Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 6

Thursday – August 20, 2026

2:00 pm – 4:30 pm ET

Welcome

- Welcome to the 6th 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 6

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
  - Quantifying Opportunities using MEASUR
  - Preparing for the VINPLT Assessment Presentation
- Kahoot Quiz Game
- Q&A

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

Safety and Housekeeping

- Safety Moment
  - Be mindful of electrical wiring and any other instrumentation conduits, etc while doing a plant walk-through - They can be tripping hazards putting you in immediate danger with electrical and rotating equipment
- 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

Eliminate Inappropriate Uses of Chilled Water / Reduce Cooling Load

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Reduction of Cooling Load

- Difficult to understand & implement
- Extreme caution required since a thorough understanding of the process will be required
- Very large energy and cost savings can be achieved by implementing a cooling load reduction strategy
- Several opportunities exist for reducing overall cooling load (RT)
- Start by asking two simple questions
  - Why is cooling needed for this end-use?
  - If cooling is required, what is the cooling load / temperature profile?

Cooling Load

- Amount of cooling (RT) required by the process / plant
- All chiller systems are designed to be Load Followers (dependent)
  - Analogous to a boiler generating steam – a boiler doesn't know how much steam is needed – it continues to produce steam until it meets the setpoint pressure
  - A chiller plant continues to produce the cooling effect until it meets the setpoint chilled water outlet (supply) temperature
- Load profile is very important for every plant
- Cooling load can vary significantly based on
  - Production rate and schedules of operation
  - Seasonality due to weather and production cycles
  - Occurrence of certain losses – distribution system loss
  - Inappropriate uses of chilled water

Inappropriate Uses of Chilled Water

- Inappropriate chilled water uses include, but not limited to:
  - Processes where cooling tower water would be adequate to remove the heat
  - Areas where cooling is not needed – scheduled-based; seasonal; decommissioned processes / plant areas
  - Applications where no pre-cooling is done
    - Temperature pinch analysis
  - Systems where a fluid or product is cooled and then immediately heated again to bring it to ambient temperature
    - Take care to make sure that this is NOT a time-temperature process requirement
  - Processes where excessive cooling is demanded (most times is reflected in the chilled water set-point temperature)

Student Exercise

- The industrial plant engineer recently completed a chilled water system audit and identified some areas of inappropriate chilled water usage
- One identified area is the use of ~100 gpm of chilled water in the packaging area
- As per the manufacturer’s recommendations, this system can use cooling tower water for cooling
- Use the MEASUR model to determine how much system energy could be saved if the plant shifted to cooling tower water for this process
- Discuss concerns and issues with the chosen option and what steps can be taken to mitigate them

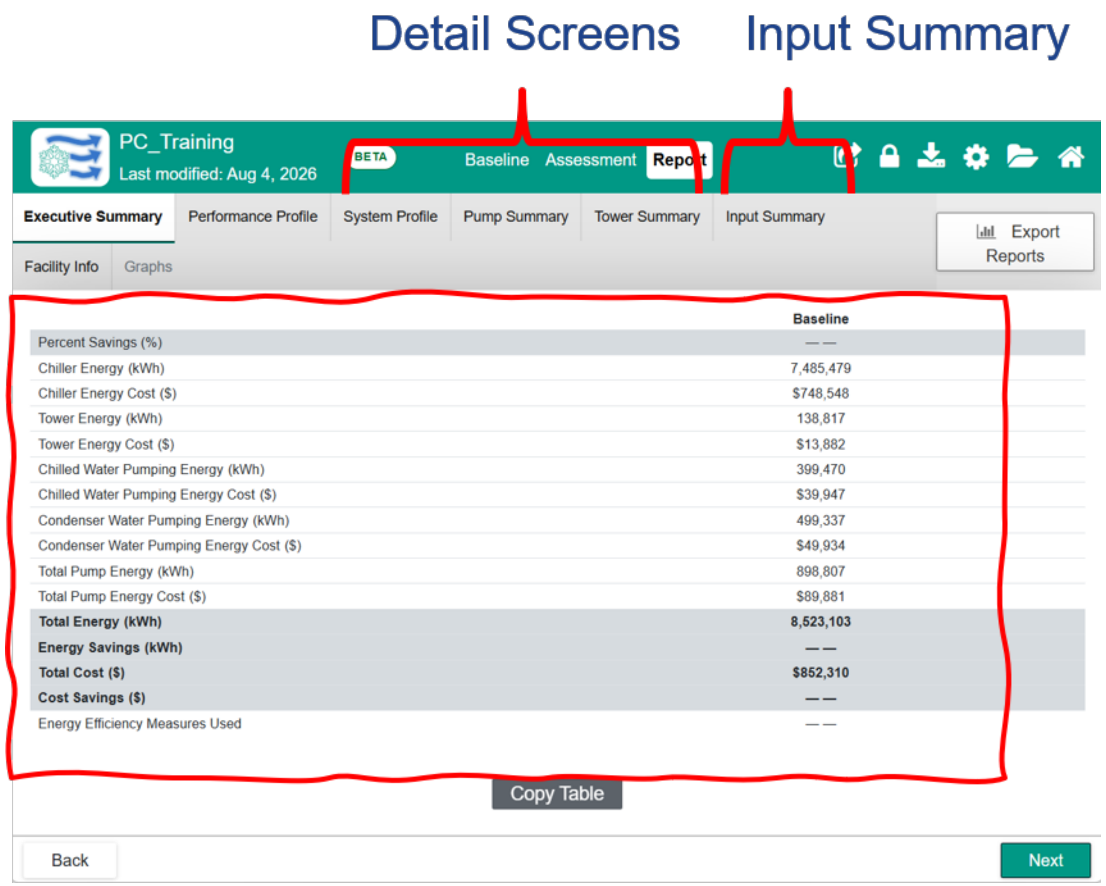
Student Exercise

- How do we calculate cooling load of 100 gpm chilled water?
- Q_{load} = m*Cp*ΔT
- $Q_{load} = 100\ \frac{gal}{min}$ *500 $\frac{lb/hr}{gpm}$ *1.0 $\frac{Btu}{lb-F}$ $*$ΔT
- ΔT = Chilled water return – Chilled water supply = 55 – 44 = 11.0°F
- $Q_{load} = 100\ \frac{gal}{min}$ *500 $\frac{lb/hr}{gpm}$ *1.0 $\frac{Btu}{lb-F}$ $*\ 11.0$°F
- $Q_{load} =$ 550,000 Btu/hr = 46 RT

Student Exercise

- What are the modeling strategies to be used in MEASUR to model this cooling demand savings opportunity?
  - 46 RT
- Simple approach (1^{st} method) – Proportionate energy and cost reduction
  - Not accurate but gets in the ballpark for detailed analysis further
  - Not representative of actual field operations but a great starting point
- Recall “base model” information and define “average cooling load”

Chilled Water System Baseline Model



	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	7,485,479
Chiller Energy Cost ($)	$748,548
Tower Energy (kWh)	138,817
Tower Energy Cost ($)	$13,882
Chilled Water Pumping Energy (kWh)	399,470
Chilled Water Pumping Energy Cost ($)	$39,947
Condenser Water Pumping Energy (kWh)	499,337
Condenser Water Pumping Energy Cost ($)	$49,934
Total Pump Energy (kWh)	898,807
Total Pump Energy Cost ($)	$89,881
Total Energy (kWh)	**8,523,103**
Energy Savings (kWh)	——
Total Cost ($)	**$852,310**
Cost Savings ($)	——
Energy Efficiency Measures Used	——

- Overall operating energy cost of the chilled water system = $852,310
- Can we determine specific cooling operating cost - $/RT
- A difficult exercise but can be obtained with significant data analysis

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

Method 1 – Simple Approach

- Determine Annual Average Operating Cooling Load (RT)
- Each chiller's annual average operating cooling load (RT) can be calculated mathematically by a weighted sum operating load and operating hours
- The annual energy consumption and energy operating cost can be divided by this average operating load to define specific (unit) cooling cost ($/RT)

Chiller Load, Ton-hours & Average Load Calculations

Chiller #1	1000	RT	
% Load	Actual Load (RT)	Hours	Ton-Hours
-	-	444	-
10	100	-	-
20	200	-	-
30	300	-	-
40	400	873	349,200
50	500	1,754	877,000
60	600	1,753	1,051,800
70	700	1,746	1,222,200
80	800	1,317	1,053,600
90	900	873	785,700
100	1,000	-	-
	Total	8,760	5,339,500
Average	610	RT	

Chiller #3	350	RT	
% Load	Actual Load (RT)	Hours	Ton-Hours
-	-	2,634	-
10	35	-	-
20	70	-	-
30	105	2,627	275,835
40	140	-	-
50	175	2,626	459,550
60	210	-	-
70	245	-	-
80	280	-	-
90	315	-	-
100	350	873	305,550
	Total	8,760	1,040,935
Average	119	RT	

Method 1 (Simple Approach)

- Average Load
  - $Q_{average}$ = (610) + (610) + (119) = 1,339 RT

	Baseline
Percent Savings (%)	— —
Chiller Energy (kWh)	7,485,479
Chiller Energy Cost ($)	$748,548
Tower Energy (kWh)	138,817
Tower Energy Cost ($)	$13,882
Chilled Water Pumping Energy (kWh)	399,470
Chilled Water Pumping Energy Cost ($)	$39,947
Condenser Water Pumping Energy (kWh)	499,337
Condenser Water Pumping Energy Cost ($)	$49,934
Total Pump Energy (kWh)	898,807
Total Pump Energy Cost ($)	$89,881
Total Energy (kWh)	**8,523,103**
Energy Savings (kWh)	**— —**
Total Cost ($)	**$852,310**
Cost Savings ($)	**— —**
Energy Efficiency Measures Used	— —

- Unit cost of cooling
  - $\text{Energy}_{average} = \frac{8{,}523{,}103}{1{,}339} = \sim 6{,}365\ \frac{kWh}{RT-yr}$
  - $\text{Cost}_{average} = \frac{852{,}310}{1{,}339} = \sim 636\ \frac{\$}{RT-yr}$
- Cost savings for 46 RT cooling load
  - Savings = $636 * 46$ = $ 29,250 annually

Method 2 – Impact Level Analysis

- This would be very representative of actual field operations
- Understand the control methodology of the chiller plant and how the chiller plant responds to a marginal change in the load
- Once the impact chiller(s) is/are identified and the representative chiller load reduction on each individual chiller is identified, then develop a NEW load profile of the impact chillers
- Run the MEASUR model with this NEW load profile and compare the energy (cost) usage to determine the energy savings
- This would be the most accurate analysis

Are the Savings Achievable?

- Be very careful and conduct a high-level of due diligence before implementing this opportunity
- Process MUST be understood
- Do not rob Peter to pay Paul!
- Was this chilled water NOT required for this end-use?
- If the process doesn’t need to be cooled at all – then these savings are achievable
- If process needs cooling tower water cooling - then an incremental fan power will be required and may offset some savings

Replacing Chiller(s)

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Replacing Chiller(s)

- A very common question for almost every chiller plant energy assessment

- Several categories
  - Replace like for like with higher energy efficiency chillers – especially, when one or more chillers are at their end-of-life with repeated failures, high maintenance costs, etc.
  - Replace with optimized rating higher energy efficiency chillers
  - Retrofit certain chillers to improve their energy efficiency – adding VFD
  - Change heat rejection methodology – air-cooled to water-cooled or vice versa

- MEASUR can be used to model all the categories of opportunities

Replacing (Adding) with Higher Energy Efficiency Chillers

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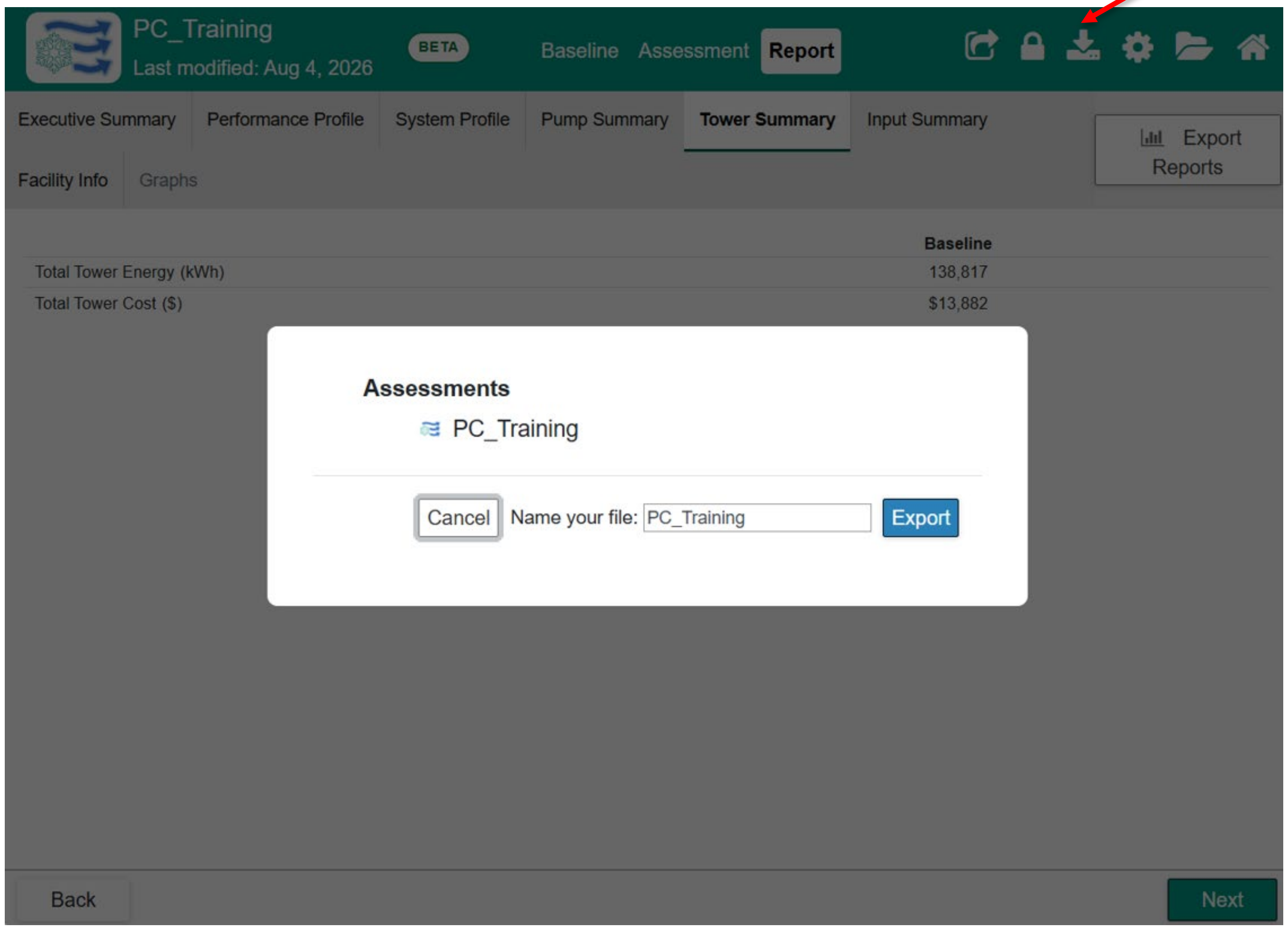
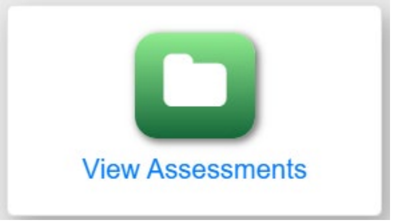
Replacing Chillers

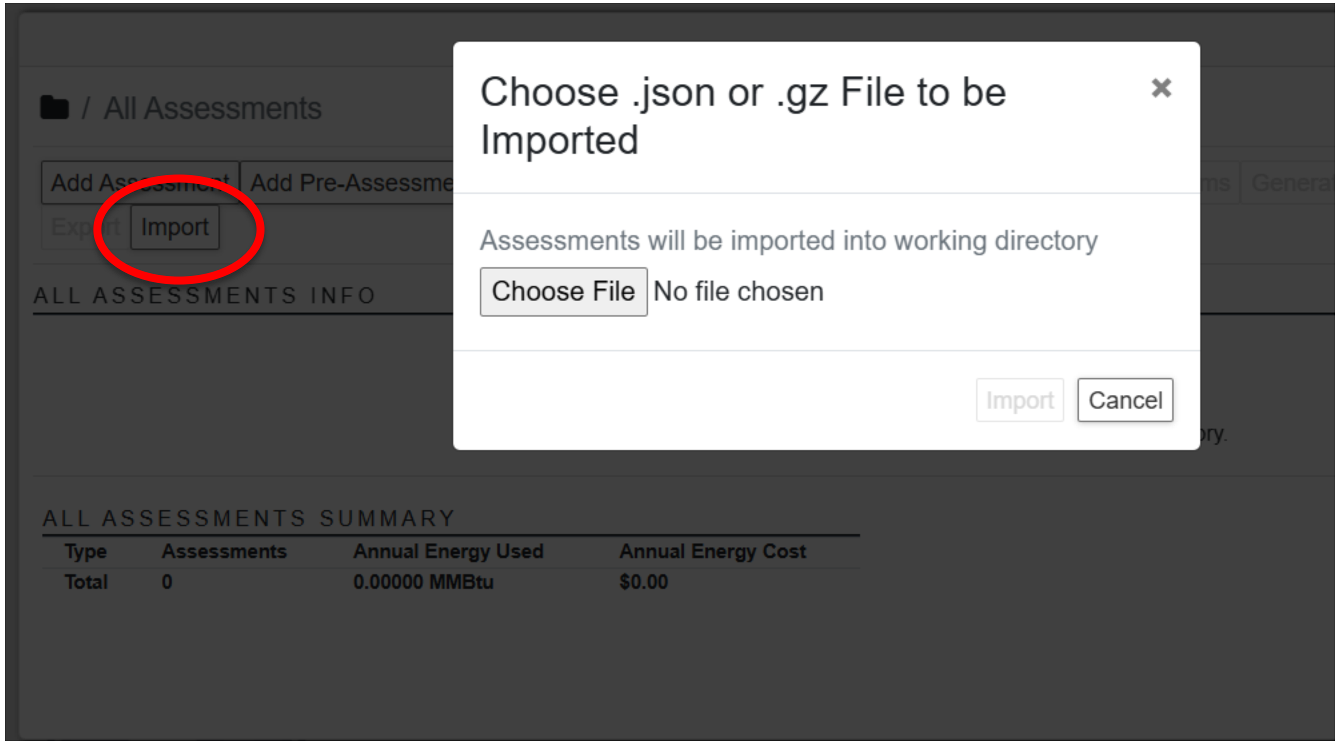
- Comparison between two separate simulations and compare – Baseline to Baseline
- Export the Baseline and Import as new Chilled Water System
- Change the Chiller(s) in Chiller Inventory
- Future version may have straight approach for chiller upgrades



Chilled Water System – MEASUR

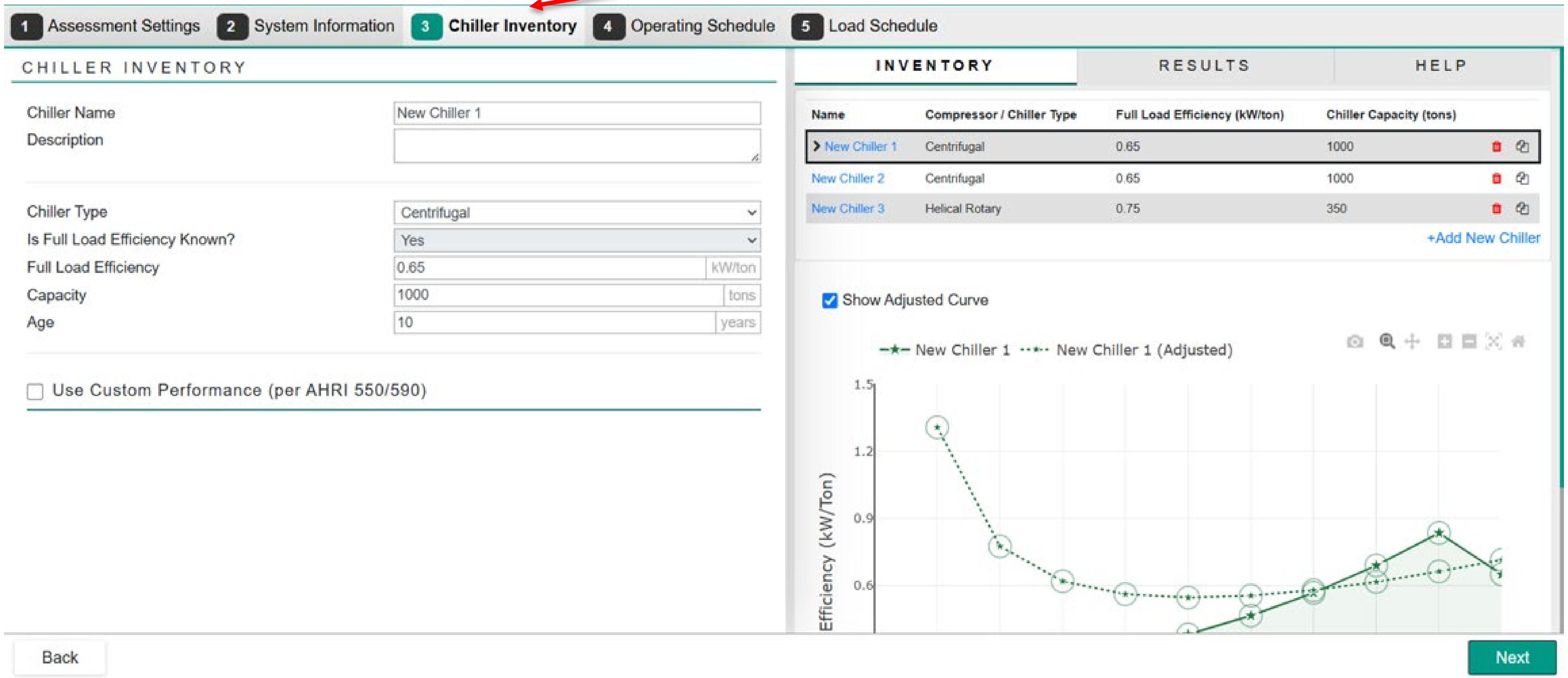
- Import Exported Baseline and Rename





Replacing Chillers

- Change the Chiller(s) performance



Better Plants
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Application of Variable Frequency Drives

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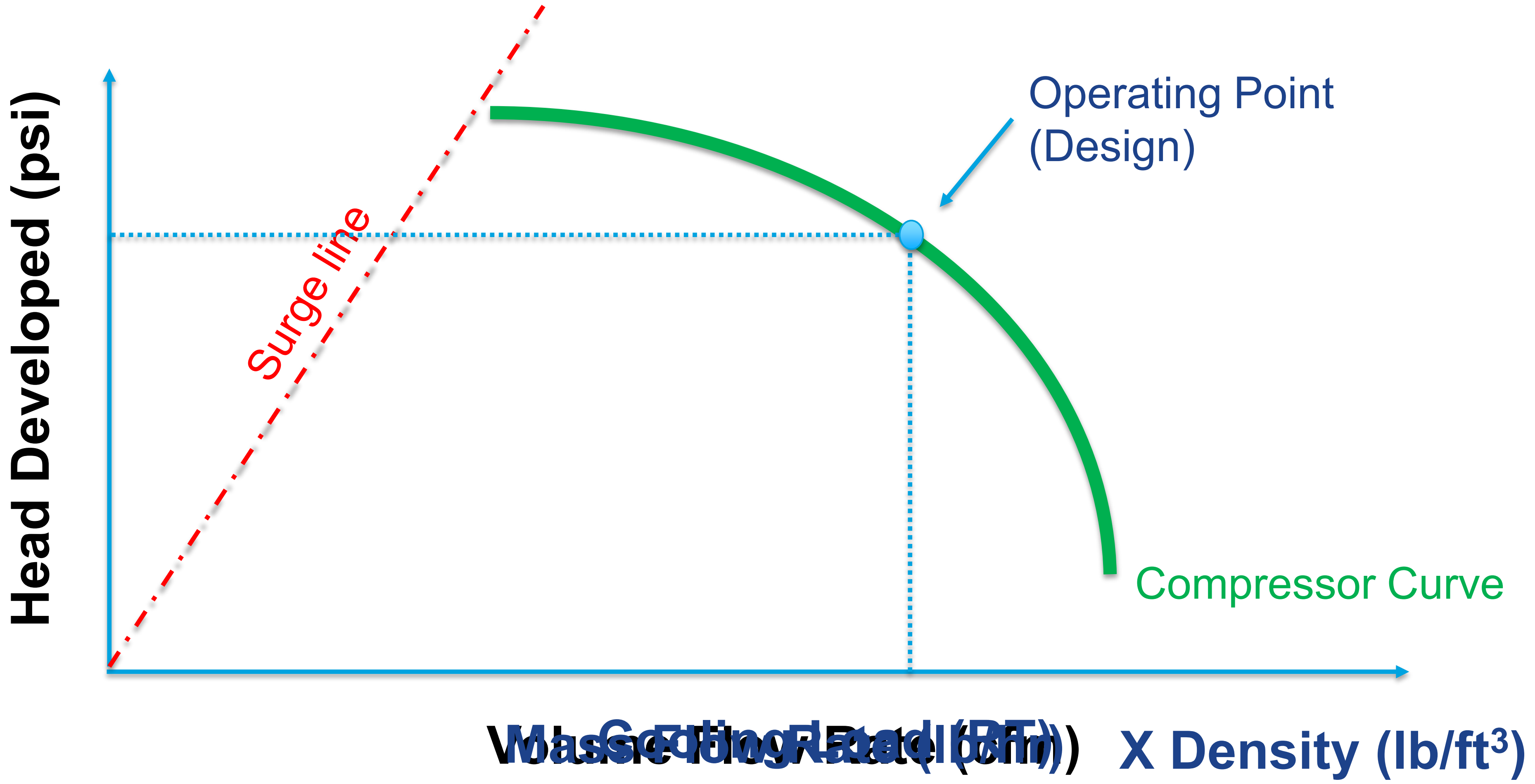
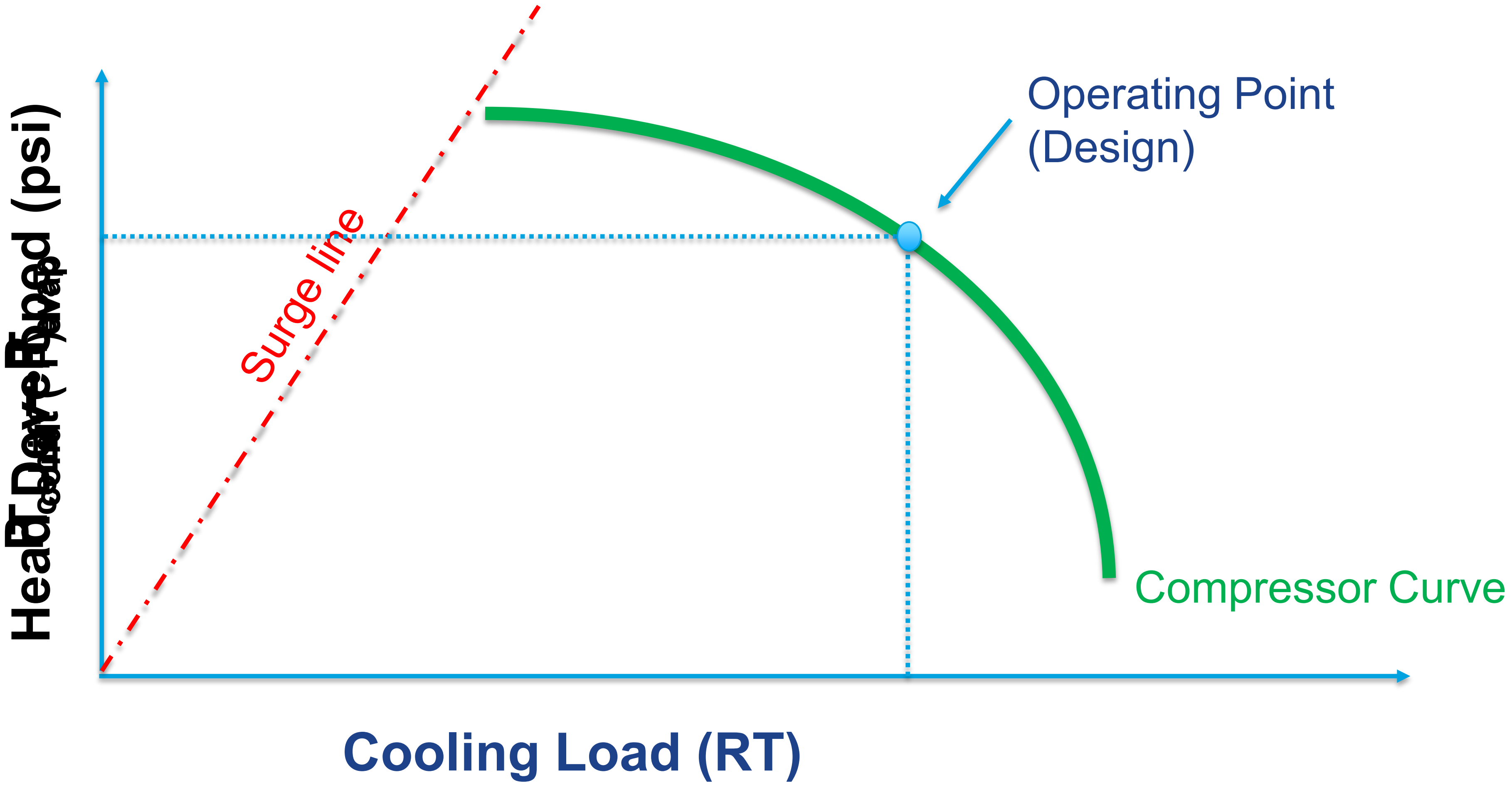
Implement Variable Frequency Driven Chillers

- This maybe a capital-intensive Energy Efficiency Opportunity but deserves a lot of merit
- Overall chiller plant efficiency can be improved by replacing old chillers with newer energy efficient systems – most new packaged chillers will come with a VFD option
- VFD chillers take advantage of lower ambient temperatures (lower lift) and correspondingly lower cooling loads (lower refrigerant flow rates) at those conditions
- The centrifugal compressor follows the cube law
  - Flow $\propto$ Speed
  - Power $\propto$ Speed^3

Understanding VFD Application on a Centrifugal Chiller

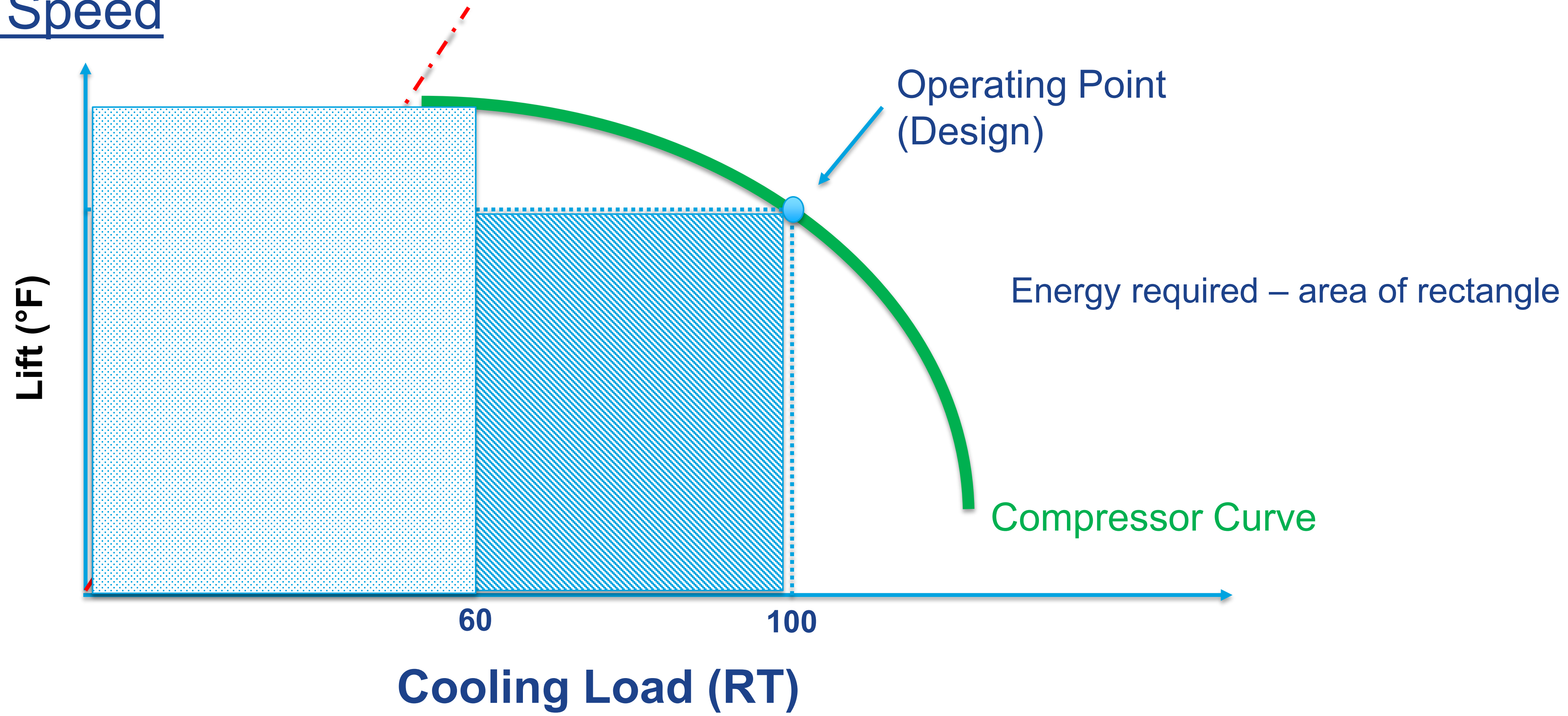


Understanding VFD Application on a Centrifugal Chiller



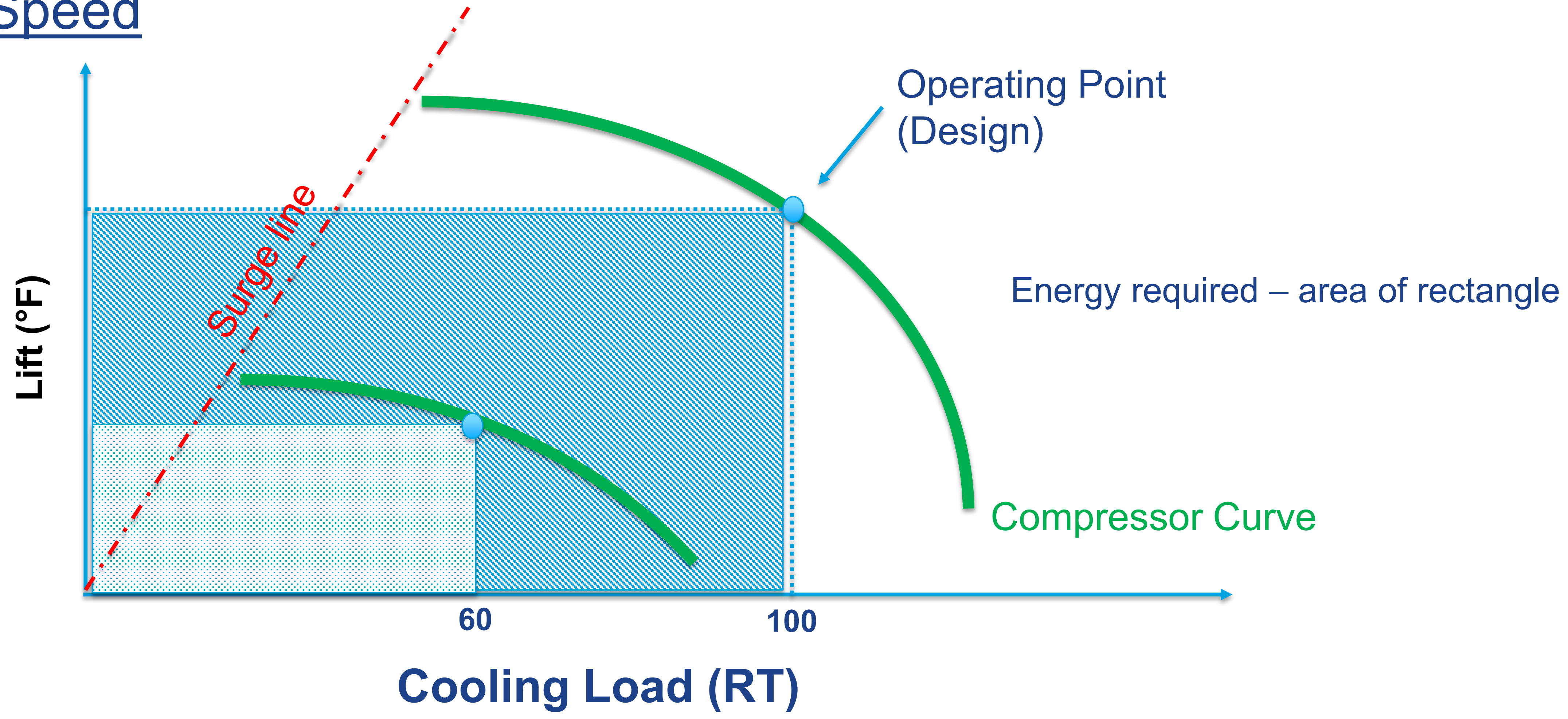
Understanding VFD Application on a Centrifugal Chiller

Constant Speed



Understanding VFD Application on a Centrifugal Chiller

Variable Speed



Understanding VFD Application on a Centrifugal Chiller

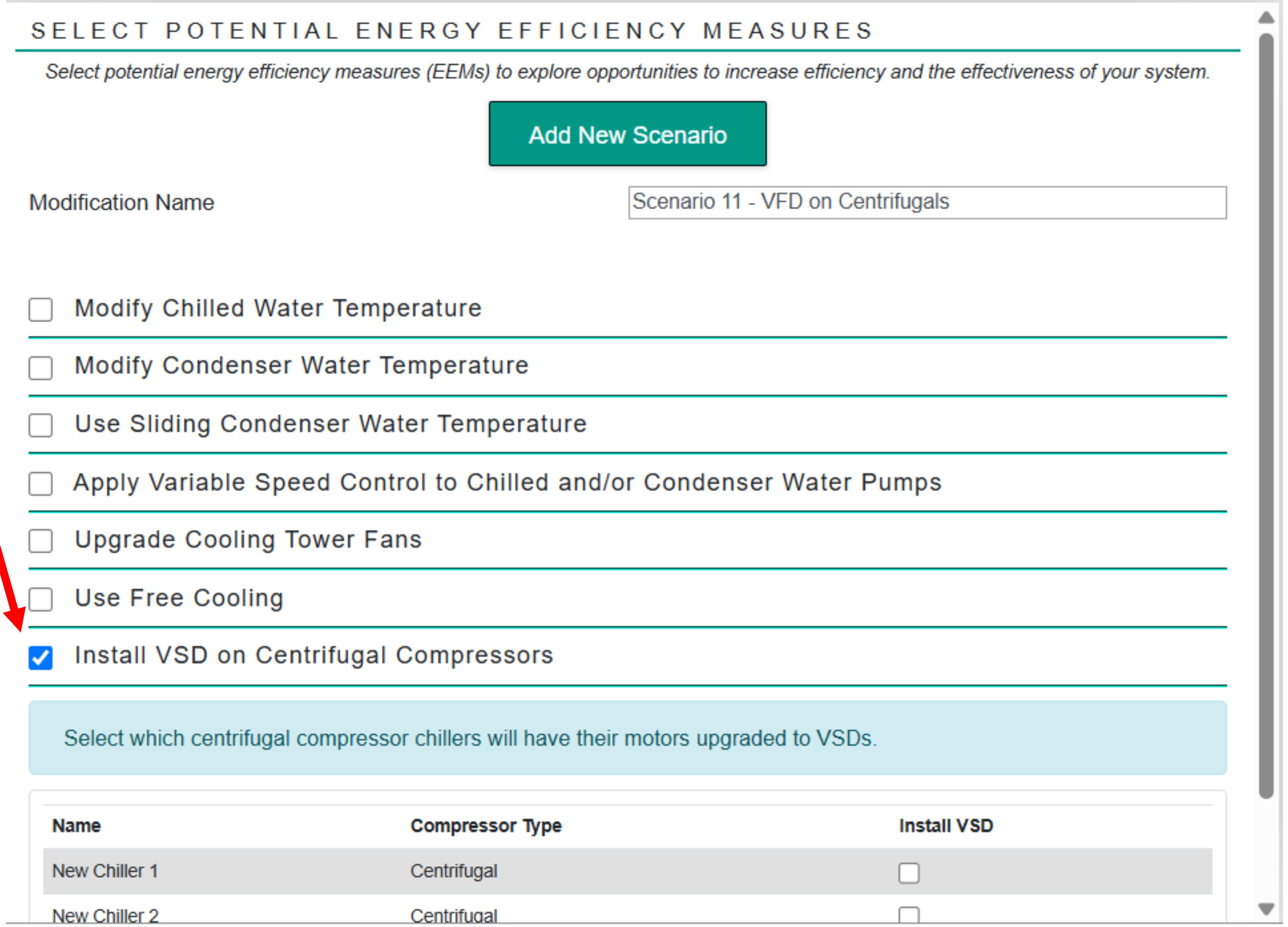
- New chiller packages now have the option of Variable Frequency Drives (VFD) for compressors
- VFD efficiency is extremely high (99%) and more importantly, it offers a benefit on the drive side by providing
  - Soft start capability
  - Power factor correction
- Reducing compressor speed reduces flow (tonnage) **proportionately** and reduces power by the **third power** – Centrifugal Law with the caveat of lift has to be considered appropriately.

Modeling Impact of VFD Chillers in MEASUR

- There are several ways to model implementation of VFD retrofit to chillers, new VFD chillers, etc.
- Method 1 – Use the MEASUR algorithm to simulate the new performance curve for the VFD chiller
- Method 2 – Use the part-load VFD chiller curve from the manufacturer and define a NEW chiller in MEASUR
- Method 3 – Use a bin analysis methodology including lift variation

Student Exercise (Retrofitting with VFDs)

- Method 1
  - Quick – Use the menu driven option provided in MEASUR
- Method 2
  - More Accurate - Define a new User Chiller with the performance characteristics of the retrofitted VFD chiller
- This opportunity requires significant system due diligence to reap the full benefits of VFDs



Student Exercise (Retrofitting with VFDs)

Savings on both Chillers & Cooling Tower

RESULTS | HELP

	Baseline	Scenario 11 - VFD on Centrifugals
Percent Savings (%)	——	17.4%
Chiller Energy (kWh)	7,485,479	6,013,348
Chiller Energy Cost ($)	$748,548	$601,335
Tower Energy (kWh)	125,435	119,512
Tower Energy Cost ($)	$12,544	$11,951
Chilled Water Pumping Energy (kWh)	399,470	399,470
Chilled Water Pumping Energy Cost ($)	$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	$89,881
Total Energy (kWh)	**8,509,721**	**7,031,667**
Energy Savings (kWh)	**——**	**1,478,054**
Total Cost ($)	**$850,972**	**$703,167**
Cost Savings ($)	**——**	**$147,805**
Energy Efficiency Measures Used	——	Install VSD on Centrifugal Compressors

Student Exercise (Retrofitting with VFDs)

PC_Training_EEM
Last modified: Aug 16, 2026
BETA

Baseline Assessment **Report**

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

Scenario 11 - VFD on Centrifugals

Load %	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
New Chiller 1												
Performance (kW/Ton)	-	0	0	0	0.33	0.337	0.411	0.498	0.576	0.642	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	131.9	168.5	246.5	348.8	461.2	578.1	0	
Energy (kWh)	0	0	0	0	115,131	295,533	432,141	608,992	607,351	504,687	0	2,563,835

VFD Issues – Work with Chiller Manufacturer/Expert

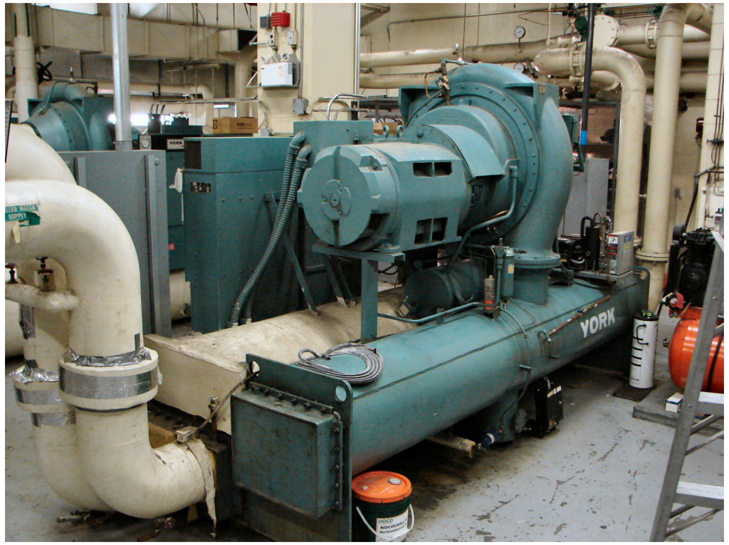
- Harmonics
  - Overheating of transformers, cables, motors, generators and capacitors connected to the same power supply
  - Electronic displays and lighting may flicker, circuit breakers can trip, computers may fail
  - Metering can give false readings
- Insulation damage for non-inverter rated motors
- Voltage spikes
  - Overshoot
  - Reflected voltage
  - Ringing
- Resonant frequency
- Bearing currents / damage

Reference: ***Chapter 45 – Motors, Motor Controls & Variable Frequency Drives*****; ASHRAE HVAC Systems & Equipment Handbook, 2020**

Air-Cooled versus Water-Cooled

Air-Cooled versus Water-Cooled Systems

Air-Cooled



Water-Cooled

Impact of Chiller Lift

- Crux of chiller plant system optimization
- Significant impact on efficiency, capacity and reliability of system
- Several optimization concepts primarily revolve around reducing chiller plant lift
- But there are operating limits
  - Manufacturer’s recommendations
  - System design
- Geography / Climate plays a strong role
  - Humid versus Dry ambient conditions

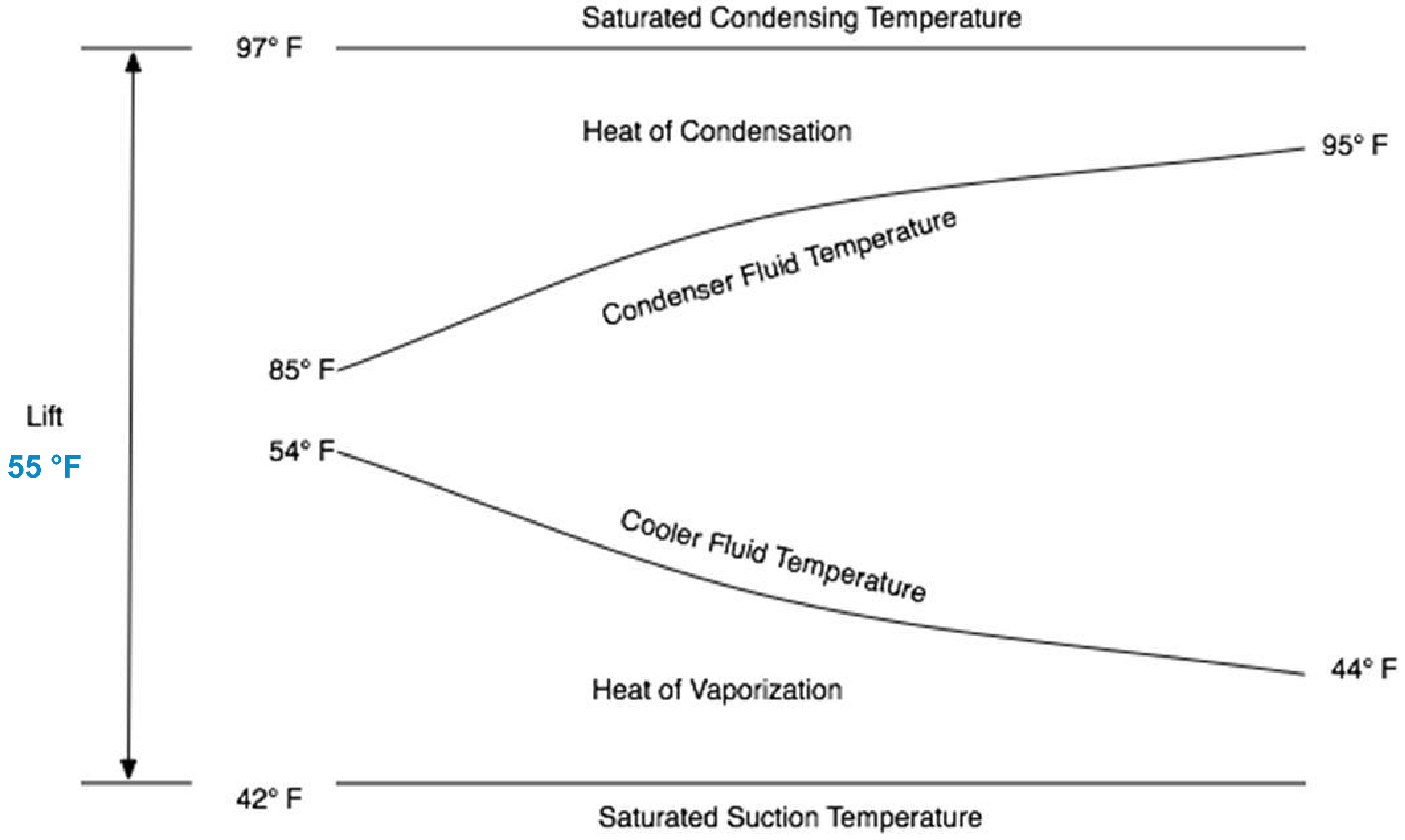
Lowering heat rejection temperature

Lowers head pressure

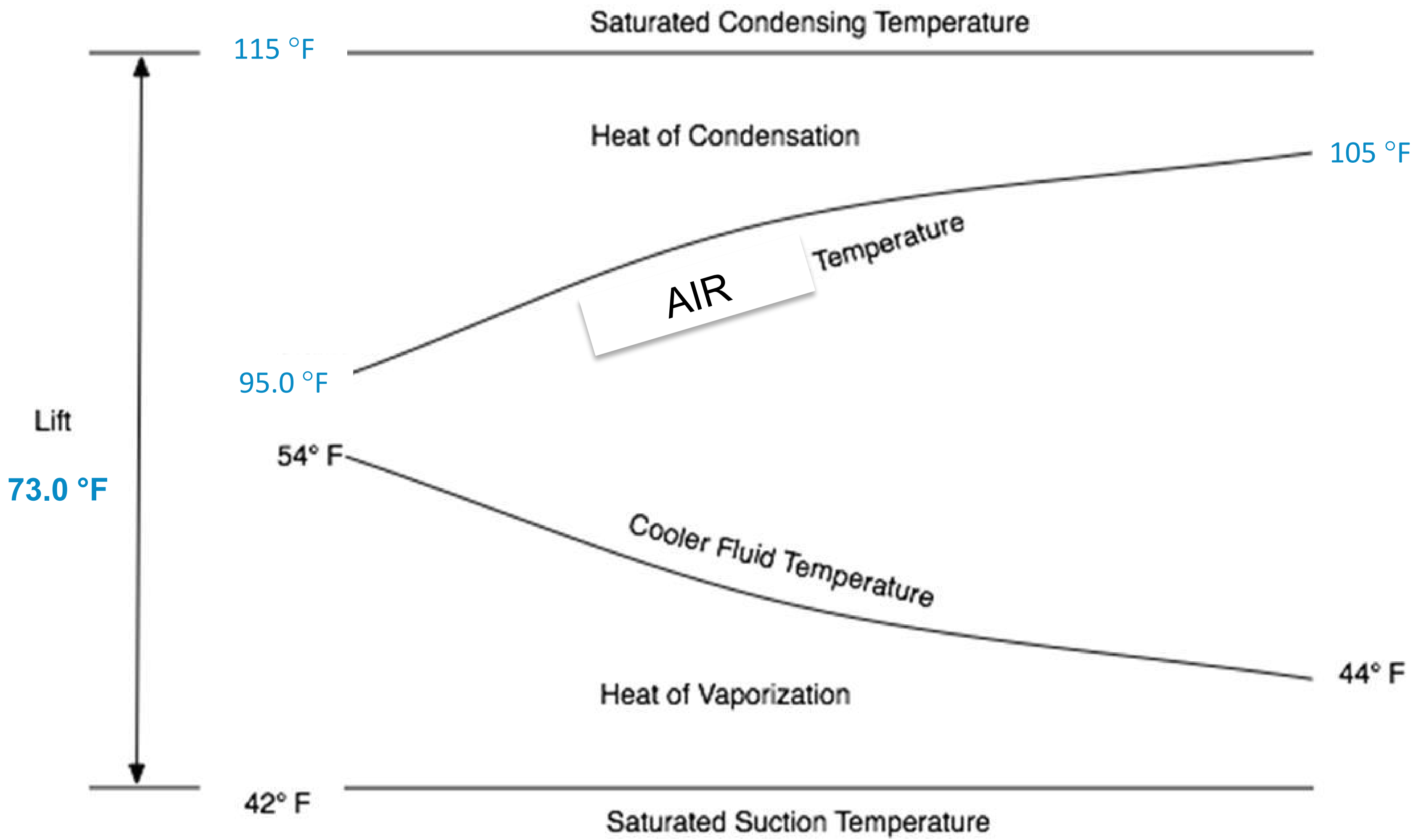
Reduces compressor work

Reduces energy consumption

Chiller Lift – Water-Cooled Chiller



Chiller Lift – Air-Cooled Chiller



Student Exercise

- The Screw chiller at the industrial plant has to be replaced and the plant engineer is evaluating two replacement options
  - Option 1: Air-Cooled chiller with identical capacity
  - Option 2: Identical Water-Cooled chiller
- Use a MEASUR model to determine which option would be beneficial if operating energy and costs have to be minimized
- Discuss concerns and issues with the chosen option and what steps can be taken to mitigate them

Student Exercise

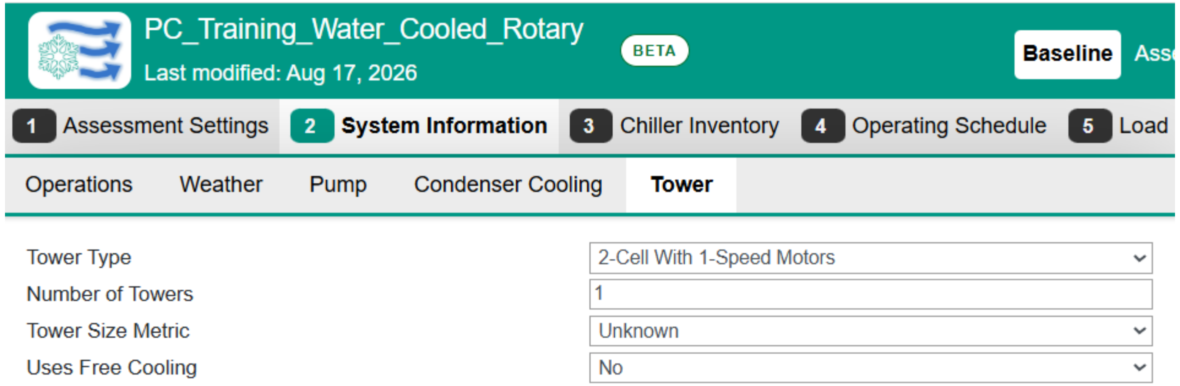
- This may sound like a simple problem but gets complicated for evaluation
  - Facility has 3 chillers and ONLY 1 chiller is being evaluated for replacement
  - MEASUR supports ONLY 1 cooling method for the whole plant

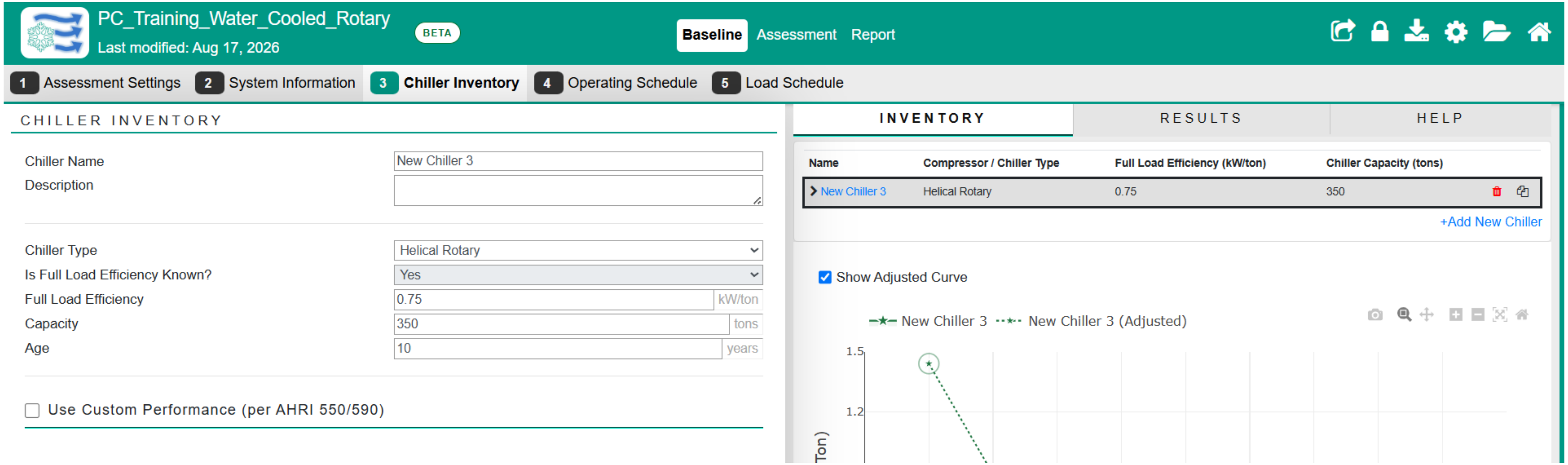
- What options exist for such an evaluation?
  - Model the whole system as air-cooled and then do a proportionality analysis
    - Not representative of the actual system per se
  - Make a new MEASUR model with ONLY the Screw chiller as the operating unit with the same schedule and then build another “air-cooled” model to compare
    - Significant more effort but more realistic and representative of actual field operations

Modeling ONLY Screw Chiller (Water-Cooled)

- One chiller system
- Screw Chiller
- Capacity – 350 RT
- Cooling tower sizing based on 350 RT
- FLE – 0.75 kW/RT

- Use the Base Model and modify inputs





Modeling ONLY Screw Chiller (Water-Cooled)

PC_Training_Water_Cooled_Rotary BETA
Last modified: Aug 17, 2026

Baseline | Assessment | Report

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

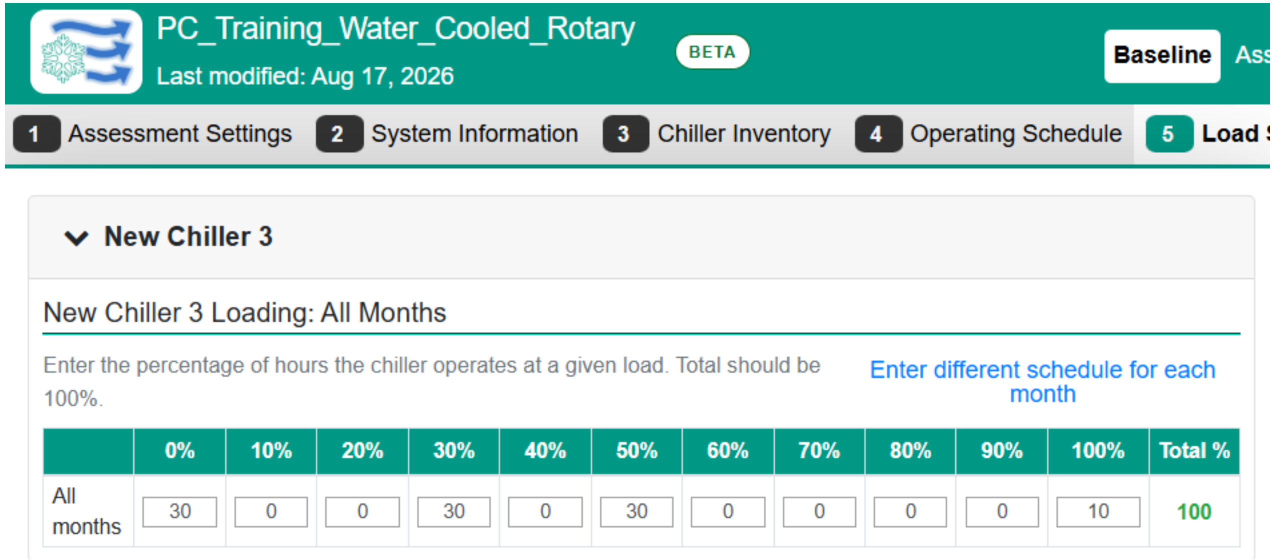
Enter number of typical operating days for each month. This information is used to calculate annual operating hours.

☑ **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

Modeling ONLY Screw Chiller (Water-Cooled)

- Input the screw chiller load profile



Modeling ONLY Screw Chiller (Water-Cooled)

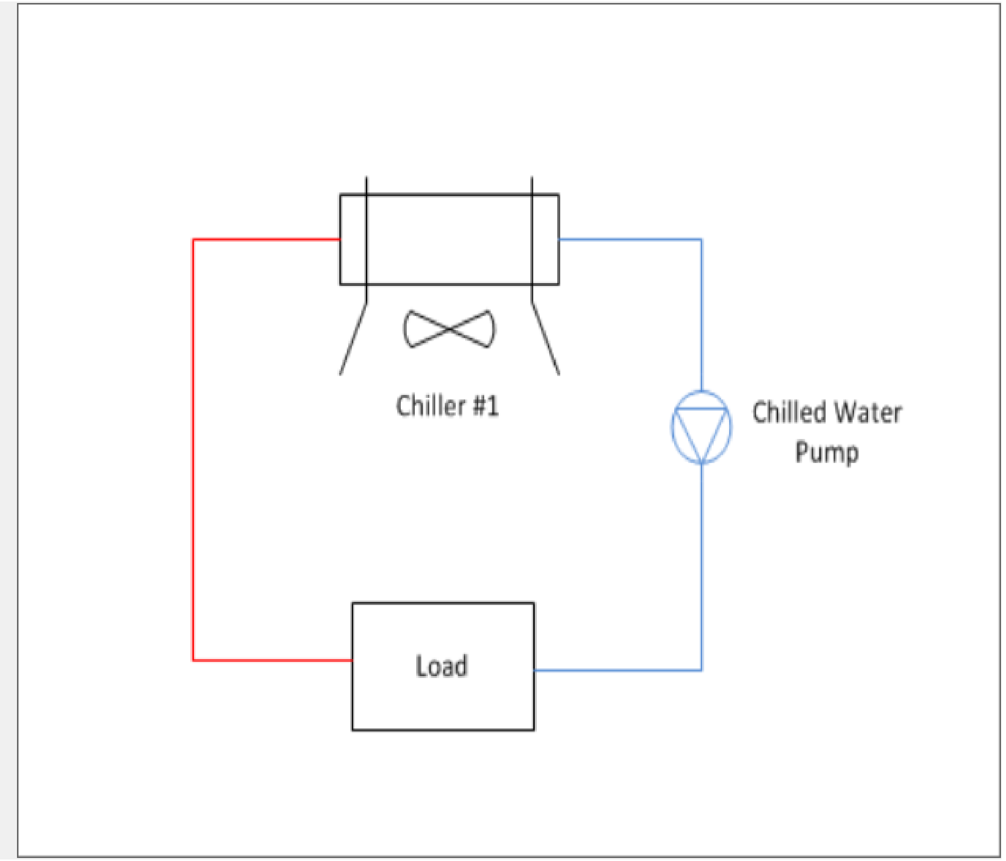
RESULTS | HELP

	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	885,790
Chiller Energy Cost ($)	$88,579
Tower Energy (kWh)	8,722
Tower Energy Cost ($)	$872
Chilled Water Pumping Energy (kWh)	53,765
Chilled Water Pumping Energy Cost ($)	$5,376
Condenser Water Pumping Energy (kWh)	80,647
Condenser Water Pumping Energy Cost ($)	$8,065
Total Pump Energy (kWh)	134,412
Total Pump Energy Cost ($)	$13,441
Total Energy (kWh)	**1,028,924**
Energy Savings (kWh)	**——**
Total Cost ($)	**$102,892**
Cost Savings ($)	**——**
Energy Efficiency Measures Used	——

Copy Table

- Check for all the information
- Once satisfied with the model, SAVE it as a new file

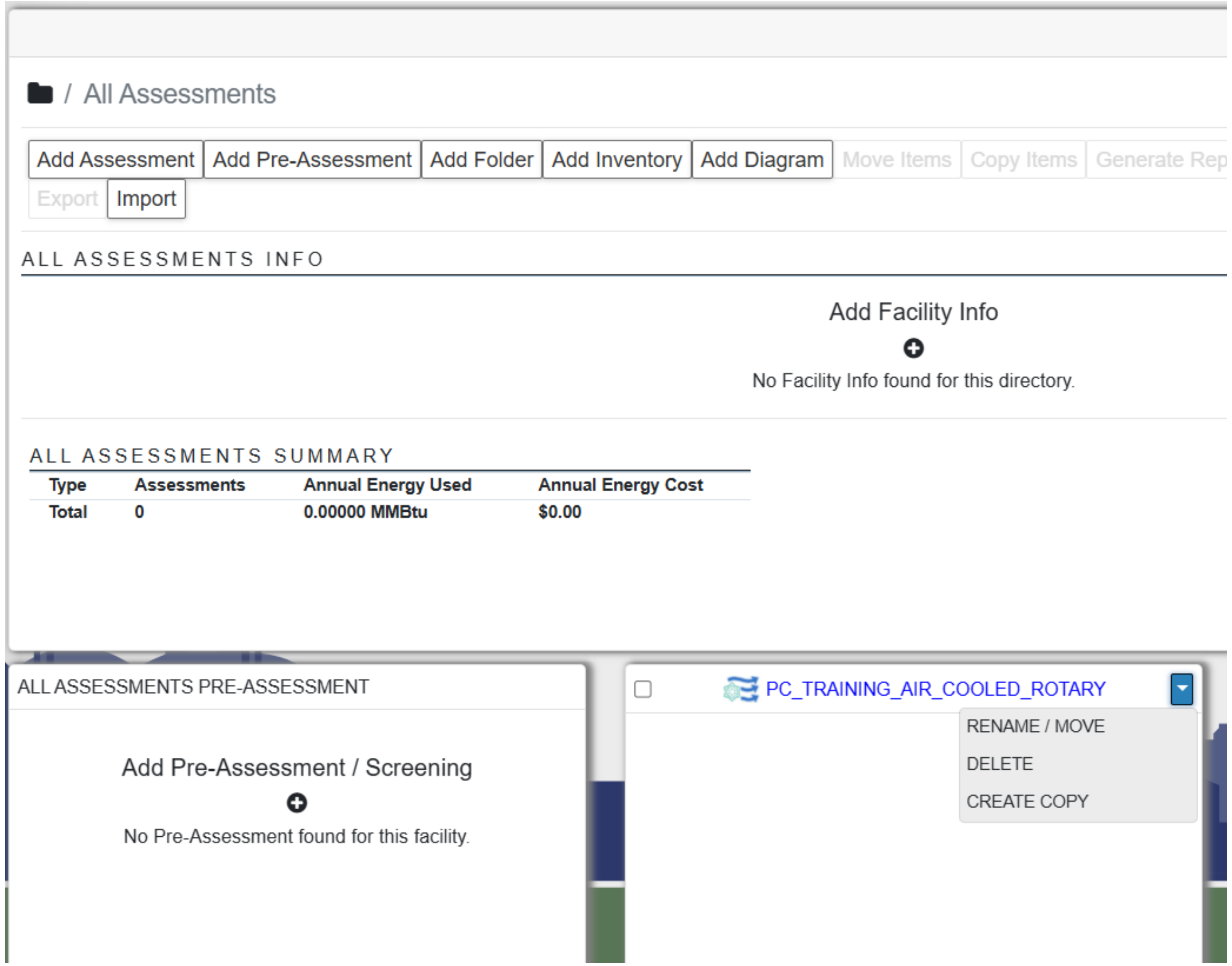
Modeling ONLY Screw Chiller (Air-Cooled)



Modeling ONLY Screw Chiller (Air-Cooled)

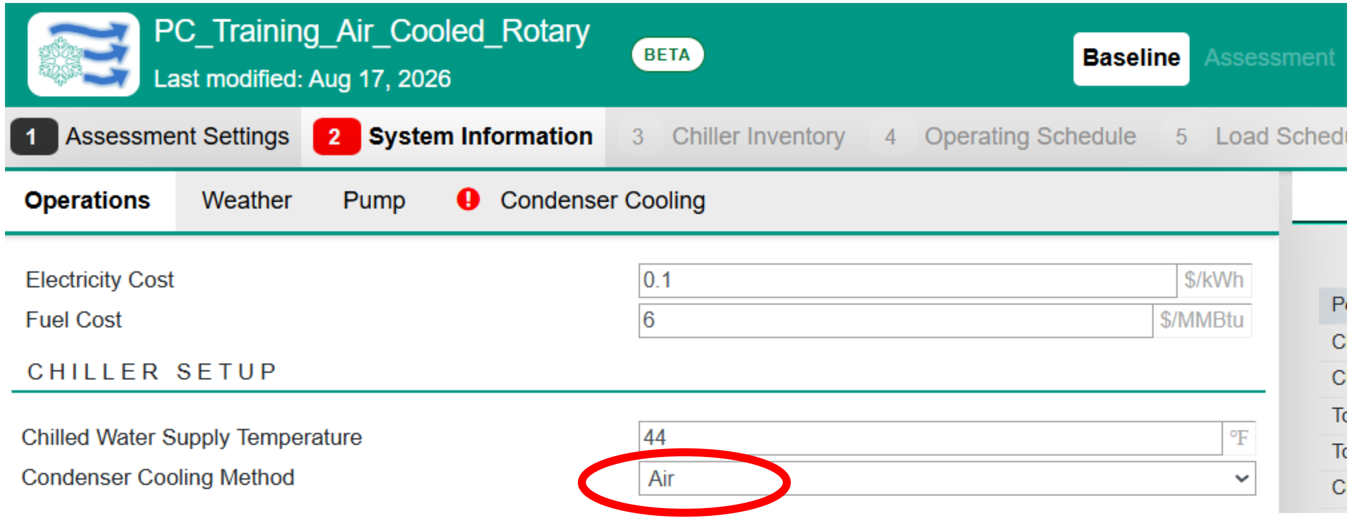
- Build a whole new MEASUR model with Air-Cooled as the method of heat rejection

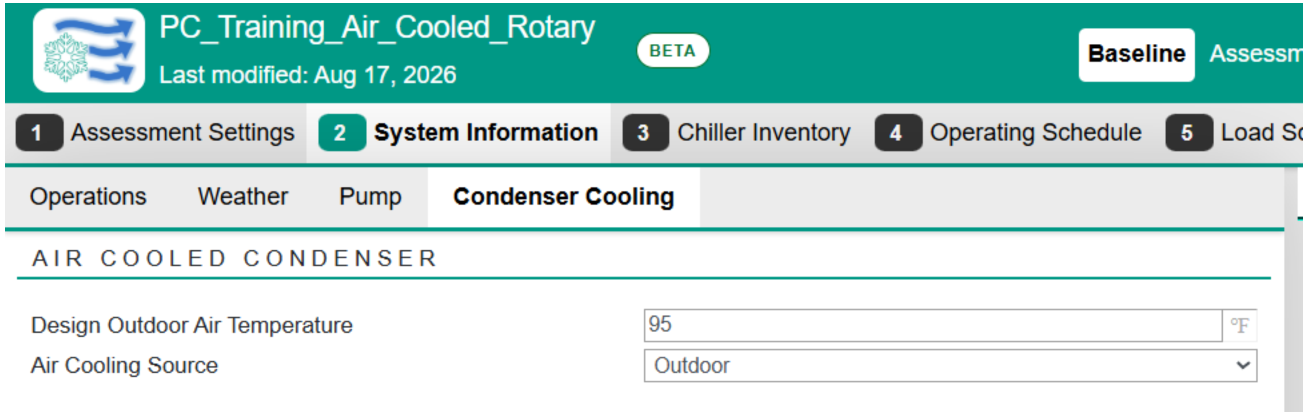
- Import and Rename the file, if needed



Modeling ONLY Screw Chiller (Air-Cooled)

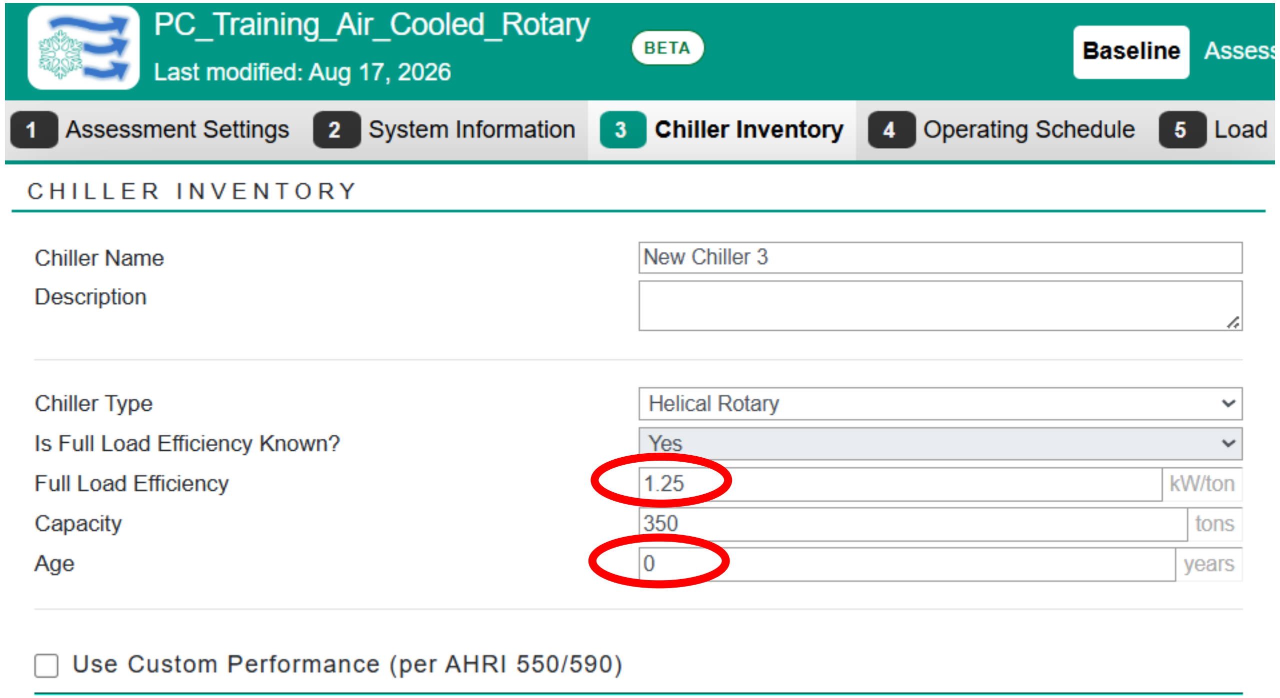
- Change Condenser Cooling Method as “Air”
- Change Condenser Cooling parameters
  - Design – 95 °F
  - Source – Outdoor
- NOTE: Fewer inputs
- Can model both indoor and outdoor installations





Modeling ONLY Screw Chiller (Air-Cooled)

- FLE – 1.25 kW/RT
- Chiller Age – 0
- Other parameters for Operating and Load schedule remains the same



Modeling ONLY Screw Chiller (Air-Cooled)

RESULTS | HELP

	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	1,014,160
Chiller Energy Cost ($)	$101,416
Tower Energy (kWh)	0
Tower Energy Cost ($)	——
Chilled Water Pumping Energy (kWh)	53,765
Chilled Water Pumping Energy Cost ($)	$5,376
Condenser Water Pumping Energy (kWh)	0
Condenser Water Pumping Energy Cost ($)	——
Total Pump Energy (kWh)	53,765
Total Pump Energy Cost ($)	——
Total Energy (kWh)	**1,067,925**
Energy Savings (kWh)	**——**
Total Cost ($)	**$106,792**
Cost Savings ($)	**——**
Energy Efficiency Measures Used	——

Copy Table

Comparing Water-Cooled vs Air-Cooled

- System Savings using Water-Cooled Screw Chiller
  = 39,001 kWh ($3,900 annually)

Air-Cooled

RESULTS	HELP
	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	1,014,160
Chiller Energy Cost ($)	$101,416
Tower Energy (kWh)	0
Tower Energy Cost ($)	——
Chilled Water Pumping Energy (kWh)	53,765
Chilled Water Pumping Energy Cost ($)	$5,376
Condenser Water Pumping Energy (kWh)	0
Condenser Water Pumping Energy Cost ($)	——
Total Pump Energy (kWh)	53,765
Total Pump Energy Cost ($)	——
Total Energy (kWh)	**1,067,925**
Energy Savings (kWh)	**——**
Total Cost ($)	**$106,792**
Cost Savings ($)	**——**
Energy Efficiency Measures Used	——

Copy Table

Water-Cooled

RESULTS	HELP
	Baseline
Percent Savings (%)	——
Chiller Energy (kWh)	885,790
Chiller Energy Cost ($)	$88,579
Tower Energy (kWh)	8,722
Tower Energy Cost ($)	$872
Chilled Water Pumping Energy (kWh)	53,765
Chilled Water Pumping Energy Cost ($)	$5,376
Condenser Water Pumping Energy (kWh)	80,647
Condenser Water Pumping Energy Cost ($)	$8,065
Total Pump Energy (kWh)	134,412
Total Pump Energy Cost ($)	$13,441
Total Energy (kWh)	**1,028,924**
Energy Savings (kWh)	**——**
Total Cost ($)	**$102,892**
Cost Savings ($)	**——**
Energy Efficiency Measures Used	——

Copy Table

Comparing Water-Cooled vs Air-Cooled

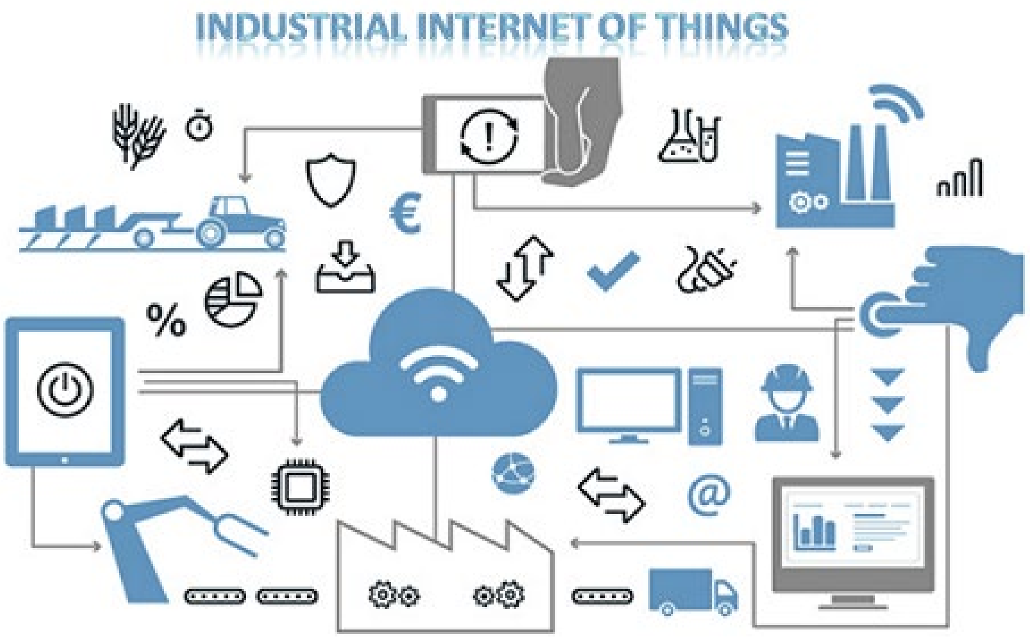
- What about water and chemical treatment costs?
- What about maintenance of extra pumps, fans, etc?
- What should be the Air-Cooled screw chiller performance curve and FLE value to offset the cost difference between the two screw chillers?
- NOTE: Strong dependence on Equipment size (Load); Operating hours and Load profile; Controls and Geographic location (Weather data)

Implementing an Intelligent Chilled Water System

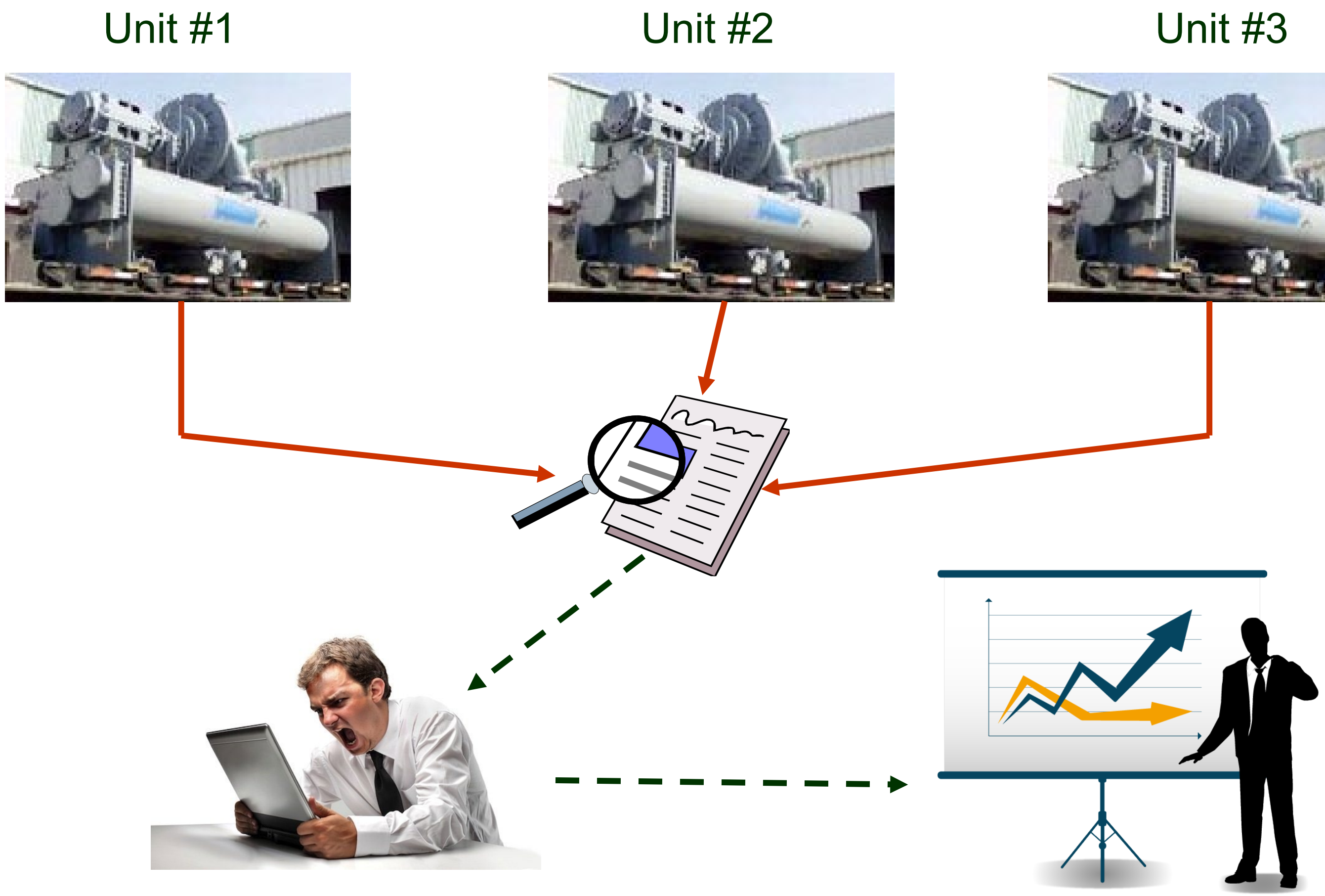
CANNOT BE MODELED in MEASUR

Intelligent Chilled Water Systems with FD&D

- Intelligent refers to the state-of-the-art Industrial Internet of Things (IIOT) managed intelligent systems
- Technology has advanced with Artificial Intelligence and Machine Learning
- Fault Detection & Diagnostics (FD&D) leads to Real-Time Optimization
- Continuous Commissioning



Where did we Start?



Basic Ingredients of Intelligent Systems

- Continuous monitoring of key data
- Trending of performance metrics
- Cloud-based system analytics
- Performance gap quantification with part load simulation (digital twin)
- Fault Detection & Diagnostics
- Seamless integration with plant's DCS
- Closed loop feedback control for optimizing systems
- Ability to benchmark operations and verify energy savings
- Multiple chiller optimization
- Cyber-security

Fault Detection & Diagnostics 101

- Critical data provide the ability to run diagnostics on system operations
- Main objective is to ensure that faults, inefficiencies and issues can be identified as soon as they occur
- Saves significant money, time and effort
- Increases system reliability
- Ensures optimum performance
- Cornerstone for Predictive & Preventative Maintenance

Application of Real-time Optimizer-based Controls

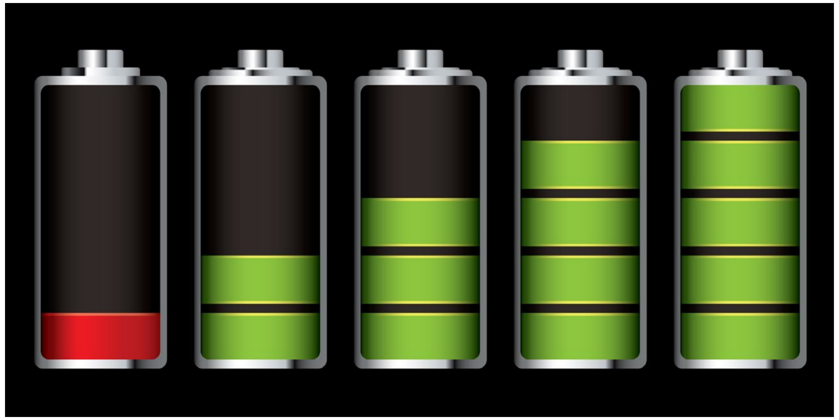
- Implementation of higher efficiency chiller systems
  - Using VFD chillers with real-time ECWT and ChWST setpoint controls
  - Using highly integrated and automated control strategies
- Full integration of pumping loops, cooling towers and end-users
- Trending and performance tracking using state-of-the-art technologies
- Continuous commissioning
- Implementing preventive and predictive maintenance BestPractices using Fault Detection and Diagnostics algorithms

Thermal Energy Storage

CANNOT BE MODELED in MEASUR

Chilled Water Systems with Thermal Energy Storage

- Thermal Energy Storage is NOT new and neither NEXT GENERATION
- Its application is what makes it unique
- Its impacts are system-wide – Peak Load Management Strategy
- Could have an influence on Energy Usage



What is Thermal Energy Storage (TES)?

- It is a battery which serves as a source or sink for energy
- Thermal storage
  - Cold – to be covered in this class
  - Hot – out of scope here
- Several different methods of thermal energy storage and can be used very effectively to
  - Minimize both operating and capital costs
  - Reduce electrical / thermal demand
  - Reduce overall energy consumption & increase system efficiency
  - Reduce greenhouse gas emissions (w/renewables mix)

Benefits of TES

- Energy cost savings
  - Reduce peak on-time electricity demand
  - Decouple time-of-use (load) and pricing
  - Higher system efficiency – constant set-point operations

- Reduced equipment size
  - Systems can be designed for average year-round load rather than peak loads which occur for less than 5% of the operating hours

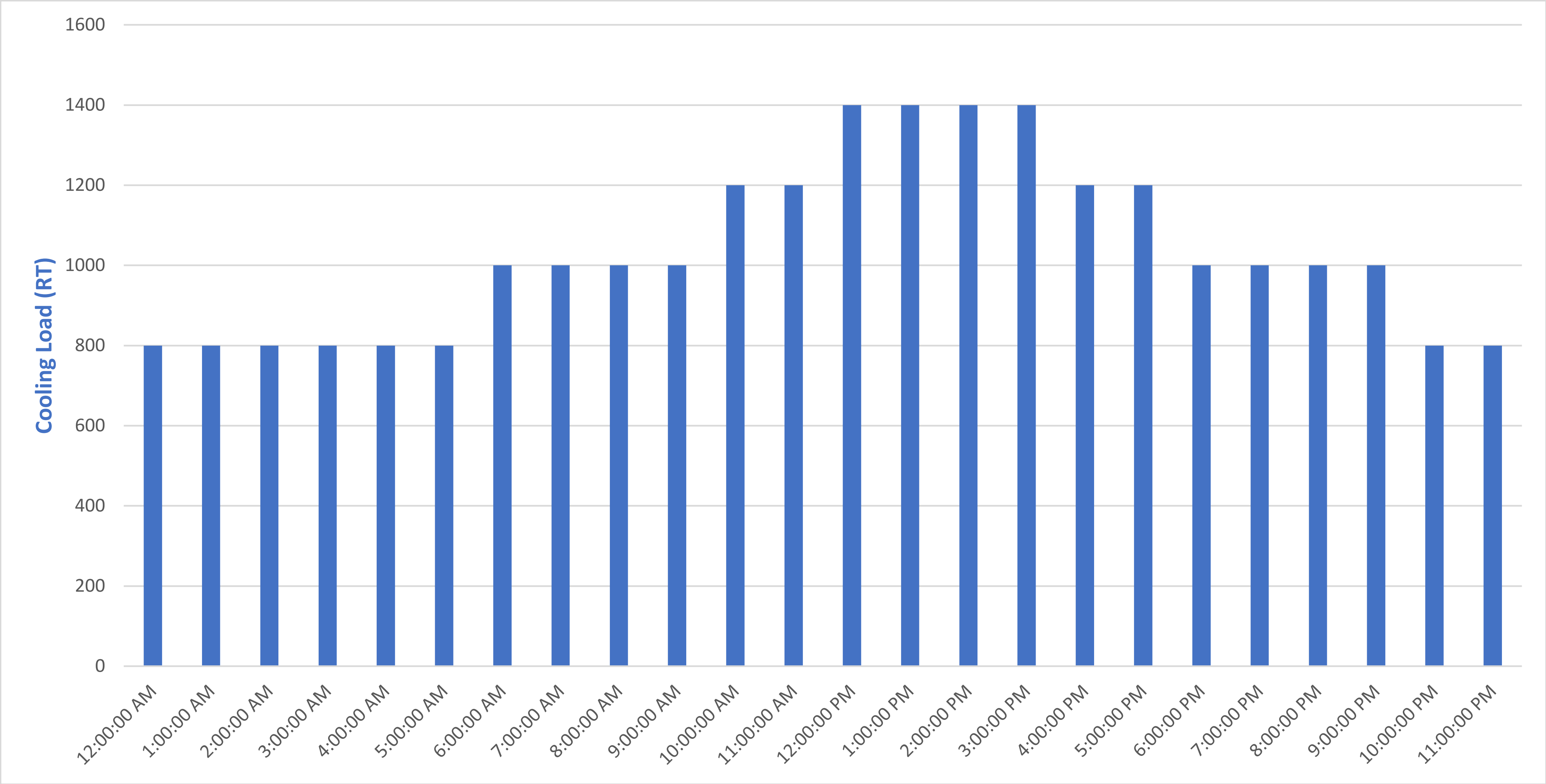
Benefits of TES

- Capital cost savings
  - Downsizing large chillers and cooling equipment at design-level
  - Smaller systems and equipment – pumps, fans, transformers, etc.
- System benefits
  - Optimization of system assets – eliminate part-load operations
  - Operate systems at favorable conditions allowing for higher system efficiency
- Increased reliability and redundancy
  - TES can provide additional capacity always and N+1 redundancy
  - Primary equipment operations are more stable enhancing reliability
  - Ability to do periodic and preventive maintenance to enhance reliability

Classification of TES

- Type of storage medium
  - Sensible heat
  - Latent heat
- Sensible thermal storage (types)
  - Horizontal tanks
  - Thermal stratification (vertical tanks)
    - Multiple compartments
    - Multiple tanks
    - Labyrinth tanks
  - Underground concrete structures
  - Aquifers
- Sensible thermal storage (materials used) – chilled water; aqueous (brines, glycols) and non-aqueous fluids; Low Temperature Fluids (LTFs)

Daily Load Profile (an example)

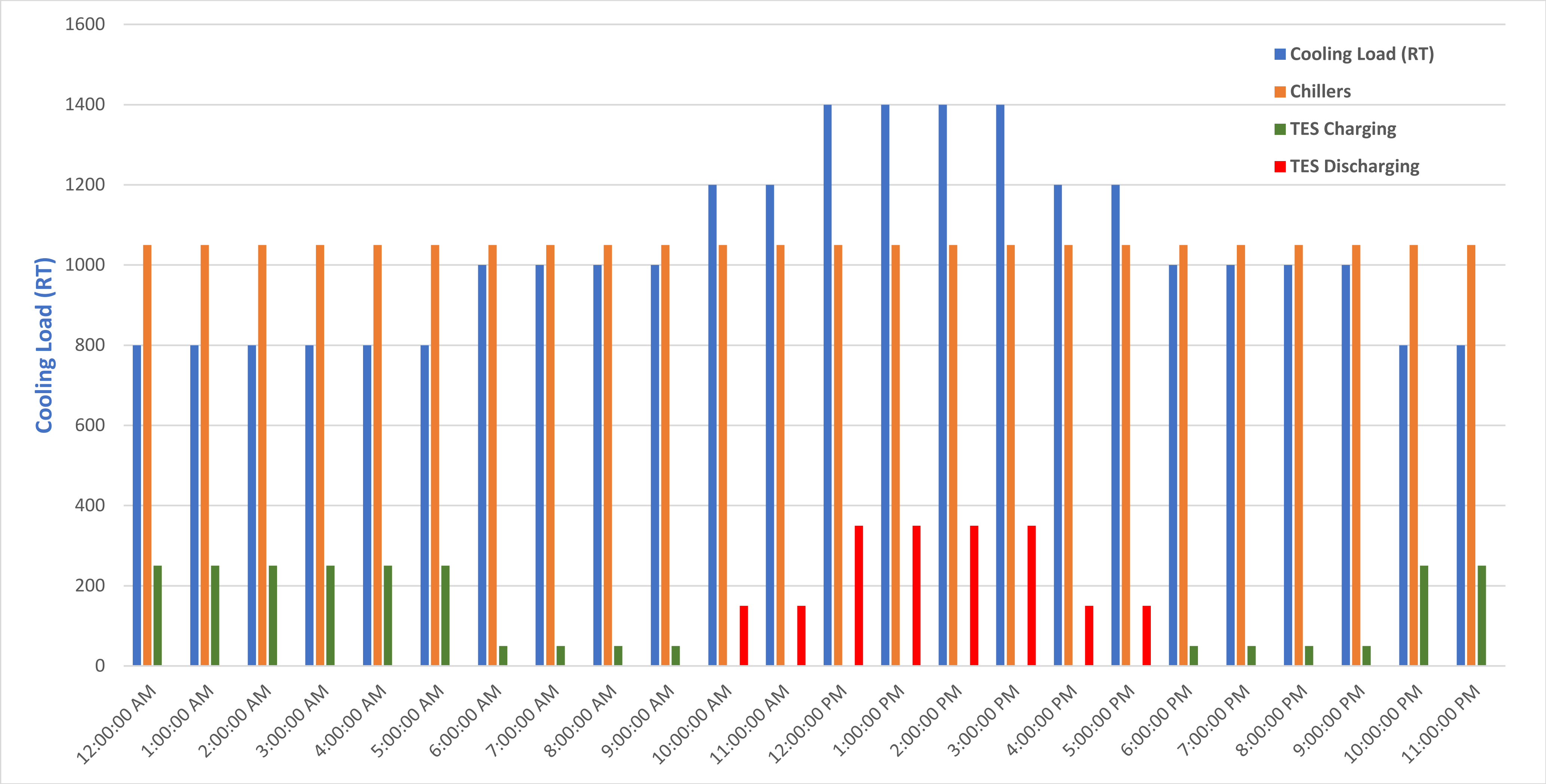


Daily Operations (an example)

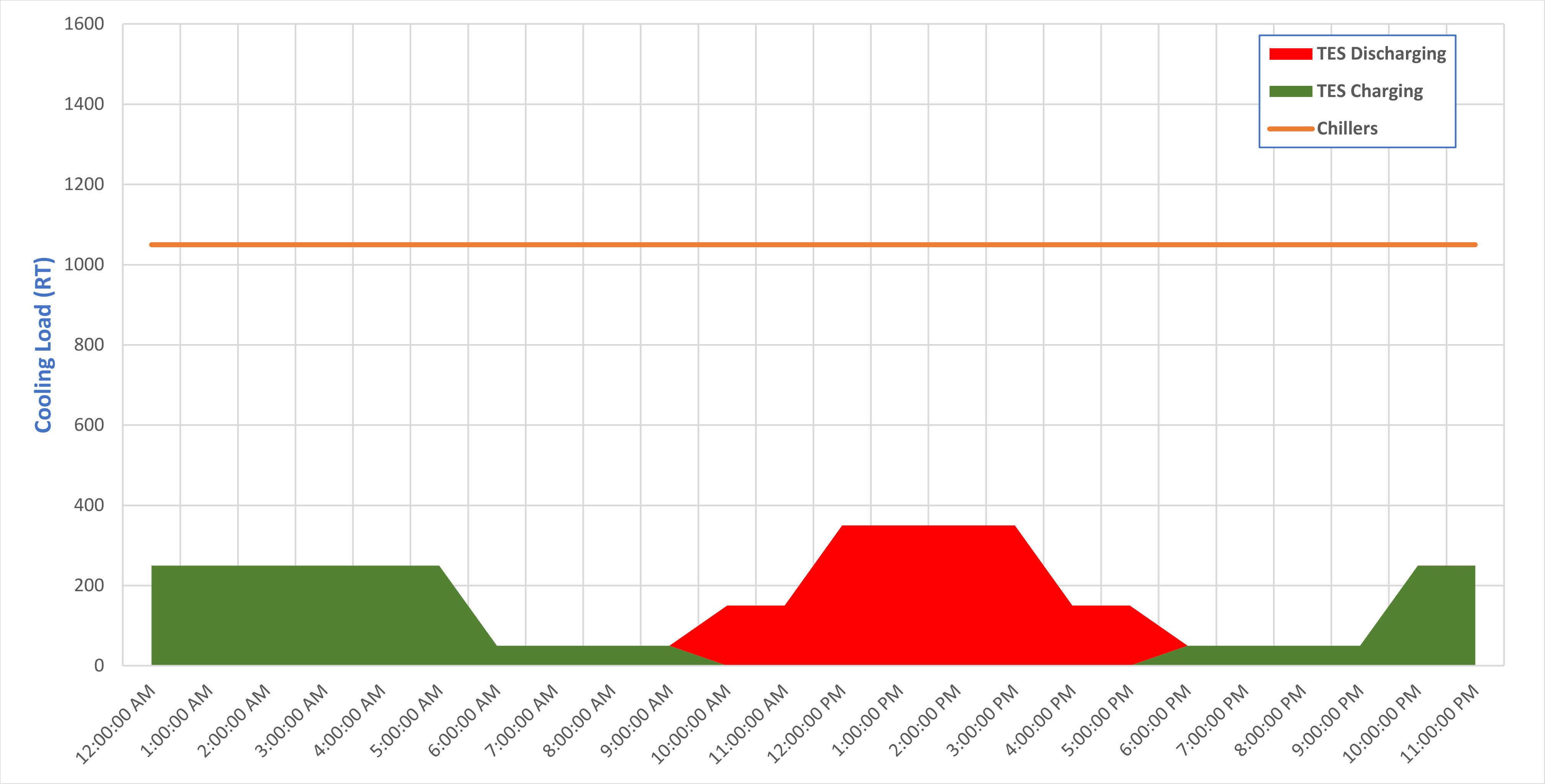
- Option 1
  - Chiller Plant Size – 1,400 RT
  - Daily cooling load – 24,800 Ton-hours

- Option 2
  - Daily cooling load – 24,800 Ton-hours + Circulating losses
  - Chiller Plant Size – 1,050 RT
  - TES size – 2,400 Ton-hours

Daily Load Profile w/TES (an example)



Daily Load Profile w/TES (an example)



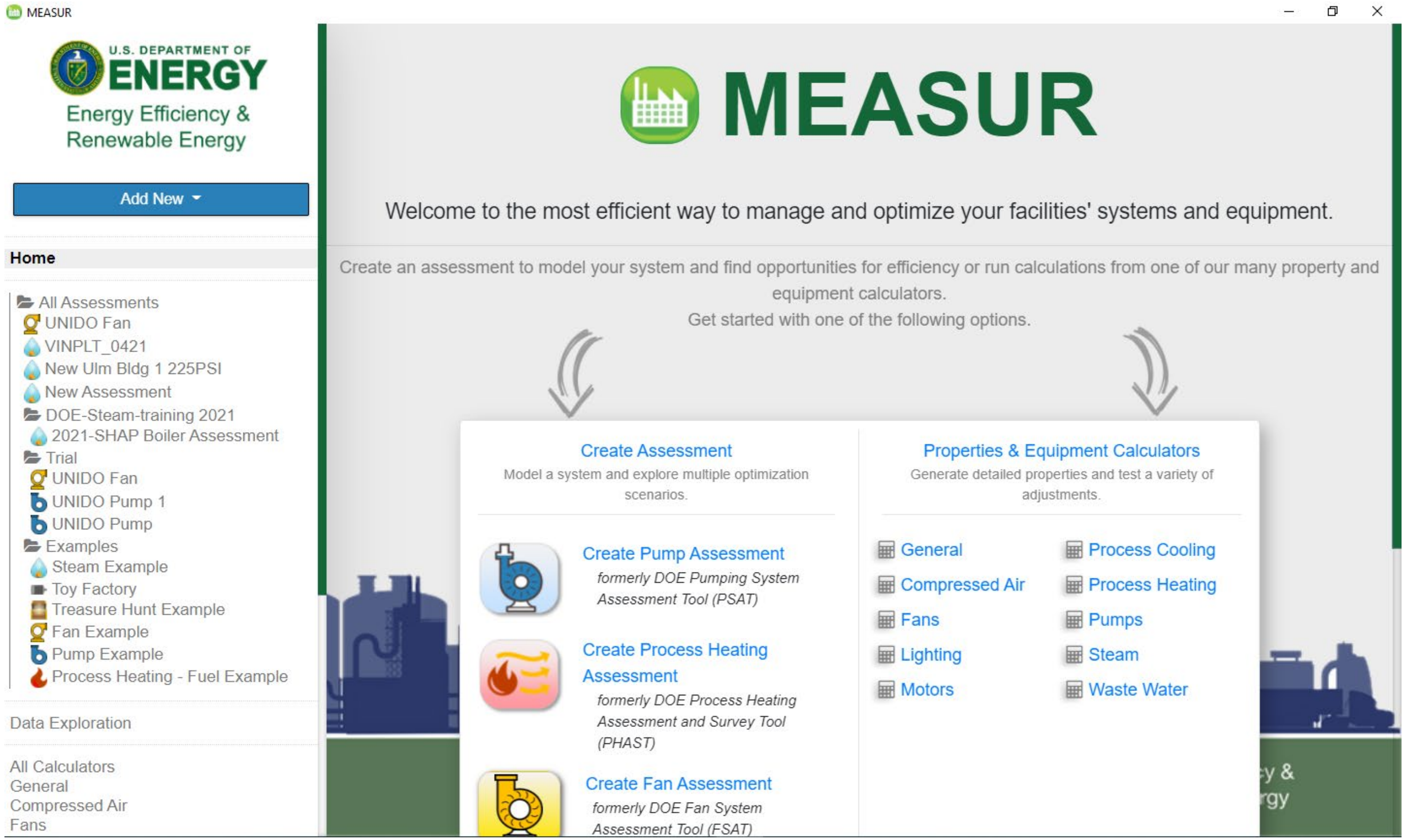
Most Favorable Scenarios for TES

- High (or very high) chilling load of relatively short duration
  - Think of cooling demand having a compressed air system profile
- High electric power demand charges
- Low (or very low or negative) electrical energy during off-peak hours
- Expansion on a very limited budget
- Mission critical systems that still need to operate with minimal backup generation capability

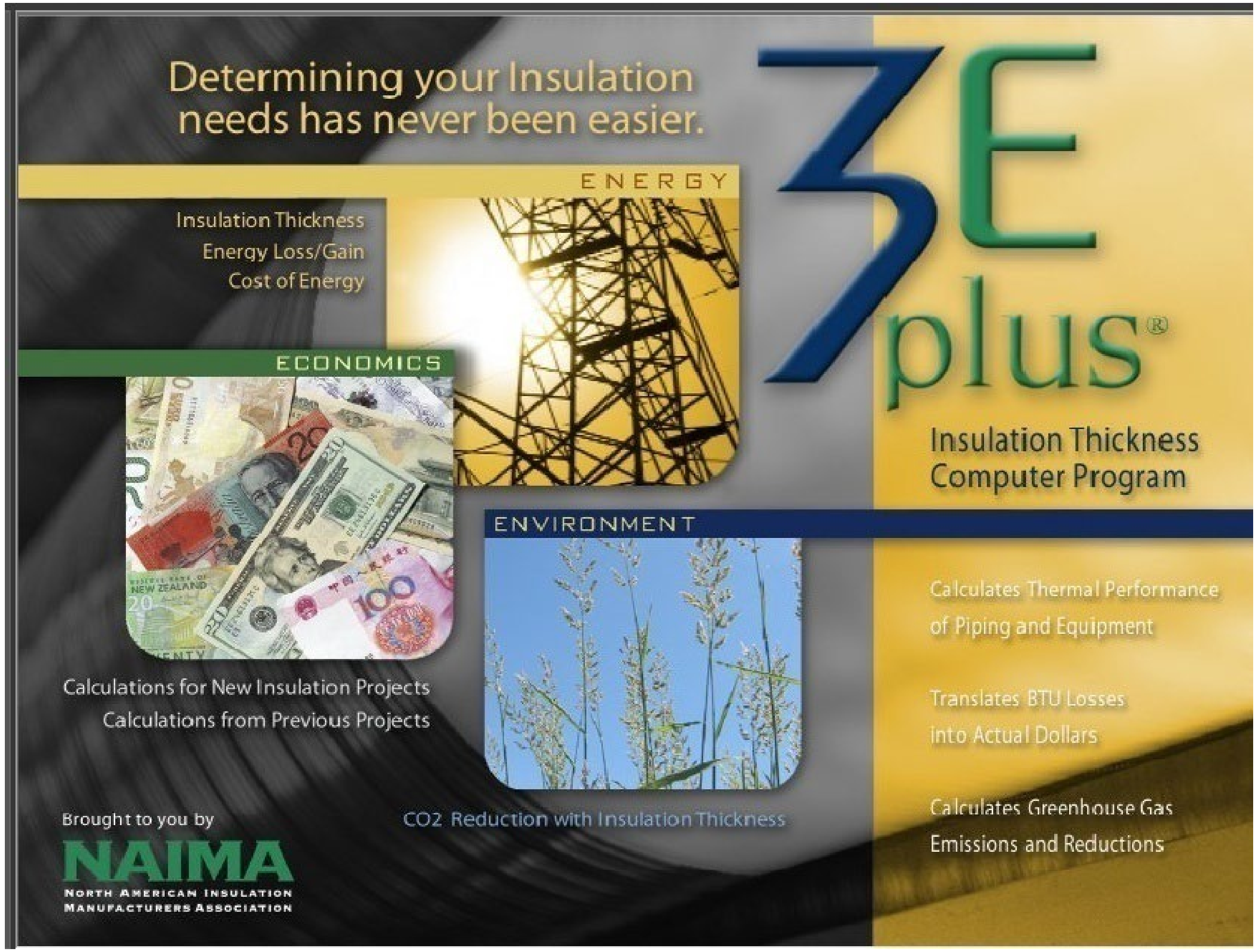
Other Tools

US DOE MEASUR Tool

- Other Modules and Calculators



3E Plus Software Tool



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Homework #6

- Finalize your plant’s chilled water system model in MEASUR and quantification of energy efficiency opportunities
- Identify discrepancies and shortcomings, if any, in the MEASUR software
- Start compiling the information to be able to put together a presentation in Session 8 for your plant
- Explore MEASUR’s other modules, calculators and 3EPlus

Thank You all for attending today's webinar.

See you all on Wednesday – August 26, 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