The California Institute of Food and Agricultural Research (CIFAR)

University of California (UC) Davis

Session IV: Introduction to Sustainable Manufacturing

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Calrecycle Zone Works Workshop
November 14, 2013

CIFAR Technical Support Services To Food And Beverage Industrial Facilities

- CIFAR integrates knowledge and resources from UC Davis researchers, field specialists and US Department of Energy (DOE) Best Practices (BP) Qualified Specialists

- CIFAR conducts Energy System Assessments (ESAs) for steam, compressed air, process heat, pump and fan systems

- CIFAR coordinates delivery of intermediate, advanced and qualifications DOE Industrial BP training workshops

- CIFAR conducts Water-Energy Nexus (WEN) Assessments

- CIFAR conducts wastewater and organic solid residue to bioenergy assessments

Introduction to Sustainable Manufacturing

A **Whole Systems Approach** that integrates **skilled labor** with the **proper** use of industrial manufacturing equipment, to **best** utilize the consumption of production **resources**

A Whole Systems Approach

Identifies the **inter-connections** that exit within an industrial production system to **reveal** inefficiencies and **discover** opportunities to **optimize** not only the performance of **system components** (steam, compressed air, pumps, cooling towers) but **the system as a whole**

Integrates Skilled Labor with Proper Use Of Industrial Manufacturing Equipment

Skilled Labor requires education and training to **best** operate system components and maintain system **efficiency. Proper** use of industrial equipment (boilers, compressors, pumps) requires **oversight** to evaluate system **performance** (steam, air, water), and to repair and replace components (impellers) **to maintain operational system efficiency**

Best Utilize the Consumption of Production Resources

Industrial Energy – Depends on Fossil Fuels

60% on-site burned natural gas and liquid fuels
40% delivered electricity consumption

Industrial Water – Depends on Ground Water and Surface Water Sources

A medium-sized tomato processing facility can utilize over 350 million gallons of fresh water to process over 1,000 tons of tomatoes per season

Industrial Waste Water – Discharged on Land or Processed at Waste Water Treatment Facilities

17 California tomato processing facilities annually discharge 5.7 billion gallons of wastewater

Industrial Air – Discharged CO2, NOx and Particulate Air Emissions

A medium-sized tomato processing facility can emit over 30,000 metric tons of carbon dioxide per season

Resource Efficiency is Sustainability

Adopting Efficiency Is Not A Risk

- Efficiency requires **leadership**
    - To continuously **assess** whole system performance
    - To continuously **improve** operational efficiency
- Efficiency requires **skilled labor**, engineers and managers
- Efficiency requires a systematic **continuous improvement process**

Practicing Industrial Efficiency

Evaluate the performance of all **energy assets** to establish a **base line**, to identify **resource conservation** and efficiency measures, to adopt **continuous improvement** practices.

Evaluate the **potential** to capture and reuse **waste heat**, to generate combined heat and power, to **integrate** efficiency with the use of **renewable energy** – solar PV, solar thermal, bioenergy

Adopt Industrial Best Practices

Industrial BPs are continuously used by **skilled labor** to reduce overall **energy intensity** per unit of product produced (therms/ton) and to reduce **water energy intensity** per unit of resource used (kWh/1000 gallons of water)

UC Davis Sustainable Winery Building

This $4 million state-of-the art building will enable the adjacent teaching and research winery, brewery and food-processing facilities to operate in a self-sustainable manner through onsite capture of energy and water. http://news.ucdavis.edu/search/news_detail.lasso?id=10608

The 8,500 square-foot building will house equipment and systems to capture and sequester carbon dioxide from wine fermentation, and to filter and recirculate water for wine, beer and food processing. The building is expected to be certified Net Zero Energy under the Living Building Challenge. http://news.ucdavis.edu/search/news_detail.lasso?id=10608

Continuous Improvement and Industrial System Assessments

Continuous Energy Improvement

The Compressed Air Challenge

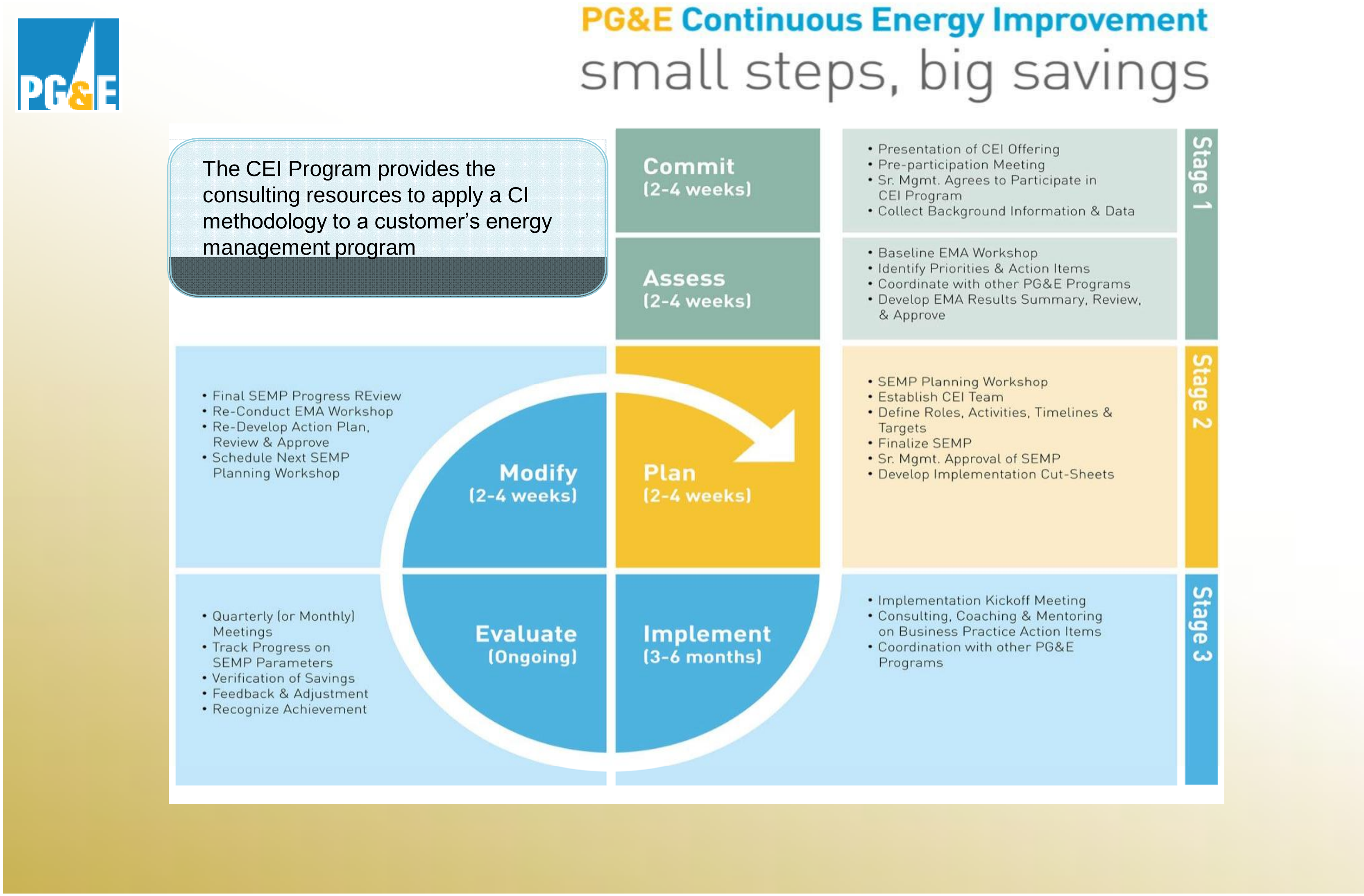
The Steam System

The Motor, Pump and Fan Systems

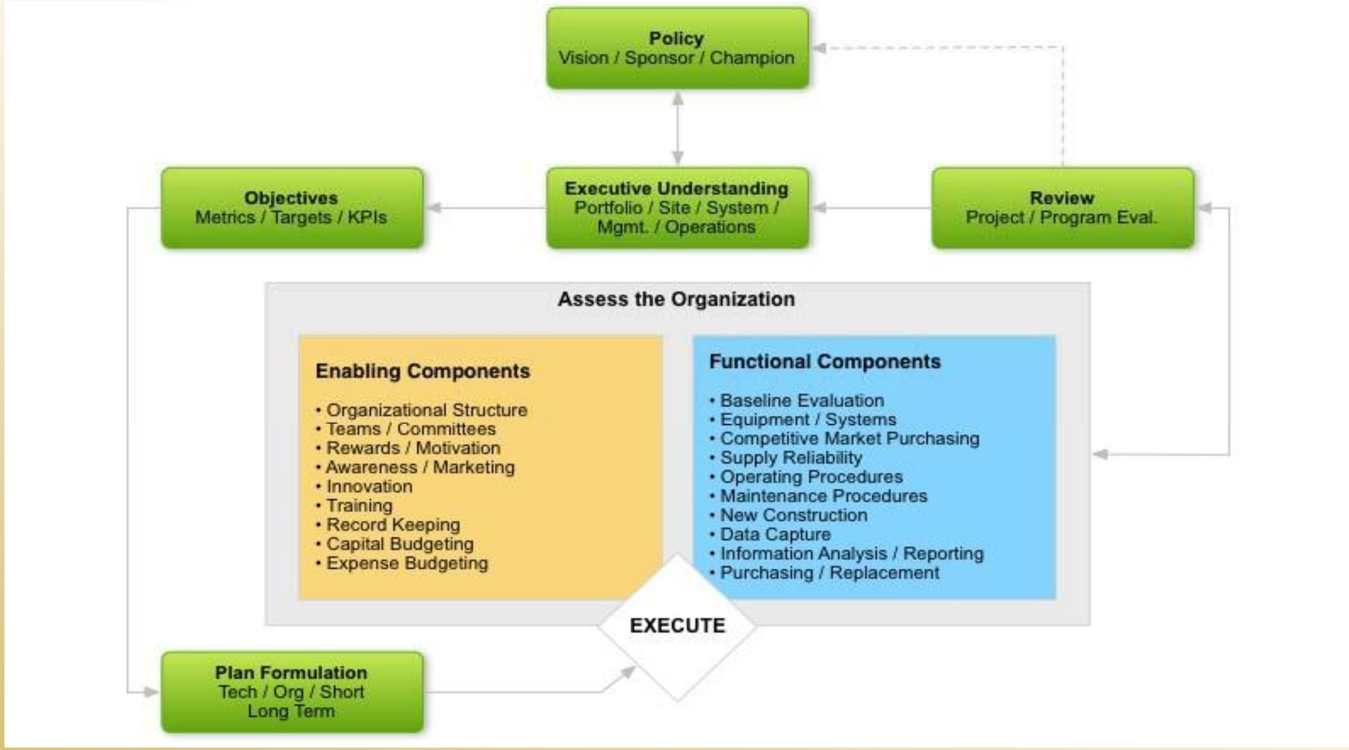
The Water Energy Nexus

CIFAR Industrial Best Practices and the Water Energy Nexus

The CEI Program provides the consulting resources to apply a CI methodology to a customer's energy management program



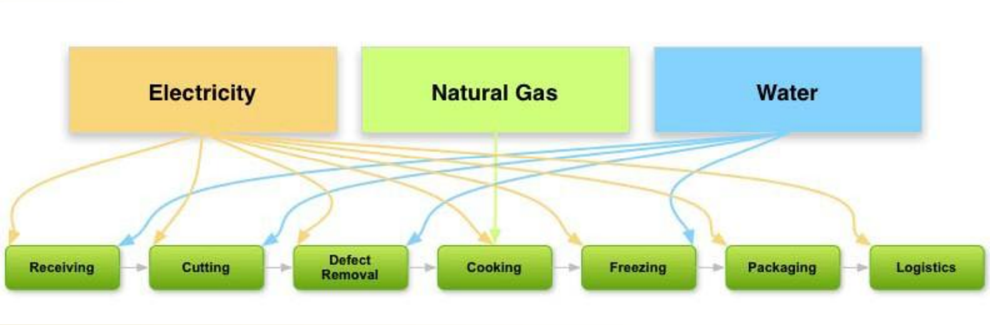
SEGEMA
Management Review
(ISO 50001 / DOE-SEP)



A maintenance excellence process is essential for reliability and the data to support continuous improvement

Action Plans

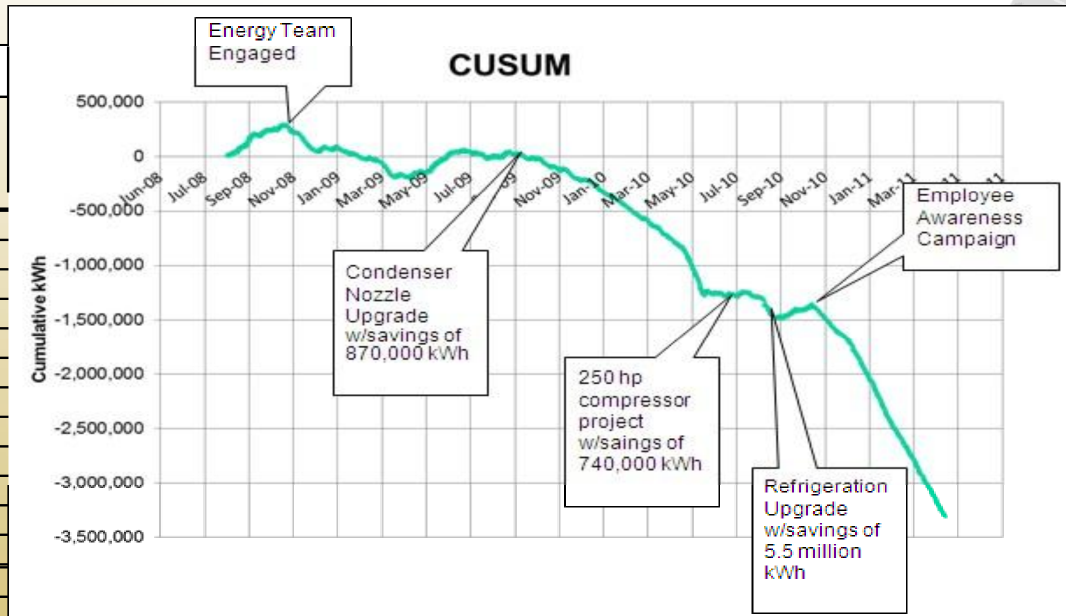
Energy Mapping



- Flow Chart Energy Use in Site Production Processes
- Consider Key Energy Streams
- Identify Attributes of Significant Energy Use's (SEU's)
- Locate Data Capture Capabilities
- Overlay Known Energy Saving Opportunities
- Identify Energy Saving Opportunities
- Note Unknowns / Systems Needing Further Analysis
- Failure analysis

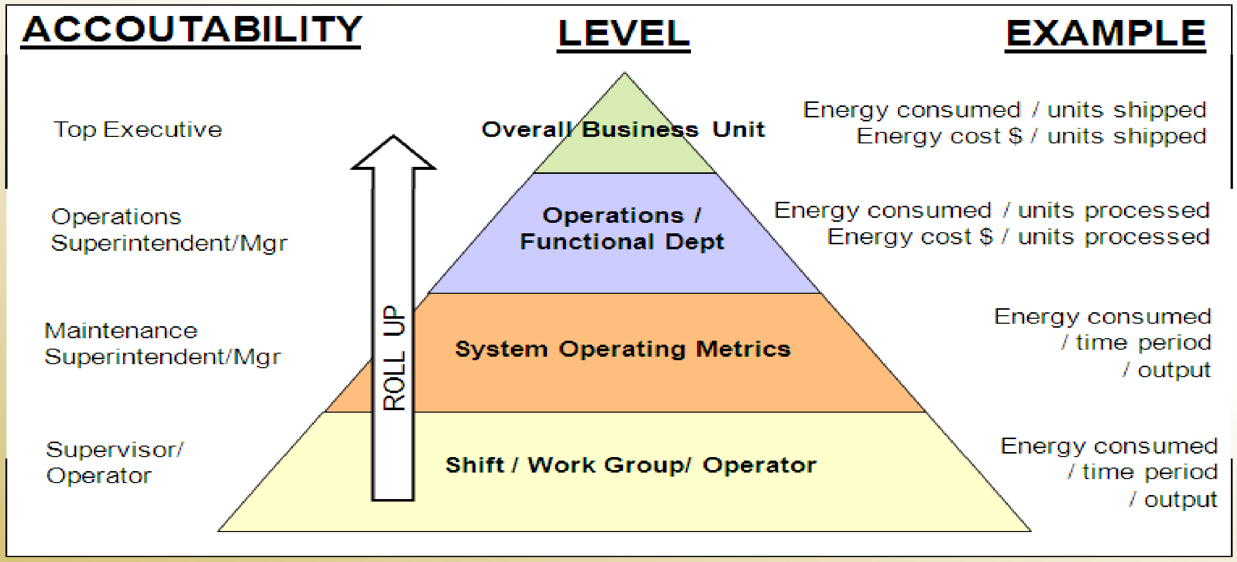
CIFAR Industrial Best Practices and the Water Energy Nexus

Monitoring, Tracking & Reporting



continuous monitoring & SCADA based feedback systems

Energy Performance Indicators



PG&E

Targets and Energy Performance Indicators

Measurement & Data Collection Plan for EnPI's

Total kWh / Unit Produced Gal Water / Produced Total kWh Saved - CUSUM (monthly)	Mfg kWh/Unit Produced Heat Treat kWh/Unit produced (daily)	kWh/CF (monthly)	kWh/month therms/month kWh & therms saved - Individual CUSUM models with temperature as driver	kWh/employee/year
OVERALL SITE	MANUFACTURING	COMPRESSED AIR	HVAC	OFFICE
<u>Total Site Electricity</u> kWh / day *Existing Site Meter*	<u>Total Output</u> Units/Shift *ERP system*	<u>Total Electricity</u> kWh/day *New Submeter*	<u>Total Electricity</u> kWh/day *New Submeter*	<u>Total Electricity</u> kWh/day *New Submeter*
<u>Total Water</u> Gal / month *Existing Water Meter*	<u>Total kWh</u> kWh / day *New Submeter*	<u>Air Volume</u> CFM delivered/ day *New Flow Meter*	<u>Total Natural Gas</u> therms/month *Existing Gas Meter*	
	<u>Heat Treat</u> kWh / day *New Submeter*	<u>Plant Pressure</u> PSI / lowest point *New Flow Meter*		

CIFAR Industrial Best Practices and the Water Energy Nexus

PG&E

Strategic E-Mgmt Plan

- Documents Current State
- Establishes Baseline and Goal
- Prioritizes Opportunities (Capital & Non Capital)
- Ties to PG&E / UCD / Other Programs
- Assigns Accountabilities
- Determines Budget
- Allocates Resources
- Scheduled Review

Sustainable Simplot

small steps, big savings

Strategic Energy Group

Helm - Projects / Activities	Status/Completion Date	Targeted Completion	Accountable	Estimated Annual Savings	Estimated Savings kWh	Estimated Savings Therms	Comments
SEMP - APPROVED							
Pre-existing Projects							
Cooling Tower Pumps, VFD	Complete		Agus Sumantri		772,834		
Cool Roof	Complete		Agus Sumantri		9,031		
Cooling Tower Fan VFD's	Complete		Agus Sumantri		59,771		
Water VFD	Complete		David Albright		60,616		
Incoming Transformer Replacement	Complete		Agus Sumantri		166,000		
Project for Implementation							
N (6) Deep Well, Motor, Pump and VFD	Pending	5/15/2011	David Albright	$26,430	222,285		
S (5) Deep Well Pump	Pending	5/15/2011	David Albright	$20,309	169,524		
Boiler Feed water Pump (Controls)	TBD	2012 - Estimate	David Albright	$38,454	320,982		
CT Blow Down Pump	TBD	2012 - Estimate	David Albright	$8,687	72,513		
Weak Acid Pumps w/VFD	TBD	2011 - Data Collected	David Albright	$3,560	29,721		
Process Condensate Pump	TBD	2011 - Data Collected	David Albright	$5,186	43,287		
Holstein Tank Pump	TBD	2012 - Data Collected	David Albright	$3,848	32,120		
Replace FAH with Radiant Heaters	Pending	3/1/2011	David Albright	$13,136		15,151	
Office/Shop lights with controls - $40,000 estimated capital - 2011	Pending	9/1/2011	David Albright	TBD		TBD	
Audit Activities							
** Cooling Tower - resizing the pump or a third cell	Started Review - Further Investigate	TBD	Gerald Schneider - LM	TBD	TBD		
Solar Power Generation Option	Have 2 Quotes - Undetermined at this point	TBD	Don Sturtevant and Mark Lynn/Martin Hunt	TBD	TBD		
Compressed Air Survey	Nexant	4/1/2011	Gus Sumantri	TBD	TBD		
Natural Gas Survey - Nexant to submit proposal for cost	Nexant	TBD	David Albright	TBD		TBD	
Improved Product Metering	TBD	9/1/2011	Gus Sumantri	TBD	TBD		
Steam Survey / Steam Traps / Piping / Insulation	Nexant	6/1/2011	Mark Lynn	TBD	TBD		
Separate Metering - Compressed Air/Electrical/Butane	TBD	TBD	Nate Kutterbush and David	TBD	TBD	TBD	
VFD for 10-34-0 Cooling Tower Fan	Data Loggers TBD	On Hold	Gerald Schneider - LM				
Organizational Activities							
Policy							
Develop Energy Policy	8/11/2010		Matt Frank	Part of CEI			
Revision		8/11/2011	David Albright	Part of CEI			
Include in new hire packets		4/30/2011	Plant Trainer	Part of CEI			
Targets / Reporting							
Establish KPIs	2/1/2011	Tier One Complete	Agus Sumantri, David Albright and Matt Frank	Savings is being tracked to goal			
Track energy savings to goal *(Plant Tracking Tool)*	9/1/2010	9/1/2011 for 2011	Mark Lynn	Calculated Monthly			
Update progress to annual goal	9/1/2010	9/1/2011 for 2011	David Albright				
Track capital, non-capital, and behavioral projects/activities *(Ongoing tracking utilizing the Energy map)*	Capital projects for 2011 are ongoing	9/1/2011 for 2011	David Albright	Tracked with Projects/ Energy Map			
Plans / Actions							
Develop SEMP - review / update on on-going basis	9/2/2010	Updated Annually	SEG/Energy Team				
Develop budgeted capital project plan *(Technical Assessments and project reccomendations are ongoing)*	9/1/2010	9/1/2011 for 2012	Matt Frank				
Estimate savings by project and cumulative							
Energy Map - Phase 1	7/8/2010	Ongoing Updates	SEG/Energy Team				
MT&R							
Initial Interview / Collect Data	Ongoing	3/1/2011	SEG				
Develop Energy Intensity Model		4/1/2011	SEG				
Training on plant EI model		4/30/2011	SEG/David Albright				
Teams / Committees							
Regular Energy Team Meetings	8/11/2010		David Albright				
Ensure Appropriate Org Representation on Eenergy Team	8/11/2010		David Albright				
Employee Awareness / Training							
Implement plant energy awareness campaign	10/27/2010		David Albright				
Plant Kickoff Event	10/27/2010		Mark Lynn				
Wheel of Energy - have recognition program	3/1/2010		David Albright				
Capture employee energy ideas *(Utilizing SharePoint for Suggestions)*		3/1/2011	David Albright				
Regular energy efficiency training (in person &/or webcast)	Will be Ongoing	4/1/2011	Mark Lynn				
Compressed Air		5/1/2011	Mark Lynn				
Pumping Systems		5/1/2011	Mark Lynn				
Motor systems		6/1/2011	Mark Lynn				
Process Heating		6/1/2011	Mark Lynn				
Steam Systems		7/1/2011	Mark Lynn				
Develop training matrix for O&M personnel		4/1/2011	Mark Lynn				
Energy Leadership Training		5/1/2011	Mark Lynn				
Execute the Energy Awareness Program (**Plant Rollout completed on 10/27/10**)		10/27/2010	David Albright				
Tool Box Cards	10/27/2010		Beant Sandu				
Monthly Energy Topics During Safety Training	1/1/2011		Matt Frank				
Leak Tag Program		4/1/2011	David Albright				
Energy Awareness Posters (PG&E Resource)	10/27/2010	Ongoing	David Albright				
Energy Bulletin Board	10/27/2010	Ongoing	David Albright				
Meeting Notes	7/1/2010	Ongoing	David Albright				
Energy Intensity Goal vs Actual	6/1/2010	Ongoing	David Albright				
Totals				$119,610	1,958,684	15,151	

PG&E

Employee Awareness & Training
Case Study: The Compressed Air Challenge

TOOLBOX TALK ON ENERGY EFFICIENCY FOR THE SHOP FLOOR: COMPRESSED AIR — Card 1

Discussion Questions

Compressed air is a very expensive utility. Performing a task with compressed air uses up to 10 times more energy than other methods!

Are we using compressed air for any of the following tasks?

- Cleaning (floors, equipment, etc)
- Drying
- Vibration
- Open Blowing
- Cooling
- Diaphragm pumps
- Air motors (i.e. for stirring)

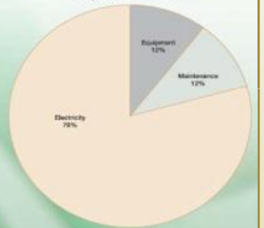
Tip

These jobs can be performed using less expensive methods.

Discussion Question

What ideas do you have for changing how we perform these tasks (without using compressed air!)

Why Care About Air?



Relative Cost Over 10 Years

TOOLBOX TALK ON ENERGY EFFICIENCY FOR THE SHOP FLOOR: COMPRESSED AIR — Card 2

Q: Where do leaks normally occur in a compressed air system? What's another name for this area?

A: Leaks normally occur in the compressed air piping system where there are valves, regulators, quick disconnects and flexible hoses with joints and o-ring seals that harden and crack.

This area is known as the **"dirty thirty"** as it is usually within thirty feet of the end-usage point.

Tip

Take the opportunity to check our "dirty thirty" for any leaks. Then tag them and take time to properly repair them.

Discussion Questions

- When was the last time we checked our "dirty thirty" for leaks?
- Have the leaks been repaired?
- Can we establish regular leak detection and repair as a part of our maintenance activities?

TOOLBOX TALK ON ENERGY EFFICIENCY FOR THE SHOP FLOOR: COMPRESSED AIR — Card 3

Q: What are some clues that there may be a problem in the compressed air line?

A:

- The line is hissing
- There is water dripping from the line
- There is dust accumulating around the line

Tip

In order to reduce the likelihood of a problem with a compressed air line, frequently clean the line.

Leaks are not only costly, but messy!

COMPRESSED AIR IS AN ESSENTIAL UTILITY

- Air is free but compressed air is not – the most expensive electric utility
- Only 20% of power input to compressor realized as useful work—80% lost to heat
- Due to distribution system losses—air leaks, inappropriate uses of air, artificial demand
- Relevance of reliable air systems

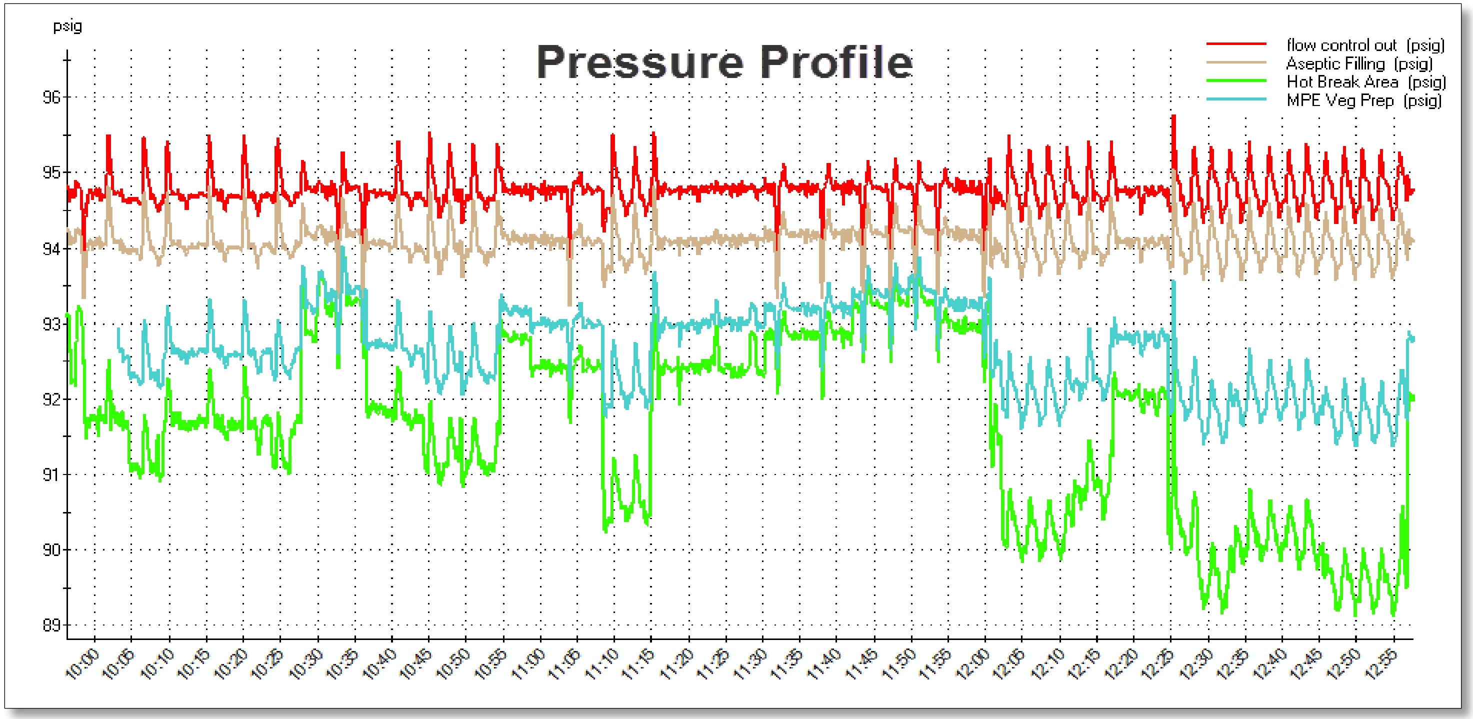
COMPRESSED AIR CHALLENGE™ ANALYSIS TOOLS

- DOE Air Qualified Specialist
- ASME Energy Assessment for Compressed Air System Standard
- Log Tool Version 2.0
- AirMaster+
- Engineering Calculations

Source: http://www1.eere.energy.gov/manufacturing/tech_assistance/software_airmaster.html

COMPRESSED AIR CHALLENGE™ ANALYSIS TOOLS

Log Tool Version 2.0



Source: http://www1.eere.energy.gov/manufacturing/tech_assistance/software_airmaster.html

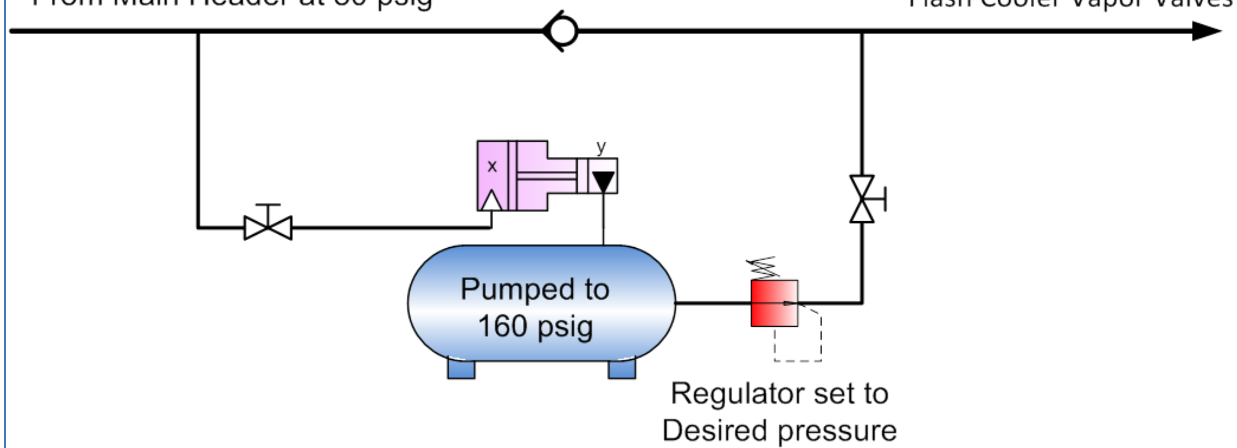
COMPRESSED AIR CHALLENGE™ ANALYSIS TOOLS

DOE AirMaster+ Software Analysis Tool

Source: http://www1.eere.energy.gov/manufacturing/tech_assistance/software_airmaster.html

COMPRESSED AIR CHALLENGE™ ANALYSIS TOOLS

Engineering Calculations



Tank Sizing

gallons =	33.89	gallons
V =	4.53	cubic feet
T =	0.5	minutes
C =	50	cfm
S=	0	cfm
Pa =	14.5	psia atm pressure
P1 =	160	Initial tank psi
p2 =	80	minimum pressure to operate

$$V_{cf} = \frac{T(C-S)(P_a)}{(P_1 - P_2)}$$

Summary of Results for Compressed Air ESAs Conducted at Eight California Food Processing Plants 2006-2013

Compresed Air ESAs 2006-13	kWh/yr	$/yr Saved	$ Estimated Cost	Payback Years	Utility Partner
Fruit Canning	1,042,018	57,311	100,000	1.74	MID
Tomato Processing	131,476	8,000	5,000	0.63	MID
Raisin Processing	482,501	48,250	100,000	2.07	PG&E
Tomato Products Canning	176,555	25,442	20,000	0.79	PG&E
Potato Chips Manufacturing	1,500,000	150,000	50,000	0.33	MID
Tomato Paste	474,417	71,163	30,000	0.42	PG&E
Cereal Manufacturer	888,816	97,770	50,000	0.51	LodiElec.
Cheese Manufacturing	827,741	49,664	65,000	1.30	Tulare ID
Totals:	**5,523,524**	**507,600**	**420,000**		
Average:	**690,441**	**63,450**	**52,500**	**1**	

Source: ttp://www.cifar.ucdavis.edu/Californias_Compressed_Air_Challenge_Final_Report.pdf

RECURRING CONDITIONS IDENTIFIED BY ESAs

- System Inefficiencies Identified
  - Excess compressor capacity
  - Inadequate compressor controls
  - Excessive pressure drop
  - Inadequate air storage capacity
  - Distribution piping too small and/or poorly laid out
  - Artificial demand
  - Inappropriate uses of air
  - Air leaks

SUMMARY

- Compressed air is an expensive utility and is frequently misused
- Establish baseline and understand the dynamics between the supply and demand sides
- Repair air leaks
- Eliminate inappropriate uses of air
- Re-evaluate plant pressure requirements and lower if justified

Steam Energy System Assessments (ESAs)
A Whole Systems Approach

- **Often between 40 to 60 percent of a food processing facility energy costs are incurred to produce steam**
- ESAs are conducted to evaluate Supply and Demand-side system components
- Focused on steam system heat recovery improvement opportunities
- Models and calculates steam and electric savings
- Whole systems approach is essential to optimize energy and cost savings

Steam System Assessment Analysis Tools

- DOE Steam Qualified Specialist
- ASME Energy Assessment for Steam System Standard
- Steam System Assessment Tool (SSAT)
- 3E Plus Insulation Calculator
- Engineering Calculations

Source: http://www1.eere.energy.gov/manufacturing/tech_assistance/steam.html

Data Required to Conduct Steam ESAs

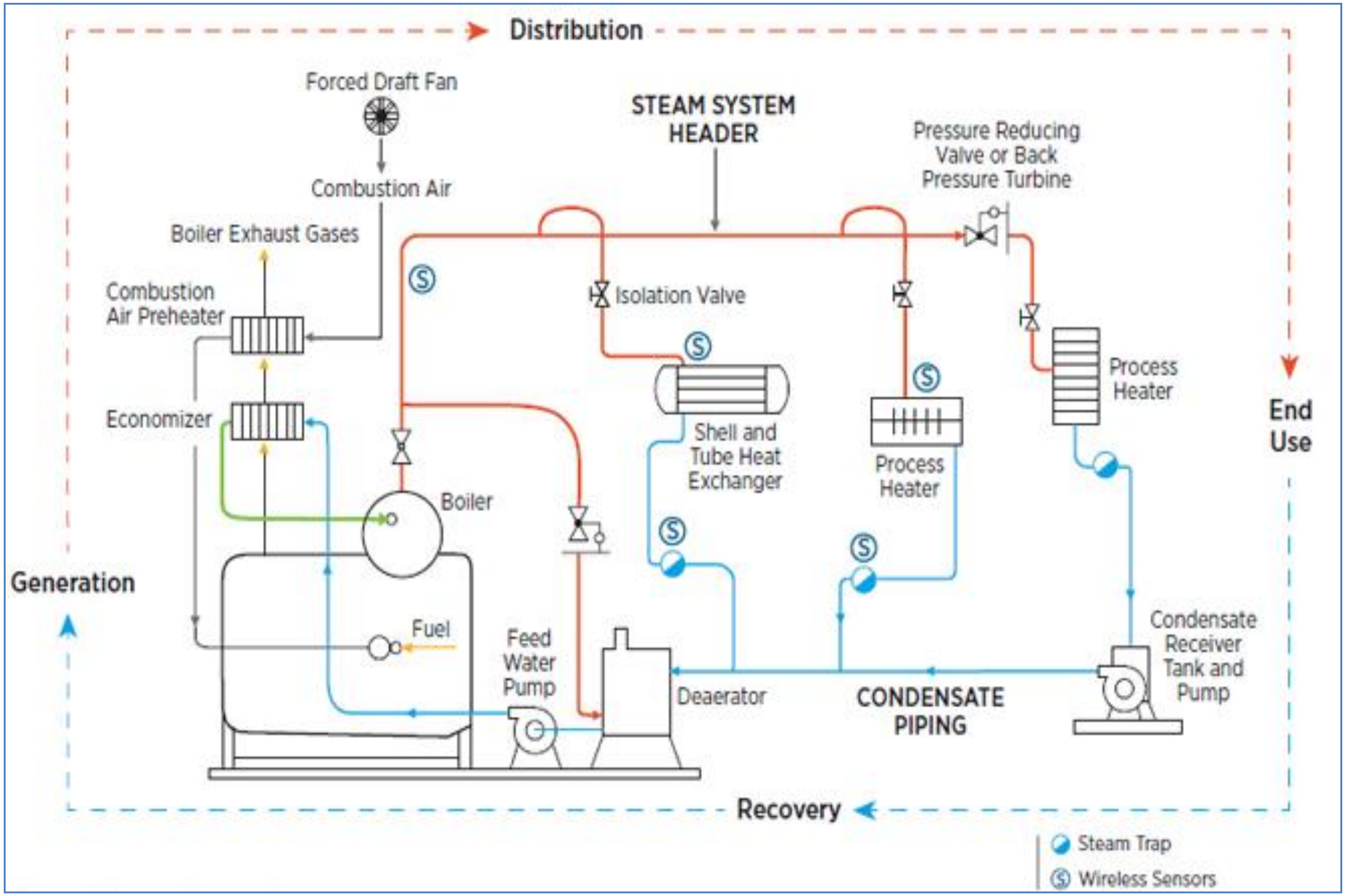
•Natural gas consumption, costs, annual operating hours

• Steam generation system data: boiler flue gas temperature and oxygen are measured to estimate boiler efficiency; blow down rates

• Steam distribution system data: wall temperature of steam distribution system is measured to estimate piping insulation needs; steam traps

• Steam end use and condensate systems data: amount of steam used by processes and steam turbines, and amount of condensate return

Standard Steam System Components



Steam System Assessment Study

Average Energy Use @ Ten California Food Processing Facilities

Average Value	Large Plant	Small Plant
Electricity Use	68.8 million kWh	4.8 million kWh
Natural Gas Use	516,000 mmBtu	87,900 mmBtu

Steam System Assessment Study
Identified Energy and Cost Savings

Large Facilities	% Gas Savings	Electricity Savings %	$K/yr
Meat Packing	27	1	$910.50
Cheese Mfg.	8.5	-	$531.30
Cheese Mfg.	2	2	$155.50
Brewery	8	-	$144.50
Beef Processor	0.5	3	$139.60
Tomato Processing	0.9	17	1,107
Avg	**7**		**$498**

Small Facilities	% Gas Savings	Electricity Savings %	$K/yr
Juice Bottling	16	18	$400
Instant Noodles	10	23	$180
Olive Co	17	10	$204
Creamery	23.5	3.4	$145
Avg	**16.6**		**$232**

Summary of Recommended Steam System Energy Efficiency Measures

Energy Efficiency Measures (# times)	NG Savings, MMBtu/yr	Cost Savings, $/yr
Improve Insulation (9)	500 – 1,870	3,500 – 14,000
Blowdown Energy Recovery (8)	1,850 – 8,800	16,000 – 68,000
Reduce Boiler Blowdown (7)	340 – 8,400	4,000 – 65,000
O2 Trim controls (6)	1,240 – 65,600	13,000 – 506,000
Increase Condensate Recovery (6)	1,359 – 7,440	13,000 – 116,000

Energy Efficiency Measures (# times)	NG Savings, MMBtu/yr	Cost Savings, $/yr
Back P Turbine for PRV (6)	-2,464 to -6,940	39,000 – 1,077,000
Steam Leak & Maintenance (6)	750 – 3,500	7,000 – 26,000
Use of flash/vent steam (4)	800 – 8,500	7,000 – 64,000
Feed water Economizer (3)	5,220 – 60,115	52,125 – 531,000
Reduce Steam Usage (2)	6,500 – 8,900	78,000 – 103,000

Summary

- Steam ESAs provide system performance base line
- Identify cost effective, environmentally sound energy efficiency measures
- Calculates steam condensate and vapor recovery efficiency
- The Steam ESA is used in the Water Energy Nexus to Identify water and energy conservation opportunities

The Water Energy Nexus @ Campbell Soup

- CIFAR has integrated data from the DOE assessment tools
  - Steam System Assessment (SSAT)
  - Pump System Assessment (PSAT)
  - Fan System Assessment Tool (FSAT)

- Data collection and software tools are integrated to conduct Water Energy Nexus (WEN) Assessments
  - Catalog and illustrate the water/energy intensity of all major process systems

- The WEN Assessment is designed to
  - Calculate pumping and fan system efficiencies
  - Identify performance inefficiencies and opportunities
  - Identify water conservation opportunities
  - Identify process design deficiencies and maintenance issues

Campbell Soup, Dixon, California, 2011
Source: Dixon Tribune

The Water Energy Nexus @ Campbell Soup

- The WEN Assessment creates an inventory of
  - Water demand/flow points (WEN Points)
  - Electrical and thermal energy inputs
- WEN Points are measured
  - Water Energy intensity (WEi) in kW/1,000 gals.
  - For each WEN point
  - Summarized for the entire facility

The Water Energy Nexus Systems Approach
Supply and Demand-Side Analysis

- **Supply-side** WEN Points
  - Groundwater pumping
  - Steam generation system and water filtration equipment
- **Demand-side** WEN Points include
  - Condensate return, evaporator condensing water, cooling towers
  - Tomato transport flumes, sanitation pumps
  - Wastewater systems
- Demand-side intensity (WEi) is driven by
  - Water velocity, pressure, volume, pump head
  - Pump types, pump wear, & instrument performance
- Demand-side has restrictions
  - Sprays, valves, orifices, pipe sizes, pump suction & discharge head

The WEN Assessment Discovery Process

- Some processes are not designed correctly
  - High water pressure, system cycling, instrumentation calibration errors
  - Excessive water flow velocity triggers excessive kW demand
  - Reverse Osmosis water misused
  - Single pass cooling
  - Lack of counter flow for $2^{nd}/3^{rd}$ water use
- Typical steam systems inefficiencies
  - Pressure let-down valves – CHP opportunity
  - Lack of combustion oxygen controls, boiler flue gas economizer configuration
  - Poor quality steam flow metering & lack of boiler blow down heat recovery
  - Inadequate or lack of insulation, failure to return steam condensate

CASE STUDY: Tomato Water Recovery

- The Nature of Tomato Water
  - Tomato Water is the condensed vapors produced in tomato evaporators
  - Tomato Water is mineral free, at temperatures ranging from 120 degrees Fahrenheit (F) to 200 degrees F
  - Tomato Water contains some carryover tomato solid residues

- The Tomato Water Resource
  - ~ 80% of the tomato tonnage for paste is condensed from vapors in evaporators
  - Index: 100 tons of tomatoes processed/hour produces ~ 320 GPM of tomato water
  - 320 GPM – TW may contain 10-11.0MM BTU/Hour of useable heat
  - Tomato Water discharged to cooling towers may represent 25-50% of plant cooling load

TOMATO WATER IS A WATER & PROCESS WASTE HEAT RESOURCE

Tomato Water Energy Conservation and Cost Savings Potential

Recovery of 70 Million Gallons of Tomato Water per Season

Avoided Energy	kWh Savings	$ Savings
Well Water	176,400	22,050
Waste Water	29,400	4,305
Cooling Towers	236,800	35,520
Total	442,600	61,876
Recovered Energy	**MMBtu**	**$4.90 MMBtu**
Tomato Water Heat	40,817	235,298

waste water cost savings are based on land application rather than more expensive municipal sewage system disposal

Summary

The Water Energy Nexus Assessment identifies:

- Individual & overall pumping, fan & boiler plant efficiency
- Cost savings & sustainability benefits
  - Preservation of ground water resources
  - Reduced wastewater organic load discharged on land
  - Commensurate air pollution reduction benefits

- Baseline data for continuous improvement

  - Identifies maintenance issues
  - Provides baseline data for continuous improvement
  - Creates data for process reliability & quality improvements
  - When implemented, may allow increased facility throughput

Wastewater management and BioEnergy Potential

Combined waste generation from 17 California tomato processors in 2009 (1):

		Annual quantity	Energy content (kWh)	Electricity potential (kWh)	Heat potential (therms)
solid waste	High moisture	38,169 dry tons	91,232,914	36,493,166	1,120,961
	Low moisture	60,916 dry tons	145,604,097	58241639	1,789,008
wastewater		5.7 billion gallons (26,805 tons BOD)	86,064,500	34,425,800	1,057,457

(1) Data collected but not reported in this form by Amón, R., M. Jenner, M., R.B. Williams, H. El-Mashad, S.R. Kaffka, *Draft California Food Processing Industry: Residue Assessment. California Energy Commission*

Management of Liquid Wastes

Best strategy is to reduce volume of waste streams

□ Process optimization

- Minimize water needed to achieve quality standards at each unit operation

□ Equipment and infrastructure repair/modification

- Replace less efficient equipment
- Take redundant, less efficient equipment offline
- Repair leaks in lines

□ Recycling

- Recycle unit operation effluent
- Reuse effluent from one unit operation in another unit operation

Background

Motivation for wastewater management strategies

- Discharging less water
- Not exceeding regulatory limits for wastewater quality
- Generating bioenergy

Potential financial benefits

Wastewater System Assessment

Organic matter

- Biochemical oxygen demand (BOD) assay

Solids

- Total suspended solids (TSS) assay, conductivity test

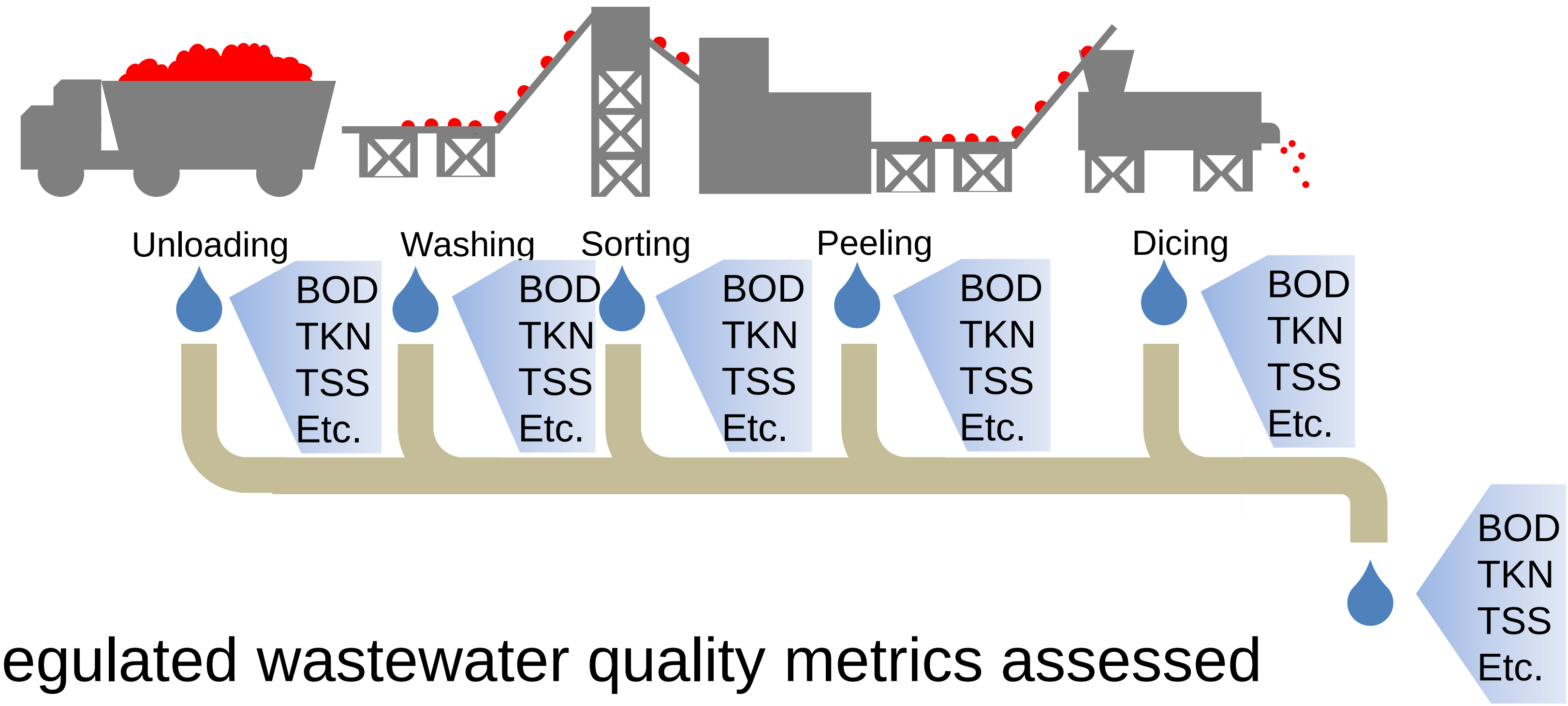
Nutrients

- Total Kjeldahl Nitrogen (TKN) assay, Total phosphorus assay

Other properties that can affect discharge

- pH, turbidity, odor etc.

Wastewater System Assessment



Regulated wastewater quality metrics assessed for discharged wastewater and for individual unit operations.

Wastewater System Assessment

Using the wastewater quality assessment data to:

1. Determine which unit operation effluent streams contribute to exceeding of regulatory limits for discharged wastewater.

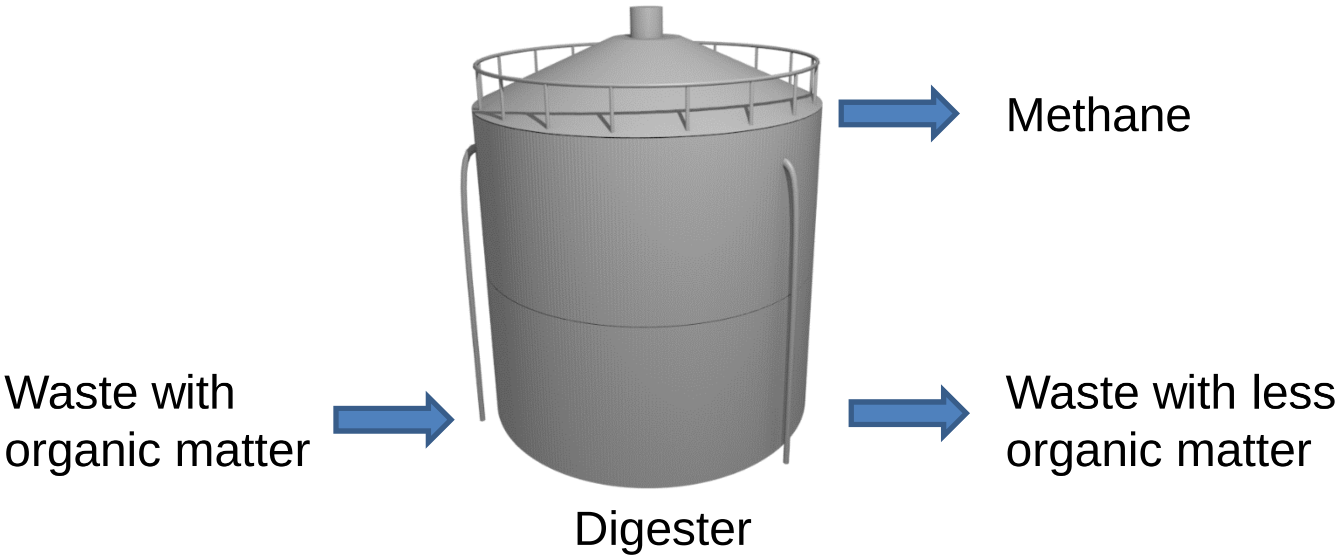
2. Determine if any unit operation streams are targets for reuse.

3. Determine which unit operation effluent streams are candidates for bioenergy production.

Wastewater System Assessment

Anaerobic digestion:

In the absence of oxygen, certain microorganisms degrade organic matter and convert it to gaseous fuels.



Wastewater System Assessment

Wastewater stream analysis from a California tomato processor

Transport leachate	Flume water	Dicing effluent	Settling pond return, Wastewater for discharge
Relative BOD = <1	Relative BOD = >9	Relative BOD = 25	Relative BOD = 1

Solid waste assessment

Generally, fewer strategies exist for decreasing the amount of solid waste generated during processing.

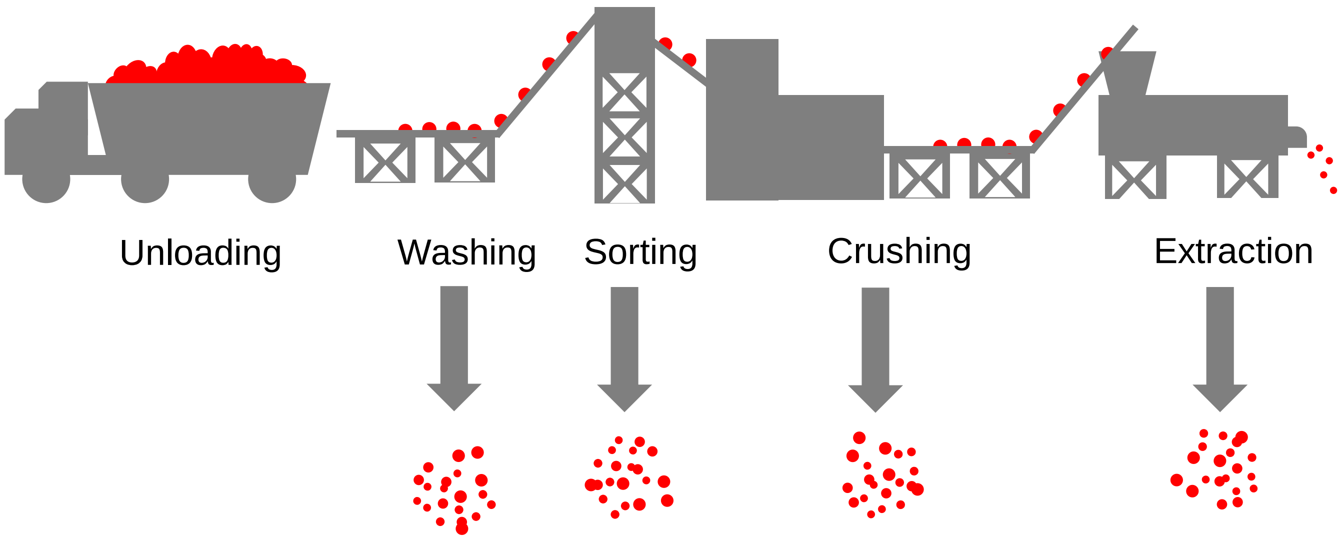
Solid Waste Assessment

Motivation for solid waste management strategies

- Decrease any waste dumped at landfills
- Generate bioenergy
- Add value to waste beyond agricultural use

Potential financial benefits

Solid Waste Assessment



Collection of solid waste generated by various operations.

Summary

Deliverables:

- Survey of wastewater streams with water quality assessment
- Identification of candidate wastewater streams for reuse
- Identification of wastewater streams for anaerobic digestion
- Estimation of wastewater remediation and biogas potential for target wastewater streams via anaerobic digestion
- Survey of solid waste streams with estimation of solids reduction and biogas yield via anaerobic digestion
- Analysis of codigestion of liquid and solid waste streams to optimize biogas yield from anaerobic digestion

Sustainable Design

The Rocky Mountain Institute (1)
10xE: Factor Ten Engineering

Factor Ten Engineering (10xE) aims to help engineers, architects and their clients attack resource intensive design problems, such as: manufacturing processes, buildings and vehicles.

Big Pipes, Small Pumps: Interface, Inc. Factor Ten Engineering Case Study

http://www.rmi.org/Knowledge-Center/Library/2011-04_BigPipesSmallPumps

(1) http://www.rmi.org/

Take Away Message

- Continuously evaluate the performance of the energy assets
- Adopt resource use reduction measures
- Achieve resource efficiency improvements: energy, water and air
- Invest in skilled labor
- Water will become more scarce without process improvement or conservation
- Invest in renewable energy sources to reduce air emissions
- Invest in efficiency to accrue cash flow benefits year after year
- Savings to support energy conservation and efficiency can also come from product quality improvement, raw material recovery increases, and increased process output

COMMENTS AND QUESTIONS

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