Africa-Europe Bioclimatic Collaboration 21

Africa-Europe BioClimatic buildings for XXI century

ICBMB 2023 conference

FCiências ID
ASSOCIAÇÃO PARA A INVESTIGAÇÃO E DESENVOLVIMENTO DE CIÊNCIAS

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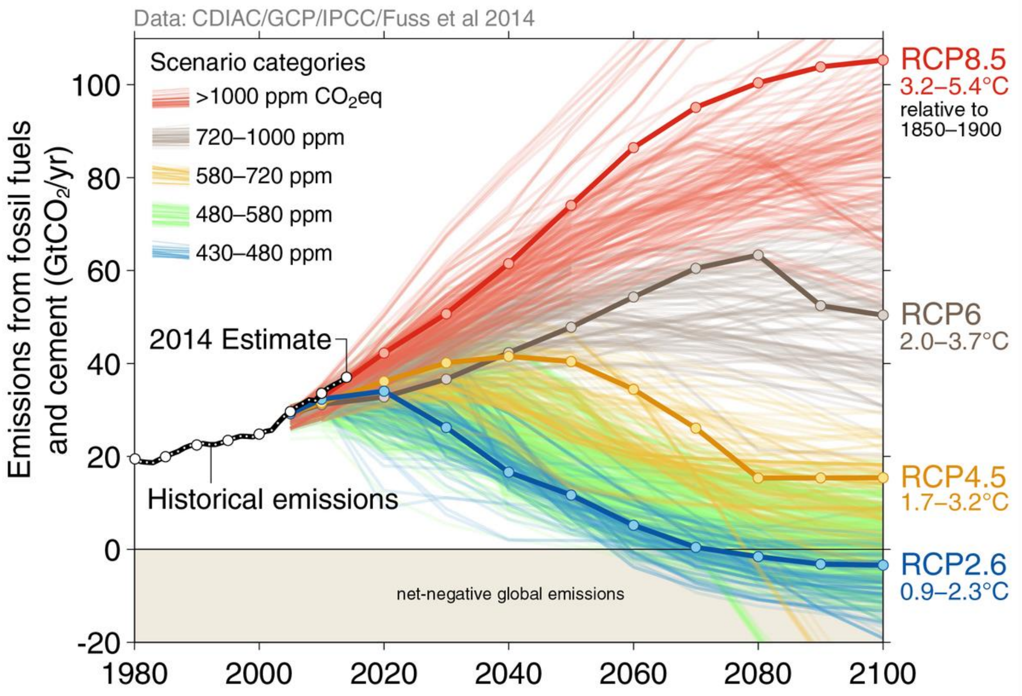
ABC 21 project has received funding from the EU's Horizon 2020 research and innovation programme under Grant Agreement No. 894712.

Upcoming climate change and chalenges

- During the last century, climate change (CC) increased global average temperature by 0.85 °C.
- In a business as usual scenario, a further increase of 4 °C is expected by the end of this century.
- This increase varies between regions of the globe, seasons and time of day.



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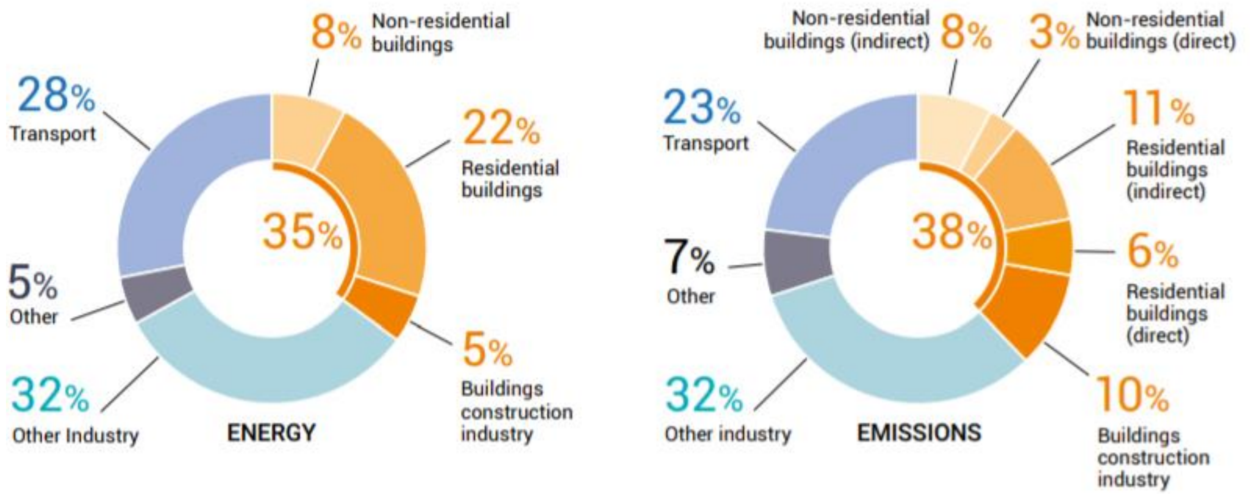
The need for future weather in building design

- To compound the problem, continuous urban development accentuates the effects of climate change in large urban areas.
- Buildings are responsible for 30% of the primary energy consumption
- Most existing of studies of the impact of CC in buildings predict a decrease in heating and an increase in cooling energy consumption or demand.
- Passive strategies may change less and their effectiveness in future climate needs to be analysed.



IEA, Shares of primary energy consumption by sector, 2020, IEA, Paris

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Generation of Future Weather Files: Weather databases

Currently there are no databases for future weather files that incorporate the most recent predictions of upcoming climate change.

Database	Type	Available for Europe	Available for Africa
EnergyPus WeatherData	free	188 locations	153 locations
Climate One Building	free	3454 locations	896 locations
Meteonorm	paid	1640 locations	600 locations
White Box Technologies	paid	+3400 locations	+800 locations
Weather Source	paid	any location	any location
PVGIS	free	any location	any location
Solcast	paid	any location	any location
SOLARGIS	paid	any location	any location
SIREN	paid	any location	any location

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Generation of Future Weather Files: Data elements present in weather files

	Element	Symbol	Unit	Resolution
	Date	-	YYYY/MM/DD	-
	Time	-	HH:MM	-
OUTDOOR AIR CONDITIONS	Dry-bulb Temperature	T_{db}	Degree Celsius	0.1 °C
	Dew-point Temperature	T_{dp}	Degree Celsius	0.1 °C
	Relative Humidity	ϕ	Percentage	1%
	Atmospheric Pressure	p	Pascal	0.1 Pa
LOCAL SOLAR DATA	Global Horizontal Irradiance	G_h	Watt-hour per square meter	1 Wh/m^2
	Direct Normal Irradiance	$G_{D,\perp}$	Watt-hour per square meter	1 Wh/m^2
	Diffuse Horizontal Irradiance	$G_{h,\mathrm{df}}$	Watt-hour per square meter	1 Wh/m^2
LOCAL WIND PROFILE	Wind Direction	θ_{w}	Degree	1 °
	Wind Speed	u_{w}	Meter per second	0.1 m/s

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Generation of Future Weather Files for Thermal Simulation

HISTORICAL DATA

Climate.OneBuilding.Org

Most recent EPW files 2004-2018

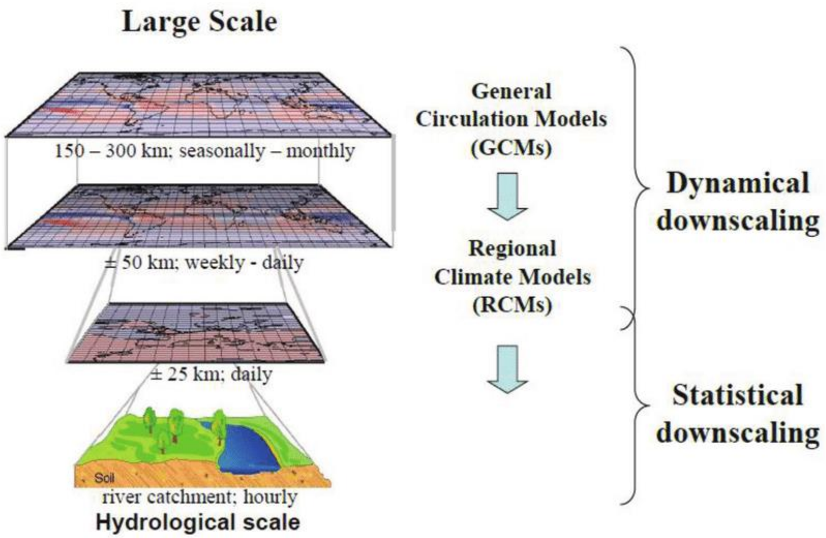
+

FUTURE DATA

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

Monthly climate data from multiple models
(CORDEX):

- Mid-century 2050 (2040-2060)
- End-century 2090 (2080-2100)



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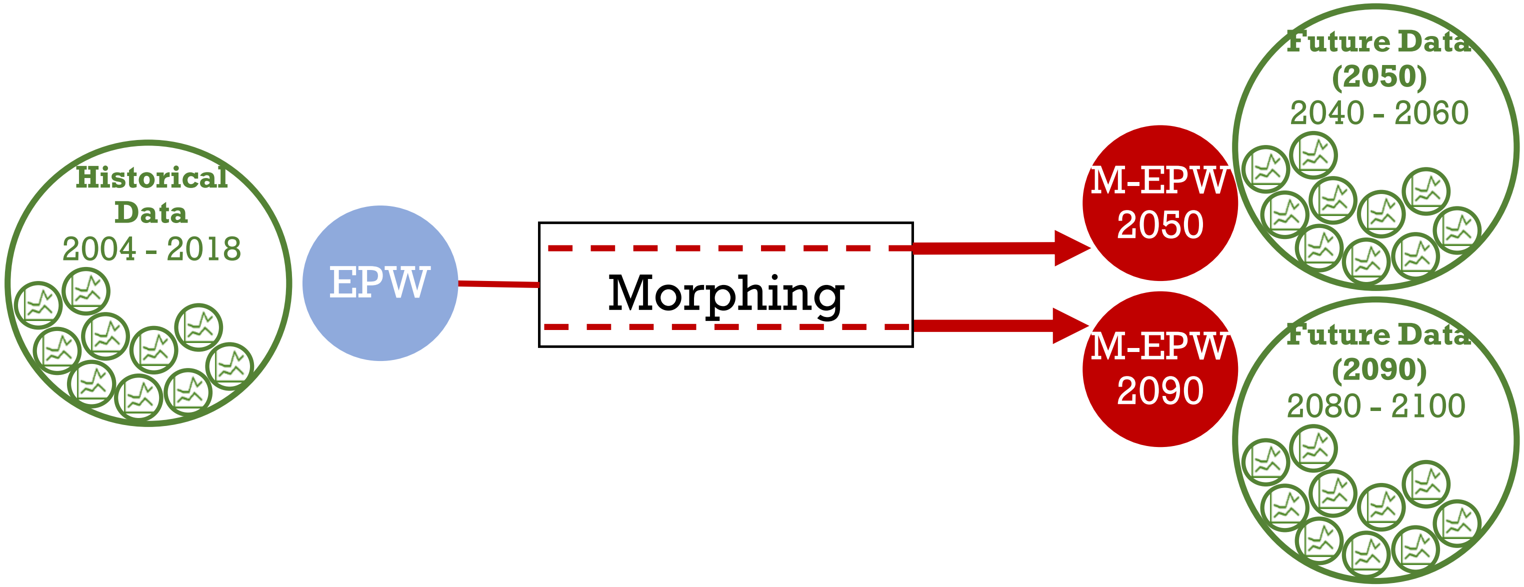
Generation of Future Weather Files for: Morphing current files into future weather files

<u>9 locations, two future periods -> 18 new files</u>



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Open Access Weather Files for Thermal Simulation

City	Weather Station Location	Weather Period	Download Link (click below to download)
Milan (Italy)	Milan-Linate Airport	2004-2018	Milan 2004-2018
		2040-2060	Milan 2040-2060
		2080-2100	Milan 2080-2100
Rabat (Morocco)	Rabat-Sale Airport	2004-2018	Rabat 2004-2018
		2040-2060	Rabat 2040-2060
		2080-2100	Rabat 2080-2100
Midelt (Morocco)	Midelt (urban area)	2004-2018	Midelt 2004-2018
		2040-2060	Midelt 2040-2060
		2080-2100	Midelt 2080-2100
Wien (Austria)	Wien (urban area)	2004-2018	Wien 2004-2018
		2040-2060	Wien 2040-2060
		2080-2100	Wien 2080-2100
Lisbon (Portugal)	Lisbon (urban area)	2004-2018	Lisbon 2004-2018
		2040-2060	Lisbon 2040-2060
		2080-2100	Lisbon 2080-2100
Nairobi (Kenya)	Nairobi-Kenyatta Airport	2004-2018	Nairobi 2004-2018
		2040-2060	Nairobi 2040-2060
		2080-2100	Nairobi 2080-2100
Dakar (Senegal)	Dakar-Senghor Airport	2004-2018	Dakar 2004-2018
		2040-2060	Dakar 2040-2060
		2080-2100	Dakar 2080-2100
Saint-Denis (La Reunion, France)	Roland Garros Airport	2004-2018	Saint-Denis 2004-2018
		2040-2060	Saint-Denis 2040-2060
		2080-2100	Saint-Denis 2080-2100
Lomé (Togo)	Lomé-Tokoin-Eyadema Airport	2004-2018	Lomé 2004-2018
		2040-2060	Lomé 2040-2060
		2080-2100	Lomé 2080-2100

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Review of available weather indicators for Africa and EU

Heating and Cooling Degree Days

Mean daily degree-days (hourly basis)

$$\text{HDD} = \sum_{d=1}^{N}\left(\frac{1}{24}\sum_{j=1}^{24}\left[T_{\text{b},h} - T_{\text{out},j}\right]^{+}\right)_{d} \qquad \text{CDD} = \sum_{d=1}^{N}\left(\frac{1}{24}\sum_{j=1}^{24}\left[T_{\text{out},j} - T_{\text{b},c}\right]^{+}\right)_{d}$$

	Lisbon	Milan	Wien	Rabat	Midelt	Nairobi	Dakar	Saint-Denis	Lomé
2010's	3 Warm	4 Mixed	4 Mixed	3 Warm	3 Warm	3 Warm	1 Very hot	1 Very hot	0 Extremely hot
2050's	3 Warm	3 Warm	4 Mixed	3 Warm	3 Warm	2 Hot	0 Extremely hot	1 Very hot	0 Extremely hot
2090's	2 Hot	3 Warm	3 Warm	2 Hot	2 Hot	2 Hot	0 Extremely hot	0 Extremely hot	0 Extremely hot

Thermal climate zone characterization.

Thermal zone	Name	SI Units
0	Extremely hot	6000 < CDD10
1	Very hot	5000 < CDD10 ≤ 6000
2	Hot	3500 < CDD10 ≤ 5000
3	Warm	CDD10 < 3500 HDD18.3 ≤ 2000
4	Mixed	CDD10 < 3500 2000 < HDD18.3 ≤ 3000
5	Cool	CDD10 < 3500 3000 < HDD18.3 ≤ 4000
6	Cold	4000 < HDD18.3 ≤ 5000
7	Very cold	5000 < HDD18.3 ≤ 7000
8	Subarctic/arctic	7000 < HDD18.3

ASHRAE 169-2020 thermal climate zone classification system.

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Review of available weather indicators for Africa and EU

Passive Cooling Indicators

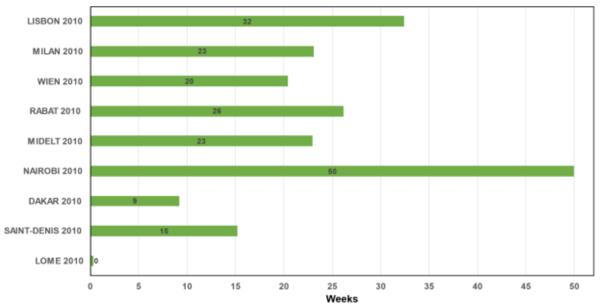
Natural Ventilation Hour (NV hour)

The concept of Natural Ventilation hour is defined as the number of hours in a typical year when the outdoor weather condition is suitable to use passive cooling strategies [Y. Chen et al.]

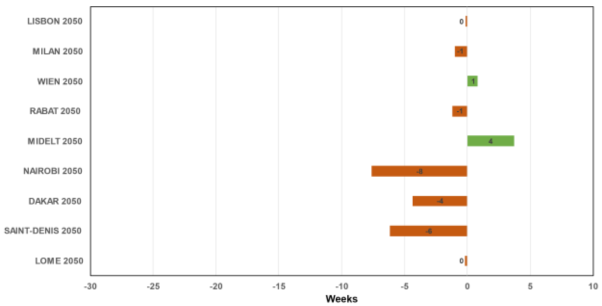
$$\tau_{NV} = \sum_{j=1}^{t_{year}} t_{NV,j} \quad \begin{cases} t_{NV,j} = 1 & T_{out,j} \in \left]12.8\,, T_{in\ max,j}\right[\cap T_{dp}\left(T_{out,j}, \phi_{out,j}\right) < 17 \cap u_{in\ max,j} \in [0\,, 0.8] \\ t_{NV,j} = 0 & T_{out,j} \notin \left]12.8\,, T_{in\ max,j}\right[\cup T_{dp}\left(T_{out,j}, \phi_{out,j}\right) \geq 17 \cup u_{in\ max,j} \notin [0\,, 0.8] \end{cases}$$

$$T_{in\ max,j} = 0.31\bar{T}_{out,j} + 21.3 \qquad u_{in\ max,j} = \sqrt{C_1 u_{out,j}^2 + C_2 H \Delta T_{max,j} + C_3} \qquad \Delta T_{max,j} = T_{in\ max,j} - T_{out,j}$$

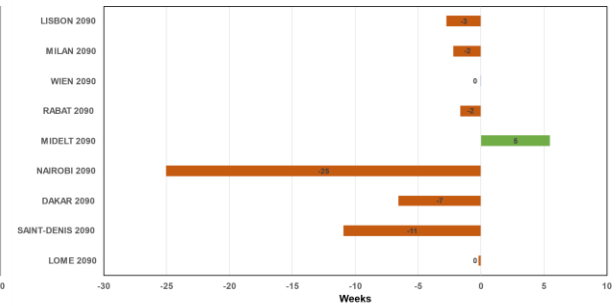
2010



2050



2090



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Review of available weather indicators for Africa and EU

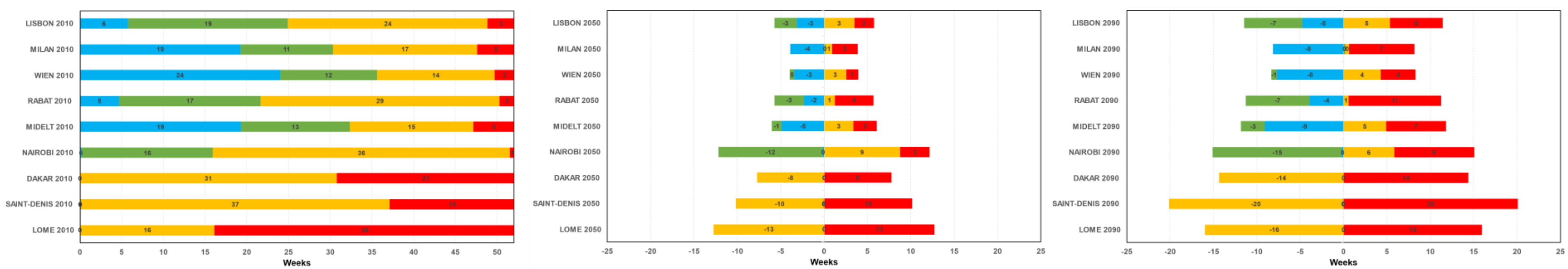
Passive Cooling Indicators

Suitability of air temperature for natural ventilation (S_{NV})

The suitability of air temperature for natural ventilation (S_{NV}) is expressed as a total number of suitable hours for NV in the typical year considering that NV can only perform during the working period (9h-18h). The assessment considers four intervals of outdoor dry-bulb temperature

$$S_{\mathrm{NV}} = \begin{cases} T_{\mathrm{out}} \leq 10 & \text{Too cold} \\ 10 < T_{\mathrm{out}} \leq 16 & \text{Suitable for NV/fresh air supply} \\ 16 < T_{\mathrm{out}} \leq 26 & \text{Suitable for NV based ventilative cooling} \\ T_{\mathrm{out}} > 26 & \text{Too warm for NV} \end{cases}$$

2010 **2050** **2090**



■ TC - Too Cold for NV ■ NV - Suitable for NV/fresh air supply ■ VC - Suitable for NV based ventilative cooling ■ TW - Too Warm for NV

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Energy efficient design: Case Study

CML KINDERGARTEN, PORTUGAL

Year of construction: 2013

Floor Area: 580 m^2

Window-to-wall ratio: 18%

Natural ventilation strategy: Single-Sided and Displacement Ventilation

Openable Area to Floor Area Ratio: 8%

Thermal Mass (ISO 13790): Heavy

Occupant density: 2,4 m^2/p

Hours of occupancy: 70 h/week

Sensible Internal loads: 53 W/m^2

Inside and exterior views of the CML Kindergarten.

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Energy efficient design: Simulation Model

Exterior view of the geometric model of the building.

25 Thermal zones

Validated Three node Displacement Ventilation model

Heat pump with a nominal COP of 3.5

PV with a total area of 10 m²

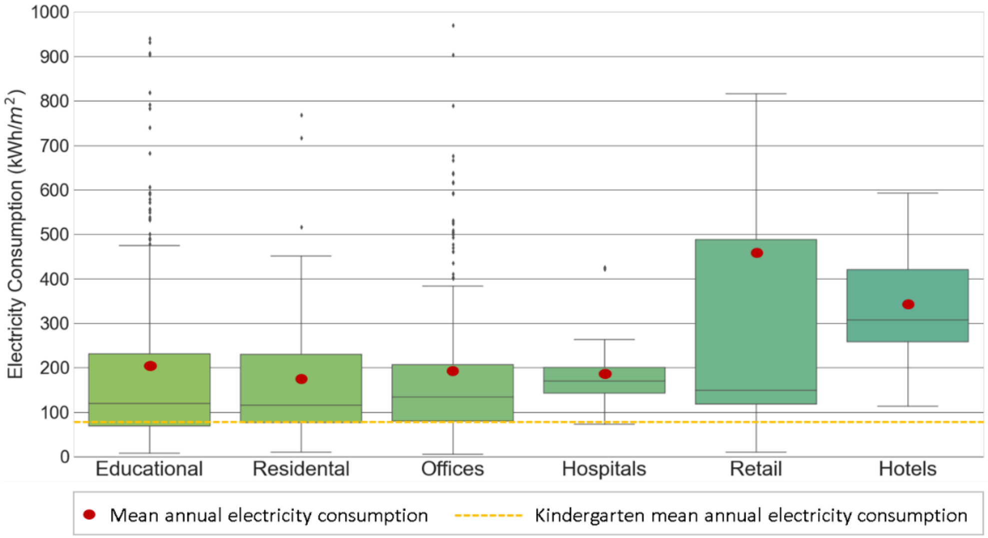
Total Electric energy use: 77.9 [kWh/m²/year]

Renewable Primary energy generated: 8.1 [kWh/m²/year]

Renewable energy self-consumed: 7.6 [kWh/m²/year]

Total Primary energy use: 193.4 [kWh/m²/year]

539 educational buildings: 199 [kWh/m²/year]



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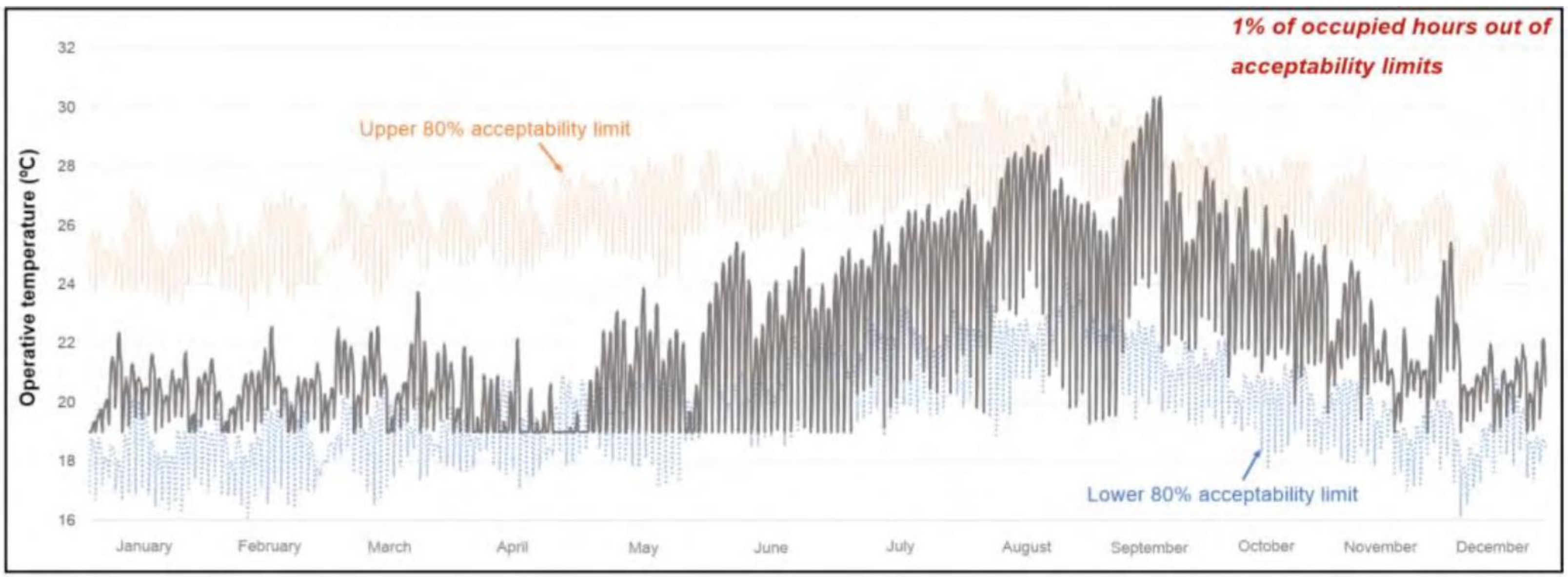
Energy efficient design: Simulation Results

Adaptative comfort approach

The base temperature is defined according to the adaptative comfort models proposed by EN 15251:2007 Standard or ASHRAE Standard 55-2017.

$0.31\bar{T}_{out} + 14.3^{o}C$ $0.31\bar{T}_{out} + 21.3^{o}C$ (ASHRAE 55-2013)



CML KINDERGARTEN OPERATIVE TEMPERATURE ADAPTIVE COMFORT ANALYSIS (ASHRAE 55-2010).

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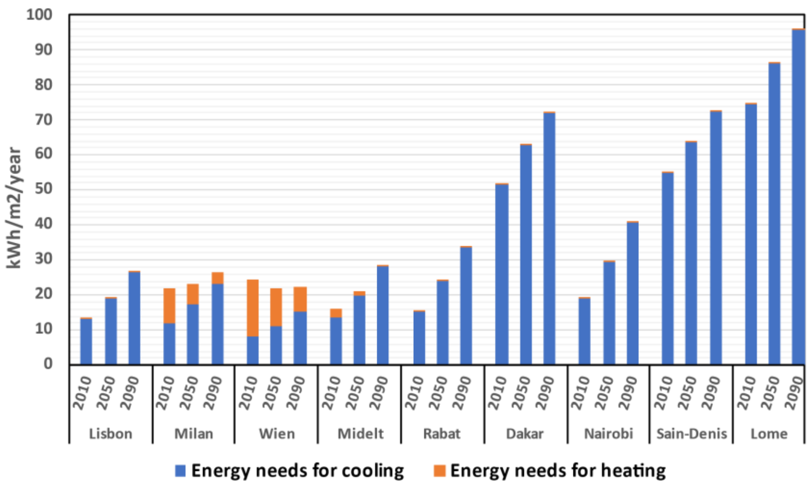
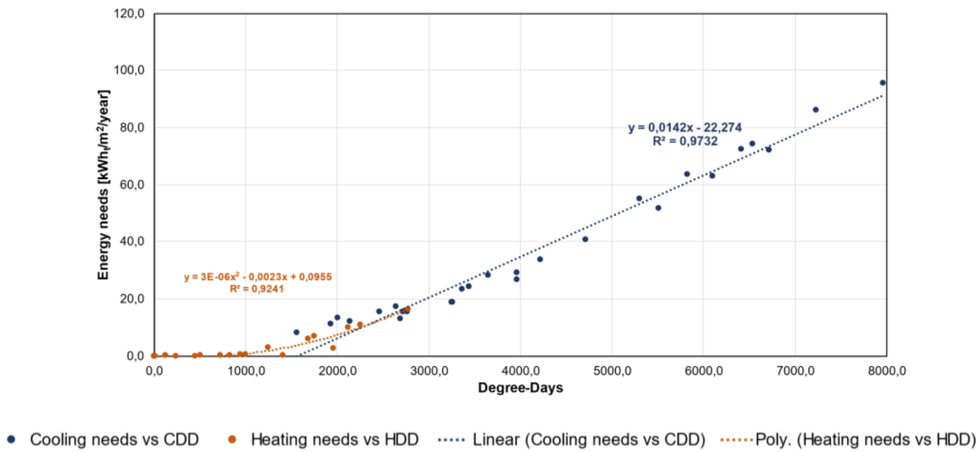
Energy efficient design: Simulation Results





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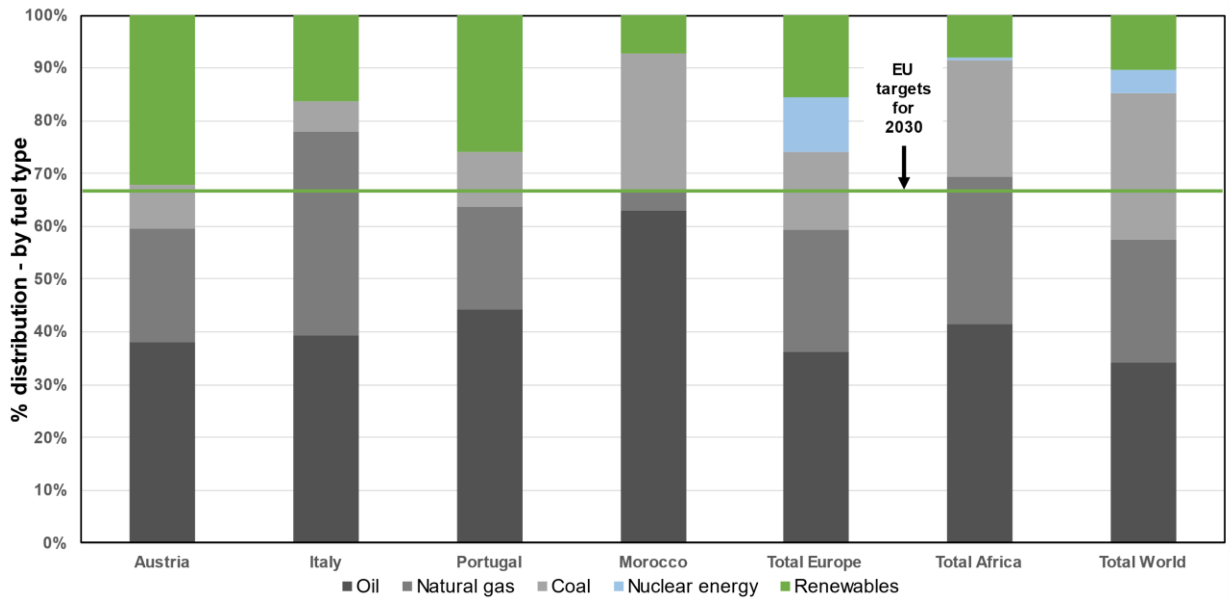
Energy efficient design: Simulation Results



British Petroleum, BP Statistical Review of World Energy, 2019, 68 edition.

Lisbon	Milan	Wien	Rabat	Midelt	Nairobi	Dakar	Saint-Denis	Lomé
2,62	2,63	2,45	3,30	3,30	3,05	3,05	3,05	3,05

Primary energy factor considered.

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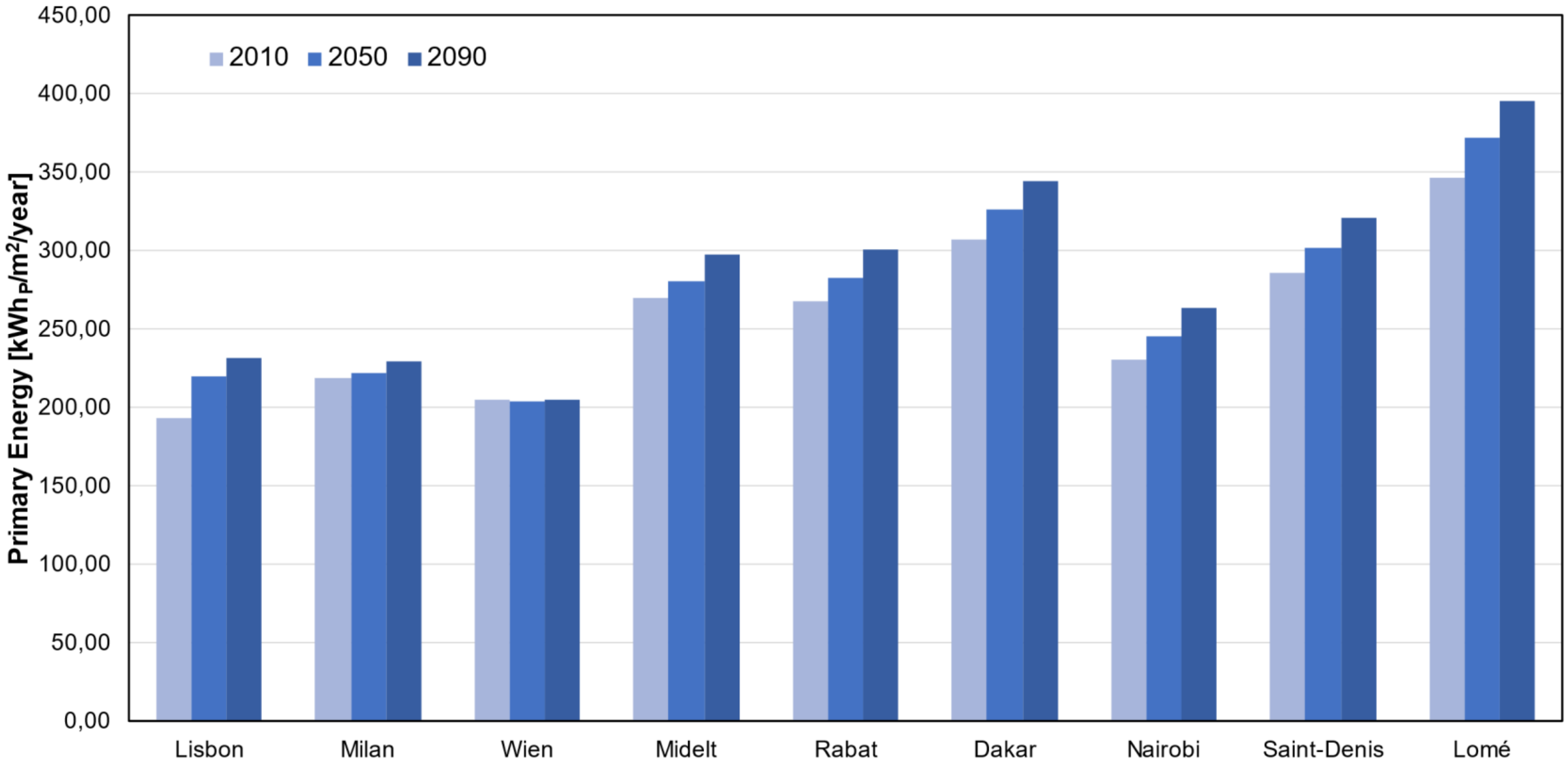
Energy efficient design: Simulation Results



Primary energy consumption for studied cities in 2010, 2050 and 2090 scenarios

The highest values of primary energy consumption correspond to those with hottest climate classifications (Dakar, Saint-Denis and Lomé)

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Thank You!
Q & A

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