Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 3

Thursday – July 30, 2026

2:00 pm – 4:30 pm ET

Welcome

- Welcome to the 3rd Chilled Water Systems Virtual INPLT training series
- Eight, 2-1/2 hour webinars, focused on Industrial Process Cooling (Chilled Water) Systems Energy Assessment and Optimization
- These webinars will help you gain a significant understanding of your industrial process cooling system, undertake an energy assessment using a systems approach, evaluate and quantify energy and cost-saving opportunities using MEASUR and other US DOE tools and resources
- Thank you for your interest!

Process Cooling (Chilled Water Systems) Virtual INPLT Facilitators

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Process Cooling Virtual INPLT Agenda (2026)

- Session 1 (July 16) – Industrial Chilled Water Systems Fundamentals
- Session 2 (July 23) – Review of Chilled Water System Scoping Tool; Efficiency Metrics & Calculations
- **Session 3 (July 30) – Introduction to Process Cooling Assessment (using MEASUR)**
- **Session 4 (August 6) – Using MEASUR to Quantify Energy Efficiency Opportunities – Part 1**
- **Session 5 (August 13) – Using MEASUR to Quantify Energy Efficiency Opportunities – Part 2**
- **Session 6 (August 20) – US DOE MEASUR other modules, 3EPlus, etc.; Assessment & Reporting**
- **Session 7 (August 27) – Case Studies; Refrigerants – Past, Present & Future; Reclamation and O&M**
- **Session 8 (September 3) – Industrial Process Cooling System VINPLT Wrap-up Presentations**

Agenda – Session 3

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
  - Review of Session 2
  - Comments on Homework
  - IPLV and Additional Energy Efficiency Metrics
  - Load profiles
  - Instrumentation Gap Analysis Worksheet
  - Introduction to Process Cooling Assessment (using MEASUR)
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

Safety and Housekeeping

- Safety Moment
  - Most refrigerants are heavier than air – hence, exercise caution when entering mechanical rooms that are below grade or not ventilated
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please <u>MUTE</u> your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

Quick Review – Session 2

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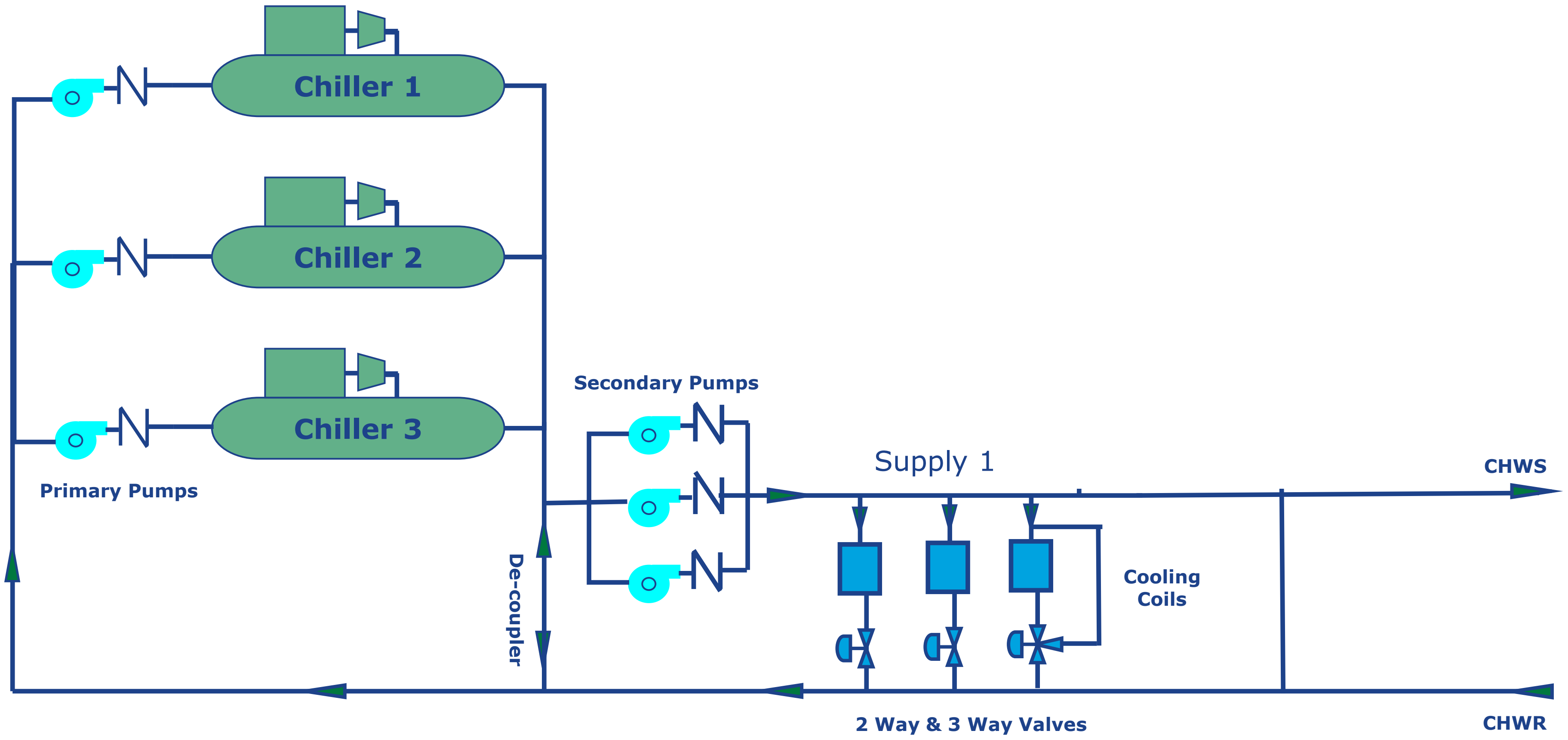
Primary & Secondary Loops Chiller Plant



* CHWR is always reverse return but shown here as direct return for simplicity

Chilled Water System Scoping Tool (CWST)

Chilled Water System Scoping Tool (CWST) Summary

Points Details	
Maximum Score =	420
Your Score =	420
Best Practices Rating =	100%

Based on plant information, there is low potential and energy savings in the range of 0-10% can be anticipated.

Section	Your Score	Maximum Score	%
General	90	90	100
System Components			
Compressors	80	80	100
Condensers	75	75	100
Evaporators	70	70	100
Cooling Towers	62	62	100
Plate Heat Exchangers/Waterside Economizers	23	23	100
Pumps	20	20	100
Total	**420**	**420**	100

Acknowledgments: National Cleaner Production Center, South Africa (UNIDO IEE Project)

Interpreting Summary Results

- Maximum possible score: Varies based on your system selections
- The scorecard reflects a general overview of existing best practices in the Chilled Water system
  - An average plant would score between 60-75%
- A "line in the sand" effort on potential energy savings possible in the chilled water system is provided based on
  - Past experiences in chilled water systems
  - Data collected over the years from different energy assessments in chilled water systems
  - Consultation with other experts in industry
- This score is "**<u>Qualitative</u>**" in nature and no effort of performance guarantees, promises of savings, etc. should be made based on the results of CWST

Chiller Unit Capacity

- Chiller unit capacity (Tonnage) is the amount of full load cooling capacity provided by the chiller unit at design conditions

- Units of cooling capacity or refrigerating effect are RT (or sometimes TR)

- In the USA and some other places - Refrigeration Ton (RT) is used
  - The amount of thermal energy to be removed from 1 short tonne (2,000 lbs) of water at 32°F to make it into ice at 32°F in one day (24 hr.) is 1 RT

- **1 RT = 12,000 Btu/hr**

Unit Performance Metrics

$$kW/RT = \frac{Compressor\ Power\ (kW)}{Cooling\ Load\ (RT)}$$

- Most standard rating in USA for Chilled Water systems - kW/RT
- Amount of compressor power (kW or hp) required to produce 1 RT of cooling or refrigeration

$$\mathbf{COP_{cooling}} = \frac{3.517}{(\frac{kW}{RT})}$$

- Conversion between Cooling COP, EER and kW/RT is simple

Comments on Homework

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Calculating Actual Operating Energy Efficiency

Chiller Operating Energy Efficiency

$$\text{Cooling Load (RT)} = \dot{M}_{water} * C_p * (T_{return} - T_{supply}) / 12{,}000$$

$$\text{Compressor Power (kW)} = 1.732 * V * I * PF / 1{,}000$$

$$\text{Chiller Performance} = \text{Compressor Power (kW)} / \text{Cooling Load (RT)}$$

Chiller Operating Energy Efficiency

- $\dot{M}_{water}$ – Mass flow rate of chilled water (lb/hr)
  - = Volume flow rate (gpm) X Density (lb/gal) X 60
  - = 500 X gpm
  - If there is glycol or another heat transfer fluid, then use the appropriate density of that fluid instead of water

- C_p – Specific heat of heat transfer fluid (Btu/lb-°F)
  - = 1.0 (for water)
  - If there is glycol or another heat transfer fluid, then use the appropriate specific heat of that fluid instead of water

Chiller Operating Data

- The utility engineer has gathered the following data:
  - Chilled water
    - Supply Temperature = 44.0°F
    - Return Temperature = 54.4°F
    - Chilled water flow rate = 2,310 gpm
  - Compressor motor (3-phase)
    - Voltage = 4,160 V
    - Current = 100 A
    - Power factor = 0.90
- Calculate the chiller tonnage (load) and the operating energy efficiency (kW/RT)

Chiller Operating Energy Efficiency

Cooling Load (RT) $= \dot{M}_{water} * C_p * (T_{return} - T_{supply}) / 12{,}000$

*Cooling Load (RT) = 2,310 * 500 * 1.0 * (54.4 – 44.0) / 12,000*

Cooling Load (RT) = 1,000 RT

*Compressor Power (kW) = 1.732 * V * I * PF / 1,000*

*Compressor Power (kW) = 1.732 * 4,160 * 100 * 0.9 / 1,000*

Compressor Power (kW) = 648.5 kW

Chiller Operating Data

Chiller Energy Efficiency = Compressor Power (kW) / Cooling Load (RT)

Chiller Energy Efficiency = 648.5 / 1,000

Chiller Energy Efficiency = 0.649 kW/RT

Seasonal Energy Efficiency Metrics

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Chiller Design Specifications

- In the US, each chiller can be tested at the manufacturer’s testing facility per AHRI Standard 550
  - There maybe an extra charge for this test
  - There maybe limitations based on size of chiller and testing facility capability
- Performance (kW/RT) for typical commercially available packaged chiller units
  - Water cooled – 0.4 – 0.8
  - Air cooled – 0.7 – 1.3
- Full load design rating conditions versus seasonal operating rating conditions
- ASHRAE Standard 90.1 provides minimum performance requirements for chillers

Seasonal Energy Efficiency of the Chiller System

- The efficiency of chilled water systems is dependent on several factors:
  - Cooling Load
  - Cooling supply temperature
  - Heat rejection temperature
  - Compressor efficiency
  - Control mechanisms
  - Variable Frequency Drives
  - Number of operating chiller units
  - Heat exchanger surface areas
  - Other site-specific factors

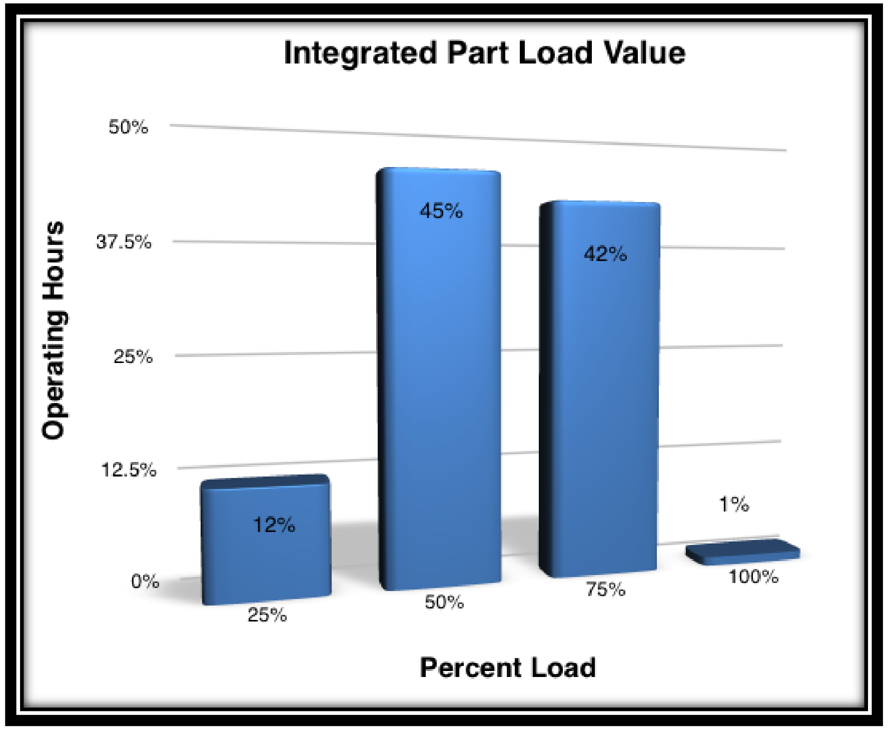
Integrated Part Load Value

- Integrated Part Load Value (IPLV) is defined by AHRI in the AHRI Standard 550/590
- It is accepted by ASHRAE and compliant with ASHRAE 90.1
- IPLV is a weighted value of 4 standard loads and Entering Condenser Water Temperatures (ECWT):
  - 100% load @ 85°F ECWT
  - 75% load @ 75°F ECWT
  - 50% load @ 65°F ECWT
  - 25% load @ 65°F ECWT

Integrated Part Load Value

- Generally, a chiller operates at full load design conditions for 1-3% **ONLY** of the total operating hours

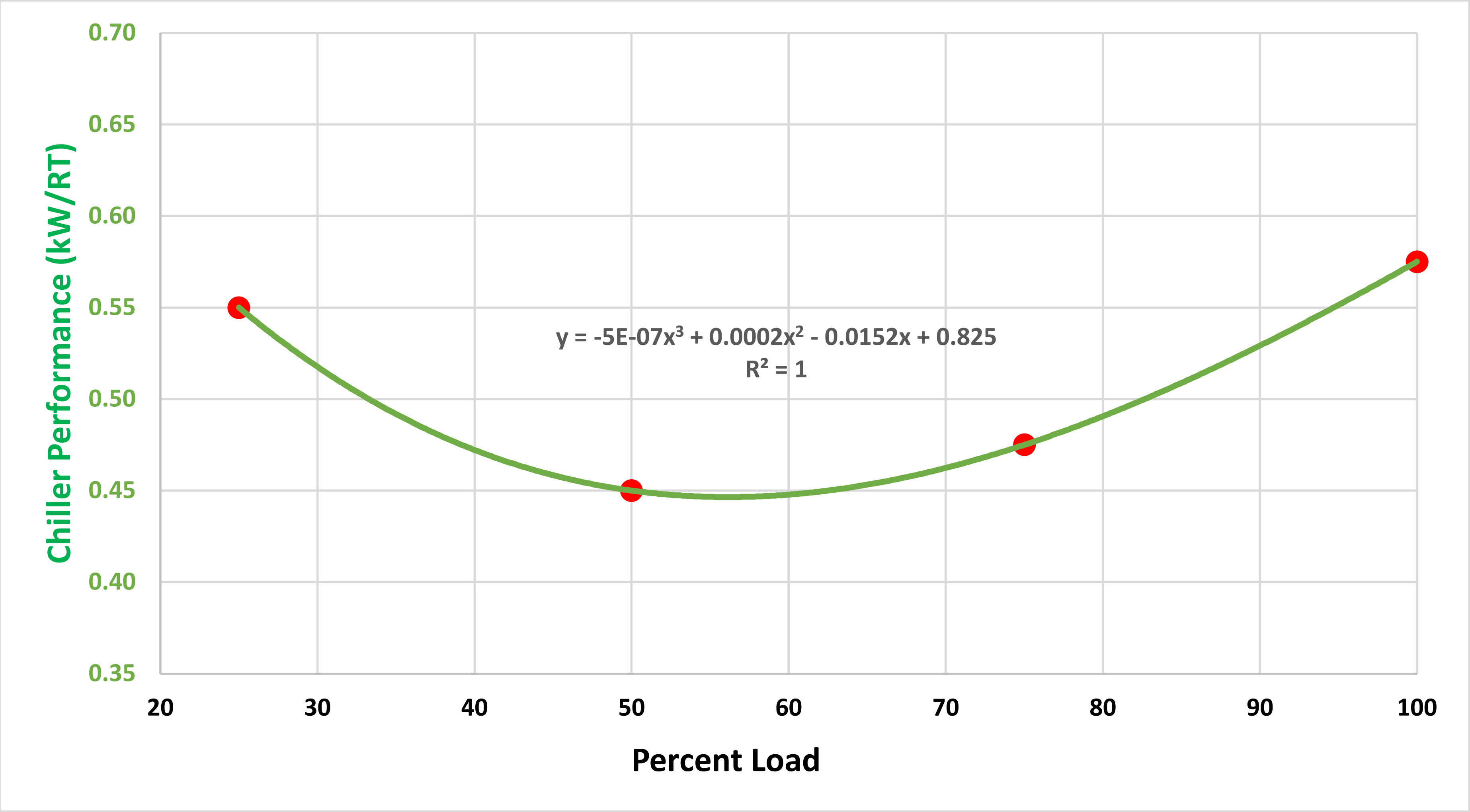
- Hence, no decisions should be based on the design efficiency but instead they should be used as a guide to reach optimal solutions



Chiller Full Load Design Specifications

Chiller ID	Chiller #6	Chiller Manufacturer	JCI
Year Commissioned	2005	Chiller Type	Constant Speed Centrifugal
Model Number	YKY4Y4J75DJF	Serial Number	YX24584BC
Refrigerant	R134a	Capacity	2,000 RT
Design Efficiency	0.625	IPLV	0.541
Full Load Amps	198	Volts	4160
Evaporator Entering Water Temperature	55°F	Condenser Entering Water Temperature	85°F
Evaporator Leaving Water Temperature	44°F	Condenser Leaving Water Temperature	95°F
Evaporator Flow	4,800 gpm	Condenser Flow	6,000 gpm
Evaporator Pressure Drop	10 psid	Condenser Pressure Drop	10 psid

Overall Chiller (Plant) Performance



Key Points / Action Items

1. kW / RT is the energy efficiency metric used for the chiller and the system
2. System Efficiency includes power consumed by the chiller compressor motor, chilled water pumps, cooling tower pumps, fans and other parasitic users
3. Chiller manufacturers design, specify and test chillers
4. IPLV is most commonly used to determine average seasonal energy efficiency rating

Additional Metrics in Chilled Water Systems

Reference Section

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Additional Performance Metrics

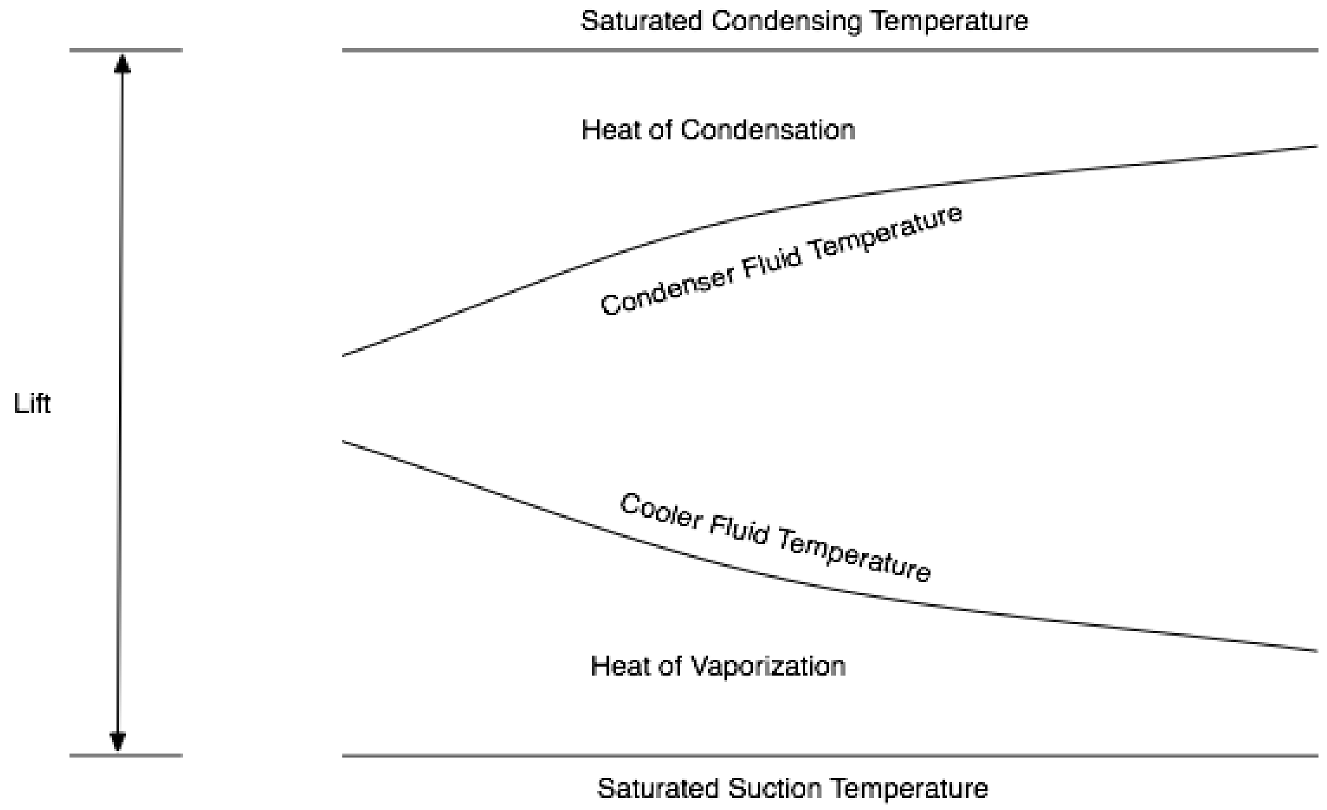
- Generally needed for more detailed analysis
- Periodic assessment (if not continuous) is recommended
- Provides a good baseline and identifies a problem before failures
- SMART algorithms can implement these metrics for trending performance
  - Closed-loop feedback controls are programmed into chilled water system controllers that optimize the operations of the chilled water system real-time

General Chiller System Performance Metrics

- Overall chiller system plant performance
  - Total cooling load
  - Total kW (including chillers and auxiliaries)
- Chiller Lift
- Chiller efficiency
  - Carnot efficiency
  - Chiller actual efficiency (kW / RT)
- Compressor isentropic efficiency
  - Suction and discharge temperatures
  - Suction and discharge pressures
- Heat exchanger effectiveness
  - Approach temperatures
  - ΔT on chilled water and cooling tower water

Chiller Lift

- Difference between Saturated Condensing Temperature and the Saturated Suction (Evaporating) Temperature



Carnot Efficiency

$$Carnot\ Efficiency = \frac{T_{cold}}{T_{reject} - Tcold}$$

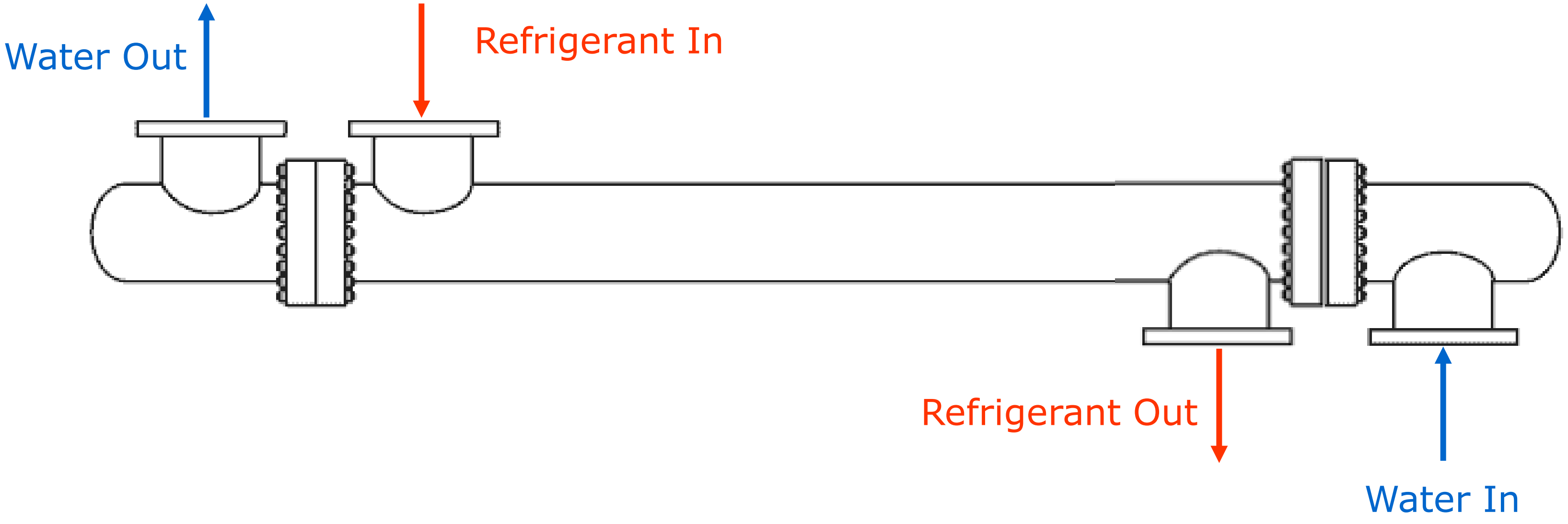
- Ideal Carnot Efficiency
  - Dependent of cooling supply temperature and heat rejection temperature ONLY
  - All temperatures should be in the absolute temperature scale (R)
    - Absolute Temperature (R) = Temperature (°F) + 460

Compressor Isentropic Efficiency

- Information required
  - Suction and discharge temperatures
  - Suction and discharge pressures
- Comparison of work done by ideal compressor (isentropic) versus the actual compressor
- Measure of energy lost in temperature increase compared to just pressure increase
- Lower efficiency implies higher compressor discharge temperatures and higher compressor power!

Heat Exchangers

- Principle of Conservation of Energy
  - First Law of Thermodynamics
  - Energy Flow In = Energy Flow Out



- Heat Exchanger Performance
  - Design Information
    - Operating Temperatures, Pressures, Flows
    - Fluid information
    - Heat exchanger area, Log Mean Temperature Difference, Fouling coefficient, Overall Heat Transfer coefficient (U)
    - Heat Duty
  - Log Mean Temperature Difference (LMTD)
    - Determines the driving force available for heat transfer
    - Higher LMTD's imply inefficiency and losses

Heat Exchangers

- Refrigerant Approach Temperatures (RAT)
  - RAT = Absolute (Leaving Water Temperature - Saturated Refrigerant Temperature)

- Saturated Refrigerant Temperature refers to the refrigerant being heated (evaporator) or cooled (condenser)

- Every chiller unit has a manufacturer full load design Evaporator RAT and Condenser RAT

- When RAT increases for the same heat load, it indicates an increase in heat exchanger fouling (heat transfer resistance)

Key Points / Action Items

1. *Actual operating performance calculations for chiller systems will require temperatures, pressures, flows and power information*

2. *It is important to calculate both overall chiller plant and individual chiller operating efficiency*

3. *The other chiller plant efficiency metrics include: Lift, Isentropic compressor efficiency, Heat Exchanger effectiveness, etc.*

4. *Fouling impact in heat exchangers has to be determined and related to reduction in efficiency and increase in operating costs*

5. *Refrigerant Approach Temperature (RAT) serves as a good proxy for LMTD (driving force)*

Chilled Water System Load Profile

Load Profile

- Chilled water systems will NEVER have a constant cooling load
- Most high-level analysis (ASHRAE Level 1, plant walk-through) can be done using design information with a load factor approach
- Every chilled water system energy efficiency and optimization analysis will need to consider the cooling load profile of the system
- Level of detail and time intervals will vary based on several factors – availability of data, time-based sensitivity of the load, repeatable patterns and significant factors, etc.

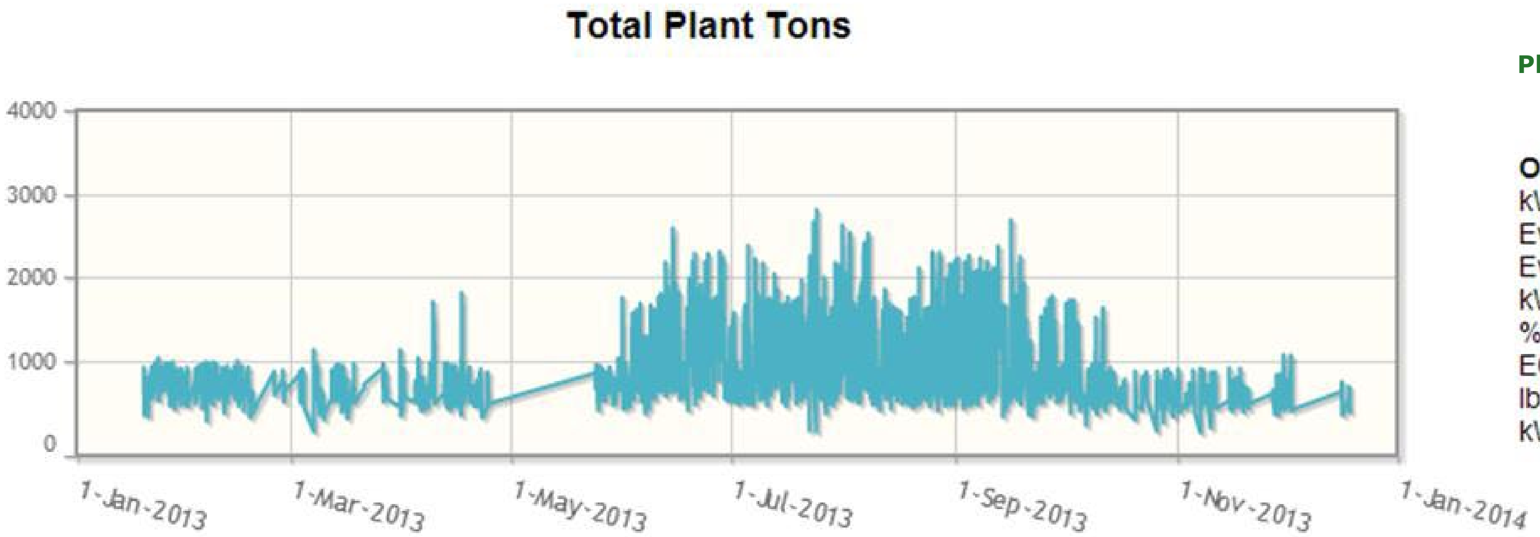
Chilled Water System Load Profile

- Every chilled water system and industrial plant is UNIQUE
- Nevertheless, the shape of the load profile may coincide across similar plants
- Determination of a true load profile is very difficult in a real-world scenario but there are several techniques and methods to define and develop a load profile for any chilled water system
- Every chilled water energy efficiency assessment should require the inclusion of a representative load profile

Chilled Water System Load Profile

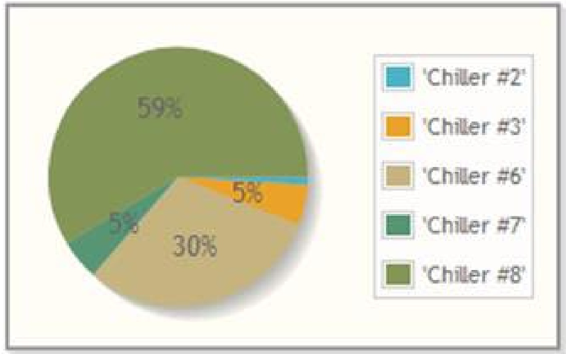
- Developing a load profile requires data collection
- Load profile should be developed for a certain time period
  - Annual – most common by using daily averages or hourly averages
  - Seasonal – production dependent; weather dependent
  - Monthly, Weekly, Daily – load is independent of weather and is strictly a function of product throughput
- Load profile can also be simulated using process modeling as well as using historian data and statistical analysis
- Actual real-time operating data – state-of-the-art

Large Commercial Central Plant

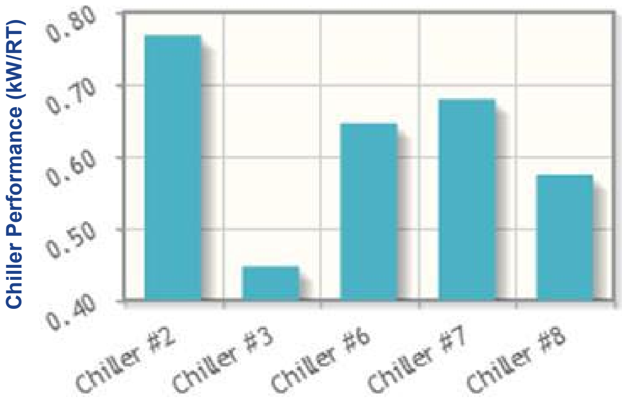


Plant Cooling Capacity - 6,000 RT

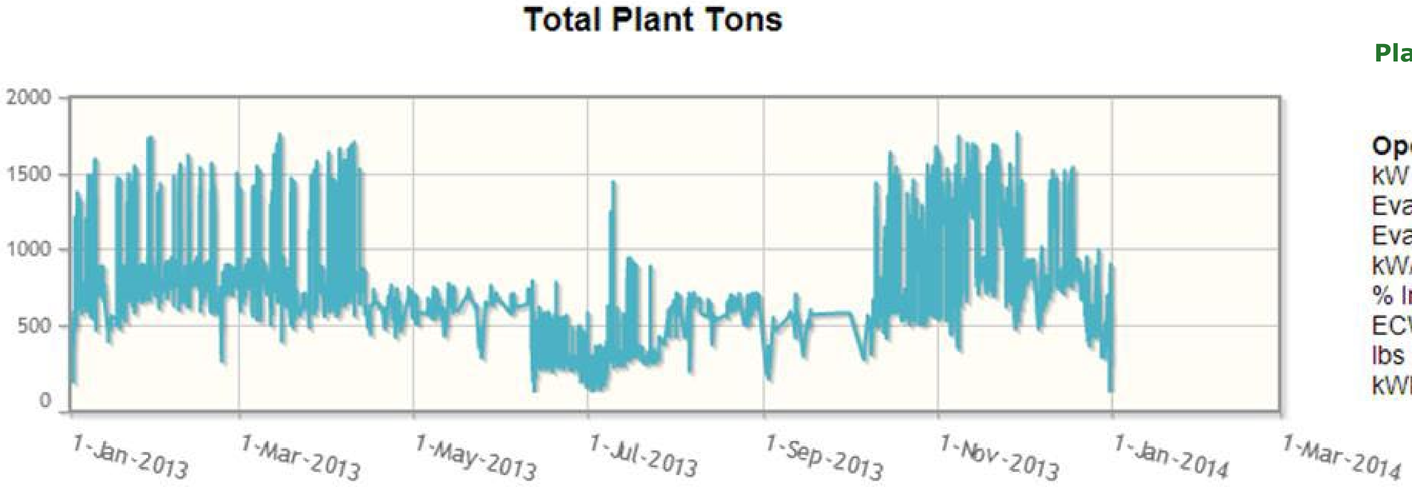
Operating Averages
kW = 410.53
Evaporator tons = 690
Evaporator Δ °F = 6.77
kW/ton = 0.596
% Input Power = 68.27
ECWT °F = 75.28
lbs CO2 Eq. produced = 562.43
kWh Cost = 24.63 per Hour



Cooling Load Hours (Ton-hours) Contribution of Operating Chillers

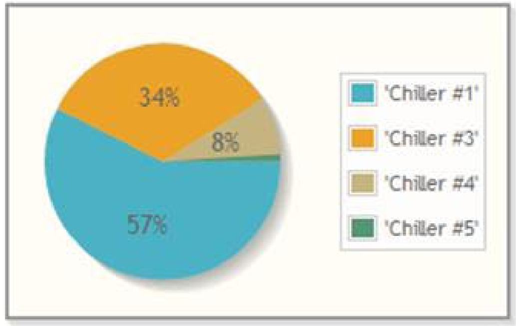


Food Manufacturing Plant Seasonal Operation

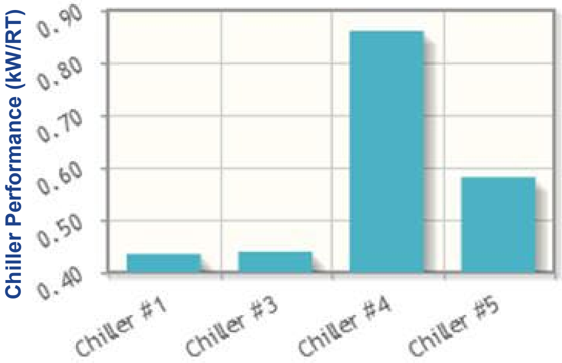


Plant Cooling Capacity - 3,500 RT

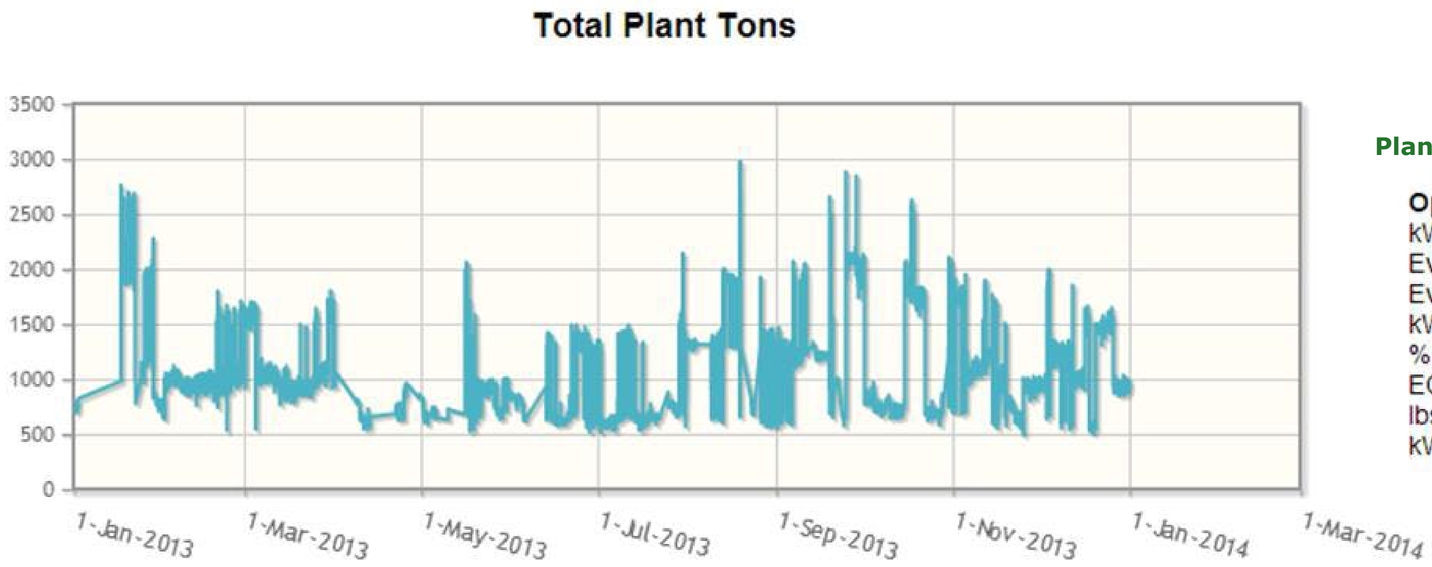
Operating Averages
kW = 273.83
Evaporator tons = 584
Evaporator Δ °F = 9.35
kW/ton = 0.515
% Input Power = 66.27
ECWT °F = 75.53
lbs CO2 Eq. produced = 375.14
kWh Cost = 13.69 per Hour



Cooling Load Hours (Ton-hours) Contribution of Operating Chillers

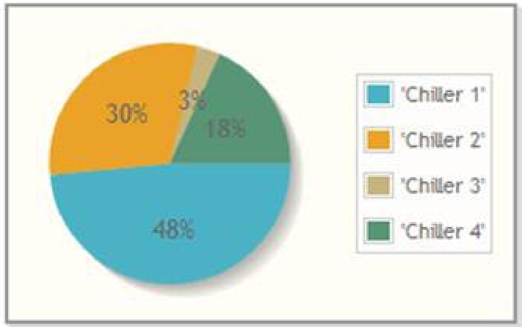


Data Center Central Plant

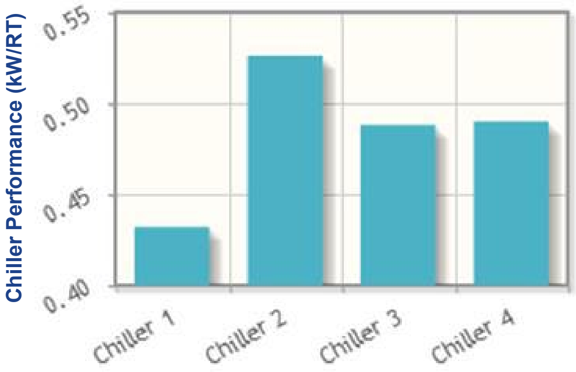


Plant Cooling Capacity - 4,500 RT

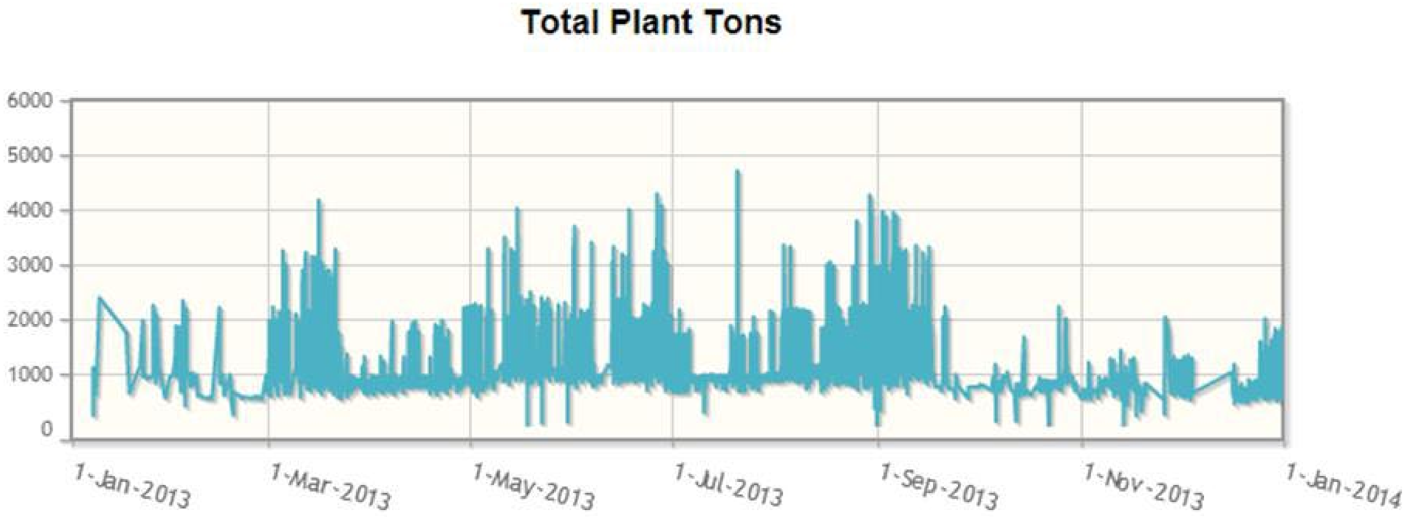
Operating Averages
kW = 391.85
Evaporator tons = 822
Evaporator Δ °F = 11.67
kW/ton = 0.481
% Input Power = 56.03
ECWT °F = 73.75
lbs CO2 Eq. produced = 1359.71
kWh Cost = 25.47 per Hour



Cooling Load Hours (Ton-hours) Contribution of Operating Chillers

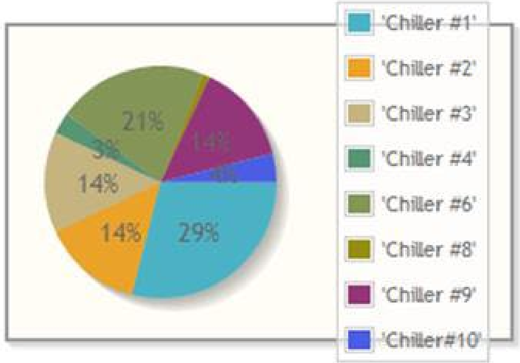


Casino Operation

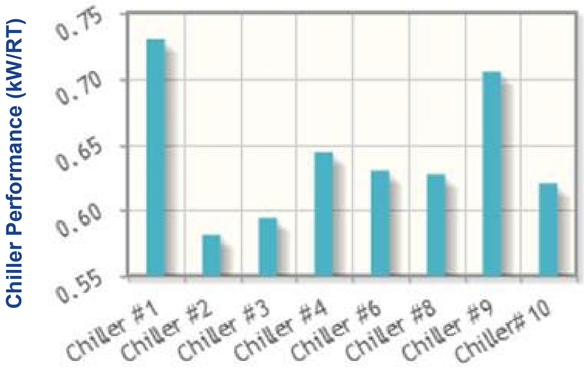


Plant Cooling Capacity - 43,000 RT

Operating Averages
kW = 585.97
Evaporator tons = 912
Evaporator Δ °F = 9.28
kW/ton = 0.663
% Input Power = 83.07
ECWT °F = 76.06
lbs CO2 Eq. produced = 802.77
kWh Cost = 64.46 per Hour



Cooling Load Hours (Ton-hours) Contribution of Operating Chillers



Instrumentation GAP Analysis for a VINPLT – Process Cooling

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Chilled Water Plant Operating Data

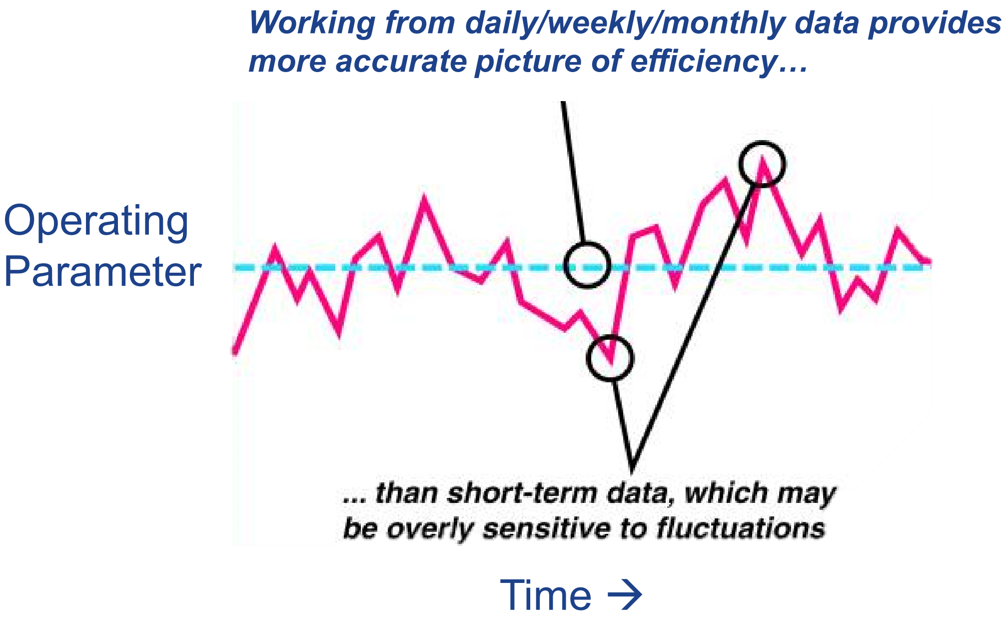
- There are several different data points that are required for a chiller plant assessment
  - Evaporator and Condenser Entering and Leaving Water Temperatures
  - Evaporator and Condenser Water Flow Rates / Delta Pressure
  - Evaporator and Condenser Refrigerant Pressures
  - Compressor suction and discharge temperatures
  - Amps, Volts and Power Factor (Input kW) or equivalent data for steam turbine horsepower
  - Pumping power (primary, secondary)
  - Cooling tower fan power

- This data can be collected at regular intervals
  - Manually through log sheets
  - By the BAS/EMS

Field Measurements

- Instantaneous measurements
- Historical data
- Measurements spread over multiple time intervals

Data Gathering – Snapshot or Movie?

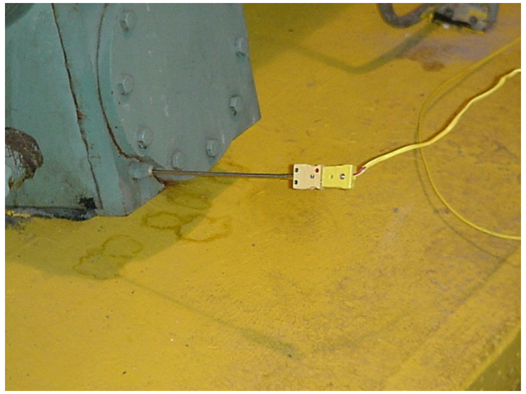


Calibration & Accuracy of Sensors

- To calculate chilled water system performance metrics, the operating data must be accurate
- All sensors drift over time
- Regular calibration is required
- Sensor Accuracy (General guidelines):
  - Temperature sensors must be accurate to within 0.2°F
  - Differential pressures (dP) must be accurate to 0.25 psid
  - Water flows must be accurate to within 2.0%
  - Refrigerant pressures must be accurate to within 0.5%

Temperature Measurements

- Different types
  - Thermometers
  - Thermocouples
  - RTD's
  - Infrared gun / camera

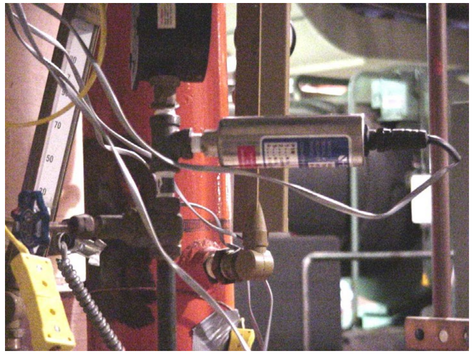


- Differential measurement can be done via a thermopile

- Load calculations require a "difference in two temperatures" – ΔT - accuracy very important

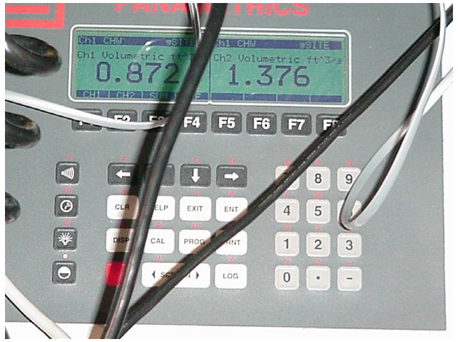
Pressure Measurements

- Most common
  - Bourdon-tube gage
  - Capacitative
- Pressure transducers used very frequently for data monitoring
- Pressure monitoring devices will require specific ranges – understanding operating range of the chiller is required



Flow Measurements

- There are different kinds of flowmeters
  - Orifice plate / Annubar / Pitot tube
  - Turbine type
  - Vortex shedder
  - Magnetic
  - Ultrasonic (non-intrusive), etc.

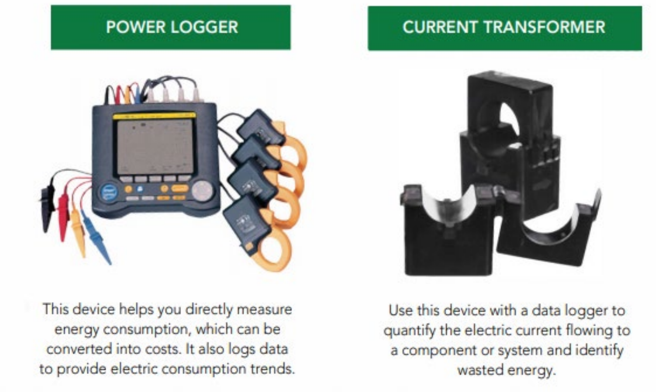


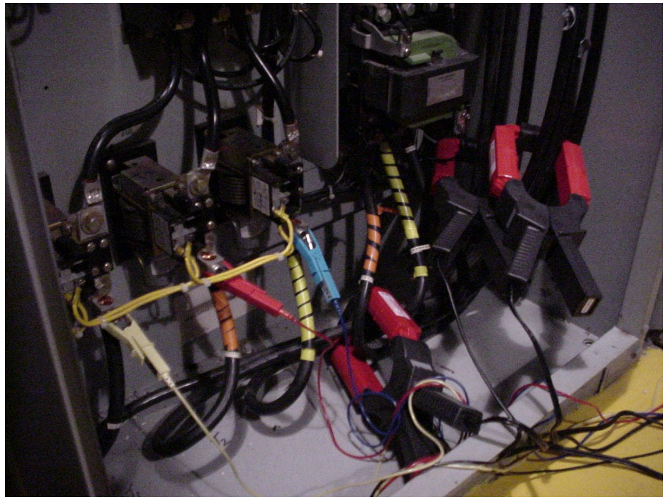
- Flow can also be measured using pressure drop (ΔP) in heat exchangers and comparing it to design flow and design pressure drop

$$Flow_{actual} = Flow_{design} \times \sqrt{\frac{\Delta Pactual}{\Delta Pdesign}}$$

Power Measurements

- Power meter is the common device for measuring power
- It will require simultaneous measurements of
  - Current on each phase
  - Voltage on each phase
  - Power factor
- First-order estimate can be made from current measurements
- Current Transducers (CTs) are very common





Long-Term Measurement / Historian

- Remember – Load as well as ambient conditions vary and the chiller unit (plant) operation varies to accommodate the varying conditions

- Collect data over a long-term time interval
  - Most cases annual (or typical seasonal / production based)
  - Representative seasonal / off-season (high / low production) times
  - Depends on availability of historian and data storage capability

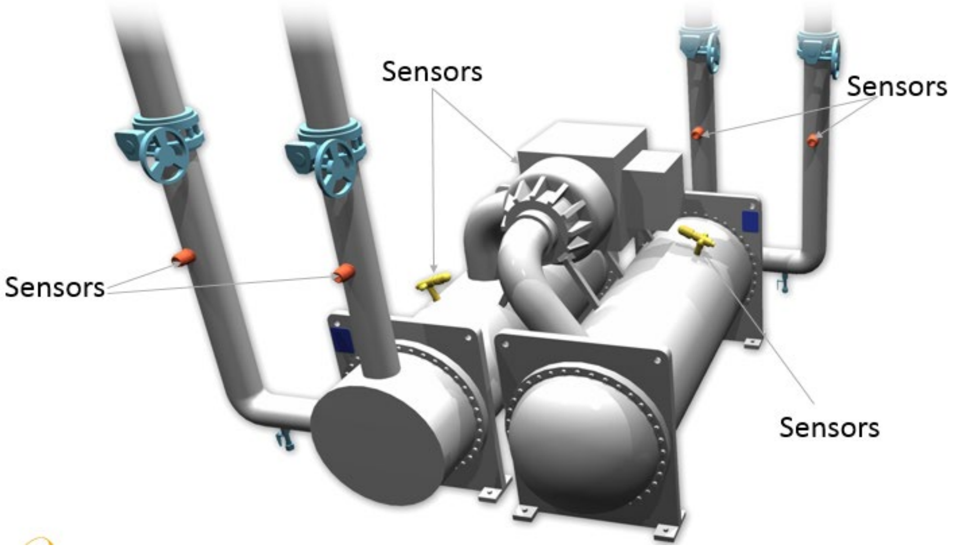
- Collect data at a reasonable frequency
  - Remember – steady state steady flow – we are NOT interested in start-up/shut-down or upset conditions
  - Hourly averages sufficient for energy assessment type work
  - 15-minute averages for detailed project analysis maybe required
  - Aim for average readings, if possible, within the interval

Measurement Locations for a Chiller Unit

Evaporator
1. Water Inlet Temp
2. Water Outlet Temp
3. Water Flow
4. Refrigerant Pressure

Condenser
5. Water Inlet Temp
6. Water Outlet Temp
7. Water Flow
8. Refrigerant Pressure

Power
9. Chiller Amps
10. Chiller Volts
11. Chiller Power Factor



Auxiliaries
12. Primary (& Secondary) CHW Pump kW
13. Primary CW Pump kW
14. Cooling Tower Fans kW

Weather - Optional
15. Outside Air Temperature
16. Relative Humidity

Planning for Measurement & Data Collection

- Use a template
- Characterize the measurement
  - Local sensor
  - Data Acquisition
  - Historian
- **Instrumentation GAP Analysis Worksheet**
- Tick mark the appropriate boxes
- Complete for the chiller system
- Define final plan

	Chiller #1		
Chiller Capacity (RT)			
Refrigerant			
Chiller Manufacturer			
Chiller Model Number			
	Local Sensor	Data Acquisition	Historian
Condenser			
Saturation Temperature (°F)			
Condenser Pressure (psig)			
Inlet Water Temperature (°F)			
Outlet Water Temperature (°F)			
Water Flow rate (gpm)			
SubCooler			
Refrigerant Outlet Temperature (°F)			
Water Inlet Temperature (°F)			
Water Outlet Temperature (°F)			
Water Flow rate (gpm)			
Economizer			
Economizer Pressure (psig)			
Evaporator			
Saturation Temperature (°F)			
Evaporator Pressure (psig)			

Better Plants Diagnostic Equipment Program (DEP)

Better Plants
U.S. DEPARTMENT OF ENERGY

Diagnostic Equipment Program (DEP)

The Better Plants **Diagnostic Equipment Program (DEP)** allows partners to borrow over 22 different kinds of tools to collect energy data and improve equipment performance in their facilities.

Through this program, partners have the opportunity to test tools firsthand before deciding to purchase a piece of equipment on their own. This not only allows for the improved testing and collection of energy data, but also helps to demonstrate the value of certain tools in different applications throughout a facility.

FULL SUITE OF DIAGNOSTIC TOOLS

- Anemometer
- Combustion Analyzer
- Conductivity Meter
- Current Transformer
- Digital Manometer
- Digital Thermometer
- Infrared Camera
- Infrared Thermometer
- Laser Distance Meter
- Light Meter
- Pitot Tube
- Power Logger
- Pressure Transducer
- Pyrometer
- Sonic Imager
- Strobe Tachometer
- Temp/RH logger
- Thermocouple
- Thermocouple Logger
- Time of Use Logger
- Ultrasonic Flow Meter
- Ultrasonic Leak Detector

EXPLORE SOME OF THE TOOLS THAT YOU CAN BORROW THROUGH BETTER PLANTS:

POWER LOGGER

This device helps you directly measure energy consumption, which can be converted into costs. It also logs data to provide electric consumption trends.

CURRENT TRANSFORMER

Use this device with a data logger to quantify the electric current flowing to a component or system and identify wasted energy.

COMBUSTION ANALYZER

This analyzer quantifies excess oxygen in boilers and combustion process exhausts, helping you save fuel and heat energy.

LEAK DETECTOR

This device helps you identify leaks in compressed air or steam systems using high frequencies that are undetectable to the human ear.

betterbuildingssolutioncenter.energy.gov/better-plants/diagnostic-tools @BetterPlantsDOE linkedin.com/showcase/better-plants

EXPLORE THE FULL SUITE OF DIAGNOSTIC EQUIPMENT AND SUBMIT AN APPLICATION:

Scan the QR Code above, or click here to download the DEP rental application.

Send this completed form to the Better Plants Diagnostic Equipment Program Manager, Daryl Cox at coxdf@ornl.gov.

HAVE QUESTIONS ABOUT BORROWING EQUIPMENT?

Scan the QR code above, or click here to email Daryl Cox, DEP Program Manager.

Daryl Cox has over 20 years of experience managing industrial technology and equipment and can help you find the right tool for your energy needs.

MEASUR – Process Cooling Module

U.S. DEPARTMENT OF
ENERGY

Introducing MEASUR – Process Cooling Module

Introducing MEASUR – Process Cooling Module

GVG_PC_Training
Last modified: Jul 28, 2026
BETA

Baseline Assessment **Report**

Executive Summary | Performance Profile | System Profile | Pump Summary | Tower Summary | Input Summary | Facility Info | Graphs

Export Reports

	Baseline	Scenario - Sliding CWT Temperature	Scenario - Raise CHWT	Scenario - Decrease CWT
Percent Savings (%)	——	-5.4%	0.9%	1.0%
Chiller Energy (kWh)	7,485,479	8,162,453	7,403,626	7,308,226
Chiller Energy Cost ($)	$748,548	$816,245	$740,363	$730,823
Tower Energy (kWh)	364,813	162,047	364,715	453,078
Tower Energy Cost ($)	$36,481	$16,205	$36,471	$45,308
Chilled Water Pumping Energy (kWh)	399,470	399,470	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881	$89,881	$89,881
Total Energy (kWh)	**8,749,100**	**9,223,307**	**8,667,148**	**8,660,111**
Energy Savings (kWh)	**——**	**-474,207**	**81,951**	**88,989**
Total Cost ($)	**$874,910**	**$922,331**	**$866,715**	**$866,011**
Cost Savings ($)	**——**	**-$47,421**	**$8,195**	**$8,899**
Energy Efficiency Measures Used	——	Use Sliding Condenser Water Temperature	Modify Chilled Water Temperature	Modify Condenser Water Temperature

Copy Table

MEASUR – Process Cooling Module Introduction

- A central chilled water system may account for a quarter to a third of facility energy consumption.
- The main goals of any cooling system
  - Provide adequate cooling to process or comfort load
  - Reduce energy consumption of the chilled water SYSTEM
- MEASUR – Process Cooling module <u>IS NOT</u> intended to determine system energy use down to the last kWh
- MEASUR – Process Cooling module <u>IS</u> intended to direct analysis effort toward the most promising cost reduction opportunities

Installation of MEASUR

- MEASUR suite is developed by ORNL

- Available on the Better Plants / ORNL website
  - https://industrialresources.ornl.gov/measur/home
  - https://github.com/ORNL-AMO/MEASUR-Tools-Suite

- Desktop application that can be used offline on either Windows, Mac, or Linux systems or Use the online web version to conduct assessments on your computer, tablet, or phone.

- Administrative privileges maybe required for Desktop based offline application, not required for web version use

MEASUR – Process Cooling Use

- Either of the following links can be used for access
  - For Online Use, visit following link and click process cooling
    - https://measur.ornl.gov/
  - For Offline Use, download or install at following links based on your system type
    - https://github.com/ORNL-AMO/MEASUR-Tools-Suite
    - https://github.com/ORNL-AMO/AMO-Tools-Desktop/releases

MEASUR – Process Cooling Use

- The assessment can use any location from large online database of weather files of various locations. The database can be accessed at https://weather.ornl.gov/api/
- The assessment uses 8,760 hourly weather data for system simulation for baselining energy use and calculate energy savings for proposed changes.
- The assessment model of your chilled water system can be exported as file to your PC for storage and future retrieval to make any changes to your model.
  - SUGGESTION – Make your personal model folder and store all your work there – easier to reach the files since they will all be in one place and will minimize searching

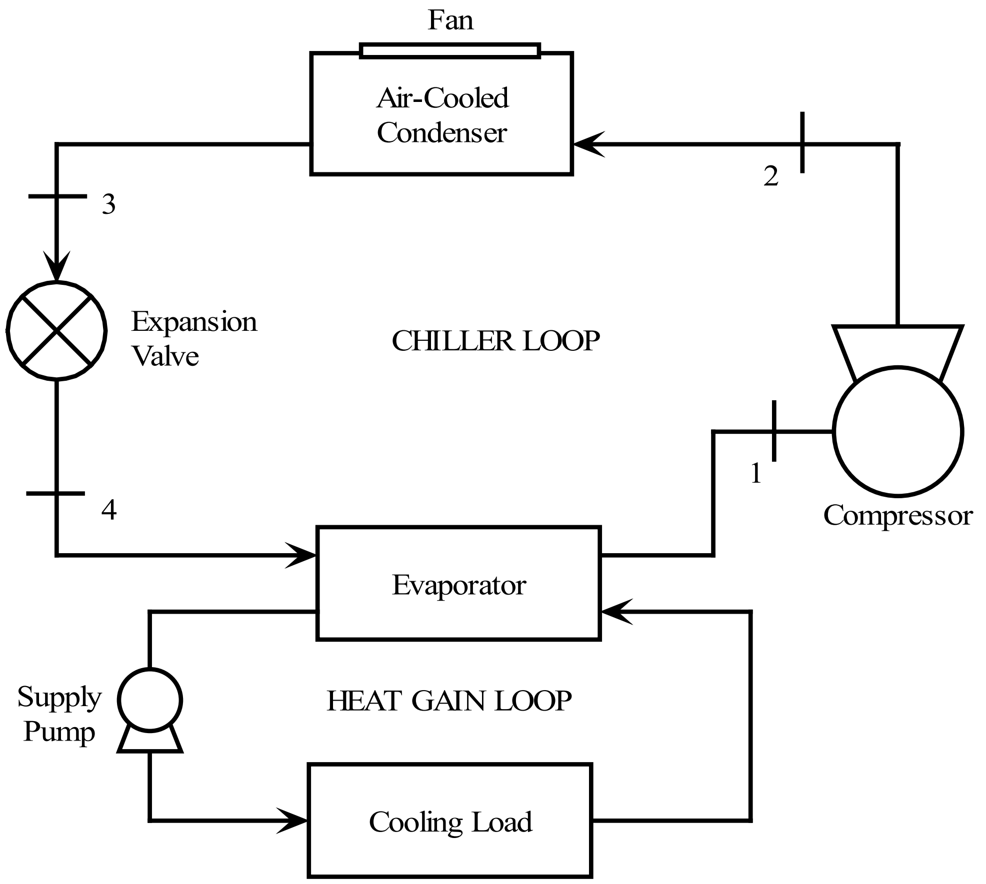
ACRONYMS

- CHWS: Chilled Water Supply
- CHWR: Chilled Water Return
- CWS: Condenser Water Supply
- CWR: Condenser Water Return

- FLE: Full Load Efficiency

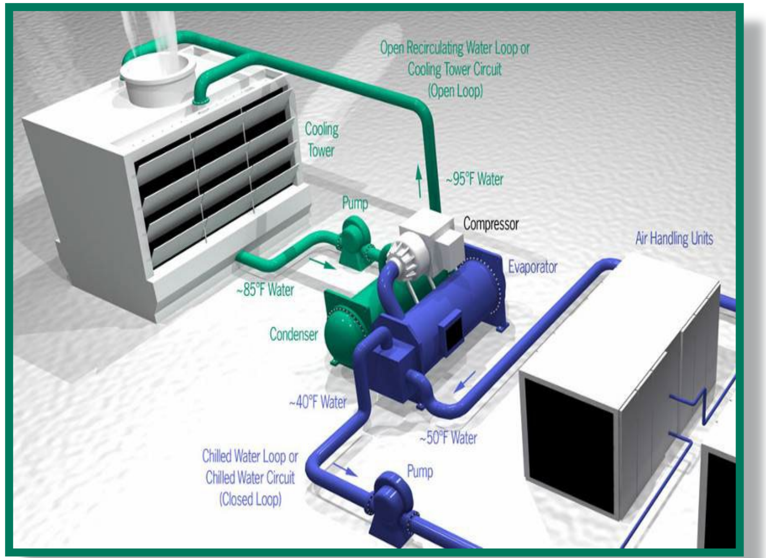
MEASUR – Process Cooling System Configurations

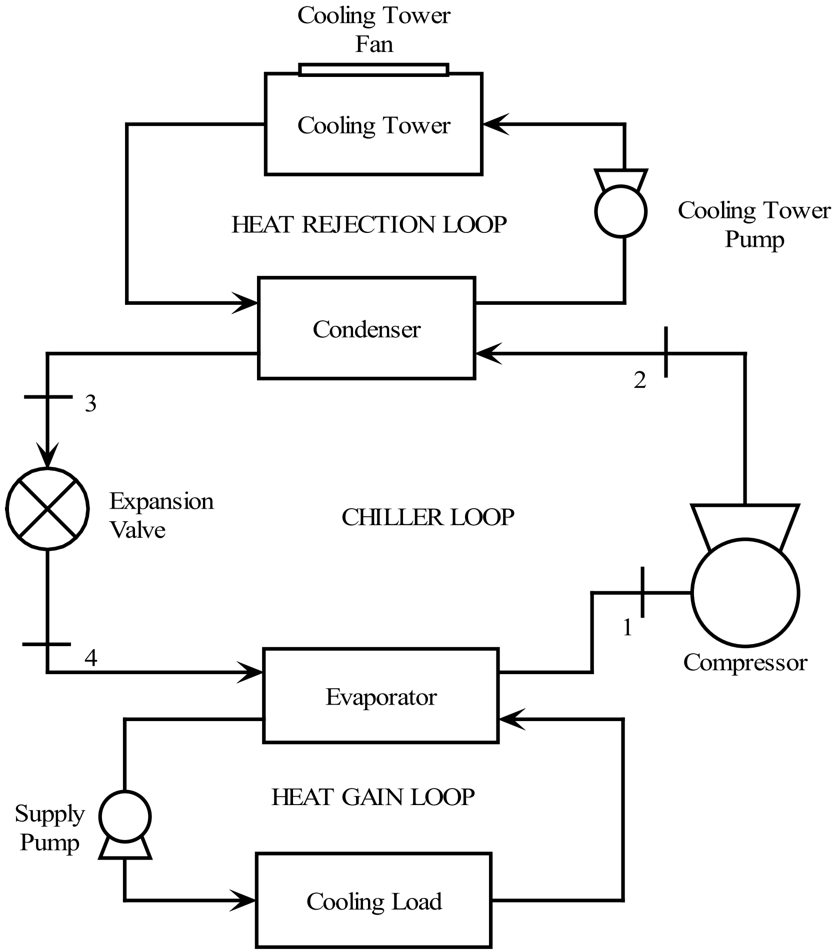
- Air-Cooled Chilled Water System:
  - Single Chiller
  - Multiple Chillers



MEASUR – Process Cooling System Configurations

- Water-Cooled Chilled Water System:
  - Single Chiller





  - Multiple Chillers

Polling Question 1

Polling Questions

1) How many chillers do you have in your chilled water plant where you will be doing your energy assessment?
   A. 1 - 3
   B. 4 - 5
   C. > 5
   D. Don't know yet

MEASUR – Process Cooling Supported Equipment Types

- Mechanical vapor compression chillers (Centrifugal, reciprocating, and twin-screw helical rotary compressors)
- Air or water-cooled condensers
- Direct contact towers
- Mechanical draft towers (crossflow or counterflow)
- Shell-and-tube evaporators (other designs are limited to low capacity applications)
- Simple pump control configurations on primary circuit (with exception for secondary)

MEASUR – Process Cooling Equipment Types NOT Supported

- Absorption chillers
- Single Screw, Scroll, or Troichoidal compressors
- Evaporative condensers
- Indirect contact towers such as wet/dry or dry towers
- Natural or spray-induced draft towers
- Secondary pumping circuit (on chilled water or condenser water loop)
- Chillers connected in series

MEASUR – Process Cooling Energy Calculations

- Chillers
  - Uses catalog & manufacturer's data to follow typical performance curves
  - Uses correlations to adjust for actual condenser water (where applicable) and chilled water temperature
  - Uses schedules to determine hours at given load

- Cooling Towers
  - Uses iterative process and prototypical performance correlation to determine fan energy
  - Correlation inputs rely on weather data, chiller load, and condenser pump flow rate

- Pumps
  - Uses power provided as an input or utilizes pump energy equation to estimate pump horsepower & energy

Data Collection from Site

- Basic System Data (Observation)
  - Understand and observe the need for cooling/chilled water requirement
  - Number of Chillers & Chiller Type (Centrifugal, Reciprocating, Screw)
  - Number of Chilled Water Pumps
  - Number of Condenser Water Pumps
  - System Type – Air Cooled or Water Cooled
    - Location of Cooling Tower
      - Dedicated
      - Supplies to other processes
  - Number of towers / air-cooled condensers

Data Collection from Site

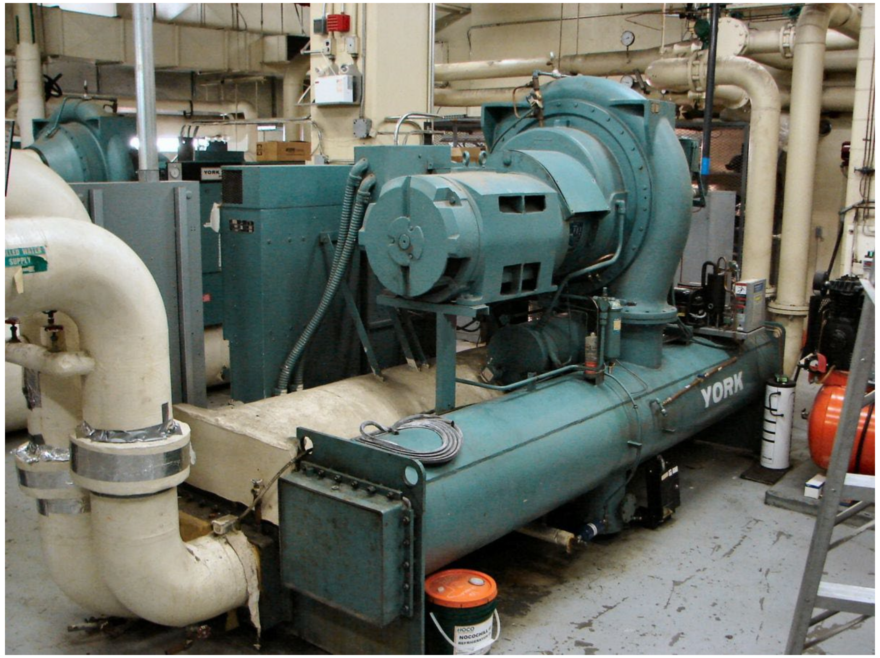
- Nameplate data
  - Chiller manufacturer & model number
    - Cooling Capacity (kW)
    - Efficiency
    - Age
  - Cooling Tower manufacturer & model number
    - Tower size (kW)
    - Efficiency
    - Tower type (# fans / # cells / motor control)
  - Pump & Pump Motor manufacturer & model number
    - Pump Curve (flow rate, efficiency)
    - Motor kW & Efficiency

Data Collection from Site

- General Operating Parameters (conversations with facility personnel, chiller control panels, temperature sensors, observations)
  - Chilled Water Supply Temperature (setpoint)
  - Condenser Water Supply Temperature (setpoint and/or strategy)
  - Chilled Water Supply Flow Control (constant or variable, primary/secondary system)
  - Condenser Water Supply Flow Control (constant or variable, Heat exchanger used)

Chilled Water System Components

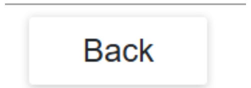
- Components Covered by MEASUR – Process Cooling
  - Chiller Types:
    - Centrifugal
    - Helical Rotary / Screw
    - Reciprocating
  - Condenser Types:
    - Water Cooled with Cooling Towers
    - Air Cooled
  - Other Equipment:
    - Pumps
    - Fans
    - Piping & Valves
    - Heat Exchangers



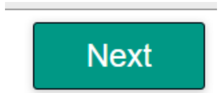
MEASUR – Process Cooling INPUT Screenshots

- Baseline
  1. Assessment Settings
  2. System Information
     - Operations
       - Utility Cost
       - Heat rejection setup
     - Weather
       - Geographic location
     - Pump(s)
       - Chilled water
       - Condenser water (if applicable)
     - Condenser Cooling
     - Tower
  3. Chiller Inventory
     - Default
     - Custom
  4. Operating Schedule
  5. Load Schedule

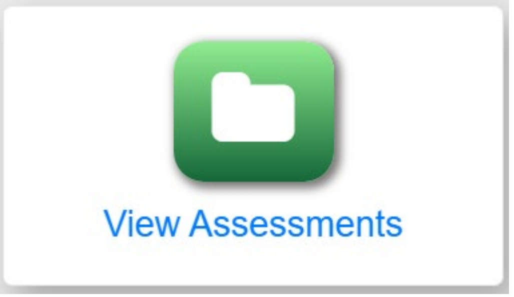
Click the “Back” to go back to previous screen

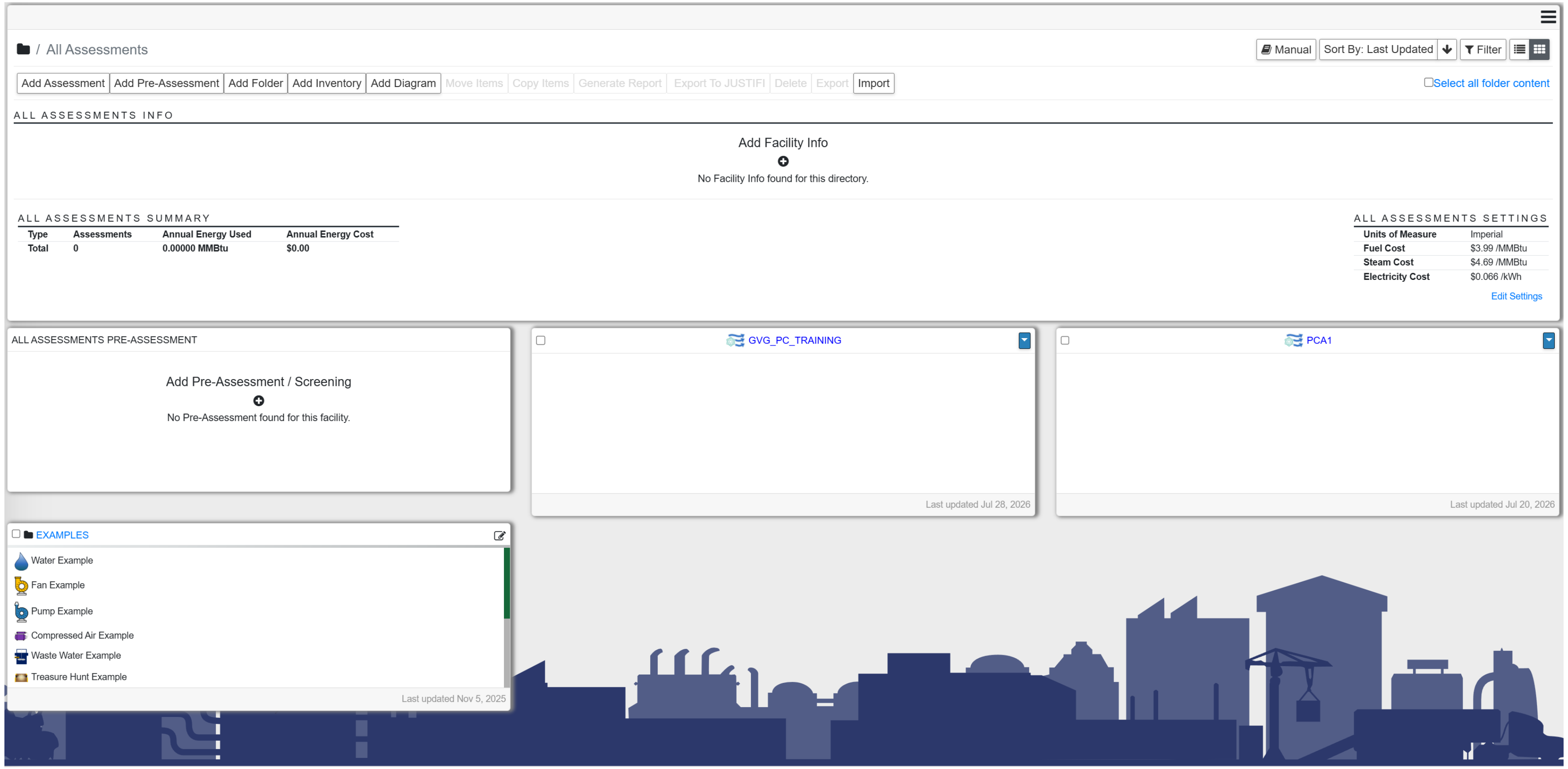


Click the “Next” Button to proceed to the next Input screen

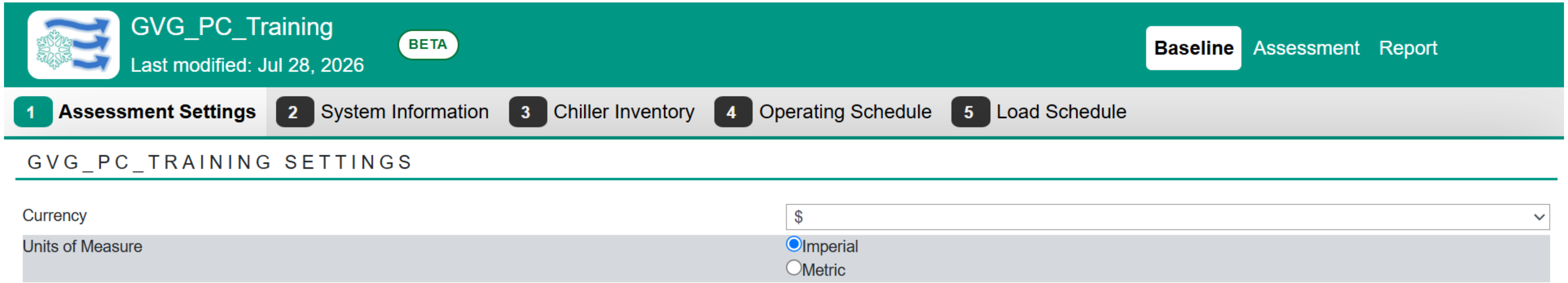


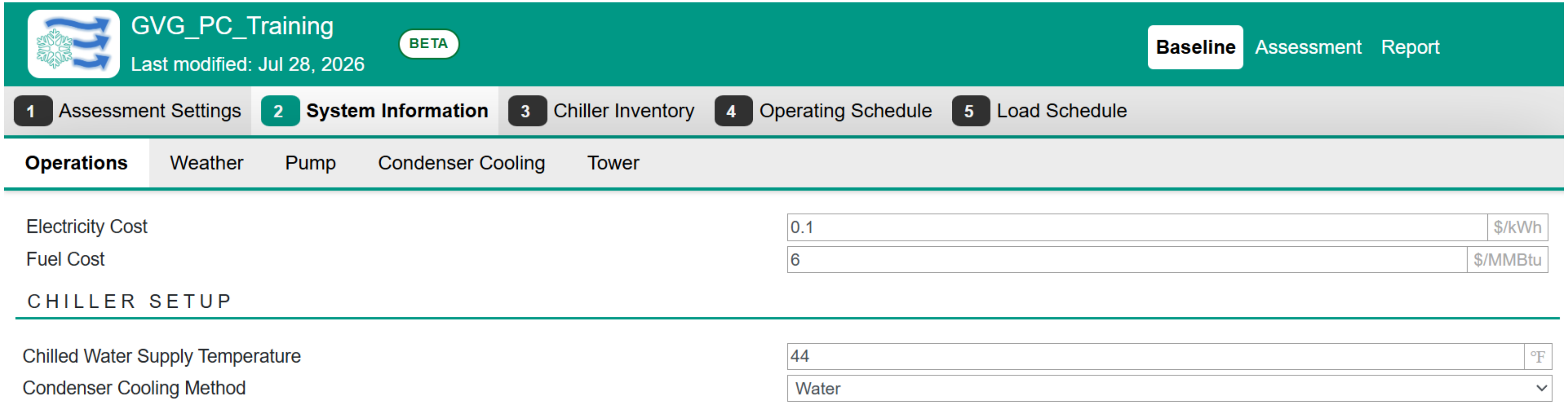
MEASUR – Process Cooling INPUT Screenshots



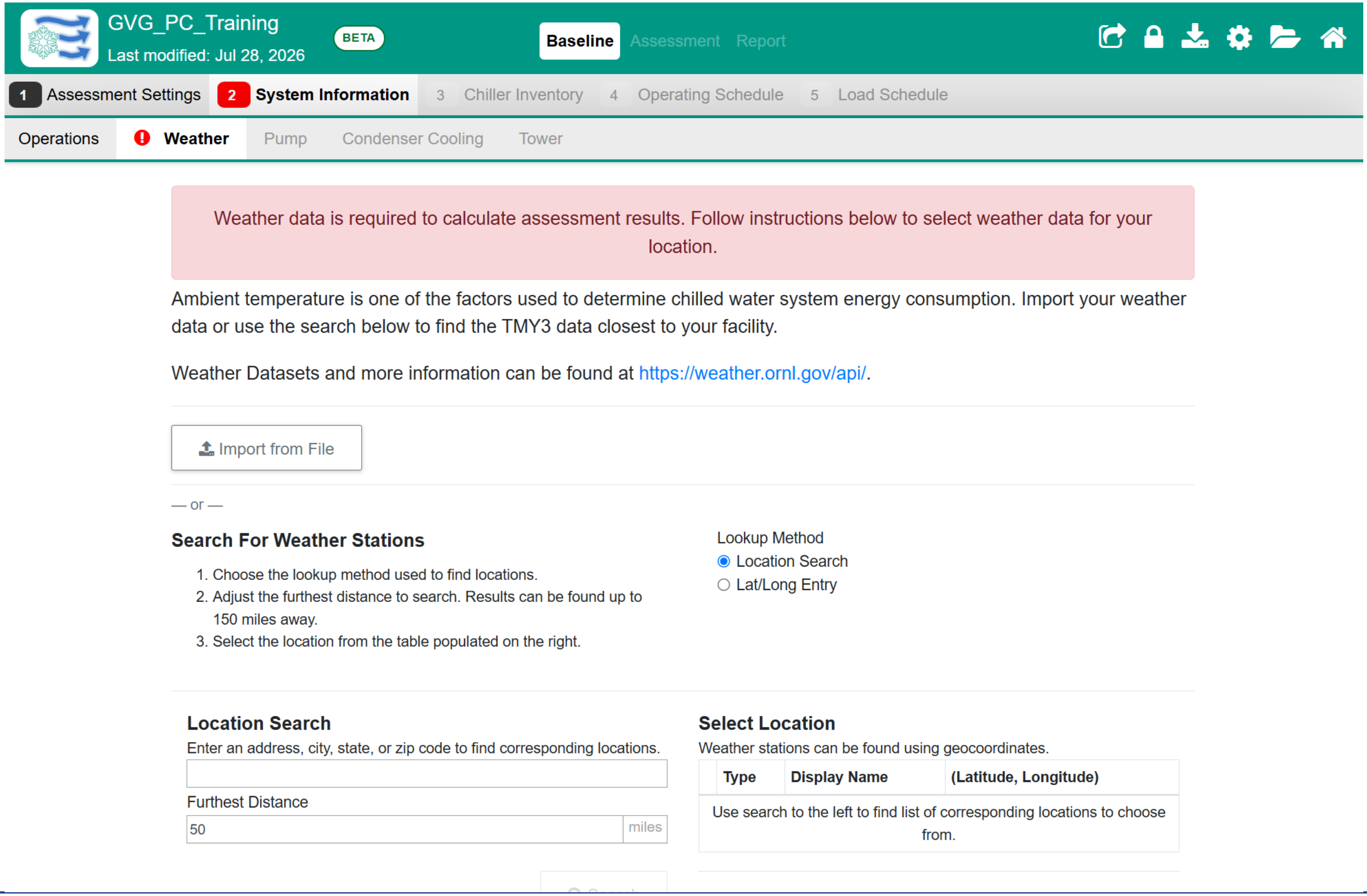


MEASUR – Process Cooling INPUT Screenshots





MEASUR – Process Cooling INPUT Screenshots



MEASUR – Process Cooling INPUT Screenshots

1 Assessment Settings | 2 **System Information** | 3 Chiller Inventory | 4 Operating Schedule | 5 Load Schedule

Operations | Weather | **Pump** | Condenser Cooling | Tower

CHILLED WATER PUMP

Variable Flow	No
Flow Rate	2.4 gpm/ton
Pump Efficiency	75 %
Motor Size	20 hp
Motor Efficiency	85 %

CONDENSER WATER PUMP

Variable Flow	No
Flow Rate	3 gpm/ton
Pump Efficiency	75 %
Motor Size	25 hp
Motor Efficiency	85 %

RESULTS | HELP

	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	7,485,479
Chiller Energy Cost ($)	$748,548
Tower Energy (kWh)	364,813
Tower Energy Cost ($)	$36,481
Chilled Water Pumping Energy (kWh)	399,470
Chilled Water Pumping Energy Cost ($)	$39,947
Condenser Water Pumping Energy (kWh)	499,337
Condenser Water Pumping Energy Cost ($)	$49,934
Total Pump Energy (kWh)	898,807
Total Pump Energy Cost ($)	$89,881
Total Energy (kWh)	**8,749,100**
Energy Savings (kWh)	**——**
Total Cost ($)	**$874,910**
Cost Savings ($)	**——**
Energy Efficiency Measures Used	——

MEASUR – Process Cooling INPUT Screenshots

1 Assessment Settings | **2 System Information** | 3 Chiller Inventory | 4 Operating Schedule | 5 Load Schedule

Operations | Weather | Pump | **Condenser Cooling** | Tower

WATER COOLED CONDENSER

Is Condenser Water Temp Constant	Yes
Condenser Water Temperature	85 °F

RESULTS | HELP

	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	7,485,479
Chiller Energy Cost ($)	$748,548
Tower Energy (kWh)	364,813
Tower Energy Cost ($)	$36,481
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Total Energy (kWh)	**8,749,100**
Energy Savings (kWh)	——
Total Cost ($)	**$874,910**
Cost Savings ($)	——
Energy Efficiency Measures Used	——

MEASUR – Process Cooling INPUT Screenshots

1 Assessment Settings | 2 **System Information** | 3 Chiller Inventory | 4 Operating Schedule | 5 Load Schedule

Operations | Weather | Pump | Condenser Cooling | **Tower**

Tower Type	2-Cell With 1-Speed Motors
Number of Towers	1
Tower Size Metric	Tons
Tower Size	2000 tons
Fan Type	Axial
Uses Free Cooling	No

RESULTS | HELP

	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	7,485,479
Chiller Energy Cost ($)	$748,548
Tower Energy (kWh)	364,813
Tower Energy Cost ($)	$36,481
Chilled Water Pumping Energy (kWh)	399,470
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Total Energy (kWh)	**8,749,100**
Energy Savings (kWh)	——
Total Cost ($)	**$874,910**
Cost Savings ($)	——
Energy Efficiency Measures Used	——

MEASUR – Process Cooling INPUT Screenshots

1 Assessment Settings | 2 System Information | 3 **Chiller Inventory** | 4 Operating Schedule | 5 Load Schedule

CHILLER INVENTORY

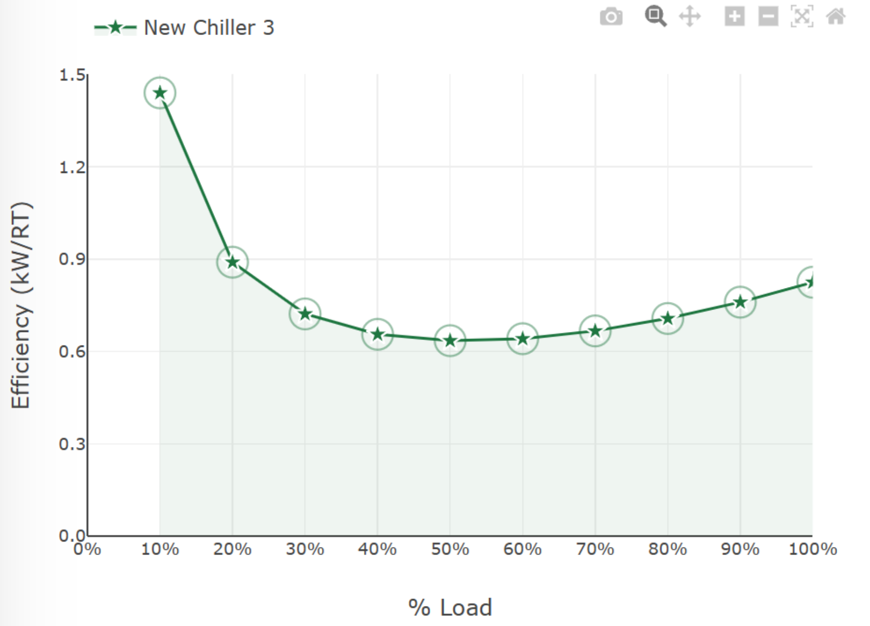
Chiller Name	New Chiller 3
Description	
Chiller Type	Helical Rotary
Is Full Load Efficiency Known?	Yes
Full Load Efficiency	0.75 kW/ton
Capacity	350 tons
Age	10 years

☐ Use Custom Performance (per AHRI 550/590)

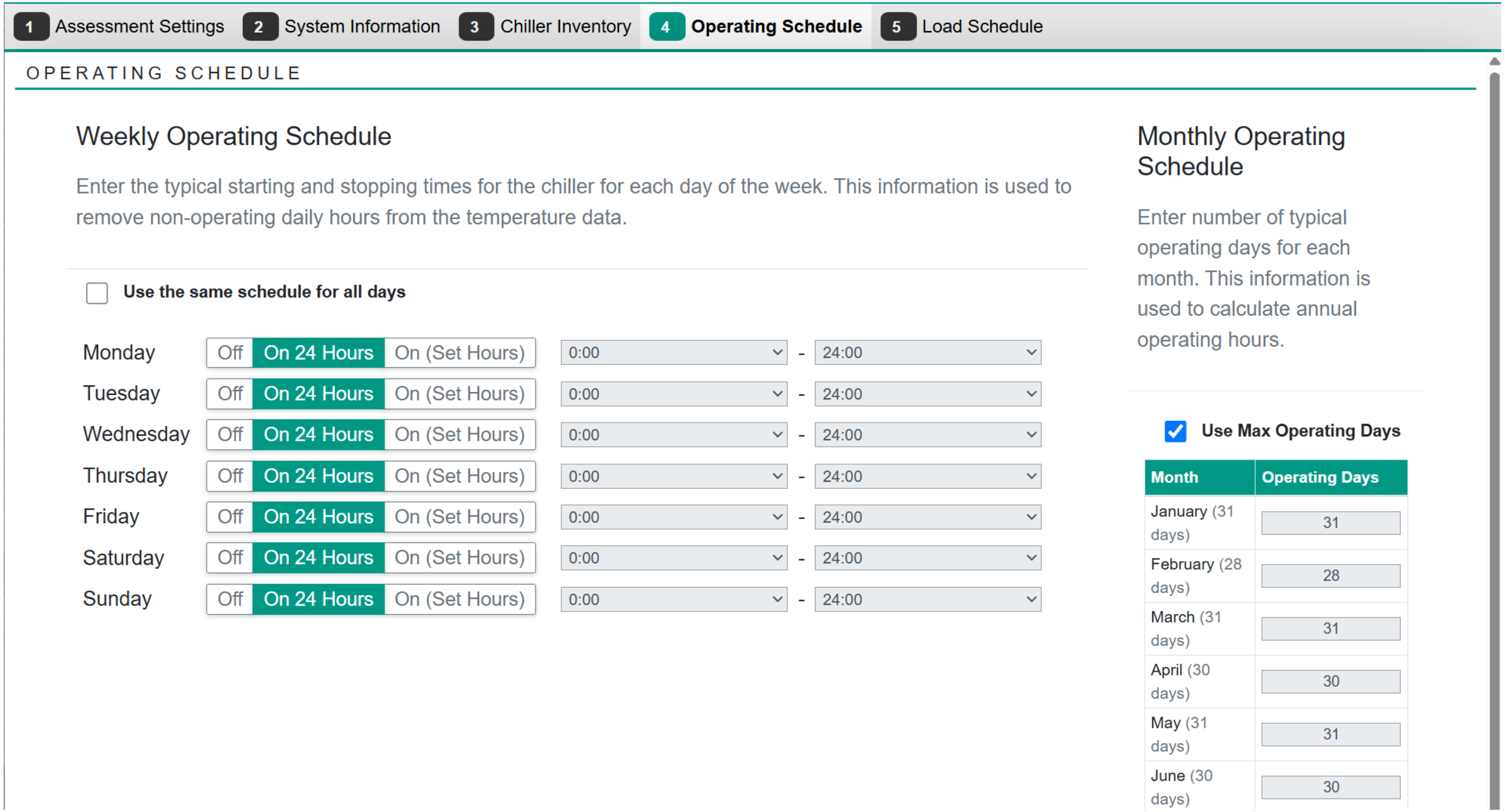
INVENTORY | RESULTS | HELP

Name	Compressor / Chiller Type	Full Load Efficiency (kW/ton)	Chiller Capacity (tons)
New Chiller 1	Centrifugal	0.65	1000
New Chiller 2	Centrifugal	0.65	1000
New Chiller 3	Helical Rotary	0.75	350

+Add New Chiller



MEASUR – Process Cooling INPUT Screenshots



MEASUR – Process Cooling INPUT Screenshots

1 Assessment Settings | 2 System Information | 3 Chiller Inventory | 4 Operating Schedule | 5 **Load Schedule**

New Chiller 1

New Chiller 1 Loading: All Months

Enter the percentage of hours the chiller operates at a given load. Total should be 100%.

Enter different schedule for each month

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total %
All months	5	0	0	0	10	20	20	20	15	10	0	100

New Chiller 2

New Chiller 2 Loading: All Months

Enter the percentage of hours the chiller operates at a given load. Total should be 100%.

Enter different schedule for each month

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total %
All months	5	0	0	0	10	20	20	20	15	10	0	100

New Chiller 3

New Chiller 3 Loading: All Months

Enter the percentage of hours the chiller operates at a given load. Total should be 100%.

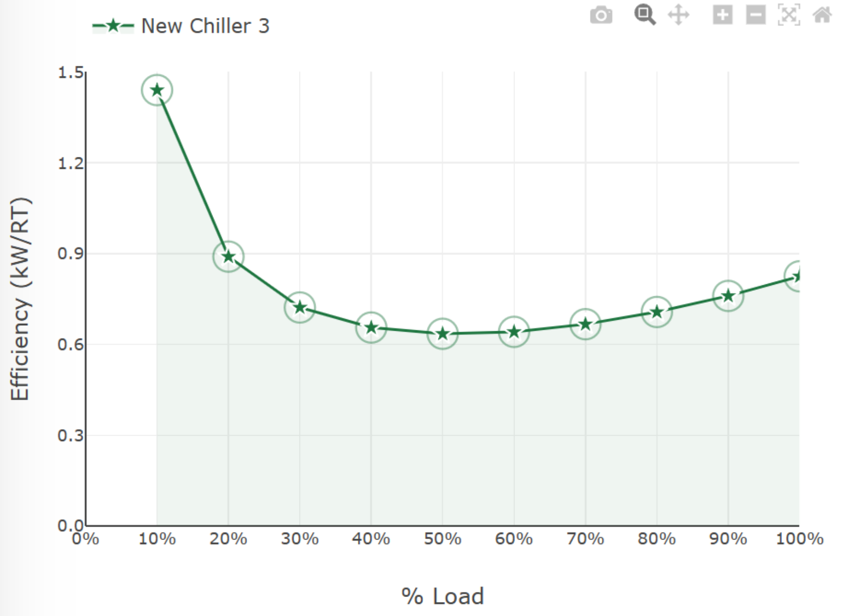
Enter different schedule for each month

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total %
All months	30	0	0	30	0	30	0	0	0	0	10	100

INVENTORY | RESULTS | HELP

Name	Compressor / Chiller Type	Full Load Efficiency (kW/ton)	Chiller Capacity (tons)
New Chiller 1	Centrifugal	0.65	1000
New Chiller 2	Centrifugal	0.65	1000
New Chiller 3	Helical Rotary	0.75	350

+Add New Chiller



MEASUR – Process Cooling INPUT Screenshots

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Last modified: Jul 28, 2026

Baseline | **Assessment** | Report

Explore Opportunities

Scenario - Sliding CWT Temperature
Selected Scenario

View / Add Scenarios

SELECT POTENTIAL ENERGY EFFICIENCY MEASURES

Select potential energy efficiency measures (EEMs) to explore opportunities to increase efficiency and the effectiveness of your system.

Add New Scenario

Modification Name: Scenario - Sliding CWT Temperature

- [ ] Modify Chilled Water Temperature
- [ ] Modify Condenser Water Temperature
- [x] Use Sliding Condenser Water Temperature

Current Following Temp Differential: 0 °F
Proposed Following Temp Differential: 6 °F

- [ ] Apply Variable Speed Control to Chilled and/or Condenser Water Pumps
- [ ] Upgrade Cooling Tower Fans
- [ ] Use Free Cooling
- [ ] Install VSD on Centrifugal Compressors

RESULTS | HELP

	Baseline	Scenario - Sliding CWT Temperature
Percent Savings (%)	— —	-5.4%
Chiller Energy (kWh)	7,485,479	8,162,453
Chiller Energy Cost ($)	$748,548	$816,245
Tower Energy (kWh)	364,813	162,047
Tower Energy Cost ($)	$36,481	$16,205
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Total Energy (kWh)	**8,749,100**	**9,223,307**
Energy Savings (kWh)	**— —**	**-474,207**
Total Cost ($)	**$874,910**	**$922,331**
Cost Savings ($)	**— —**	**-$47,421**
Energy Efficiency Measures Used	— —	Use Sliding Condenser Water Temperature

Copy Table

MEASUR – Process Cooling INPUT Screenshots

GVG_PC_Training BETA

Last modified: Jul 28, 2026

Baseline Assessment **Report**

Executive Summary | Performance Profile | System Profile | Pump Summary | Tower Summary | Input Summary | Facility Info | Graphs | Export Reports

	Baseline	Scenario - Sliding CWT Temperature	Scenario - Raise CHWT	Scenario - Decrease CWT
Percent Savings (%)	— —	-5.4%	0.9%	1.0%
Chiller Energy (kWh)	7,485,479	8,162,453	7,403,626	7,308,226
Chiller Energy Cost ($)	$748,548	$816,245	$740,363	$730,823
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Cost Savings ($)	**— —**	**-$47,421**	**$8,195**	**$8,899**
Energy Efficiency Measures Used	— —	Use Sliding Condenser Water Temperature	Modify Chilled Water Temperature	Modify Condenser Water Temperature

Copy Table

Homework #3

- Review the Instrumentation Gap Analysis worksheet and complete it for the Chilled Water Plant that is going to be assessed
- Review the instrumentation available from the Better Plants ORNL Loan program and identify any instruments that you will need to get from ORNL for the VINPLT assessment
- Download or Use the MEASUR software from the US DOE / ORNL website

- For the Brave Hearts - Attempt to build a chilled water system model in MEASUR of your own chilled water plant

Thank You all for attending today's webinar.

See you next Thursday – August 6, 2026 – 2 pm ET

If you have specific questions, please stay online and we will try and answer them.

Alternately, you can email questions to us at paparra@ornl.gov and g@greensystemio.com

U.S. DEPARTMENT OF ENERGY

Kahoot Quiz Time