How Buildings Use Heat

How Buildings Use Heat

- Heating
- Preheat
- Reheat
- Cooling
- Processes
- Power Generation

Revisiting a Definition

Heating

- A process that adds energy
  - For a space, this is often accomplished by circulating air through it at a temperature above the required set point
  - For a fluid stream, this is often accomplished by passing it over a surface that is above the required supply temperature

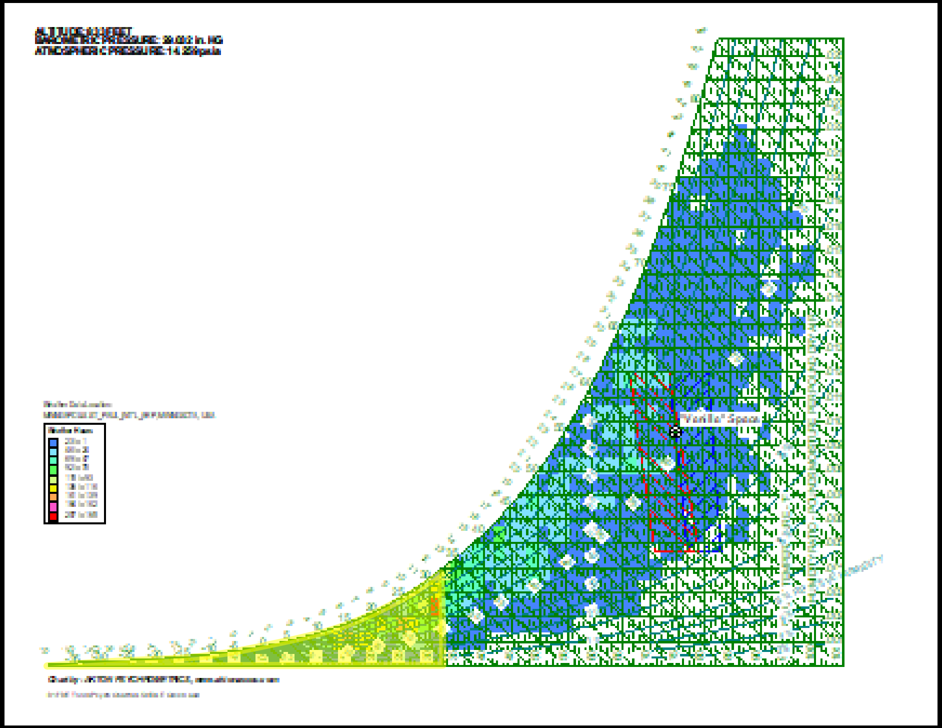
A Few More Definitions

Ventilation

- Outdoor air that is brought into the building to manage contaminates, generally by dilution
- The outdoor air volume is dictated by:
  - Type of contaminant
  - Capture velocity
  - Occupant count
  - Code requirements
- ASHRAE Standard 62.1 is usually the basis for design
- Ventilation air typically is removed by exhaust systems

Keeping Things Safe by Controlling Contaminants

Becomes more challenging when outdoor air is below 32°F



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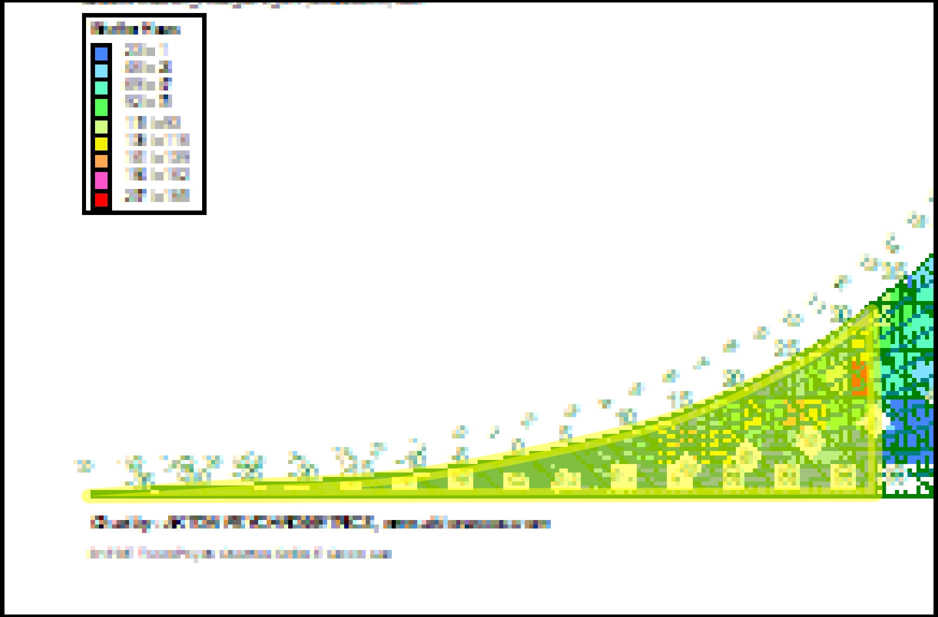

A Few More Definitions

Freezing

- A condition that occurs when water is cooled to the point where it changes phase from a solid to a liquid

A Few More Definitions

Water Damage

- A condition that occurs after frozen water contained in a HVAC coil changes back to the liquid phase

A Few More Definitions

Expletive

– A generic reference to the field terminology used to describe and discuss water damage when it occurs

A Few More Definitions

Significant Emotional Event

- An event that has life-changing emotions associated with it
- Triggering conditions:
  - Flurry of expletives
  - Lawsuits
- Freezing a coil is an example

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A Few More Definitions

Preheat

- A process that heats a fluid stream to prepare it for a subsequent HVAC process
- In air handling systems, this process is used to raise subfreezing air above freezing to protect water filled elements down stream from damage due to freezing

See the Functional Testing Guide (https://www.av8rdas.com/functional-testing-guide.html) Air Handling System Reference Guide Chapter 5 – Preheat, Table 5.1 to contrast preheat, reheat and heating applications

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A Few More Definitions

Reheat

- A process that uses heat to warm air being delivered to a zone to prevent over cooling
  - The temperature of the air was set by the need to hit a dehumidification target, *or*
  - By the requirements of another zone
    - Thus, it can not be raised at the central system
    - The volume can not be reduced because it has been set to assure proper ventilation (contaminant control)

A Few More Definitions

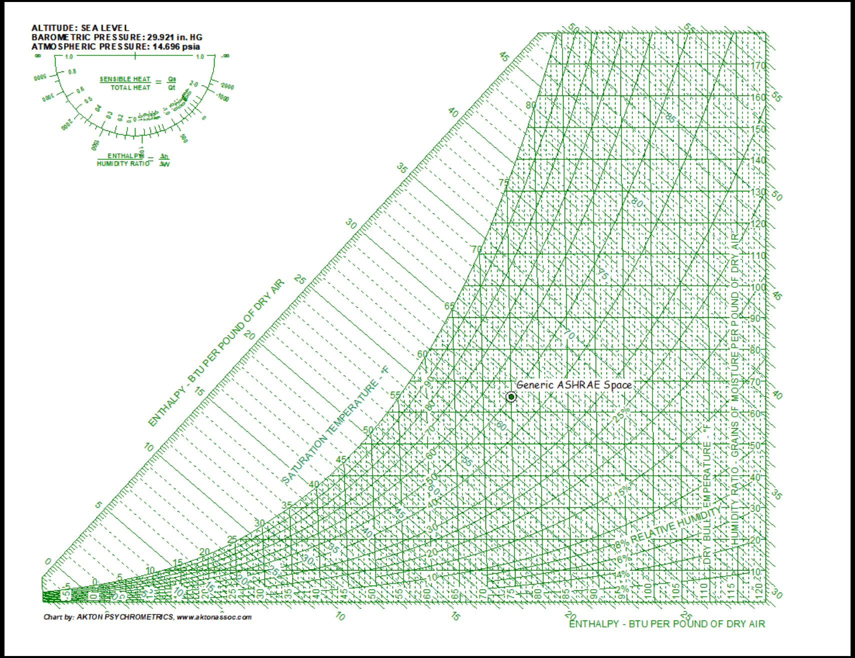
Reheat

- In the limit, *at the most*:
  - Reheat will raise the supply temperature *to* the zone temperature but not *above* it

Why Do We Overcool the Air?

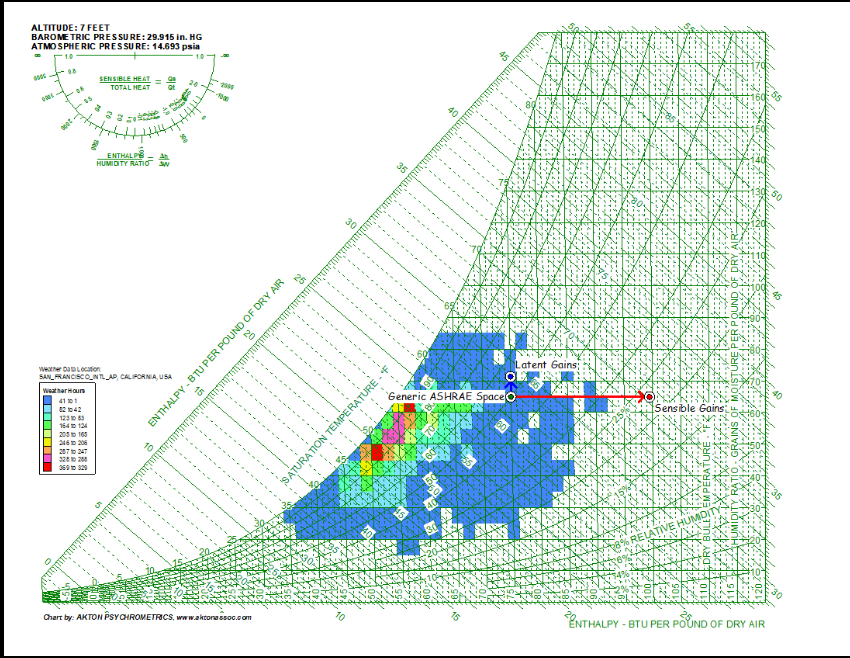
What are the fundamental goals of our HVAC processes and systems?

https://tinyurl.com/HeatPumpHVACGoals



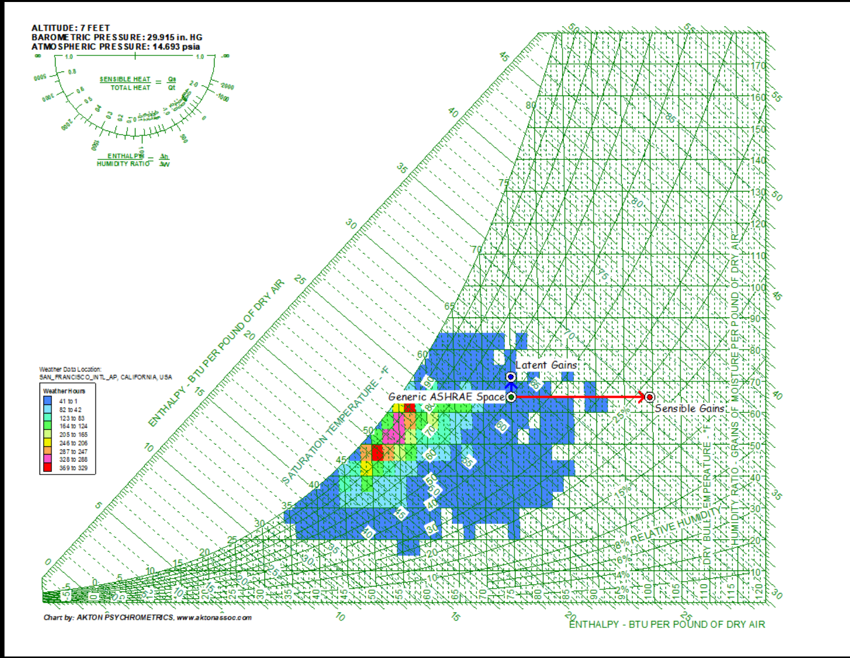
Addressing the HVAC Goals

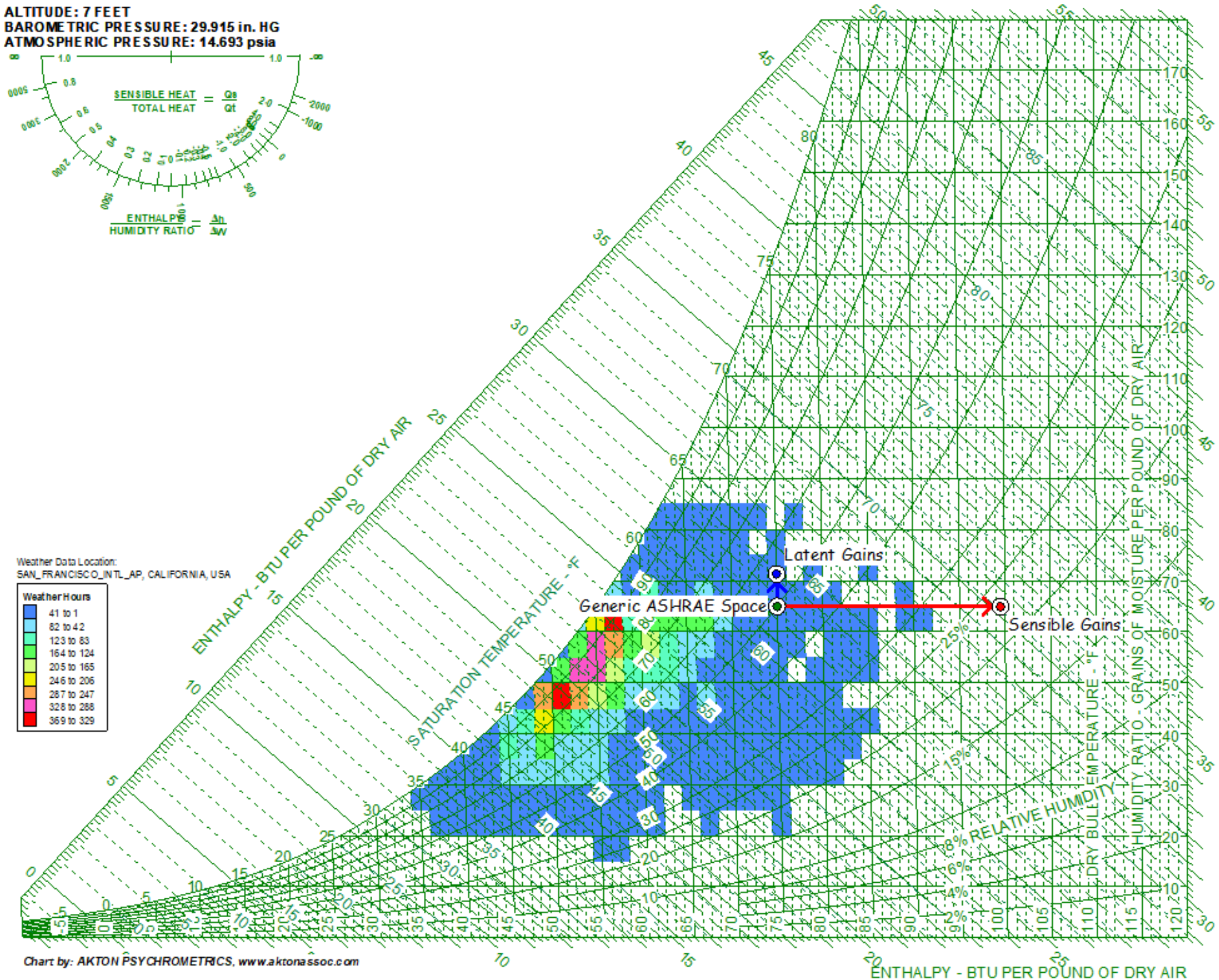
Given that there are people in the space, we will need to provide some quantity of fresh outdoor air to control contaminants



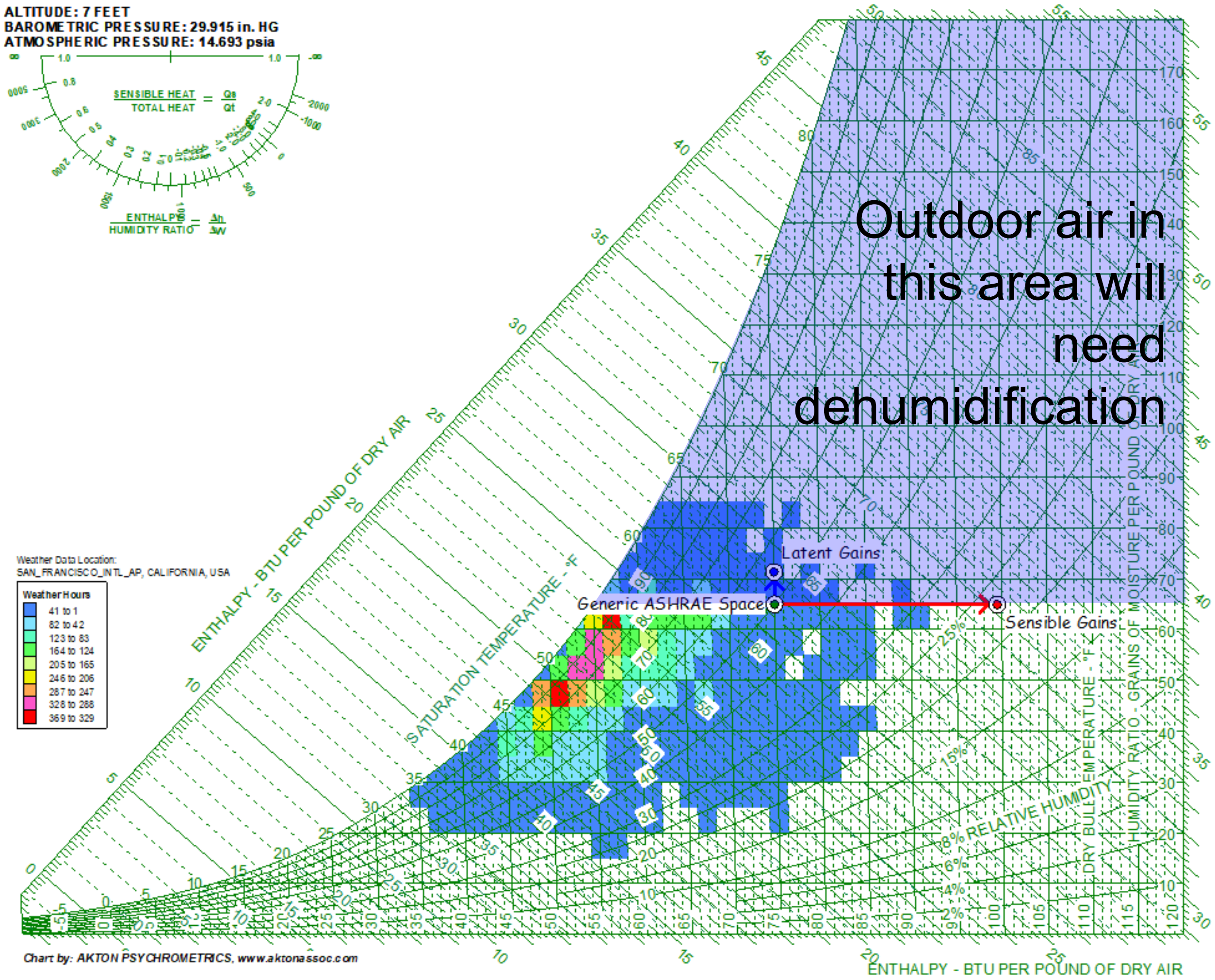
Addressing the HVAC Goals

Given the nature of the climate and the loads, this air and any recirculated air will need to be cooled and dehumidified during warm, humid weather





ALTITUDE: 7 FEET
BAROMETRIC PRESSURE: 29.915 in. HG
ATMOSPHERIC PRESSURE: 14.693 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Weather Data Location:
SAN_FRANCISCO_INTL_AP, CALIFORNIA, USA
Weather Hours
41 to 1
82 to 42
123 to 83
164 to 124
205 to 165
246 to 206
287 to 247
328 to 288
369 to 329
Latent Gains
Generic ASHRAE Space
Sensible Gains
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com



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Outdoor air in this area will need dehumidification
Latent Gains
Generic ASHRAE Space
Sensible Gains
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SAN_FRANCISCO_INTL_AP, CALIFORNIA, USA
Weather Hours
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164 to 124
205 to 165
246 to 206
287 to 247
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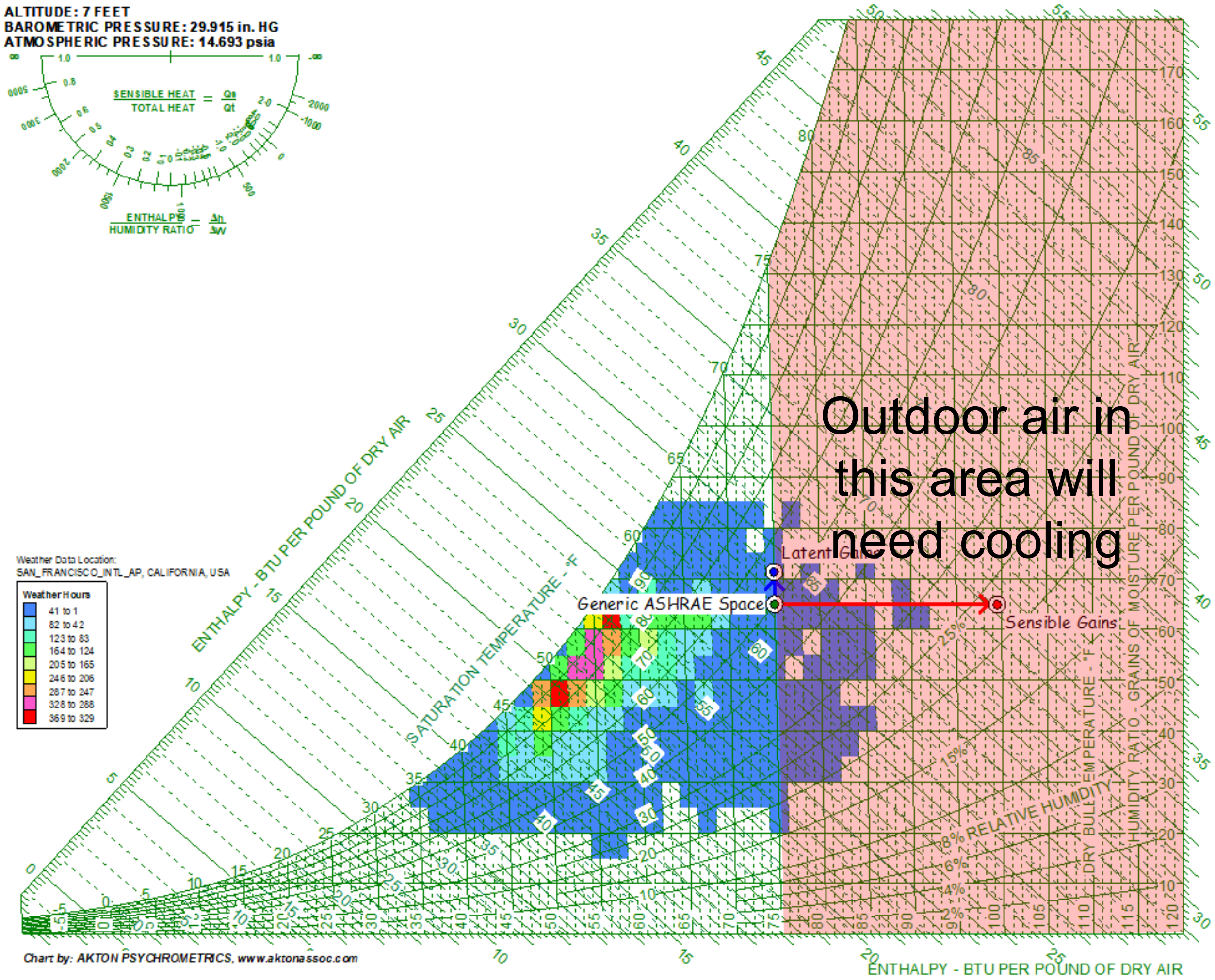

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ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
Outdoor air in this area will need cooling
Latent Gains
Generic ASHRAE Space
Sensible Gains
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
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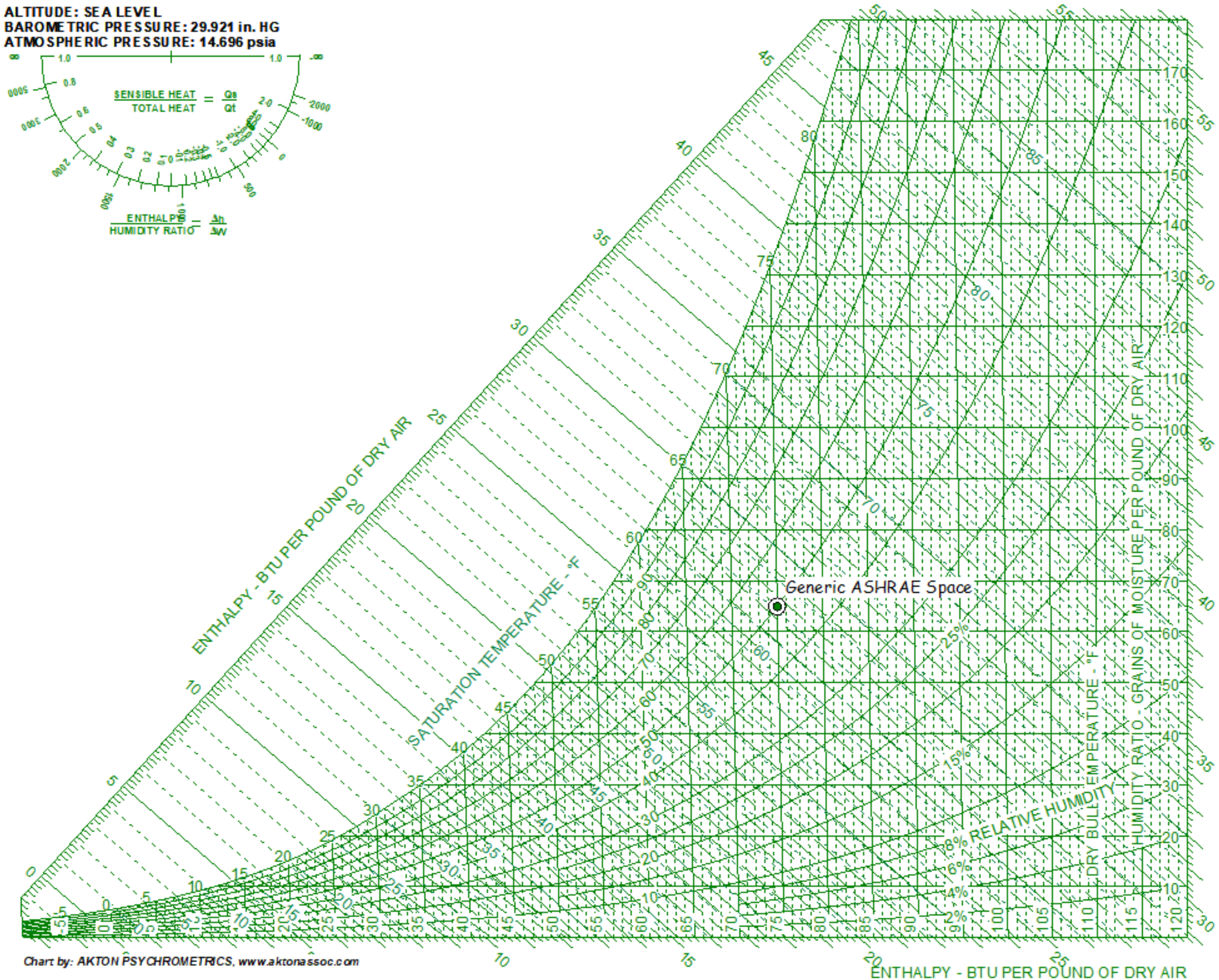

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SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
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Generic ASHRAE Space
RELATIVE HUMIDITY
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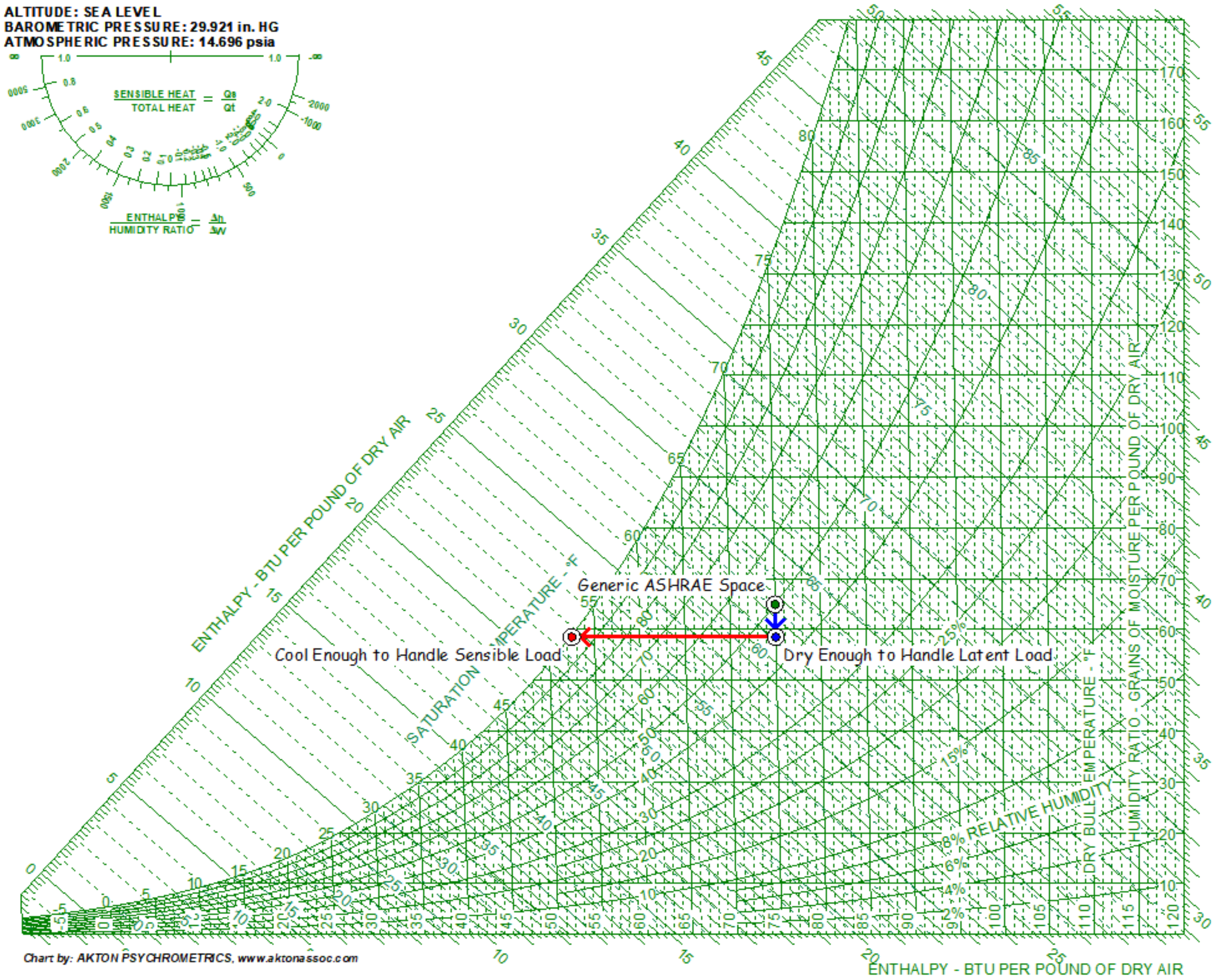

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Generic ASHRAE Space
Cool Enough to Handle Sensible Load
Dry Enough to Handle Latent Load
RELATIVE HUMIDITY
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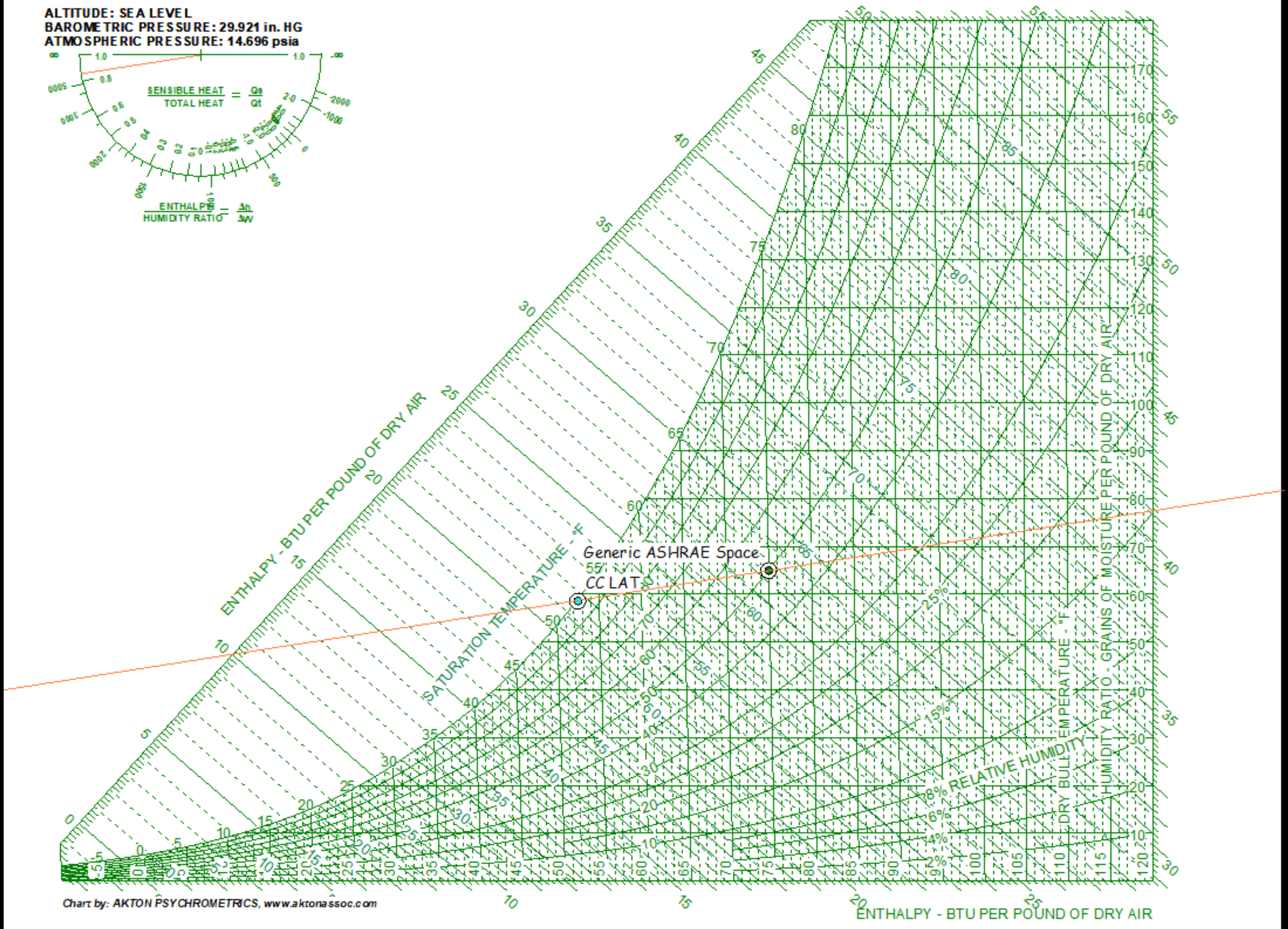

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SATURATION TEMPERATURE - °F
Generic ASHRAE Space
55
CC LAT
RELATIVE HUMIDITY
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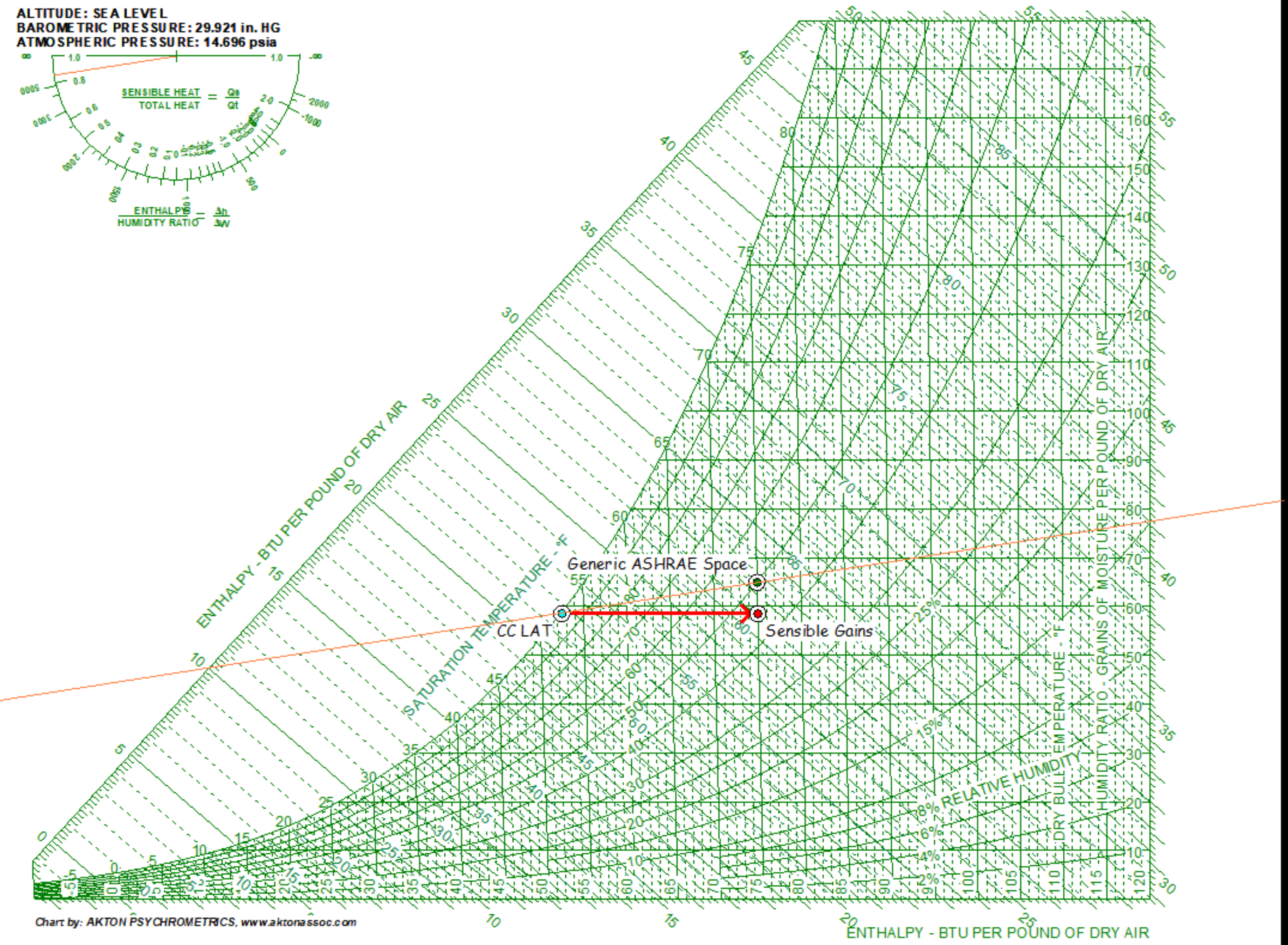

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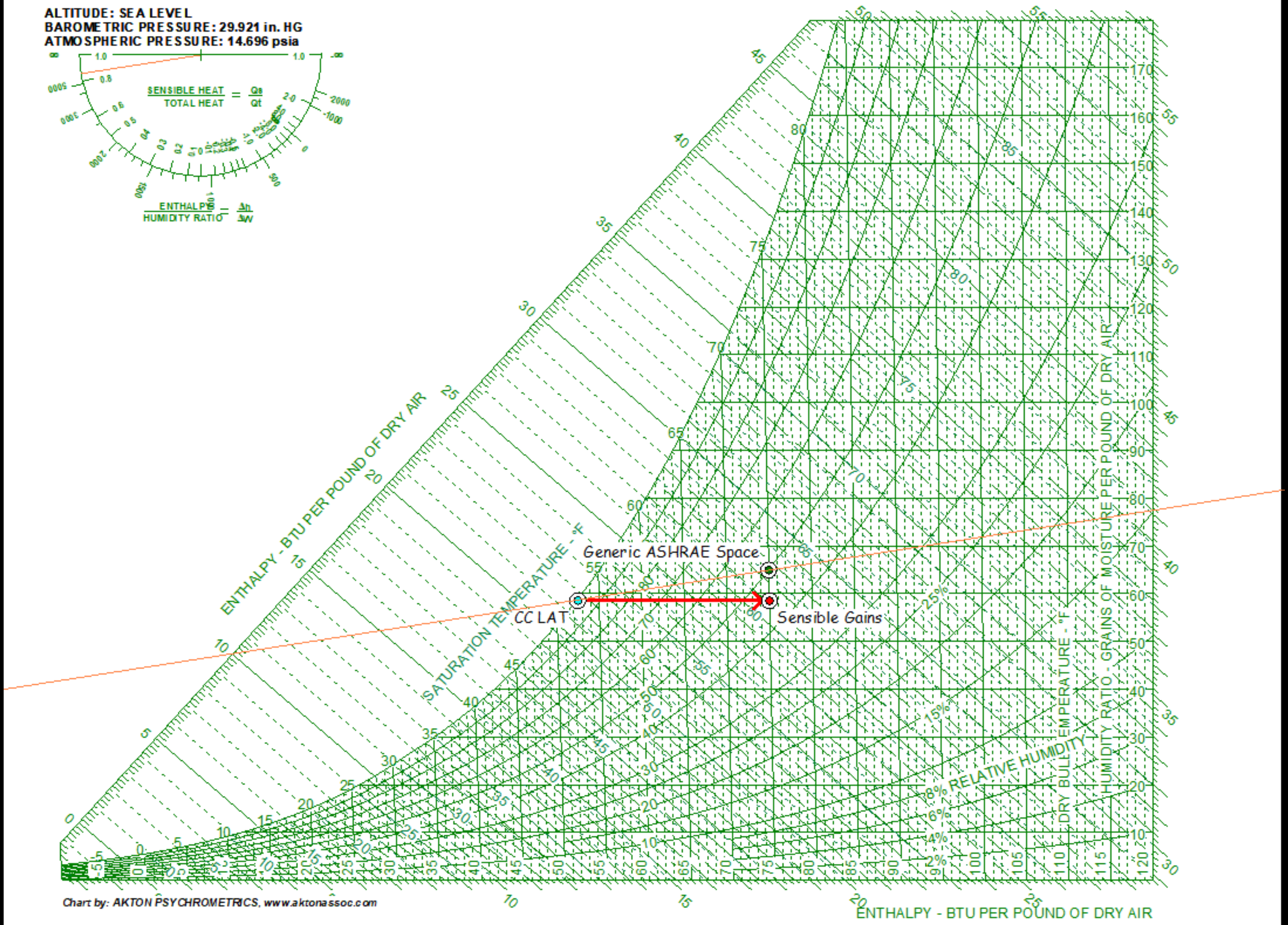

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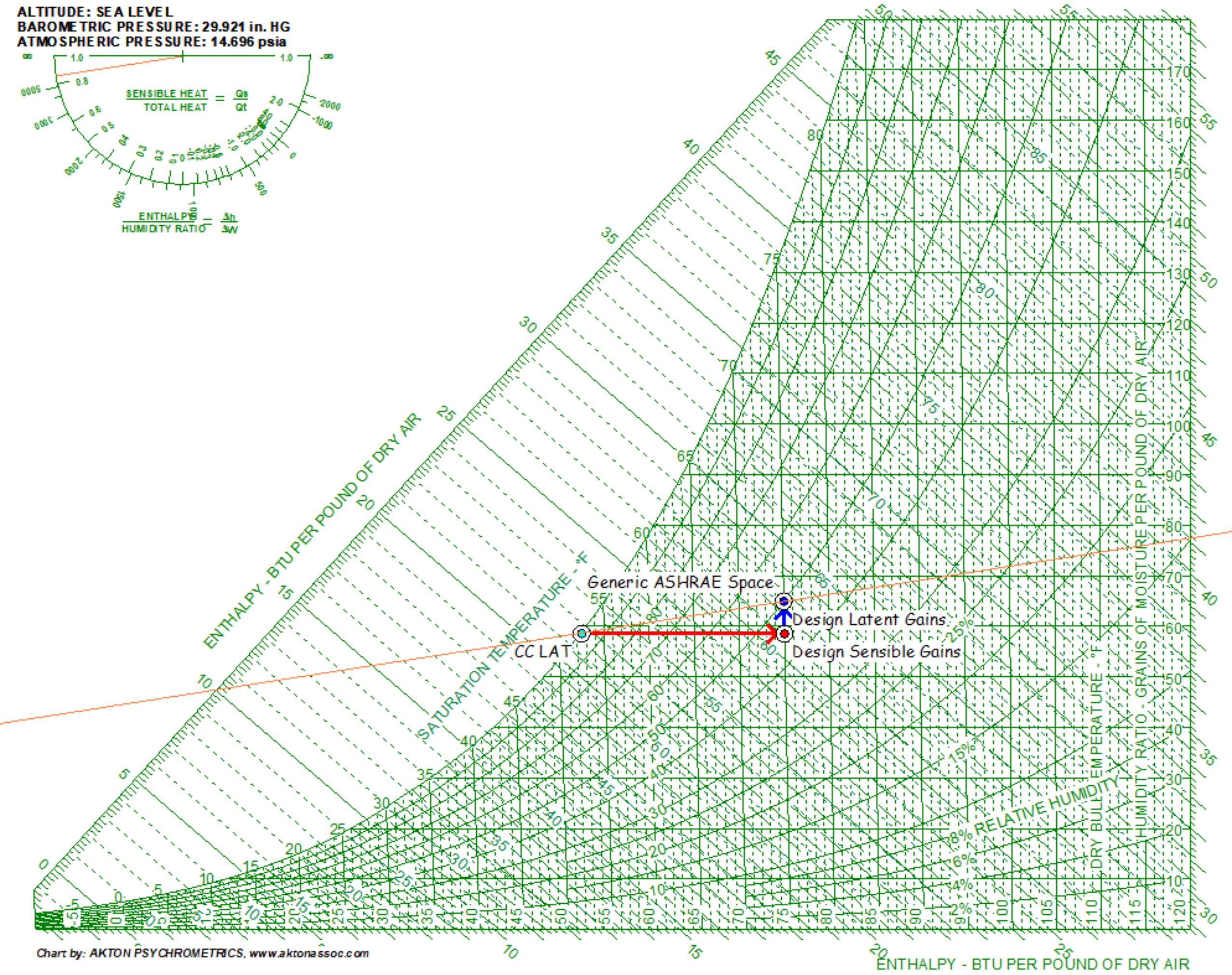

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CC LAT
Design Sensible Gains
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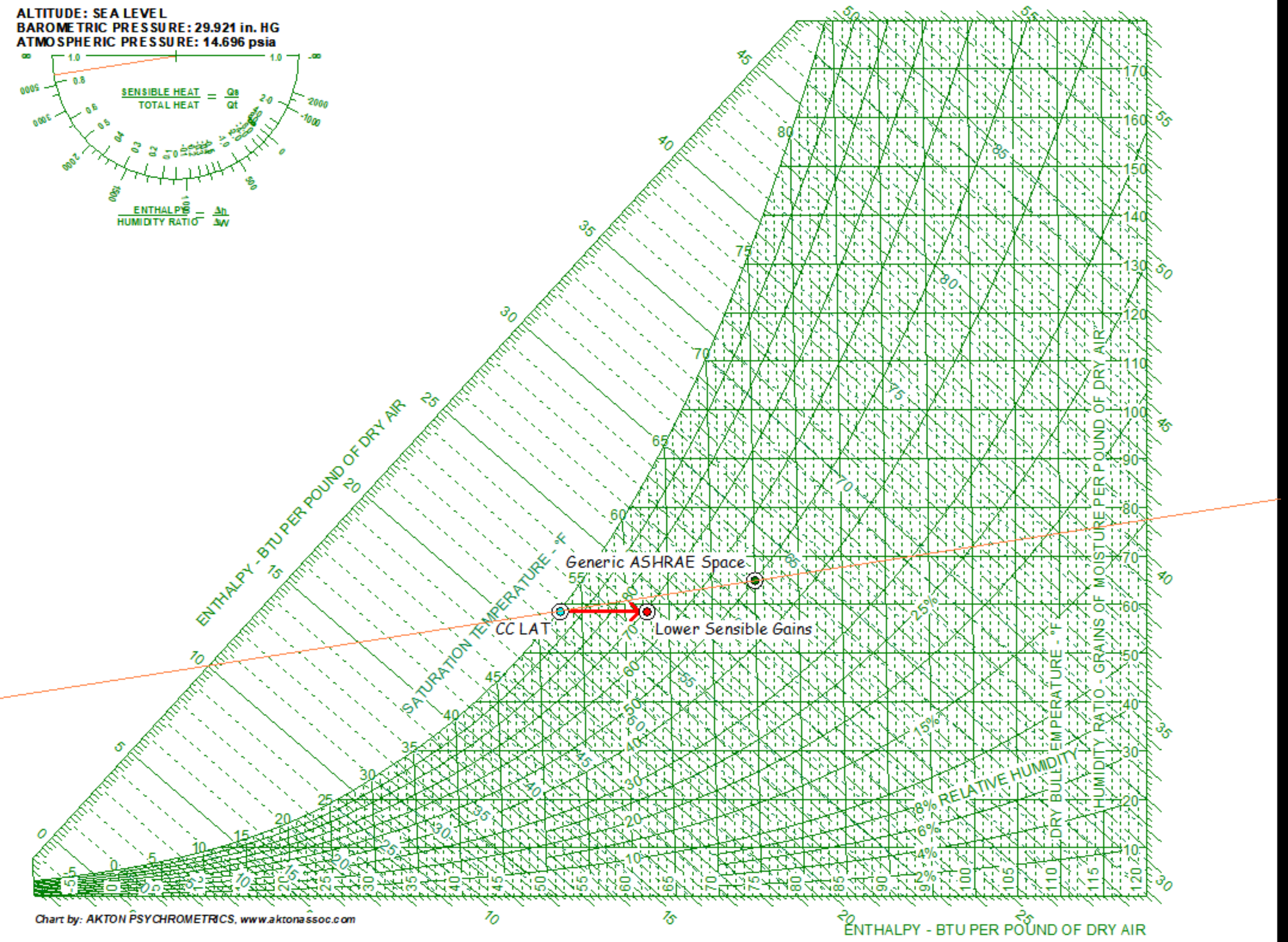

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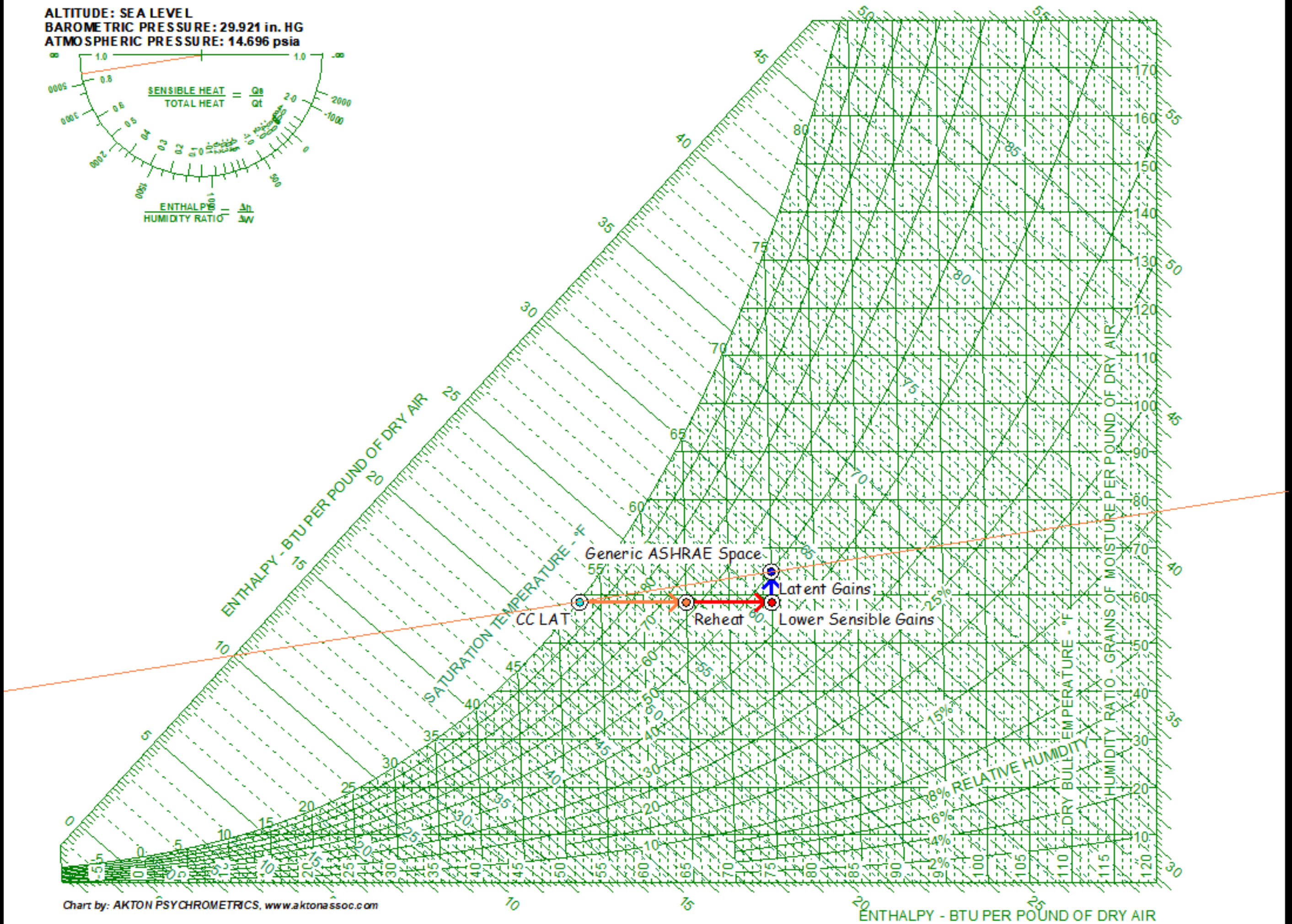

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- Cooling
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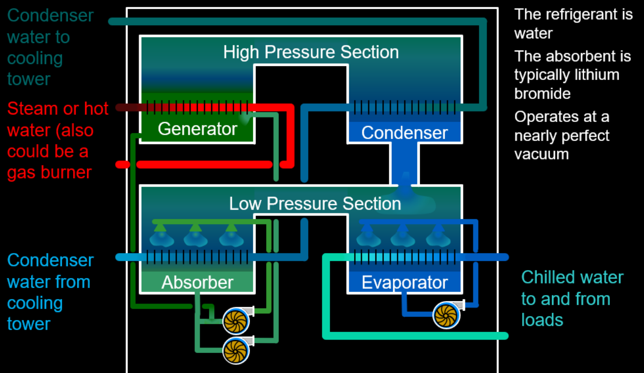
A Few More Definitions

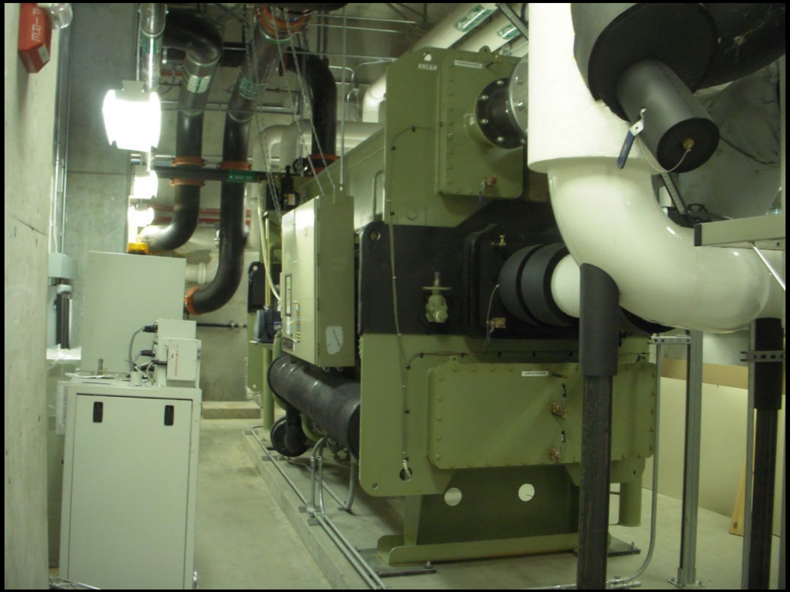
Absorption Refrigeration

– A cooling process that is driven by heat

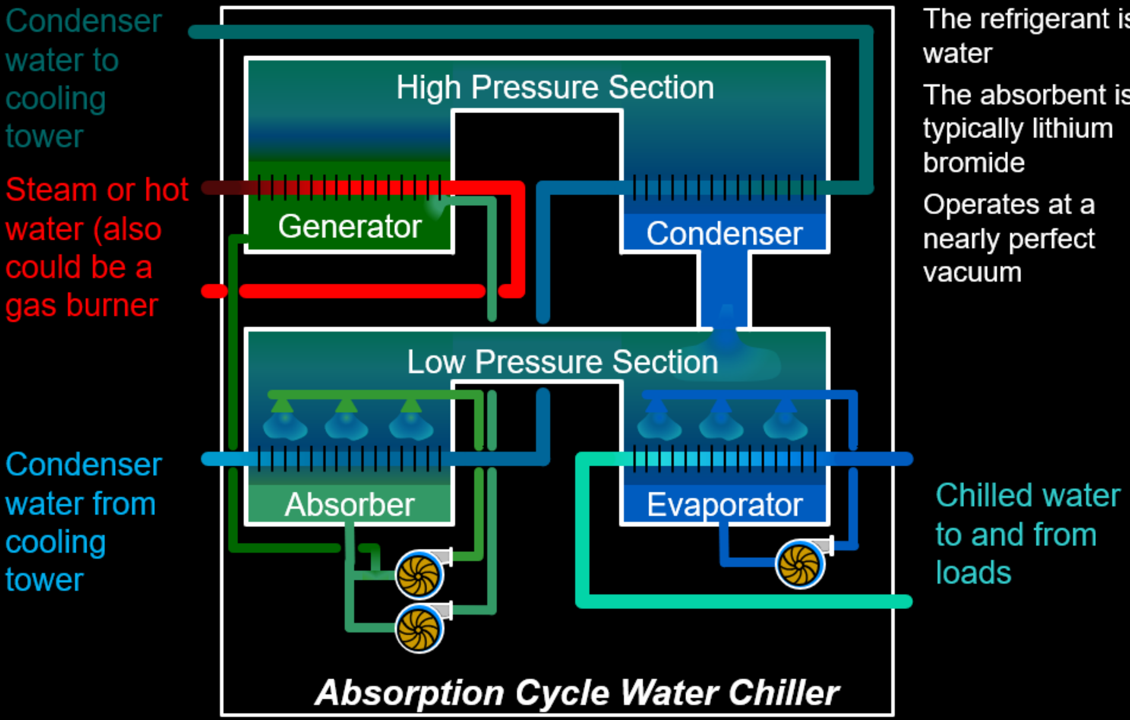
Absorption Chiller



Absorption Cycle Water Chiller



Absorption Chiller



The refrigerant is water

The absorbent is typically lithium bromide

Operates at a nearly perfect vacuum

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- Cooling ✓ Can move heat to where its needed
- Processes
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A Few More Definitions

Humidification

- A process that adds moisture to the air
  - RH levels between 40 and 60 percent are optimum for comfort and disease prevention
  - The influenza virus has its highest mortality rate at 50% percent RH
  - Equipment may require specific humidity levels for optimum performance
  - Production may require specific humidity levels to maintain manufacturing tolerance

A Few More Definitions

Sterilization

- A process that makes something free from bacteria or other living microorganisms
  - Common in health care and laboratory applications

Indirect Steam Humidifier

Evaporative Cooler

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- Cooling ✓ Can move heat to where its needed
- Processes ✓ Harder to address with a heat pump
- Power Generation

A Few More Definitions

Power Generation

- A process that generates power by converting one form of energy into a different, more useful form for the task at hand

State	% of Total Electric Power Generation											Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Renewable					Renewable					Nuclear				
	Combustion Processes						Non-Combustion Processes								
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass	Hydro	Wind	Solar	Geothermal					
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

– The heat can come from burning things like coal

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Few More Definitions

Power Generation

– The heat can come from burning things like coal, gas

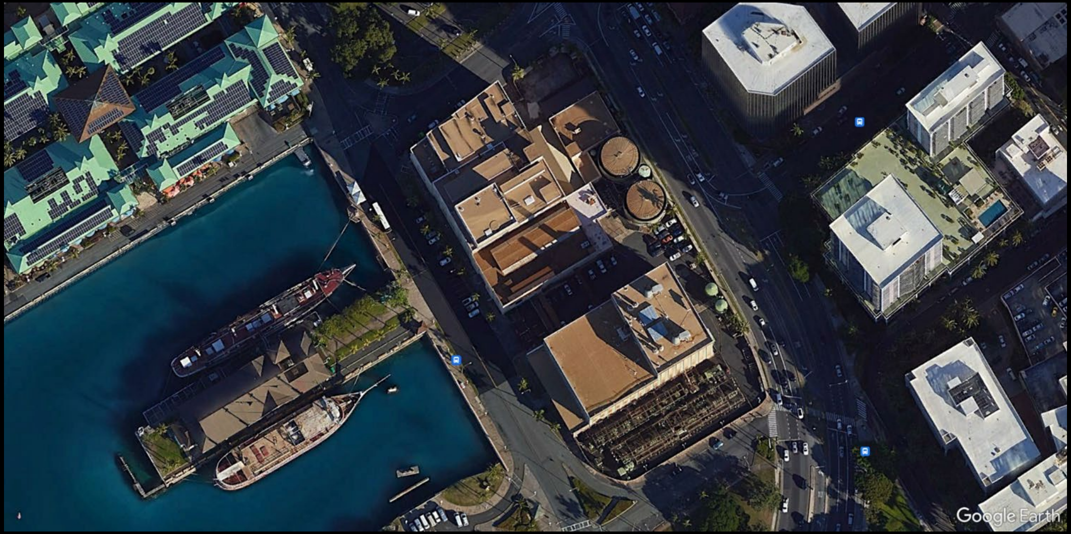
State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Few More Definitions

Power Generation

– The heat can come from burning things like coal, gas, oil

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%



A Few More Definitions

Power Generation

- The heat can come from burning things like coal, gas, oil, or biomass …

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Few More Definitions

Power Generation

- … or it can come non-combustion process-based sources like hydro, wind

Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

– … or it can come non-combustion process-based sources like hydro, wind

lectric Power Generation							Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Renewable					Nuclear				
	Non-Combustion Processes									
Biomass	Hydro	Wind	Solar	Geothermal						
3.0%	11.0%	7.0%	15.7%	5.9%		8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%		0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%		0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%		0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%		4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%		60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%		0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%		0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%		0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%		0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%		0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**		**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**		**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**		**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%		19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

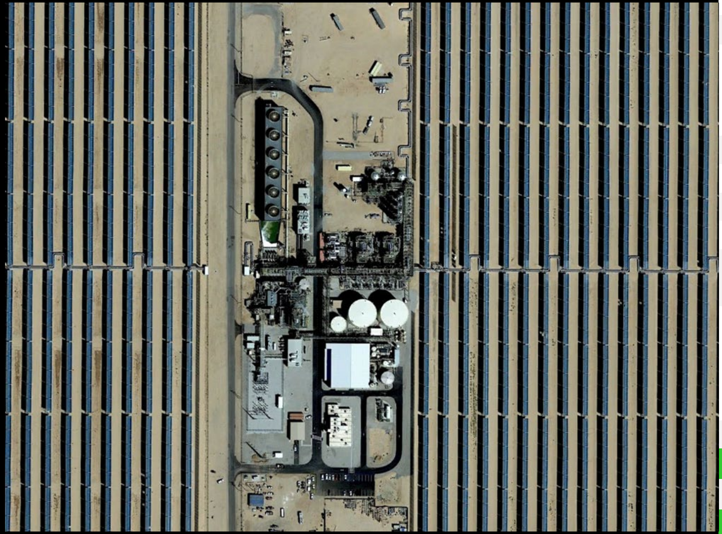
– … or it can come non-combustion process-based sources like hydro, wind, solar

Electric Power Generation: Biomass	Renewable Non-Combustion Processes: Hydro	Wind	Solar	Geothermal	Nuclear	Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

- … or it can come non-combustion process-based sources like hydro, wind, solar

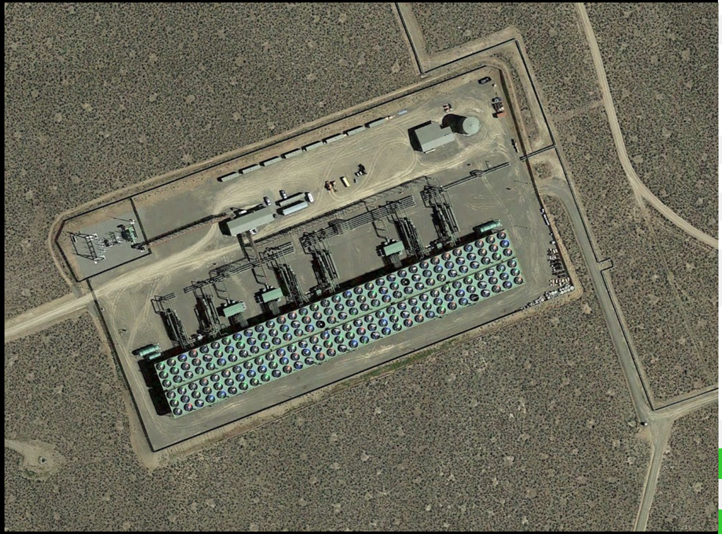


Electric Power Generation									
	Renewable				Nuclear	Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

- … or it can come non-combustion process-based sources like hydro, wind, solar, geothermal



Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Renewable				Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Few More Definitions

Power Generation

- … or it can come non-combustion process-based sources like hydro, wind, solar, geothermal, and nuclear energy

Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

How Buildings Use Heat

- Heating ✓ Core is rejecting heat when we need to do this
- Preheat ✓ Core is rejecting heat when we need to do this
- Reheat ✓ Core is rejecting heat when we need to do this
- Cooling ✓ Can move heat to where its needed
- Processes ✓ Harder to address with a heat pump
- Power Generation ✓

How Buildings Use Heat

- Heating ✓ Core is rejecting heat when we need to do this
- Preheat ✓ Core is rejecting heat when we need to do this
- Reheat ✓ Core is rejecting heat when we need to do this
- Cooling ✓ Can move heat to where its needed
- Processes ✓ Harder to address with a heat pump
- Power Generation ✓ Heat pumps can leverage this

How Buildings Use Heat

Application	Electrification Target
• Heating ✓	✓
• Preheat ✓	✓
• Reheat ✓	✓
• Cooling ✓	✓
• Humidification ✓	
• Power Generation ✓	

Why Electrification?

The traditional approach to generating heat has been to burn fossil fuels

Good News

- Fairly simple
- High grade heat
- Fairly inexpensive

Why Electrification?

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Good News

- Fairly simple
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Bad News

- CO_2 Intensive

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered						
		Boiler Efficiency						
		95%	90%	85%	80%	75%	70%	65%
Natural Gas	117	123	130	137	146	156	167	179
Propane	139	146	154	163	173	185	198	213
Oil	163	172	182	192	204	218	234	251
Coal	212	223	235	249	265	282	303	326
Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php								

The Goal

Stop burning fossil fuels by switching to an all-electric grid powered by renewable resources

The Challenges

1. Currently about 60-63% of our electricity is generated by burning something

The Challenges

2. Heat rates (efficiencies) for our power plants are not particularly high …

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
Natural Gas with Cogeneration	5,000	68%	6,500	53%	117	0.58	0.76
Natural Gas Combined Cycle	6,200	55%	8,000	43%	117	0.72	0.93
Natural Gas Reciprocating Engine	7,500	46%	8,500	40%	117	0.87	0.99
Natural Gas Combustion Turbine	8,000	43%	10,000	34%	117	0.93	1.17
Coal Steam Turbine	9,000	38%	11,000	31%	212	1.91	2.33
Natural Gas Steam Turbine	10,000	34%	12,000	28%	117	1.17	1.40
Nuclear Power Plant	10,446	33%	10,459	33%	0	0.00	0.00
Heat Rate Source -	https://energyknowledgebase.com/topics/heat-rate.asp						
Emmissions Factor Source -	https://www.eia.gov/environment/emissions/co2_vol_mass.php						

2. Heat rates (efficiencies) for our power plants are not particularly high and CO2 emissions potentially would not be much different

Heat Rates for Different Types of Power Plants

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CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered as Electric Resistance Heat *
		Boiler Efficiency							
		95%	90%	85%	80%	75%	70%	65%	
Natural Gas	117	123	130	137	146	156	167	179	214
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Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

The Challenges

3. Distribution losses are in the range of 5-6% between the switch yard at the power plant and your meter

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
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The Challenges

4. It will take a very significant investment in additional infrastructure to support the distribution required for an all-electric renewable energy supplied grid

Heat Rates for Different Types of Power Plants

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The Challenges

4. Energy storage systems will also be needed with related investments


5818 ft
Google Earth


212 ft
Google Ear


Google Earth


Google Earth


Google Earth


Google Earth

The Challenges

5. There may be things going on that we have yet to fully appreciate

The relative contribution of waste heat from power plants to global warming

R. Zevenhoven [a,*], A. Beyene [b]

[a] *Department of Chemical Engineering, Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo/Turku, Finland*
[b] *Department of Mechanical Engineering, San Diego State University, 5500 Campanile Drive, San Diego, CA, USA*

A R T I C L E I N F O

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Waste heat

A B S T R A C T

Evidence on global climate change, being caused primarily by rising levels of greenhouse gases in the atmosphere, is perceived as fairly conclusive. It is generally attributed to the enhanced greenhouse effect, resulting from higher levels of trapped heat radiation by increasing atmospheric concentrations of gases such as CO_2 (carbon dioxide). Much of these gases originate from power plants and fossil fuel combustion. However, the fate of vast amounts of waste heat rejected into the environment has evaded serious scholarly research. While 1 kWh electricity generation in a typical condensing coal-fired power plant emits around 1 kg of CO_2, it also puts about 2 kWh energy into the environment as low grade heat. For nuclear (fission) electricity the waste heat release per kWh is somewhat higher despite much lower CO_2 releases. This paper evaluates the impact of waste heat rejection combined with CO_2 emissions using Finland and California as case examples. The immediate effects of waste heat release from power production and radiative forcing by CO_2 are shown to be similar. However, the long-term (hundred years) global warming by CO_2-caused radiative forcing is about twenty-five times stronger than the immediate effects, being responsible for around 92% of the heat-up caused by electricity production.

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The Challenges

5. There may be things going on that we have yet to fully appreciate

The relative contribution of waste heat from power plants to global warming

R. Zevenhoven [a,*], A. Beyene [b]

[a] Department of Chemical Engineering, Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo/Turku, Finland
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Time for Another Question

Let’s “connect a few dots”

https://tinyurl.com/HeatPumpConnectDots

Recall That:

- Heat pumps don’t create energy; they use energy to move energy from a Cold Location to a Hot Location

Recall That:

- Heat pumps don't create energy; they use energy to move energy from a Cold Location to a Hot Location
- The COP (Coefficient of Performance) defines how much energy they need to spend relative to the energy they move
- COPs can be easily be 3 or higher

Coefficient of performance for a heat pump

$$COP_{Heating} = \frac{Q_{Heat}}{W_{In}}$$

or, solving for Q_{Heat}

$$Q_{Heat} = COP_{Heating} \times W_{In}$$

Where:

$COP_{Heating}$	=	Coefficient of performance as a heat pump
Q_{Heat}	=	The heat delivered to the area served in consistent units, which is the heat rejected by the heat pump
W_{In}	=	The work done to deliver the heat in consistent units

As a Result:

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers — Boiler Efficiency 95%	90%	85%	80%	75%	70%	65%	lb CO_2 per Million Btu Delivered as Electric Resistance Heat *	lb CO_2 per Million Btu Delivered by a Heat Pump with a COP of 3.7*
Natural Gas	117	123	130	137	146	156	167	179	214	91
Propane	139	146	154	163	173	185	198	213		
Oil	163	172	182	192	204	218	234	251		
Coal	212	223	235	249	265	282	303	326		

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Heat Rate Source - "Heat Rates" tab of this spreadsheet

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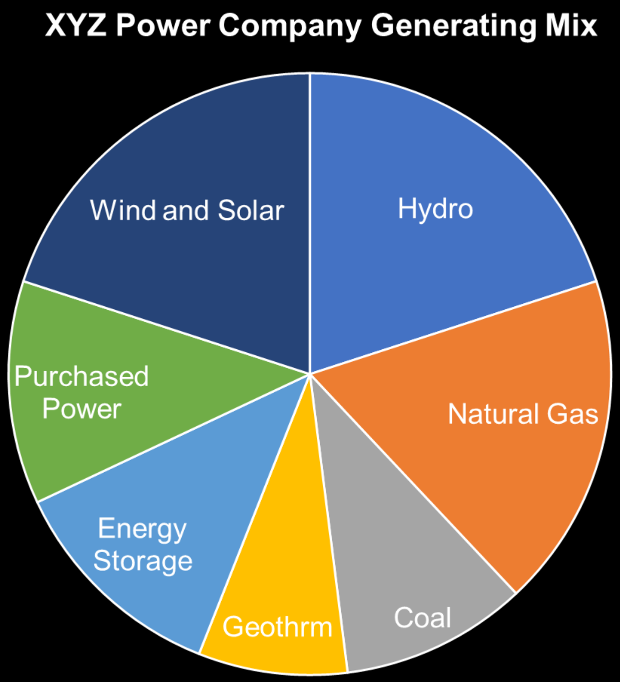
Reducing Atmospheric Impacts

We expect our energy mix to be 70% carbon free by 2040 based on current commitments and mandates, and we're working to deliver the right resources and technologies to make that happen

Energy Strategy; www.portlandgeneral.com

Reducing Atmospheric Impacts

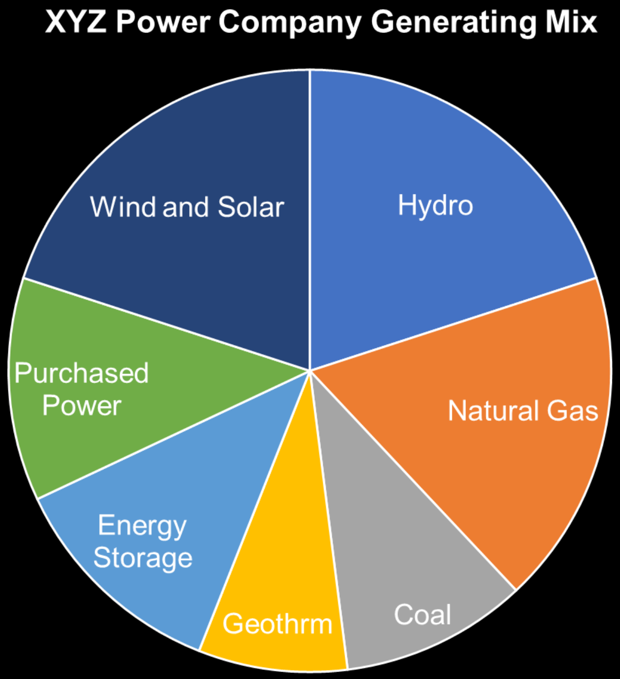
Moving away from carbon fuels is a common, long-term goal for many utilities



Reducing Atmospheric Impacts

- Applying the commissioning tool set can have an immediate impact by reducing the need for energy in the first place
- Using heat pumps to leverage the electricity we use to create heat makes best use of the electricity consumed to create heat

It's a win-win situation



How Buildings Use Heat

Application	Electrification Target	Heat Pump Target
• Heating ✓	✓	✓
• Preheat ✓	✓	✓
• Reheat ✓	✓	✓
• Cooling ✓	✓	✓
• Humidification ✓		
• Power Generation		

How Buildings Use Heat

Application	Electrification Target	Heat Pump Target	Conservation/ EBCx Target
• Heating ✓	✓	✓	✓
• Preheat ✓	✓	✓	✓
• Reheat ✓	✓	✓	✓
• Cooling ✓	✓	✓	✓
• Humidification ✓	✓		✓
• Power Generation			

How Buildings Use Heat

Application	Electrification Target	Heat Pump Target	Conservation/ EBCx Target
• Heating ✓	✓	✓	✓
• Preheat ✓	✓	✓	✓
• Reheat ✓	✓	✓	✓
• Cooling ✓	✓	✓	✓
• Humidification ✓	✓		✓
• Power Generation	*Heat pumps and best practices in terms of ongong commissioning use our power to best advantage*		

Question?

Together, Building
a Better California