Key Study of Energy Savings

based on Eurovent Classification of AHU's Mechanical Characteristics

Thanasis Paliogiannis, Stefanos Gaitanos

AHI Carrier S.E. Europe Air-Conditioning S.A.

ABOUT AHI CARRIER SE EUROPE AIR-CONDITIONING S.A.

Founded in Athens in 1952, our company has evolved rapidly, currently being responsible for the distribution and SEE rights of Carrier & Toshiba HVAC products and Totaline parts & accessories, in Central and SE Europe region

We provide **innovative** & **reliable** solutions for residential, commercial, industrial & marine applications of any scale

With strong commitment to our **environmental responsibility**, our products deliver industry-leading **energy efficiency** & lead the ozone-depleting refrigerants phase-out

Our company is nurtured with the values of exceptional **performance**, **quality** & **customer care**, driven from our most valuable asset, our **people**

OVERVIEW

- Eurovent Certified Air Handling Unit Mechanical Characteristics
- Building Model Description
- Methods used for the Determination of System Behaviour
- Examination of Energy Savings Potential
- Summary

SCOPE

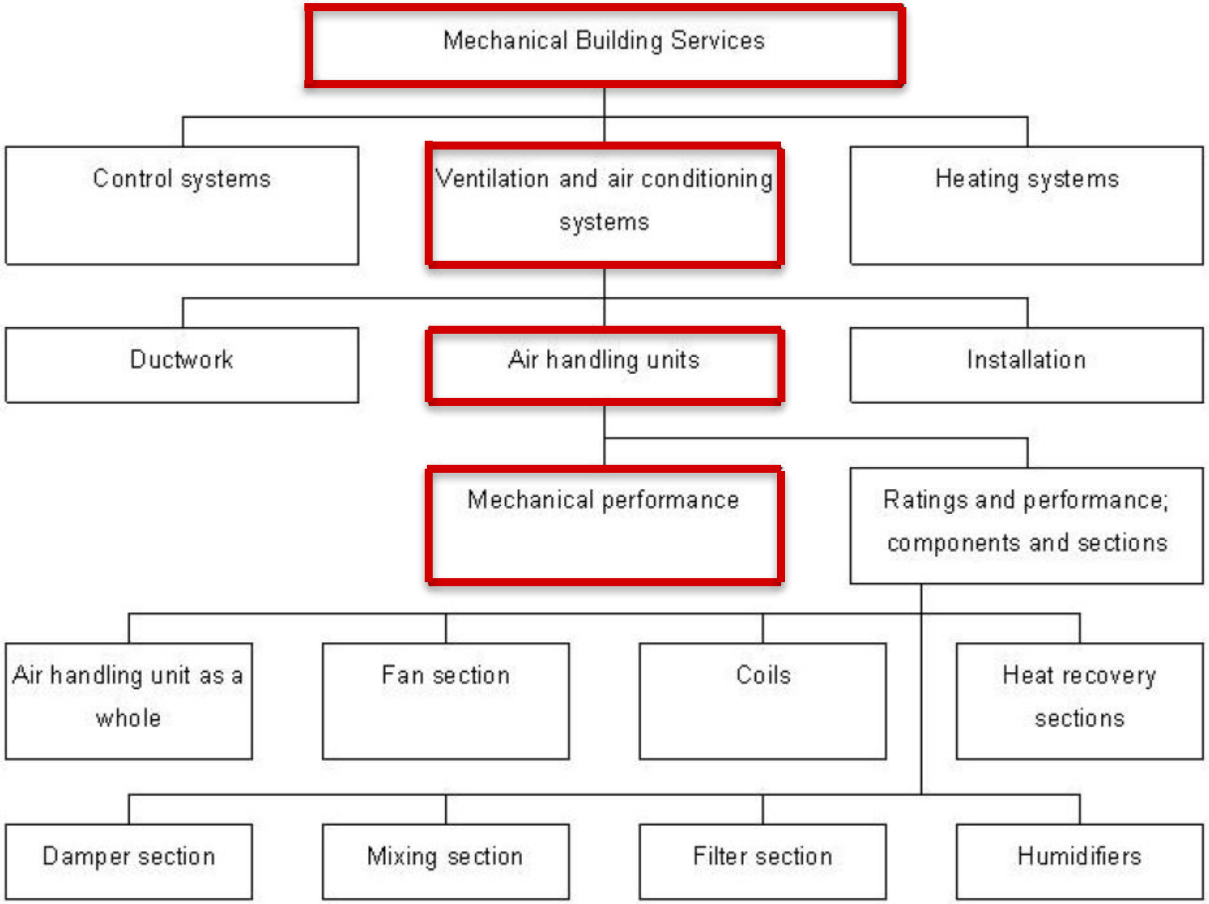
SCOPE

The test method for the mechanical performance of the casing is applicable to the comparison of different constructions – EN 1886:2009

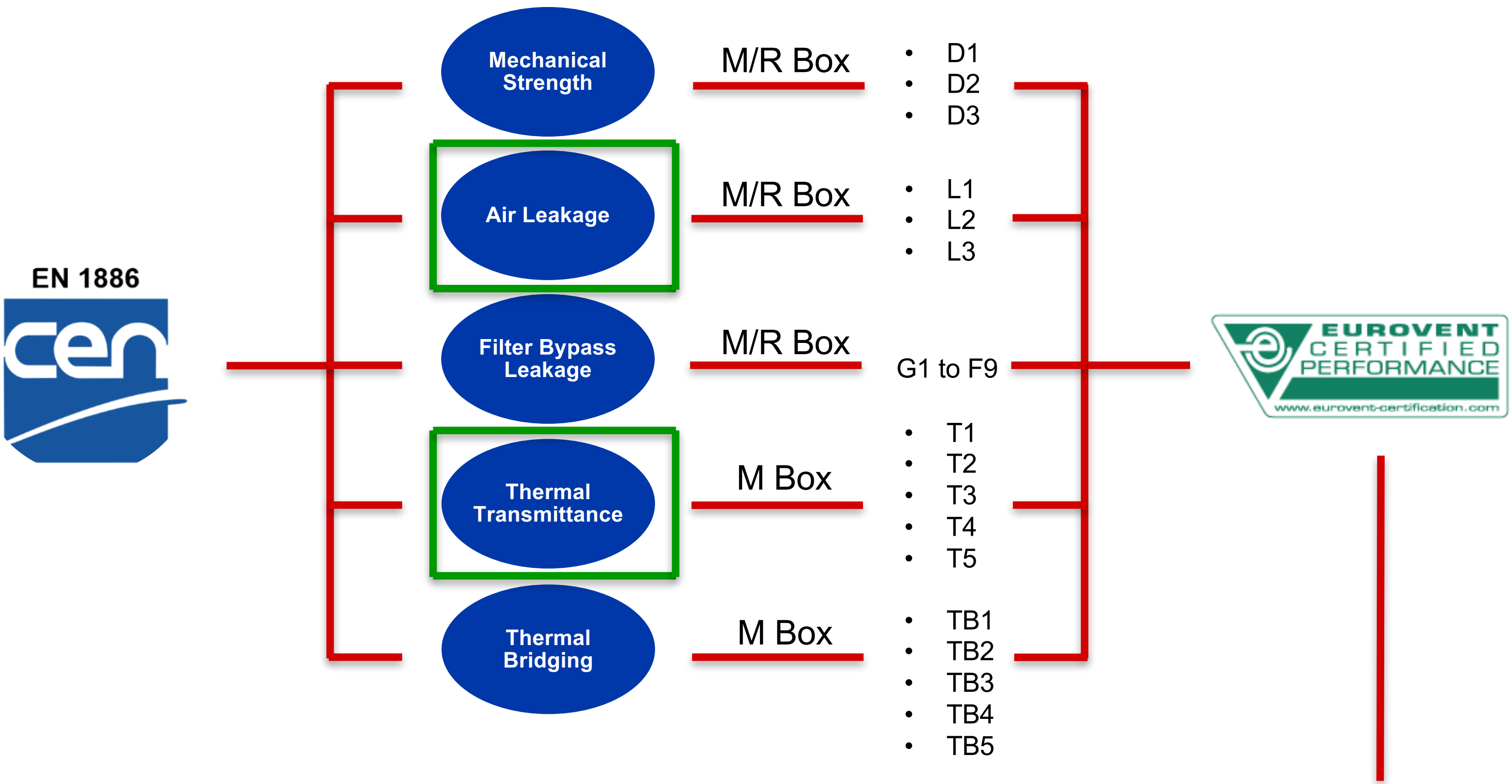
To determine whether Eurovent Certified AHU Mechanical Characteristics can provide a basis for the comparison of energy savings of different units

SCOPE

EN 1886



SCOPE



FEATURE	VALUE	UNIT
STANDARD		
TT class	T2	
TBF class	TB2	
CS class	D1(M)	
CAL class @ -400 Pa	L1(M)	
CAL Class @ +700 Pa	L1(M)	
FBL class	F9(M)	

BACKGROUND

Casing Air Leakage

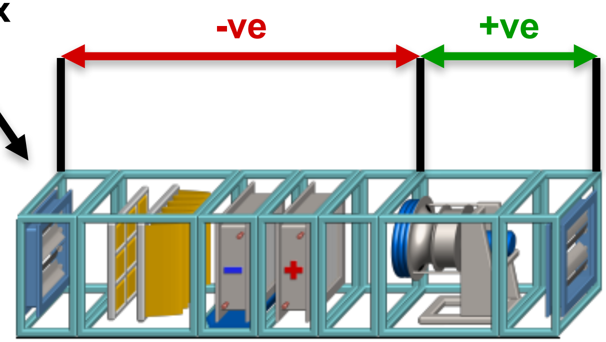
$$l_{400} = l_m \left(\frac{400}{test\ pressure}\right)^{0.65}$$

$$l_{700} = l_m \left(\frac{700}{test\ pressure}\right)^{0.65}$$

Model or **Real Box**

- Model enclosure of at least **two (2) unit** sections of identical design and assembly to real AHU including at least one access door fitted with hinges and standard closures but no window
- 0.9 m ≤ Box Height & Width ≤ 1.4 m
- $10\ m^2 \leq A_{total,\ ext} \leq 30\ m^2$

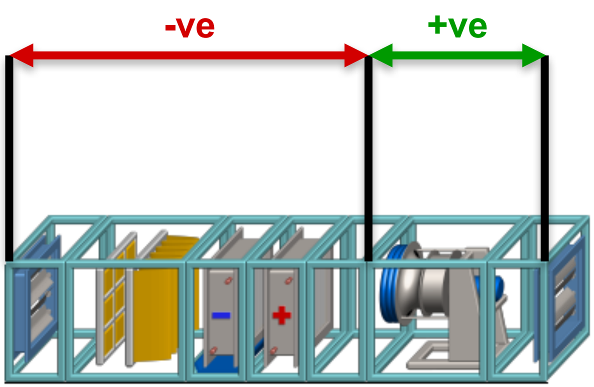
Tested @ -400 Pa & +700 Pa



- -ve Sections: Tested @ -400 Pa
- +ve Sections (Pressure<250 Pa): Tested @ -400 Pa
- +ve Sections (Pressure>250 Pa): Tested @ +700 Pa **or** @ fan operating pressure **whichever is greater**

BACKGROUND

Casing Air Leakage



$$Area = A_{unit,ext} - A_{dampers} - A_{openings}$$

$$Area = 2(WH + HL + WL) - n_1(lh) - n_2(WH)$$

Table 4 — Casing air leakage classes of air handling units, 400 Pa negative test pressure

Leakage class of casing	Maximum leakage rate (f_{400}) $l \times s^{-1} \times m^{-2}$
L1	0,15
L2	0,44
L3	1,32

NOTE The maximal leakage rates given in Table 4 are according to the ductwork leakage classes specified in EN 1507 and EN 12237, (e.g. L2 = B), but the test pressures are different.

Table 5 — Casing air leakage classes of air handling units, 700 Pa positive test pressure

Leakage class of casing	Maximum leakage rate (f_{700}) $l \times s^{-1} \times m^{-2}$
L1	0,22
L2	0,63
L3	1,90

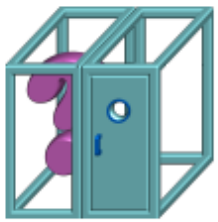
NOTE Class L1 for units for special application e.g cleanrooms.

BACKGROUND

Thermal Transmittance

Steady State ΔT = 20 K

Model Box



$Area = A_{unit,ext}$

excluding baseframe & weatherproof roof

Table 8 — Classification of thermal transmittance *U* of the casing of air handling units

Class	**Thermal transmittance (*U*)** $W \times m^{-2} \times K^{-1}$
T1	$U \leq 0,5$
T2	$0,5 < U \leq 1,0$
T3	$1,0 < U \leq 1,4$
T4	$1,4 < U \leq 2,0$
T5	No requirements

MODEL

Building Performance Simulation Model

❖ <u>Office Space</u>

- **1000 m²** of Model Space $(L = W = 10\sqrt{10}\ m)$
- H = 3.20 m
- Total Window Surface of **48 m²** placed along the S-N walls
- $U_{ext.walls}$ = 0.45 $Wm^{-2}K^{-1}$
- $U_{windows}$ = 1.90 $Wm^{-2}K^{-1}$
- U_{roof} = 0.40 $Wm^{-2}K^{-1}$
- U_{floor} = 0.80 $Wm^{-2}K^{-1}$
- No Infiltration/Exfiltration
- **100** Occupants during **Office Operating Hours**
- Lighting Load = **16.00 Wm^{-2}**
- Miscellaneous Electrical Loads = **15.00 Wm^{-2}**

❖ <u>Design Conditions</u>

Indoor Design Conditions @ Cooling:
25 °C DB/50% R.H.

Indoor Design Conditions @ Heating:
22 °C DB/50% R.H.

❖ Typical Meteorological Year

❖ Cities

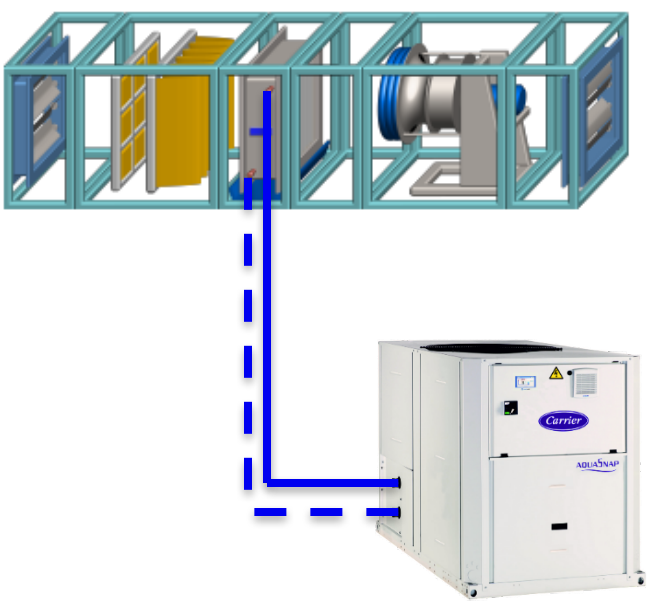
Athens
Thessaloniki
Heraklion
Rhodes

❖ Software

HAP
HOURLY ANALYSIS PROGRAM

Building Performance Simulation Model

HVAC System



- Single Zone **Constant Air Volume System** with thermostatic control
- Heating Mode: **November to April**
- Cooling Mode: **May to October**
- AHU equipped with a common cooling/heating coil to meet space requirements
- Cooling/Heating Coil paired with an air-cooled heat pump to provide chilled/heated water
- Unit Operating Hours: **8.00 am to 6.00 pm excluding weekends**
- Fresh Air Flow Rate in accordance with minimum requirements specified in **T.O.T.E.E. 20701-1/2017**

ANALYSIS

ANALYSIS

Air Leakage & Thermal Transmittance Energy Cost for Operating Hours / Year

Air Leakage

- Additional/apparent fan power energy cost (easy to calculate)
- Leakage air cooling and heating cost requires calculation of:
  1. AHU's air supply temperature, based on AHUs Cooling/Heating Load (Cooling/Heating Coil Simulation)
  2. Heat Pump's additional energy consumption, based on AHU's Cooling/Heating Load and Weather Conditions (Heat Pump Simulation)

Thermal Transmittance

- Heat Loss through AHU Casing based on mean internal and external air temperature (easy to calculate

Common Cooling / Heating Coil Operation

- Cooling
- Cooling with No Space Loads
- Heating
- Heating with No Space Loads

→ **Coil OFF**

→ **Coil ON Cooling**

*IF Air Dew Point Temperature < Water Inlet Temperature **

→ **Sensible Heat Removal ONLY**

$$\dot{Q}_{coil} = \dot{m}_{air} C_{p,air} \left(T_{coil,in} - T_{supply}\right)$$

→ **Sensible & Latent Heat Removal**

*IF Air Dew Point Temperature > Water Inlet Temperature**

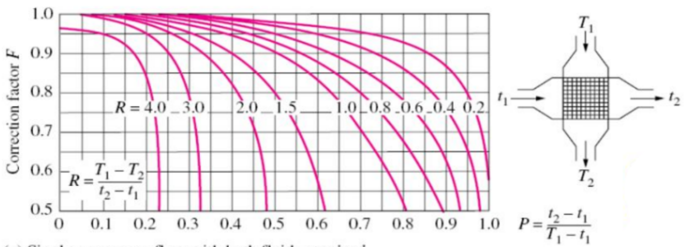
$$\dot{Q}_{coil} = \dot{m}_{air} \left(h_{coil,in} - h_{supply}\right)$$

→ **Coil ON Heating**

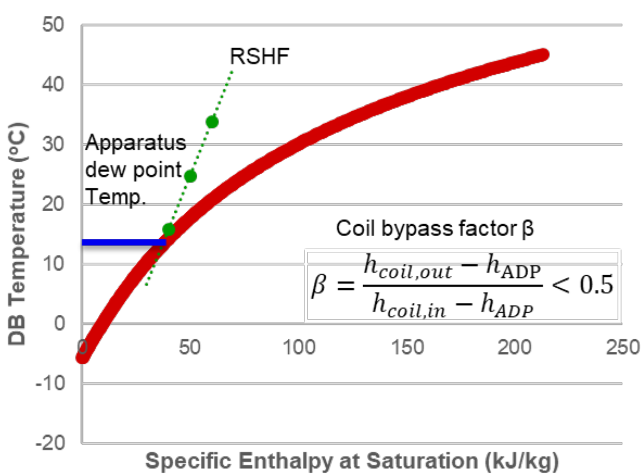
→ **Sensible Heat Addition**

$$\dot{Q}_{coil} = \dot{m}_{air} C_{p,air} \left(T_{supply} - T_{coil,in}\right)$$

Common Cooling / Heating Coil Operation



(c) Single-pass cross-flow with both fluids *unmixed*



$$\dot{Q}_{coil} = \dot{m}\left(h_{supply} - h_{coil,in}\right)$$

$$UA \times F \times LMHD = \dot{m}\left(h_{supply} - h_{coil,in}\right)$$

Sensible & Latent Heat Removal

$$\Delta T_{water} = 5\,K$$

$$\dot{m}_{water} = Variable$$

Effectiveness – NTU Method

$$\varepsilon = 1 - exp\left\{\frac{exp(-NTU \times C_r \times NTU^{-0.22}) - 1}{C_r \times NTU^{-0.22}}\right\}$$

$$NTU = \frac{UA}{min(\dot{m}_{water} \times C_{p,water}, \dot{m}_{air} \times C_{p,air})}$$

$$C_r = \frac{min(\dot{m}_{water} \times C_{p,water}, \dot{m}_{air} \times C_{p,air})}{max(\dot{m}_{water} \times C_{p,water}, \dot{m}_{air} \times C_{p,air})}$$

$$T_{air,out} = T_{air,in} - \varepsilon \times \frac{Q_{max}}{\dot{m}_{air} C_{p,air}}$$

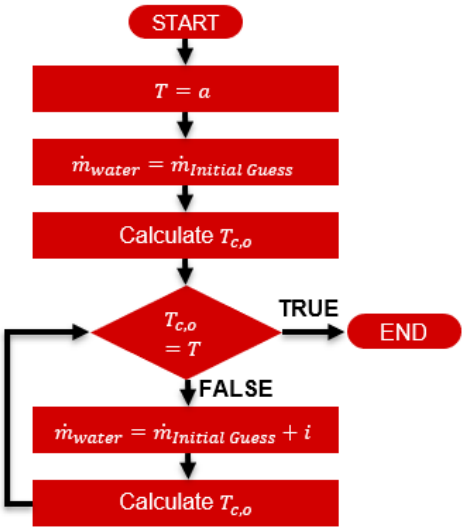
$$T_{water,out} = T_{water,in} + \varepsilon \times \frac{Q_{max}}{\dot{m}_{water} C_{p,water}}$$

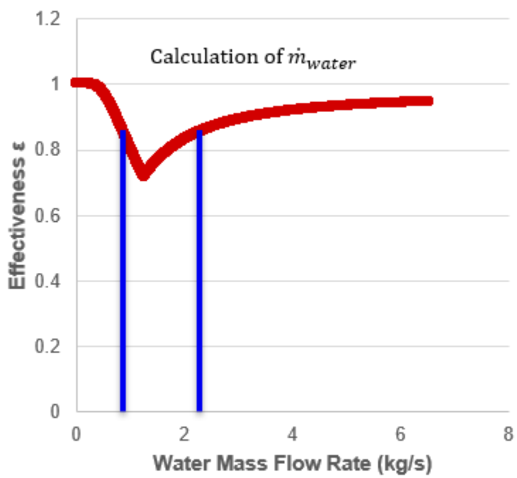
$$H_{air,out} = H_{air,in} - \varepsilon \times \frac{Q_{max}}{\dot{m}_{air}}$$

$$H_{water,out} = H_{water,in} + \varepsilon \times \frac{Q_{max}}{\dot{m}_{water}}$$

$$Q_{max} = min(\dot{m}_{water} C_{p,water}, \dot{m}_{air} C_{p,air}) \times (T_{air,in} - T_{water,in})$$

Common Cooling / Heating Coil Operation





$$UA_{coil,enthalpy} = \frac{\dot{Q}_{coil}}{LMHD}$$

$$UA_{coil,ext} = C_{p,air} UA_{coil,enthalpy}$$

$$UA_{coil,total} = \frac{1}{\frac{1}{UA_{coil,int}} + \frac{1}{UA_{coil,ext}}}$$

$$UA = \left(\frac{1}{(hA)_{water}} + \frac{1}{\eta_f (hA)_{air}}\right)^{-1}$$

$$(hA)_{water} = x_{water} \left(\frac{\dot{m}_{water}}{\dot{m}_{water,0}}\right)^{0.85} (hA)_{water,0}$$

$$x_{water} = 1 + \left(\frac{0.014}{1 + 0.014 \times T_{water,in,0}}\right)\left(T_{water,in} - T_{water,in,0}\right)$$

$$\eta_f (hA)_{air} = x_{air} \left(\frac{\dot{m}_{air}}{\dot{m}_{air,0}}\right)^{0.80} \left(\eta_f (hA)_{air,0}\right)$$

$$Q_{max} = f\left[min\left(\dot{m}_{air} C_{p,air}, \dot{m}_{water} C_{p,water}\right)\right]$$

$$\dot{Q}_{sens} = \dot{m}_{air} C_{p,air} \left(T_{supply} - T_{coil,in}\right)$$

$$\dot{m}_{water} = \frac{\dot{Q}_{sens}}{\Delta T_{water} \times C_{p,water}}$$

ANALYSIS

Heat Pump – Cooling Mode Efficiency Simulation

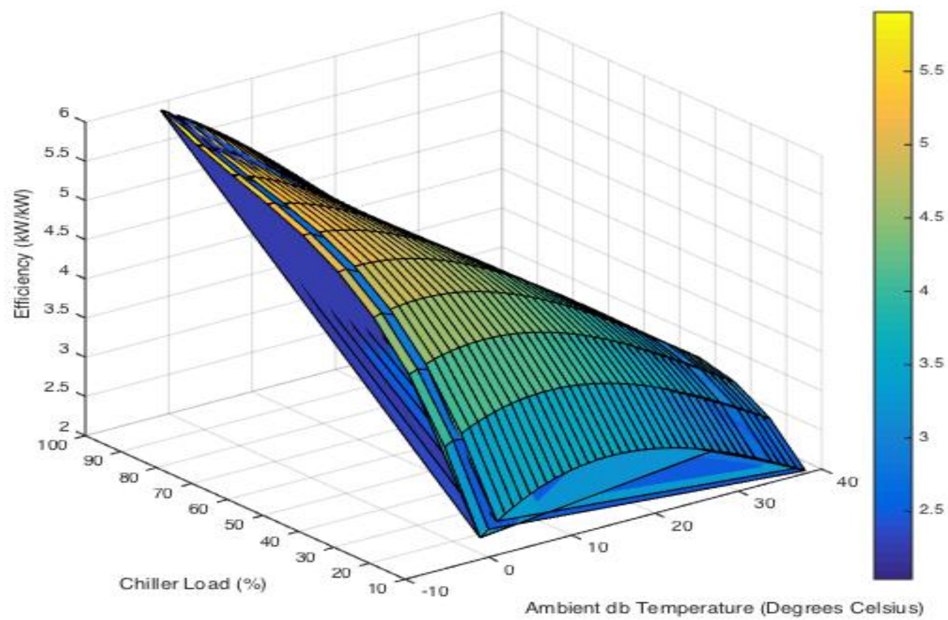
$eff = f(Amb.Temp, Chiller\ Load) = f(x, y)$

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

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

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

$R^2 = 0.9978, RMSE = 0.0502$



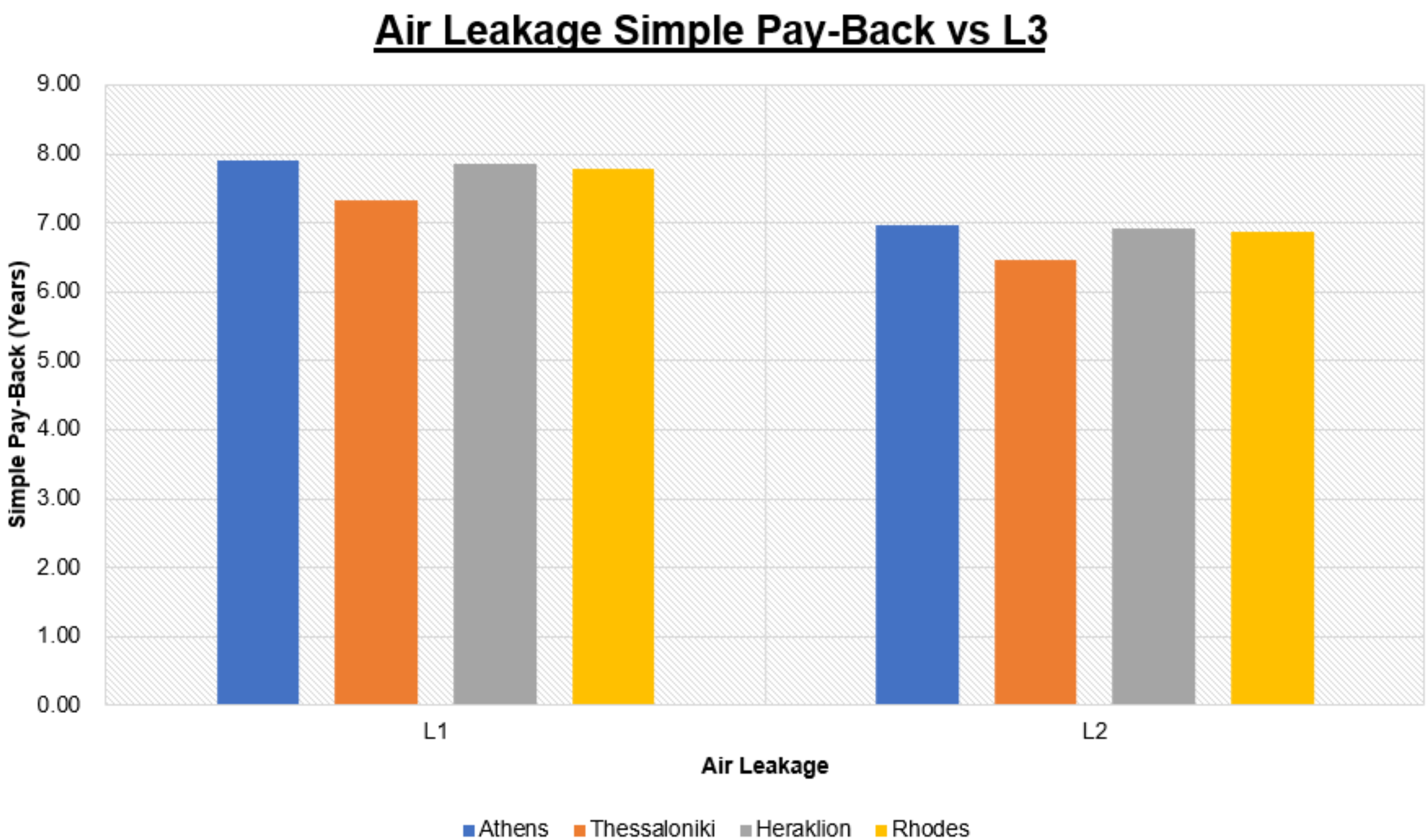
RESULTS

Assumptions

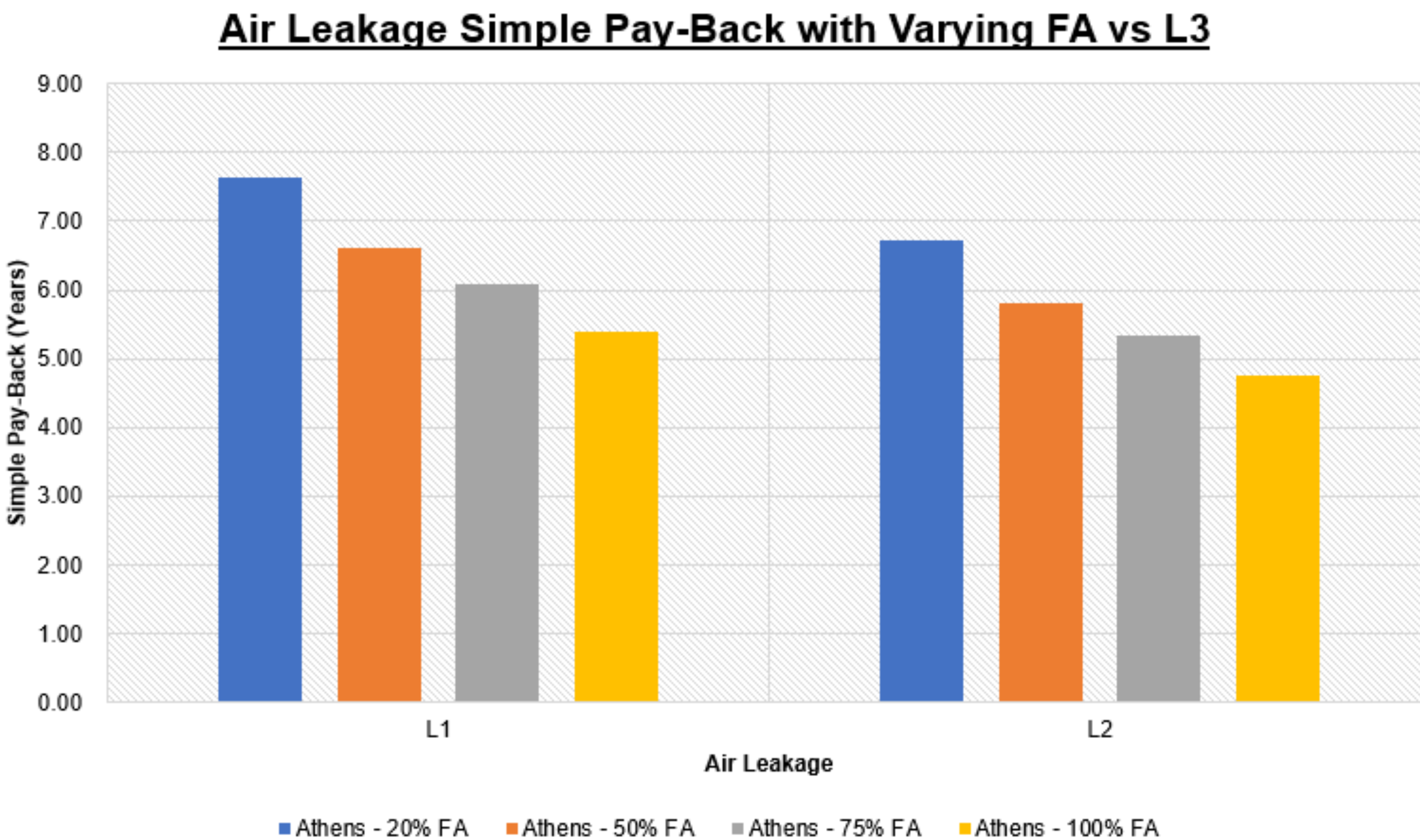
Electricity Cost = **0.145 €/kWh**

Cost Difference between AHUs of
Different Mechanical Performance Class in the range of **2 to 4%**

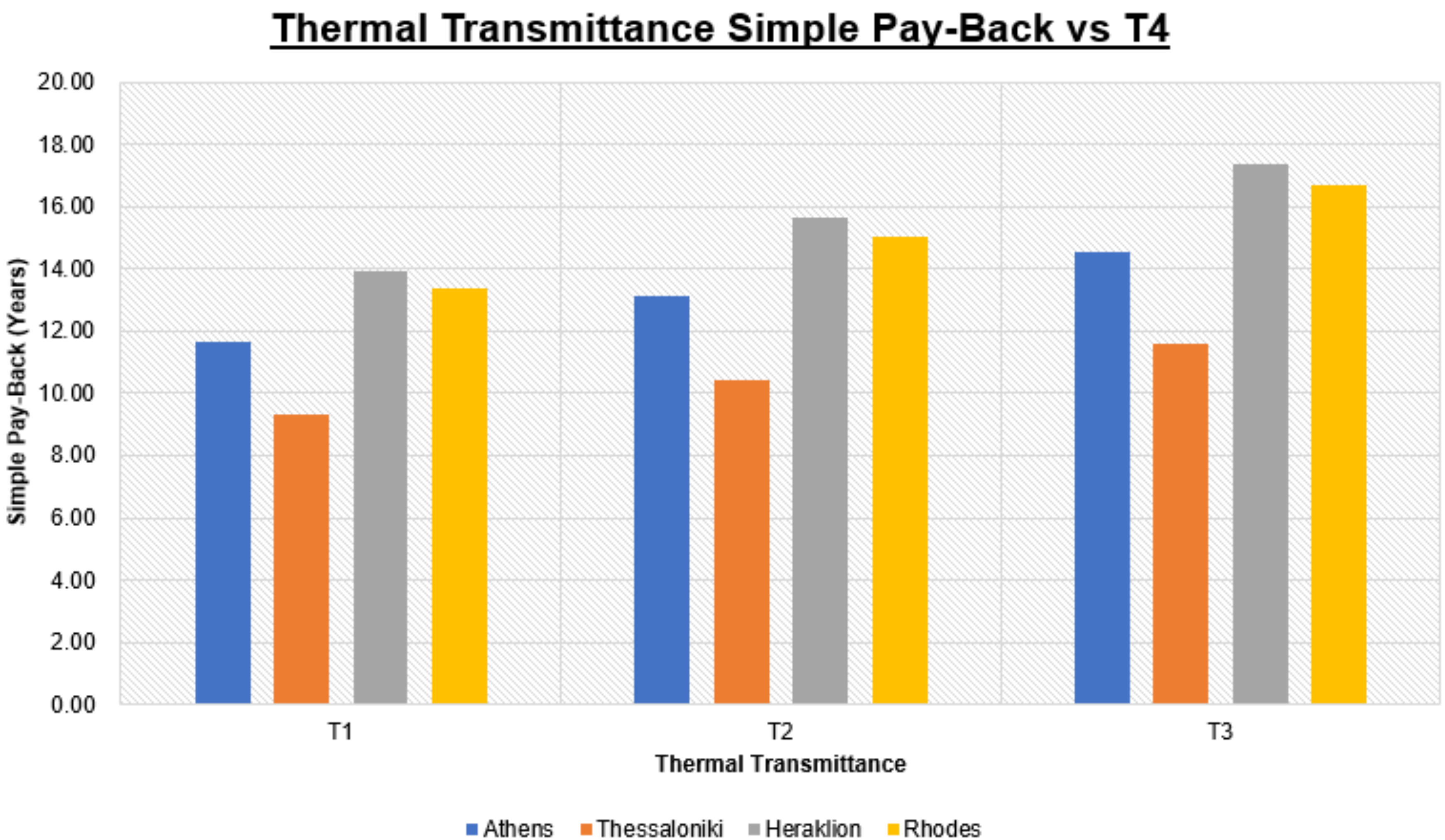
RESULTS


Air Leakage Simple Pay-Back vs L3
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Simple Pay-Back (Years)
L1
L2
Air Leakage
Athens
Thessaloniki
Heraklion
Rhodes

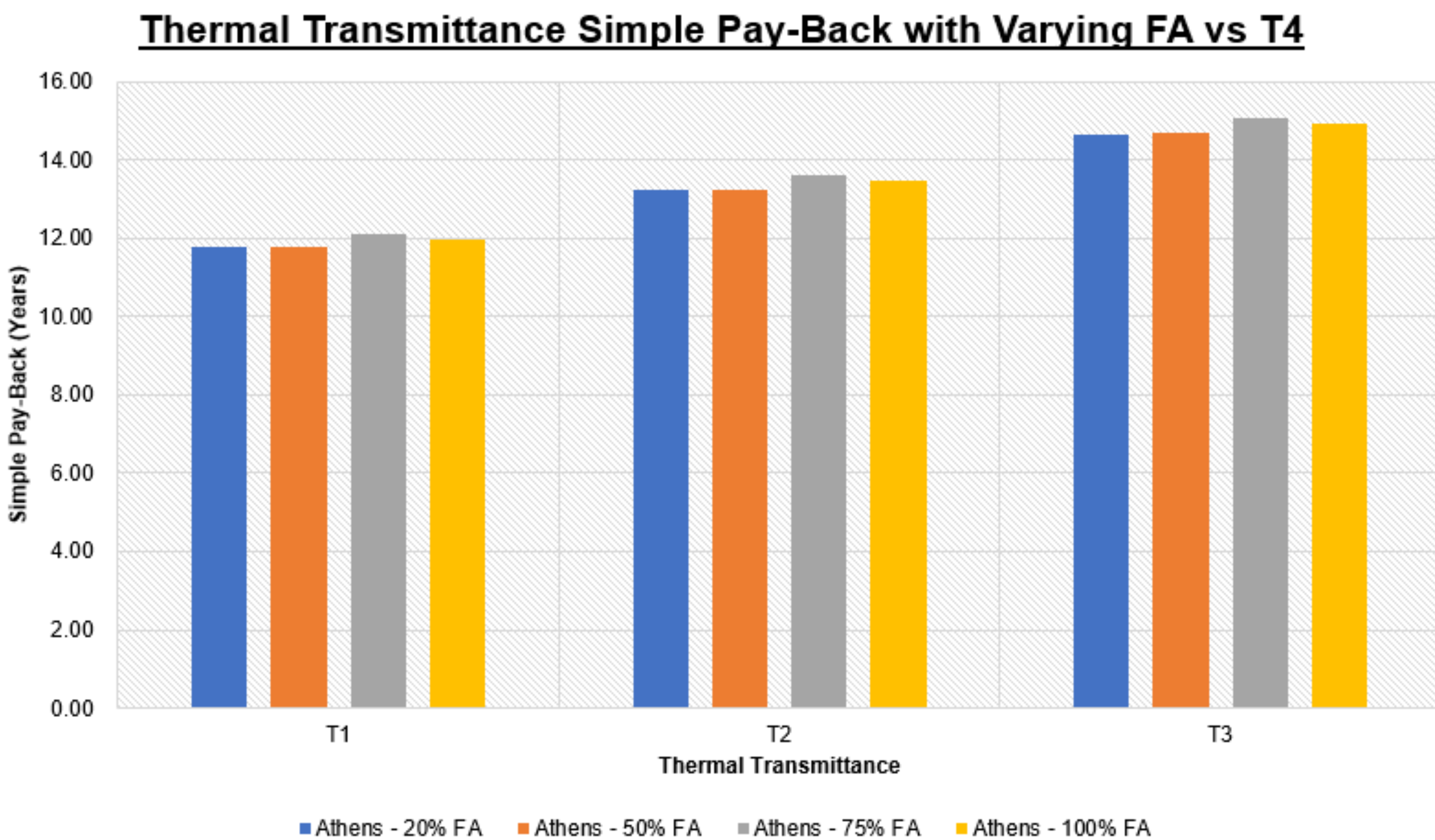
RESULTS


Air Leakage Simple Pay-Back with Varying FA vs L3
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Simple Pay-Back (Years)
L1
L2
Air Leakage
Athens - 20% FA
Athens - 50% FA
Athens - 75% FA
Athens - 100% FA

RESULTS


Thermal Transmittance Simple Pay-Back vs T4
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Simple Pay-Back (Years)
T1
T2
T3
Thermal Transmittance
Athens
Thessaloniki
Heraklion
Rhodes

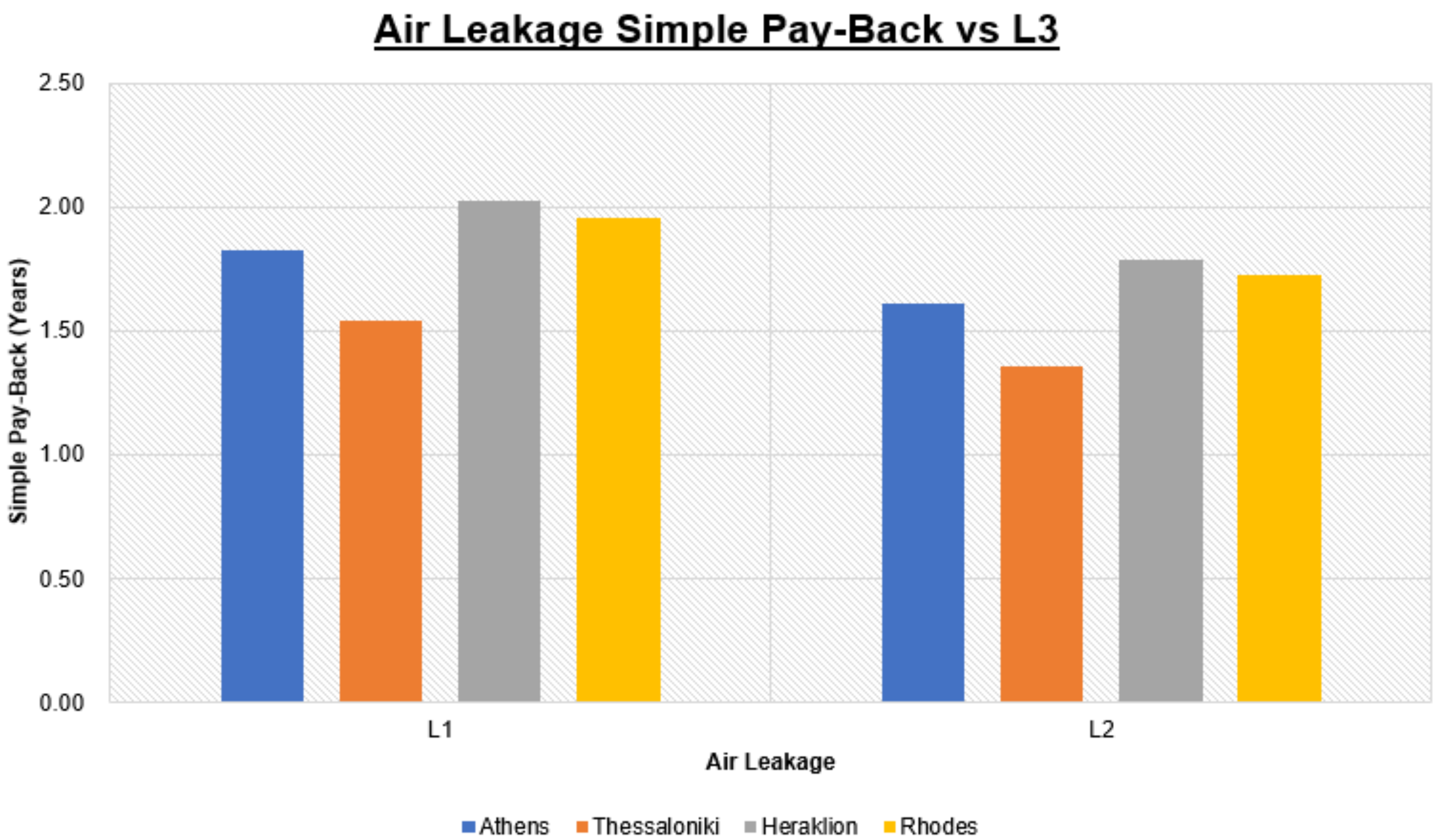
RESULTS



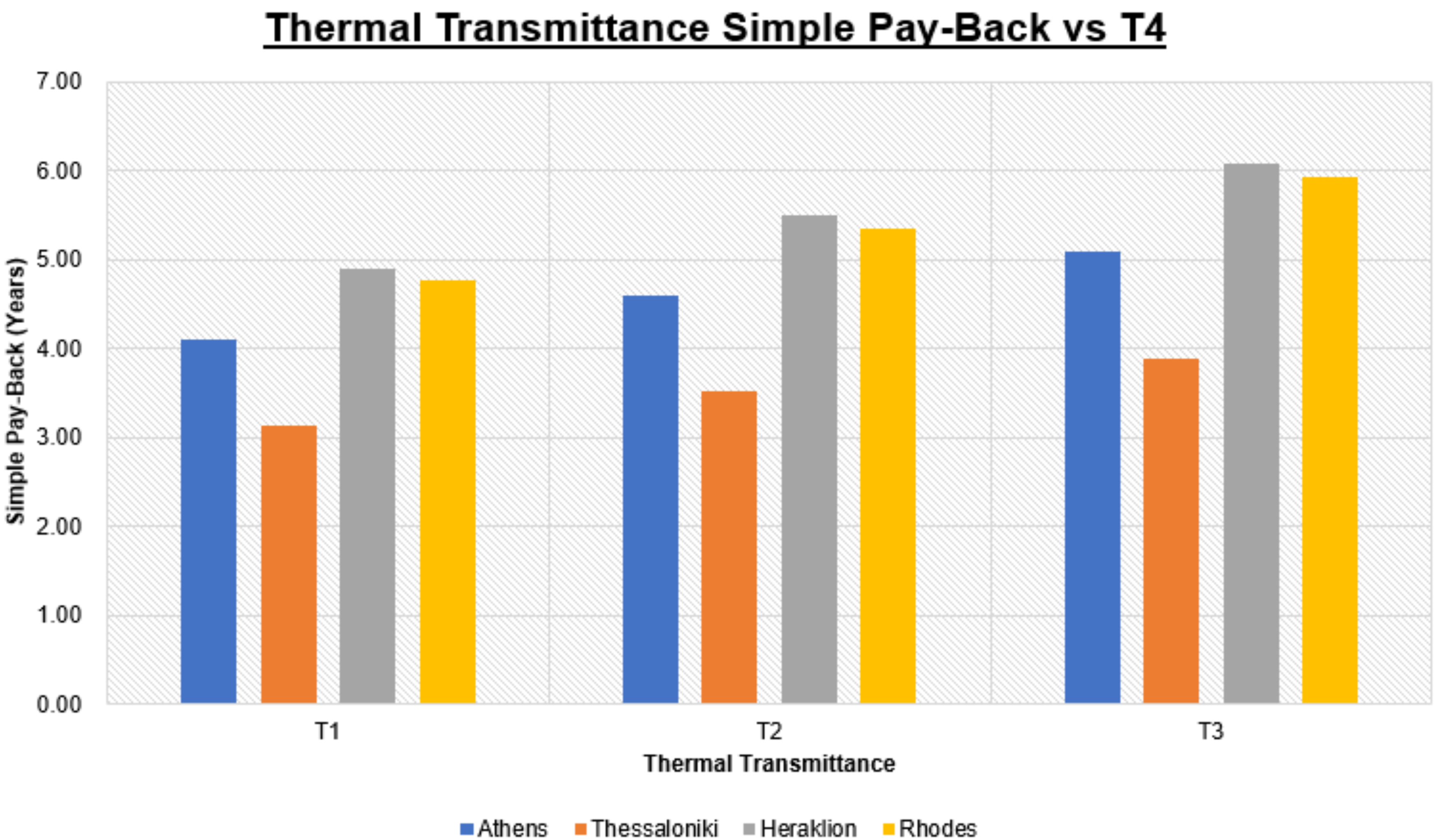
Thermal Transmittance Simple Pay-Back with Varying FA vs T4
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Simple Pay-Back (Years)
T1
T2
T3
Thermal Transmittance
Athens - 20% FA
Athens - 50% FA
Athens - 75% FA
Athens - 100% FA

RESULTS

Hospital Application



Hospital Application



SUMMARY

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- Eurovent Certified Air Handling Unit Mechanical Characteristics can provide a basis for the comparison of AHUs Energy Savings Potential

- Pay-back period is **heavily influenced** by unit operating hours (**application requirement**) and AHU fresh air flow rate

- In terms of Air Leakage Class **(L)**, units appear to offer **competitive** pay-back periods across all 4 cities, particularly in Fresh Air AHU applications

- In terms of Thermal Transmittance Class **(T)**, units appear to offer longer pay-back periods across all 4 cities. Cities with extreme weather conditions tend to offer the most competitive pay-back periods

QUESTIONS?