# Dedicated Outdoor Air Handling Units (DOAHUs)

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# Discussion Topics

- The role of dedicated outdoor air systems in maintaining acceptable indoor air quality
- Overview of dedicated outdoor air handling unit arrangements
- Methodology for assessing the energy efficiency of different dedicated outdoor air handling unit arrangements
- Assessment of dedicated outdoor air handling units’ purchasing- and operating- costs
- Summary/Conclusions

# Introduction

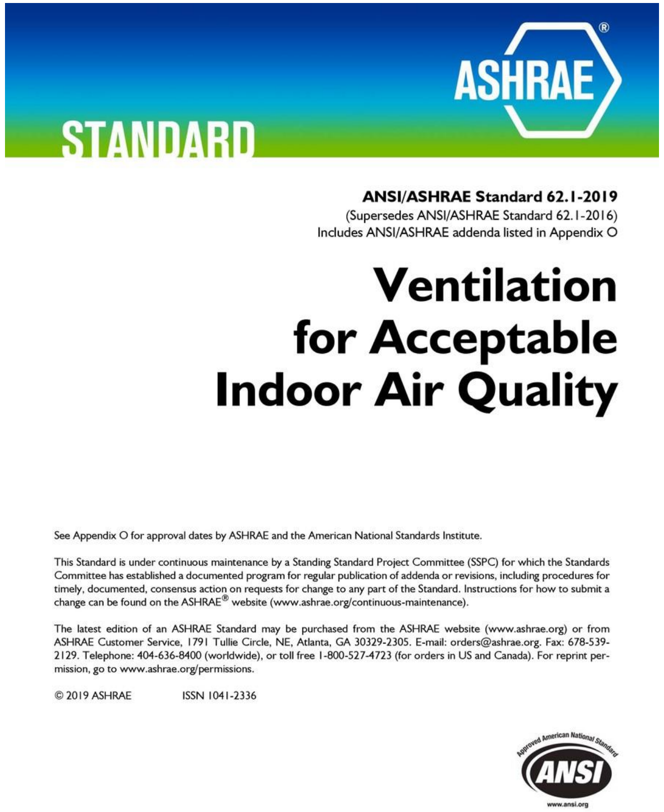
# Indoor Air Quality (IAQ)


Indoor air quality is determined by the concentration of contaminants in conditioned spaces

- Biological Contaminants
- Particle Pollutants
- Gaseous Pollutants
- Volatile Organic Compounds

# ASHRAE Standard 62.1-2019

*Ventilation for **Acceptable** Indoor Air Quality*



STANDARD

ASHRAE

**ANSI/ASHRAE Standard 62.1-2019**
(Supersedes ANSI/ASHRAE Standard 62.1-2016)
Includes ANSI/ASHRAE addenda listed in Appendix O

**Ventilation for Acceptable Indoor Air Quality**

See Appendix O for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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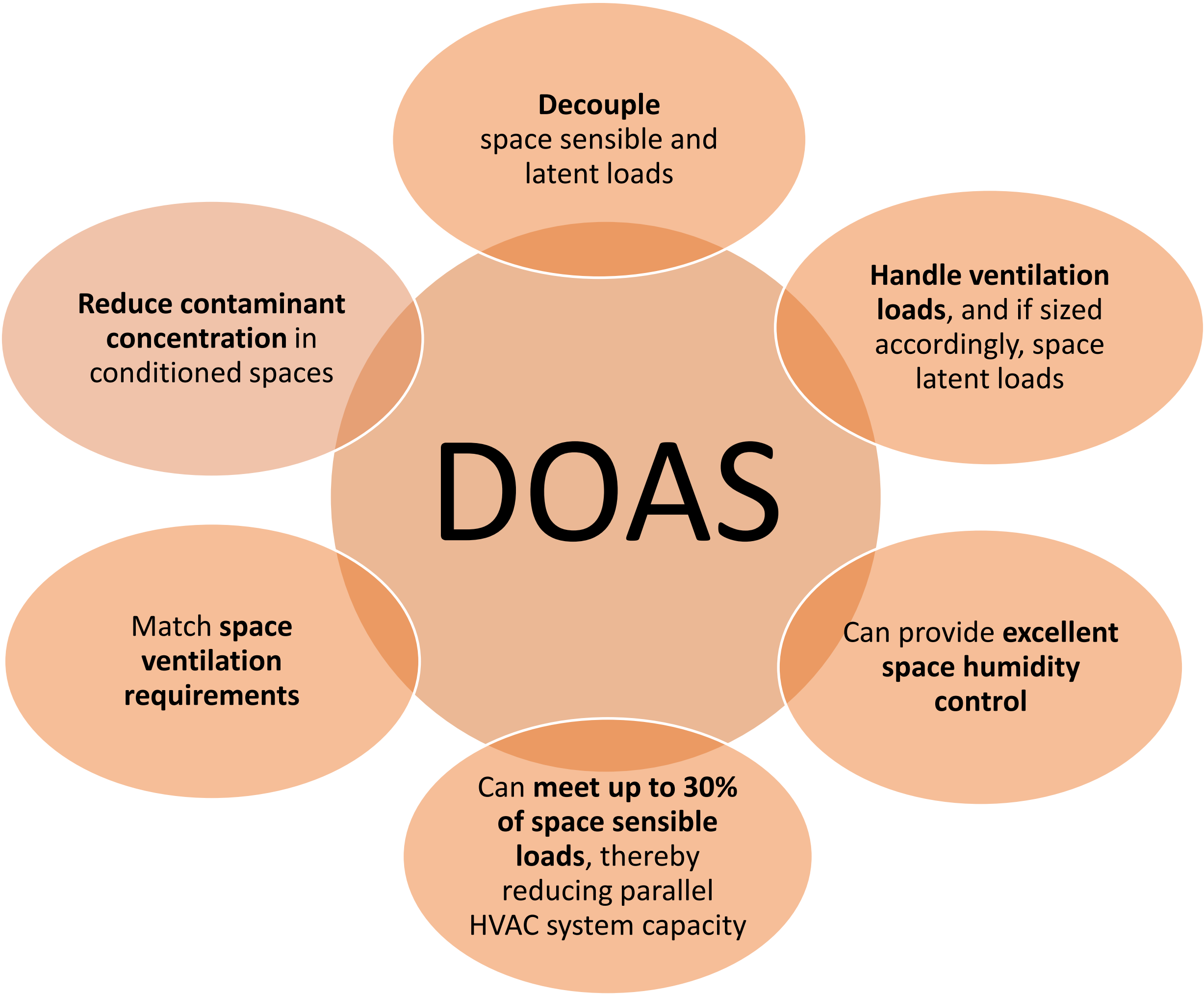
Approved American National Standard ANSI www.ansi.org

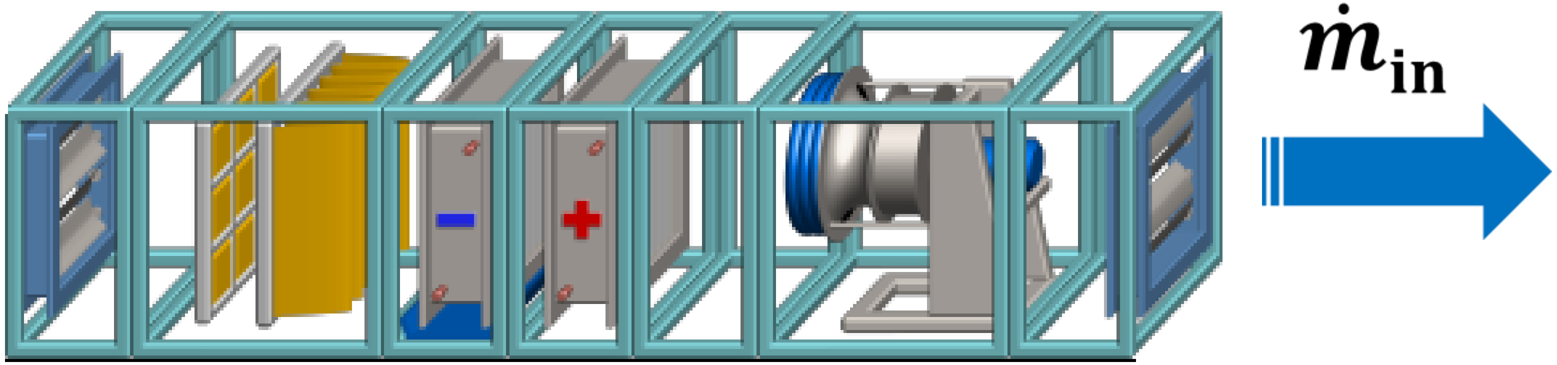
- ☑ New method for assessing ventilation requirements for conditioned spaces
- ☑ Does not regard ventilation of conditioned spaces where smoking is allowed
- ☑ Stated outdoor air flow rates constitute minimum, not suggested, requirements for acceptable IAQ

# Dedicated Outdoor Air Systems (DOAS)



# Dedicated Outdoor Air Handling Unit Arrangements

The simplest DOAHU arrangement…



# DOAHU Arrangements (2)

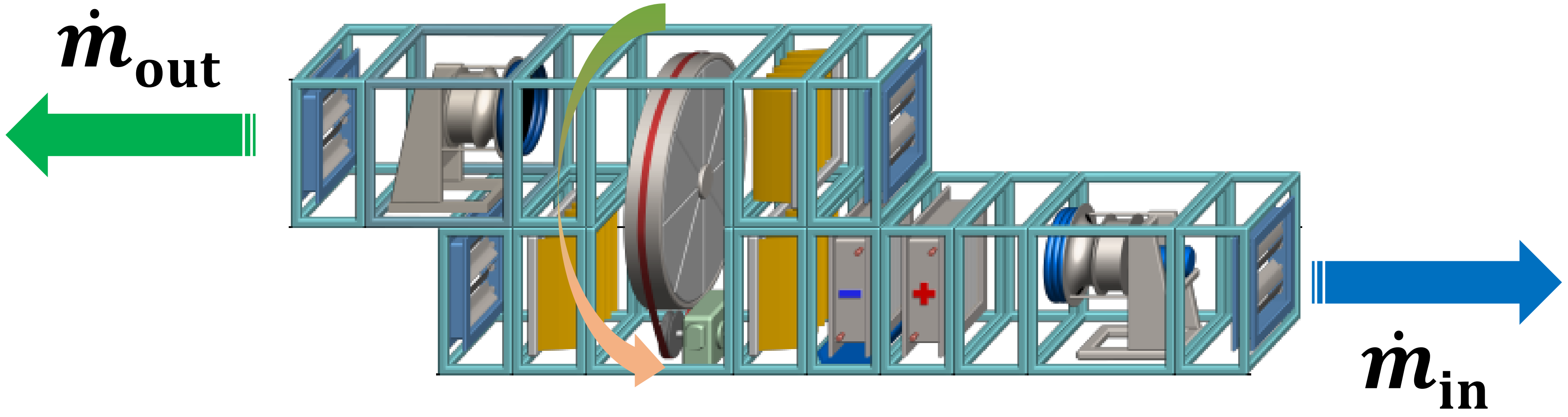
The simplest arrangement, for BVUs, as per EU Regulation 1253/2014

**ErP 2016**

$\eta_{min,wheel} = 67\%$

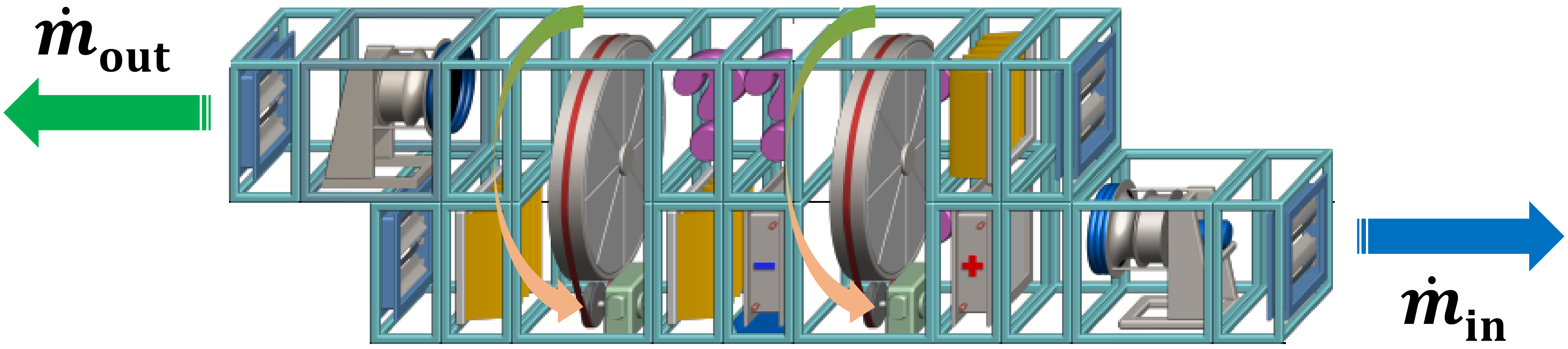
**ErP 2018**

$\eta_{min,wheel} = 73\%$



# DOAHU Arrangements (3)

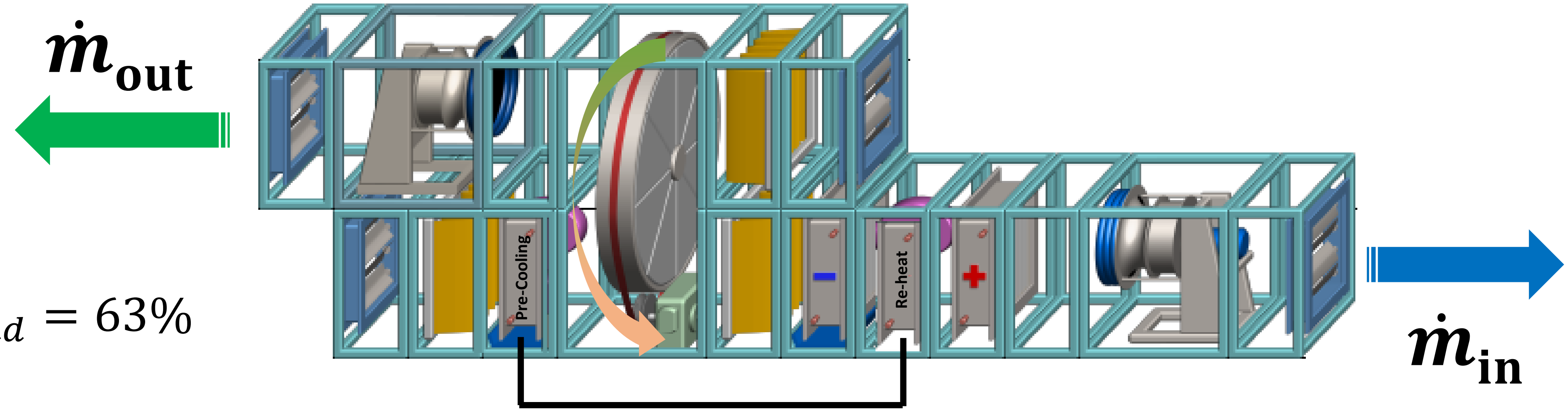
An energy efficient alternative featuring 2 RHWs



# DOAHU Arrangements (4)

DOAHU with a Run-Around Coil Heat Exchanger and a Sorption RHW

$\dot{m}_{out}$




$\dot{m}_{in}$

**ErP 2016**

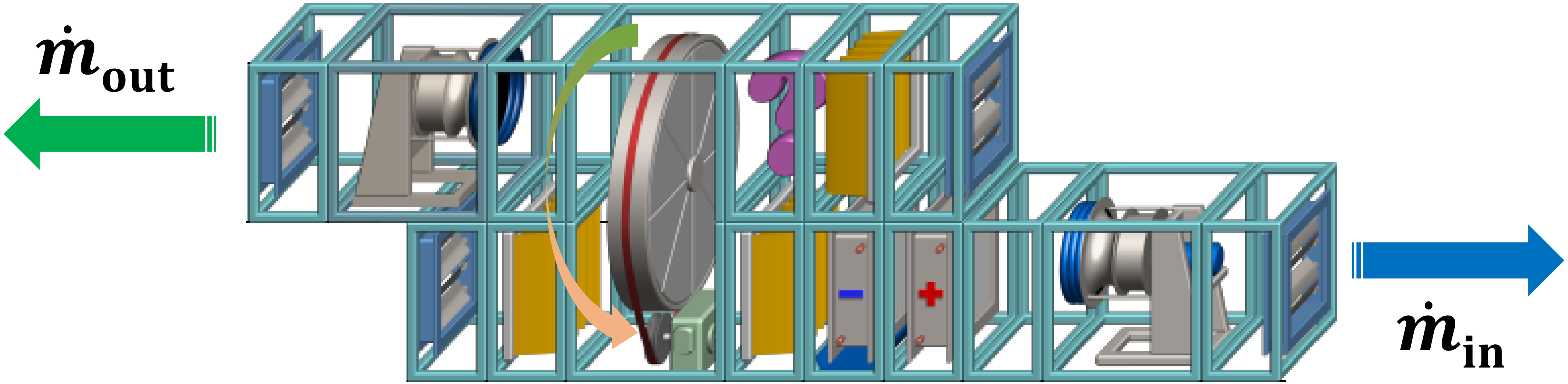
$\eta_{min,run-around} = 63\%$

**ErP 2018**

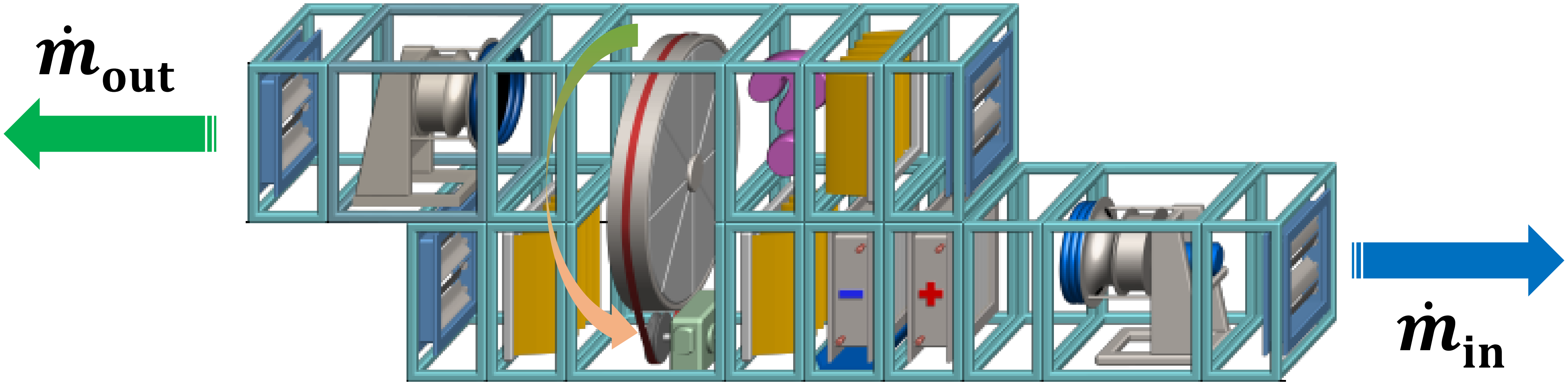
$\eta_{min,run-around} = 68\%$

# DOAHU Arrangements (5)

DOAHU with a Sorption RHW and Wet Cell Humidifier at Return Air- Side



## DOAHU with a Condensation RHW and Wet Cell Humidifier at Return Air- Side



# Model for Assessing DOAHUs' Operating Costs

# Selection Data for Reference DOAHU

Space Design Condition: **23 °C db/50% r.h.**
Space Dew Point Temperature: **12.1 °C dp**

| Selection Data for Reference DOAHU | |
|---|---|
| Supply Air Flow Rate | **10,000 $m^3/h$** |
| Return Air Flow Rate* | **10,000 $m^3/h$** |
| Supply Fan External Static Pressure | **300 Pa** |
| Return Fan External Static Pressure* | **250 Pa** |

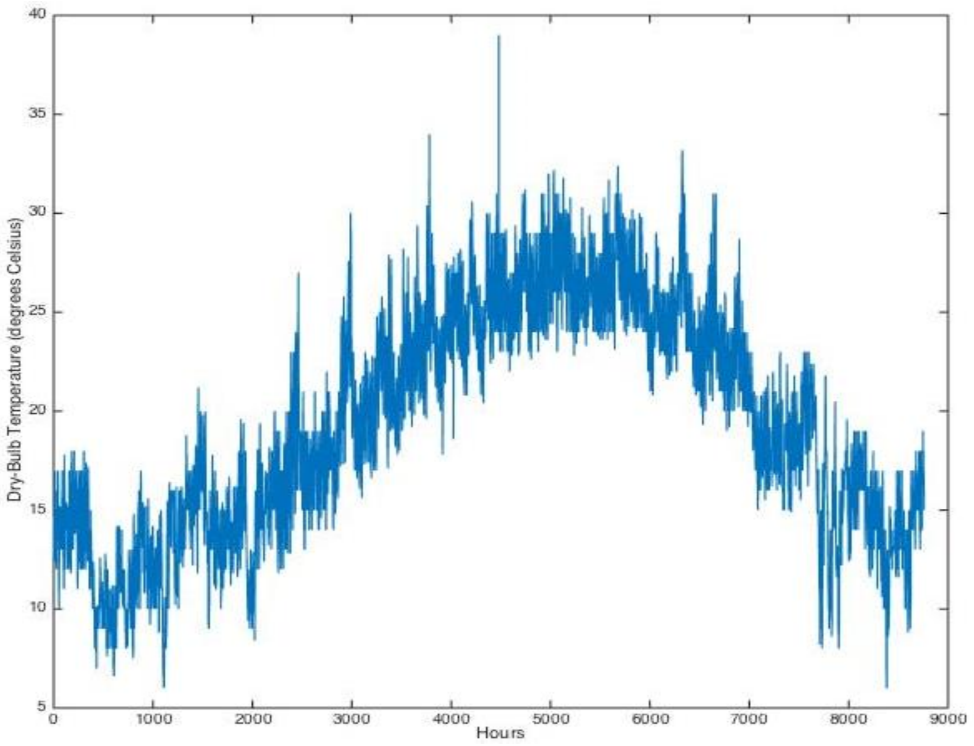
***** Variable that regards DOAHUs with return air fan section

# Climatic Data

Typical Meteorological Year (TMY) data was used (database: ASHRAE International Weather Files for Energy Calculations - IWEC2)

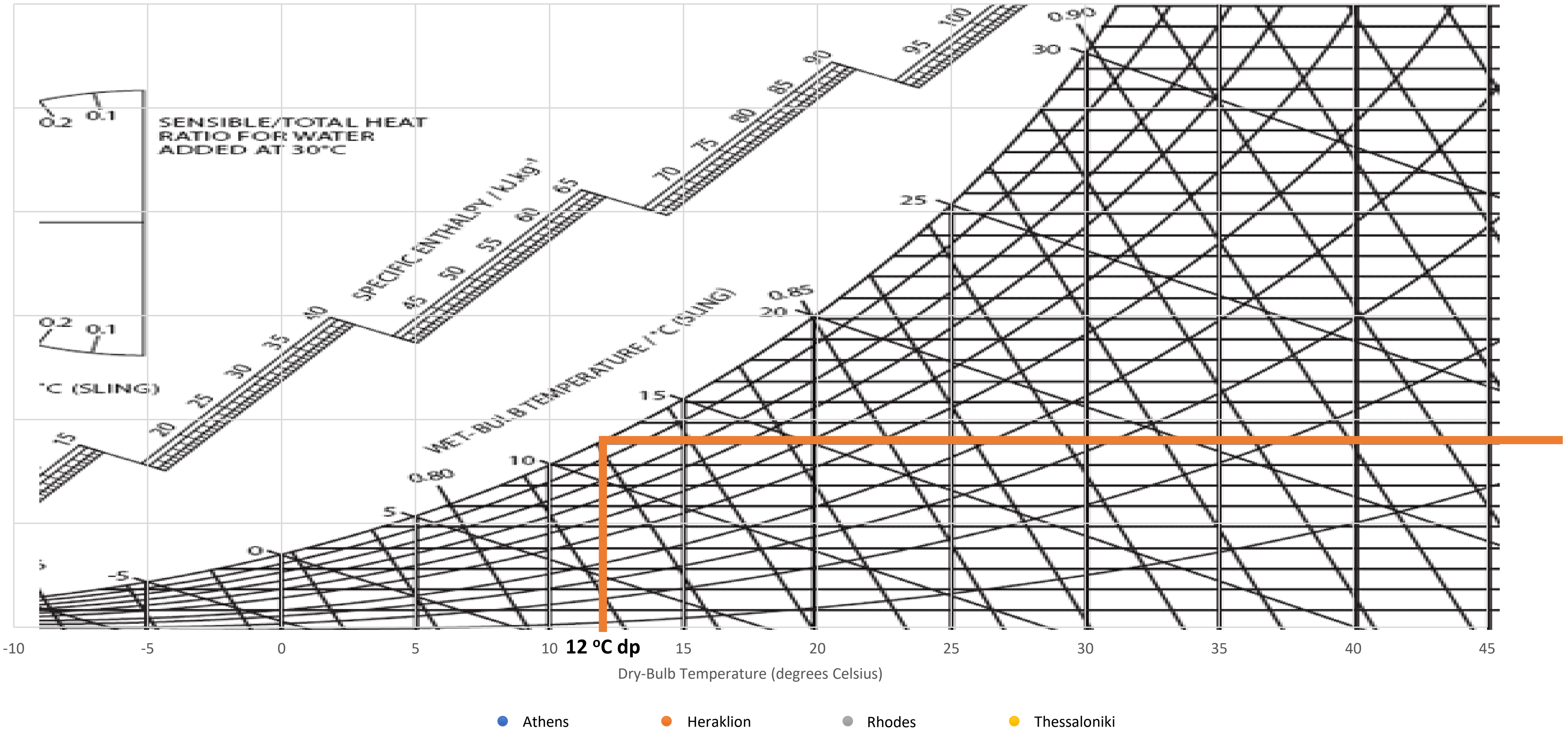
TMY data was of 4 major cities in Greece and was collected between 1985 and 2007

- Athens
- Thessaloniki
- Heraklion
- Rhodes




**Annual Variation of Outdoor Air Dry Bulb Temperature for the city of Rhodes**

# Climatic Data for Major Greek Cities



# Cooling Coil Sizing

Maximum load at cooling coil occurs at
**highest coil air-in wet bulb temperature**

Coil Load at Max. Coil Air-In DB Temp.

$$T_{db} = 39°\text{C}, T_{wb} = 24.7°\text{C}, \Delta\text{h} = 40.01\,\frac{kJ}{kg}$$

$$\dot{Q}_t = \rho \times q \times \Delta\text{h} \Longrightarrow$$

$$\dot{Q}_t = 1.225\left(\frac{kg}{m^3}\right) \times 2.78\left(\frac{m^3}{s}\right) \times 40.01\left(\frac{kJ}{kg}\right) \Longrightarrow$$

$$\boldsymbol{\dot{Q}_t = 136.25\ kW}$$

Coil Load at Max. Coil Air-In WB Temp.

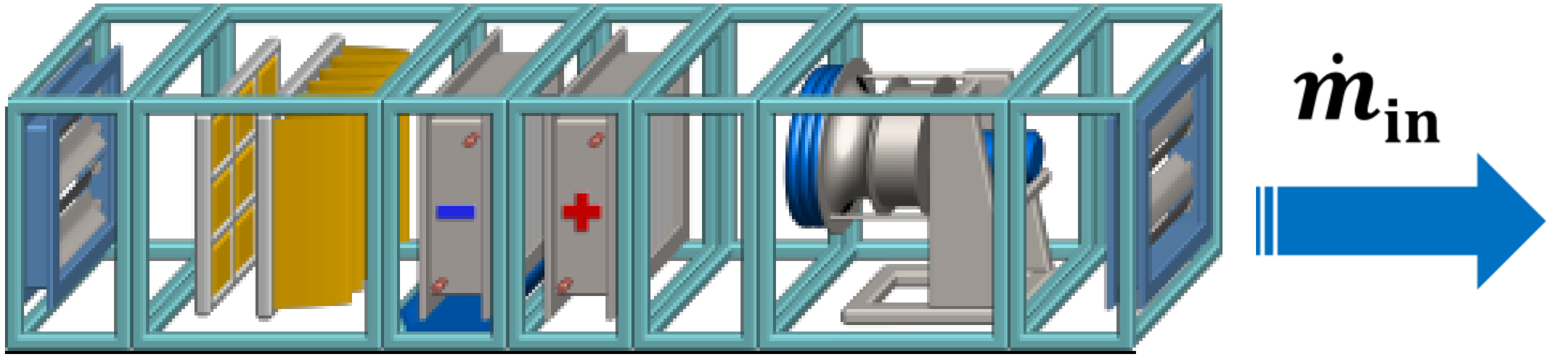
$$T_{db} = 27.8°\text{C}, T_{wb} = 25.7°\text{C}, \Delta\text{h} = 45.12\,\frac{kJ}{kg}$$

$$\dot{Q}_t = \rho \times q \times \Delta\text{h} \Longrightarrow$$

$$\dot{Q}_t = 1.225\left(\frac{kg}{m^3}\right) \times 2.78\left(\frac{m^3}{s}\right) \times 45.12\left(\frac{kJ}{kg}\right) \Longrightarrow$$

$$\boldsymbol{\dot{Q}_t = 153.66\ kW}$$

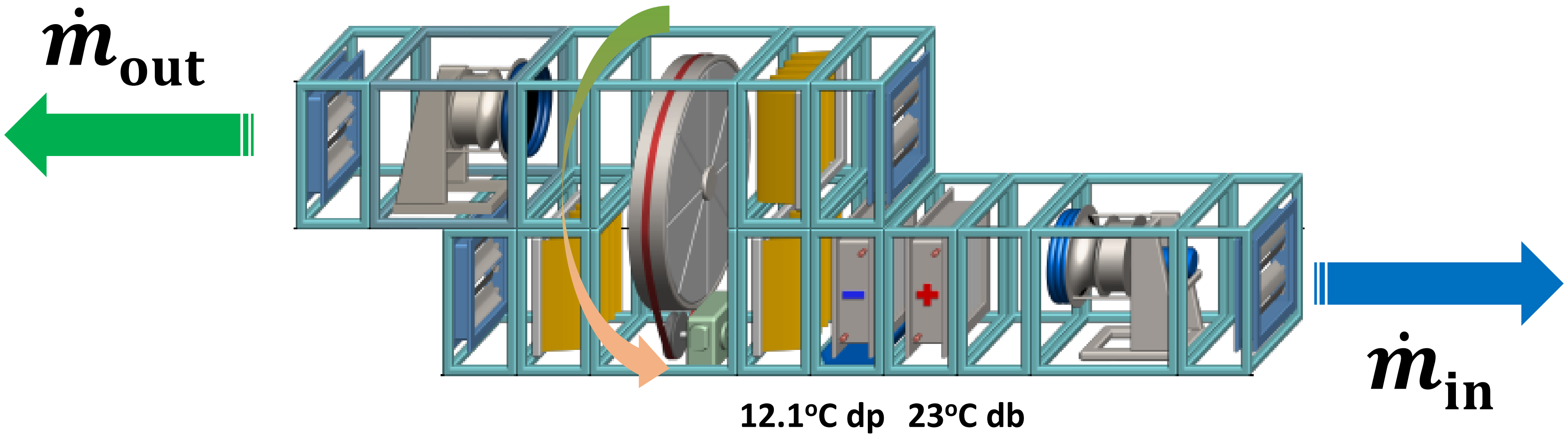
# UVU DOAHU




Coil Cooling Capacity: **163.82 kW**

Coil Heating Capacity : **75.37 kW**

# BVU DOAHU with Sorption RHW




Coil Cooling Capacity: **85.66 kW**

Coil Heating Capacity: **37.48 kW**

# BVU DOAHU with Sorption RHW

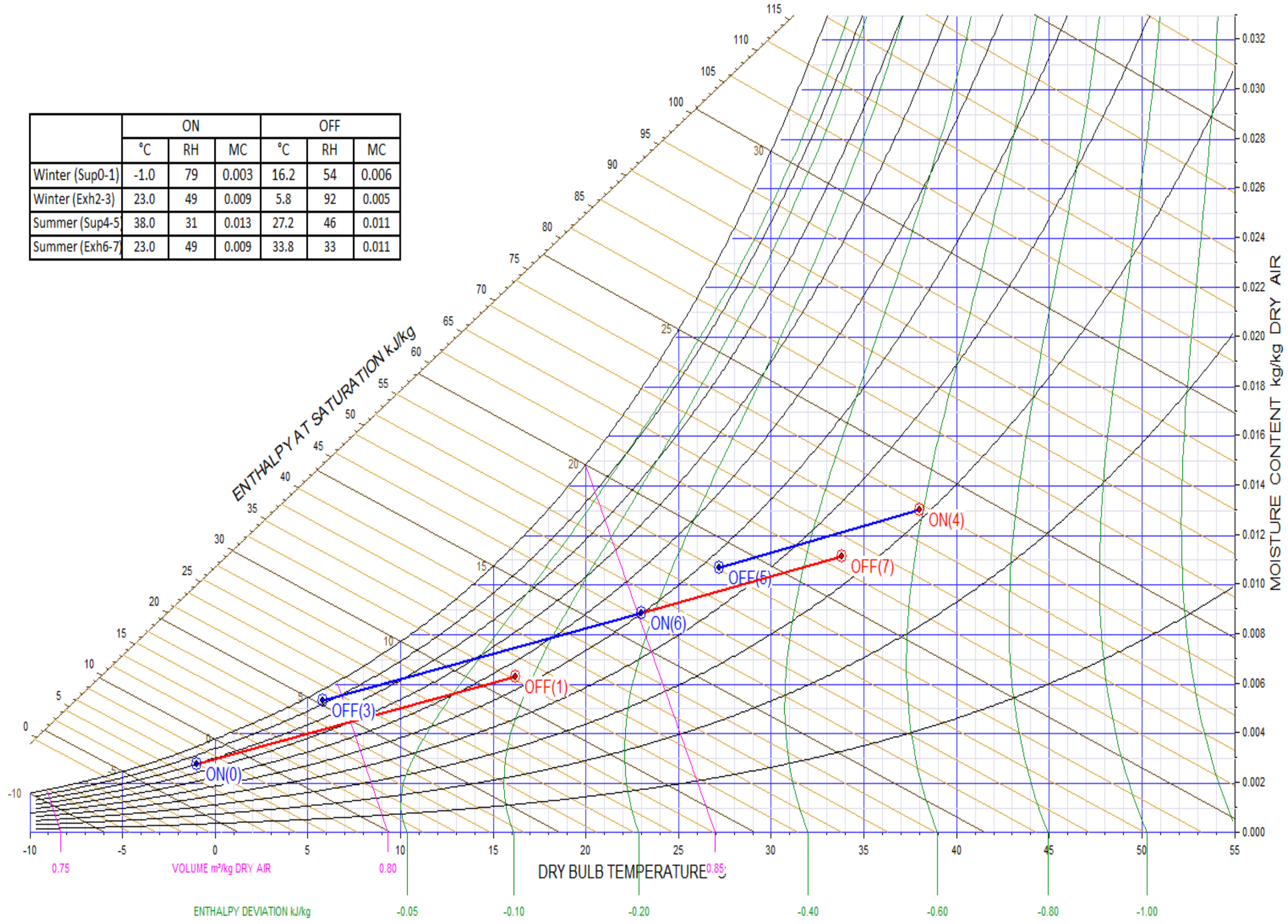
Sorption RHW:

**SH1-NL-WV-1600-CS-K2-A1**

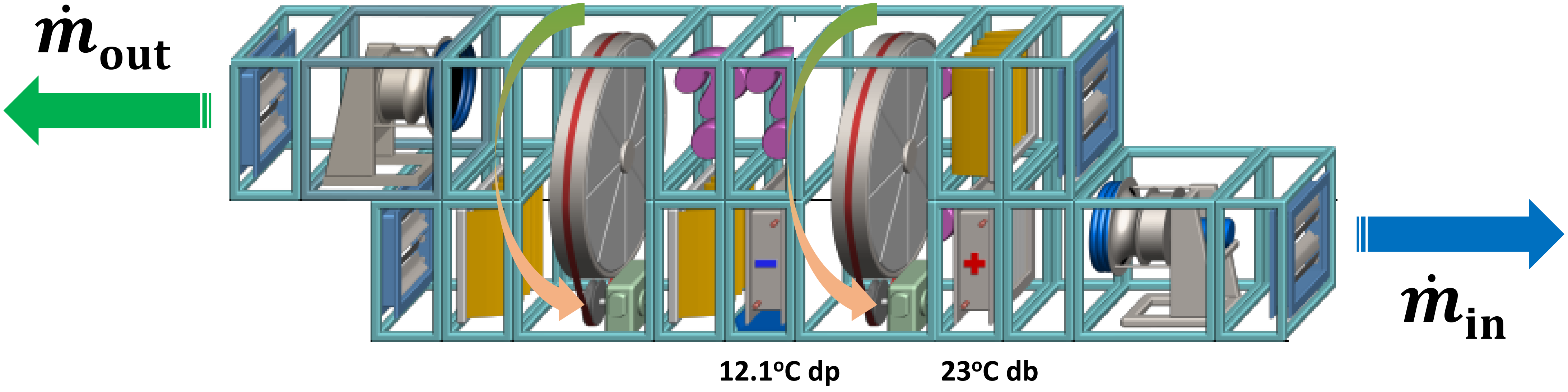
Heat Exchanger Sensible Efficiency (at chosen conditions): 73%

Heat Exchanger Latent Efficiency (at chosen conditions): 58%

| | ON | | | OFF | | |
|---|---|---|---|---|---|---|
| | °C | RH | MC | °C | RH | MC |
| Winter (Sup0-1) | -1.0 | 79 | 0.003 | 16.2 | 54 | 0.006 |
| Winter (Exh2-3) | 23.0 | 49 | 0.009 | 5.8 | 92 | 0.005 |
| Summer (Sup4-5) | 38.0 | 31 | 0.013 | 27.2 | 46 | 0.011 |
| Summer (Exh6-7) | 23.0 | 49 | 0.009 | 33.8 | 33 | 0.011 |



# BVU DOAHU with 2 Sorption RHWs




Coil Cooling Capacity: **65.97 kW**

Coil Heating Capacity: **9.27 kW**

# BVU DOAHU with 2 Sorption RHWs

## Sorption RHW

**SH1-NL-WV-1600-CS-K2-A1**

Heat Exchanger Sensible Efficiency (at chosen conditions): 73%

Heat Exchanger Latent Efficiency (at chosen conditions): 58%

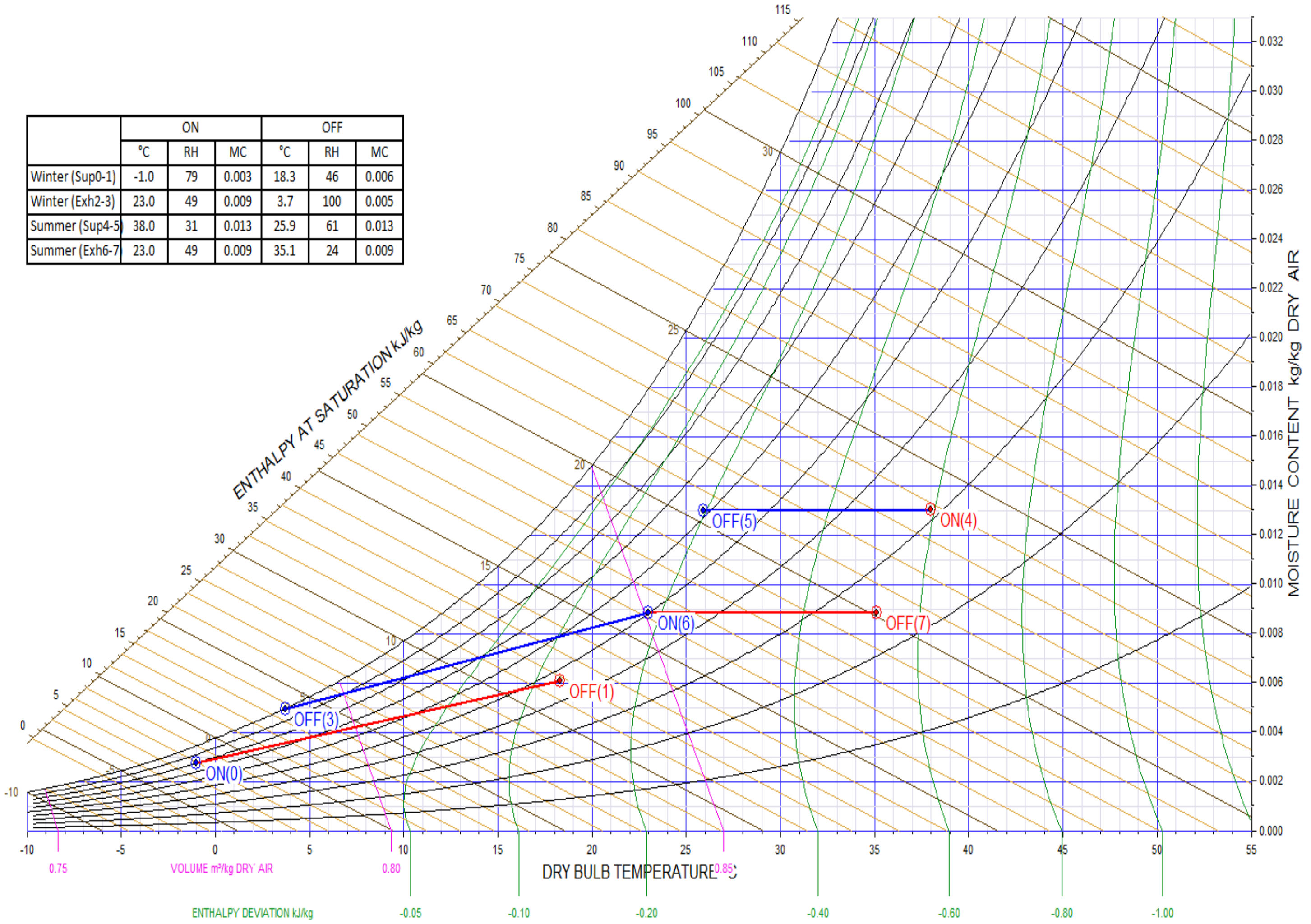
## Condensation RHW

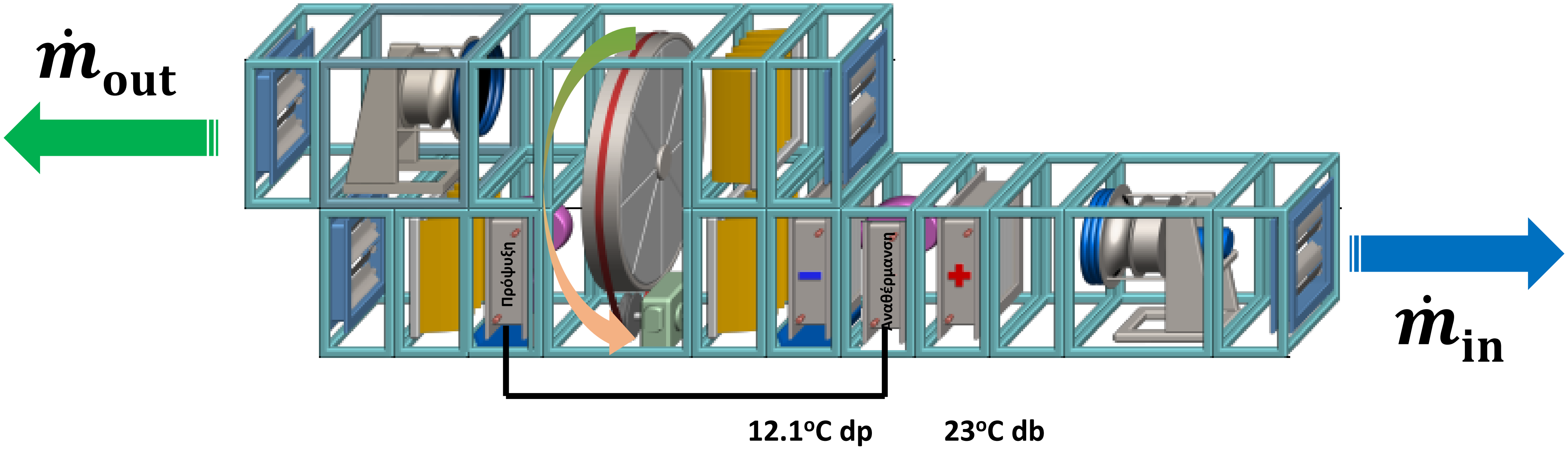
**ST1L-XL-WV-1900-CS-K2-A1**

Heat Exchanger Sensible Efficiency (at chosen conditions): 81%

Heat Exchanger Latent Efficiency (at chosen conditions): 0%

| | ON | | | OFF | | |
|---|---|---|---|---|---|---|
| | °C | RH | MC | °C | RH | MC |
| Winter (Sup0-1) | -1.0 | 79 | 0.003 | 18.3 | 46 | 0.006 |
| Winter (Exh2-3) | 23.0 | 49 | 0.009 | 3.7 | 100 | 0.005 |
| Summer (Sup4-5) | 38.0 | 31 | 0.013 | 25.9 | 61 | 0.013 |
| Summer (Exh6-7) | 23.0 | 49 | 0.009 | 35.1 | 24 | 0.009 |

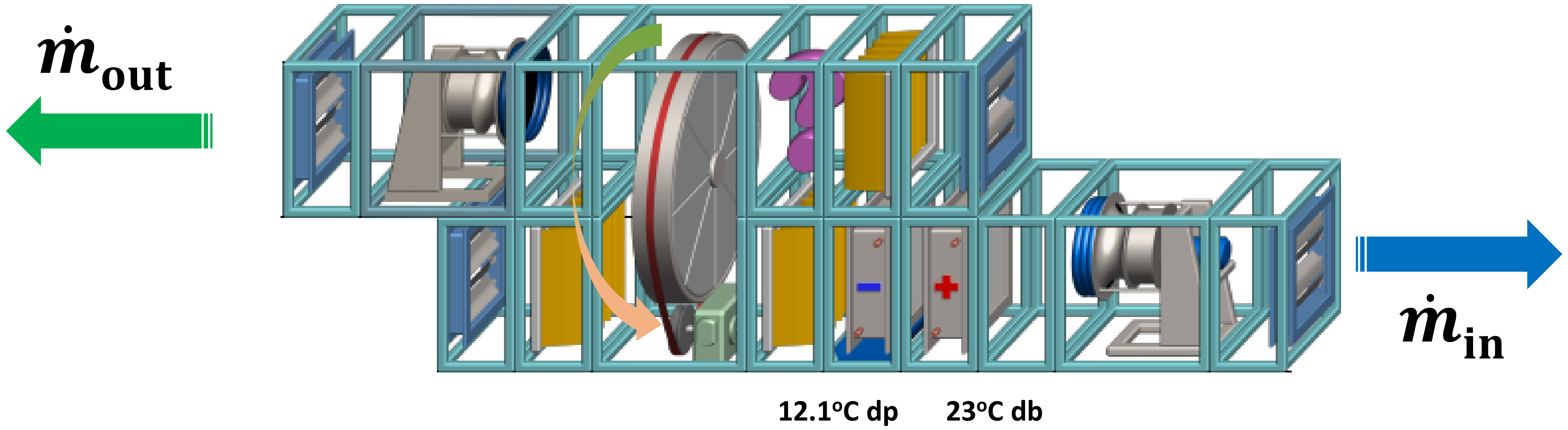





Coil Cooling Capacity: **70.25 kW**

Coil Heating Capacity: **37.48 kW**

# BVU DOAHU with Sorption RHW & Wet Cell Humidifier at Return Air- Side




Coil Cooling Capacity: **86.53 kW**

Coil Heating Capacity: **37.48 kW**

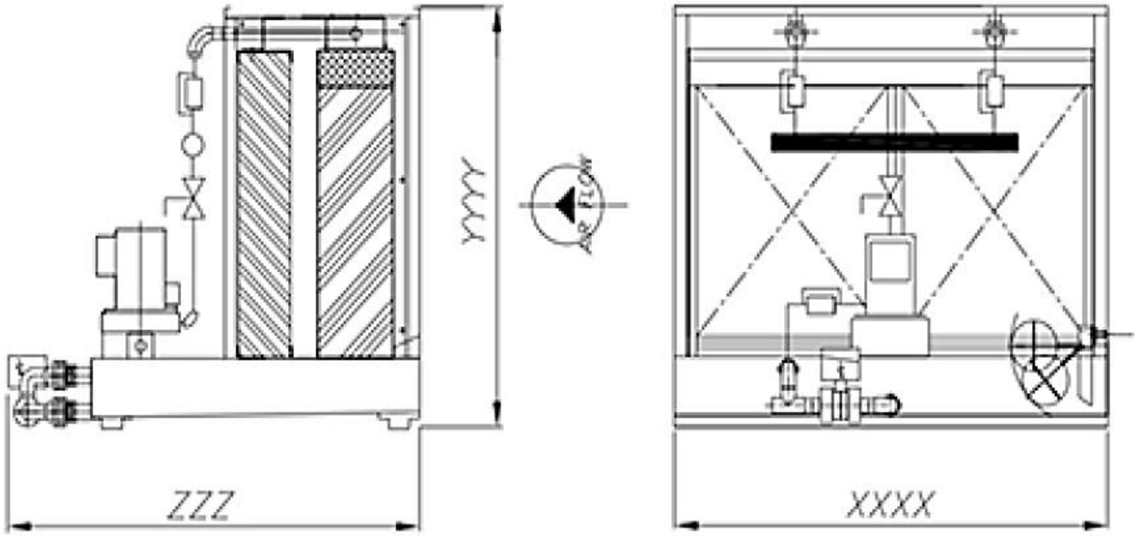
# BVU DOAHU with Sorption RHW & Wet Cell Humidifier at Return Air- Side

Saturation Efficiency: **70.7%**

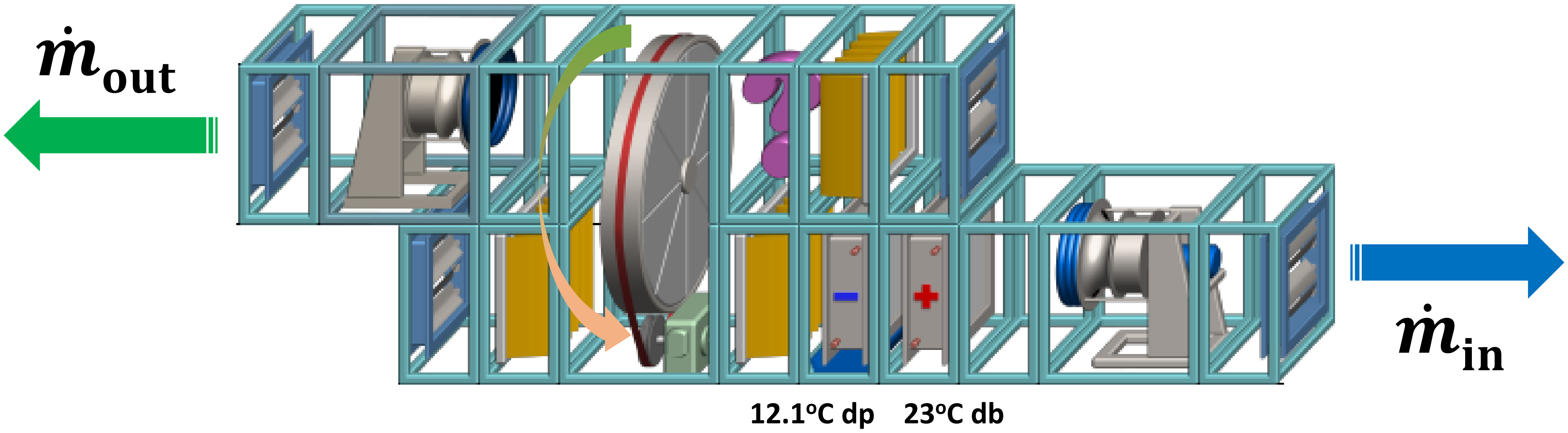
Water Consumption: **0.69 l/min**

Absorbed Electric Power of Water Circulation Pump: **60 W**

Humidifier Air Pressure Drop: **59 Pa**



# BVU DOAHU with Conden. RHW & Wet Cell Humidifier at Return Air- Side




Coil Cooling Capacity: **122.79 kW**

Coil Heating Capacity: **37.48 kW**

# Data Analysis Methodology

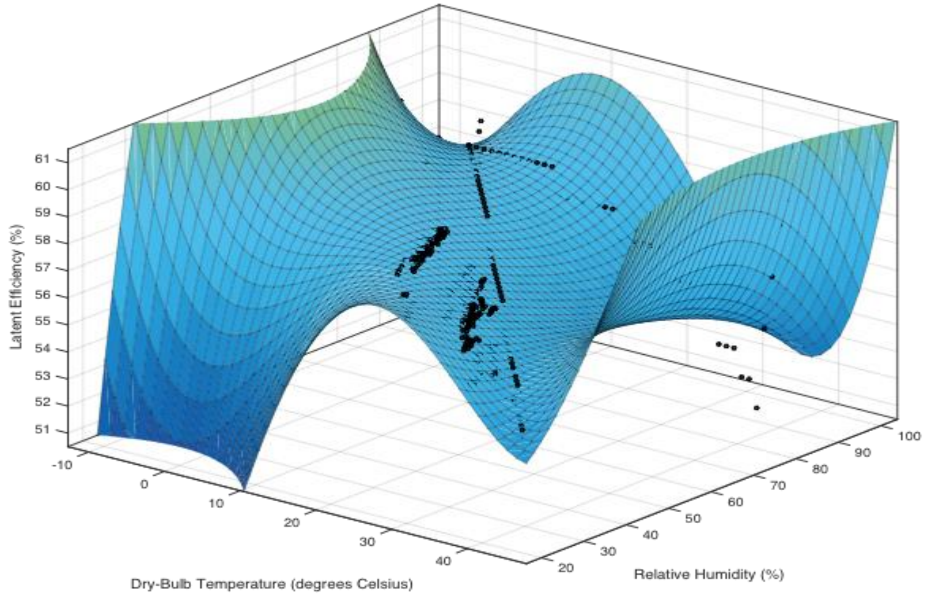
# RHW Latent Efficiency

$$\eta(Amb.Temp, Amb.R.H.\%) = \eta(x, y)$$

$$\eta = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}xy + p_{02}y^2 + p_{30}x^3 + p_{21}x^2y + p_{12}xy^2 + p_{03}y^3 + p_{40}x^4 + p_{31}x^3y + p_{22}x^2y^2 + p_{13}xy^3$$

$p_{00} = 15.02$
$p_{10} = 2.194$
$p_{01} = 2.018$
$p_{20} = 0.01248$
$p_{11} = -0.1039$
$p_{02} = -0.02866$
$p_{30} = -0.001668$

$p_{21} = 0.0007618$
$p_{12} = 0.001291$
$p_{03} = 0.0001282$
$p_{40} = 1.68E-05$
$p_{31} = 9.70E-06$
$p_{22} = -9.57E-06$
$p_{13} = -4.50E-06$



# RHW Latent Efficiency

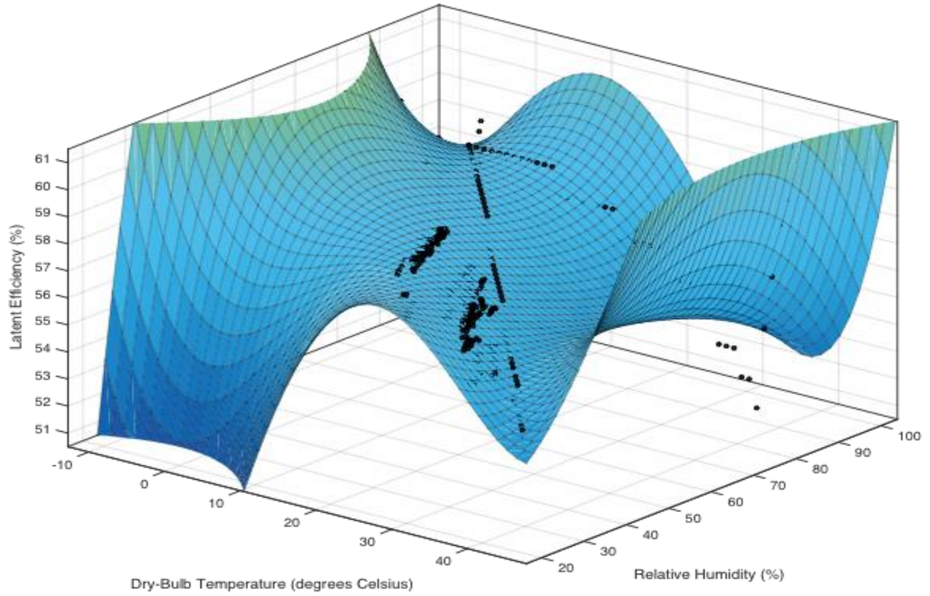
## Statistical Parameters

$SSE = 21.2$

$R^2 = 0.9503$

$Adj.R^2 = 0.9486$

$RMSE = 0.2384$



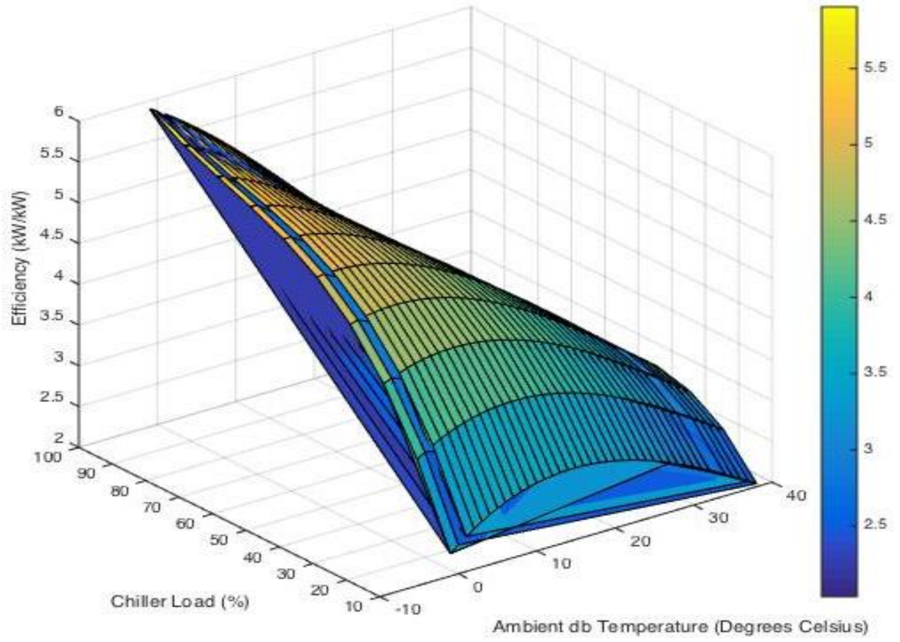
# Chiller/Heat Pump Efficiency

$$\eta(Amb.Temp, Chiller\ Load) = \eta(x, y)$$

$$\eta = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}xy + p_{02}y^2 + p_{30}x^3 + p_{21}x^2y + p_{12}xy^2 + p_{03}y^3$$

$p_{00} = 1.147$
$p_{10} = 0.09668$
$p_{01} = 0.136$
$p_{20} = -0.003331$
$p_{11} = -0.002015$
$p_{02} = -0.001576$
$p_{30} = 2.406E-05$

$p_{21} = 1.705E-05$
$p_{12} = 4.365E-06$
$p_{03} = 6.858E-06$



# Chiller/Heat Pump Efficiency

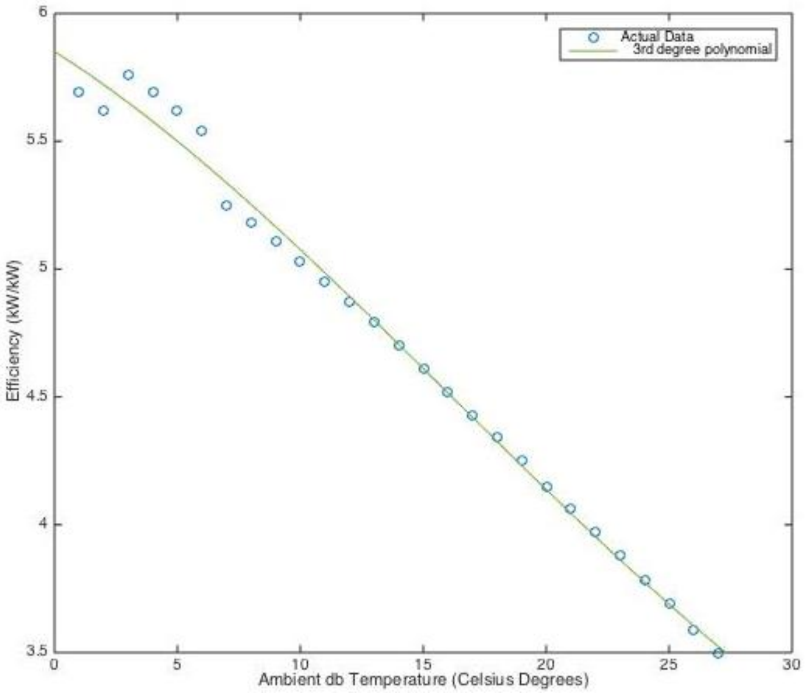
**Statistical Parameters**

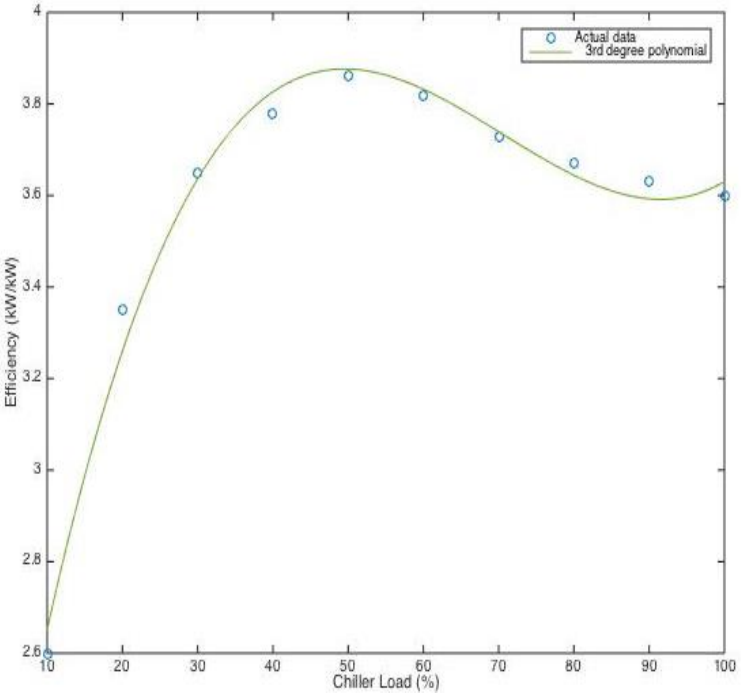
$SSE = 0.169$

$R^2 = 0.9978$

$Adj.R^2 = 0.9975$

$RMSE = 0.05022$



# DOAHUs' Fan Sections

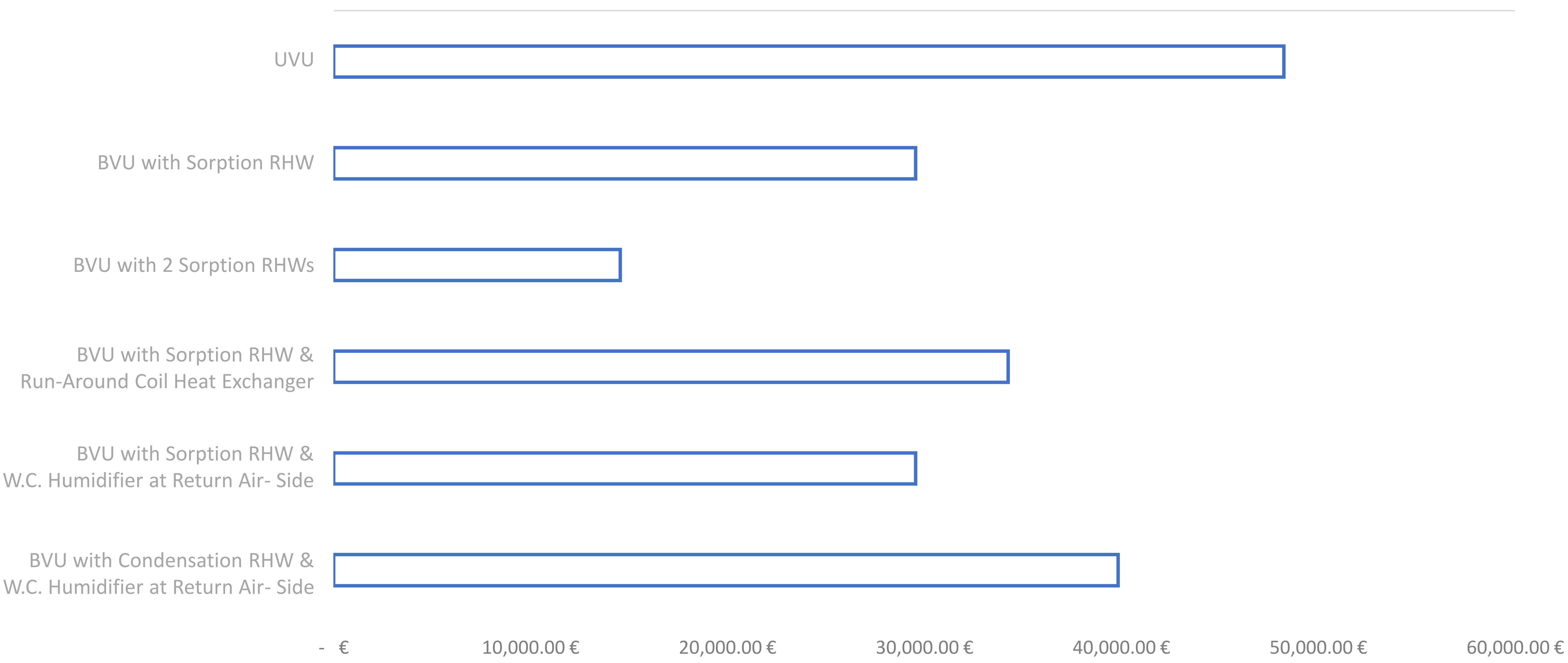
| DOAHU Arrangements | Total Static Pressure (Pa) | | Installed Motor Power (kW) | | |
|---|---|---|---|---|---|
| | Supply Fan | Return Fan | Supply Fan | Return Fan | Sum |
| UVU | 848 | - | 5.5 | - | **5.5** |
| BVU with Sorption RHW | 887 | 524 | 5.5 | 4 | **9.5** |
| BVU with 2 Sorption RHWs | 880 | 682 | 5.5 | 4 | **9.5** |
| BVU with Sorption RHW & Run-Around Coil Heat Exchanger | 1166 | 524 | 5.5 | 4 | **9.5** |
| BVU with Sorption RHW & Wet Cell Humidifier at Return Air- Side | 887 | 588 | 5.5 | 4 | **9.5** |
| BVU with Condensation RHW & Wet Cell Humidifier at Return Air- Side | 823 | 561 | 5.5 | 4 | **9.5** |

# Simulation Results

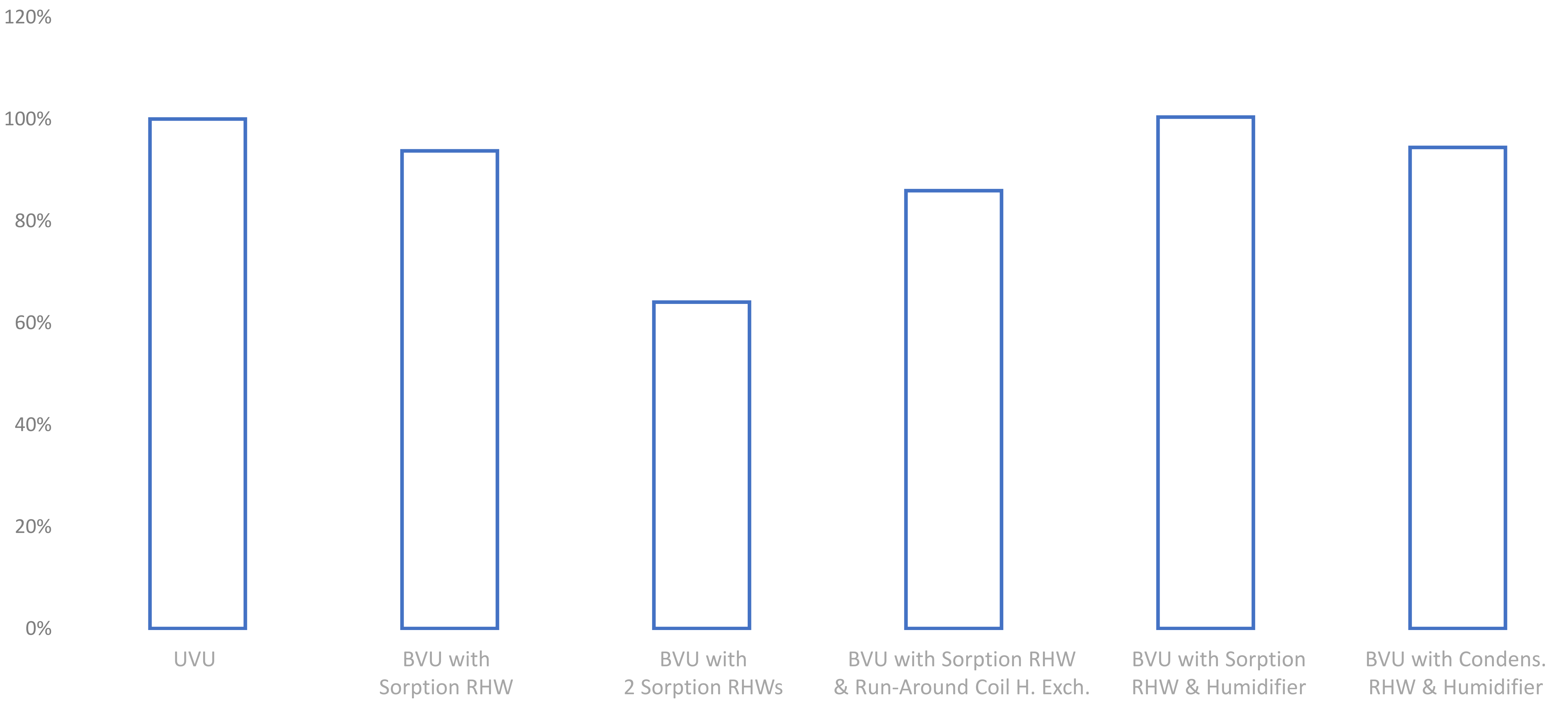
# DOAHUs’ Purchasing Costs

| DOAHU Arrangements | Purchasing Cost (€) |
| --- | --- |
| UVU | 9,000 |
| BVU with Sorption RHW | 18,600 |
| BVU with 2 Sorption RHWs | 23,500 |
| BVU with Sorption RHW & Run-Around Coil Heat Exchanger | 19,000 |
| BVU with Sorption RHW & Wet Cell Humidifier at Return Air- Side | 20,800 |
| BVU with Condensation RHW & Wet Cell Humidifier at Return Air- Side | 21,250 |

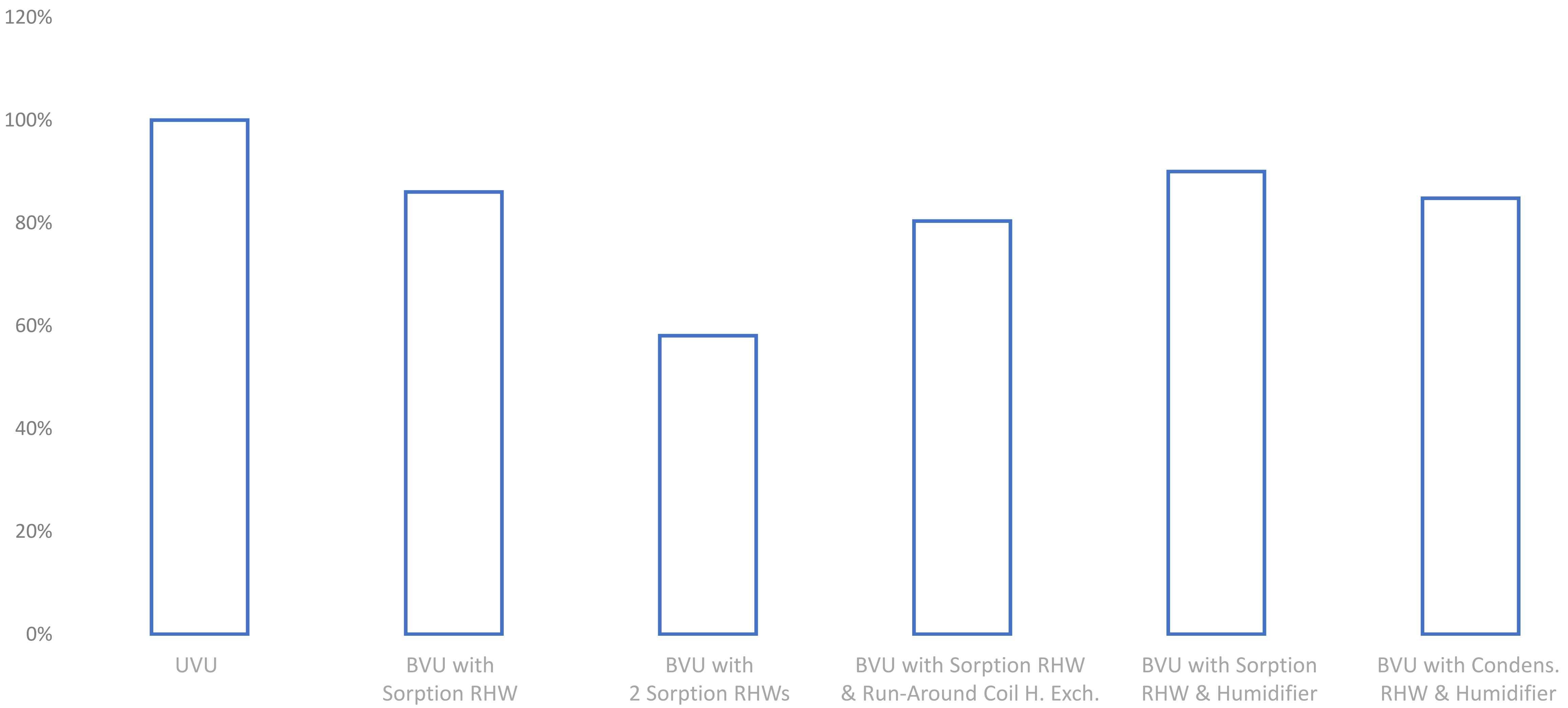
# Chiller/Heat Pump Purchasing Costs



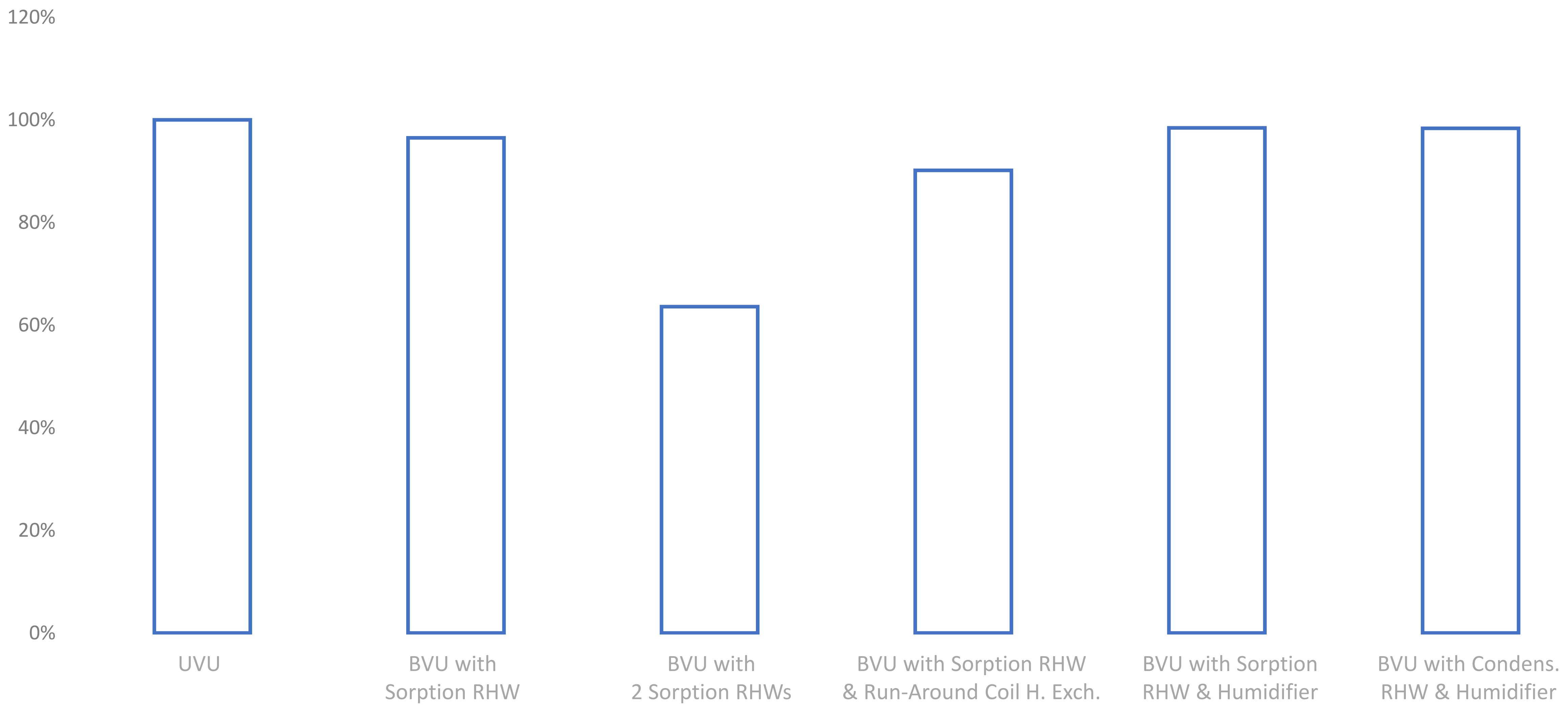
# Athens: DOAHUs' Operating Costs



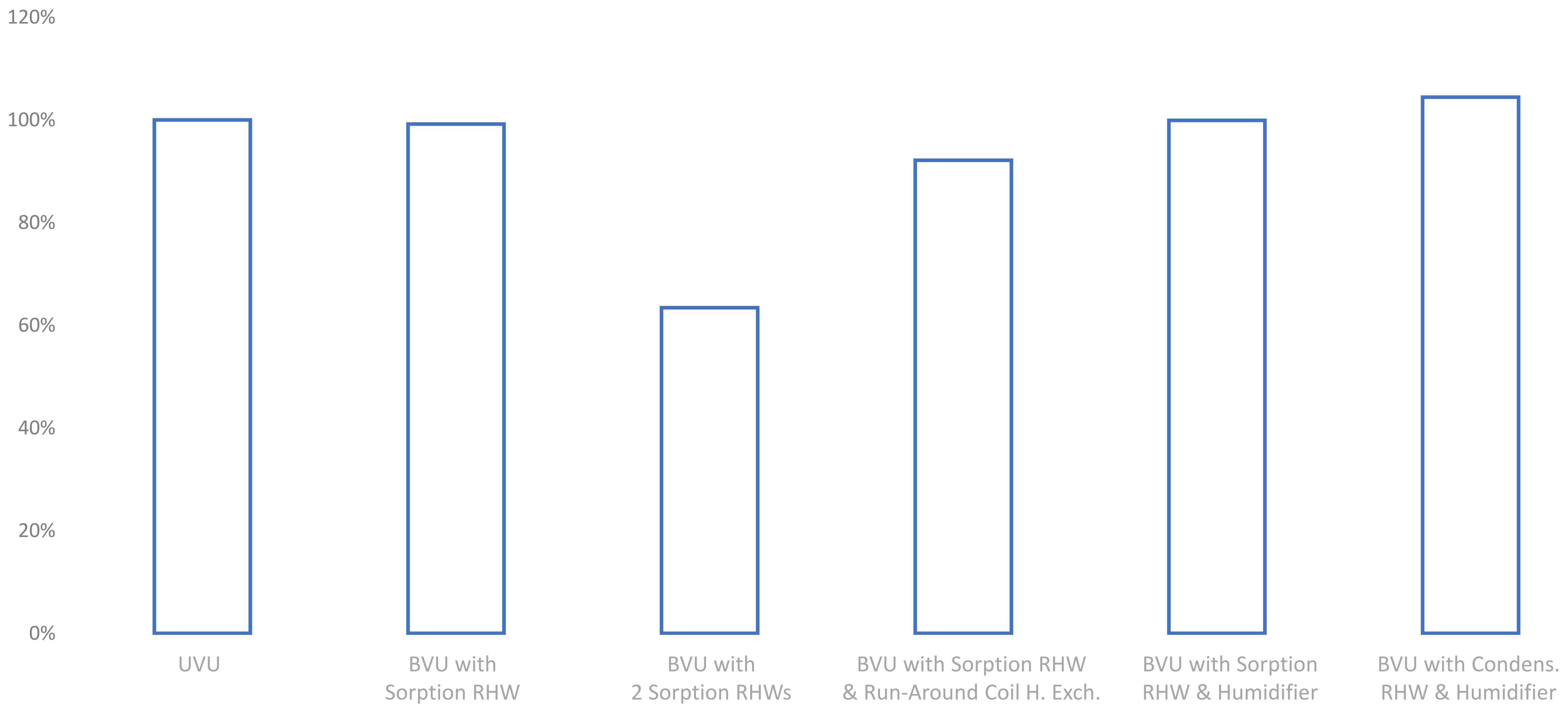
# Thessaloniki: DOAHUs' Operating Costs



# Heraklion: DOAHUs’ Operating Costs



# Rhodes: DOAHUs' Operating Costs



# Simple Payback Period (in Years)

Carrier

# Conclusion

- Choosing the best, in terms of simple payback period, DOAHU arrangement depends on regional climatic conditions.
- DOAHUs with 2 Sorption RHWs and units with a Sorption RHW and Run-Around Coil Heat Exchanger, amongst considered arrangements, offer the most attractive simple payback periods for all 4 Greek cities considered.
- Typically, when compared with UVU DOAHUs, units with 2 Sorption RHWs have lower operating costs by **36-42%**.

# Thank you!
# Questions?