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Webinar Series

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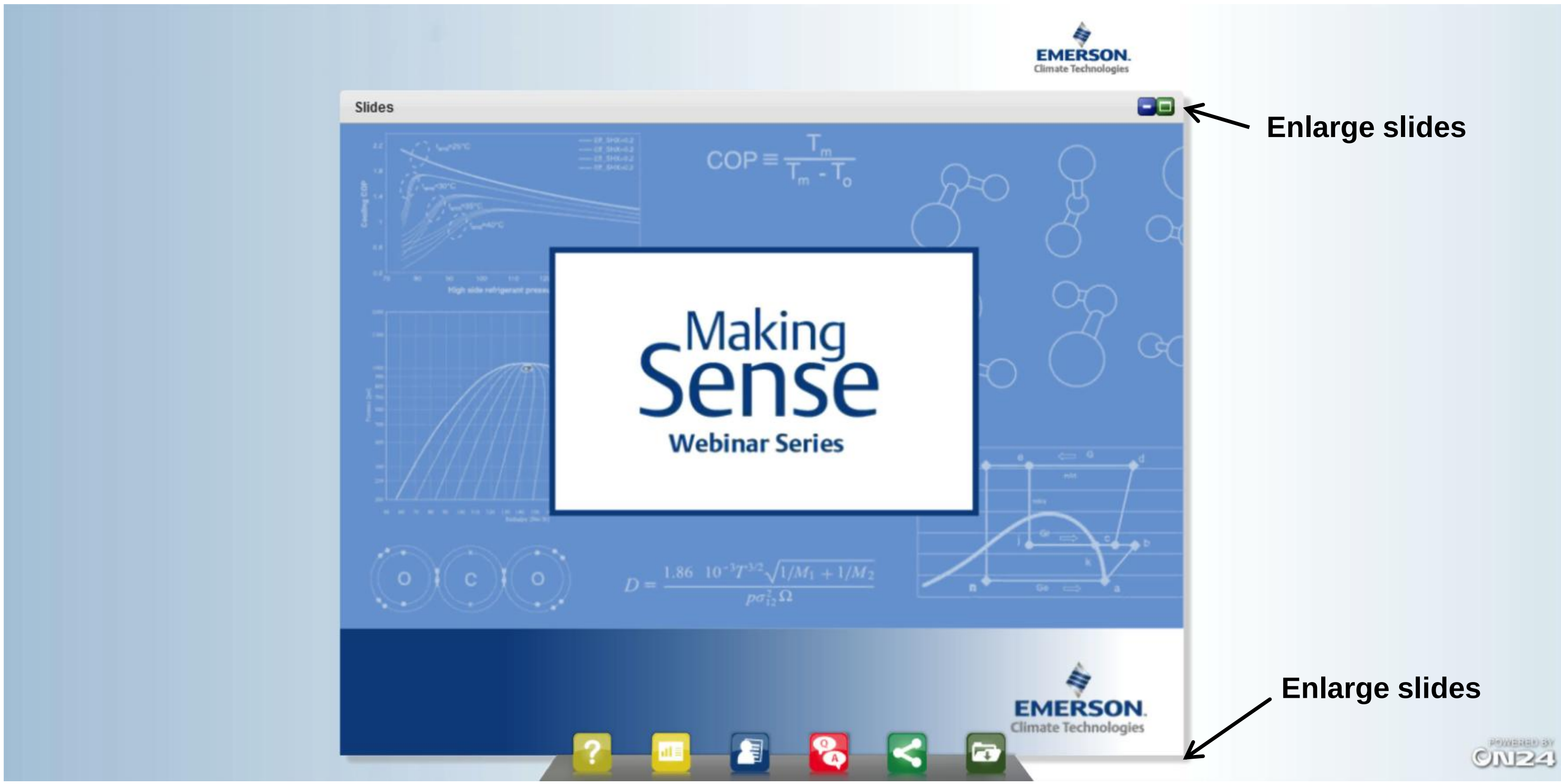

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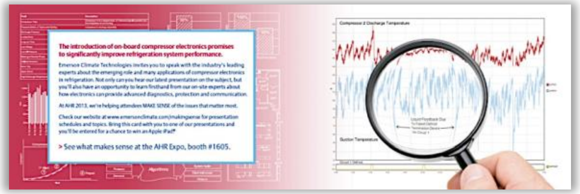
Making Sense Webinars

Emerson and Our Partners Giving Insight on the Three Most Important Issues in Refrigeration

We're Making Sense of the promising role of **new refrigerants.**

We're Making Sense of **energy reduction** technologies.

We're Making Sense of the application of electronics to improve **operational visibility.**



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of the application of electronics to improve **operational visibility.**

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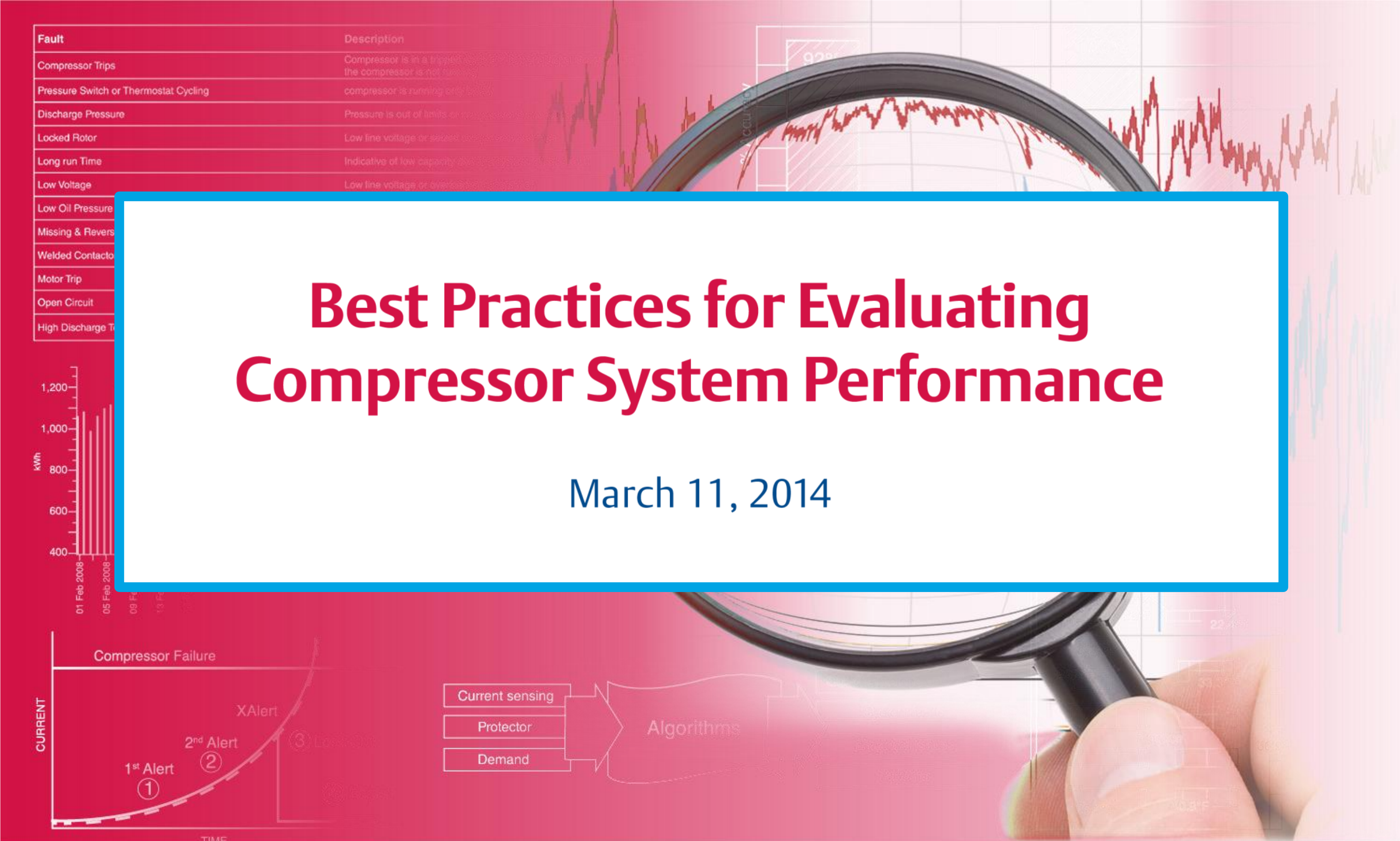


Best Practices for Evaluating Compressor System Performance

March 11, 2014

Presented By:

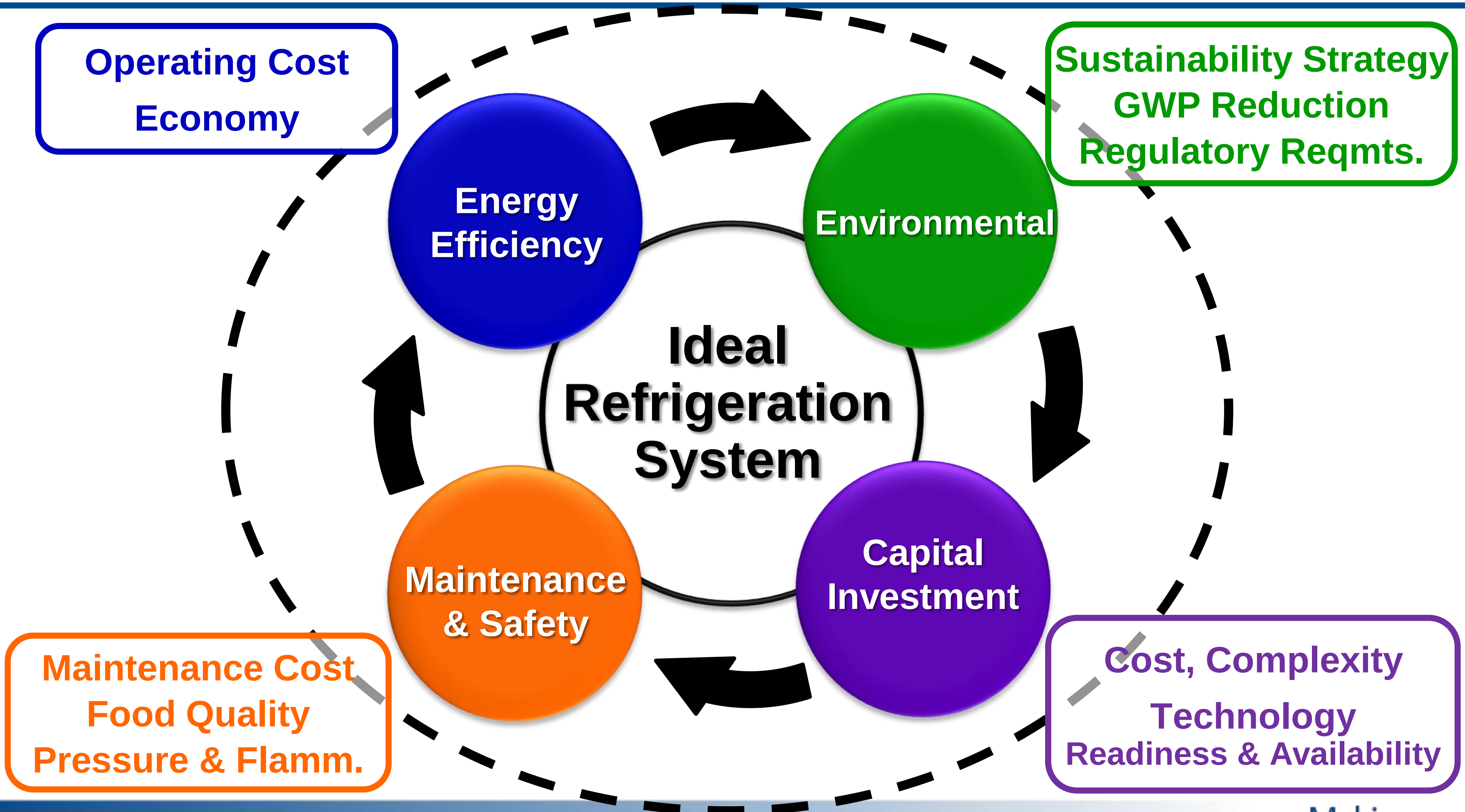
Mike Saunders
Director of End User Technical Sales and Support
Emerson Climate Technologies

Autumn Nicholson
Senior Sales Engineer
Emerson Climate Technologies

Agenda

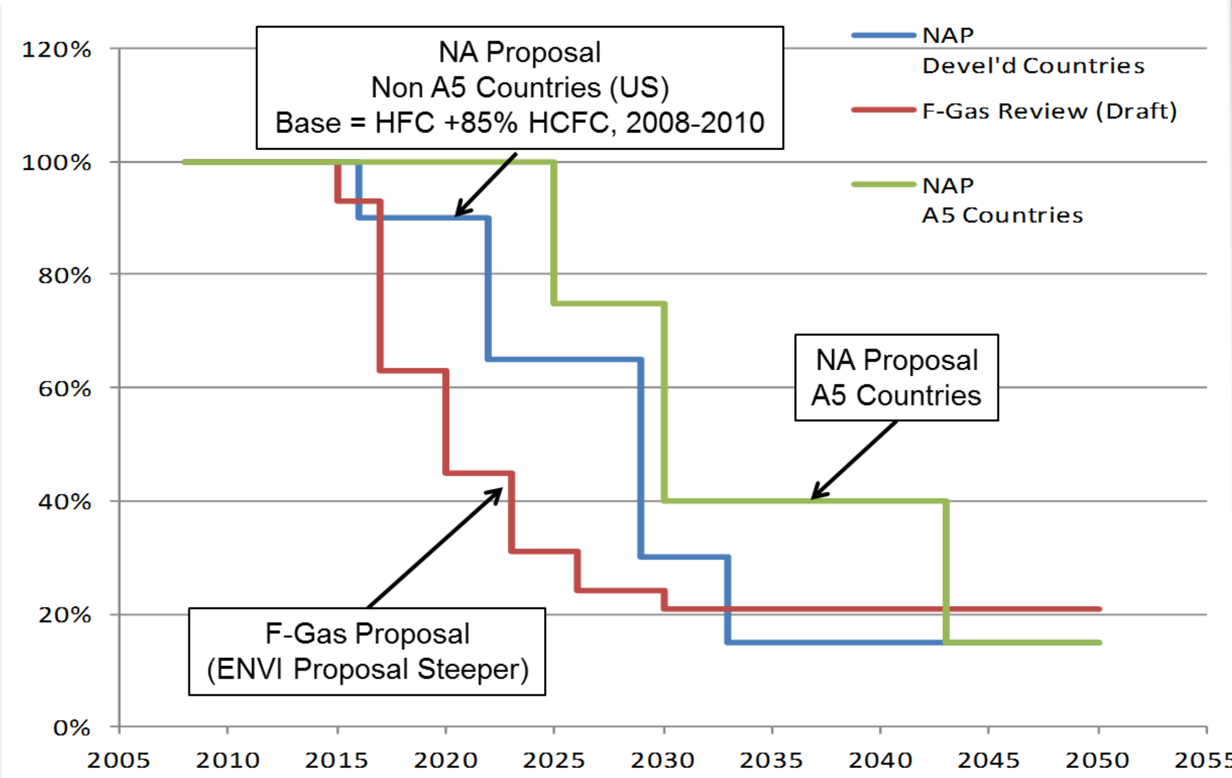
- **Background**
- **What's Important When Selecting Compressors?**
  - Mid-Point/Dew Point Differences
  - Evaporator vs. Compressor Capacity
  - Mechanical Subcooling and Vapor Injection
- **EER vs. AEER**
- **Annual Energy Analysis**

Industry Market Drivers



What's Important, And How Can I Evaluate Options?

HFC Phase-Down Proposals: North American Proposal (NAP) and European F-Gas



Will Potential Regulation Drive Me to More or Less Energy-Efficient Options?

Lower GWP Refrigerant Landscape

Options for New and Existing Applications

Refrigerant	GWP
R404A	3922
R407A	2107
R407F	1825
R134a	1430
R410A	2088
N40	<1500
XP40	<1500
XP10	<600
N13	<600
L40	<300
DR7	<300
R1234yf	<4
Propane	3
CO_2	1

Which Refrigerant Is Right For Me?

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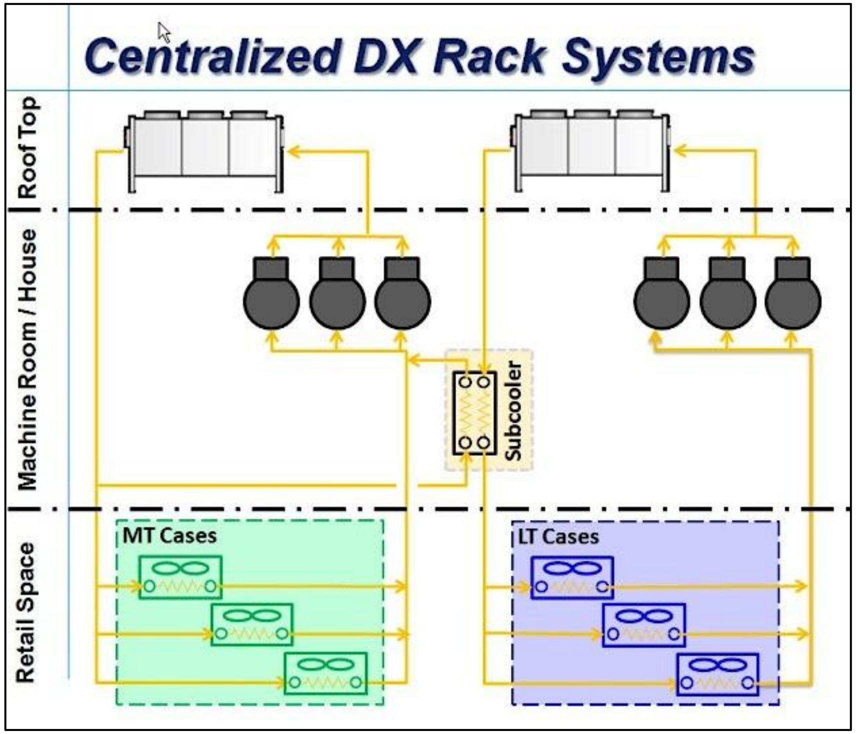
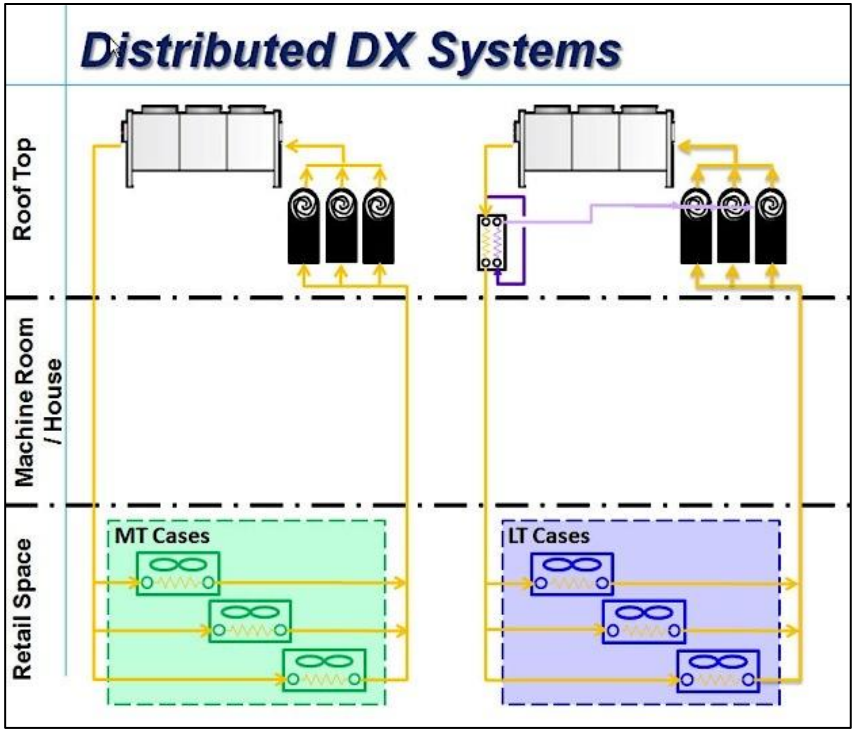
Increasing Variations in System Architectures

Traditional Direct Expansion





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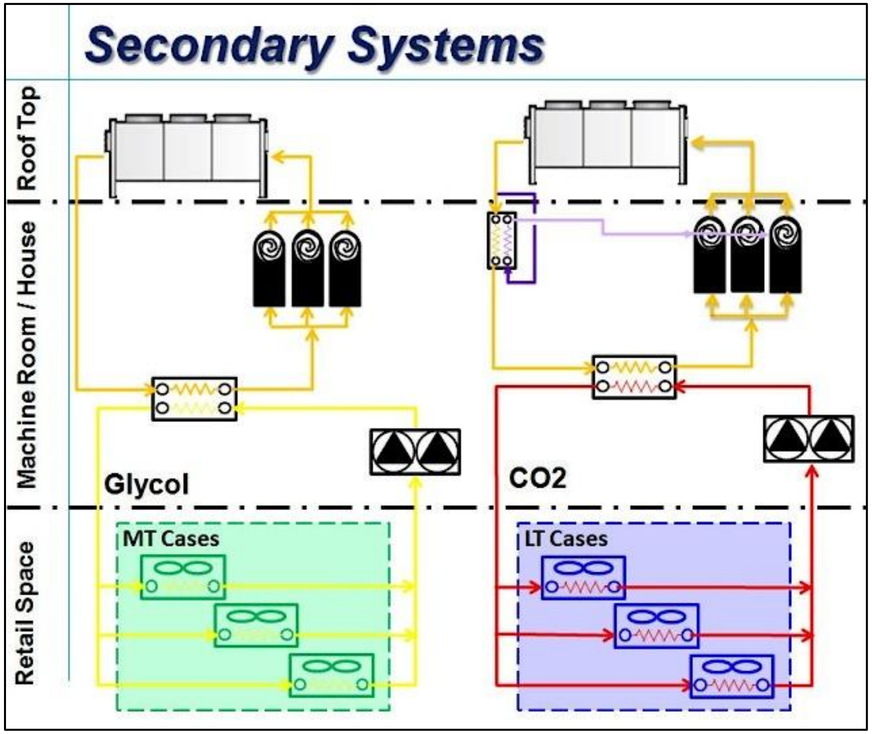
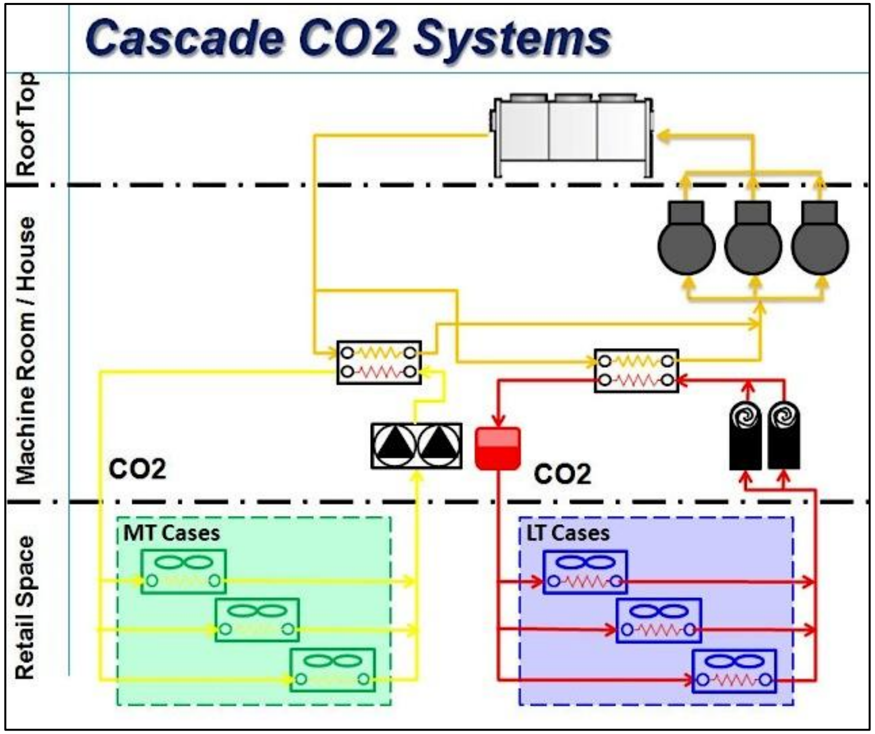
Increasing Variations in System Architectures

Increasingly Complex Systems





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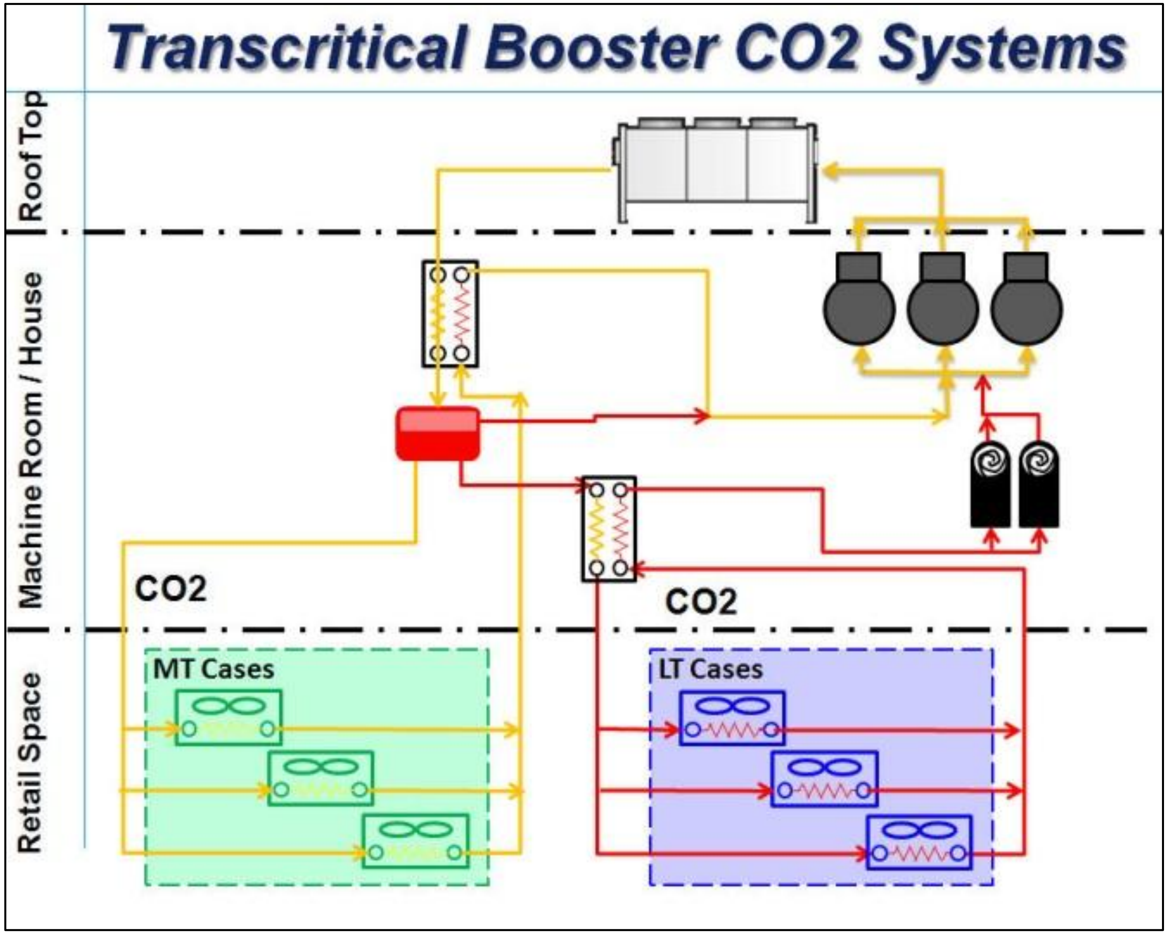
Increasing Variations in System Architectures



System Choices And Complexity Are Increasing

Agenda

- Background
- **What's Important When Selecting Compressors?**
  - Mid Pt/Dew Pt Differences
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  - Mechanical Subcooling and Vapor Injection
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Mid-Point vs. Dew Point

Azeotropic / No Glide

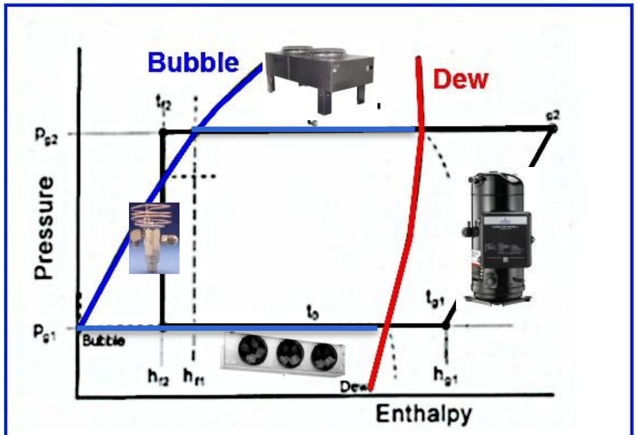

Figure C1: Cycle Process for Single Component Refrigerants and Azeotropic Mixtures

Zeotropic / Glide

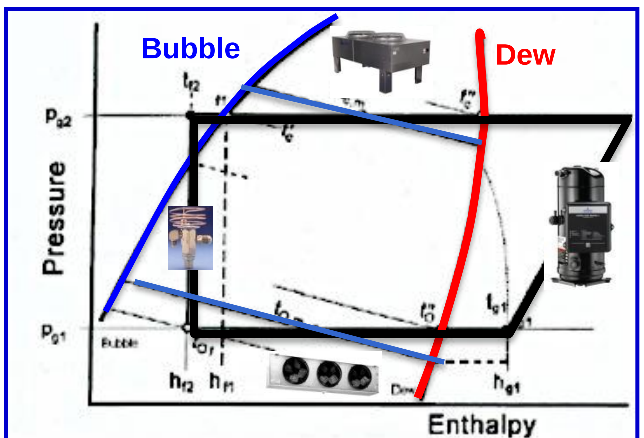

Figure C2: Cycle Process for Zeotropic Refrigerant Mixtures

- **Per AHRI Standards, Compressors Are Rated Based on Dew Point Pressure/ Temperatures**
  - When there is no glide and assuming little/no pressure drop, the temperature at mid-point equals temperature at dew point
  - Mid-Point = Average Coil Temperature
    - $T_{mid,cond} = T_{dew,cond} + T_{bubble,cond} /2$
    - $T_{mid,evap} = T_{evap,in} + T_{evap,out} /2$

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Example: R-22 vs. R-407A Compressor Performance

Azeotropic / No Glide

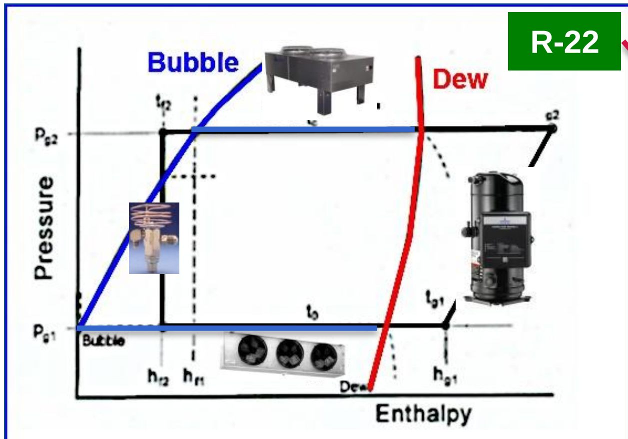
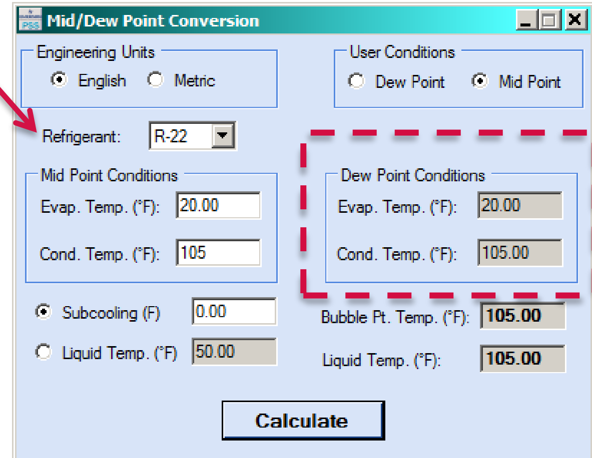


Figure C1: Cycle Process for Single Component Refrigerants and Azeotropic Mixtures



R-22: 20/105°F

Compressor Capacity (Btu/hr):
48,400
Power (W):
4,560
Compressor EER (Btu/Whr):
10.61

Zeotropic / Glide

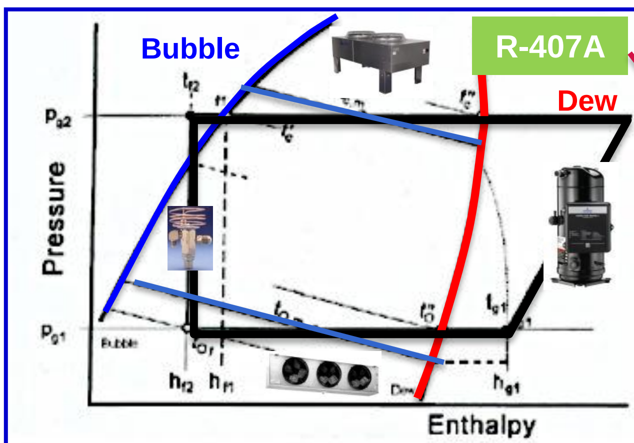
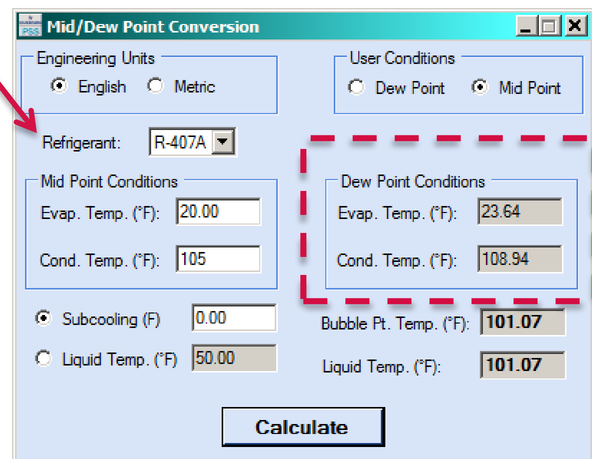


Figure C2: Cycle Process for Zeotropic Refrigerant Mixtures



R-407A:24/109°F

Compressor Capacity (Btu/hr):
50,500
Power (W):
5,050
Compressor EER (Btu/Whr):
10.00

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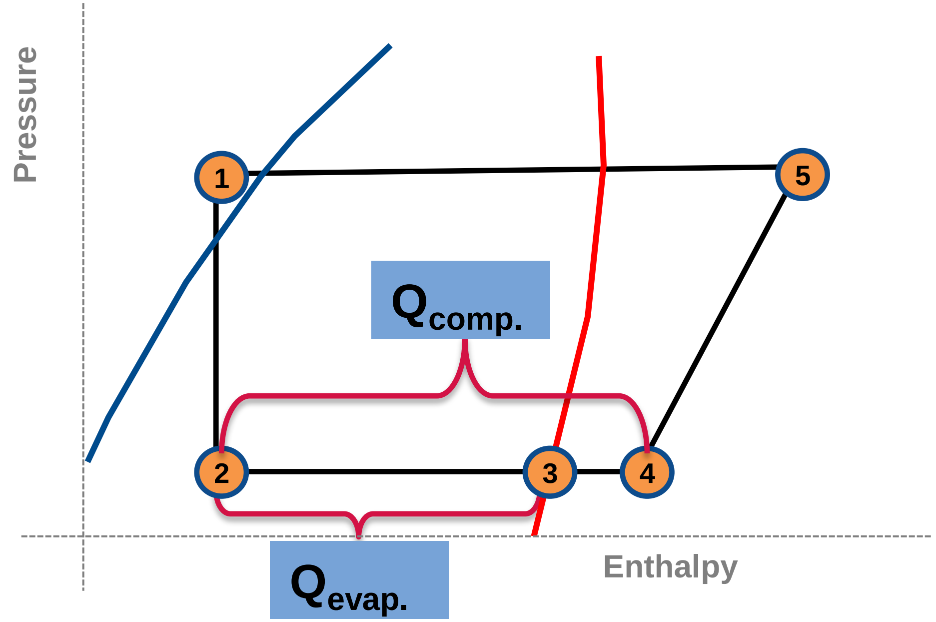
Evaporator Capacity vs. Compressor Capacity

- **Evaporator capacity or Net Refrigeration Effect (NRE) is the available effective cooling generated from the system**
- **Compressor capacity is the cooling capacity generated from the evaporator capacity as well as the heat gained in the line between the exit of the evaporator to suction of the compressor**



Evaporator Capacity vs. Compressor Capacity

- $\dot{Q} = \dot{m}(h_{out,vap} - h_{in,liq})$
- When compressor superheat* is increased, $h_{out,vap} \uparrow, \dot{m} \downarrow$ compressor capacity increases and evaporator capacity decreases
- When compressor superheat decreases, $h_{out,vap} \downarrow, \dot{m} \uparrow$ compressor capacity decreases and evaporator capacity increases

Traditionally, Compressor Selections Are Based on 65°F Return Gas and Compressor Capacity at Dew Point With Enough "Safety Factor" to Ensure There Is Adequate Net Refrigeration Effect for the Required Load

****Compressor Superheat (SH) is often considered in terms of Compressor Return Gas Temperature (RGT) where RGT = Evap. Temp. + SH***

Example: Capacity at Design vs. Application

- **Required Load: 40,000 Btu/hr**
- **Design Condition: R-407A, +20/105/65RG/0SC/10eSH °F**

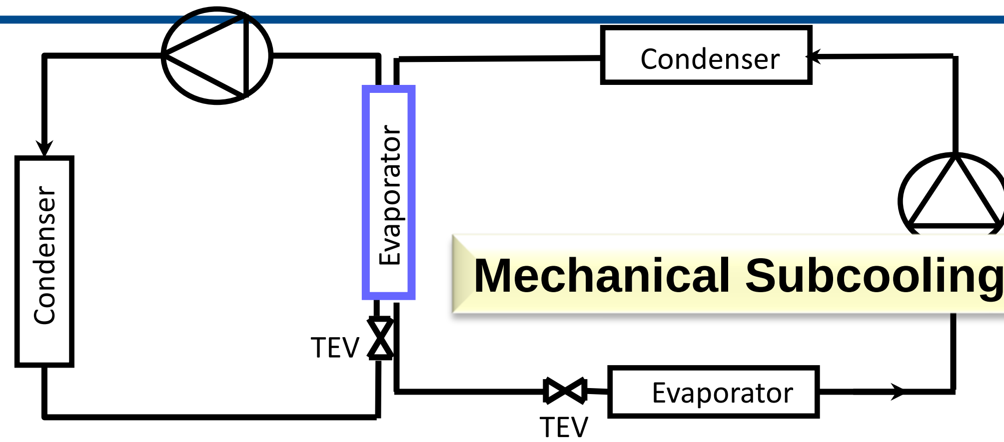
Model	HP	Compressor Capacity (Btu/hr)	Compressor EER (Btu/Wh)	Evaporator Capacity (Btu/hr)	Evaporator EER (Btu/Wh)	Total Req'd Load (%)	Cond. Heat Rejection (Btu/hr)
ZB45KCE-TFD	6.00	47,800	10.04	42,700	8.97	119.5	64,046

Condition 407A, ZB45KCE-TFD 20/105/65RG/10eSH °F	Comp. Cap. (MBH)	Vs. Design Load	Evap. Cap. (MBH)	Vs. Design Load
Dew Point Design	47.8	119%	42.7	107%
Mid-Point Design	50.5 ↑	126%	45.3 ↑	113%
45RG/10eSH (Lower RG)	49.6 ↓	124%	47.7 ↑	119%
ZB38KCE-TFD (Smaller Comp)	43.3	108%	41.6	104%

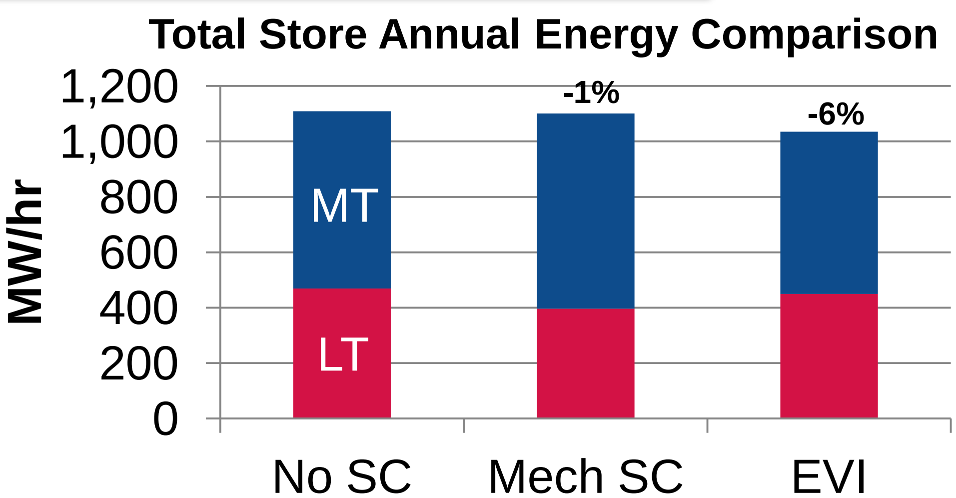
Subcooling

Mechanical SC System:
Q_{LT} = LT Case Load
Q_{MT} = MT Case Load + SC Load

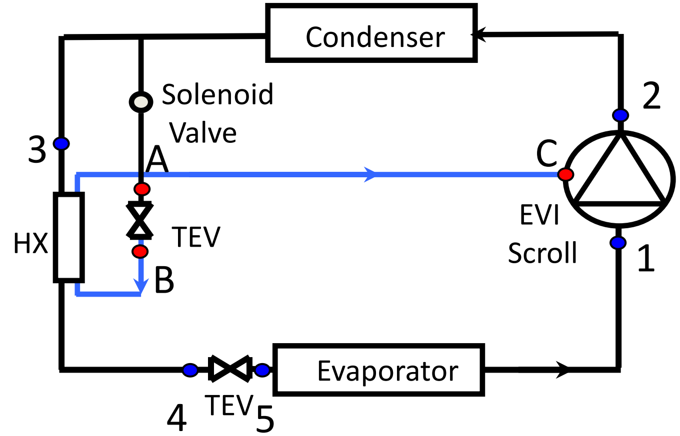
EVI System
Q_{LT} = LT Case Load
Q_{MT} = MT Case Load ~~+ SC Load~~



Mechanical Subcooling



Assumes LT: 300MBH, MT: 900MBH in Atlanta, GA



"Self" Subcooling With EVI

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EER vs. AEER

- **EER (Energy Efficiency Ratio) is the measure of compressor efficiency at a single rating condition found by dividing the capacity by input power at that rating condition**
  - Often, the rating condition is based on design for “worst case” condition for the system/location
- **AEER (Annual Energy Efficiency Ratio) is a weighted average performance for a refrigeration system, using varying condensing temperatures tied to the actual weather data for a location**

EER vs. AEER Example: Atlanta, Georgia

- ## Design Ambient

2013 ASHRAE Handbook - Fundamentals (IP) © 2013 ASHRAE, Inc.

ATLANTA MUNICIPAL, GA, USA WMO#: 722190

Lat: 33.64N Long: 84.43W Elev: 1027 StdP: 14.16 Time Zone: -5 (NAE) Period: 86-10 WBAN: 13874

Annual Heating and Humidification Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
		99.6%	99%	99.6%			99%			0.4%		1%				
				DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
(1)	1	21.5	26.4	4.2	7.1	28.6	9.1	9.1	32.2	24.9	39.9	23.5	40.0	11.9	320	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	7	17.0	93.9	74.2	91.7	73.9	89.8	73.5	77.3	88.5	76.4	86.7	75.4	85.0	8.7	300	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 55/69	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	74.3	133.1	81.3	73.3	128.7	80.2	72.6	125.5	79.6	41.4	88.5	40.4	86.7	39.5	85.6	800	(3)

Extreme Annual Design Conditions

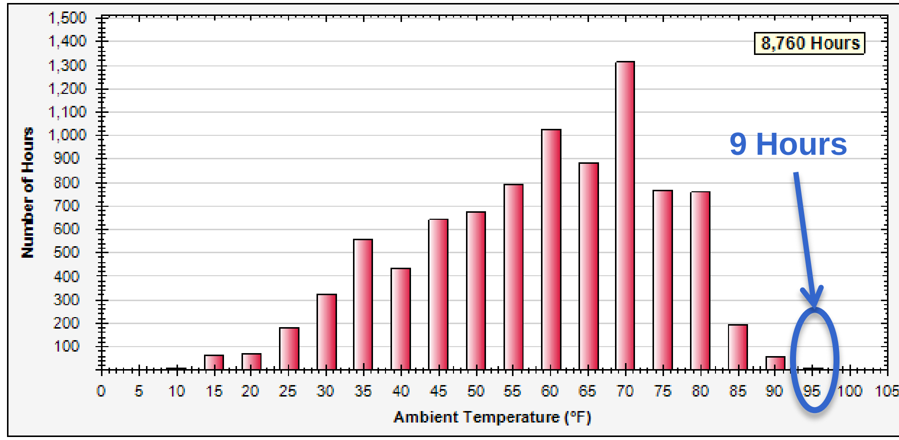
	Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB								
					Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(4)	21.5	19.0	17.1	82.4	14.1	96.7	4.4	3.3	10.9	99.1	8.3	101.0	5.8	102.9	2.6	105.3	(4)

Extreme Annual Design Conditions

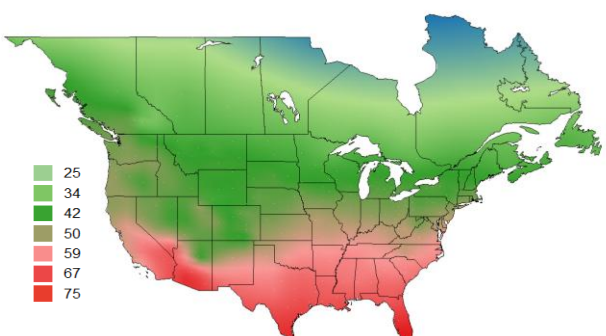
Extreme Annual WS			Extreme Max WB	Extreme Annual DB			
				Mean		Standard deviation	
1%	2.5%	5%		Min	Max	Min	Max
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
21.5	19.0	17.1	82.4	14.1	96.7	4.4	3.3

2013 ASHRAE Handbook Fundamentals (IP)

- ## Annual Ambient



Weather Data Based on Typical Metrological Year (National Solar Radiation Database, Years: 1961 – 1990).



https://www.ashrae.org/news/2014/revisions-to-climate-data-standard-from-ashrae-include-new-climate-zone-climatic-data

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Estimated kWh/yr for 15MBH Design R-404A, +20/112/40RG/0SC/10eSH °F

- **EER**

Results

Compressor Capacity (Btu/hr):	15,950
Net Refrigeration Effect (Btu/hr):	15,150
Power (W):	2,050
Compressor EER (Btu/Wh):	7.78
Evaporator EER (Btu/Wh):	7.39

- **AEER**

Output

Annual (Hours):	8,760
Evap. Capacity (Btu/hr):	15,150
Evap. Capacity Over Design (%):	1.0
Overall AEER (Btu/Wh):	13.91

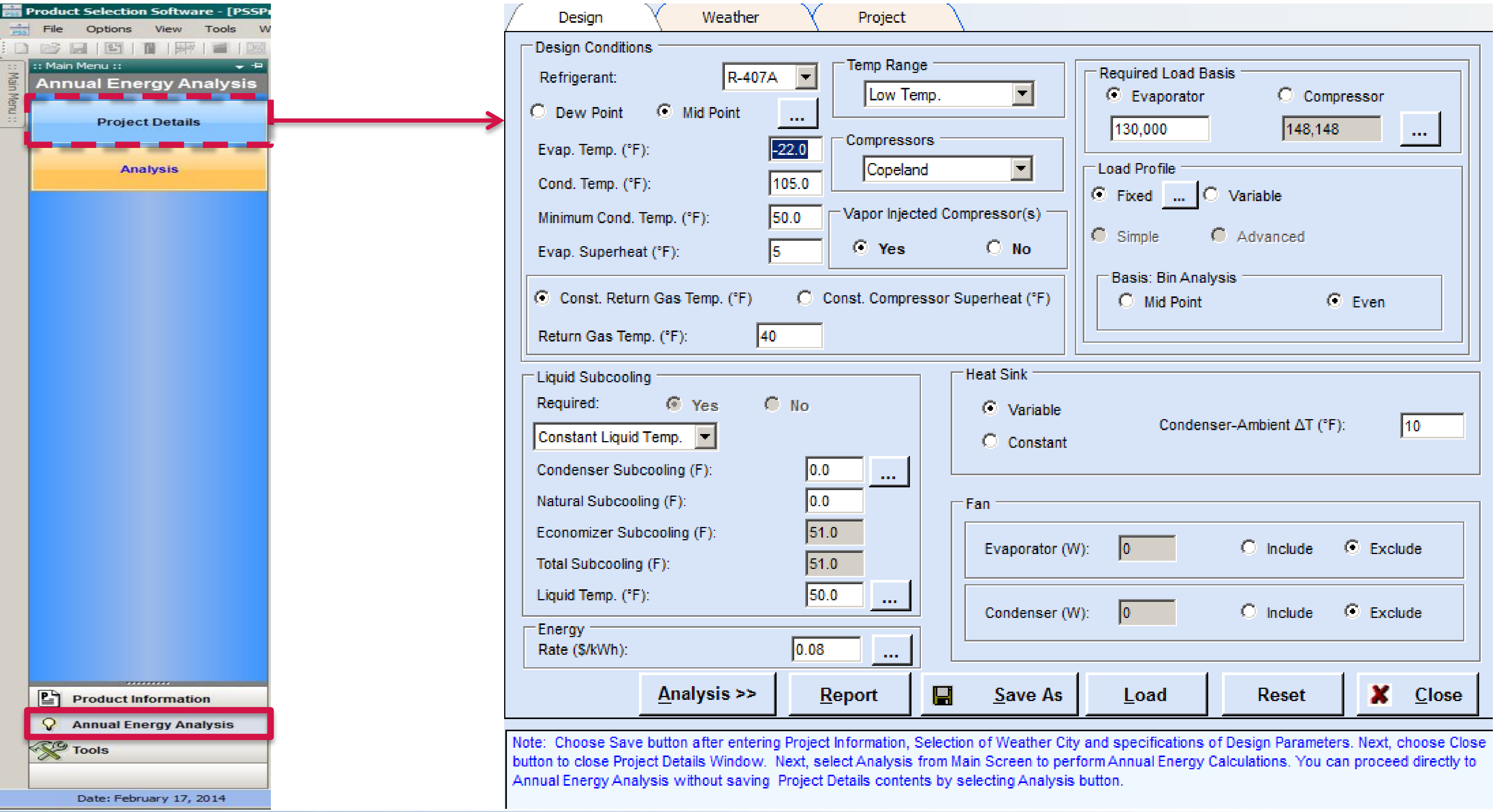
Design Point

System Capacity (Btu/hr):	15,150
System EER (Btu/Wh):	7.39
Cond. Heat Rejection (Btu/hr):	22,947

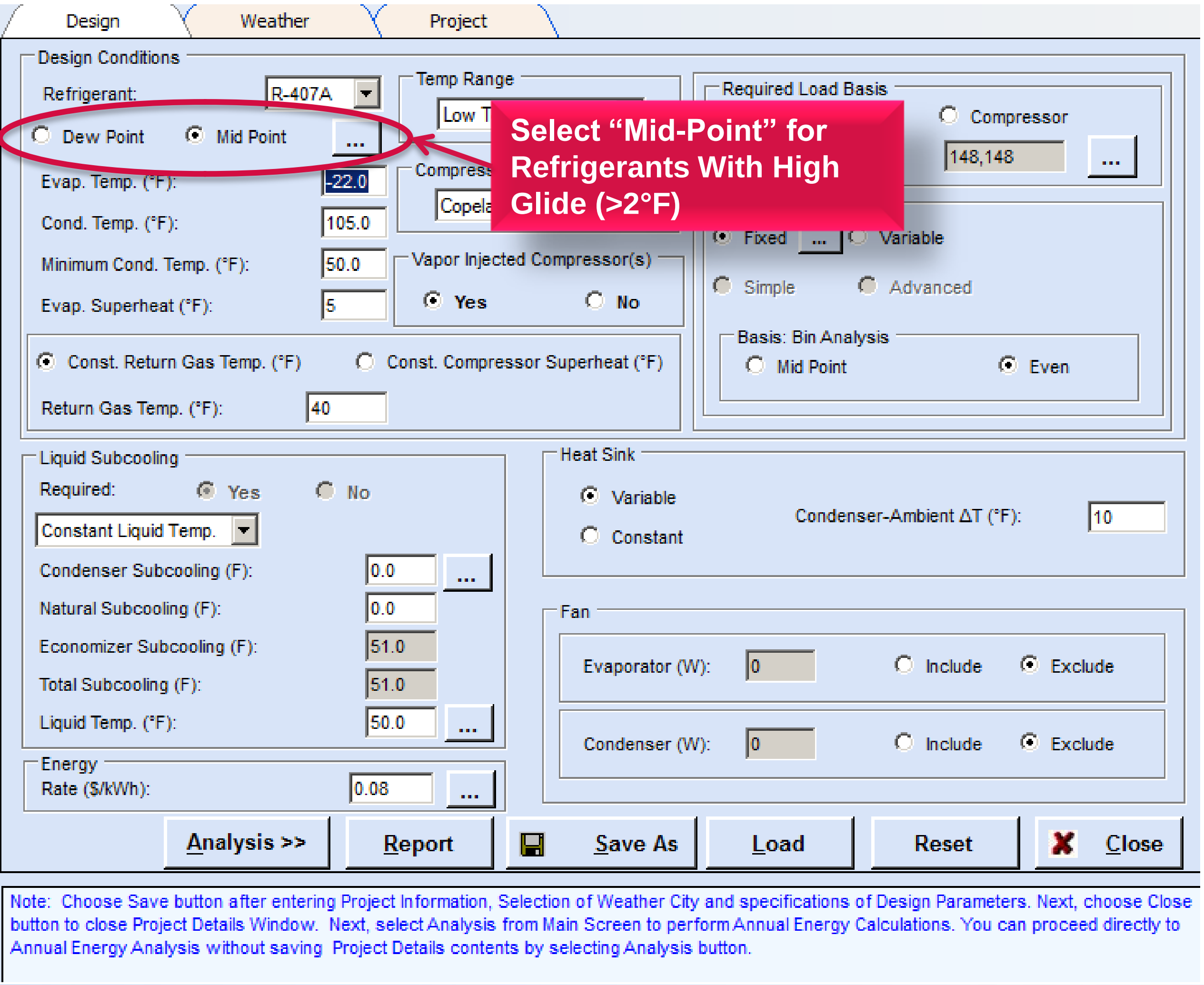
Annual Energy Used by Primary Comp. (kWh):	9,445
Annual Energy Used by Mech. Subcooling Comp. (kWh):	0
Annual Energy Used by Evap. Fan (kWh):	0
Annual Energy Used by Cond. Fan (kWh):	0
Total Annual Energy Used (kWh):	9,445
Total Annual Energy Cost ($):	756

- Atlanta, GA
- Fixed Load
- Min. Cond 70°F
- Evaporator Based

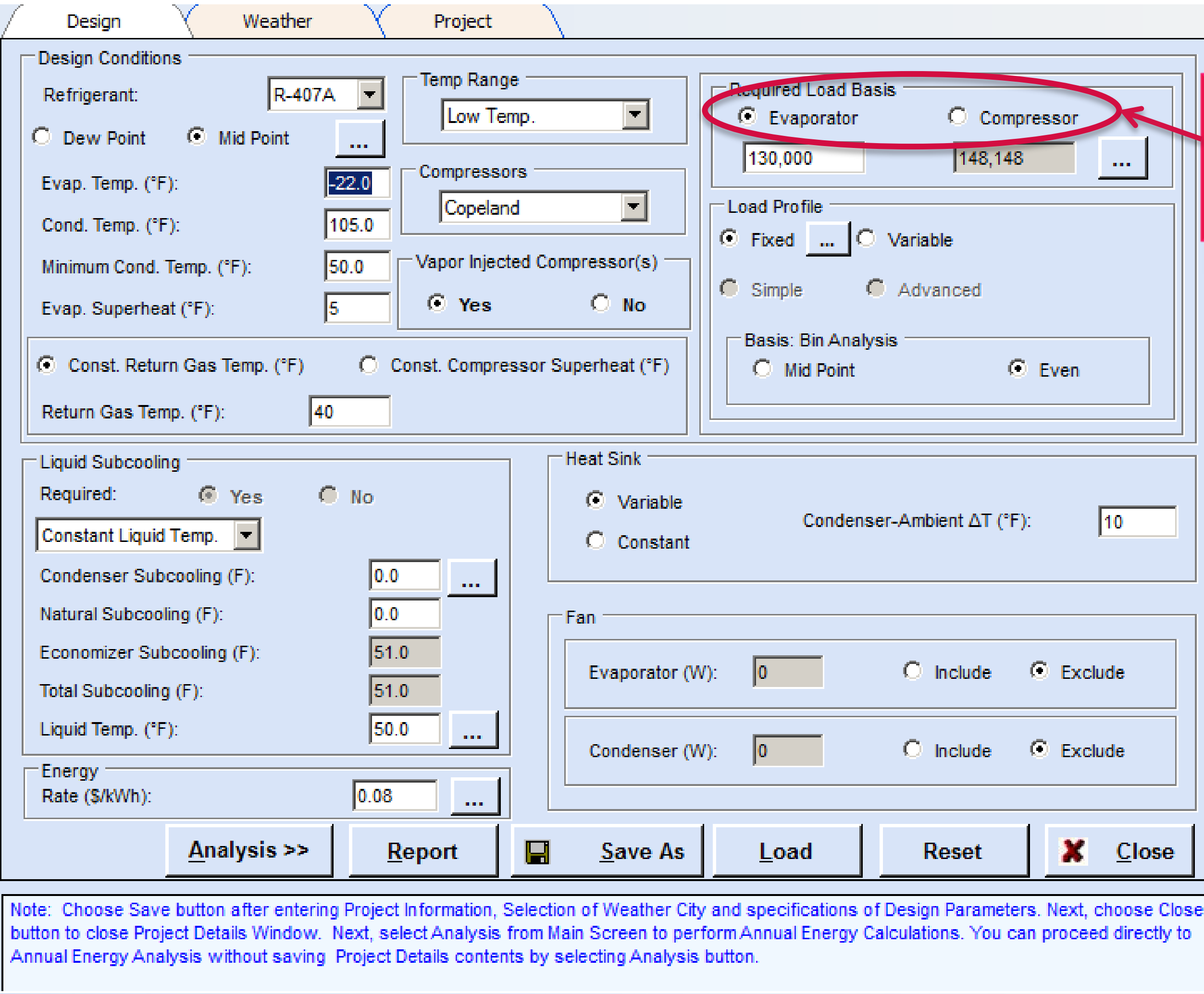
Emerson Product Selection Software Annual Energy Analysis



Emerson Product Selection Software
Annual Energy Analysis



Emerson Product Selection Software Annual Energy Analysis



Required Load Basis, Matches Compressors Based on Evaporator or Compressor Capacity

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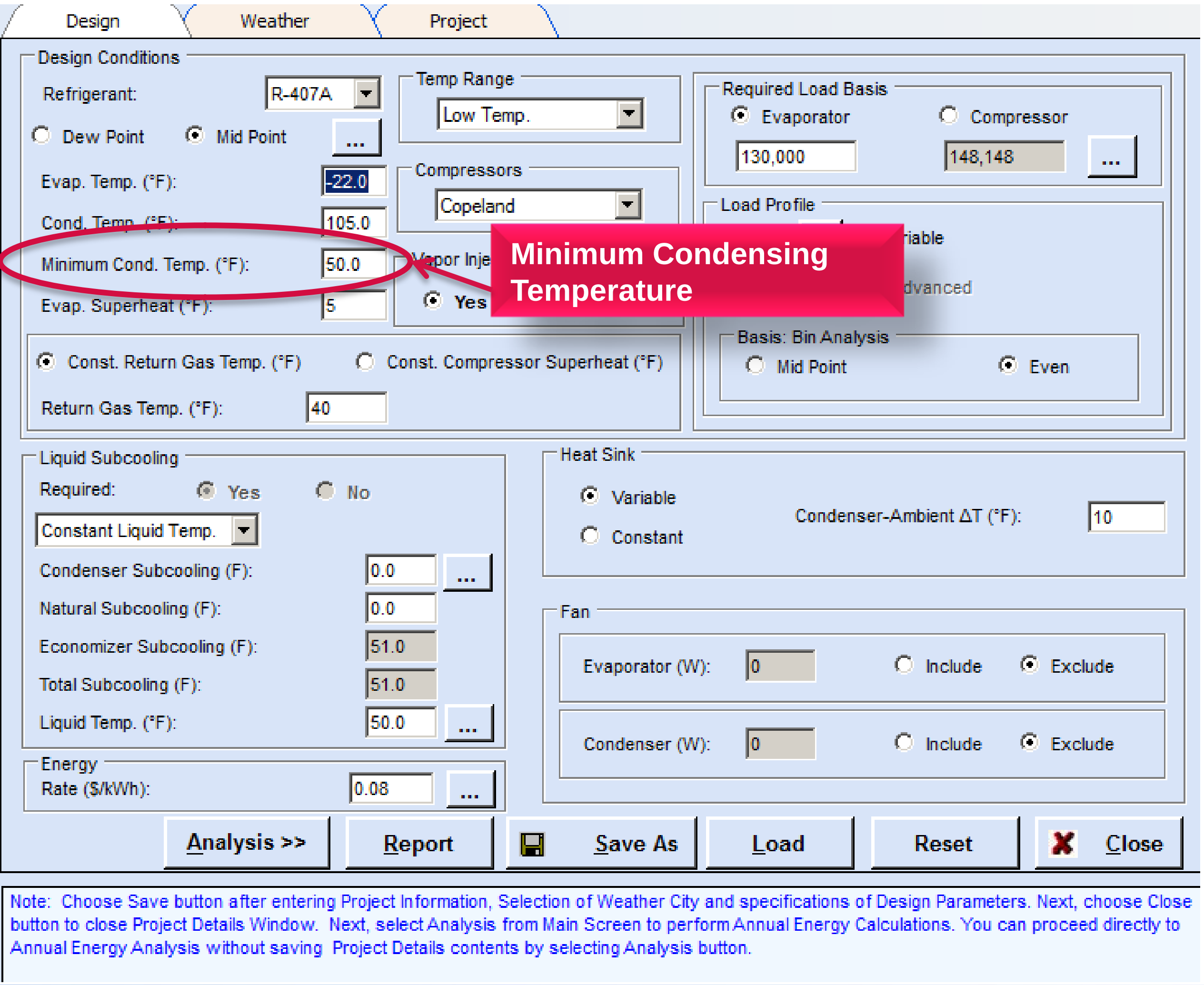
Annual Energy Analysis



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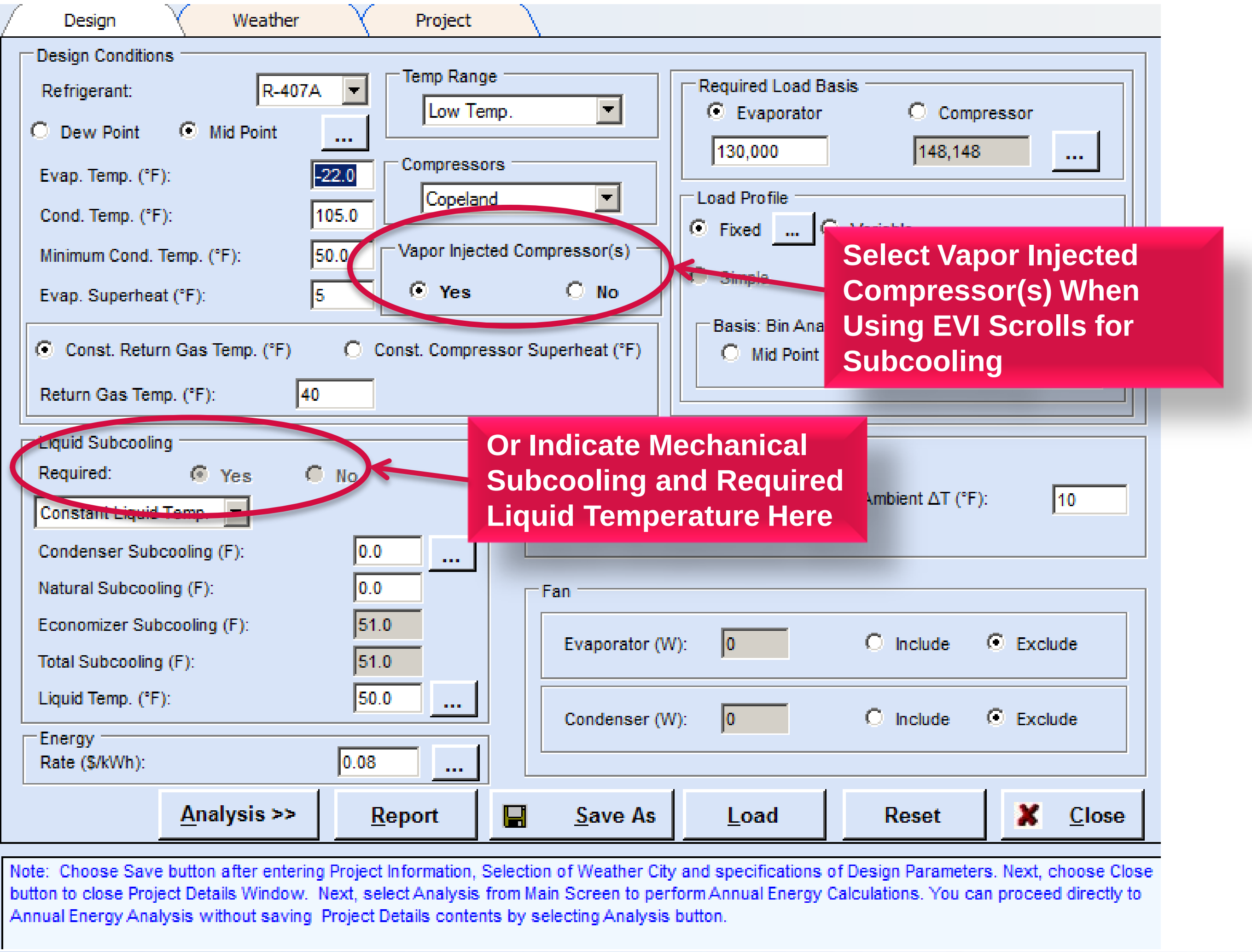
Annual Energy Analysis



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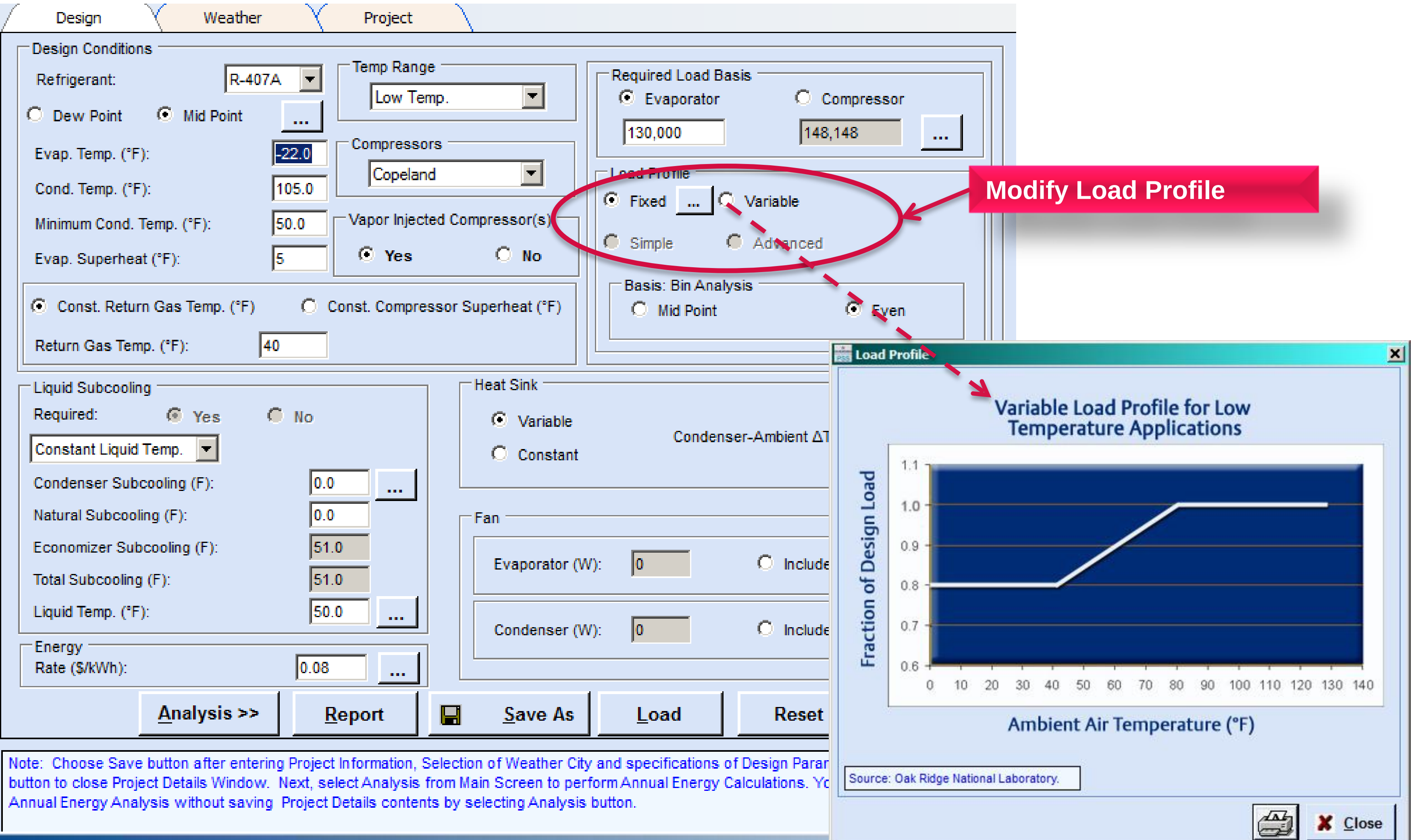
Annual Energy Analysis



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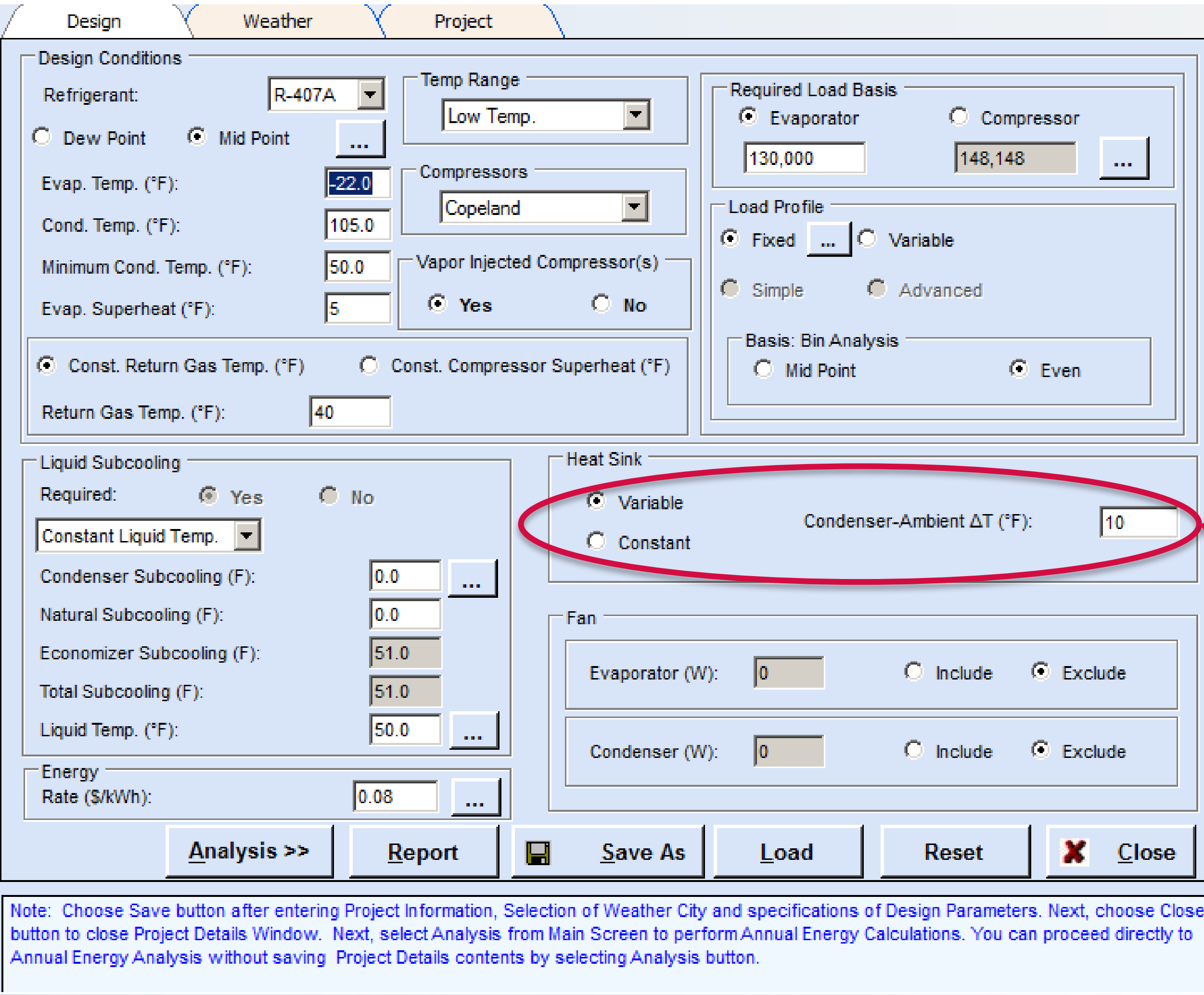
Annual Energy Analysis



Adjust Condenser-Ambient TD

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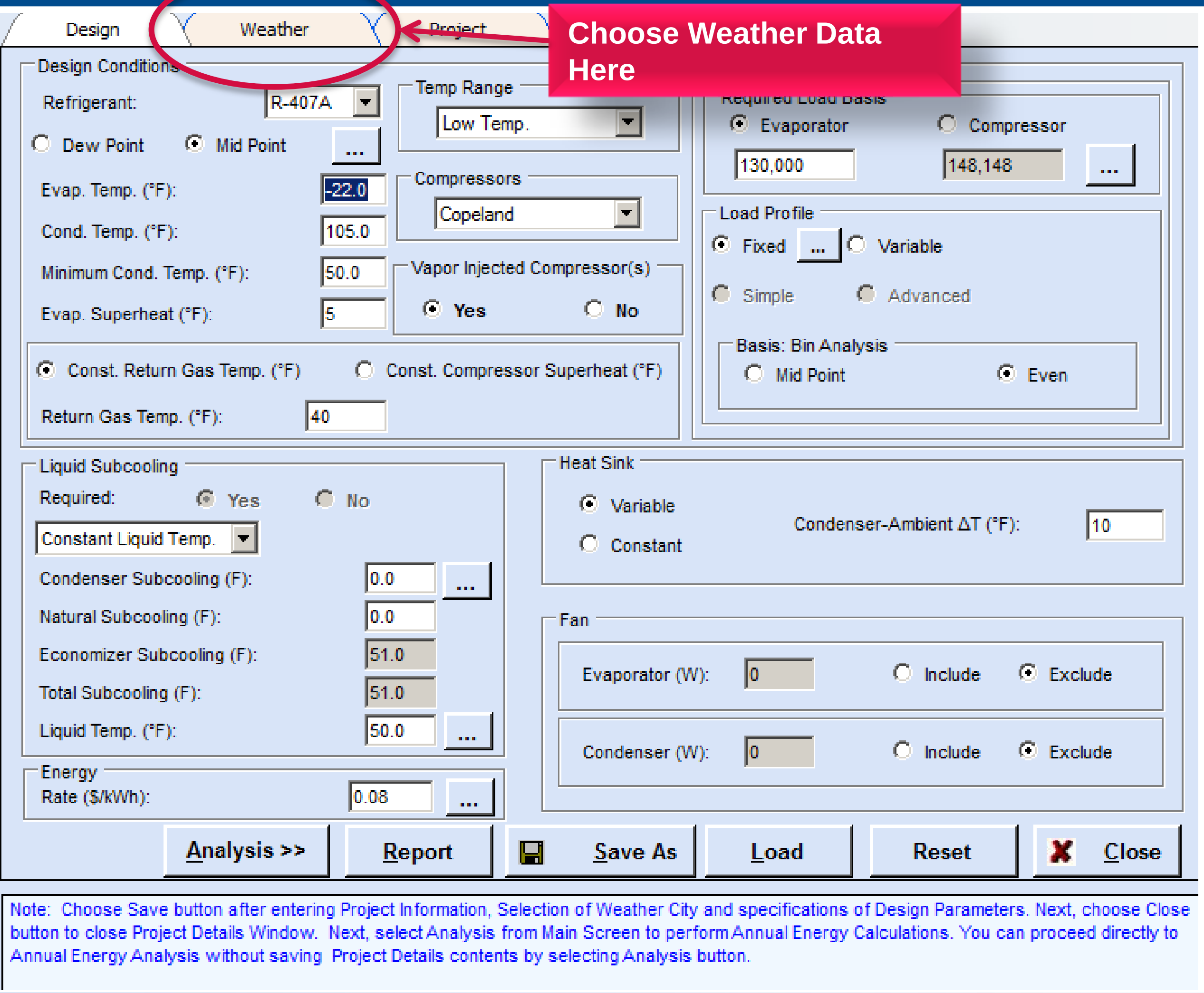
Annual Energy Analysis



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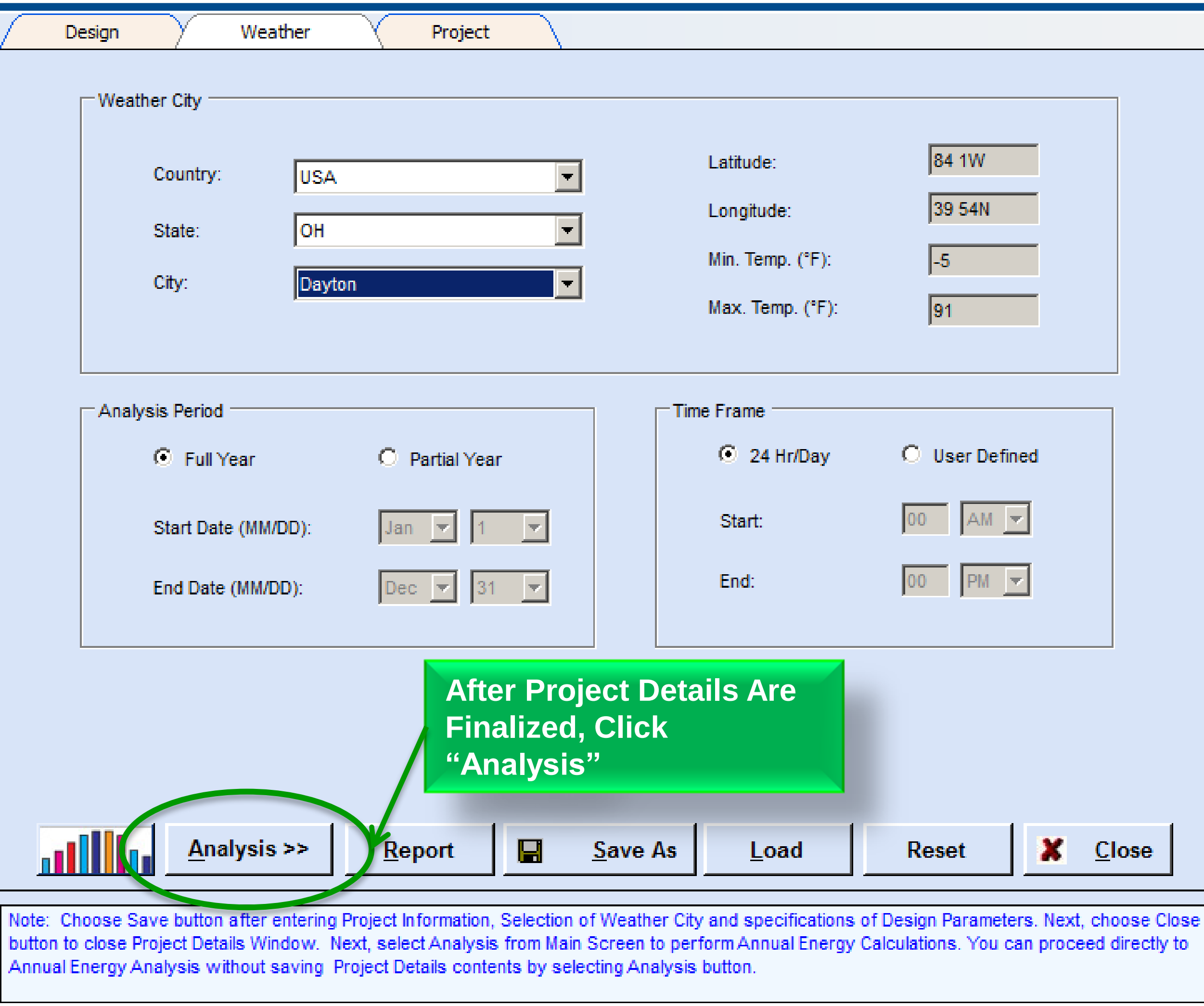
Annual Energy Analysis



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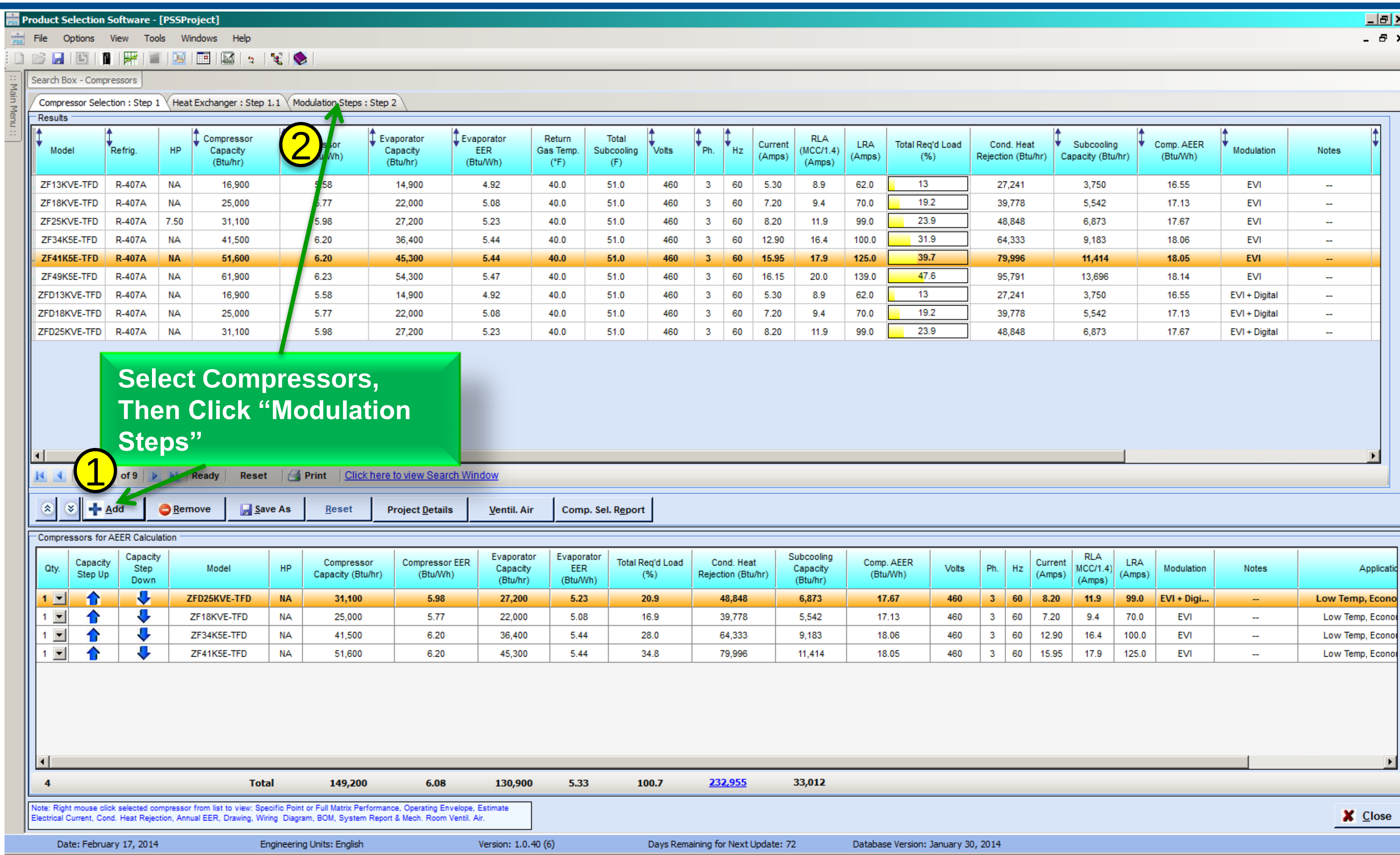
Annual Energy Analysis



Model	Refrig.	HP	Compressor Capacity (Btu/hr)	[illegible]	Evaporator Capacity (Btu/hr)	Evaporator EER (Btu/Wh)	Return Gas Temp. (°F)	Total Subcooling (F)	Volts	Ph.	Hz	Current (Amps)	RLA (MCC/1.4) (Amps)	LRA (Amps)	Total Req'd Load (%)	Cond. Heat Rejection (Btu/hr)	Subcooling Capacity (Btu/hr)	Comp. AEER (Btu/Wh)	Modulation	Notes
ZF13KVE-TFD	R-407A	NA	16,900	5.58	14,900	4.92	40.0	51.0	460	3	60	5.30	8.9	62.0	13	27,241	3,750	16.55	EVI	--
ZF18KVE-TFD	R-407A	NA	25,000	5.77	22,000	5.08	40.0	51.0	460	3	60	7.20	9.4	70.0	19.2	39,778	5,542	17.13	EVI	--
ZF25KVE-TFD	R-407A	7.50	31,100	5.98	27,200	5.23	40.0	51.0	460	3	60	8.20	11.9	99.0	23.9	48,848	6,873	17.67	EVI	--
ZF34K5E-TFD	R-407A	NA	41,500	6.20	36,400	5.44	40.0	51.0	460	3	60	12.90	16.4	100.0	31.9	64,333	9,183	18.06	EVI	--
ZF41K5E-TFD	**R-407A**	**NA**	**51,600**	**6.20**	**45,300**	**5.44**	**40.0**	**51.0**	**460**	**3**	**60**	**15.95**	**17.9**	**125.0**	**39.7**	**79,996**	**11,414**	**18.05**	**EVI**	**--**
ZF49K5E-TFD	R-407A	NA	61,900	6.23	54,300	5.47	40.0	51.0	460	3	60	16.15	20.0	139.0	47.6	95,791	13,696	18.14	EVI	--
ZFD13KVE-TFD	R-407A	NA	16,900	5.58	14,900	4.92	40.0	51.0	460	3	60	5.30	8.9	62.0	13	27,241	3,750	16.55	EVI + Digital	--
ZFD18KVE-TFD	R-407A	NA	25,000	5.77	22,000	5.08	40.0	51.0	460	3	60	7.20	9.4	70.0	19.2	39,778	5,542	17.13	EVI + Digital	--
ZFD25KVE-TFD	R-407A	NA	31,100	5.98	27,200	5.23	40.0	51.0	460	3	60	8.20	11.9	99.0	23.9	48,848	6,873	17.67	EVI + Digital	--

Qty.	Capacity Step Up	Capacity Step Down	Model	HP	Compressor Capacity (Btu/hr)	Compressor EER (Btu/Wh)	Evaporator Capacity (Btu/hr)	Evaporator EER (Btu/Wh)	Total Req'd Load (%)	Cond. Heat Rejection (Btu/hr)	Subcooling Capacity (Btu/hr)	Comp. AEER (Btu/Wh)	Volts	Ph.	Hz	Current (Amps)	RLA MCC/1.4) (Amps)	LRA (Amps)	Modulation	Notes	Applicatio
1			**ZFD25KVE-TFD**	**NA**	**31,100**	**5.98**	**27,200**	**5.23**	**20.9**	**48,848**	**6,873**	**17.67**	**460**	**3**	**60**	**8.20**	**11.9**	**99.0**	**EVI + Digi...**	**--**	**Low Temp, Econo**
1			ZF18KVE-TFD	NA	25,000	5.77	22,000	5.08	16.9	39,778	5,542	17.13	460	3	60	7.20	9.4	70.0	EVI	--	Low Temp, Econo
1			ZF34K5E-TFD	NA	41,500	6.20	36,400	5.44	28.0	64,333	9,183	18.06	460	3	60	12.90	16.4	100.0	EVI	--	Low Temp, Econo
1			ZF41K5E-TFD	NA	51,600	6.20	45,300	5.44	34.8	79,996	11,414	18.05	460	3	60	15.95	17.9	125.0	EVI	--	Low Temp, Econo
4			**Total**		**149,200**	**6.08**	**130,900**	**5.33**	**100.7**	**232,955**	**33,012**										

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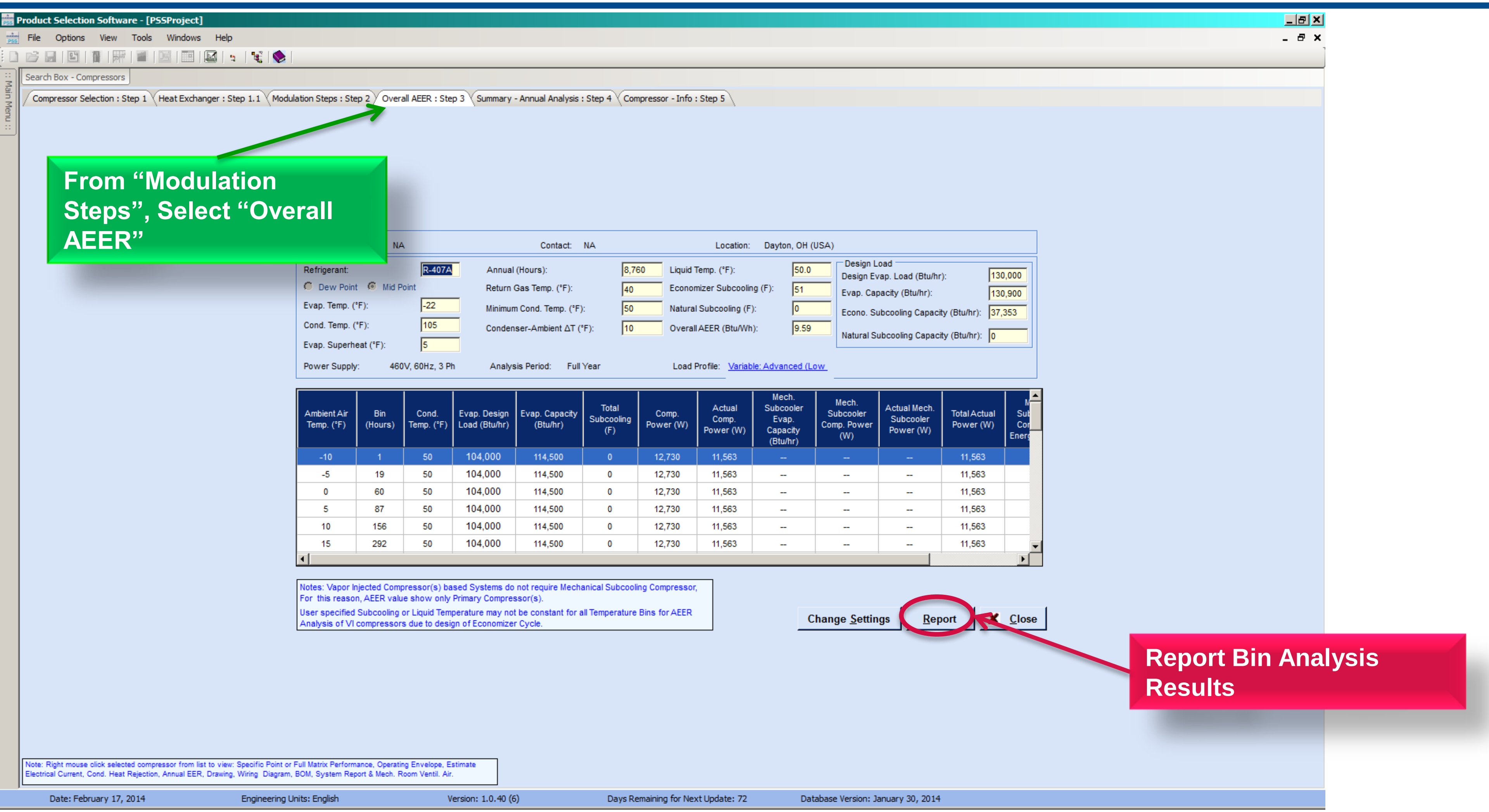
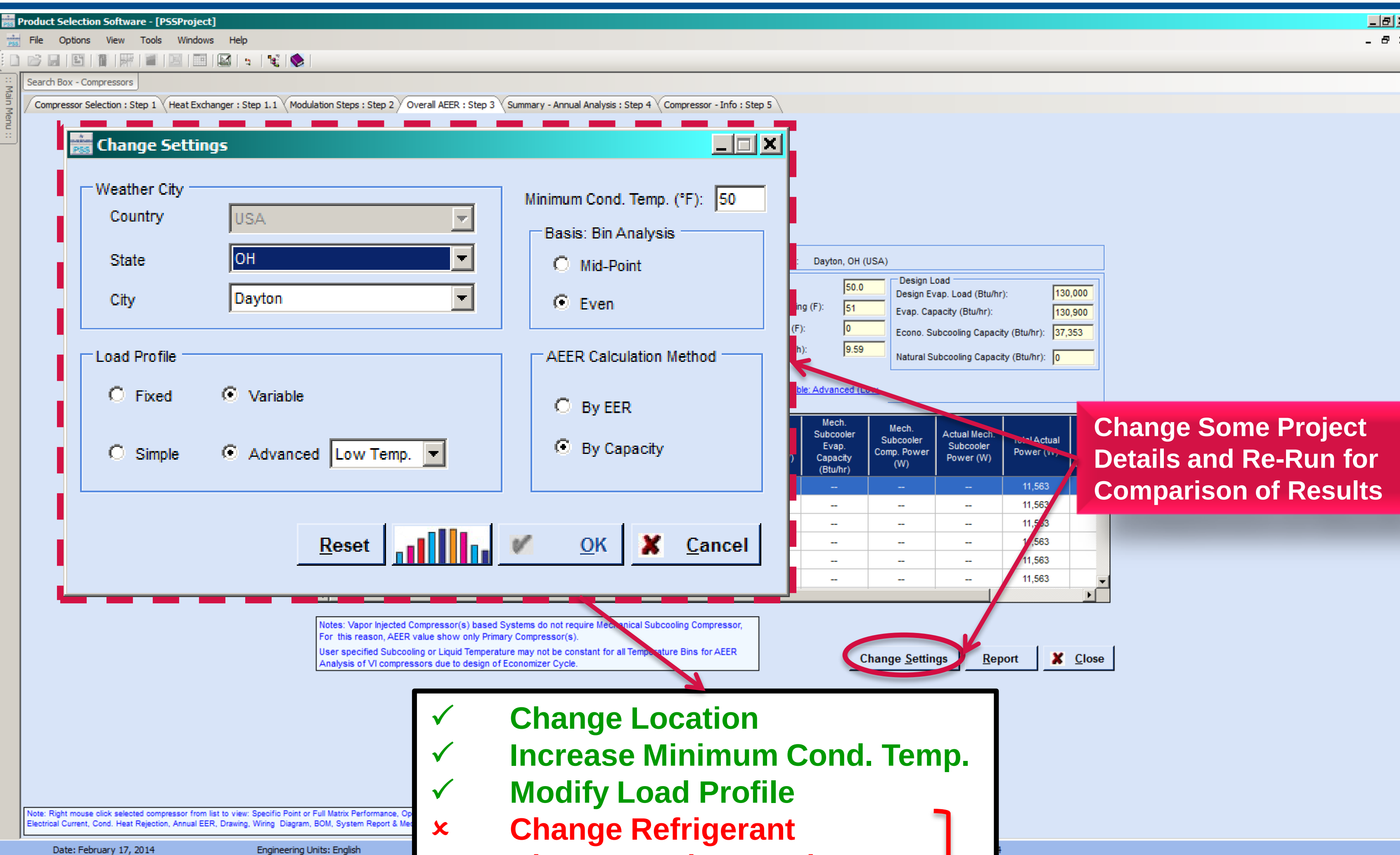
Emerson Product Selection Software Annual Energy Analysis



Emerson Product Selection Software
Annual Energy Analysis

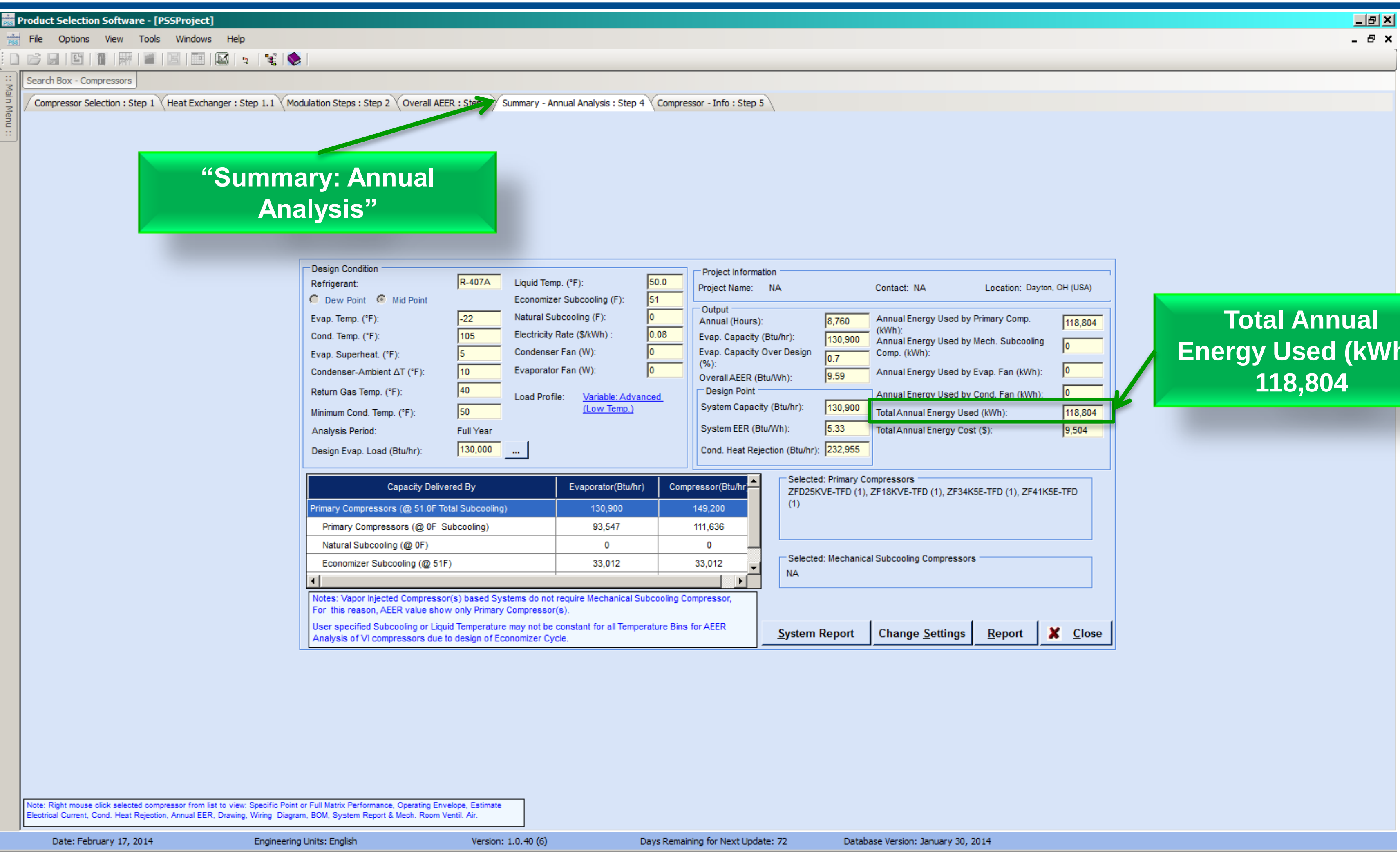


Change Some Project Details and Re-Run for Comparison of Results

- ✓ Change Location
- ✓ Increase Minimum Cond. Temp.
- ✓ Modify Load Profile
- ✗ Change Refrigerant
- ✗ Change Design Load
- ✗ Change Design Condition

Requires a New "Project"

Emerson Product Selection Software Annual Energy Analysis



Software Available From Online Product Information (OPI) at http://www.emersonclimate.com

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Thank You!

Questions and Answers

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