Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 2

Thursday – July 18, 2024

10 am – 12:30 pm

Welcome

- Welcome to the 2nd 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 CWSAT and other US DOE tools and resources
- Thank you for your interest!

Acknowledgments

- US Department of Energy, Industrial Efficiency & Decarbonization Office (IEDO)
- Oak Ridge National Laboratory
- Dr. Beka Kosanovic – University of Massachusetts, Amherst, MA
- Several industrial clients – both in the US and internationally

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Process Cooling (Chilled Water Systems) Virtual INPLT Facilitator

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Agenda – Session 2

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
    - Compressor drives
    - Types of chilled water plants
    - Chilled Water system Scoping Tool
    - Description of example chilled water system
    - Chilled water system efficiency metrics
- Kahoot Quiz Game
- Q&A

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

Safety and Housekeeping

- Safety Moment
  - Chillers (compressors) are extremely loud – use hearing protection whenever near large turbomachinery equipment
- You are welcome to ask questions at any time during the webinar

- When you are not asking a question, please MUTE 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

Process Cooling Virtual INPLT Agenda (2024)

- Session 1 (July 17) – Industrial Chilled Water Systems Fundamentals
- **Session 2 (July 18) – Review of Chilled Water System Scoping Tool; Efficiency Metrics & Calculations**
- **Session 3 (July 31) – Introduction to Chilled Water System Assessment Tool (CWSAT)**
- **Session 4 (August 1) – Using CWSAT to Quantify Energy Efficiency Opportunities – Part 1**
- **Session 5 (August 14) – Using CWSAT to Quantify Energy Efficiency Opportunities – Part 2**
- **Session 6 (August 15) – US DOE MEASUR, 3EPlus, etc.; Undertaking a VINPLT Assessment & Reporting**
- **Session 7 (August 28) – Case Studies; Refrigerants – Past, Present & Future; Reclamation and O&M**
- **Session 8 (August 29) – Industrial Process Cooling (Chilled water) System VINPLT Wrap-up Presentations**

Types of Compressor Drives & Controls

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Chiller Compressor Drives

- The refrigerant compressor needs rotational shaft "horsepower" to compress the refrigerant vapor and move it from the evaporator (low pressure) to the condenser (high pressure)

- Several options exist
  - Electric motor drives
    - Constant speed (most common)
    - Variable frequency (have become a standard offering)
  - Steam turbine drives
  - Engine drives (least common)

Electric Motor Drives (Fixed Speed)

- Most common and standard option with all packaged chiller systems
- Motor efficiency >93% and stays relatively flat and high unless loads drop below 35-40%
- Compressor flow is controlled by one of the following mechanisms
  - Inlet guide vanes
  - Exit dampers
  - Slide valves
  - Unloading
  - Hot gas bypass
- Generally, these systems will show strong part-load impacts – depending on other parameters also

Electric Motor Drives (Variable Frequency)

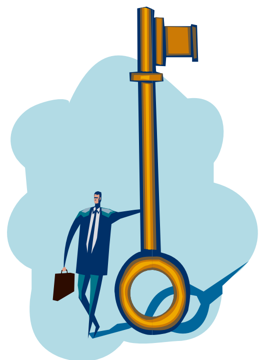
- Becoming a standard option with new chillers and also a retrofit option
- Provides for very high power factors (>0.97)
- Provides soft start capability
- VFD efficiency is very high >98% and so doesn't introduce any major losses
- Compressor flow is controlled by varying the speed of the compressor
- Tremendous ability to match Loads with Lift and provide significant savings at part-load conditions
  - Temperature Lift is the difference in the refrigerant saturation temperatures between the condenser and evaporator

Steam Turbine Drives

- Classic cogeneration (CHP) application where both steam and chilled water are required simultaneously
  - Backpressure steam turbines
- Condensing steam turbines are used for large tonnage chillers
- Compressor flow is controlled by
  - Speed control
  - Inlet guide vanes
  - Hot gas bypass
- Used also for
  - Emergency purposes
  - In locations where electric grid reliability maybe an issue
  - Existing electric infrastructure cannot support additional capacity
  - Significant amounts of low (or no) cost fuel available

Steam Turbine Drives

Key Points / Action Items



1. The most common compressor drive is the fixed-speed (or VFD) electric motor but other drivers are available

2. There are several control mechanisms to control the compressor operation to meet the cooling load

3. Part-load operation can be very inefficient and several state-of-the-art technologies are available including VFDs to improve efficiency

Types of Industrial Chiller Plant Distribution Systems

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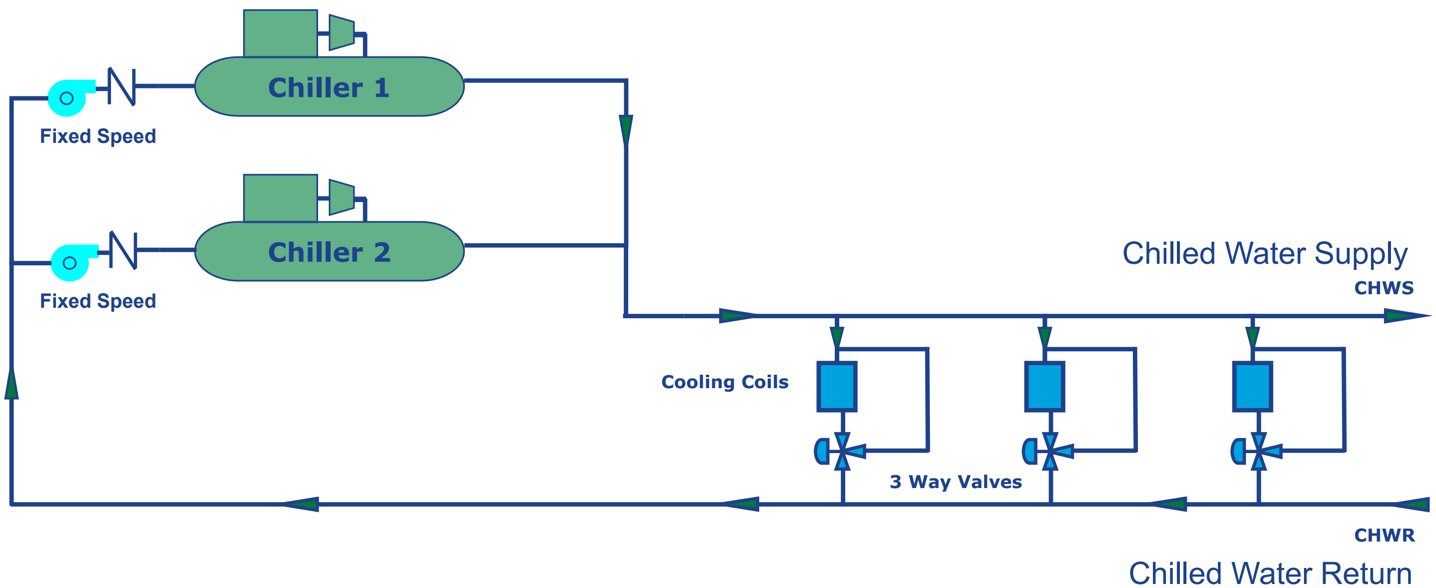
Chilled Water Distribution

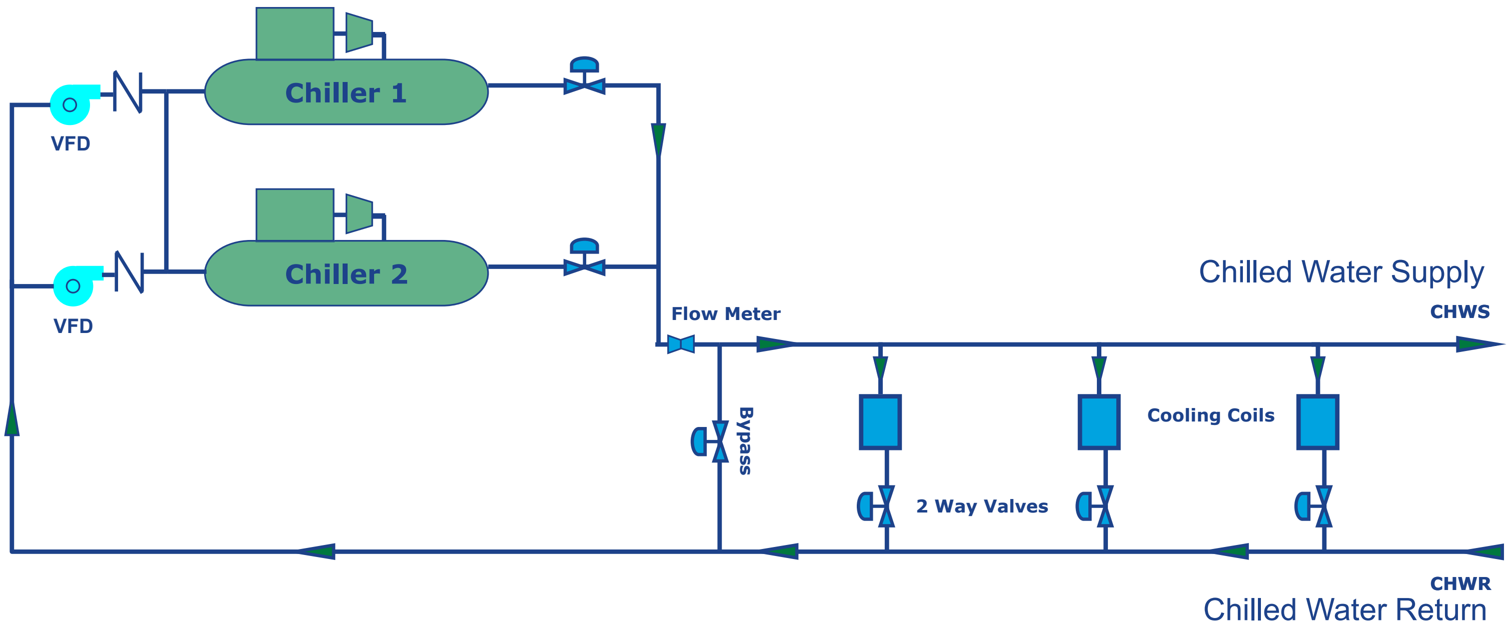
- Chillers represent the “Generation” area
- End-use is spread out everywhere in the plant / facility
- Multiple options exist for providing chilled water to end-uses
  - Dedicated chillers (decentralized system) – very common w/air-cooled smaller systems
  - Centralized chilled water plant
  - Combination – based on end-use, temperature requirement, location, etc.
- The distribution system (closed loop) is an extremely important piece of the puzzle
  - Remember “Systems Approach”

Fixed Speed Primary ONLY Chiller Plant



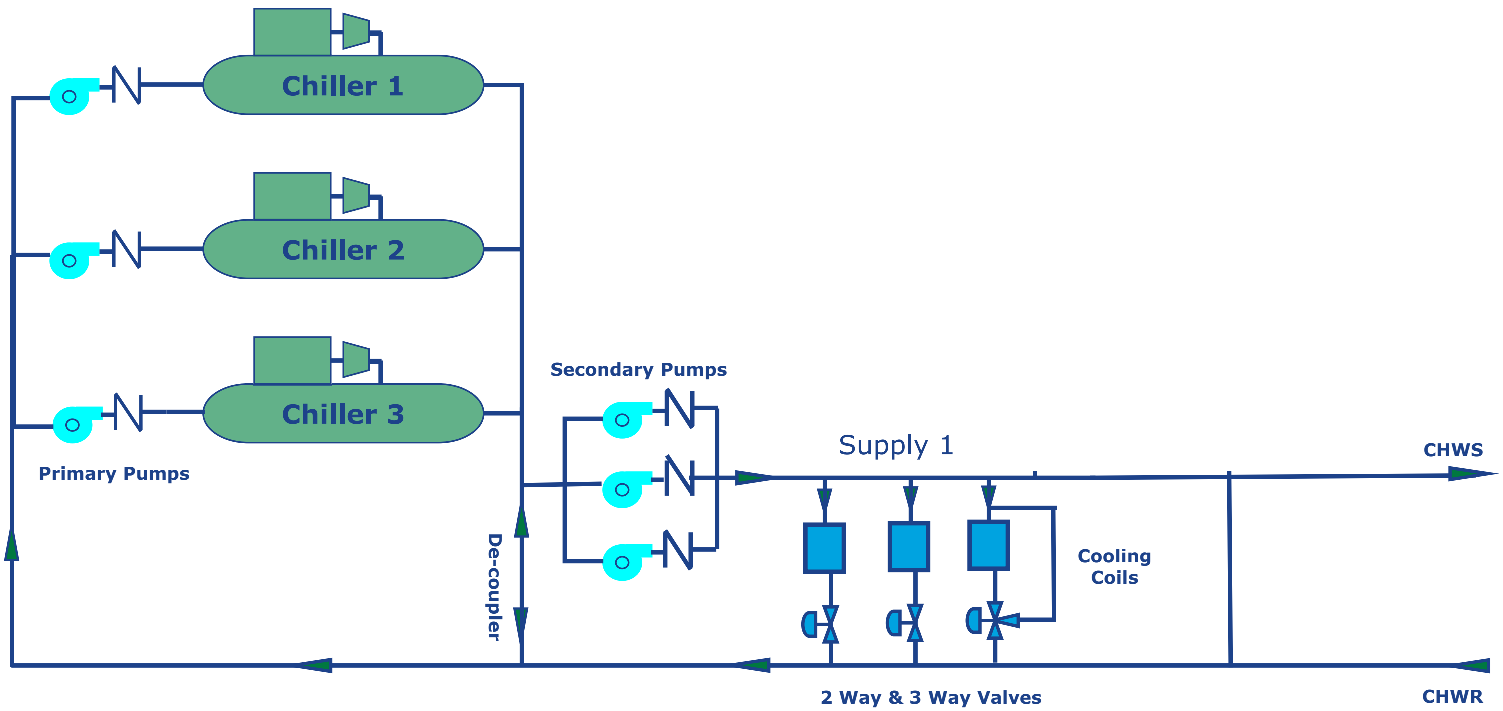
* CHWR is always reverse return but shown here as direct return for simplicity

Variable Speed Primary ONLY Chiller Plant



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

Primary & Secondary Loops Chiller Plant



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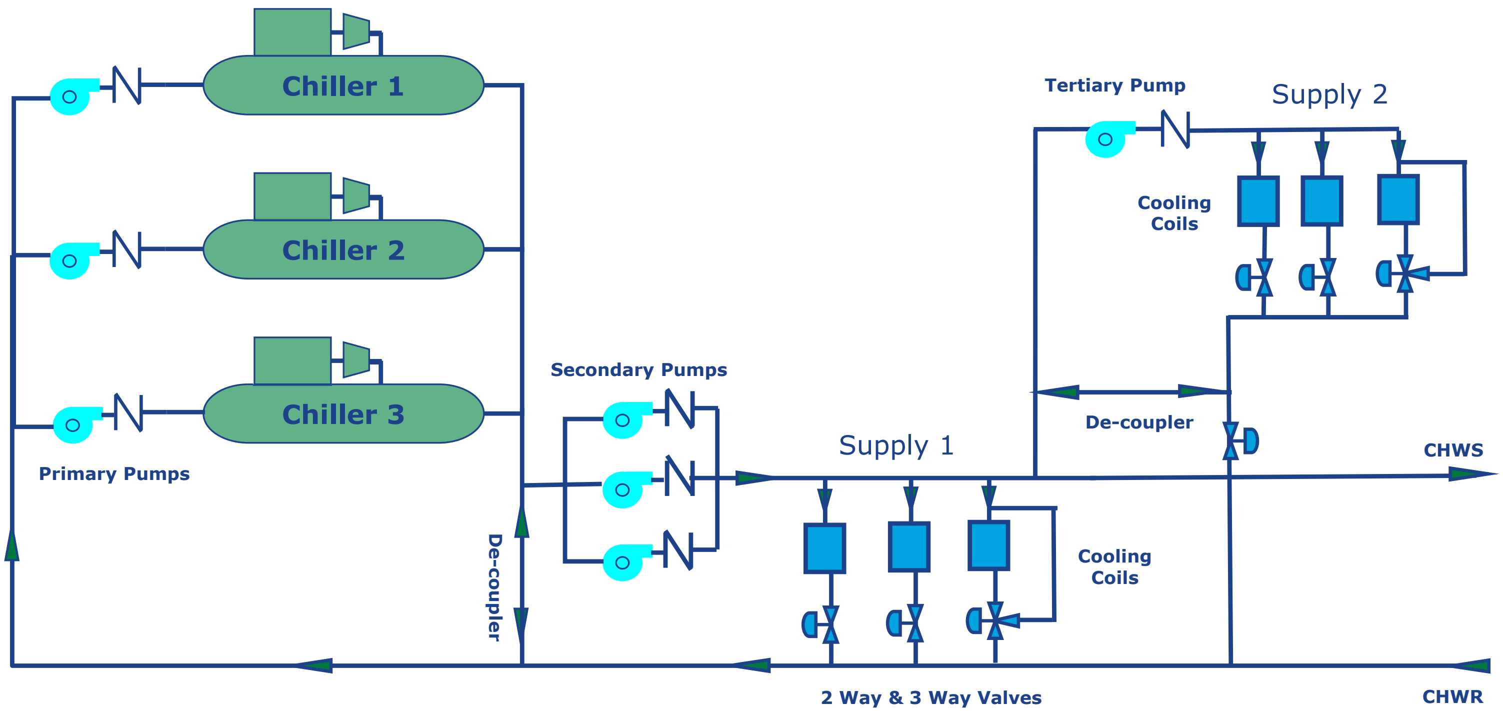
Primary, Secondary & Tertiary Loop Chiller Plant



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

Key Points / Action Items

1. *Chillers are generally centralized and located in the mechanical room (compressor room)*

2. *End-use is spread out and it is imperative that the chilled water is supplied to and returned from the end-use most effectively (and efficiently)*

3. *Primary and secondary chilled water loop systems are very common but dedicated chiller systems also exist*

4. *A distribution system can play a major role in energy efficiency improvements*

Polling Question 1

Polling Questions

1) What type of chilled water distribution system do you have in your plant?
   A. None, dedicated end-use chillers only
   B. Primary ONLY
   C. Primary, Secondary
   D. Combination of dedicated and central loop
   E. Don’t know

Chilled Water System Scoping Tool (CWST)

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Introduction & Scope of CWST

- The Chilled Water System Scoping Tool (CWST) is an excel-based software questionnaire
- It is designed to enhance awareness of areas of chilled water plant system management
- Divided into typical chilled water system focus areas
- Provides the user a score that is indicative of management intensity and serves as a guide to useful information
- Tool to identify potential improvement opportunity areas
- Will NOT quantify the energy savings opportunities

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)

Intended CWST Users

- Industrial manufacturers
  - Plant managers
  - Utility managers
  - Plant process engineers

- Energy consultants
  - Energy efficiency experts (high-level)
  - System-focused experts

- Can also be used by institutional, commercial chilled water HVAC users

CWST Organization

- Instructions
- Background information
  - Contact and site information
  - Operating hours, etc.
- General questions on the chilled water plant system
- Chilled water system component questions
  - Compressors
  - Condensers (Water / Air – cooled)
  - Evaporators
  - Cooling towers
  - Waterside economizers / heat exchangers
  - Pumping systems

Obtaining Data for CWST Input

- Sources of data:
  - Information on operational equipment/data from:
    - Plant engineer/utilities/maintenance manager(s)
    - Piping & Instrumentation Diagrams
    - Chilled water system walk-through
    - Chilled water system operators
  - Actual current measurements
  - Computerized or print copy of historical records

- Expected time: 1.0 hours (60 minutes)

Steps for Use of CWST

- Open CWST file in Excel
- Review CWST sections to identify needed input data
- Work with very knowledgeable chilled water system personnel at the plant
- Obtain input data
- Insert answer choices or use pull-down menus provided for each question in the different CWST sections
- Be honest and be conservative w/answers
- SAVE file manually

Demonstration and Functionality of CWST

Chilled Water System Scorecard

Sr.	Question	Answer	Score
	Chilled Water Plant		
	General		90
1	How old is the chilled water plant system (equipment)?	<10 Years	10
2	When was the last time the chilled water system was audited?	1 year or less	10
3	Is the chilled water system operating energy cost monitored? How often?	Yes, monthly or more frequently	10
4	How is the chilled water plant controlled?	DCS / BMS & state of the art optimization package	10
5	Has a detailed chilled water system load analysis ever done to minimize the cooling done?	Yes	10
6	What percent of the chilled water plant capacity is generally utilized versus design?	Close to design or higher (>=80%)	10
7	Is there a regular maintenance program?	Yes	10
8	How is the overall quality of insulation of the chilled water system?	Very Good	10
9	Is the refrigerant charge level in each chiller inspected regularly? How often?	Yes, monthly or more frequently	10

CWST – Instructions

Chilled Water System Scoping Tool (CWST)

Color Legend

Orange	**User Input / Choose Value**
Green	**User Input / Numeric / Text**
Grey	**Intermediate/ Calculation**

Objective/Intended Use Notes:

The tool uses two evaluation question sets to infer the general energy efficiency potential of a facility. The first set of questions requires users to input company and plant level information that includes the background information, industry sector, and application type. This information is used to determine the fraction of energy consumed for process cooling compared to overall energy consumed by the plant. Then the user is asked about general plant-level operations and bestpractices. The second level of questionnaire is more detailed and looks at individual equipment and their operations in the system. The tool uses information from these questionnaires to evaluate operating practices and general upkeep of the individual equipment. Based on the answers provided the tool assigns highest scores to most efficient equipment and practices and lower scores to less efficient equipment or practice. This allows the tool to estimate the level of energy efficiency opportunity present in the system.

Instructions for filling out details:

1. Please use the color legend indicated above to input answers to the questions indicated.
2. Include information for all chilled water plant system equipment such as compressors, evaporators, condensers, cooling towers, heat exchangers, associated fans and pumps etc.

Disclaimer:

This scoping tool is created as a supplemental guidance tool to accompany 'Process Cooling Virtual INPLT Training' delivered by the US DOE. US DOE, ORNL, C2A Sustainable Solutions makes no warranty, express or implied, or assumes any legal liability or responsibility for the accuracy or completeness of any information provided or recommended. This tool should be used as a general guidance only.

Acknowledgments:

The developers of CWST would like to acknowledge the efforts of Subodh Chaudhari (Oak Ridge National Laboratory) and Hudson Technologies Company in helping to develop this tool. Additionally, the funding for this tool in its final form was provided by the Industrial Energy Efficiency UNIDO Project (National Cleaner Production Center - South Africa).

CWST – Basic Facility Information

Basic Facility Information

Contact Information

Company Name:		Location:	
Plant/Facility Name:		Primary Contact Person	
Address:		Industry Sector:	Pulp & Paper
Phone:		Application:	Process Cooling
Fax:		Specify if other:	
Email:		Primary Product:	

Operation Hours

Shift No.	Hours of Operation / Day	Days/Week	Weeks/Year	Annual Hours
1				0
2				0
3				0
Office Hours				0
Others				0

Specific Pre-Identified Problems:	1. 2. 3.
Energy Efficiency Ideas of Interest to Plant Personnel:	1. 2. 3.
Energy Use:	Based on the industry, the major application selected accounts for < 10% of the annual plant energy spend

CWST – Chilled Water System Scorecard - General

Chilled Water System Scorecard

Sr.	Question	Answer	Score
	Chilled Water Plant		
	General		90
1	How old is the chilled water plant system (equipment)?	<10 Years	10
2	When was the last time the chilled water system was audited?	1 year or less	10
3	Is the chilled water system operating energy cost monitored? How often?	Yes, monthly or more frequently	10
4	How is the chilled water plant controlled?	DCS / BMS & state of the art optimization package	10
5	Has a detailed chilled water system load analysis ever done to minimize the cooling done?	Yes	10
6	What percent of the chilled water plant capacity is generally utilized versus design?	Close to design or higher (>=80%)	10
7	Is there a regular maintenance program?	Yes	10
8	How is the overall quality of insulation of the chilled water system?	Very Good	10
9	Is the refrigerant charge level in each chiller inspected regularly? How often?	Yes, monthly or more frequently	10

CWST – Chilled Water System Scorecard – System Components

	System Components		
1	Choose main components for the chilled water system		
	Compressors	Yes	1
	Condensers (Water-Cooled or Air-Cooled)	Yes	1
	Evaporators	Yes	1
	Cooling Towers	Yes	1
	Water Side Economizers/Plate Heat Exchangers	Yes	1
	Pumps	Yes	1

CWST – Chilled Water System Scorecard

	Condensers		75
1	What is the most common heat rejection methodology in the chilled water system?	Cooling Towers	10
2	Is inspection and regular maintenance conducted on the condensers?	Yes, as per manufacturers recommendations	10
3	Are there any condenser issues such as fouling, non-condensables, etc.?	No	10
4	Are the following operating parameters monitored continuously:		
	(i) Water flow	Yes	5
	(ii) Water supply & return temperature	Yes	5
	(iii) Refrigerant pressure	Yes	5
5	Are the following conditions representative during normal operations:		
	(i) Water flow lower than design	No	10
	(ii) Waterside pressure drop (dP) higher than design	No	10
	(iii) Approach temperature higher than design	No	10

Interpreting Summary Results

- Maximum possible score: Varies based on your system selections
- The scorecard reflects a general overview of existing bestpractices 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 "**Qualitative**" in nature and no effort of performance guarantees, promises of savings, etc. should be made based on the results of CWST

CWST – Chilled Water System Summary Results

Chilled Water System Scoping Tool (CWST) Summary

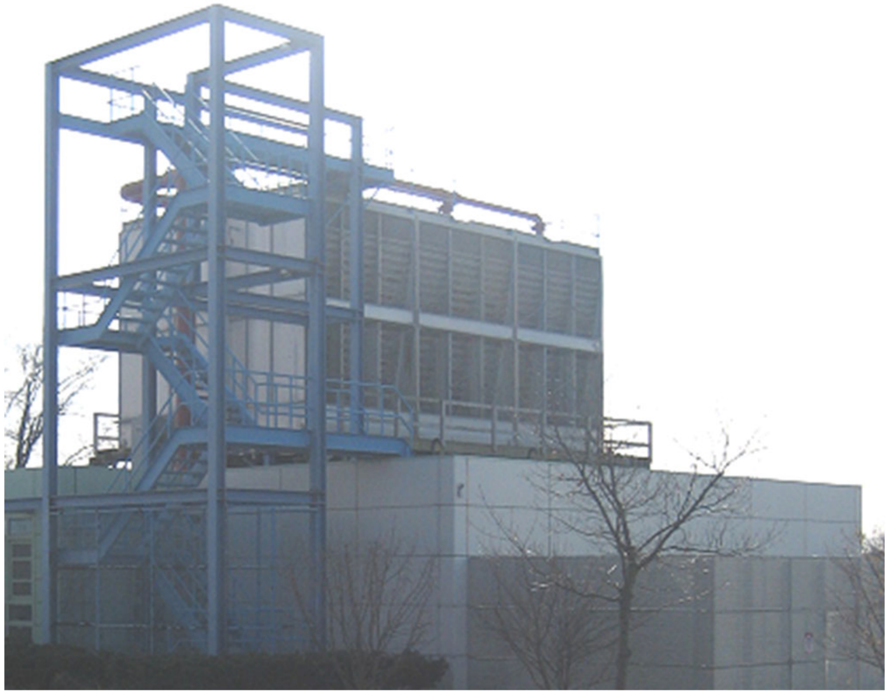
Points Details	
Maximum Score =	420
Your Score =	420
Best Practices Rating =	100%

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**

Example Chilled Water System

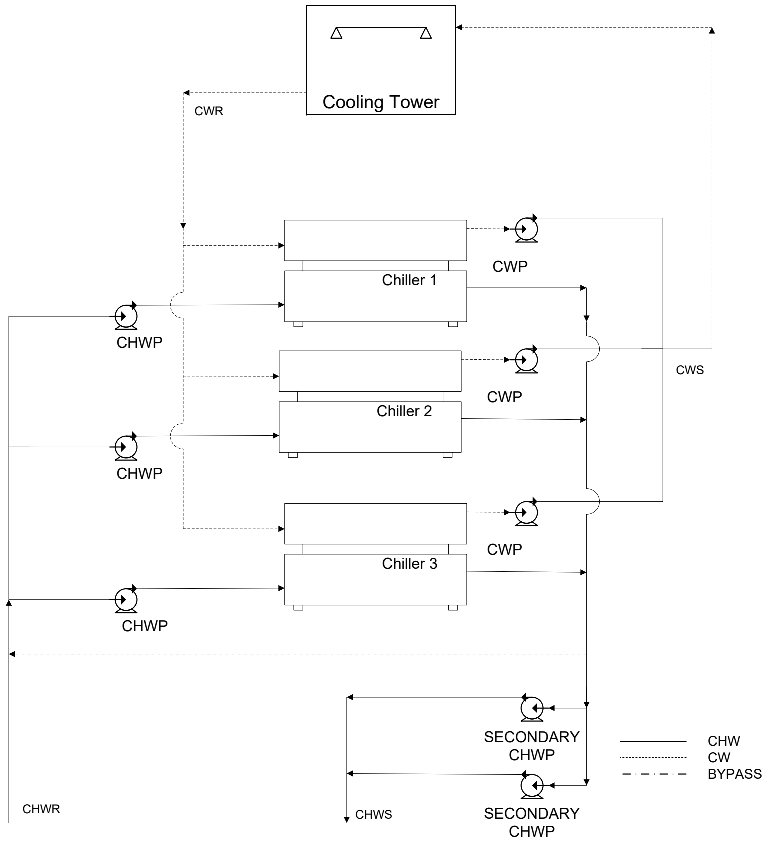
- You have been tasked with a Chilled water system assessment at a food and beverages plant
- The plant Utilities Manager & Utilities Engineer are available to provide information to you about the plant
- Open CWST and input available plant data
- Identify missing data and determine appropriate plant source for this data
- List possible Chilled water system improvement opportunities that you would like to investigate during the energy assessment



Facility Description

- The plant / facility is a large Food & Beverages plant located in the St. Louis, MO area
- The system selected for the energy assessment provides chilled water for process, packaging, air-conditioning plant areas and warehouse storage
- The plant operates a 3-shift per day operation, 8-hour per shift and runs all year round
- Possible shut-downs are planned for periodic maintenance activities
- The Plant Engineering Manager and the Plant Engineer/Maintenance person are available to answer questions and complete the CWST software tool

System Schematic



Chilled Water System Information

- The facility is 15-20 years old
- It has been a while since an energy assessment was done on the system
- Plant personnel do keep a tab on annual spend / budget for the operations
- The chilled water system has been upgraded with some dashboards and controls for operator / user interface
- Overall, there is a consistent demand on the chilled water system but system is not close to any capacity limitations
- Insulation is generally good but no audit has ever been performed on it
- A maintenance contractor provides regular support (quarterly site visit) to keep the plant in operation without any issues

Sub-System Information

- Compressors
- Water-cooled condensers
- Chiller barrels (evaporators)
- Cooling tower
- Pumps
  - Primary chilled water
  - Secondary chilled water
  - Condenser Water

Sub-System Information (Compressors)

- The system is relatively old and maintenance is done on an as-needed basis
- There are two centrifugal compressor chillers – they are run to collect equal operating hours annually but there are times when they are both operating at high loads (>60%)
- Manual operator logs indicate load levels – guide vane positions
- The compressors have capacity control with guide vanes but don't have much instrumentation on the compressors per se
- Compressors are believed to be running in their expected operating ranges

Sub-System Information (Condensers)

- Maintenance is done on an as-needed basis
- During the high-load season, scaling does occur in the condenser tubes
- Temperature monitors exist on the supply and return water and manual operator logs provide the information, if required
- A tab is kept on the wet-bulb approach temperature periodically and the maintenance contractor keeps a record of that during the visit

Sub-System Information (Evaporators)

- Since the system is mostly a closed loop on the chilled water side, maintenance is done only on an as-needed basis
- No issues with evaporator operations and it meets process setpoints always
- Instrumentation is fairly limited on the evaporator but inlet and outlet temperatures and pressure of the refrigerant is measured
- Manual operator logs to provide the information, if required
- A tab is kept on the approach temperature

Sub-System Information (Cooling Tower)

- The system is relatively old and no upgrades other than basic maintenance and fixing flow nozzle heads, basin cleaning, etc.
- No issues with cooling tower operations
- Fans are controlled automatically to meet setpoint
- Water chemistry is maintained by fixed blowdown
- Water outlet temperature, ambient temperature are monitored and periodically checked with wet-bulb temperature
- Manual operator logs record this information and 10-12°F approach to wet-bulb temperature on the cooling tower is very normal

Sub-System Information (Pumps)

- The primary chilled water and cooling tower water pumps are constant speed electric motor drives
- The secondary chilled water pumps are variable speed drives
- It is not exactly clear as to how many pumps are needed to run based on the cooling load but enough pumps are run so that all the chillers are satisfied with water flow all the time when they are operating and so also the end-users

CWST Hands-on Exercise Instructions

- For the plant information presented, provide data input to the CWST and arrive at scores for each CWST sub-section and the summary listing
- For all questions for which input data is unavailable or insufficient, specify how you would obtain the needed information during your plant visit
- Based on your CWST analysis results, develop a list of energy efficiency opportunities in the example chilled water plant

CWST Hands-on Exercise Results

Basic Facility Information

Contact Information

Company Name:	ABC Food Industries	Location:	St. Louis, MO
Plant/Facility Name:	St. Louis, MO Plant	Primary Contact Person	John Doe
Address:	1234 Main Street, St. Louis, MO	Industry Sector:	Food & Beverage
Phone:		Application:	Process Cooling
Fax:		Specify if other:	
Email:		Primary Product:	Fruit products

Operation Hours

Shift No.	Hours of Operation / Day	Days/Week	Weeks/Year	Annual Hours
1	8	7	52	2,912
2	8	7	52	2,912
3	8	7	52	2,912
Office Hours				0
Others				0

Specific Pre-Identified Problems:	1. 2. 3.
Energy Efficiency Ideas of Interest to Plant Personnel:	1. 2. 3.
Energy Use:	Based on the industry, the major application selected accounts for > 40% of the annual plant energy spend

CWST Hands-on Exercise Results

Sr.	Question	Answer	Score
	Chilled Water Plant		
	General		46
1	How old is the chilled water plant system (equipment)?	10- 20 years	5
2	When was the last time the chilled water system was audited?	>5 years ago or Never	0
3	Is the chilled water system operating energy cost monitored? How often?	Yes, annually	5
4	How is the chilled water plant controlled?	DCS / BMS	5
5	Has a detailed chilled water system load analysis ever done to minimize the cooling done?	Don't know	5
6	What percent of the chilled water plant capacity is generally utilized versus design?	Higher than 50%	5
7	Is there a regular maintenance program?	Yes	10
8	How is the overall quality of insulation of the chilled water system?	Good but can be improved	5
9	Is the refrigerant charge level in each chiller inspected regularly? How often?	Yes, Quarterly	6

	System Components		
1	Choose main components for the chilled water system		
	Compressors	Yes	1
	Condensers (Water-Cooled or Air-Cooled)	Yes	1
	Evaporators	Yes	1
	Cooling Towers	Yes	1
	Water Side Economizers/Plate Heat Exchangers	No	0
	Pumps	Yes	1

CWST Hands-on Exercise Results

	Compressors		53
1	Do you inspect and conduct regular maintenance on the compressors?	Yes, as needed only	5
2	What is your average running compressor load factor versus design?	Higher than 50%	5
3	What percent of operating time do you spend at less than 50% load?	30% or less	10
4	Do you monitor compressor efficiencies? How often?	No	0
5	Select the most common control mechanism for your compressors	Variable inlet guide vanes (centrifugal)	8
6	Is the operating suction pressure lower than the design suction pressure by more than 15%?	No	10
7	Is the operating discharge pressure higher than the design discharge pressure by more than 10%?	No	10
8	What percent of your compressor power is delivered via the following drive types? (Total must be less than or equal to 100%)		5
	Backpressure (extraction) steam turbines	0%	
	Variable Speed Electric Motor	0%	
	Electric motor w/o variable speed drives	100%	
	Condensing steam turbines	0%	
	Total	100%	

CWST Hands-on Exercise Results

	Condensers		35
1	What is your most common heat rejection methodology?	Cooling Towers	10
2	Do you inspect and conduct regular maintenance on the condensers?	Yes, as needed only	5
3	Do you have condenser issues such as fouling, non-condensables, etc.?	Yes, sometimes	5
4	Do you monitor following operating parameters continuously:		
	(i) Water flow	No	0
	(ii) Water supply & return temperature	Yes	5
	(iii) Refrigerant pressure	No	0
5	Are the following conditions representative during operations:		
	(i) Water flow lower than design	Don't Know	0
	(ii) Waterside pressure drop (dP) higher than design	Don't Know	0
	(iii) Approach temperature higher than design	No	10

	Evaporators		35
1	Do you inspect and conduct regular maintenance on the evaporator for fouling?	Yes, as needed only	5
2	Do you monitor chilled water exchanger pressure drop (ΔP)?	No	0
3	Do you have evaporator issues such as fouling, high superheat, frosting issues, etc.?	No	10
4	Do you monitor following operating parameters continuously:		
	(i) Coolant flow	No	0
	(ii) Coolant supply and return temperatures	Yes	5
	(iii) Refrigerant pressure	Yes	5
5	Are the following conditions representative during operations:		
	(i) Coolant flow lower than design	Don't Know	0
	(ii) Coolant pressure drop (dP) higher than design	Don't Know	0
	(iii) Approach temperature higher than design	No	10

CWST Hands-on Exercise Results

	Cooling Towers		33
1	What is general condition of the cooling towers?	Good	5
2	How are your cooling tower fans controlled?	Automated ON/OFF	4
3	How is your cooling tower water blowdown controlled?	Manual	2
4	Do you monitor the following operating parameters continuously?		
	(i) Cooling tower water flow	No	0
	(ii) Water outlet temperature	Yes	5
	(iii) Water Inlet Temperature	No	0
	(iv) Ambient air wet bulb temperature	No	0
	(v) Ambient air temperature	Yes	2
	(vi) Cooling tower water chemistry	No	0
5	Are your overall cooling water flow rates lower than design?	No	5
6	Do you see an evenly spread and uniform water distribution in your cooling towers?	Yes	5
7	How close is the approach of supply cooling water temperature to the wet bulb temperature?	10°F to 20°F	5

	Pumps		7
1	What percent of cooling water pump power delivered by the following drive types (Total must be less than or equal to 100%)		7
	Backpressure turbine drives	0%	
	Variable speed drives	25%	
	Constant speed motors	75%	
	Condensing turbine drives	0%	
	Total	100%	
2	Are you only running the minimum number of pumps?	No	0

CWST Hands-on Exercise Results

Chilled Water System Scoping Tool (CWST) Summary

Points Details	
Maximum Score =	397
Your Score =	209
Best Practices Rating =	53%

Based on plant information, there is medium potential and energy savings in the range of 5-15% can be anticipated.

Section	Your Score	Maximum Score	%
General	46	90	51
System Components			
Compressors	53	80	66
Condensers	35	75	47
Evaporators	35	70	50
Cooling Towers	33	62	53
Plate Heat Exchangers/Waterside Economizers	0	0	-
Pumps	7	20	35
Total	**209**	**397**	53

CWST Hands-on Exercise Next Steps

- Overall Chilled Water System (51%)
  - Calculate chilled water costs & trend
  - Correlate chilled water costs with production and benchmark
  - Undertake insulation appraisal
  - Consider doing a chilled water system audit, possible process integration and improve to state-of-the-art controls

- Compressors (66%)
  - Incorporate appropriate instrumentation to allow for compressor efficiency calculations
  - Investigate compressor capacity control using variable speed drives
  - Optimize load and compressor operations given there are multiple chiller units

CWST Hands-on Exercise Next Steps

- Condensers (47%)
  - Improve maintenance practices
  - Add instrumentation and apply fault detection and diagnostics to provide for optimized operations
- Evaporators (50%)
  - Improve maintenance practices
  - Add instrumentation and apply fault detection and diagnostics to provide for optimized operations
  - Evaluate changes in set-point temperature, if possible

CWST Hands-on Exercise Next Steps

- Cooling Towers (53%)
  - Improve cooling tower controls and maybe evaluate floating cooling tower water temperature
  - Add instrumentation and apply fault detection and diagnostics to provide for optimized operations
  - Automate blowdown based on water chemistry
- Pumps (35%)
  - Evaluate potential of operating the optimal number of pumps
  - Consider a separate energy system audit on the pump systems
  - Look for bypass flows and low temperature differences to identify excess pump flows

Key Points / Action Items

1. Use a systematic approach (gap analysis, comparison to BestPractices) to identify potential energy saving opportunities that may exist in Chilled Water systems
2. The Chilled Water System Scoping Tool (CWST) can be used to identify these improvement opportunities
3. The CWST is an intake questionnaire to collect preliminary plant level information
4. It shouldn't take more than 60 minutes to complete but we need to be speaking to the RIGHT (knowledgeable) person in the plant

Chilled Water System Energy Efficiency Metrics

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System Efficiency Metrics

- Every chilled water system is built up of multiple chiller units
  - Individual packaged units serving a specific load
  - Packaged units combined with a central loop system
  - Distributed chilled water systems with certain components integrated with process while others in a central loop (typical of multiple temperature levels)
  - One or more combinations of the above
- Every chilled water system will provide a cooling effect (load, demand) – summation of multiple chiller units
- Every chilled water system will need energy (most times electric) but in certain systems can be thermal (steam, hot water, etc.)

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

$$COP = \frac{Cooling\ or\ Heating\ Load}{Energy\ Required}$$

- Coefficient of Performance (COP)
  - ASHRAE definition - Ratio of the benefit provided to the energy used
  - COP is dimensionless – units of Cooling / Heating Load and Energy used should be the same
  - Depending on the system
    - Cooling COP
    - Heating COP

Unit Performance Metrics

$$\text{EER} = \frac{\textit{Cooling Load}}{\textit{Compressor Power}}$$

- Energy Efficiency Ratio (EER)
  - Used for packaged cooling systems that are electric motor driven with compressors
  - EER has units – Btuh/W
  - EER is calculated at a single point of operation (design)

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) required to produce 1 RT of cooling or refrigeration

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

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

Chiller Unit Performance Metric Ranges

- Best place to obtain Chiller Efficiency (Performance) information is manufacturer's catalogs and websites
- Every manufacturer will define design conditions for heat rejection
  - Water-cooled – (85 / 95°F)
  - Air-cooled – (95°F)
- Every manufacturer will define design conditions for chilled water
  - 44 / 55°F
- Efficiency ranges from OEMs – 0.3 to 1.0 kW/RT
  - This is dependent on several factors and control mechanisms

Polling Question 2

Polling Question

2) What is the typical average operational range for kW / RT for your chiller plant efficiency?

A. < 0.5

B. 0.5 – 0.75

C. 0.75 – 1.00

D. > 1.0

E. Do not know

Example - Determining Chiller Unit Energy and Costs

- Chiller unit information provided
  - Cooling capacity = 1,000 RT
  - Chiller performance (efficiency) = 0.65 kW/RT
  - Annual operation = 6,250 hours
  - Electric power cost = 0.10 $/kWh

$$Power = Cooling\ Load * Efficiency$$

$$Annual\ Energy = Power * Hours$$

$$Operating\ Cost = Annual\ Energy * Energy\ Cost$$

Example - Determining Chiller Unit Energy and Costs

- Chiller unit information provided
  - Cooling capacity = 1,000 RT
  - Chiller performance (efficiency) = 0.65 kW/RT
  - Annual operation = 6,250 hours
  - Electric power cost = 0.10 $/kWh

$$\textbf{Power} = \textbf{1,000} * 0.5 = 500 \text{ kW}$$

$$\textbf{Annual Energy} = \textbf{650} * 6{,}250 = 4{,}062{,}500 \text{ kWh}$$

$$\textbf{Operating Cost} = \textbf{4,062,500} * 0.10 = \$406{,}250$$

Example - Determining Chiller System Energy and Costs

- Additional Chiller System information provided
  - Pump motors = 75 kW
  - Cooling tower fan motor = 15 kW

Example - Determining Chiller System Efficiency

- Chiller System information provided
  - Cooling capacity = 1,000 RT
  - Chiller Unit Efficiency = 0.65 kW/RT

$$System\ Efficiency = \frac{\sum_n Power\ kW}{\sum_m Chiller\ Cooling\ RT}$$

Example - Determining Chiller System Energy and Costs

$$\text{System Power} = (1,000 * 0.65 + 75 + 15) = 740 \text{ kW}$$

$$\text{System Annual Energy} = 740 * 6,250 = 4,625,000 \text{ kWh}$$

$$\text{System Operating Cost} = 4,625,000 * 0.10 = \$462,500$$

$$\text{System Efficiency} = \text{Total Power} / \text{Cooling Tons}$$

$$= 740 / 1,000 = 0.740 \text{ kW/RT}$$

Polling Question 3

Polling Question

3) What do you believe is the typical annual operating energy cost for your chiller plant?

A. < $250,000

B. $250,000 - $1,000,000

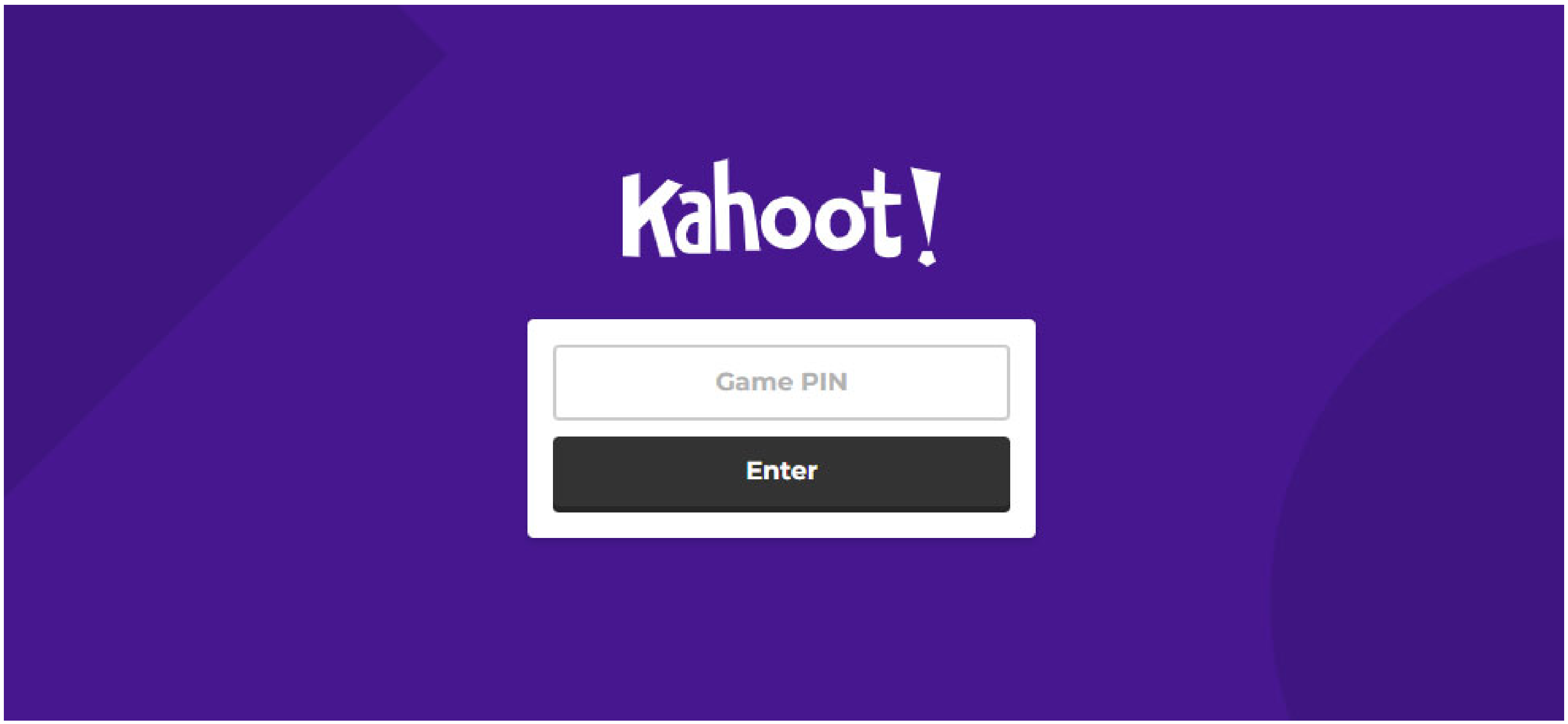
C. > $1,000,000

D. Do not know

Homework #2

- Complete the Chilled Water system Scoping Tool (CWST) on your specific plant and understand the current bestpractices and potential gaps in your plant
- How well is your chilled water system compared to a state-of-the-art system?
- Identify 3 bestpractices that have been implemented in your chilled water system operations and management
- Identify 3 energy efficiency improvement opportunities in your chilled water system after completing the CWST

Kahoot Quiz Time



Thank You all for attending today's webinar.

See you all on Wednesday – July 31, 2024 – 10 am ET

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

Alternately, you can email questions to me at paparra@ornl.gov

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