Mass balance of vapour

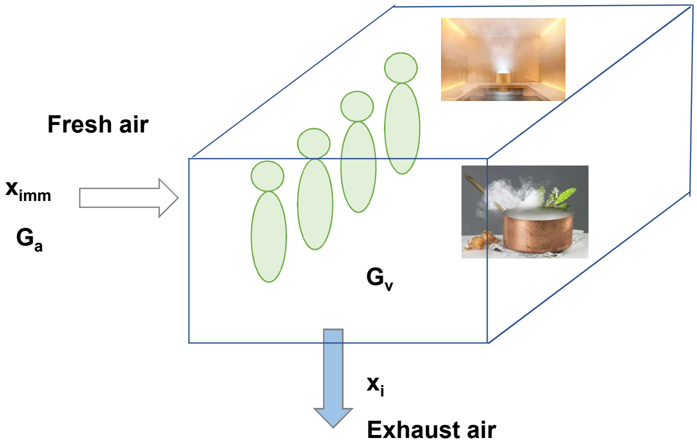
RESIDENTIAL ACTIVITIES			VAPOUR RATE
Hob (electric)			2 kg/day
Hob (gas)			3 kg/day
Dish washing			0,4 kg/day
Personnel hygiene (shower, etc.)			0.2 kg/(day px)
Washing clothes (hand or washing maschine)			0.5 kg/day
Drying clothes (dryer or hanging clothes)			Up to 1.5 kg/(day px)
DAILY HUMIDITY FOR THE DIFFERENT ACTIVITIES			
Number of persons	Humidity [kg/day]		
	Low rate of humidity	Average rate of humidity	High rate of humidity
1	3.5	6	9
2	4	8	11
3	4	9	12
4	5	10	14
5	6	11	15
6	7	12	16

Vapour Balance

$$G_a\,(x_i - x_{imm}) = G_v$$

- G_a: Mass flow rate of the air
- x_{imm}
- G_v: Vapour rate

$$x_i = x_{imm} + G_v / G_a$$



Two cases:

1. Supply air with the outdoor humidity ratio ($x_{imm} = x_o$)
2. Supply handled air ($x_{imm} \neq x_o$)

Example 1 (winter):

Residential building
Volume: 3 x 8 x 12 = 288 m^3
ACH: n = 0.5 h^{-1}
G_v = 10 kg_v / (day)

$G_a\,(x_i - x_e) = G_v$

$x_e = 3.5\ g_v/kg_{da}$

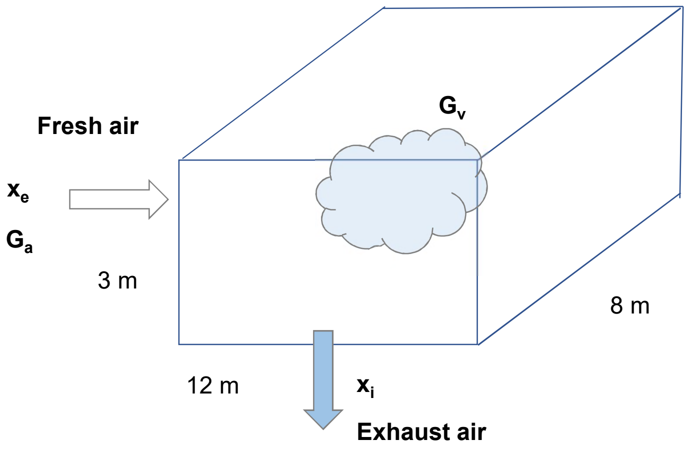
$G_a = n\,V\,\rho\ = 0.5 \times 288 \times 1.2 = 173$ kg/h

$x_i = x_e + G_v / G_a$

G_v = 10 kg_v / (day) = 10/24 = 417 g_v/h

$x_i = 3.5 + 417 / 173 = 5.9\ g_v/kg_{da}$

With ti = 20°C, RH = 40%



If ACR: n = 0.2 h^{-1}
G_a = 0.3 x 288 x 1.2 = 70 kg_a / h

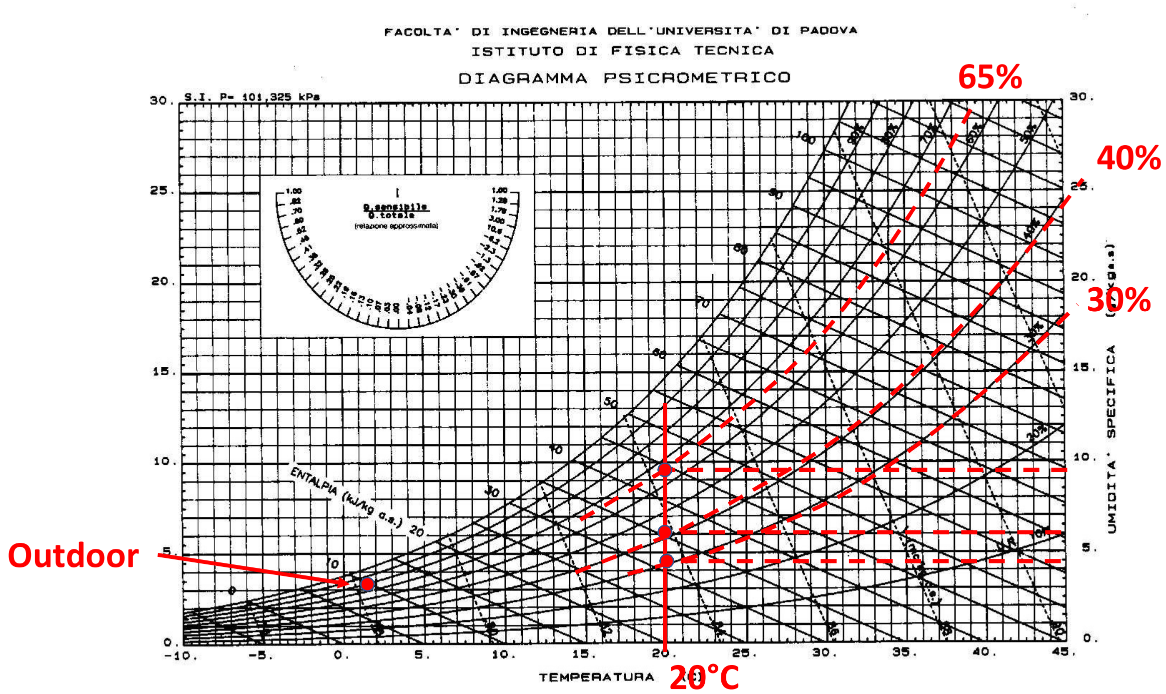
$x_i = 3.5 + 417 / 70 = 9.75\ g_v/kg_{da}$

With ti = 20°C, RH = 65%

If ACR: n = 1.0 h^{-1}
G_a = 1.0 x 288 x 1.2 = 346 kg_a / h

$x_i = 3.5 + 417 / 346 = 4.7\ g_v/kg_{da}$

With ti = 20°C, RH = 30%



Example 2 (summer):

Residential building
Volume: 3 x 8 x 12 = 288 m^3
ACR: n = 0.5 h^{-1}
$G_v = 10\ kg_v$ / (day)

$G_a (x_i - x_e) = G_v$

$x_e = 13.5\ g_v/kg_{da}$

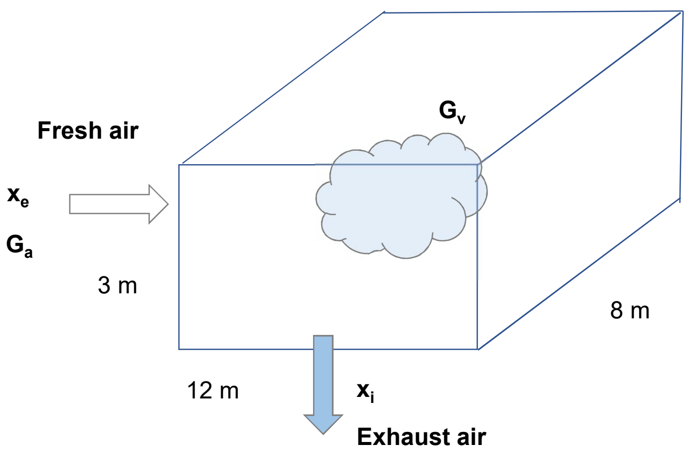
$G_a = n\ V\ \rho\ \ = 0.5 \times 288 \times 1.2 = 173$ kg/h

$x_i = x_e + G_v / G_a$

$G_v = 10\ kg_v / (day) = 10/24 = 417\ g_v/h$

$x_i = 13.5 + 417 / 173 = 15.9\ g_v/kg_{da}$

With ti = 26°C, RH = 75%

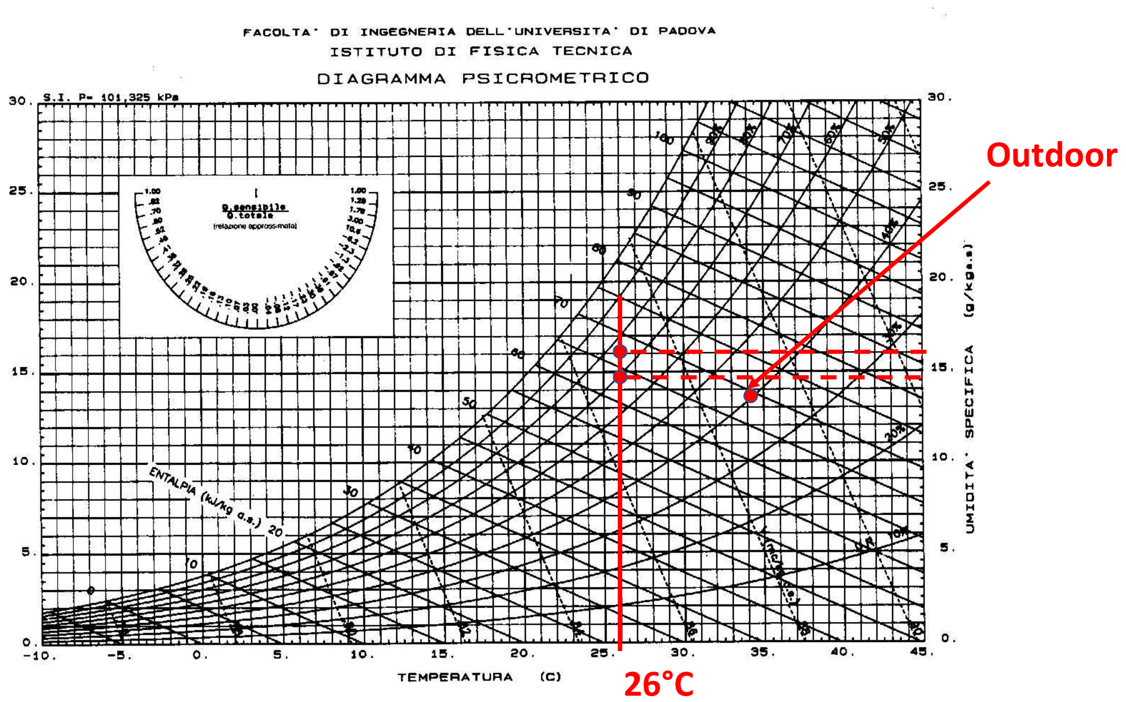


If ACR: n = 1.0 h^{-1}
$G_a = 1.0 \times 288 \times 1.2 = 346\ kg_a$ / h

$x_i = 13.5 + 417 / 70 = 14.7\ g_v/kg_{da}$

With ti = 26°C, RH = 70%

In summer it is necessary to dehumidify the air



Example 3 (summer):

Residential building

Volume: 3 x 8 x 12 = 288 m^3

ACR: n = 0.5 h^{-1}

G_v = 10 kg_v / (day)

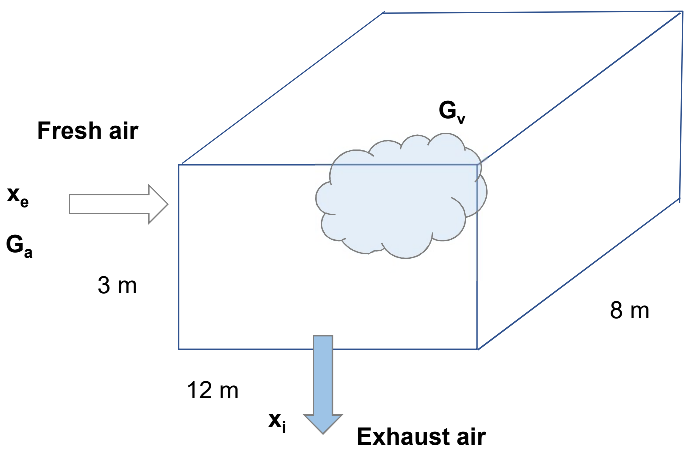
$G_a (x_i - x_e) = G_v$

x_e = 13.5 g_v/kg_{da}

$G_a = n V \rho$ = 0.5 x 288 x 1.2 = 173 kg/h

$x_i = x_e + G_v / G_a$

G_v = 10 kg_v / (day) = 10/24 = 417 g_v/h



Cooling and dehumidification coil

t_{imm} = 16°C

x_{imm} = 8.5 g_v/kg_{as}

x_i = 8.5 + 417 / 173 = 10.9 g_v/kg_{da}

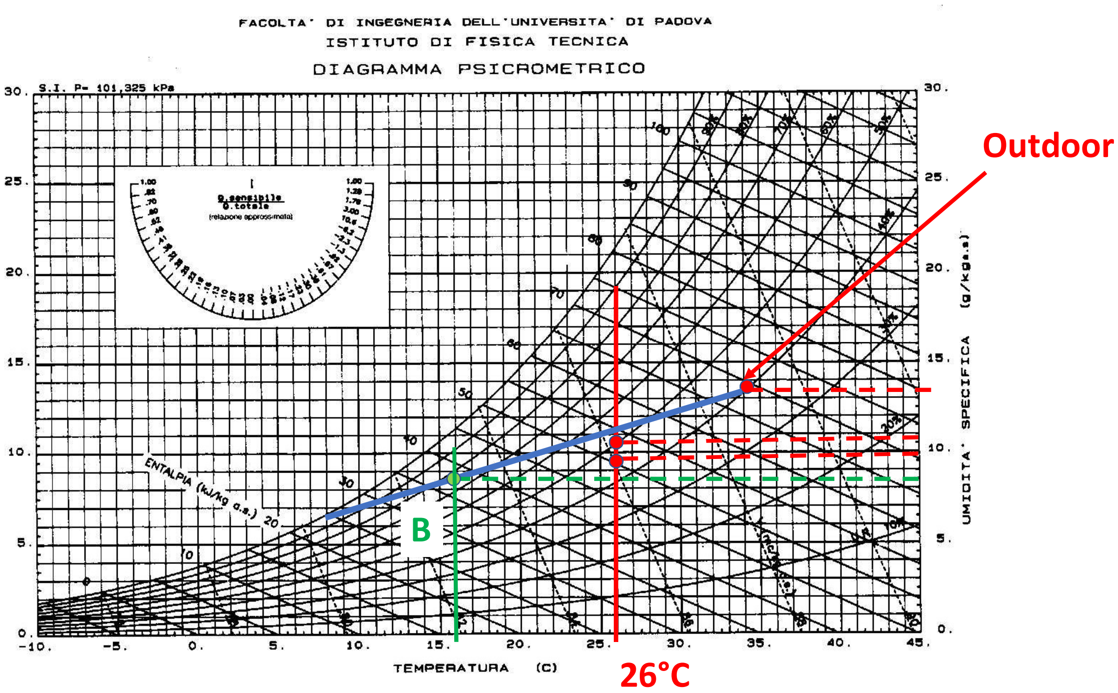
With ti = 26°C, RH = 50%

If n = 1.0 h^{-1}

G_a = 1.0 x 288 x 1.2 = 346 kg_a / h

x_i = 8.5 + 417 / 346 = 9.7 g_v/kg_{da}

With ti = 26°C, RH = 45%



At the same time the supply air at 16°C will provide cooling:

$q_g = G_a\, c_p\, (t_{imm} - t_i) = 173 \times 1007 \times (16 – 26) / 3600 = -483$ W

$q_{g,specific} = q_g / A_f = 483 / 96 = -5$ W/m^2 → Useful cooling for the dwelling

$q_{coil} = G_a\, (h_B - h_o) = 173 \times (37 – 69) / 3600 = -1.54$ kW → Power of the chiller

$q_g = G_a\, c_p\, (t_{imm} - t_i) = 346 \times 1007 \times (16 – 26) / 3600 = -967$ W

$q_{g,specific} = q_g / A_f = -967 / 96 = -10$ W/m^2 → Useful cooling for the dwelling

$q_{coil} = G_a\, (h_B - h_o) = 346 \times (37 – 69) / 3600 = -3.07$ kW → Power of the chiller

Supposing a specific power 30 W/m²: $P_{dwelling}$ = -30 x 96 = -2880 W → Power of the dwelling

$G_a = P_{dwelling} / [c_p (t_{imm} - t_i)]$ = - 2880 / [1007 x (16 – 26) = 0.286 kg/s

$n = G_a$ x 3600 / (ρ V) = 0.286 x 3600 / (1.2 x 288) = 3 h^{-1}

There are 2 options:

- All fresh air

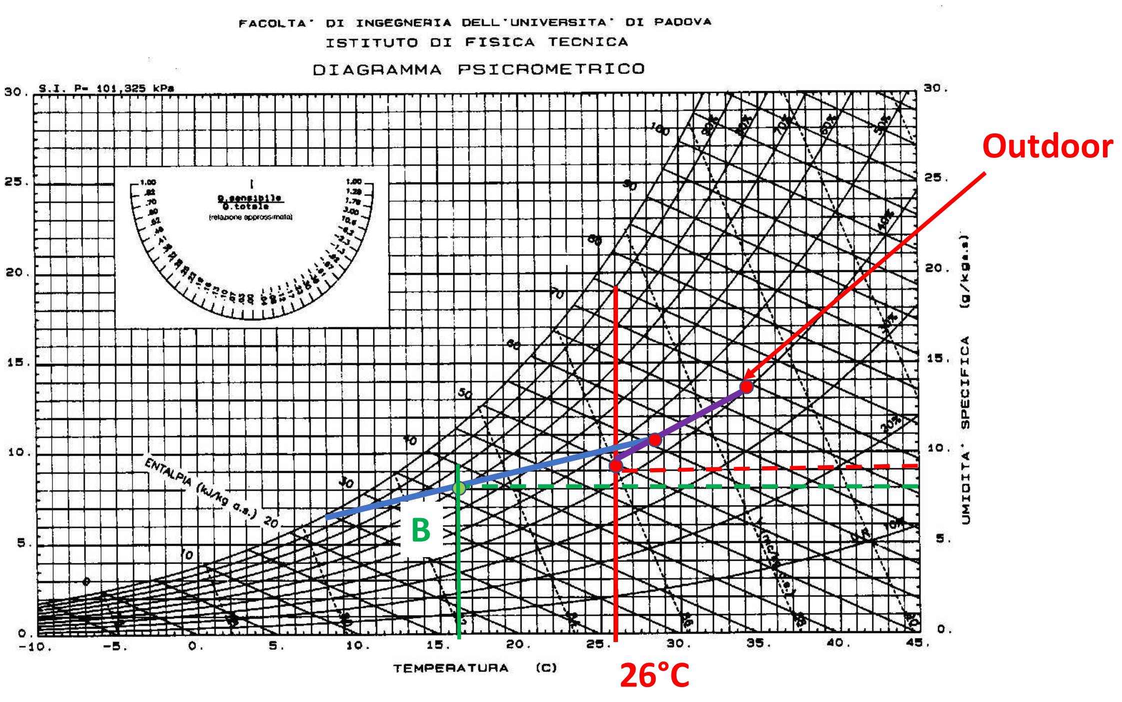
  $q_{coil} = G_a (h_B - h_o)$ = 0.286 x (37 – 69) = -9.1 kW → Power of the chiller

- Recirculating air:

  n = 1 h^{-1} outdoor air t_o = 34°C, RH_o = 40%

  n = 2 h^{-1} recirculation air t_i = 26°C, RH_o = 45%

  $q_{coil} = G_a (h_B - h_o)$ = 0.286 x (37 – 56) = -5.7 kW → Power of the chiller



Winter power:

Residential building

$P_{transmission}$ = 3900 W

Let's fix: t_{imm} = 40°C

$G_a = P_{transmission} / [c_p (t_{imm} – t_i)] = 3900 / [1007 \times (40 – 20)] = 0.174$ kg/s

$n = G_a \times 3600 / (\rho V) = 0.174 \times 3600 / (1.2 \times 288) = 1.8\ h^{-1}$

$P_{coil} = G_a \times c_p (t_{imm} – t_o) = 0.174 \times 1007 \times (40 + 5) = 7885$ W

Residential building

$P_{transmission}$ = 1050 W

$n = 1.0\ h^{-1}$

$G_a = n \times \rho \times V / 3600 / = 1.0 \times 1.2 \times 288 / 3600 = 0.096$ kg/s

$t_{imm} = t_i + P_{transmission} / (G_a\ c_p) = 20 + 1050 / (0.096 \times 1007) = 31$°C

$P_{coil} = G_a \times c_p (t_{imm} – t_o) = 0.096 \times 1007 \times (31 + 5) = 3480$ W