# Summary

# FREE COOLING

Process applications for cooling systems that have constant production loads and generate high process fluid temperatures (water 20/15 °C or higher) are particularly good candidates to take advantage of low ambient temperatures and therefore the functionality of free cooling.

Low ambient temperatures can be used as a "free" energy source, replacing the electricity needed to run the compressors, in what is known as a free cooling or free cooling system.

## - FREE COOLING METHODS:

Free-cooling can be:

- **TOTAL**: The external air temperature allows to satisfy the entire refrigeration request. All the cooling capacity is therefore guaranteed by the only external air that passes through the free-cooling coils while the compressors remain off.
  In this case, maximum energy savings are achieved.

- **PARTIAL**: When the external air temperature is lower than that of the return water, but not enough to obtain total free-cooling, there is a partial one.
  A part of the cooling capacity is supplied by the external air while the remainder by the compressors, thanks to the optimized management of resources, hybrid refrigeration is therefore achieved.

## - ABOUT HITEMA:

The free cooling system used by Hitema International is in partial mode. This system allows to use the most of the low temperatures of the winter months and also offers significant advantages in terms of energy savings even in transition seasons such as autumn or spring. Integrated in a chiller system, the system automatically decides, based on the ambient temperature and the operating logic, whether to operate as a chiller or as a partial or total free cooler.

The free cooling of the water can be carried out in all seasons of the year, both with the refrigeration compressors “ON” (Partial Free-Cooling) and with the compressors “OFF” (Total Free-Cooling).

Free cooling in partial mode is made possible by the separation of the chiller and free cooling systems, consequently the **chiller and** the **free cooling will have their respective fans**.

In partial free cooling mode, the system starts cooling when the ambient temperature is 3.6 / 4 °F below the fluid inlet temperature. The water is conveyed through a three-way valve first to the free-cooler and then goes to the chiller. The controller automatically reduces the work of the compressors by limiting the cooling capacity by controlling the 3-way valve (or two gate valve) (which controls where the incoming water goes). During the transitional months of autumn and spring, free-cooling acts as a pre-cooler and significantly reduces the power absorbed by the compressors and consequently the energy consumption of the chiller.

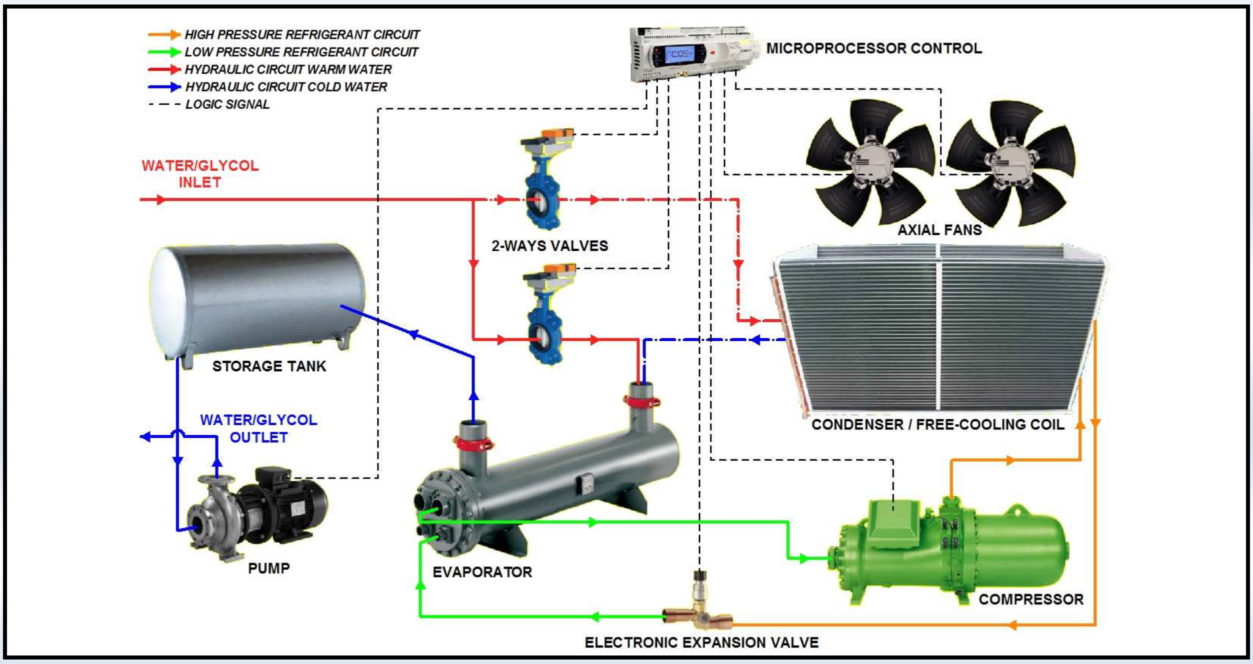


Figure 1 A semplified free cooling scheme

In the case that the ambient temperature drops to extremely low levels, the 3-way valve (or the two gate valve in this case) modulates and bypasses part of the flow, mixing it with the fluid leaving the coil, always maintaining perfect control of the fluid temperature at the outlet.

## - PRACTICAL EXAMPLES:

Let's now make a couple of practical examples to better understand how partial free cooling works.

### • 1° EXAMPLE:

In this first example we take as a reference a STD HITEMA chiller with:

- **Cooling Capacity**: 200 kW
- **EWT** (Entering Water Temperature): 12 °C (53,6 °F)
- **LWT** (Leaving Water Temperature): 7 °C (44,6 °F)
- **100% free cooling temperature**: 2 °C (35,6 °F)
- **Ambient temperature**: 35 °C (95 °F)

In the diagram shown in figure 2, 4 points and 2 fundamental areas can be noted:

- **Point D**: Indicates the temperature at which the process water enters the chiller.
- **Point C**: Indicates the temperature at which We have the possibility to have free cooling inside the chiller, this point is linked to the EWT, the higher the EWT the more this point will move to the right of the graph and will allow me to have free cooling first.
- **Point B / A**: they are located in correspondence with the free cooling temperature at 100%, for this type of chiller this temperature is 2 °C (35,6 °F), if the ambient temperature drops further the chiller will work fully in free mode cooling and the yield will be the maximum.

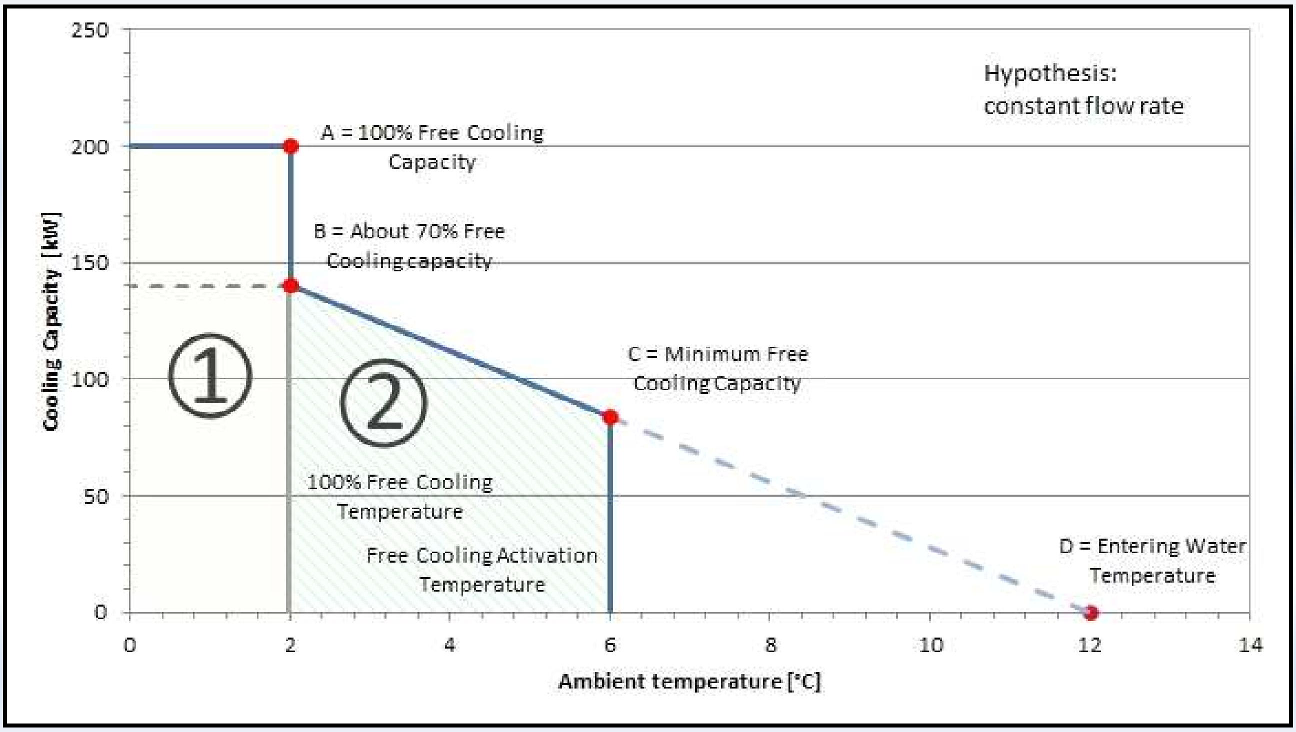


Figure 2 12°C - 7°C water, 35°C ambient

- **Zone 2**: In this operating zone the chiller is working in partial free cooling. Above 6 °C (42,8 °F) the conditions do not allow me to take advantage of free cooling.
- **Zone 1**: The external temperature is low enough to be able to use free cooling at 100%, and 100% of the yield is satisfied by free cooling.

Here are some data obtained by crossing the curves in Figure 2:

| | | |
|---|---|---|
| **free cooling capacity** | 100 | kW |
| **% of free-cooling (FC%)** | 50 | % |
| **water outlet temperature from FC** | 9,5 | °C |

Table 1 Dates for 100 kW with free cooling (example 1)

If I wanted 100 kW of the chiller in example 1 generated by free cooling, the free cooling output temperature would be 9,5 °C (49 °F), the calculation formula is very simple and is as follows:

$$EWT - (EWT - LWT) * FC\%$$

And in doing so, the following examples have the same logic:

| | | |
|---|---|---|
| **free cooling capacity** | 150 | kW |
| **% of free-cooling (FC%)** | 75 | % |
| **water outlet temperature from FC** | 8,25 | °C |

Table 2 Dates for 150 kW with free cooling (example 1)

| | | |
|---|---|---|
| **free cooling capacity** | 180 | kW |
| **% of free-cooling (FC%)** | 90 | % |
| **water outlet temperature from FC** | 7,50 | °C |

Table 3 Dates for 180 kW with free cooling (example 1)

- ## 2° EXAMPLE:

In this second example we take as a reference a machine with a higher yield:

- **Cooling Capacity**: 1000 kW
- **EWT** (Entering Water Temperature): 25 °C (77 °F)
- **LWT** (Leaving Water Temperature): 20 °C (68 °F)
- **100% free cooling temperature**: 10 °C (50 °F)
- **Ambient temperature**: 35 °C (95 °F)

The points and areas highlighted in Figure 3 follow the same logic as in example 1, the same applies to the tables:

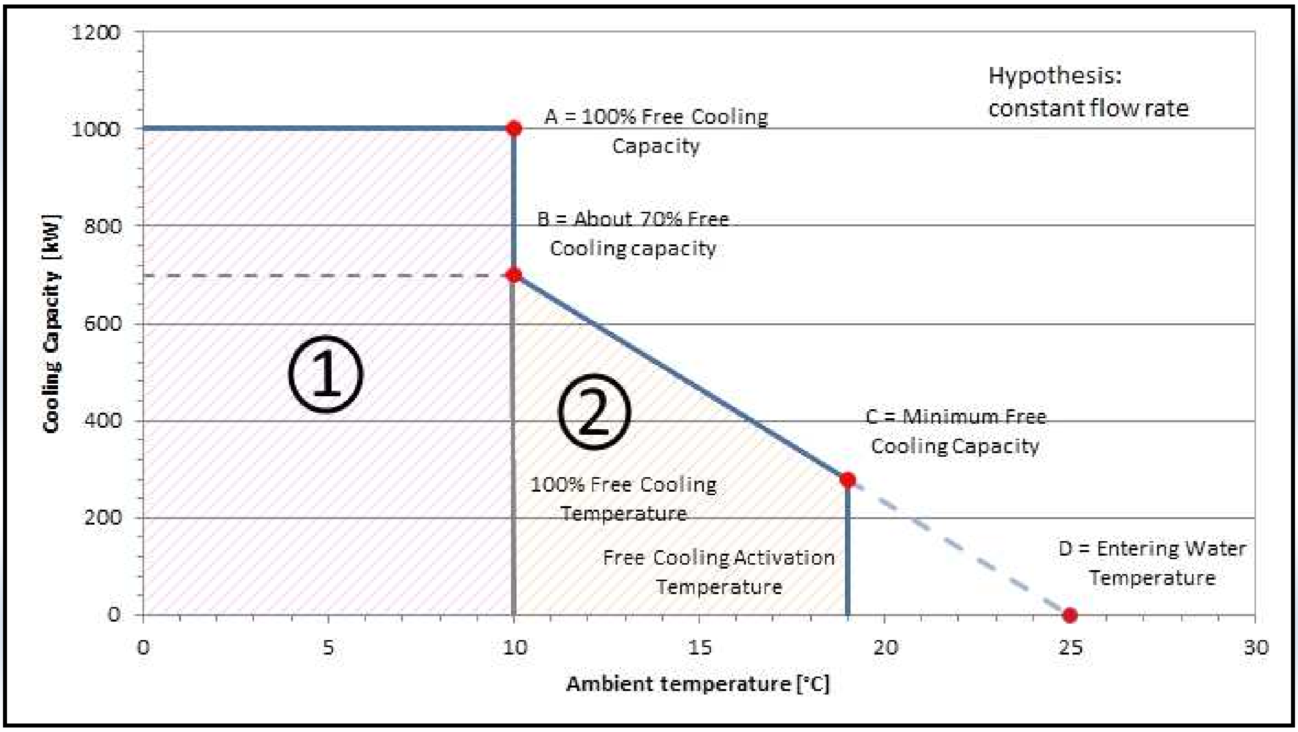


Figure 3 25°C - 20°C water, 35°C ambient

| | | |
|---|---|---|
| **free cooling capacity** | 500 | kW |
| **% of free-cooling (FC%)** | 50 | % |
| **water outlet temperature from FC** | 22,5 | °C |

Table 4 Dates for 500 kW with free cooling (example 2)

| | | |
|---|---|---|
| **free cooling capacity** | 900 | kW |
| **% of free-cooling (FC%)** | 90 | % |
| **water outlet temperature from FC** | 20,5 | °C |

Table 5 Dates for 900 kW with free cooling (example 2)

## - ECONOMIC RETUN:

A chiller with free cooling is an average machine that costs 25% - 30% more than a machine without, it is natural to ask if it is convenient to buy a free cooling machine.

To carry out this analysis it is necessary to set conditions that vary according to where the chiller is located and how long it has to work.

Below we make some examples that better clarify this point, the analyzes will all be done taking as a reference the city of Warsaw in Poland:

### • 1° EXAMPLE – ENR.061 / ENRF.061 – 720 h/month:

Datas:

- **EWT** (Entering Water Temperature): 12 °C (53,6 °F)
- **LWT** (Leaving Water Temperature): 7 °C (44,6 °F)
- **100% free cooling temperature**: 1,7 °C (35 °F)
- **Ambient temperature**: 35 °C (95 °F)

| **Month** | **Average ambient temperature** | **Working hour per month** |
|---|---|---|
| | $T_{amb}$ [°C] | [h/month] |
| January | -4 | 720 |
| February | -4 | 720 |
| March | -1 | 720 |
| April | 3 | 720 |
| May | 8 | 720 |
| June | 11 | 720 |
| July | 14 | 720 |
| August | 13 | 720 |
| September | 9 | 720 |
| October | 4 | 720 |
| November | 0 | 720 |
| December | -3 | 720 |

Table 6 Temperature at Warsaw (Poland) with 720 h/month

With the cost:

| **Model** | **Price [€]** |
|---|---|
| ENR.061 | 22.016 |
| ENRF.061 | 30.189 |

Table 7 Costs for ENR.061 and ENRF.061

It is possible to draw two important graphs:

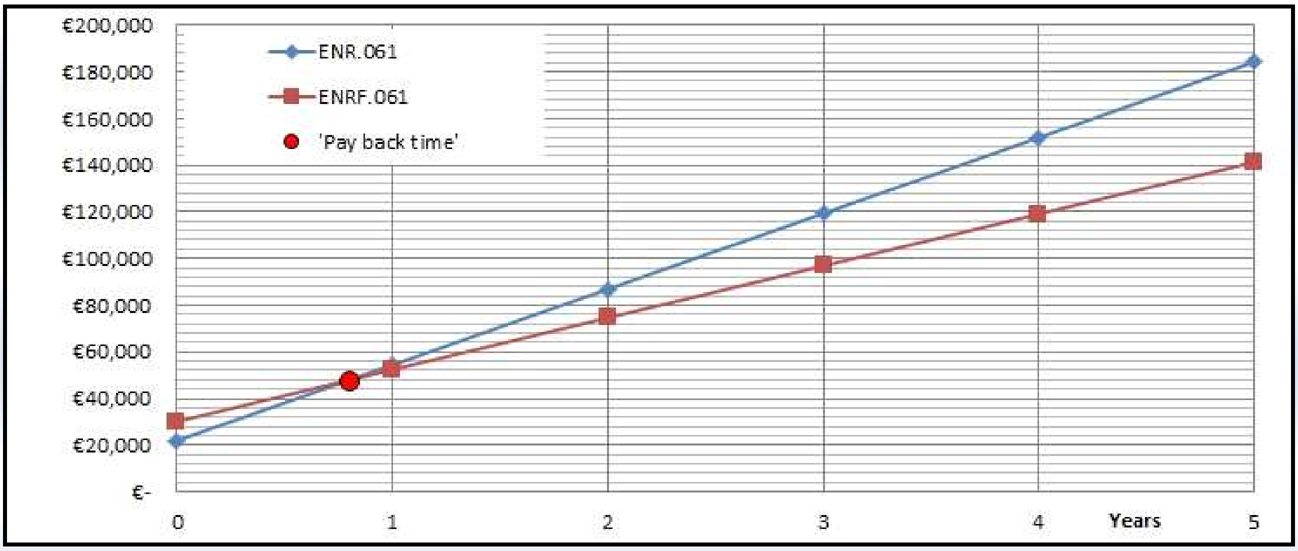


Figure 4 Pay back time - example 1 - 720 h/month

Figure 4 refers to the payback time for the conditions considered, and based on the data considered, the return on investment occurs after 9 months of use.

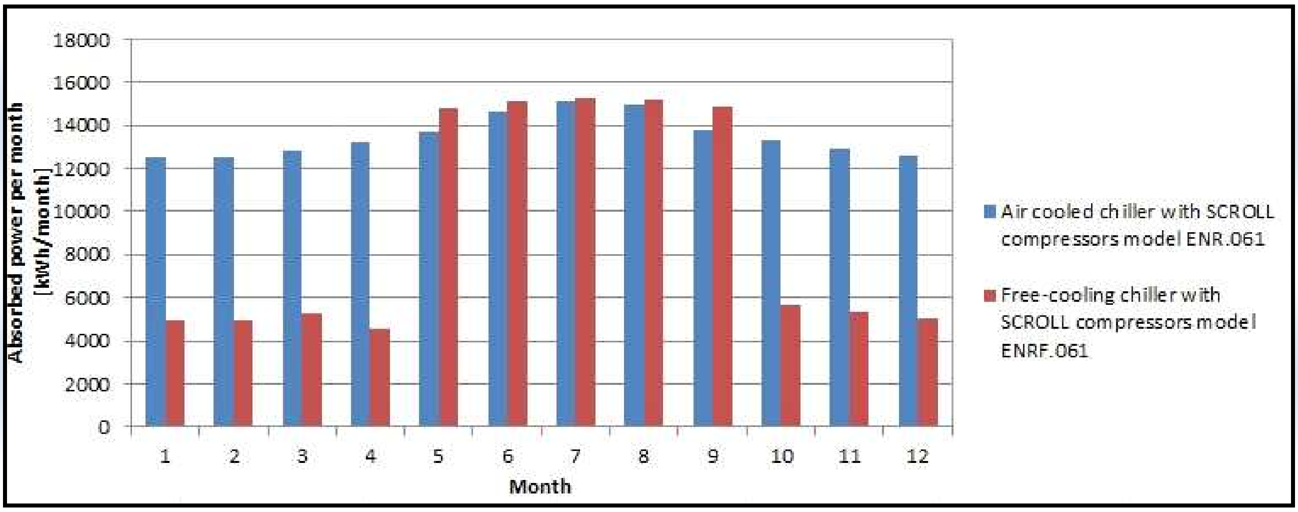


Figure 5 Absorbed power per month - example 1 - 720 h/month

Figure 5 refers to the energy consumption of the two chillers during the year, as can be seen during the colder months the ENRF works much less than the ENR, precisely because the free cooling comes into operation, and this is the strong point of free cooling technology.

- ## 2° EXAMPLE – ENR.061 / ENRF.061 – 240 h/month:

The analysis that needs to be done for chillers of the same type but which work 1/3 of the time (8 hours a day) is quite simple, since taking into account that many data do not change the payback time will be triple and the consumption of energy of the machine will be 1/3 of the previous one.

This means that the more the free cooling machine works, the better it is, therefore the free cooling chillers are suitable for systems that require a constant energy supply over time, and these are not recommended for systems with occasional supplies.

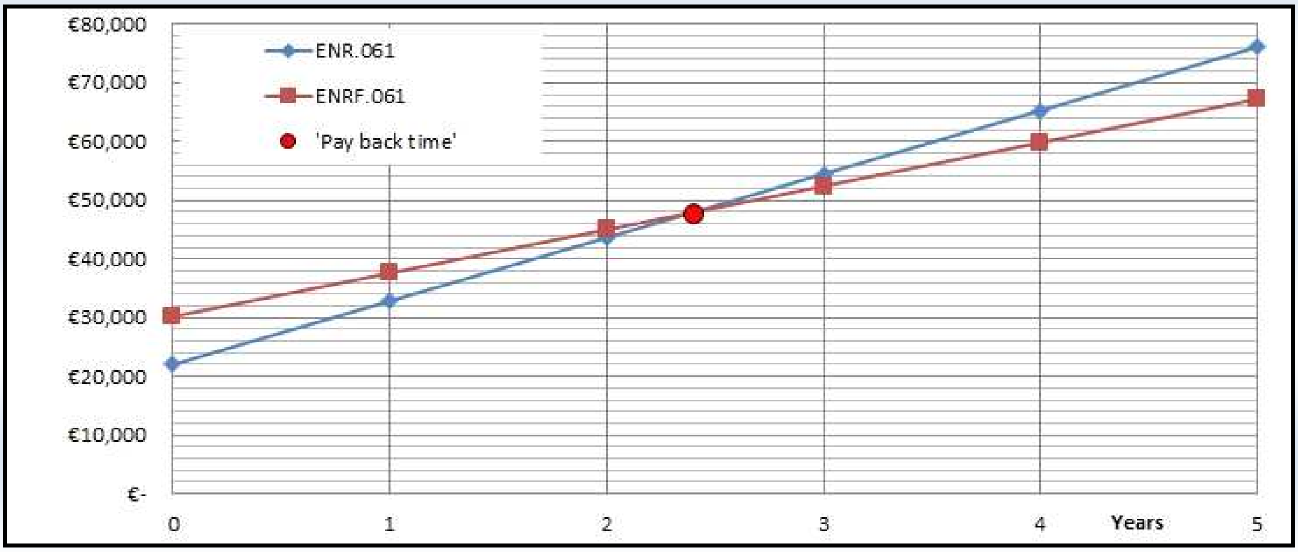


Figure 6 Pay back time - example 2 - 240 h/month

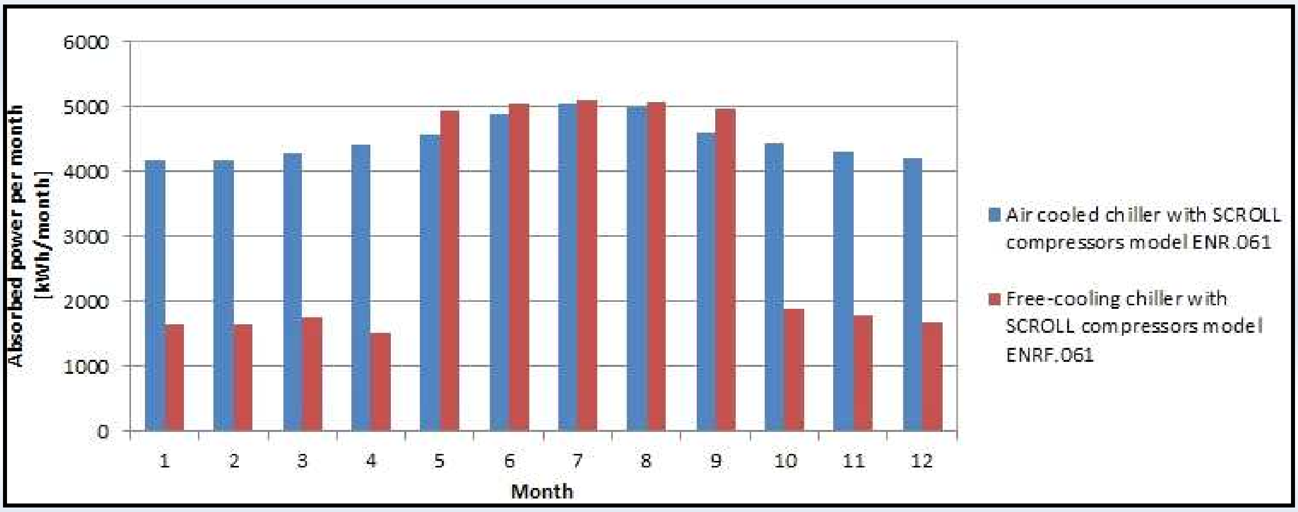


Figure 7 Absorbed power per month - example 2 - 240 h/month

## • 3° EXAMPLE – SBS.240 / SBSF.240 – 240 h/month:

Dati:

- **EWT** (Entering Water Temperature): 25 °C (77 °F)
- **LWT** (Leaving Water Temperature): 18 °C (64,4 °F)
- **100% free cooling temperature**: 8,5 °C (47,3 °F)
- **Ambient temperature**: 35 °C (95 °F)

For this third example, the EWT and LWT temperatures chosen are higher, with this what we see will be a flattening of the curve relating to the investment of the chiller in free cooling, this is because it will be easier for the chiller to work in free cooling and therefore guarantee more I work in that mode.

The price is the following:

| Model | Price [€] |
|---|---|
| SBS.240 | 37.700 |
| SBSF.240 | 44.433 |

Table 8 Costs for SBS.240 and SBSF.240

The tables that come out are the following:

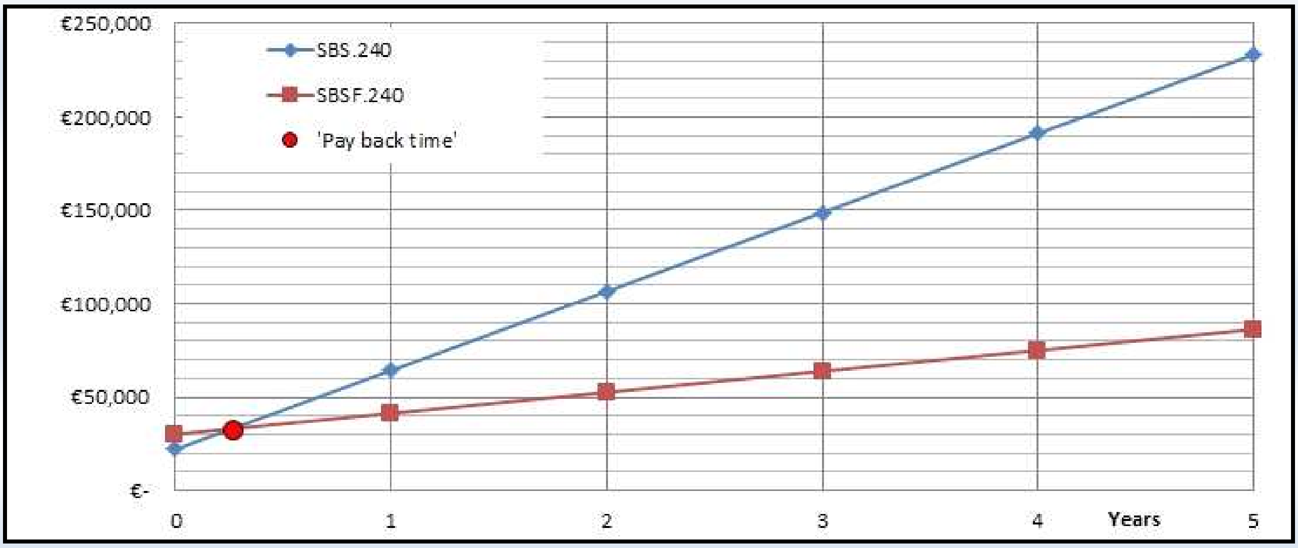


Figure 8 Pay back time - example 3 - 240 h/month

The payback time is about 4 months, because the chiller always works in free cooling and as can be seen from figure 9, the energy absorbed during all months is always lower than that absorbed by the SBS.240. this is because the free cooling temperature is high.

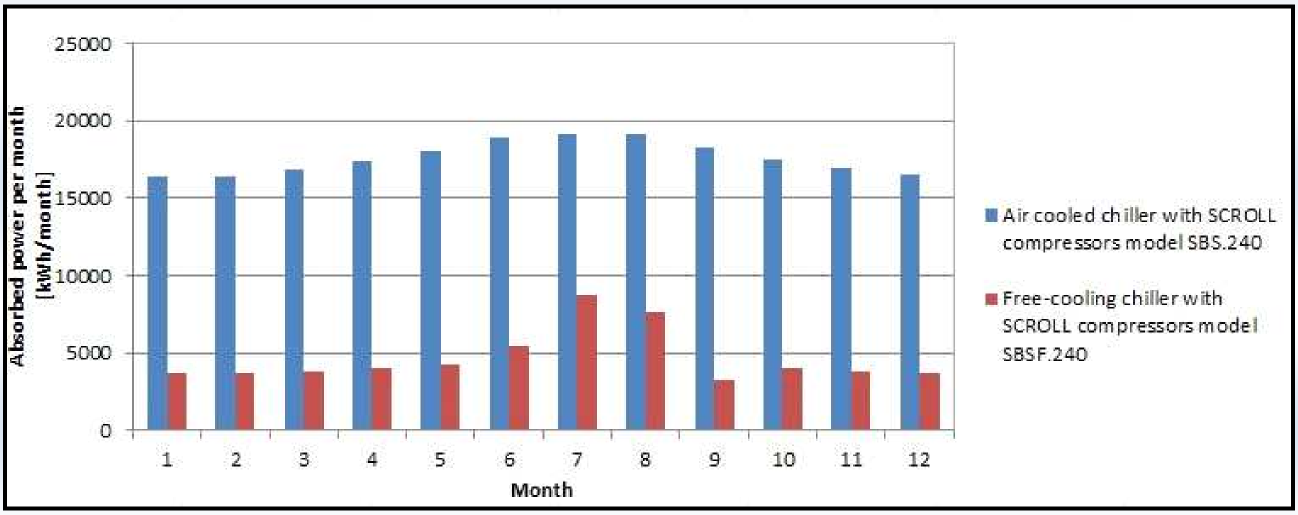


Figure 9 Absorbed power per month - example 3 - 240 h/month

Summing up:

- If the 100% free cooling temperature decreases, the payback time increases and the energy consumption increases.
- If we increase EWT, We flatten the curve, the payback time decreases and the energy consumption decreases.
- If we decrease the running time of the chiller, the payback time increases.

## - CONCLUSION:

The use of free cooling technology allows users to achieve a reliable payback time compared to traditional water chillers.

Depending on the weather conditions and the fluid temperatures, the return on investment is almost always close to the year.

An innovation in free cooling has been developed with the introduction of free cooling in partial mode, allowing for a significantly wider range of application temperatures and significant energy savings.