilities and other water intensive industrial facilities. The WEN Assessment methodology requires data collection to estimate efficiency of pumps, fans, boilers, turbines and other equipment dedicated to industrial water-related activities.

Each conglomeration of equipment engaged in the WEN relationship is identified as a WEN Point. The supply-side WEN Point includes the equipment to pump groundwater and to operate filters and water treatment equipment. In the demand-side, among others, the collection, treatment and discharge of wastewater is identified as a WEN Point. All supply and demand-side WEN Points are identified and measured to estimate a Water Energy intensity (WEi) ratio, for the facility as a whole and for each WEN Point.

CIFAR's capabilities will be utilized to deliver the following professional expertise:

1. Design and analysis of thermodynamic processes
2. Design and analysis of industrial water treatment processes
3. Assessment of on-site water reclamation, recycling and reuse in the industrial sector
4. Water and wastewater management
5. Water system feasibility studies
6. Economic and financial analysis
7. Water-use efficiency assessments and surveys
8. Knowledge of industrial waste processes and discharge requirements
9. Qualifications to provide cross platform analysis, measurement and recommendations within the water/energy nexus
10. Analysis of potential to generate bioenergy from the treatment of liquid and solid residue streams

The CIFAR methodology can be utilized at any industrial food and beverage processing facility as well as other water-intensive industrial sectors. Additionally, the methodology could be adapted to evaluate the performance of water systems in the commercial and institutional sectors as well.

Practical Experience Implementing the CIFAR WEN Assessment

The WEN Assessment methodology was successfully implemented in 2012, at the Campbell Soup, tomato processing facility in Dixon California[4]. Comprehensive technical reports were published for Campbell Soup to document the results of the WEN assessment. In brief, the following resource conservation and efficiency improvements were identified and recommended:

- Achieve water conservation from "tomato water" recovery opportunities
- Improve Energy Efficiency Measures (EEMs) to lower WEi in boiler feedwater and wastewater discharge systems

[4] Amón, R, Wong, T, Kazama, D, Maulhardt, M, Campbell Soup Water Energy Nexus Assessment, 2013.

- Improve steam system condensate recovery
- Redesign wastewater discharge pumping system

The adoption of these recommendations can deliver economic benefits from reduced groundwater pumping and lower wastewater surcharges, as well as environmental benefits by preserving ground water resources, lower air pollution emissions and reduced wastewater discharge. The emission reduction benefits available from implementing recommendations can also help industrial facilities comply with California's Cap and Trade program.

CIFAR is conducting a WEN Assessment at the Ingomar Packing Company tomato processing facility in Los Banos, California. By early 2014, CIFAR will deliver technical reports to Ingomar, establishing a WEN baseline and identifying water conservation and efficiency opportunities. The baseline will be used to compare the economic and environmental benefits of adopting industrial Best Practices.

CIFAR's Systems Approach

CIFAR performs water energy system assessments of industrial facilities utilizing a whole-systems approach. Specifically, this methodology includes the following elements.

Fresh Water and Wastewater System Assessments

CIFAR conducts walkthrough inspections at industrial facilities to identify Supply and Demand WEN Points. An inventory of the equipment that powers and consumes water at each of these WEN Points is conducted, including pumps, boilers, fans, turbines, evaporators, cookers, kettles, and other demand-side equipment.

ASME Energy System Assessments (ESAs) are conducted to estimate individual equipment and system efficiencies. WEi metrics are calculated for each WEN Point, establishing a baseline of information. Water conservation and energy efficiency measures are identified and documented. Support is offered to implement recommendations using a Continuous Systems Improvement (CSI) approach.

Steam System Assessments

If the industrial facility produces steam or hot water using industrial boilers, a Steam Energy System Assessment (Steam ESA) is conducted to estimate the ratio of gallons of water used per pound of steam produced.

CIFAR conducts a Steam ESA utilizing ASME data collection protocols and evaluation software tools[5]. The ESA's whole systems approach includes data collection and analysis of the steam system's generation, distribution, end-use and recovery assets. The Steam ESA calculates system efficiency and identifies water and energy conservation measures. The Steam ESA also identifies electric energy efficiency and conservation opportunities to improve the steam system's water supply and recovery infrastructure.

The following information is obtained to conduct the Steam ESA:

- Natural gas consumption, costs, annual operating hours, boiler nameplate information

[5] US DOE Steam Systems Program
http://www1.eere.energy.gov/manufacturing/tech_deployment/steambasics.html

- Steam generation system data: boiler flue gas temperature and oxygen content are measured to estimate boiler efficiency; and blow down rates are estimated or measured; boiler feedwater and fresh water makeup flows are estimated or measured; boiler firing rates are estimated
- Steam distribution system data: wall temperature of steam distribution system is measured to estimate piping insulation needs; and the number of steam traps in the system are estimated and their general operating conditions noted
- Steam end use and condensate systems data: amount of steam used by processes and steam turbines, and amount of condensate return
- Feedwater and condensate return systems power data: motor and pump name plate, flow rates and total dynamic head data of installed motors and pumps
- Maintenance information

The Steam ESA provides an evaluation of the facility's boiler efficiency and identifies opportunities to enhance steam system productivity. The following examples are identified from Steam ESAs conducted at tomato processing facilities[6].

Supply-side efficiency improvements may include: installation of blow down heat exchangers, blow down flash steam recovery systems, insulating the boiler's main steam valves, installing and maintaining steam traps and the installation of fuel and steam flow meters.

Demand-side efficiency improvements may include infrastructure projects and industrial Best Practice measures, i.e., installation of insulation on uncovered valves and piping in the distribution system, insulating process heat exchangers, new steam traps and steam trap maintenance programs, and the installation of condensate drainage systems on steam headers.

Any improvements to the performance of the steam system will result in a reduced amount of water used per pound of steam produced. Understanding the performance of the steam system and addressing system inefficiencies is critical to achieving water conservation and efficiency improvements at industrial facilities.

Pumping System Assessments
After the Steam ESA is completed, CIFAR conducts a Pump Energy System Assessment (Pump ESA) utilizing ASME data collection protocols and data evaluation software tools[7]. The Pump ESA includes an inventory of all motors, pumps, fans and steam turbines used to power and cool process water in the facility.

The following information is obtained to conduct the Pump ESA:

- Electricity demand, consumption and cost
- Operating hours
- Pump and motor nameplate ratings
- Operating duty (fraction of time the pump runs at specified condition)
- Flow rate

[6] Amón, R, Wong, T, Kazama, D, Maulhardt, M. Tomato Processing Facility; Steam System Assessment, California Energy Commission, December 2012.
[7] US DOE Industrial Best Practices Program http://www1.eere.energy.gov/manufacturing/tech_deployment/software_psat.html

- Pump total head (calculated from pressure and line dimensional data)
- Electric power current and voltage
- Maintenance information

A site-specific Pump Calculator (Calculator) is developed to evaluate each pump performance and derive the WEi ratios. The Calculator is used to identify the WEN Points where Overall Pumping Efficiency (OPE) can be improved. The improvements will increase pumping plant productivity and reduce total kilowatt hours (kWh) of electricity used per unit of water pumped. The calculator also shows technical deviations among pumps that may be under- or over-sized. The Pump ESA results are used to establish a baseline of information that can be used to compare results after recommended resource improvements are adopted.

Table 1 presents the summary data that was obtained through the Pump ESA conducted at a tomato processing facility[8]. The results provide a measure of how much energy (kWh) is used for every 1,000 gallons of water used. It also provides a measure of the total number of gallons of water used per ton of raw tomatoes processed at the facility.

Table 1. Example of Overall Water Energy Nexus

Facility Water Energy Nexus	Values
Total Water Pumped (Gallons)	357,297,000
Total WEN Pumps (kWh)	3,902,929
WEN Intensity (kWh/1,000G)	11
Processed Tomatoes (Tons)	15,750,000
WEN Intensity (PT/1,000G)	44

As previously mentioned, the water energy relationship of each WEN Point is established by the Pump ESA. Table 2 provides a summary of the WEi from supplying water to the tomato processing facility. The data is used by managers to evaluate the efficiency of the equipment that supply water to the facility.

Table 2. Supply-Side Water Energy Intensity

Supply -Side Well Pump Energy Intensity	**Water G/2250h**	**kWh**	**kWh/1000G**	**G/kWh**
North Well	189,297,000	456,233	2.41	415
South Well	168,000,000	291,240	1.73	577
Both Wells	357,297,000	747,473	2.09	478

Another example of the WEN Point analysis conducted with the Pump ESA is shown in Table 3.

[8] Amón, R, Maulhardt, M, Wong, T, Kazama, D. Water Energy Nexus at a California Tomato Processing Facility; Pumping System Assessment, California Energy Commission, December 2012.

It provides data to evaluate the performance of equipment dedicated to wastewater systems.

Table 3. Wastewater Pumping System WEi

Wastewater Energy Intensity	Water G/2250h	kWh	kWh/1,000G
In-Plant Pump Delivery System	183,708,000	20,042	0.11
Flume Pond System	153,792,000	30,460	0.20
Central Wastewater System	337,500,000	89,653	0.27

Wastewater Treatment Process Evaluation and Selection

To fully understand the wastewater system at industrials facilities, CIFAR conducts targeted WEN assessments concentrating efforts in the wastewater WEN Points. The following methodologies are used to identify highest priority opportunities.

Goals

- Develop strategies for decreasing biochemical oxygen demand (BOD) and total suspended solids (TSS) in wastewater effluent prior to disposal
- Determine which wastewater effluent streams can be segregated for reuse
- Reclaim energy from liquid and solid biomass residues for use by the plant

Approach

- Identify all locations where water is consumed and wastewater is produced, treated and discharged
- Characterize water quality of individual effluent streams to consolidate reusable streams and separate them from discharge streams
- Potential to produce biogas from waste biomass via anaerobic digestion

Methods

- Conduct a process analysis to identify and characterize the WEN equipment, collect data and evaluate operational efficiencies
- Collect samples of effluent streams; conduct BOD, chemical oxygen demand (COD), TSS, and compositional analyses; and perform bench-scale anaerobic digestion tests to estimate BOD, TSS removal and biogas potential
- Collect effluent samples from each source operation and characterize water quality using standard United States Environmental Protection Agency (EPA) metrics to estimate reuse potential for each effluent stream
- Collect solid residue biomass samples; conduct BOD, COD and compositional analyses, and perform preliminary anaerobic digestion tests to estimate biogas production potential

The results from the WEN Assessment (Steam, Pump and Wastewater ESAs) provide a comprehensive understanding of the industrial water system. The analysis of these results and the establishment of WEi base line metrics are required to identify water conservation opportunities and EEMs. CIFAR publishes technical reports with calculations, analysis and recommendations, accounting for economic and environmental benefits.

CIFAR Qualifications

Within CIFAR, the Energy Nexus Group provides technical expertise to conduct Water Energy Nexus Assessments. CIFAR staff, associates and sub-consultants develop project research methodologies, undertake data collection surveys and conduct energy system assessments.

The CIFAR Water Energy Nexus Group includes the following personnel:

Dr. Sharon Shoemaker is CIFAR Director and the Principal Investigator (PI). The PI provides administrative support to the Water Energy Nexus Group.

Mr. Ricardo Amón, Water Energy Nexus Group Lead. Provides expertise to design and manage industrial and agricultural resource conservation and efficiency projects, collects field data, conducts data analysis and evaluation, compiles ESA data results and writes technical reports. Provides work scope coordination and supervision, writes progress reports and administers funding.

Mr. Mike Maulhardt, Food Industry Expert. Provides expertise in the management and operations of food industry facilities; collects field data and conducts data analysis and evaluation.

Dr. Chris Simmons, Food Science and Technology, Energy Efficiency Center, UC Davis Assistant Professor. Provides expertise in wastewater treatment strategies; collects field data and conducts data analysis and evaluation to determine the potential to convert organic residues to bioenergy resources.

Mr. Donald Kazama, P.E., Mechanical Engineer; Principal, KWW Energy Services LP; sub-consultant. ASME Certified Practitioner. Conducts Steam, Pump, and Compressed Air ESAs; collects field data and conducts data analysis and evaluation.

Mr. Tony Wong, P.E., Mechanical Engineer; Principal KWW Energy Services LP; sub-consultant. ASME Certified Practitioner. Conducts Steam and Pump ESAs; collects field data and conducts data analysis and evaluation.

Mr. Joseph Wang, P.E., Mechanical Engineer; Principal, KWW Energy Services LP; sub-consultant. ASME Certified Practitioner. Conducts Steam and Pump ESAs; collects field data and conducts data analysis and evaluation.

Mr. Ken Henderson, P.E., Civil Engineer; Associate, KWW Energy Services LP; sub-consultant. Provides expertise in wastewater management practices; collects field data and conducts data analysis and evaluation.

UC Davis under-graduate students. Provide services to collect field data and conduct laboratory data analysis.

CIFAR’s Performance

The CIFAR Energy Nexus Group has demonstrated knowledge and experience of process engineering; engineering economic and financial analysis; industrial sector water use and practices; industrial water treatment processes; wastewater management and recycling; specification of water conservation improvements and advances in the treatment of wastewater and solid residues for conversion to bioenergy resources.

CIFAR is currently completing the second year of a water energy nexus food industry contract with the California Energy Commission. The results of this contract have demonstrated successful ability to organize, interpret and evaluate data, to accurately review, analyze, and prepare technical reports, to prepare case studies and to deliver oral presentations.

The managers at the Campbell Soup Dixon California, facility can also attest to CIFAR’s professionalism delivering valuable technical information and cost saving recommendations. All these services have been delivered within the agreed upon schedules.