# VPF SYSTEMS

## *The RHOSS solution*

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- Traditional plant solutions
- The variable flow systems
- Critical issues of traditional primary-only VPF systems
- The Rhoss solution

# The variable flow systems

- The energy consumption related to the pumping of heat transfer fluids are a minority voice but not negligible compared to the total building consumption

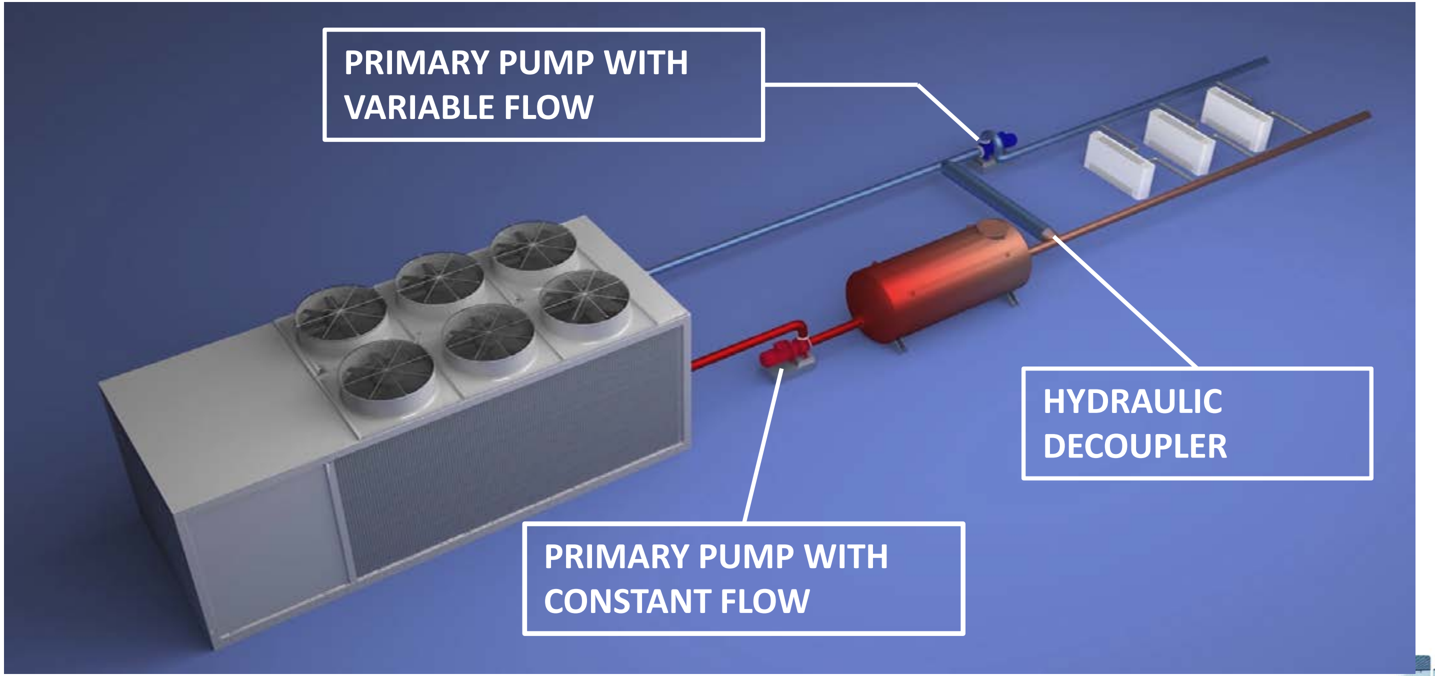
- The modern NZEB buildings require the use of plant solutions able to reduce energy consumption as a total value, with an integrated design approach.

- Airside variable flow systems (VAV) represent a well-established plant solution.

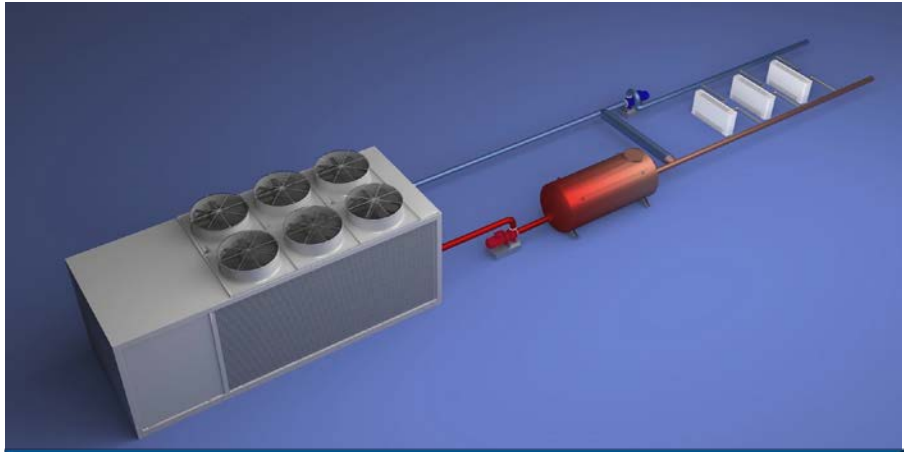
- The variable water flow systems allow further opportunities for energy savings.

# The variable flow systems

The most commonly used  and consolidated plant solution is the primary/secondary solution, with primary at a constant flow and secondary with variable flow rate.



# The variable flow systems



Primary constant
Secondary variable

- High stability without oscillations
- High reliability of the chiller
- High reliability of the system-plant components
- **High energy consumption for the pumps**

# The variable flow systems

But which are the parameters involved?

Obviously there is an extreme variation depending on:

- Building type and plant layout
- Use destination
- Load profile
- Technological solutions
- Climatic zone

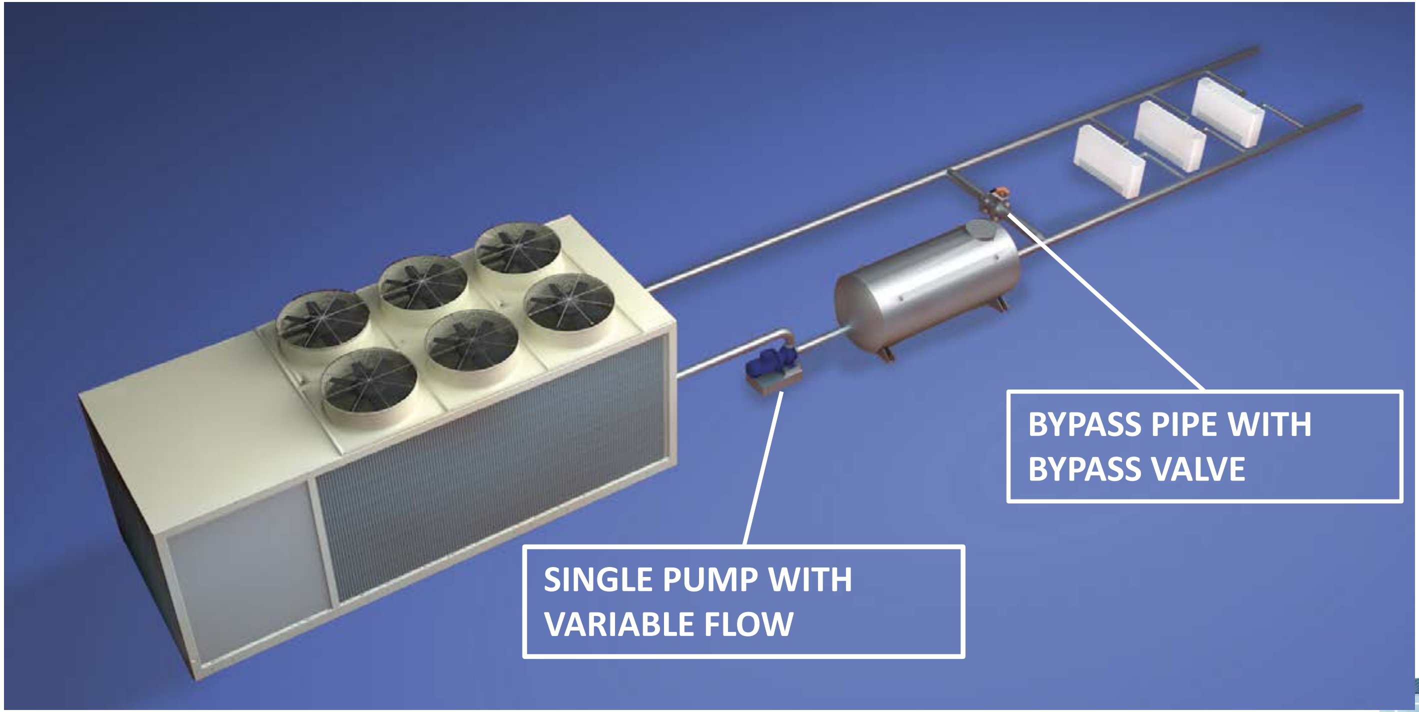
But the energy pumping consumption may become a significant value

# The variable flow systems

- The results can vary a lot from one building to another, but the energy pumping costs represent 20% to 40% of the consumption of the chillers
- At the level of the whole building, the pumping consumption may exceed 10% of the total
- The primary circuit at a constant flow rate represents the largest part of pumping consumption
- The solution with constant primary and variable secondary is reliable and safe.

# The variable flow systems

One way to reduce the pumping consumption is to realize a system with a single and unique primary circuit with variable pump speed, with bypass pipe and by-pass valve (VPF Traditional, called also «Primary only»).



# The variable flow systems

VPF traditional
Called “Primary Only”

- Low stability with oscillations
- Low reliability of the chiller
- Low reliability of the system-plant components
- Low energy consumption for the pumps, but there is bypass effect

# The variable flow systems

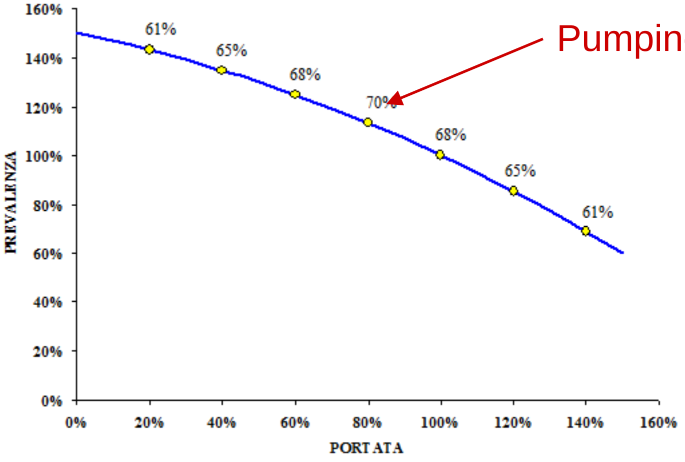
This solution acts on the pumping costs of the primary circuit with a constant flow rate.

But what are the real savings achievable?

$$Q = kn \qquad H = yn^2$$

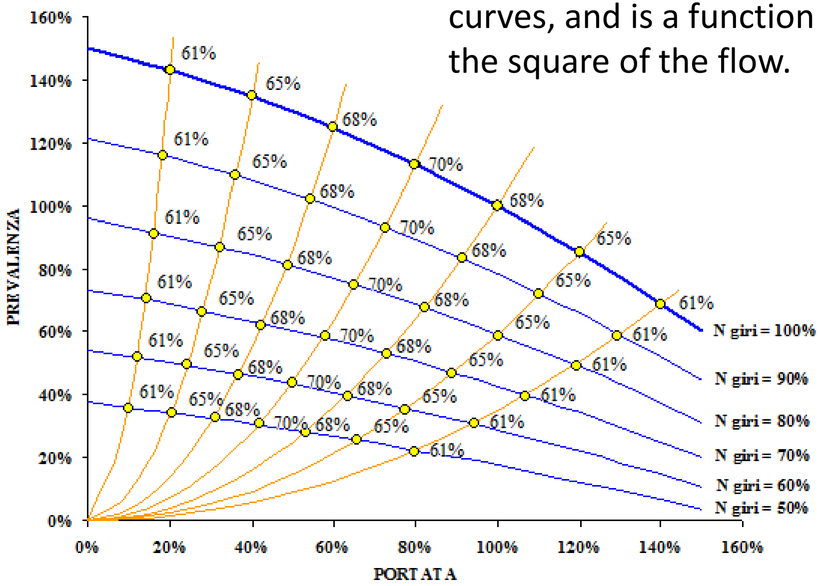
$$P = \frac{\rho g Q H}{\eta} = \frac{f(n)^3}{\eta}$$

# The variable flow systems




Pumping curve: BEP (Best Efficiency Point)

The efficiency of a pump remains constant along the curves, and is a function of the square of the flow.




If the pump modulates its speed according to a constant efficiency curve, the pumping power P varies with flow $Q^3$ and result:

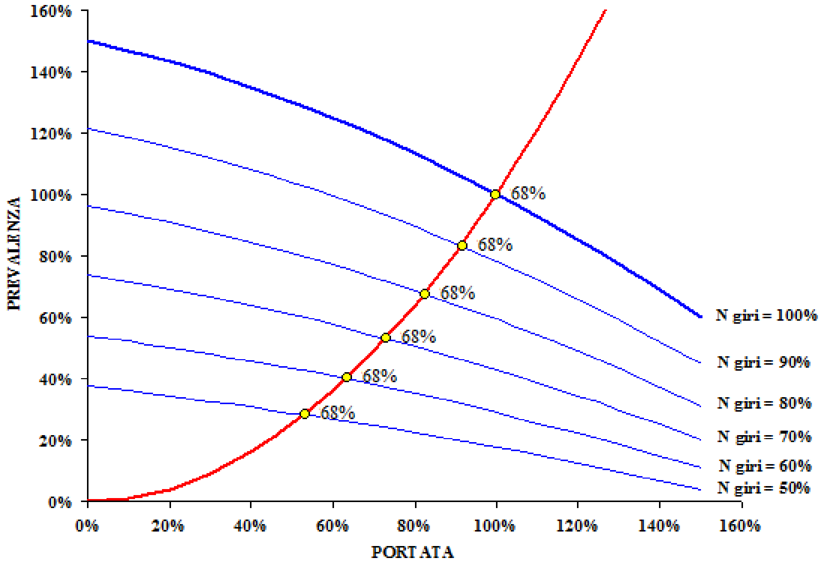
$Q = f(n)$

$H = f(n^2)$

$P = f(n^3)$

# The variable flow systems

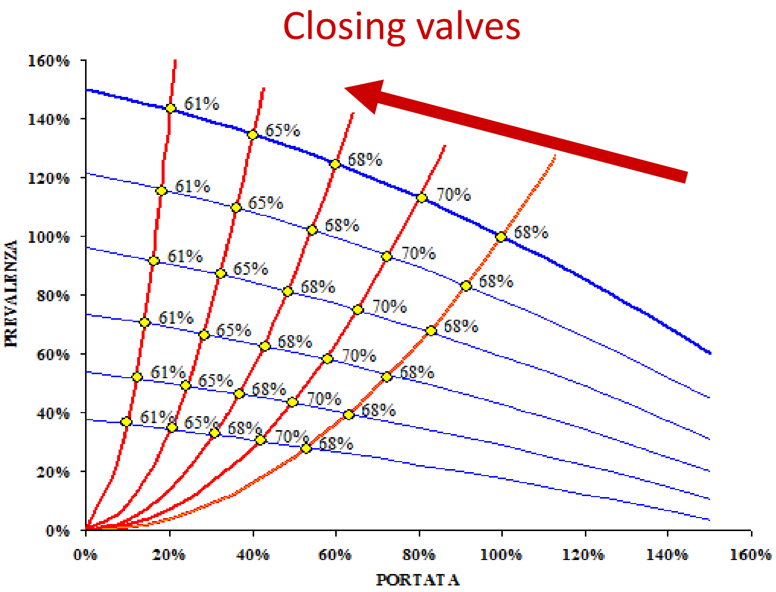
Circuit: also the resistant curve of the circuit varies with the square of the flow.




So, if the water flow rate varies and the geometry of the circuit remains unchanged, the power of the pump varies exactly with the cube of the water flow and there is a direct correspondence between the pump speed rpm and the flow involved.

# The variable flow systems

When the valves close, the geometry of the circuit is modified and the resistant curve shifts to the left.



# The variable flow systems

When the geometry of the circuit is changed, the pumping power no longer varies with the cube of the flow rate, but follows a curve that is hard to identify theoretically.

There is definitely a reduction of the pumping consumption, but not so relevant as in the case of constant geometry circuit.

What are the real potential savings with the primary variable flow solution?

# The variable flow systems



The technical literature and bibliography do not help:

- Many anecdotes, and few real cases
- Only few general studies validated
- Poor «quantitative» bibliography

One of the most significant studies in the field VPF Vs. traditional P/S is the following of 2004 :
«Variable primary flow chilled water systems: potential benefits and application issues» W.P. Banfleth, E. Peyer – Pennsylvania State University

# The variable flow systems



The conclusions of the study, often cited in favor of the VPF systems, seem to confirm the convenience generally in medium-sized plants

- VPF systems, compared to conventional constant primary / variable secondary systems, allow annual savings in the range 4-8% (average <5%) in the operating costs.

- The saving is higher proportionally to the minimum load of the plant: the more frequent the adjustments with the by-pass valve, the more they reduce the savings.

- VPF systems allow savings in investment costs by reducing the size of the technical room (a pumping group less) and the number of pumps.

# Criticitical issues of the traditional VPF systems

The main problems of the VPF systems are basically two :

- Ensure compliance with the minimum flow rate of the evaporator of cooling units in all operating conditions. This means adjusting the by-pass valve to a flow rate value such that it takes into account the inevitable oscillations and fluctuations of the system.

- In case of several chillers in parallel, ensure proper connection and disconnection of the individual chillers avoiding potential danger.

# Criticitical issues of the traditional VPF systems

The evaporators manufacturers admit a range of variable flow rates between 40% and 130% of the nominal flow rate, with 3:1 or higher turndown

Compliance with the minimum flow requirements is crucial for the protection of refrigeration units.

The function of the by-pass valve in the bypass pipe is to ensure the minimum flow rate through the evaporator in all operating conditions.

But it is also the most critical plant component of the entire system.

# Criticitical issues of the traditional VPF systems

As a matter of fact, the oscillations force to limit the flow reduction well before the 40% theoretically accepted by the exchanger.

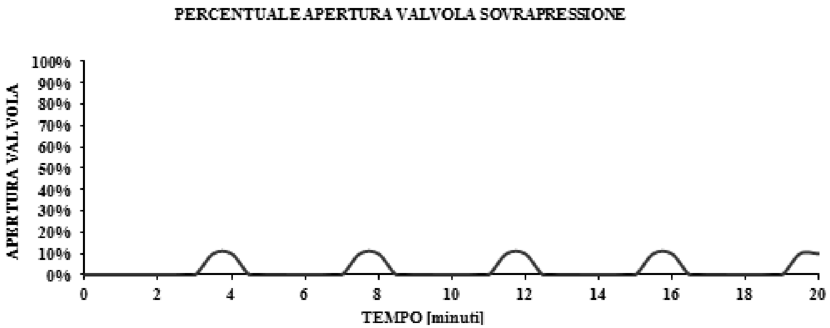
On average, the variation of flow is reduced down to 50%, but sometimes the lack of unique correspondence between the number of revolutions and the pump flow obliges to stop the flow rate reduction even before, to avoid dangerous situations.

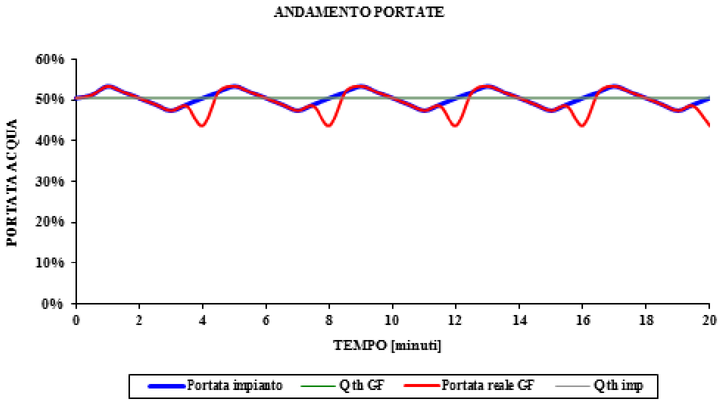
Therefore it remains a potential savings that is not used and is **not usable**.

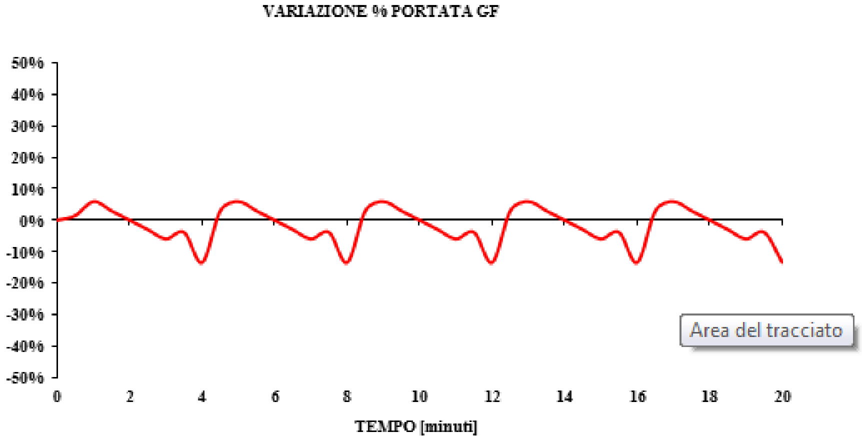
# Criticitical issues of the traditional VPF systems

Results of the real flow rate of a chiller unit in a VPF system at the 50% of nominal flow, with by-pass valve set at 50% of nominal, assuming periodic oscillation of flow rate of **3%**.

Tests carried out in an approved Eurovent Laboratory. Air-cooled chiller, 2 circuits, 4 scroll compressors. 240 kW Eurovent nominal capacity.

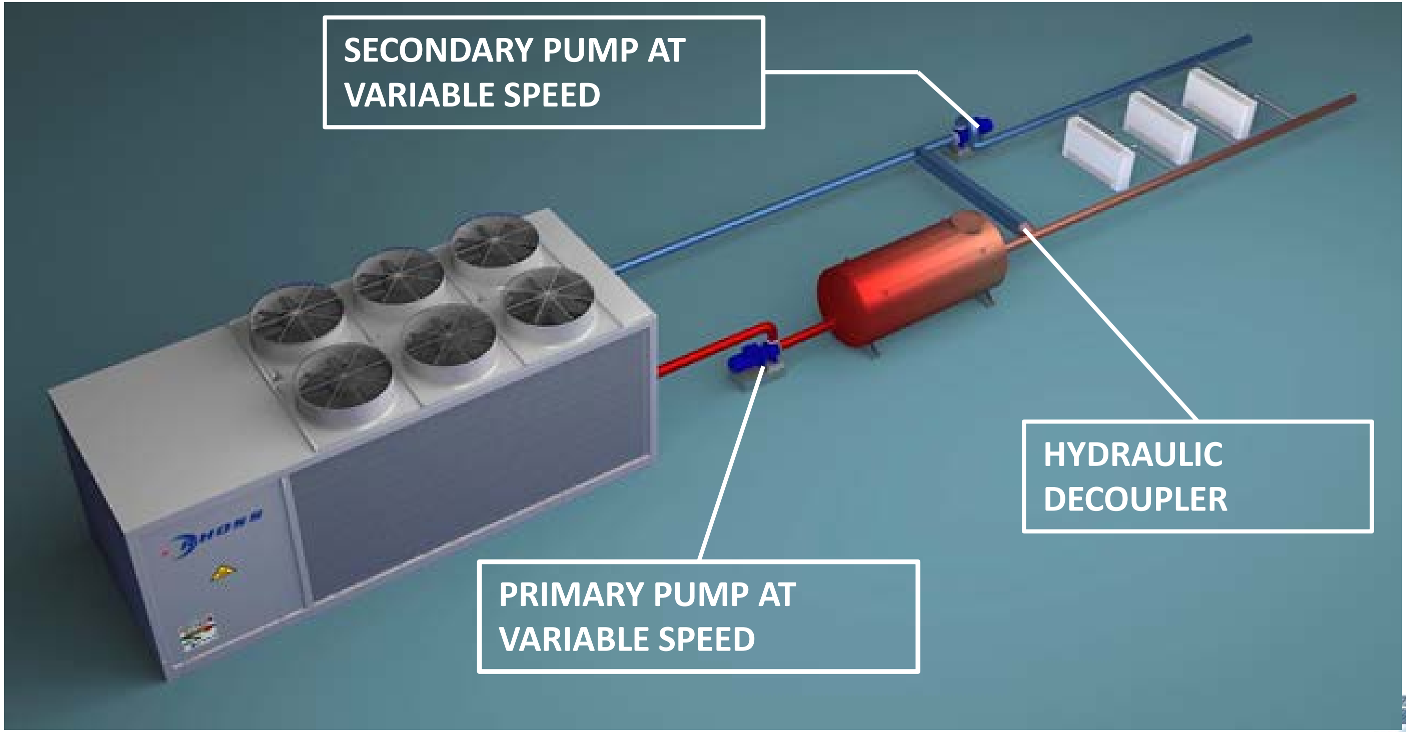


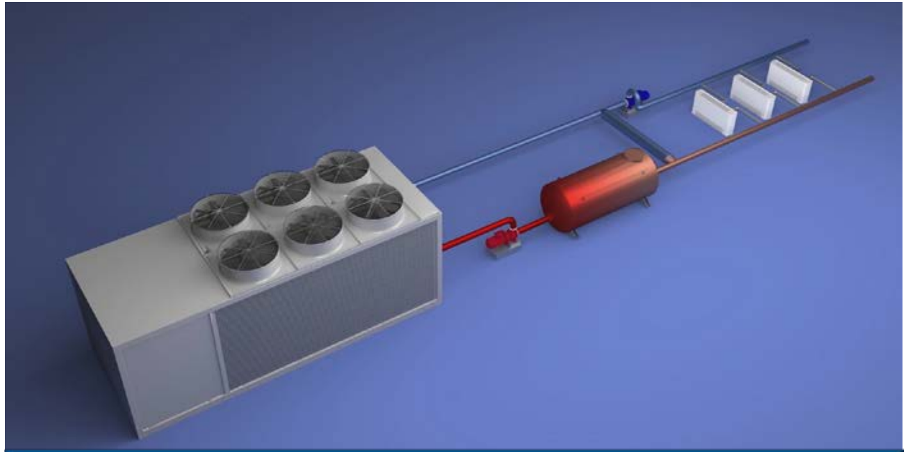



# The Rhoss solution

The solution introduced by Rhoss eliminates the critical issues of traditional VPF systems and allows to take advantage of the savings in pumping costs related to variable flow.



# The Rhoss solution



Variable Primary
Variable Secondary

- High stability without oscillations
- High reliability of the chiller
- High reliability of the system-plant components
- **Reduced pumping energy consumption**

# Criticitical issues of the traditional VPF systems

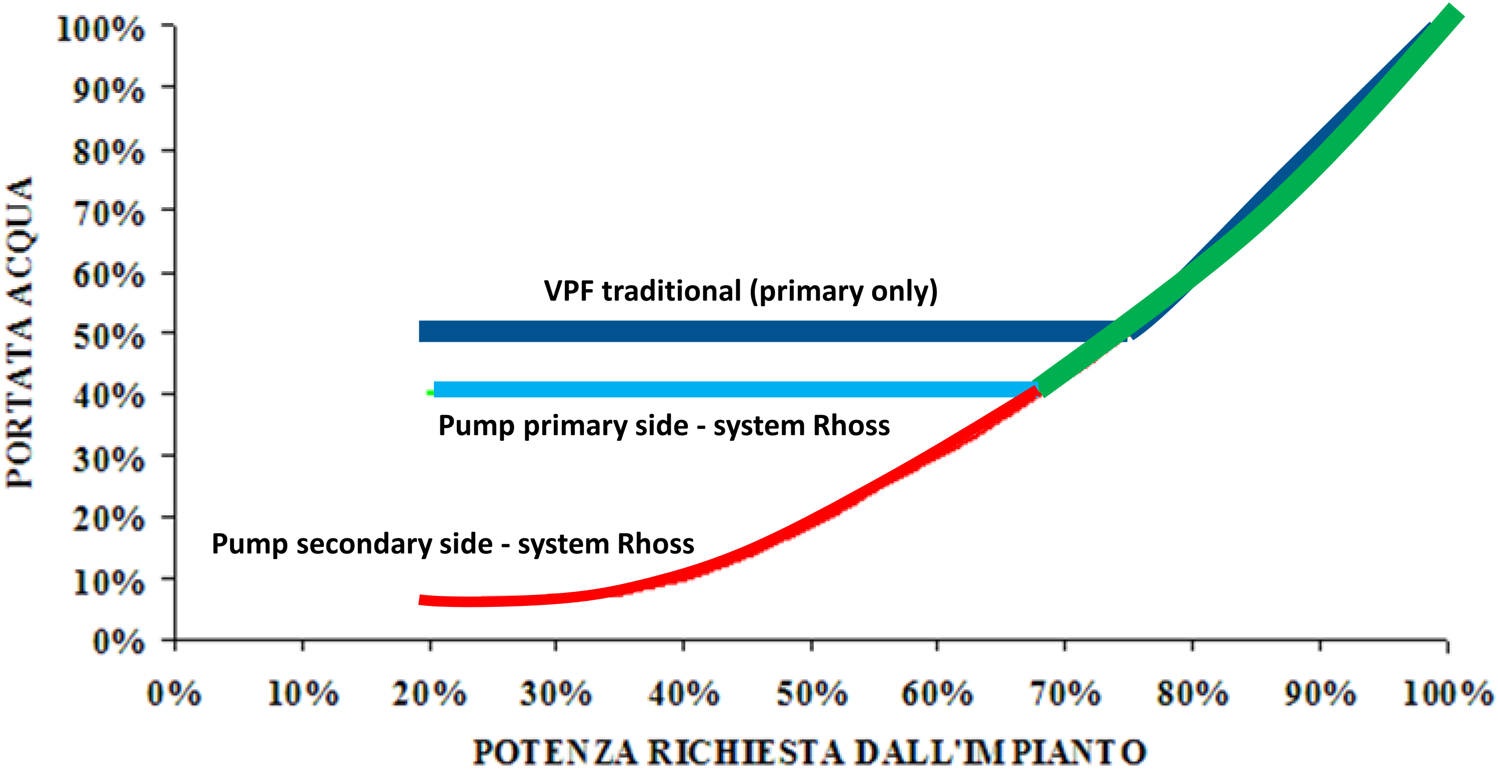

Simulation of the behavior of a VPF system with an air-cooled chiller - 2 circuits, 4 scroll compressors - 240 kW nominal capacity at Eurovent conditions.
Water circuit with single inverter pump and 130 kPa of total external pressure.

# The Rhoss solution



- The primary circuit remains with constant geometry: $P=f(n^3)$ and direct correspondence between the number of revolutions of the pump and water flow rate.
- The flow rate in the secondary circuit, free from the limits of the evaporator, can decrease “at will”: the lower limit is represented only by the technology used.
- The flow rate of the primary circuit can decrease down to the theoretical limit of 40%. There are no dangerous fluctuations on the evaporator.
- Installations with more chillers in parallel does not present the critical issues discussed.

# The Rhoss solution (VPF traditional vs VPF by Rhoss)

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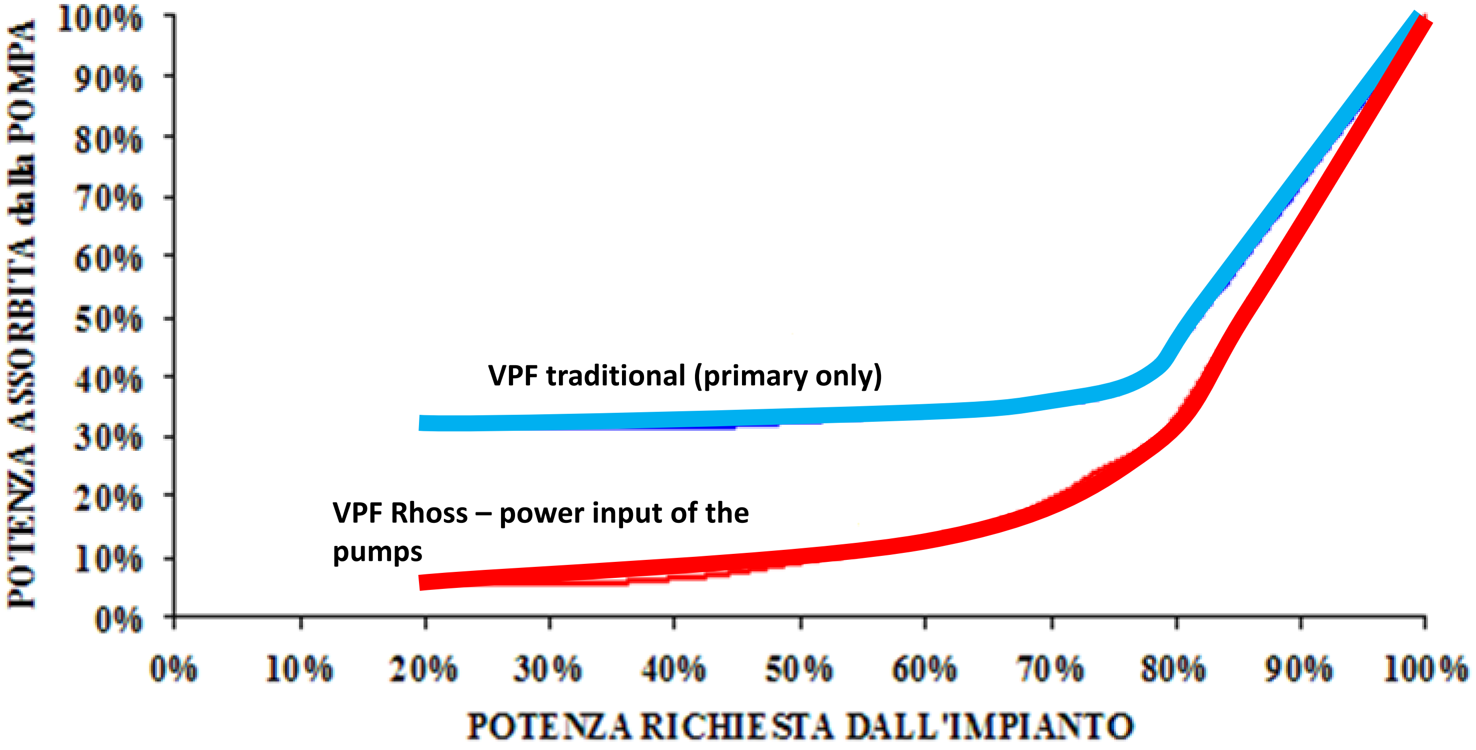
# Pump power input and plant demand (VPF traditional vs VPF by Rhoss)



# The variable flow systems



## Building for office use in Milan

- Project cooling capacity 589 kW
- Minimum cooling capacity requested for the entire year (CED, prolonged use of the building …)

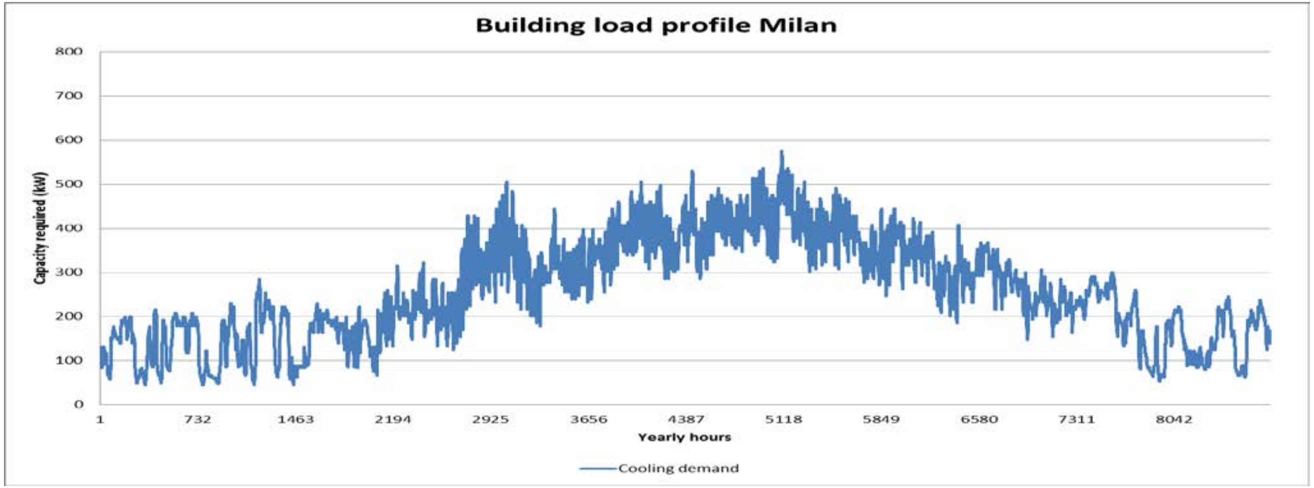
## Chiller A class with EER (gross) 3,13

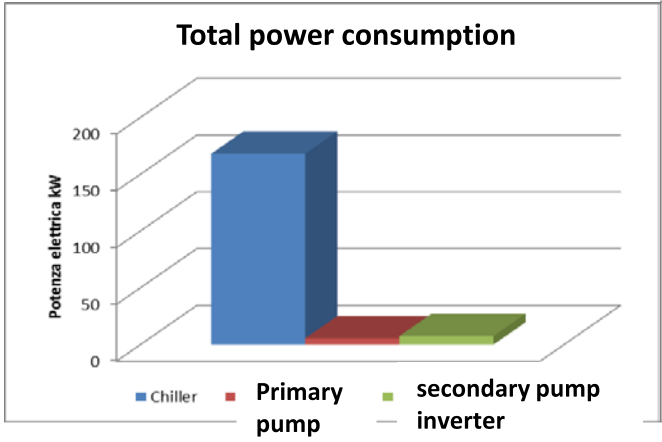
- Multiscroll air condensed
- 168 kW El. Power installed (compressors + fans)
- 101,3 mc/h design water flow rate

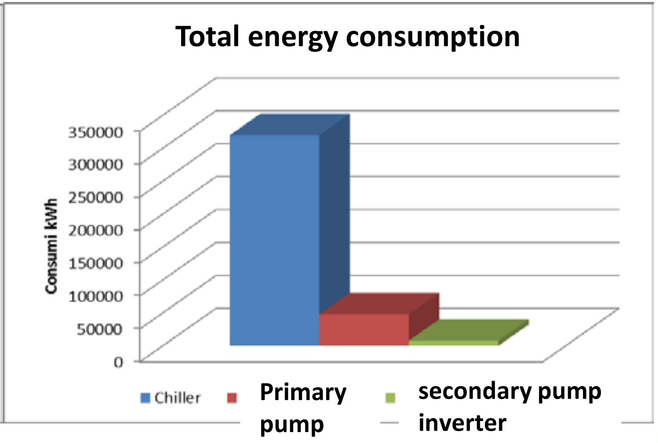
## Primary and secondary system with decoupler

- Primary with constant flow rate – 5,5 kW installed pump, about 100 kPa as total
- Secondary with variable flow rate – 7,5 kW installed pump, about 150 kPa as total

# Simulation: primary pump + secondary pump inverter

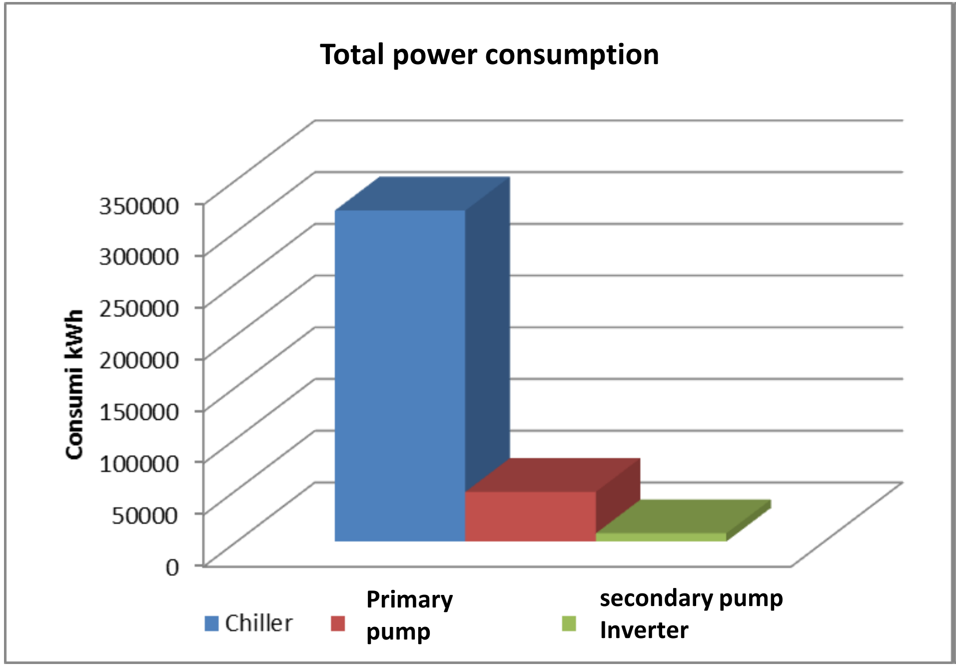


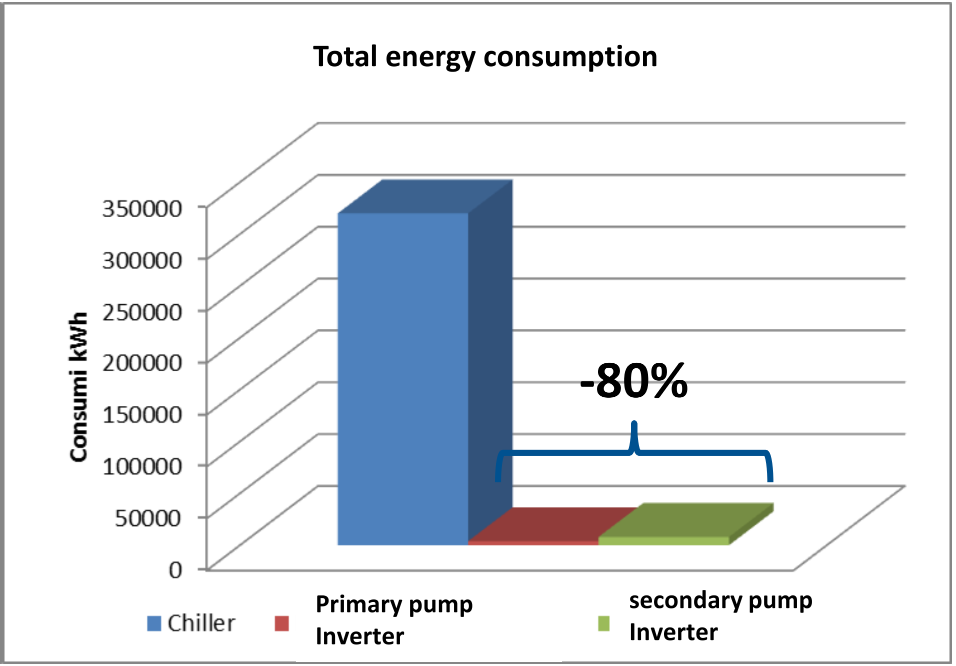



# Comparison: primary/secondary system with Rhoss solution

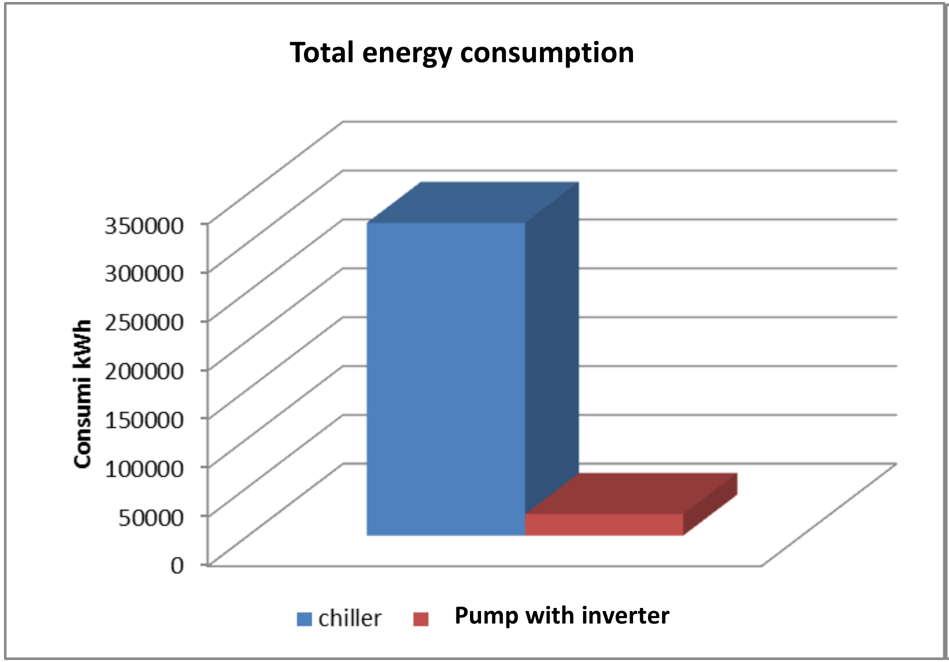
The variable flow in the primary circuit helps to save part of the pumping consumption of the Primary/Secondary system, and simultaneously eliminating the critical points of the traditional VPF system.

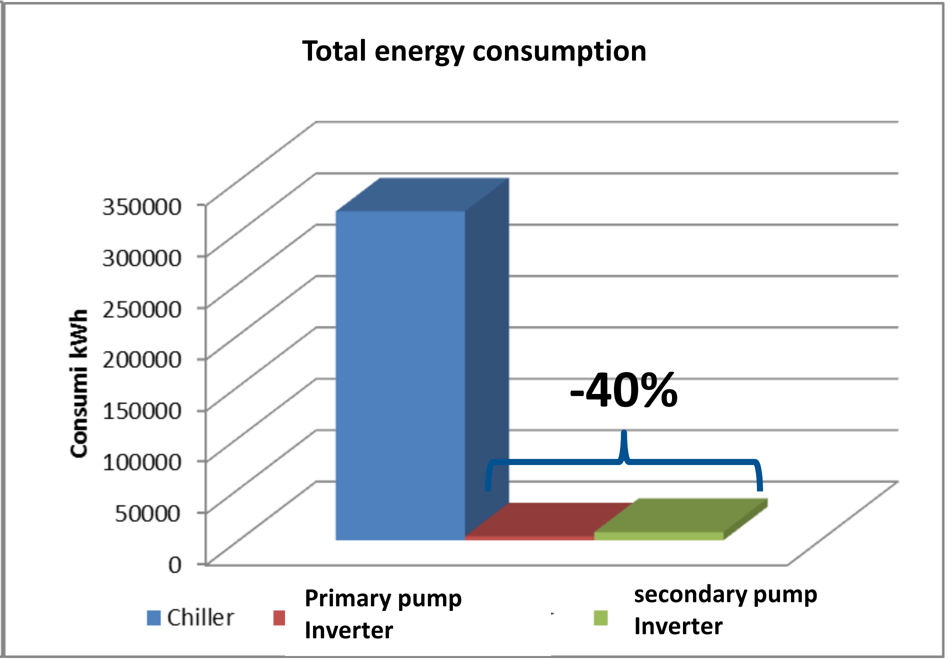


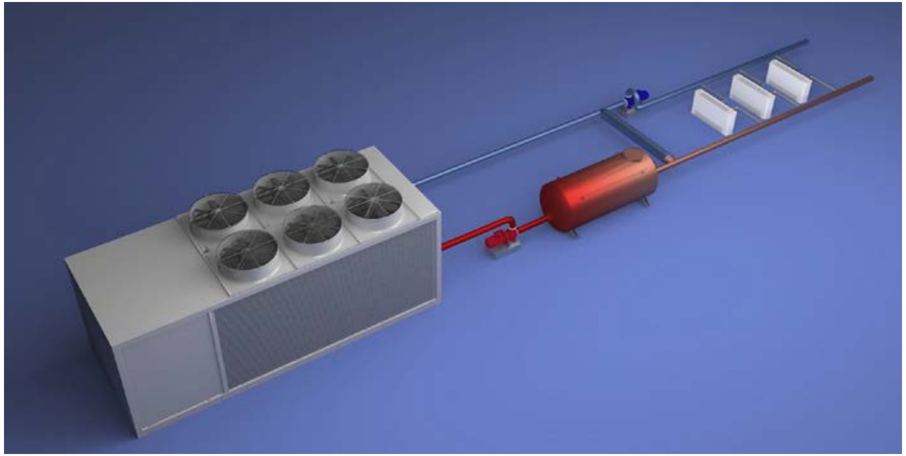
# Comparison: VPF traditional with Rhoss solution

The Primary / Secondary system, as both variable flows, is a winning solution, even in comparison with the traditional VPF system: each of the two separate pumps can operate at the best of their characteristics.



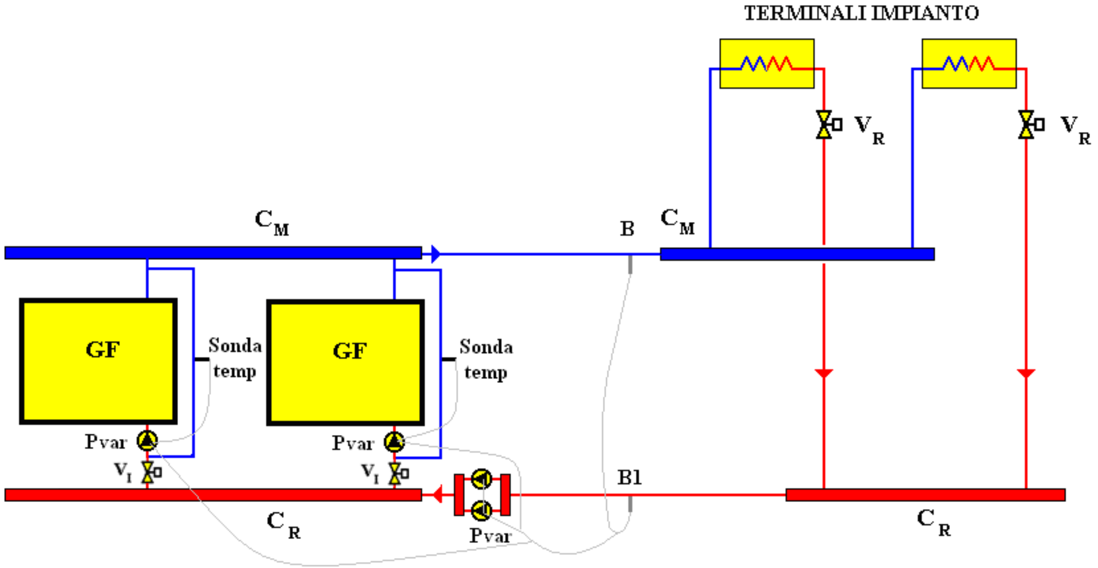
# Find the differences….
# VPF traditional vs VPF by Rhoss



# The Rhoss solution

In case of multiple units installed in parallel, the variable P/S system can avoid all the dangerous situations highlighted in the case of traditional VPF system.

- There is no critical flow reduction when a chiller is re-activated: the primary pump will be blocked just before.
- Flow fluctuations do not occur on the evaporator generally: the decoupler prevents them.
- In any case it is always possible to block the primary pump in a safe position, leaving the secondary pump free to vary its flow rate following the plant demand.



# Conclusions

- The variable flow on the hydraulic circuit is an effective way to reduce pumping consumption.

- The traditional VPF system with by-pass valve has the inherent problems which make it potentially dangerous.

- The system with both primary and secondary variable flow allows to combine the advantages of the primary / secondary system and of the variable flow rate, minimizing the risks.

- The Rhoss solution also allows economical savings compared to the traditional VPF

- Laboratory tests in a laboratory homologated by Eurovent have demonstrated the reliability of the system.

# THANK YOU
# FOR THE ATTENTION