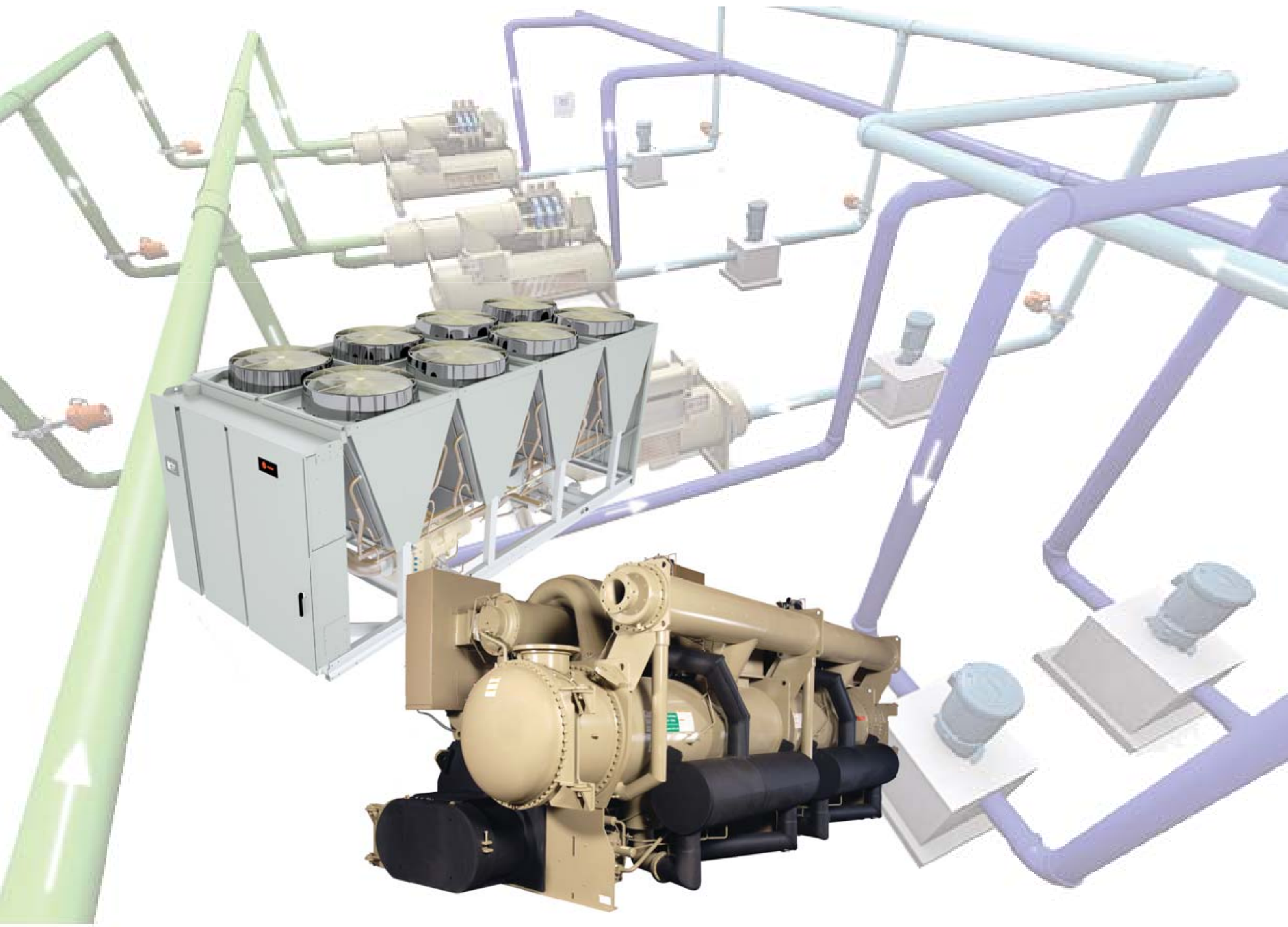
TRANE

Trane Engineers Newsletter Live

DIY Chiller Plant Performance Modeling: Easy and Easier

Presenters: Chris Hsieh, Mick Schwedler, Charlie Jelen and Jeanne Harshaw (host)



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GBCI CMP

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TRANE

Agenda

Trane *Engineers Newsletter Live* Series

DIY Chiller Plant Performance Modeling: Easy and Easier

Abstract
Analyzing chilled-water plants and optimizing their performance with building loads is desirable to minimize energy use. However, chiller plant design often is set during the schematic design phase, when there are many unknowns. This ENL examines a number of quick analysis tools available that help system designers determine which chilled-water plant design options benefit the building owner and result in efficient system operation.

Presenters: Trane engineers Chris Hsieh, Mick Schwedler and Charlie Jelen

After viewing attendees will be able to:

1. Identify key criteria needed for an accurate chiller plant model
2. Summarize various tools available today and the benefits as well as drawbacks of each
3. Compare results of various tools
4. Explain the methodology used in the latest tool from Trane (myPLV™)

Agenda

- What makes an accurate analysis?
- What makes a simple analysis?
- Analysis tools available today - benefits and drawbacks
- myPLV overview and demo
- Chiller Plant Analyzer overview
- Analysis comparison of results

Ingersoll Rand

Presenter biographies

DIY Chiller Plant Performance Modeling: Easy and Easier

Chris Hsieh | systems engineer | Trane

Chris serves as Trane liaison to all industry-related green/environmental initiatives, including programs such as ENERGY STAR®, LEED, and Green Globes. He served as a past member of the TFM Green Building Advisory Board, CSI's GreenFormat™ task team, and USGBC's Education Events Committee. Chris is a consultant for ASHRAE SSPC 189.1 committee since 2013. He holds bachelor and master degree in electrical engineering from National Kaohsiung Institute of Technology in Taiwan and Southern Methodist University, respectively. Chris assisted with LEED certification (Silver, Gold and Certified) for several Trane office and facility buildings. He is a LEED-Accredited Professional BD+C, UL Environment DfS Gold certified, as well as a member of ASHRAE.

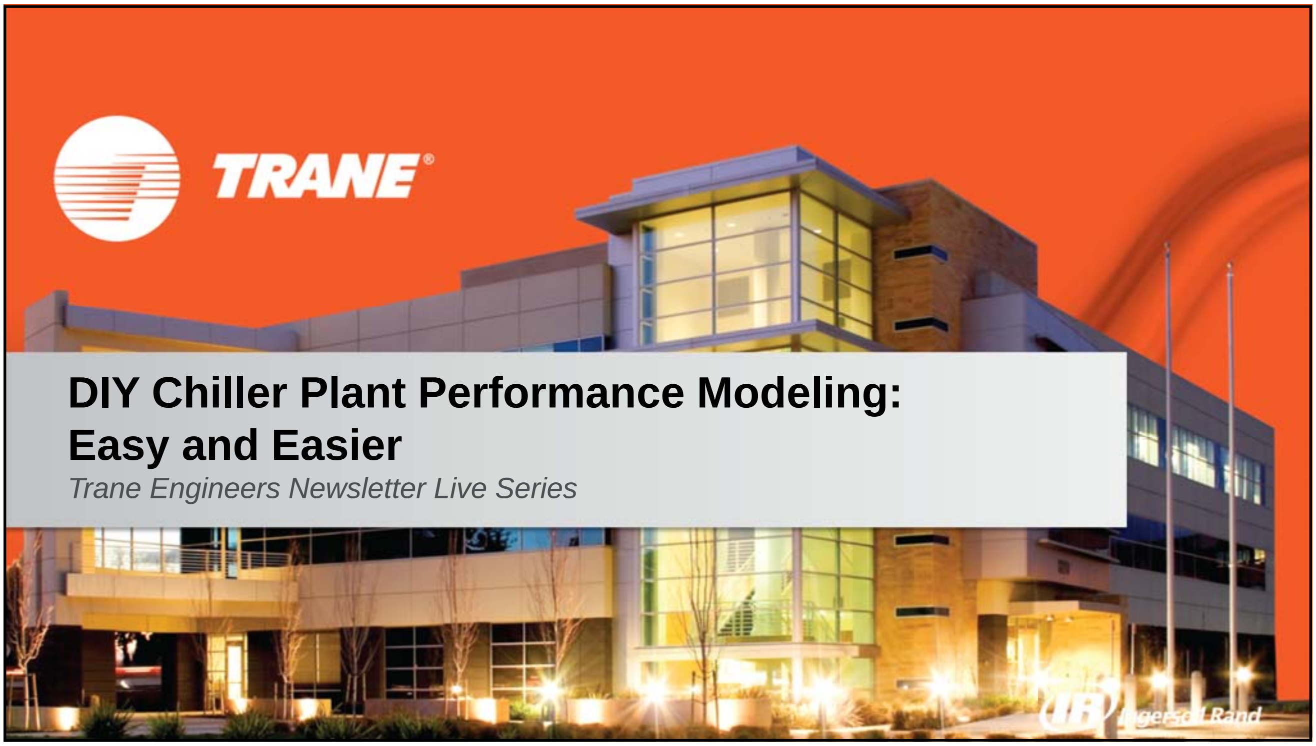
Charlie Jelen | chiller marketing engineer | Trane

Charlie joined Trane in 2012 after graduating from the University of Minnesota with a Bachelor of Science degree in mechanical engineering. Prior to joining the Trane chiller team, Charlie worked in the Customer Direct Services (C.D.S.) department as a product manager for the TRACE™ 700 load design and energy simulation software. As a C.D.S. marketing engineer he supported and trained customers globally. In his current role, Charlie is primarily responsible for pre-sale support to the sales organization for all of Trane's water-cooled portfolio. Charlie is currently involved with ASHRAE at the local level serving on the board of governors.

Mick Schwedler | application engineer | Trane

Mick has been involved in the development, training, and support of mechanical systems for Trane since 1982. With expertise in system optimization and control (in which he holds patents), and in chilled-water system design, Mick's primary responsibility is to help designers properly apply Trane products and systems. Mick provides one-on-one support, writes technical publications, and presents seminars.

Mick is an ASHRAE Fellow and member of the Board of Directors. He is a recipient of ASHRAE's Distinguished Service and Standards Achievement Awards. He is past Chair of SSPC 90.1 and contributed to the ASHRAE GreenGuide. Mick earned his mechanical engineering degree from Northwestern University and holds a master's degree from the University of Wisconsin Solar Energy Laboratory.



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www.RCEP.net

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Learning Objectives

1. Identify criteria that is needed for an accurate analysis tool
2. Summarize the various types of analysis tools available today and the pros and cons of each
3. Explain the methodology used in myPLV
4. Identify key data in myPLV reports

Today's Presenters

Mick Schwedler
Manager, Applications Engineer

Chris Hsieh
Systems Engineer

Charlie Jelen
Chiller Marketing Engineer

Agenda

- What makes an accurate model
- Various analysis tools available
  - Pros and cons
- Chiller performance analysis example

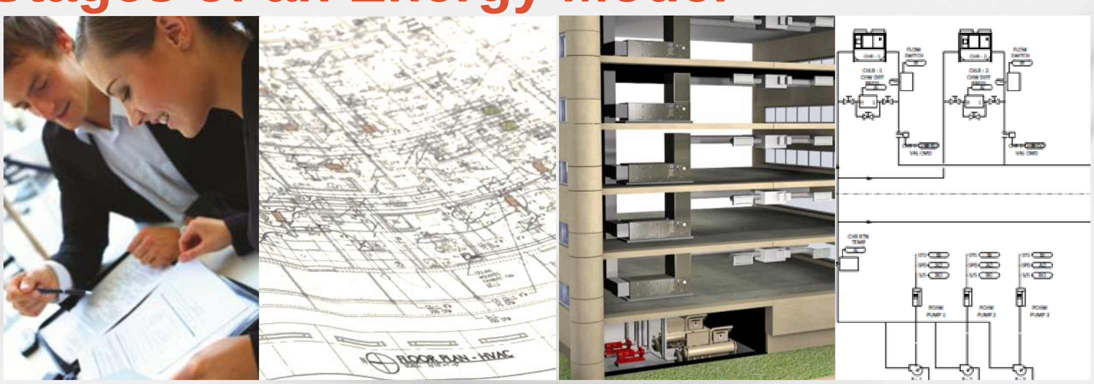
Energy Modeling

Purpose
- Serve entire building and chiller plant

Process
- Find the right tool
  - Variables tailored to your locale and market
  - Leverage current available tools
- Recognize strength and limitation
- Serve each stage of design and construction

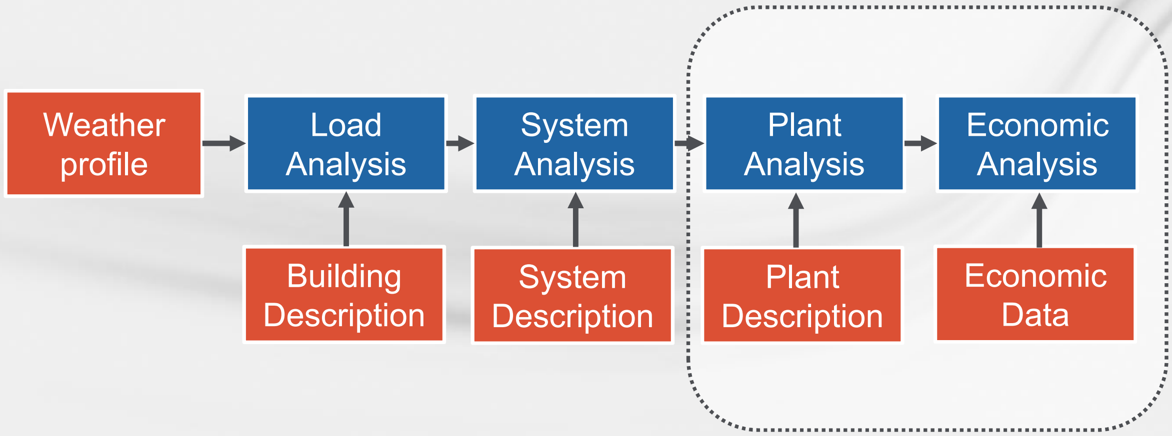
Payoff
- Compare and validate

Stages of an Energy Model



Pre-design/ conceptual design | Schematic design | Design development | Construction documentation

Building Energy Simulation



Source: Chapter 19 of ASHRAE handbook 2013 – fundamentals

Chiller Specific Tool

Integrated Part Load Value (IPLV)

In summary, **it is best to use a comprehensive analysis** that reflects the **actual weather data**, **building load characteristics**, **operational hours**, **economizer capabilities** and energy drawn by auxiliaries such as **pumps and cooling towers**, when calculating the chiller and system efficiency. The intended use of the IPLV (NPLV) rating is to compare the performance of similar technologies, enabling a side-by-side relative comparison, and to provide a second certifiable rating point that can be referenced by energy codes. **A single metric, such as design efficiency or IPLV shall not be used to quantify energy savings.**

Source: ANSI/AHRI 550/590 Appendix D

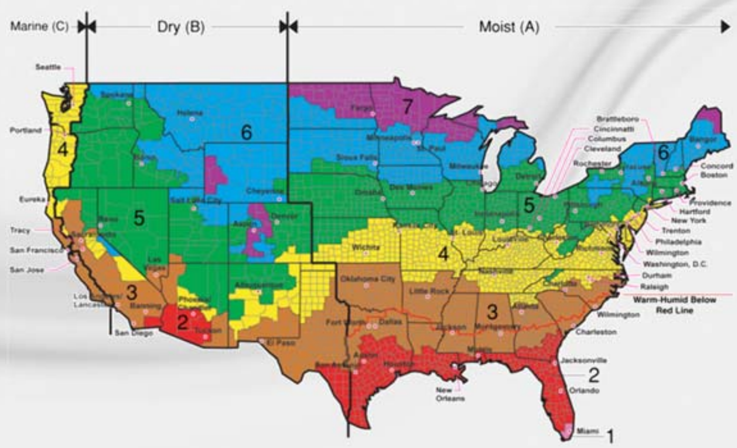
Key Parameters for an Energy Model

1. **Weather**
2. **Building type/load**
3. **Utilization schedule**
4. **Utility rate (actual)**
5. Economizers
6. Optimization controls
7. Chiller performance
8. Chiller pump/tower energy use
9. Calculation engine

Key parameter for an energy model

Weather Library

- Dry-bulb temperature
- Wet-bulb temperature
- Cloud factor
- Wind speed
- Pressure



Source: ASHRAE

Key parameter for an energy model

Building Type

- Office
- Government
- School
- Healthcare
- Retail
- Multi-family

Key parameter for an energy model

Utilization

- Occupancy schedule
- Heating schedule and setpoints
- Cooling schedule and setpoints

Key parameter for an energy model

Utility Rates

- Energy types
- Demand and consumption rate
- Renewable energy

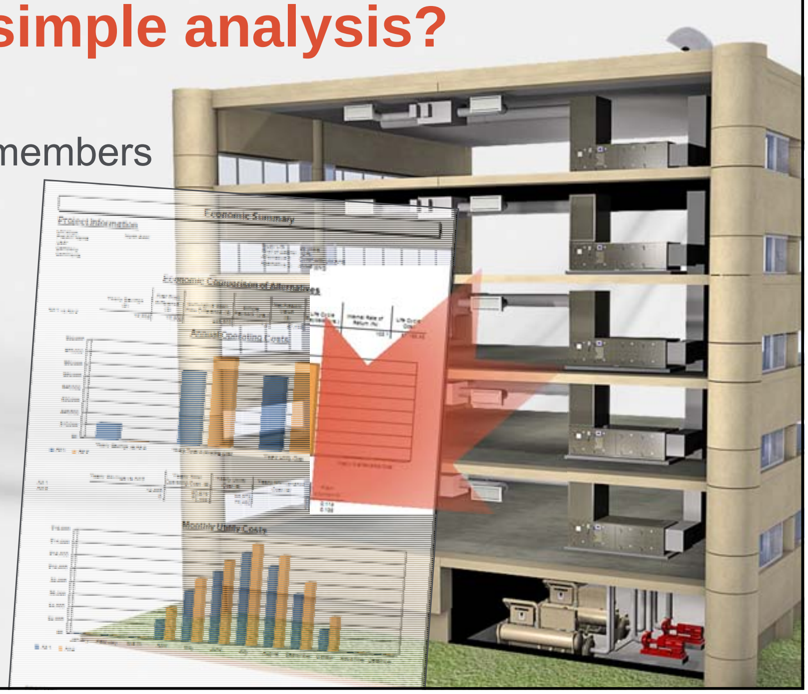
What makes a simple analysis?

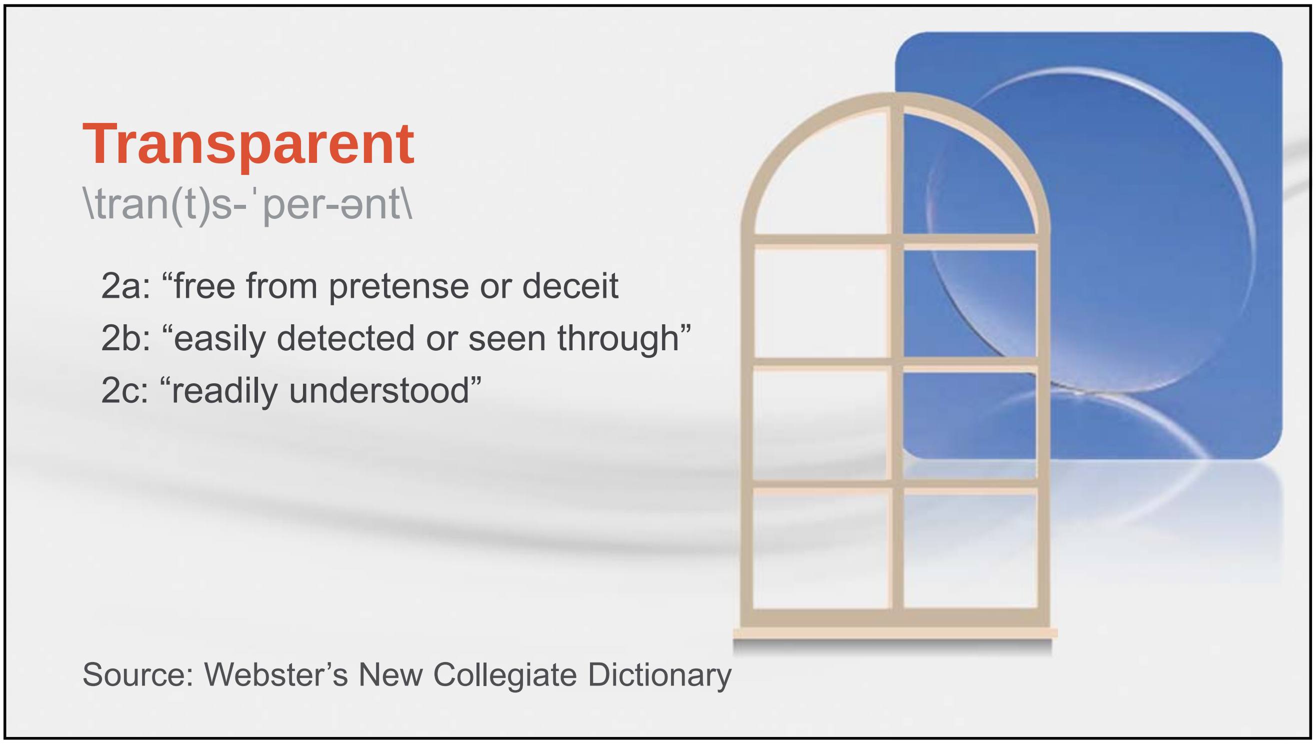
Modeling Program

- Pre-packaged library members
  - Weather files
  - Utilization schedules
  - Equipment library
  - Templates
  - Airside systems
  - Materials
- Wizards

Rapid Analysis

- Spreadsheets
- Dedicated software




Transparent
\tran(t)s-ˈper-ənt\
2a: “free from pretense or deceit
2b: “easily detected or seen through”
2c: “readily understood”
Source: Webster’s New Collegiate Dictionary

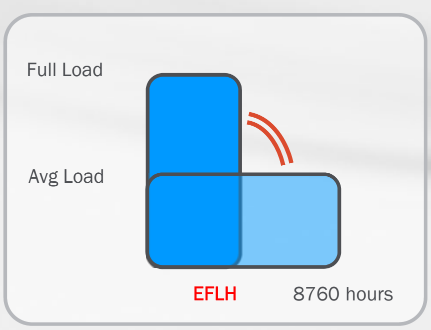

Agenda
• What makes an accurate model
• Various analysis tools available
• Pros and cons
• Chiller performance analysis example

Available Tools

- Equivalent Full Load Hours (EFLH)
- Integrated Part-Load Value (IPLV)
- Spreadsheets
- Energy analysis programs

Definition
Annual Equivalent Full Load Hours

Number of hours that an air-conditioner would run at full load to consume the same amount of electric energy it consumes on average over the course of an entire year.

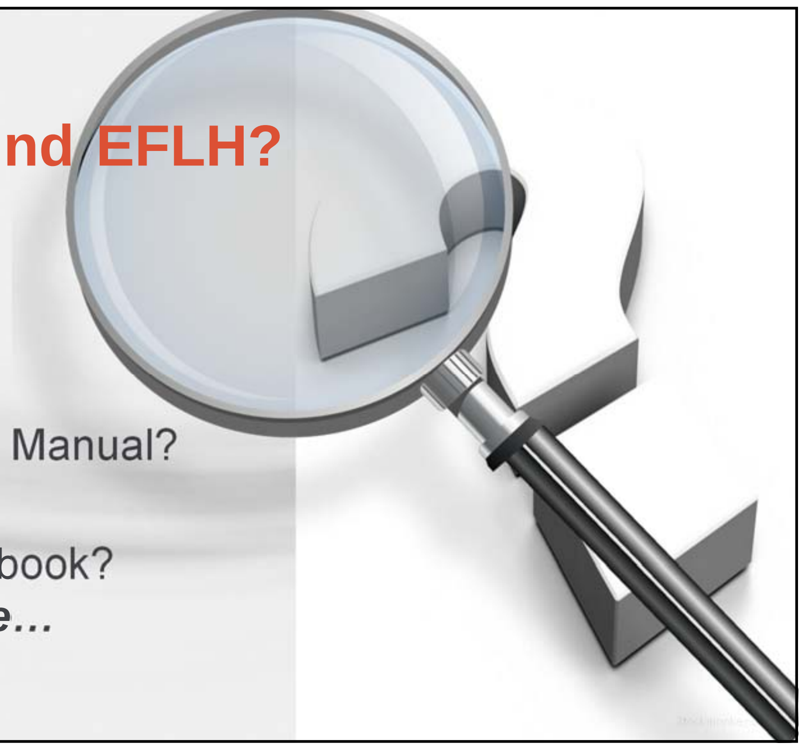


- ASHRAE Handbook of Fundamentals 1985
- ENERGY STAR Center Air Conditioner – savings calculator
- Local experience (California, Minnesota, Massachusetts)
- U.S. Deptartment.of Housing and Urban Development

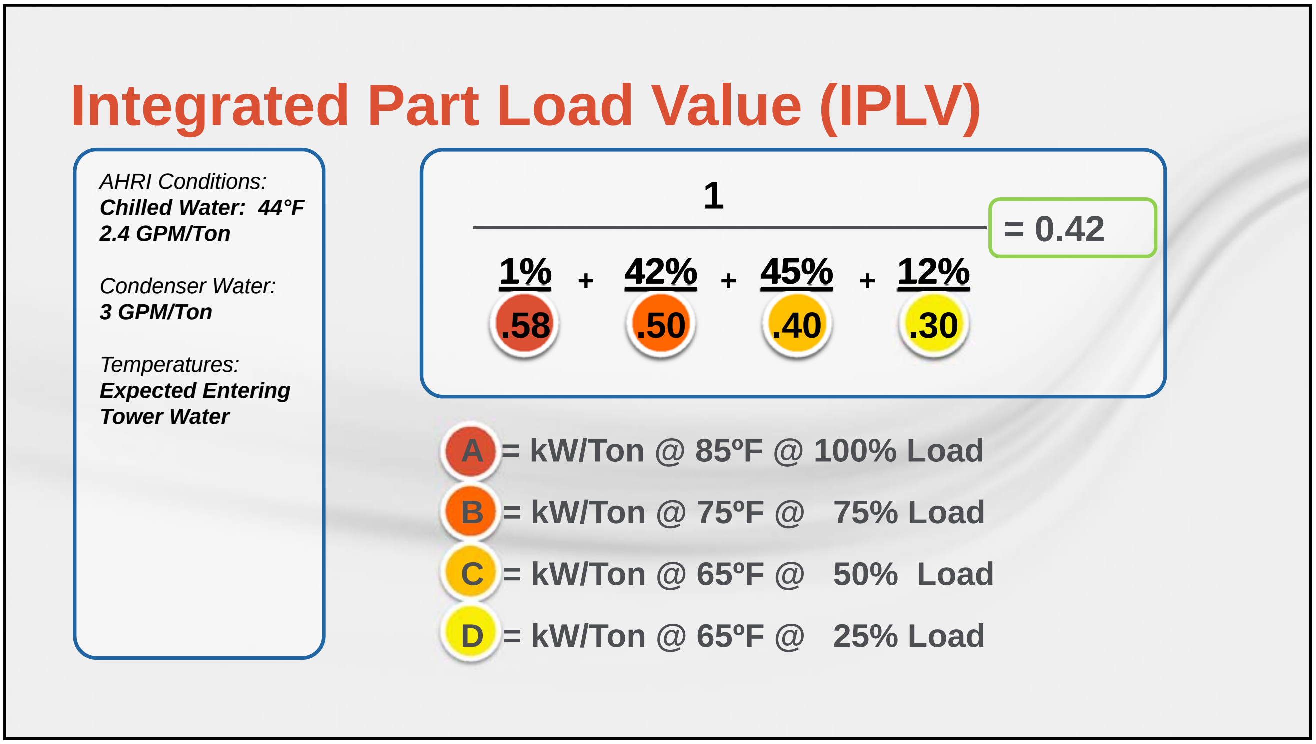
Estimate Annual Energy Consumption

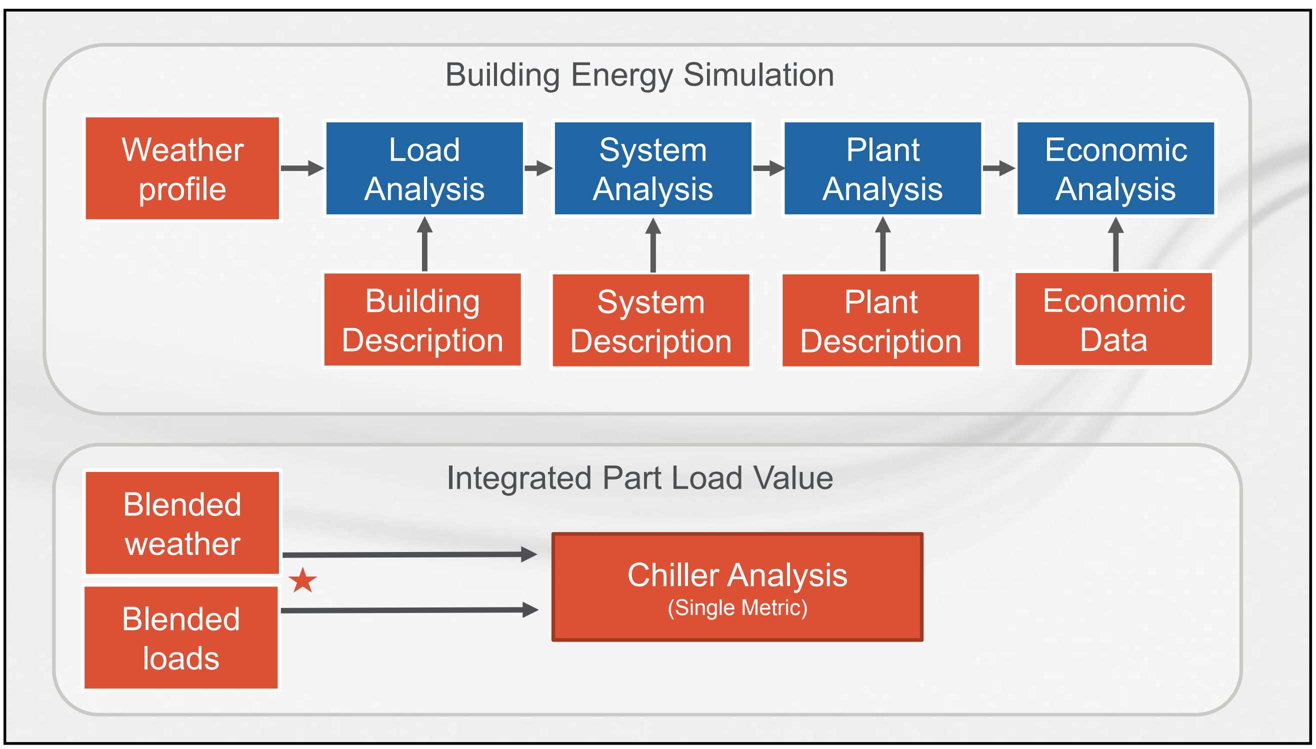
Annual $ = EFLH x Peak Tons x Full Load kW/ton x $/kWh

Where do you find EFLH?



- Google? ***No***
- Wiki? ***No***
- App? ***No***
- Trane Air Conditional Manual? ***Not really…***
- 1985 ASHRAE Handbook? ***Not by building type…***


Integrated Part Load Value (IPLV)
AHRI Conditions:
Chilled Water: 44°F
2.4 GPM/Ton
Condenser Water:
3 GPM/Ton
Temperatures:
Expected Entering Tower Water
1
1% + 42% + 45% + 12%
.58 .50 .40 .30
= 0.42
A = kW/Ton @ 85ºF @ 100% Load
B = kW/Ton @ 75ºF @ 75% Load
C = kW/Ton @ 65ºF @ 50% Load
D = kW/Ton @ 65ºF @ 25% Load


Building Energy Simulation
Weather profile
Load Analysis
System Analysis
Plant Analysis
Economic Analysis
Building Description
System Description
Plant Description
Economic Data
Integrated Part Load Value
Blended weather
Blended loads
Chiller Analysis
(Single Metric)

IPLV

$$\frac{1}{\frac{1\%}{.58} + \frac{42\%}{.50} + \frac{45\%}{.40} + \frac{12\%}{.30}} = 0.42$$

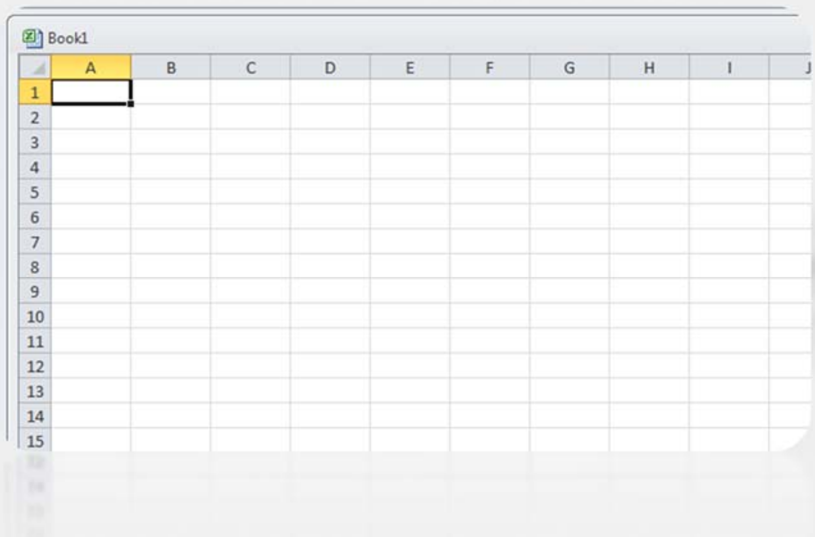
Energy Analysis

$$Annual\ \$ = IPLV\ x\ Peak\ Load\ x\ \ E.F.L.H\ x\ \frac{\$}{kwh}$$

Issues IPLV

- Weighted, but…
- Uses combined utility rates
- What do we multiply by?

Spreadsheet



Spreadsheets

Dry Bulb	Load	Wet Bulb	# Hours	Tower Approach
90-95	100			
85-90	90			
80-85	80			
75-80	70			Hard to get right
70-75	60			
65-70	50			
60-65	40			

Accurate

Three essential components for forward modeling

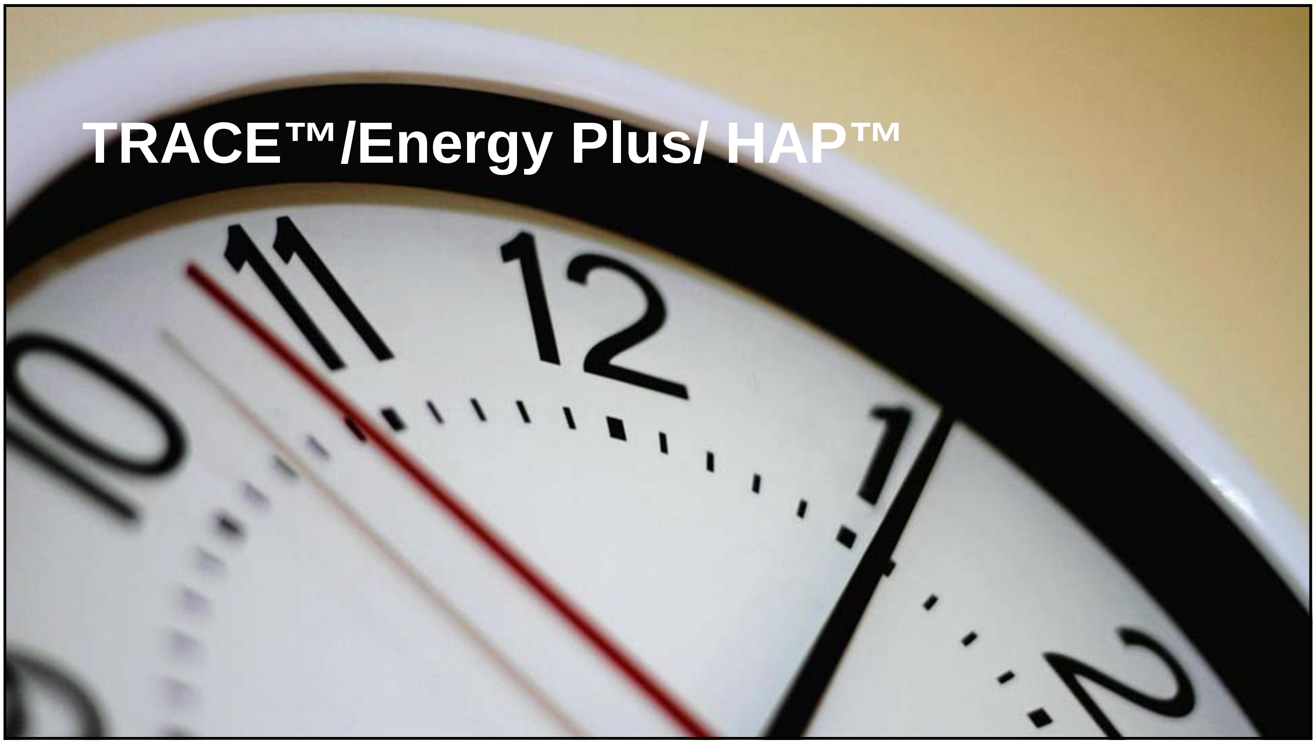
- **Input variables**
  - Weather
  - Building type/load
  - Utilization schedule
  - Economizers
  - Optimization controls
  - Utility rate (actual)
  - Chiller performance
  - Chiller pump/tower energy use
- **System structure and parameters**
- **Output**

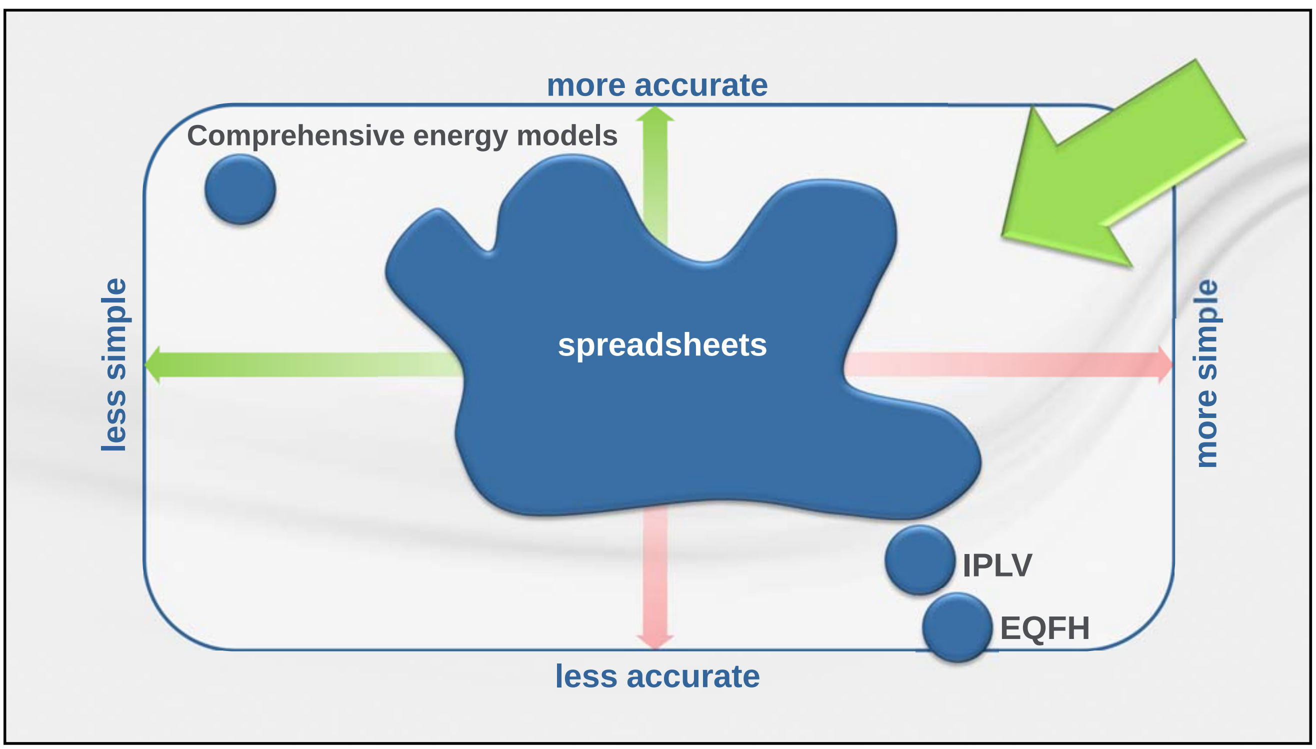
Calculation engine

- **ANSI/ASHRAE Standard 140: Standard method of test for the evaluation of building energy analysis computer programs**

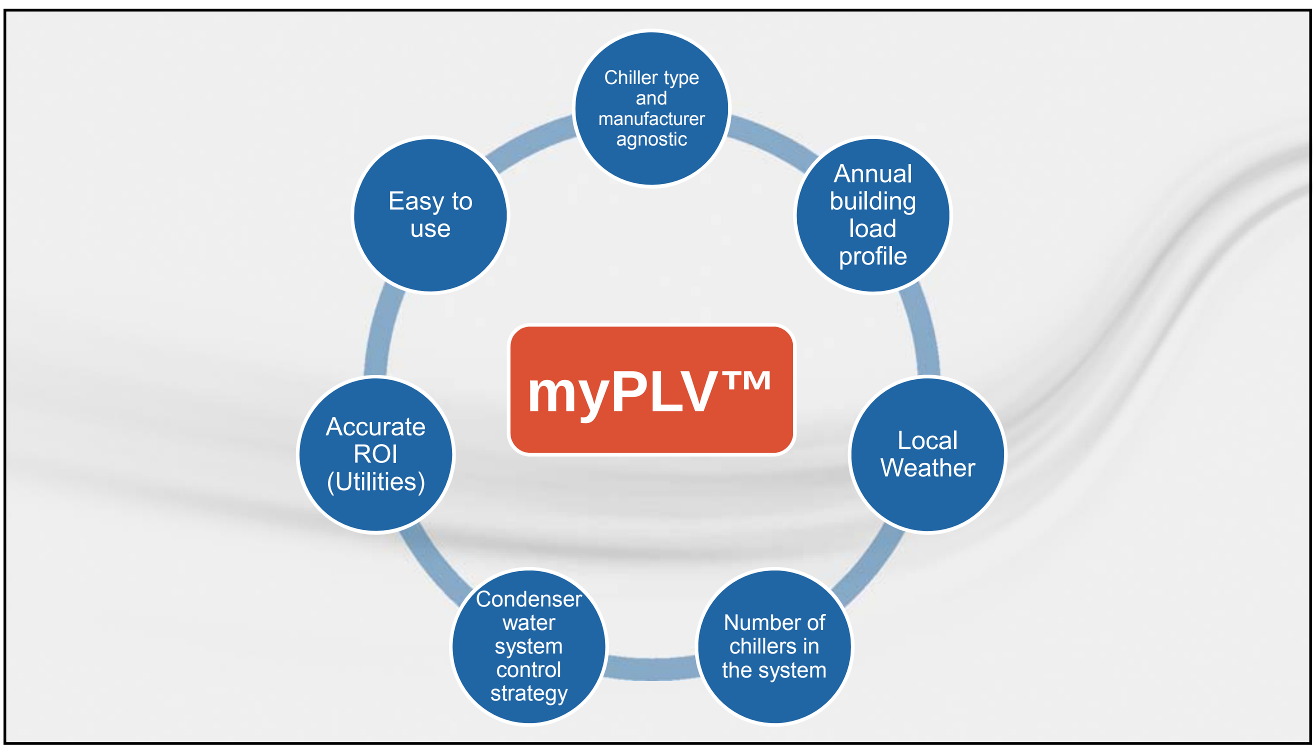
Source: ASHRAE Handbook 2013 – Fundamentals
ASHRAE Standard 140
Building Energy Software Tools at IBPSA-USA

TRACE™ 700


TRACE™/Energy Plus/ HAP™


more accurate
Comprehensive energy models
less simple
spreadsheets
more simple
IPLV
EQFH
less accurate


Agenda
• What makes an accurate model
• Various analysis tools available
• Pros and cons
• Chiller performance analysis example


myPLV™
Chiller type and manufacturer agnostic
Annual building load profile
Local Weather
Number of chillers in the system
Condenser water system control strategy
Accurate ROI (Utilities)
Easy to use

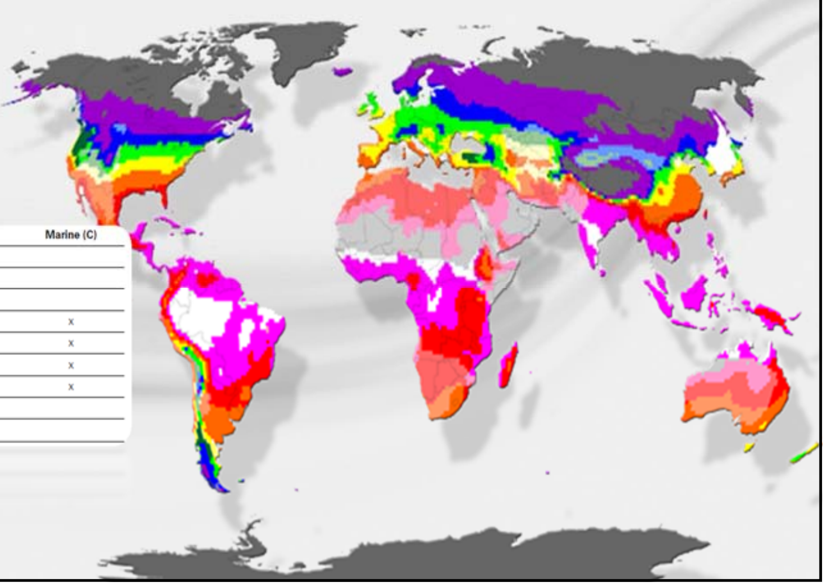
myPLV

- Measure
- Region/country/state/city
- Custom load profile

Location

- Global Locations
- 8760 TMY Weather
- Condenser Control

Zone	Cold	Humid (A)	Dry (B)	Marine (C)
0		x	x	
1		x	x	
2		x	x	
3		x	x	x
4		x	x	x
5		x	x	x
6		x		x
7	x			
8	x			

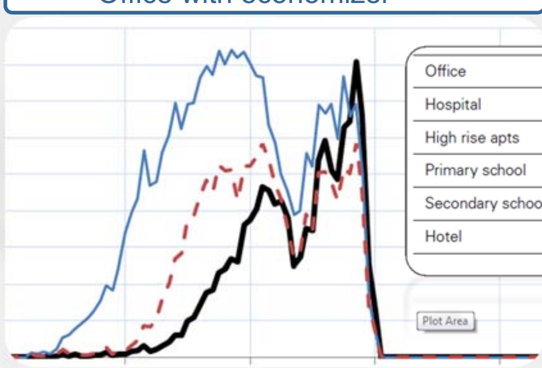


myPLV

- Load profiles
- Chiller type
- Peak load
- Number of chillers
- Size of each chiller

Load Profiles

Office with economizer



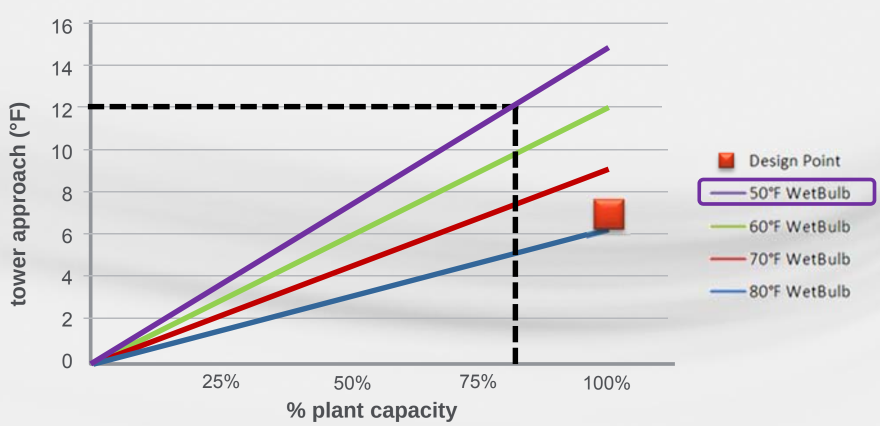
Office	(with, without econ)	12 hour operation; 5 days a week
Hospital	(with, without econ)	24 hour operation; 7 days a week; heavier day occupancy
High rise apts	(without econ)	24 hour operation; 7 days a week; lighter day occupancy
Primary school	(with, without econ)	12 hour operation; 5 days a week; seasonal
Secondary school	(with, without econ)	12 hour operation; 5 days a week; seasonal
Hotel	(without econ)	24 hour operation; 7 days a week

myPLV

- Tower control

Tower Control

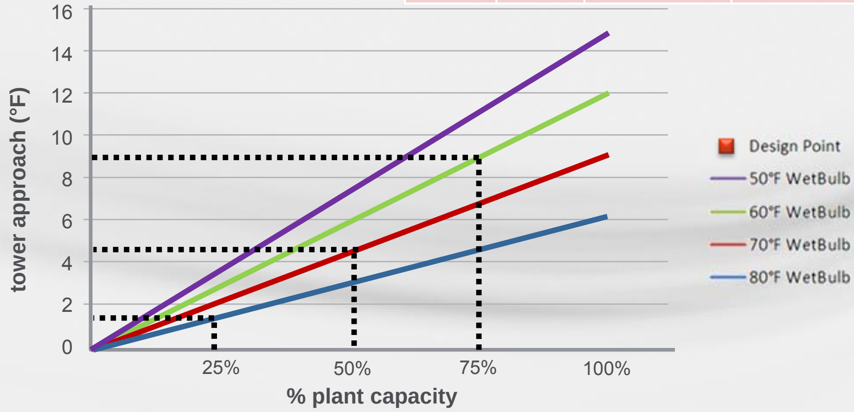
Full Tower Fan Flow



Tower Control

Fixed temperature: Setpoint 70º F

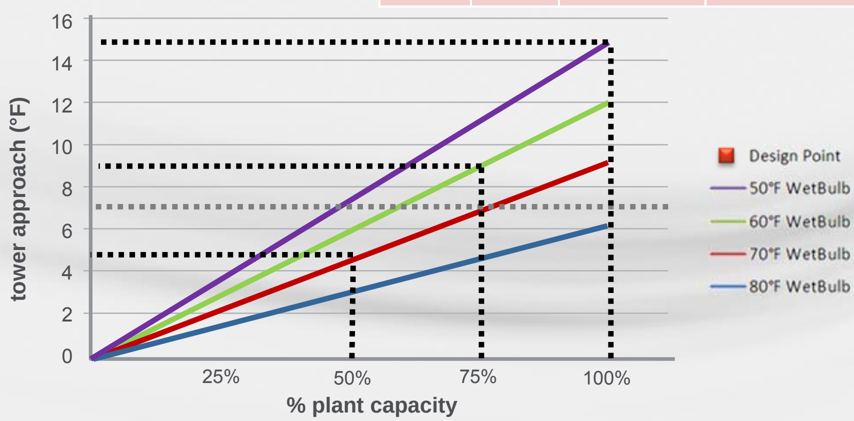
Hour	Load	Wet Bulb	Approach	Calc ECWT	ECWT
1	75	60	9	69	70
2	50	70	4.5	74.5	74.5
3	25	80	1.5	81.5	81.5



Tower Control

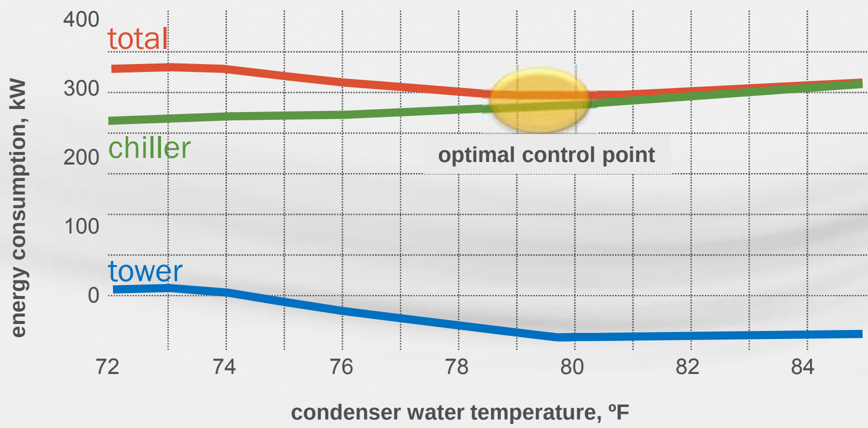
Fixed approach = 7º F

Hour	Load	Wet Bulb	Calc Approach	Approach	ECWT
1	100	50	15	15	65
2	75	60	9	9	69
3	50	70	5	7	77



Tower Control

Chiller tower optimization



myPLV

- myPLV inputs
- Weightings
- ECWT
- Ton-hrs

myPLV

- Bid Form

myPLV

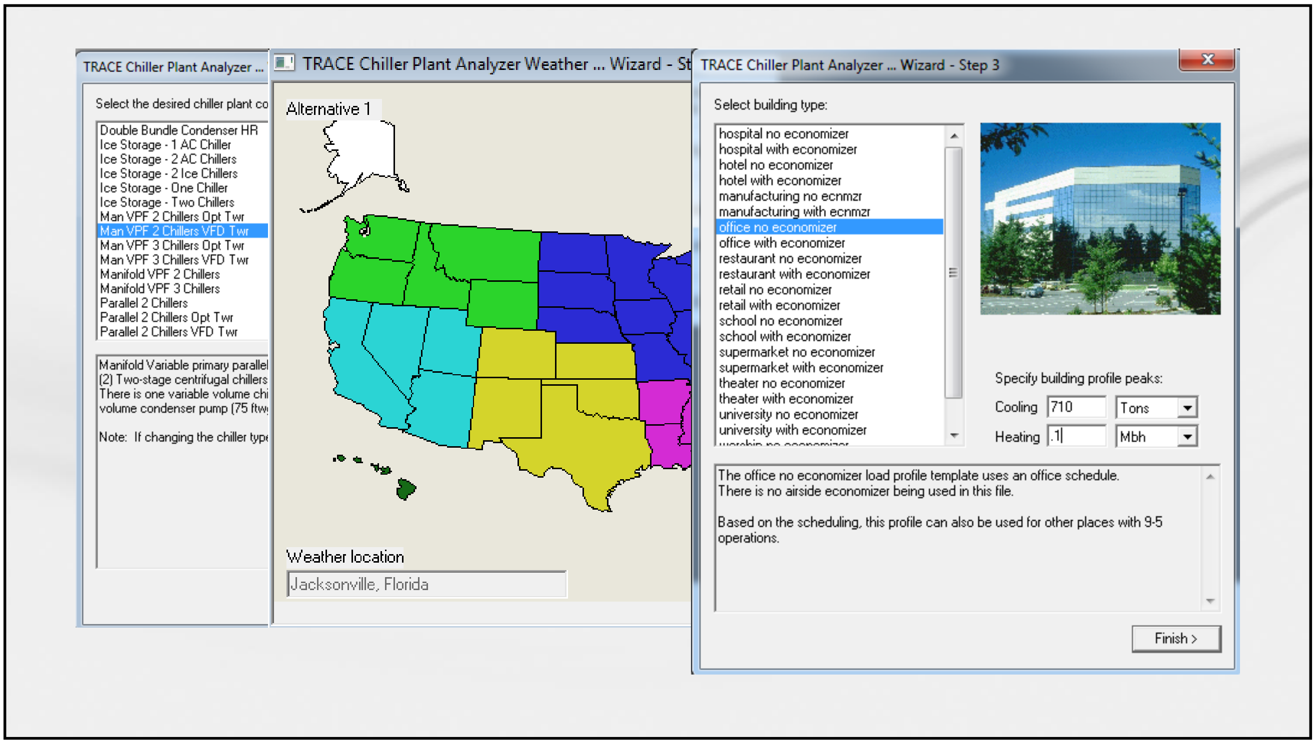
- Charts

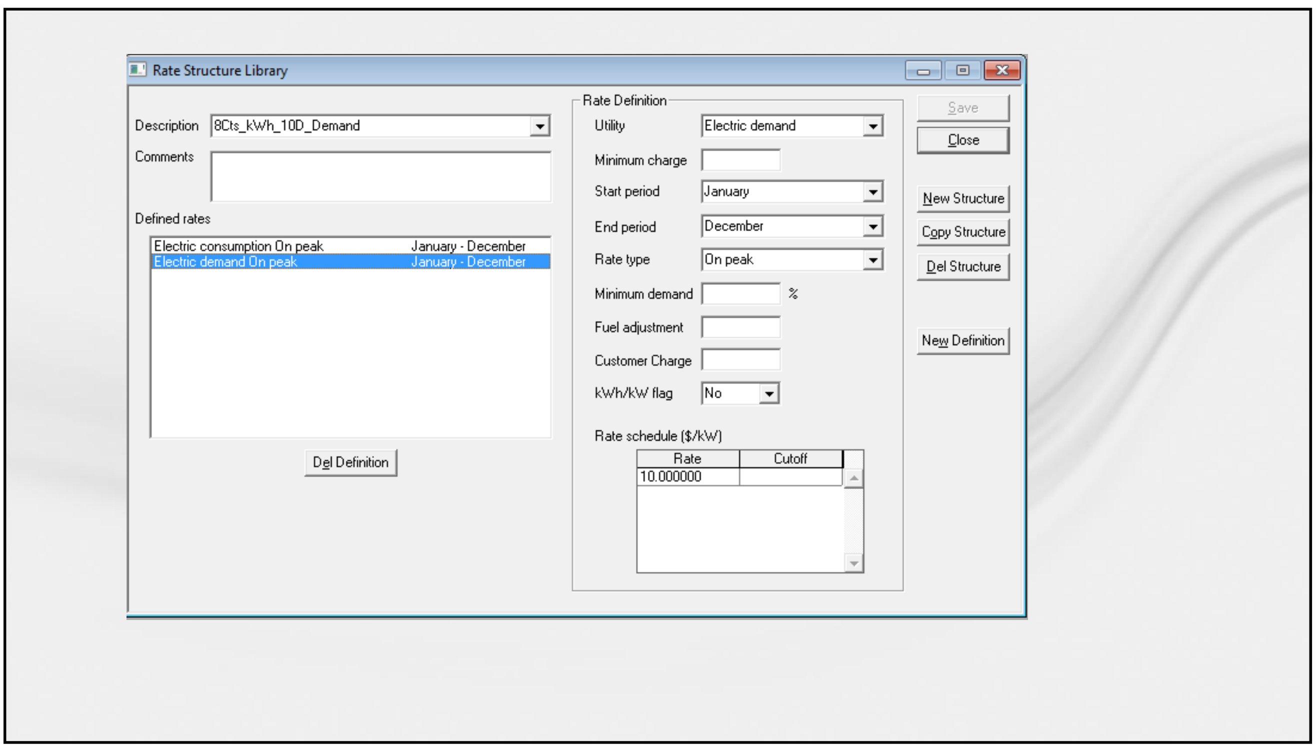
myPLV Benefits

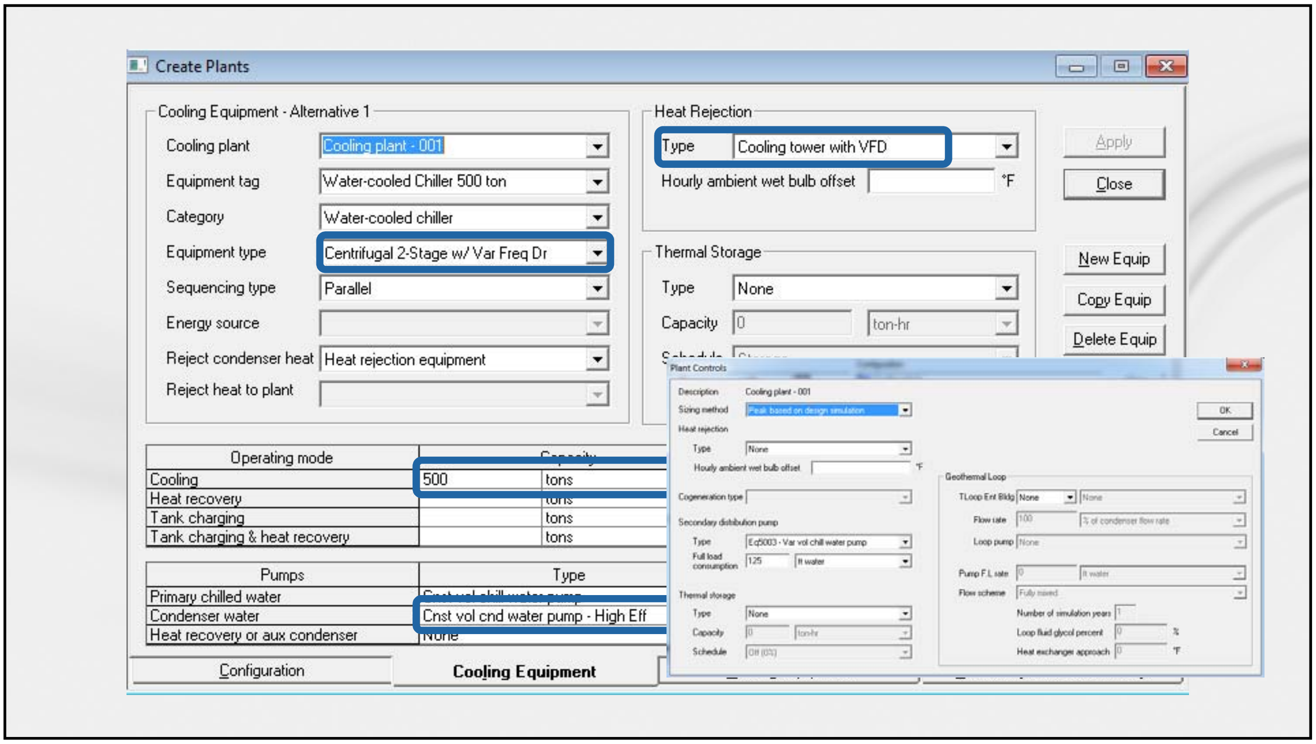
- Third-party load profiles
  - Building type
  - Location
  - Economizer use
- Demand and consumption charges
- Number of chillers
- **Calculates the ton-hours**
- Tower control
- Manufacturer agnostic

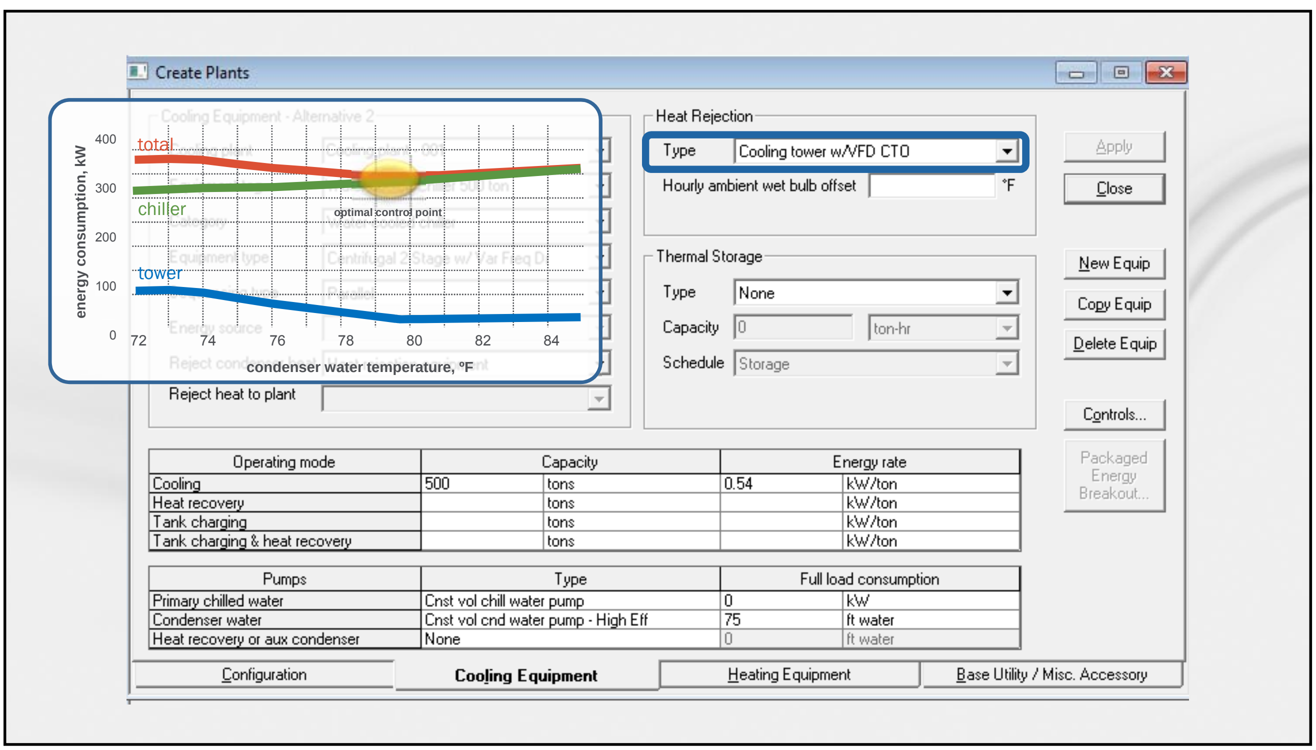
myPLV Drawbacks

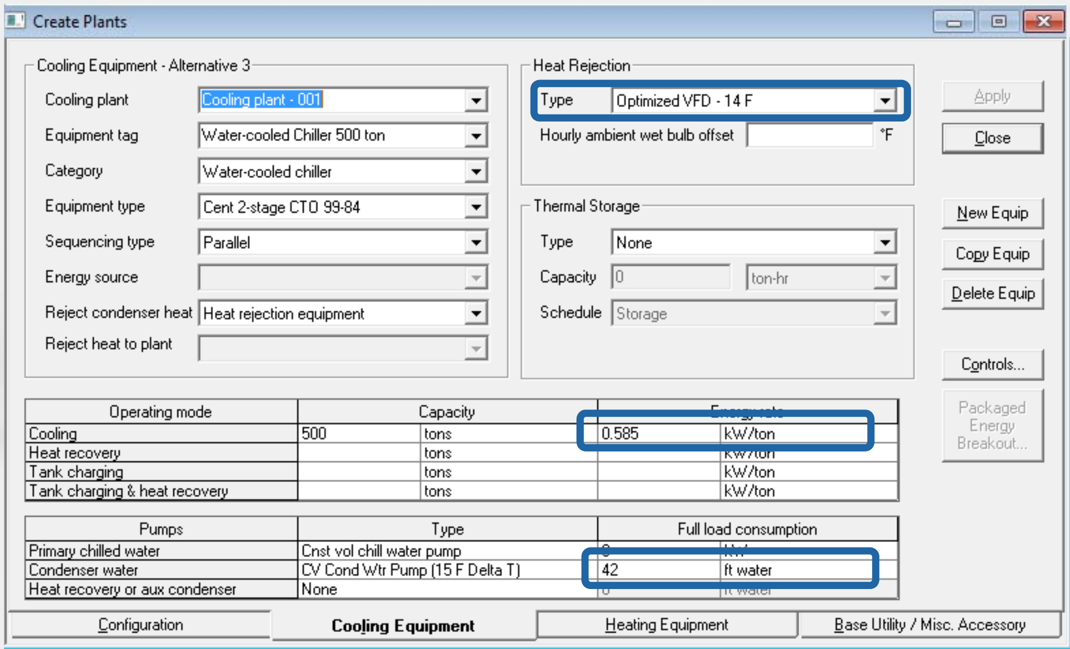
- Not for system comparison


TRACE Chiller Plant Analyzer ...
Select the desired chiller plant co
Double Bundle Condenser HR
Ice Storage - 1 AC Chiller
Ice Storage - 2 AC Chillers
Ice Storage - 2 Ice Chillers
Ice Storage - One Chiller
Ice Storage - Two Chillers
Man VPF 2 Chillers Opt Twr
Man VPF 2 Chillers VFD Twr
Man VPF 3 Chillers Opt Twr
Man VPF 3 Chillers VFD Twr
Manifold VPF 2 Chillers
Manifold VPF 3 Chillers
Parallel 2 Chillers
Parallel 2 Chillers Opt Twr
Parallel 2 Chillers VFD Twr
Manifold Variable primary parallel
(2) Two-stage centrifugal chillers
There is one variable volume chi
volume condenser pump (75 ftw
Note: If changing the chiller type
TRACE Chiller Plant Analyzer Weather ... Wizard - St
Alternative 1
Weather location
Jacksonville, Florida
TRACE Chiller Plant Analyzer ... Wizard - Step 3
Select building type:
hospital no economizer
hospital with economizer
hotel no economizer
hotel with economizer
manufacturing no ecnmzr
manufacturing with ecnmzr
office no economizer
office with economizer
restaurant no economizer
restaurant with economizer
retail no economizer
retail with economizer
school no economizer
school with economizer
supermarket no economizer
supermarket with economizer
theater no economizer
theater with economizer
university no economizer
university with economizer
Specify building profile peaks:
Cooling 710 Tons
Heating .1 Mbh
The office no economizer load profile template uses an office schedule.
There is no airside economizer being used in this file.
Based on the scheduling, this profile can also be used for other places with 9-5 operations.
Finish >


Rate Structure Library
Description 8Cts_kWh_10D_Demand
Comments
Defined rates
Electric consumption On peak January - December
Electric demand On peak January - December
Del Definition
Rate Definition
Utility Electric demand
Minimum charge
Start period January
End period December
Rate type On peak
Minimum demand %
Fuel adjustment
Customer Charge
kWh/kW flag No
Rate schedule ($/kW)
Rate Cutoff
10.000000
Save
Close
New Structure
Copy Structure
Del Structure
New Definition


Create Plants
Cooling Equipment - Alternative 1
Cooling plant Cooling plant - 001
Equipment tag Water-cooled Chiller 500 ton
Category Water-cooled chiller
Equipment type Centrifugal 2-Stage w/ Var Freq Dr
Sequencing type Parallel
Energy source
Reject condenser heat Heat rejection equipment
Reject heat to plant
Heat Rejection
Type Cooling tower with VFD
Hourly ambient wet bulb offset °F
Thermal Storage
Type None
Capacity 0 ton-hr
Apply
Close
New Equip
Copy Equip
Delete Equip
Operating mode Capacity
Cooling 500 tons
Heat recovery tons
Tank charging tons
Tank charging & heat recovery tons
Pumps Type
Primary chilled water Cnst vol chill water pump
Condenser water Cnst vol cnd water pump - High Eff
Heat recovery or aux condenser None
Configuration
Cooling Equipment
Plant Controls
OK
Cancel


Create Plants
energy consumption, kW
400
300
200
100
0
total
chiller
tower
optimal control point
72 74 76 78 80 82 84
condenser water temperature, °F
Reject heat to plant
Heat Rejection
Type Cooling tower w/VFD CTO
Hourly ambient wet bulb offset °F
Thermal Storage
Type None
Capacity 0 ton-hr
Schedule Storage
Apply
Close
New Equip
Copy Equip
Delete Equip
Controls...
Packaged Energy Breakout...
Operating mode Capacity Energy rate
Cooling 500 tons 0.54 kW/ton
Heat recovery tons kW/ton
Tank charging tons kW/ton
Tank charging & heat recovery tons kW/ton
Pumps Type Full load consumption
Primary chilled water Cnst vol chill water pump 0 kW
Condenser water Cnst vol cnd water pump - High Eff 75 ft water
Heat recovery or aux condenser None 0 ft water
Configuration
Cooling Equipment
Heating Equipment
Base Utility / Misc. Accessory



myPLV vs NPLV

710 ton Office with two 500-ton WC chillers with AFDs
Tower control = Fixed temp 55°F

Load	Jacksonville		Wash DC		Grand Rapids		Calgary	
Tons	Weight	ECWT	Weight	ECWT	Weight	ECWT	Weight	ECWT
125	11.3	64.2	25.6	62.8	22.9	64.7	30.0	61.3
250	42.8	76.9	35.8	75.1	38.3	73.1	34.0	68.8
375	33.6	79.4	28.2	78.2	29.8	75.9	27.0	73.0
470	12.3	82.3	10.4	80.1	9.0	79.5	9.0	76.1
Ton-hrs	1,434,230		797,333		582,672		372,684	

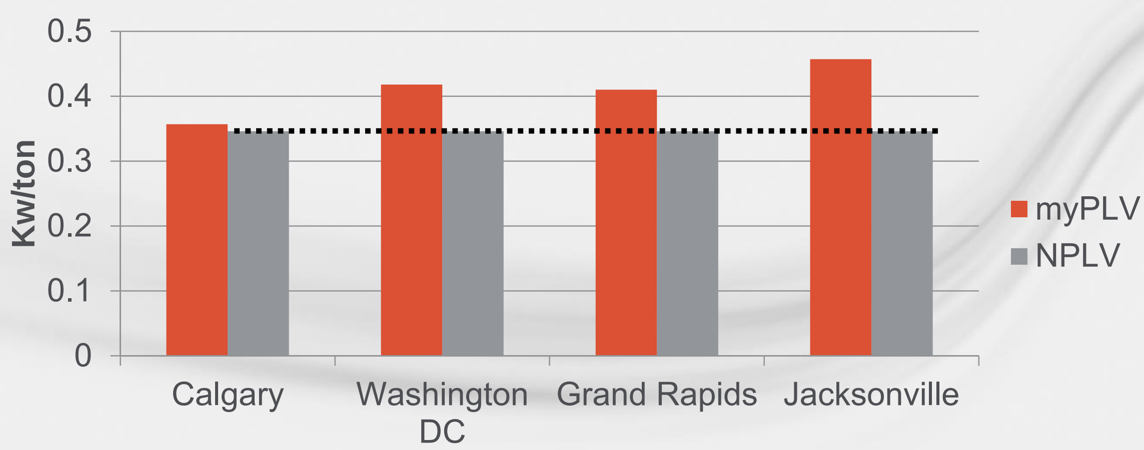
myPLV vs NPLV

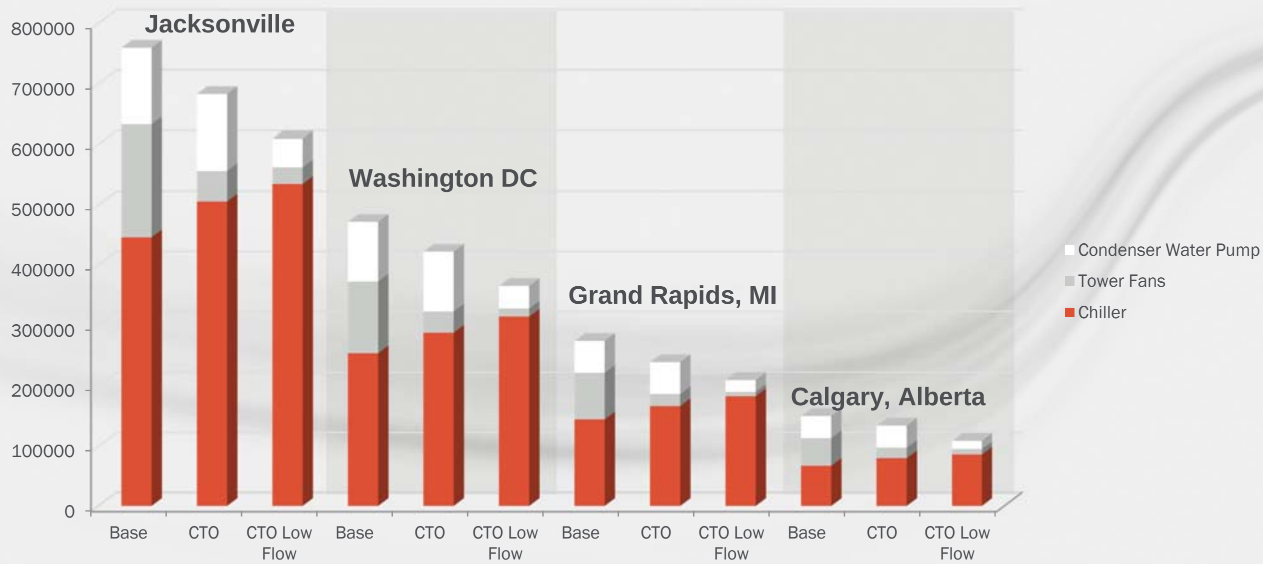
710 ton Office with two 500-ton WC chillers with AFDs
Tower control = Fixed temp 55°F

Load	Jacksonville		Wash DC		Grand Rapids		Calgary	
Tons	Weight	ECWT	Weight	ECWT	Weight	ECWT	Weight	ECWT
125	11.3	64.2	25.6	62.8	22.9	64.7	30.0	61.3
250	42.8	76.9	35.8	75.1	38.3	73.1	34.0	68.8
375	33.6	79.4	28.2	78.2	29.8	75.9	27.0	73.0
470	12.3	82.3	10.4	80.1	9.0	79.5	9.0	76.1
Ton-hrs	1,434,230		797,333		582,672		372,684	
myPLV	**0.457**		**0.418**		**0.410**		**0.357**	
NPLV	**0.346**							

myPLV vs NPLV

710 ton office with 2 x 500 ton chillers





Coefficient of Performance

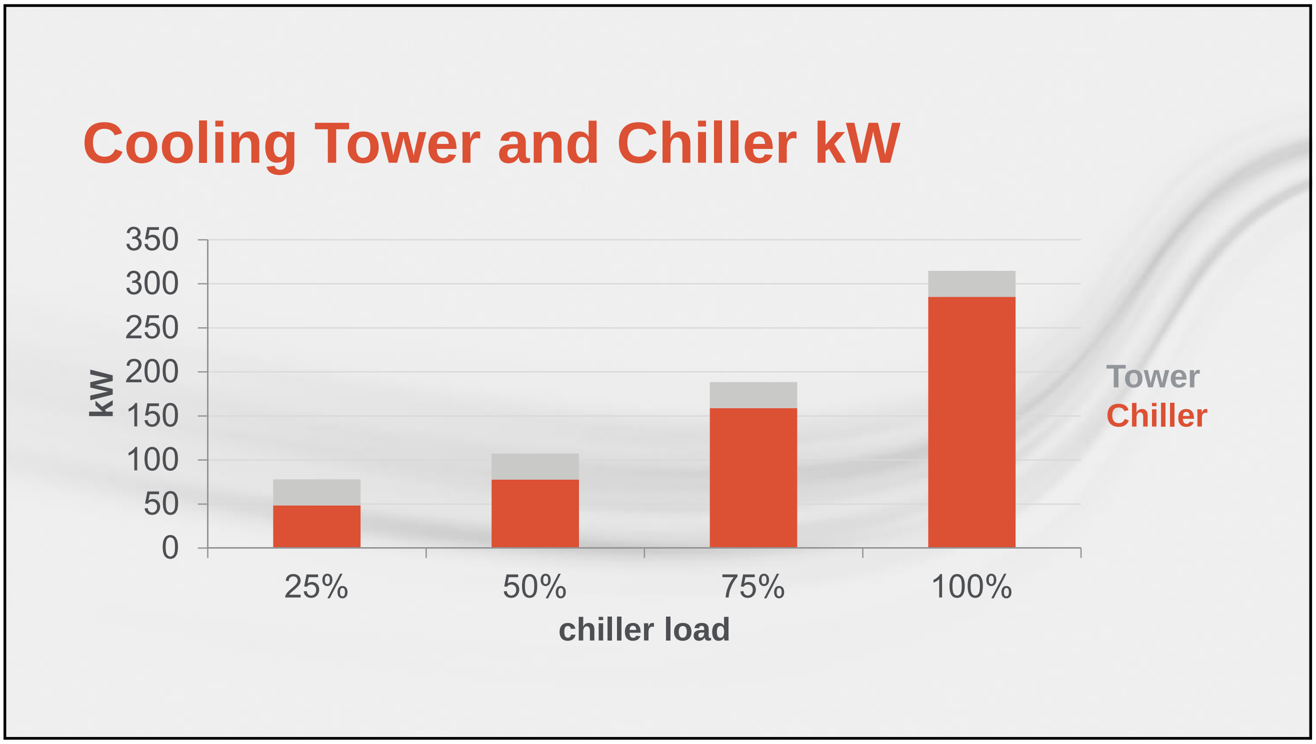
COP = Useful work out/power in

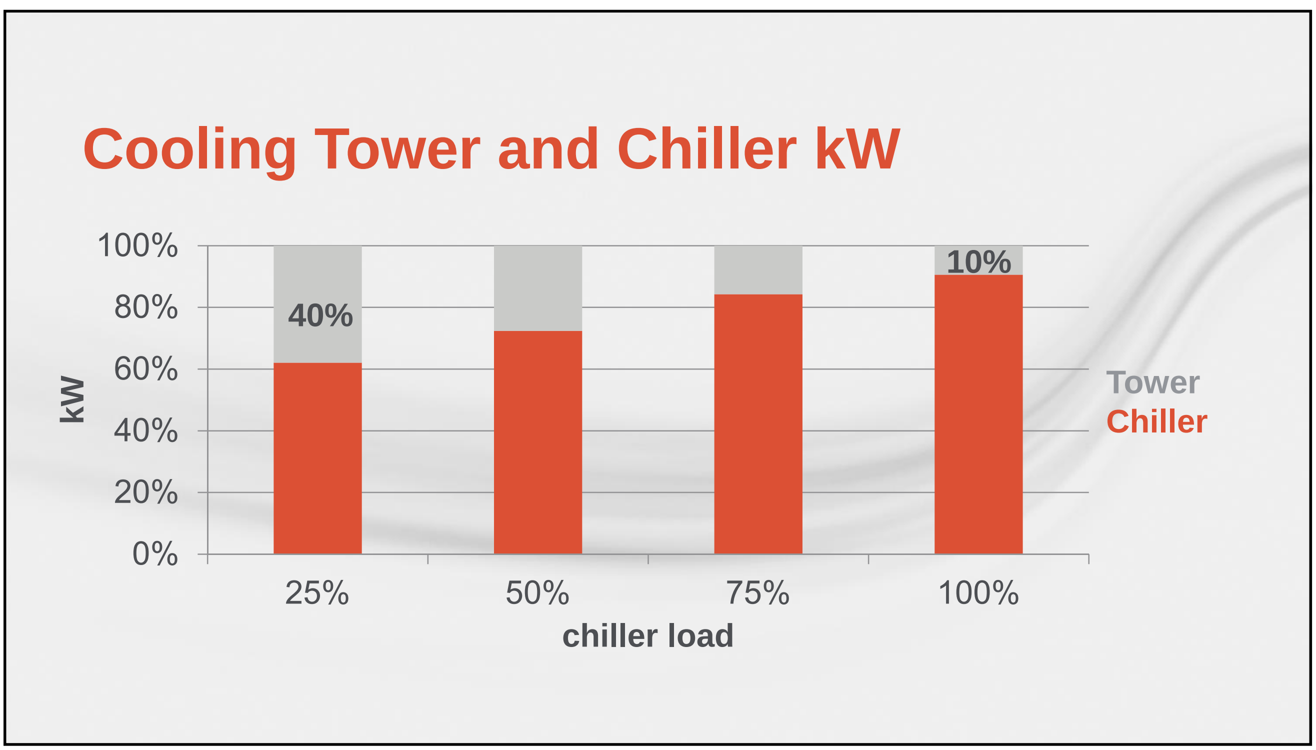
Chiller

- COP = 3.516 / (kW/ton)
- kW/ton = 0.580
  - COP = 3.516 / 0.580
  - COP = 6.06

Pump

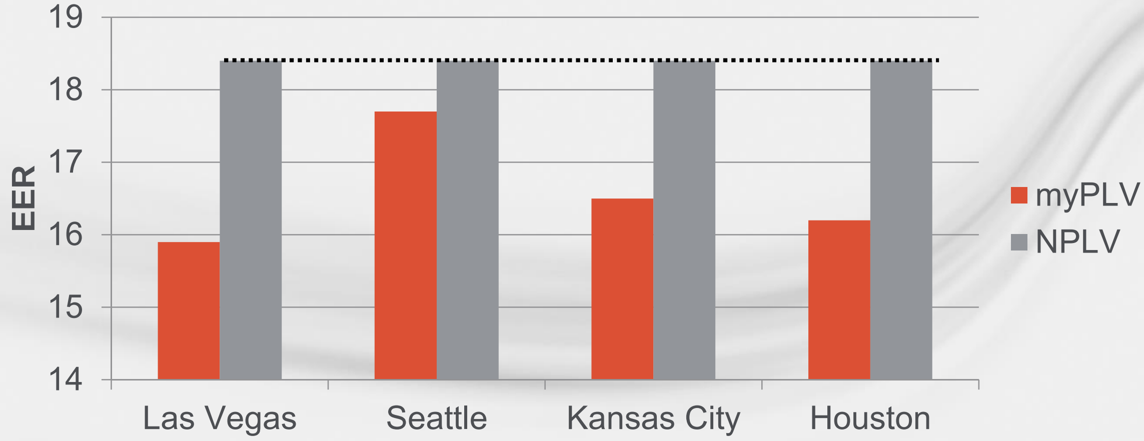
- COP = Efficiency
- Efficiency = 70%
  - COP = 0.70


Cooling Tower and Chiller kW
350
300
250
200
150
100
50
0
kW
25%
50%
75%
100%
chiller load
Tower
Chiller


Cooling Tower and Chiller kW
100%
80%
60%
40%
20%
0%
kW
40%
10%
25%
50%
75%
100%
chiller load
Tower
Chiller

myPLV vs NPLV

400-ton School with two 200-ton AC chillers



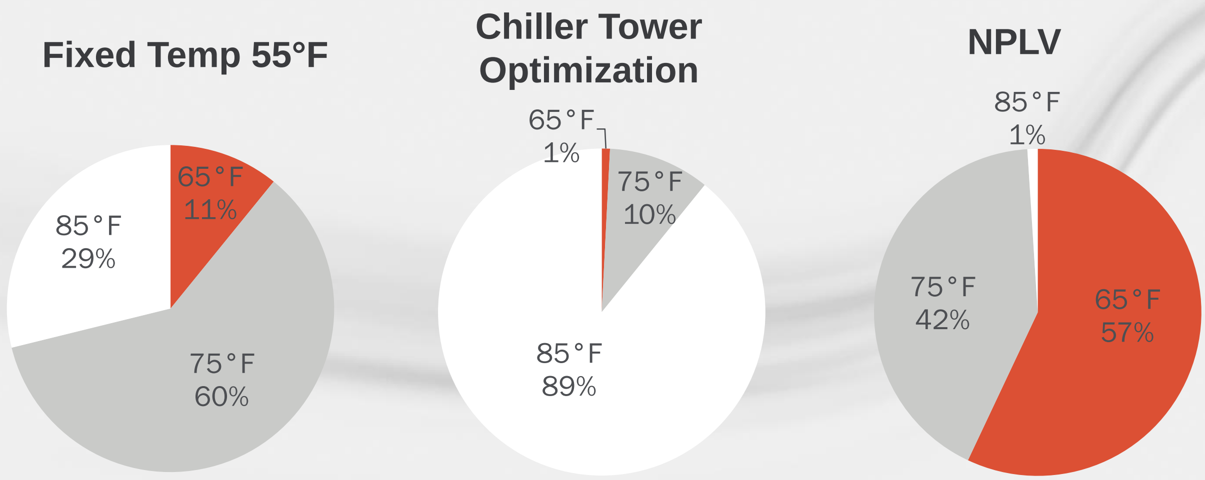
High School

VPF Series

- Lower installed cost
- Lower operating cost
- Simpler control

Tower Control

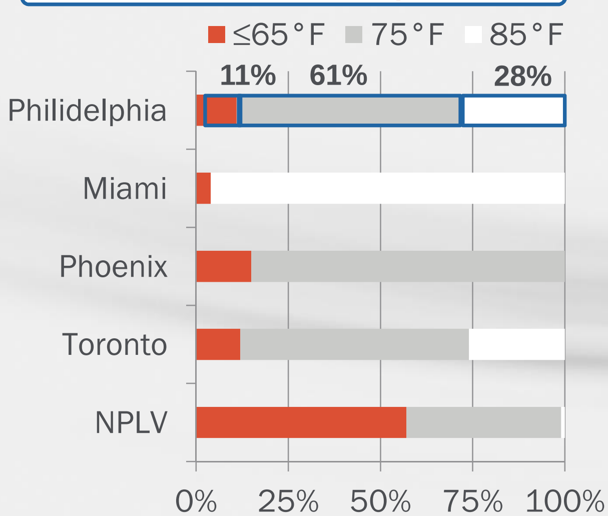
2000-ton Hospital with three 700-ton WC chillers

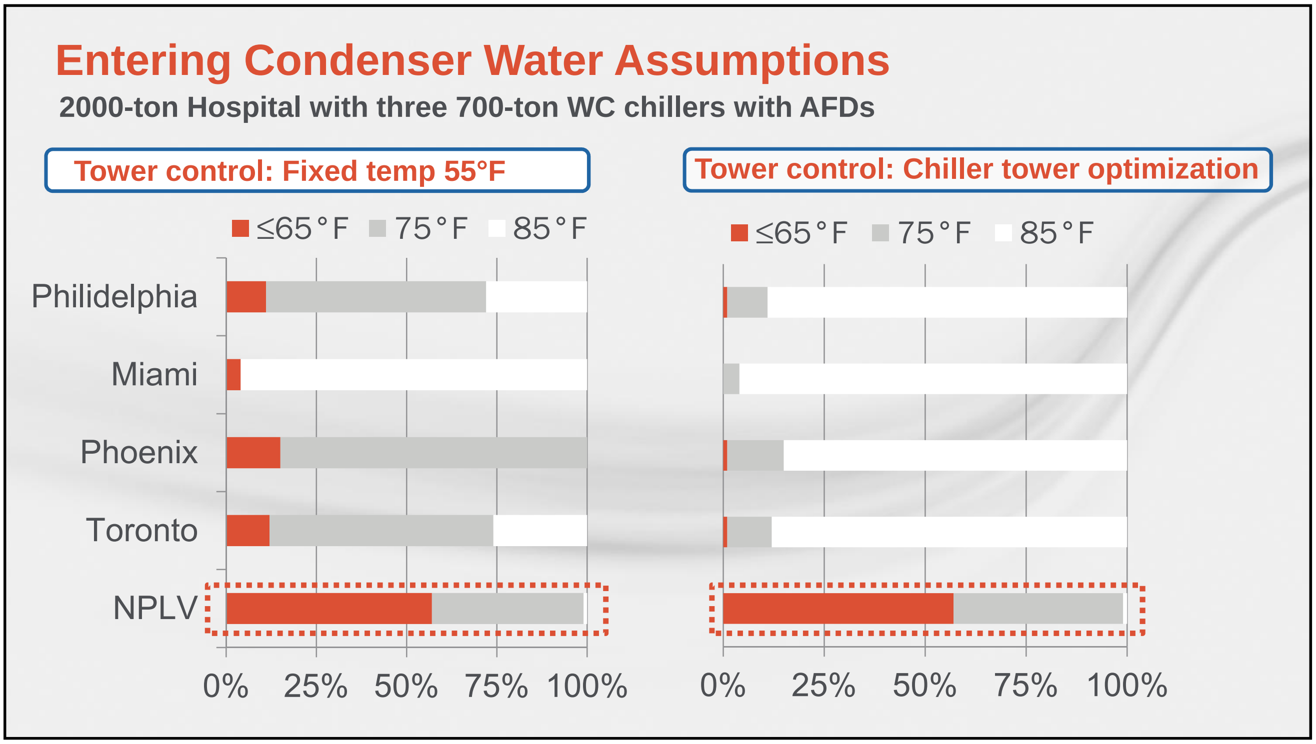


Entering Condenser Water Assumptions

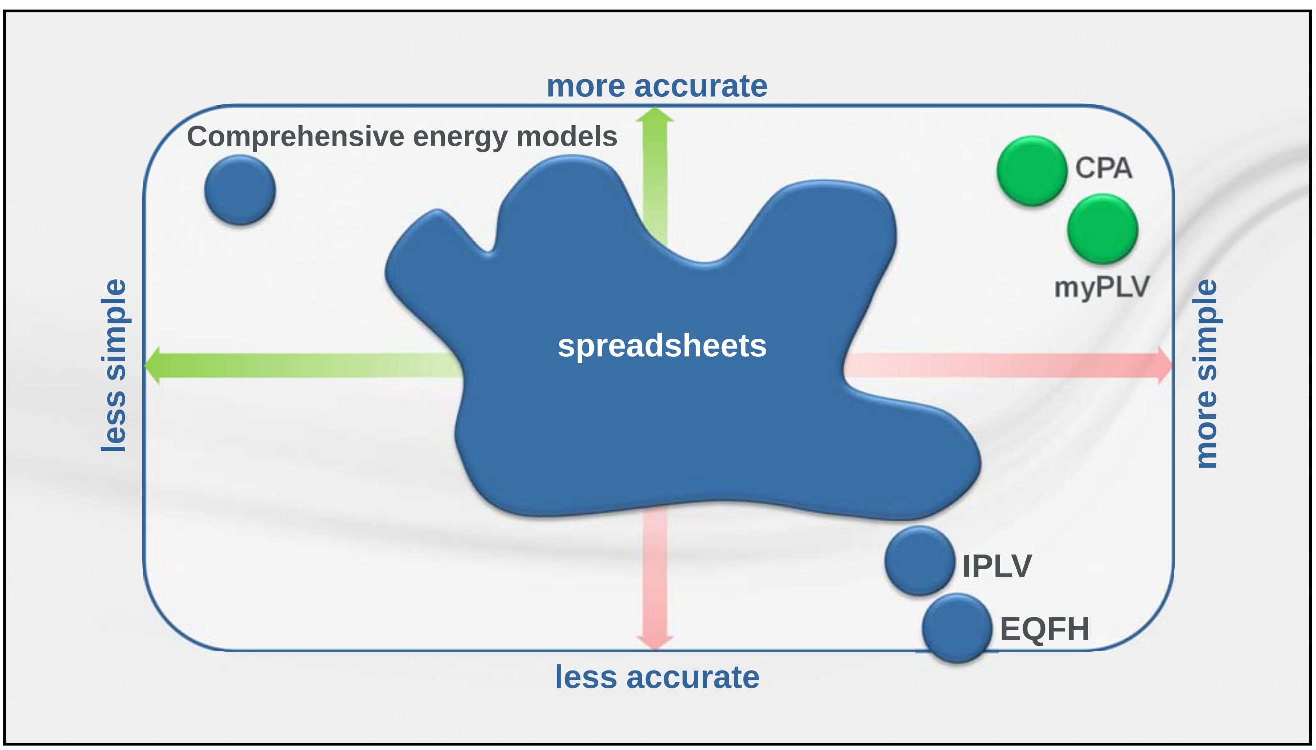
2000-ton Hospital with three 700-ton WC chillers with AFDs

Tower control: Fixed temp 55°F





Entering Condenser Water Assumptions
2000-ton Hospital with three 700-ton WC chillers with AFDs
Tower control: Fixed temp 55°F
Tower control: Chiller tower optimization
≤65°F 75°F 85°F
≤65°F 75°F 85°F
Philidelphia
Miami
Phoenix
Toronto
NPLV
0% 25% 50% 75% 100%
0% 25% 50% 75% 100%



more accurate
Comprehensive energy models
CPA
myPLV
spreadsheets
less simple
more simple
IPLV
EQFH
less accurate

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APP-CMC057-EN QUIZ

1) Should weather data and building type load be considered as part of the energy analysis?
   a. True
   b. False

2) According to IPLV Appendix D, which of the following factors had not been considered?
   a. a. actual weather data
   b. b. building load characteristics
   c. c. operational hours
   d. d. economizer capabilities
   e. e. pumps and cooling towers
   f. f. all of the above

3) Why choose Energy modeling software over IPLV or Equivalent Full Load Hours?
   a. a. LEED compliance
   b. b. Energy Policy Act
   c. c. Owner's requirement
   d. d. Local code requirement
   e. e. all of the above

4) IPLV Stands for Isometric Part Load Value.
   a. True
   b. False

5) What weighting does IPLV give to the 100% Load and 85 Entering Condenser Water bucket?
   a. 1%
   b. 10%
   c. 55%
   d. 99%

6) How many cooling tower control strategies are included in myPLV for water-cooled chillers?
   a. 1
   b. 2
   c. 3
   d. 4

Bibliography

March 2016

DIY Chiller Plant Performance Modeling: Easy and Easier

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Helical Rotary Water Chillers (1999) TRG-TRC012-EN.
Centrifugal Water Chillers (1999) TRG-TRC010-EN

Analysis Software (trial versions available for download)

Trane Air-Conditioning and Economics (TRACE™ 700). Available at www.trane.com/TRACE
Trane myPLV™ chiller performance evaluation tool available at www.trane.com/myplv
Trane Chiller Plant Analyzer evaluation tool available at www.traneCDS.com (see Analysis Tools)

Product Information

Optimus™ Chiller Model RTHD: Sales Brochure: RLC-SLB031-EN**,** Catalog: RLC-PRC020F-EN
Stealth™ Chiller Model RTAE: Sales Brochure: RLC-SLB026-EN**,** Catalog: RLC-PRC042D-EN
Sintesis™ Chiller Model RTAF: Sales Brochure: RLC-SLB036-EN**,** Catalog: RLC-PRC049-EN
EarthWise™ CenTraVac™ Chillers: Brochures: CTV-SLB026-EN, CTV-SLB041-EN, CTV-SLB042-EN, Catalog: CTV-PRC007L-EN (120-3950 ton, 50 and 60 Hz), AFDJ-PRC001-EN (AFD with Tracer™ AdaptiView™)