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Application of Nature-Based Solutions for local adaptation of educational and social buildings to Climate Change

Deliverable: Help document for "Prototype Design".

01-Analysis of climate data at the Porto, Évora and Badajoz locations.

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Analysis of climate data at the Porto, Évora and Badajoz locations.

1. OBJECTIVE

This document is part of the deliverable "Prototype Design". It aims to provide climatic information on the 3 locations in order to define the most appropriate bioclimatic strategies.

2. CLIMATIC DATA AT THE 3 LOCATIONS

For each of the locations, the relevant climate data for the selection of appropriate strategies are shown. They come from energyPlus SWEC files and can be downloaded from the following address:

https://energyplus.net/weather/sources

Climate Consultant 6.0 software was used for data analysis and visualization.

2.1. Porto

Geographical Coordinates: 41.5º North // 8.6º West

Porto's climate is humid and temperate. Summers are generally sunny and hot with average temperatures ranging from 15°C minimum to 24°C maximum. Winter temperatures are not very cold and average 6°C minimum and 16°C maximum. Prolonged rains are very common during these months.

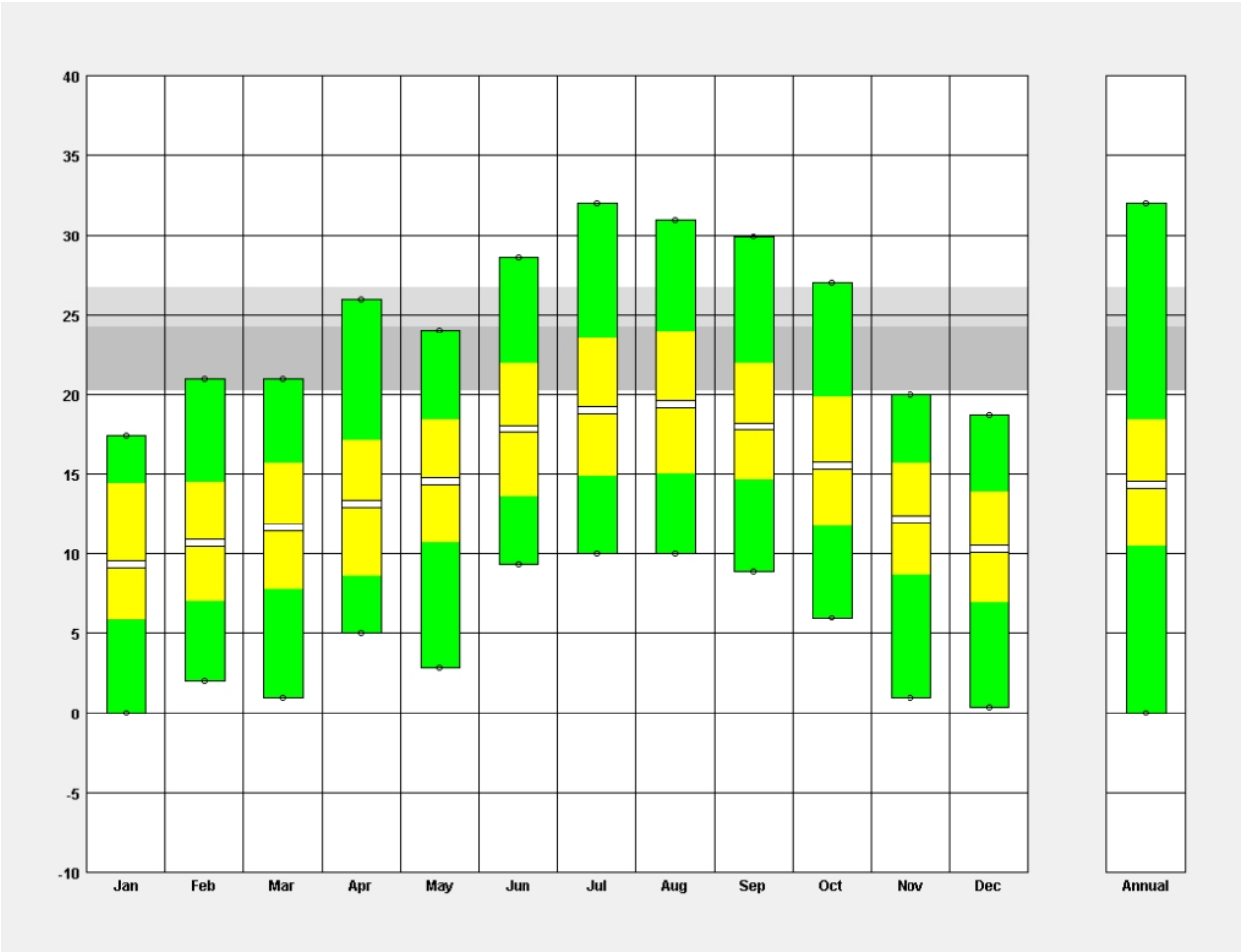
The warm season lasts 3.1 months, from June 19 to September 24. The hottest day of the year is July 29, with an average maximum temperature of 24 °C and an average minimum temperature of 15 °C.

The cool season lasts 3.5 months, from November 22 to March 6. The coldest day of the year is January 24, with an average minimum temperature of 6 °C and an average maximum of 14 °C.

2.1.1 Table of general climatic data

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	187	253	346	425	443	474	457	450	374	293	181	164	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	200	273	352	372	381	420	417	415	356	315	166	211	Wh/sq.m
Diffuse Radiation (Avg Hourly)	109	125	138	161	165	157	143	153	148	128	110	88	Wh/sq.m
Global Horiz Radiation (Max Hourly)	449	598	816	907	961	976	961	930	842	719	493	421	Wh/sq.m
Direct Normal Radiation (Max Hourly)	656	815	895	824	914	880	907	889	899	849	659	729	Wh/sq.m
Diffuse Radiation (Max Hourly)	274	299	383	460	506	436	455	485	466	337	292	283	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	1765	2614	4089	5615	6360	7077	6686	6129	4615	3195	1758	1495	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	1881	2806	4174	4932	5459	6278	6092	5663	4399	3455	1610	1921	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1024	1293	1631	2122	2379	2355	2108	2089	1815	1383	1068	804	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	20278	27455	37548	46111	48402	51749	50348	49497	41206	31961	19753	17804	lux
Direct Normal Illumination (Avg Hourly)	17800	25380	33924	36437	37302	41274	41139	40510	34409	29633	15046	18477	lux
Dry Bulb Temperature (Avg Monthly)	9	10	11	13	14	17	18	19	18	15	12	10	degrees C
Dew Point Temperature (Avg Monthly)	5	7	7	8	10	13	15	14	14	11	8	7	degrees C
Relative Humidity (Avg Monthly)	80	81	78	76	78	75	80	76	81	76	80	82	percent
Wind Direction (Monthly Mode)	110	90	90	350	300	320	300	0	190	170	110	100	degrees
Wind Speed (Avg Monthly)	2	4	3	3	4	1	3	2	1	3	3	1	m/s
Ground Temperature (Avg Monthly of 3 Depths)	11	10	11	11	13	15	16	17	17	16	14	12	degrees C

2.1.2. Monthly maximum and minimum temperatures



Maximum comfort T: Summer 27ºC; Winter 24ºC

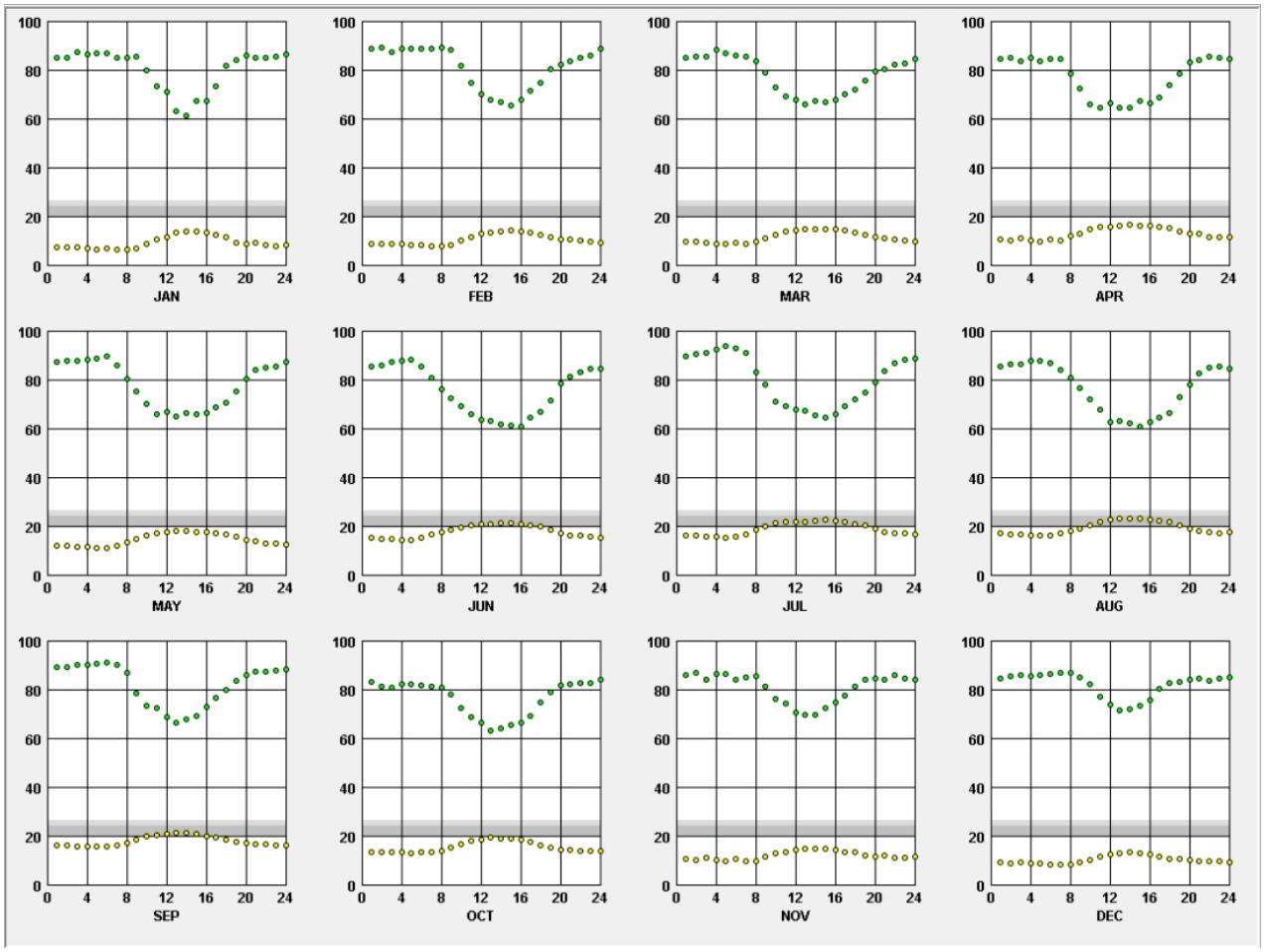
Green: Maximum and minimum design temperatures.

Yellow: Maximum and minimum temperatures with average data.

White: Average temperatures.

Between the months of June and September, inclusive, daily maximum temperatures exceed 27 degrees Celsius.

2.1.3. Hourly temperature and humidity on a typical day/month.

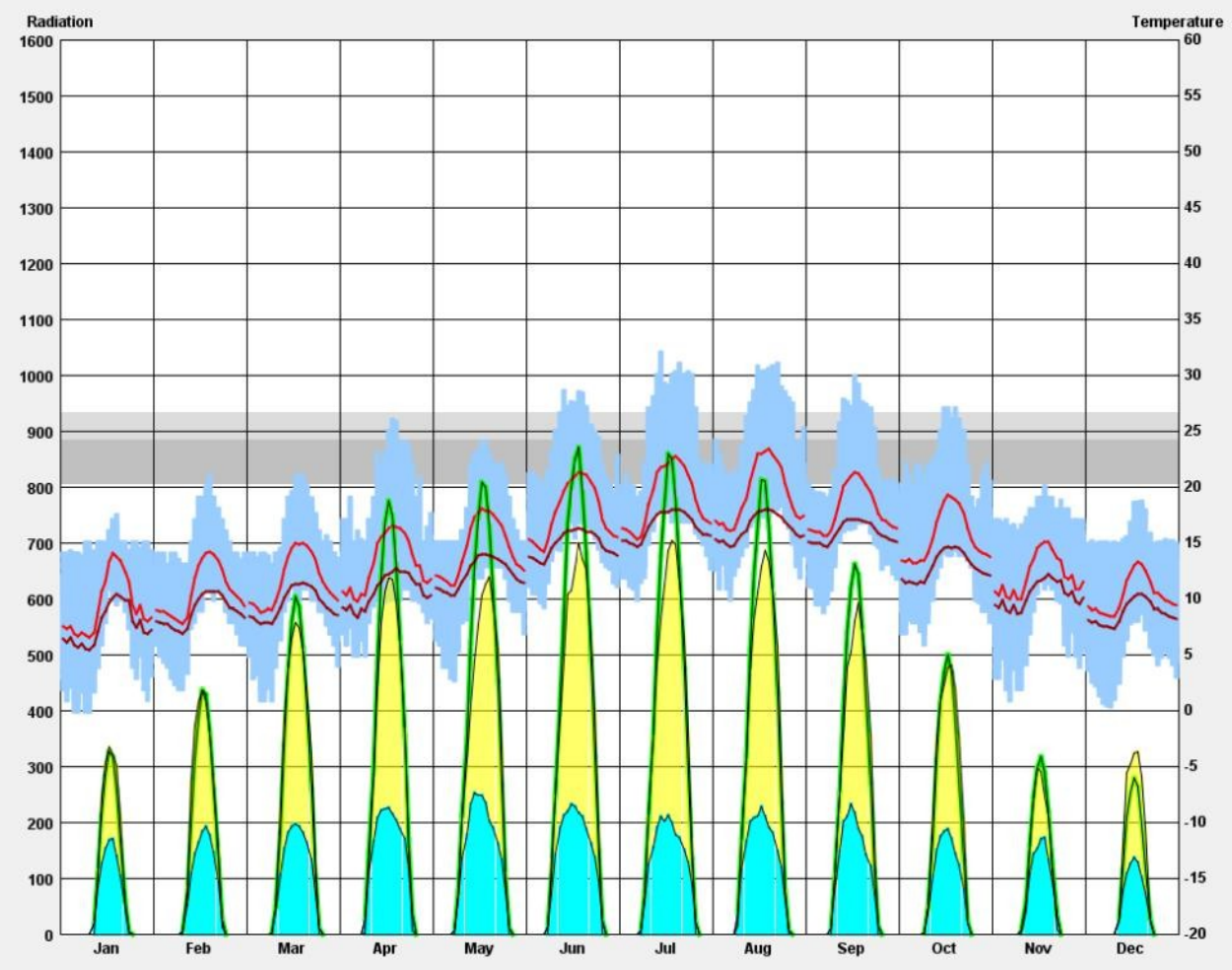


Green: Relative humidity

Yellow: Dry bulb temperature

There is a high degree of ambient humidity ranging between 60 and 90%.

2.1.4. Radiation



Radiation (Wh/m^2): Incident radiation in normal plane for a typical day of each month.

Blue: Diffuse

Yellow: Direct normal Green:

Total horizontal plane

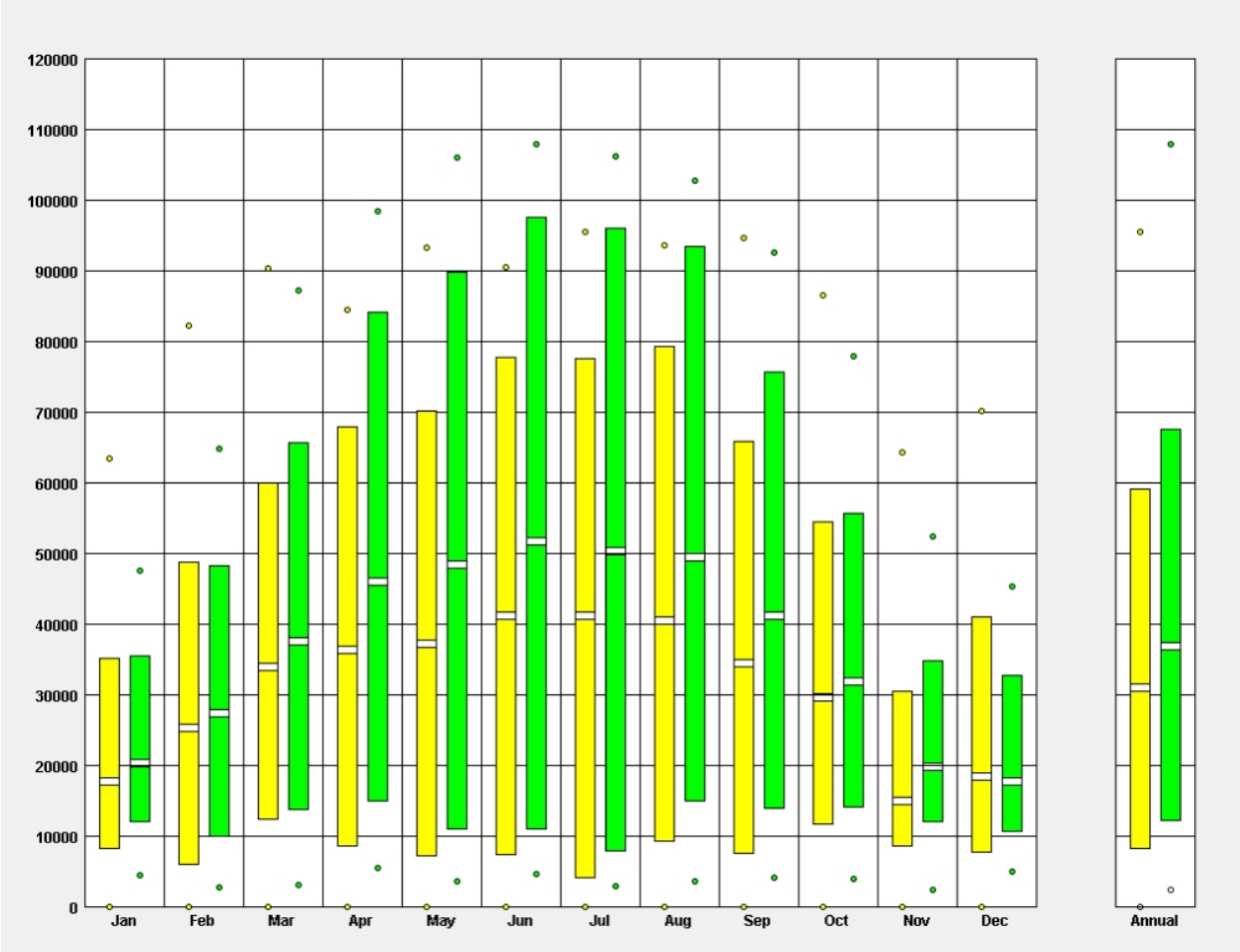
Temperature:

Red line: Dry bulb temperature. Hourly average

Dark red line: Wet bulb temperature. Blue hourly mean: Dry bulb temperature. All hours

Between the months of June and October, daily temperatures exceed 27ºC.

2.1.5. Lighting

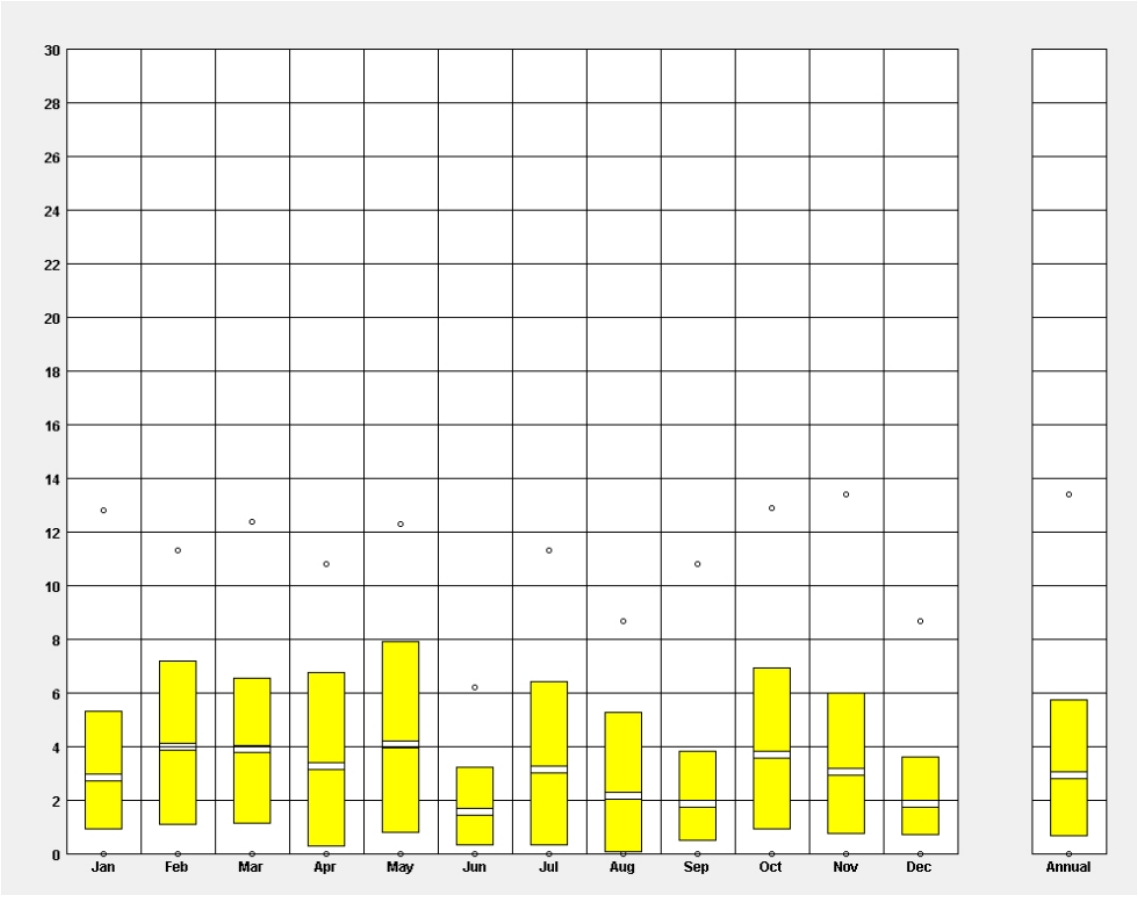


Yellow: Hourly illumination. Normal direct (lux). Average // Average maximum value // Average minimum value.

Green: Hourly illumination. Global horizontal (lux). Average // Average maximum value // Average minimum value.

These values indicate the amount of natural lighting that can be captured for interior lighting control. Their use implies reductions in energy expenditure on artificial lighting. However, an inadequate use can lead to excessive solar gains and therefore to interior overheating in undesired months.

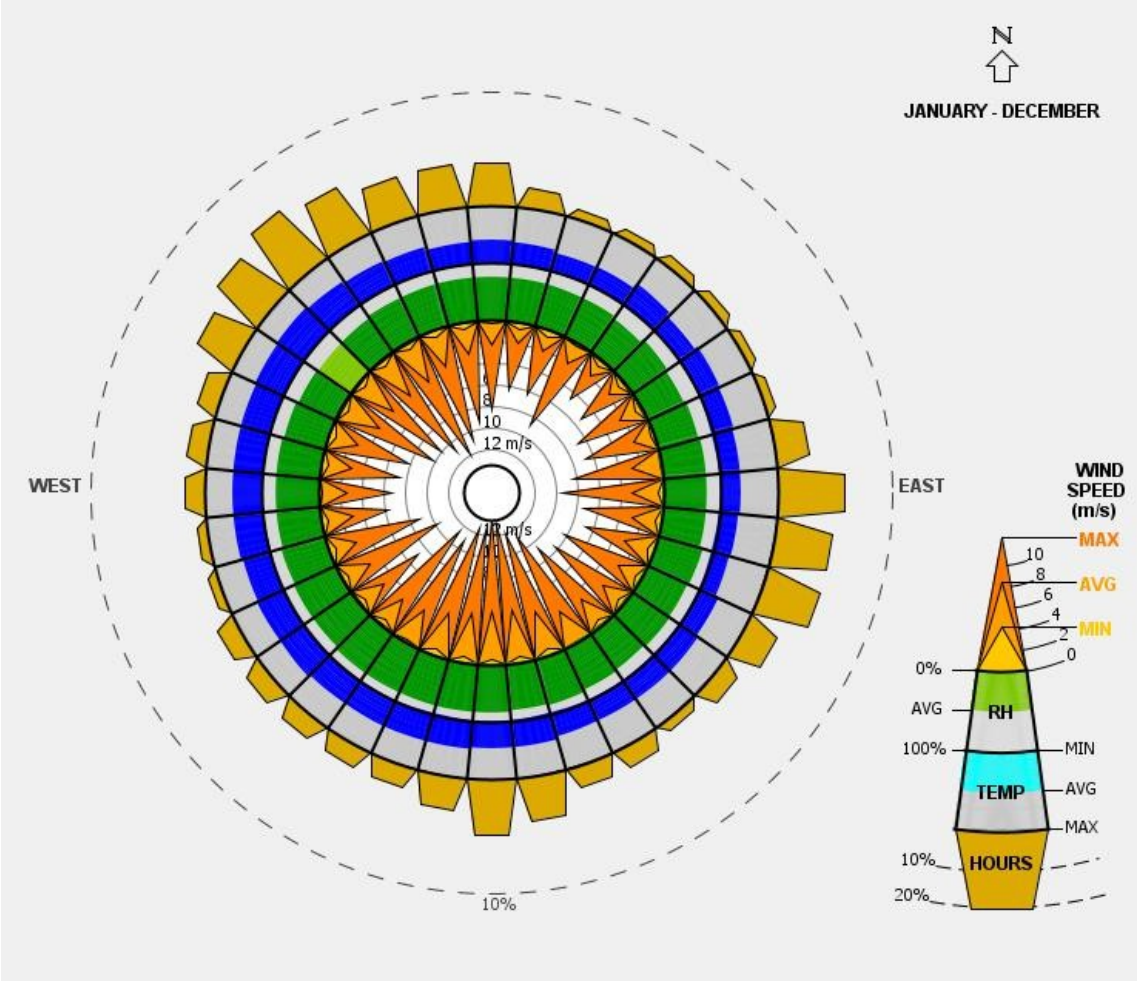
2.1.6. Wind

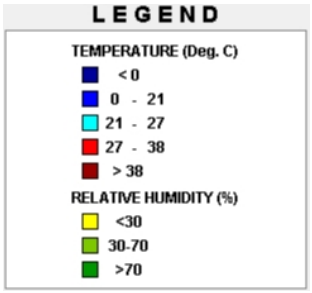


White: Average wind speed value for day type month (m/s) Yellow: Average maximum and average minimum values of wind speed

Warmer months have lower wind speeds. This must be taken into account for the design of the induced natural ventilation action.

Wind rose.





The wind rose indicates the direction of the prevailing winds, with their average, minimum and maximum speeds, and with information on the associated temperature and humidity parameters.

Predominantly northwesterly and easterly winds with average speeds of 4 m/s.

2.2. Évora

Geographical Coordinates: 38.6º North // 7.9º West

Summers are short, very hot, dry and mostly clear. Winters are long, cold and partly cloudy. During the course of the year, the temperature generally varies from 5 °C to 33 °C and rarely drops below 1 °C or rises above 38 °C (https://es.weatherspark.com).

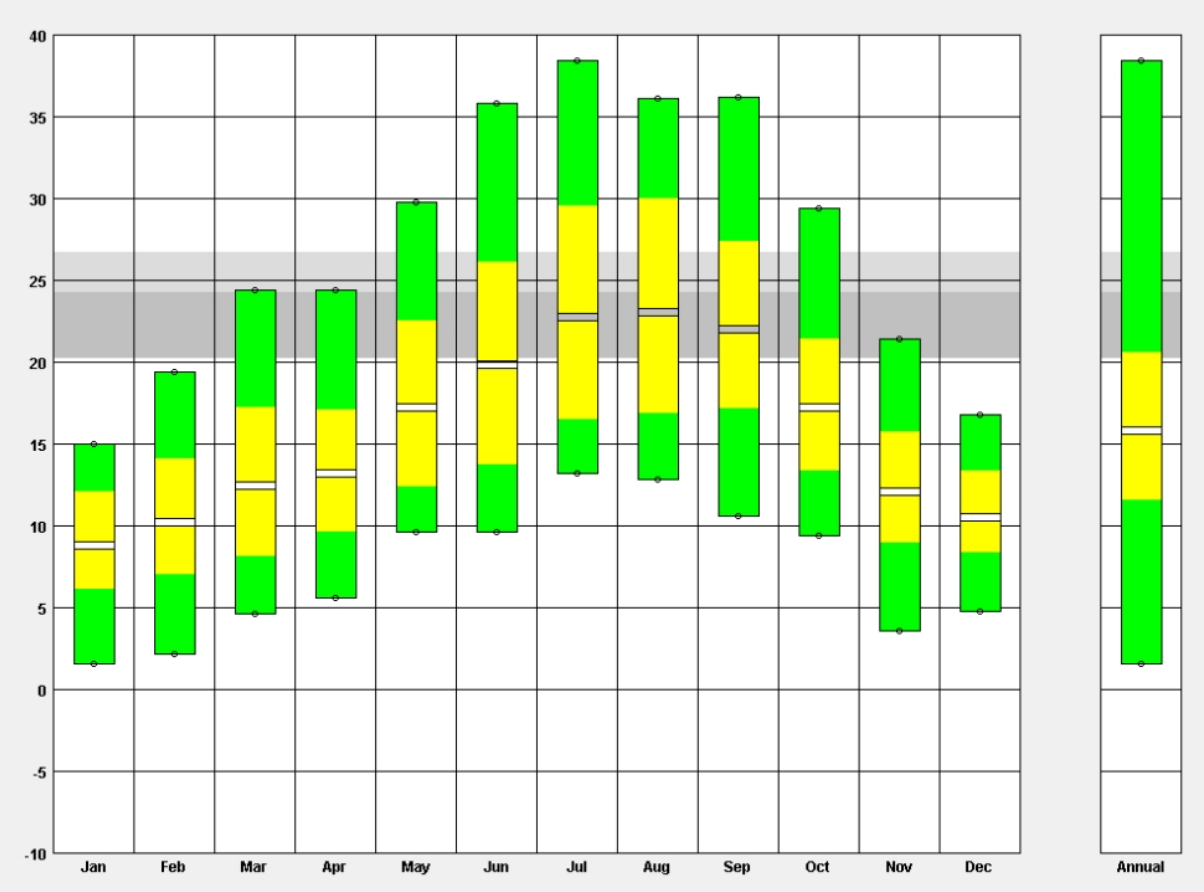
The hot season lasts 2.9 months, from June 18 to September 13, and the average daily maximum temperature is more than 29 °C (79 °F). The hottest day of the year is July 29, with an average maximum temperature of 33 °C and an average minimum temperature of 16 °C.

The cool season lasts 3.7 months, from November 15 to March 6, and the average daily maximum temperature is less than 17 °C (59 °F). The coldest day of the year is January 18, with an average minimum temperature of 5°C and an average maximum of 13°C.
°C.

2.2.1. Table of general climatic data

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	232	276	404	405	479	483	518	499	410	321	230	198	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	294	242	454	267	390	384	492	489	360	315	210	222	Wh/sq.m
Diffuse Radiation (Avg Hourly)	111	152	136	223	195	196	151	147	179	153	133	114	Wh/sq.m
Global Horiz Radiation (Max Hourly)	538	665	846	940	1002	1003	996	956	859	750	560	461	Wh/sq.m
Direct Normal Radiation (Max Hourly)	849	797	922	901	931	905	909	915	867	882	771	808	Wh/sq.m
Diffuse Radiation (Max Hourly)	282	309	431	664	664	690	479	467	428	365	312	240	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2237	2891	4757	5292	6770	7077	7452	6719	5040	3532	2292	1852	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2840	2527	5324	3492	5513	5631	7077	6579	4428	3470	2106	2077	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1072	1598	1609	2916	2763	2871	2184	1981	2188	1676	1321	1067	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	25016	29936	43475	44239	52053	52621	56292	54415	44837	35044	25028	21437	lux
Direct Normal Illumination (Avg Hourly)	26778	23067	43915	25628	38033	37495	48520	48065	34190	29291	19452	19638	lux
Dry Bulb Temperature (Avg Monthly)	8	10	12	13	17	19	22	23	21	17	12	10	degrees C
Dew Point Temperature (Avg Monthly)	5	4	5	8	8	10	12	12	12	11	6	7	degrees C
Relative Humidity (Avg Monthly)	81	68	65	74	61	61	58	55	61	72	72	81	percent
Wind Direction (Monthly Mode)	330	60	340	300	320	320	320	320	330	180	350	340	degrees
Wind Speed (Avg Monthly)	4	3	4	4	4	4	4	4	4	3	4	4	m/s
Ground Temperature (Avg Monthly of 3 Depths)	11	10	11	11	14	17	19	20	20	18	16	13	degrees C

2.2.2. Monthly maximum and minimum temperatures



Maximum comfort T: Summer 27ºC; Winter 24ºC

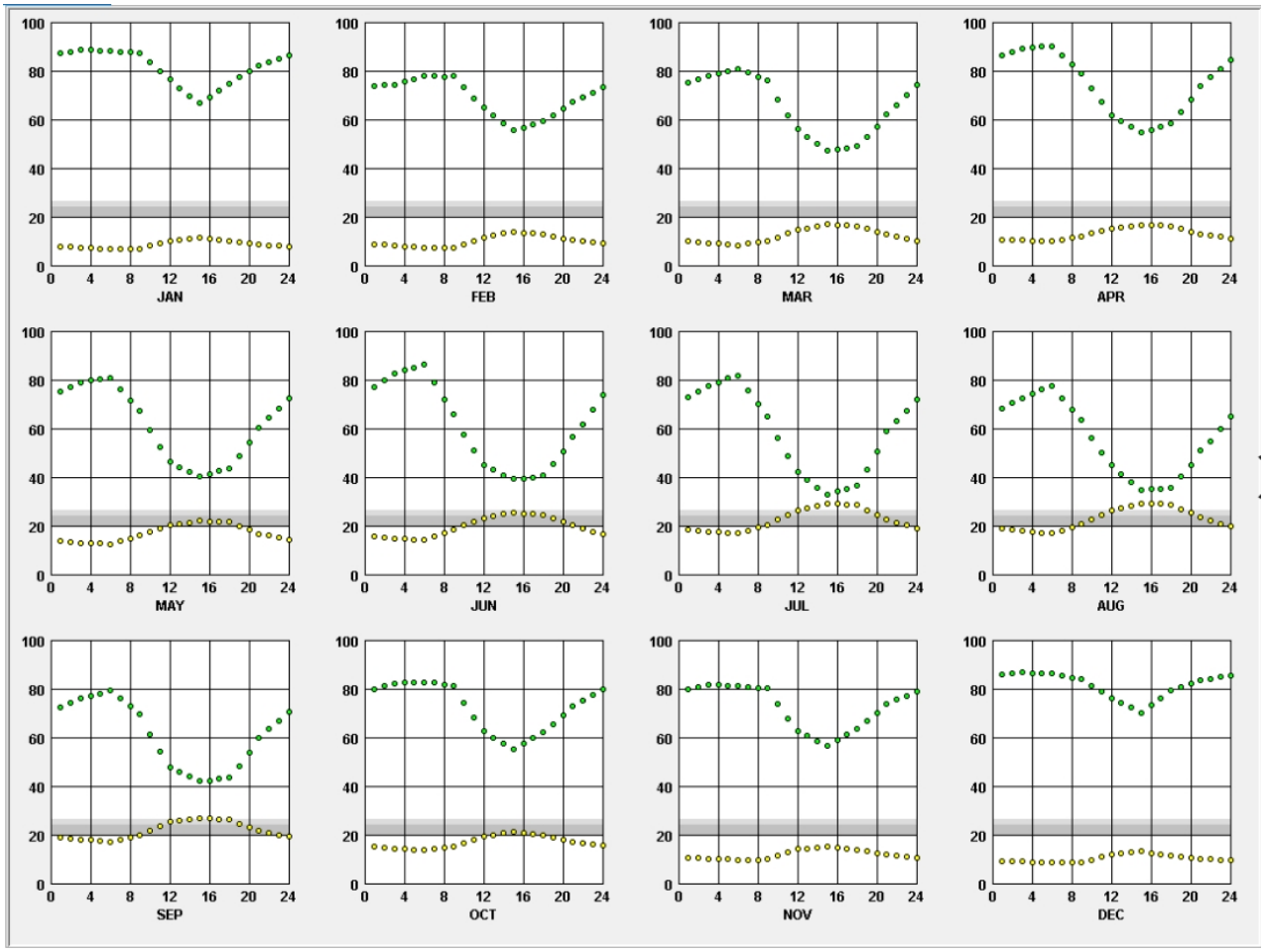
Green: Maximum and minimum design temperatures.

Yellow: Maximum and minimum temperatures with average data.

White: Average temperatures.

Between the months of May to October, inclusive, daily maximum temperatures exceed 27 degrees Celsius. In contrast to the climate of Porto, the climate of Evora is much hotter, exceeding 35 degrees Celsius from June to September. These data are relevant for the purpose of controlling overheating in this period.

2.2.3. Hourly temperature and humidity on a typical day/month.

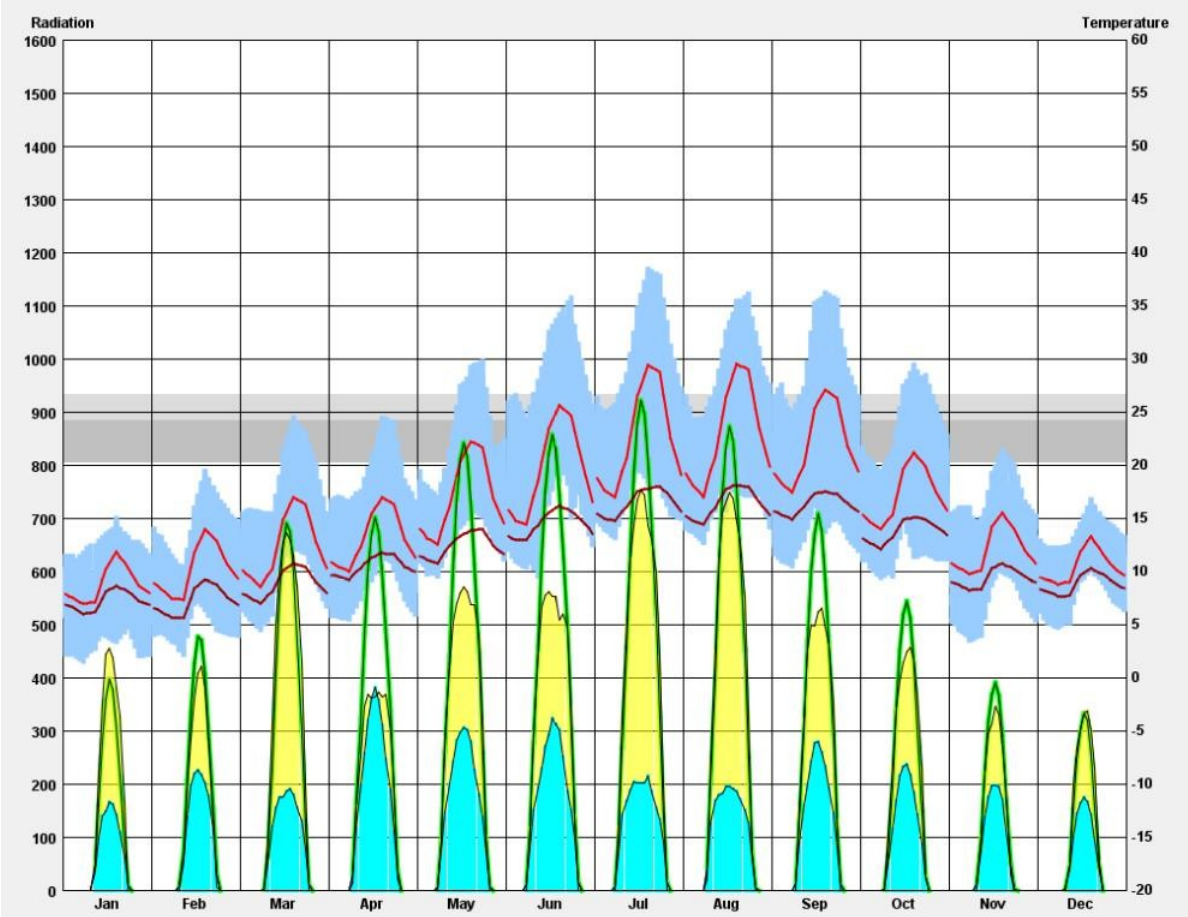


Green: Relative humidity

Yellow: Dry bulb temperature

As the graphs show, the climate in Évora is characterized by being drier than in Porto. In the hot months, from May to September, the relative humidity in the central hours of the day drops to 40%.

2.2.4. Radiation



Radiation (Wh/m^2): Incident radiation in normal plane for a typical day of each month.

Blue: Diffuse

Yellow: Direct normal Green:

Total horizontal plane

Temperature:

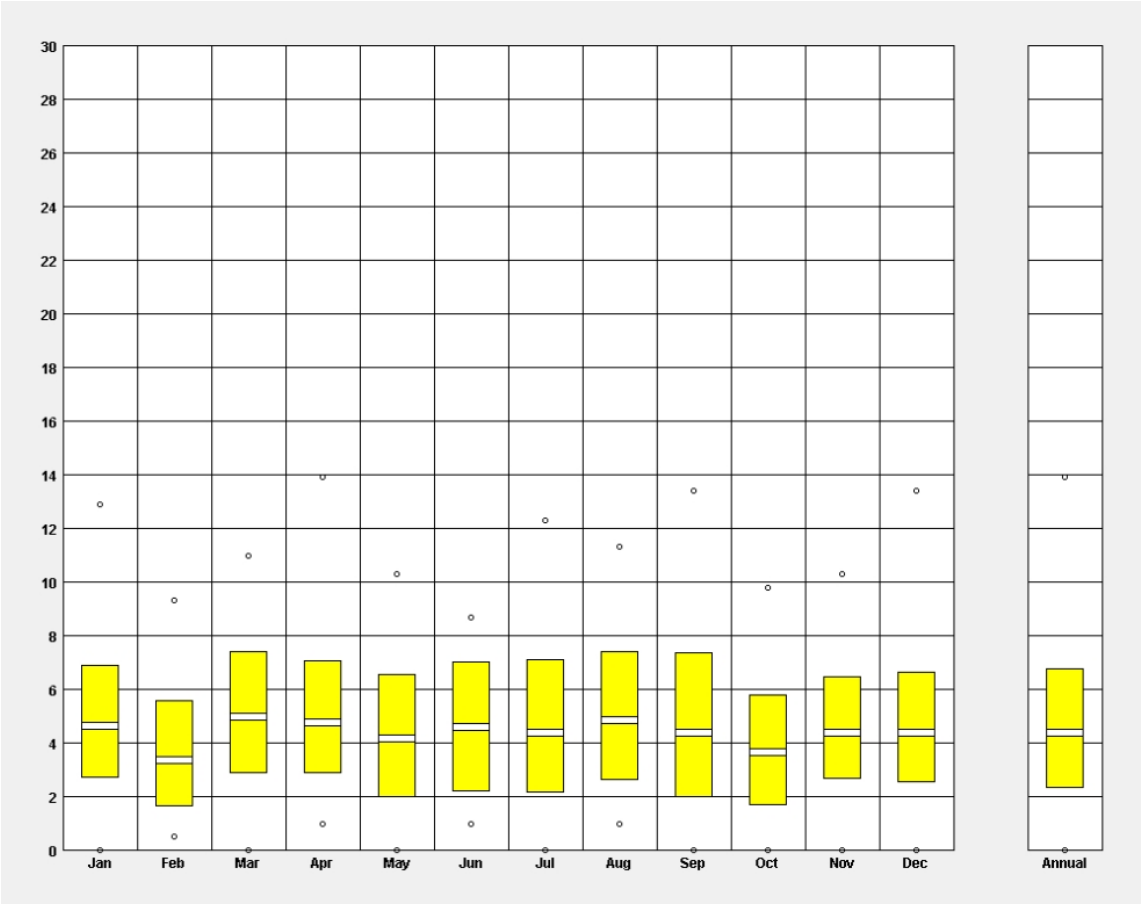
Red line: Dry bulb temperature. Hourly average

Dark red line: Wet bulb temperature. Blue hourly mean: Dry bulb

temperature. All hours

A higher solar incidence, together with the drier continental climate, is reflected in higher temperatures than in Oporto. Between the months of May and October, daily temperatures are in excess of 30ºC.

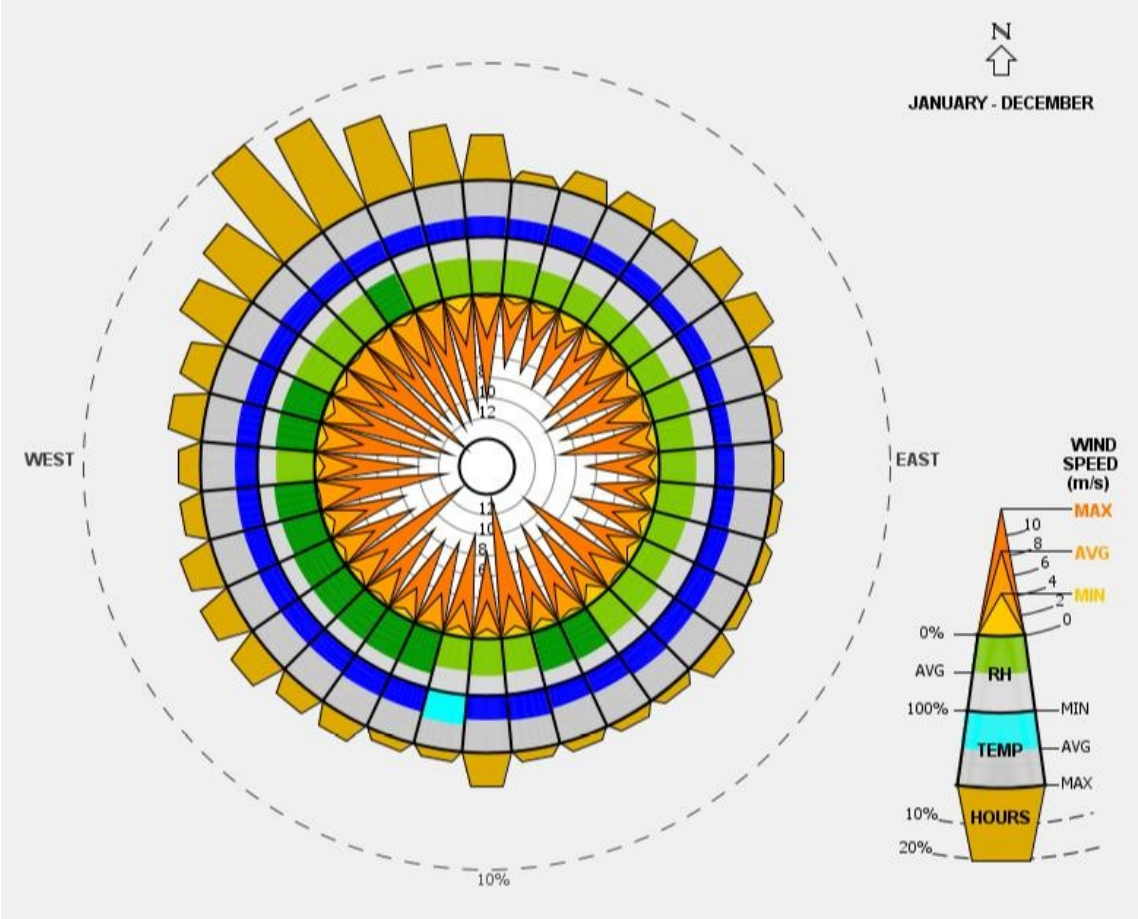
2.2.5. Wind

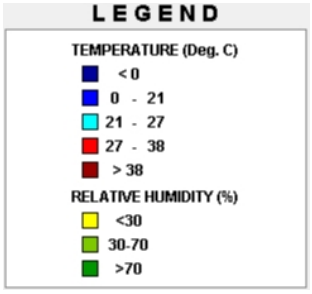


White: Average wind speed value for day type month (m/s) Yellow: Average maximum and average minimum values of wind speed

Homogeneous wind speeds are observed among the stations. The average speed, around 4 m/s, is slightly higher than the data found for the climate of Porto.

Wind rose.





The wind rose indicates the direction of the prevailing winds, with their average, minimum and maximum speeds, and with information on the associated temperature and humidity parameters.

This climate is dominated by northwesterly winds with average speeds of 6 m/s for this orientation.

2.3. Badajoz

Geographical Coordinates: 38.9º North // 6.9º West

In Badajoz, summers are very hot, dry and mostly clear and winters are cold and partly cloudy. During the course of the year, the temperature generally varies from 3 °C to 35 °C and rarely drops below -2 °C or rises above 39 °C. (https://es.weatherspark.com).

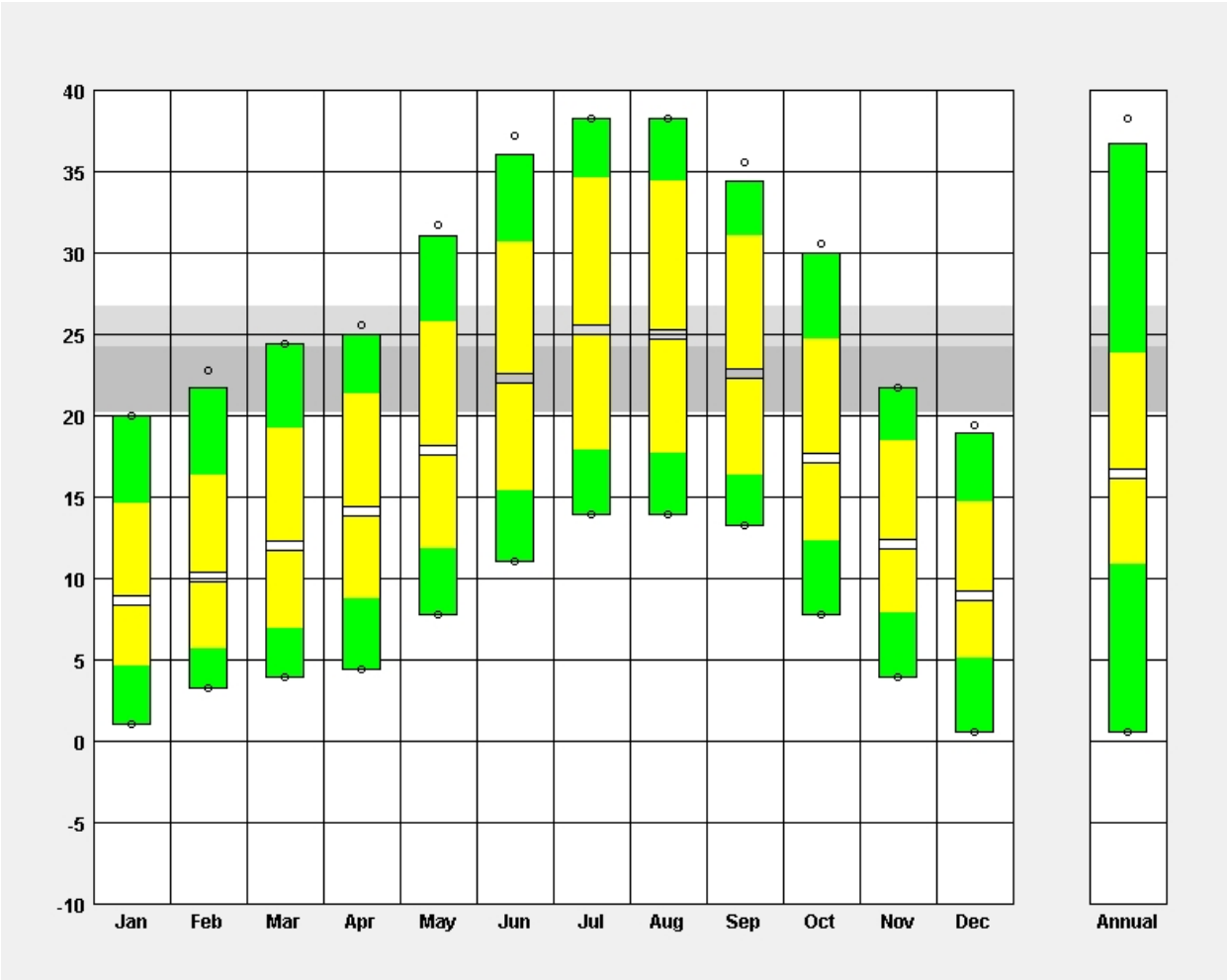
The hot season lasts 3.0 months, from June 14 to September 13, and the average daily maximum temperature is more than 30 °C. The hottest day of the year is July 29, with an average maximum temperature of 35 °C and an average minimum temperature of 18 °C.

The cool season lasts 3.6 months, from November 16 to March 4, and the average daily maximum temperature is less than 18 °C (64 °F). The coldest day of the year is January 18, with an average minimum temperature of 3°C and an average maximum of 14°C.
°C.

2.3.1. Table of general climatic data

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	230	291	362	409	466	483	529	509	424	342	261	212	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	274	326	376	336	418	430	537	529	471	394	336	273	Wh/sq.m
Diffuse Radiation (Avg Hourly)	118	135	152	185	173	170	147	152	137	137	117	105	Wh/sq.m
Global Horiz Radiation (Max Hourly)	533	700	810	933	974	974	971	940	858	744	558	479	Wh/sq.m
Direct Normal Radiation (Max Hourly)	788	858	889	911	899	883	892	880	858	845	794	769	Wh/sq.m
Diffuse Radiation (Max Hourly)	252	340	407	419	415	474	444	399	388	349	266	228	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2219	3064	4260	5355	6606	7090	7635	6870	5212	3741	2590	1978	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2642	3441	4413	4415	5939	6327	7742	7154	5771	4297	3335	2553	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1134	1413	1793	2417	2448	2495	2131	2051	1683	1506	1161	985	Wh/sq.m
Global Horiz Illumination (Avg Hourly)													lux
Direct Normal Illumination (Avg Hourly)													lux
Dry Bulb Temperature (Avg Monthly)	8	10	12	14	17	22	25	24	22	17	12	8	degrees C
Dew Point Temperature (Avg Monthly)	4	4	5	7	9	11	12	12	11	10	8	5	degrees C
Relative Humidity (Avg Monthly)	79	68	68	68	60	54	50	49	54	66	80	81	percent
Wind Direction (Monthly Mode)	0	0	0	0	0	0	0	0	0	0	0	0	degrees
Wind Speed (Avg Monthly)	6	6	6	6	6	6	6	6	6	6	6	6	m/s
Ground Temperature (Avg Monthly of 3 Depths)	10	11	12	14	18	20	21	21	19	16	13	11	degrees C

2.3.2. Monthly maximum and minimum temperatures



Maximum comfort T: Summer 27ºC; Winter 24ºC

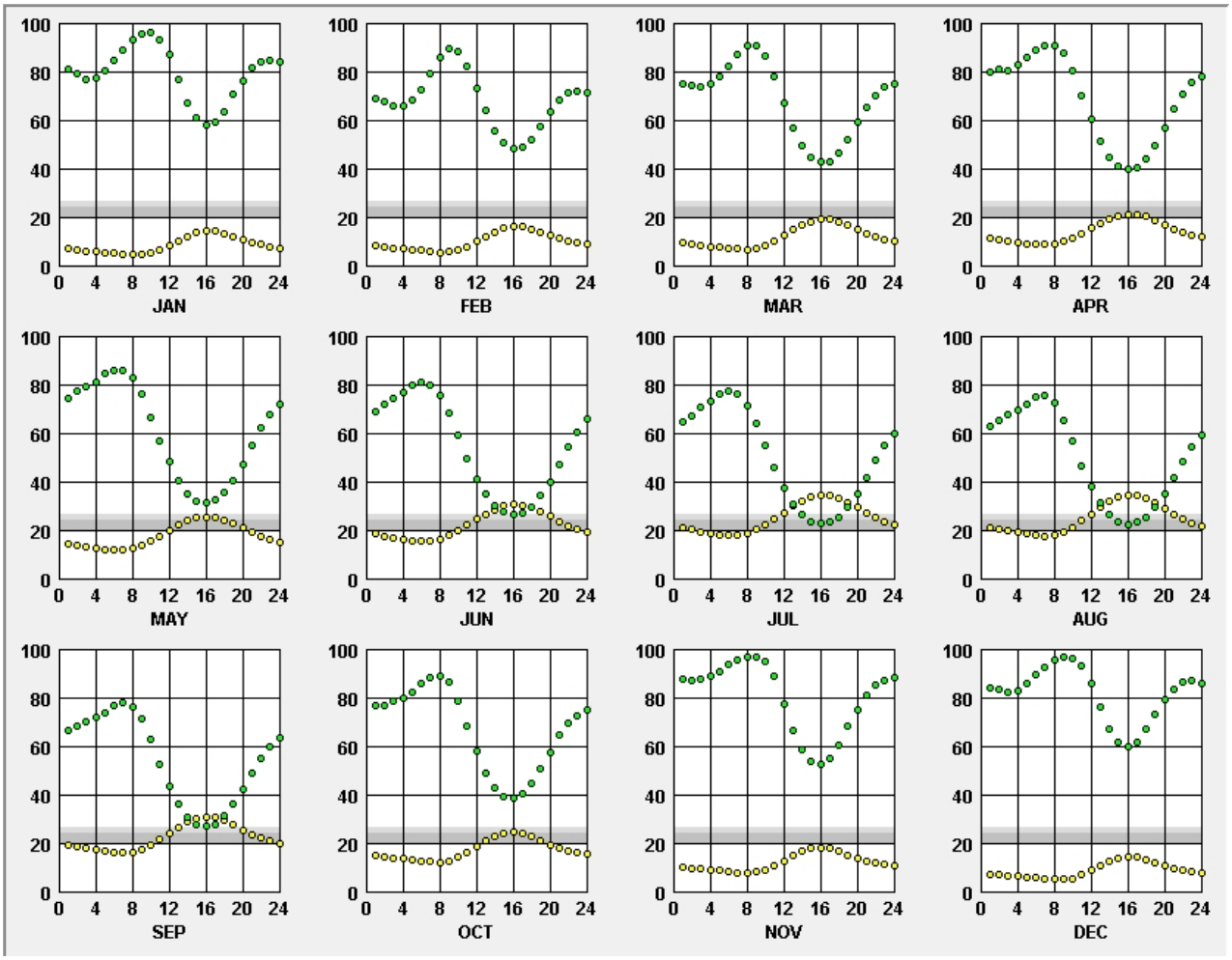
Green: Maximum and minimum design temperatures.

Yellow: Maximum and minimum temperatures with average data.

White: Average temperatures.

Between the months of May to October, inclusive, daily maximum temperatures exceeding 27 degrees Celsius are observed. Being a climate similar to that of Évora, slightly higher temperatures are observed in the warm months, exceeding 35 between the months of June to September.

2.2.3. Hourly temperature and humidity on a typical day/month.

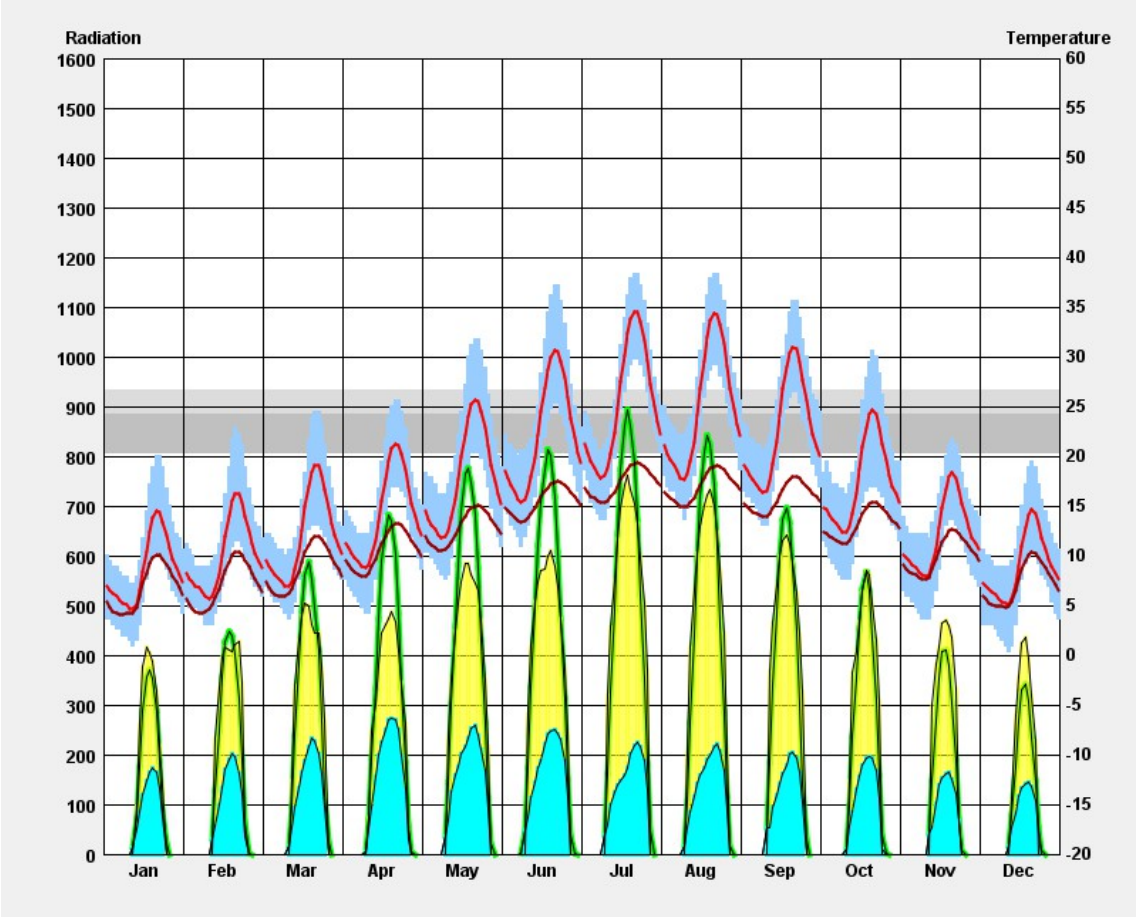


Green: Relative humidity

Yellow: Dry bulb temperature

The high temperatures in the summer months and the dry climate result in relative humidity below 40% from May to October.

2.2.4. Radiation



Radiation (Wh/m^2): Incident radiation in normal plane for a typical day of each month.

Blue: Diffuse

Yellow: Direct normal Green:

Total horizontal plane

Temperature:

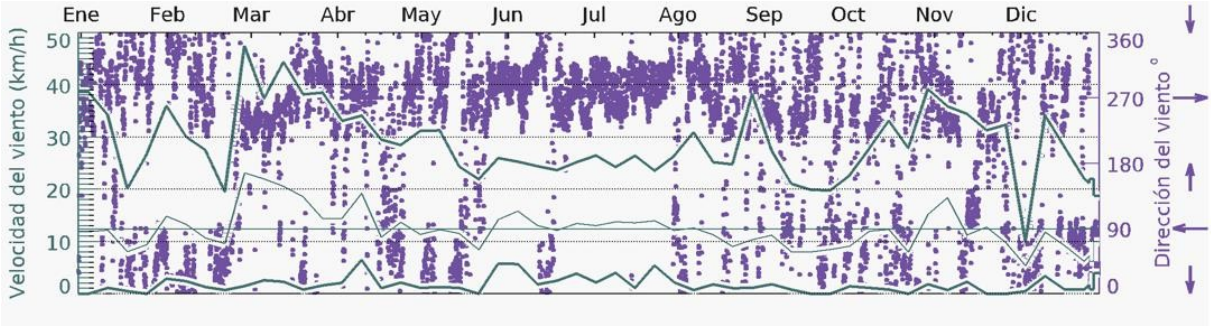
Red line: Dry bulb temperature. Hourly average

Dark red line: Wet bulb temperature. Blue hourly mean: Dry bulb

temperature. All hours

The solar incidence is similar to the location of Évora. However, the temperatures reached are higher, with similar maximum and average records.

2.2.5. Wind



Wind speed data with orientations. https://my.meteoblue.com/

3. CONCLUSIONS

Climatic data from the three locations are presented as a starting basis for the analysis of comfort needs at the application sites.

These data constitute the starting point for the analysis of the environmental conditions against which the different systems or strategies proposed in the schools must operate in order to achieve comfort conditions. Fundamentally in two of them, temperature and humidity.

Data on radiation, illumination, winds, etc., are useful in the management of strategies to achieve comfort. This is discussed in the document 02 and 03 of help to the design of prototypes.

As a general comment on the climates of the 3 locations, it can be said that there is a great similarity between Évora and Badajoz due to their proximity and the same latitude. Porto has significant differences in temperature, being more moderate in both winter and summer. Humidity is higher and solar incidence is lower.

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