Hall 9

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Chillventa Specialist Forums 2022
Chillventa Fachforen 2022

CONNECTING
EXPERTS.

R-744 unit: The future of heat exchangers

Stefano Filippini
Technical director, LU-VE Group
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R-744 unit: the future of heat exchangers

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Agenda:

- Introduction on CO_2 units and advantages on the Environment
- CO_2 : Advantages on the heat exchangers market
- Technical aspects of CO_2 and advantages
- Certification of CO_2 units
- Impact of overestimated performance of CO2 gas coolers on plant efficiency
- Conclusion
- Certification by Eurovent Certita Certification
  - How does it work?
  - Certification Programmes (including Heat Exchangers programme)

Introduction on CO2 units and advantages on the Environment

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Why CO2 as fluid?

- Nowadays, the HFC refrigerants are phased down on the heat exchangers market because of their high Global Warming Potential (GWP)
- Carbon dioxide (CO_2) is a non-toxic and non-flammable natural refrigerant
- The use of CO_2 as working fluid is a well-established reality in the refrigeration industry and the number of new CO_2 plants is continuously increasing.
- CO_2 unit coolers and air-cooled CO_2 gas coolers have to ensure high and reliable performances
- The Eurovent program Heat Exchangers for refrigeration (HE) involves the major manufacturers of the market. The program, based on a voluntary approach, certifies the products performance through selection software validation and product testing in a third part laboratory.
- CO_2 unit coolers and gas coolers are included in the certification of heat exchangers. Due to the peculiar properties of CO_2, a dedicated performance evaluation process was established and in the third part laboratory was realized a new state of the art test ring.

Refrigerant	GWP
R 404a	3922
R507	3985
R 404a	3922
R 422a	4143
R 422d	2729
R 407a	2107
R 407f	1825
R 407c	1774
R 410a	2088
R 452a	2141
R32	675
R 134a	1430
R 448a	1273
R 449a	1397
R 450a	600
R 513	631
R 152a	124
R 454c	148
R 455a	145
R 290 (propane)	3
R 717 (NH3)	0
R 744 (CO2)	**1**
1234ze	6
1234yf	4

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CO_2 : Advantages on the heat exchangers market

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- NATURAL: no need to recover, reclaim or recycle as synthetic refrigerants
- LOW MASS VOLUME: compact equipment
- LOW COMPRESSION RATIO
- LOW ENVIRONMENTAL IMPACT: ODP = 0; GWP = 1
- AVAILABILITY IN NATURE
- COMPATIBILITY WITH ALL MATERIALS: non-corrosive
- HIGH REFRIGERATION CAPACITY: down to -54°C
- SAFETY: non-flammable; non-toxic
- MISCIBILITY:– Compatible with oil compressors

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CO_2 : Advantages on the heat exchangers market

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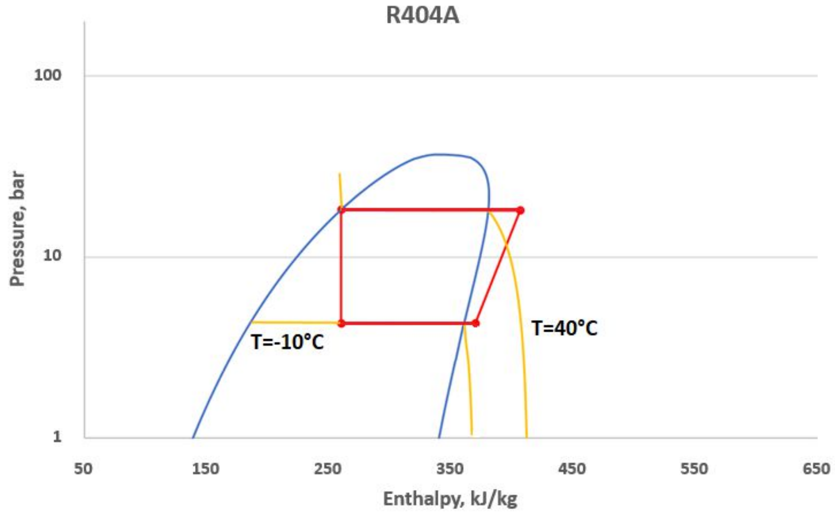
Comparison CO_2 – R404A

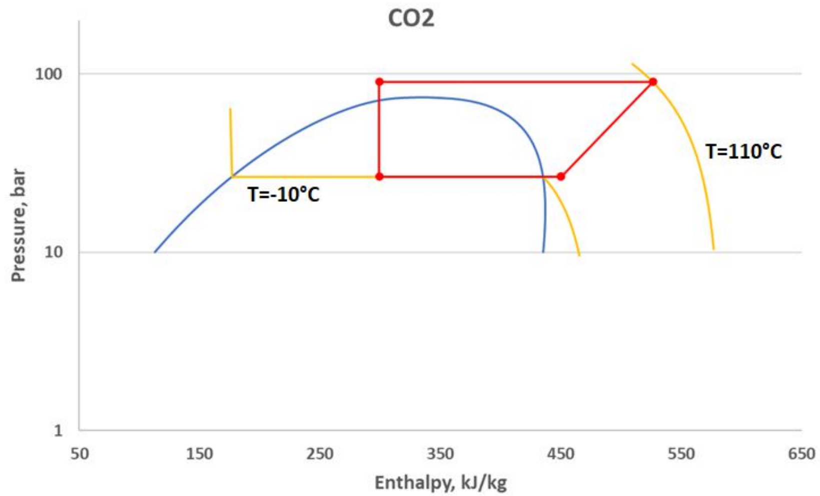
- As example, the theoretical performance of two refrigerants such as CO2 and R404A is compared.
- The working hypotheses are as follows:
  - the CO_2 cooling stage is in the "transcritical" zone (cooling above the critical point: 31°C, 73.6 bar);
  - the evaporation temperature is -10°C in both cases (classic application of positive cold);
  - the condensation temperature for R404A is 40°C
  - The gas cooling pressure for CO2 is 90 bar

➔The energy efficiency in refrigeration application is relatively good if the cooling phase (with " gas cooler") at the temperature level is well controlled.

➔The temperatures at the inlet of the " gas cooler" or any exchanger can reach values over 100°C, which is interesting for conventional heating applications by heat pump.

➔ The energy efficiency in heat production can be very good insofar as the installation can hold significant pressures (around 90 bar).





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The impact on performances while using CO2 fluid

Impact on cooling capacity when replacing the HFC refrigerant by CO_2.

– Evaporators using HFC vs CO_2:

Evaporators using HFC as fluid	Evaporators using CO2 as fluid	Impact of CO2 on cooling capacity
UN HFC DX1	UN CO_2 DX1	11%
UN HFC DX2	UN CO_2 DX2	9%
UN HFC DX3	UN CO_2 DX3	13%
UN HFC DX4	UN CO_2 DX4	16%
UN HFC DX5	UN CO_2 DX5	-10%
UN HFC DX6	UN CO_2 DX6	12%
UN HFC DX7	UN CO_2 DX7	17%
UN HFC DX8	UN CO_2 DX8	14%
UN HFC DX9	UN CO_2 DX9	-12%
UN HFC DX10	UN CO_2 DX10	5%

By replacing the HFC by CO_2 as fluid, the average increase of more than 10% in cooling capacity !!!

CO_2 certification: performance declaration, standard conditions

– Certified performance items for CO_2 evaporators:
  - Standard capacity [kW]
  - Fan power input [W]
  - Energy Ratio R [-]
  - Energy class [-]
  - Air volume flow [m3/h]

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Certification of CO_2 units

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CO_2 certification: performance declaration, standard conditions

– For CO_2 Evaporators, the cooling capacity can be declared within four (4) standard conditions :

Standard Conditions for Refrigerants	Air Inlet Temperature (°C)	Evaporating Temperature (°C)
SC1	10	0
SC2	0	-8
SC3	-18	-25
SC4	-25	-31

The participant declares all working conditions !!!

– During the selection of units to be tested, the standard condition SC2 is privileged:

– The test is done according to EN 328:2014

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Certification of CO_2 units

Energy ratio and Energy class for CO_2 DX Air Coolers:

$$R_{CO_2DX\ air\ coolers} = \frac{\text{Thermal capacity @ SC2 wet}}{\text{Fan power consumption}} \times \sqrt{\frac{\text{fin spacing}}{4.5}}$$

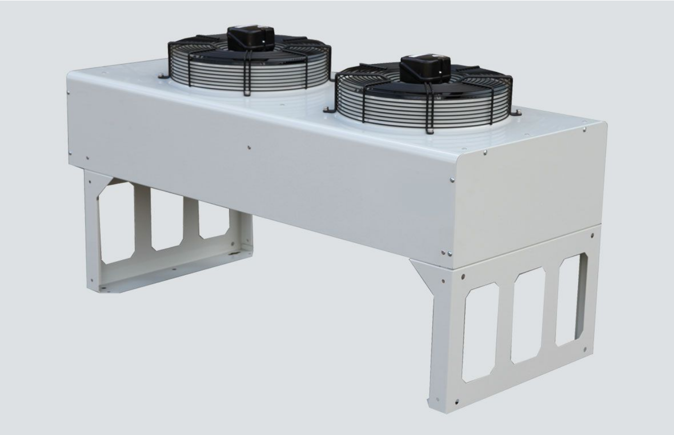
Energy class	Energy consumption	CO_2 DX Air coolers
A+	Extremely low	R ≥ 73
A	Very Low	47 ≤ R<73
B	Low	35 ≤ R< 47
C	Medium	25 ≤ R< 35
D	High	16 ≤ R< 25
E	Very high	R< 16

EN 328:2014

Certification of CO_2 units

CO2 certification: performance declaration, standard conditions

– Certified performance items for CO_2 Gas coolers:
  - Standard capacity [kW]
  - Fan power input [W]
  - Energy Ratio R [-]
  - Energy class [-]
  - Air volume flow [m3/h]
  - Refrigerant side pressure drops [kPa]
  - A-weighted sound pressure level [dB(A)]
  - A-weighted sound power level [dB(A)]



Certification of CO_2 units

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CO_2 certification: performance declaration, standard conditions

- For CO_2 Gas coolers, the cooling capacity is to be declared within two (2) standard conditions :

  - **Transcritical mode**:

Standard condition	Air inlet temperature [± 1 K]	Gas cooler inlet pressure [± 1 bar]	Gas cooler inlet temperature [± 5 K]	Gas cooler outlet temperature [± 1 K]
SC20	30°C	90 bar	110°C	35°C

-Subcritical mode:

Standard condition	Air inlet temperature	Condensing temperature	Refrigerant inlet temperature	Subcooling
SC25	5°C	15°C	60°C	<3 K

CO_2 gas coolers shall be tested under Eurovent Standard Conditions for CO_2 Gas Coolers (both transcritical and subcritical conditions)

EN 327:2014

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Certification of CO_2 units

Certified performances and correction factors according to the market condition

– For CO_2 Gas coolers, the correction factors are the following:

Condition in transcritical mode	Correction factor
A5 (SC20)	1.00
A3	0.82
A2	0.71
B5	1.08
B3	0.88
B2	0.76
C5	0.80
C3	0.62
C2	0.52

Conditions of the market that were defined within HE programme

↓

Condition in transcritical mode	Gas cooler inlet pressure	Gas cooler inlet temperature	Air Inlet temperature	Gas cooler outlet temperature	DT (temperature approach)
A5 (SC20)	90 bar	110 °C	30 °C	35 °C	5 K
A3	90 bar	110 °C	32 °C	35 °C	3 K
A2	90 bar	110 °C	33 °C	35 °C	2 K
B5	95 bar	120 °C	33 °C	38 °C	5 K
B3	95 bar	120 °C	35 °C	38 °C	3 K
B2	95 bar	120 °C	36 °C	38 °C	2 K
C5	80 bar	100 °C	27 °C	32 °C	5 K
C3	80 bar	100 °C	29 °C	32 °C	3 K
C2	80 bar	100 °C	30 °C	32 °C	2 K

EUROVENT makes sure that the factors are applied accordingly before certifying Gas cooler manufactures!!!

Certification of CO_2 units

Test campaigns: TUV SUD lab, description of the test plant.

Description of CO_2 test rig:

– The new state of the art test rig in the “Center of Competence for Refrigeration and Air-Conditioning” of TÜV SÜD Industrie Service realizes high precision measurements of capacities in standard conditions as well as outside the usual needed conditions.

– Thus, the test rig meets the requirements of :

  - DIN EN 327 (forced convection air cooled refrigerant condensers), which includes gas coolers in its scope
  - DIN EN 328 (forced convection unit air coolers for refrigeration).

– With the test rig it is possible to measure evaporators with capacities up to 40 kW and gas coolers up to 100 kW.

– Units of various sizes and capacities can be tested due to the use of four compressors with different performance levels.

Certification of CO_2 units

Test campaigns: TUV SUD lab, description of the test plant.

Description of CO_2 test rig:

- Because of the high-pressure strength of the used refrigerant-bearing components, measurements are possible in trans-critical and sub-critical operation.
- The incorporated components include pipes, safety valves, connections, and flexible hoses to meet the requirements of a wide range of applications and test units.
- In addition, the test rig can withstand thermal stress in a temperature range down to -40°C in evaporating mode and up to 120°C in the gas cooling mode.
- Since carbon dioxide is odorless and displaces oxygen, the test chambers in TÜV SÜD laboratory are equipped with the appropriate sensors and warning systems to guarantee a safe operation.

Certification of CO_2 units

Test campaigns: TUV SUD lab, description of the test plant.

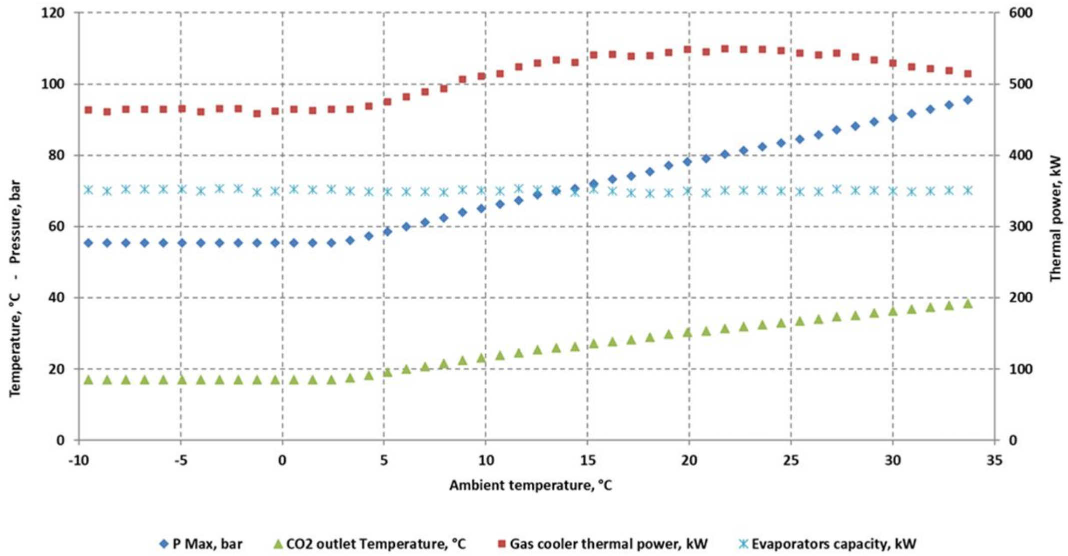
Impact of overestimated performance of CO2 gas coolers on plant efficiency

Let's now try to investigate the impact of an overestimation of CO_2 gas cooler on the efficiency of a refrigeration plant, i.e. on the annual power consumption (and on its related cost) of the system.

A couple of simulations were performed to estimate the efficiency of the thermodynamic cycle, coupling some theoretical and empirical rules to the rated thermal capacity of the CO_2 gas cooler. Here below the main assumptions for the simulations:

- Two temperature levels:
  - Medium temperature (MT): $T_{evap,MT}$ = -8 °C; $Q_{evap,MT}$ = 250 kW
  - Low temperature (LT): $T_{evap,LT}$ = -30 °C; $Q_{evap,LT}$ = 100 kW
- Design ambient temperature: 35°C
- Maximum operating pressure: 95 bar
- Design gas cooler capacity (SC20) = 490 kW
- Electricity specific cost: 0,25 €/kWh

If we perform the simulation considering that design capacity is in line with the real performance of the CO_2 gas cooler (case 1), we obtain the following results:



Economic simulation (case 1) considering Energy cost of 0.25 €/kWh

Plant electricity consumption, MWh/year	1.456
Gas cooler fans electricity cost, €/year	8.134
Compressor electricity cost, €/year	355.746
Total cost, €/year	363.880

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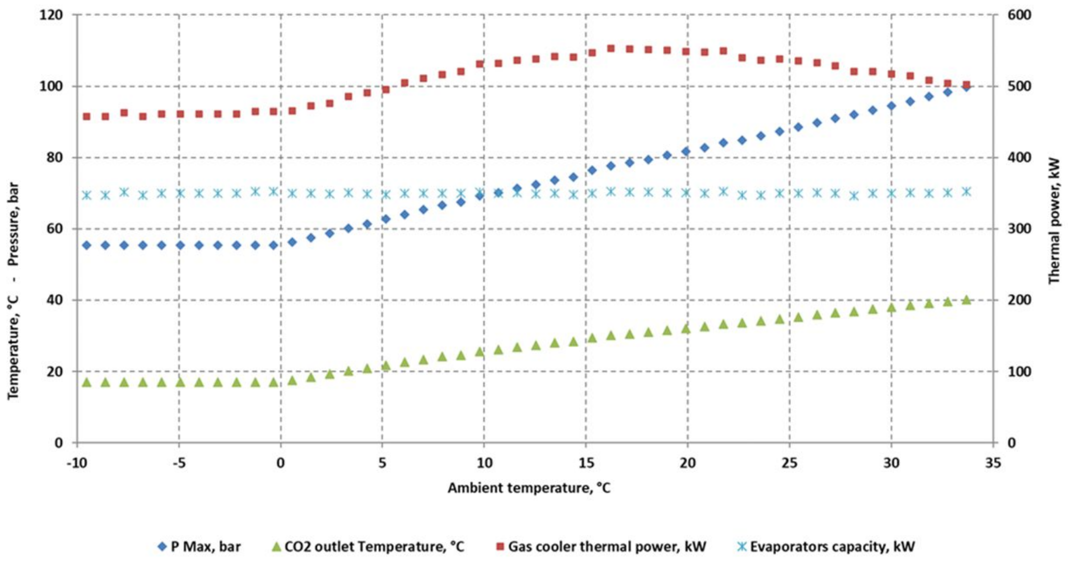
Which can be the results if the real capacity of the gas cooler is lower than the declared value? To answer this question, let's now consider a second example (case 2) in which the manufacturer has applied, for instance, a 25% oversizing coefficient: this would result in a real thermal capacity lower than the declared one.



Economic simulation (case 2) considering Energy cost of 0.25 €/kWh

Plant electricity consumption, MWh/year	1.518
Gas cooler fans electricity cost, €/year	8.633
Compressor electricity cost, €/year	370.824
Total cost, €/year	379.457

Of course, in this case, the compressor has to compensate the lack of capacity of the gas cooler to keep the useful effect at the evaporators as expected. In particular, the maximum pressure reached by the system in the design condition is over 99 bar, more than 4 bar higher than the design maximum pressure.

This difference may appear insignificant, but the impact on the annual consumption is absolutely non-negligible:

Plant electricity consumption, MWh/year	+4,2%	62
Gas cooler fans electricity cost, €/year	+6,1%	499
Compressor electricity cost, €/year	+4,2%	15.078
Total cost, €/year	+4,3%	15.577

The annual increase of cost considering a gas cooler capacity 25% lower than expect is therefore about 15.600€, resulting in 156.000 € in a 10-years lifetime.

Of course, the higher is the gap between declared and real gas cooler capacity, the higher is the impact on the plant consumptions.

Conclusions

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- Carbon dioxide (CO_2) is a non-toxic and non-flammable natural refrigerant, with a **low environmental impact** (GWP=0). The use of CO_2 as working fluid is a well-established reality in the refrigeration industry and the number of new CO_2 plants is continuously increasing.

- The **Eurovent program Heat Exchangers for refrigeration** (HE) involves the major manufacturers of the market. The program, based on a voluntary approach, certifies the products performance through selection software validation and product testing in a third part laboratory.

- CO_2 unit coolers and gas coolers are included in the certification of heat exchangers. Due to the peculiar properties of CO_2, a dedicated performance evaluation process was established and in the third part laboratory was realized a new state of the art test ring.

- Anyway, to avoid that the installation of CO2 systems is intended only as a green-washing operation, it is necessary that all the components of the plant, including the heat exchangers, are designed and run efficiently.

- Eurovent mark is a warranty in this sense, certifying the **reliability of the performance** of the CO2 unit coolers and gas coolers, whose importance has been explained through some thermodynamic simulations shown in this presentation.

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Certification by EUROVENT CERTITA CERTIFICATION

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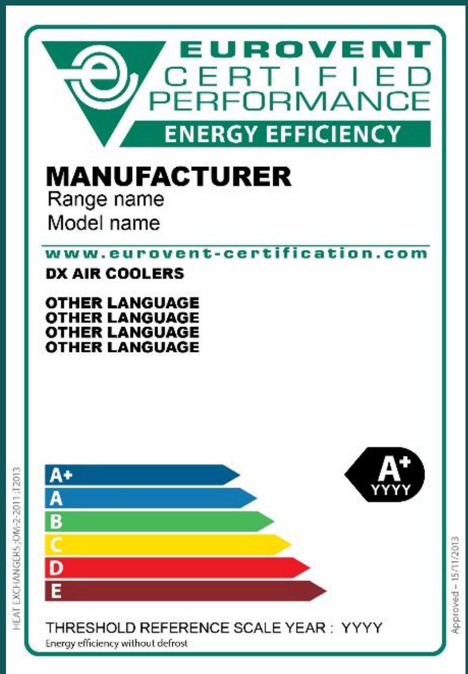
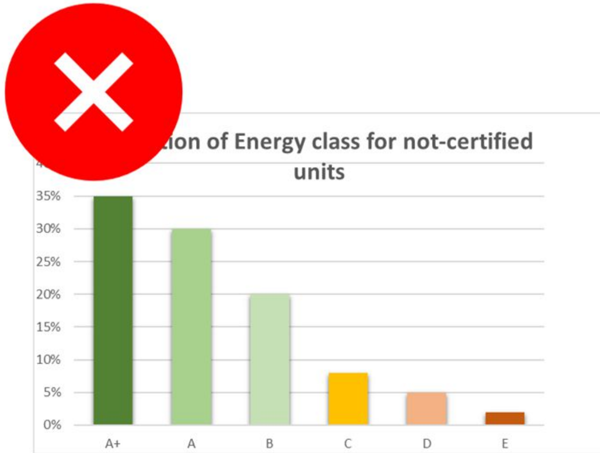
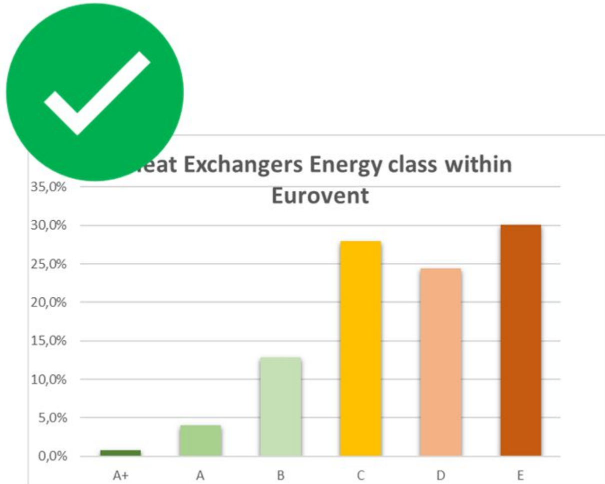
ECC Voluntary labelling for CO_2 units

How and by who is labelling prepared?

❖ Based on European testing standards (EN 327:2014 for CO_2 Gas coolers and EN 328:2014 for CO_2 air coolers)







Meaningful ratings and balanced distribution of classes are the key points

Acc. to Certification Manual Ed. 19 art. 318:
A+ < 1 %, A < 5 %, B < 15 %, C < 30 %, D and E > 50 %

Certification by EUROVENT CERTITA CERTIFICATION

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Eurovent Certita Certification in numbers

44
Certification programmes

+300K
Certified products

+1800
Tests / years

24/7
Performance data available on website

+2600
Certificates delivered / year

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Certification Programmes

EUROVENT CERTIFIED PERFORMANCE

CERTIFICATION PROGRAMMES

FOR DOMESTIC, COMMERCIAL AND INDUSTRIAL FACILITIES

VENTILATION & AIR QUALITY

- Air cleaners*
- Air filters*
- Air handling units*
- Air handling units - Hygienic
- Chimneys and ducts
- Chimneys and metal linings
- Clay/ceramic chimney products
- Controlled mechanical ventilation
- Fans
- Humidity-controlled ventilation
- Indoor air quality and energy efficiency of ventilation systems
- Plate heat exchangers*
- Residential air filters
- Residential air handling units
- Rotary heat exchangers*
- Ventilation ducts

INDOOR CLIMATE

- Air conditioners*
- Chilled beams*
- Comfort chillers
- Domestic appliances that use liquid or solid fuels
- Domestic solar water heaters
- Fan coil units
- Heat interface units*
- Heat pumps
- Hybrid heat pumps
- Liquid-to-liquid plate heat exchangers
- Micro combined heat and power
- Mobile heaters
- Radiators
- Rooftop units*
- Solar processes
- Temporal variation of thermostatic valves
- Thermostatic radiator valves
- Variable refrigerant flow systems*

PROCESS COOLING & FOOD COLD CHAIN

- Condensing units
- Cooling and heating coils
- Cooling towers
- Drift eliminators
- Evaporative cooling
- Heat exchangers
- IT cooling units*
- Process chillers*
- Refrigerated display cabinets
- Twin coils heat exchangers

*All models in the production must be certified: Certify all principle

44 certification programmes

For buildings and homes

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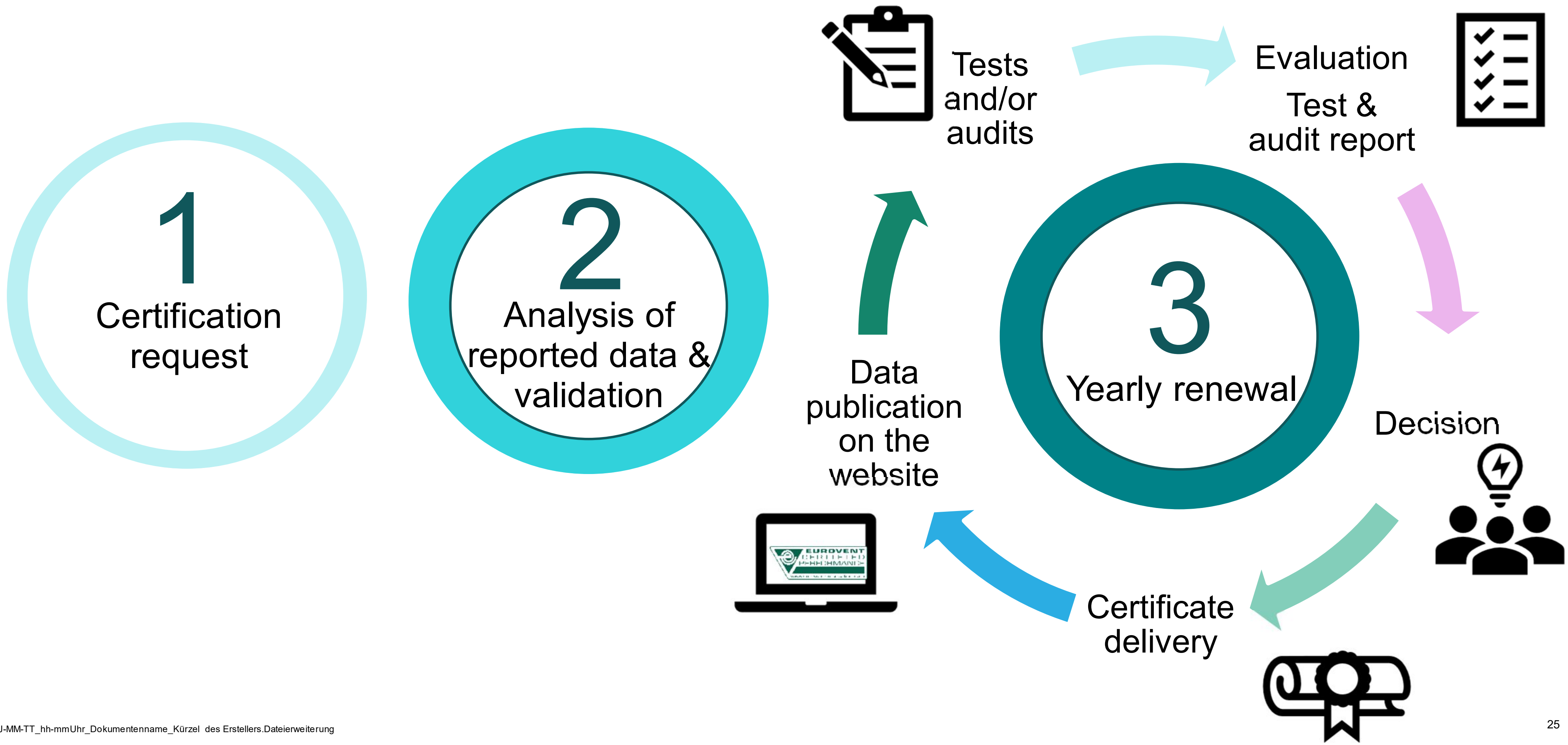
How does it work?



Certification: Programme of Heat Exchangers for Refrigeration

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Zoom on the programme

Scope

Direct Expansion (Dx) Air Coolers using HFC	Dx Air Coolers using CO_2	Air Cooled Condensers	CO_2 Gas Coolers	Dry Coolers.

CERTIFY-ALL PRINCIPLE

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Thank you for your attention !

Any question?

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