Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 5

Thursday – August 13, 2026

2:00 pm – 4:30 pm ET

Welcome

- Welcome to the 5th 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 26) – Case Studies; Refrigerants – Past, Present & Future; Reclamation and O&M**
- **Session 8 (September 3) – Industrial Process Cooling System VINPLT Wrap-up Presentations**

Agenda – Session 5

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
  - Review of Session 4; Homework Discussion
  - Energy Efficiency Opportunities in chilled water systems
  - Quantifying Opportunities using MEASUR
- Kahoot Quiz Game
- Q&A

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

Safety and Housekeeping

- Safety Moment
  - As you trace chilled water supply and return headers to end-uses, watch for hazards along the way – follow human traffic pathways as much as possible
  - Wear hard hats to protect your head from bumping against headers
- 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

Quick Review – Session 4

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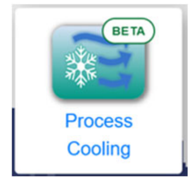
Introducing MEASUR – Process Cooling Module

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



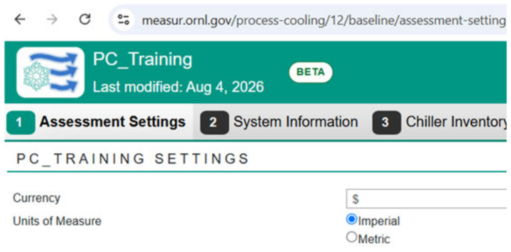
MEASUR – Process Cooling INPUT Screenshots

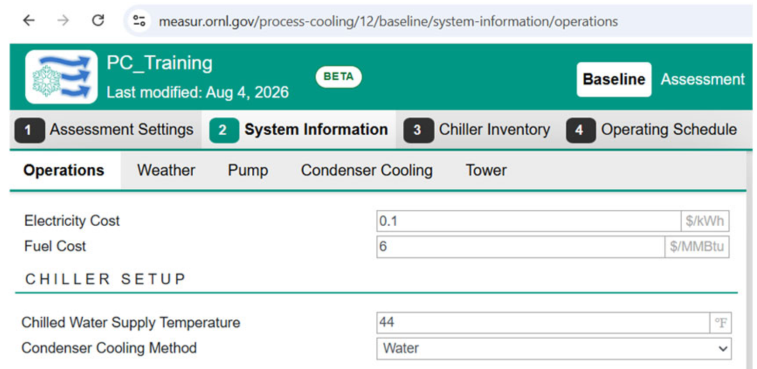
- **Baseline**
  1. Assessment Settings
  2. System Information
     - Operations
       - Utility Cost
       - Heat rejection setup
     - Weather
       - Geographic location
     - Pump(s)
       - Chilled water
       - Condenser water (if applicable)
     - Condenser Cooling
     - Tower
  3. Chiller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

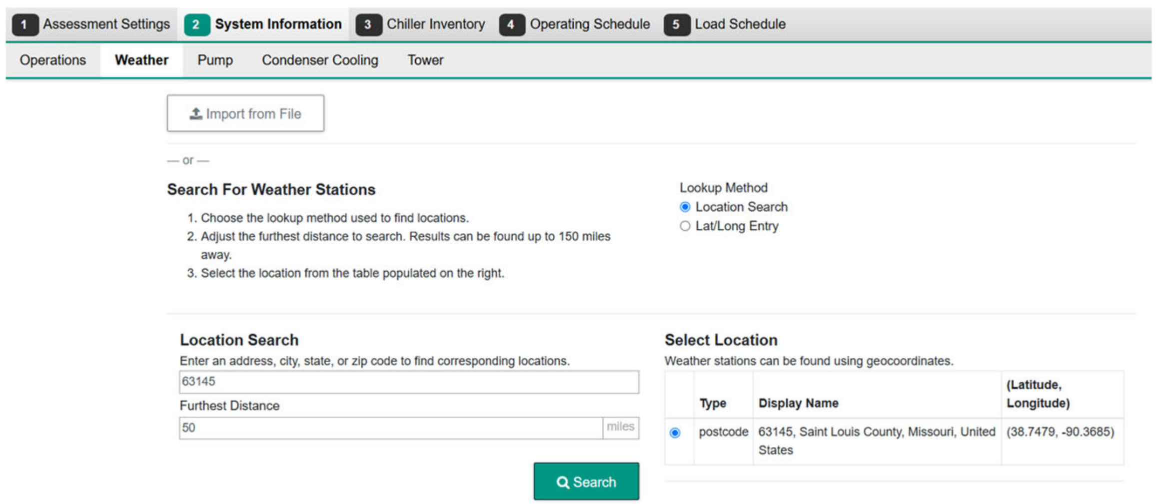
Click the “Back” to go back to previous screen

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

Input Summary







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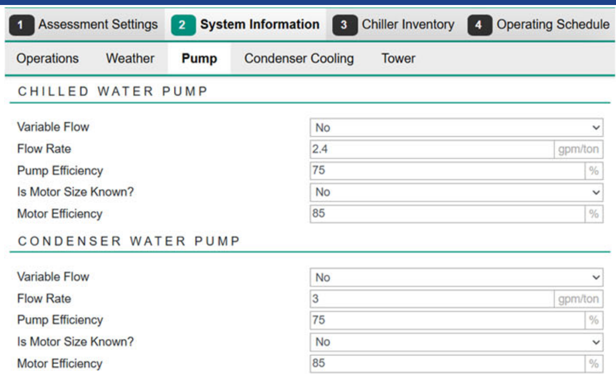
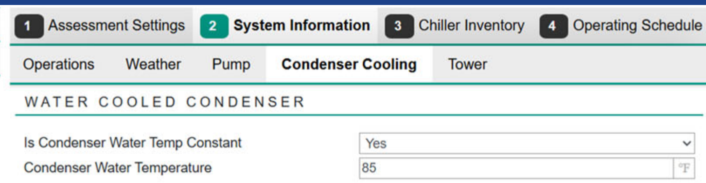
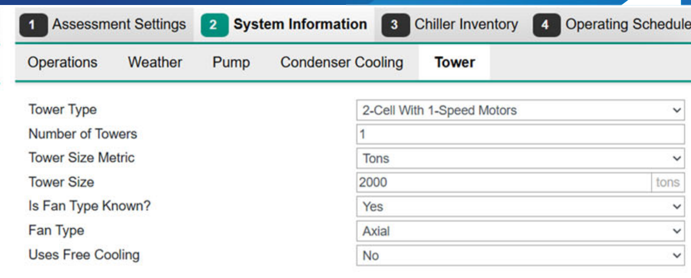
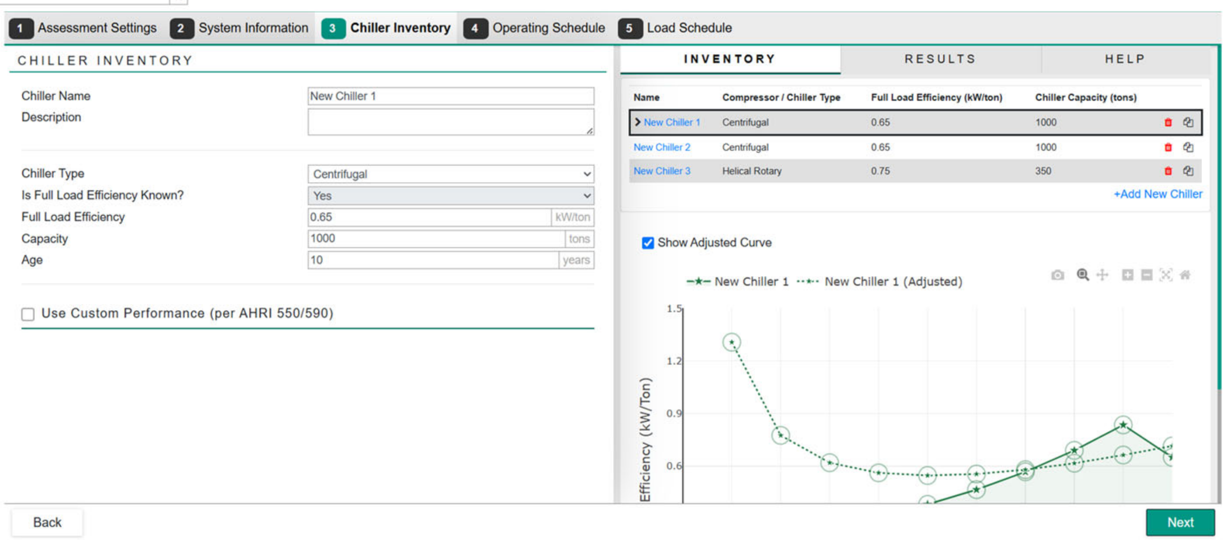
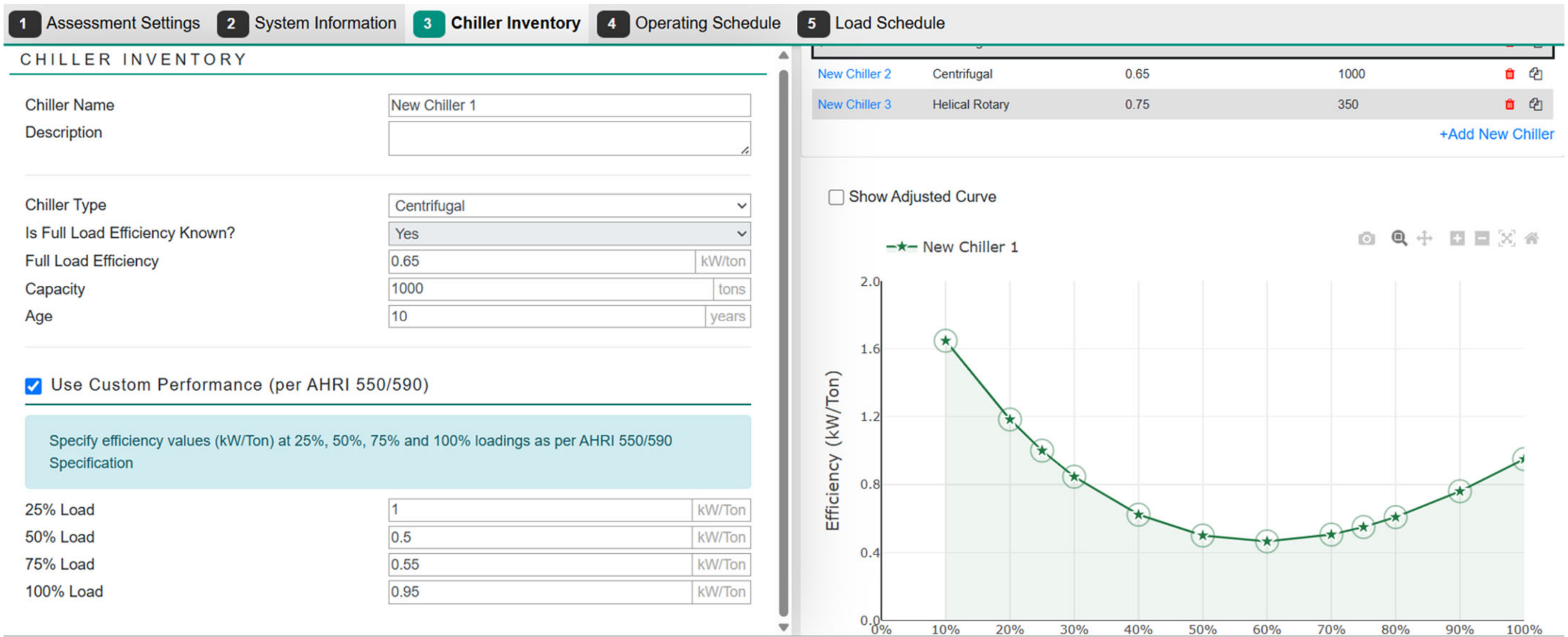








Input Summary



Input Summary

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

OPERATING SCHEDULE

Weekly Operating Schedule

Enter the typical starting and stopping times for the chiller for each day of the week. This information is used to remove non-operating daily hours from the temperature data.

☐ **Use the same schedule for all days**

Monday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Tuesday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Wednesday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Thursday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Friday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Saturday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00
Sunday	Off	On 24 Hours	On (Set Hours)	0:00	-	24:00

Monthly Operating Schedule

Enter number of typical operating days for each month. This information is used to calculate annual operating hours.

☑ **Use Max Operating Days**

Month	Operating Days
January (31 days)	31
February (28 days)	28
March (31 days)	31
April (30 days)	30
May (31 days)	31
June (30 days)	30
July (31 days)	31
August (31 days)	31

Back

Next

Input Summary

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

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

Back

New Chiller 3

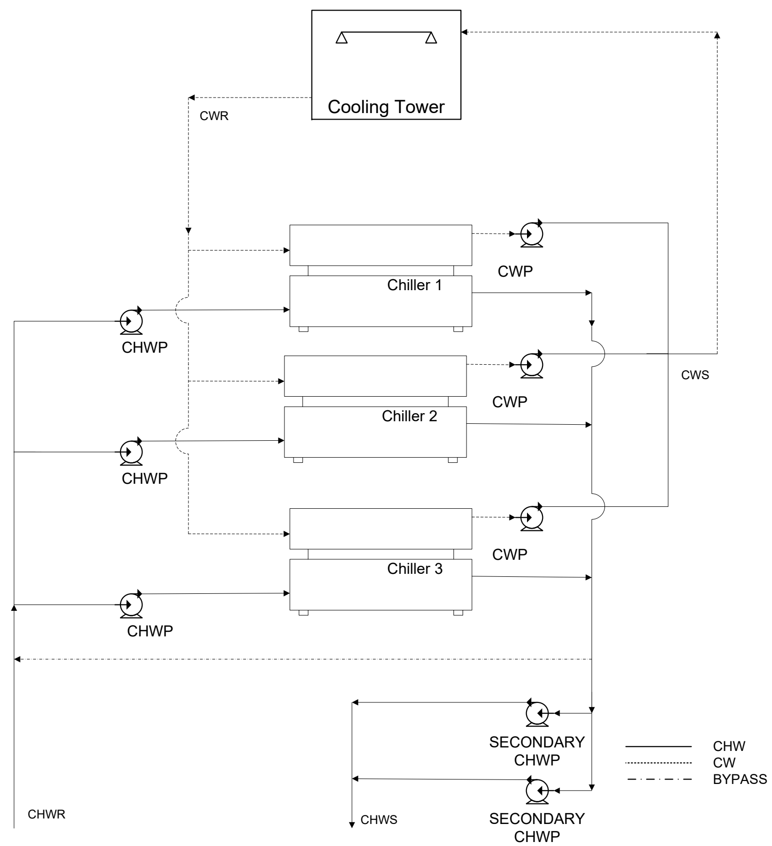
New Chiller 3 Loading: All Months

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

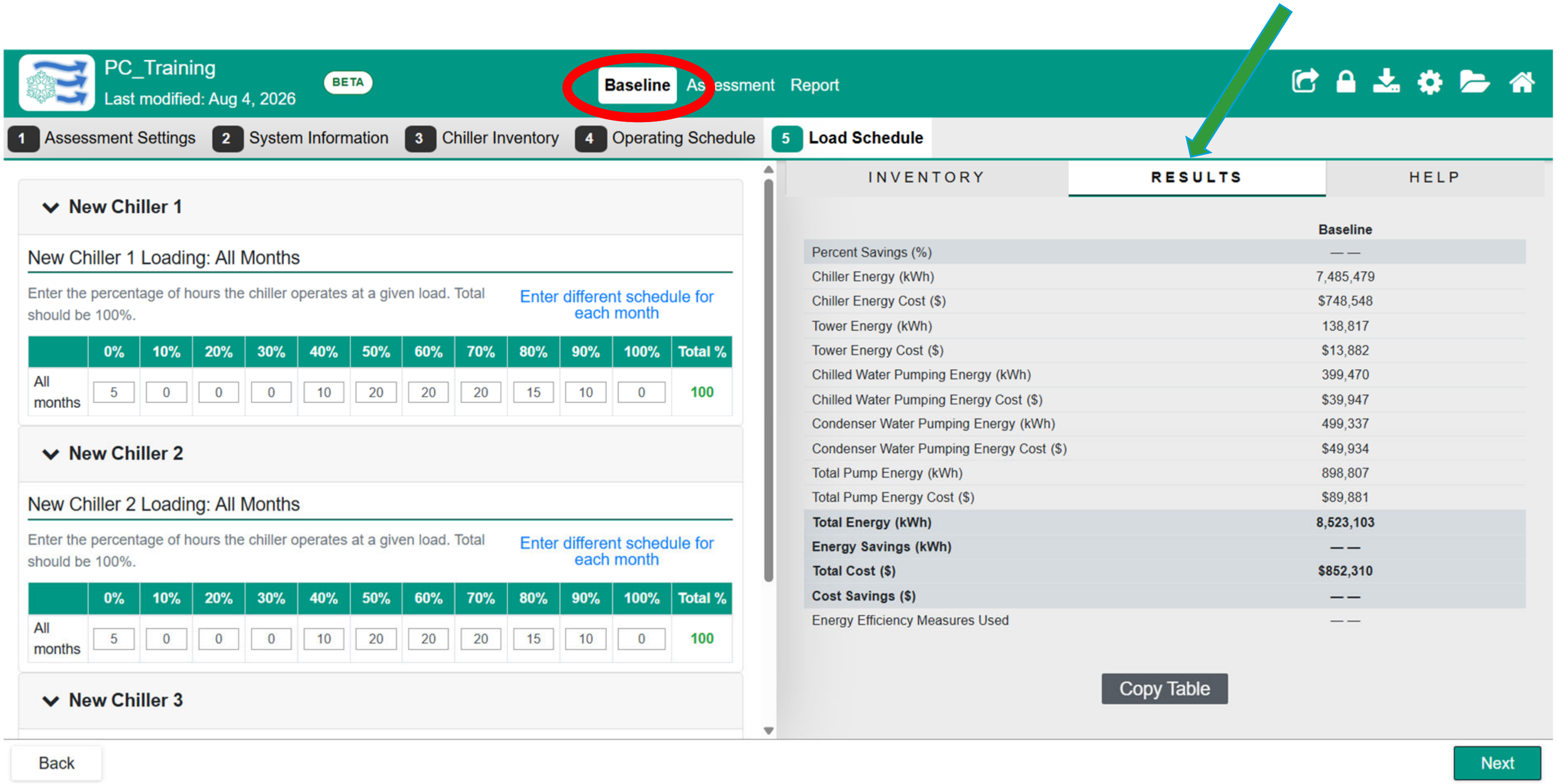
Enter different schedule for each month

	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

High-level System Schematic



Baseline - Results



Chiller Operating Details Screen (Baseline)

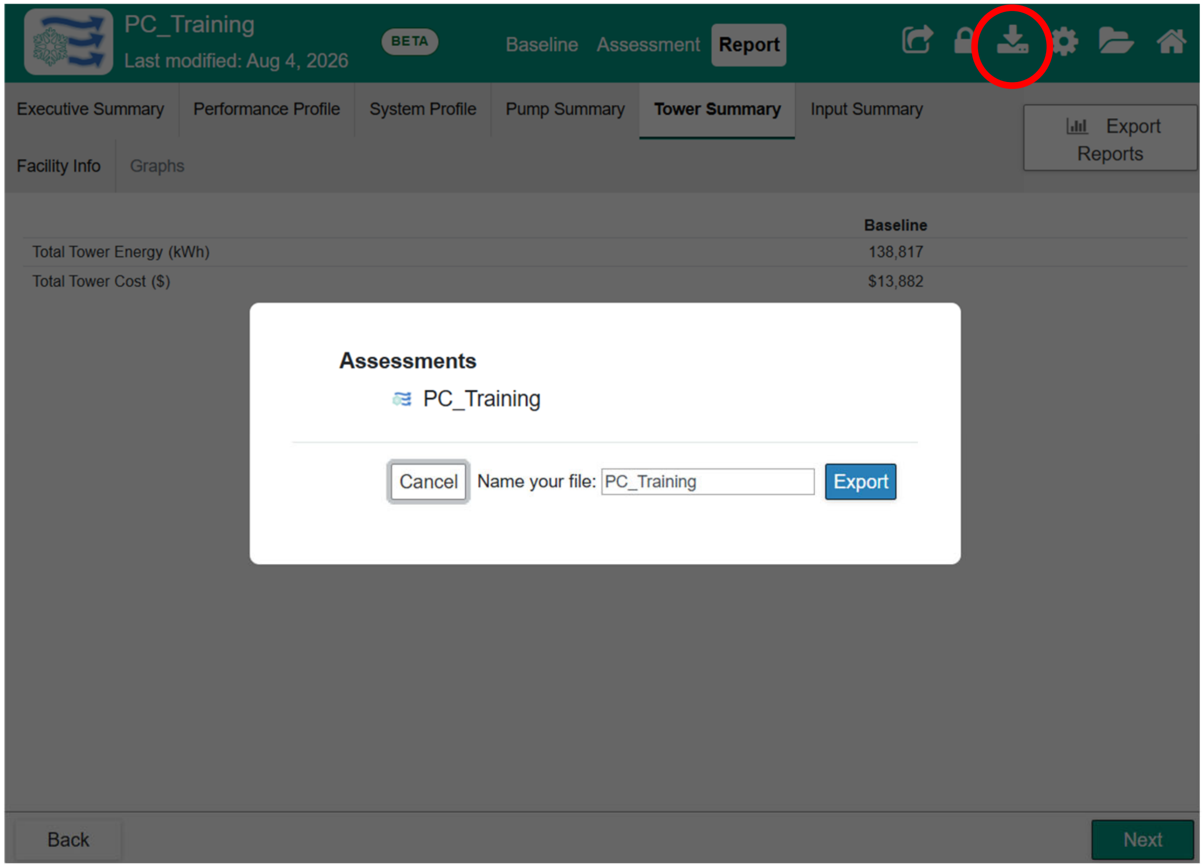
Executive Summary | Performance Profile | **System Profile** | Pump Summary | Tower Summary | Input Summary | Facility Info | Graphs | Export Reports

Baseline

Load %	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
New Chiller 1												
Performance (kW/Ton)	-	0	0	0	0.608	0.591	0.592	0.609	0.638	0.675	0	
Hours	444	0	0	0	873	1,754	1,753	1,746	1,317	873	0	8,760
Power (kW)	0	0	0	0	243.1	295.6	355.2	426.4	510.1	607.3	0	
Energy (kWh)	0	0	0	0	212,214	518,479	622,681	744,489	671,849	530,133	0	3,299,844
New Chiller 2												
Performance (kW/Ton)	-	0	0	0	0.608	0.591	0.592	0.609	0.638	0.675	0	
Hours	444	0	0	0	873	1,754	1,753	1,746	1,317	873	0	8,760
Power (kW)	0	0	0	0	243.1	295.6	355.2	426.4	510.1	607.3	0	
Energy (kWh)	0	0	0	0	212,214	518,479	622,681	744,489	671,849	530,133	0	3,299,844
New Chiller 3												
Performance (kW/Ton)	-	0	0	0.932	0	0.82	0	0	0	0	0.825	
Hours	2,634	0	0	2,627	0	2,626	0	0	0	0	873	8,760
Power (kW)	0	0	0	97.8	0	143.4	0	0	0	0	288.8	
Energy (kWh)	0	0	0	257,034	0	376,678	0	0	0	0	252,079	885,790

Saving the Baseline Model file – MOST IMPORTANT!

- Can be accessed from any screen
- Exported files can be imported in future
- Recommended to export once all baseline inputs are entered



Energy Efficiency Opportunities in Chilled Water Systems

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Chiller System Optimization Objectives

- **Reducing Operating Costs**
- Improving energy efficiency of the system
- Improving overall system reliability
- Implementing operational and maintenance BestPractices
- Retrofitting with state-of-the-art controls
- Avoiding costly and unplanned shutdowns
- Enhancing product quality
- Reducing energy use

Typical Chiller Energy Management

- The current standard practice is to provide enough cooling capacity to meet the needs of the facility while minimizing ton hours
- This is achieved manually by operators or by a Building Automation System (BAS) / Energy Management System (EMS) with operator oversight

This Does Not Address the Enormous Potential Savings Opportunity of Maximizing Chiller Efficiency!

Typical Chiller Energy Management

- Modern Energy Management Systems can easily do the following:
  - Collect chiller operating data
  - Perform calculation blocks (such as kW/Ton)
  - Sequence multiple chillers with auto on and off capability
  - Control chiller and cooling tower set-points
  - Notify plant personnel when limit alarms are exceeded
  - Provide simple trending (e.g., chilled water temps, loads, etc.)
  - Basic Fault Detection and Diagnostics (FD&D)

3 Methods of Maximizing Chiller Plant Efficiency

- Preventive
  - Identify problems before they become expensive (cost avoidance)
  - Maintain optimum chiller plant efficiency
- Restorative
  - Identify heat transfer problems (i.e. off-design water flow, fouling or scaling, etc.)
  - Remove non-condensable gases
  - Maintain proper refrigerant levels
- Opportunity
  - Identify optimal chilled water set points
  - Proper chiller sequencing and load balancing
  - Proper tower basin water management
  - Peak demand management
  - Condition-based maintenance versus scheduled preventive maintenance

EXAMPLES

Examples of Energy Efficiency Opportunities (EEOs)

- Implement Entering Condenser Water Temperature (ECWT) management
- Optimize settings for Chilled Water Set-Point Temperature (ChWST)
- Eliminate refrigerant leaks
- Maintain design water flow rates in evaporator / condenser
- Remove non-condensable gases and moisture
- Reclaim refrigerant
- Insulate chilled water lines, tanks and end-users

No Cost / Low Cost EEOs

Examples of Energy Efficiency Opportunities (EEOs)

- Clean fouled and scaled evaporators
- Clean fouled and scaled condensers
- Sequence multiple chillers to optimize efficiency
- Maintain compressor isentropic efficiency
- Investigate application of VFDs to pumps and fans
- Minimize compressor surging
- Improve drive efficiency
- Eliminate inappropriate uses of chilled water

Medium Cost EEOs

Examples of Energy Efficiency Opportunities (EEOs)

- Apply VFDs to chillers
- Investigate implementation of high-efficiency chillers
  - Retrofit from air-cooled to water-cooled
- Undertake peak load management strategy
  - Thermal Energy Storage
- Install water-side economizers (free cooling)
- Evaluate process heat recovery & integration
- Implement a smart real-time chilled water plant optimizer
  - Artificial intelligence / Machine Learning based
  - Continuous commissioning

Higher Cost EEOs

Quantifying EEOs using MEASUR Software

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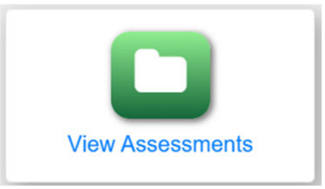
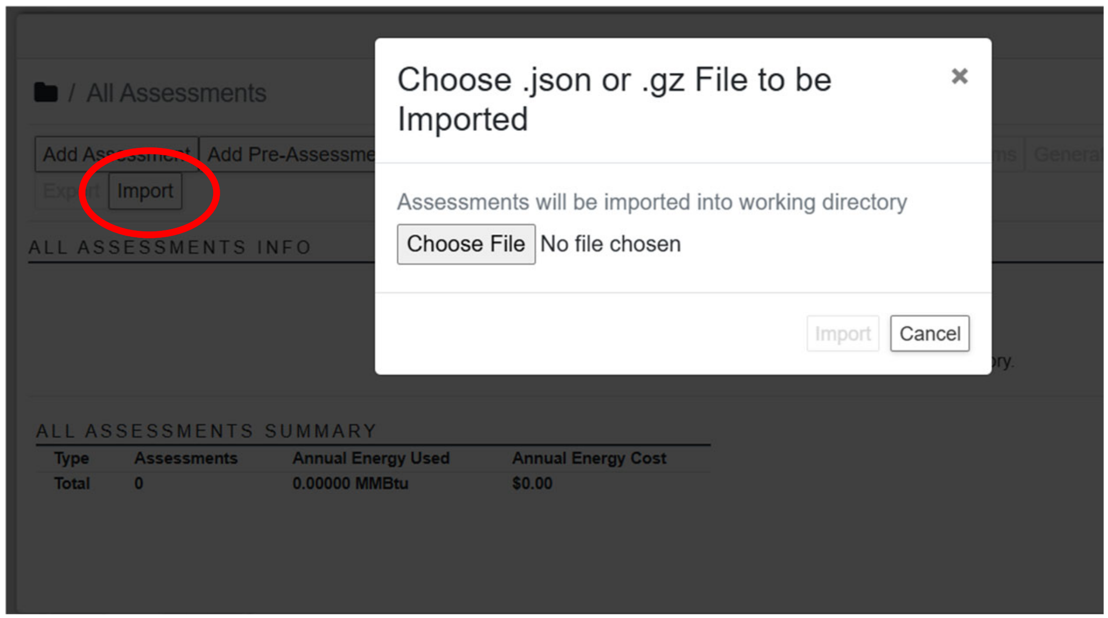
Chilled Water System – MEASUR

- Open MEASUR
- Import the system model file
- Review the Baseline
  - Schematic
  - Overall system energy and costs including sub-systems
- Data Validation
  - Can be done if actual energy numbers are available for the whole system and/or sub-systems
  - Aim to be within 10% of actual energy usage and costs

Chilled Water System – MEASUR

- Import File Shared from Chat Session





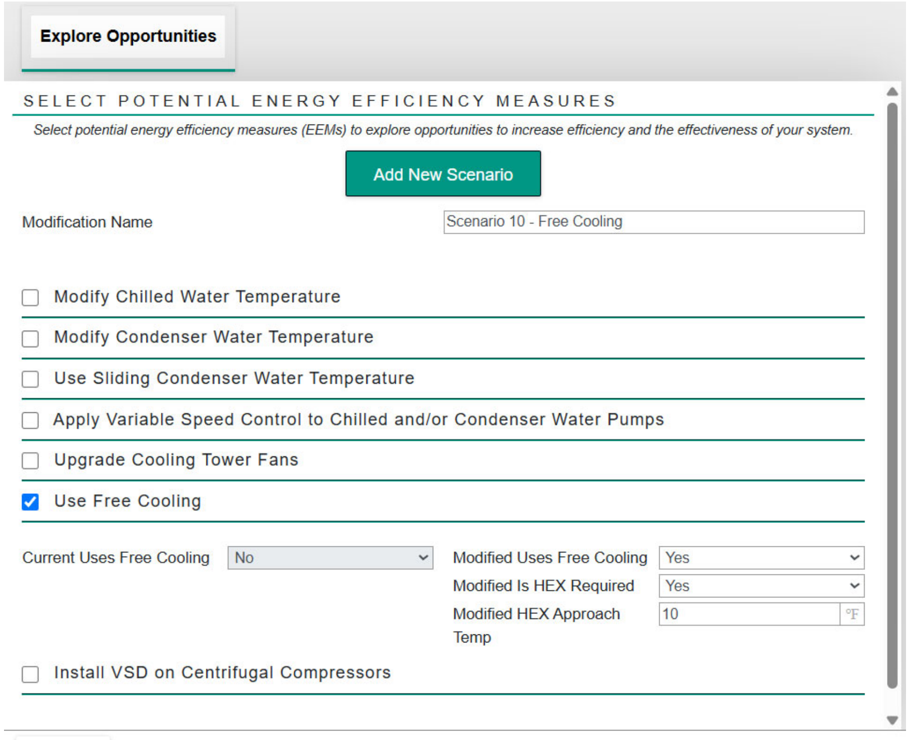
Next Steps with MEASUR Baseline Model

- Several system optimization opportunities can be modeled using a parametric "what-if" scenario configuration

- MEASUR allows for the following Scenarios ("Scenario Model"):
  - Variable Speed Drive Installation
    - Centrifugal Chillers, Tower Fans, & Pumps
  - Various Chilled and Condenser Water Strategies
  - Using Free Cooling, when possible
  - New Equipment Specification (Comparison of baseline to baseline models)
    - Chillers, Towers, Pumps

Operating Cost Reduction Screen – Scenarios & EEMs

- Asks basic questions to allow the user to understand gaps
- Analyze energy conservation options simply by modifying one or more of the system inputs
- This feature allows combinatorial "What-If?" analyses



Results Screen (Comparison w/Baseline)

- Annual energy consumption (kWh)
- Annual operating cost ($)
- Energy Savings (kWh)
- Cost Savings ($)

RESULTS | HELP

	Baseline	Scenario 1
Percent Savings (%)	——	1.9%
Chiller Energy (kWh)	7,485,479	7,321,774
Chiller Energy Cost ($)	$748,548	$732,177
Tower Energy (kWh)	83,130	82,756
Tower Energy Cost ($)	$8,313	$8,276
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,467,416**	**8,303,337**
Energy Savings (kWh)	**——**	**164,079**
Total Cost ($)	**$846,742**	**$830,334**
Cost Savings ($)	**——**	**$16,408**
Energy Efficiency Measures Used	——	Modify Chilled Water Temperature

Entering Condenser Water Temperature (ECWT) Management

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Implement ECWT Management

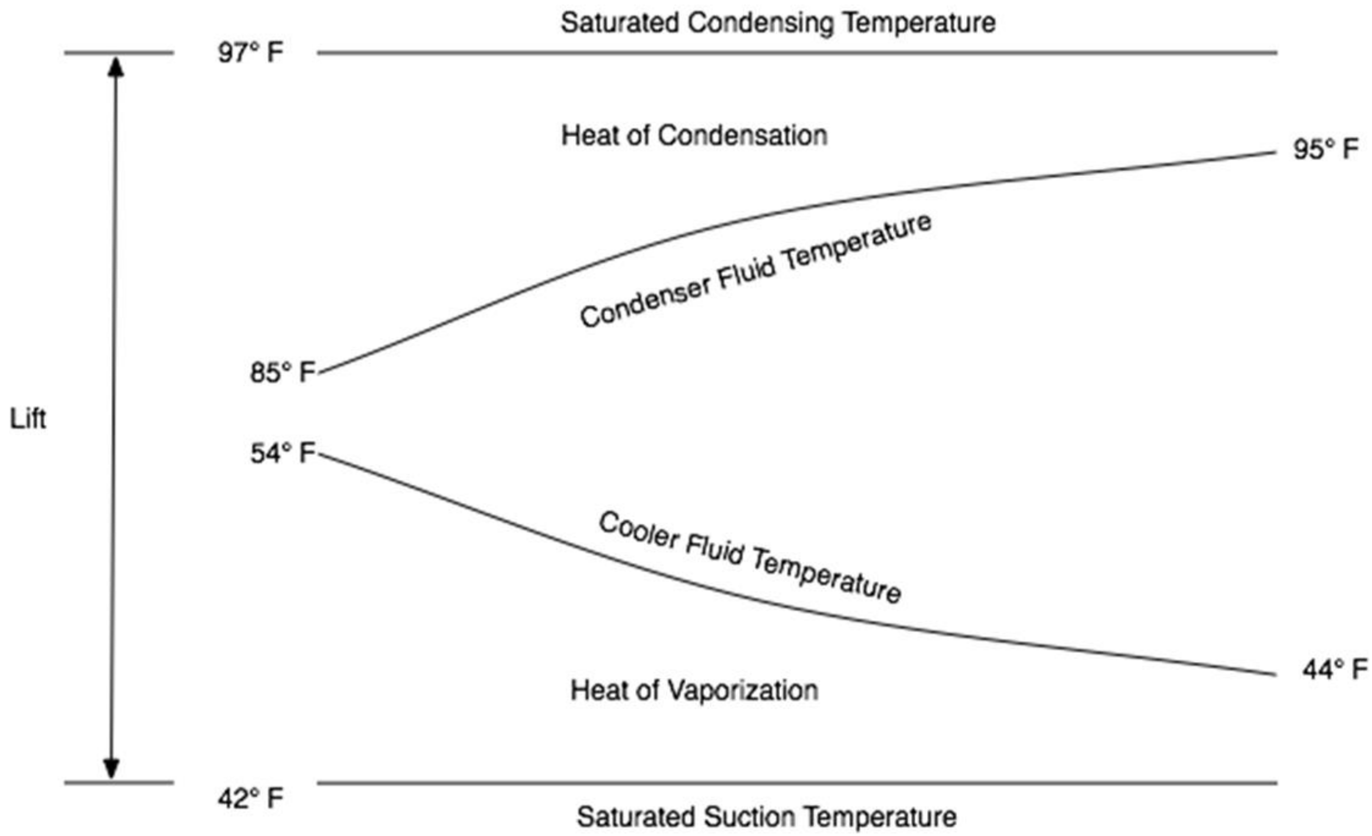
- ECWT – **E**ntering **C**ondenser **W**ater **T**emperature

- Cooling Tower Approach
  - The approach is the difference in temperature between the cooled-water temperature and the air "wet bulb temperature"

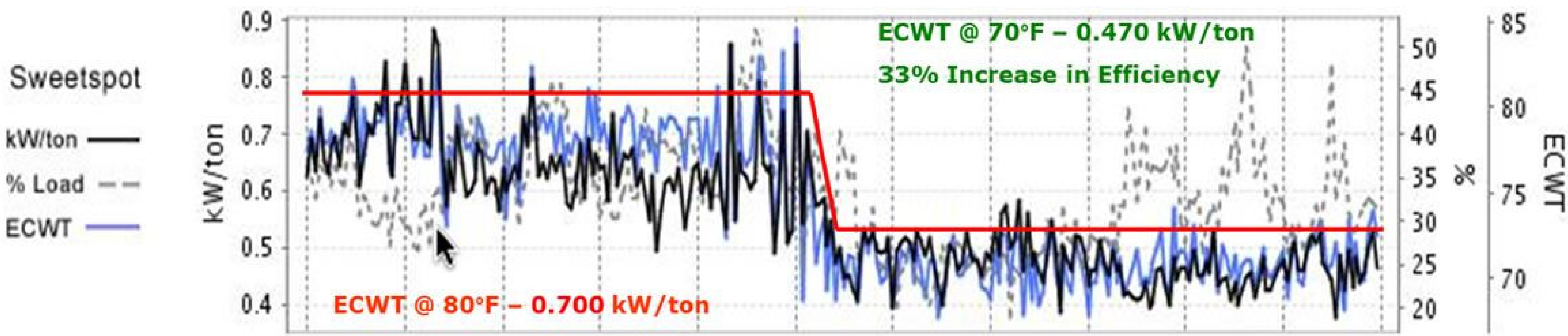
- Wet Bulb
  - Wet bulb temperature is the lowest temperature that can be reached by the evaporation of water only
  - It is determined by the atmospheric pressure, ambient temperature and relative humidity

Remember Lift!

$$\text{Lift} = 97 - 42 = 55°\text{F}$$



ECWT Management

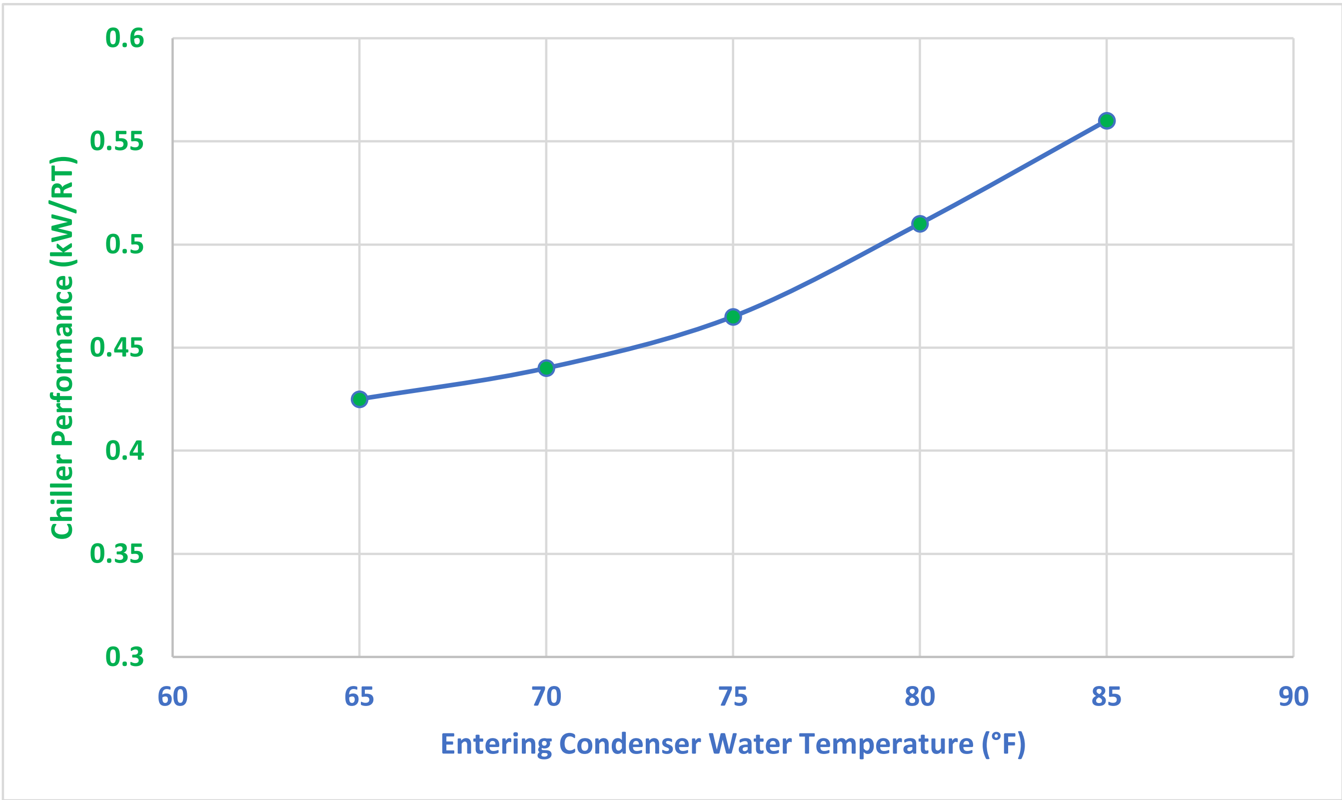


80°F ECWT drops to 70°F ECWT

kW/ton drops from 0.7 to 0.47 (33% improvement)

Questions: Can it be achieved? At what cost?

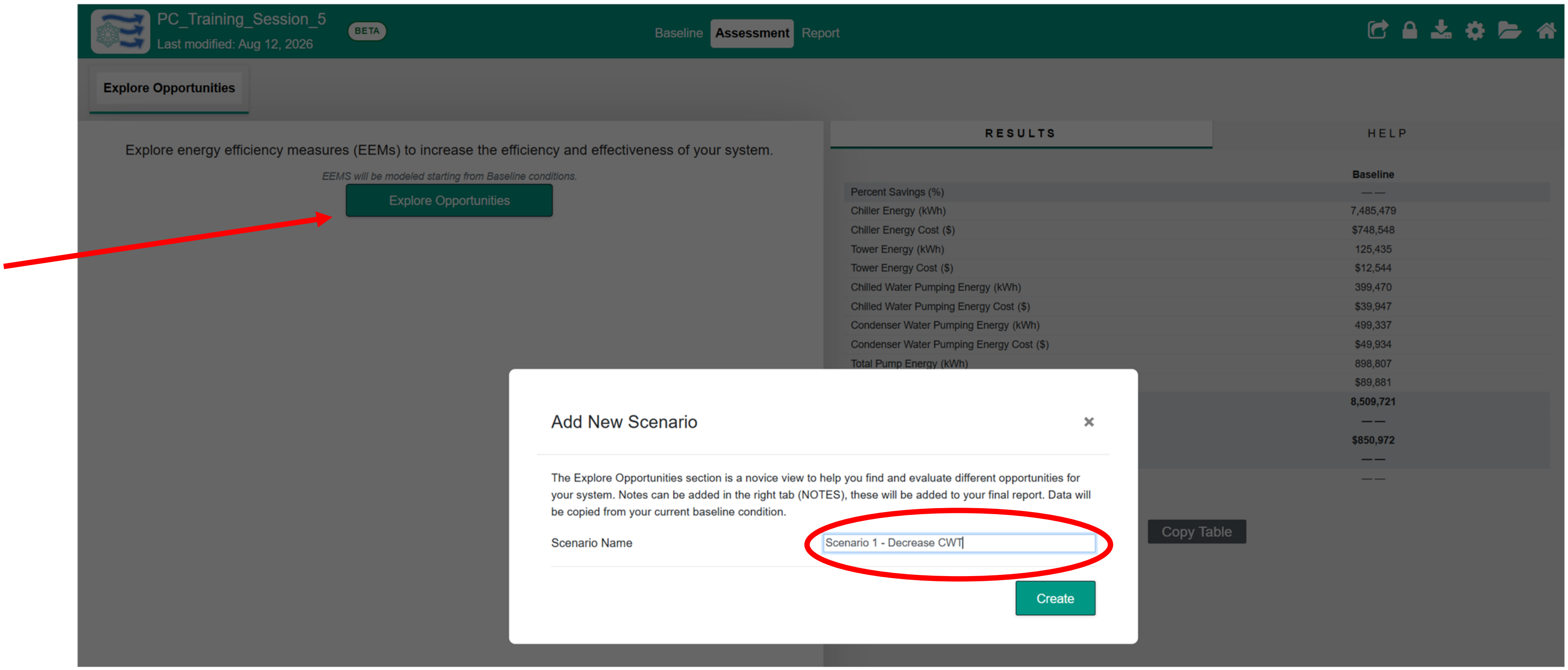
Implement ECWT Management



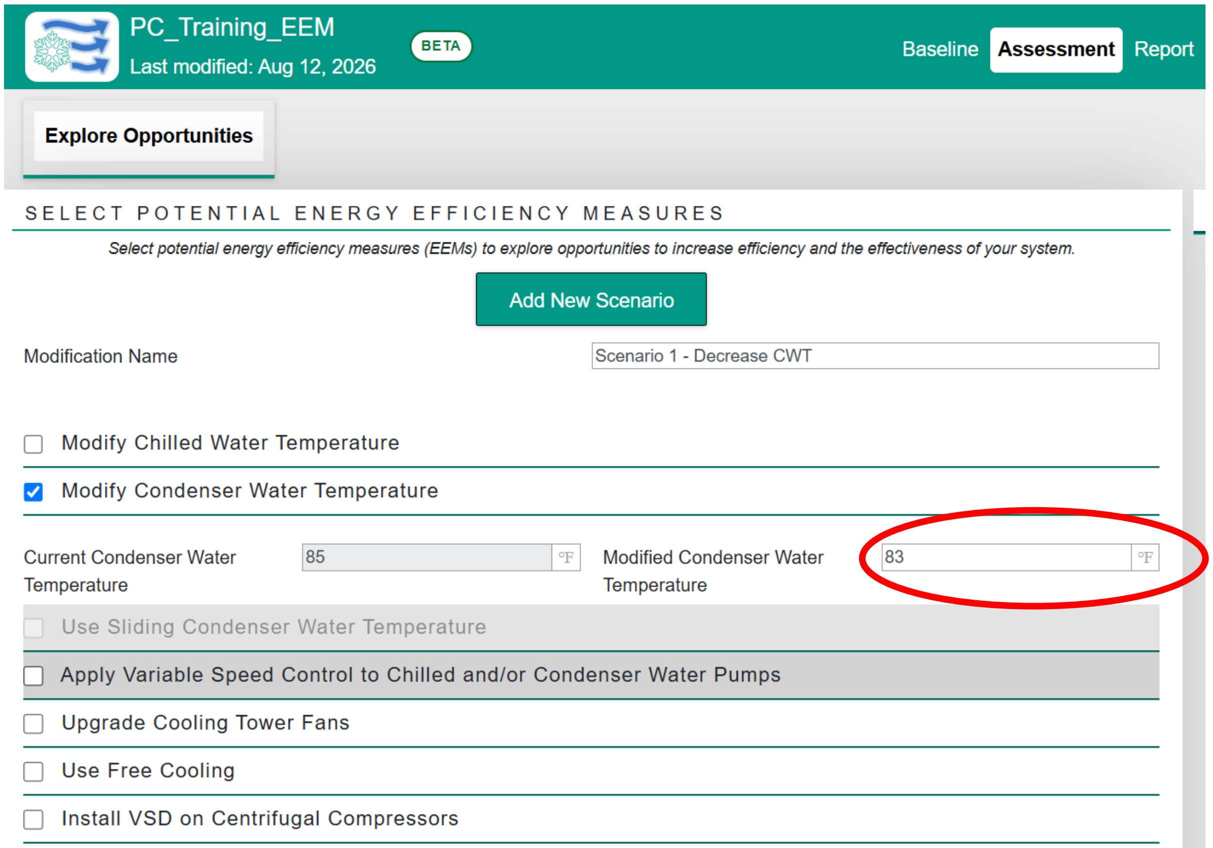
Student Exercise

- The industrial plant engineer recently completed a chilled water system audit and found that the cooling tower water supply temperature was fixed at 85°F.
- They wanted to determine if there would be a benefit to let the cooling tower water supply temperature be reduced by 2°F.
- Use the MEASUR model to determine how much system energy could be saved if the plant was able to reduce the cooling tower supply temperature by 2°F.
- Additionally, determine the energy and cost savings if the cooling tower water be allowed to float automatically based on the ambient conditions
- Discuss concerns and issues with the chosen option and what steps can be taken to mitigate them

Student Exercise (Reduce Entering Condenser Water Temperature)



Student Exercise (Reduce Entering Condenser Water Temperature)



Student Exercise (Reduce Entering Condenser Water Temperature)

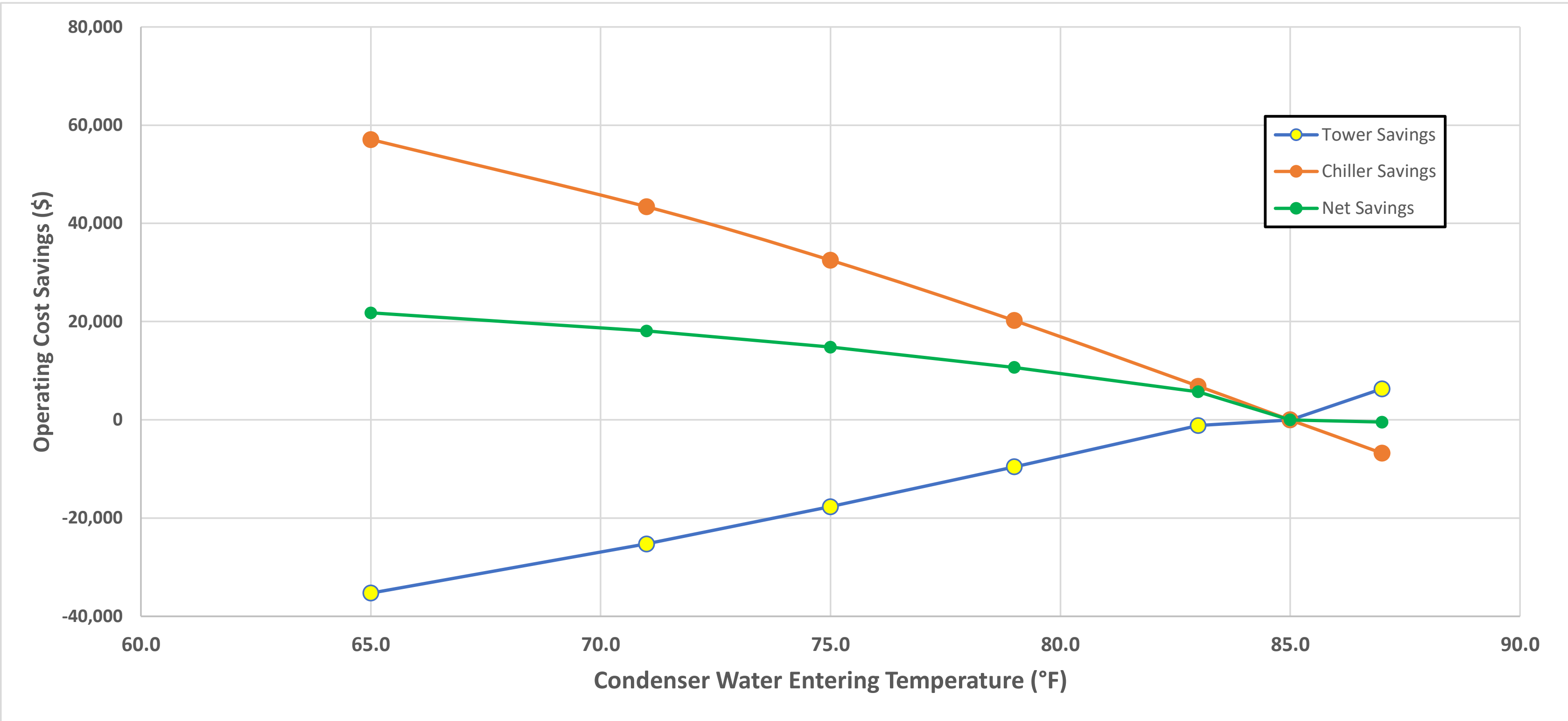
RESULTS | HELP

	Baseline	Scenario 1 - Decrease CWT
Percent Savings (%)	——	0.3%
Chiller Energy (kWh)	7,485,479	7,415,498
Chiller Energy Cost ($)	$748,548	$741,550
Tower Energy (kWh)	125,435	172,998
Tower Energy Cost ($)	$12,544	$17,300
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,487,303**
Energy Savings (kWh)	——	**22,419**
Total Cost ($)	**$850,972**	**$848,730**
Cost Savings ($)	——	**$2,242**
Energy Efficiency Measures Used	——	Modify Condenser Water Temperature

ECWT Management

- Can the plant continue to reduce the entering condenser water temperature further?
- Is there is an OPTIMUM cooling tower water temperature?
- What is the optimum temperature dependent on?
- MEASUR can be used iteratively to determine if such an optimum does exist and where

Optimal Entering Condenser Water Temperature Setpoint



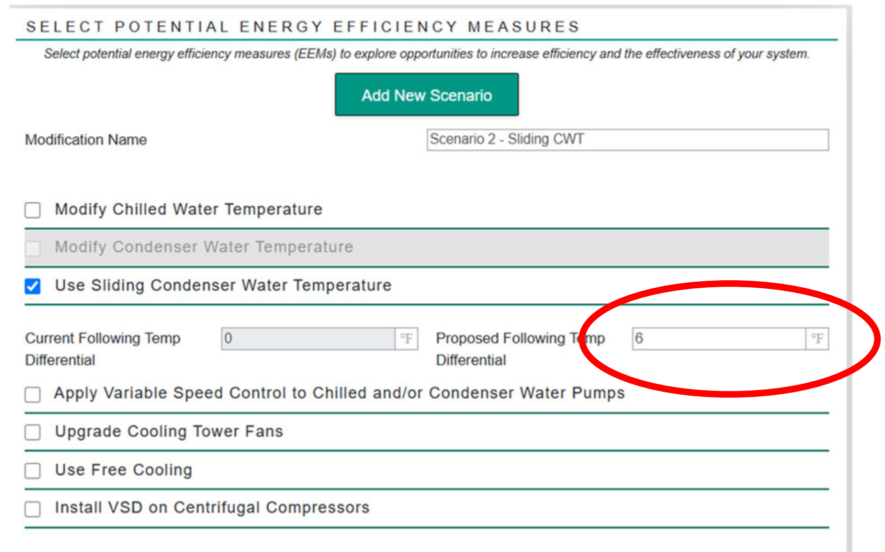
Constant Condenser Water Flow Rate; Same Load/Load Profile

ECWT Management

- Another control strategy for controlling ECWT is by managing (fixing / floating) approach to wet-bulb
  - This will automatically float the ECWT based on the ambient conditions
- Is there is an OPTIMUM approach to wet-bulb temperature?
- What factors determine this optimum approach temperature?
- MEASUR can be used iteratively to determine if such an optimum does exist and where

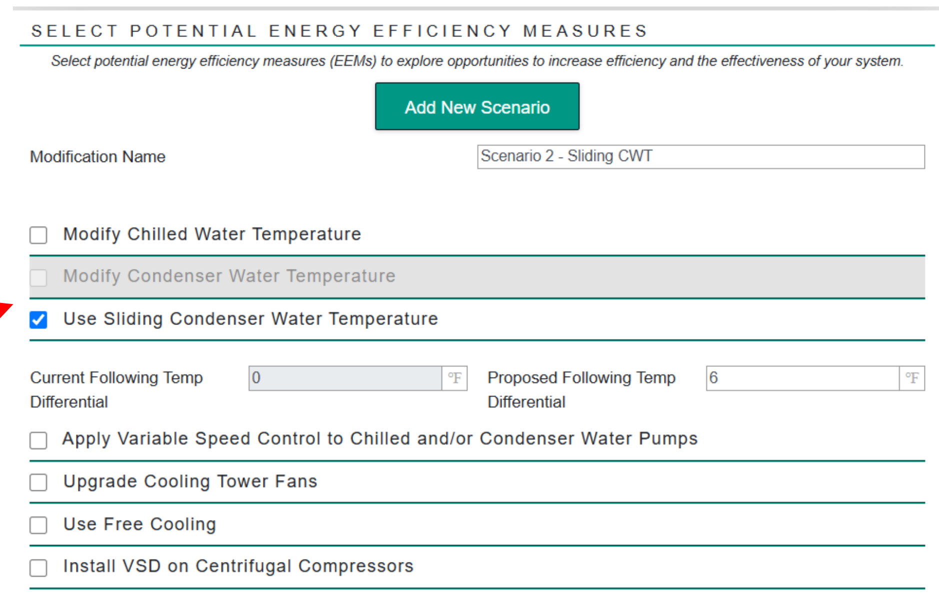
Student Exercise (Floating Entering Condenser Water Temperature)

- There are 2 separate analysis that will be required to determine the optimum
- 1st Step – comparison of fixed ECWT with varying ECWT (but with a fixed wet-bulb approach)
- 2nd Step – vary the wet-bulb approach temperature to determine optimum



Student Exercise (Floating Entering Condenser Water Temperature)

- 1st Step – comparison of fixed ECWT with varying ECWT (but with a fixed wet-bulb approach)
- Use Base Model
- Turn on “Use Sliding Condenser Water Temperature”
- Set Approach to 6°F



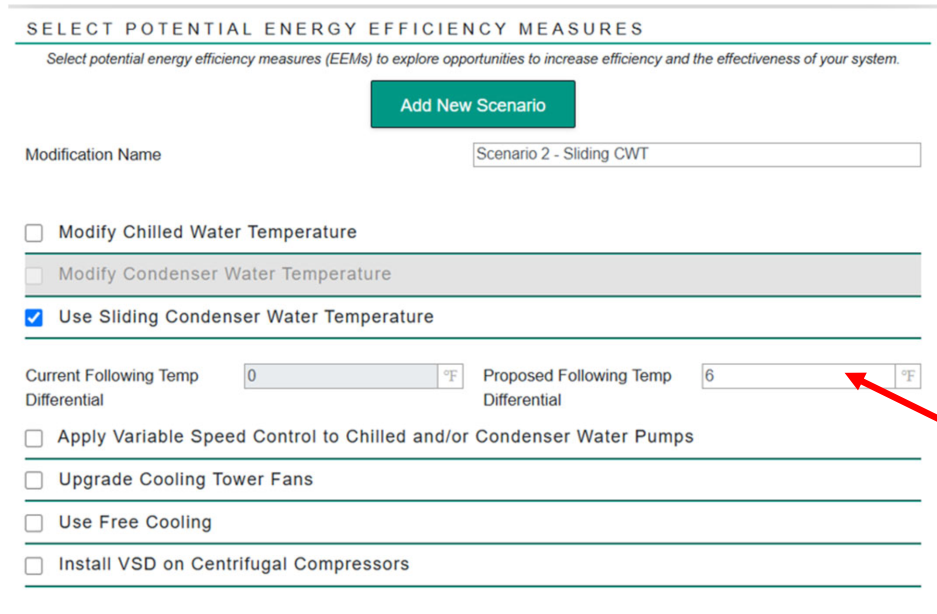
Student Exercise (Floating Entering Condenser Water Temperature)

RESULTS | HELP

	Baseline	Scenario 2 - Sliding CWT
Percent Savings (%)	——	1.7%
Chiller Energy (kWh)	7,485,479	6,759,781
Chiller Energy Cost ($)	$748,548	$675,978
Tower Energy (kWh)	125,435	703,749
Tower Energy Cost ($)	$12,544	$70,375
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,362,337**
Energy Savings (kWh)	**——**	**147,384**
Total Cost ($)	**$850,972**	**$836,234**
Cost Savings ($)	**——**	**$14,738**
Energy Efficiency Measures Used	——	Use Sliding Condenser Water Temperature

Student Exercise (Floating Condenser Water Temperature Setpoint)

- Create a new base model with ECWT following 6°F approach to wet-bulb
- Do a parametric analysis by changing the approach to wet-bulb in the energy efficiency opportunity



Eliminate Refrigerant Stacking

- Refrigerant <u>stacking</u> is an abnormal accumulation of refrigerant in the condenser
- Common causes
  - Decrease in the differential pressure or “lift” between the condenser and the evaporator
  - Reduced pressure drop prevents the refrigerant from flowing back to the evaporator to complete the refrigerant cycle
  - Too low ECWT for the part load of the chiller
- Refrigerant stacking impacts heat transfer efficiency in both the evaporator and condenser
  - Higher kW/Ton and energy costs
- Leads to reduced compressor capacity
- May Cause:
  - Chiller surging or stalling
  - Shut down on low refrigerant temperature/pressure

Optimizing Chilled Water Set-Point (ChWST)

U.S. DEPARTMENT OF
ENERGY

Optimize Settings for ChWST

- **ChWST** – **Ch**illed **W**ater **S**upply **T**emperature

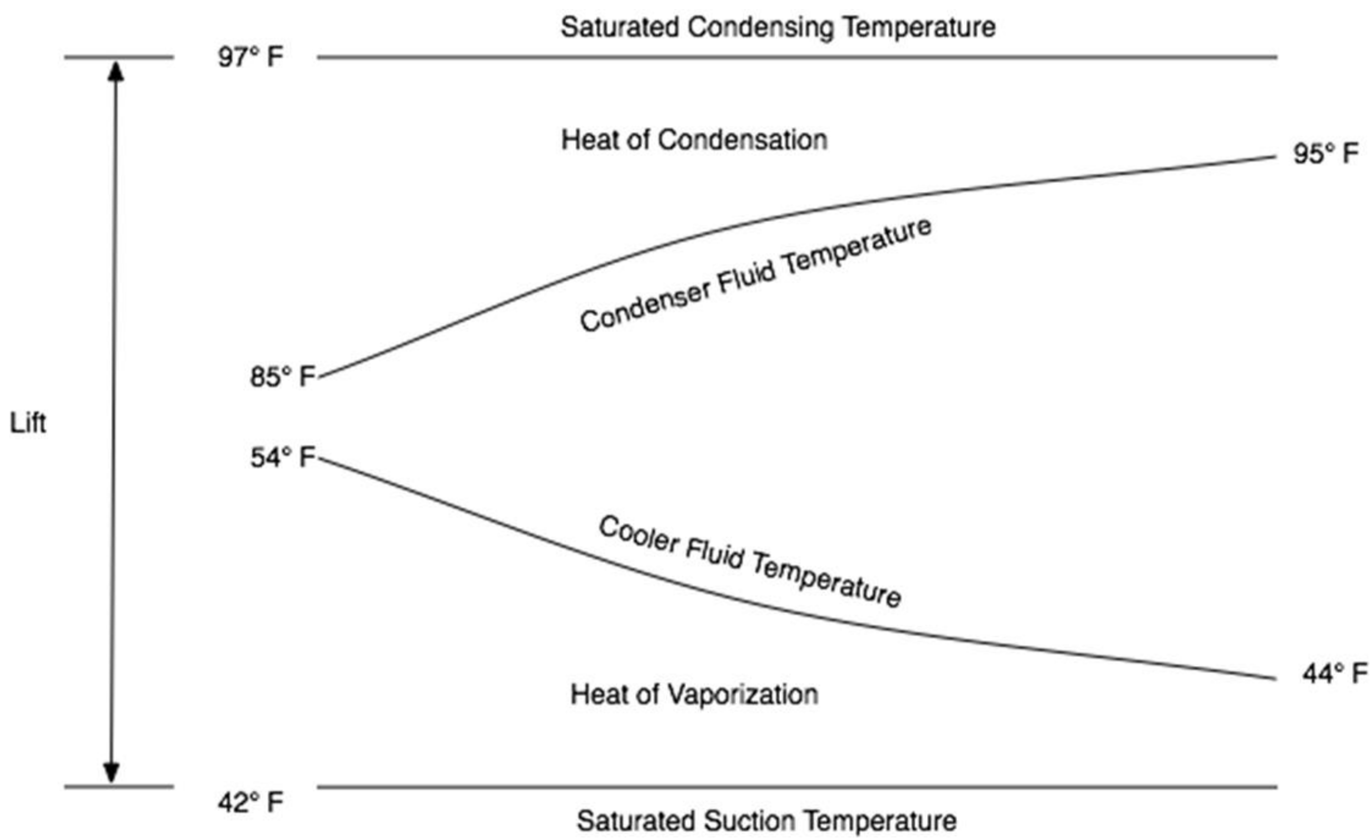
- Approach
  - The Refrigerant Approach Temperature is the difference in temperature between the chilled-water supply temperature and the refrigerant saturated temperature in the evaporator
  - It provides the driving force to transfer the heat from the water to the refrigerant

- Tell-tale signs for sub-optimal operations in chiller plants
  - Lower chilled water return temperature than design
  - High chilled water bypass flows
  - Chilled water flow control valves throttled at end-users

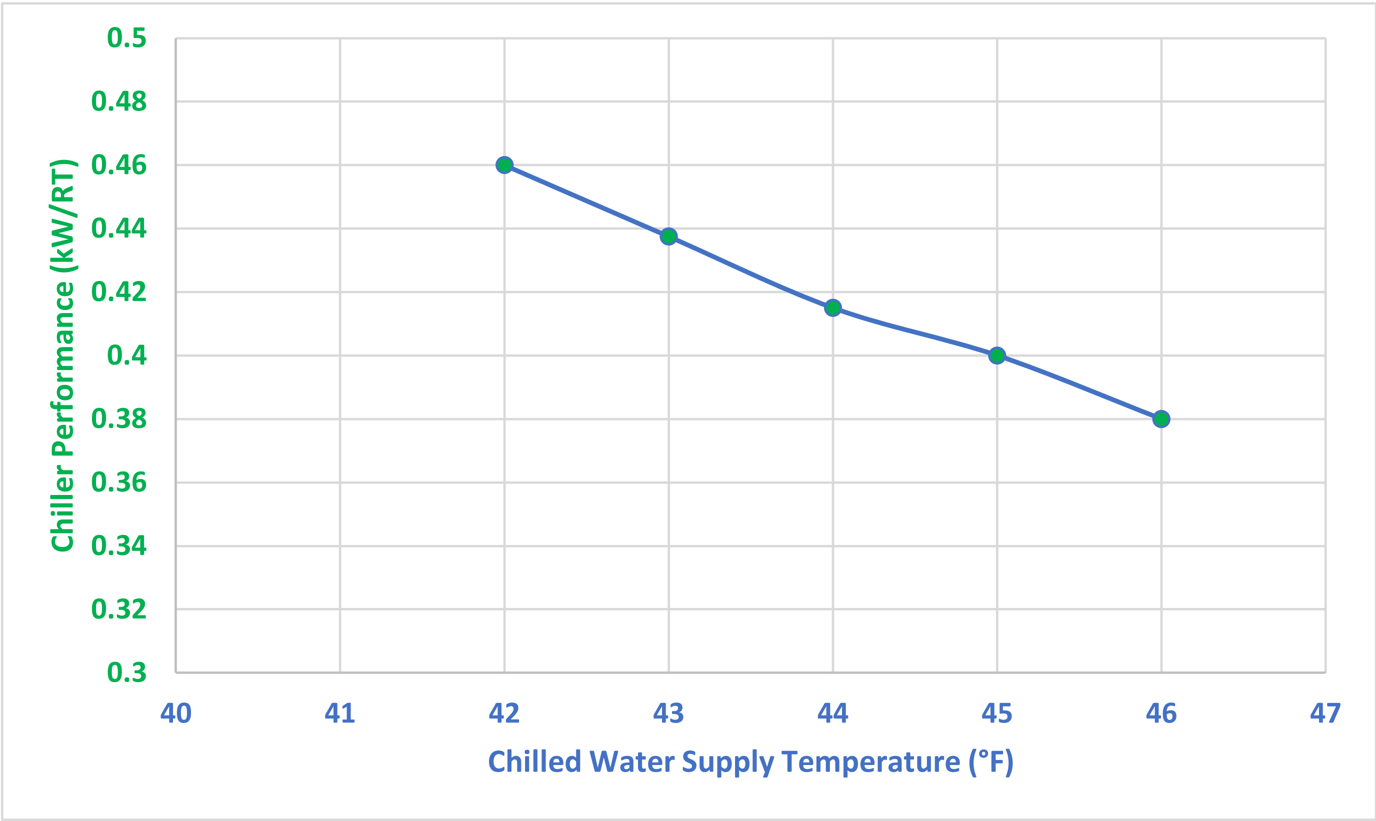
- Optimized ChWST will also allow for better load control and optimal number of chiller operation
  - Required cooling controlled by chilled water flow bypass
  - Alternate methodology – variable pumping

Remember Lift!

Lift = 97 – 42 = 55°F



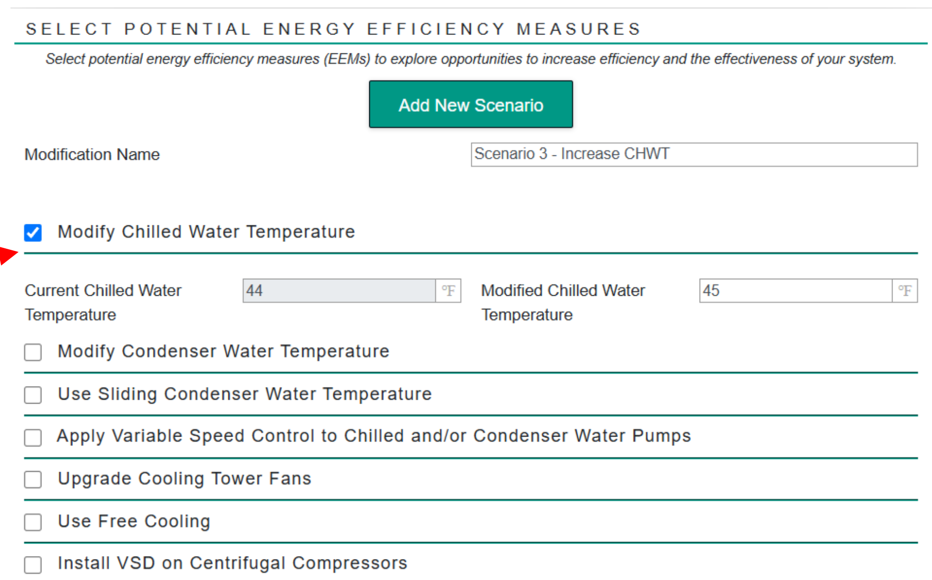
Chiller Plant Efficiency and Chilled Water Set-Point



Student Exercise

- The industrial plant engineer recently completed a chilled water system audit and found that the chilled water supply temperature was fixed at 44°F.
- They wanted to determine if there would be a benefit to let the chilled water supply temperature be increased by 1°F.
- Use the MEASUR model to determine how much system energy could be saved if the plant was able to increase the chilled water supply temperature by 1°F.
- Discuss concerns and issues with the chosen option and what steps can be taken to mitigate them

Student Exercise (Increase Chilled Water Supply Temperature)



NOTE: This opportunity does not change the chilled water flow rate

Student Exercise (Increase Chilled Water Supply Temperature)

Savings on both – Chiller & Tower

RESULTS	HELP	
	Baseline	Scenario 3 - Increase CHWT
Percent Savings (%)	——	1.0%
Chiller Energy (kWh)	7,485,479	7,403,626
Chiller Energy Cost ($)	$748,548	$740,363
Tower Energy (kWh)	125,435	125,333
Tower Energy Cost ($)	$12,544	$12,533
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,427,766**
Energy Savings (kWh)	**——**	**81,955**
Total Cost ($)	**$850,972**	**$842,777**
Cost Savings ($)	**——**	**$8,196**
Energy Efficiency Measures Used	——	Modify Chilled Water Temperature

Combinatorial Savings

- As the chilled water supply temperature setpoint is increased
  - The Lift reduces
  - This reduces the work done by the compressor implying a lower kW/RT
  - This results in direct chiller savings
  - The heat rejected by the condenser is the sum of the evaporator load (which is the same) and the compressor work (which has reduced)
  - So the heat rejected by the condenser reduces
  - This reduces the cooling tower fan energy

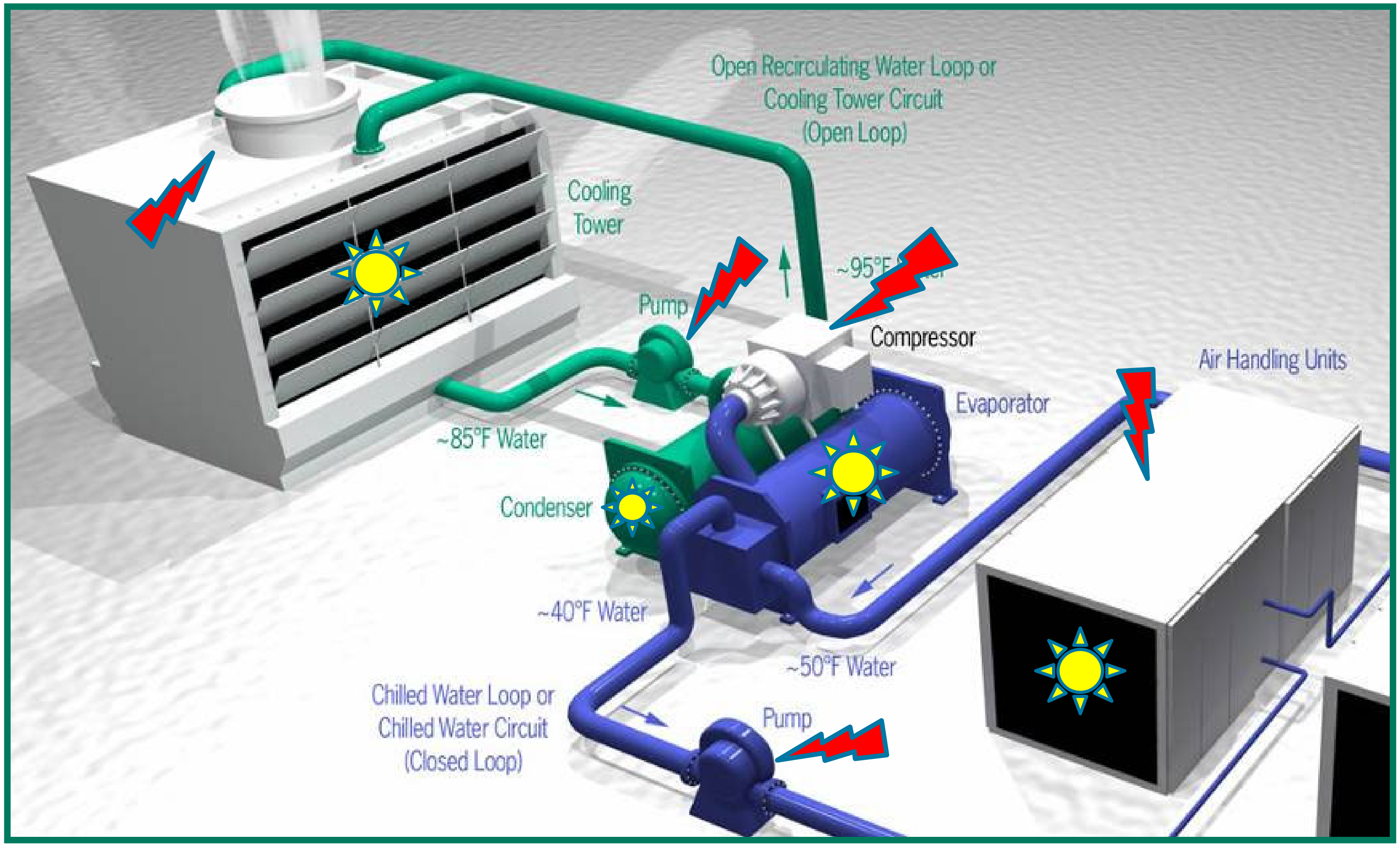
- Hence, the savings are combinatorial and higher the chilled water supply temperature, higher the savings – <u>if the chilled water flow remains constant</u>

A Simple Chilled Water System

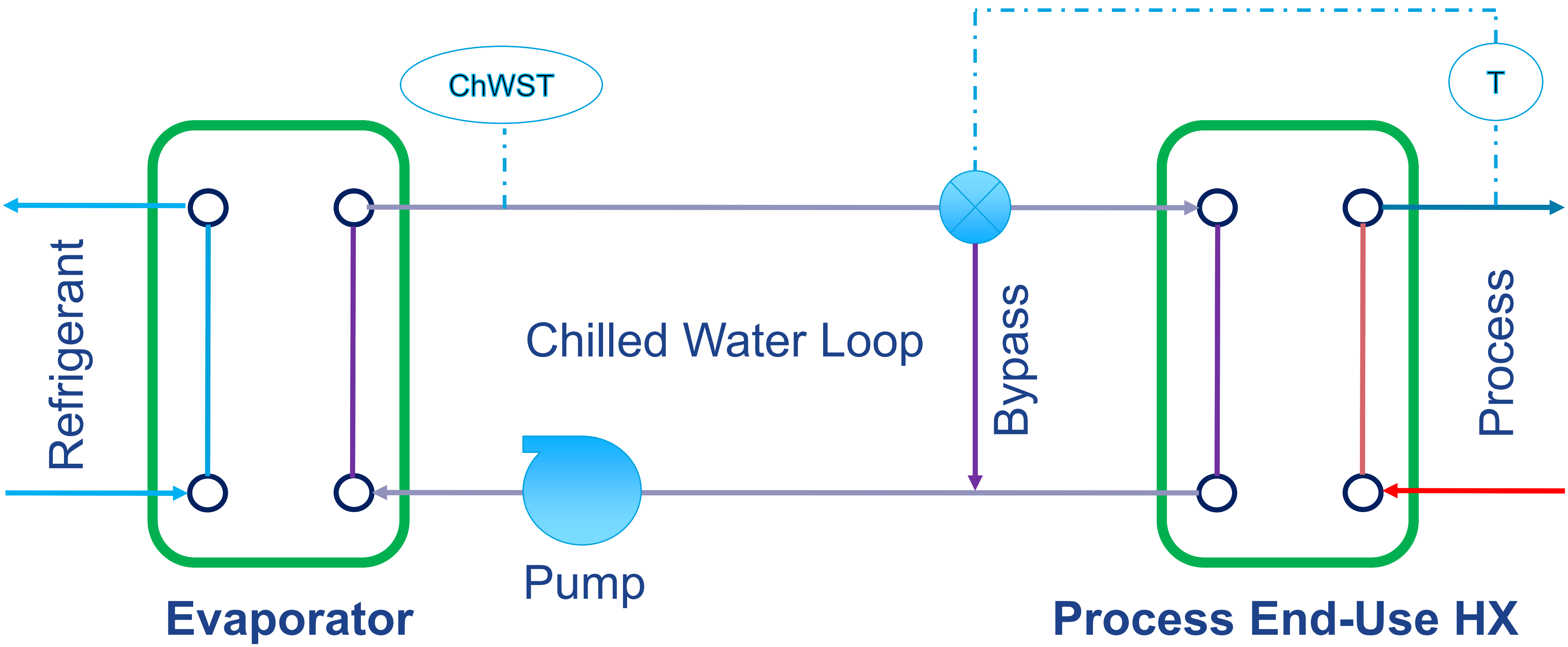
Electrical

Nexus

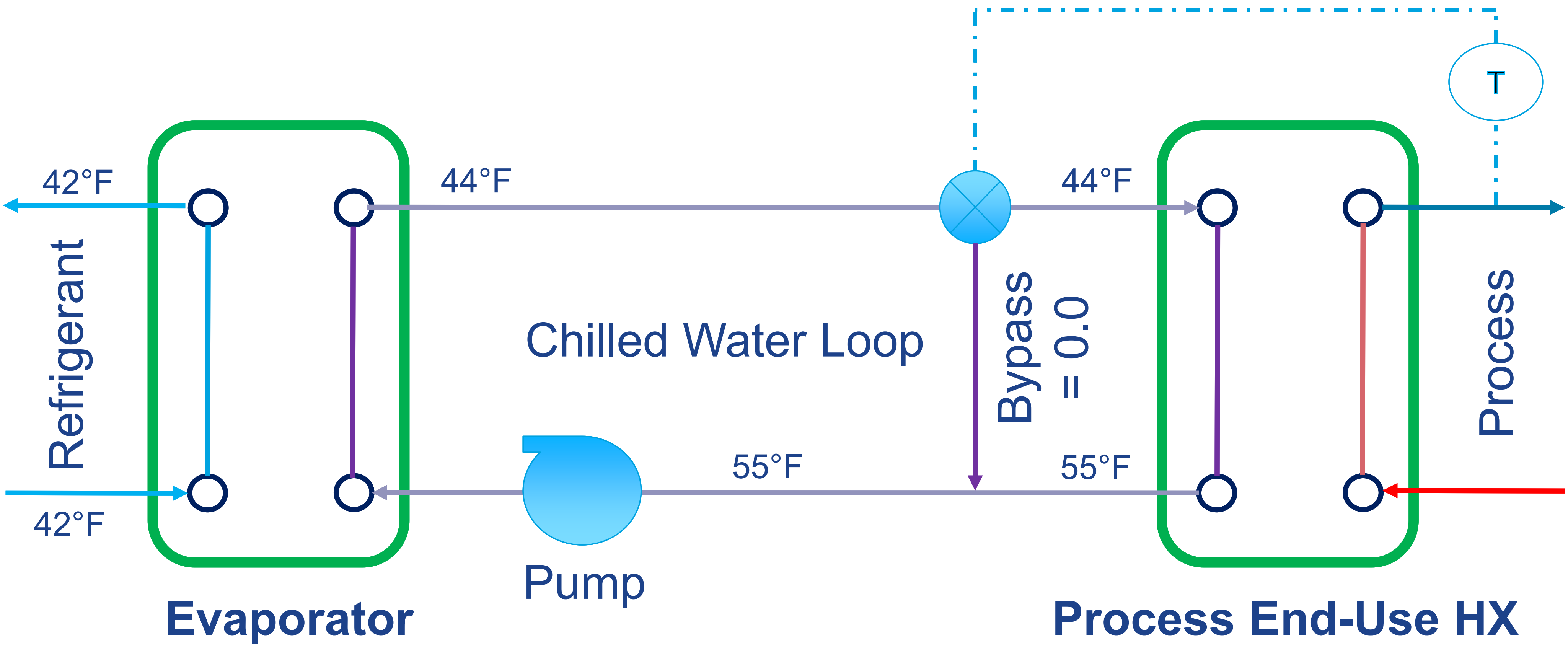
Thermal



Simplified Chilled Water Loop (Constant Speed Pump)



Simplified Chilled Water Loop (Constant Speed Pump)



Simplified Chilled Water Loop (Constant Speed Pump)

- Normal (Design) Operation
  - Bypass flow = 0
  - Process end use cooling demand = 100 RT
  - Chilled water flow through HX = 240 gpm
  - Chilled water supply temperature = 44°F
  - Chilled water return temperature = 55°F
  - Evaporator refrigerant saturation temperature = 42°F
  - LMTD on the evaporator = 5.88°F
  - Qevap = UA*LMTD
  - UAevap = Qevap / LMTD = 17.01 RT/°F

$$\boxed{\text{LMTD} = \frac{(Tout - Tsat) - (Tin - Tsat)}{\ln\frac{(Tout - Tsat)}{(Tin - Tsat)}}}$$

Easy Tell-tale Signs to Raise ChWST

- An inline valve – typically, at chilled water pump discharge – is throttled
  - Chilled water flow is being restricted
  - Pump may not be designed properly
  - The end-use HX may not be designed correctly for full design flow
- Opportunity to raise ChWST and increase flow in the loop
- Opportunity to use VFD on pump and also raise ChWST

Easy Tell-tale Signs to Raise ChWST

- The Bypass flow is significant (> 20%)
  - Flow to the process end-use HX is less than 80% of the chilled water supply flow
  - Pump may not be designed properly
  - The end-use HX may not be designed correctly for the full design flow
  - The end-use HX has significant more area than required for the process heat duty
  - Process end-use demand is LOWER than design
- Opportunity to raise ChWST and increase flow in the end-use HX
- Opportunity to raise ChWST and may be to use VFD on pump

Impact of Optimizing ECWT & ChWST

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Modeling Multiple EEOs in MEASUR

- MEASUR has the ability to model combinatorial impacts of multiple energy efficiency opportunities (EEOs)
  - Allows the user to NOT double-count
  - Avoids pitfalls where one EEO may negate or offset another EEO
  - System Approach

- While doing an overall analysis model MEASUR with all the EEOs together

- For each specific project and to determine priority in EEOs based on budget constraints, schedules and return on investments – also model each opportunity in MEASUR individually

Individual EEO Results

- Reduce ECWT by 2°F

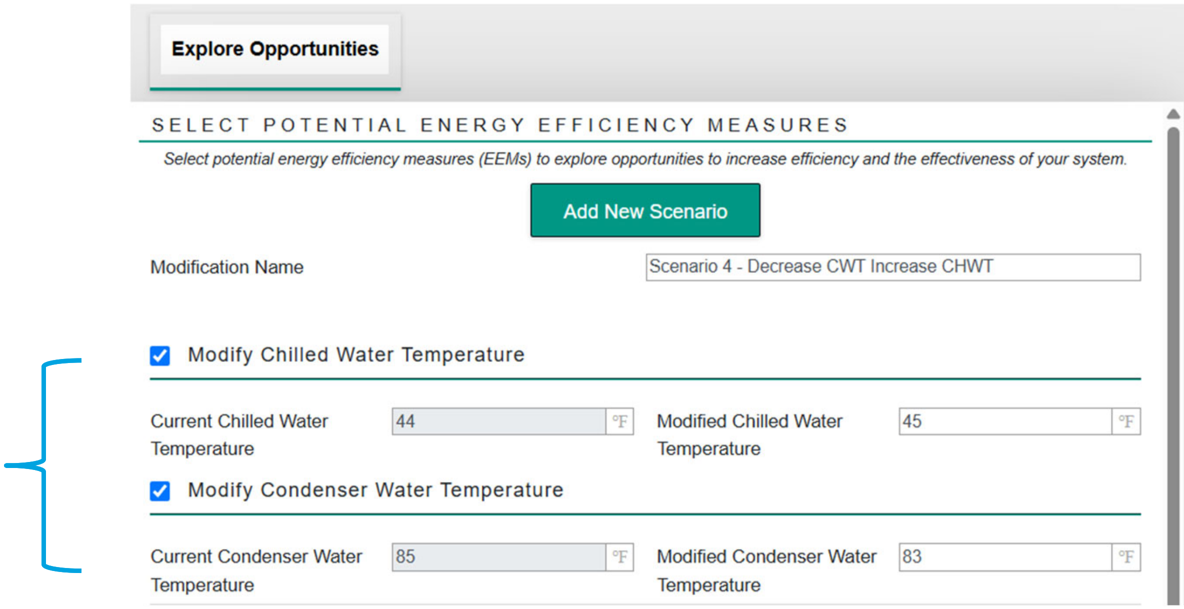
	Baseline	Scenario 1 - Decrease CWT
Percent Savings (%)	——	0.3%
Chiller Energy (kWh)	7,485,479	7,415,498
Chiller Energy Cost ($)	$748,548	$741,550
Tower Energy (kWh)	125,435	172,998
Tower Energy Cost ($)	$12,544	$17,300
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,487,303**
Energy Savings (kWh)	**——**	**22,419**
Total Cost ($)	**$850,972**	**$848,730**
Cost Savings ($)	**——**	**$2,242**

- Increase ChWST by 1°F

	Baseline	Scenario 3 - Increase CHWT
Percent Savings (%)	——	1.0%
Chiller Energy (kWh)	7,485,479	7,403,626
Chiller Energy Cost ($)	$748,548	$740,363
Tower Energy (kWh)	125,435	125,333
Tower Energy Cost ($)	$12,544	$12,533
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,427,766**
Energy Savings (kWh)	**——**	**81,955**
Total Cost ($)	**$850,972**	**$842,777**
Cost Savings ($)	**——**	**$8,196**

Total Savings: 104,374 kWh, $10,438

Modeling both the EEOs together in MEASUR



- One word of caution – It is always best to start MEASUR from the base model whenever modeling EEOs
  - It avoids leaving past evaluated projects ON in error

Modeling both the EEOs together in MEASUR

RESULTS	HELP

	Baseline	Scenario 4 - Decrease CWT Increase CHWT
Percent Savings (%)	——	1.2%
Chiller Energy (kWh)	7,485,479	7,334,496
Chiller Energy Cost ($)	$748,548	$733,450
Tower Energy (kWh)	125,435	172,698
Tower Energy Cost ($)	$12,544	$17,270
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,406,001**
Energy Savings (kWh)	**——**	**103,720**
Total Cost ($)	**$850,972**	**$840,600**
Cost Savings ($)	**——**	**$10,372**
Energy Efficiency Measures Used	——	Modify Chilled Water Temperature Modify Condenser Water Temperature

NOTE: Savings less than sum of individual EEOs

Why do the Savings NOT Match

- EEO savings may not be additive
  - Savings may not be linear when comparing them with Lift
- Chiller performance curves (kW/RT) are not linear when comparing them with changes in Lift
- The distribution of load, operation of cooling tower fan can all play a very significant role
- The higher the confidence level in the base model results, chiller performance curves – higher the fidelity of the MEASUR EEOs results

Applying VFDs to Pumps

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ENERGY

Application of Variable Frequency Drives to Pumps

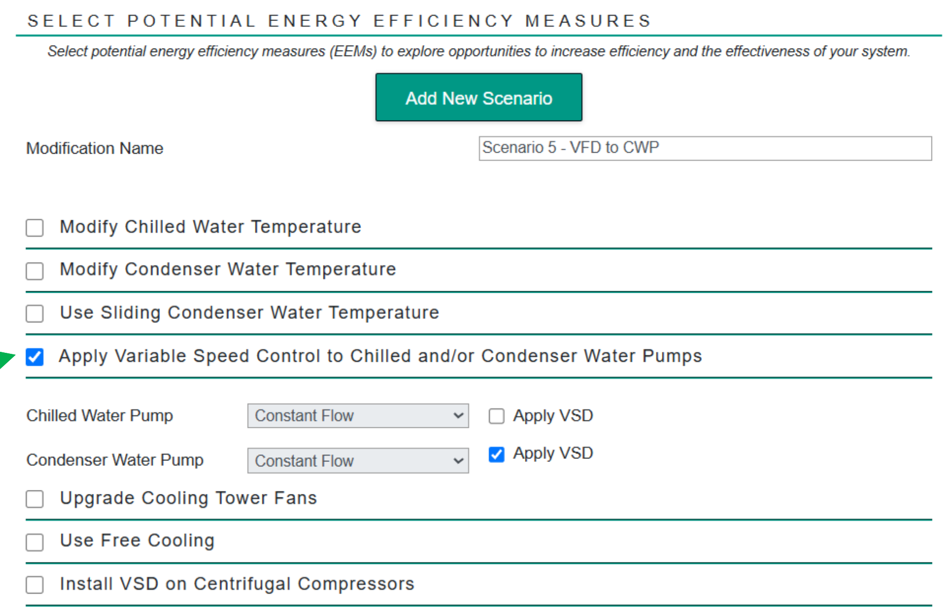
- VFD pumps can play a very important role in reducing total system energy consumption

- The centrifugal pump follows the cube law
  - Flow $\propto$ Speed
  - Power $\propto$ Speed^3

- The example chilled water central plant facility
  - Primary chilled water pumps
  - Secondary chilled water pumps
  - Condenser water (cooling tower) pumps

Modeling Application of VFDs to Pumps in MEASUR

- Remember – MEASUR models primary chilled water loop ONLY
- Model the VFD pumps application individually
  - Chilled water
  - Condenser water



Modeling Application of VFDs to CW Pumps in MEASUR

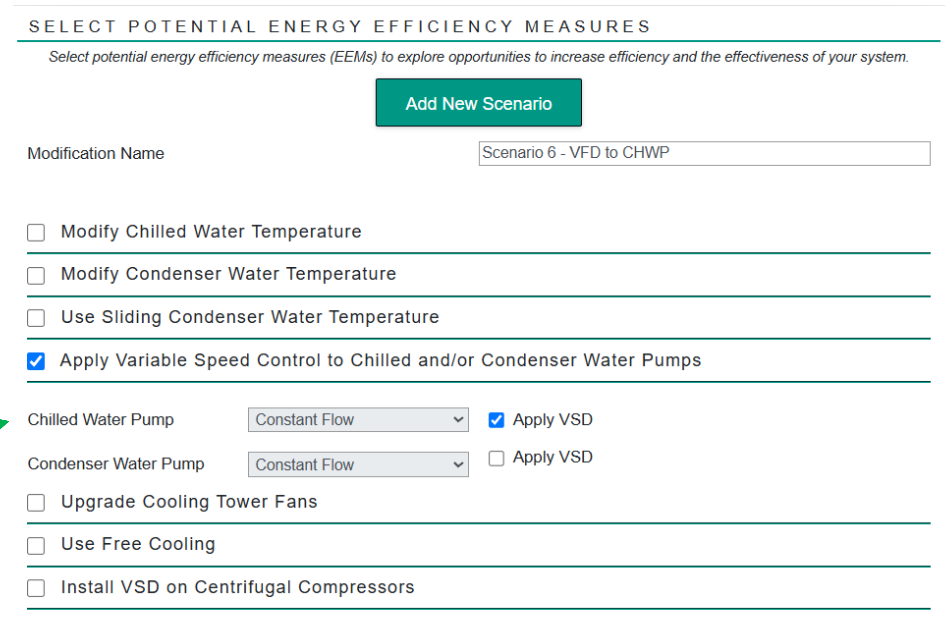
RESULTS | HELP

	Baseline	Scenario 5 - VFD to CWP
Percent Savings (%)	— —	3.8%
Chiller Energy (kWh)	7,485,479	7,485,479
Chiller Energy Cost ($)	$748,548	$748,548
Tower Energy (kWh)	125,435	73,102
Tower Energy Cost ($)	$12,544	$7,310
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	231,559
Condenser Water Pumping Energy Cost ($)	$49,934	$23,156
Total Pump Energy (kWh)	898,807	631,029
Total Pump Energy Cost ($)	$89,881	$63,103
Total Energy (kWh)	**8,509,721**	**8,189,610**
Energy Savings (kWh)	**— —**	**320,112**
Total Cost ($)	**$850,972**	**$818,961**
Cost Savings ($)	**— —**	**$32,011**
Energy Efficiency Measures Used	— —	Apply Variable Speed Controls

Modeling Application of VFDs to Pumps in MEASUR

- Remember – MEASUR models primary chilled water loop ONLY

- Model the VFD pumps application individually
  - Chilled water
  - Condenser water



Modeling Application of VFDs to CHW Pumps in MEASUR

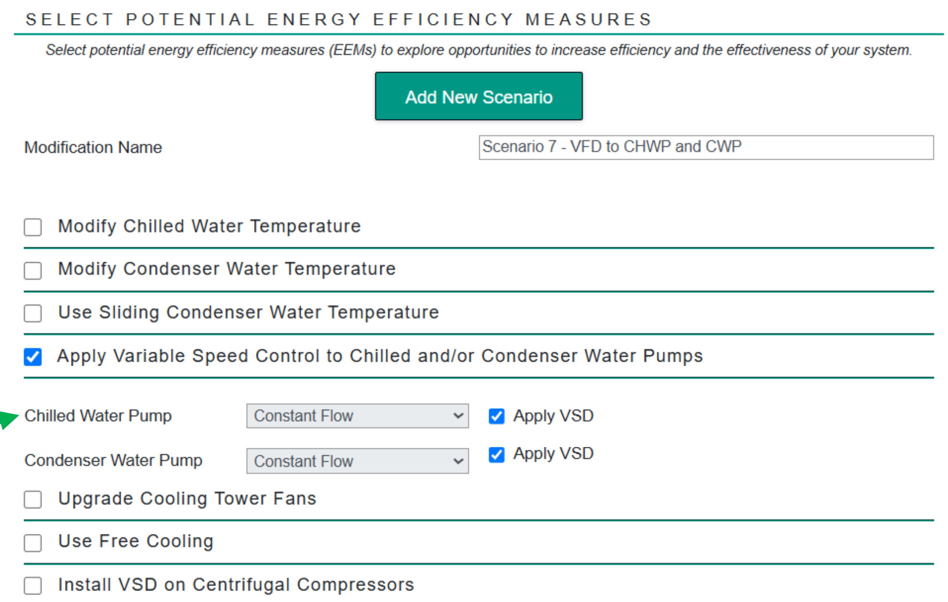
RESULTS | HELP

	Baseline	Scenario 6 - VFD to CHWP
Percent Savings (%)	——	2.5%
Chiller Energy (kWh)	7,485,479	7,485,479
Chiller Energy Cost ($)	$748,548	$748,548
Tower Energy (kWh)	125,435	125,435
Tower Energy Cost ($)	$12,544	$12,544
Chilled Water Pumping Energy (kWh)	399,470	185,247
Chilled Water Pumping Energy Cost ($)	$39,947	$18,525
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	684,585
Total Pump Energy Cost ($)	$89,881	$68,458
Total Energy (kWh)	**8,509,721**	**8,295,499**
Energy Savings (kWh)	**——**	**214,223**
Total Cost ($)	**$850,972**	**$829,550**
Cost Savings ($)	**——**	**$21,422**
Energy Efficiency Measures Used	——	Apply Variable Speed Controls

Modeling Application of VFDs to CHW & CW Pumps

- Remember – MEASUR models primary chilled water loop ONLY

- Model the VFD pumps application together
  - Chilled water
  - Condenser water



Modeling Application of VFDs to CHW & CW Pumps

RESULTS | HELP

	Baseline	Scenario 7 - VFD to CHWP and CWP
Percent Savings (%)	——	6.3%
Chiller Energy (kWh)	7,485,479	7,485,479
Chiller Energy Cost ($)	$748,548	$748,548
Tower Energy (kWh)	125,435	73,102
Tower Energy Cost ($)	$12,544	$7,310
Chilled Water Pumping Energy (kWh)	399,470	185,247
Chilled Water Pumping Energy Cost ($)	$39,947	$18,525
Condenser Water Pumping Energy (kWh)	499,337	231,559
Condenser Water Pumping Energy Cost ($)	$49,934	$23,156
Total Pump Energy (kWh)	898,807	416,806
Total Pump Energy Cost ($)	$89,881	$41,681
Total Energy (kWh)	**8,509,721**	**7,975,387**
Energy Savings (kWh)	**——**	**534,334**
Total Cost ($)	**$850,972**	**$797,539**
Cost Savings ($)	**——**	**$53,433**
Energy Efficiency Measures Used	——	Apply Variable Speed Controls

Comments on Using Process Cooling module for VFD on Pumps

- Remember – Process Cooling allows user to get a good idea of the potential energy and cost savings of VFDs on pumps
- Better tools exist – USDOE MEASUR Pump Assessment – that can be used to more accurately quantify VFD savings on pumps
- MEASUR – Process Cooling Module has a limited pump loop definition
- The specific pump curve at the plant may be very different compared to the generic pump curve in Process Cooling Module

Cooling Tower Fan Speed Control

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Application of Cooling Tower Fan Speed Control

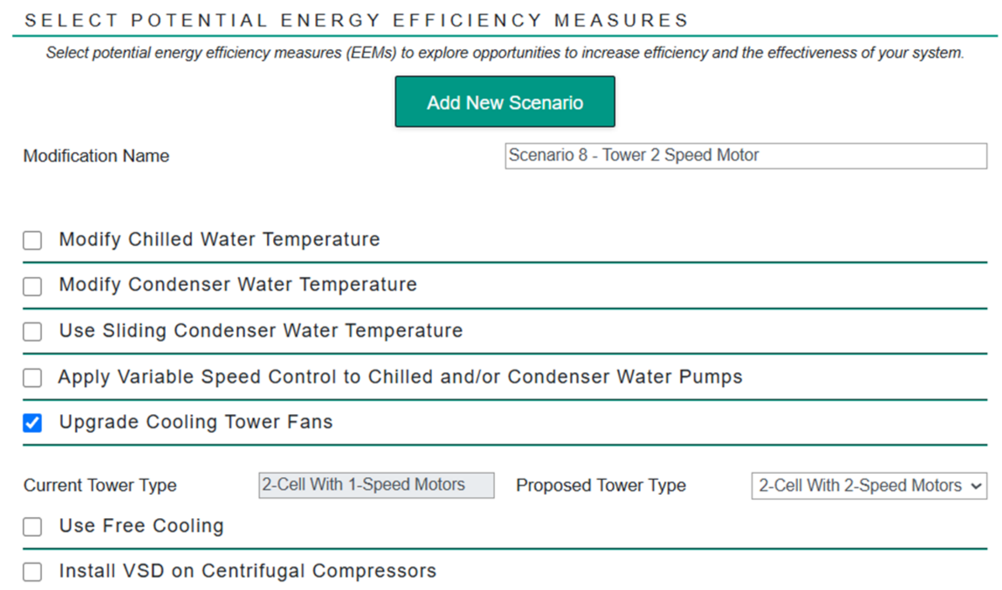
- There are different types of cooling tower fan controls
  - Constant speed – motor goes ON/OFF
  - 2-speed control – motor goes High speed, Low speed and Off
  - Variable speed control
  - Fan pitch control – in axial fans ONLY

- The centrifugal fan follows the cube law
  - Flow $\propto$ Speed
  - Power $\propto$ Speed^3

- MEASUR allows selection of fan and type of speed control

Application of Cooling Tower Fan Speed Control

- Cooling tower model uses the fundamental principles of psychrometrics, heat transfer, mass transfer and fluid flow
- Evaluate the cooling tower fan control
  - 2-speed



Application of Cooling Tower Fan Speed Control

- Cooling tower model w/2-speed fan control

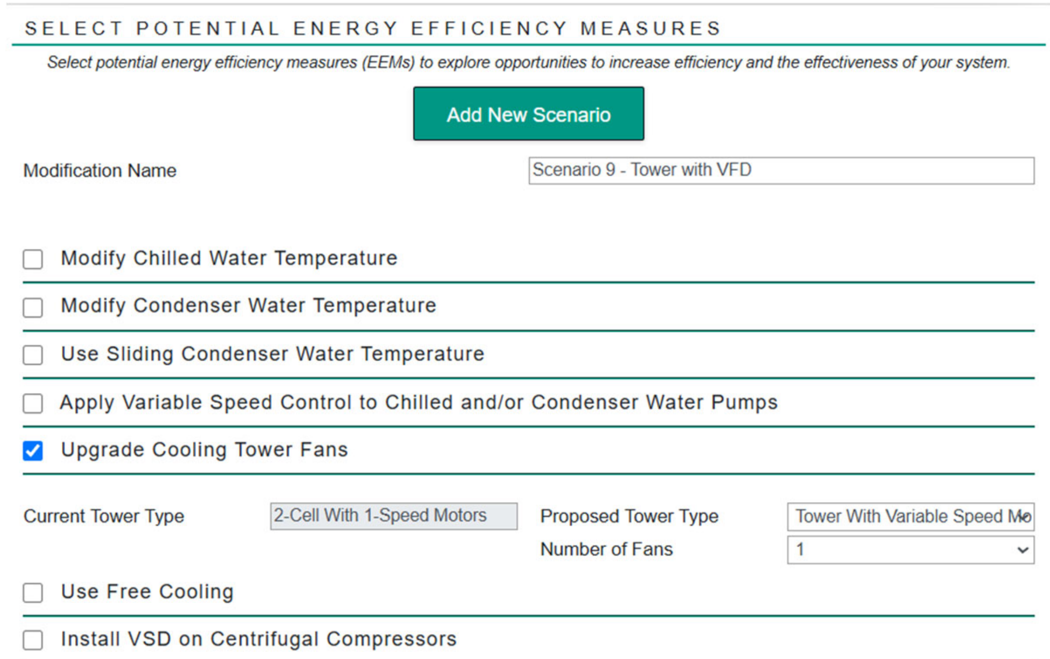
RESULTS | HELP

	Baseline	Scenario 8 - Tower 2 Speed Motor
Percent Savings (%)	— —	0.7%
Chiller Energy (kWh)	7,485,479	7,485,479
Chiller Energy Cost ($)	$748,548	$748,548
Tower Energy (kWh)	125,435	61,688
Tower Energy Cost ($)	$12,544	$6,169
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,445,974**
Energy Savings (kWh)	**— —**	**63,747**
Total Cost ($)	**$850,972**	**$844,597**
Cost Savings ($)	**— —**	**$6,375**
Energy Efficiency Measures Used	— —	Upgrade Cooling Tower Fans

Application of Cooling Tower Fan Speed Control

- Cooling tower model uses the fundamental principles of psychrometrics, heat transfer, mass transfer and fluid flow

- Evaluate the cooling tower fan control
  - VFD



Application of Cooling Tower Fan Speed Control

- Cooling tower model w/VFD fan control

RESULTS | HELP

	Baseline	Scenario 9 - Tower with VFD
Percent Savings (%)	— —	0.9%
Chiller Energy (kWh)	7,485,479	7,485,479
Chiller Energy Cost ($)	$748,548	$748,548
Tower Energy (kWh)	125,435	51,645
Tower Energy Cost ($)	$12,544	$5,165
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**8,435,931**
Energy Savings (kWh)	**— —**	**73,790**
Total Cost ($)	**$850,972**	**$843,593**
Cost Savings ($)	**— —**	**$7,379**
Energy Efficiency Measures Used	— —	Upgrade Cooling Tower Fans

Implement Free Cooling (Water side Economizer)

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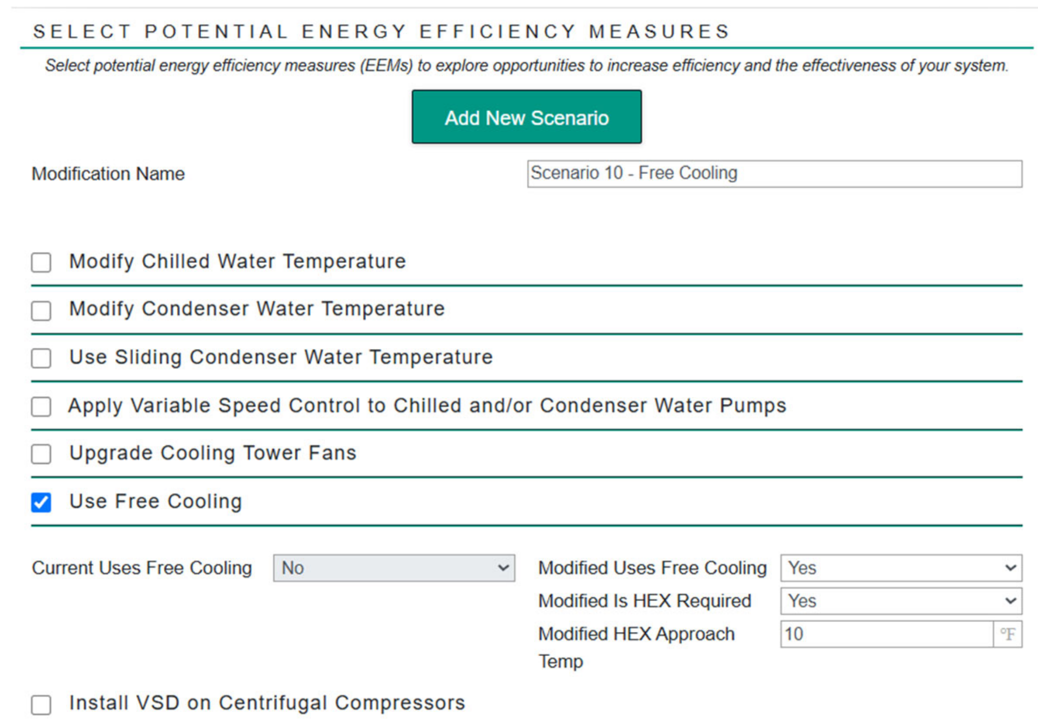
Install Water-side Economizers (Free Cooling)

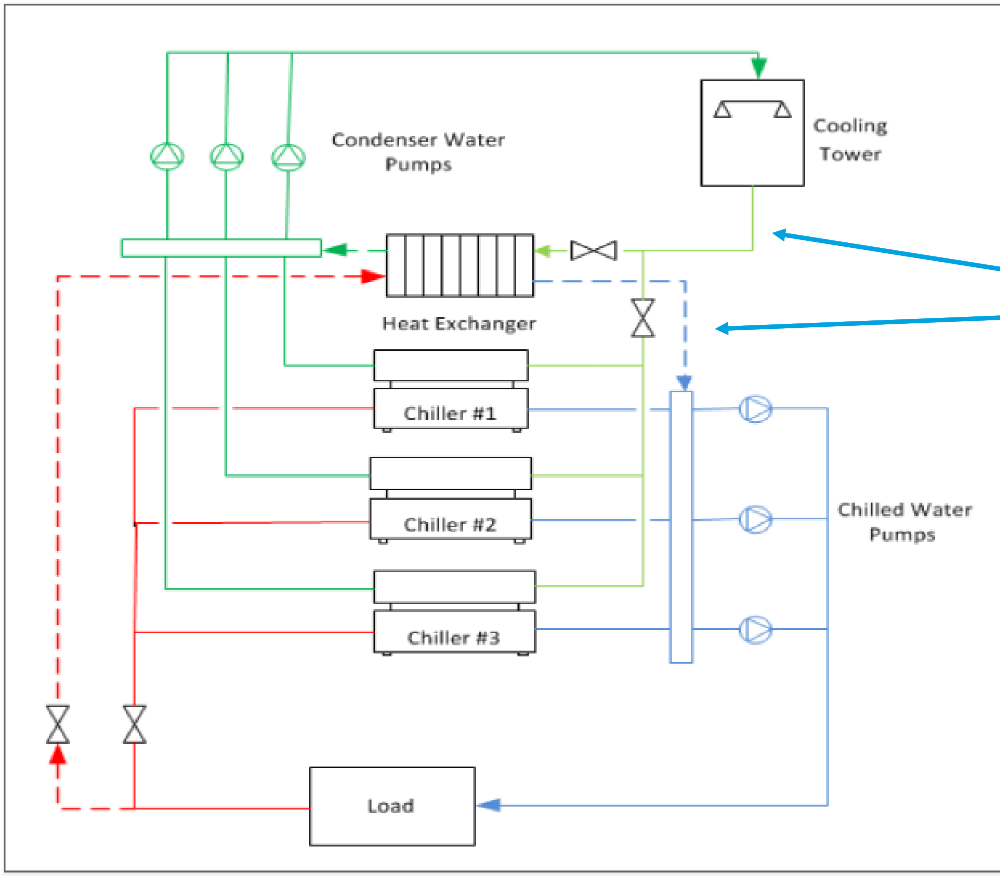
- This energy efficiency opportunity is applicable and cost-effective in certain geographical areas only but can have a huge impact on energy savings
- Installing a water-side economizer allows for “free cooling” during times of the year when the outdoor ambient conditions allow for very low wet-bulb temperatures
- The cooling tower water provides a portion or all of the chilled water load and reduces the chilled water plant’s operating time
- NOTE: Always evaluate if any portion of the chilled water end-use load can be offset by using cooling tower water!

Student Exercise (Using Free Cooling)

- Different configurations of free cooling are possible
- Direct (without HX) allows for maximum potential but may not be practical in chilled water loops
- Indirect (with HX) requires temperature approach as an input



Student Exercise (Using Free Cooling)



Approach of HX
Temperature difference between these 2 streams

Student Exercise (Using Free Cooling)

RESULTS | HELP

	Baseline	Scenario 10 - Free Cooling
Percent Savings (%)	——	6.5%
Chiller Energy (kWh)	7,485,479	6,858,534
Chiller Energy Cost ($)	$748,548	$685,853
Tower Energy (kWh)	125,435	203,481
Tower Energy Cost ($)	$12,544	$20,348
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$39,947	$39,947
Condenser Water Pumping Energy (kWh)	499,337	499,337
Condenser Water Pumping Energy Cost ($)	$49,934	$49,934
Total Pump Energy (kWh)	898,807	898,807
Total Pump Energy Cost ($)	$89,881	$89,881
Total Energy (kWh)	**8,509,721**	**7,960,822**
Energy Savings (kWh)	**——**	**548,899**
Total Cost ($)	**$850,972**	**$796,082**
Cost Savings ($)	**——**	**$54,890**
Energy Efficiency Measures Used	——	Use Free Cooling

Implementing Free Cooling – Exercise Caution

- Be careful with this opportunity – a lot of misapplications occur
- Proper temperature and flow control loops have to be incorporated and retrofitting may make it a little more challenging if 3-way tie-ins on the chilled water loop and cooling tower loop are not easily available
- On several occasions, a separate cooling tower (separate basin) and water loop maybe needed

Implementing Free Cooling – Exercise Caution

- When cooling towers are sized by Tower Tons in MEASUR, the algorithm continues to optimize and evaluate the cooling tower fan power necessary - which does reduce as chiller load reduces

- Nevertheless, pay attention to proposed tower details screen to understand if it all makes sense – overall tower energy use has to increase with this opportunity!

- MEASUR is limited in some ways – there maybe increased pumping power depending on the loop and flow control configuration

Homework #5

- Finalize your plant's chilled water system model in MEASUR
- Build confidence in the total energy consumed and the cost of operation of your chilled water system
- From CWST exercises (HW#2), identify two or three opportunities that can be modeled in MEASUR as operating cost reduction strategies
- Use the MEASUR model to quantify these opportunities
- Identify discrepancies and shortcomings, if any, in the MEASUR software

Thank You all for attending today's webinar.

See you all on Thursday – August 20, 2026 – 2 pm ET

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

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

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Kahoot Quiz Time