While waiting for the workshop to start…

Get ready to participate!

- Turn on your camera
- Find the unmute button and say "Hi" to check your audio

- Find the "raise hand" button

Answer our opening question!

What process cooling or refrigeration projects are you planning?

Answer in chat or raise hand and unmute

OCTOBER 24, 2024

Save on Energy webinar: Estimating project savings — process cooling and refrigeration

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Follow along in the participant workbook!

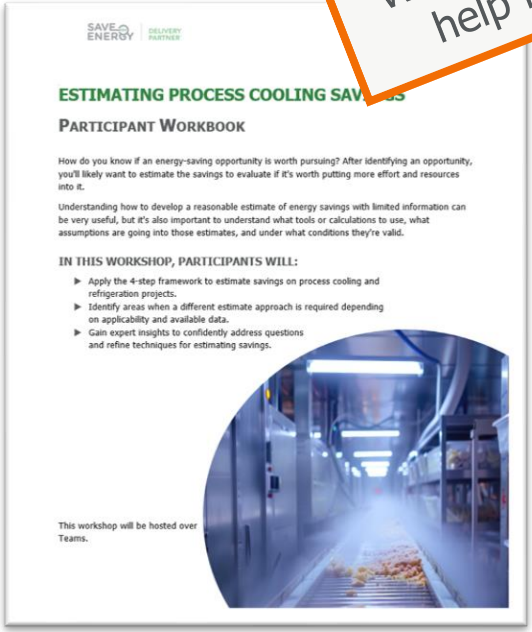
Watch for this icon to help follow along

1

Have the workbook open or printed out

Where to find the workbook:

- In the chat



SAVE ON ENERGY | DELIVERY PARTNER

ESTIMATING PROCESS COOLING SAV

PARTICIPANT WORKBOOK

How do you know if an energy-saving opportunity is worth pursuing? After identifying an opportunity, you'll likely want to estimate the savings to evaluate if it's worth putting more effort and resources into it.

Understanding how to develop a reasonable estimate of energy savings with limited information can be very useful, but it's also important to understand what tools or calculations to use, what assumptions are going into those estimates, and under what conditions they're valid.

IN THIS WORKSHOP, PARTICIPANTS WILL:

- Apply the 4-step framework to estimate savings on process cooling and refrigeration projects.
- Identify areas when a different estimate approach is required depending on applicability and available data.
- Gain expert insights to confidently address questions and refine techniques for estimating savings.

This workshop will be hosted over Teams.

Pathway to estimating project savings

- Apply the four-step framework to estimate savings
- Include specific considerations for process cooling
- Gain expert insights

Applying a structured approach to estimating savings

Reduce the risk of savings estimation errors by:

- Aligning savings estimates with the required level of accuracy.
- Avoiding assumptions that don't apply to your specific system.
- Making it easier to identify when savings estimates are unreasonable.

Four-step framework to estimate savings

Assess available data

- Know if you have the right data to meet your required level of uncertainty.

Establish a baseline

- Understand total energy use to know that savings estimates are in the right ballpark

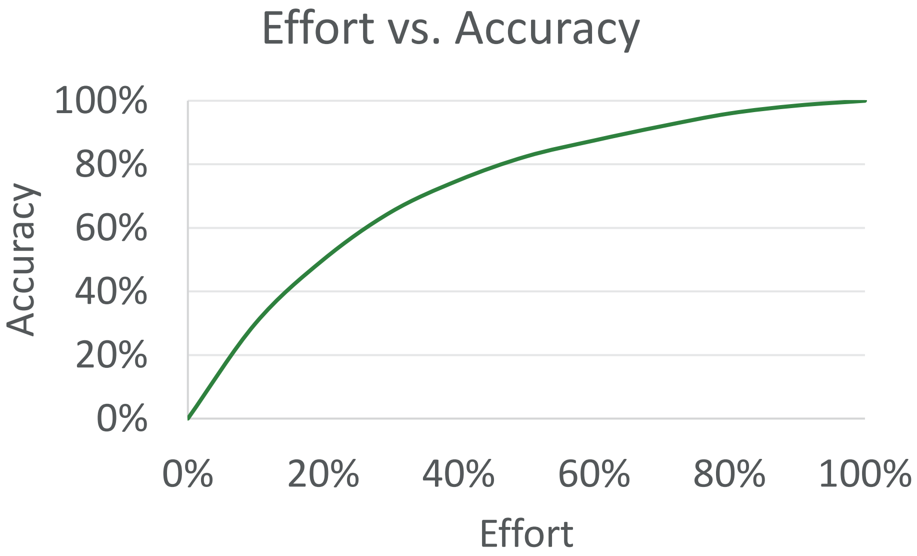
Understand savings mechanisms

- Know how your system reacts to changes to avoid incorrect assumptions in estimates

Estimate savings

- Choose the right calculations or rules of thumb

Appropriate accuracy



- What decision are you trying to make?
- What are the risks associated with the decision?

Decision / Risk Examples

- Capital spend / Underperformance
- Proceed with further study / Non-viable
- Trial a setpoint change / Reverse decision

Welcome our guest experts

Todd Salerno
Conservation and Energy Lead, CEM, CMVP, CRE,
Aladaco Consulting Inc.

Sean Pittman
Conservation and Energy Lead, P. Eng, CEM, CMVP,
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Aladaco Consulting Inc.

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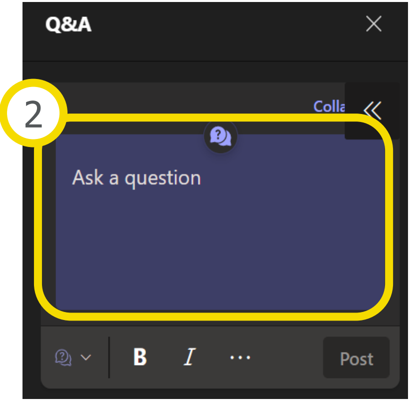
- Conservation program design and delivery for system operators and utilities; and
- Energy and carbon management services to help businesses improve their environmental and economic performance.

Visit **aladaco.com** to discover how we can support your energy and carbon management goals.

Ask the experts

Use the Q&A function to type out your questions.



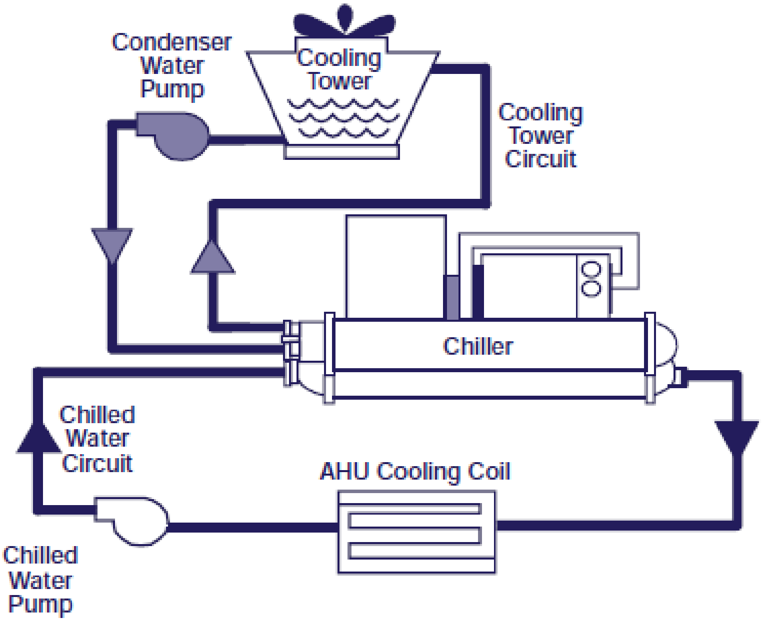
Feel free to turn on your camera to ask questions as well!

Energy savings in process cooling

Process cooling:

- Chillers (air and water cooled), pumps, fans, motors, distribution systems (pipes, valves, etc.)
- Up to 15-40% of total energy consumption in energy-intensive industries.

Assess available data: Take a systems approach

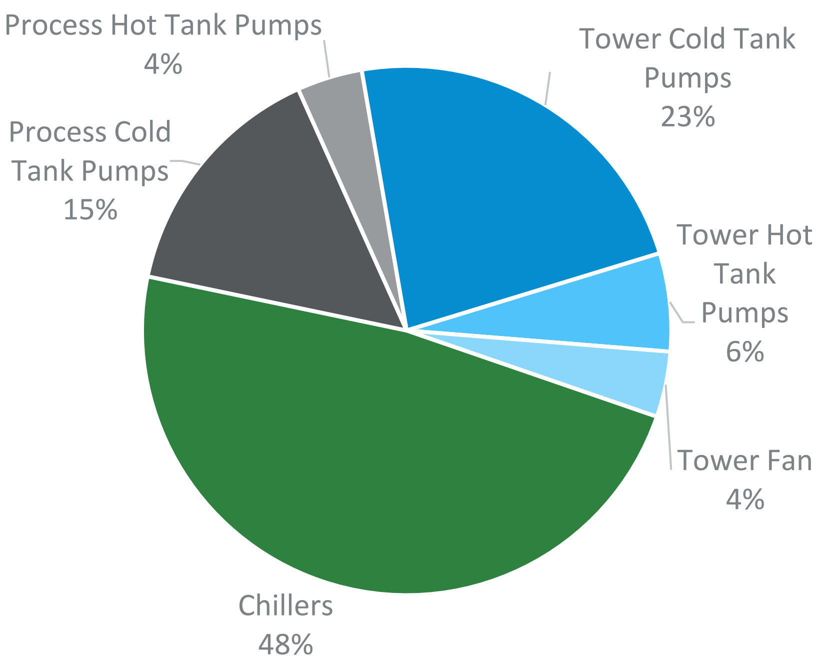


Typical water-cooled chiller system:

- Cooling tower
- Condenser water pump
- Chiller
- Chilled water pump
- AHU cooling coil

Source: Energy-models.com. Heating and Cooling System Upgrades.

Example of cooling energy end-use



Energy-saving opportunities often have trade-offs between how much energy is used in different components so it’s important to take a systems view.

Source: ACEEE. Energy Efficiency in Industrial Process Cooling. 2003.

Assess available data: What to look for

Ideal

- Measured kW or amps for key components
- Logged temperature and flow of:
  - Chilled water circuit
  - Cooling tower circuit
- Pressure
- Logged production data

Minimum

- Equipment details and specifications including:
  - Constant or variable speed chiller and pumps
  - Compressor and pump ratings and efficiencies
  - Chiller load profiles
- Operating hours
- Temperature set points
- Logged temperature and flow of chilled water circuit

Question

What data do you have available for your process cooling equipment?

*Answer in chat or raise hand and unmute

Mitigation strategies: filling data gaps

Using engineering calculations

$$Q = mC_p\Delta T$$

Where:

- Q is the heat energy (J/s or W)
- m is the mass flow (kg/s) in flow obtained by multiplying flow rate (m^3/s) by density (kg/m^3)
- C_p = specific heat capacity of the substance (J/kgK)
- ΔT = is the temperature change (K)

Additional information

- Operating hours
- Average COP (should be based on the chiller performance curve and cooling load: Q)

Important

Incorrect estimates of flow are one of the largest sources of error when estimating energy consumption.

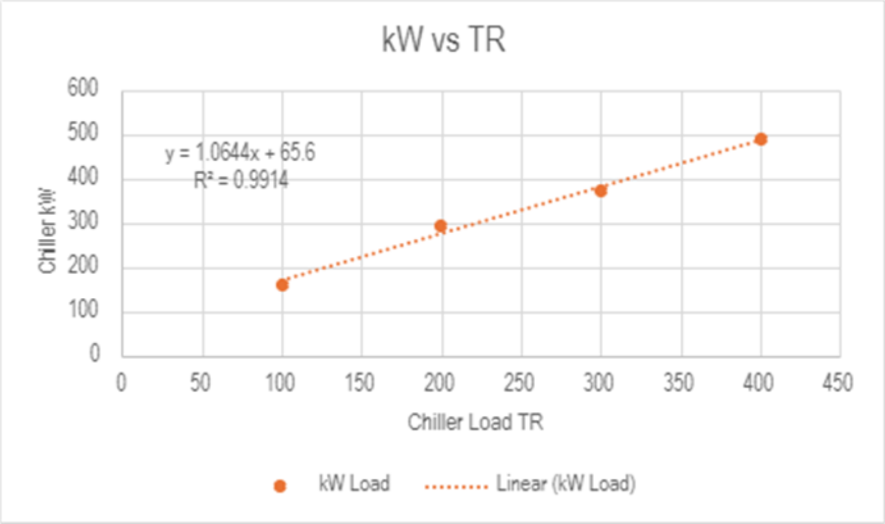
Whenever possible flow of chilled water should be measured.

Mitigation strategies: what to do about missing data

Real world data can be challenging to find and gaps in information are common. Strategies for further data generation include:

- Regular data logging
- Using proxy data
- Modelling and estimating
- Data filling, extrapolation/interpolation, averaging, etc.

Regression analysis with available data



Common errors – what most people get wrong

- Using spot measurements instead of trends
- Assuming cooling demands are constant
- Using whole-building utility metering without considering the load % of the cooling process
- Not appropriately considering production or manufacturing levels
- Using too small a dataset, or one that doesn't span a full operating cycle

Outcome of Step 1: Accurate data assessment

- A reliable and defensible dataset is established
- A foundation of data that meets your accuracy requirements is built
- Uncertainty and data gaps are understood
- By understanding what data is available you can have confidence that your energy savings calculation will reflect the reality of your systems

Establish an energy baseline (1/2)

The second step in the framework is establishing an accurate baseline of energy consumption:

- Estimate or measure the total energy consumption
- Understand energy consumption over different seasons, production schedules and types of operation
- Consider run time, duty cycle and partial loads

Establish an energy baseline (2/2)

Methods of estimation:

- **Basic formula-based approach**: power (kW) x time (hours)
- **Formula-based approach**: using specifications, load profiles, temperatures and process load data to develop an excel based baseline model
- **Modelled approach**: an MS Excel-based linear regression model OR a software-based model (e.g., vendor software)

Question:

What approach do you typically use in your daily analyses?

*Answer in chat or raise hand and unmute

Developing a basic baseline

For small projects or a low-effort estimate, a basic formula approach can be used:

Energy (kWh) = Power (kW) x Hours of Operation (h)

Power (kW) = V x I x PF x $\sqrt{3}$

Efficiency (COP) = Useful Cooling (kW) / Power Input (kW)

Example: Calculating baseline (part 1)

Calculate cooling load (Q) under different operating conditions using:

- Chilled water flow rate varies between 0.05 to 0.1 m^3/s
- Inlet temperature varies between 10 to 12 C
- Outlet temperature varies between 6 to 7 C

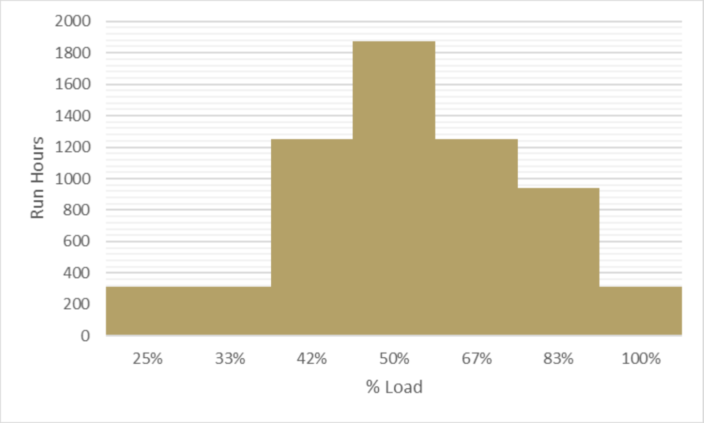


Image source: F.W. Yu, K.T. Chan. 2006.

Example: Calculating baseline (part 2)

- Rated cooling capacity = 2,500 kW or 711 tons

% load	Q (kW)	Hours	COP	Input kW	MWh
25%	628.5	312.5	1.7	370	116
33%	838	312.5	2.25	372	116
42%	1047.5	1250	2.8	374	468
50%	1257	1875	3	419	786
67%	1676	1250	3.3	508	635
83%	2095	937.5	3.3	635	595
100%	2514	312.5	3.15	798	249
		6250		**Annual MWh**	**2,965**

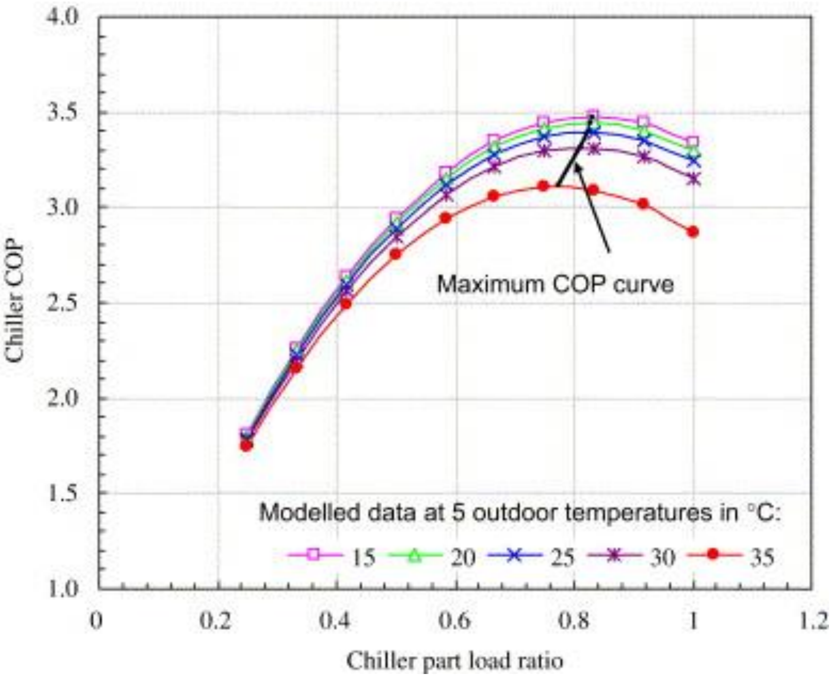


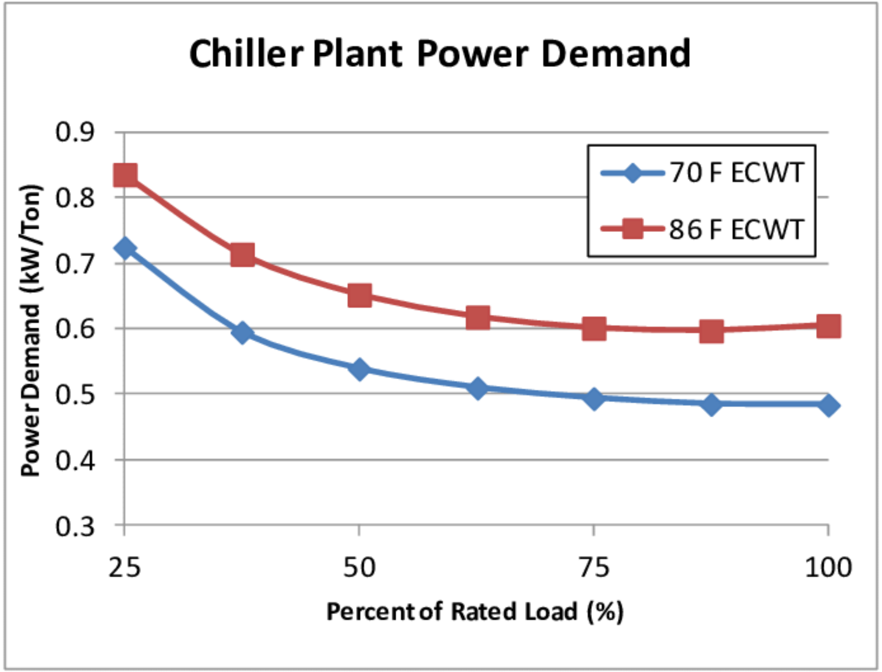
Image source: F.W. Yu, K.T. Chan. 2006.

Developing a model for more accuracy

If higher accuracy is required, use a model-based approach.

Often Excel-based, using a combination of bin analysis, regression formulas, hourly temperature or weather data.

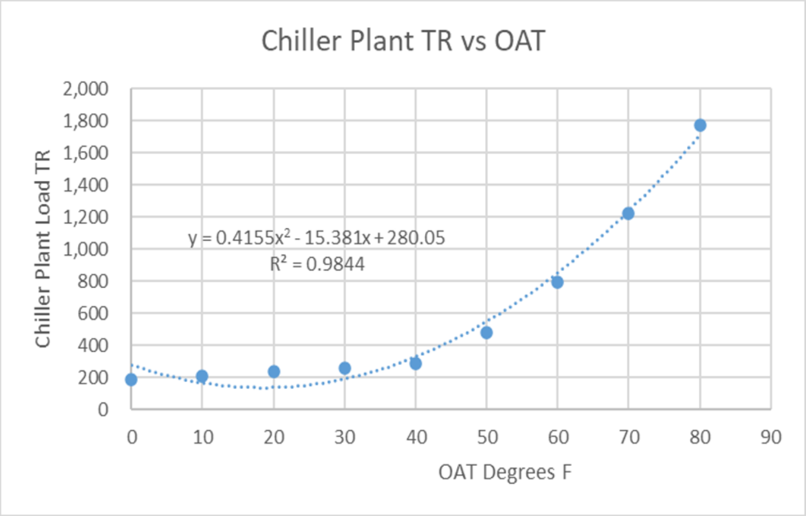
Can be used for budgetary estimates, incentives, and pre-design project evaluations.

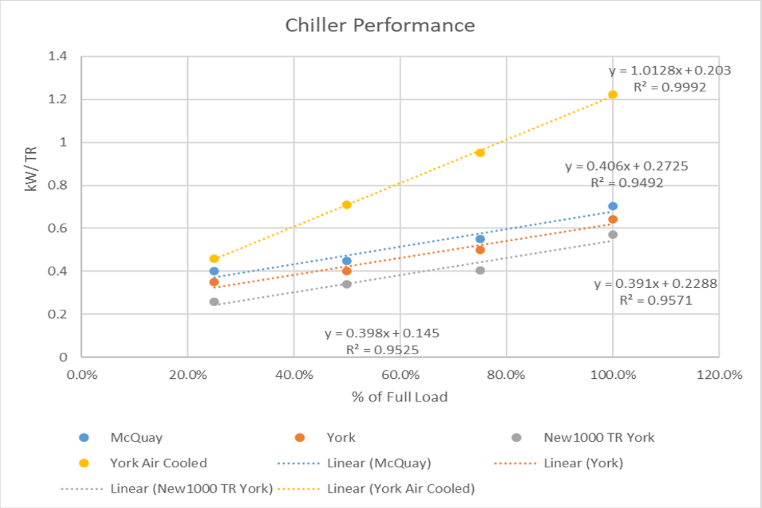


Source: Peter B. Backlund. All-Electric Ship Energy Systems Design Using Classifier-Guided Sampling. 2015.

Real-world example of intermedial modelling: cooling a mushroom farm

The graphs below show the relationship between temperature and chiller plant loading





Calculating a baseline from a model

Steps to calculate energy baseline from the model:

1. Collect annual dataset of hourly outdoor air temperature
2. Use regression formula to calculate hourly chiller plant load (TR)
3. Transpose hourly TR to % load of chiller on the chiller performance curves
4. Convert hourly % load of chiller to input kW using curves and hourly TR data

Common baselining errors- what most people get wrong

- Not accounting for seasonal variability- make sure your system is operating independent of outdoor air temperature (OAT) if weather is not included in the analysis.
- Overlooking system interactions- consider how other systems are impacting your cooling process.
- Plan ahead- ensure trending and logging of all baseline variables continues through to implementation and post-retrofit.
- Correlation does not mean causation. High R^2 values do not always mean the correlation is relevant, especially in multi-variable or non-linear analysis.

Outcome of step 2: Establishing a baseline

By establishing a baseline, you will:

- Develop an understanding of the total energy consumption of the system across all mode of operation is developed
- Uncover errors in savings estimates that become obvious when seen as an unreasonable percentage of total consumption

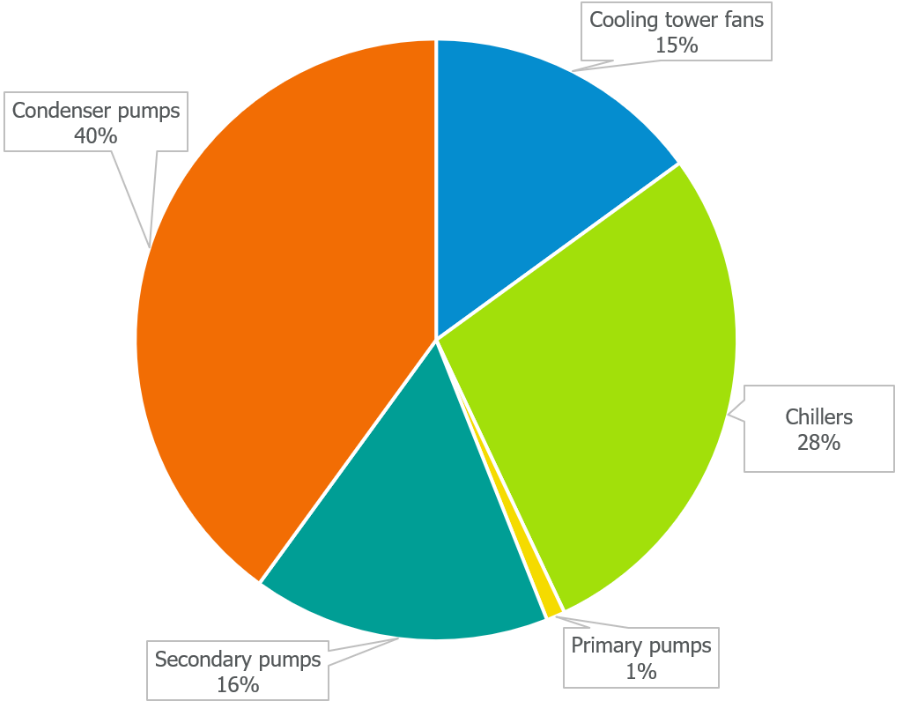
An accurate baseline provides guardrails to keep savings estimates on track.

Understanding the savings mechanism

The third step in the framework is understanding the savings mechanism:

- Understand how changes to the system affect how equipment works and how those changes can lead to energy savings
- Ensure the estimated reflects how the equipment operated to avoid under-or over-estimation
- Verify that the estimated savings reflect reality

All components in the system can contribute to savings



Chiller savings mechanisms

- Reduce cooling load
- Reduce chiller lift
- Improve efficiency of cooling
- Reduce flow/pressure

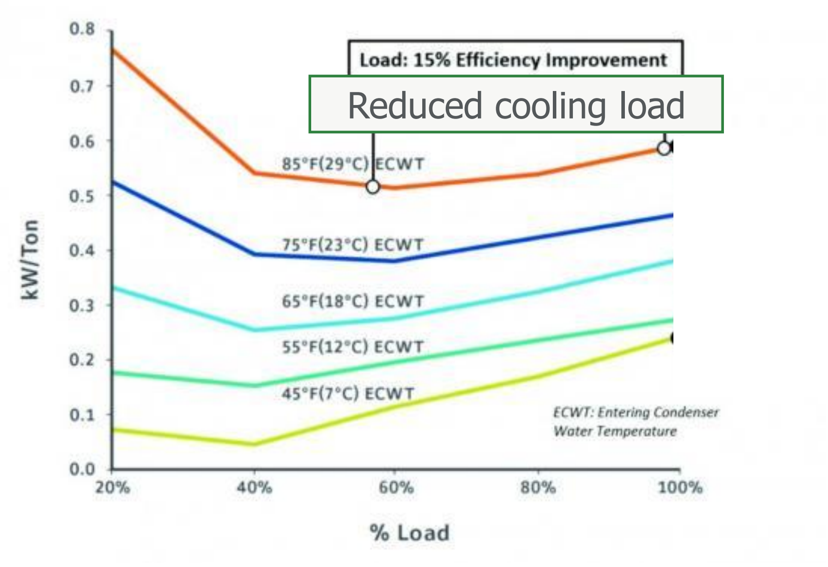
Reduce cooling load

Examples of opportunities:

- Pipe insulation
- Removing unnecessary piping / disconnecting old loads
- Reducing heat sources in cooled areas
- Remove scaling

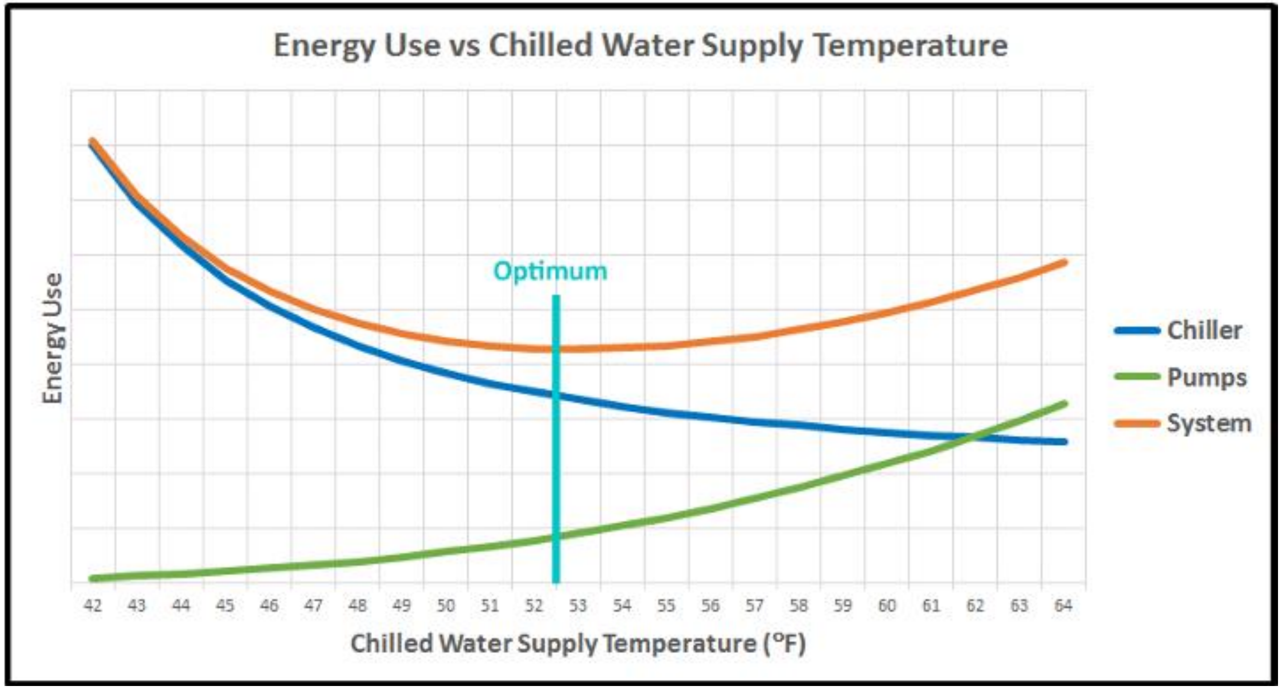
Impact:

- Chiller runs at lower load %
- Part-load efficiency is important



Source: Fred Berry. Chiller & Cooling Best Practices. VSD Chillers Deliver Energy Savings Under Real World Conditions. 2017.

Increase chilled water supply temperature



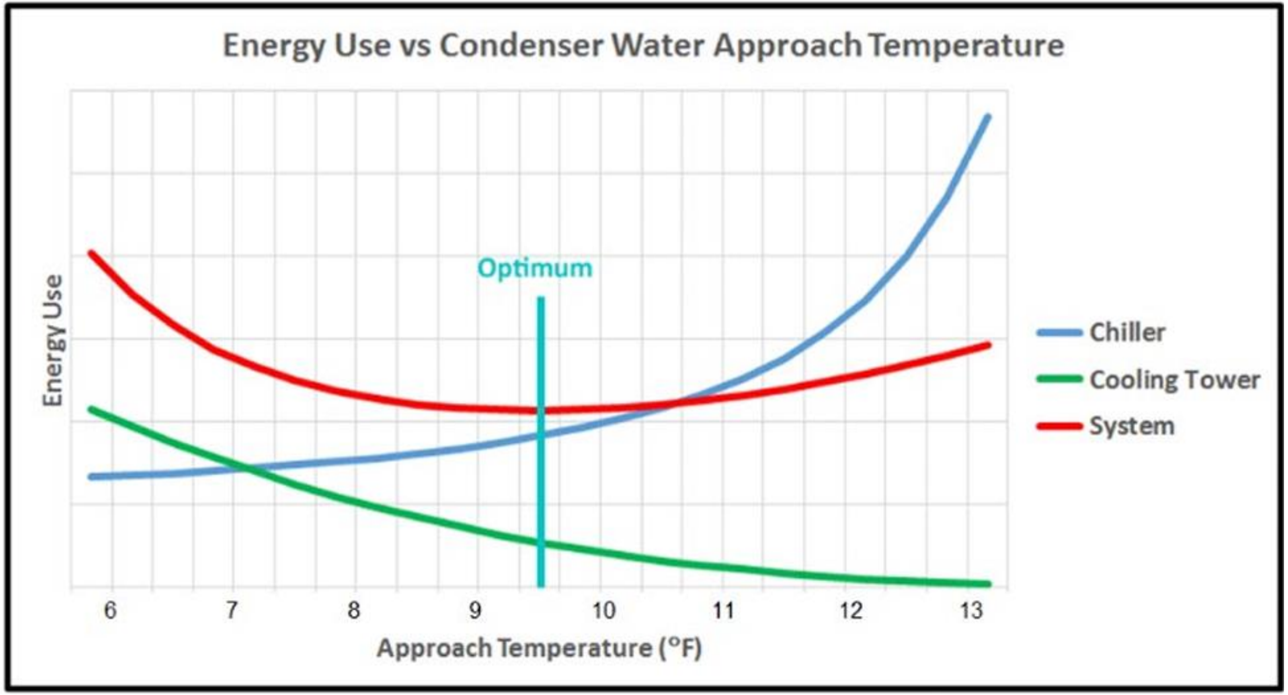
Chiller doesn't work as hard…

BUT

…pumps work harder
(in a variable flow system)

Source: Carrier. Chilled Water System Optimizer. 2017.

Decrease condensing water temperature



Chiller doesn't work as hard…

BUT

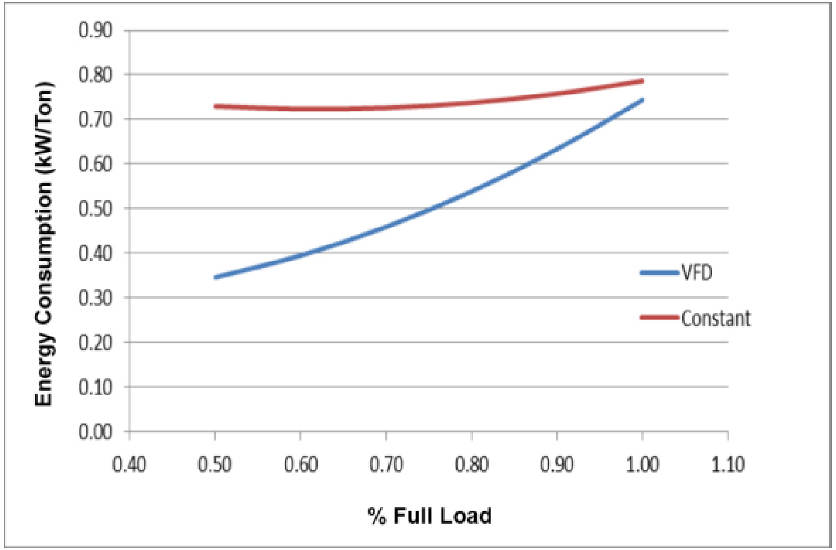
…cooling tower works harder

Source: Carrier. Chilled Water System Optimizer. 2017.

Improve efficiency of cooling

Opportunities

- Higher efficiency units
- Upgrade to variable speed chiller to improve part-load efficiency
- Improve sequencing of multiple chillers
- Water-side economizer
- Improve efficiency of other components



Source: Yakasawa. How to Cut Chiller Energy Costs by 30%. 2015.

Reduce flow

Opportunities:

- Advanced controls with VSDs
- Reducing flow of pumps in a constant flow system (want to maintain ΔT of ~10 C)

Source: MTA Construction & Development.

Common errors in assumptions about savings mechanisms: what most people get wrong

- Assuming linear savings: believing that energy savings scale directly with changes in load or temperature without considering system inefficiencies or part-load performance.
- Not adequately considering the role of control strategies. The best controls are worthless if they aren't managed properly.
- Not considering future production or manufacturing rates. Under-sizing or over-sizing equipment can lead to poor system performance.

Outcome of step 3: Understanding the savings mechanism

At the completion of Step 3:

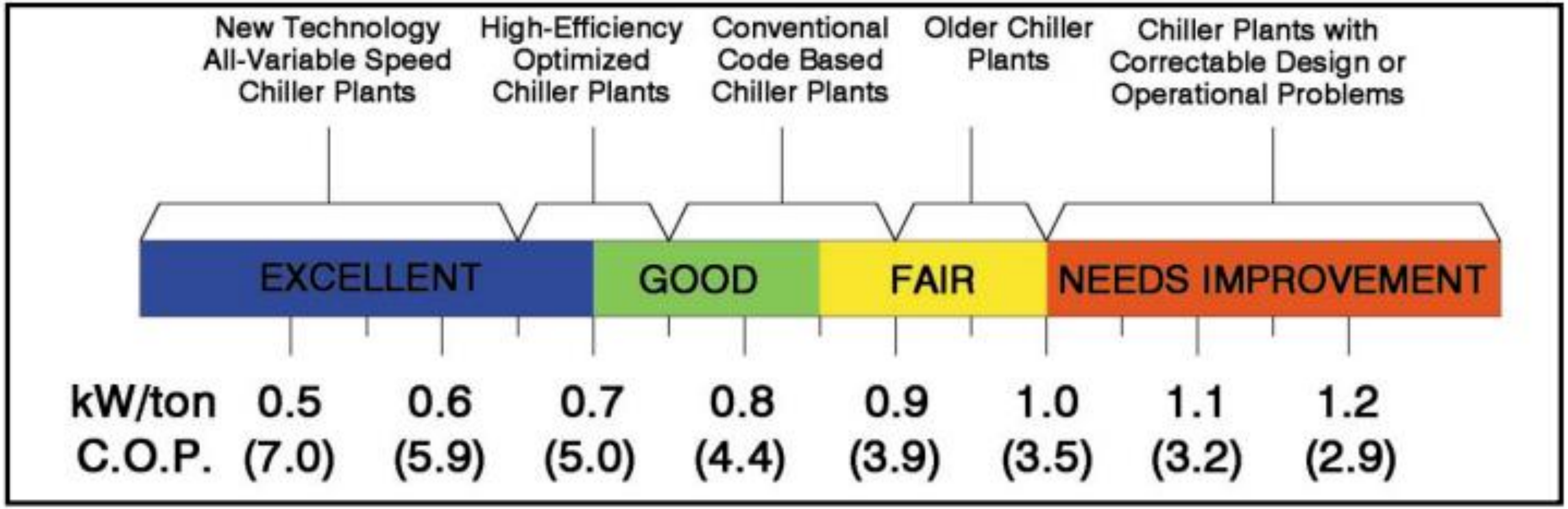
- Expected savings outcomes are achieved
- An energy savings analysis capturing all relevant data and system interactions is prepared
- Control strategies can be planned and implemented

Understanding the savings mechanisms within your system, and your assumptions concerning those mechanisms, ensures the savings estimated will reflect reality.

Common rules of thumb

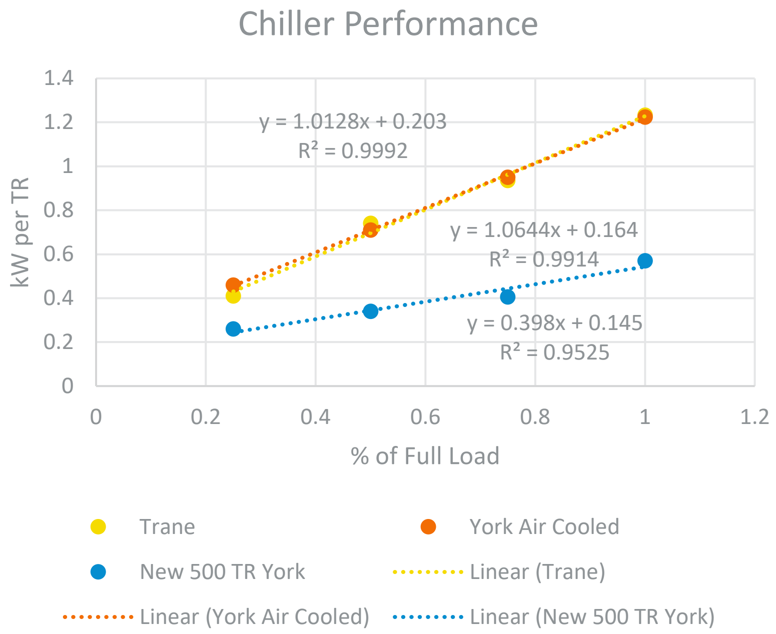
- Each degree C reduction in **entering condensing water temperature** results in 1.2% increase in chiller efficiency.
- Each degree C increase in **chilled water supply temperature** results in 1-2% increase in chiller efficiency.
- **Older chillers** can consume 0.60kW per ton of cooling
- **Variable speed drives** on chillers can result in up to 30% energy savings

Chiller plant efficiency in HVAC applications



Source: https://triangleashrae.com/images/meeting/111616/Meeting_Presentations/all_variable_speed_centrifugal_chiller_plants__journal_2001_09_thomas_hartman_.pdf

Example: Upgrading to variable speed chiller



Baseline measured			Taken from chart		Calculated from table		
Load-%	***Load - TR***	***Hrs/ yr***	***Existing Chiller kW/TR***	***Retrofit Chiller kW/TR***	***Existing Chiller kWh***	***Retrofit Chiller kWh***	***Savings kWh***
100%	500	438	1.22	0.54	266,260	118,917	147,343
90%	450	1,314	1.11	0.50	659,016	297,542	361,474
80%	400	2,803	1.01	0.46	1,136,126	519,601	616,525
70%	350	3,066	0.91	0.42	978,624	454,565	524,059
60%	300	438	0.81	0.38	106,523	50,431	56,092
50%	250	263	0.71	0.34	46,608	22,601	24,007
40%	200	438	0.61	0.30	53,271	26,648	26,623
					3,246,428	***1,490,306***	***1,756,123***

Conclusion

By employing the systematic approach provided by the four-step framework, you can be confident that your savings estimates are grounded in reality.

The final output is a defensible and repeatable analysis that can be used to prove project savings to evaluators and internal stakeholders.

Additionally, you can avoid inaccurate estimates that put your reputation at risk and question the value of energy efficiency initiatives.

Finally, a reminder that ongoing data logging, measurement and verification activities will ensure that the energy savings persist in the future.

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