



Seeking Strategies in Searing Settings

Passively-cooled mid-rise housing

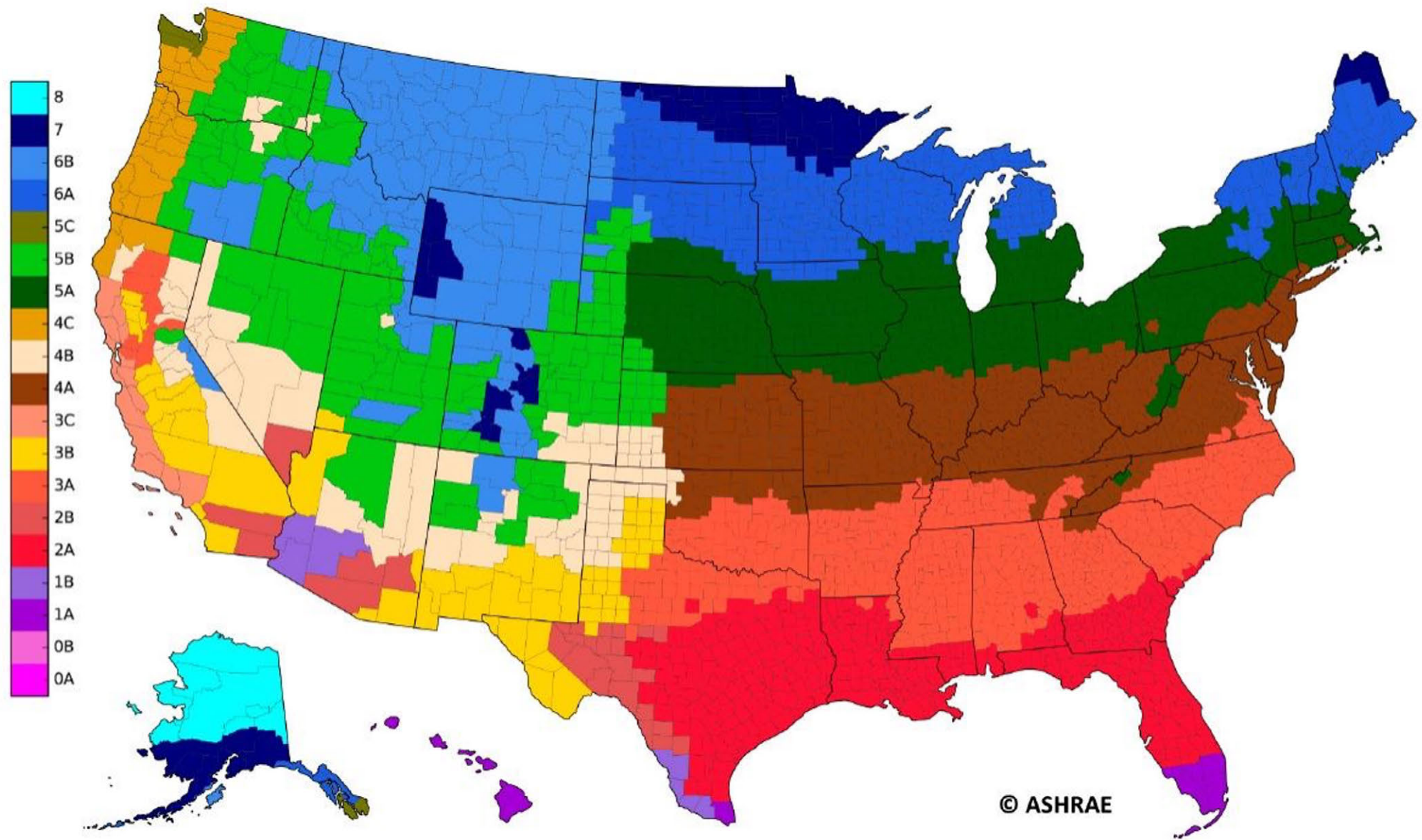
Mark DeKay
Aram Yeretzian



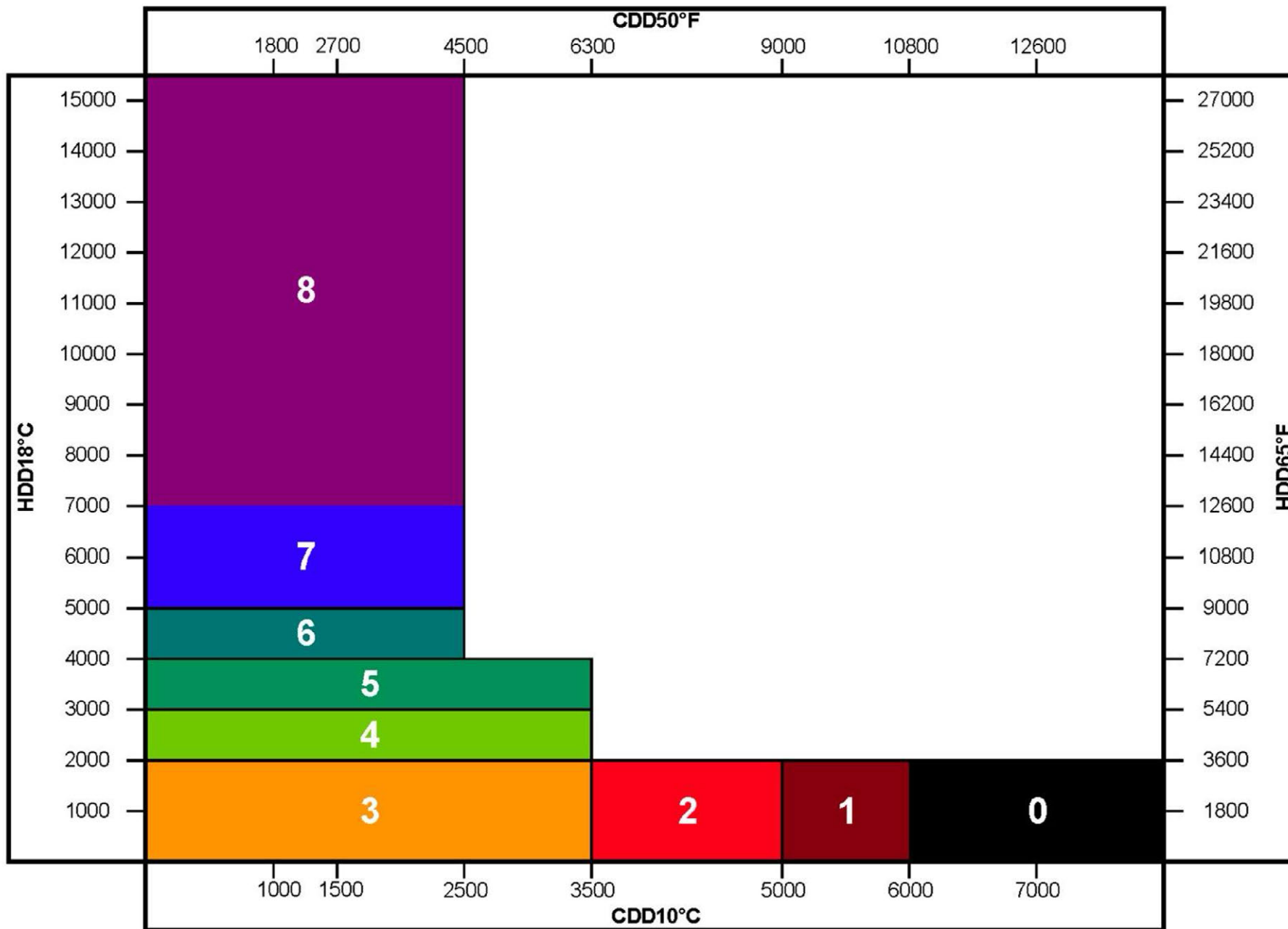


RESEARCH QUESTIONS

- 1 What passive and low-energy cooling strategies can we recommend in hot climates?**
- 2 How can the mid-rise housing typology be transformed to incorporate passive cooling?**

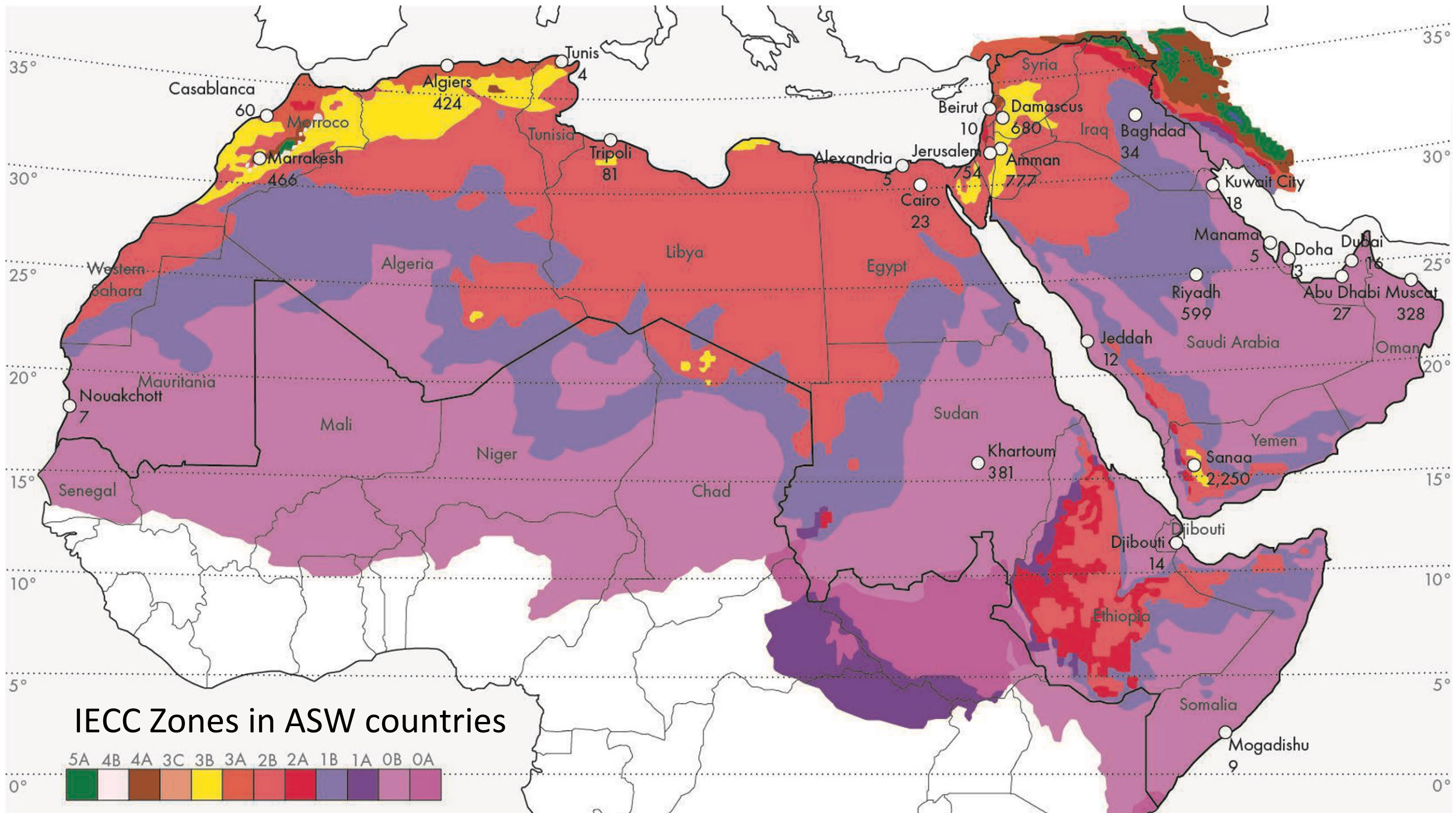


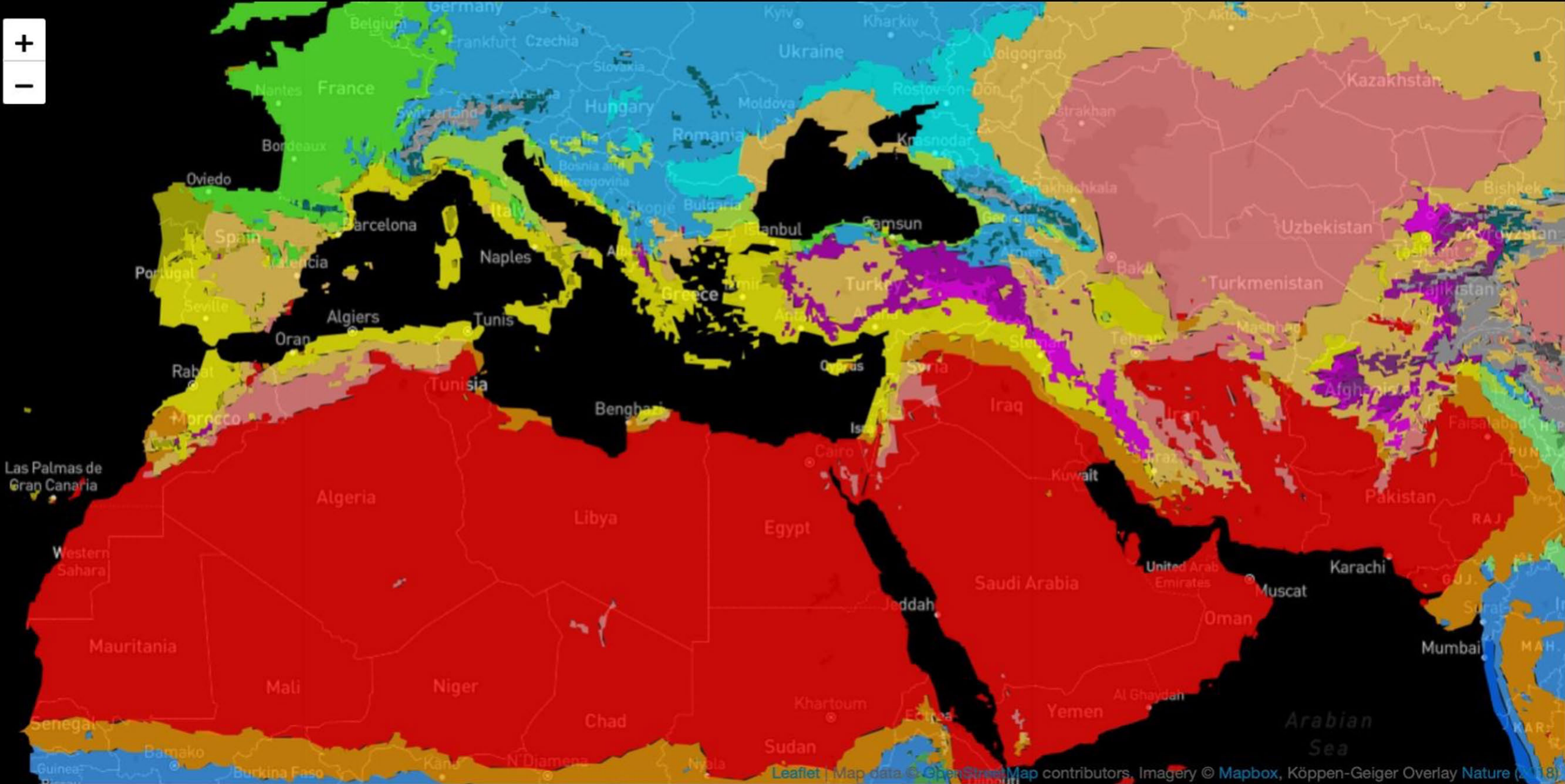
ASHRAE / IECC Climate Zones 2021



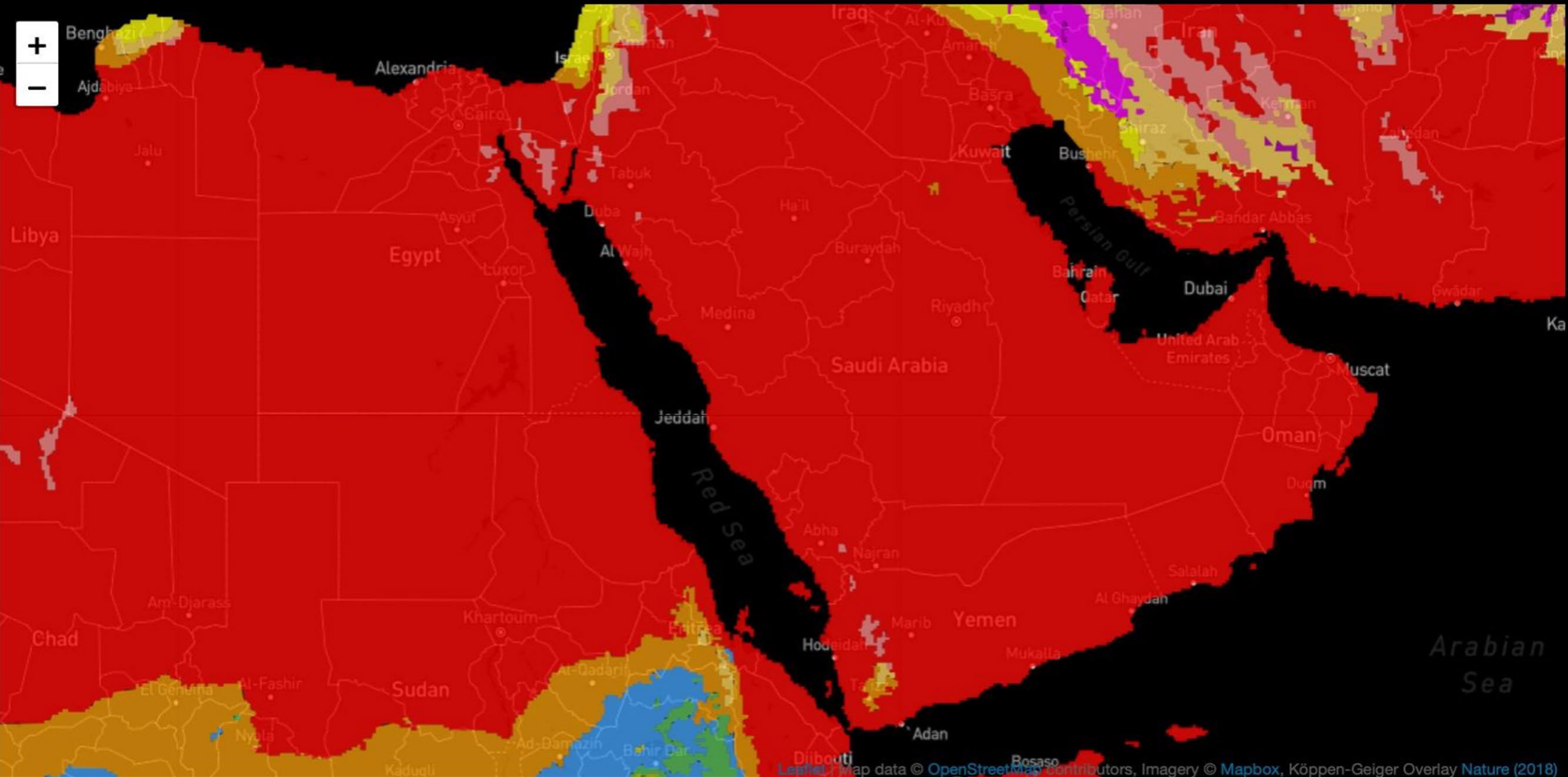
Zones defined by
HDD18°C and
CDD10°C

Figure A-1 Thermal climate zones as a function of heating and cooling degree-days.





Koppen-Geiger Climate Zones in ASW

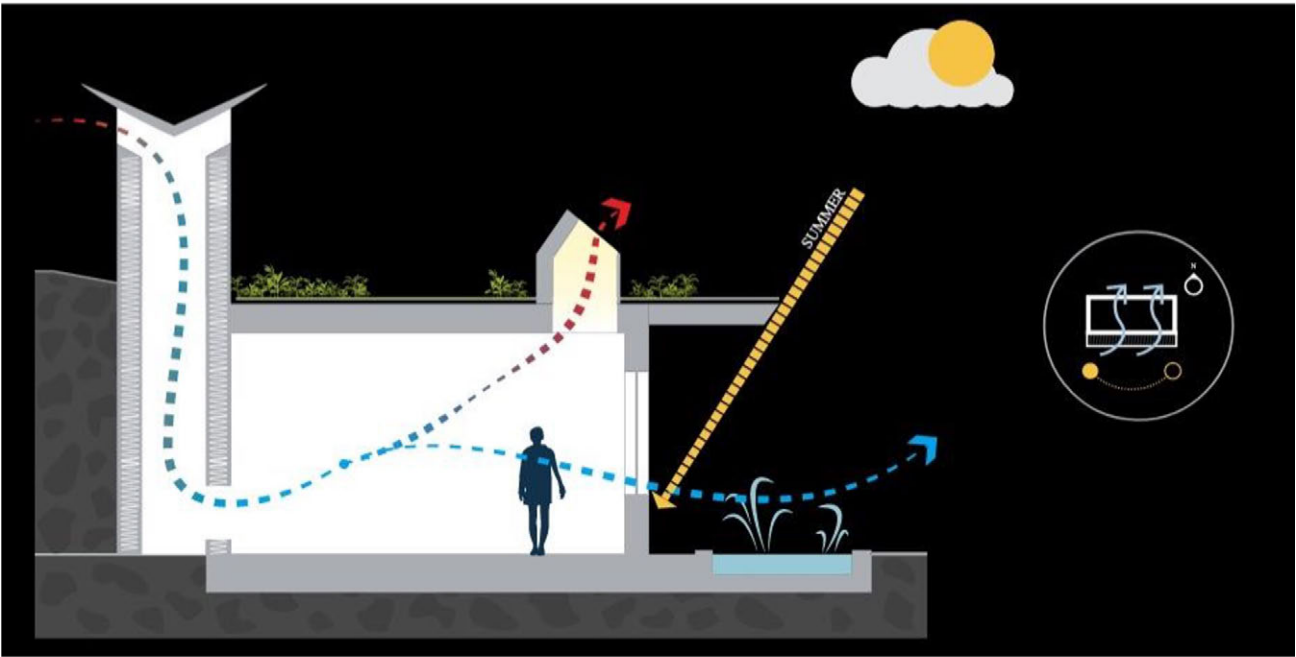


Koppen-Geiger Climate Zones: very coarse

CLIMATE ZONE

BWh_Hot Desert

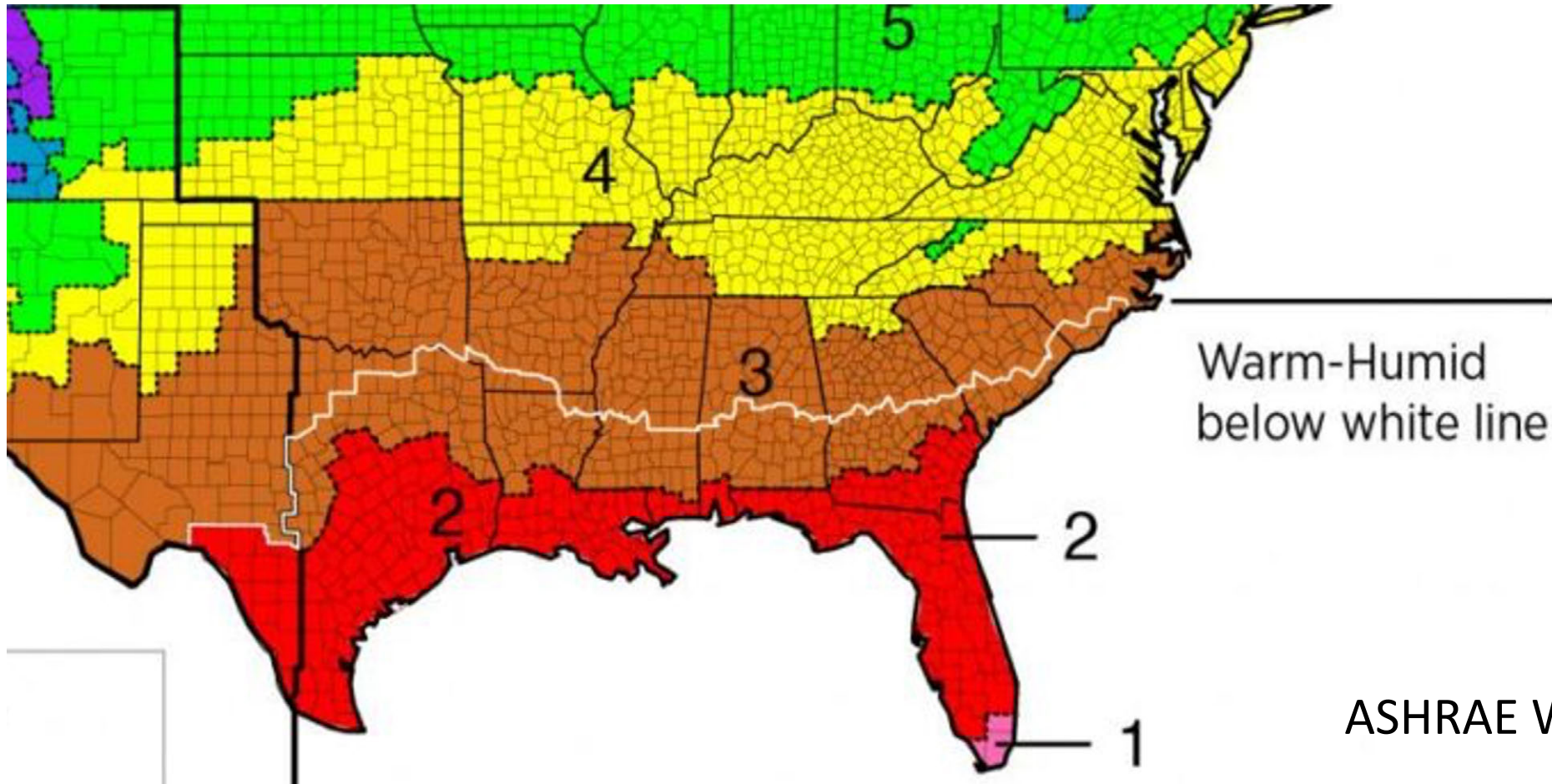
Low-latitude desert. Evaporation exceeds precipitation on average but is **less than half** potential evaporation. Average temperature is **more** than 64°F (18°C). Frost is absent or infrequent.



DESIGN STRATEGIES FOR BWH_HOT DESERT ?

 Building Facades +	 Clerestories and Skylights +	 Cool Roof -	 Cross Ventilation +
 Daylighting from Multiple Sides +	 Earth Sheltering -	 East/West Shading +	 Evaporative Cooling Towers -
 Form for Cooling -	 Form for Daylighting +	 Green Roof -	 Intermediate Light Shelves +
 Night Vent Cooling +	 Shading Devices +	 Side Daylighting +	 Side Daylighting Controls +
 Solar Shading -	 Stack Ventilation -		

Climate Scout: *Same strategies in humid Jeddah and arid Riyadh*



ASHRAE Warm-Humid Line

WB >19.5° C for 3000 hours or more
OR
WB >23° C for 1500 hours or more

ASHRAE Fundamentals, 1993

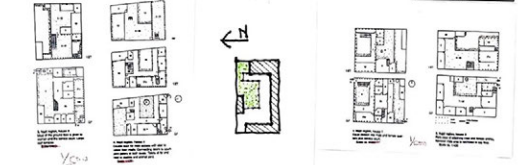
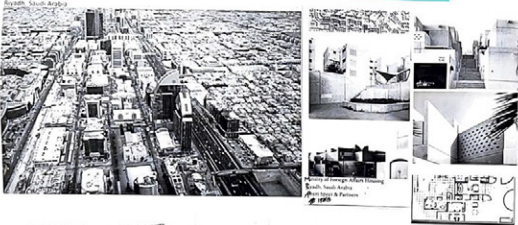
City	Wet Bulb Hrs-Hot 6		ASHRAE/IECC Climate Zone
	Hrs>19.5	Hrs >23	
Muscat	4,416	4,416	0B
Djibouti	4,410	4,227	
Mogadishu	4,364	3,718	
Manama	4,349	3,488	
Jeddah	4,308	3,183	
Dubai	4,281	3,341	
Abu Dhabi	4,152	2,828	
Doha	4,111	2,910	
Khartoum	2,906	811	0B
Riyadh	147	7	
Nouakchott	3,505	1,818	1B
Algiers	2,029	335	
Baghdad	1,688	108	
Kuwait City	1,360	210	

City	Wet Bulb Hrs-Hot 6		ASHRAE/IECC Climate Zone
	Hrs>19.5	Hrs >23	
Beirut	2,970	1,169	2A
Alexandria	2,975	879	2B
Cairo	2,742	581	
Tripoli	2,621	557	
Marrakesh	824	22	
Tunis	2,210	431	3A
Casablanca	1,593	74	
Jerusalem	317	31	
Amman	383	2	3B
Damascus	210	0	
Sanaa	0	0	

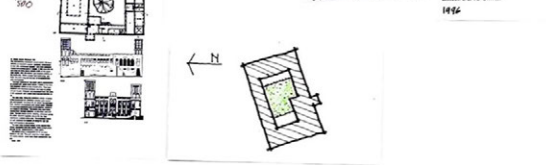
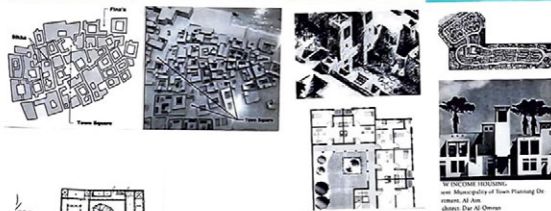
ASHRAE Warm-Humid Criteria: *better than precipitation!*

OB

RIYADH	RIYADH	RIYADH	RIYADH
P&C = 99 %	P&C = 7	P&C = 52% → 97%	P&C = 2
M.V.C. = 0 %	M.V.C. = (147)	M.V.C. = 2.5%	M.V.C. = 0
A.C. = 12 %	A.C. = 0	A.C. = 4%	A.C. = 0



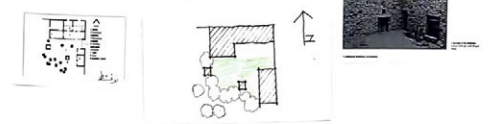
DUBAI	DUBAI	DUBAI	DUBAI
P&C = 4 %	P&C = 3341	P&C = 43% → 61%	P&C = 1032
M.V.C. = 8 %	M.V.C. = (4282)	M.V.C. = 52%	M.V.C. = 431
A.C. = 4 %	A.C. = 0	A.C. = 5%	A.C. = 57



KHARTOUM	KHARTOUM	KHARTOUM	KHARTOUM
P&C = 37 %	P&C = 311	P&C = 14% → 50%	P&C = 811
M.V.C. = 1 %	M.V.C. = 8	M.V.C. = 23%	M.V.C. = (2906)
A.C. = 12 %	A.C. = 0	A.C. = 5%	A.C. = 0

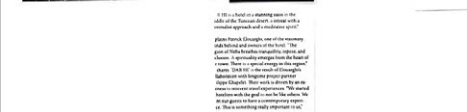
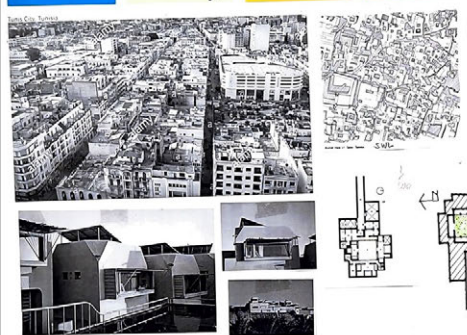


NOUAKHOTT	NOUAKHOTT	NOUAKHOTT	NOUAKHOTT
P&C = 23 %	P&C = 484	P&C = 54% → 73%	P&C = 1818
M.V.C. = 12 %	M.V.C. = 98	M.V.C. = 52%	M.V.C. = (3505)
A.C. = 49 %	A.C. = 0	A.C. = 5%	A.C. = 0

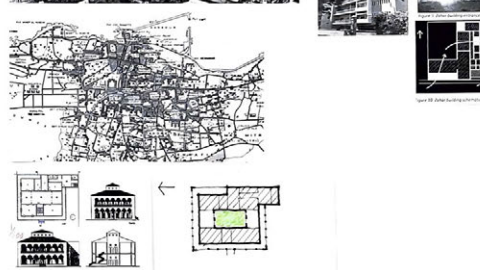


2A

TUNIS	TUNIS	TUNIS	TUNIS
P&C = 21 %	P&C = 431	P&C = 61% → 82%	P&C = 175
M.V.C. = 16 %	M.V.C. = (2210)	M.V.C. = 22%	M.V.C. = 16
A.C. = 54 %	A.C. = 0	A.C. = 4%	A.C. = 0

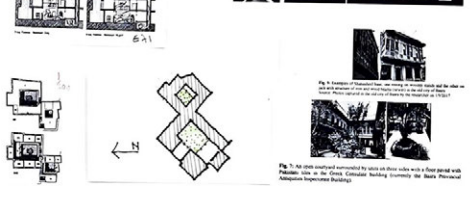
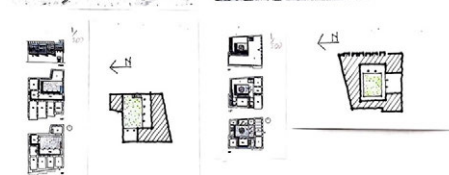


BEIRUT	BEIRUT	BEIRUT	BEIRUT
P&C = 11 %	P&C = 1169	P&C = 57% → 70%	P&C = 349
M.V.C. = 26 %	M.V.C. = (2970)	M.V.C. = 65%	M.V.C. = 27
A.C. = 74 %	A.C. = 0	A.C. = 4%	A.C. = 0



1B

BAGHDAD	BAGHDAD	BAGHDAD	BAGHDAD
P&C = 54 %	P&C = 108	P&C = 21% → 61%	P&C = 60
M.V.C. = 1 %	M.V.C. = (688)	M.V.C. = 4%	M.V.C. = 0
A.C. = 12 %	A.C. = 0	A.C. = 5%	A.C. = 0



Sorting built examples + climate metrics

0B

RIYADH
2
0
0
0

0B

JEDDAH
881
273
13
0

0B

DOHA
957
411
87
0

2B

TRIPOLI
219
11
0
0

2B

ALEXANDRIA
406
120
96
89

2A

BEIRUT
349
27
0
0

WB DD 19.5° C

WB DD 23.0° C

WB DD 26.5° C

WB DD 30.0° C

3B

CASABLANCA
30
0
0
0

3A

JERUSALEM
6
0
0
0

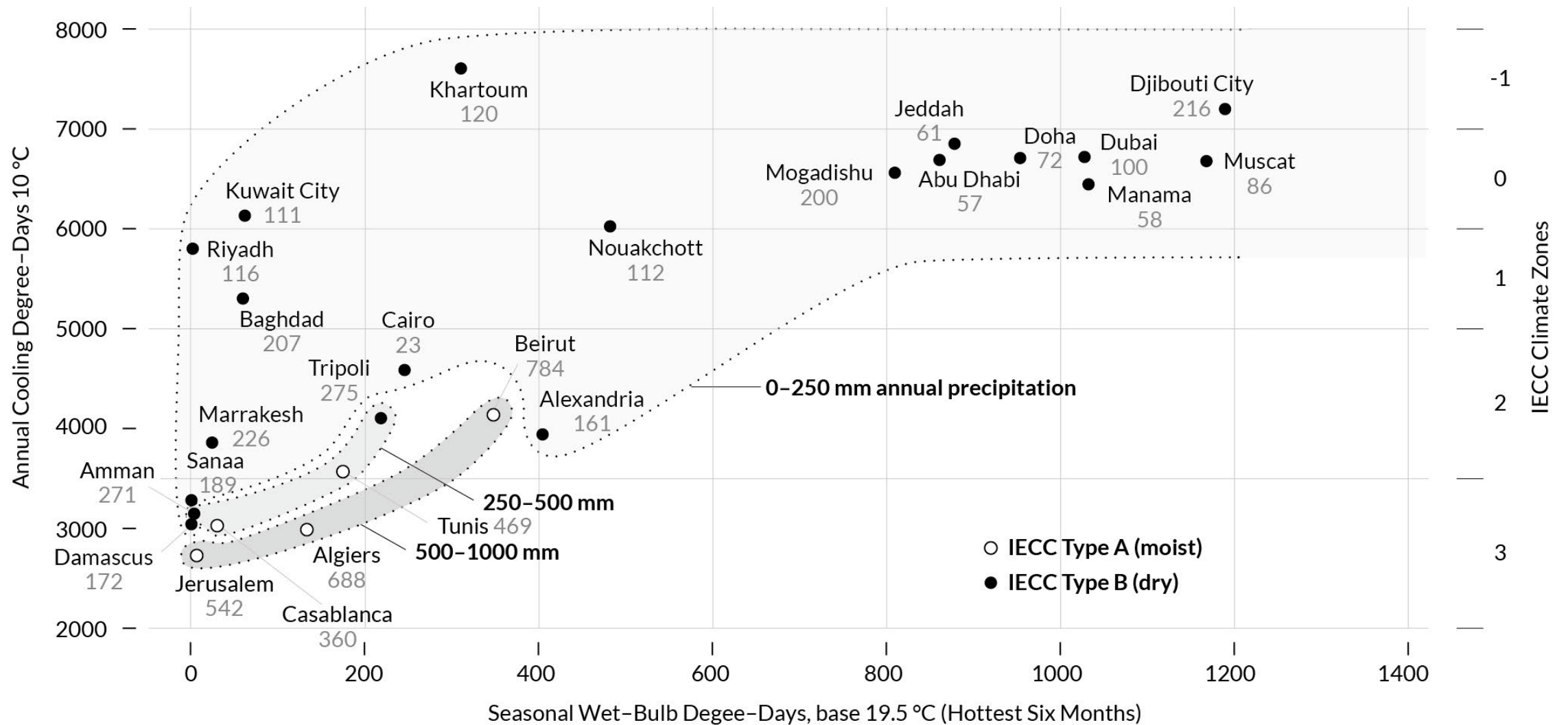
3A

ALGIERS
133
0
0
0

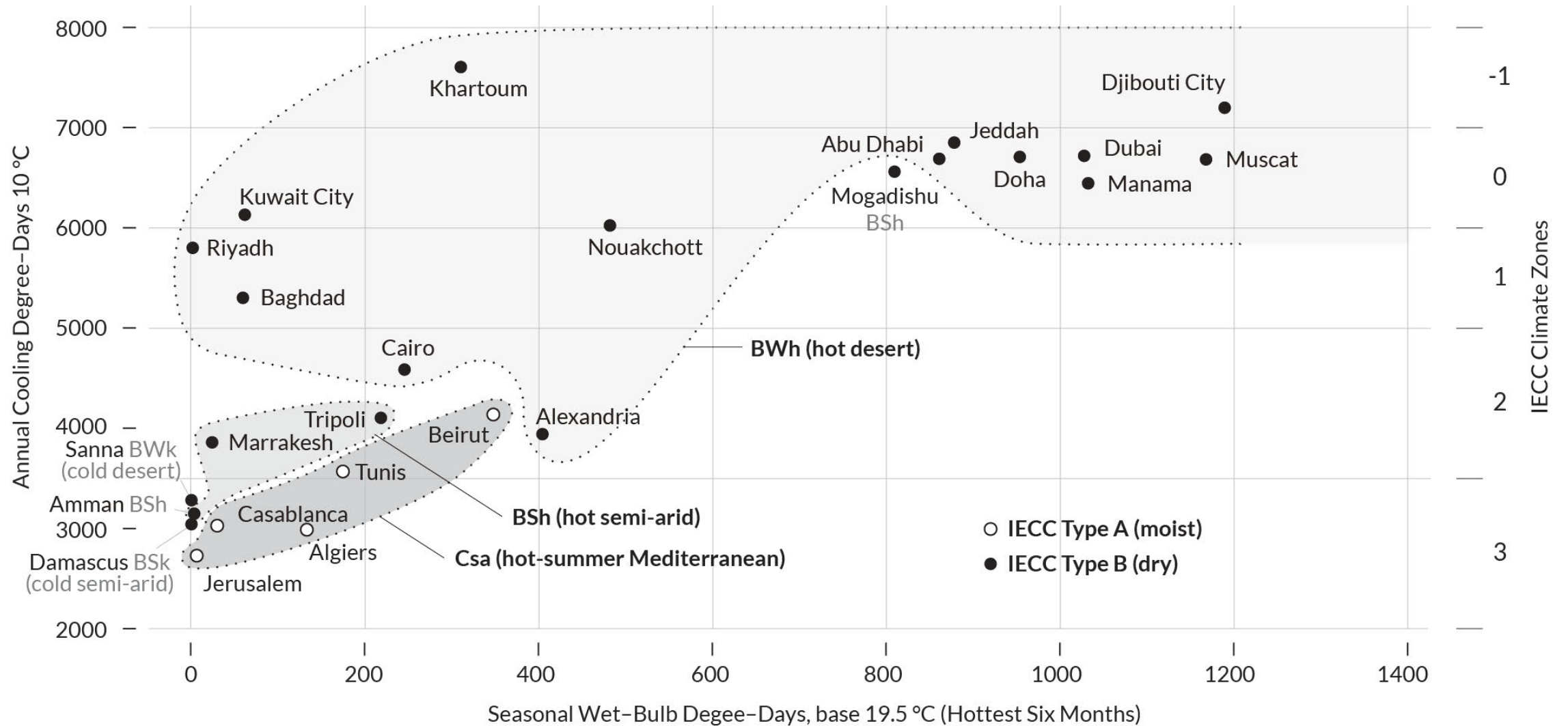
Wet Bulb Degree Days
(hottest 6 months)

Sum of all hours where:

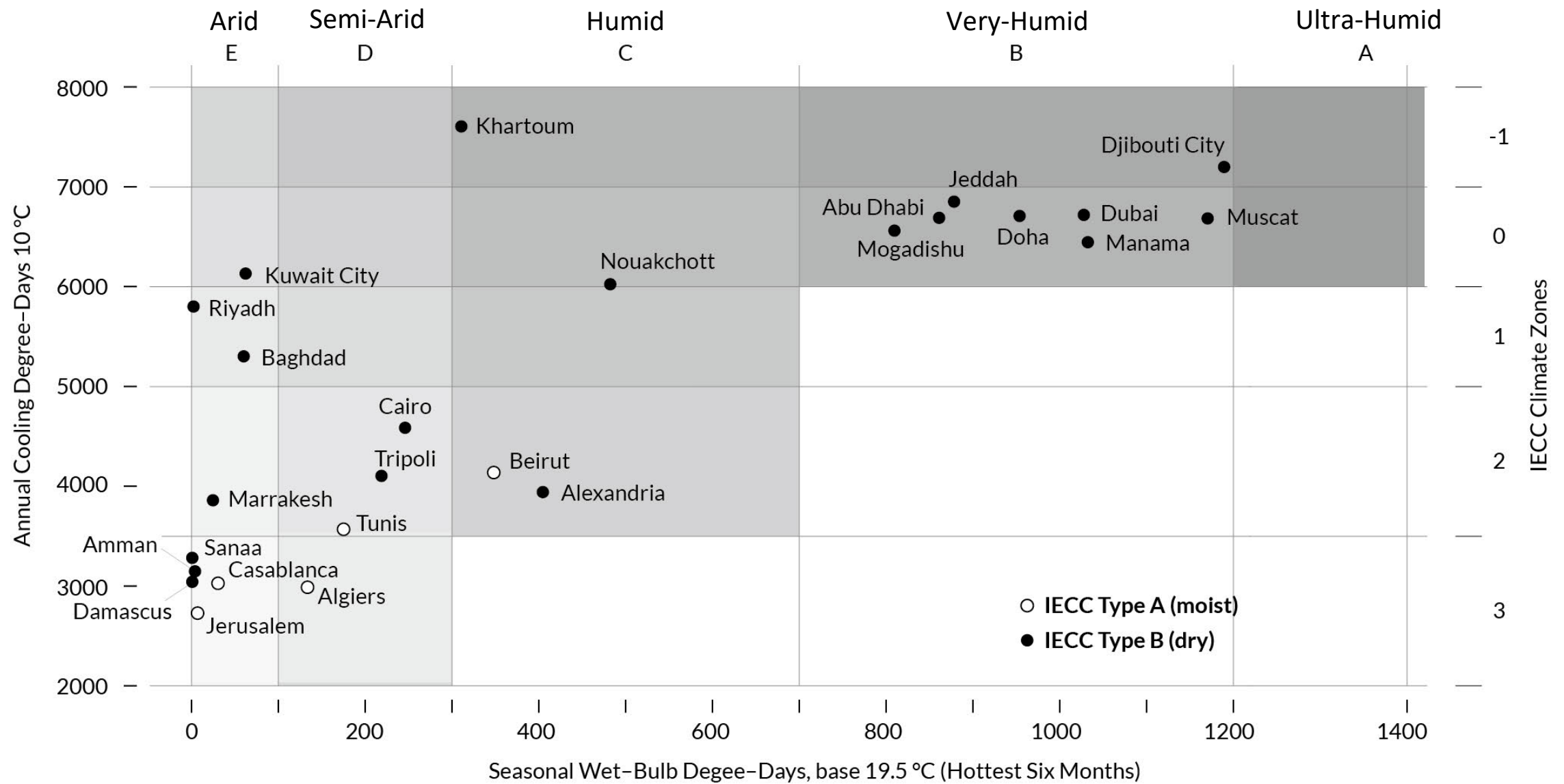
$$WBDD = T_{WB \text{ daily ave}} - T_{WB@ \text{ BASE}}$$



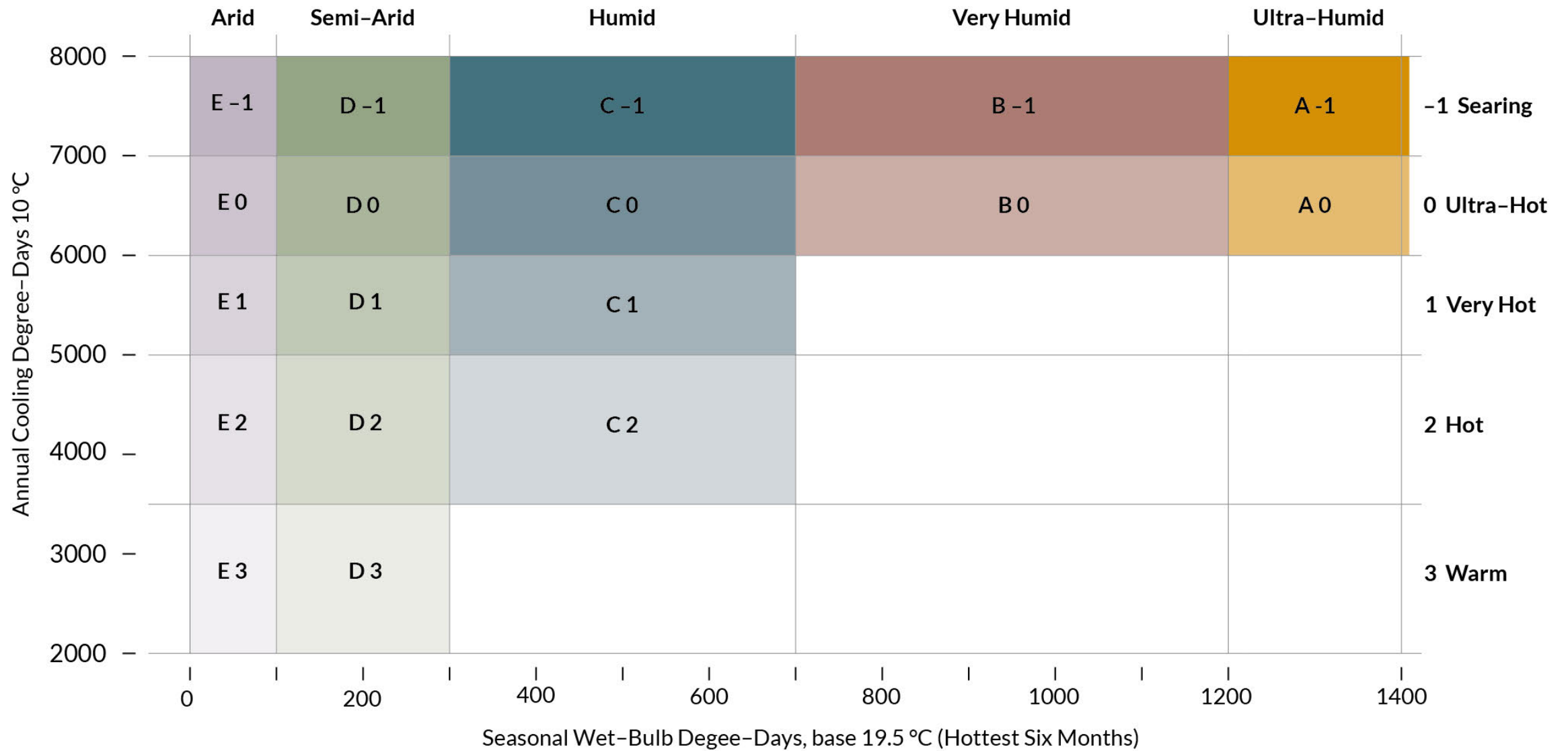
Precipitation as poor indicator for climate humidity



Koppen-Geiger as poor indicator for climate humidity



MENA Cities in Proposed Climate Zones



Climate Types by Hotness + Humidity

QUESTIONS + ANSWERS

1 What PLEA cooling strategies can we recommend in hot climates?

A *What ARE Hot Climates?*

- ***Not the climates*** of the IECC system
- ***Better defined*** by seasonal WBDD
- ***A wide range*** from very Arid to very Humid
- **A range** from Searingly Hot to Mixed Warm

CLIMATE TYPING: NEXT STEPS

- **CALCULATE: Annual WBDD**
- **EXPAND: Arid WBDD + Comfort + Humid WBDD**
- **DEFINE: PLEA-relevant Seasonal HDD + Free-Run + CDD**
- **COMBINE for new Climate Types:**

A	Arid WBDD	1	HDD
B	“Comfort” Humidities	2	“Free Running” Temps.
C	Humid WBDD	3	CDD

RESEARCH QUESTIONS

1 What PLEA cooling strategies can we recommend in hot climates?

B *What strategies work best in each of these climates?*

Baghdad, Iraq

Temperature Range Design Day

June

Design Low - 28.1°
Design High - 45.1°

July

Design Low - 30.1°
Design High - 47.2°

August

Design Low - 29.5°
Design High - 47.1°

December

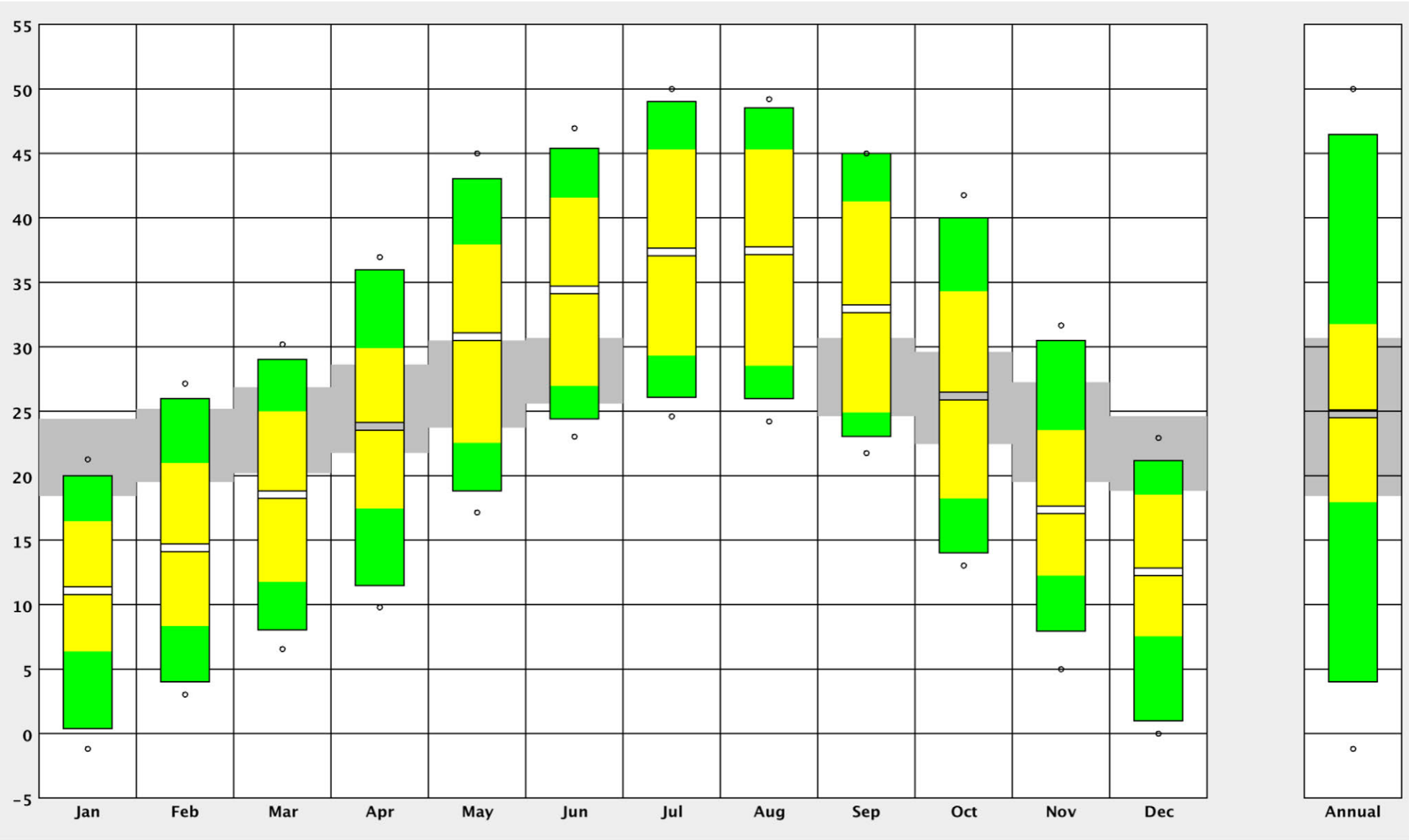
Design Low - 12°
Design High - 21.9°

January

Design Low - 7.5°
Design High - 19.2°

February

Design Low - 10.9°
Design High - 23.8°



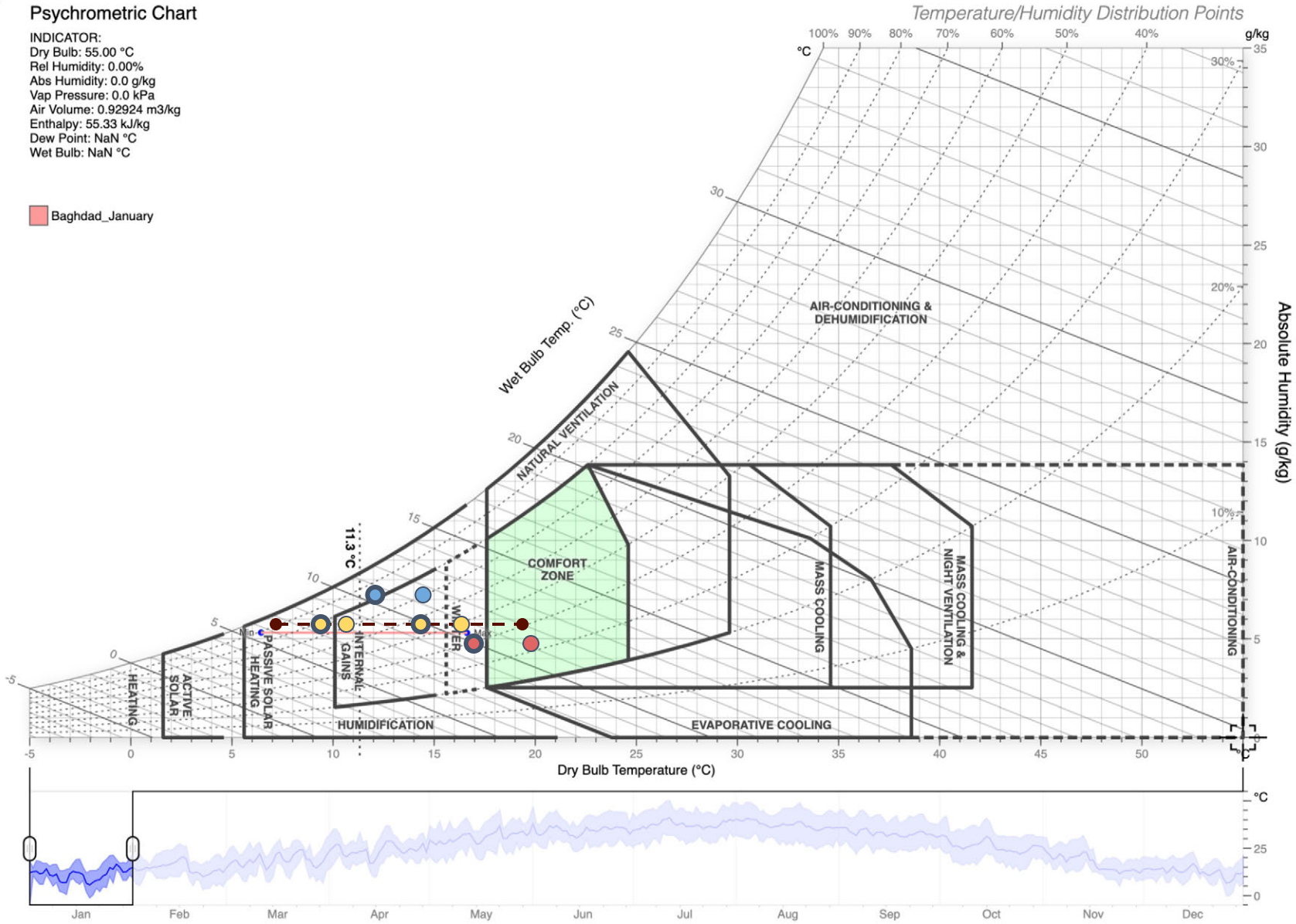
Adaptive Comfort Zone

Baghdad in January

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m³/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_January



Working Strategies

Comfort Ventilation

- Monthly avg - Not Needed
- Design day - Not Needed
- Cooling Vent: Effective

High Mass

- Monthly avg - Not Needed
- Design day - Effective

High Mass + Night Vent.

- Monthly avg - Not Needed
- Design day - Not Needed

Evaporative Cooling

- Monthly avg - Not Needed
- Design day - Not Needed

January Data

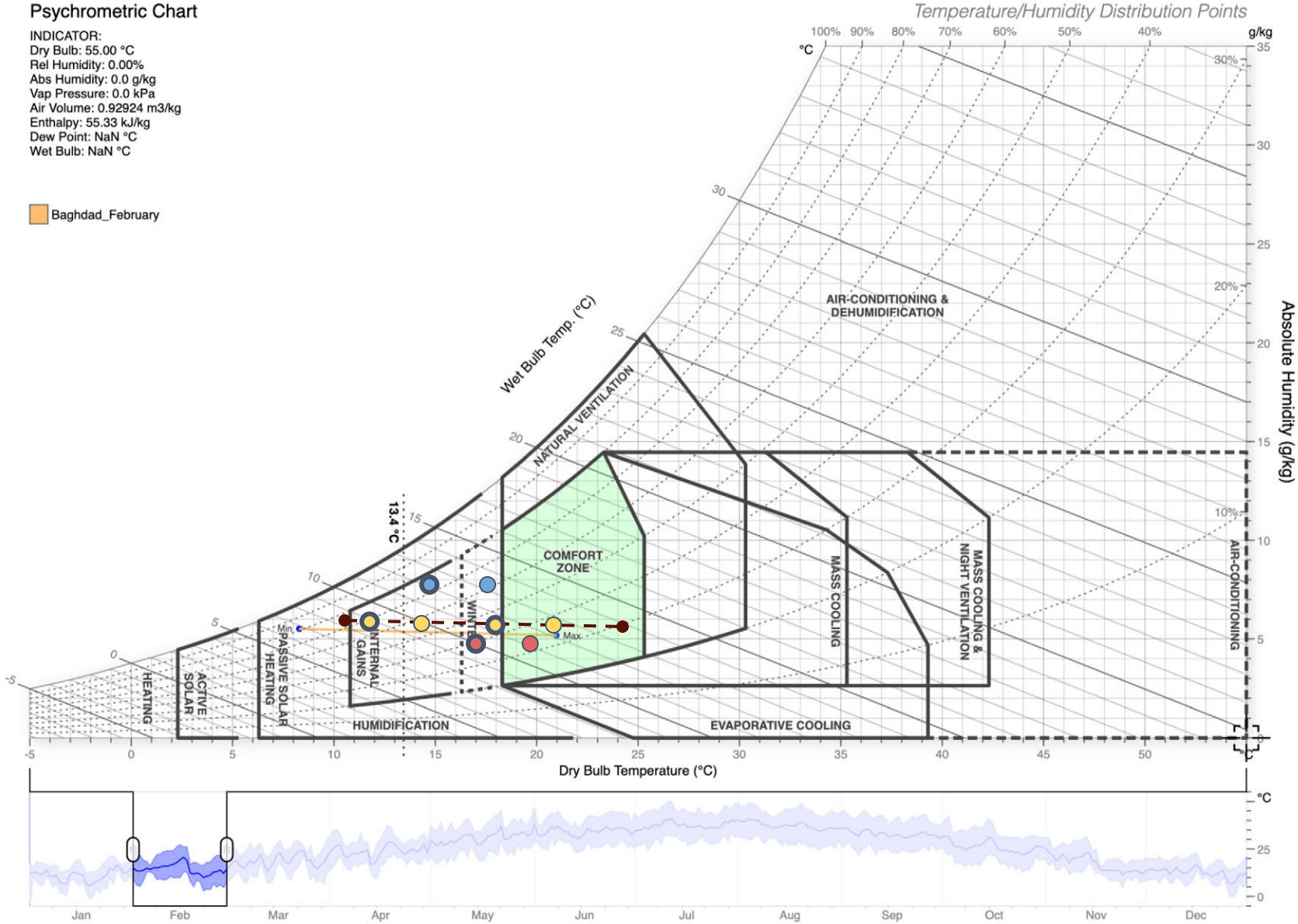
Design Low - 7.5°	T in Min D.D. - 10.7°
Design High - 19.2°	T in Max D.D. - 16.6°
T in Max Avg. - 1	T in Max Avg. - 9.3°
3.7°	T in Max Avg. - 14.4°
T in Max D.D. -15.7°	

Baghdad in February

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_February



Working Strategies

Comfort Ventilation

Monthly avg - Not Needed

Design day - Not Needed

Cooling Vent: Effective

High Mass

Monthly avg - Not Needed

Design day - Effective

High Mass + Night Vent.

Monthly avg - Not Needed

Design day - Effective

Evaporative Cooling

Monthly avg - Not Needed

Design day - Not Needed

February Data

Design Low - 10.9°

T in Min D.D. - 14.4°

Design High - 23.8°

T in Max D.D. - 20.8°

T in Max Avg. - 17.0°

T in Max Avg. - 11.7°

T in Max D.D. - 19.8°

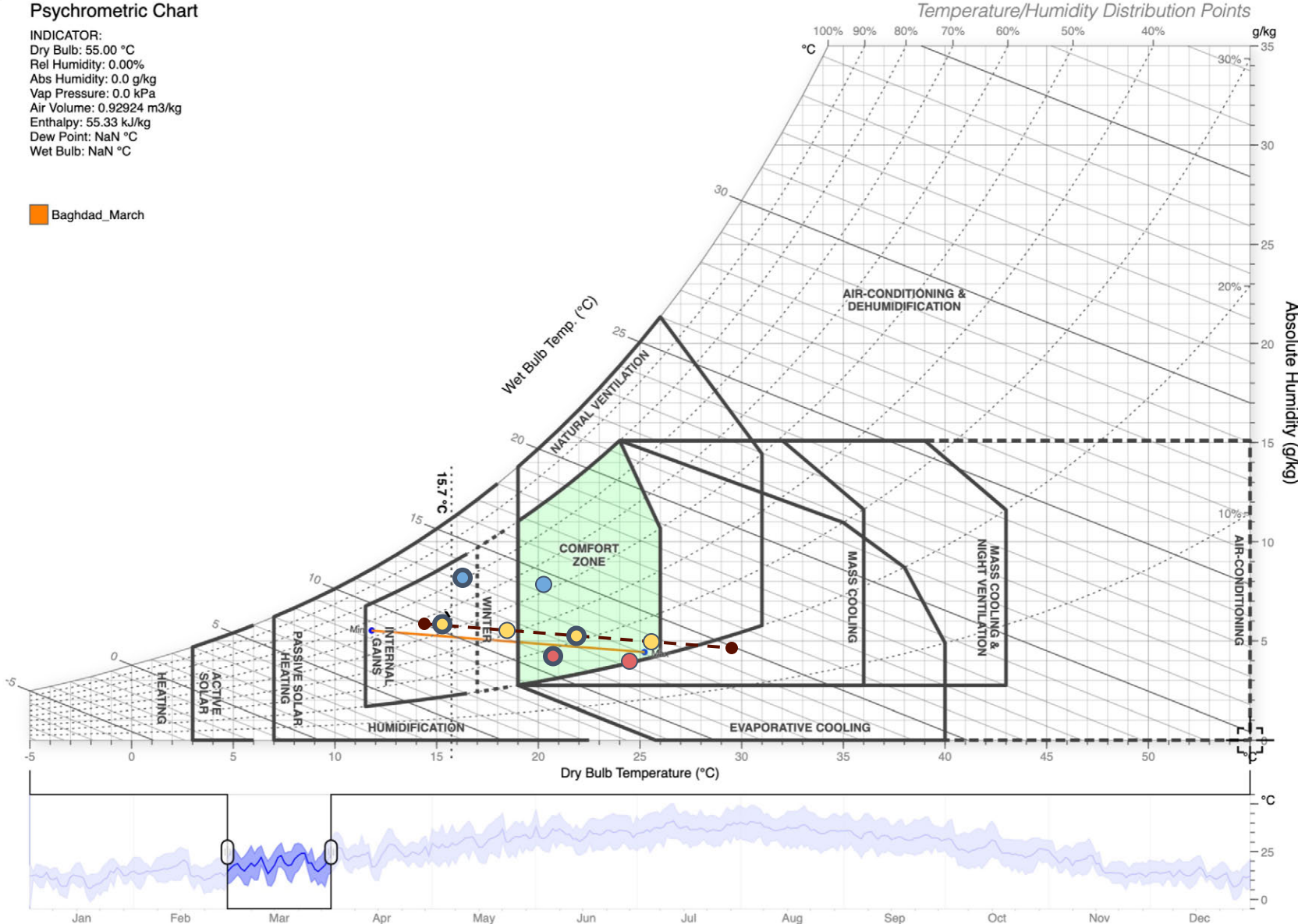
T in Max Avg. - 18.0°

Baghdad in March

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m³/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_March



Working Strategies

Comfort Ventilation

- Monthly avg - Not Needed
- Design day - Not Effective
- Cooling Vent: Not Effective

High Mass

- Monthly avg - Effective
- Design day - Effective

High Mass + Night Vent.

- Monthly avg - Effective
- Design day - Effective

Evaporative Cooling

- Monthly avg - Not Needed
- Design day - Effective

March Data

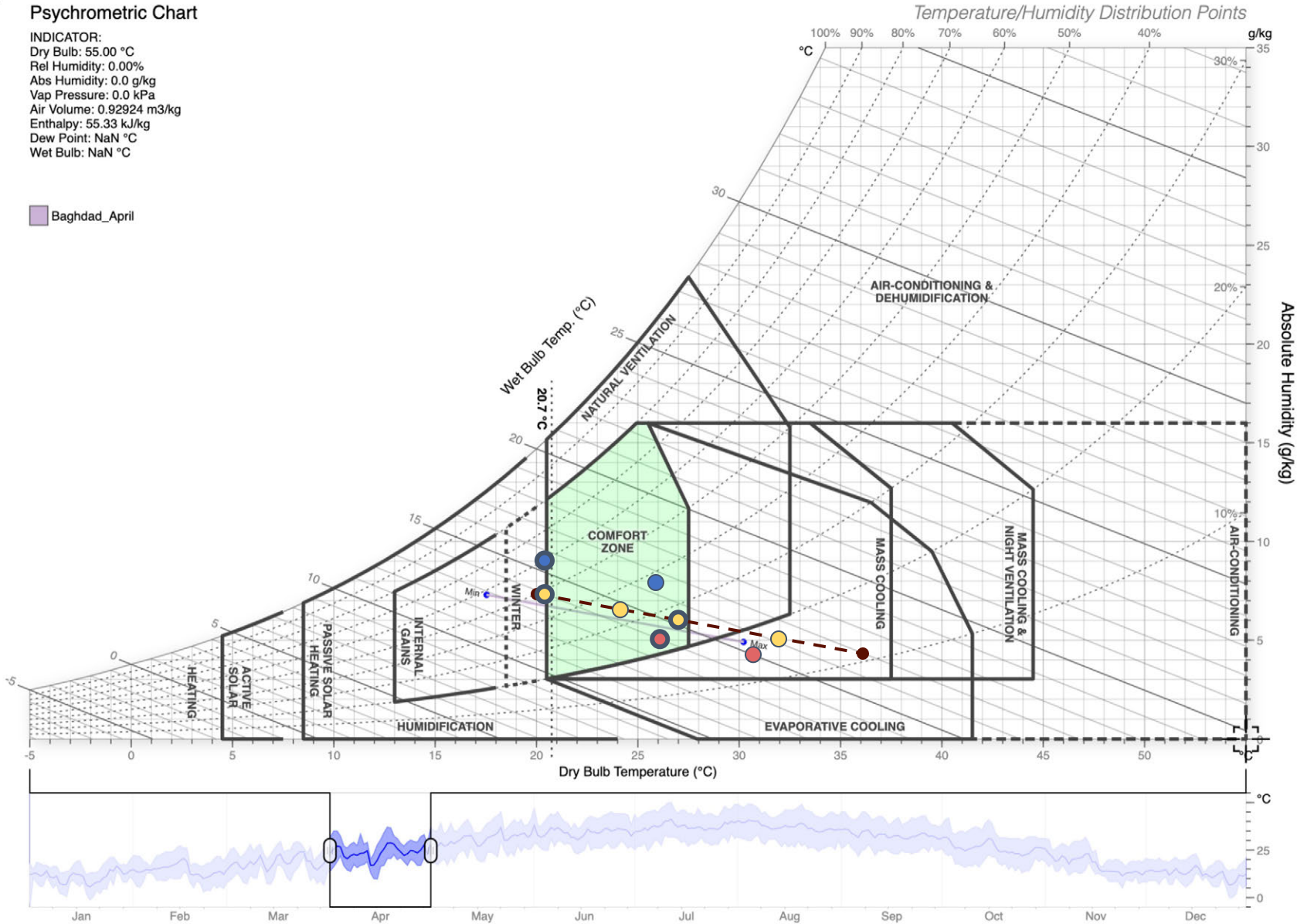
Design Low - 14.7°	T in Min D.D. - 18.5°
Design High - 29.2°	T in Max D.D. - 25.7°
T in Max Avg. - 20.8°	T in Max Avg. - 15.3°
T in Max D.D. - 24.5°	T in Max Avg. - 21.9°

Baghdad in April

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_April



Working Strategies

Comfort Ventilation

Monthly avg - Not Effective

Design day - Not Effective

Cooling Vent: Not Effective

High Mass

Monthly avg - Effective

Design day - Not Effective

High Mass + Night Vent.

Monthly avg - Effective

Design day - Not Effective

Evaporative Cooling

Monthly avg - Effective

Design day - Effective

April Data

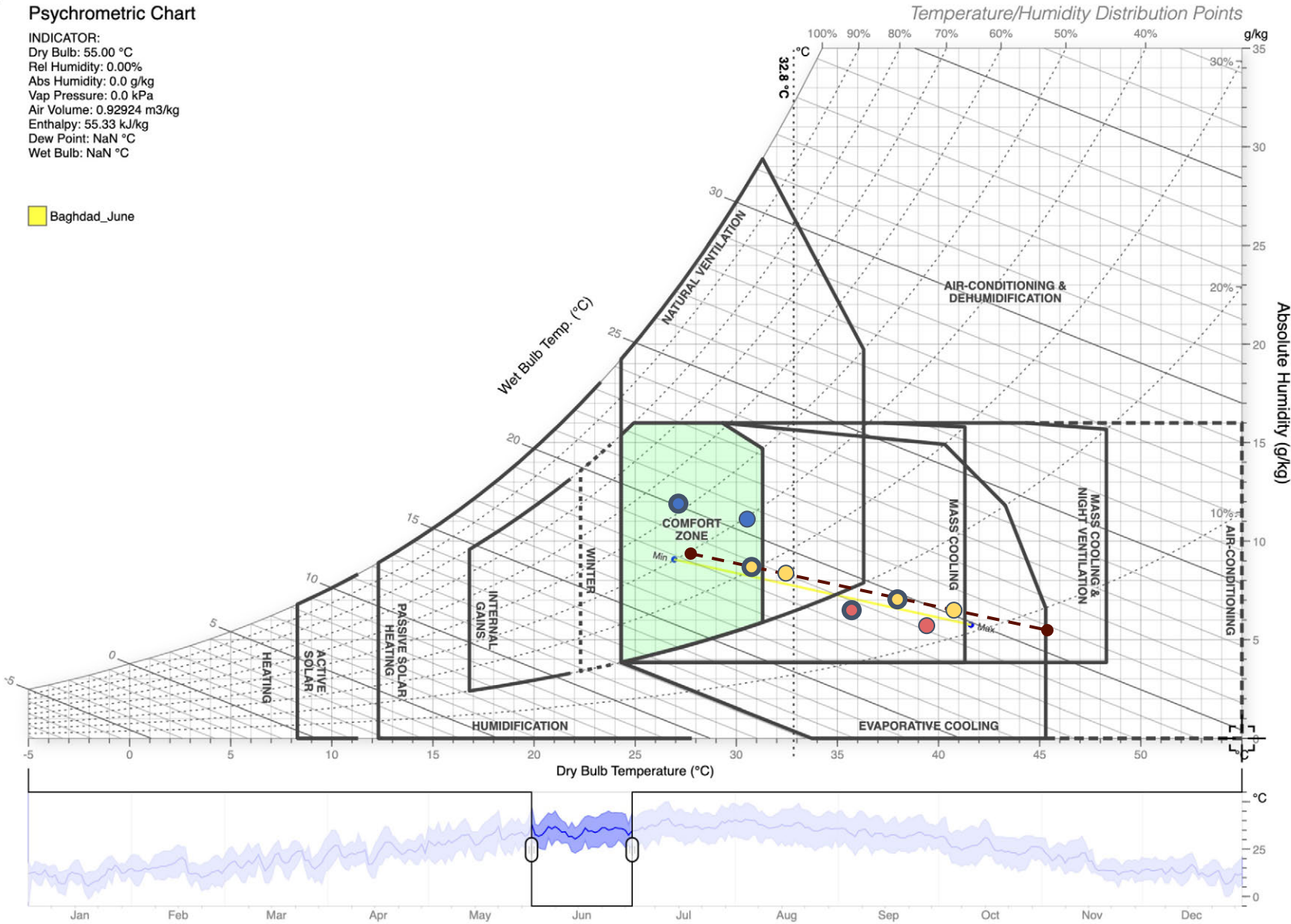
Design Low - 20.3°	T in Min D.D. - 24.3°
Design High - 35.8°	T in Max D.D. - 32.0°
T in Max Avg. - 26.1°	T in Max Avg. - 20.8°
T in Max D.D. - 30.7°	T in Max Avg. - 27.0°

Baghdad in June

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_June



Working Strategies

Comfort Ventilation

Monthly avg - Not Effective

Design day - Not Effective

Cooling Vent: Not Effective

High Mass

Monthly avg - Not Effective

Design day - Not Effective

High Mass + Night Vent.

Monthly avg - Not Effective

Design day - Not Effective

Evaporative Cooling

Monthly avg - Effective

Design day - Effective

June Data

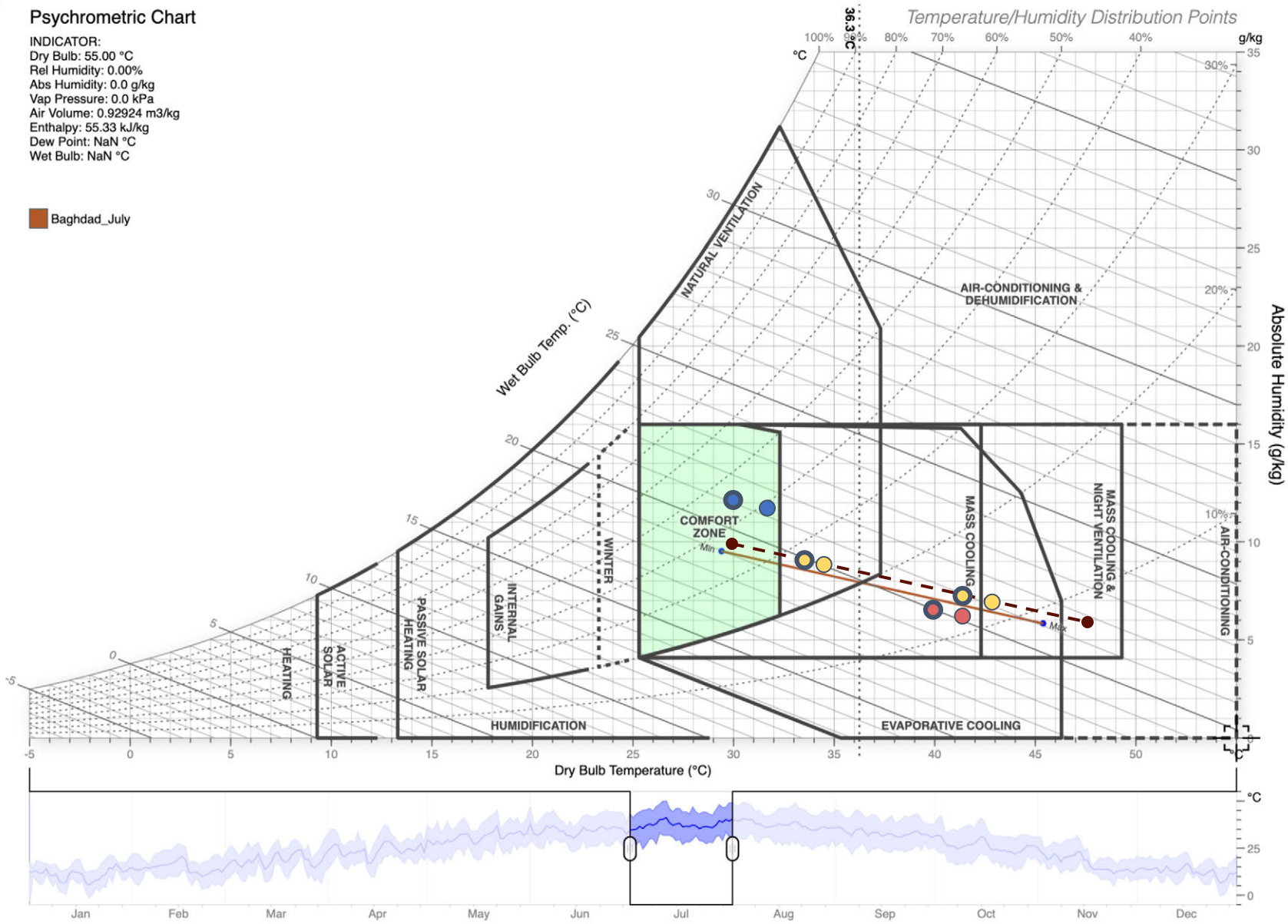
Design Low - 28.1°	T in Min D.D. - 32.5°
Design High - 45.1°	T in Max D.D. - 40.8°
T in Max Avg. - 36.8°	T in Max Avg. - 30.8°
T in Max D.D. - 39.4°	T in Max Avg. - 38.0°

Baghdad in July

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_July



Working Strategies

Comfort Ventilation

- Monthly avg - Not Effective
- Design day - Not Effective
- Cooling Vent: Not Effective

High Mass

- Monthly avg - Not Effective
- Design day - Not Effective

High Mass + Night Vent.

- Monthly avg - Not Effective
- Design day - Not Effective

Evaporative Cooling

- Monthly avg - Effective
- Design day - Effective

July Data

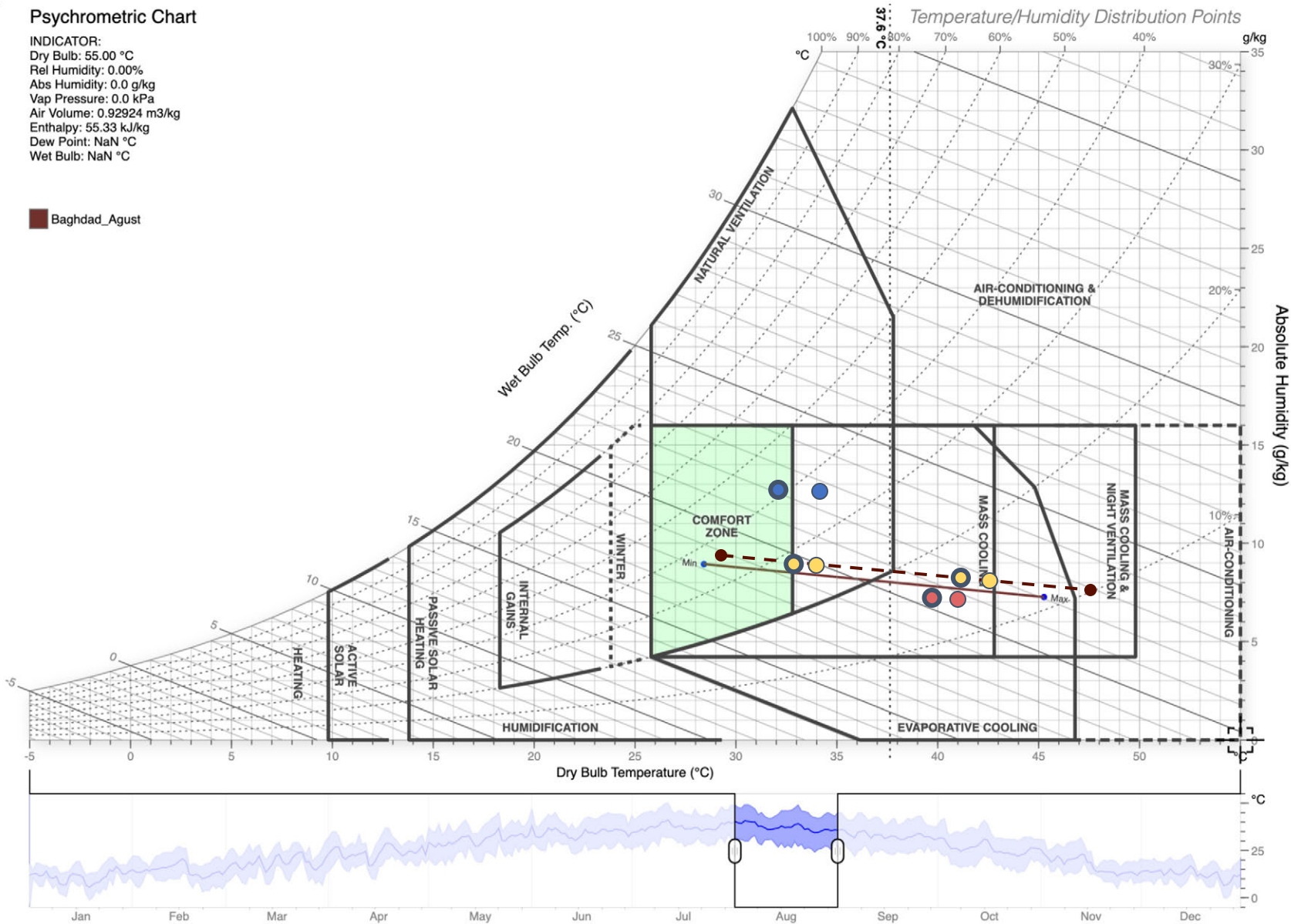
Design Low - 30.1°	T in Min D.D. - 34.5°
Design High - 47.2°	T in Max D.D. - 42.9°
T in Max Avg. - 40.0°	T in Max Avg. - 33.5°
T in Max D.D. - 41.4°	T in Max Avg. - 41.3°

Baghdad in August

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_Agust



Working Strategies

■ Comfort Ventilation

● Monthly avg - Not Effective

- Design day - Not Effective

Cooling Vent: Not Effective

 High Mass

● Monthly avg - Not Effective

- Design day - Not Effective

High Mass + Night Vent.

● Monthly avg - Not Effective

- Design day - Not Effective

Evaporative Cooling

● Monthly avg - Effective

- Design day - Not Effective

August Data

Design Low - 29.5°

T in Min D.D. - 34.0°

Design High - 47.1°

T in Max D.D. - 42.6°

T in Max Avg. - 39.7°

T in Max Avg. - 32.8°

T in Max D.D. - 41.1°

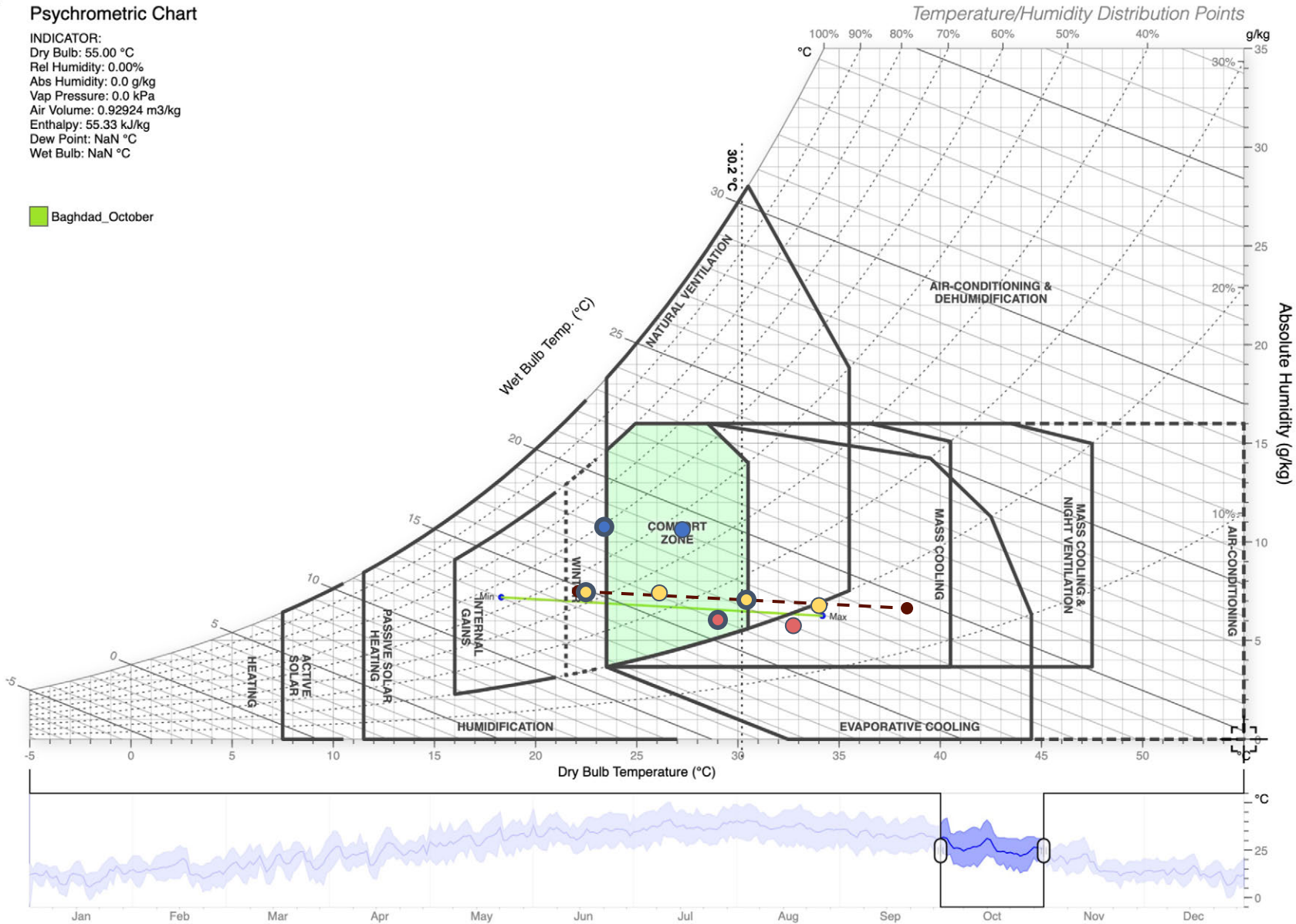
T in Max Avg. - 41.1°

Baghdad in October

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_October



Working Strategies

Comfort Ventilation

Monthly avg - Not Effective

Design day - Not Effective

Cooling Vent: Not Effective

High Mass

Monthly avg - Effective

Design day - Not Effective

High Mass + Night Vent.

Monthly avg - Effective

Design day - Not Effective

Evaporative Cooling

Monthly avg - Effective

Design day - Effective

October Data

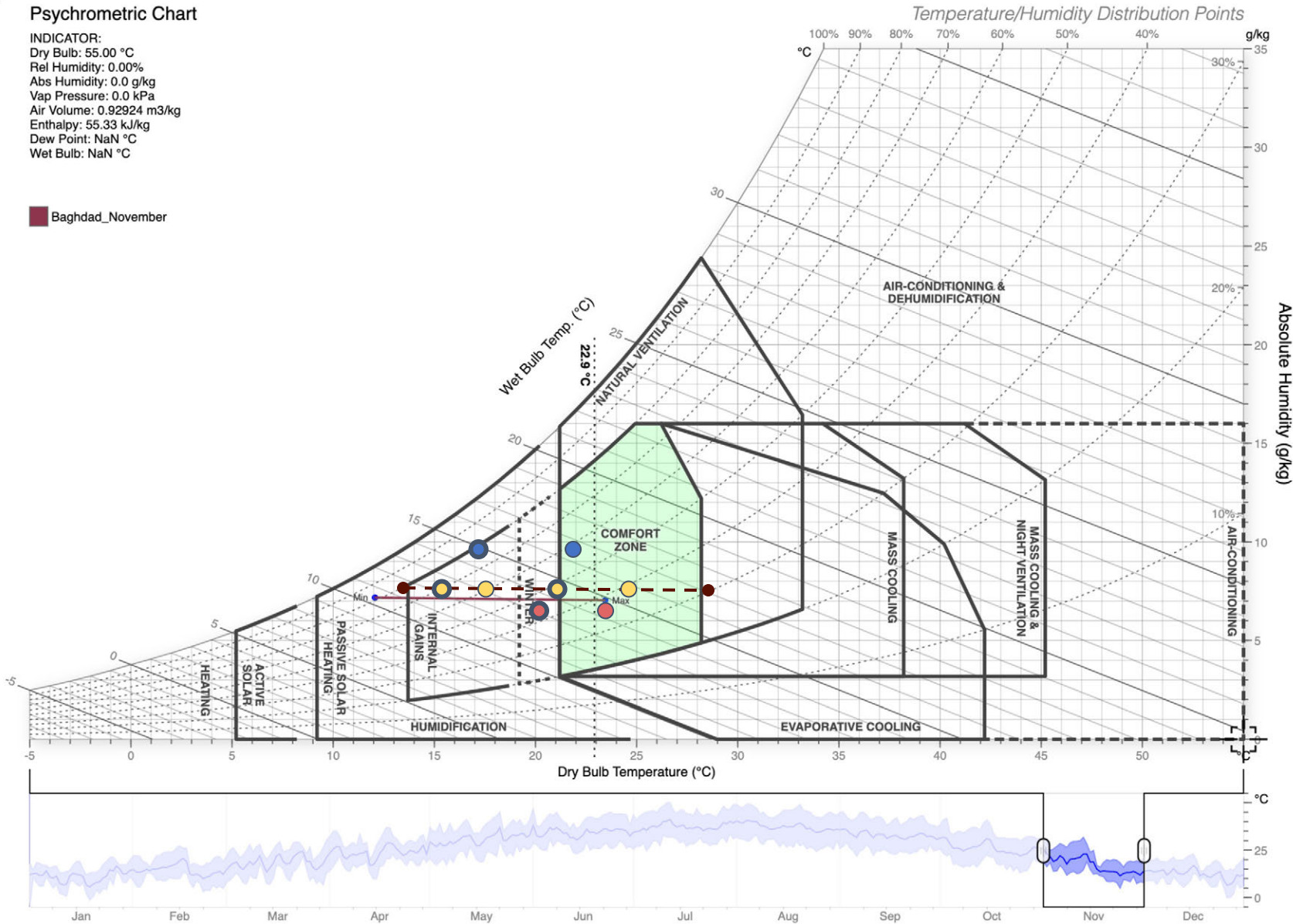
Design Low - 22.2°	T in Min D.D. - 26.3°
Design High - 37.9°	T in Max D.D. - 34.0°
T in Max Avg. - 29.0°	T in Max Avg. - 22.5°
T in Max D.D. - 32.7°	T in Max Avg. - 30.3°

Baghdad in November

Psychrometric Chart

INDICATOR:
 Dry Bulb: 55.00 °C
 Rel Humidity: 0.00%
 Abs Humidity: 0.0 g/kg
 Vap Pressure: 0.0 kPa
 Air Volume: 0.92924 m³/kg
 Enthalpy: 55.33 kJ/kg
 Dew Point: NaN °C
 Wet Bulb: NaN °C

Baghdad_November



Working Strategies

Comfort Ventilation

- Monthly avg - Not Needed
- Design day - Not Needed
- Cooling Vent: Effective

High Mass

- Monthly avg - Not Needed
- Design day - Effective

High Mass + Night Vent.

- Monthly avg - Not Needed
- Design day - Effective

Evaporative Cooling

- Monthly avg - Not Needed
- Design day - Effective

November Data

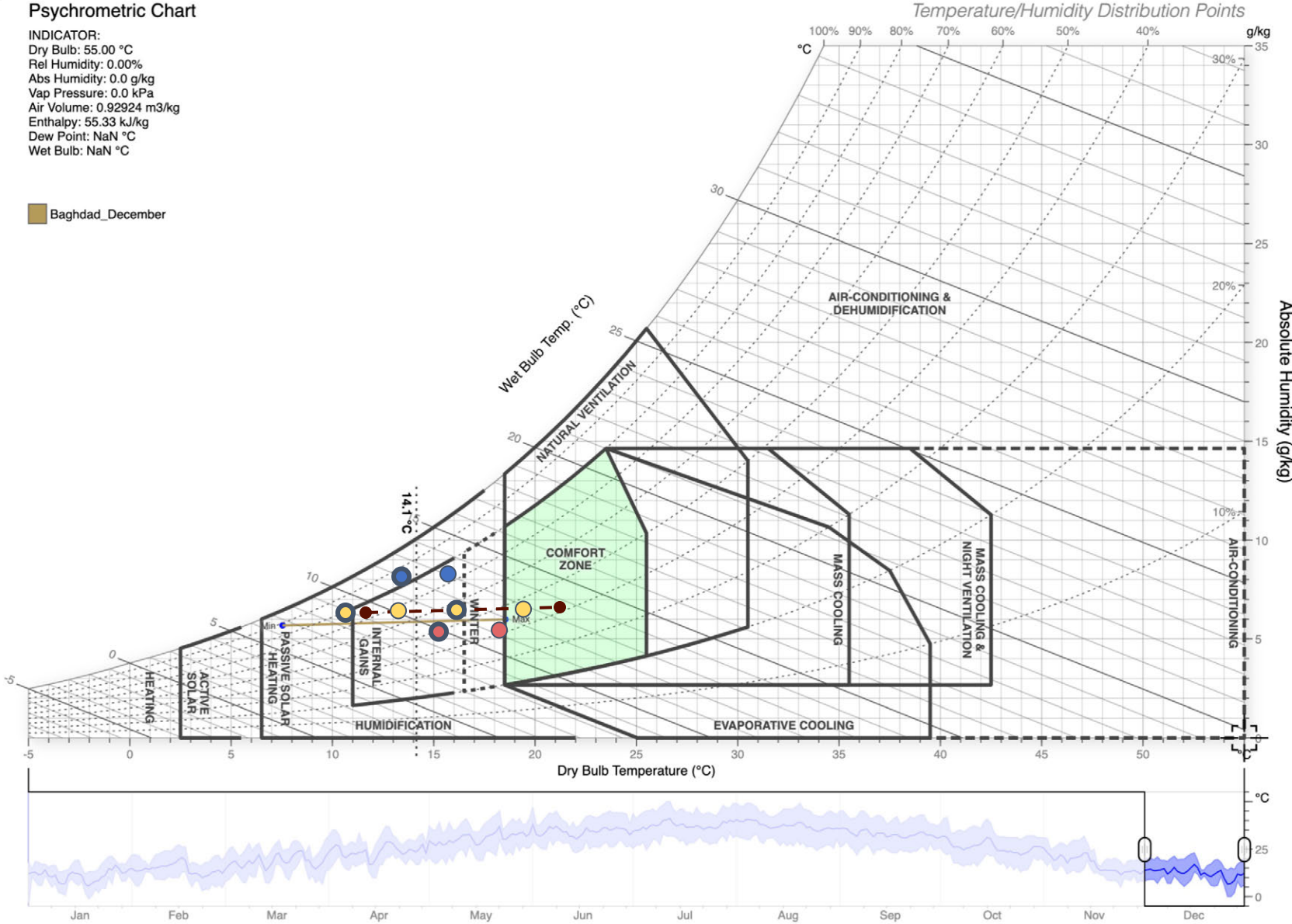
Design Low - 13.8°	T in Min D.D. - 17.6°
Design High - 28.2°	T in Max D.D. - 24.7°
T in Max Avg. - 20.2°	T in Max Avg. - 15.4°
T in Max D.D. - 23.6°	T in Max Avg. - 21.0°

Baghdad in December

Psychrometric Chart

INDICATOR:
Dry Bulb: 55.00 °C
Rel Humidity: 0.00%
Abs Humidity: 0.0 g/kg
Vap Pressure: 0.0 kPa
Air Volume: 0.92924 m3/kg
Enthalpy: 55.33 kJ/kg
Dew Point: NaN °C
Wet Bulb: NaN °C

Baghdad_December



Working Strategies

Comfort Ventilation

- Monthly avg - Not Needed
- Design day - Not Needed
- Cooling Vent: Effective

High Mass

- Monthly avg - Not Needed
- Design day - Not Needed

High Mass + Night Vent.

- Monthly avg - Not Needed
- Design day - Effective

Evaporative Cooling

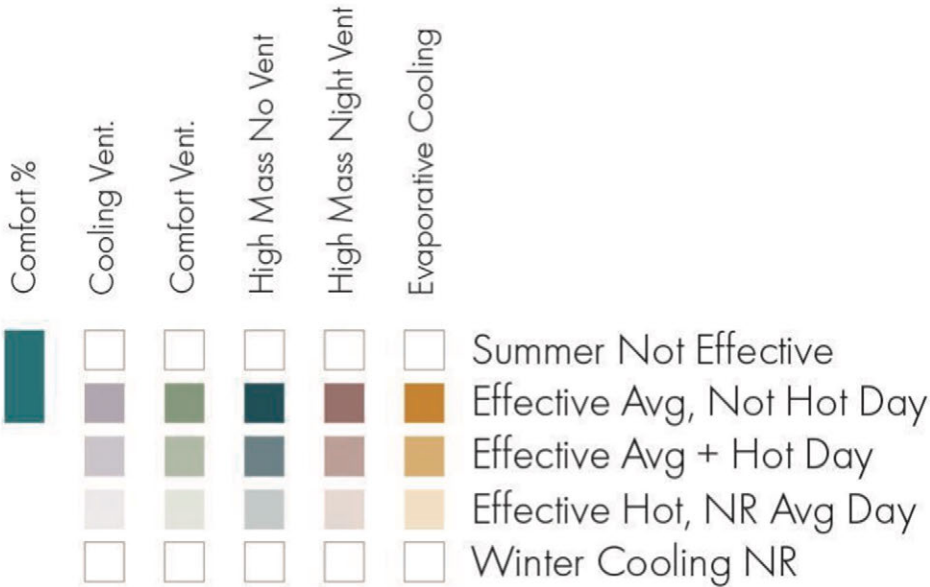
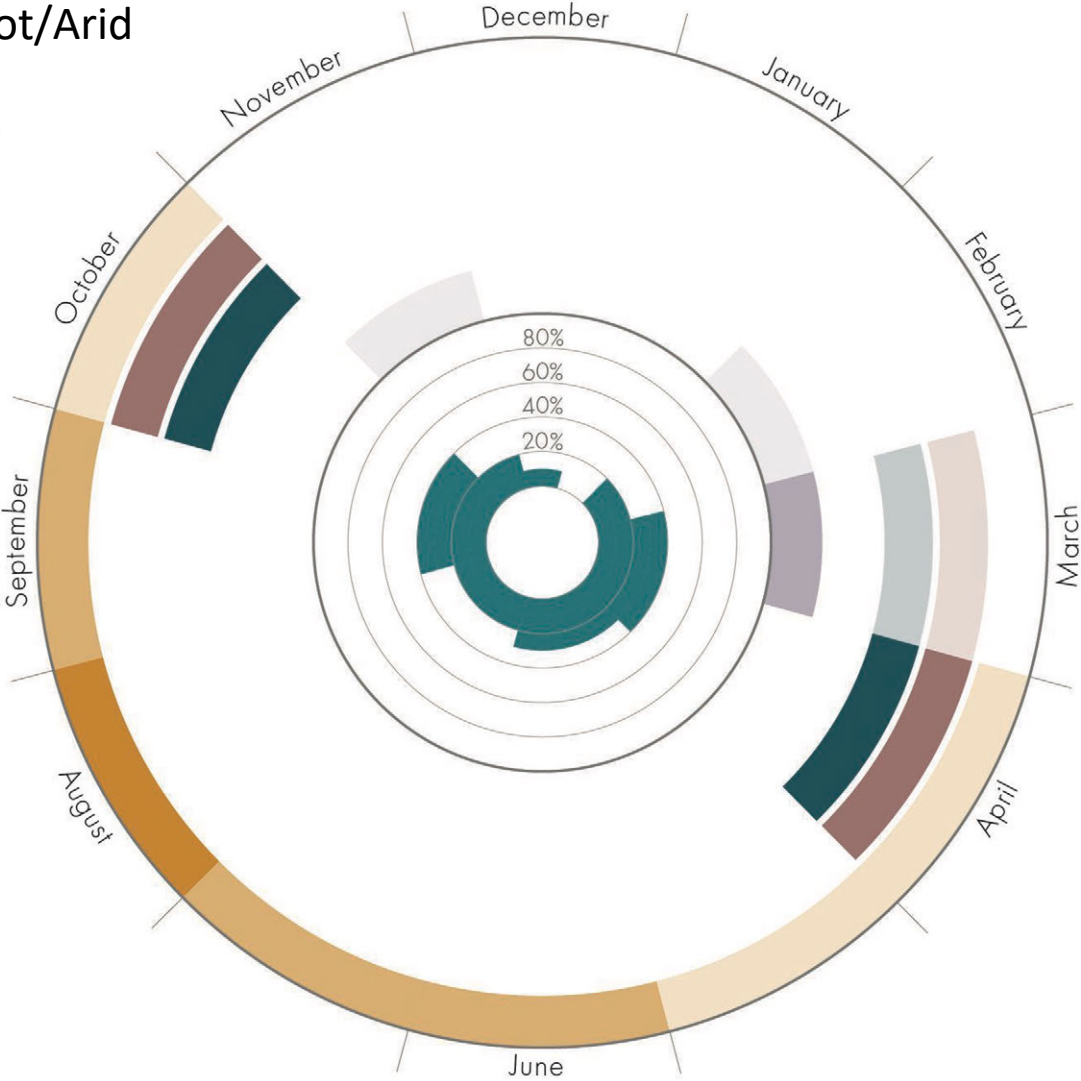
- Monthly avg - Not Needed
- Design day - Not Needed

December Data

Design Low - 12°	T in Min D.D. - 13.2°
Design High - 21.9°	T in Max D.D. - 19.2°
T in Max Avg. - 15.3°	T in Max Avg. - 10.6°
T in Max D.D. - 18.3°	T in Max Avg. - 16.1°

IECC 1B: Very Hot/Dry
New Zone:
1E: Very Hot/Arid

Baghdad, Iran
Latitude: 33.267N
Elevation: 35m



Strategy Glyph
A passive cooling signature by city

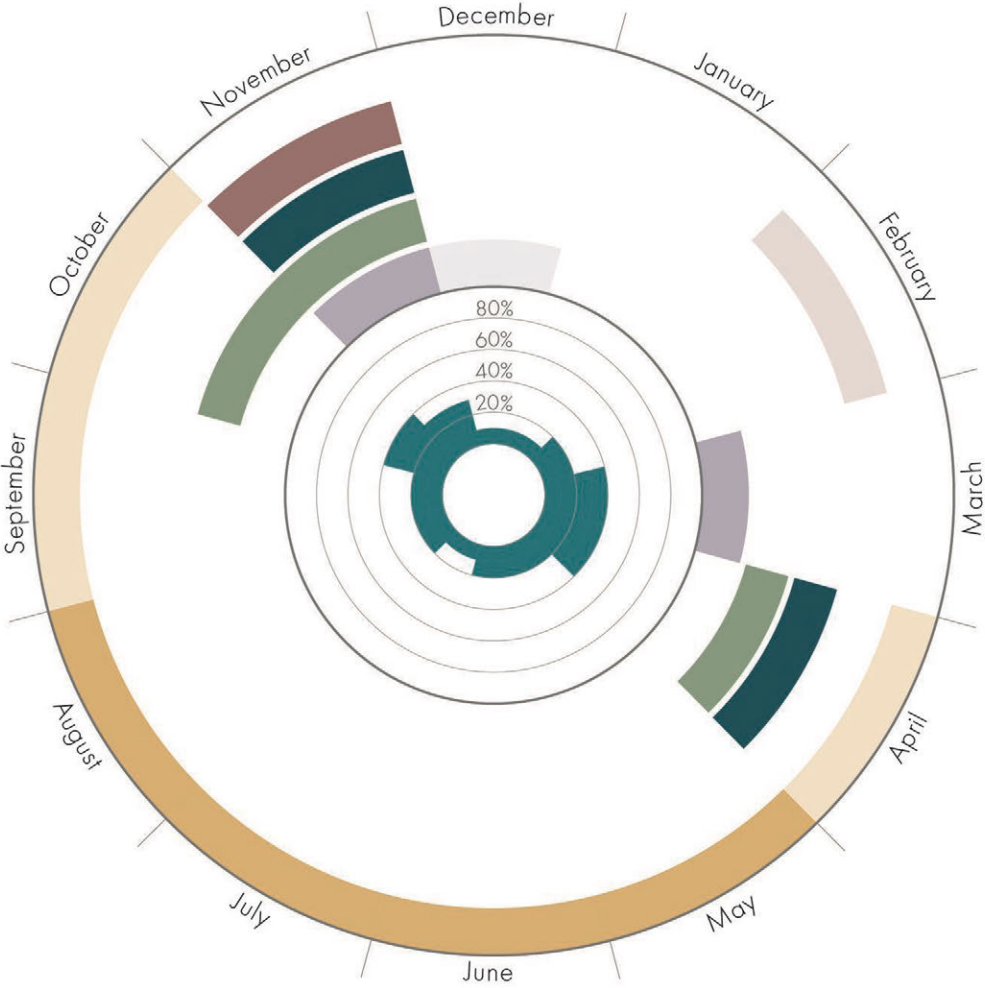
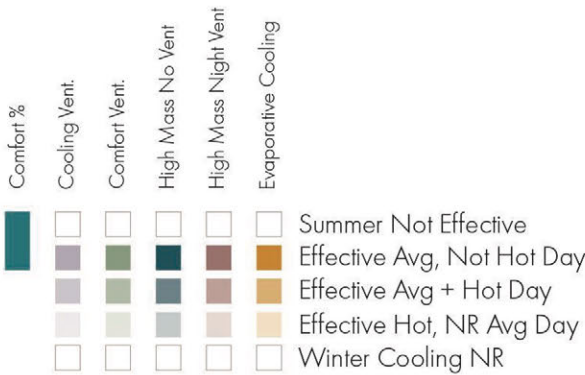
IECC 0B: 0-Dry

New Zone 0E:
Ultra Hot/Arid

WBDD 62

Kuwait City, Kuwait

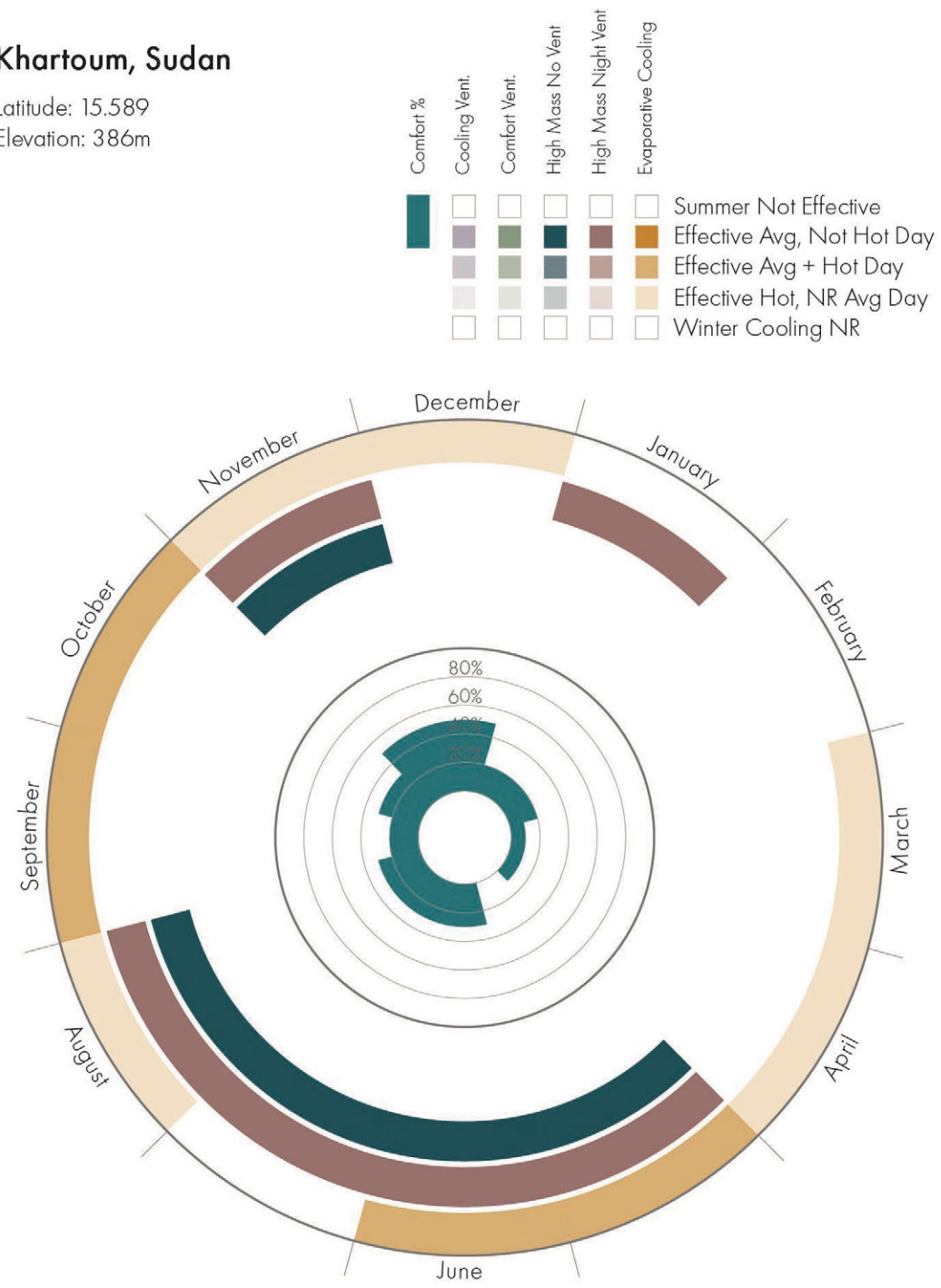
Latitude: 29.227
Elevation: 63m



Zone 0/1
Arid to Humid
Sequence

New Zone –1C:
Searing/Humid

Latitude: 15.589
Elevation: 386m



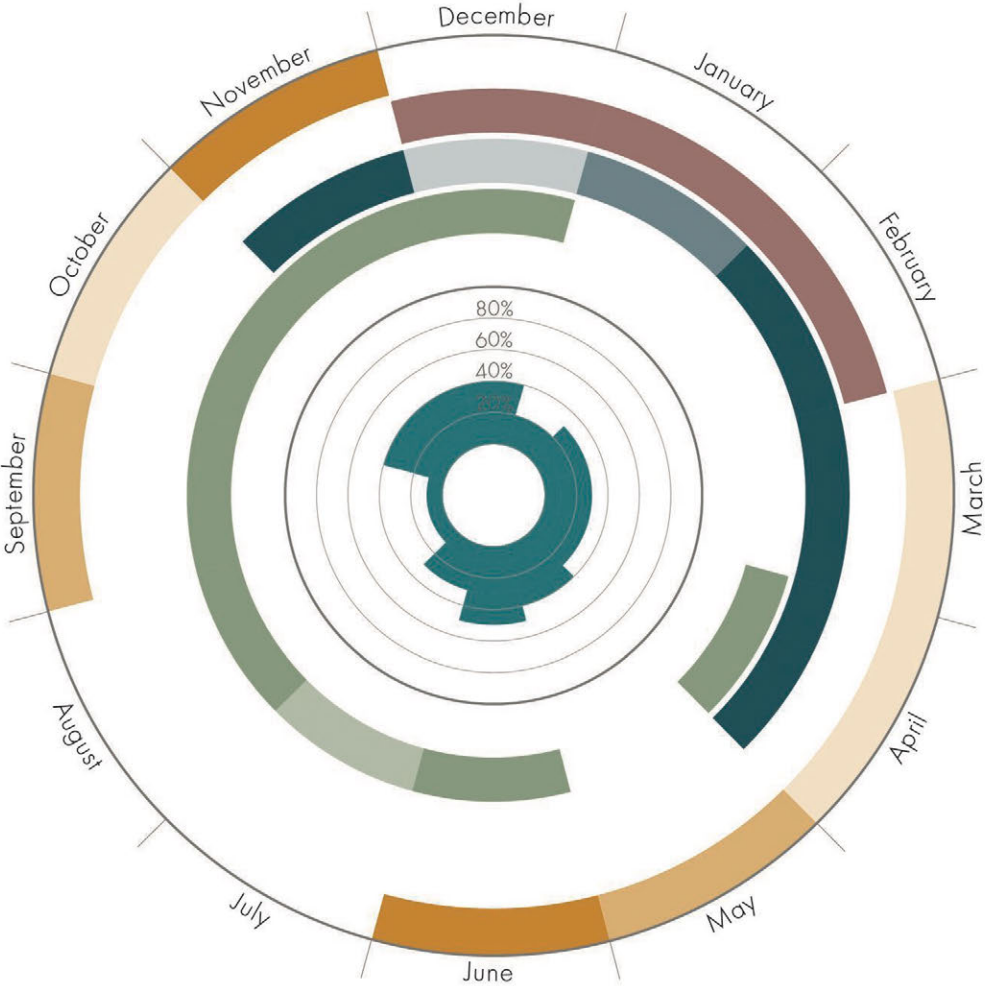
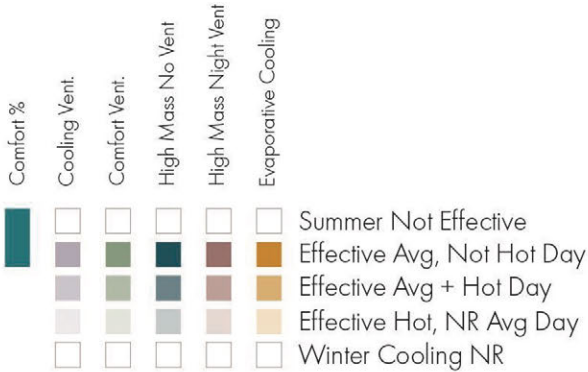
IECC 1B: Very Hot/Dry

New Zone –1C:
Very Hot/Humid

WBDD 484

Nouakchott, Mauritania

Latitude: 18.3N
Elevation: 8m



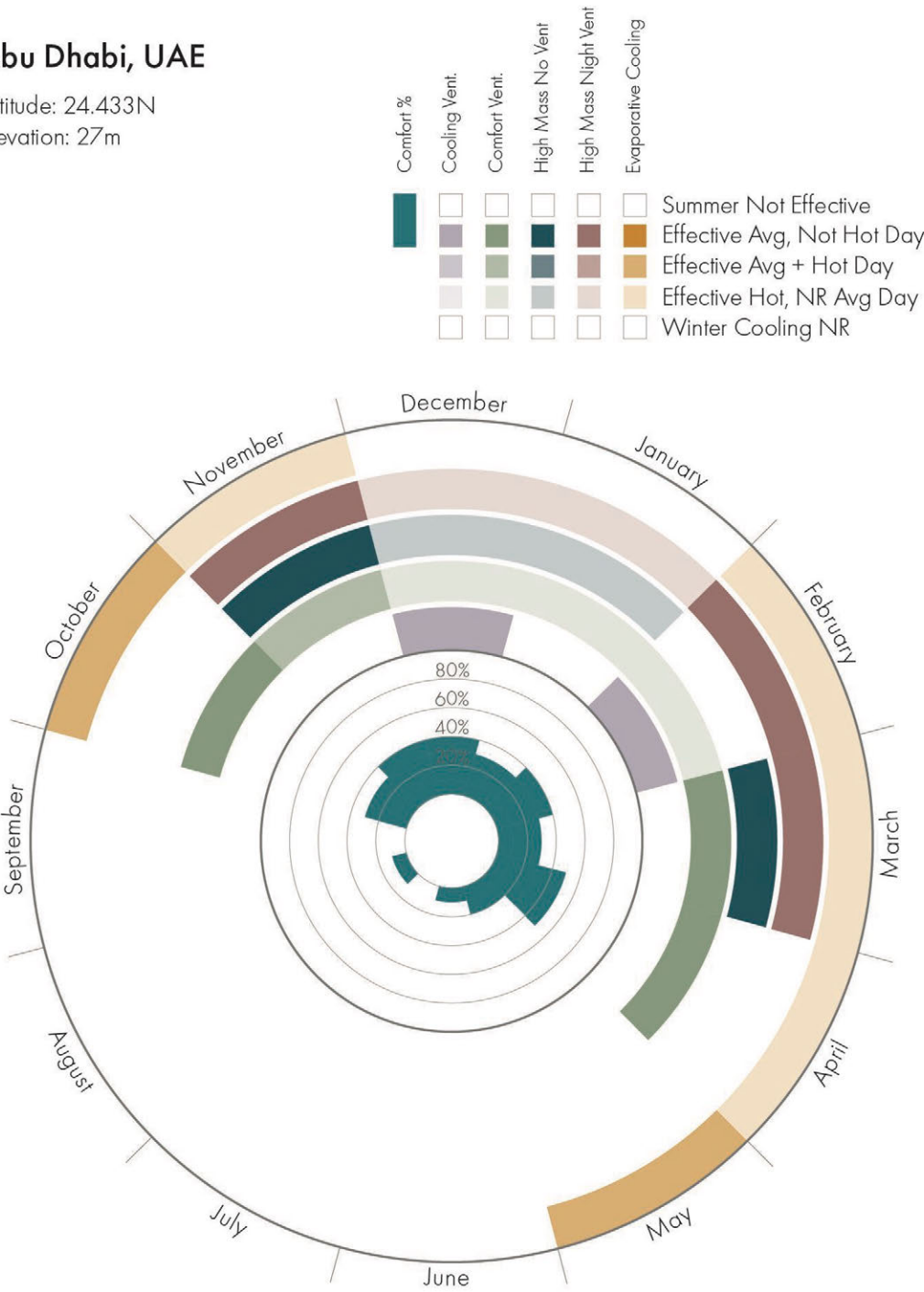
IECC 0B: 0-Dry

New Zone 0B:
Ultra Hot/Very Humid

WBDD 864

Abu Dhabi, UAE

Latitude: 24.433N
Elevation: 27m



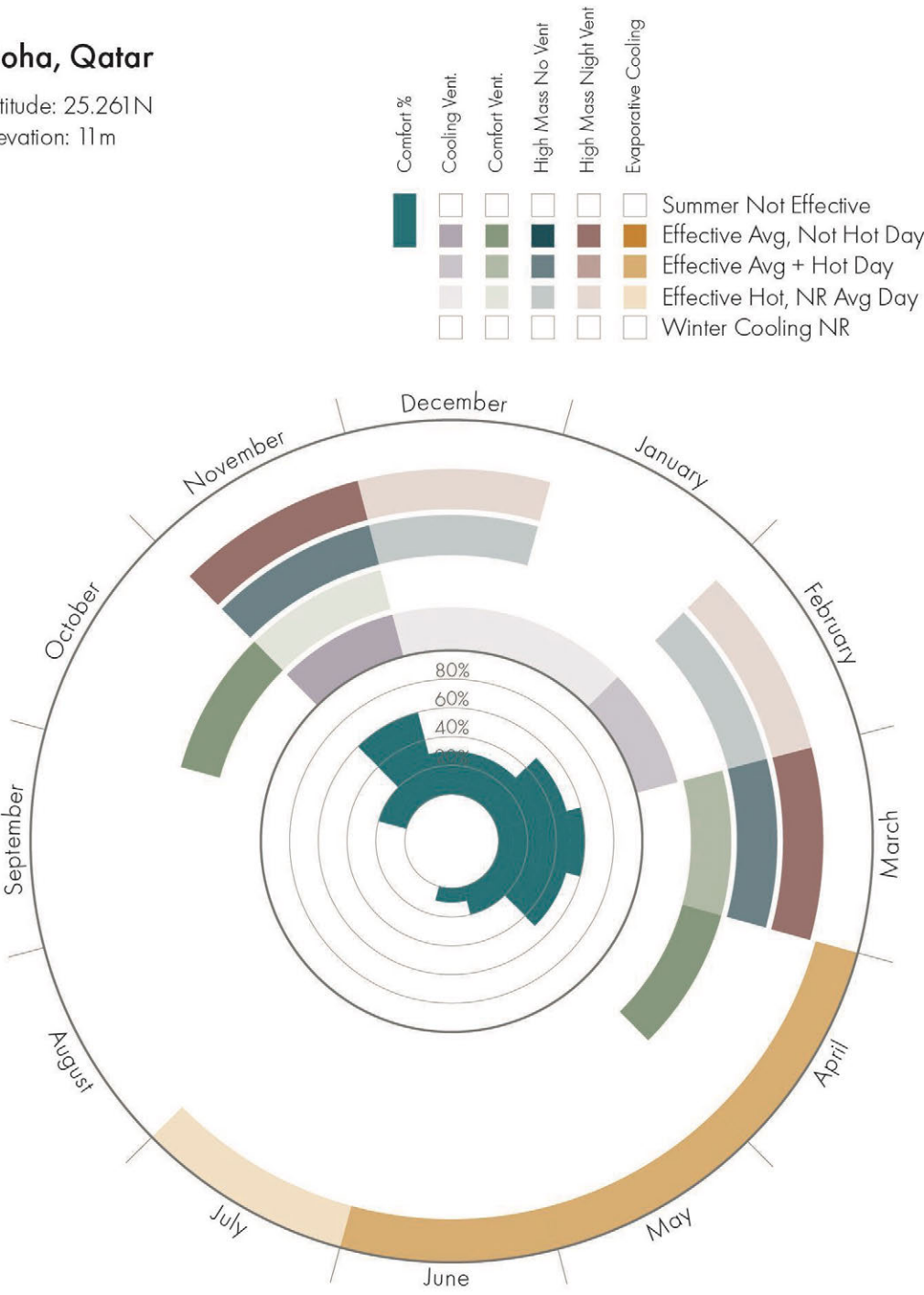
IECC 0B: 0-Dry

New Zone 0B:
Ultra Hot/Very Humid

WBDD 957

Doha, Qatar

Latitude: 25.261N
Elevation: 11m



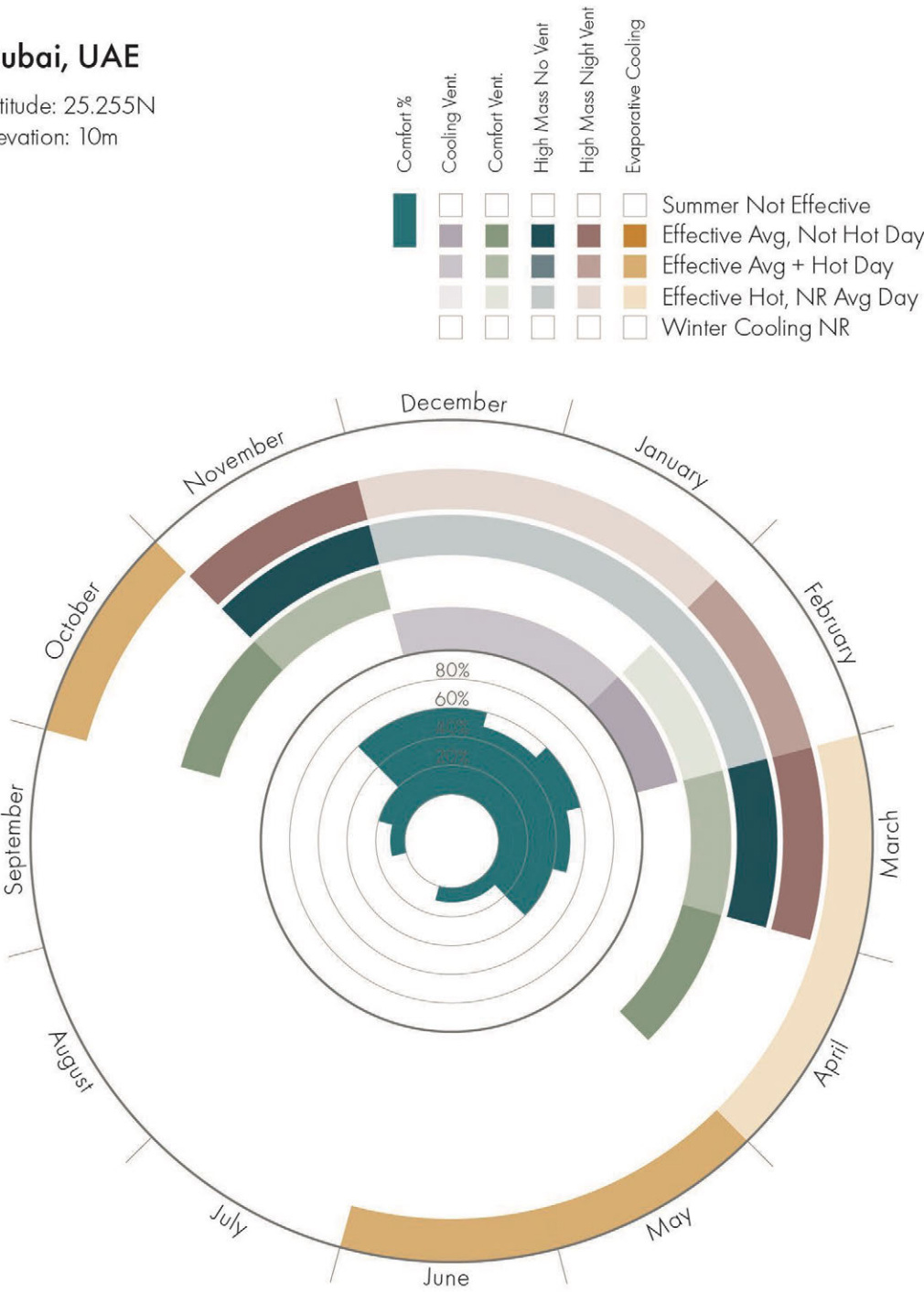
IECC OB: 0-Dry

New Zone OB:
Ultra Hot/Very Humid

WBDD 1032

Dubai, UAE

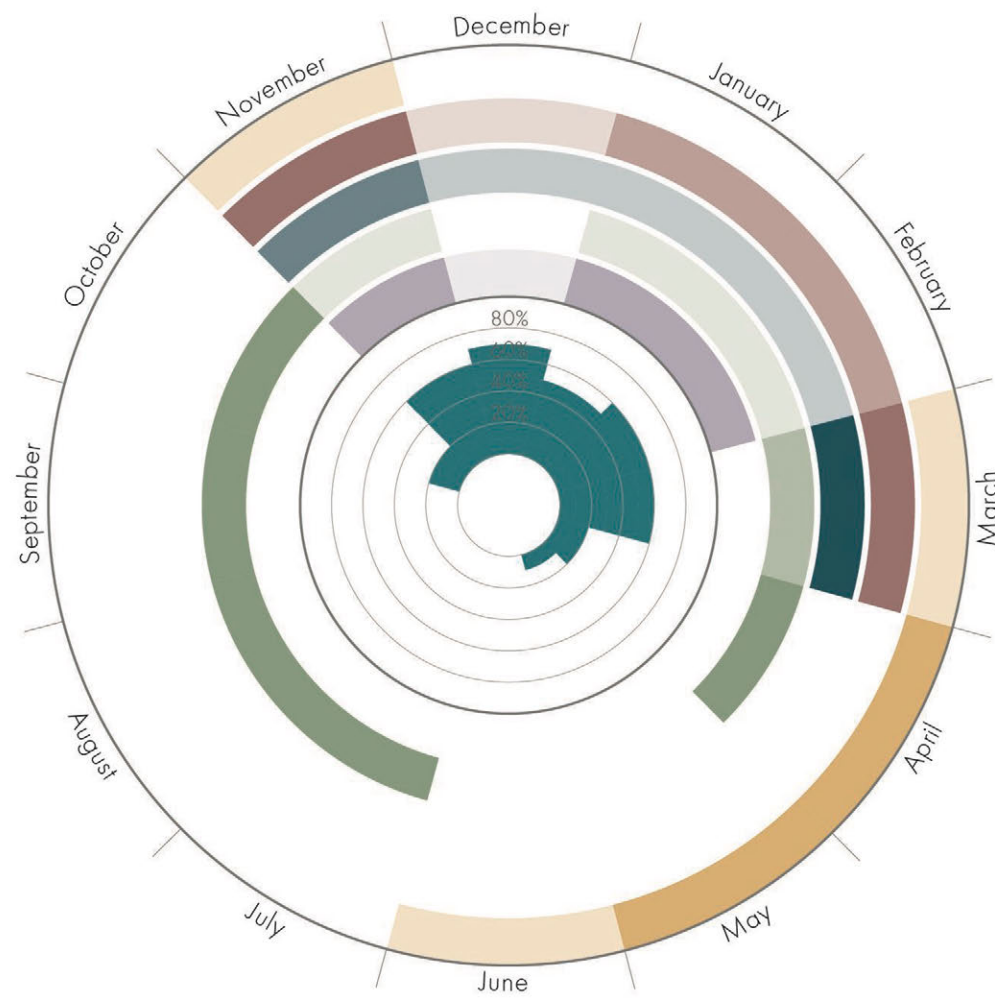
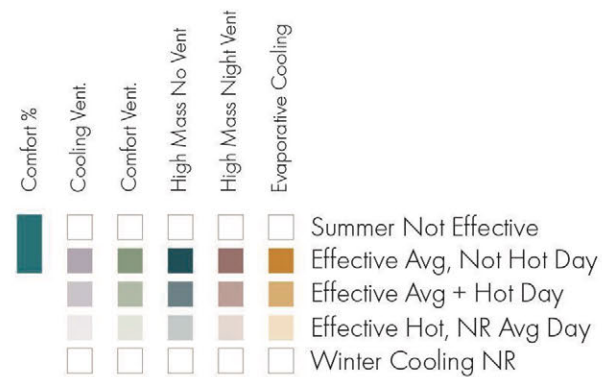
Latitude: 25.255N
Elevation: 10m



New Zone 0B:
Ultra Hot/Very Humid

Muscat, Oman

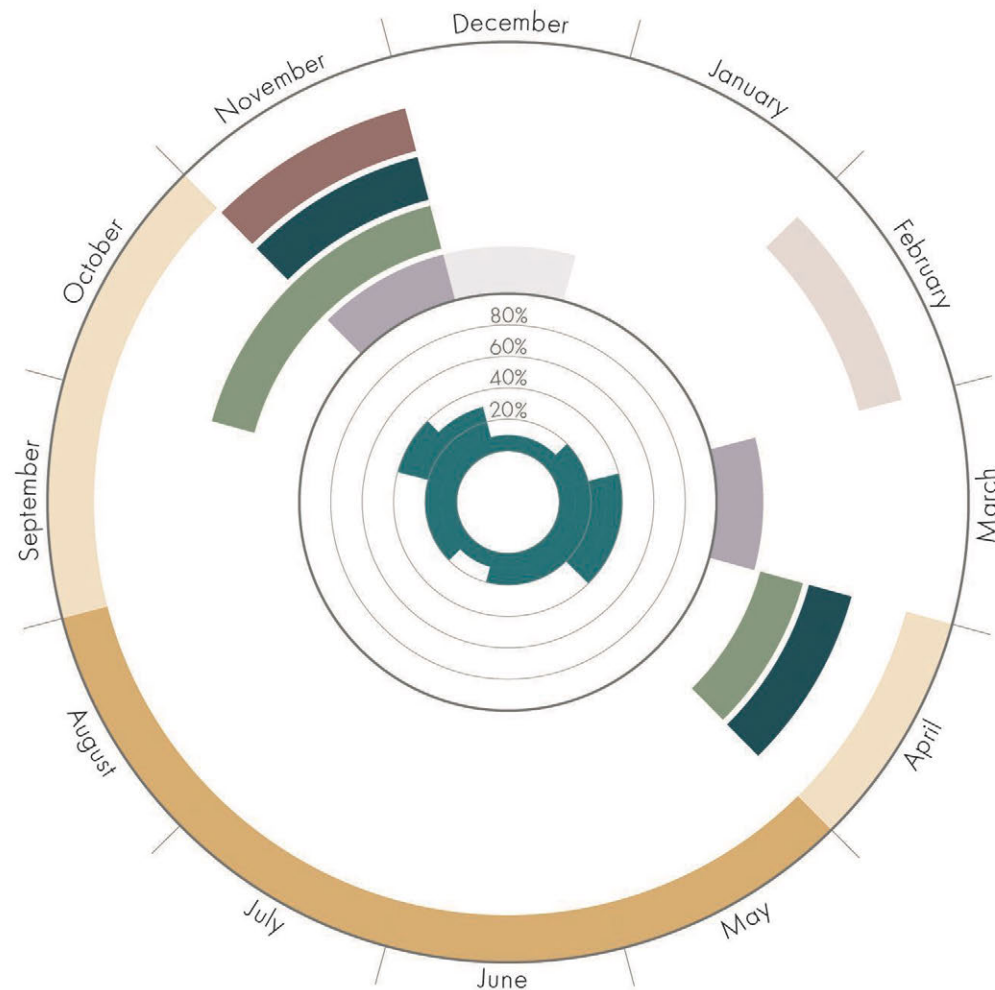
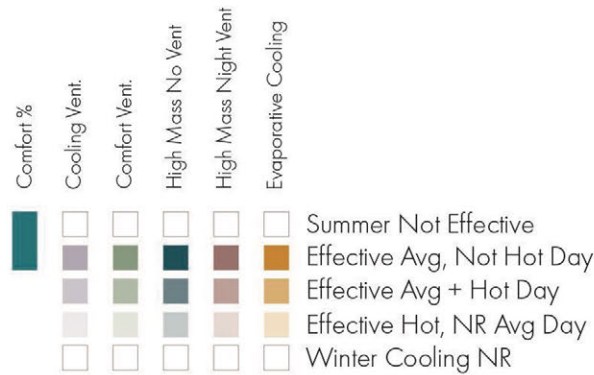
Latitude: 23.6086N
Elevation: 8m



Kuwait City, Kuwait

Latitude: 29.227
Elevation: 63m

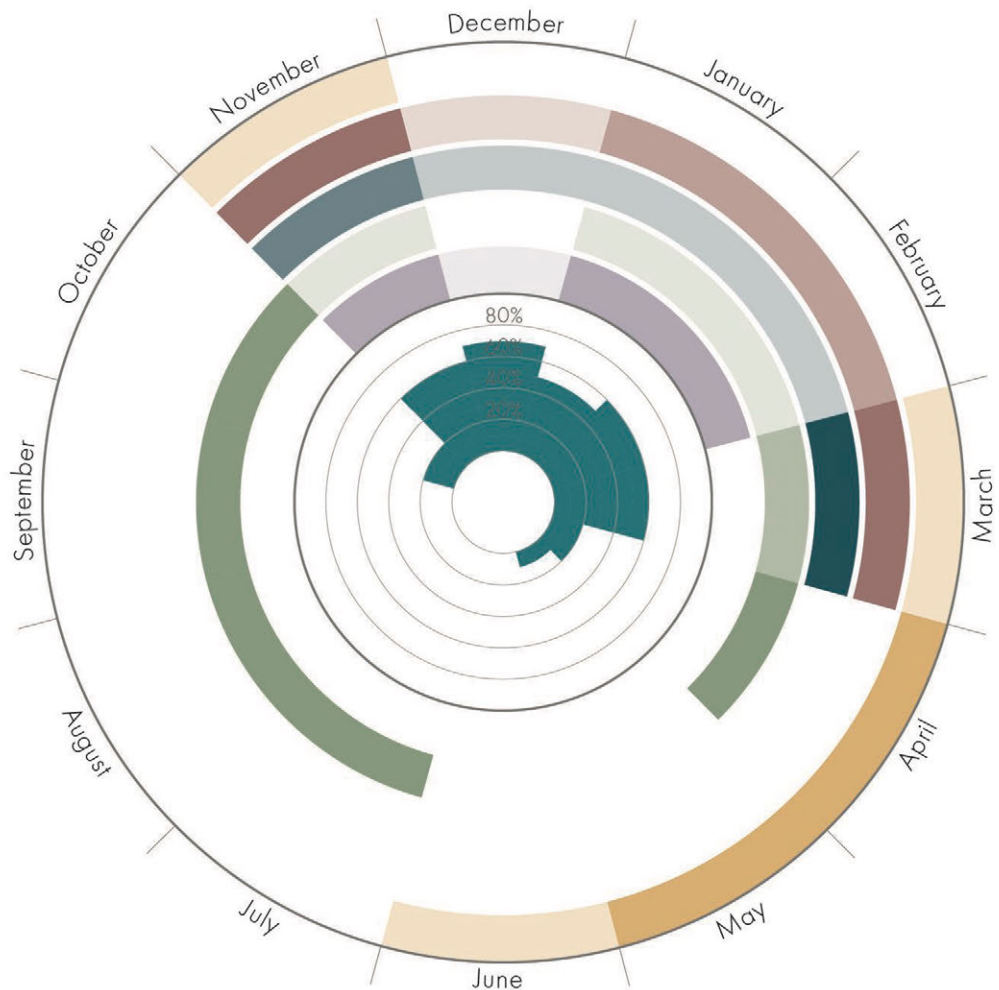
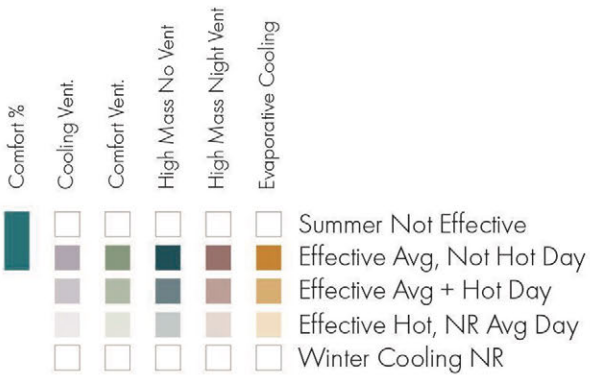
0 Ultra Hot
E Arid



Muscat, Oman

Latitude: 23.6086N
Elevation: 8m

0 Ultra Hot
Very Humid



IECC 0B: 0-Dry

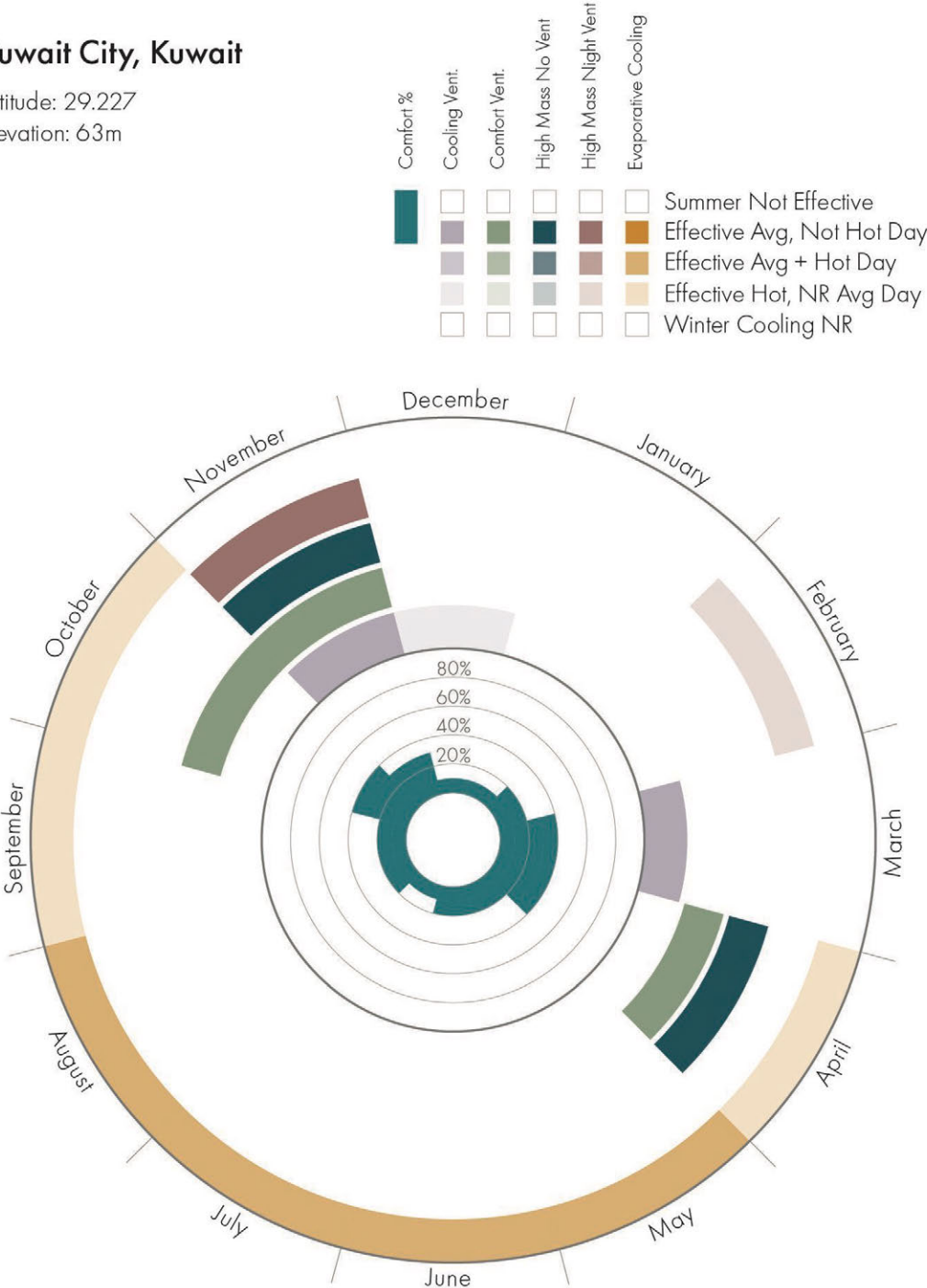
New Zone 0B:
Ultra Hot/Arid

CDD 10C 6132

Temperature Sequence
Zone 0 Very Hot —
Zone 3 Warm
(all Arid)

Kuwait City, Kuwait

Latitude: 29.227
Elevation: 63m



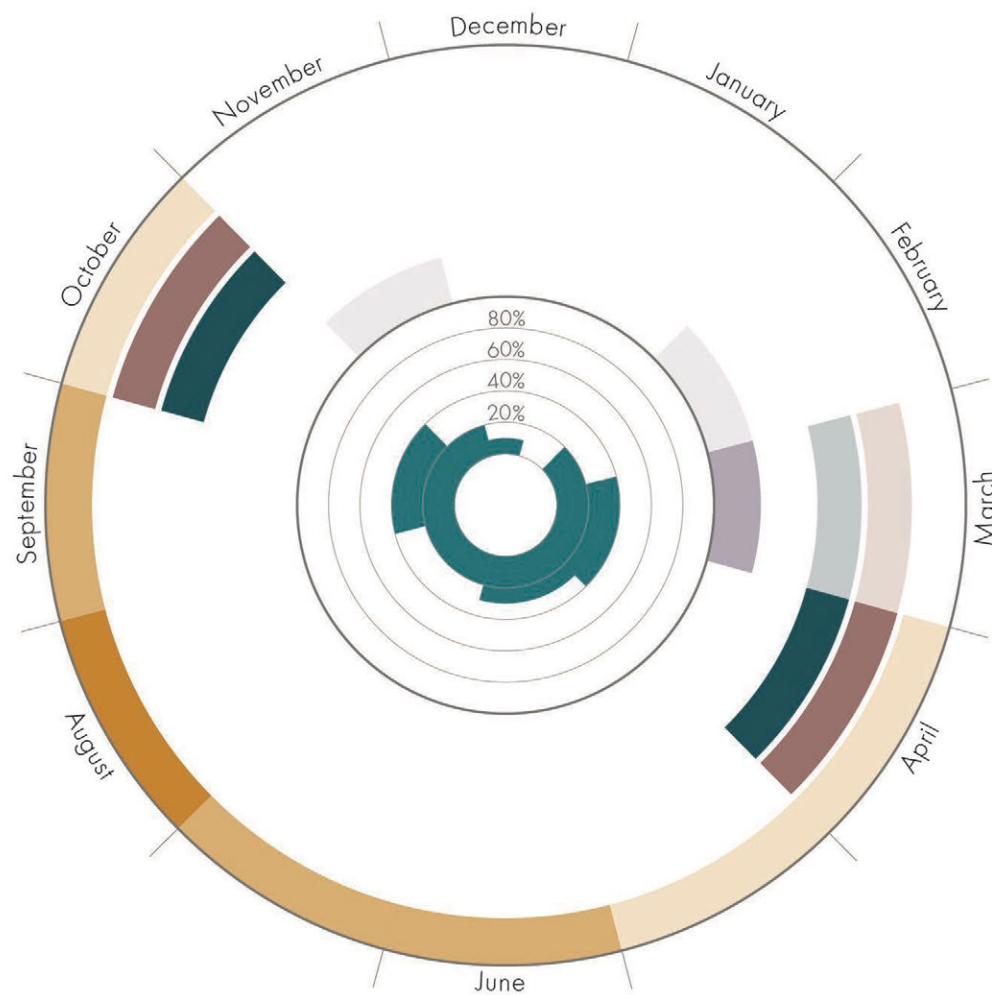
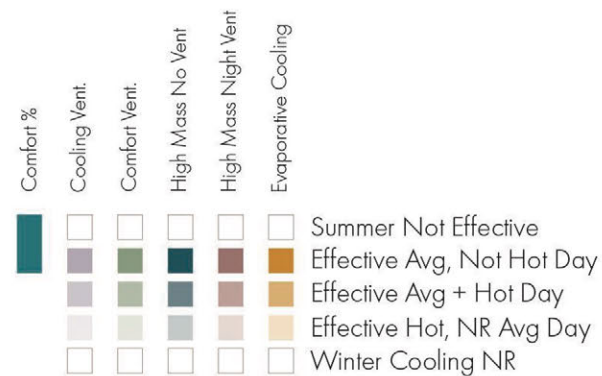
New Zone 1D:
Very Hot/Semi-Arid

CDD 10C 5303

Baghdad, Iraq

Latitude: 33.267N

Elevation: 35m



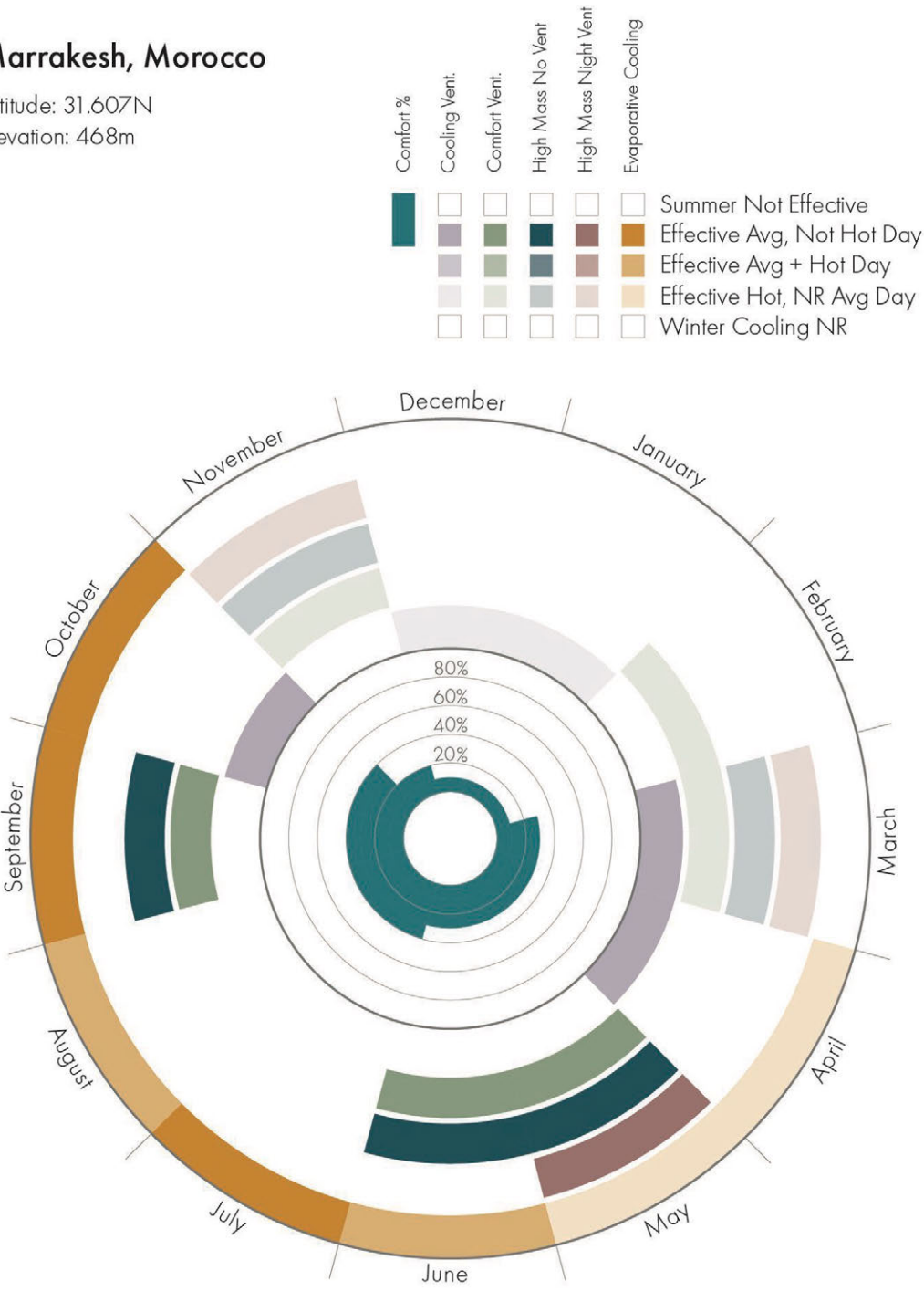
IECC 2B: Hot/Dry

New Zone 2E:
Hot/Arid

CDD 10C 3861

Marrakesh, Morocco

Latitude: 31.607N
Elevation: 468m



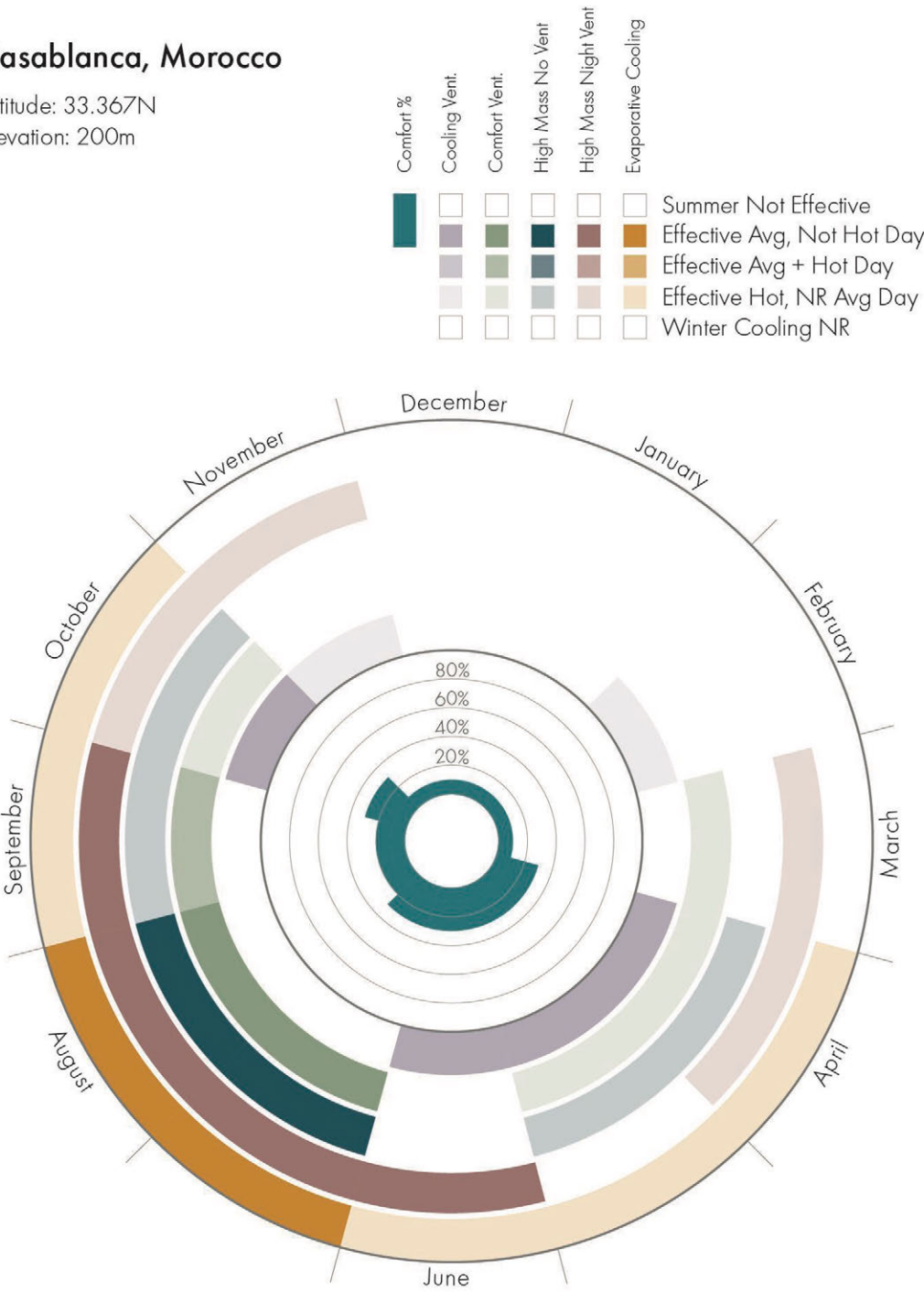
IECC 3B: Warm/Dry

New Zone 3E:
Warm/Arid

CDD 10C 3057

Casablanca, Morocco

Latitude: 33.367N
Elevation: 200m



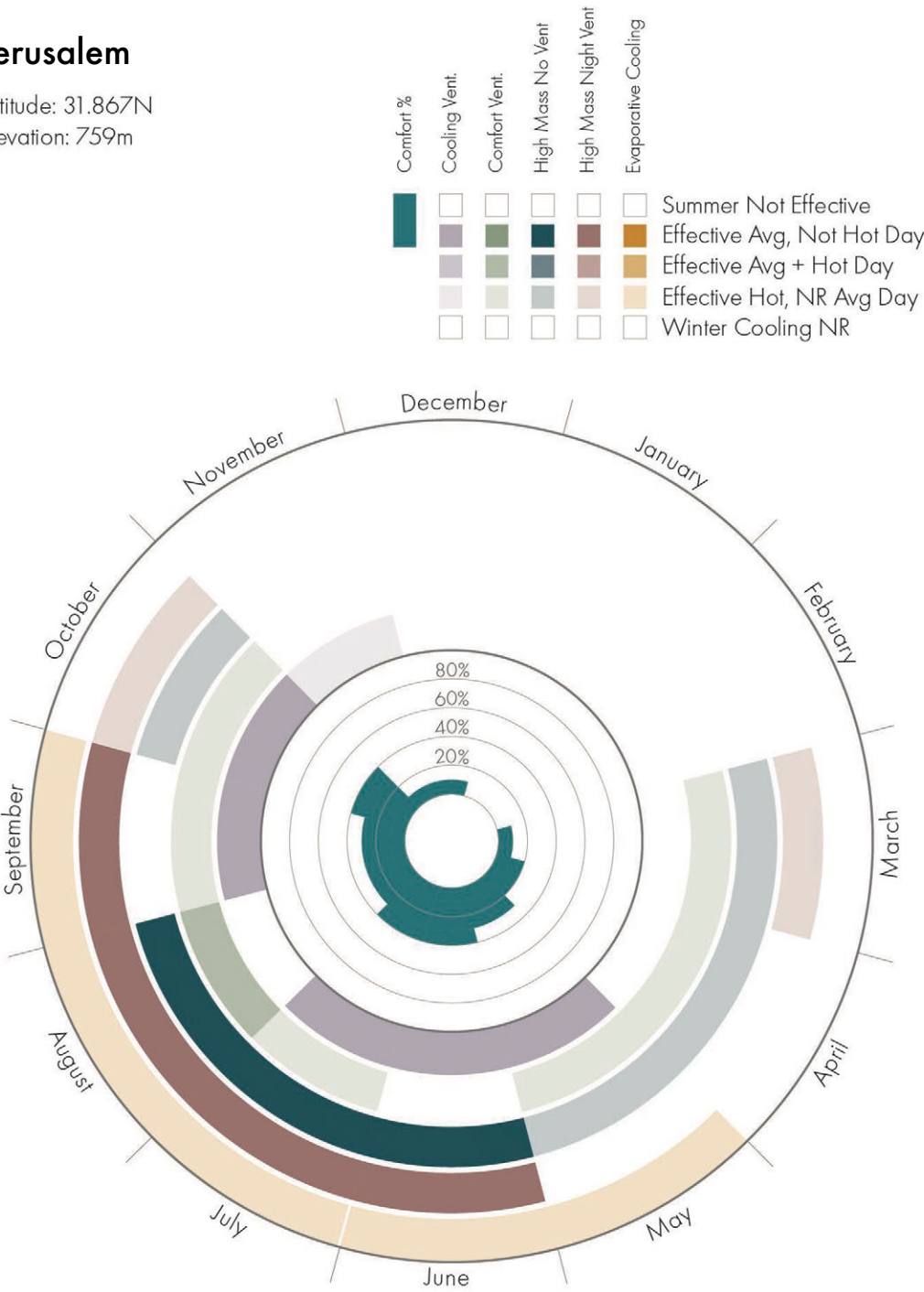
IECC 3A: Warm/Moist

New Zone 3E:
Warm/Arid

CDD 10C 2729

Jerusalem

Latitude: 31.867N
Elevation: 759m



Kuwait City, Kuwait

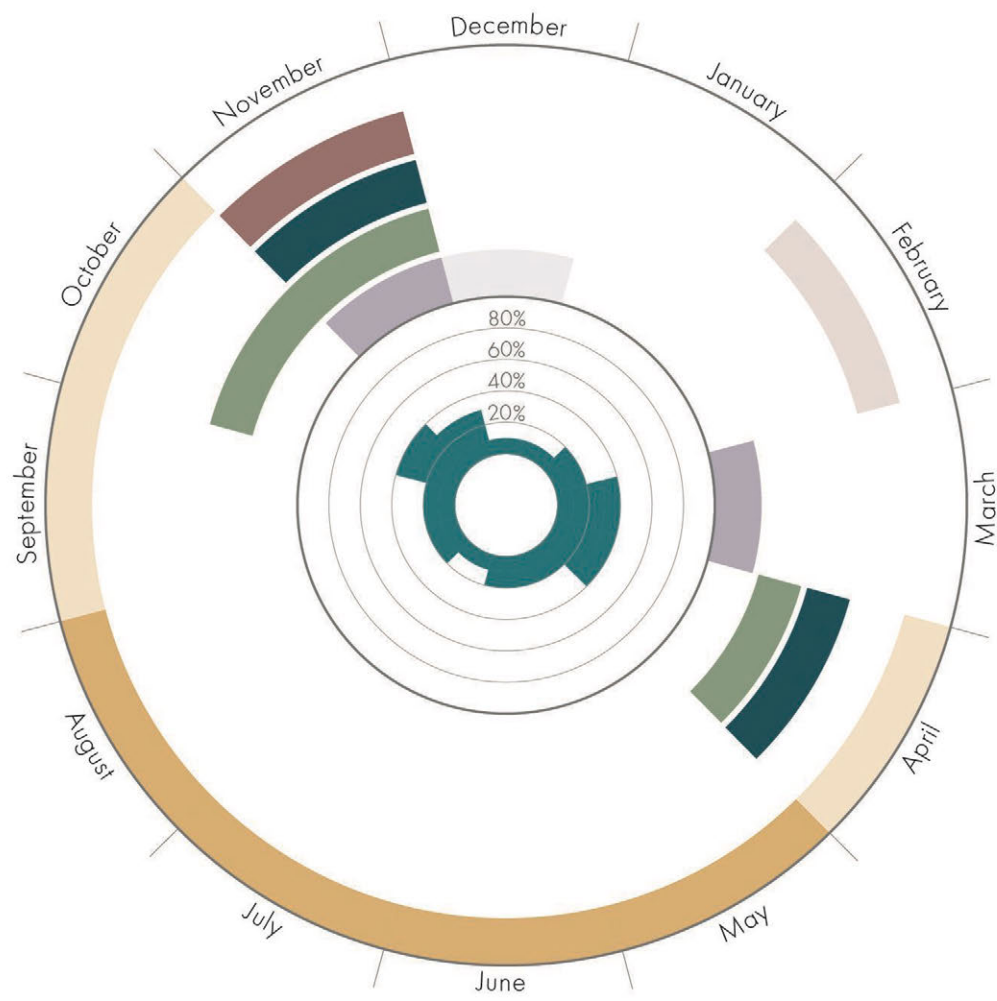
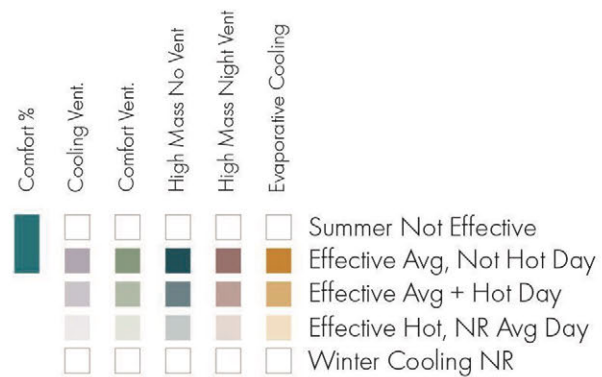
Latitude: 29.227

Elevation: 63m

Zone 0B

Searing + Arid

CDD 10C 6132



Jerusalem

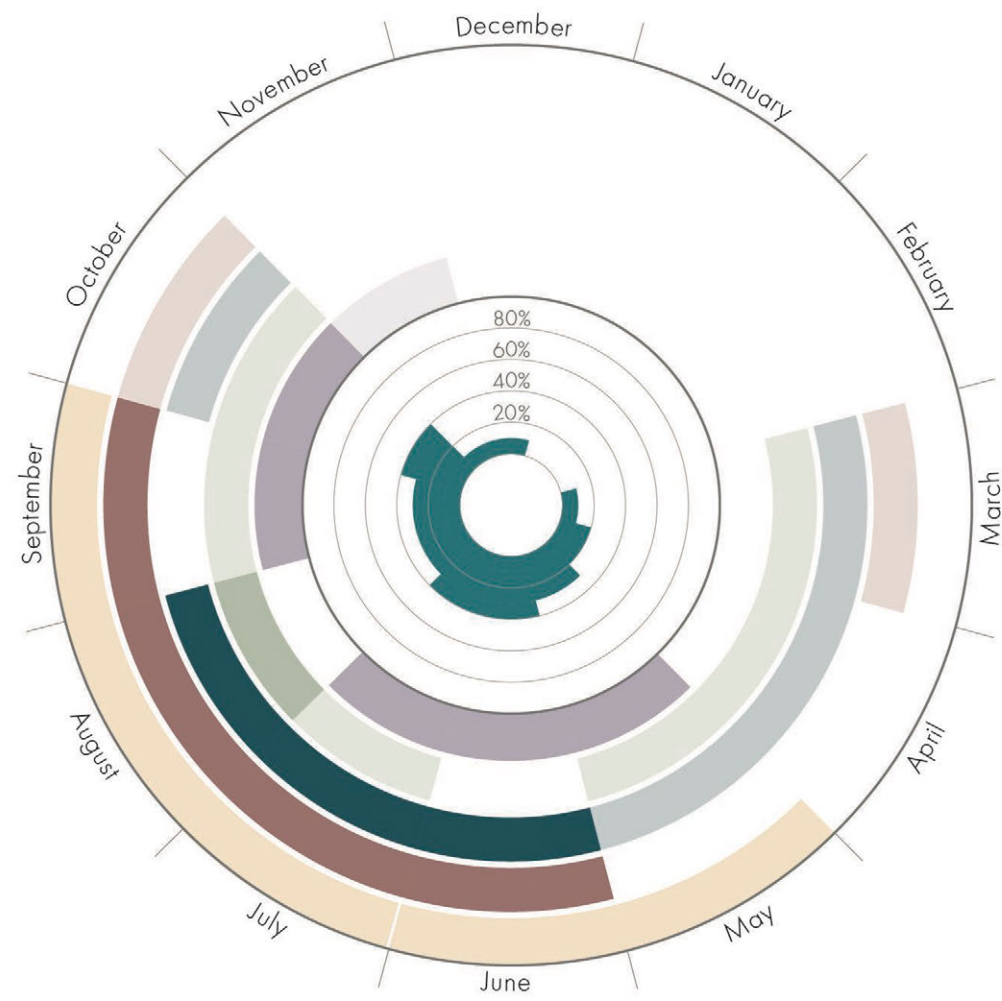
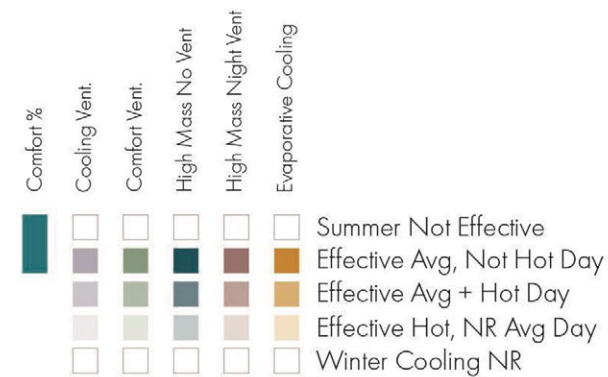
Latitude: 31.867N

Elevation: 759m

Zone 3E

Warm + Arid

CDD 10C 2729



QUESTIONS + ANSWERS

1 What PLEA cooling strategies can we recommend in hot climates?

B *What strategies work best in each of these climates?*

- ***Different climates*** have different lengths of cooling seasons.
- ***Different strategies*** work in different months in different climates.
- ***All climates*** require multiple cooling strategies.
- ***PLEA cooling*** works in all climates for some months.

QUESTIONS + ANSWERS

1 What PLEA cooling strategies can we recommend in hot climates?

B *What strategies work best in each of these climates?*

- **COOLING CALENDARS: Each city has a distinct PLEA Profile!**
- **Cooling Calibration is required.**
- **Conventional Design Guidelines only work within their set parameters**

COOLING CALENDARS: NEXT STEPS

- **AUTOMATE:** Processing directly from EPW
- **EXPAND SCOPE:** Build EPW from ERA5
- **BROADEN:** Add more PLEA strategies
- **COMMUNICATE:** Refine graphics and explore other options
- **DISSEMINATE:** Deliver online with interactive GUI



Seeking Strategies in Searing Settings

Passively-cooled mid-rise housing

Mark DeKay
Aram Yeretzian

