Cost-Effective Code Compliance

HVAC

Seattle City Light

Lighting Design Lab

September 28, 2021

Before we Begin…

During the Webinar

- Attendees will be muted
- Please use the chat feature in the control panel to submit questions to LDL staff
- The presenter will pause to address questions periodically.
- Please participate in the online polls.

Following the Webinar

- Please take the short survey
- A recording and the slide deck will be posted on LDL's webpage
- Reach out to LightingDesignLab@seattle.gov with comments or questions.

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Board Chair Emeritus, USGBC-MD

AIA MD COTE Chair

Sustainable Mechanical Engineering

Energy Modeling and Auditing

130+ LEED Projects

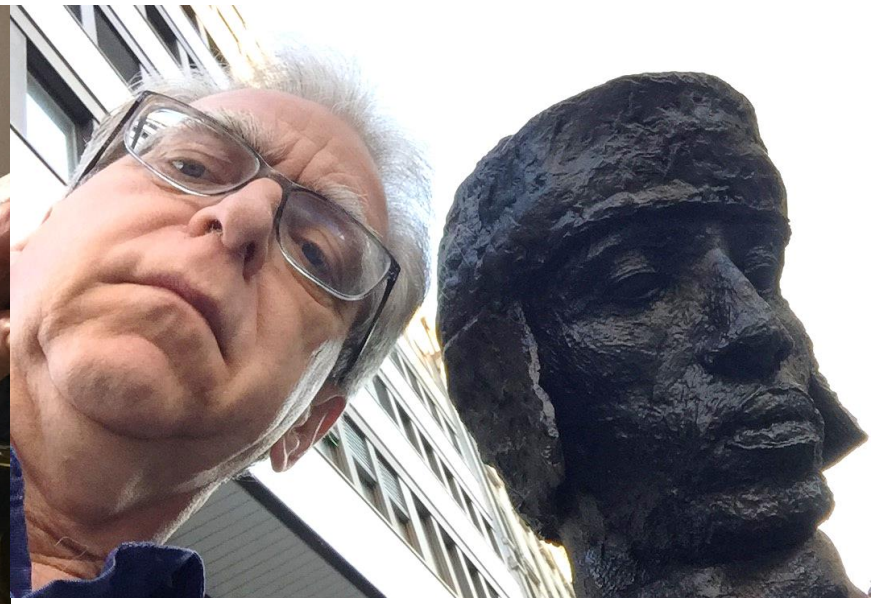
2 Certified Living Buildings

9 current projects targeting Net Zero

Code Nerd

Duane Jonlin, FAIA

- 30 years as technical architect
- 9 years as Energy Code guy
- 4th generation Seattleite



We got this.

It's not *whether* we're going to do this, it's *how*

Washington state:
70% less building energy use by 2030

- Zero-carbon buildings
- Gov says move faster

Washington state:
45% reduction in GHG emissions by 2030

- 95% reduction by 2050

Seattle: Carbon-neutral building & vehicle operations by 2050

- …or sooner with Green New Deal?

Seattle amendments: 4 Guiding Principles

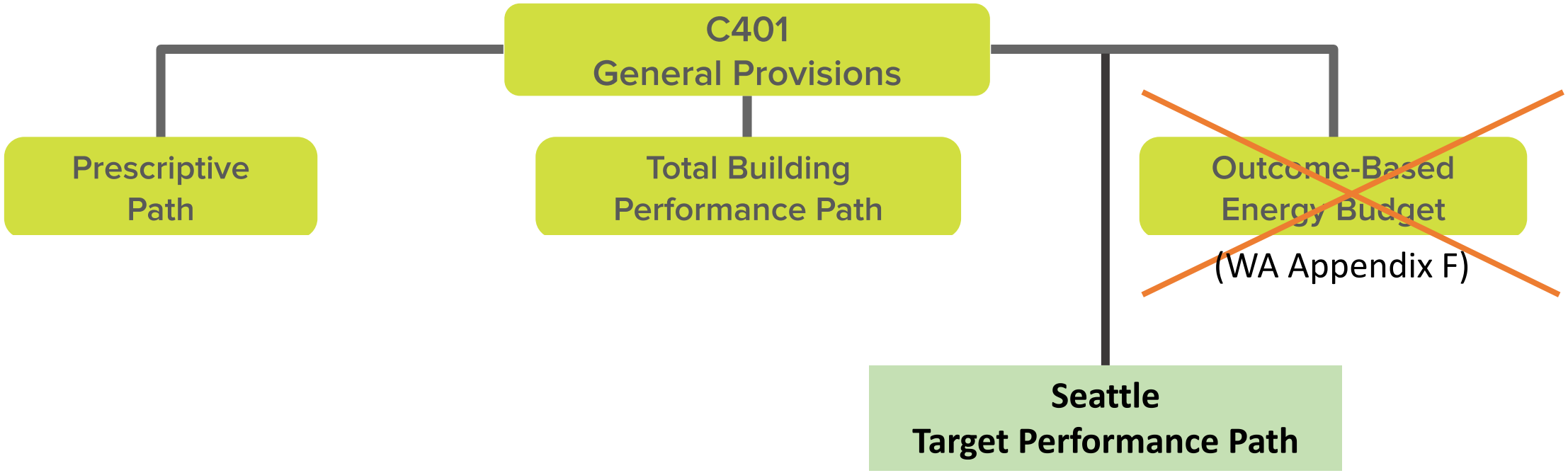
1. Envelopes meet our “2050” standard
   - We have to decide what that 2050 standard is
2. No “internal combustion buildings”
   - Electrical infrastructure for exceptions
3. Efficient use of electricity
   - Typically heat pumps for space heating & water heating
4. Increased on-site renewables
   - Options for off-site purchase
   - Plus “solar readiness” for bigger future system

Today: HVAC

Seattle: “Intent” section now includes “reduction of carbon emissions”

New buildings must be *capable of* meeting Seattle’s 2050 targets.

Code Paths


C401
General Provisions
Prescriptive
Path
Total Building
Performance Path
Outcome-Based
Energy Budget
(WA Appendix F)
Seattle
Target Performance Path

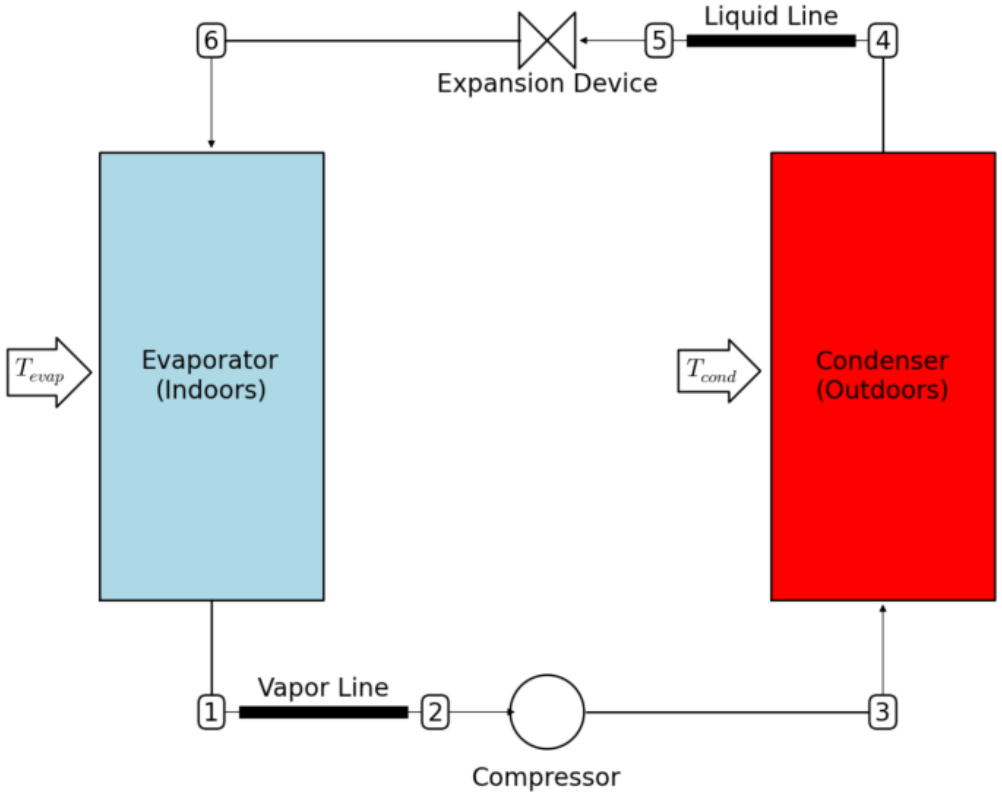
Engineering Terms

Heat Pump

Performance

COP

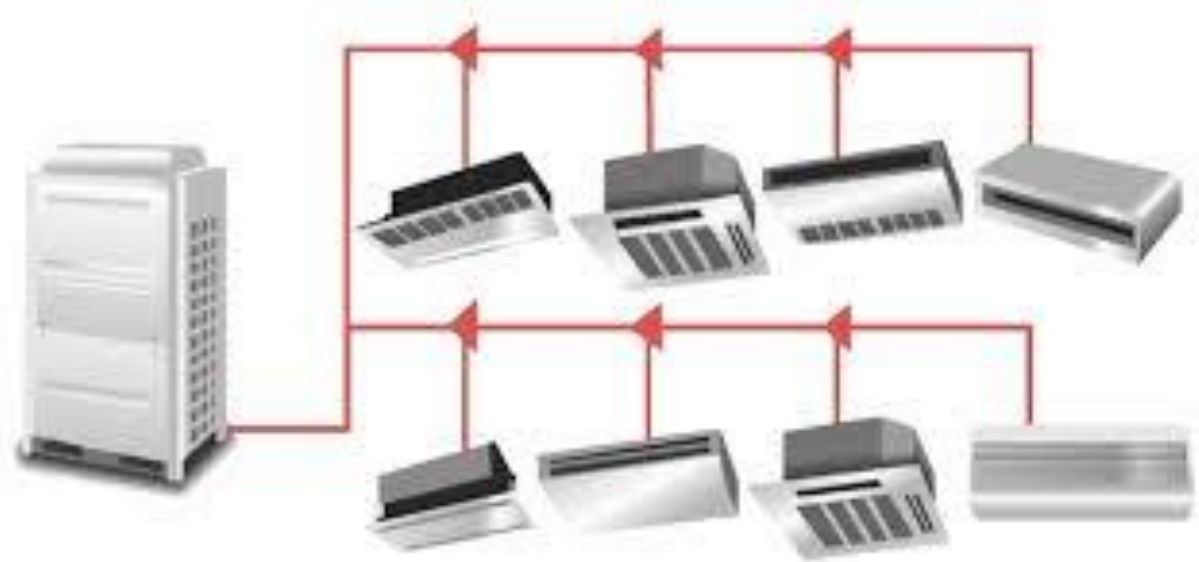
Resistance:
1kW in=1kW Work Out



Refrigeration cycle:
1kW in=3kW Work Out

Heat Pump Layout

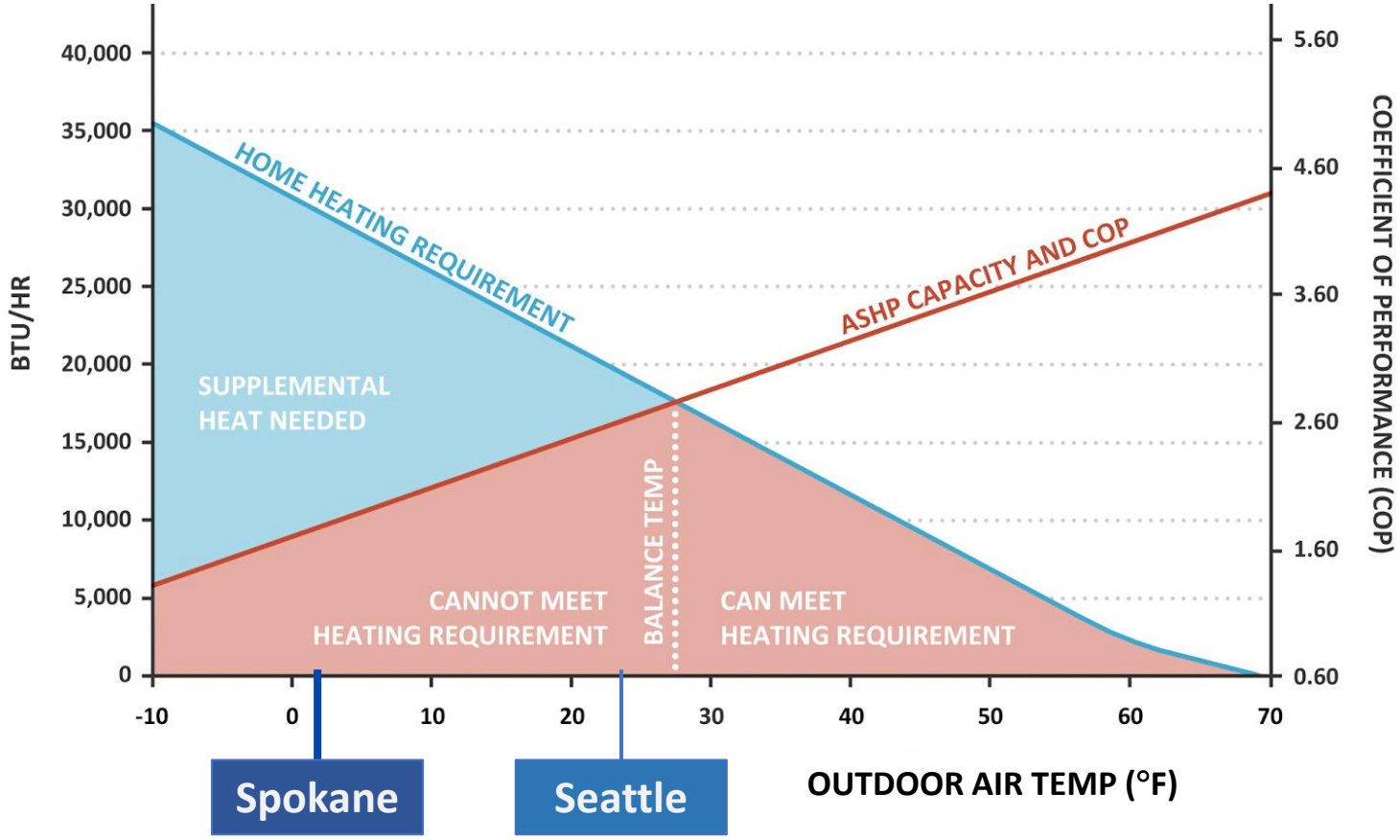
Heat Pump Layout, variable speed



Engineering View, Limitations

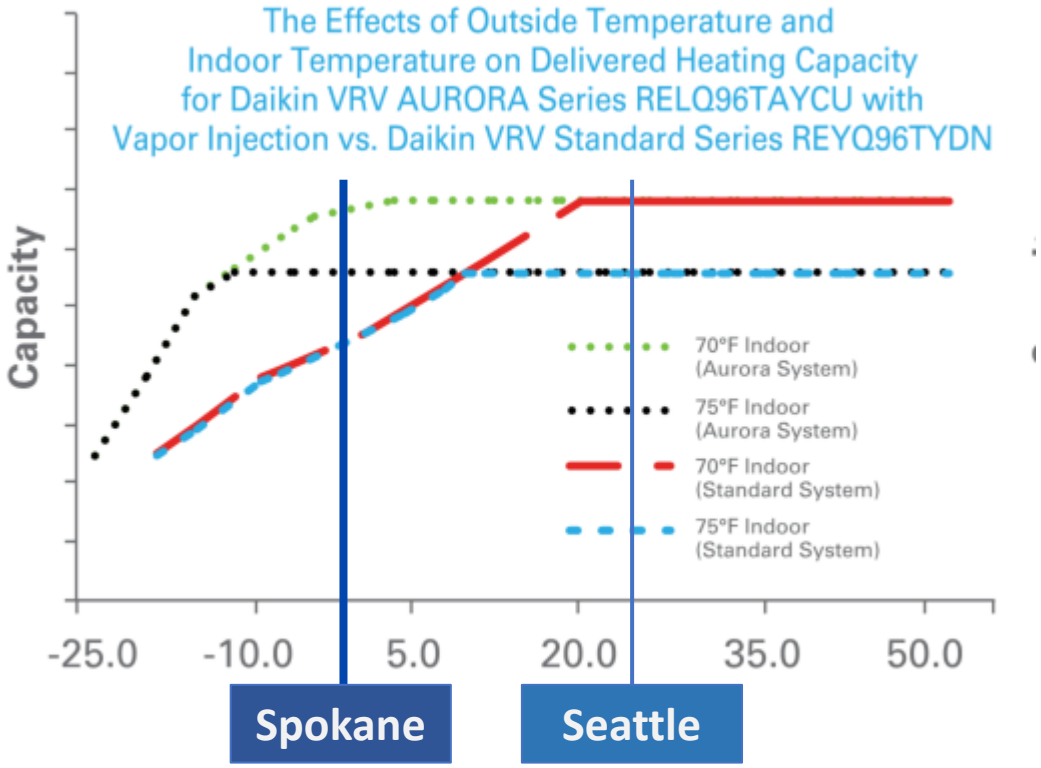
Heat Pump Performance, Cold Temp Impacts (cheap version)

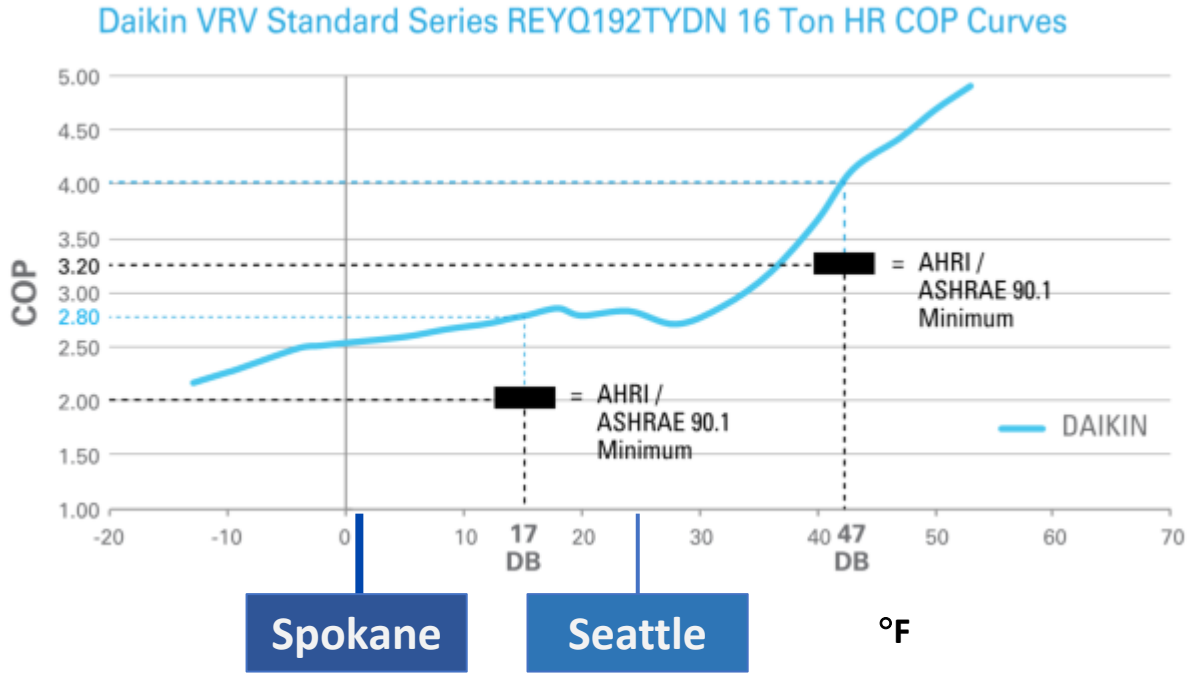
Performance of typical 2-ton air-source heat pump



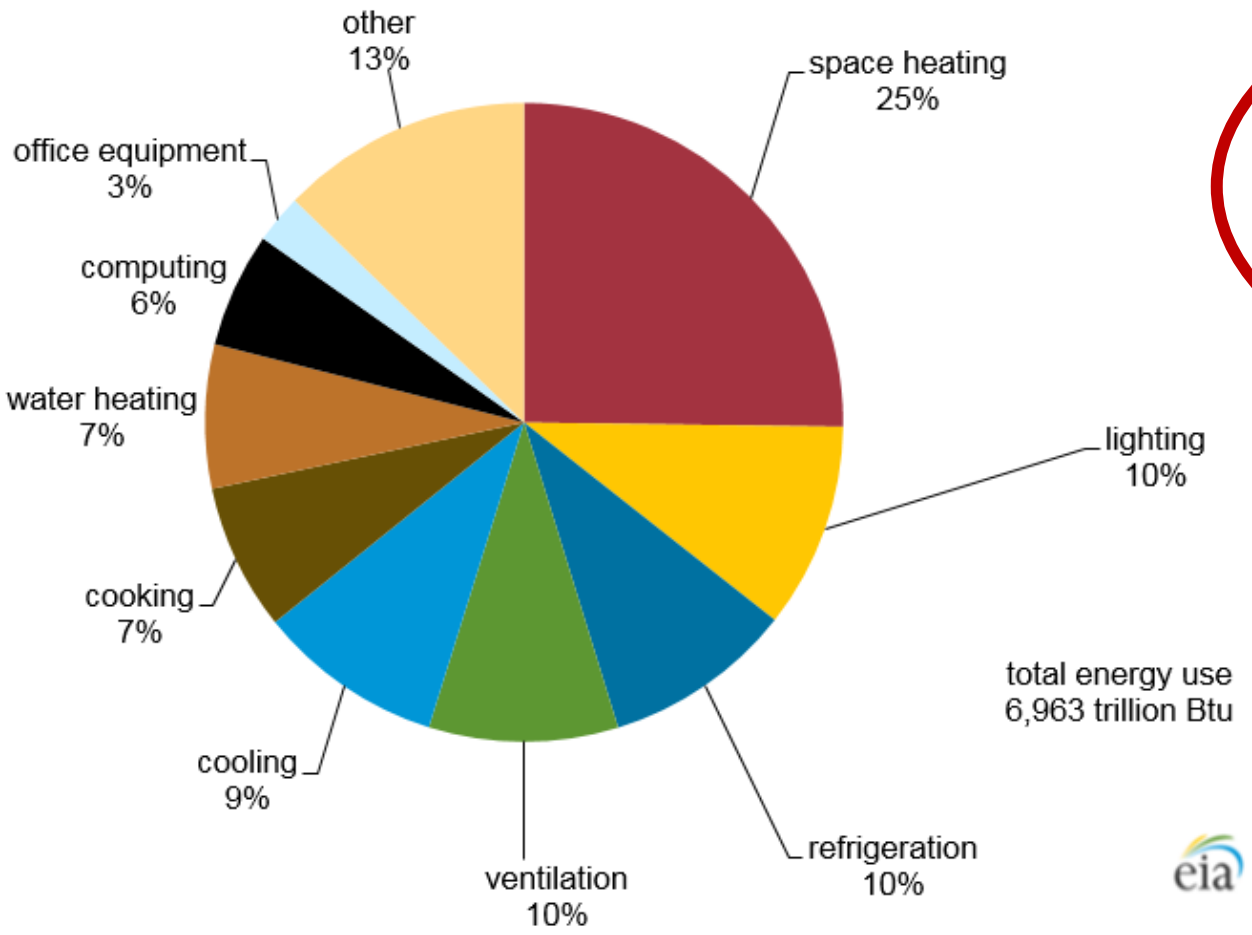
Engineering View, Less Limitations

Variable Speed Version





Start with the big slices



- **Space heating**
  - **System efficiency**
  - **Heat recovery**
  - Envelope UA & air tightness
- **Cooling**
  - **System efficiency**
  - Fenestration size & shading
- Lighting
  - Efficiency
  - Controls
- Water heating
  - System efficiency
- Plug loads

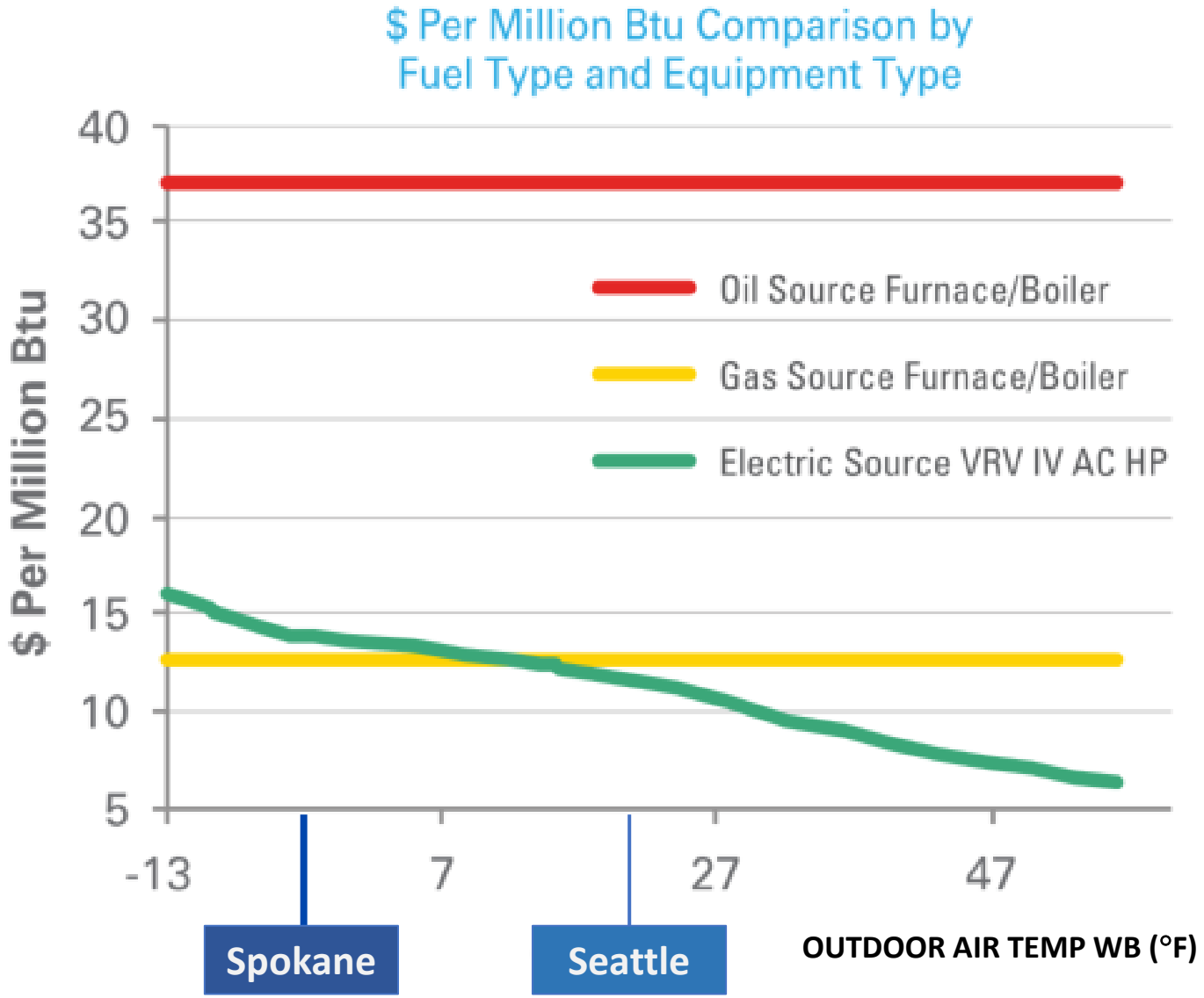
Today: HVAC

COST-EFFECTIVENESS

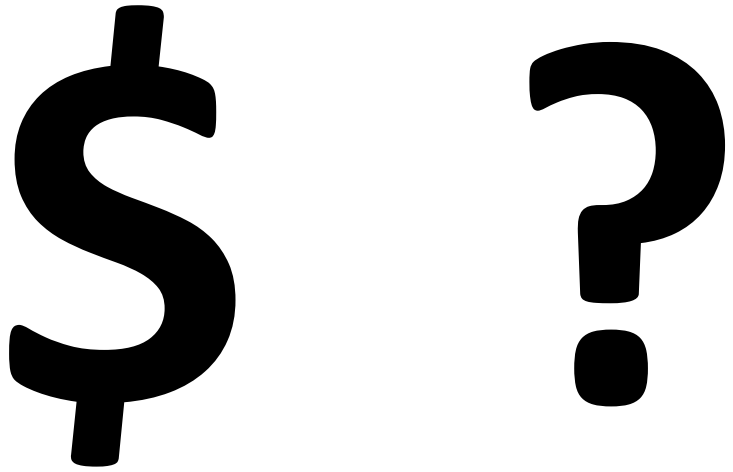
New energy code provisions should be:

- …*necessary* for meeting the City's goals…
- …and *as cost-effective as possible* for owners and tenants
  - Costs typically moderate after new code becomes "business as usual."

Engineering View, Cost



Engineering View, Cost



Seattle: Envelope U-value of PTAC/PTHP units

- Conventional PTAC & PTHP units leak heat & leak air badly
- Through-wall mech units assigned default U-value of 0.50
  - Unless mfr has tested U-value
  - 10x typical wall heat loss

Air Barrier Testing

- Test standard reduced to 0.25 cfm/sf of envelope

- Passing test now mandatory
  - …at the old std: 0.40 cfm/sf

Q: Do your HVAC design calcs account for reduced leakage?

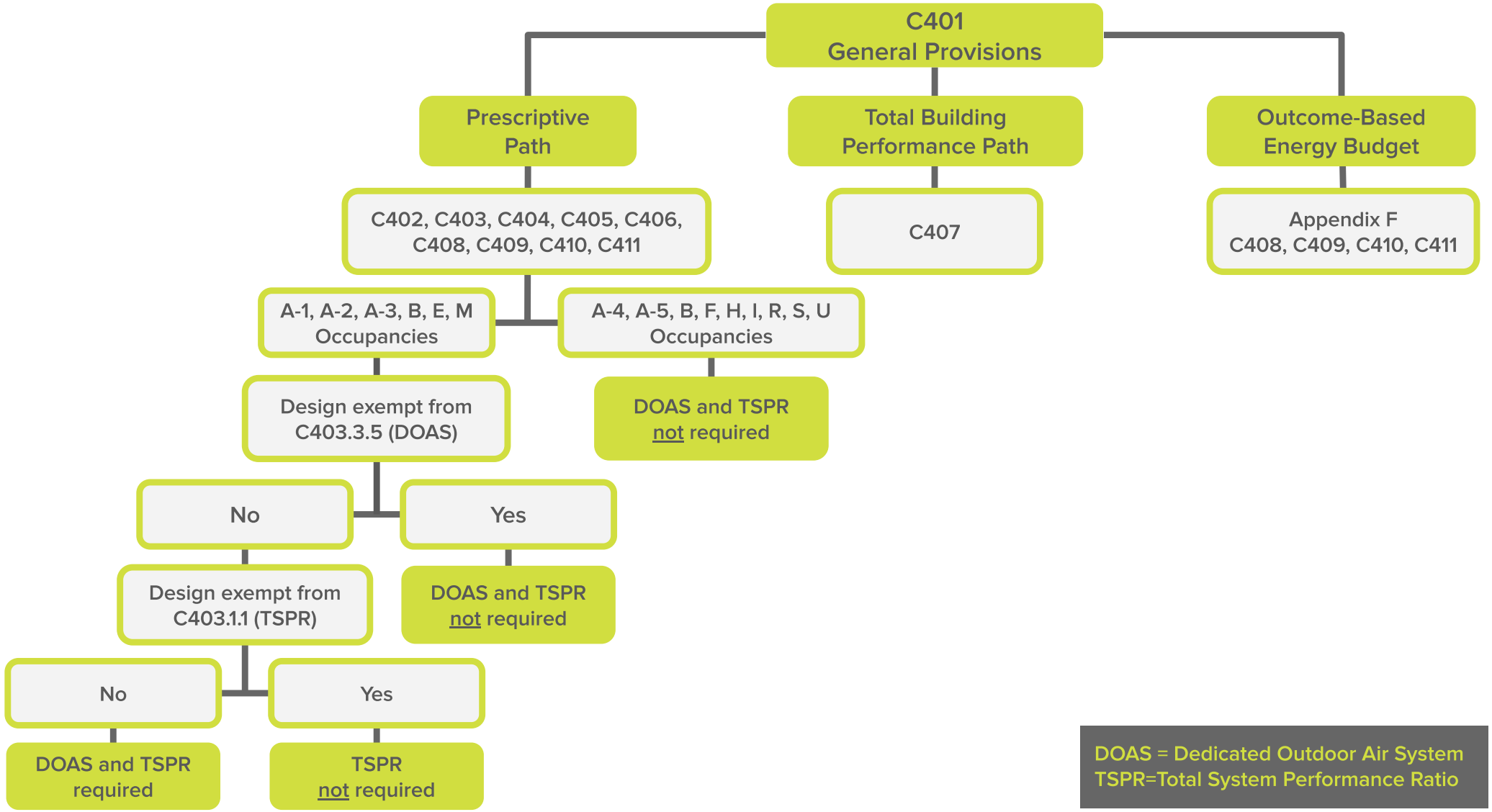
How is HVAC section organized? (It's not)

C403.1.1 TSPR
C403.1.2 Load calculations
C403.1.3 Data centers
C403.1.4 Fossil fuel and electric resistance (Seattle)
C403.2 System design. (zone isolation, ventilation & exhaust, variable speed drives)
C403.3 Equipment selection & Tables (sizing, performance, chillers, humidification)
C403.3.5 DOAS (occupancy table, energy recovery, decoupled supply air)
C403.3.6 Balanced ventilation for R-2
C403.3.7 Hydronic flow rate

C403.4 HVAC system controls (thermostats, heat pump supplementary heat, deadband, vestibules, door switch tstat control
C403.4.3 Hydronic system controls (hydronic heat pump controls, dead band, heat rejection, isolation valves, part load controls, pump isolation, variable flow controls)
C403.4.9 Multifamily units
C403.4.11 DDC
C403.5 Economizers
C403.6 Multi-zone systems
C403.6.10 High-efficiency VAV systems (alternative to DOAS)
C403.7 Ventilation and exhaust (DCV, occ sensor, loading dock, garage)

C403.7.6 Energy recovery ventilation
C403.7.7 Exhaust systems (kitchen, laboratory)
C403.7.8 Shutoff dampers
C403.8 Fans and fan controls
C403.9 Heat rejection & heat recovery
C403.10 HVAC system construction (ducts, pipes, insulation, sealing)
C403.11 Systems outside thermal envelope (radiant heaters, snow melt, freeze protection)
C403.12 High-efficiency single-zone VAV (alternative to DOAS)
C403.13 Commissioning
C403. 14 Compressed air & vacuum air
C403.15 Commercial food service

Flow Chart Moment!



DOAS = Dedicated Outdoor Air System
TSPR=Total System Performance Ratio

Mechanical Changes

Largely unchanged mechanical efficiencies

Mechanical Controls

DOAS Clarifications

Total System Performance Ratio

C407 changes

Table C403.4.11.1
DDC Applications and Qualifications

Building Status	Application	Qualifications
New building	Air-handling system and all zones served by the system	All air-handling systems in buildings with building cooling capacity greater than 780,000 Btu/h
	Air-handling system and all zones served by the system	Individual systems supplying more than three zones and with fan system bhp of 10 hp and larger
	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300,000 Btu/h and larger
	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300,000 Btu/h and larger
Alteration or addition	Zone terminal unit such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
	Air-handling system or fan coil	Where existing air-handling system(s) and fan coil(s) served by the same chilled- or hot-water plant have DDC
	New air-handling system and all new zones served by the system	Individual systems with fan system bhp of 10 hp and larger and supplying more than three zones and more than 75 percent of zones are new
	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

Data Center Cooling Efficiency C403.1.3

- WA: ASHRAE 90.4 – **2016**, with modified MLC values
- Seattle: ASHRAE 90.4 – **2019**, no modifications
- 2019 version is much better – separate values for large and small data centers

90.4 Basics

- Sections 6 and 8

DATA CENTER. A room or series of rooms that share *Data Center Systems* whose primary function is to house equipment for the processing and storage of electronic data, which has a design total *information technology equipment (ITE)* equipment power density exceeding 20 watts per square foot of conditioned area and a total design ITE equipment load greater than 10 kW.

COMPUTER ROOM. A room whose primary function is to house equipment for the processing and storage of electronic data and that has a design total *information technology equipment (ITE)* equipment less than or equal to 20 watts per square foot of conditioned area or a design *ITE* equipment load less than or equal to 10 kW.

Seattle Department of Construction & Inspections

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TSPR = (annual) $\frac{\text{Heating + Cooling Loads}}{\text{Carbon Emissions}}$

TSPR: Total System Performance Ratio

Office, Retail, Library, Education

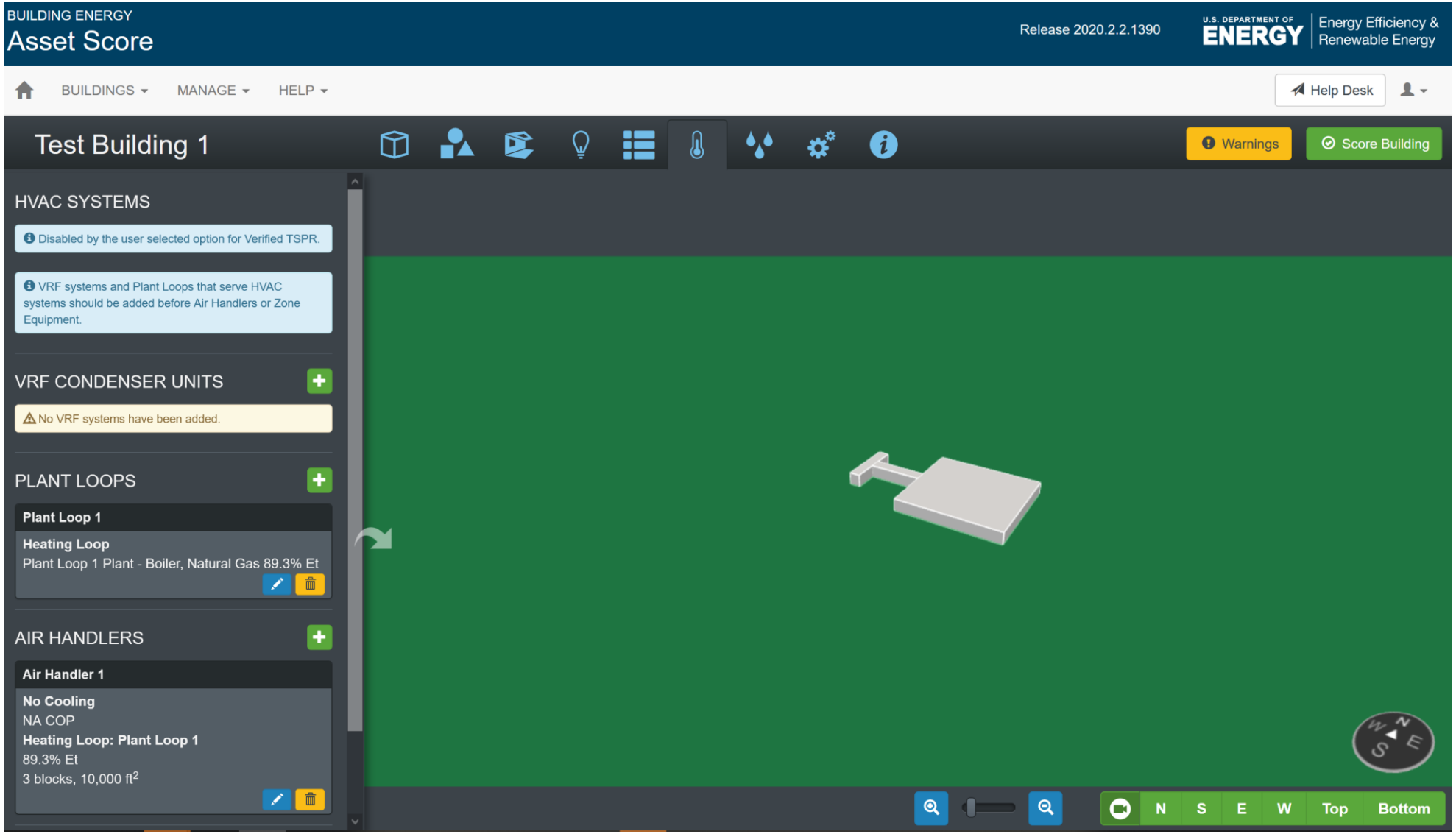
Seattle adds multifamily and medical office

TSPR evaluates HVAC efficiency by comparing:

- required annual heating & cooling, to
- carbon emissions due to heating & cooling

Free online calculation tool from PNNL

TSPR, guesses on outcomes



TSPR, guesses on outcomes

Table C407.1 (Reprinted from Chapter 4)
Carbon Emissions Factors

Type	CO2e (lb/unit)	Unit
Electricity	0.70	kWh
Natural gas	11.70	Therm
Oil	19.2	Gallon
Propane	10.5	Gallon
Other[a]	195.00	mmBtu
On-site renewable energy	0.00	

[a] District energy systems may use alternative emissions factors supported by calculations approved by the *code official*.

Equivalent Electric to Gas:

- Electric in Therms is 20.5 lb/Therm
- Gas in kWH is 0.40 lb/kWh
- Heat Pumps

$$\text{TSPR}_{\text{(annual)}} = \frac{\text{Heating + Cooling Loads}}{\text{Carbon Emissions}}$$

TSPR, guesses on outcomes

D602.11 HVAC equipment. The *standard reference design* HVAC equipment consists of separate space conditioning systems and dedicated outside air systems as described in Table D602.11 for the appropriate building occupancies.

Table D602.11
Standard Reference Design HVAC Systems

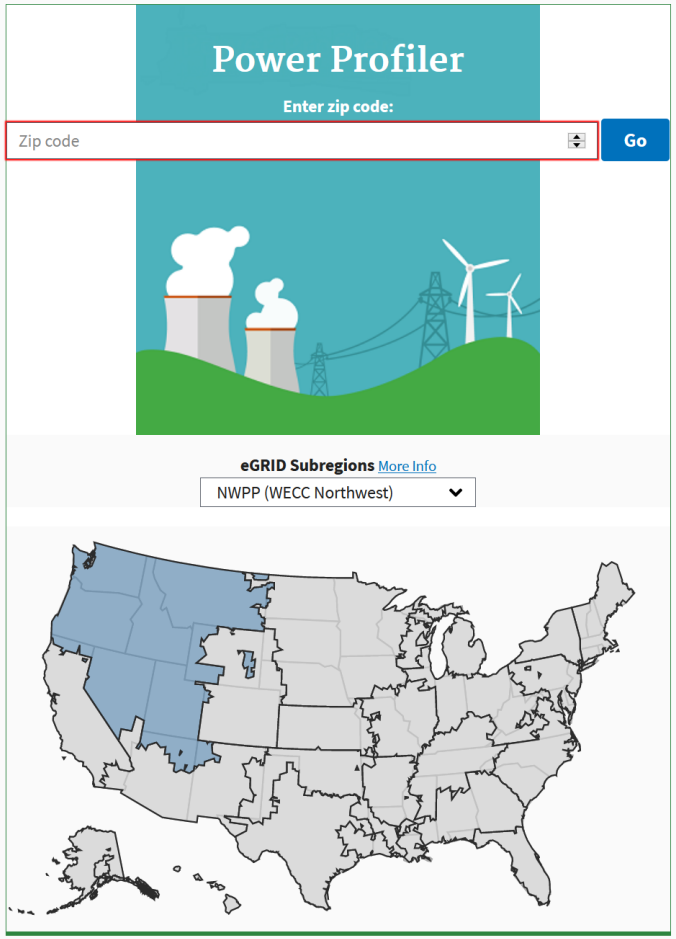
Parameter	Building Type			
	Large Office[a]	Small Office and Libraries[a]	Retail	School
System Type	Water-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump
Fan Control[b]	Cycle on Load	Cycle on Load	Cycle on Load	Cycle on Load
Space Condition Fan Power (W/cfm)	0.528	0.528	0.522	0.528
Heating/Cooling Sizing Factor[c]	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental Heating Availability	NA	<40°F	<40°F	<40°F
Modeled cooling COP (Net of Fan) [d]	4.46	3.83	4.25	3.83
Modeled heating COP (Net of Fan) [d]	4.61	3.81	3.57	3.81
Cooling Source	DX (Heat Pump)	DX (Heat Pump)	DX (Heat Pump)	DX (Heat Pump)
Heat Source	Heat Pump	Heat Pump	Heat Pump	Heat Pump
OSA Economizer[e]	No	No	Yes	Yes
Occupied Ventilation Source[f]	DOAS	DOAS	DOAS	DOAS
DOAS Fan Power (W/cfm of Outside Air)	0.819	0.819	0.730	0.742

Parameter	Building Type			
	Large Office[a]	Small Office and Libraries[a]	Retail	School
System Type	Water-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump
DOAS Temperature Control [g, h]	Bypass	Wild	Bypass	Bypass
ERV Efficiency (Sensible Only)	70 percent	70 percent	70 percent	70 percent
WSHP Loop Heat Rejection	Cooling Tower[i]	NA	NA	NA
WSHP Loop Heat Source	Gas Boiler [j]	NA	NA	NA
WSHP Loop Temperature Control[k]	50°F to 70°F	NA	NA	NA
WSHP Circulation Pump W/gpm[l]	16	NA	NA	NA
WSHP Loop Pumping Control[m]	HP Valves & Pump VSD	NA	NA	NA

Engineering View, CO2

How clean is the electricity you use?

Electricity is produced by many different sources of energy, including, but not limited to, wind, solar, nuclear, and fossil fuels. The type and amount of emissions produced depend on how electricity is generated in your region. Type in your zip code (or select a region) to view your power profile. More Info

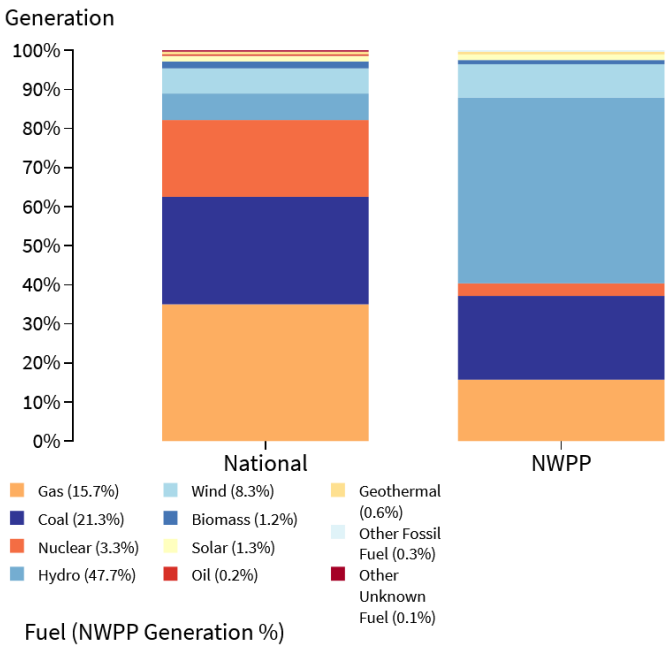


NWPP Emission Rates

CO_2	SO_2	NO_X
639.0	0.4	0.6
(lbs/MWh)	(lbs/MWh)	(lbs/MWh)

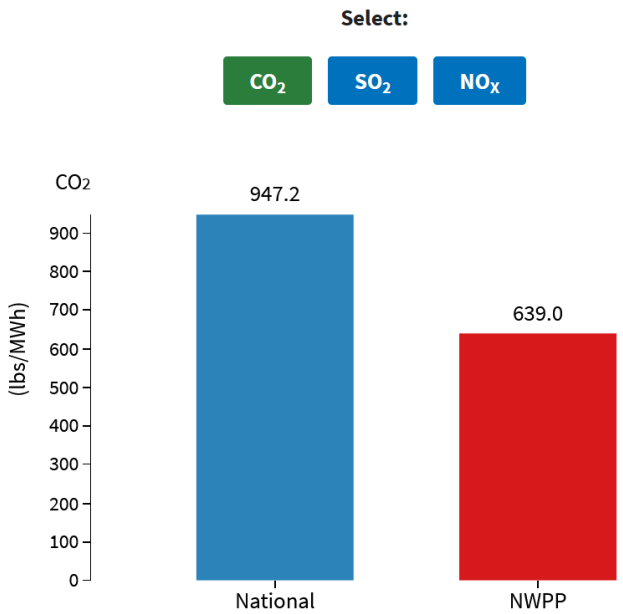
Fuel Mix

This chart compares fuel mix (%) of sources used to generate electricity in the selected eGRID subregion to the national fuel mix (%).



Emission Rates

This chart compares the average emission rates (lbs/MWh) in the selected eGRID subregion to the national average emission rates (lbs/MWh) for carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_X).

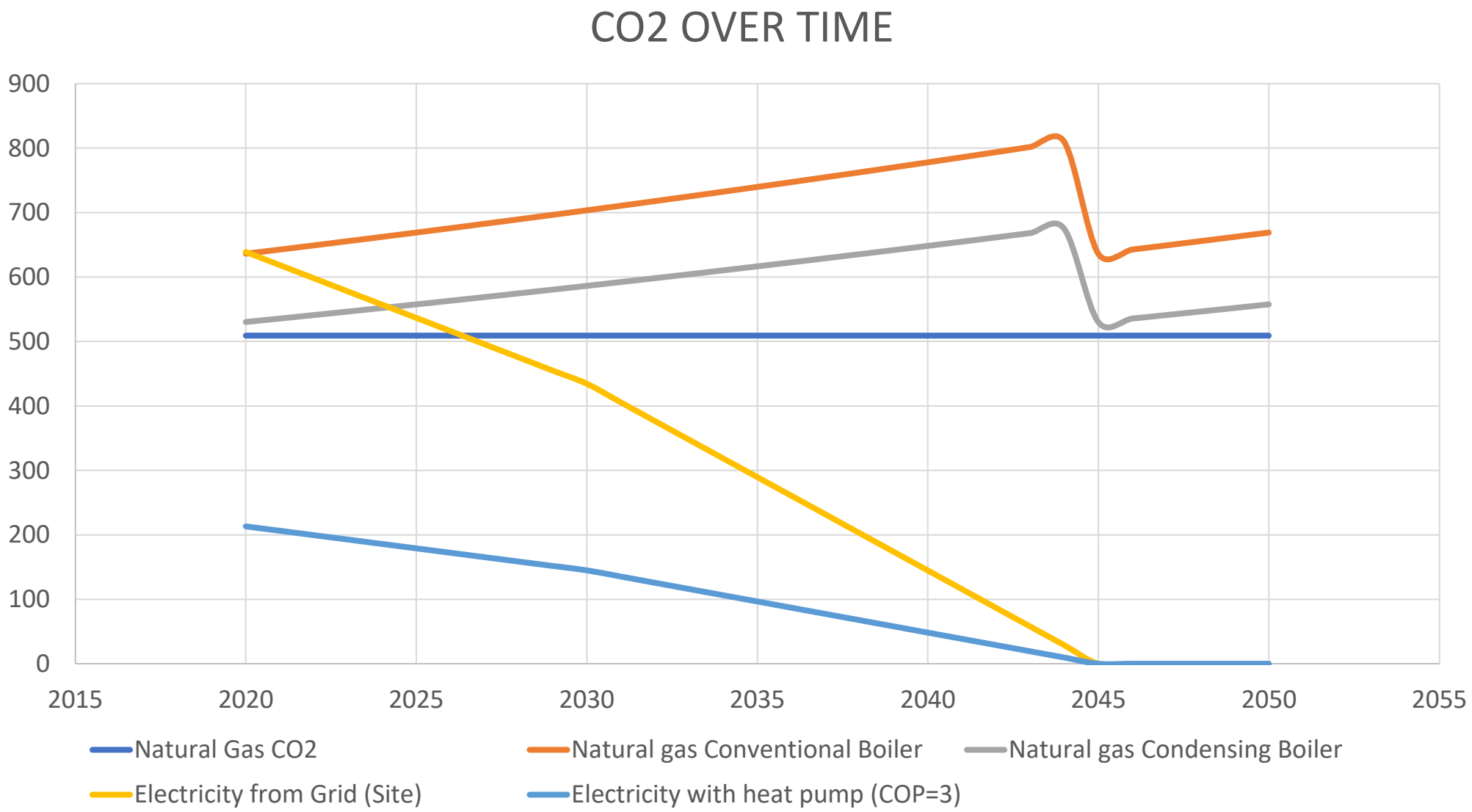


eGRID

Engineering View, Future CO2

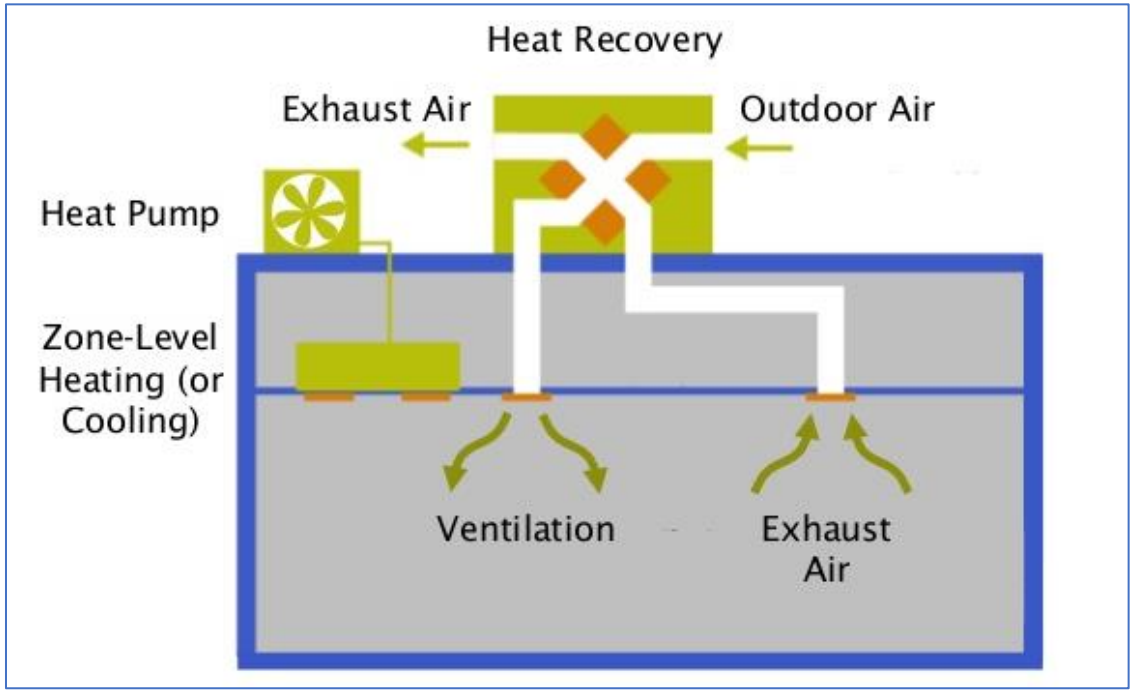
Washington Senate Bill 5116 (2019-2020) established goals of carbon neutrality in 2030 and carbon-free by 2045

Engineering View, Future CO2



WA: DOAS scope expansion

- Office, education, retail, library
- **Now required for "assembly" (auditorium, conference, etc.)**
- Removed some exceptions:
  - No double-dipping with C406
  - Don't get extra glazing area
  - No economizer exemption
    - if equipment is outside, or if mech room is next to exterior wall
- Seattle: "Accessory Occupancies" exempted



Dedicated Outdoor Air System: Ventilation is "decoupled" from heating & cooling, has energy recovery

OCCUPANCY CLASSIFICATIONS REQUIRING DOAS

TABLE C403.3.5

Occupancy Classification[a]	Inclusions	Exempted
A-1	All occupancies not specifically exempted	Television and radio studios
A-2	Casinos (gaming area)	All other A-2 occupancies
A-3	Lecture halls, community halls, exhibition halls, gymnasiums, courtrooms, libraries, places of religious worship	All other A-3 occupancies
A-4, A-5		All occupancies excluded
B	All occupancies not specifically exempted	Food processing establishments including commercial kitchens, restaurants, cafeterias; laboratories for testing and research; data processing facilities and telephone exchanges; air traffic control towers; animal hospitals, kennels, pounds; ambulatory care facilities.
F, H, I, R, S, U		All occupancies excluded
E, M	All occupancies included	

Special Assembly Occupancies

- Large Concert Halls
- Small Lecture Rooms
- Gymnasiums
- Places of Religious Worship

DOAS & Economizers

- Economizer now *required* for DOAS if cooling equipment is outdoors or in a space with an exterior wall or roof.
  - Exception only applies if chiller is buried in some interior room

C403.5 Economizers. *Air economizer*s shall be provided on all new cooling systems including those serving computer server rooms, electronic equipment, radio equipment, and telephone switchgear. Economizers shall comply with Sections C403.5.1 through C403.5.5.

Exception: Economizers are not required for the systems listed below:

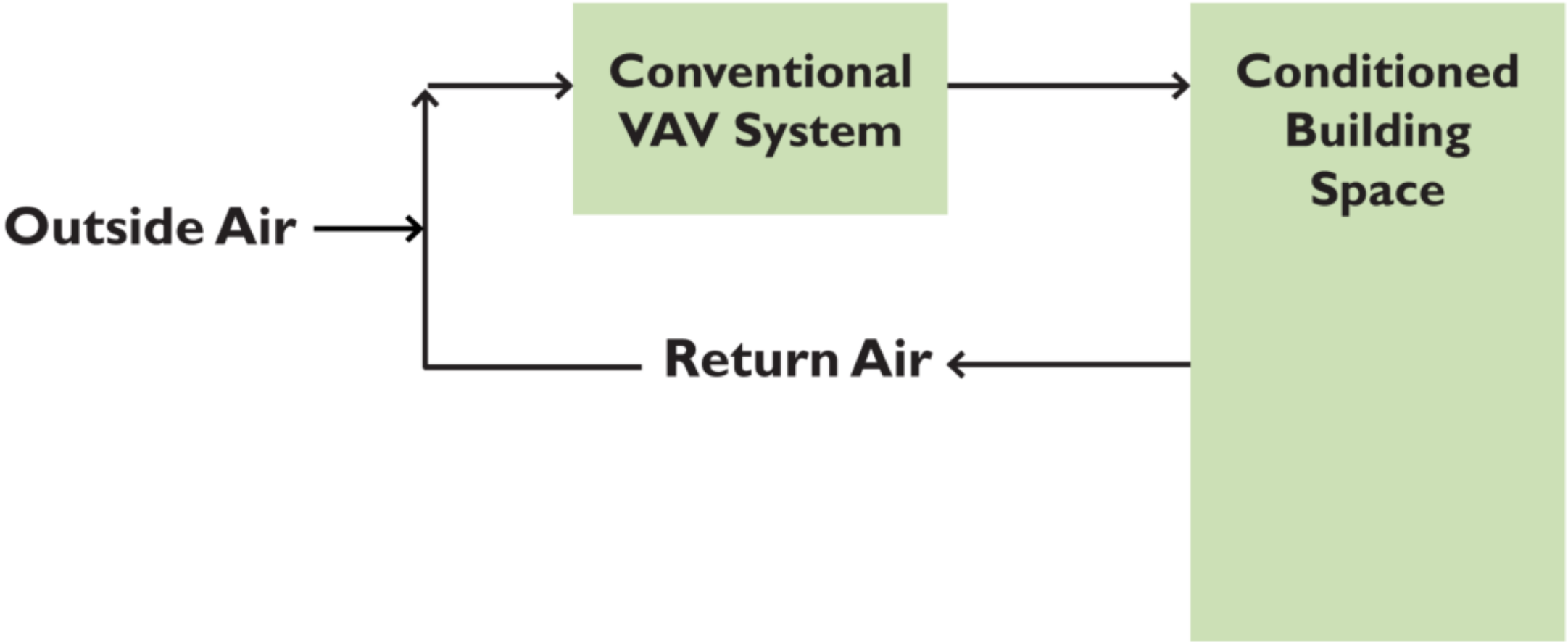
1. Cooling systems not installed outdoors nor in a mechanical room adjacent to outdoors and installed in conjunction with DOAS complying with Section C403.3.5 and serving only spaces with year-round cooling loads from lights and equipment of less than 5 watts per square foot.

DOAS & DCV & Energy Recovery

- WA: *No* spaces with DOAS and DCV need energy recovery
- Seattle: Spaces over 650 sf with DOAS & DCV *do* need energy recovery
- Seattle: Spaces over 500 sf with 15 occ's per 1000 sf need DCV
  - Mostly just adds retail (exempts dorms)
- Seattle: increase ERV effectiveness to 60%

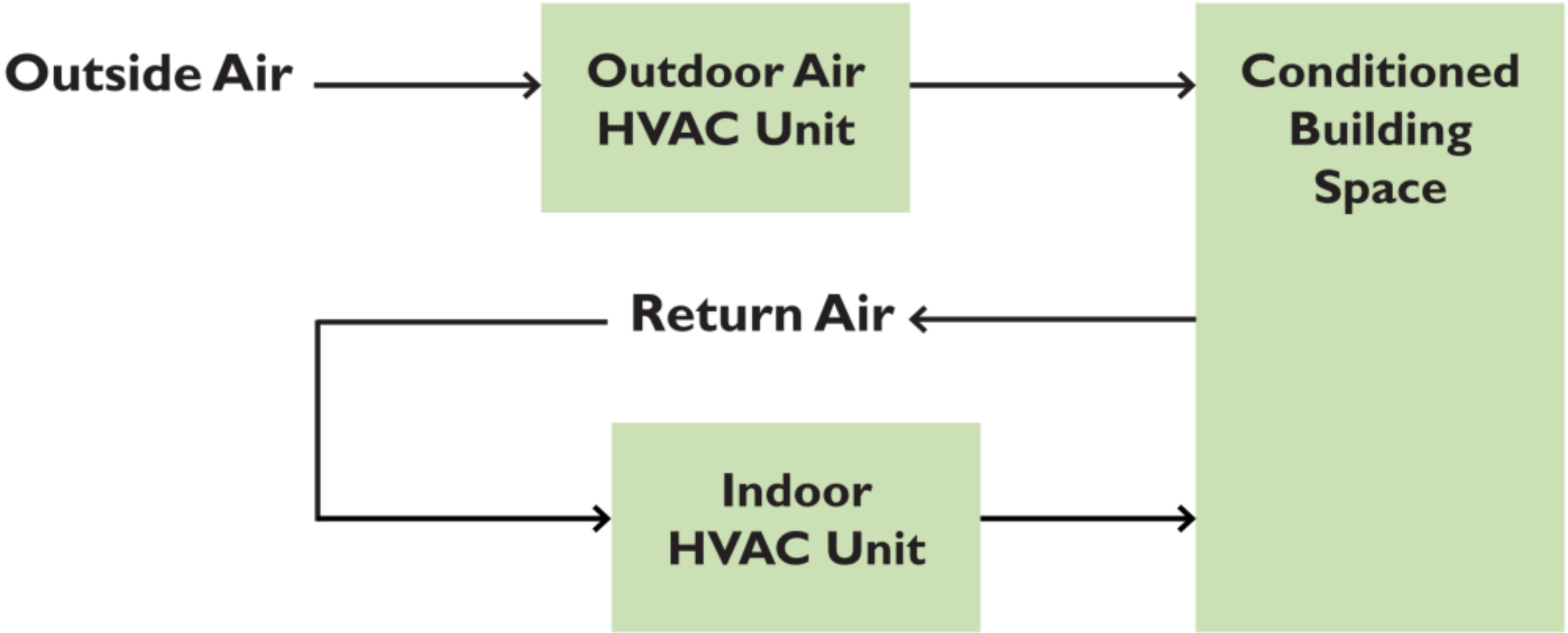
DOAS, demystified

A. Basic arrangement of a conventional all-air VAV system



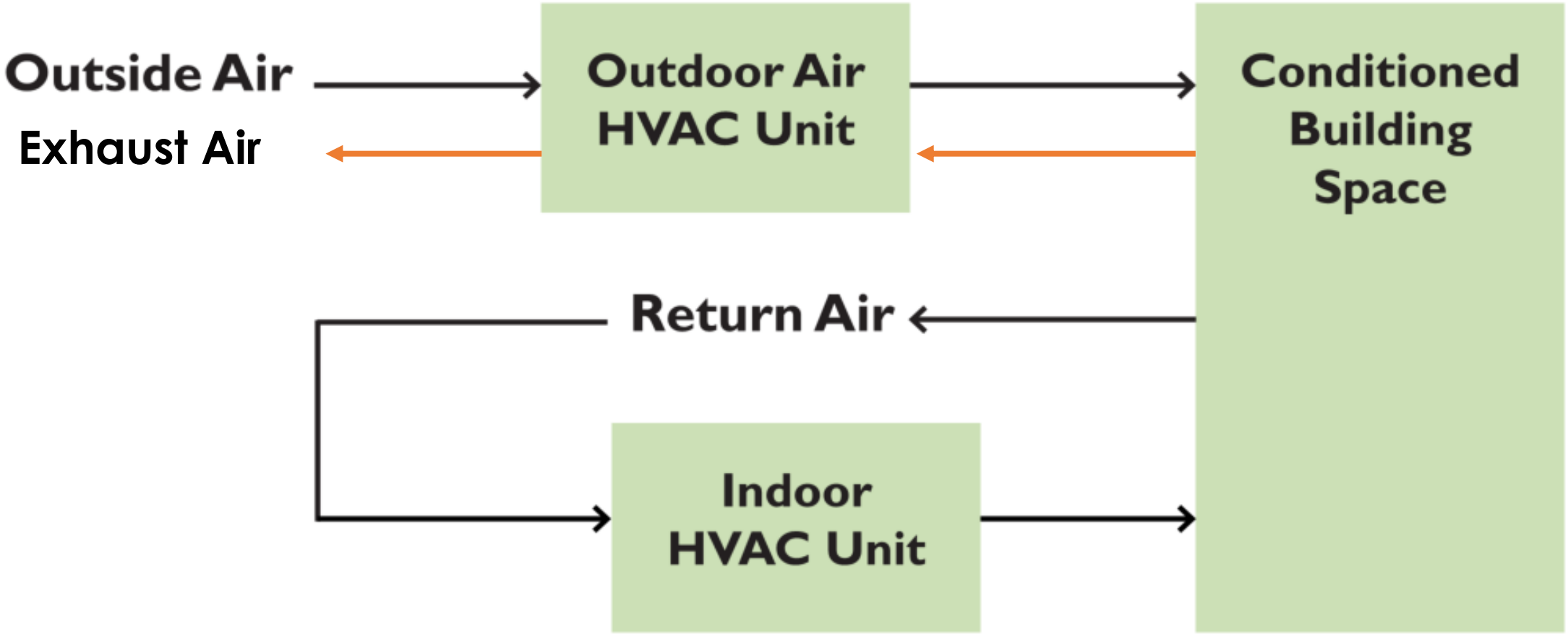
DOAS, demystified

B. DOAS with separate conditioning of outdoor and return air

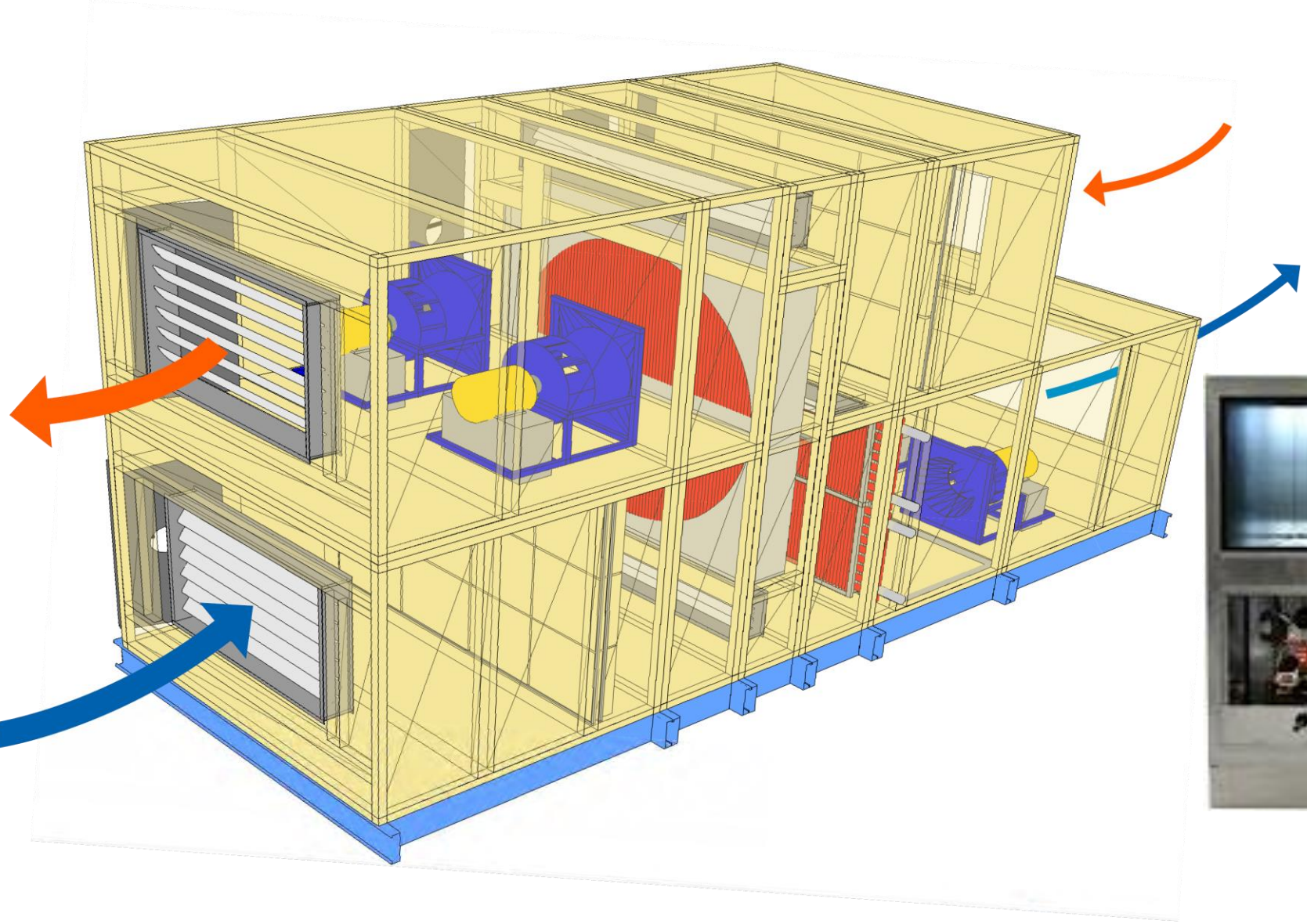


DOAS, demystified, ERV/HRV

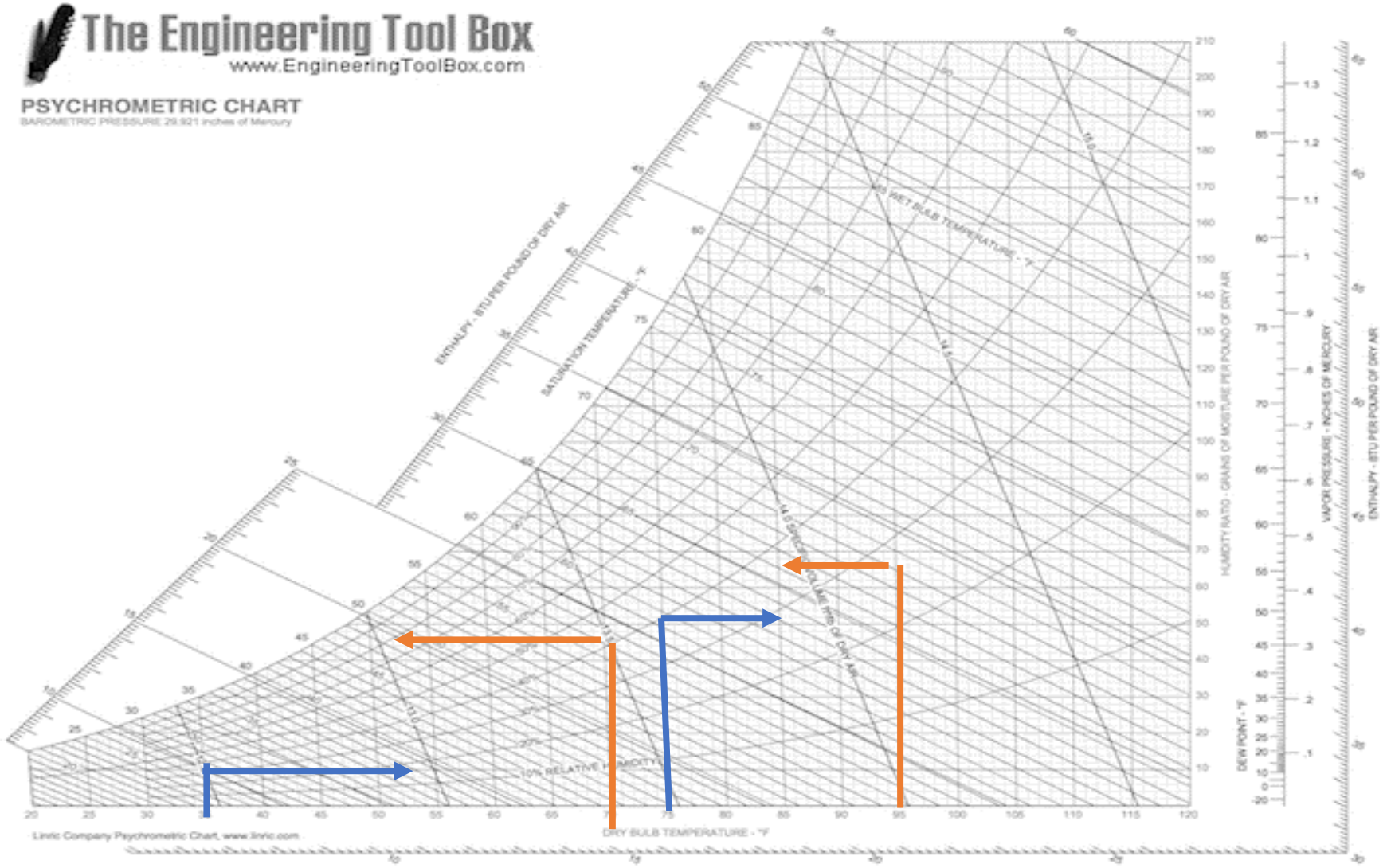
B. DOAS with separate conditioning of outdoor and return air



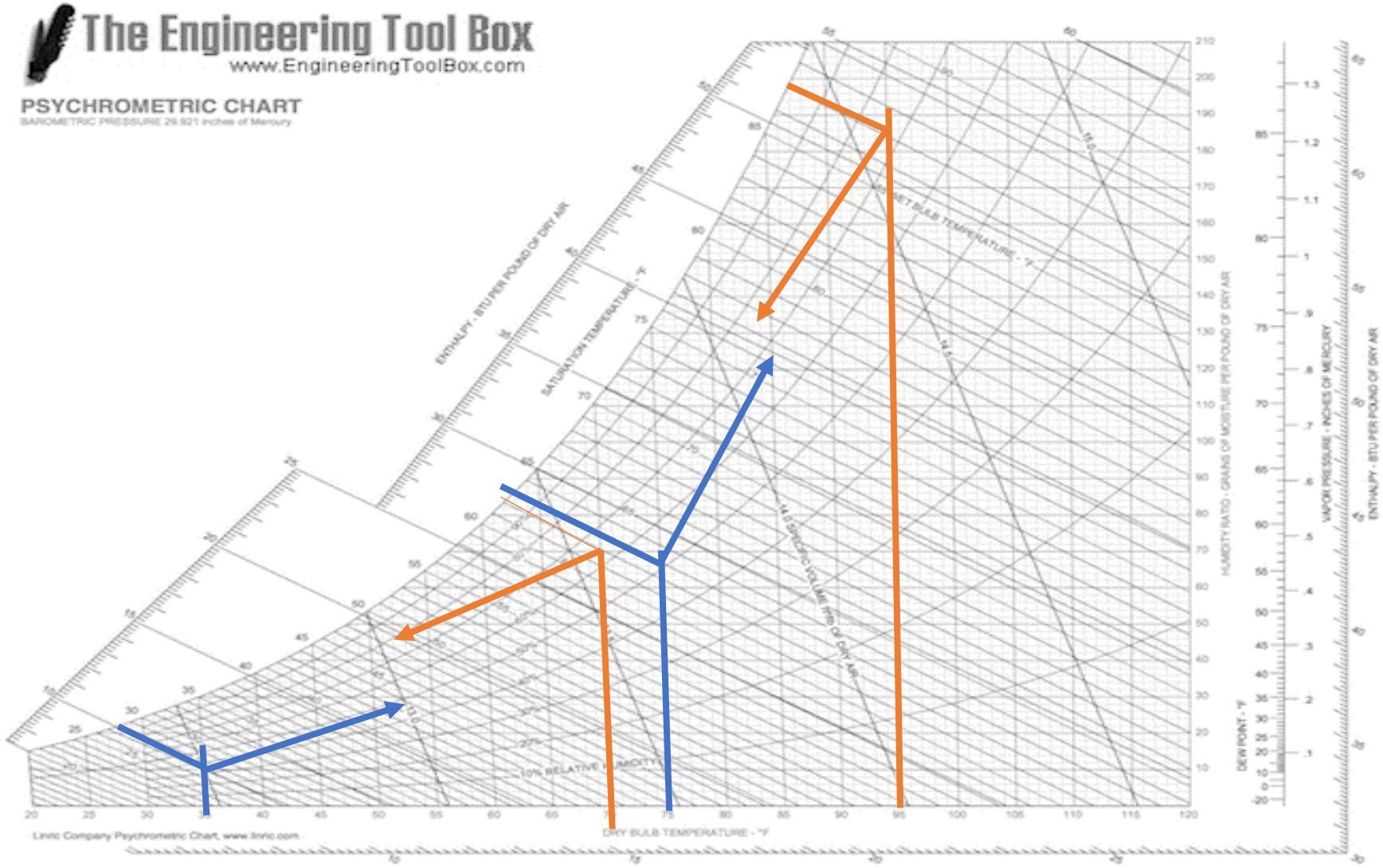
DOAS, ERV, and economizer



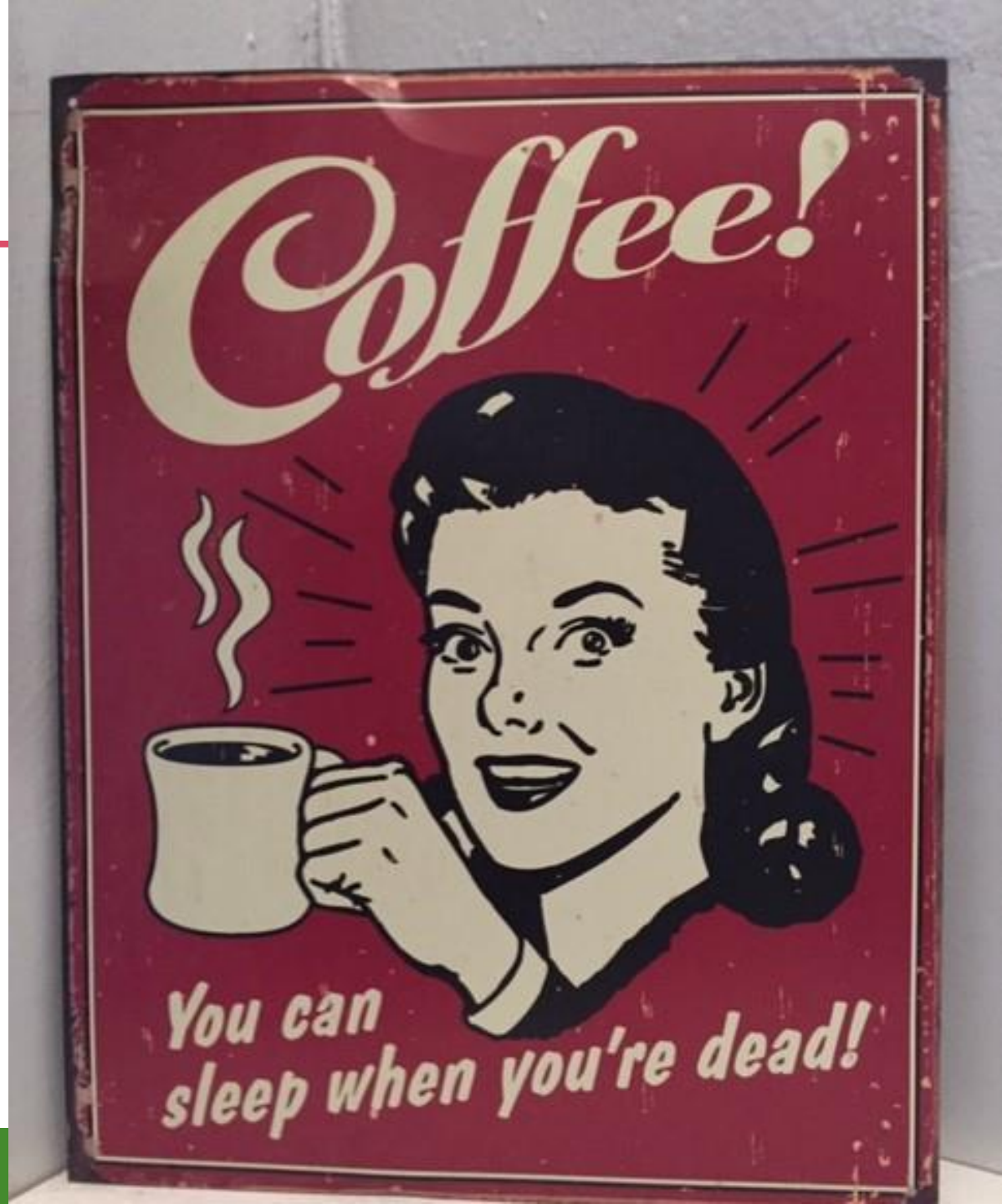
Effectiveness and Efficiency



Effectiveness (Energy)



Break Time!



New Table

Heat Pumps & Heat Recovery Chillers

From ASHRAE 90.1-2019

But, no AHRI ratings yet.

See C403.3.2 for more info

Table C403.3.2(13) f, g, h, i

Heat Pump and Heat Recovery Chiller Packages – Minimum Efficiency Requirements

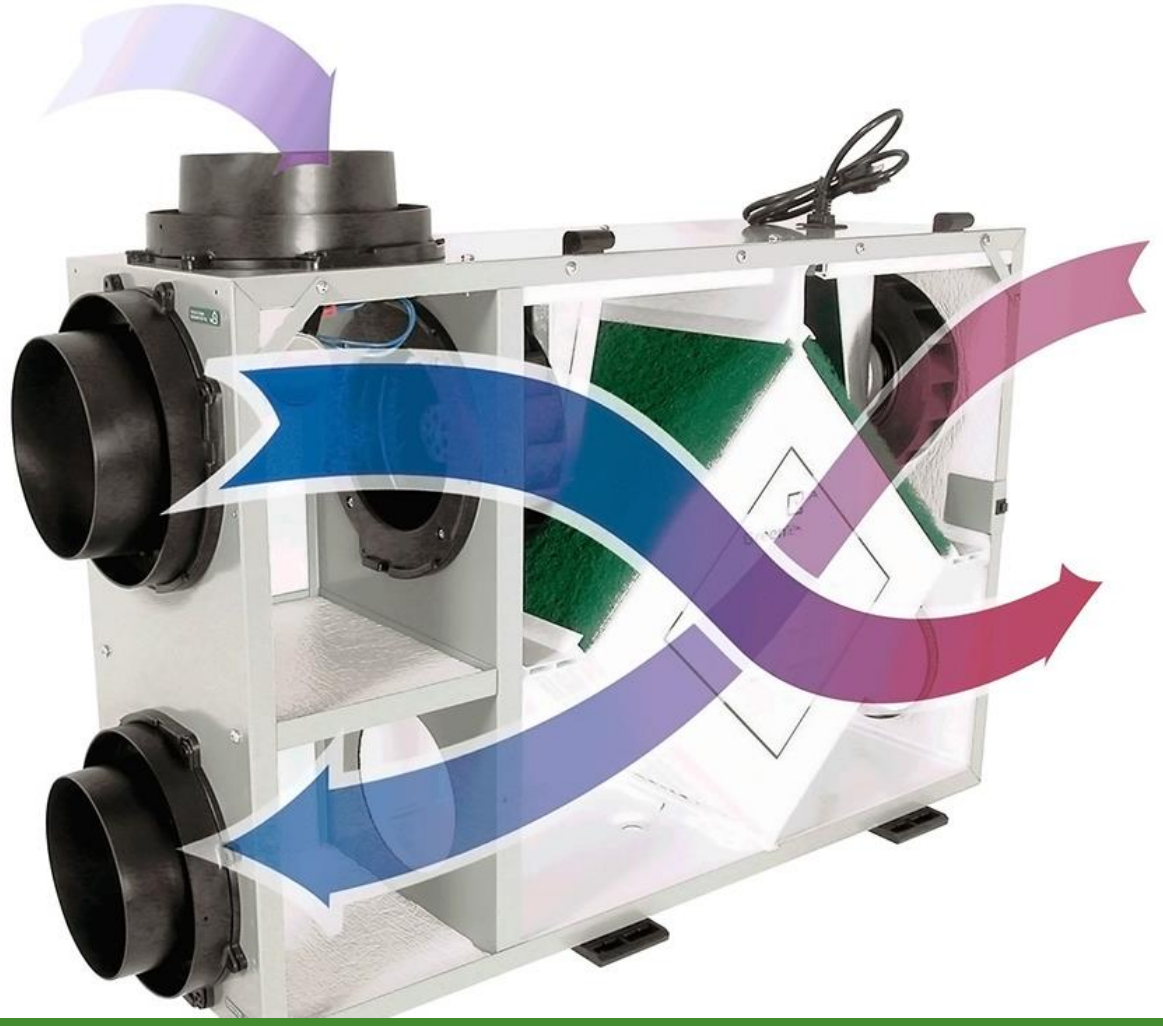
Equipment Type	Size Category (tons$_R$)	Cooling only Operation Cooling Efficiency[a] (Air EER FL/IPLV-Btu/W-h) Water Source Power Input per Capacity FL/IPLV-(kW/ton$_R$)		Heating Operation									Test Procedure
				Heating Source Conditions (Entering/ leaving water) or OAT (db/wb) °F	Heat Pump Heating Full Load Efficiency (COP$_H$)[a,b] (W/W)				Heat Recovery Chiller Full Load Efficiency Full Load Efficiency (COP$_{HR}$)[b,c] (W/W) Simultaneous Cooling and Heating Full Load Efficiency (COP$_{SHC}$)[b] (W/W)				
					Leaving Heating Water Temperature				Leaving Heating Water Temperature				
					Low	Medium	High	Boost	Low	Medium	High	Boost	
		Path A	Path B		105°F	120°F	140°F	140°F	105°F	120°F	140°F	140°F	
Air Source	All sizes	≥9.595 FL ≥13.02 IPLV.IP	≥9.215 FL ≥15.01 IPLV.IP	47 db 43 wb[d]	≥3.290	≥2.770	≥2.310	NA	NA	NA	NA	NA	AHRI 550/590
		≥9.595 FL ≥13.30 IPLV.IP	≥9.215 FL ≥15.30 IPLV.IP	17 db 15 wb[d]	≥2.230	≥1.950	≥1.630	NA	NA	NA	NA	NA	
	< 75	≤0.7885 FL ≤0.6316 IPLV.IP	≤0.7875 FL ≤0.5145 IPLV.IP	54/44[e]	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	
				75/65[e]	NA	NA	NA	>3.550	NA	NA	NA	6.150	

English (United States) Focus

“Balanced ventilation” for R-2 dwelling units

R-2 dwelling & sleeping units

- Deliver ventilation air directly to each “habitable space”
  - Living room, bedrooms
  - Trickle vents & bathroom exhaust doesn’t work anymore
- Heat recovery required
  - w/ 60% sensible heat recovery effectiveness
  - “Informative note” about how to determine sensible heat recovery effectiveness from HVI publication



DOAS, Balanced R-2

ERV and HRV

Cost impacts

Energy impacts

Fsi critiques Duane's ideas

- Individual HRVs in apartments?
  - Remember you still need to clean each filter twice a year
- Rooftop units with vertical shafts?
  - Eats up some rentable floor area
- Floor-by-floor HRVs?
  - Each serving 6 – 8 units
  - Ducts running above bathrooms
    - So you don't need fire dampers
    - But is there a noise/privacy problem?

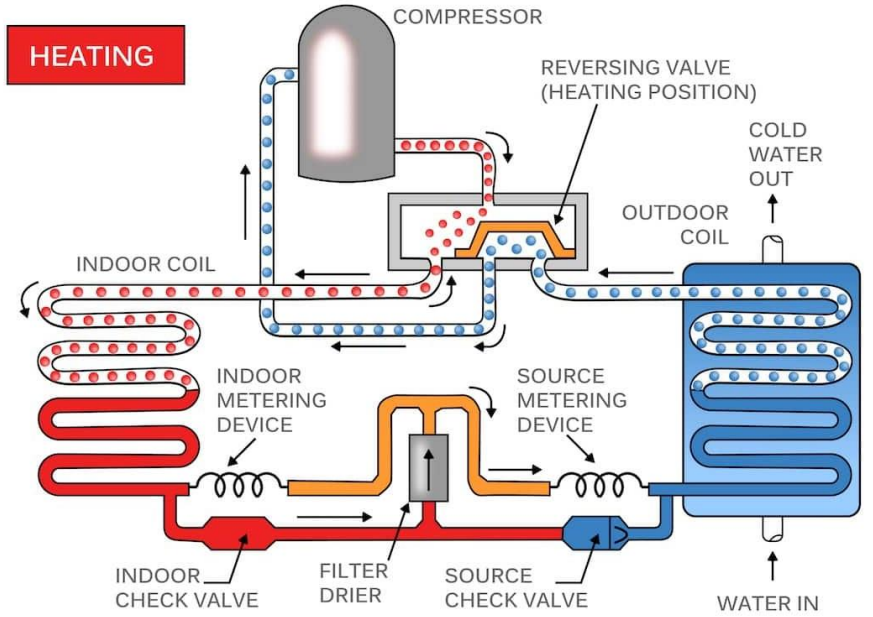
Seattle: Space heating

No electric resistance or fossil fuel combustion for space heating

- Usually means “use heat pumps”

Exceptions allow electric resistance heat for:

1. Permits applied for prior to 6/1/2021
2. Dwelling units: Max ~~500~~ ~~600~~ **750 W** per habitable room
   - **1000 W** for corner room
3. Other space types: Max 2.5 W/sf total installed heating (The “Passive House” rule)
4. Heat pump auxiliary heat in cold weather
5. Buildings smaller than 2,500 sf…



Heat pumps squeeze warmth out of cold air

C403.1.4 (space heating) More Exceptions

5. Air-to-air heat pumps
    1. Compressor is first stage of heat down to 17°F , capacity is 2X elec resistance
6. Air-to-water HP <2,000 MBH
    1. Compressor is first stage of heat down to 17°F , capacity is **2X** elec resistance
7. Air-to-water HP <3,000 MBH
    1. Compressor is first stage of heat down to 17°F , capacity is **1.75** X elec resistance
8. Air-to-water HP >3,000 MBH
    1. Compressor is first stage of heat down to 17°F , capacity is **1.5** X elec resistance
9. Ground-source HP
10. Small systems
11. Specific conditions
12. Kitchen exhaust
13. District energy
14. Heat tape
15. Temporary systems
16. Emergency generators
17. Pasteurization cycle

No electric resistance or gas heat (Seattle)

Airside systems we can use

No electric resistance or gas heat (Seattle)

Waterside systems we can use

Simultaneous heating/cooling

C403.4.1

- In “thermostatic control” section
- You can’t have heating in the perimeter zone with cooling in the interior zone of the same space at the same time.
  - Duh-oh!
  - You *can* have one zone in heating or cooling while the other is neutral
- Seattle has clearer language for what constitutes “the same space”:
  - Permanent opening between areas bigger than 10% of either floor area

Simultaneous Heating and Cooling

C403.7, Ventilation and Exhaust Systems

- DCV (already mentioned)
- Occupancy Sensors
- Ventilation heating control
- Garage Ventilation
- Energy Recovery Ventilation
- Kitchen Hoods
- Labs
- Building Isolation Dampers

C403.7, Ventilation and Exhaust Systems

TABLE C403.7.7.1.2
MAXIMUM NET EXHAUST FLOW RATE,
CFM PER LINEAR FOOT OF HOOD LENGTH

TYPE OF HOOD	LIGHT-DUTY EQUIPMENT	MEDIUM-DUTY EQUIPMENT	HEAVY-DUTY EQUIPMENT	EXTRA-HEAVY-DUTY EQUIPMENT
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	NA	NA
Backshelf/Pass-over	210	210	280	NA

For SI: 1 cfm = 0.4719 L/s; 1 foot = 305 mm.
NA = Not Allowed

Fans: FEG vs. FEI C403.8.3

- FEG – Fan efficiency grade – being phased out
- FEI – Fan energy index – new standard
- Still FEG in WA code
- Seattle allows FEI as an alternate (exception 8):

8. “Fans and fan arrays having a fan energy index (FEI) of not less than 1.00, or 0.95 for VAV systems, at the design point of operation, as determined in accordance with AMCA 208 by an approved, independent testing laboratory and labeled by the manufacturer. The FEI for fan arrays shall be calculated in accordance with AMCA 208 Annex C.”

- ALSO: Table C403.8.4 – errors in WA code, fixed in Seattle code

Heat Recovery C403.9.2

- **Heat recovery required** for service water heating in buildings (like hospitals) with:
  - 24/7 operations
  - 1.5 MBTUH total heat capacity of water-cooled systems
  - 250 kBTUH service water heating load
- **Steam: condensate** water recovery required
  - Or condensate *heat recovery* for off-site steam with no return
- **Refrigeration condenser** heat recovery (like groceries)
  - 500 kBTUH remote refrigeration condensers
  - Use heat for service water, space heating, or dehumidification
- and…

Heat recovery for space heating C403.9.2.4

- Water-source condenser heat recovery system required if:
  - Operating hours over 70 hours per week
  - Heat rejection equip capacity over 1.5 MBTUH
  - Min 0.45 cfm/sf airflow in zones with reheat
  - EXCEPTION: DOAS – dedicated outdoor air systems
- 90% of heating from heat recovery chiller or water-to-water heat pump, rejecting heat from cooling loop to heating loop as first stage of heating
- Heat recovery from 90% of exhaust airflow
  - Leaving exhaust air temp max 55F in full heat recovery mode
- Process heat recovery (like data center or computer room) over 5 W/sf
  - Cooling loops must be served by water-cooled equip & heat recovery
  - Economizer override required

Heat Recovery Engineering Notes

Heating the great outdoors

C403.11

- Outdoor heat must be “radiant” (but no one regulates portable devices)
- Seattle adds “…or in unheated spaces” (repair garage, desk at warehouse…)
- Auto-off by timer or occ sensor
- Seattle adds “…in the area heated by each individual device for a period not to exceed 20 minutes.”
- There is no such thing as “space heating for freeze protection” in code!

Fireplaces & fire pits C403.4.7.1

- Manual on
- Auto-off with 1-hour timer, or
- Auto-off with 15-minute occ sensor

C406 Efficiency Package Credits

- **WA: Now a "points-based" table**
  - 2 (old) credits = 6 (new) credits
- WA: 6 credits required
  - 3 credits for low-energy occupancies
- **Seattle: Require 8 credits**
  - Instead of 6
- Seattle: Gas equip doesn't qualify
- Integrated design team advised!

	R1	R2	B	E	M	Other
1. More efficient HVAC performance in accordance with Section C406.2	**2.0**	**3.0**	**3.0**	**2.0**	**1.0**	**2.0**
2. Reduced lighting power: Option 1 in accordance with Section C406.3.1	**1.0**	**1.0**	**2.0**	**2.0**	**3.0**	**2.0**
3. Reduced lighting power: Option 2 in accordance with Section C406.3.2[a]	**2.0**	**3.0**	**4.0**	**4.0**	**6.0**	**4.0**

TABLE C406.1
Partial credit for standard DOAS in R-1 & R-2

Code Section	Commercial Building Occupancy					
	Group R-1	Group R-2	Group B	Group E	Group M	All Other
	Additional Efficiency Credits					
6. Dedicated outdoor air system in accordance with Section C406.6[b]	4.0	((~~4.0~~)) 2.0[d]	4.0	NA	NA	4.0
7. High performance dedicated outdoor air system in accordance with Section C406.7	4.0	4.0	4.0	4.0	4.0	4.0
8. High-efficiency service water heating in accordance with Sections C406.8.1 and C406.8.2	4.0 NA after 1/1/2022	5.0 NA after 1/1/2022	NA	NA	NA	8.0
9. High performance service water heating in ((~~multi-family~~)) R-1 and R-2 buildings in accordance with Section C406.9	7.0 prior to 1/1/2022 5.0 after 1/1/2022	8.0 prior to 1/1/2022 5.0 after 1/1/2022	NA	NA	NA	NA

High-Performance HVAC option C406.2

- 90% of HVAC capacity
- Must be equipment listed in the 13 tables
- Seattle: No gas-fired equipment can get credit
- **15% better efficiency than table value**
  - Weighted average efficiency OK, but all equipment must be min 5% better than table
- WA exempts air-to-water heat pumps and heat recovery chillers, but not Seattle
  - Because we have the new table
- WA exempts large boilers, but not Seattle

C406.2 Engineering Notes

HVAC C406 credit for tenant spaces C406.1.1.2

- **Where shell & core permit includes C406.2 (HVAC) credit, tenant spaces also qualify if they connect to building HVAC system.**
- Tenant space can also qualify for HVAC credit independently

C406.1.1.2 Applicable HVAC and service water heating credits. Where HVAC and service water heating systems and services are installed and comply with Section C406.2 or C406.8 under an initial tenant improvement permit, those systems and services shall be considered a part of the tenant space. **Tenant spaces qualify for the credits assigned to the occupancy type of the tenant space in accordance with Table C406.1 if the tenant space includes the distribution system and equipment that the central HVAC systems or service water heating systems were designed to support.**

Exception: Previously occupied tenant spaces in existing buildings that comply with this code in accordance with Section C501.

- Seattle: Initial TI permit can use S&C permit code edition within 18 months of C/O

C406 Engineering Notes

Seattle: No C406 credits for fossil fuel equipment

- **C406.6 Dedicated outdoor air system (DOAS).** Not less than 90 percent of the total conditioned floor area of the whole building, building *addition* or tenant space, excluding floor area of unoccupied spaces that do not require ventilation per the *International Mechanical Code*, shall be served by DOAS installed in accordance with Section C403.3.5. This option is not available to buildings subject to the prescriptive requirements of Section C403.3.5. **No HVAC systems incorporating fossil fuel-fired equipment, or heat from district energy systems that are primarily heated by fossil fuel combustion, are permitted to utilize this credit.**
- **Same** for:
  - C406.1 HVAC system selection
  - C406.7 High-performance DOAS
  - C406.8 Service water heating

C406 Credits, Popularity Contest

Table C406.1
Efficiency Package Credits

Code Section	Commercial Building Occupancy					
	Group R-1	Group R-2	Group B	Group E	Group M	All Other
	Additional Efficiency Credits					
1. More efficient HVAC performance in accordance with Section C406.2	2.0	3.0	3.0	2.0	1.0	2.0
2. Reduced lighting power: Option 1 in accordance with Section C406.3.1	1.0	1.0	2.0	2.0	3.0	2.0
3. Reduced lighting power: Option 2 in accordance with Section C406.3.2[a]	2.0	3.0	4.0	4.0	6.0	4.0
4. Enhanced lighting controls in accordance with Section C406.4	NA	NA	1.0	1.0	1.0	1.0
5. On-site supply of renewable energy in accordance with C406.5	3.0	3.0	3.0	3.0	3.0	3.0
6. Dedicated outdoor air system in accordance with Section C406.6[b]	4.0	4.0	4.0	NA	NA	4.0
7. High performance dedicated outdoor air system in accordance with Section C406.7	4.0	4.0	4.0	4.0	4.0	4.0
8. High-efficiency service water heating in accordance with Sections C406.8.1 and C406.8.2	4.0	5.0	NA	NA	NA	8.0
9. High performance service water heating in multi-family buildings in accordance with Section C406.9	7.0	8.0	NA	NA	NA	NA
10. Enhanced [illegible] performance in accordance with Section C406.10[c]	[illegible]	[illegible]	3.0	3.0	3.0	4.0
11. Reduced air infiltration in accordance with Section C406.11[c]	1.0	2.0	1.0	1.0	1.0	1.0
12. Enhanced commercial kitchen equipment in accordance with Section C406.12	5.0	NA	NA	NA	5.0	5.0 (Group A-2 Only)

[a] Projects using this option may not use Item 2.
[b] This option is not available to buildings subject to the prescriptive requirements of Section C403.3.5.
[c] Buildings or building areas that are exempt from the thermal envelope requirements in accordance with Sections C402.1.1 and C402.1.2, do not qualify for this package.

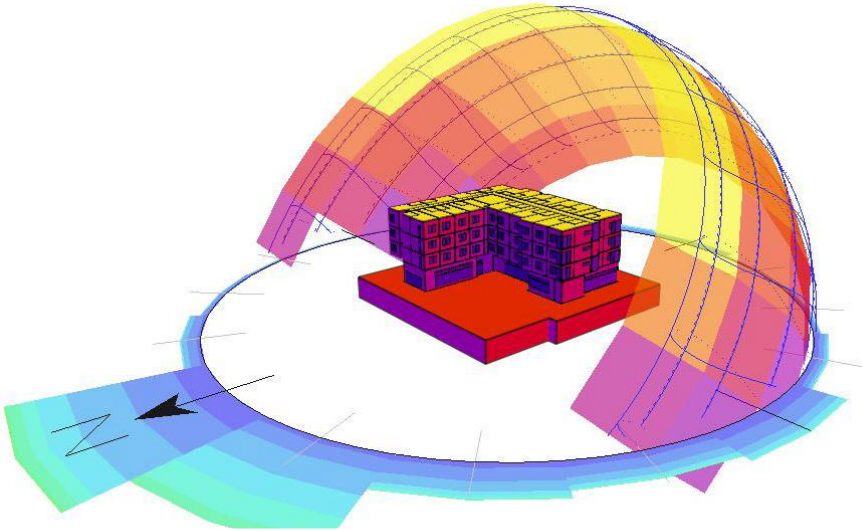
WA – Modeling: Appendix G & carbon metric

- Switch to ASHRAE Appendix G method
  - Allowable emissions compared to a 2004 ASHRAE baseline
  - See table below
- Switch from “site energy” to “carbon” metric
  - Advantages heat pump, disadvantages electric resistance
  - Carbon content of electricity = 0.70#/kwh
    - 0.80#/kwh for low-rise “residential buildings”

Building Area Type	Multi family	Health care	Hotel	Office	Rest.	Retail	School	Ware house	Others
BPF – Building Performance Factor	0.56	0.54	0.64	0.54	0.70	0.47	0.36	0.48	0.54

Energy Modeling – whole new system

- BPF (Building Performance Factor)
  - Percent lower carbon emissions than 2004 ASHRAE 90.1
- Seattle: 10% *lower* than WA code
  - To align with more stringent prescriptive Seattle Energy Code



SEATTLE 10% lower									
Building Area Type	Multi family	Health care	Hotel	Office	Rest.	Retail	School	Ware house	Others
Building Performance Factor	~~0.56~~ 0.50	~~0.54~~ 0.49	~~0.64~~ 0.58	~~0.54~~ 0.49	~~0.73~~ 0.66	~~0.47~~ 0.42	~~0.36~~ 0.32	~~0.48~~ 0.43	~~0.54~~ 0.49

Emissions factors & BPFs (WA & Seattle)

TABLE C407.3(1)
CARBON EMISSIONS FACTORS

	CO2e (lb/unit)	Unit
Electricity	0.70	kWh
Natural Gas	11.7	Therm
Oil	19.2	Gallon
Propane	10.5	Gallon
Other [a]	195.00	mmBtu
On-site renewable[b]	0.00	

a. District energy systems may use alternative emission factors supported by calculations approved by the code official.

b. The TSPR calculation does not separately account for the use of renewable energy.

TABLE C407.3(2)
BUILDING PERFORMANCE FACTORS (BPF) TO BE USED FOR COMPLIANCE WITH SECTION C407.3

Building Area Type	Building Performance Factor
Multifamily	((~~0.58~~)) 0.52
Healthcare/hospital	((~~0.54~~)) 0.49
Hotel/motel	((~~0.64~~)) 0.58
Office	((~~0.56~~)) 0.51
Restaurant	((~~0.70~~)) 0.63
Retail	((~~0.47~~)) 0.43
School	((~~0.36~~)) 0.32
Warehouse	((~~0.48~~)) 0.43
All Others	((~~0.54~~)) 0.49

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C407, Welcome to ASHRAE 90.1

C407.3 Performance-based compliance. Compliance with this section requires compliance with ASHRAE Standard 90.1 Appendix G, Performance Rating Method, in accordance with Standard 90.1 Section 4.2.1 with the following modifications.

1. The mandatory requirements of Section G1.2.1a of Standard 90.1 are not required to be met.
2. The reduction in annual carbon emissions of the proposed building design associated with on-site renewable energy shall not be more than 3 percent of the total carbon emissions of the baseline building design. This limitation only applies to onsite renewable energy provided in excess of the renewable energy required by Section C412.
    a. The equation PCI + [(PBP_{nre} – PBP)/BBP] – 0.05 < PCIt in Section 4.2.1.1 shall be modified to read PCI + [(PBP_{nre} – PBP)/BBP] – 0.03 < PCIt.
    b. The term PBP_{nre} shall be defined as the proposed building performance without credit for reduced annual energy emissions from on-site renewable energy generation system capacity in excess of that installed to satisfy the requirements of Section C412.
3. References to energy cost in Section 4.2.1.1 and Appendix G shall be replaced by carbon emissions calculated by multiplying site energy consumption by the carbon emission factor from Table C407.3(1).
4. …

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PCI = Proposed Building (Carbon)/Baseline Building (Carbon)

$$PCI_t = [BBUEC + (BPF \times BBREC)]/BBP$$

where

PCI = Performance Cost Index calculated in accordance with Section G1.2.

BBUEC = Baseline *Building* Unregulated *Energy* Cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *unregulated energy use*.

BBREC = Baseline *Building* Regulated *Energy* Cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *regulated energy use*.

BPF = *Building* Performance Factor from Table 4.2.1.1. For *building* area types not listed in Table 4.2.1.1 use "All others." Where a *building* has multiple *building* area types, the required BPF shall be equal to the area-weighted average of the *building* area types.

BBP = *Baseline Building Performance*.

Building Area Type	Building Performance Factor
Multifamily	0.58
Healthcare/hospital	0.54
Hotel/motel	0.64
Office	0.56
Restaurant	0.70
Retail	0.47
School	0.36
Warehouse	0.48
All others	0.54

PCI<PCI Target and building passes

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Table C407.3(1)
Carbon Emissions Factors

Type	CO2e (lb/unit)	Unit
Electricity	0.70	kWh
Natural Gas	11.7	Therm
Oil	19.2	Gallon
Propane	10.5	Gallon
Other[a]	195.00	mmBtu
On-site renewable energy	0.00	

[a] District energy systems may use alternative emissions factors supported by calculations approved by the *code official*.

Table G3.1.1-1 Baseline *Building Vertical Fenestration* Percentage of Gross *Above-Grade-Wall* Area

Building Area Types[a]	Baseline *Building* Gross *Above-Grade-Wall* Area
Grocery store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤75 rooms)	24%
Hotel/motel (>75 rooms)	34%
Office (≤5000 ft^2)	19%
Office (5000 to 50,000 ft^2)	31%
Office (>50,000 ft^2)	40%
Restaurant (quick service)	34%
Restaurant (full service)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

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How hard is this?

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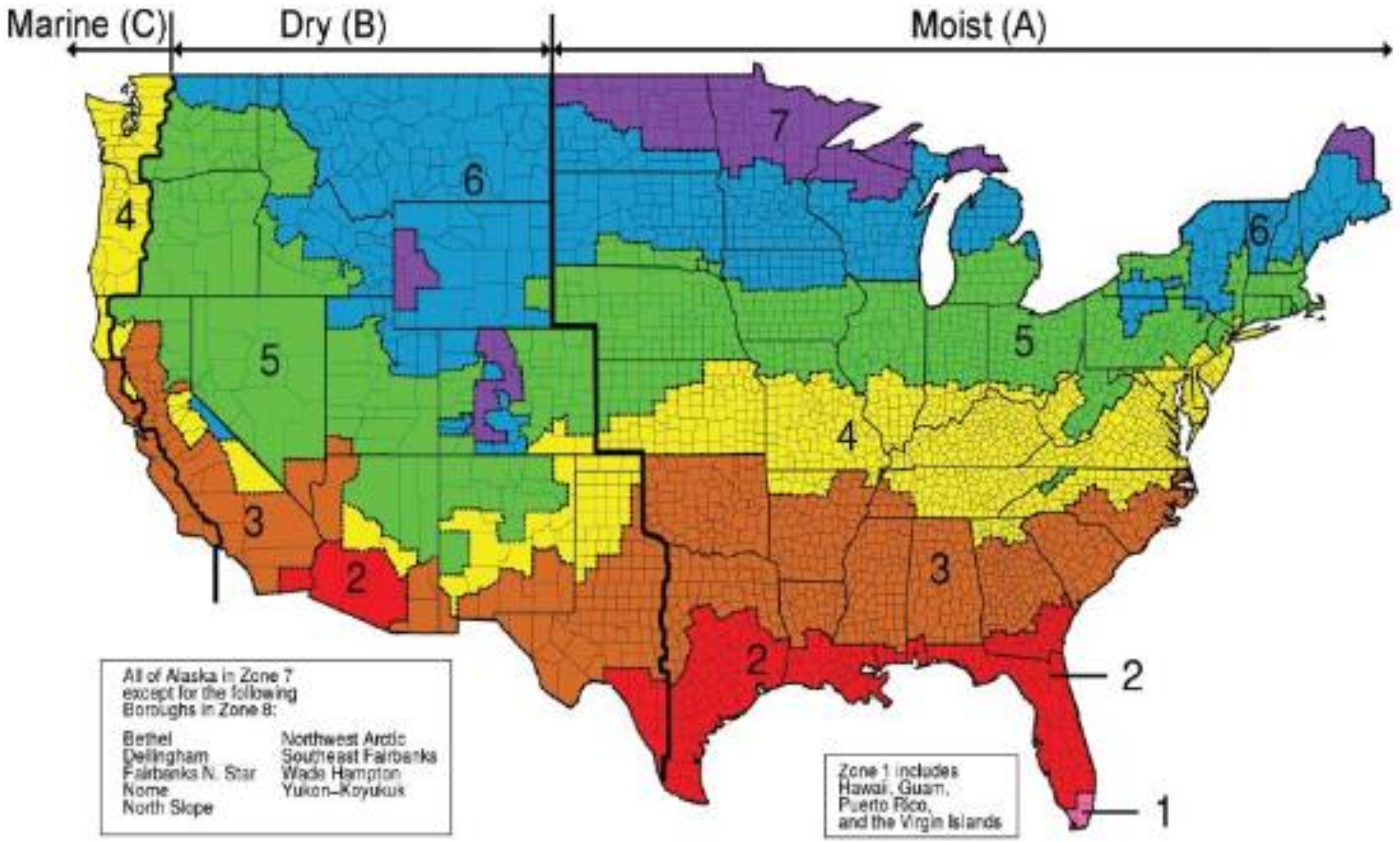

- 1A: Miami, Florida (very hot, humid)
- 1B: Riyadh, Saudi Arabia (very hot, dry)
- 2A: Houston, Texas (hot, humid)
- 2B: Phoenix, Arizona (hot, dry)
- 3A: Memphis, Tennessee (warm, humid)
- 3B: El Paso, Texas (warm, dry)
- 3C: San Francisco, California (warm, marine)
- 4A: Baltimore, Maryland (mixed, humid)
- 4B: Albuquerque, New Mexico (mixed, dry)
- 4C: Salem, Oregon (mixed, marine)
- 5A: Chicago, Illinois (cool, humid)
- 5B: Boise, Idaho (cool, dry)
- 5C: Vancouver, B.C. Canada (cool, marine)
- 6A: Burlington, Vermont (cold, humid)
- 6B: Helena, Montana (cold, dry)
- 7: Duluth, Minnesota (very cold)
- 8: Fairbanks, Alaska (subarctic)

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Table 2.2 Building Performance Factors (BPF) for Compliance with Standard 90.1-2010

	Climate Zone																	Building Type Average
Building Type	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	
Office	0.74	0.77	0.73	0.76	0.72	0.76	0.66	0.70	0.73	0.70	0.72	0.73	0.70	0.71	0.72	0.70	0.75	0.72
Retail	0.71	0.75	0.68	0.71	0.68	0.74	0.75	0.69	0.74	0.75	0.69	0.73	0.76	0.69	0.74	0.66	0.69	0.72
School	0.68	0.68	0.64	0.67	0.63	0.67	0.68	0.63	0.67	0.64	0.63	0.63	0.63	0.63	0.62	0.61	0.64	0.65
Healthcare	0.72	0.75	0.70	0.70	0.69	0.72	0.64	0.66	0.73	0.66	0.69	0.70	0.66	0.69	0.68	0.69	0.71	0.69
Restaurant	0.76	0.73	0.71	0.72	0.72	0.72	0.78	0.70	0.71	0.76	0.74	0.72	0.75	0.75	0.74	0.78	0.79	0.74
Hotel	0.80	0.82	0.76	0.77	0.77	0.81	0.80	0.76	0.81	0.78	0.72	0.77	0.73	0.71	0.73	0.69	0.70	0.76
Warehouse	0.63	0.62	0.67	0.69	0.67	0.69	0.73	0.69	0.71	0.72	0.70	0.71	0.74	0.74	0.73	0.73	0.76	0.70
Apartment	0.92	0.91	0.88	0.86	0.87	0.87	0.80	0.90	0.93	0.92	0.88	0.92	0.92	0.88	0.91	0.83	0.89	0.89
All Others	0.81	0.76	0.70	0.71	0.69	0.74	0.72	0.71	0.73	0.73	0.69	0.72	0.73	0.69	0.70	0.67	0.67	0.72

Table 2.3 Building Performance Factors (BPF) for Compliance with Standard 90.1-2013

	Climate Zone																	Building Type Average
Building Type	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	
Office	0.63	0.67	0.62	0.67	0.65	0.69	0.59	0.63	0.65	0.63	0.65	0.66	0.63	0.66	0.66	0.62	0.66	0.65
Retail	0.57	0.63	0.58	0.63	0.59	0.67	0.65	0.60	0.65	0.65	0.60	0.64	0.66	0.60	0.63	0.58	0.58	0.62
School	0.51	0.58	0.52	0.58	0.54	0.57	0.55	0.54	0.55	0.54	0.55	0.55	0.55	0.54	0.55	0.52	0.56	0.55
Healthcare	0.69	0.61	0.65	0.61	0.65	0.61	0.59	0.62	0.58	0.60	0.64	0.57	0.60	0.62	0.57	0.61	0.61	0.61
Restaurant	0.67	0.67	0.63	0.66	0.65	0.65	0.66	0.63	0.60	0.65	0.67	0.63	0.65	0.68	0.65	0.70	0.73	0.66
Hotel	0.69	0.70	0.67	0.65	0.68	0.70	0.69	0.67	0.69	0.67	0.65	0.66	0.65	0.64	0.66	0.62	0.63	0.67
Warehouse	0.56	0.57	0.61	0.63	0.62	0.64	0.68	0.63	0.65	0.68	0.65	0.66	0.70	0.71	0.71	0.72	0.72	0.66
Apartment	0.78	0.78	0.76	0.74	0.79	0.78	0.73	0.83	0.86	0.86	0.81	0.85	0.86	0.81	0.84	0.79	0.85	0.81
All Others	0.67	0.66	0.60	0.62	0.61	0.66	0.64	0.63	0.62	0.66	0.62	0.62	0.66	0.61	0.61	0.58	0.57	0.63

https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25202Rev1.pdf

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Table 2.4 Building Performance Factors (BPF) for Compliance with Standard 90.1-2016

Building Type	Climate Zone 0A & 1A	0A & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Building Type Average
Office	0.58	0.62	0.57	0.62	0.60	0.64	0.54	0.58	0.60	0.58	0.60	0.61	0.58	0.61	0.61	0.57	0.61	0.60
Retail	0.52	0.58	0.53	0.58	0.54	0.62	0.60	0.55	0.60	0.60	0.55	0.59	0.61	0.55	0.58	0.53	0.53	0.57
School	0.46	0.53	0.47	0.53	0.49	0.52	0.50	0.49	0.50	0.49	0.50	0.50	0.50	0.49	0.50	0.47	0.51	0.50
Healthcare	0.64	0.56	0.60	0.56	0.60	0.56	0.54	0.57	0.53	0.55	0.59	0.52	0.55	0.57	0.52	0.56	0.56	0.56
Restaurant	0.62	0.62	0.58	0.61	0.60	0.60	0.61	0.58	0.55	0.60	0.62	0.58	0.60	0.63	0.60	0.65	0.68	0.61
Hotel	0.64	0.65	0.62	0.60	0.63	0.65	0.64	0.62	0.64	0.62	0.60	0.61	0.60	0.59	0.61	0.57	0.58	0.62
Warehouse	0.51	0.52	0.56	0.58	0.57	0.59	0.63	0.58	0.60	0.63	0.60	0.61	0.65	0.66	0.66	0.67	0.67	0.61
Apartment	0.73	0.73	0.71	0.69	0.74	0.73	0.68	0.78	0.81	0.81	0.76	0.80	0.81	0.76	0.79	0.74	0.80	0.76
All Others	0.62	0.61	0.55	0.57	0.56	0.61	0.59	0.58	0.57	0.61	0.57	0.57	0.61	0.56	0.56	0.53	0.52	0.58

https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25202Rev1.pdf

C407, Welcome to ASHRAE 90.1

Building Type	4C	5A	5B	5C
Office	0.58	0.60	0.61	0.58
Retail	0.60	0.55	0.59	0.61
School	0.49	0.50	0.50	0.50
Healthcare	0.55	0.59	0.52	0.55
Restaurant	0.60	0.62	0.58	0.60
Hotel	0.62	0.60	0.61	0.60
Warehouse	0.63	0.60	0.61	0.65
Apartment	0.81	0.76	0.80	0.81
All Others	0.61	0.57	0.57	0.61

Building Area Type	Building Performance Factor
Multifamily	0.58
Healthcare/hospital	0.54
Hotel/motel	0.64
Office	0.56
Restaurant	0.70
Retail	0.47
School	0.36
Warehouse	0.48
All others	0.54

WSEC

Building Area Type	Building Performance Factor
Multifamily	((~~0.58~~)) 0.52
Healthcare/hospital	((~~0.54~~)) 0.49
Hotel/motel	((~~0.64~~)) 0.58
Office	((~~0.56~~)) 0.51
Restaurant	((~~0.70~~)) 0.63
Retail	((~~0.47~~)) 0.43
School	((~~0.36~~)) 0.32
Warehouse	((~~0.48~~)) 0.43
All Others	((~~0.54~~)) 0.49

SEC

C407, Welcome to ASHRAE 90.1

Model based on 2011 LEED Gold Building
EUI = 42.85
37% better than ASHRAE 2010

C407, Welcome to ASHRAE 90.1

Model based on 2011 LEED Gold Building
EUI = 42.85
37% better than ASHRAE 2010

Code	Washington State Energy Code				Seattle Energy Code							
Version	2012	2015	2018 VAV	2018 DOAS	2012	2012 w/ Solar	2015	2015 w/ Solar	2018 VAV	2018 DOAS	2018 VAV w/ Solar	2018 DOAS w/ Solar
EUI	60.2	59.6	45.9	48.1	60.0	59.7	51.8	50.6	44.6	47.1	43.7	46.2
Cost Savings v. ASHRAE 2010 (EUI = 61.0)	-1.3%	0.1%	18%	9%	0.0%	0.1%	15.1%	17.0%	20.7%	10.9%	22.4%	12.6%

C407, Welcome to ASHRAE 90.1

Cost Based	
BBUEC	22539.47
BBREC	75130
BPF (WSEC)	0.56
BPF (SEC)	0.51
BBP	97669.47
PCIt (WSEC)	0.662
PCIt (SEC)	0.623
PCI (2018 WSEC DOAS)	0.861
PCI (2018 SEC DOAS)	0.840
PCI Actual	0.630

Carbon Based	
BBUEC	243380.6
BBREC	822652.7
BPF (WSEC)	0.56
BPF (SEC)	0.51
BBP	1066033
PCIt (WSEC)	0.660
PCIt (SEC)	0.622
PCI (2018 WSEC DOAS)	0.853
PCI (2018 SEC DOAS)	0.833
PCI Actual	0.624

$$PCI_t = [BBUEC + (BPF \times BBREC)]/BBP$$

where

PCI = Performance Cost Index calculated in accordance with Section G1.2.

BBUEC = Baseline *Building* Unregulated *Energy* Cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *unregulated energy use*.

BBREC = Baseline *Building* Regulated *Energy* Cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *regulated energy use*.

BPF = *Building* Performance Factor from Table 4.2.1.1. For *building* area types not listed in Table 4.2.1.1 use "All others." Where a *building* has multiple *building* area types, the required BPF shall be equal to the area-weighted average of the *building* area types.

BBP = *Baseline Building Performance*.

C407, Welcome to ASHRAE 90.1

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BBP = *Baseline Building Performance*.

C407, Welcome to ASHRAE 90.1

How hard is this (reprise)?

Commissioning of HVAC required, plus…

- Cx qualifications
- Conflict of interest statement
- Checklist
- CX plan and Cx report
  - Lighting, controlled receptacles
  - HVAC, water heating
  - Refrigeration
  - Metering
- HVAC Cx thresholds:
  - 240 kBtu/h cooling
  - 300 Kbtu/h heating

Getting HVAC systems all the way to the finish line

C408, Brief note on Cx

Required (except very small systems)

Certified Commissioning Professional

CERTIFIED COMMISSIONING PROFESSIONAL. An individual who is certified by an ANSI/ISO/IEC 17024:2012 accredited organization to lead, plan, coordinate, and manage commissioning teams and implement the commissioning process.

~~Metering~~ Actionable energy display

- Graphic energy use display for bldgs. 20,000+ SF
  - Source meters (usually gas & elec pulse meters)
  - HVAC & water heating sub-meters
  - Lighting, plug load & process load sub-meters
- Also required for replacement HVAC systems
- Planning can reduce number of meters

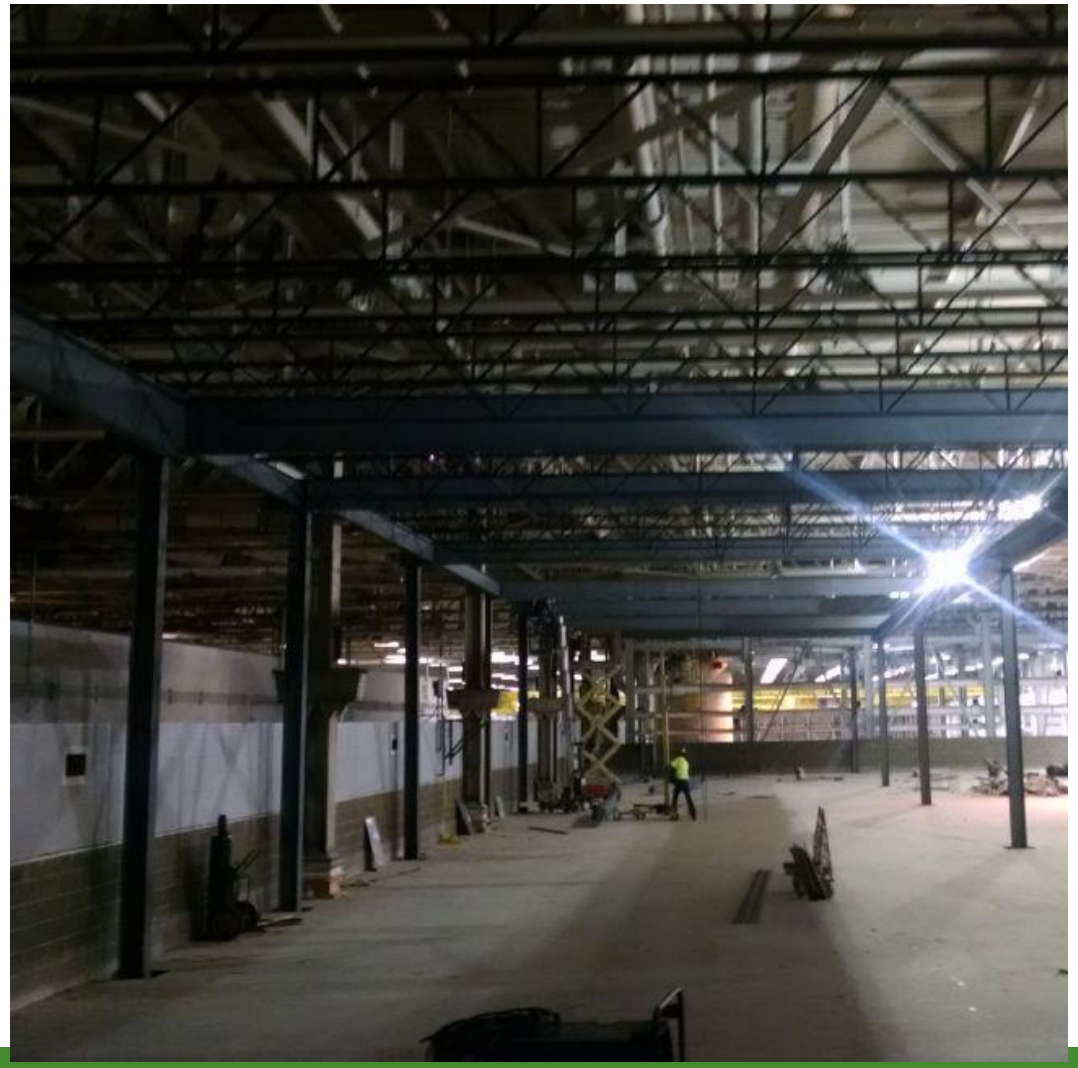
C409, The Cx Perspective

Meters, what are they good for anyway?

Alterations C503

General principles:

- Existing (untouched) can remain as-is
- Service and repairs OK
- New equipment and new systems must meet code
- Seattle “Substantial Alterations” Whole *building* meets code
  - With a small break for UA *or* BPF
- … same with change of occupancy, change of space conditioning



Cooling system alterations C503.4.1

- When adding cooling to an “uncool” space, must provide either DOAS or economizer, both at the individual equipment level and the total system level
- Alteration or replacement of cooling system: Table C503.4 - Economizers

TABLE C503.4

ECONOMIZER COMPLIANCE OPTIONS FOR MECHANICAL *ALTERATIONS*

	Option A	Option B (alternate to A)	Option C (alternate to A)	Option D (alternate to A)
Unit Type	**Any *alteration* with new or replacement equipment**	**Replacement unit of the same type with the same or smaller output capacity**	**Replacement unit of the same type with a larger output capacity**	**New equipment added to existing system or replacement unit of a different type**
1. Packaged Units	Efficiency: min.[a] Economizer: C403.5[b]	Efficiency: min.[a] Economizer: C403.5[b]	Efficiency: min.[a] Economizer: CC403.5[b]	Efficiency: min.[a] Economizer: C403.5[b]
2. Split Systems	Efficiency: min.[a] Economizer: C403.5[b]	For units ≤ 60,000 Btuh, comply with two of two measures: 1. Efficiency: + 10%[e] 2. Economizer: shall	For units ≤ 60,000 Btuh replacing unit installed prior to 1991, comply with at least one of two measures:	Efficiency: min.[a] Economizer: C403.5[b]

(Note some corrections to footnotes in Seattle code)

Adding cooling: a sticky situation

New & replacement heating systems Seattle

C503.4.6 New and replacement HVAC heating system equipment. For substantial alterations as defined in Section C503.8.1, or where a building's central HVAC heating system equipment is augmented or replaced, the building shall comply with Section C403.1.4.

Exception. Where only one heating appliance is failing and is replaced by another having the same or lesser heating capacity and the same or higher efficiency, no other alterations are made to the central HVAC system, and this exception has not been used within the same building in the previous 24-month period, this provision does not apply.

SDCI Informative Note: The term "central HVAC heating system" for the purposes of this section means a heating system that provides heating to multiple spaces or multiple dwelling or sleeping units (as opposed to a distributed heating system such as a baseboard heater or PTHP that provides heating to only a single space). A central heating system may include multiple pieces of heating equipment.
The exception permits like-for-like replacement of a single boiler, furnace or heat pump, where no other HVAC work is planned, so that a failed heating appliance can be expediently replaced.

Substantial Alterations: (Also) a sticky situation

HFC refrigerant phaseout – HB 1112 & HB 1050

- Cutoff dates for equipment using HFCs
  - Supermarket & warehouse refrigeration 2020
  - Chillers 2024, Heat pumps 2025, VRF 2026
  - Equipment manufacture date, not permit date
- R-410, R134…going, going, gone!
- R-32 approved, but no equipment yet
- CO2 systems already viable for HPWH

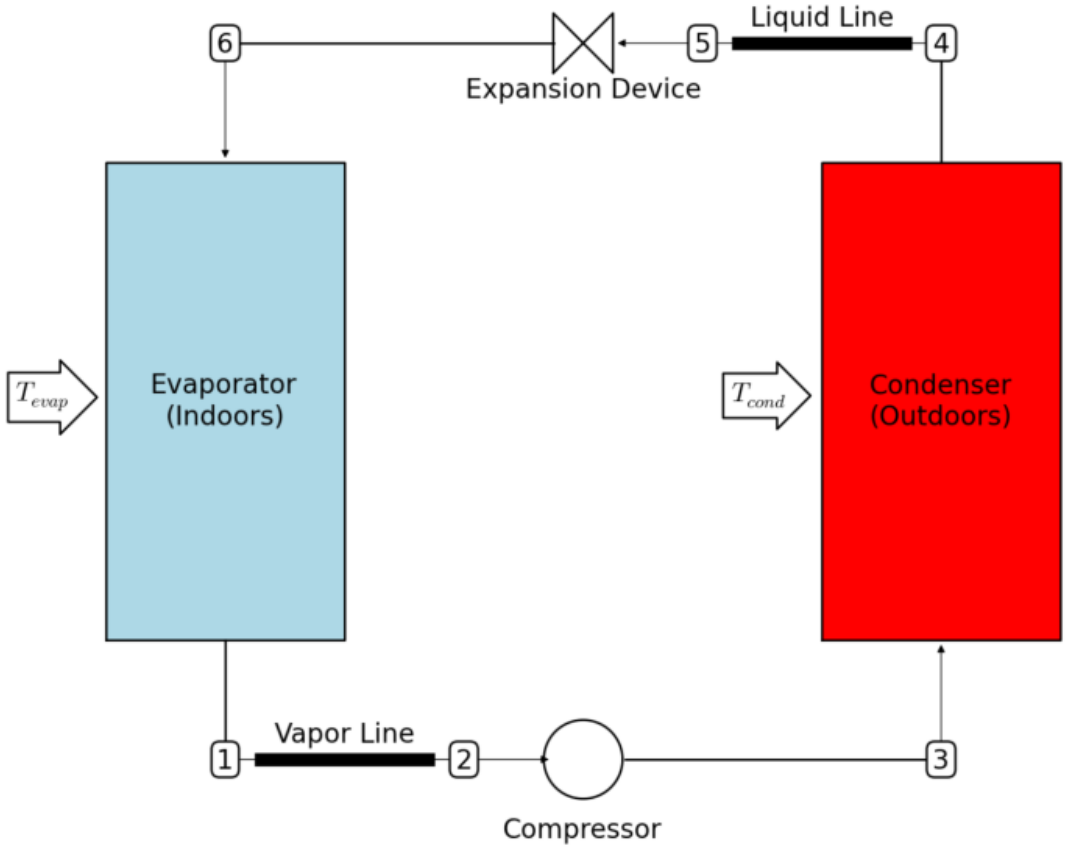
HB1112, Refrigerants

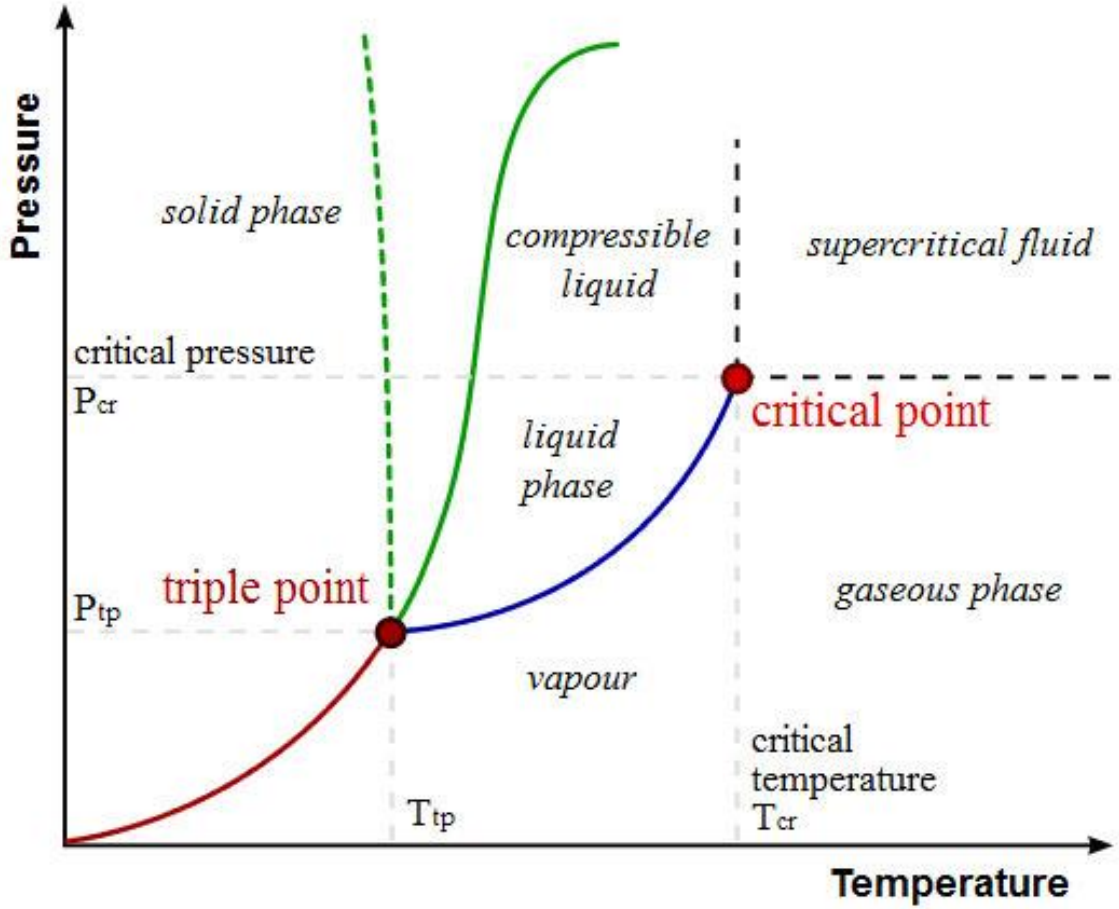
Refrigerant	ODP	GWP	Common Building Applications
Chlorofluorocarbons			
CFC-11	1.0	4,680	Centrifugal chillers
CFC-12	1.0	10,720	Refrigerators, chillers
CFC-114	0.94	9,800	Centrifugal chillers
CFC-500	0.605	7,900	Centrifugal chillers, humidifiers
CFC-502	0.221	4,600	Low-temperature refrigeration
Hydrochlorofluorocarbons			
HCFC-22	0.04	1,780	Air-conditioning, chillers
HCFC-123	0.02	76	CFC-11 replacement
Hydrofluorocarbons			
HFC-23	~ 0	12,240	Ultra-low-temperature refrigeration
HFC-134a	~ 0	1,320	CFC-12 or HCFC-22 replacement
HFC-245fa	~ 0	1,020	Insulation agent, centrifugal chillers
HFC-404A	~ 0	3,900	Low-temperature refrigeration
HFC-407C	~ 0	1,700	HCFC-22 replacement
HFC-410A	~ 0	1,890	Air-conditioning
HFC-507A	~ 0	3,900	Low-temperature refrigeration
Natural refrigerants			
Carbon dioxide (CO_2)	0	1.0	
Ammonia (NH_3)	0	0	
Propane	0	3	

LEED v2.2 Guide

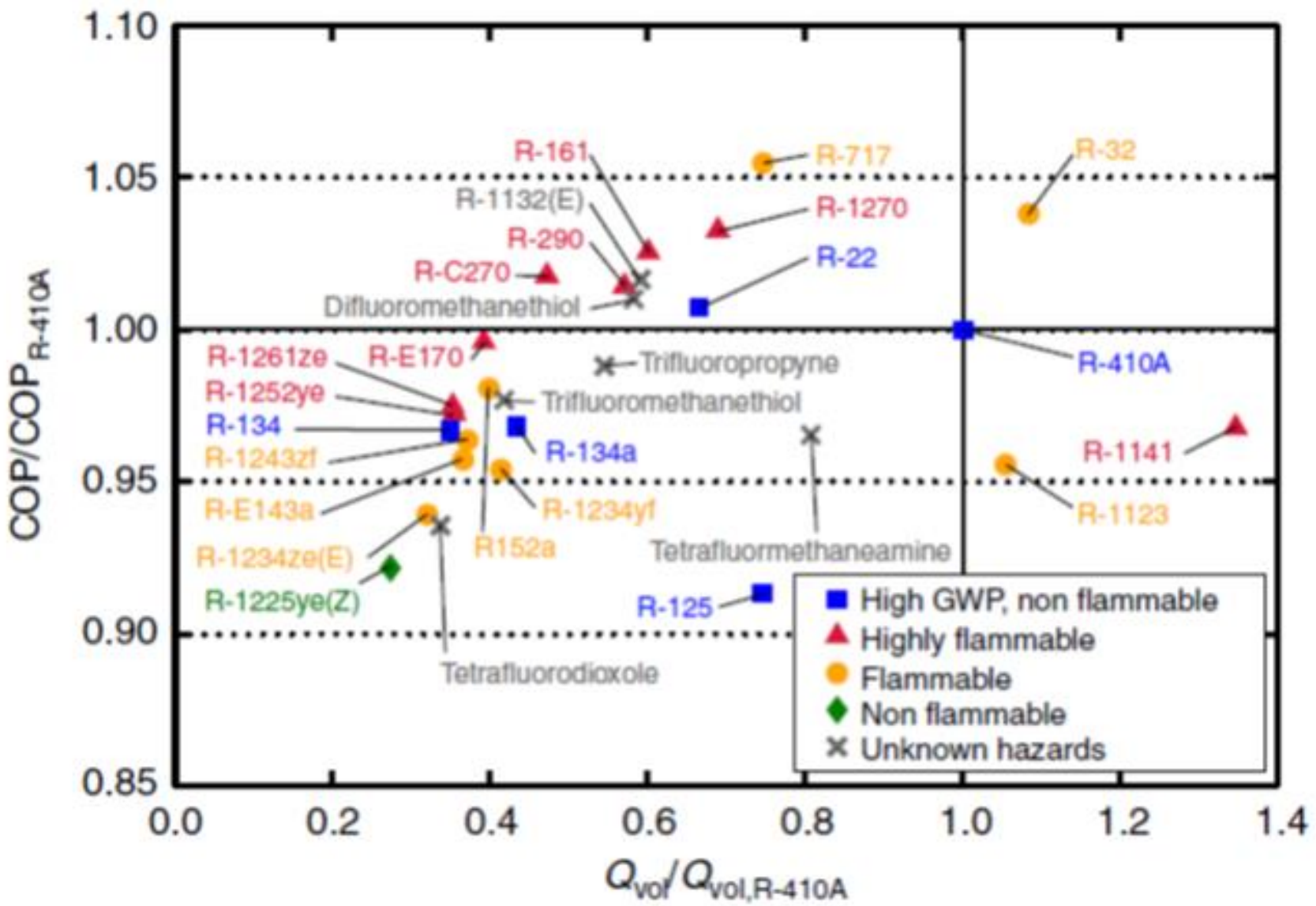
HB1112, Refrigerants

Refrigeration Cycle





HB1112, Refrigerants



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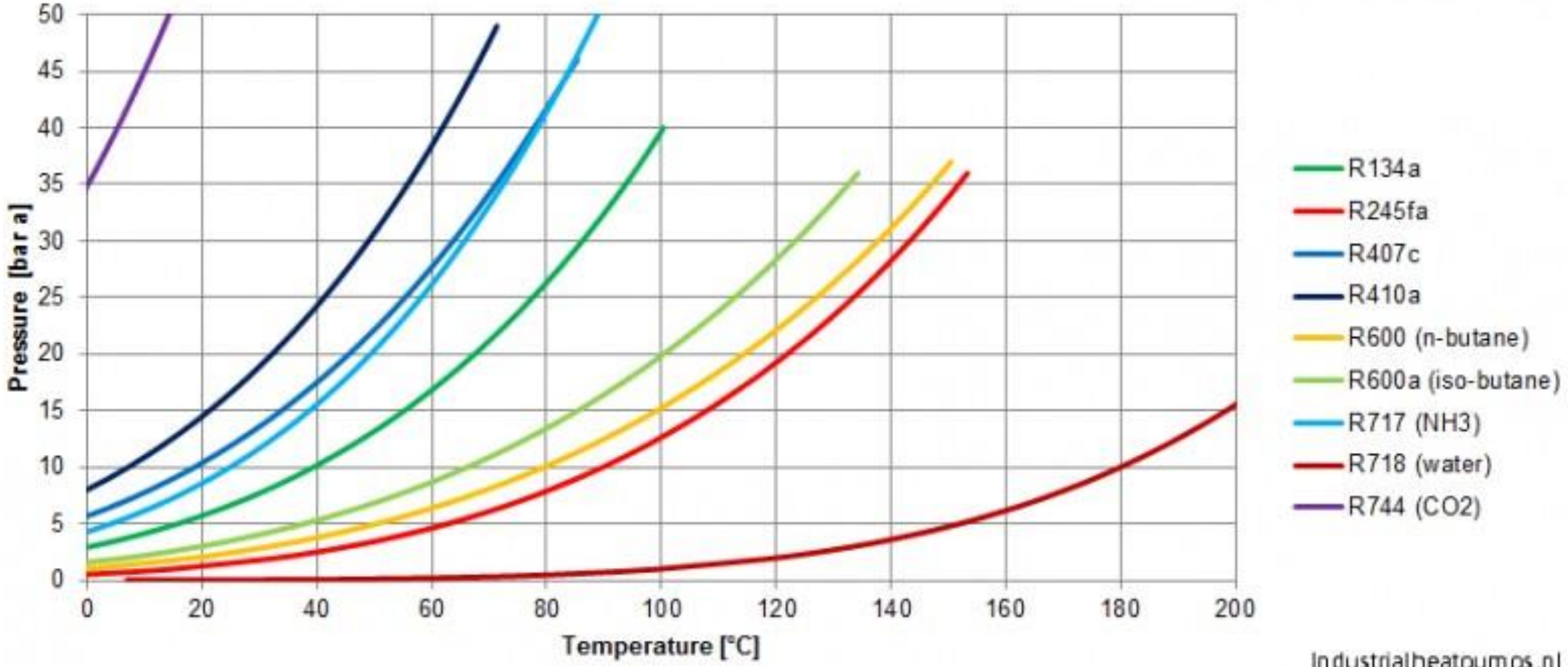
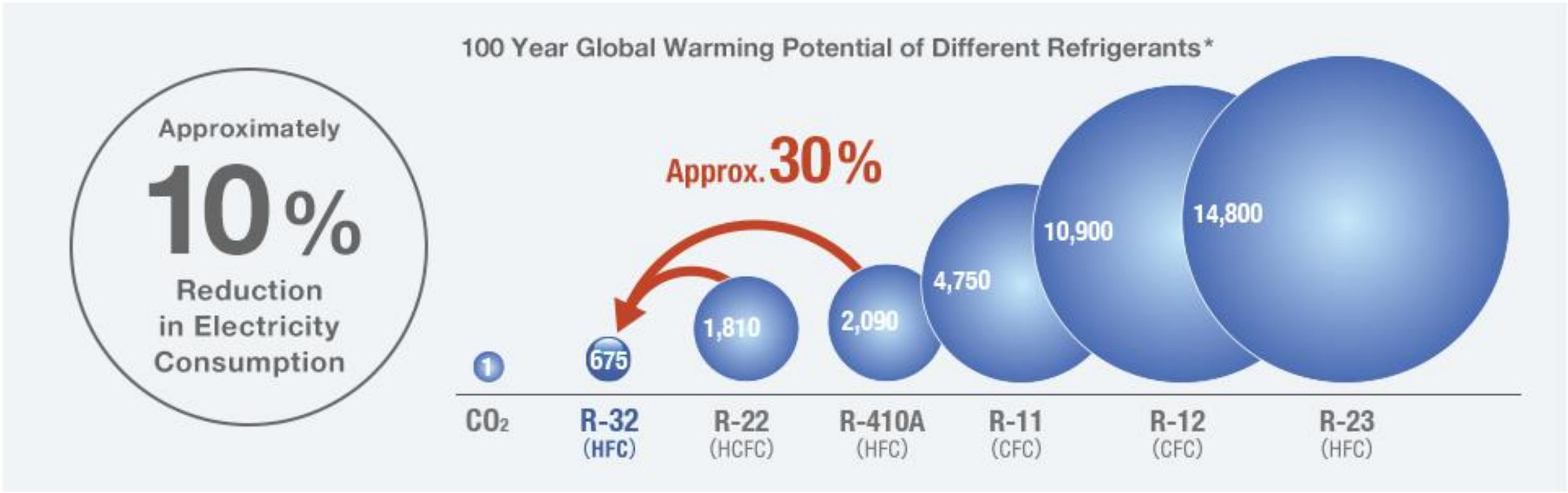


Industrialheatpumps.nl

HB1112, Refrigerants



*Source: Values for 100 year global warming potential (GWP) from IPCC Fourth Assessment Report. Comparative 100 year GWP: HFC410A, 2,090; HFC32, 675.

HB1112, Refrigerants

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(But wait, there's more!)

Upcoming HPWH Webinars Sept – Oct

Webinar Topic	Delivery Date	Time
The Whys and Hows of Heat Pump Water Heater Systems for Multifamily and Commercial Applications	September 15	10:00 – 11:00
How to Select and Design a Heat Pump Water Heater System in Your Next Multifamily or Commercial Project	September 16	10:00 – 11:00
Commercial HPWH: Engineering Deep Dive Part 1	October 11	10:00 – Noon
Commercial HPWH: Engineering Deep Dive Part 2	October 13	10:00 - Noon

Today's slide deck and video recording can be found on
www.lightingdesignlab.com

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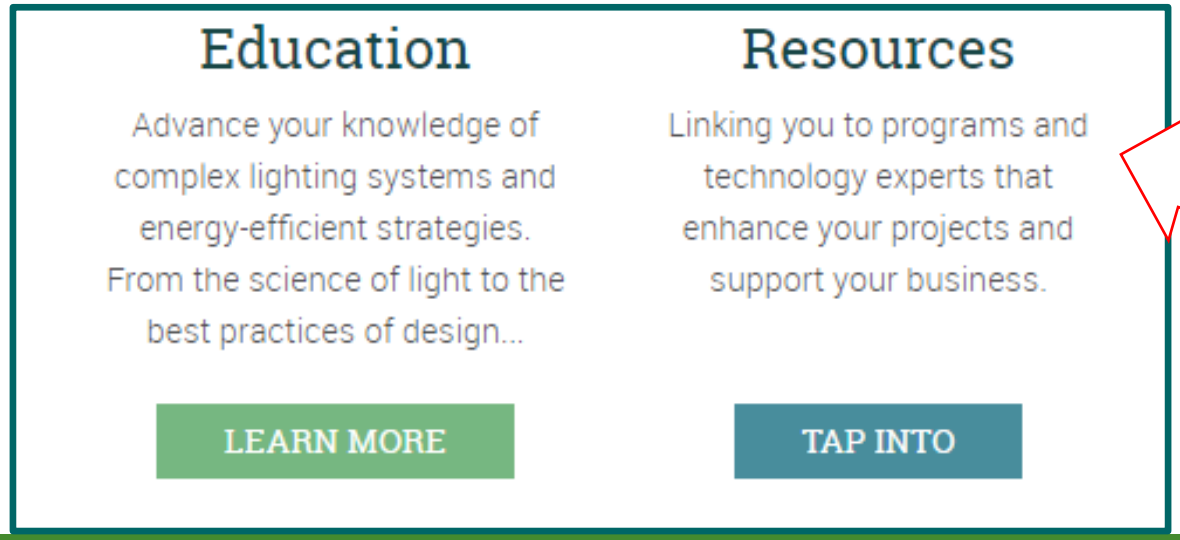

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Todays slide deck will be posted here!

Please take the online survey once you exit the webinar

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