Climatic conditions for HVAC calculations

HEATING VENTILATION AIR CONDITIONING SYSTEMS
04-03-2025
Jacopo Vivian

Climatic conditions

Weather vs Climate

Weather and climate are not the same thing!

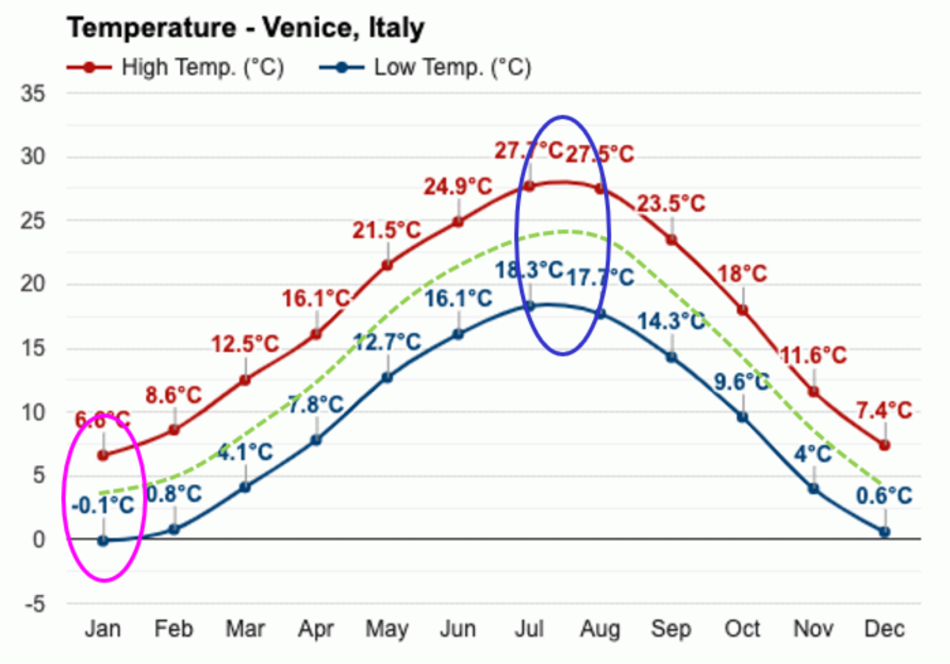
	Weather	Climate
Period to be evaluated	Short-term (hours to days)	Long-term (decades to centuries)
Variability	High Difficult to predict due to sudden changes (storms, heatwaves, cold air fronts etc)	Low Consistent patterns over time (average temperatures, humidity etc in different season)

Climatic conditions

Weather vs Climate

For HVAC systems calculations we use climate data:

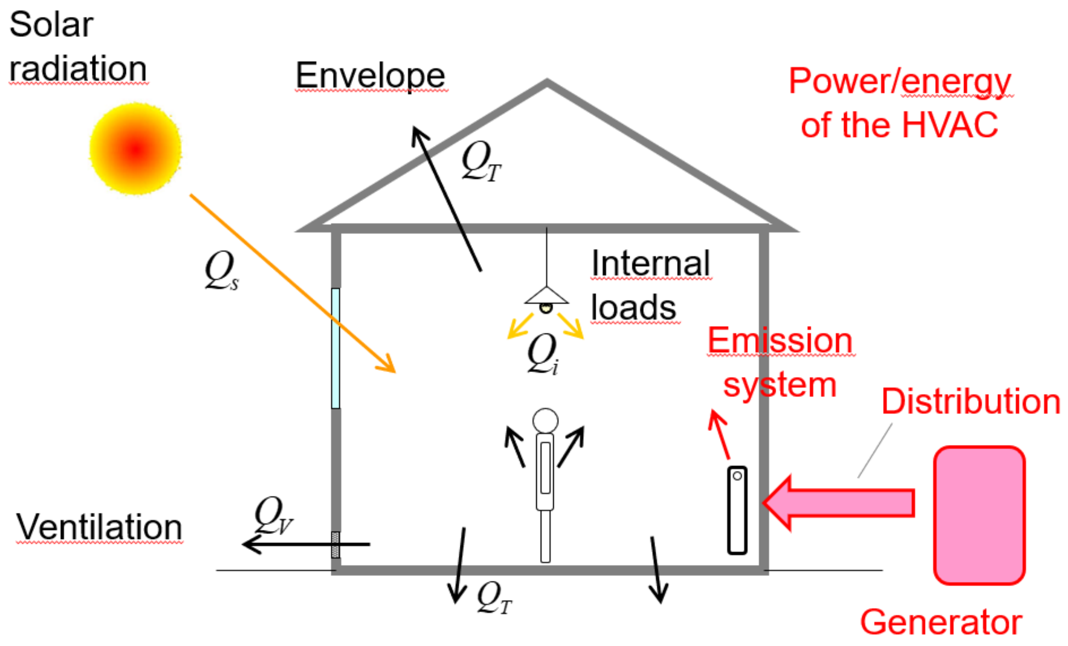
- Outdoor air temperature
- Humidity
- Wind speed and direction
- Solar radiation



Climatic conditions

Boundary conditions for the heating season

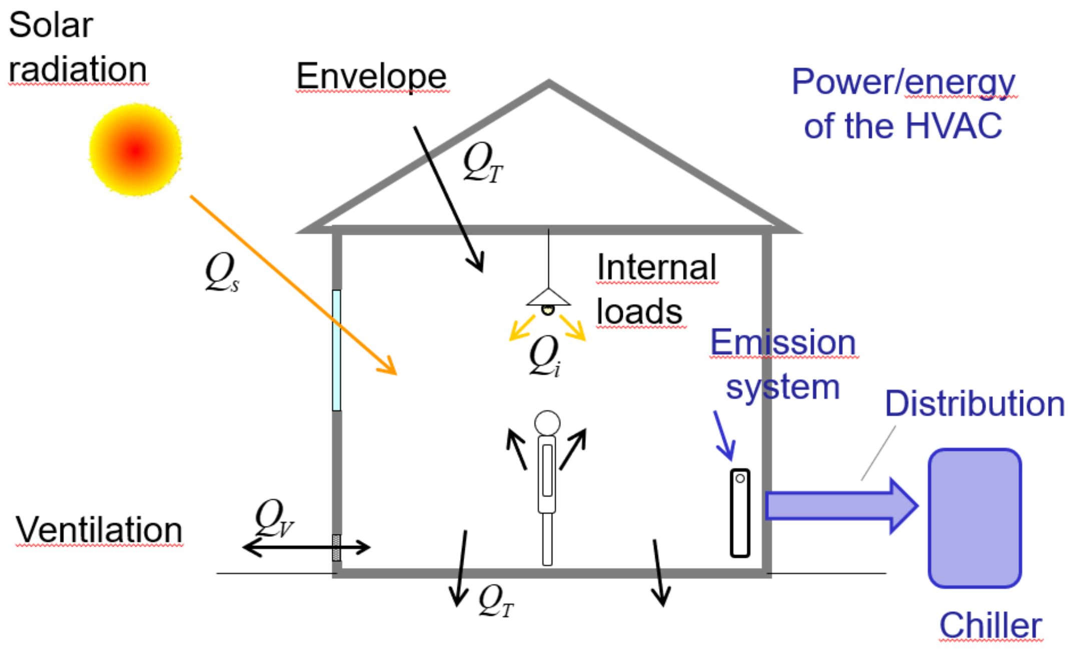
Heating peak load (kW) and heating demand (kWh/year).



Climatic conditions

Boundary conditions for the cooling season

Cooling peak load (kW) and cooling demand (kWh/year).



Climatic conditions

Objectives

Climatic variables are boundary conditions for the calculation of HVAC system.

	Constraint	Calculation method (heating)	Calculation method (cooling)
Design	Peak load (kW)	Steady-state	Dynamic
Consumption	Energy demand (kWh)	Quasi steady-state Dynamic	Dynamic

Climatic conditions

Formats

Climatic variables can be formulated as:

- Test Reference Year: 8760 hourly values;
- Average monthly: 12 average monthly values
- Typical days: 24 hourly values for a representative day of the selected month
- Design temperature: minimum/maximum air temperature
- Only for air temperatures: degree days

Design

Design conditions for the heating system

Boundary conditions for the design of the heating system:

- Lowest outdoor air temperature
- No solar radiation
- No internal heat gains
- Constant indoor air temperature (20°C)

Design

Design conditions for the heating system

Lowest outdoor air temperature

from the analysis of climate data

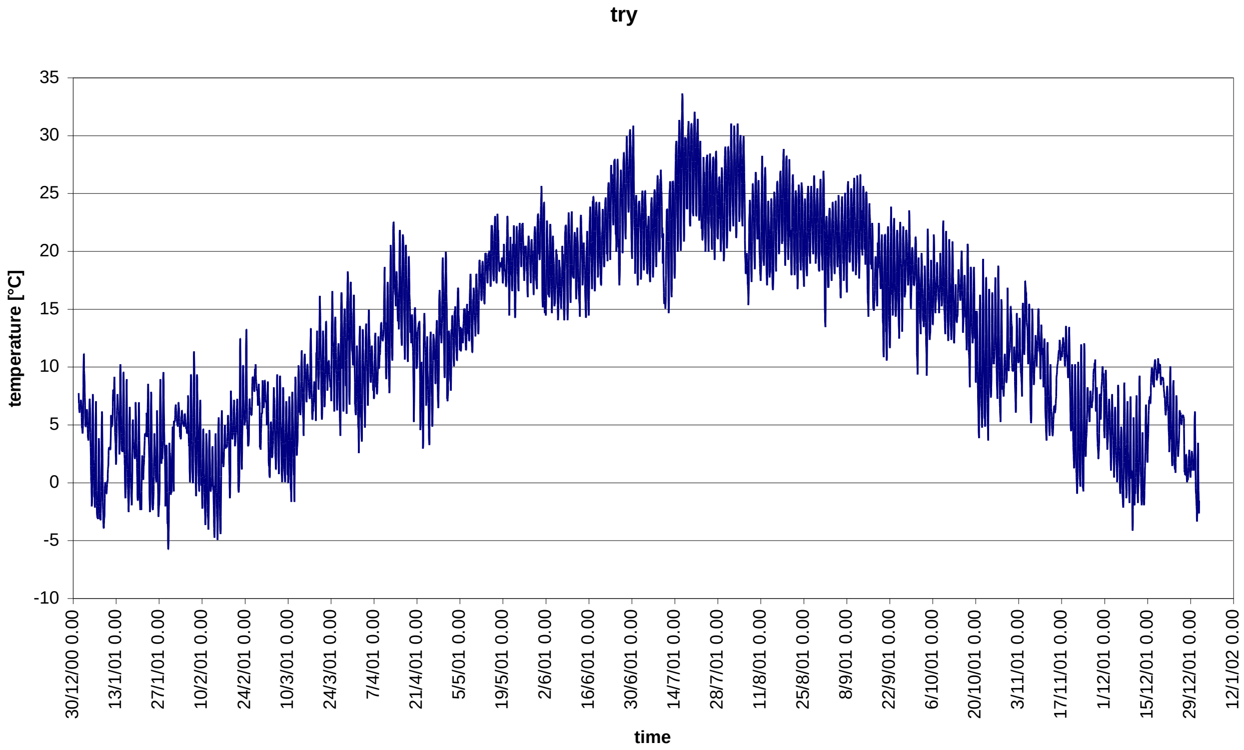
	Heating coldest month		
	[n]	DB 99.6% [°C]	DB 99.0% [°C]
Abu Dhabi	1	11.5	12.9
Athens	2	1.6	3.1
Auckland	7	1.8	2.9
Bangkok	12	19	20.4
Beijing	1	-10.8	-9.1
Berlin	2	-11.8	-10.8
Buenos Aires	7	-0.1	1.3
Cairo	1	7.7	8.7
Cape Town	7	3.8	5
Caracas	2	20.7	21.2
Chicago	1	-20	-16.6
Dakar	2	16.5	16.9
Debrecen	1	-13.8	-10.9
Helsinki	2	-22.8	-19.1
Houston	1	-1.6	0.5
Lima	8	14	14.6
London	2	-4.6	-3
Melbourne	7	2.8	3.8
Mexico City	1	4.1	5.6
Montreal	1	-23.7	-21.1
Moscow	2	-23.1	-19.8
Mumbai	1	16.5	17.8

	Heating coldest month		
	[n]	DB 99.6% [°C]	DB 99.0% [°C]
Nairobi	7	9.8	11
New Delhi	1	6.3	7.3
New York	1	-10.7	-8.2
Paris	1	-5.9	-3.8
Phoenix	12	3.7	5.2
Riyadh	1	5.9	7.2
Salt Lake City	1	-12.6	-9.9
San Paulo	7	8.9	10
Seville	1	1.3	2.9
Sidney	7	6	7
Singapore	12	23	23.5
Stockholm	2	-17.8	-14.2
Strasburg	1	-9.8	-7
Tehran	1	-2.8	-1.3
Tokyo	1	-6.9	-5.1
Vancouver	12	-7	-4
Venice	1	-4	-2.8
Washington DC	1	-10.6	-8.2

Design

Design conditions for the heating system

Lowest outdoor air temperature from the analysis of climate data



Design

Design conditions for the heating system

Design outdoor air temperature from UNI 10339 and UNI 10349 useful to size:

- Emission systems (radiators, fancoils etc)
- Generation systems (gas boiler, heat pump etc)

Location	θ_{des} [°C]
Palermo	5
Napoli	2
Roma	0
Firenze	0
Padova	-5
Belluno	-10

Design

Design conditions for the cooling system

Boundary conditions for the design of the heating system:

- Outdoor air temperature profile of warmest summer day
- Constant value of outdoor air absolute humidity
- Solar radiation
- Internal heat gains
- Constant indoor air temperature (26°C) and relative humidity (50%)

Design

Design conditions for the cooling system

Outdoor air temperature profile and humidity of warmest summer day from UNI 10339 and UNI 10349.

Location	$\theta_{e,max}$ [°C]	$\Delta\theta_{e,amb}$ [°C]	$x_{e,max}$ [g/kg]
Palermo	32.6	6.5	13.3
Napoli	32.4	10.5	13.3
Roma	33.8	11	14.2
Firenze	33.6	13	14.6
Padova	32.5	13	15.4
Belluno	31.1	13	12.6

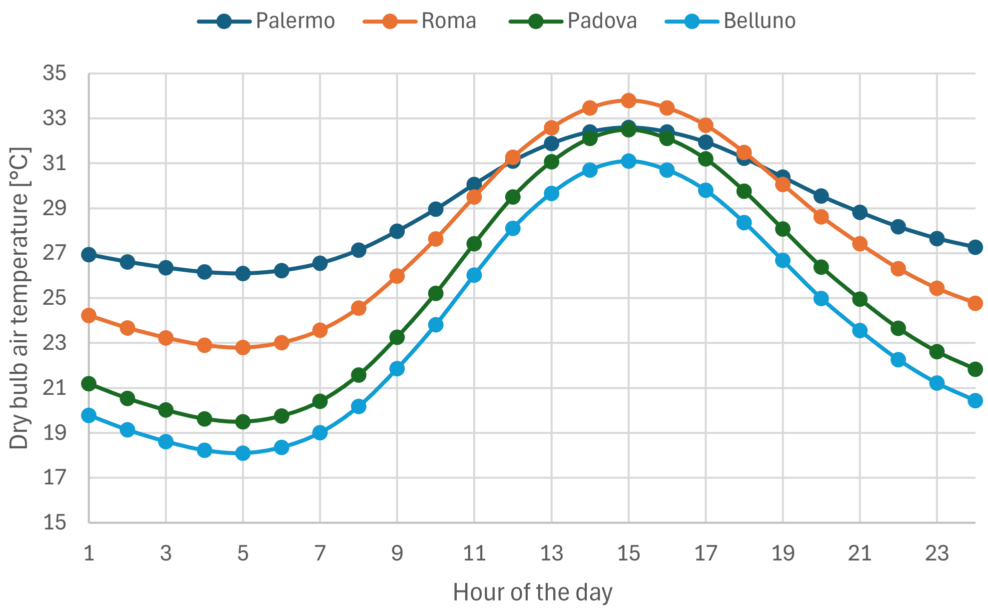
Design

Design conditions for the cooling system

Outdoor air temperature profile of warmest summer day from UNI 10339 and UNI 10349.

$$\theta_e(h) = \theta_{e,max} - p(h)\,\Delta\theta_{e,amb}$$

1	2	3	4	5	6	7	8	9	10	11	12
0.87	0.92	0.96	0.99	1	0.98	0.93	0.84	0.71	0.56	0.39	0.23
13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
0.11	0.03	0	0.03	0.1	0.21	0.34	0.47	0.58	0.68	0.76	0.82



Heating demand

Degree Days method

Degree days (DD): simplified representation of outside air temperature data (effect of outside air temperature on building energy consumptions).

Heating Degree Days (HDD) are a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific base temperature or balance point. They are often used for calculations related to energy consumption required to heat buildings.

Heating demand

Degree Days method

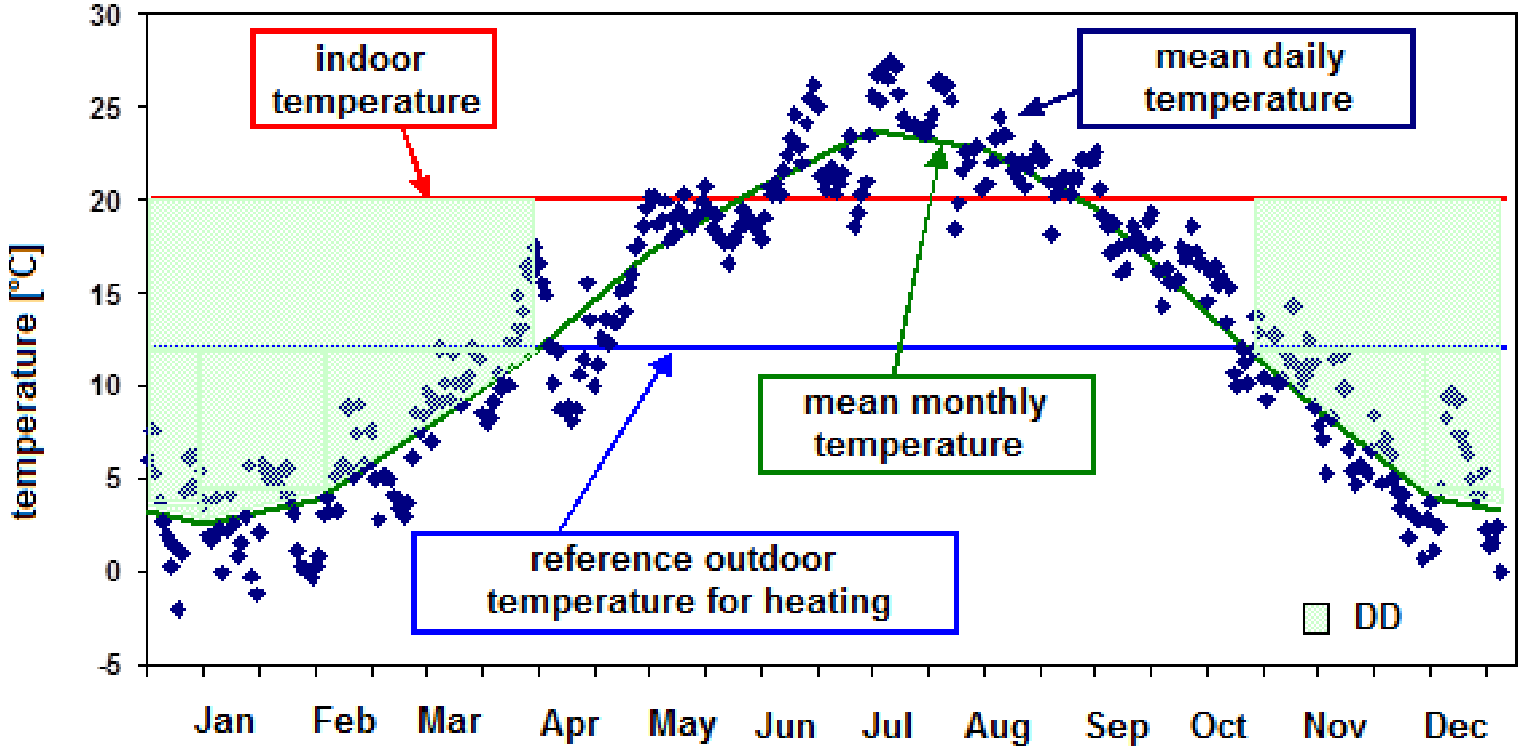
Heating Degree Days (HDD) are the sum over each day j, of the difference between the internal temperature (t_i) and the daily average external (ambient) temperature ($t_{amb,d,j}$).

The limits of the heating/cooling season are usually defined by a threshold external reference temperature below which there is heating and above which there is cooling:

$$HDD = \sum_{j=1}^{365} (t_i - \bar{t}_{amb,d,j}) \qquad \text{if } \bar{t}_{amb,d,j} < t_{threshold,heating}$$

Heating demand

Degree Days method



Cooling demand

Degree Days method

Cooling Degree Days (HDD) are the same in the cooling season, when ambient (outdoor) temperature is above a certain threshold.

CDD is <u>not</u> a reliable method to estimate the cooling demand in our climate because it does not account for the effect of solar radiation and relative humidity.

Cooling demand

Solar radiation

Solar radiation has two components: direct (beam) and diffuse. It is usually represented by at least two variables

Example: Global and Diffuse, Global and Direct, Direct and Diffuse

Sometimes DNI can be used instead of Direct Radiation.

Cooling demand

Solar radiation

Solar radiation increases cooling demand because it increases the heat gains in the indoor environment:

- radiation transmitted through glazed components
- radiation absorbed by opaque components

Cooling demand

Solar radiation

Consequences of the orientation of the surfaces.