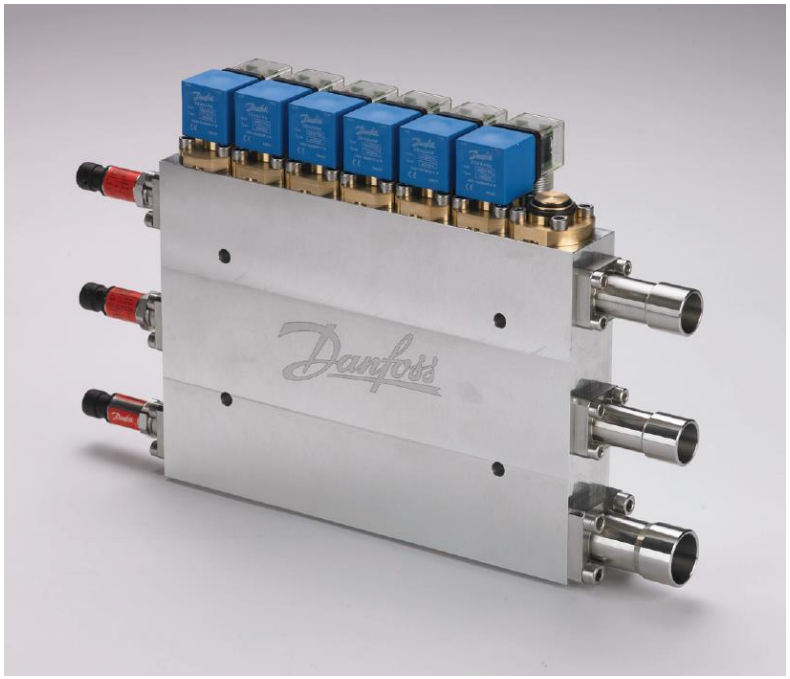
Welkom

Optimalisatie CO2 systemen m.b.v. ejecteur



Today's speaker

- Kenneth Bank Madsen.
- Global Application Expert at Danfoss since 2008.
- 7 years at Danish Technological Institute, responsible for commercial cooling.
- Bachelor in Mechanical Engineering in year 2000 from Engineering College of Aarhus, Denmark.

Agenda

1. What is an ejector and how does it work?

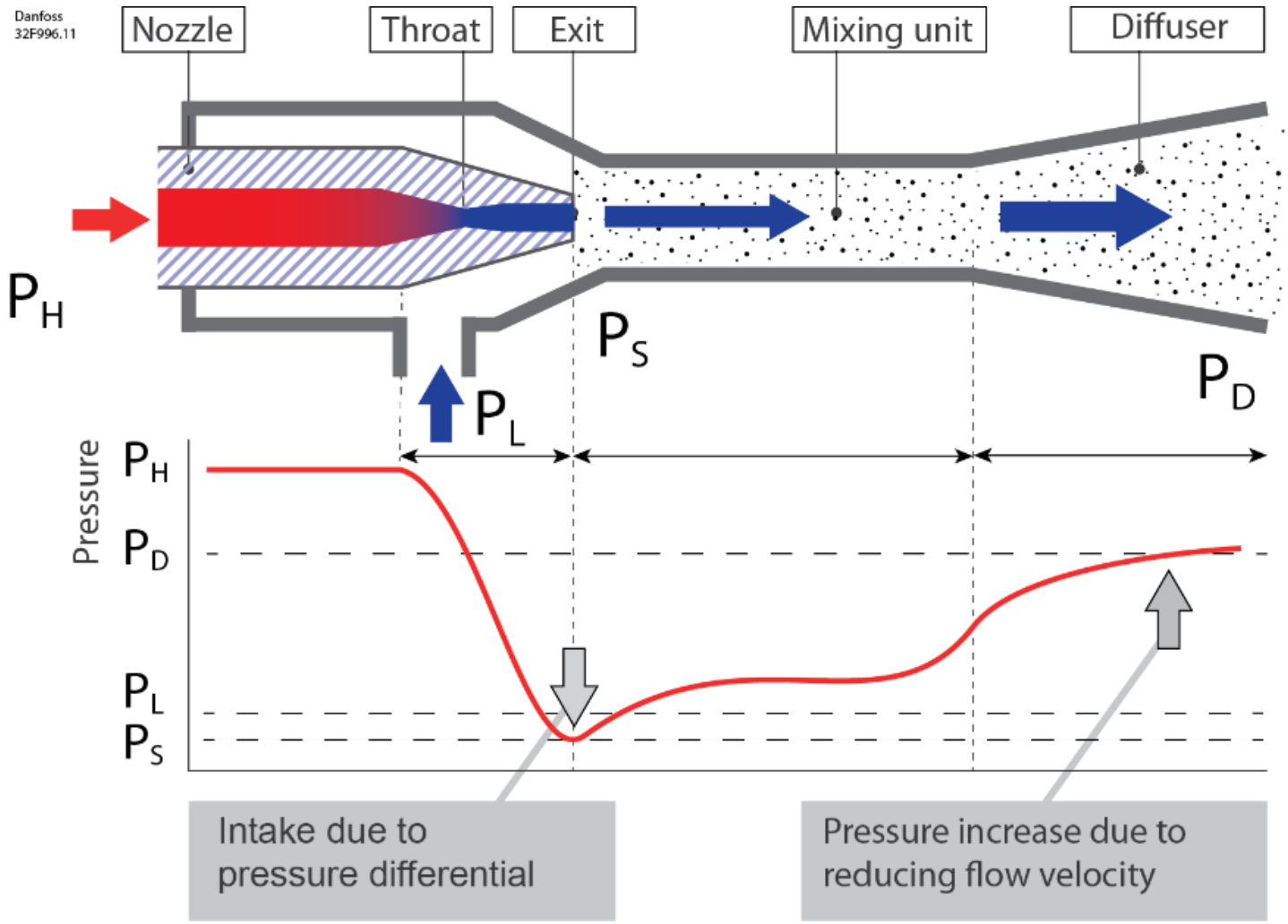
2. Transcritical CO2 systems moving forward

- Booster system
- Parallel compression
- Parallel compression with ejector
- Flooded systems with liquid ejector
- Low pressure lift ejector

3. Energy consumption and pay back

4. Questions

What is an ejector and how does it work?



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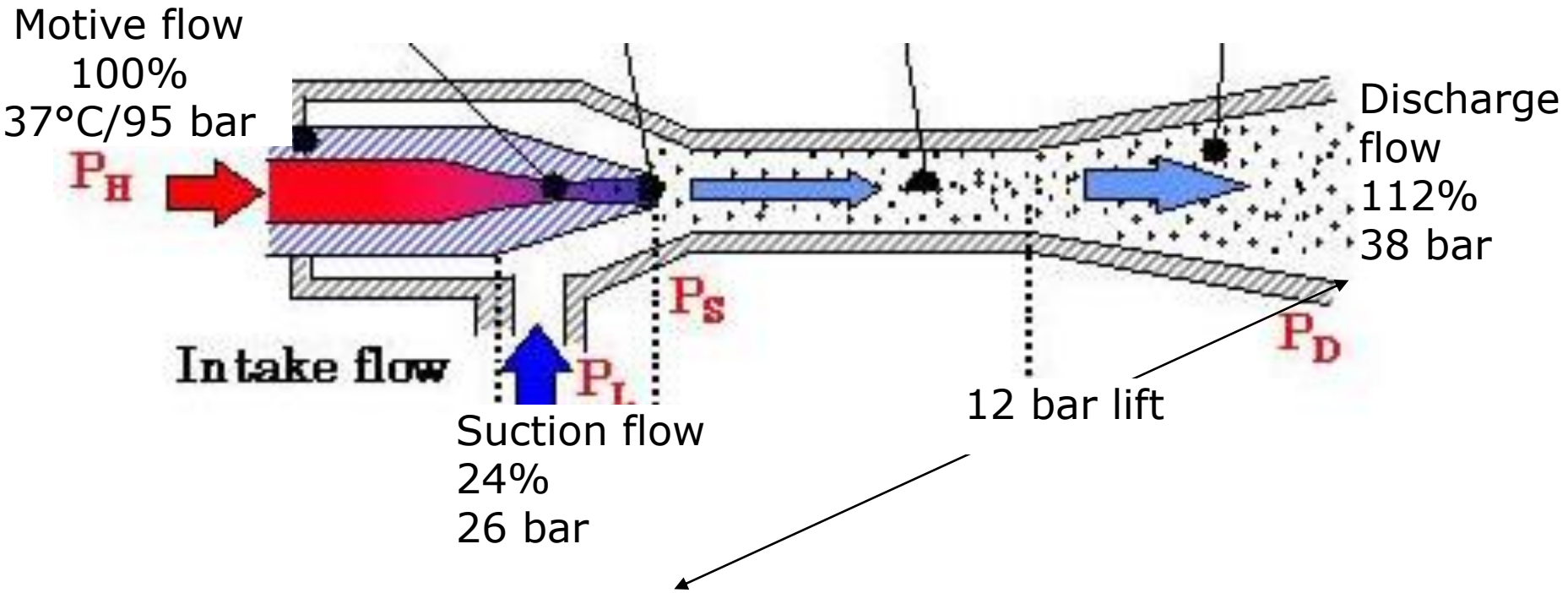
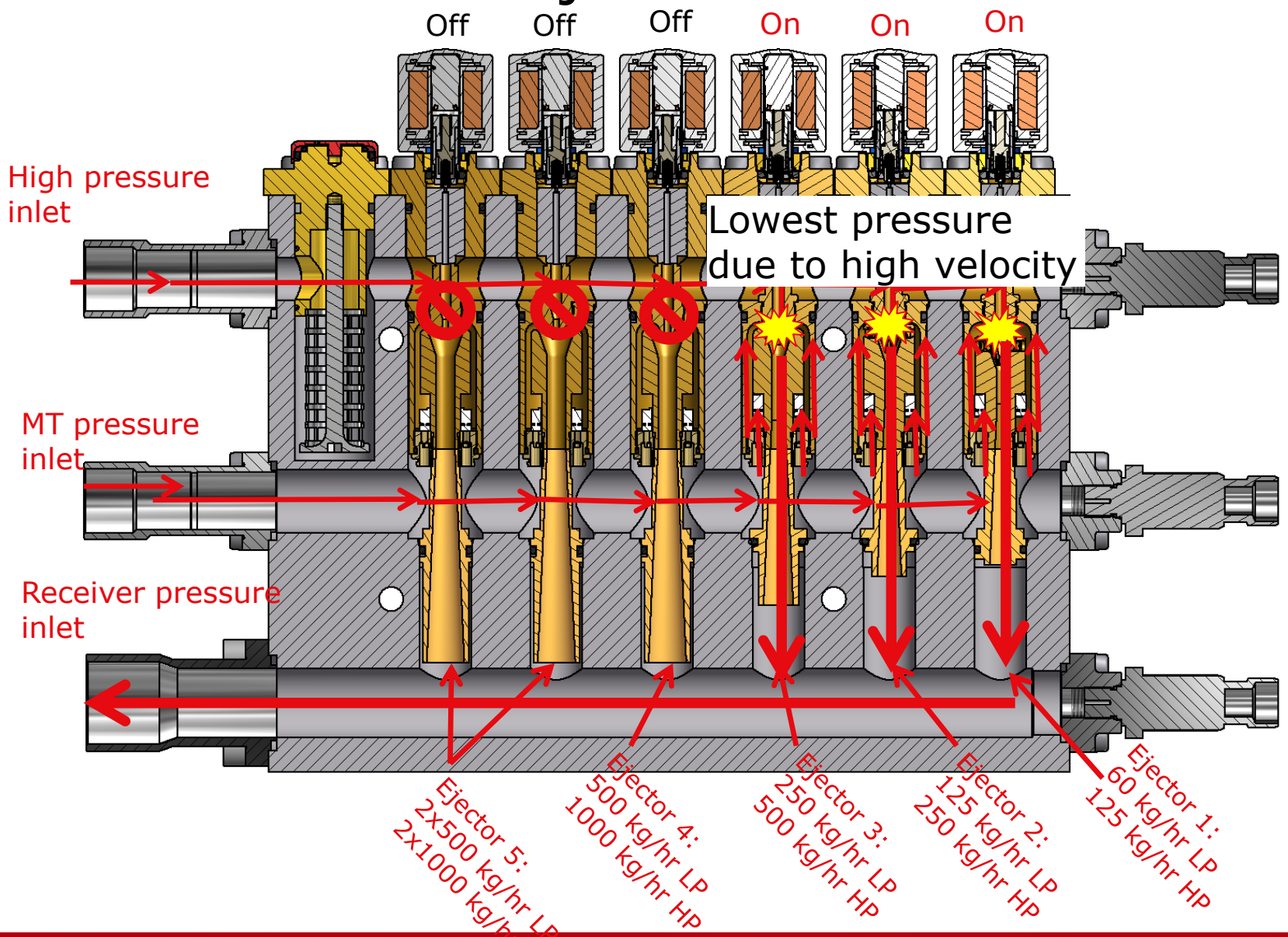


Danfoss Ejector offering overview

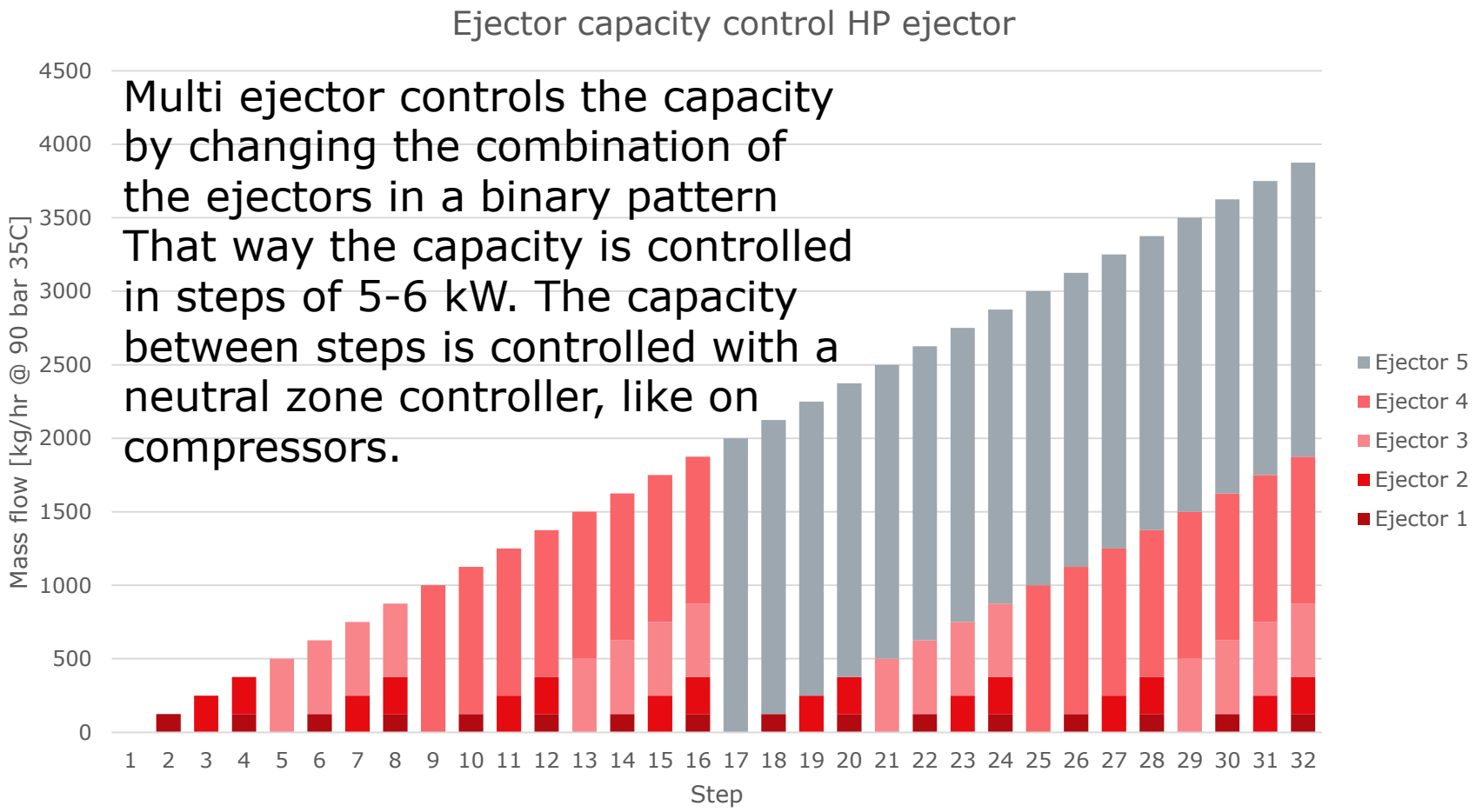
Type	Pressure lift / entrainment ratio	Media on suction side
High pressure lift	5 bar/12% @ 18°C 12 bar/24% @ 37°C	CO2 Gas (up to 10% liquid)
Low pressure lift	3 bar/60%@24°C 7 bar/50%@36°C	CO2 Gas (up to 10% liquid)
Liquid ejector	5 bar/17% @ 5°C 5 bar/36% @ 20°C	Liguid CO2 (Gas will reduce entrainment)

5 bar/12% @ 18°C: 5 bar lift, 12% entrainment at 18°C inlet temp pressure using Danfoss algorithem.

How does the Multi Ejector work?



Capacity control Multi ejector VS proportional control ejector



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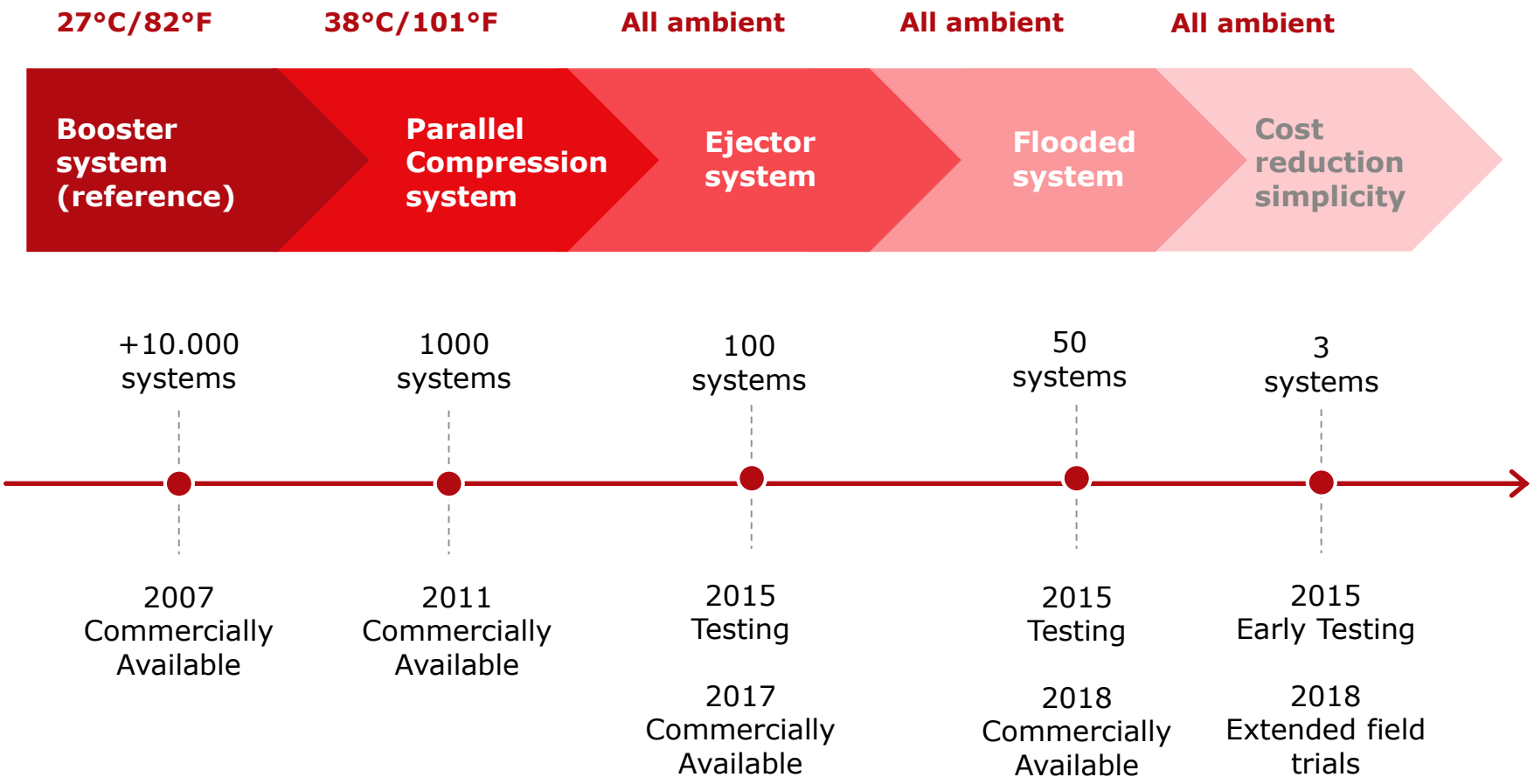
Transcritical CO_2 systems moving forward

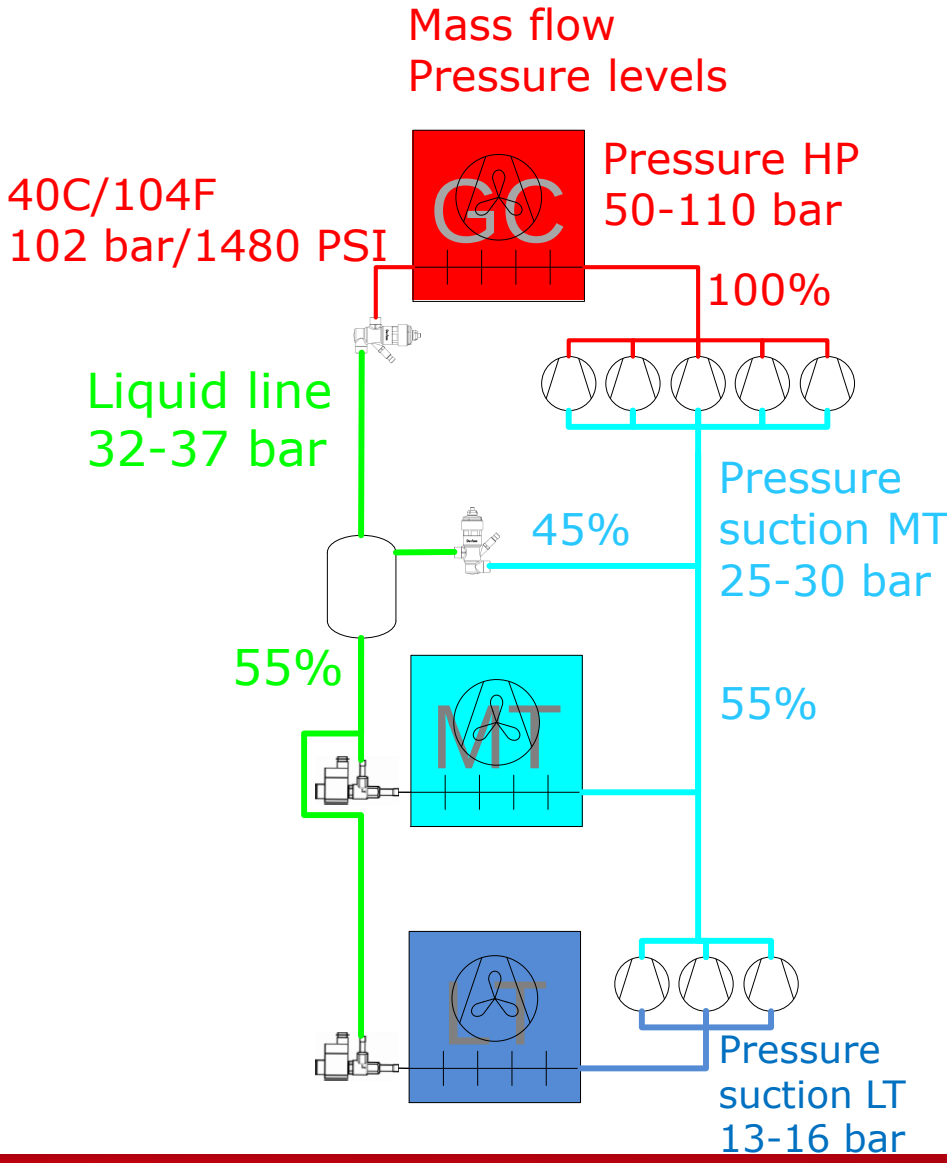
Technology status

Technology allows for world wide adoption of CO_2 only systems



1st generation: Booster system

- The transcritical booster system is the most commonly used CO_2 system today.
- The installed base is +10.000 systems with Danfoss components (as of August 2017).
- The market has chosen this as the standard system.



1st generation: Booster system

Pros:

- Long track record with large install base mainly in colder climates.
- Relatively simple compared to most of the other systems on the market.
- Approx. 12% lower energy consumption than R404a in Amsterdam.

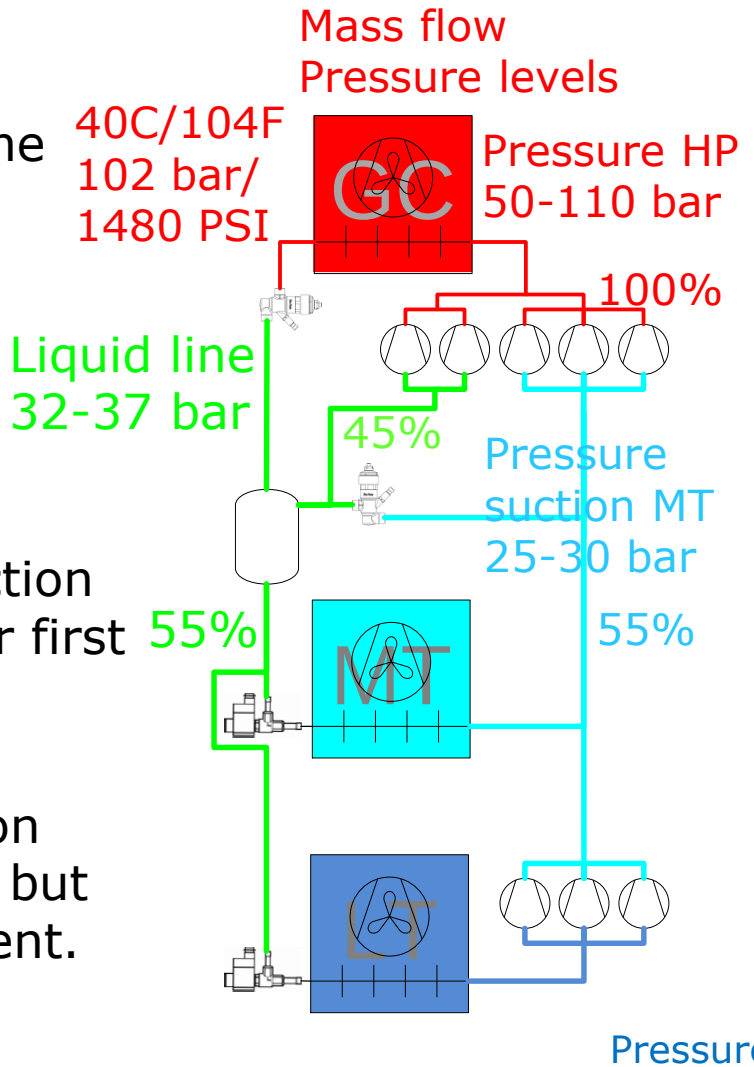
Cons:

- Energy consumption in warm ambient temperature is the main problem.
- Swept volume increases dramatically in warm ambient temperatures.

Application:
The system covers from small and all the way up to very large systems (CDU, Discounters up to Hypermarkets).
Geographically, the system has a very good foothold in the northern European climate.

2nd generation: Parallel compression

- Parallel compression is the first step into the development towards bringing CO_2 into a warmer climate.
- Parallel compression is giving a significant improvement of COP in warm climates.
- In addition to that, it is also giving a reduction of swept volume of the compressors (lower first cost).
- This reduction of cost can not be realized on systems smaller than approx 100-150 kW, but on larger systems a reduction in cost present.



2nd generation: Parallel compression

Pros

- The system has been on the market for some years and the installations are counted in several hundreds.
- Approx. 18% saving on energy consumption in Amsterdam VS R404A
- Compressor sizes are smaller and not as growing as fast in warm ambient
- Integration with AC makes sense

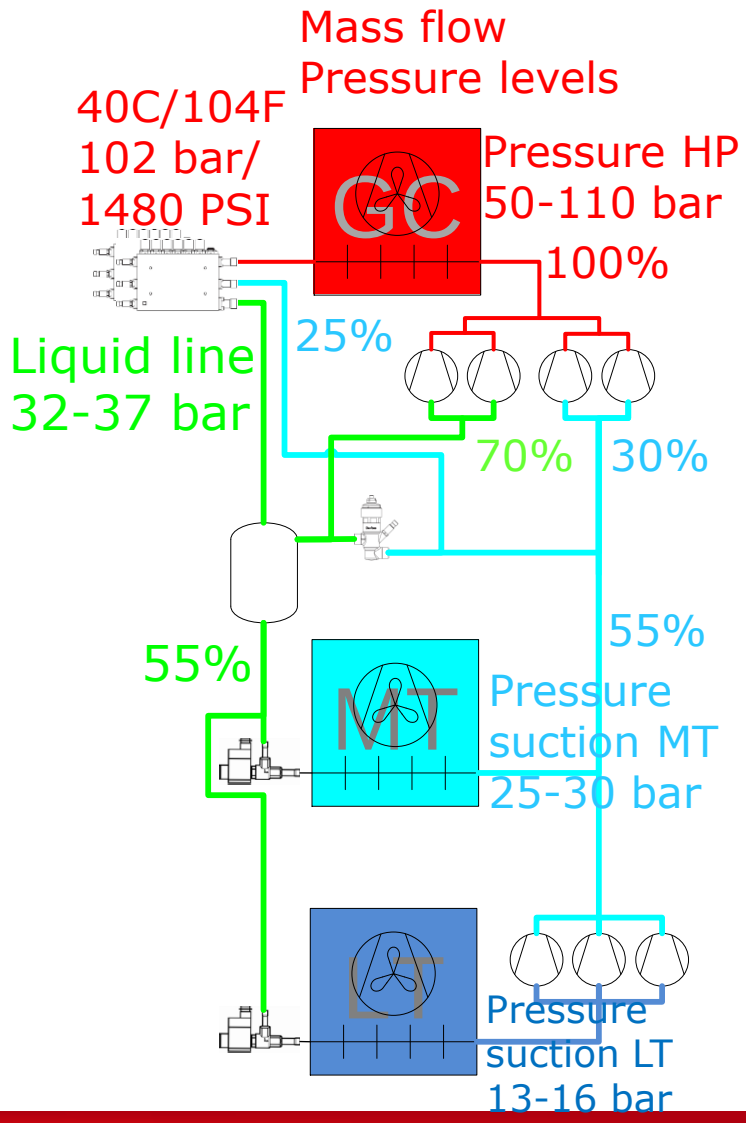
Cons

- The system is more complex than the booster system.
- Small systems are difficult because the compressors are divided in to 2 suction groups

Application:
The system fits system sizes from approx. 100-150 kW and up. System can be combined with AC with good results.
Geographically, the system has the largest install base in southern Europe and warmer ambient.

3rd generation: Parallel compression with gas ejector

- First system in opperation with Danfoss Multi Ejector started in January 2015.
- The ejectors are moving gas from MT suction to parallel compressor.
- In some cases, all gas can be moved from MT to parallel compressor (high ambient temperature or 100% heat recovery).



3rd generation: Parallel compression with gas ejector

Pros:

- System is penetrating the market this years
- Solutions shows better energy consumption in any climate and removes the "CO_2 equator"
- Compressor sizes are smaller and not as grooving as fast
- Combination with AC makes very good sense
- Approx. 20% savings VS R404A in Amsterdam

Cons:

- The system is more complex than the booster systems and also parallel compression
- Small systems are difficult because of the compressors divided in to 2 suction groups

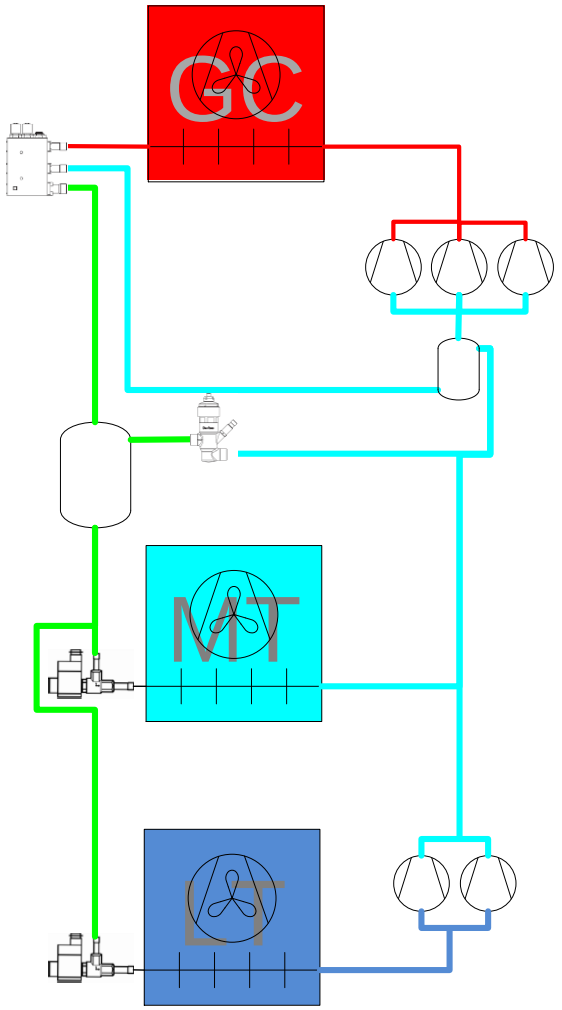
Application:

The system fits system sizes from approx. 100-150 kW and up. System can be combined with AC with very good results.
Geographically the system can be installed in any climate with lower energy consumption than R404a.

Next generation: Liquid ejector

Add on to transcritical systems

- Liquid ejector systems allow the MT evaporator to be flooded.
- The saving is coming from the higher suction pressure of the compressors.
- Ejector is in this case substituting a pump or other means of removing the liquid from the suction side
- Trials has been running since 2013 with good results. Evaporation temperature is in average raised by 5K.
- Saving is load dependent and dependent on most leaded evaporator



Next generation: Liquid ejector

Pros:

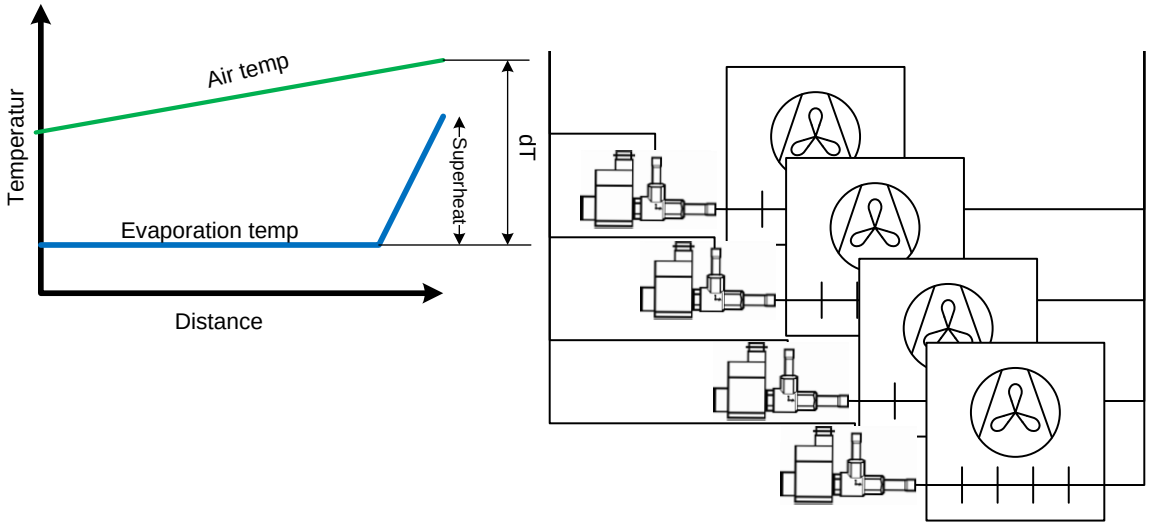
- Very promising results from the tests running
- Relatively simple system where the complexity is in the controllers and not in the lay out.
- Commercially available Q2 2018
- Approx. 10% saving in energy and can be added to the previous savings

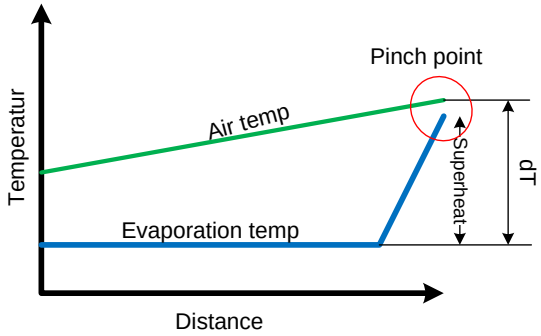
Cons:

- Increases complexity slightly of the systems and controls
- Reducing superheat will give some of the same effects

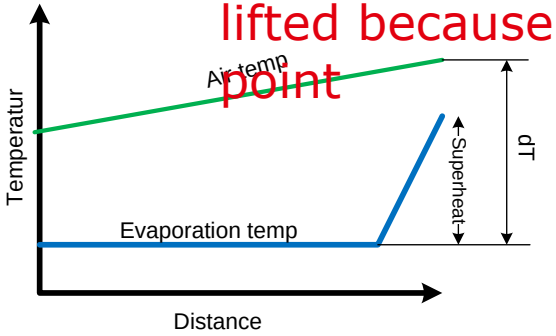
Application:
The system covers from small and all the way up to very large systems (CDU, Discounters up to Hypermarkets).
Geographically the system will provide the saving in any climate.

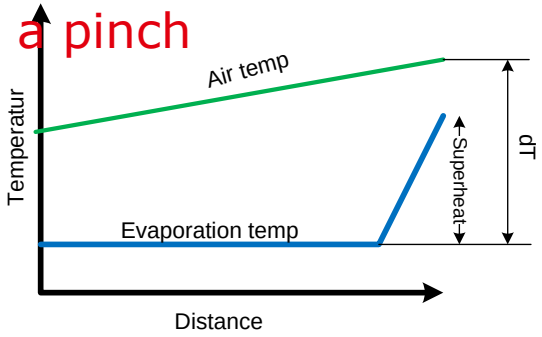
Direct expansion



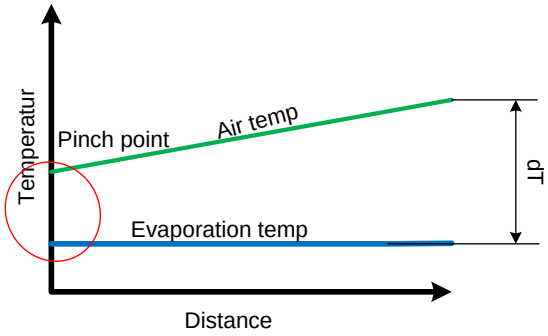


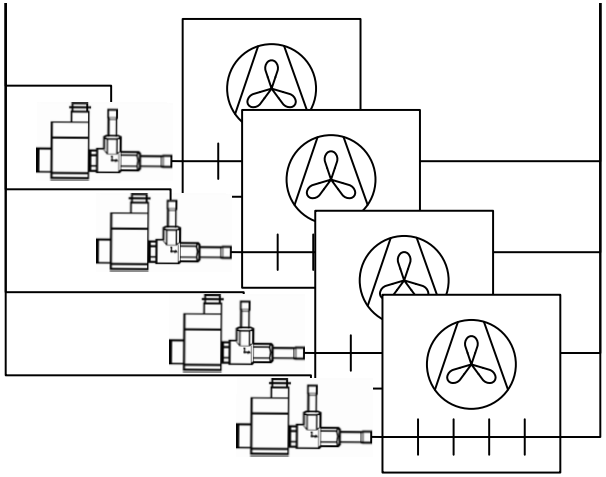
Evaporation temperature can not be lifted because the SH creates a pinch point

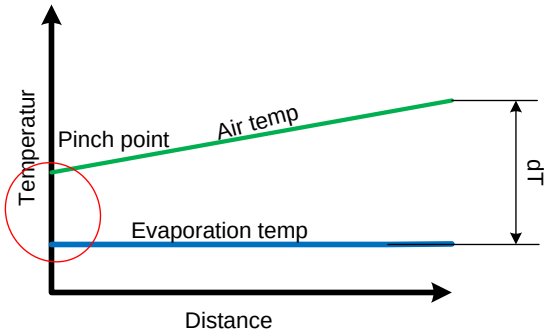




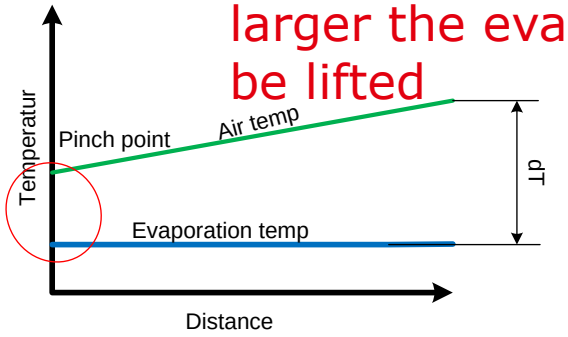
Flooded evaporator without Po optimization

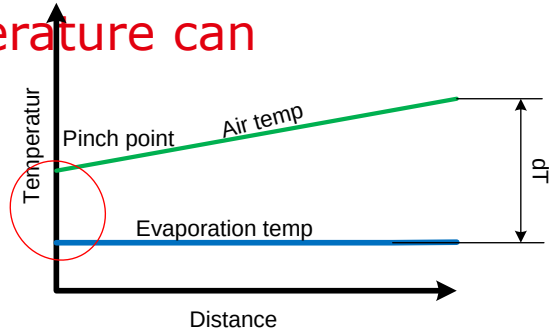




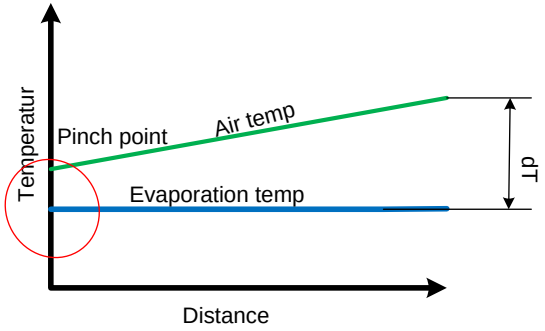


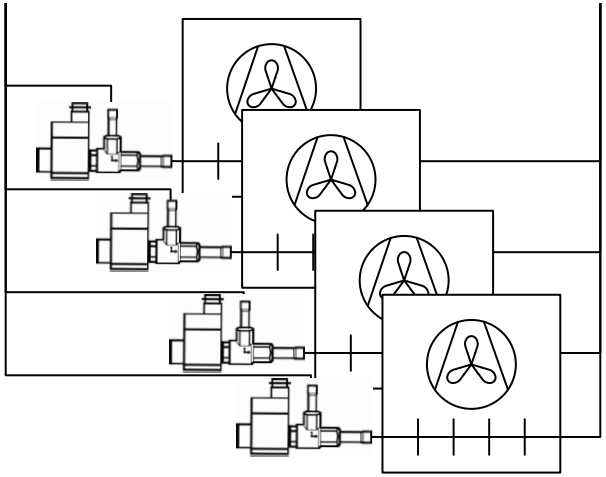
When the pinch point is moved and larger the evaporation temperature can be lifted

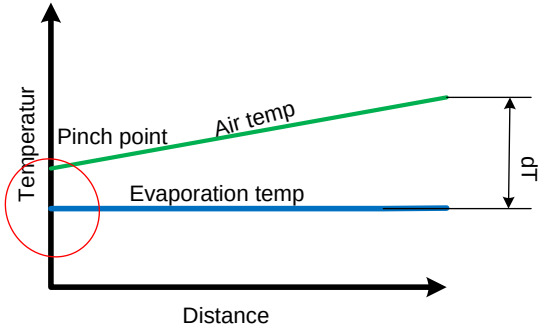




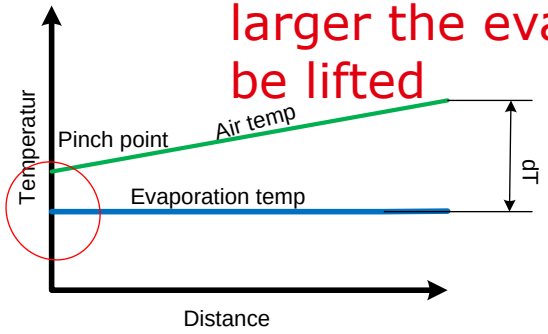
Flooded evaporator and Po optimization

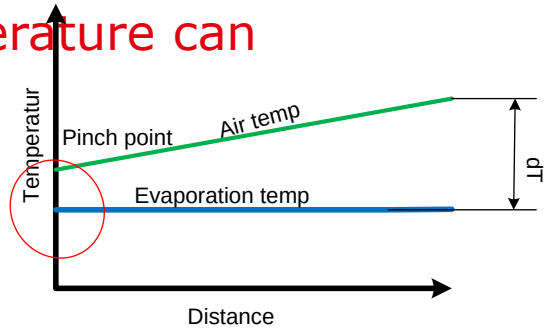




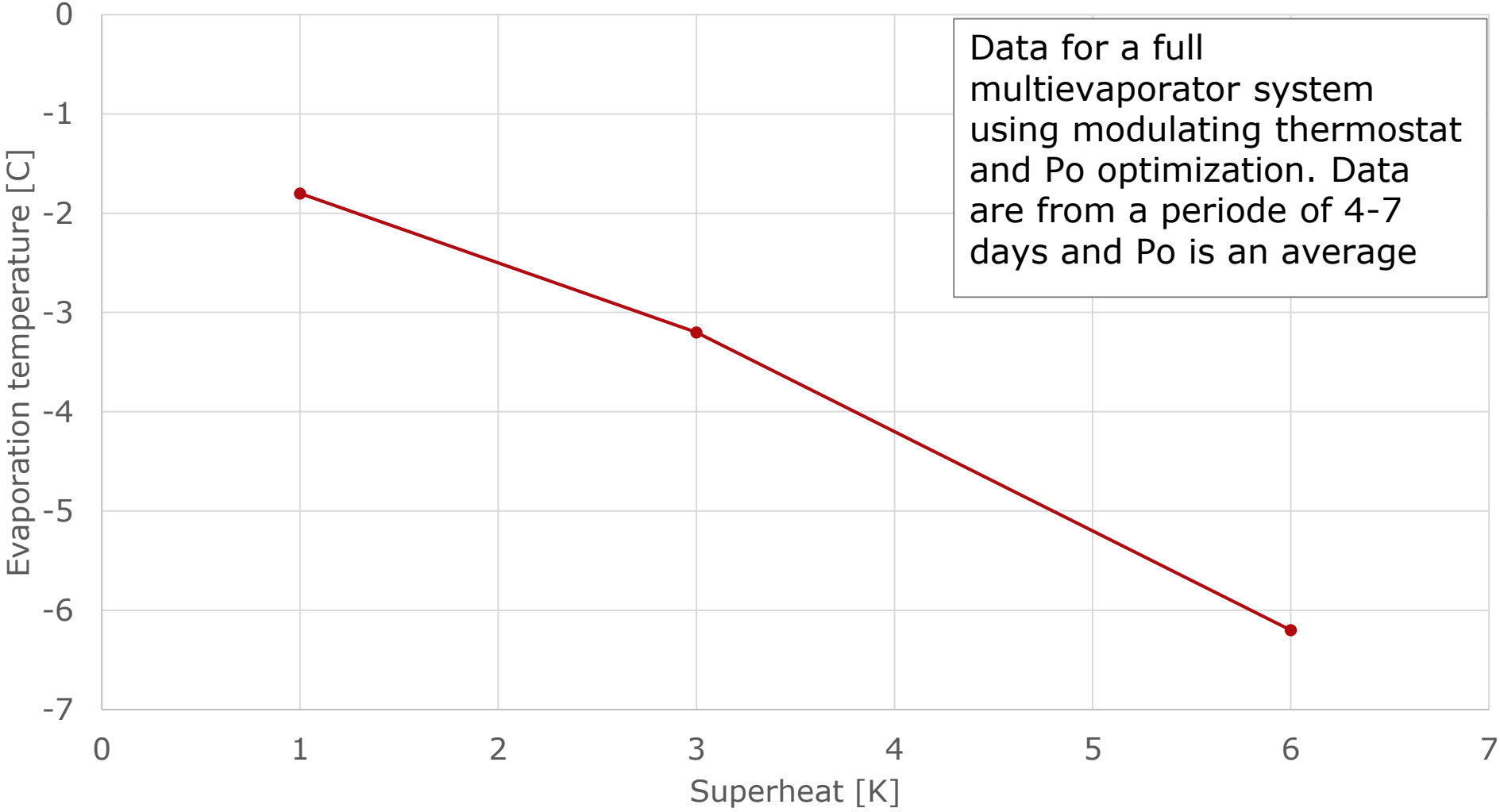


When the pinch point is moved and larger the evaporation temperature can be lifted

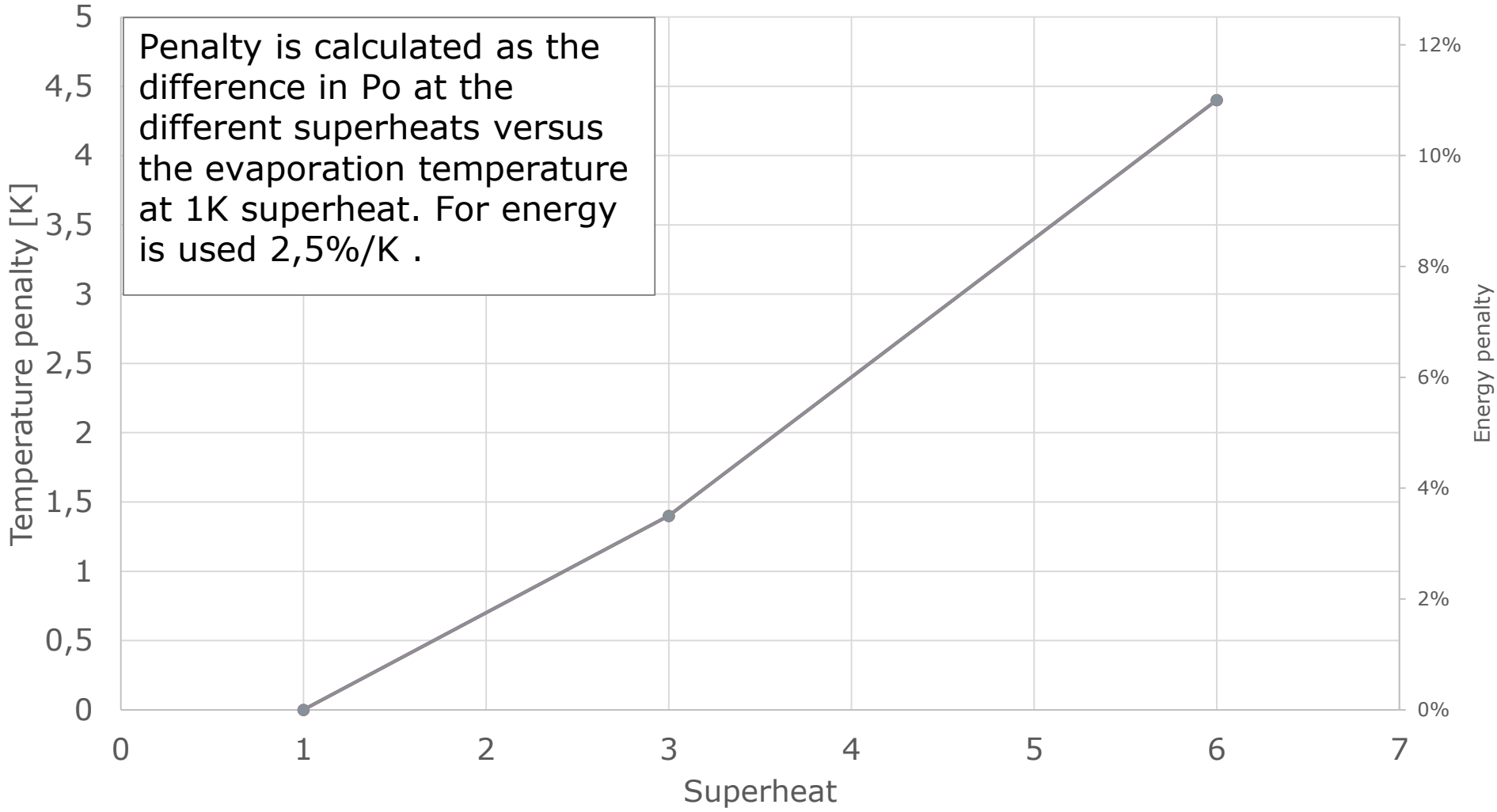




Evaporation temperature as a function of superheat

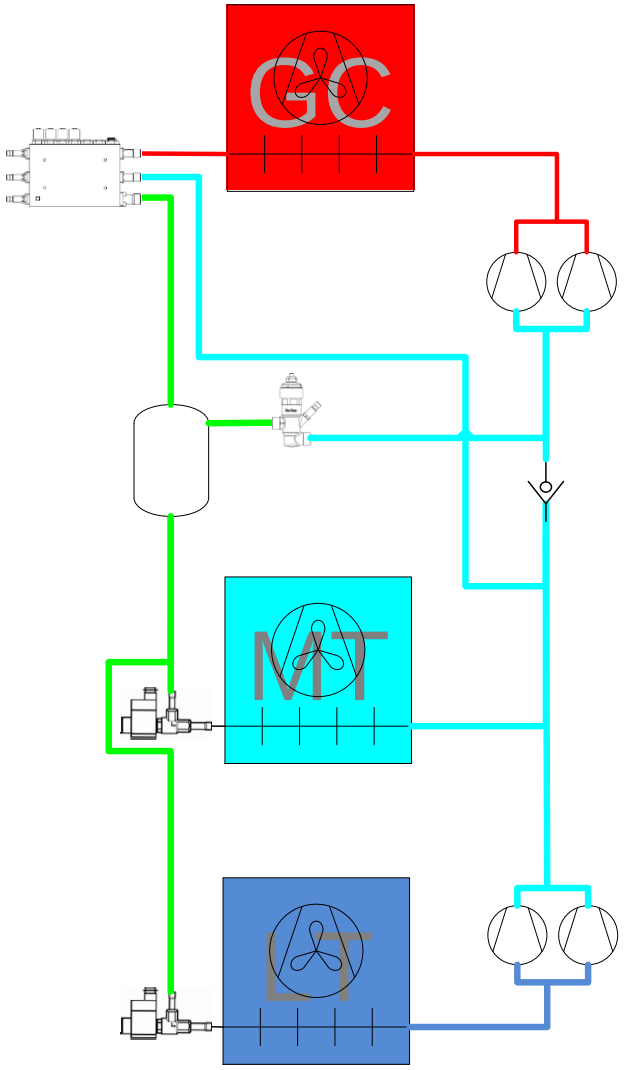


Evaporation temperature penalty VS superheat



Next generation: Low pressure lift ejectors for small systems

- The Low pressure lift ejector system can be used for smaller applications
- Simple setup very much like a booster systems
- Can also be combined with liquid ejector and in warm periods there is no need for suction accumulator (receiver will work as suction accumulator)



Next generation: Low pressure lift ejectors for small systems

Pros:

- Very promising results from the tests running Cost savings and energy savings go hand in hand.
- Suited for systems small systems
- Simple system
- Flooded evap. Is easy to implement
- 16 – 28% saving in Amsterdam Vs R404A

Cons:

- Only limited results from the field (only 3 systems in operation)
- Patents can be a problem in some regions (not in Holland)

Application:
Condensing units, smaller supermarket systems.

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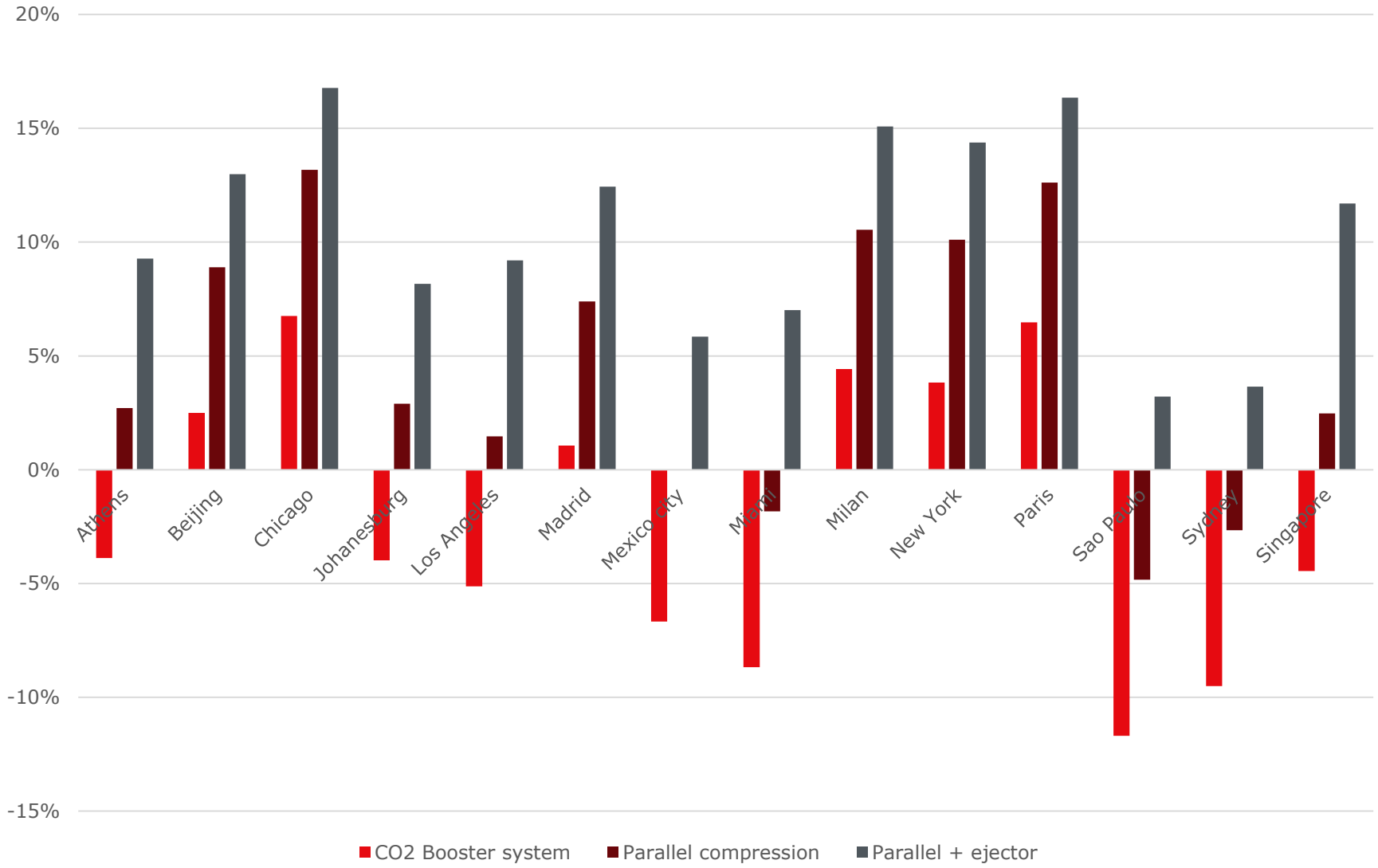
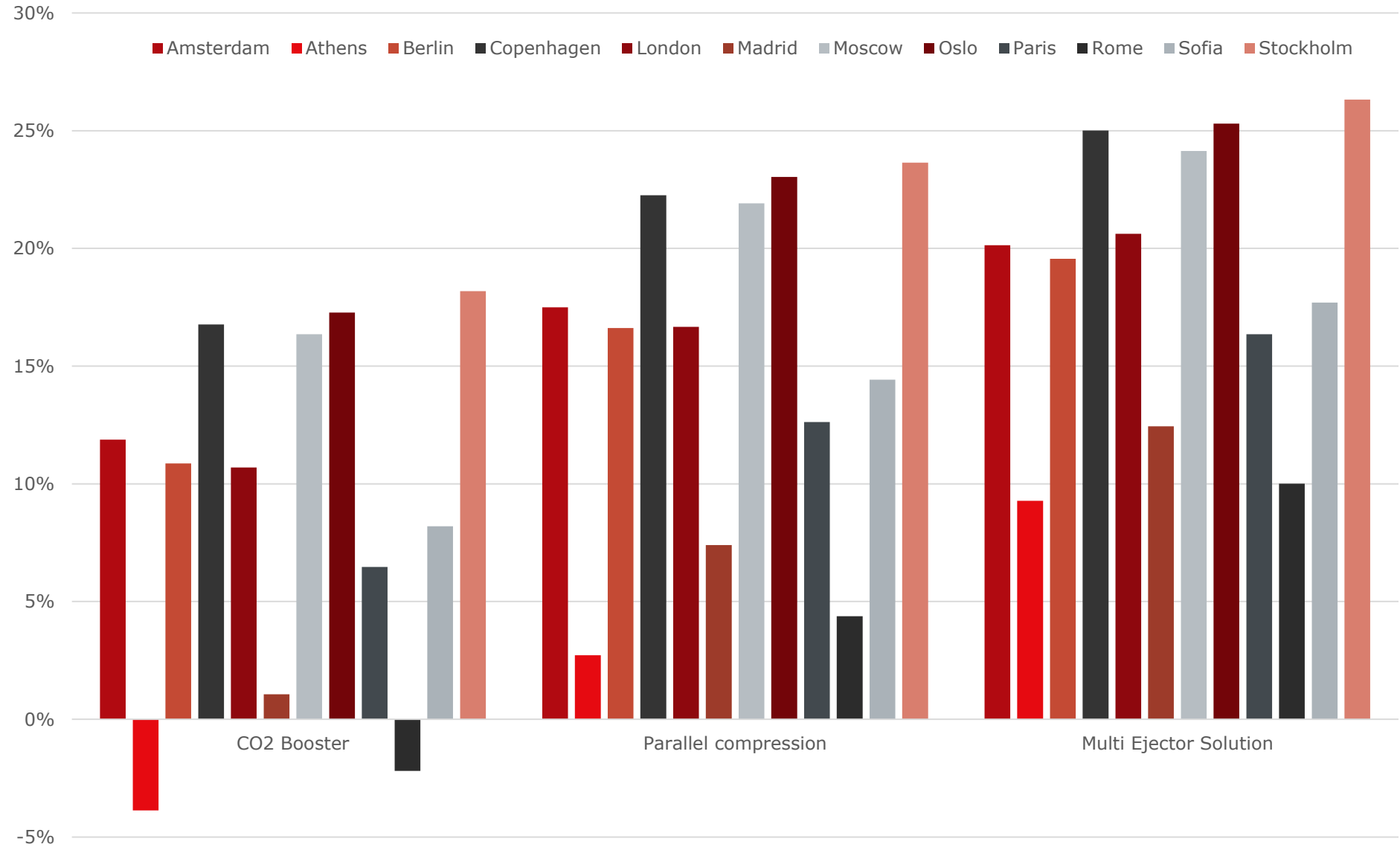
Energy savings and Pay back

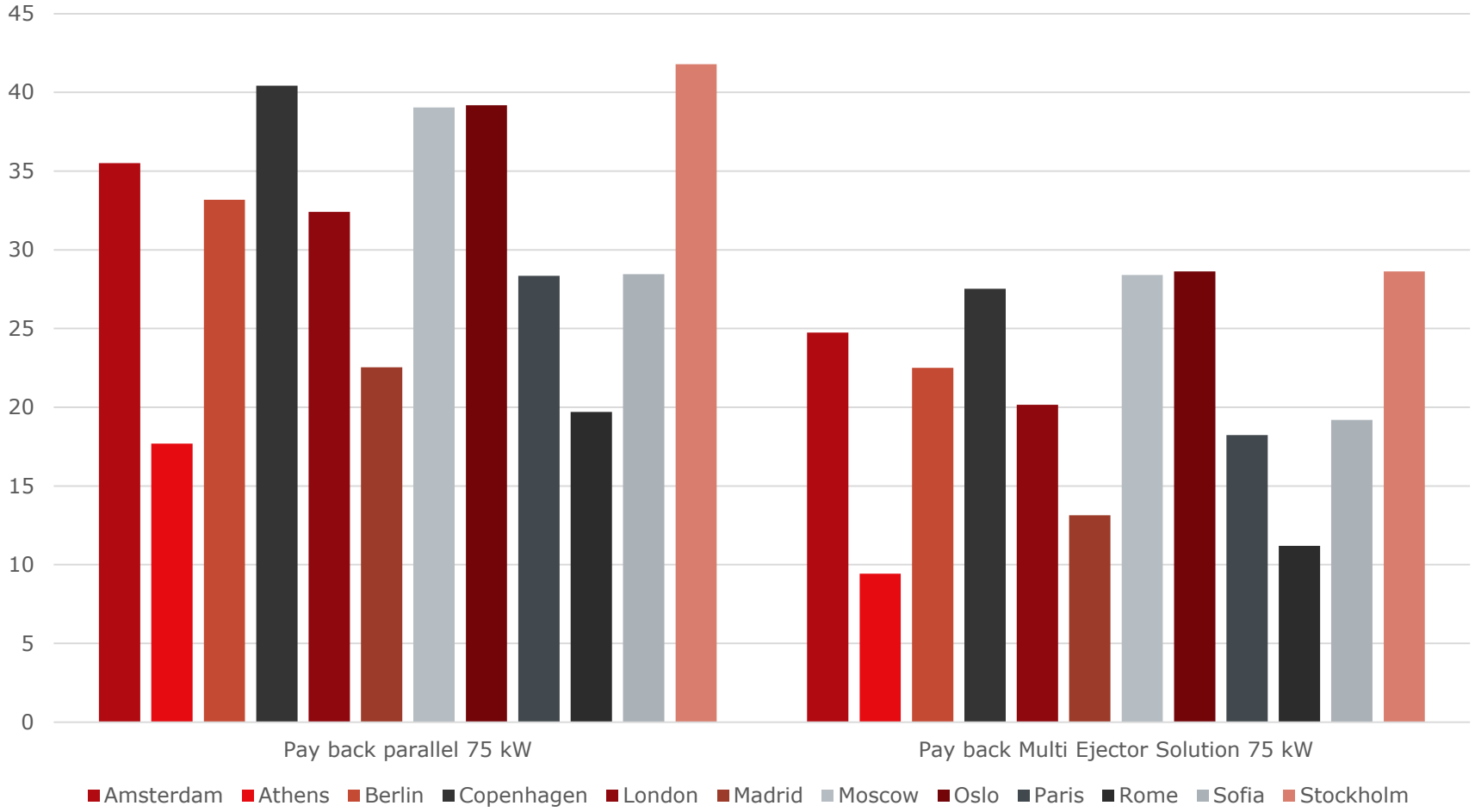
Energy saving CO_2 VS R404A



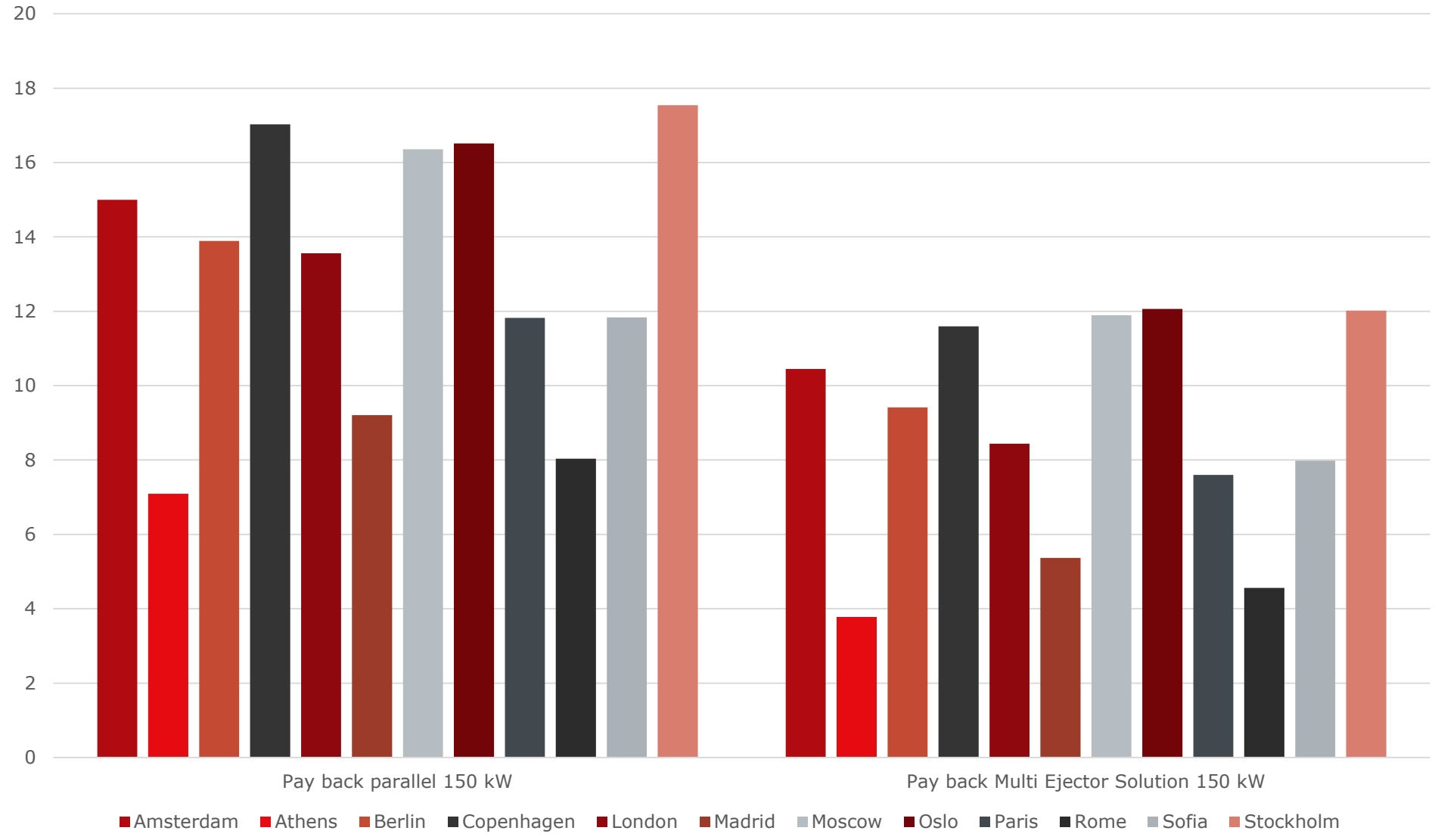
Energy saving CO_2 VS R404A



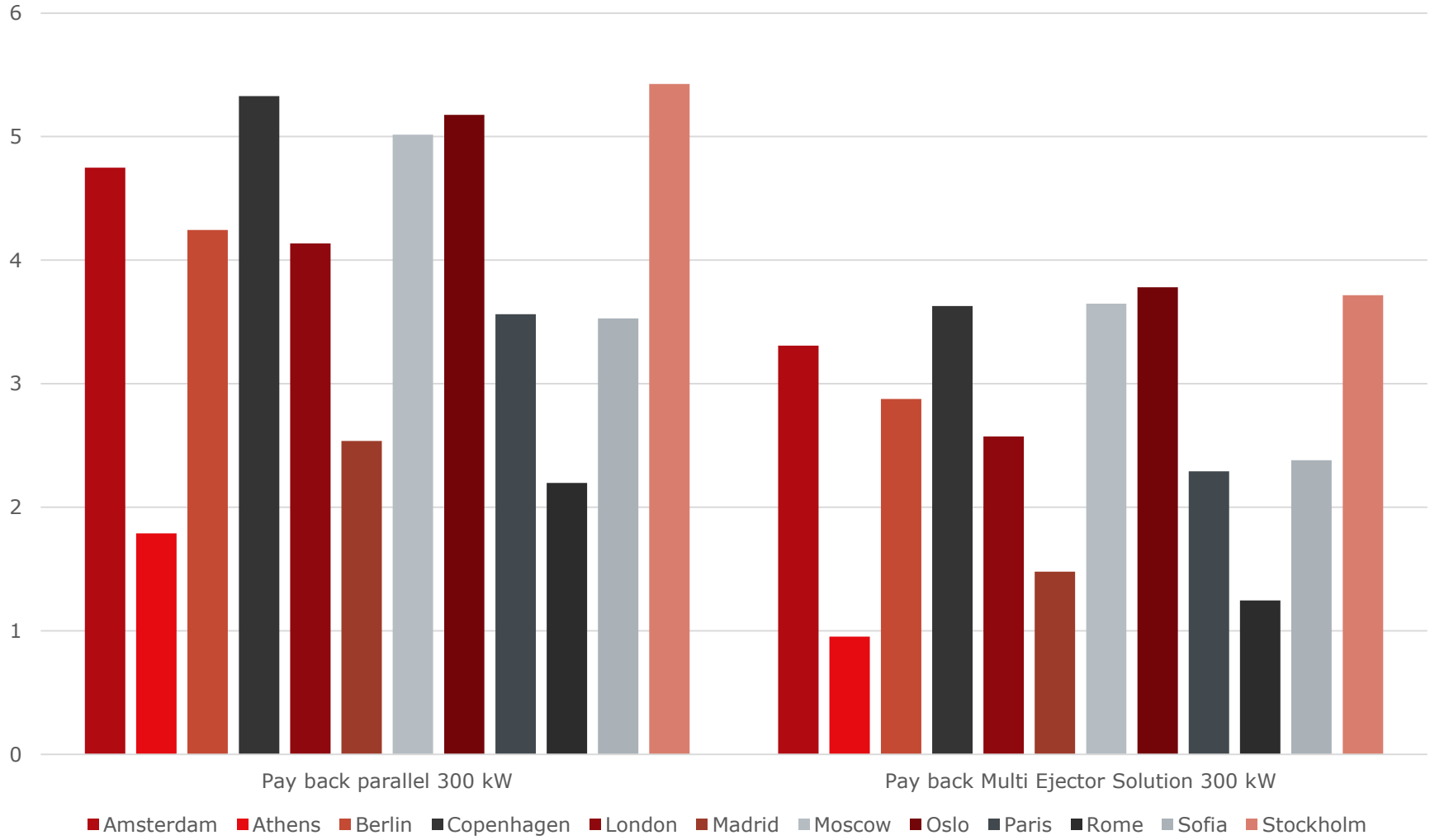
Pay back 75 kW system VS Booster



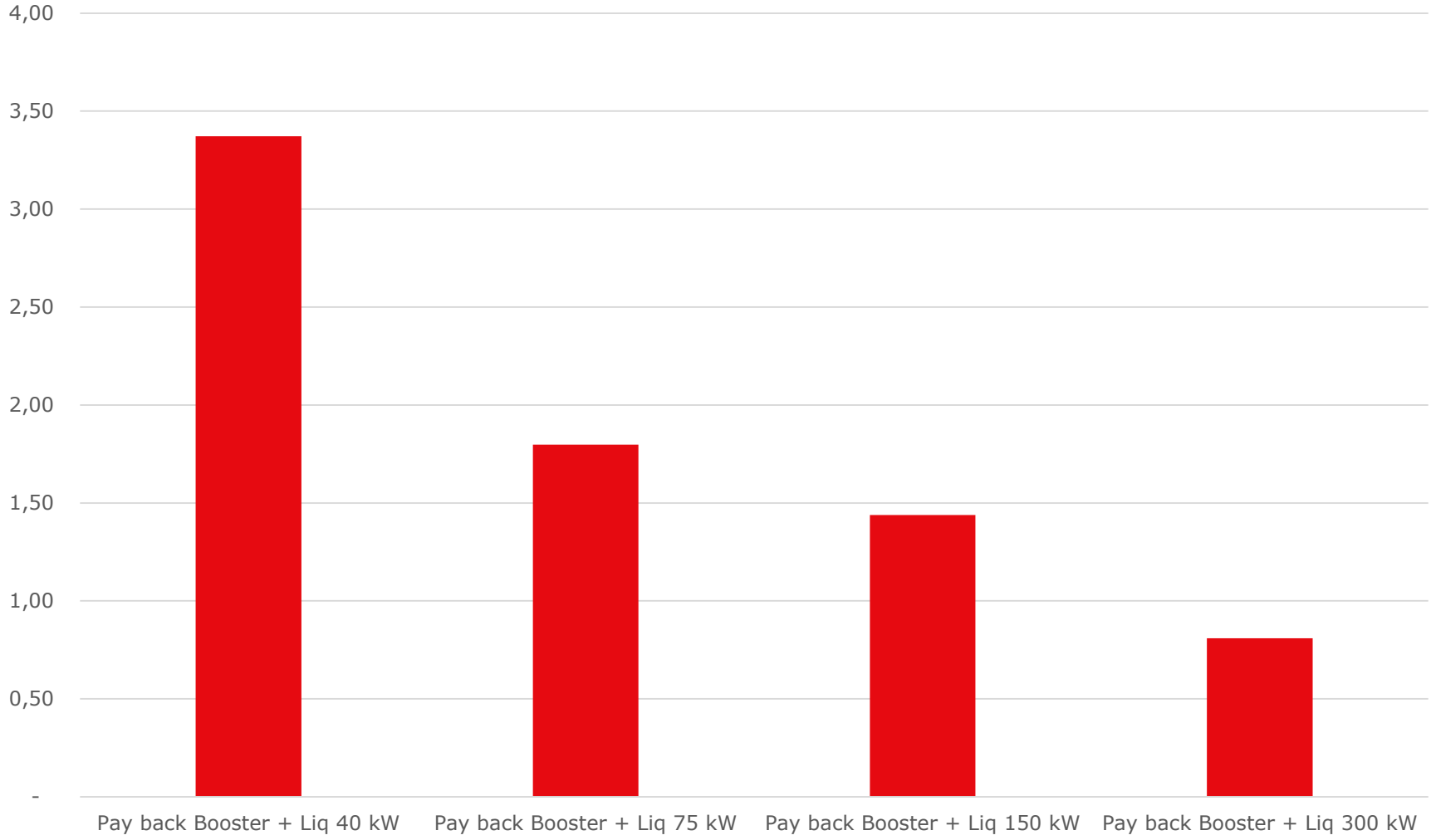
Pay back 150 kW system VS booster



Pay back 300 kW system VS booster



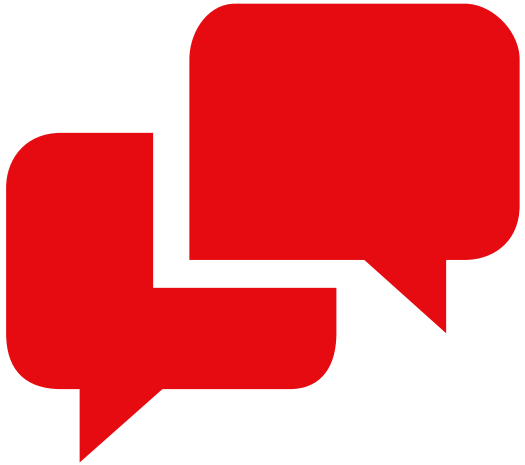
Pay back time liquid ejector solutions in Amsterdam



Pay back for Low pressure lift ejector system

- Not enough data to say something precise at this moment
- When technology is matured there is a potential for lower cost than a booster system even on smaller systems. This combined with energy savings makes it very interesting.

Questions?



Questions and feedback

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