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VUB

16-11-2023 – 12H15 – 19H – VUB BRUSSELS

STUDIEDAG ATIC: INDIRECTE VERDAMPINGSKOELING – IEA – ANNEX 85

JOURNEE D'ETUDE ATIC: REFROIDISSEMENT EVAPORATIF INDIRECT – AIE – ANNEXE 85

STUDIEDAG/JOURNEE D'ETUDE ATIC
16 NOVEMBER 2023

Evaporative cooling – IEA Annexe85
Feasibility of IEC/DEC a climatic point of view

MARBAIX Jean-claude - ATIC

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Evaporative cooling !

The key difference between common mechanical refrigeration processes and evaporative cooling process:

- Mechanical refrigeration is feasible in all climates
  => the most important is efficiency, energy saving, COP calculation
- Evaporative cooling is affected by climatic conditions
  =>the most important is feasibility analysis,
  * if it is feasible, then calculation of the efficiency, electricity consumption and COP, water consumption.
  * if it is not feasible, the combination of IEC/DEC with extra power of mechanical refrigeration or dehumidification “could” be studied.

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Definition of feasibility of DEC/IEC

Feasible means : all refrigeration demand can be met independently by Evaporative cooling technology and does not require assistance of other technologies

Non-feasible means : part of the time the refrigeration demand cannot be met independently by Evaporative cooling technology and some other technology is required.

=> first use evaporative cooling technology to pre-cool the supply air and then use electric refrigeration to further decrease the temperature of the supply air

=> first use the rotor recovery to decrease the humidity content of the supply air and then use the evaporative cooling technology to get the required state of supply air

!! use of evaporative technology affect the power consumption of the other technologies (air flow!)

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Indicator method (temperature)

- Wet bulb efficiency
  - $\varepsilon_{wet} = \frac{t_{point} - t_{supply}}{t_{point} - t_{wb,point}}$

- Dew point efficiency
  - $\varepsilon_{dew} = \frac{t_{point} - t_{supply}}{t_{point} - t_{dp,point}}$

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Definition of feasibility

- First compare the humidity ratio of the outdoor air x_{out} with the humidity ratio of the required indoor state point, x_{in}. => If $x_{out} > x_{in}$, it is considered infeasible for that outdoor air condition.

- Then in the area where $x_{out} < x_{in}$, using 1 as the criterion of the indicators (ε_{wet} and ε_{dew}) for judging feasibility, it is considered infeasible if the indicator value is greater than 1. => Calculate the number of non-feasible hours for the two scenarios above. => take some values to bound the feasible region, like 150h, 300h (to discuss)

  - less than 150h, … the climate region is feasible
  - between 150h-300h, … the climate region is partially feasible; some supplementary methods to meet the loads
  - more than 300h, … the climate region is non-feasible to use IEC/DEC alone

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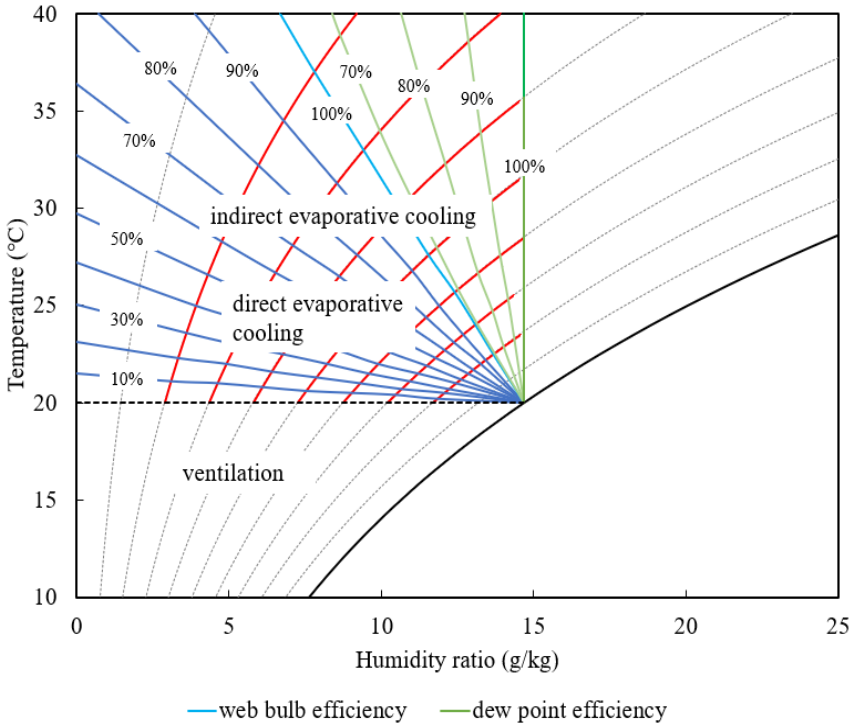
- **Feasibility of IEC/DEC Indicator method Air Cooler t_{supply} = 20° C**

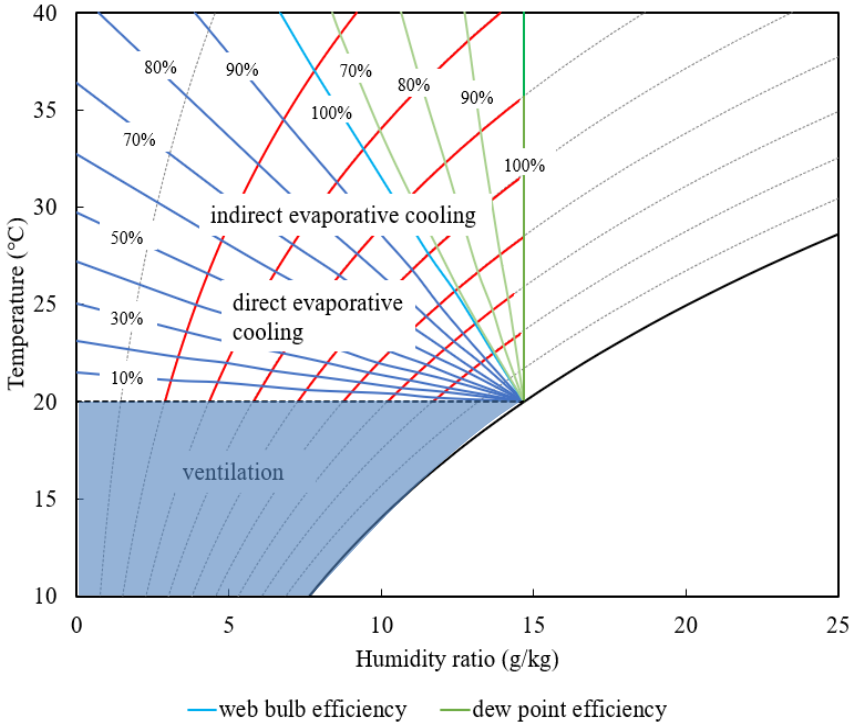


t_{confort} = 26° C
φ = 60%
x = 0,0126 kg/kg
t_{dp} = 17,65° C

<= Iso-efficency lines in psychrometric diagram for 20°C (Mollier !)

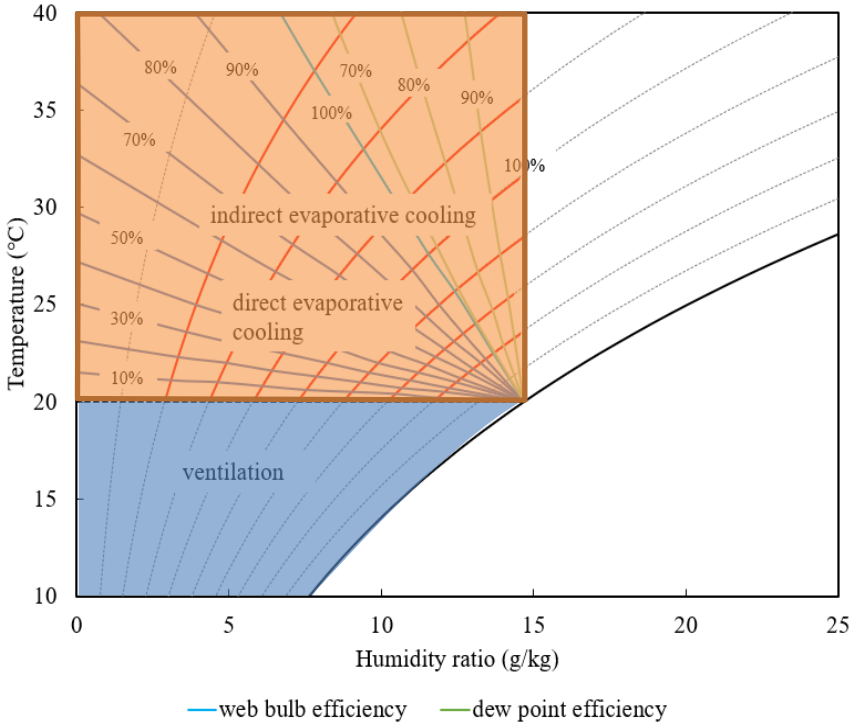
Suitable regions for IEC or DEC

- **Feasibility of IEC/DEC Indicator method Air Cooler t_{supply} = 20° C**



- ✓ Direct ventilation cooling can be used when the outdoor temperature is below 20 ° C
- ✓ In blue area, direct ventilation cooling can be used

- **Feasibility of IEC/DEC Indicator method Air Cooler t_{supply} = 20° C**



- ✓ Direct ventilation cooling can be used when the outdoor temperature is below 20 ° C
- ✓ In blue area, direct ventilation cooling can be used
- ✓ In orange area, only be achieved by evaporative cooling process

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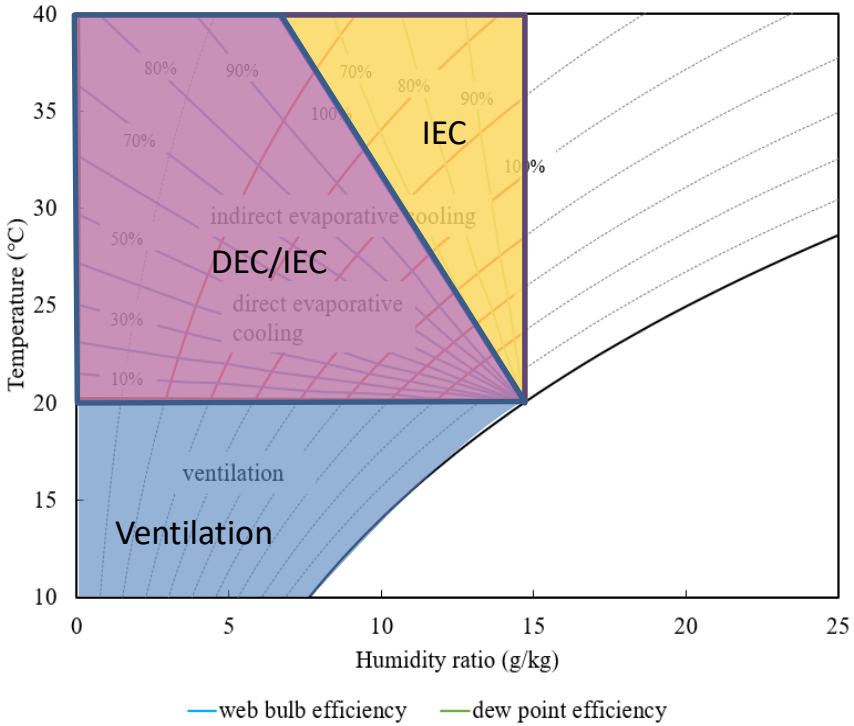
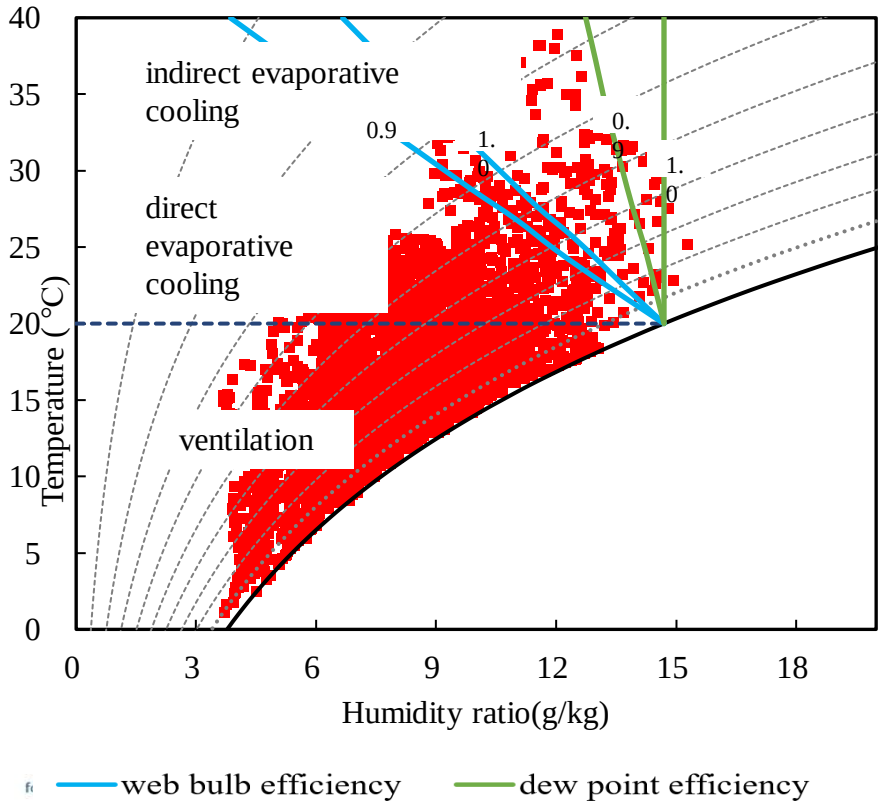


- ✓ Direct ventilation cooling can be used when the outdoor temperature is below 20 ° C

- ✓ In blue area, direct ventilation cooling can be used
- ✓ In orange area, only be achieved by evaporative cooling process
- ✓ In yellow area, only be achieved by an indirect evaporative cooling process
- ✓ In purple area, can be achieved by a direct evaporative cooling or an indirect evaporative cooling process.

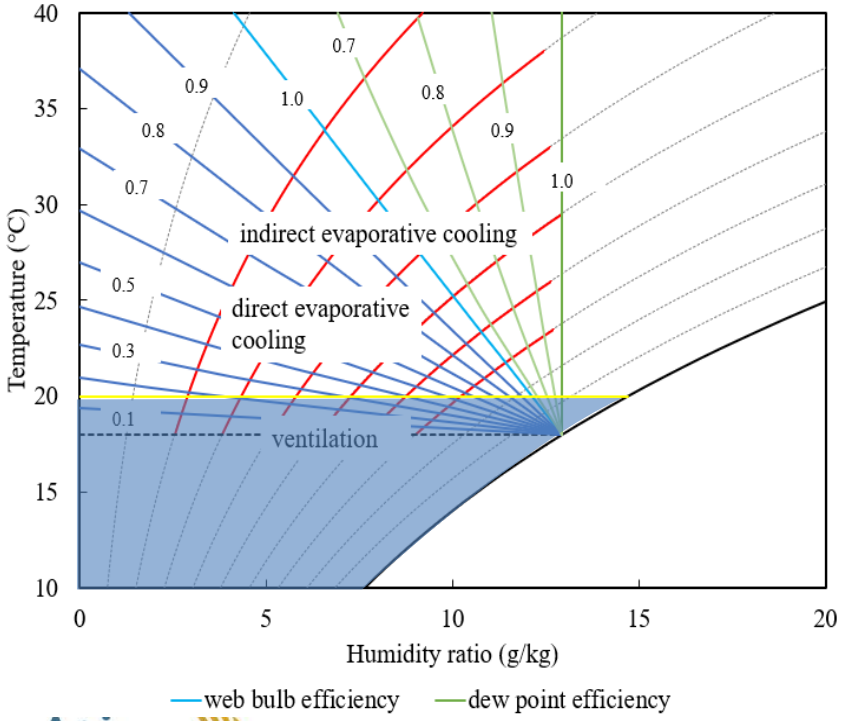
Suitable regions for IEC or DEC

➢ Brussel, Belgium



- ✓ the non-guarantee rate = $\frac{\text{non-feasible hours}}{\text{total hours}}$
- ✓ If using IEC,
  - ✓ When dew point efficiency < 1, the non-guarantee rate is 0.08%.(3h)
  - ✓ When dew point efficiency < 0.9, the non-guarantee rate is 0.52%.(20h)
- ✓ If using DEC,
  - ✓ When wet bulb efficiency < 1, the non-guarantee rate is 3.10%.(119h)
  - ✓ When wet bulb efficiency < 0.9, the non-guarantee rate is 4.58%.(176h)

- **Feasibility of IEC/DEC Indicator method Water chiller system**



t_{water} = 18° C

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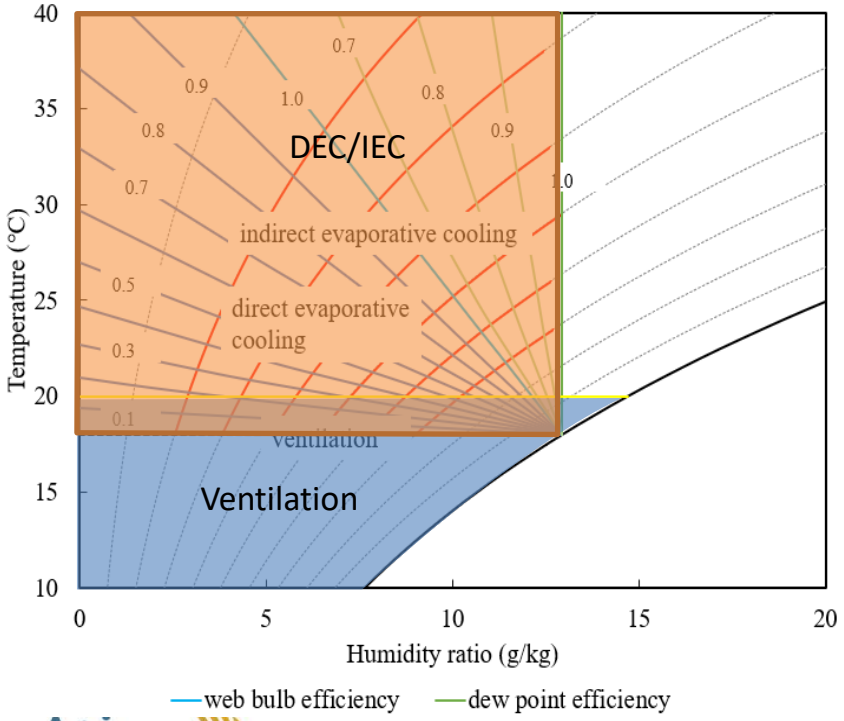
- **Feasibility of IEC/DEC Indicator method Water chiller system**



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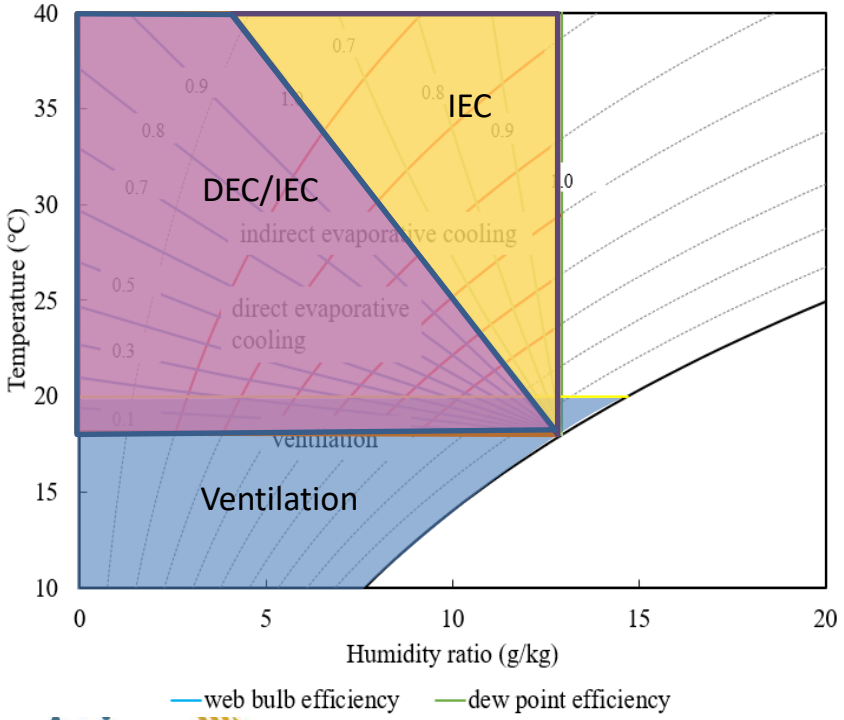

t_{water} = 18° C

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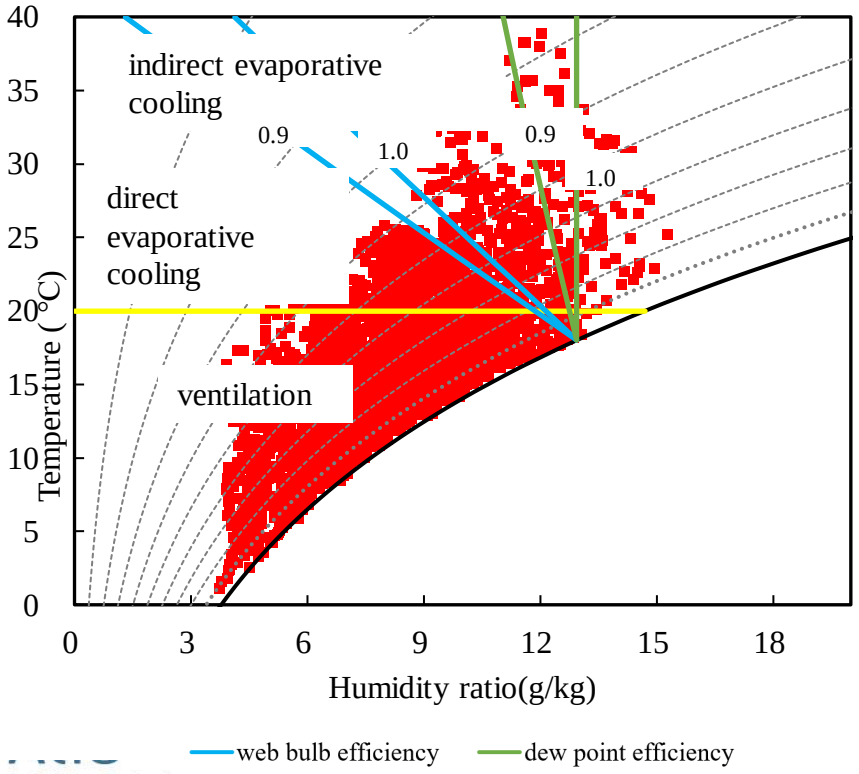

- ✓ the non-guarantee rate = $\frac{\text{non-feasible hours}}{\text{total hours}}$
- ✓ If using IEC,
  - ✓ When dew point efficiency < 1, the non-guarantee rate is 1.72%.(66h)
  - ✓ When dew point efficiency < 0.9, the non-guarantee rate is 3.44%.(132h)
- ✓ If using DEC,
  - ✓ When wet bulb efficiency < 1, the non-guarantee rate is 9.01%.(346h)
  - ✓ When wet bulb efficiency < 0.9, the non-guarantee rate is 10.57%.(406h)

Case study : Building

Sensible heat load: Q_{room} kW
Humidity load generated by personnel is h_{per} g/h
Fresh air volume required per personne m³/h
Temperature & RH confort

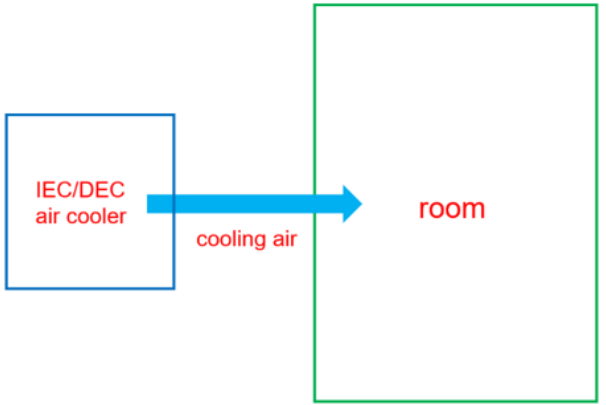

Figure 1. IEC/DEC air cooler system

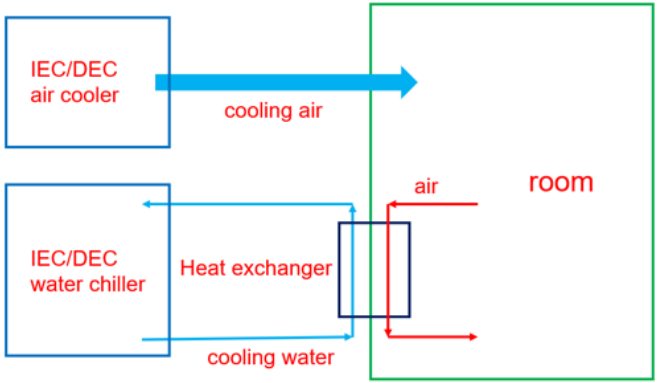

Figure 2. IEC/DEC water chiller system

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Calculation of flow rate of fresh air

- to remove the indoor latent heat load M_d and - to fulfil the healthy requirements of the personnel M_h

$$M_s = \max(M_h, M_d)$$

Choice of $\boldsymbol{t_{supply}}$

$$\Delta t = t_{room} - t_{supply}$$

calculate Q_s removable load $Q_s = M_s * C_{pa}(t_{room} - t_{supply}) = M_s * C_{pa} * \Delta t$

If $Q_s > Q_{room}$ => We can increase t_supply

If $Q_{room} > Q_s$ => IEC/DEC air cooler

- Increase the supply air volume to equalize the two loads.
- Decrease the temperature of the supply air.

=> IEC/DEC water chiller

- Using IEC water chiller to remove the remaining load.

- the value of Δt and Δt_w affects the feasibility judgment,

  => decrease Δt or Δt_w could decrease the demand of the indicator as a result increase the feasible area of IEC/DEC.

  => The smaller the value of Δt or Δt_w, the larger the feasible region will be,

  but at the same time the supply air volume or chilled water flow rate increases, which will lead to an increase in the power consumption, affecting the performance of the system.

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• Climatic point of view for Bruxelles …

TMY Typical Meteorological Year

- standard EN-ISO-15927-4 : 2005 Reference years for building energy simulation
- collection of 12 real months statistically representative
- weighting of the 4 factors that significantly influence building behavior:

air temperature, relative humidity, irradiation and wind speed.

=> Past : [very old 1970-1990!]; [2004-2018]; [2007-2021]
=> Future : based on Climatic Model, Scenario … [2035-2050]
But :
TMY collection of 12 projected months statistically representative, weighted by 2 factors :
air temperature and irradiation
XMY idem but most deviating …

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• Climatic point of view for Bruxelles …

t_supply 20°C	Old file !	TMY2004-18	TMY2007-21	TMY2035-50	
	hours	hours	hours	hours	
ε_wet >1	24	44	30	78	
ε_wet > 0.9	34	81	59	139	
ε_wet > 0.5	145	325	317	588	
ε_dp > 1	0	8	1	0	
ε_dp > 0.9	2	11	5	0	
ε_dp > 0.5	51	136	111	255	
t ≥ 20°C	497	851	873	1215	
x > 0.0126		37	31	34	
T_max °C	30	32.4	33.6	39.48	

t_supply 18°C	Old file !	TMY2004-18	TMY2007-21	TMY2035-50	
	hours	hours	hours	hours	
ε_wet >1	101	232	228	337	
ε_wet > 0.9	130	316	291	463	
ε_wet > 0.5	413	762	794	1062	
ε_dp > 1	22	31	19	32	
ε_dp > 0.9	36	51	40	44	
ε_dp > 0.5	193	399	382	591	
t ≥ 20°C	946	1339	1418	1726	

TIPS !

1 year = 365 days = 8760 h

tconfort = 26°C φ = 60 %

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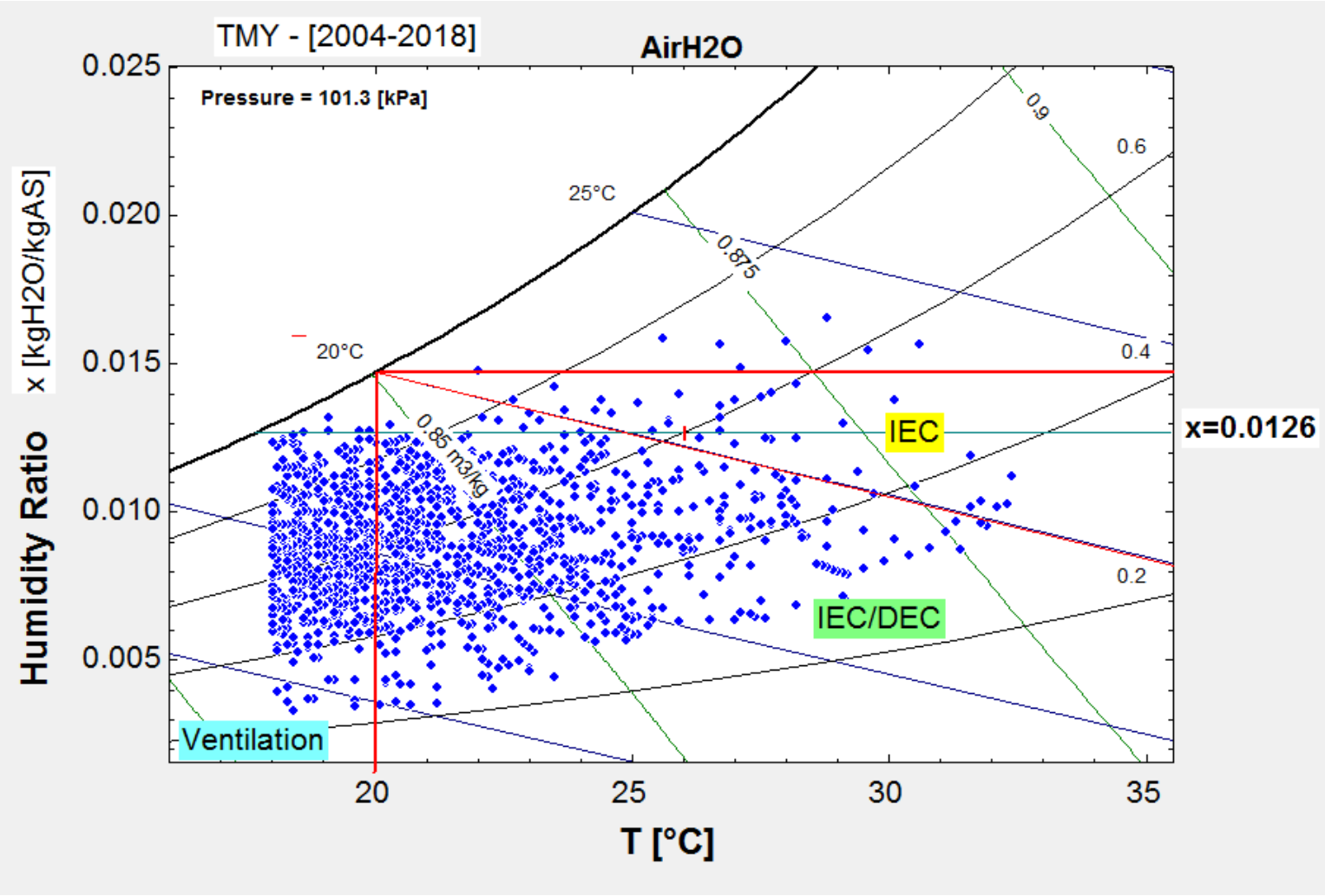
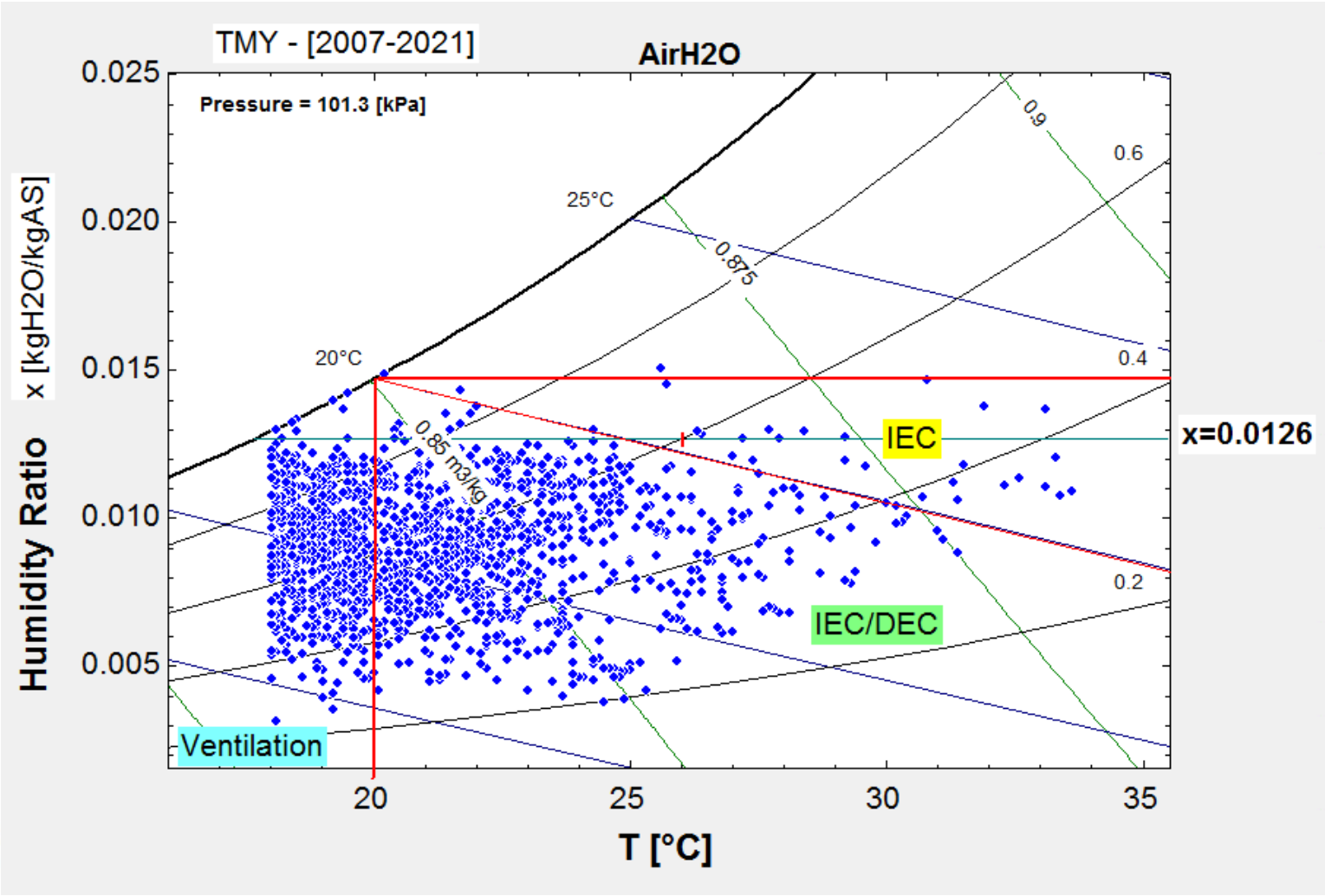

TMY - [2004-2018]
AirH2O
Pressure = 101.3 [kPa]
Humidity Ratio x [kgH2O/kgAS]
0.025
0.020
0.015
0.010
0.005
25°C
20°C
0.9
0.6
0.875
0.4
0.2
0.85 m3/kg
IEC
x=0.0126
IEC/DEC
Ventilation
20
25
30
35
T [°C]


TMY - [2007-2021]
AirH2O
Pressure = 101.3 [kPa]
Humidity Ratio x [kgH2O/kgAS]
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0.020
0.015
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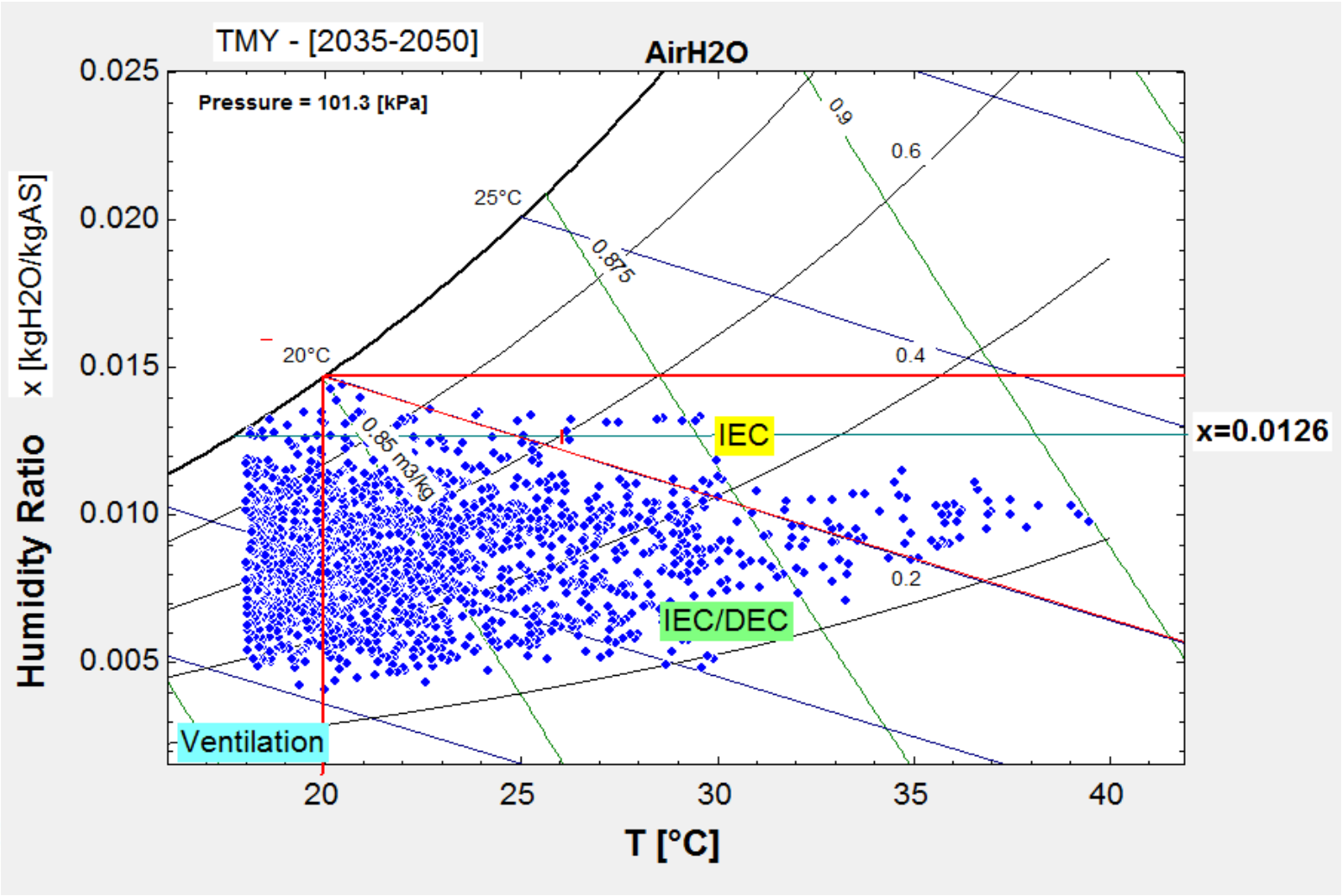
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Pressure = 101.3 [kPa]
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20°C
0.85 m3/kg
IEC
x=0.0126
IEC/DEC
Ventilation

• Climatic point of view for Bruxelles …

Extreme data !

t_supply 20°C	Old file !	TMY2004-18	TMY2007-21	TMY2035-50	xmy2035-50
	hours	hours	hours	hours	hours
ε_wet >1	24	44	30	78	767
ε_wet > 0.9	34	81	59	139	1032
ε_wet > 0.5	145	325	317	588	1667
ε_dp > 1	0	8	1	0	35
ε_dp > 0.9	2	11	5	0	104
ε_dp > 0.5	51	136	111	255	1227
t ≥ 20°C	497	851	873	1215	2361
x > 0.0126		37	31	34	421
T_max °C	30	32.4	33.6	39.48	41,19

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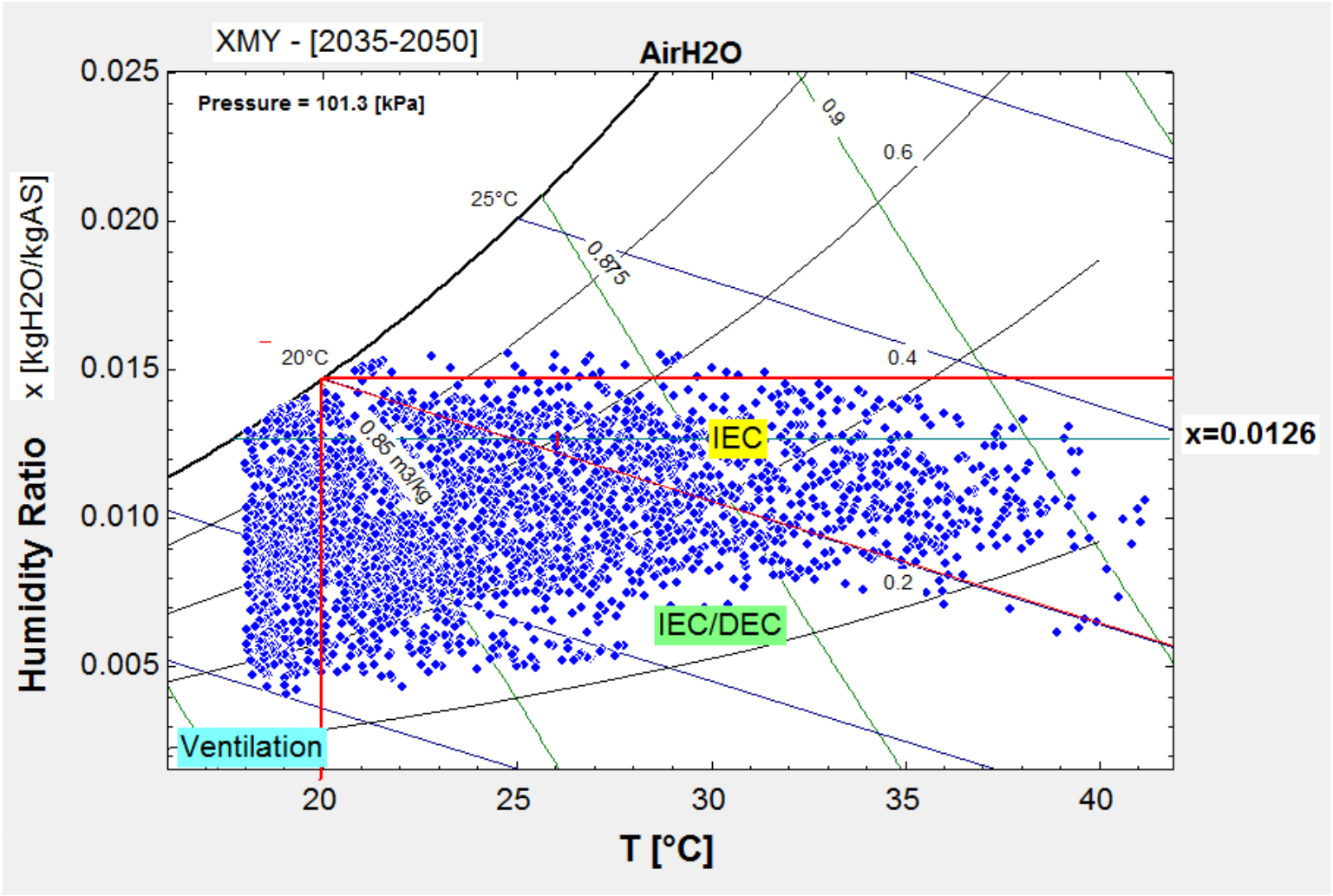
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IEC/DEC
Ventilation
20
25
30
35
40
T [°C]

- **Performance Analysis of a specific IEC/DEC**

For a **Building Load profil** and **one type of Equipment** :

– **The floor area and cost:** the heat and mass transfer performance of paddings as well as heat exchangers;

– **Electricity used:** the flow resistance performance of paddings and air coolers ...

– **Water consumption performance:** give the unified indicator of water consumed, equivalent electricity used.

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- **References :**
  - Meteorological TMY past [2004-2018], [2007-2021] https://climate.onebuilding.org/WMO_Region_6_Europe/BEL_Belgium/index.html
  - TMY XMY Future [2035-2050] https://climato.uliege.be/
  - Calculations via Excel spreadsheet and CoolProp extension http://www.coolprop.org/coolprop/wrappers/Excel/index.html
  - Graph via EES software https://fchartsoftware.com/ees/
  - IEA Annexe 85 https://annex85.iea-ebc.org/
  - Atic IEC past conferences 22/29-04-2021 =>> [pdf of presentation] : https://www.atic.be/fr/webinar/webinar/indirect-evaporative-cooling-iec-an-alternative-complement-to-mechanical-cooling-in-commercial-buildings-in-belgium and https://www.atic.be/nl/webinar/webinar/indirect-evaporative-cooling-iec-an-alternative-complement-to-mechanical-cooling-in-commercial-buildings-in-belgium =>> [videos] : https://www.youtube.com/watch?v=8aV2TFG4BTw&ab_channel=Atic and https://www.youtube.com/watch?v=mvLBWriWun0&ab_channel=Atic

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Thanks for your attention.

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Questions time !