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# Refrigeration Energy-Efficiency Opportunities

## For the Australian Meat Processing Industry

Industrial Ammonia Systems

Part 2

# REFRIGERATION ENERGY-EFFICIENCY OPPORTUNITIES

## FOR THE AUSTRALIAN MEAT PROCESSING INDUSTRY

GUIDEBOOK #2 – INDUSTRIAL AMMONIA SYSTEMS PART 2

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# CONTENT OVERVIEW

## PART 1

### ESSENTIALS

### HARD YARDS

## PART 2



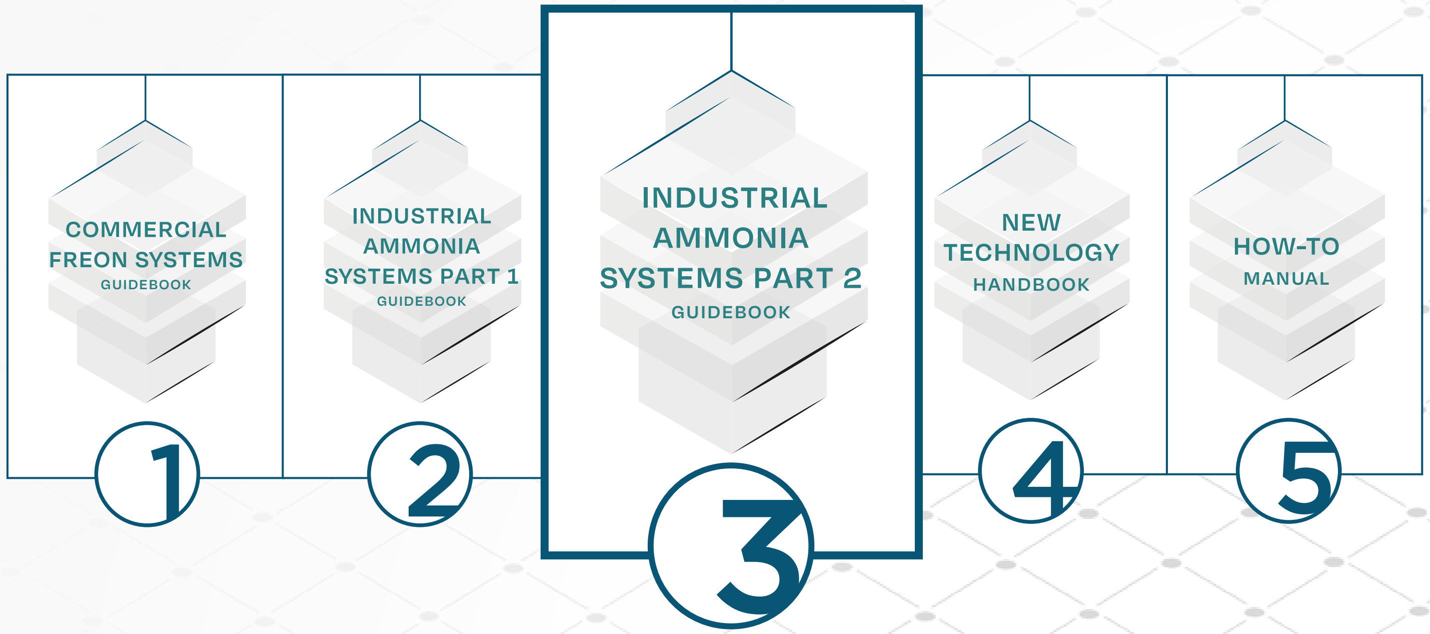
### REFINEMENT



### INTEGRATION

# INTRODUCTION

This Guidebook is one of 5 Guidebooks/Manuals which were developed during the **"Refrigeration Plant Energy Improvement"** research project.




Guidebook: Commercial Freon Systems covers **smaller abattoirs** which often use multiple small commercial refrigeration systems with freon refrigerants.

Guidebook: Industrial Ammonia Systems Part 1 & 2 cover **medium to large sized abattoirs** which use big, centralized ammonia systems for refrigeration. These systems are much more complex than small commercial systems and require a stepped, strategic approach to improve energy efficiency.

The New Technology Handbook covers the **most recent developments** in refrigeration as applicable to the red meat industry. Refrigeration is undergoing some decisive changes which will have major impacts on the operational costs of refrigeration systems. **Awareness of these developments** is crucial when it comes to decision-making on major plant upgrades/restorations as investments into outdated technologies could result in a competitive disadvantage.

To further **determine the viability** of opportunities discussed in the books mentioned above, the How-To Manual gives guidance on how to initially assess opportunities and use the Energy Efficiency Opportunity Calculation Tool where applicable.



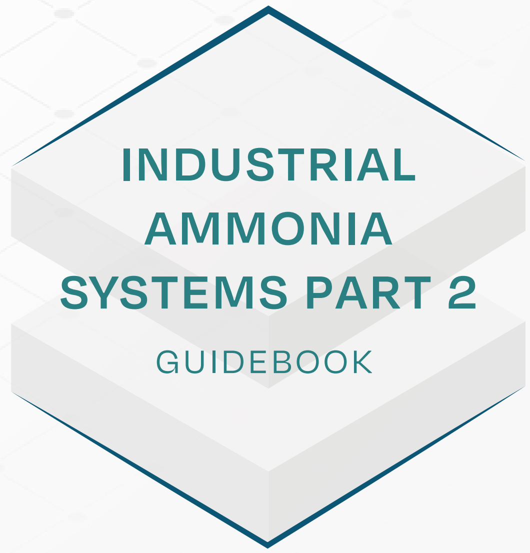
# GUIDEBOOK: INDUSTRIAL AMMONIA SYSTEMS PART 2

**Centralized ammonia plants are complex systems,** custom-tailored to each site. This makes optimizing them more difficult than commercial systems. On the bright side, they allow for much more sophisticated measures to be implemented due to their scale and leave you more room for improvement. Because they are custom-tailored and production at meat works and the associated cooling and heating demands vary over a wide margin, what opportunities apply to one site might be totally different to the next. This is amplified by the drastically **differing states of respective refrigeration plants** regarding how they are controlled, and which energy efficiency opportunities already may have been implemented.

Some sites might be further ahead and tick off many of the opportunities presented. Others might still have more groundwork to do. Furthermore, some opportunities built on the foundation laid out by others. This is why a **staged approach** was chosen for the industrial ammonia systems guidebooks, with Part 1 & 2.

Part 1 gave a brief overview of ammonia refrigeration systems and then focusses on the very first important steps which must be taken care of. This first stage was referred to as the **"Essentials"** and aims to get the plant into a good running order while making use of some of the more fundamental energy efficiency opportunities. Then follow the **"Hard Yards",** which aimed to replace hardware that is holding back the plant's efficiency. Even if your plant is more advanced and has most of this covered, make sure each essential step has properly been taken care of. Be aware, with time and changes to the plant from when it was first commissioned faults might have crept in. Omissions in these first stages might significantly hinder savings achieved by more sophisticated measures discussed in Part 2.

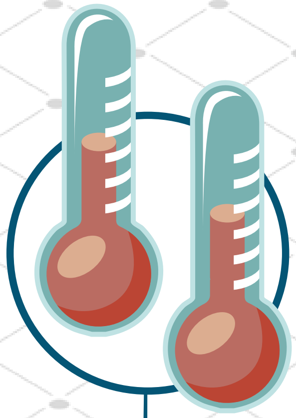
Part 2 delves into the **"Refinement",** some more advanced features which mostly focus on control strategies and tease out the last bits of efficiency. Lastly, it will examine the **"Integration"** of refrigeration plants into providing hot water needs for the site as well.



# TERMINOLOGY

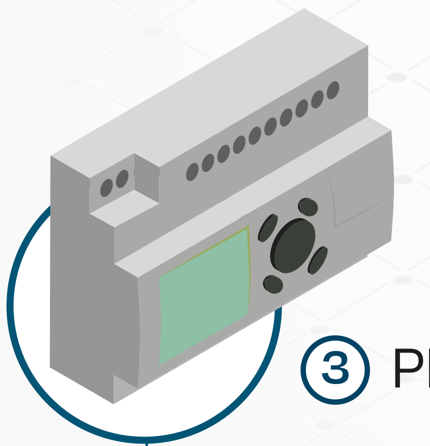
## 1 EEO

Opportunities to improve your plant's efficiency in these guidebooks are referred to as **E**nergy **E**fficiency **O**pportunities, or in short **EEO**s.



## KELVIN [K] 2

Scientific unit for absolute temperature and temperature differences. E.g. the difference between 30 °C and 20 °C is **10 K.**



## 3 PLC

**P**rogrammable **L**ogic **C**ontrollers or **PLC**s are commonly used to control refrigeration systems. As the name suggests, they are programmed to follow specific control logics and can be re-programmed by knowledgeable persons.

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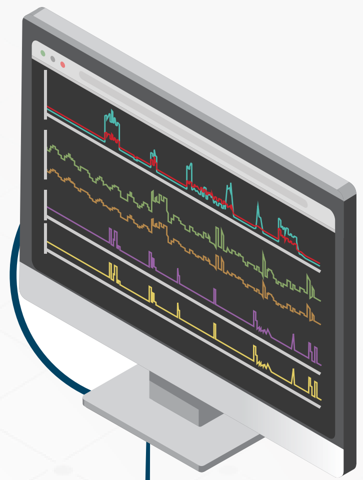
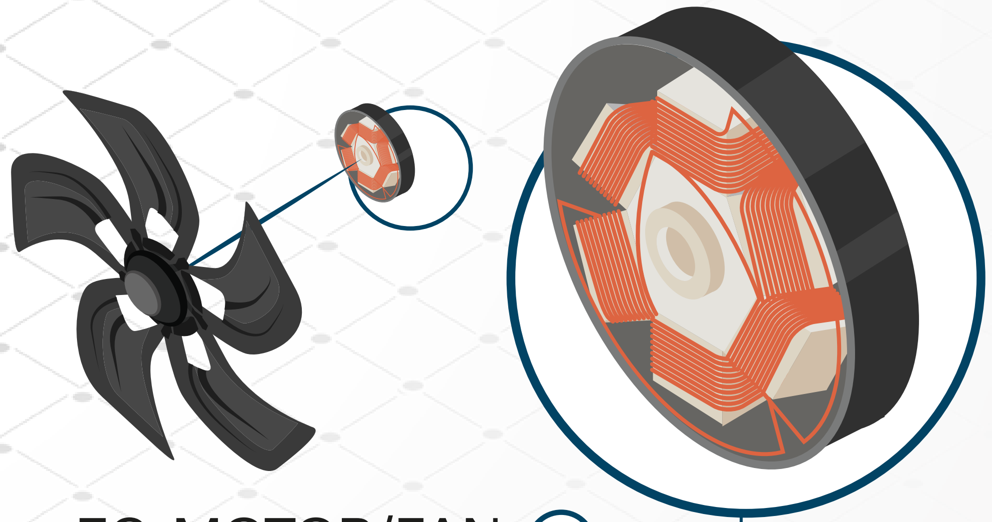


## SCADA 4

**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition, or in short **SCADA**, is the broad term used for human-machine interfaces which allow personnel to visualize and understand operational system data and if necessary to interact with the system.

## 5 VSD

**V**arible **S**peed **D**rive (sometimes refered to as VFD, AFD and others) is the broad term used for power electronic controllers that allow you to run AC-motors as commonly used in refrigeration at varying speeds. This allows for **speed control** which brings many benefits.

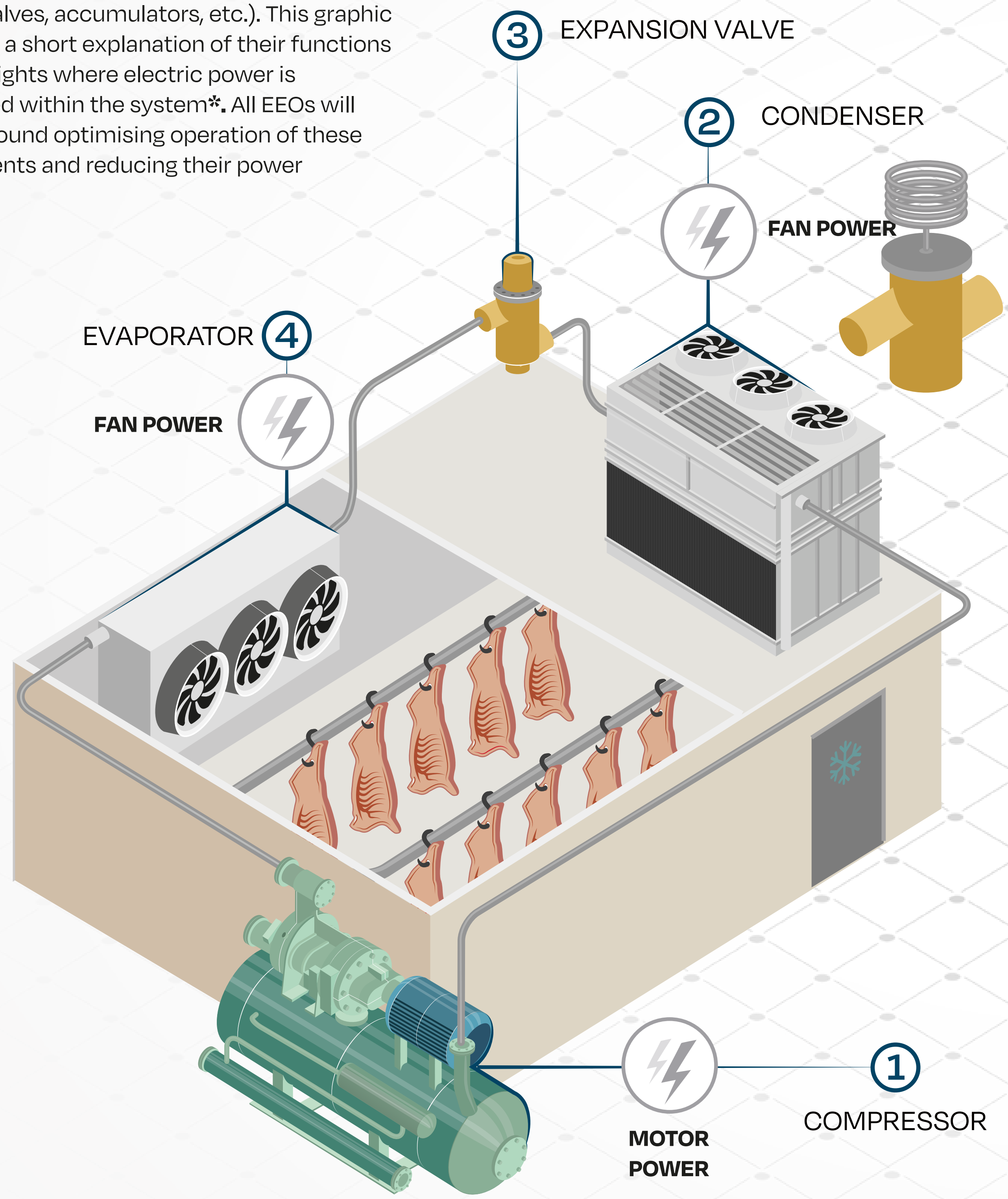


## EC-MOTOR/FAN 6

**EC** stands for **E**lectronically **C**ommutated. These motors possess a controller which commutates the electric current in such a way that it can **vary the speed** of the motor. As for VSDs this allows for **speed control** and its benefits.

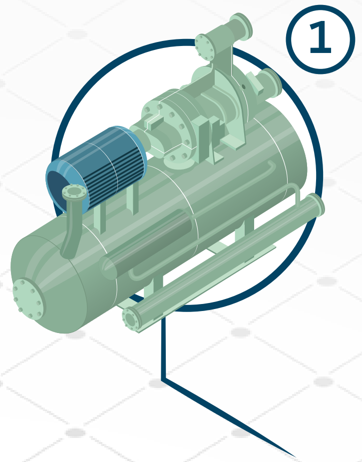
# REFRIGERATION BASICS

The refrigeration systems we encounter in most meat works are **vapour compression systems.** They consist of **4 basic components** + miscellaneous equipment (filters, valves, accumulators, etc.). This graphic gives you a short explanation of their functions and highlights where electric power is consumed within the system*****. All EEOs will evolve around optimising operation of these components and reducing their power draw.




**There are other power consumers like pumps, electronics, controls, etc. But these are of less concern.*

## 1 COMPRESSOR

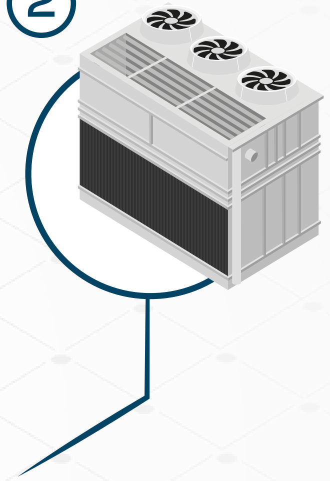


Takes in cold vapour coming from the evaporator and expansion valve at **suction pressure.** Compresses it to hot gas at **discharge pressure** using electric power.

▼

**Biggest power demand** in the system. The higher the pressure difference between suction & discharge, the more power is needed. E.g. it takes more energy to compress vapour from a **colder** evaporator (pressure is **lower**) or to discharge into a **warmer** condenser (pressure is **higher**).

## CONDENSER 2

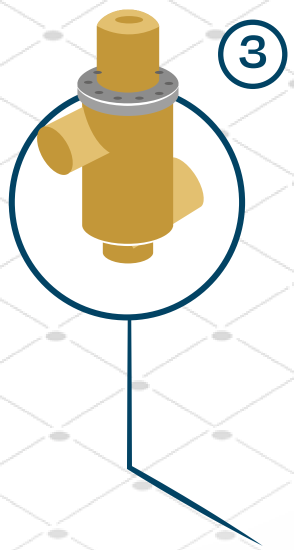


Refrigerant **rejects heat** to ambient. Most of the heat is rejected by turning from vapour to liquid at **condensing pressure**. For practical purposes condensing and compressor discharge pressure are the same. This is also commonly referred to as head pressure. Capacity depends on temperature difference to ambient, air flow and heat exchanging surface.

▼

If **ambient temperature rises** and the condenser is already at full capacity, the condensing pressure rises and with it **compressor power**.

## 3 EXPANSION VALVE

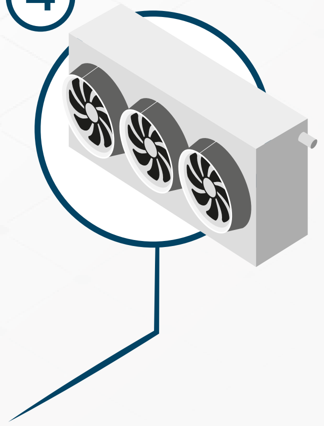


Creates a **large pressure drop** between high and low pressure side by restricting refrigerant flow. After the valve, part of the refrigerant flashes into vapour cooling the remaining liquid to lower temperature.

▼

The valve itself does not consume power, but **flash gas generation** from the valve requires **compressor power** for subsequent re-compression.

## EVAPORATOR 4



Refrigerant **absorbs heat** by evaporating from liquid to vapour at **evaporation pressure**. For practical purposes evaporation pressure and suction pressure are the same.

▼

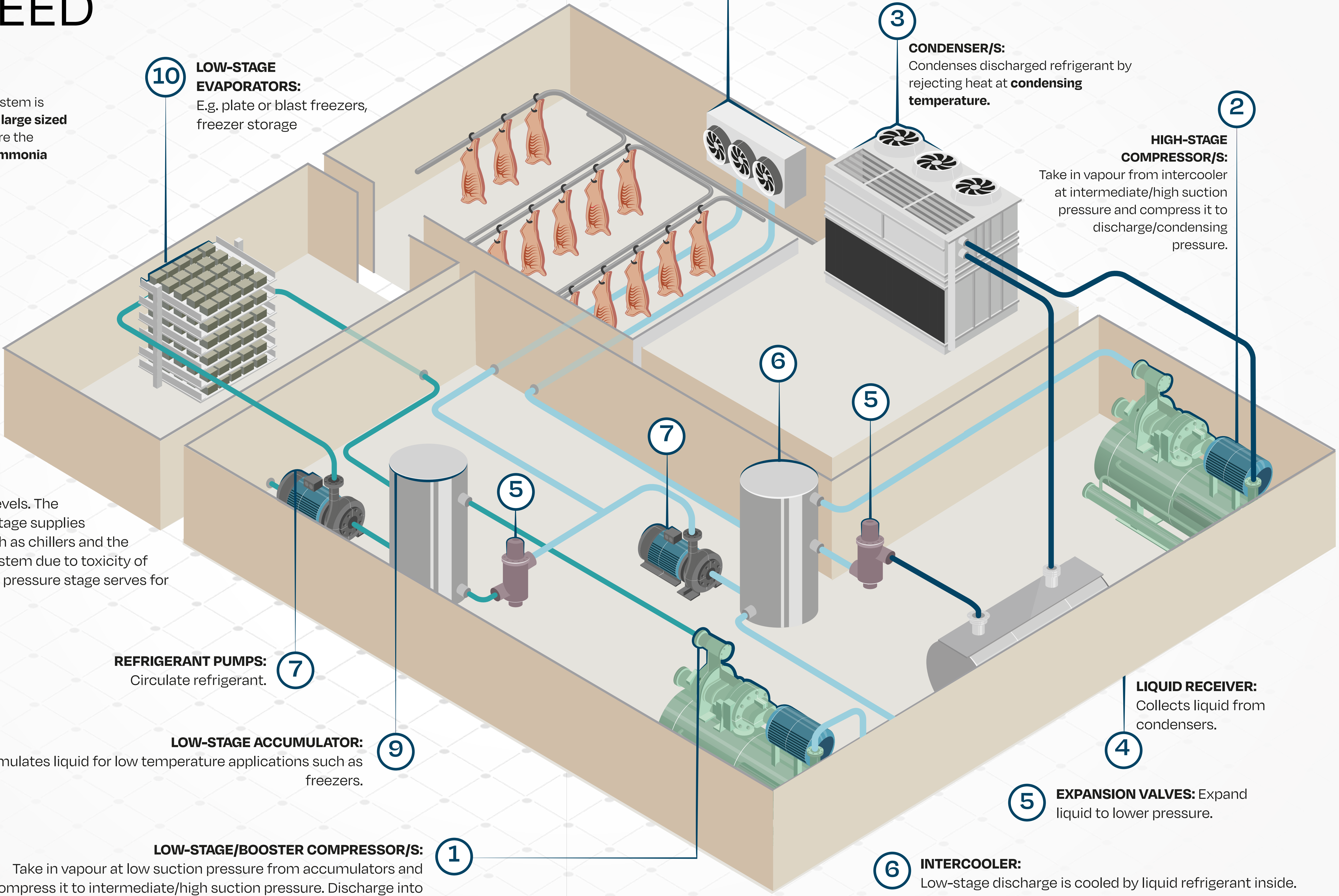
To reach **colder temperatures** evaporation pressure must be lowered, in turn **compressor power** rises.

# 2-STAGE LIQUID OVERFEED

AMMONIA PLANT

This type of refrigeration system is found in most **medium and large sized abattoirs** in Australia, and are the subject of the **"Industrial Ammonia Systems"** guidebooks.

The 2-stage system supplies cooling at two different temperature/pressure levels. The intermediate pressure stage supplies chilling applications such as chillers and the boning room (+glycol system due to toxicity of ammonia) while the low pressure stage serves for freezing.

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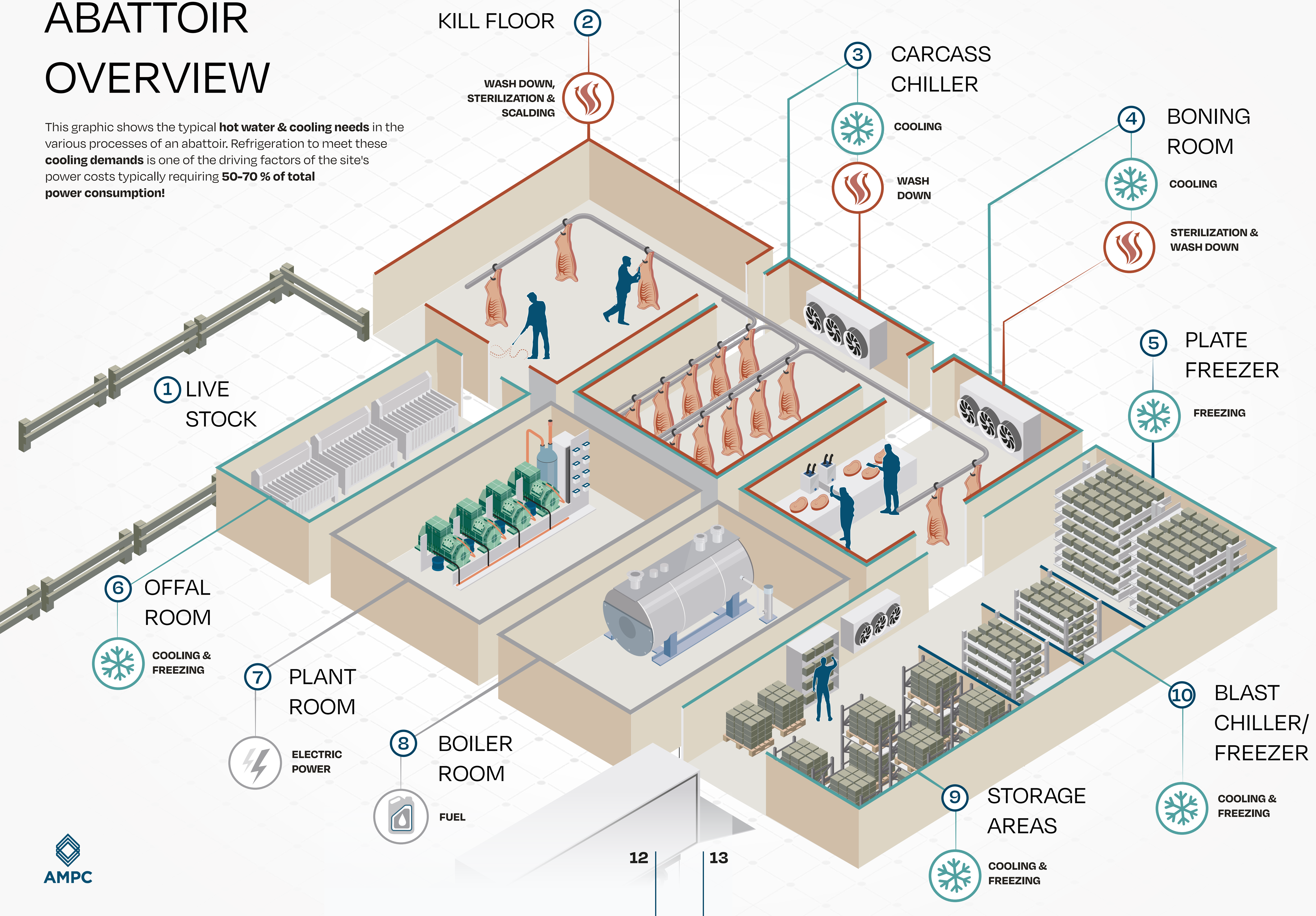
# ABATTOIR OVERVIEW

This graphic shows the typical **hot water & cooling needs** in the various processes of an abattoir. Refrigeration to meet these **cooling demands** is one of the driving factors of the site's power costs typically requiring **50-70 % of total power consumption!**

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# REFINEMENT

## BEST FOR LAST

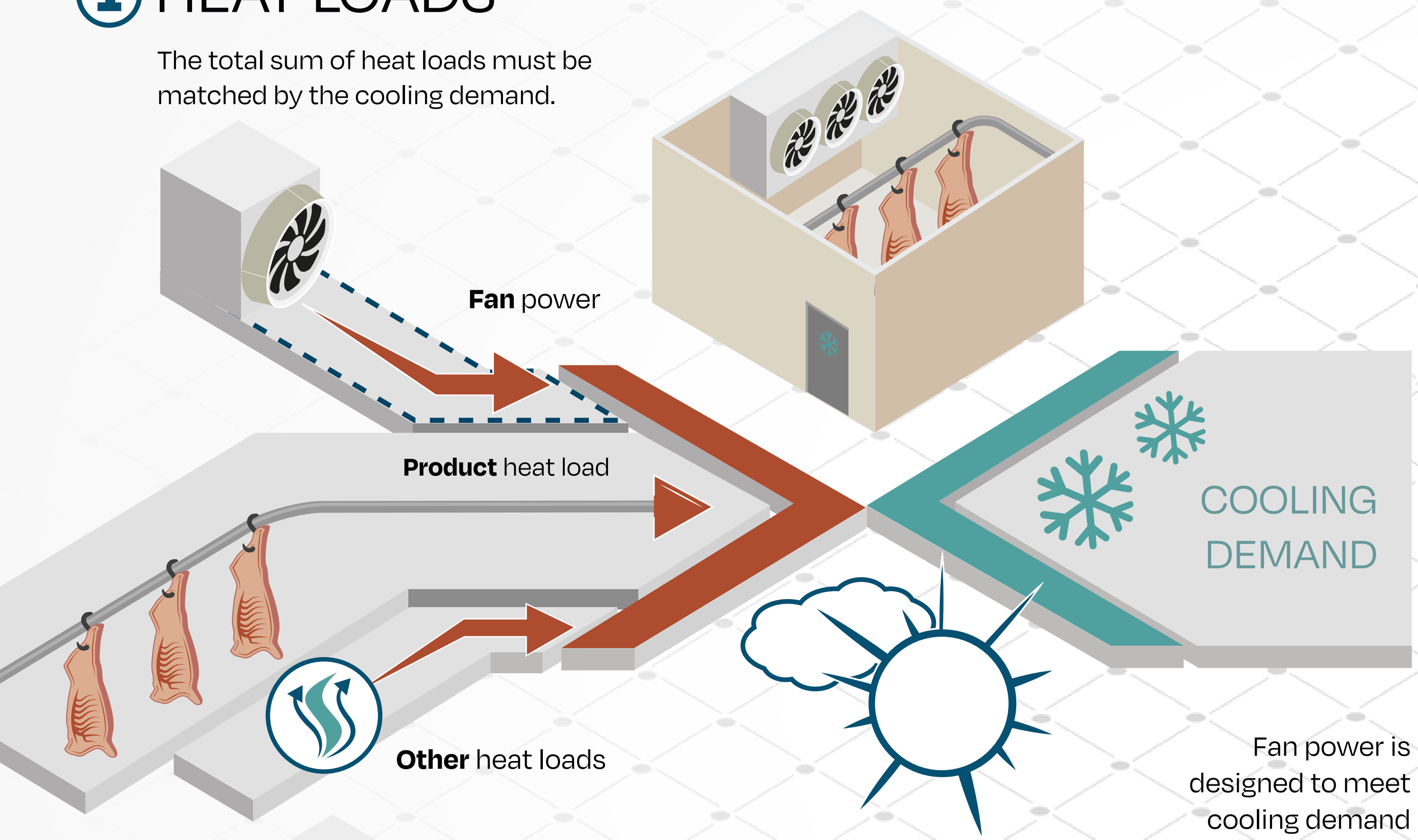
After laying out the foundation of an efficient plant with the "ESSENTIALS" and overcoming the "HARD YARDS" in Part 1, all the enablers have been unlocked to put the finishing touches onto the refrigeration plant to achieve the objective of a truly energy efficient plant.

# EVAPORATOR FAN SPEED CONTROL

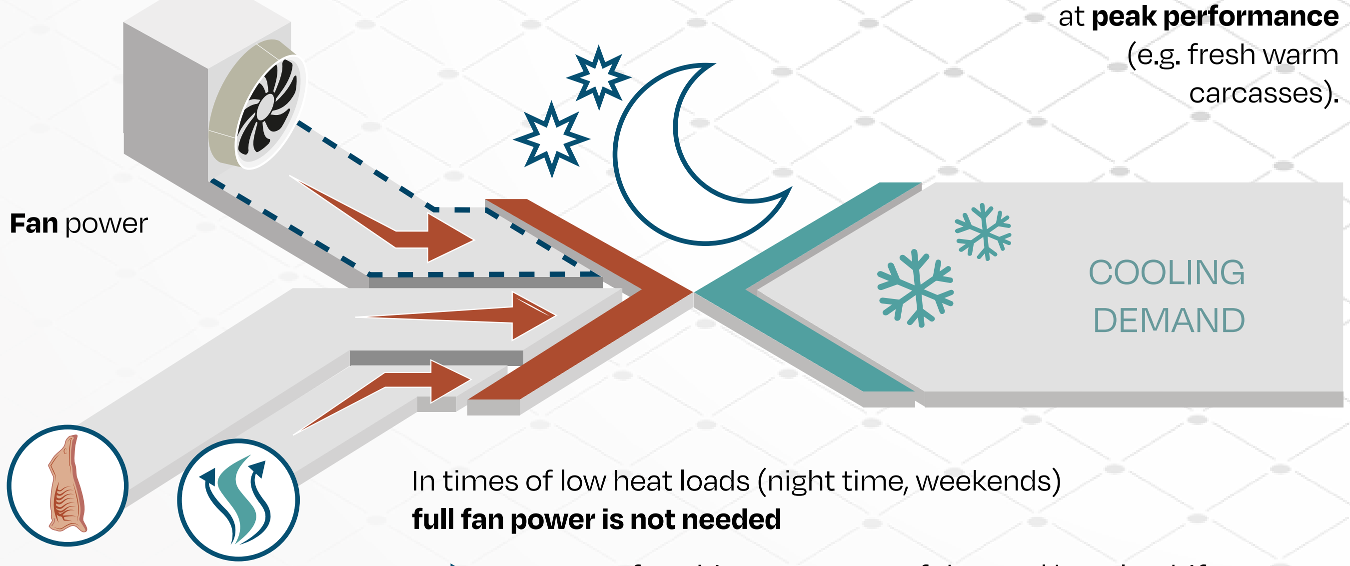
AND/OR REPLACEMENT

## 1 HEAT LOADS

The total sum of heat loads must be matched by the cooling demand.




Fan power is designed to meet cooling demand at **peak performance** (e.g. fresh warm carcasses).




In times of low heat loads (night time, weekends) **full fan power is not needed**

- Accounts for a big percentage of the total heat load, if left running at **full capacity.**
- **You pay twice.** First to **power the fans**, later to **remove fan power** by means of cooling.

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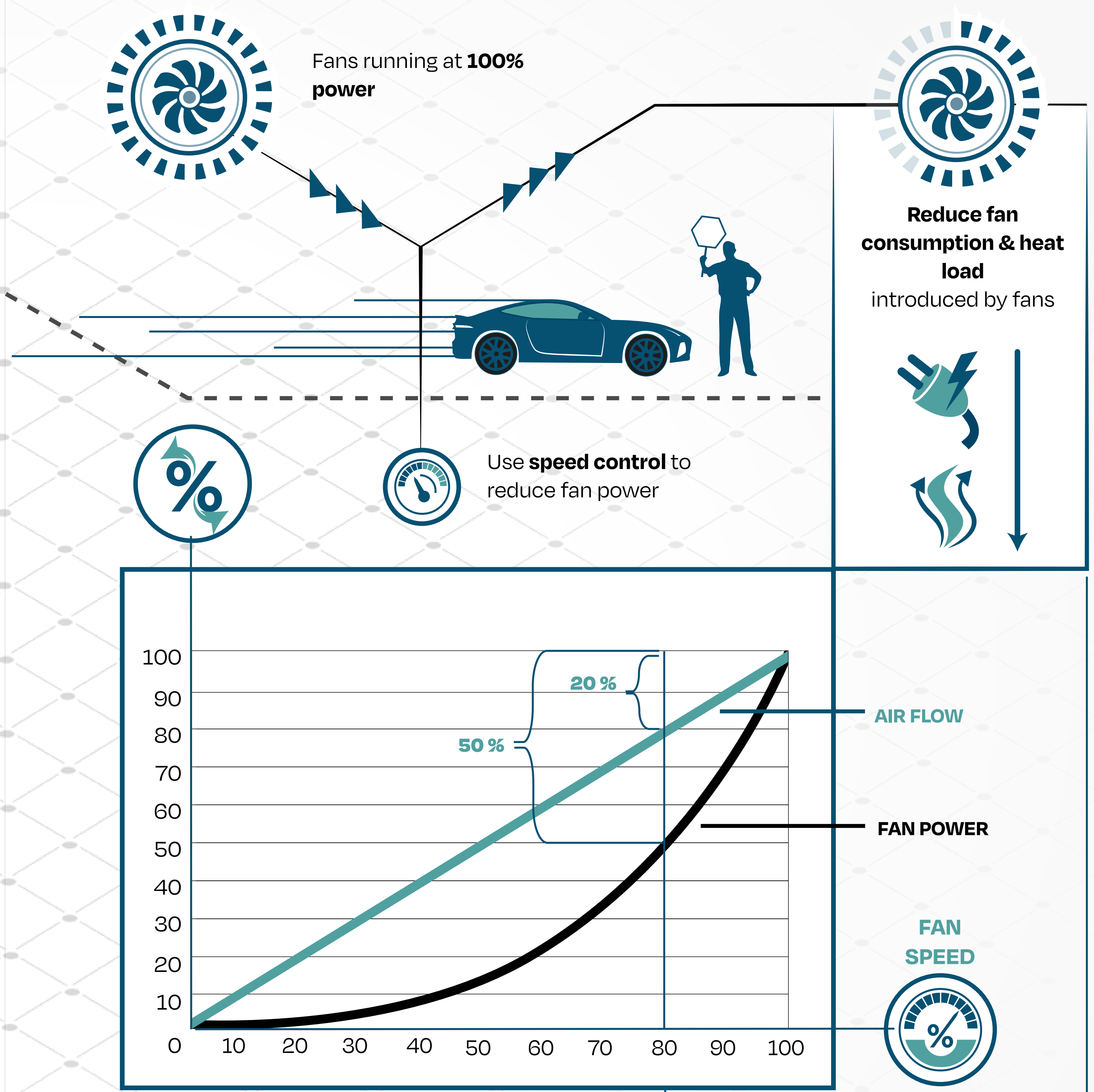
## 2 FAN SPEED CONTROL

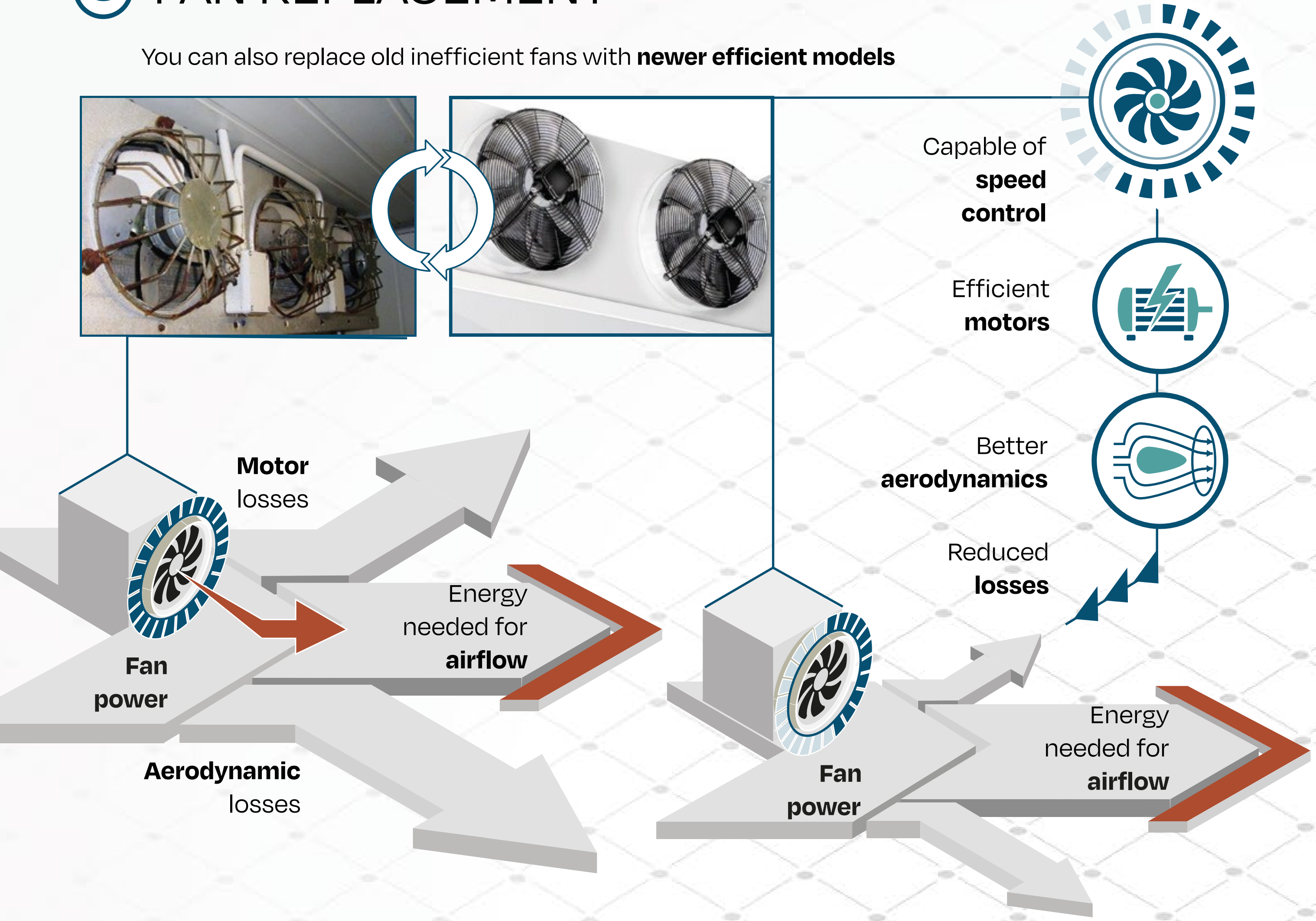



As shown by the graphs, fan power drops drastically, if air flow/speed is reduced. E.g. by reducing the air flow/fan speed by only **20 %** you can save close to **50 %** fan power.

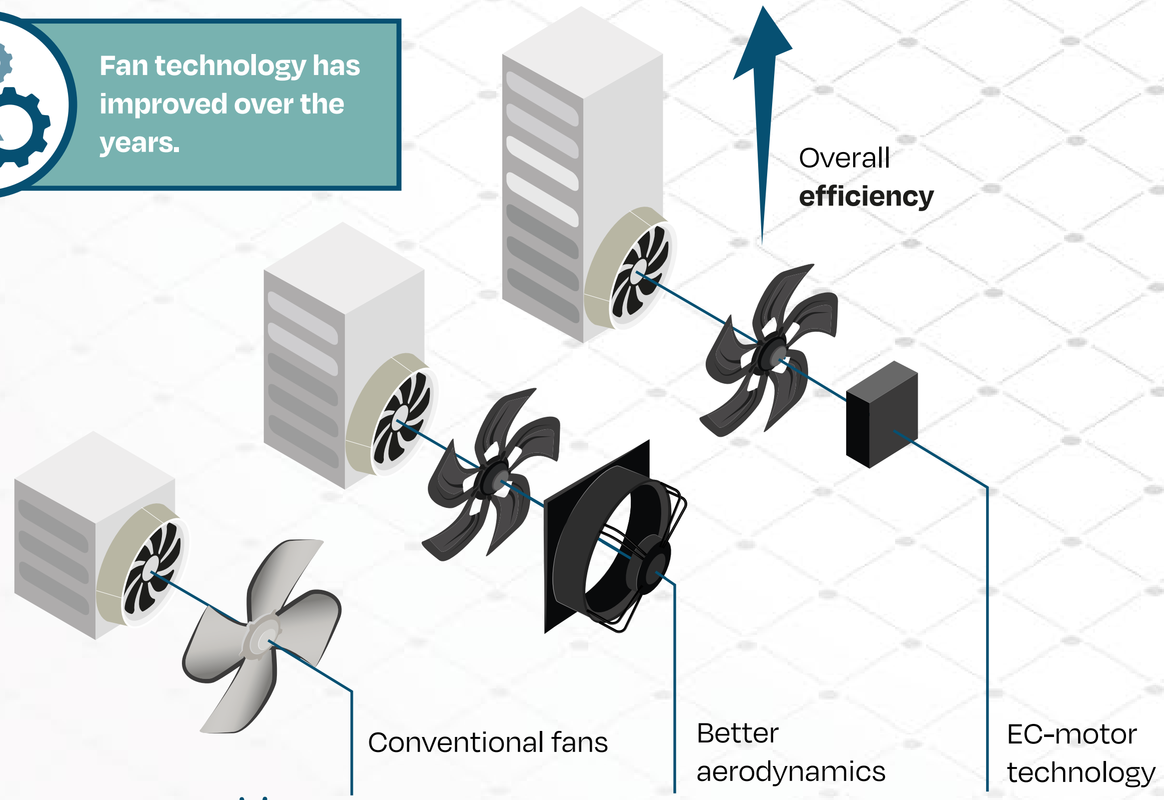
**Retrofit** existing fans with variable speed drive (VSD) or voltage speed control, or **replace** old fans with new **EC-fans** capable of speed control.

## 3 FAN REPLACEMENT

You can also replace old inefficient fans with **newer efficient models**




**Fan technology has improved over the years.**




Same as speed control, efficient fans save energy simply by consuming less power & **reducing the heat load** introduced into the cool rooms.

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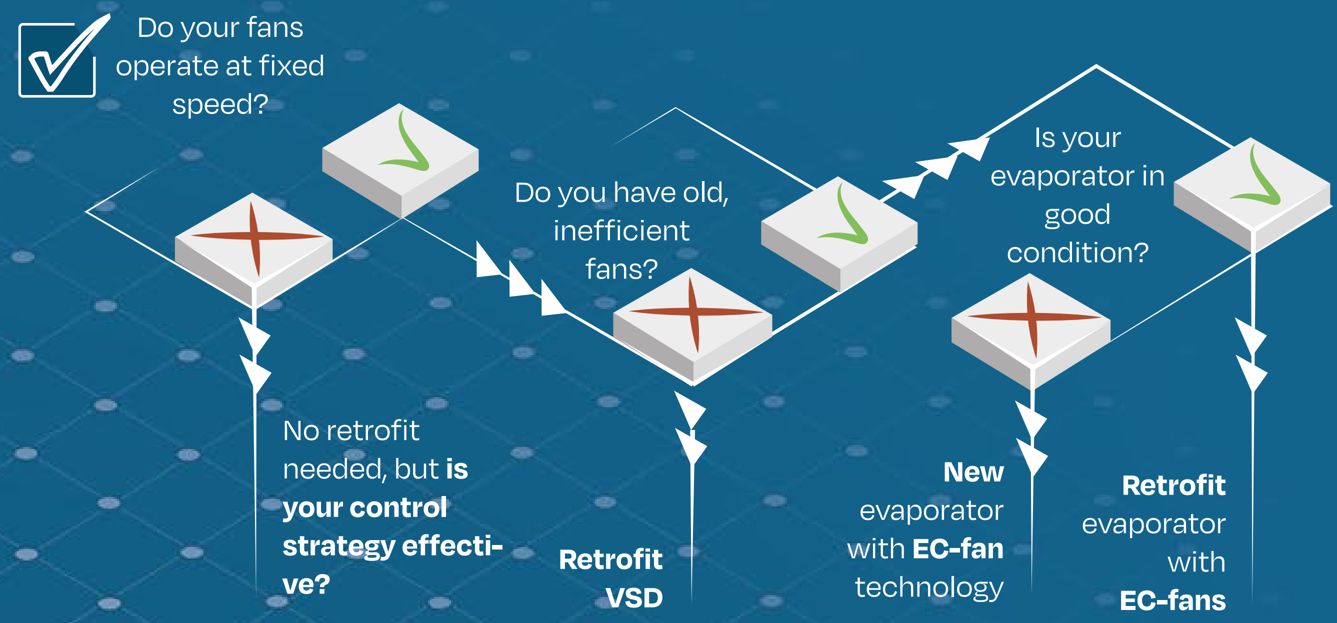
## 4 DOES THIS WORK FOR ME?



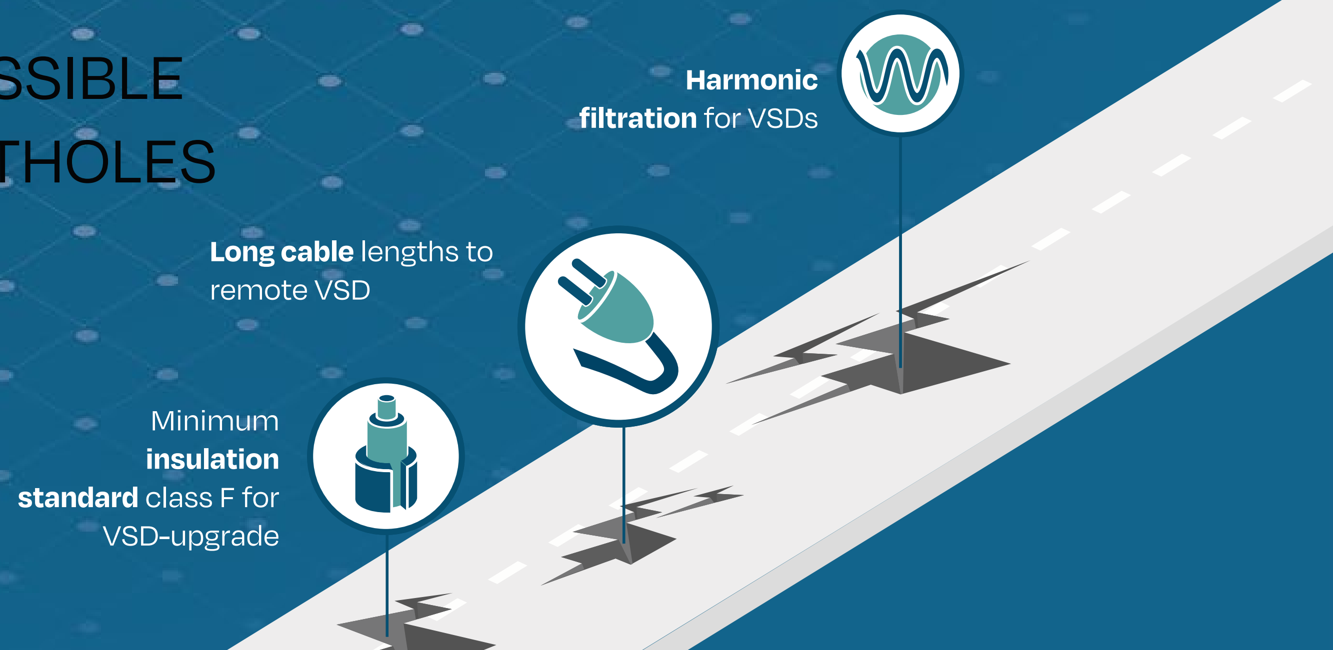

## 5 SYNERGIES

This EEO best follows after **"Plant Stabilisation" & "Compressor Staging & Speed Control"**, because it saves energy at **part-load**. If your plant does **not unload efficiently**, savings from heat load reduction do **not translate well** into compressor savings. However, pure reduction of fan power which accounts for roughly 75 % of savings does not need any enablers.

## GOOD TO KNOW 6

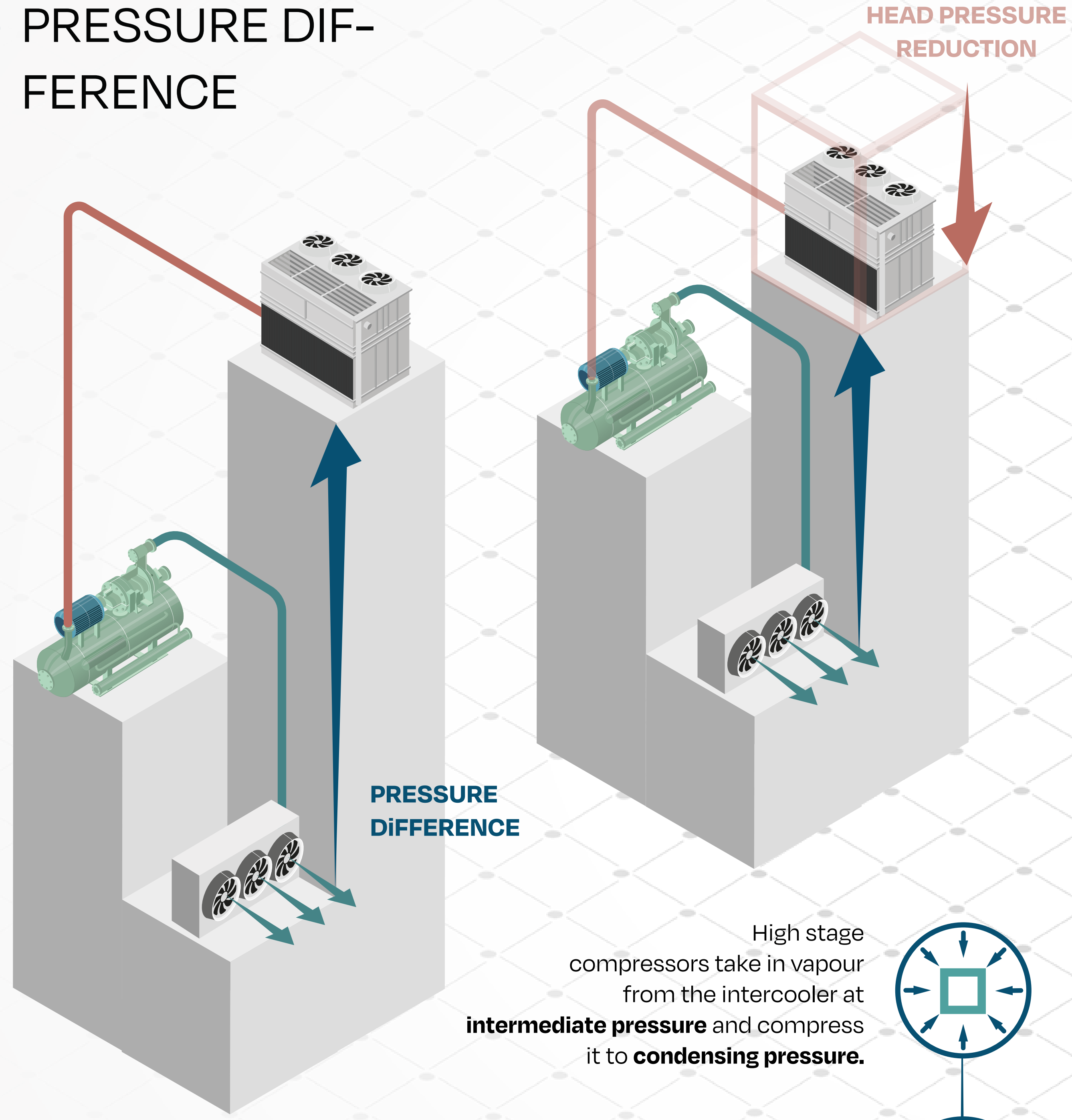
- **Consult VSD supplier** to match VSDs to existing fan motors.
- Consider installing **door switches** for control logic input.
- Hardware capable of speed control is not a guarantee for energy savings! You must have **smart control strategy** to achieve this.

## 7 POSSIBLE POTHOLES



# VARIABLE HEAD PRESSURE CONTROL

## ① PRESSURE DIF- FERENCE




High stage compressors take in vapour from the intercooler at **intermediate pressure** and compress it to **condensing pressure.**

**Condensing pressure** depends on **ambient wet-bulb temperature and condenser fan operation.** The latter is used to actively control condensing pressure, see **Condenser Fan Speed Control in Part 1.**

If **condensing pressure is high**, so is the **pressure difference** which must be overcome by the compressors. Also, **cooling capacity** is reduced!

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The compressor discharge, also commonly referred to as **head pressure**, is driven by the condensing pressure, reducing the latter also results in a head pressure reduction.

2-3 %

Refrigeration requires **2-3 % more energy per Kelvin** increase in condensing temperature. E.g. dropping condensing temperature from 30 °C to 20 °C (= 10 K) would result in a 20-30 % energy saving for the entire high stage!

Condensing/head pressure should be **as low as possible** to save energy.

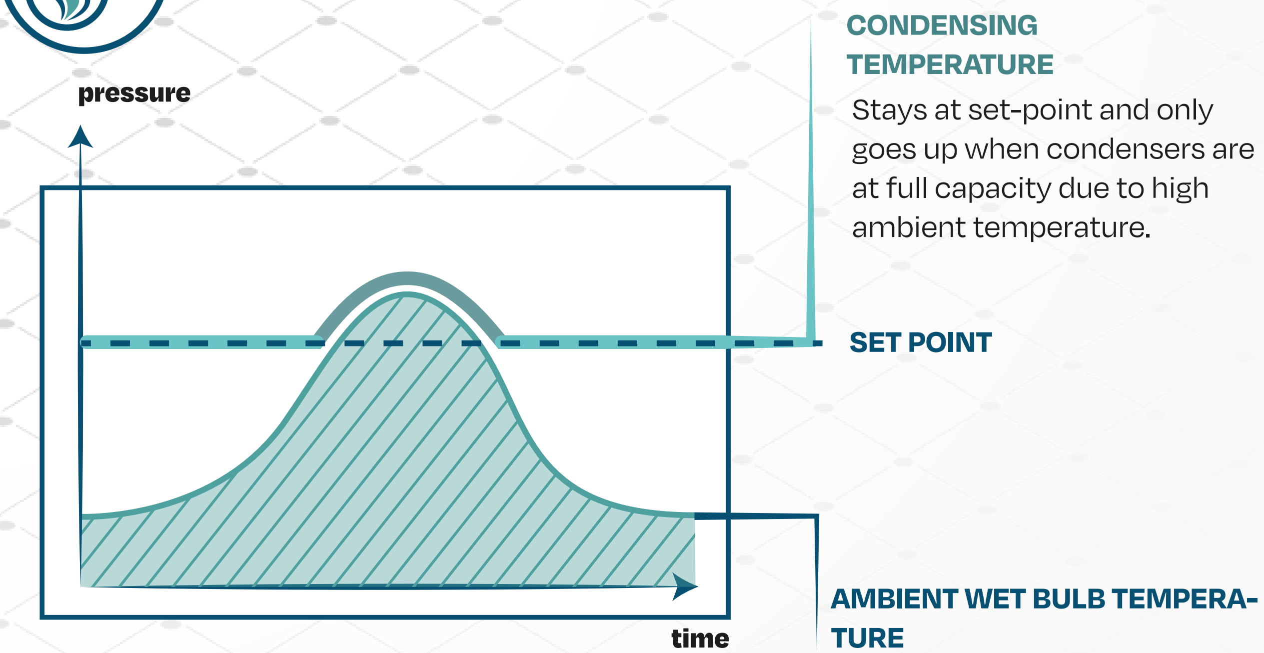
## ② STANDARD PRACTICE

Usually, head pressure is maintained at a set **fixed** level.

Maintaining a set point pressure is easier from a control perspective and requires very **few sensor inputs** for the controller.

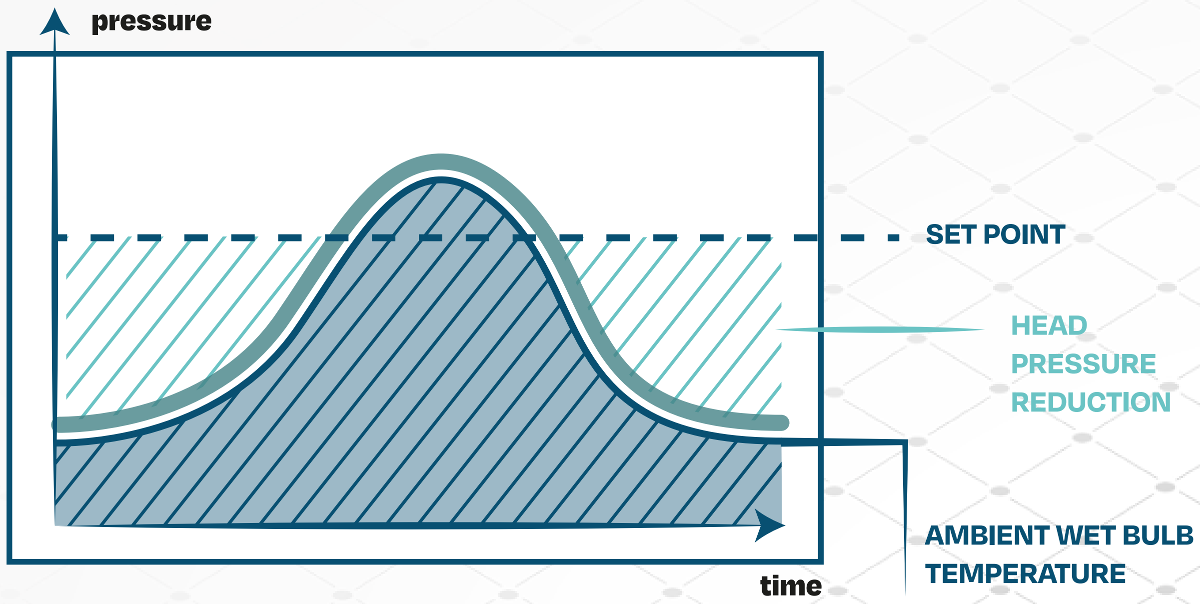
In addition, head pressure is commonly maintained at a certain **minimum** level for **hot gas defrost/carcass reheat.**

Prior implementation of a **dedicated hot gas compressor** can solve this problem.




**Lower ambient temperatures have no positive effect on head presN sure & compressor power consumption.**

## ③ VARIABLE HEAD PRESSURE CONTROL




Instead of maintaining a constant head pressure, it is varied in accordance with ambient wet-bulb temperature and other inputs such as total plant load.

Requires installation of ambient wet-bulb sensor and its implementation into the control & monitoring system.

This means fans run faster to drop condensing pressure and save compressor energy in turn.

→ Efficient condensers and plenty of condenser capacity benefit VHPC by reducing energy penalty from higher fan use.

## DOES THIS WORK FOR ME? ④

Variable Head Pressure Control is beneficial for all ammonia plants with liquid overfeed. Sometimes you might hear about reservations why it cannot work for some sites, but this is probably due to other underlying issues that just need to be resolved!

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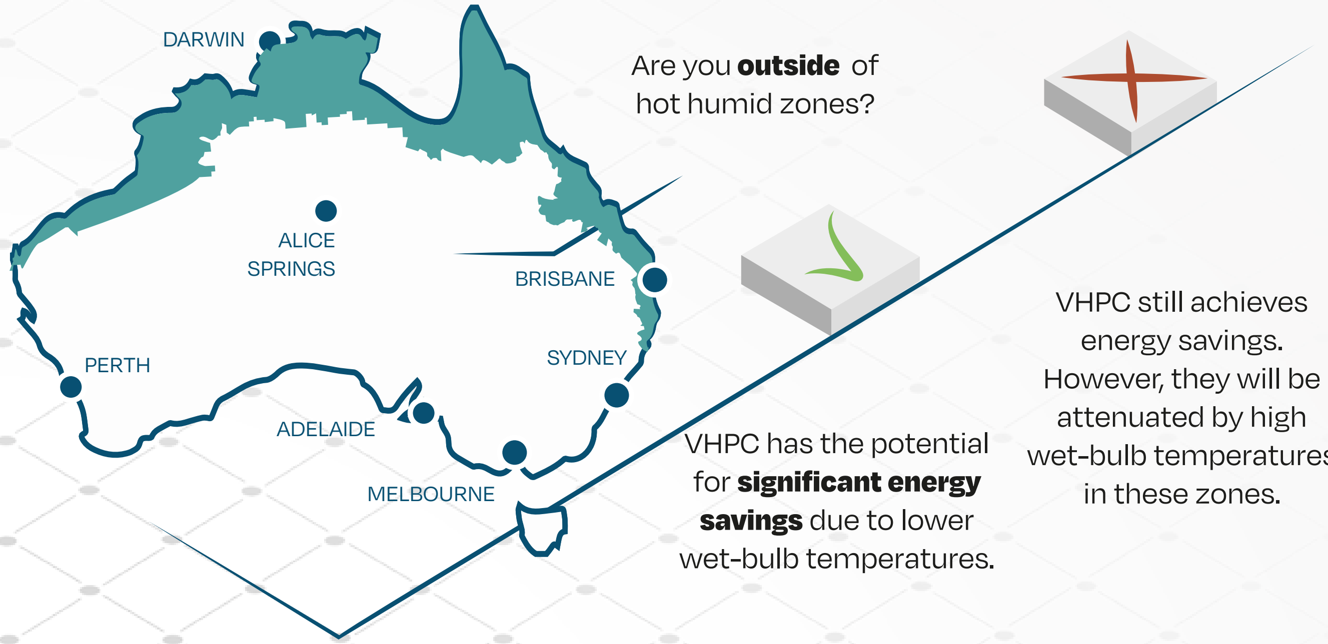


Are you **outside** of hot humid zones?

VHPC has the potential for **significant energy savings** due to lower wet-bulb temperatures.

VHPC still achieves energy savings. However, they will be attenuated by high wet-bulb temperatures in these zones.

### RESERVATIONS

**Head pressure cannot be dropped, because •••**

••• Hot gas at high pressure is needed for the hot gas defrost

→ Have a **designated hot gas compressor** for defrost. all other compressors can run at lower head pressure.

••• I tried it once and lost all the oil!

→ **Oil separators are undersized** and lose the oil due to **higher hot gas velocities** at lower head pressure. Install bigger separators!

••• There is not enough liquid coming through the liquid lines due to reduced pressure!

→ The liquid lines or their valves are **undersized** and create pressure losses. Typical bottle neck that needs to be removed

These potholes might not be obvious from the start. If you put variable head pressure into operation, lower pressure gradually and observe your plant. This way e.g. you do not lose all oil in case there is a problem with oil separators.

# 5 SYNERGIES

**Enables:**

- **Control & Monitoring Upgrade** (addition of wet-bulb temperature sensor) – This control strategy requires more sensor inputs and a control system/PLC that can handle more complex control logic and is easy to program.
- **Plant Stabilisation** – to be able to maintain condensing pressure at calculated set point, the plant must run stably.
- **Condenser Fan Speed Control** – is needed to precisely manage condensing pressure and lessen impact of additional condenser fan power demand.
- **Air and Water Removal** – Removing accumulating air from condensers maintains their capacity which is needed to drop condensing pressure.
- **Compressor Block Replacement** –If you replace or add a compressor, make sure it is capable of variable volume ratio which greatly benefits VHPC.
- **Dedicated Hot Gas Compressor** – enables you to drop the head pressure across all other compressors even when hot gas is needed!
- **Bottle Neck Removal** (undersized condenser, undersized liquid lines & valves, redundant valves) – Undersized condenser capacity will make it difficult to drop head pressure. Undersized liquid lines might give you troubles due to lower condensing pressure and hence liquid pressure. Another bottle neck that is specific to VHPC would be an undersized oil separator, which might not be able to handle higher gas velocities and lose the oil.
- **Condenser Upgrade** – As aforementioned, efficient condensers benefit VHPC by reducing fan power penalty.

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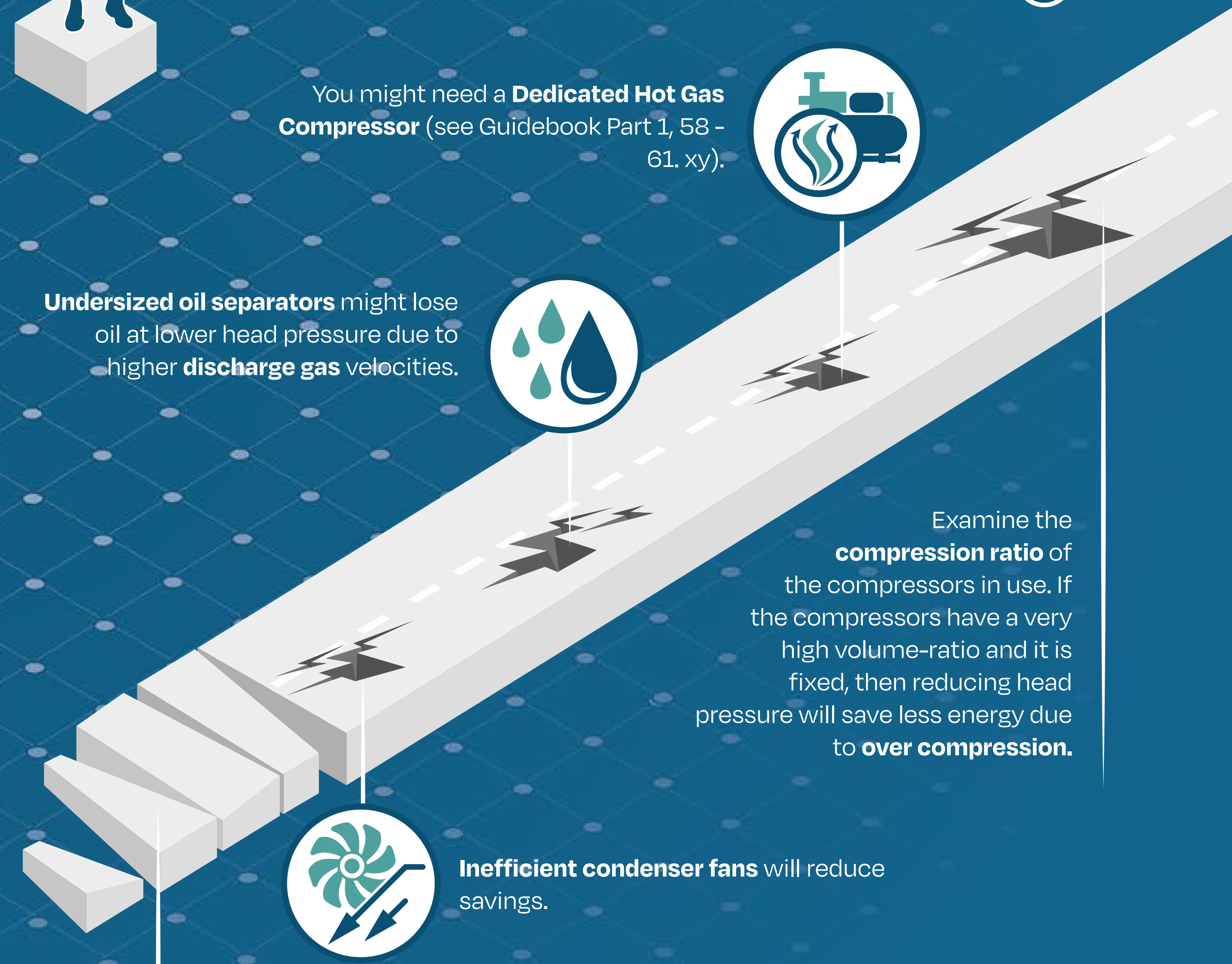
# 6 GOOD TO KNOW

- VHPC is even more effective, if you have compressors with **variable volume ratio!**
- You can implement your **own control logic** for VHPC. There are also ready-made optimiser units with internal control logic available on the market. Check out the How-To Manual for more!

## POSSIBLE POTHOLES 7



You might need a **Dedicated Hot Gas Compressor** (see Guidebook Part 1, 58 - 61. xy).

**Undersized oil separators** might lose oil at lower head pressure due to higher **discharge gas** velocities.

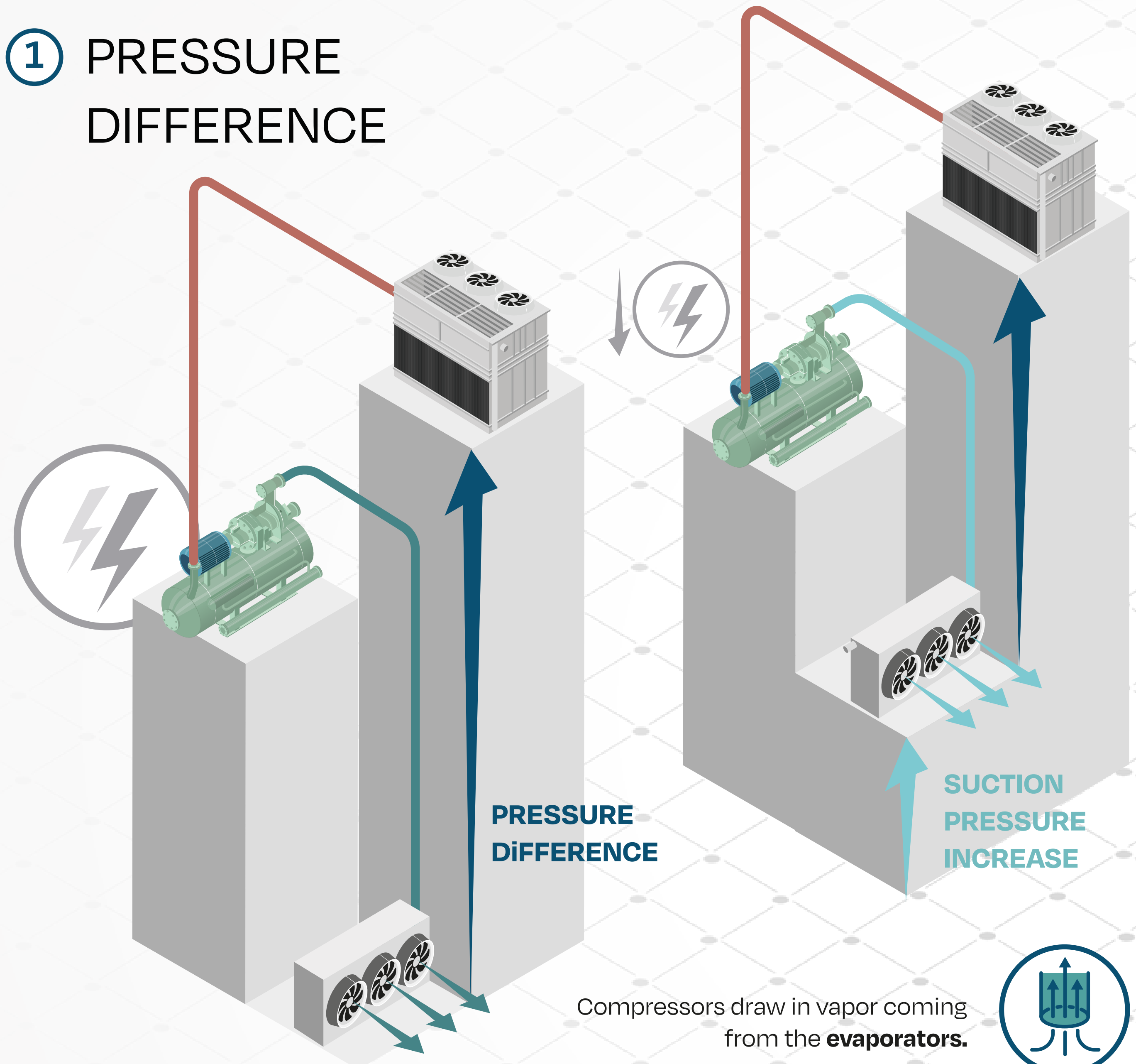
Examine the **compression ratio** of the compressors in use. If the compressors have a very high volume-ratio and it is fixed, then reducing head pressure will save less energy due to **over compression.**

**Inefficient condenser fans** will reduce savings.

VHPC will almost always save electrical energy but will also reduce potential heat recovery (see pg. 48 - 51) or use of an integrated heat pump (see pg. 52 - 55) during cooler weather. Depending on your heating costs, it may be economical to limit variable head pressure, **if you rely on heat recovery** – this needs analysis.

# SUCTION PRESSURE OPTIMISATION

## 1 PRESSURE DIFFERENCE




Compressors draw in vapor coming from the **evaporators.**

Suction pressure is set so that **evaporation temperature** in evaporators is **low enough to achieve cooling needs.**

The **lower the suction pressure, the bigger the pressure difference** to overcome and the more energy is needed.

Cooling requires **2-3 % more energy per Kelvin** drop in evaporation temperature. E.g. raising low stage suction pressure from -40 °C to -35 °C (= 5 K) would result in a 10-15 % energy saving for the entire low stage!

2-3 %

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Suction pressure should be **as low as necessary** to meet production, **but as high as possible** for energy efficiency.

## 2 PRODUCTION OPTIMISATION


Are room temperatures still being maintained?

If freezing/chilling times have gone up, can they be any longer?

The slimmed down process to optimise suction pressures is depicted here. For more detail refer to the **How-To Manual.**

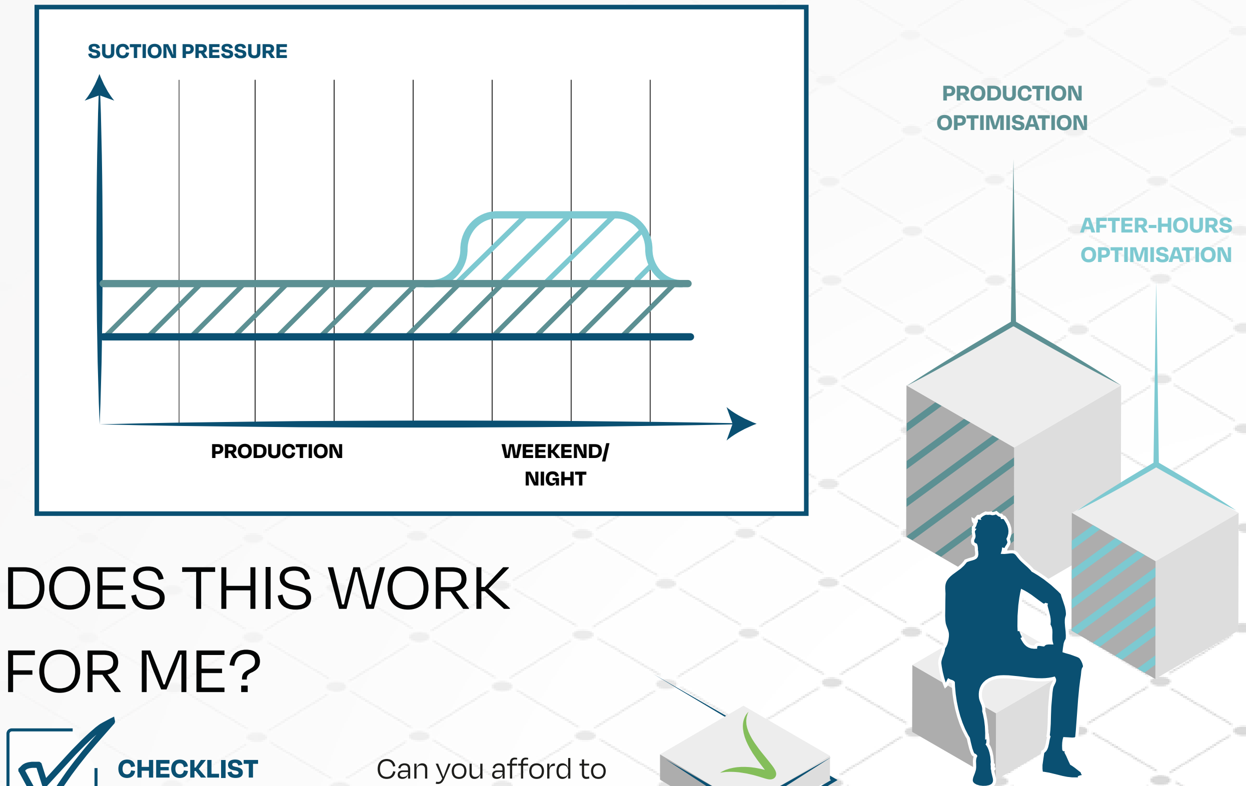
HOW-TO MANUAL

Try to run **close to** the suction pressure **limits dictated by production**, leaving a small buffer. Do not choose arbitrary pressure set points.

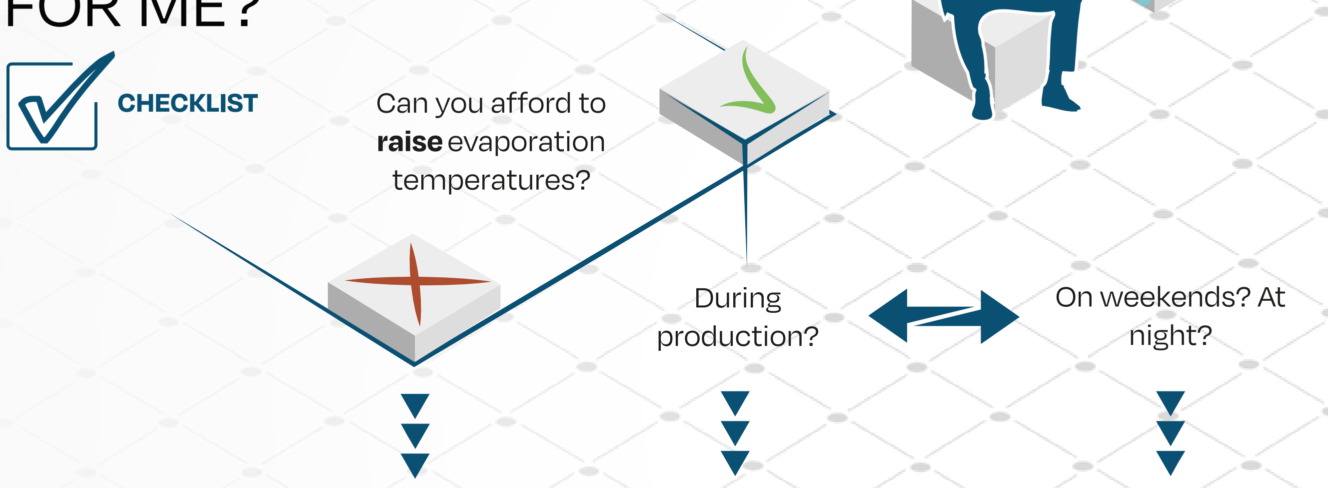
## 3 AFTER-HOURS OPTIMISATION

During production you need to **achieve certain cool-down times.** Your suction pressures will be set to achieve those.

These conditions do not apply to the **weekend/holidays** or maybe even late in the night, when product end temperatures have been reached and must only be held.




## 4 DOES THIS WORK FOR ME?




## 5 SYNERGIES

**Follows:**

**Control & Monitoring Upgrade** – Implement different control strategies for production and after-hours. Closely monitor your plant and the aftermath of a suction pressure increase during the optimisation process

**Plant Stabilisation + Compressor Speed Control & Staging** - It is difficult to optimise suction pressures, if they fluctuate heavily. Stable suction pressure and efficient part-load operation lay the foundation for optimisations like this to build on.

**Air & Water Removal** – Water content increases evaporation temperature at constant pressure. So, it requires suction pressure to be dropped. By removing the water, suction pressure can be restored back to normal.

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**Bottle Neck Removal** – Potential bottle necks you might encounter when trying to raise suction pressure:

- **Undersized compressor motors**
  - → increasing **intermediate** suction results in bigger pressure difference on booster compressors and might overwhelm motors.
- **Undersized evaporators**
  - → require lower evaporation temperature/pressure to meet cooling demand.
- **Poorly designed wet suction risers, undersized suction lines & valves, redundant valves**
  - → create pressure drop that must be accommodated by lower suction pressure.

## 6 GOOD TO KNOW

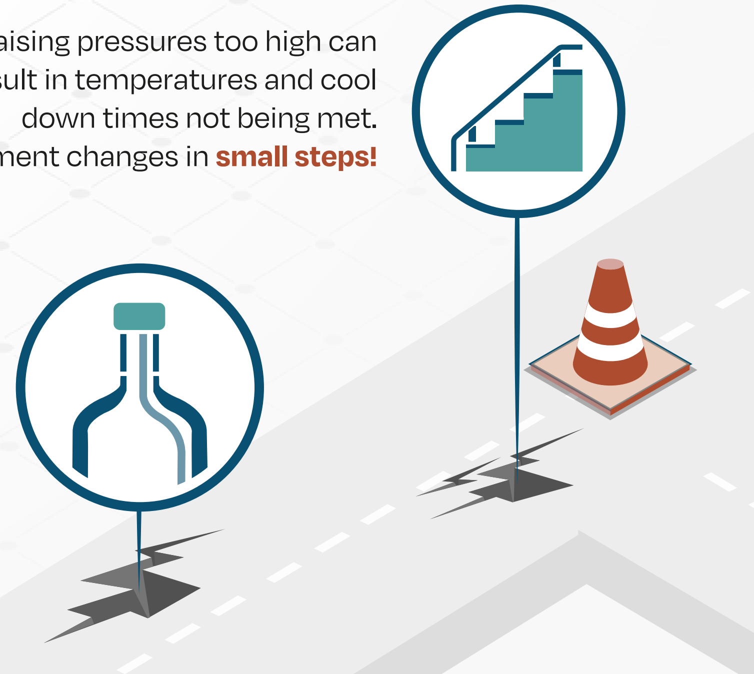
- Higher suction pressures also increase compressor **capacity.**
- Try raising **both**, low stage and high stage suction pressures.
- Production and plant operation **change** over time, sometimes in our favour. Maybe you do not require the same low evaporation temperatures as you did a year ago and could afford to raise them.
  - → Revisit pressure settings regularly.
- Lowering suction pressure is often a **band-aid fix** to an underlying issue. One that comes with a **hefty energy penalty**. Avoid band-aid fixes and make sure suction pressure levels are restored to normal after band-aid has been removed. This might also be the reason suction pressures are too low in the first place. They were dropped at one point and never restored to normal.

## 7 POSSIBLE POTHOLES

Raising pressures too high can result in temperatures and cool down times not being met. Implement changes in **small steps!**

**Bottle necks** will keep you from raising suction pressures.

See Bottle Neck Removal in Part 1



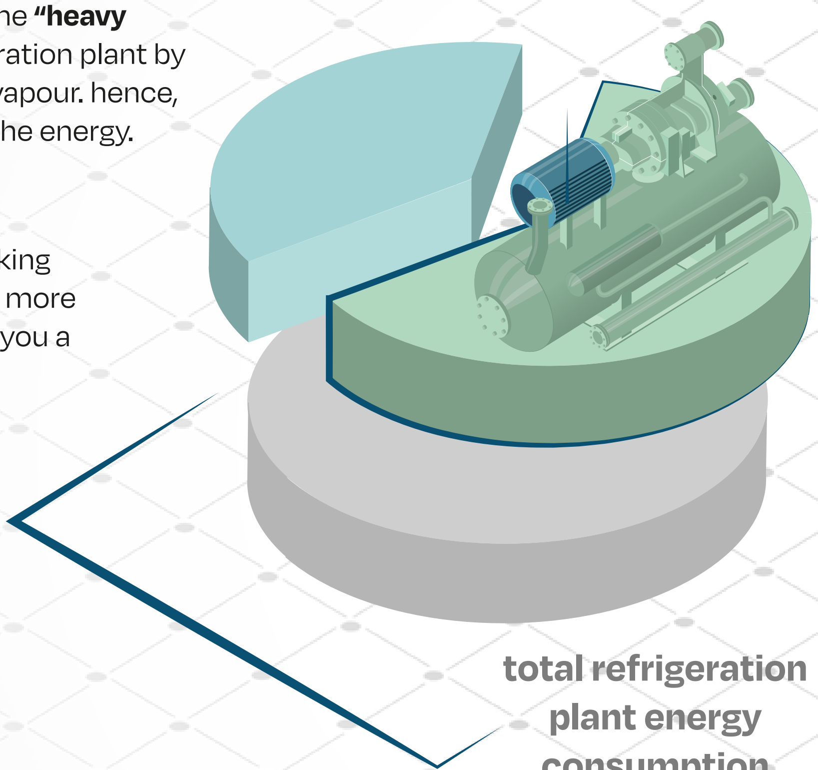
# EFFICIENT COMPRESSOR MOTORS

## ① OPEN SCREW COMPRESSORS

Industrial refrigerant utilises open screw compressor blocks that are driven by an **external motor.**

Compressors do the **"heavy lifting"** in a refrigeration plant by compressing the vapour. hence, they use most of the energy.

Consequently, making your compressors more efficient can save you a lot of money.

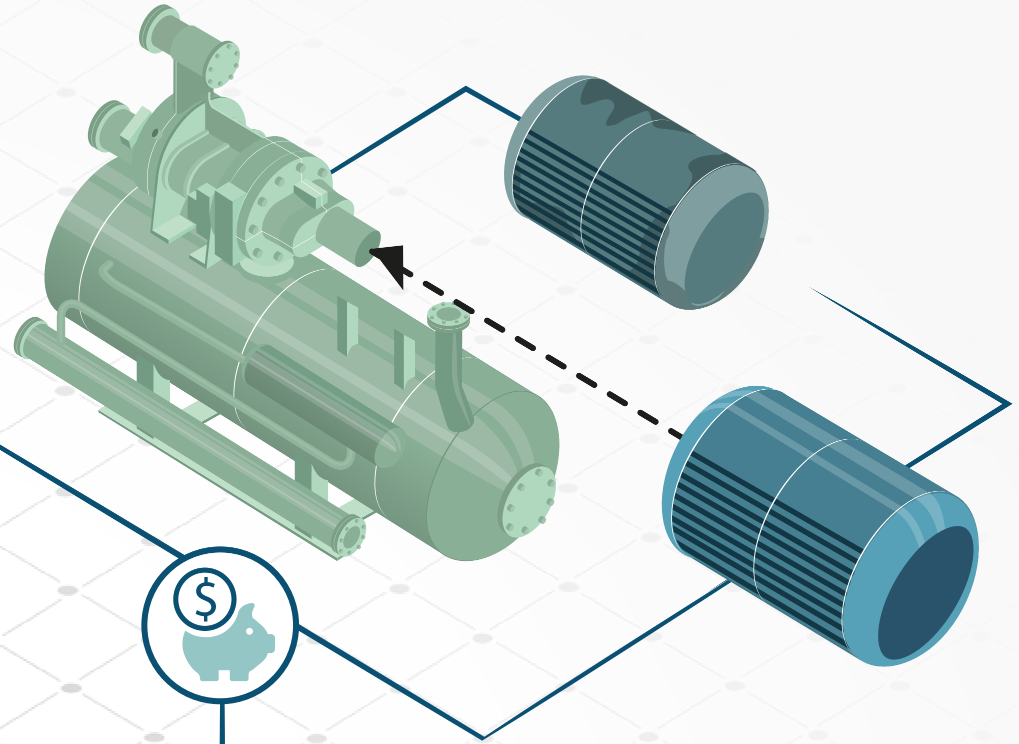



## ② MOTOR REPLACEMENT

All energy needed for compression is converted from electric energy by the motors. This conversion comes with losses.

→ motor efficiency

Less electricity is needed, the more efficient motors are.



Old and especially refurbished motors might not have the same **efficiency** as new models.

Every motor-efficiency percentage point translates well into energy savings.

"Replace old, inefficient motors with new **high-efficiency** models on compressors which take on the **heaviest workloads** in the plant. Also, make sure to invest into highly efficient motors when **purchasing a new compressor** unit."

- Instead of replacing motors, operators often decide to refurbish burned out motors, thinking they are saving a bit of money.
- What is done to "refurbish" these motors? **How confident are you that efficiency has been reinstated?** Losing even a few percentage points on efficiency would be devastating.
- If, in comparison to a motor replacement, operational costs from higher energy use are considered, this might be **a bad investment!**

**Consider operational costs when deciding between replacement vs. refurbishment.**

## ③ DOES THIS WORK FOR ME?

### EFFICIENT MOTORS

| | |
|---|---|
| Hard to tell motor's efficiency? | Do some research regarding the motor model. |
| Have the motor's copper windings been rewound after a burn-out? | Refurbished motors might not have the same efficiency as before. |

## ④ SYNERGIES

**Follows:**

- **Compressor Speed Control & Staging** – Staging strategy determines which compressors run most of the time.

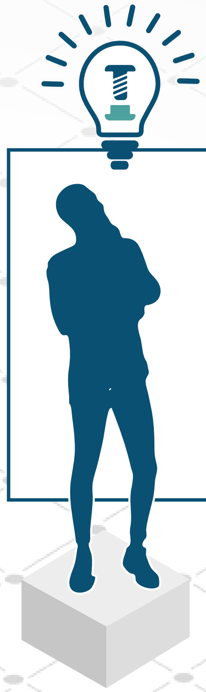
  → Lead compressors should be equipped with highly efficient motors!

  An investment into a VSD for speed control could go hand in hand with a suitable motor replacement.

- **Suction Flow Meters + Compressor Block Replacement** – will help you determine which compressors are most efficient and should therefore run the most. Again, these should be fitted with high-efficiency motors. This also applies to new compressor unit acquisitions.

- **Bottle Neck Removal (Undersized Compressor Motor)** – If you are already incentivised to replace an undersized motor, do so with a highly efficient model.

## ⑤ GOOD TO KNOW

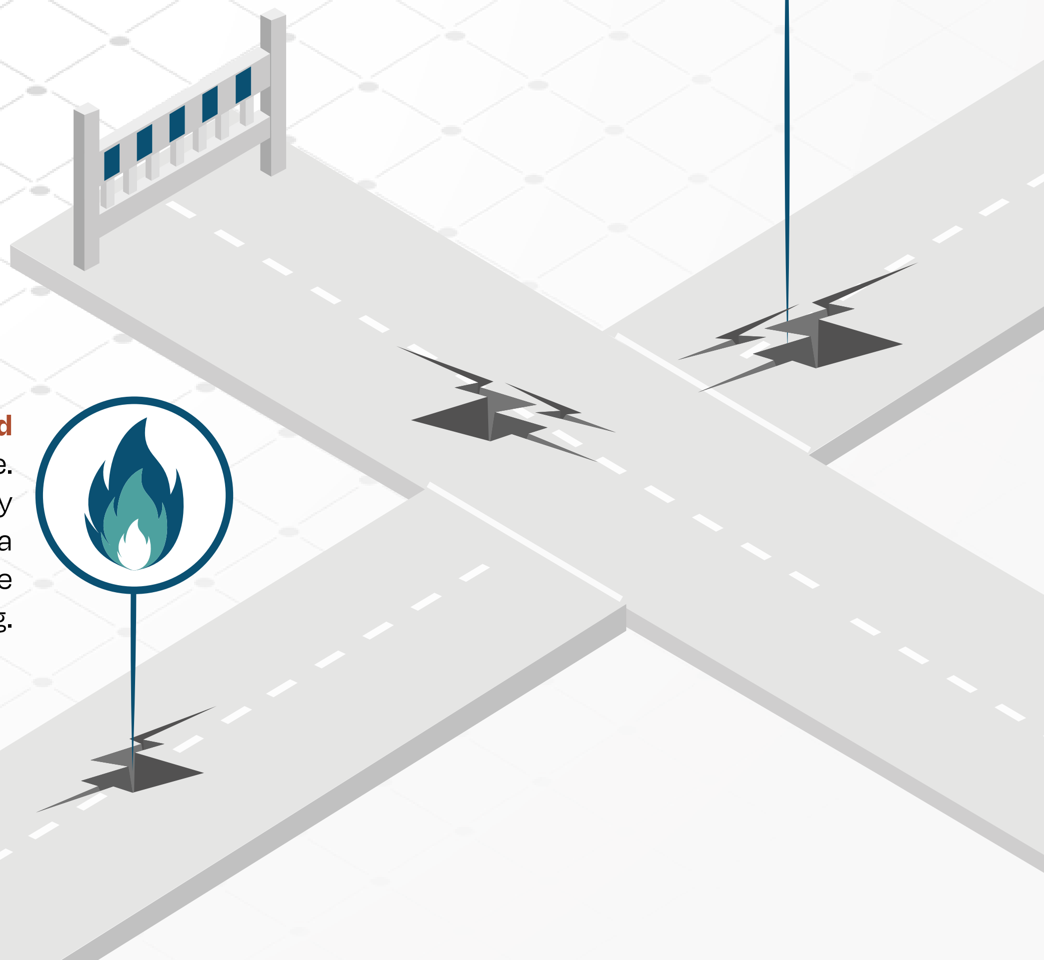


- When purchasing a new compressor unit including the motor, make the **little extra investment** into a highly efficient motor. The difference in price is small compared to **life-time costs** of inefficient motors.

## POSSIBLE POTHOLES ⑥

Replacing motors on compressors that **barely ever run**, will give you bad returns.

Make sure **motors and VSDs** are compatible. Burning out a newly acquired motor with a faulty VSD would be maddening.



# DEFROST DRAIN

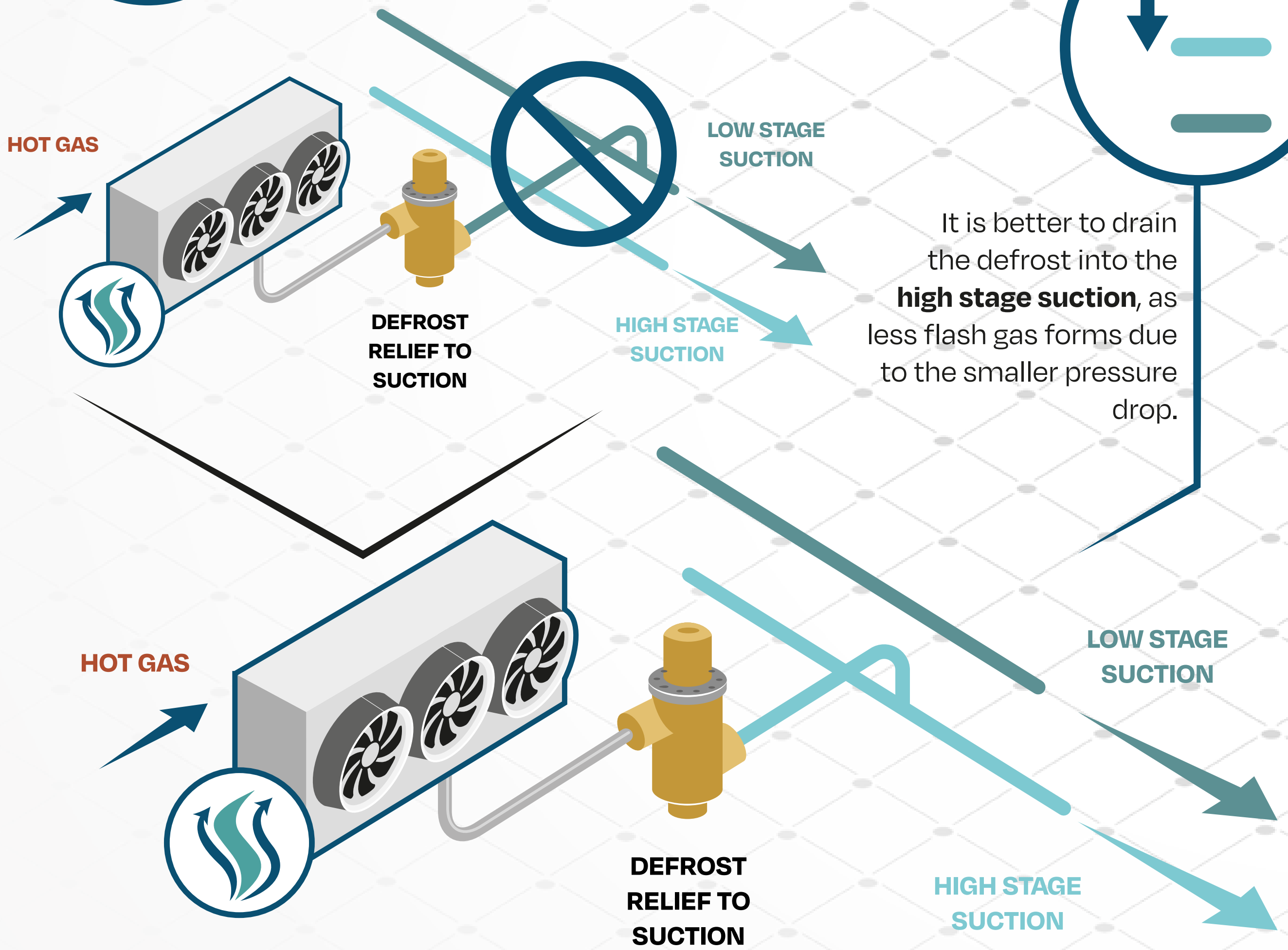
## INTO HIGH STAGE SUCTION

## 1 DEFROST DRAIN

During defrost hot gas releases its heat by **condensing** inside the evaporator, melting the ice.

The condensed liquid is then **drained back into the suction line.**

Even though it does not make sense from an energy efficiency perspective, often **low stage evaporators drain into the low stage suction.**




It is better to drain the defrost into the **high stage suction**, as less flash gas forms due to the smaller pressure drop.

"If not already the case, rework evaporator piping so that defrosts drain into the high stage suction. Often there is a high stage suction very close by but drains go into the low stage due to lack of awareness."

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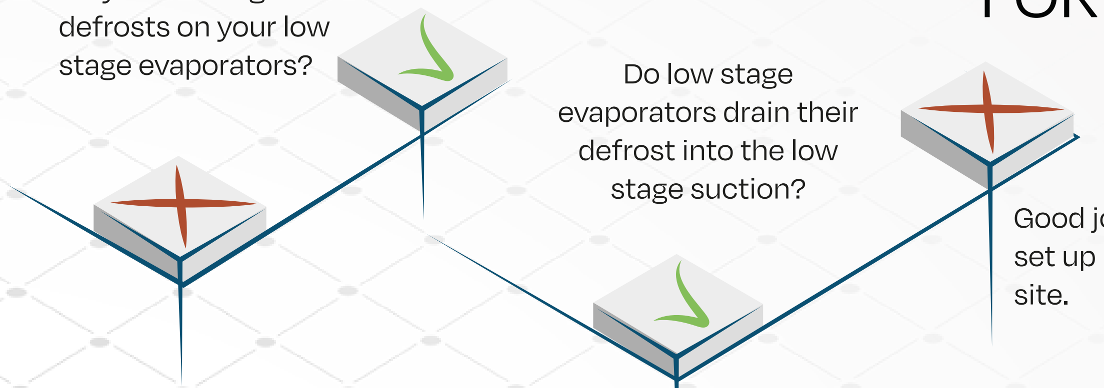
## DOES THIS WORK 2 FOR ME?




## 3 SYNERGIES

**Enablers:**

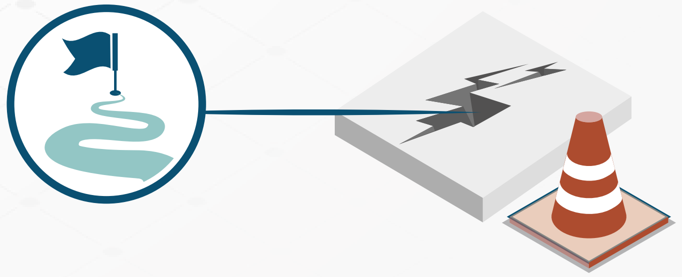
Defrosts have a negative impact on **Plant Stabilization.** Defrosts put a sudden flash gas load (pressure fluctuation) on the system the moment they start draining. This forces compressors to respond. Draining into the low stage creates more flash gas that could be avoided. Hence, draining into the high stage, creates a smaller load spike on high stage compressors and completely bypasses the **low stage compressors.**

## 4 GOOD TO KNOW

- Do the **low stage compressors load up whenever you do a defrost?**
  → Sure sign of low stage defrost draining!
- This works for **both** float drain and blow-through defrost techniques.
- This of course also applies to new evaporators. If defrosts drained into the low stage in the past, make sure new installations are **set out correctly to begin with.**

## POSSIBLE POTHOLES 5

If high stage suction lines are too far away, piping **costs can be high!**



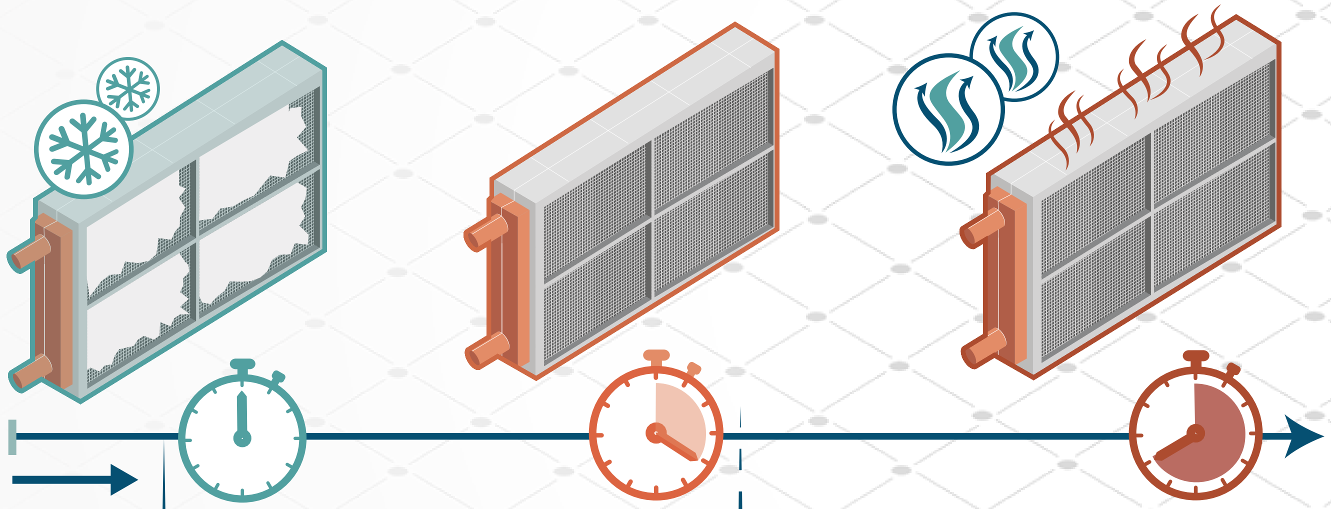
# DEFROST OPTIMISATION

## 1 STANDARD PRACTICE

**Defrost cycles** are usually set to **reoccur after a fixed time span** and to **last for another fixed time span**, irrespective of changed conditions from one day to another.

Fixed frequency and duration of defrost cycles are chosen from **experience** to assure evaporators are always freed from ice and operation is sound on any given day. They might be adjusted for summer and winter operation, but that is it.

Each defrost is the **same**, irrespective of conditions.



DEFROST STARTS

**Irrespective of ice** built-up. Probably defrost **was not yet required** & **could have been delayed.**

ICE FREE

DEFROST STOPS

not until **fixed time** has passed even if evaporator was ice-free well before.

Excess defrost time **heats up evaporators** & adds unwanted **heat** to cool room.

Excess heat has to be removed & **increases** cooling demand.

Two ways to make defrosts more efficient:

Delay defrost until it is required.

→ Duty counter

Abort defrost as soon as evaporators are free of ice.

→ Defrost termination sensors

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## 2 DEFROST TERMINATION

Install defrost termination **sensors** on evaporators.

▼

Sensors measure temperature of evaporators. Control logic will **termiN nate defrost cycle** as soon as evapoN rators begin to heat up, hence are freed from ice.

▼

**No excess heat** introduced into cool rooms

ENERGY SAVINGS


*TEMPERATURE SENSOR ON EVAPORATOR*

## DUTY COUNN TER 3

If defrost starts after fixed time, this does **not consider how much cooling was done** by the evaporator during that time. The more cooling it does, the more ice builds up. On a weekend or at night when the evaporator is not working as much as during production, **defrosts could be further delayed.**

The solution here is an internal **duty counter** in the control system. By **tracking opening time** of the evaporator's solenoid valve, cooling done by the evaporator can be tracked.

Implement a control logic that tracks solenoid opening time (=cooling duty) and **only start defrost after accumulated opening time** has reached a set limit.

Defrosts are avoided when they are not yet necessary.

**Energy savings**

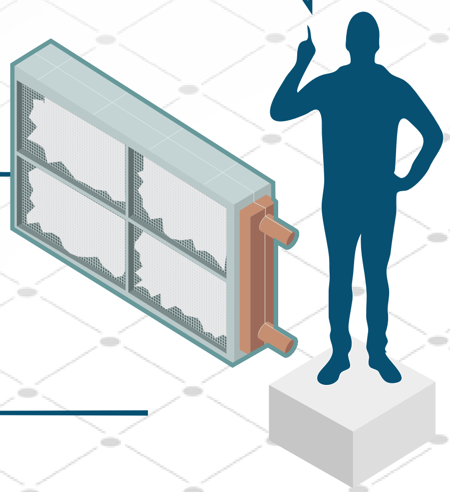
## 4 DOES THIS WORK FOR ME?

> **It is common sense, wherever defrosts are used, it makes sense to optimise them.**

Do you have evaporators that are **defrosted** with hot gas or electric heaters?

Do you have a **competent PLC programmer** to program duty counters and defrost termination logic into the PLC?

Do you have a **timed** defrost?



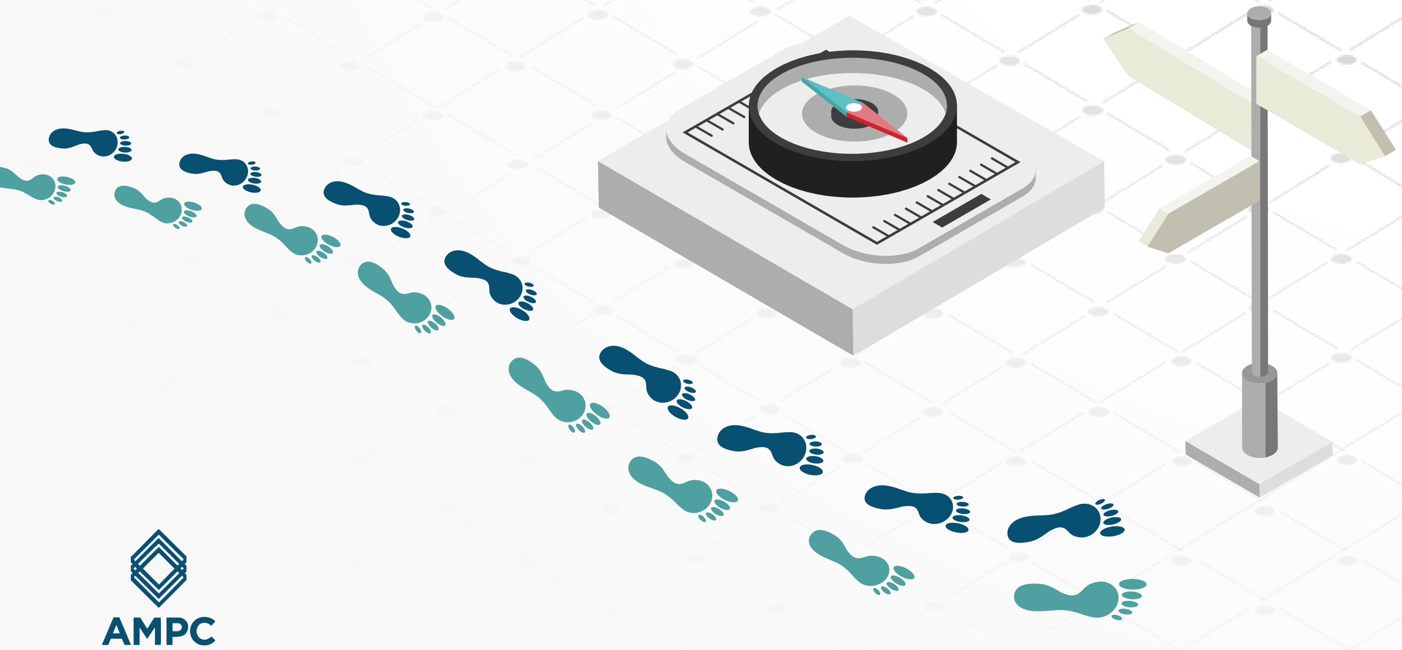
## 5 SYNERGIES

**Follows:**

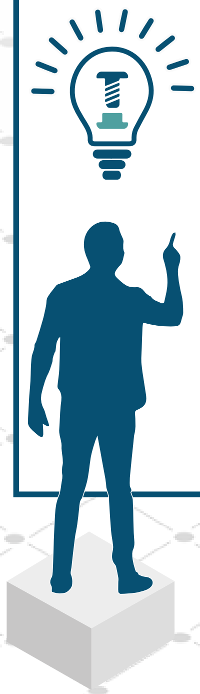
Control & Monitoring Upgrade - enables you to get creative with the way you program defrost control logic into the PLC/control system (termination & duty counter logic).

**Enables:**

Plant Stabilisation - defrosts have a destabilising effect due to the load they create. This load is reduced by shorter defrosts (termination) which occur less often (duty counter).



## 6 GOOD TO KNOW



- Place the defrost termination sensor at the **most heavily iced-up positiN on** on the coil to ensure it is fully defrosted.
- **No more re-adjusting** of defrost settings throughout the year needed
- Some sensors clip onto the **evaporator fins** – this is better than just fixing the sensor to the coil face.
- Sensor location **deep within the coil** is ideal, but difficult to retrofit.
- Ice melts at 0° C – hence a defrost sensor temperature of 5° C = no ice!! **Do not overheat** the coil.

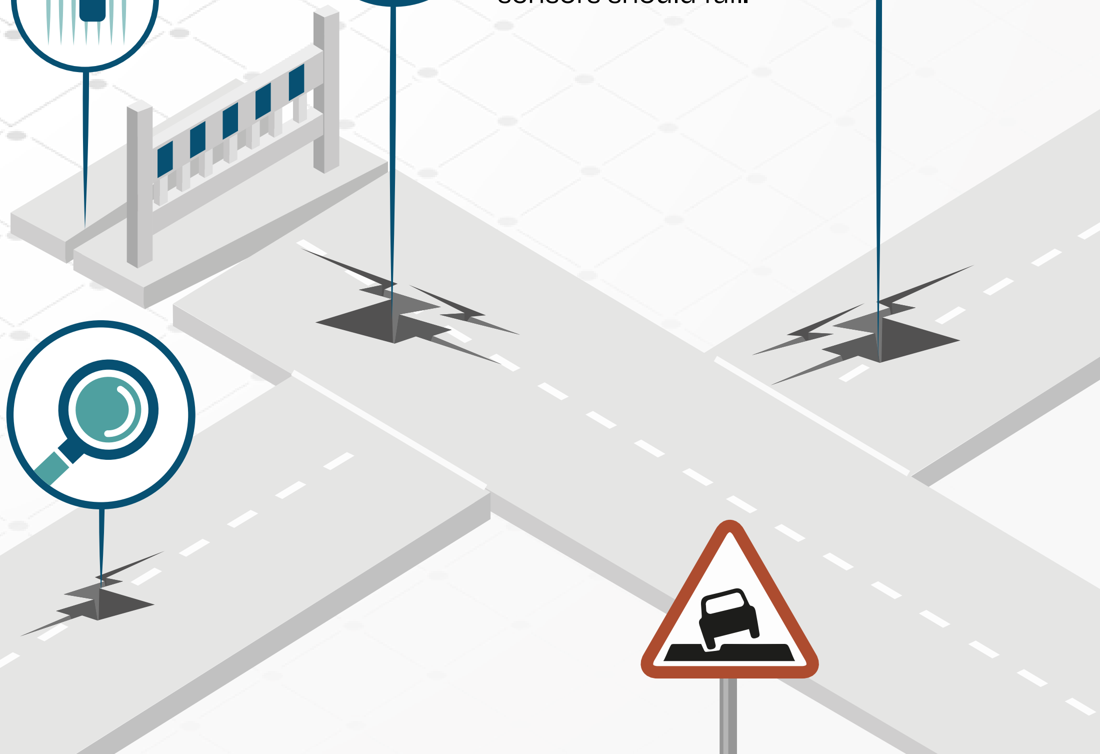
## POSSIBLE POTHOLES 7

If you do **carcass reheats,** make sure to implement specific control logic for reheats that **does not terminate hot gas** when evaporators start to warm up, as this is the actual objective in this case.

Important to keep conventional timed defrost **settings as backup,** in case the sensors should fail.

**Bad sensor location** can cause the sensor to measure air temperature, not coil temperature.

Make sure you can detect **sensor failure** easily or automatically.



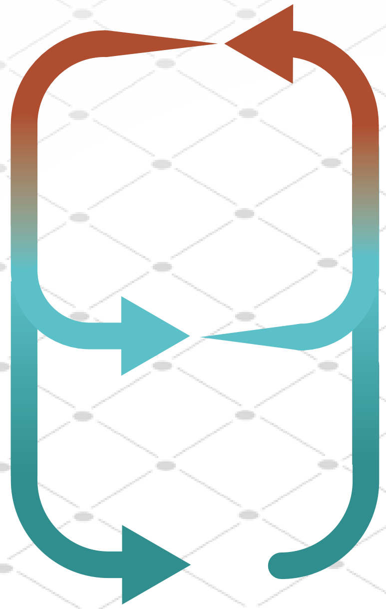
# HIGH STAGE ECONOMISERS

①

“

**Flash gas** forms when liquid refrigerant passes through an expansion valve. Some of the refrigerant instantaneously evaporates, consuming heat by doing so. This cools the remaining liquid down. By turning from liquid to gas it **expands** in volume, hence the name „expansion valve“. The further remaining liquid must be cooled down, the more flash gas is generated. This gas generation acts as a load on compressors just like vapour coming from evaporators due to cooling load.

”



By taking part of the refrigerant from the receiver and expanding it to a pressure level that is lower than condensing pressure but **above intercooler** pressure, the remaining liquid going to the intercooler is **subcooled** and **will not generate as much flash gas** there as it would otherwise.

This way part of **flash gas generation takes place at higher pressure** than in the intercooler, making it easier to compress it back to condensing pressure.

## ECONOMISERS ②

In addition to the vessel itself, an economiser requires some additional piping and valves (hardware & installation). The vapour outlet of the economiser vessel is connected to the **economiser port** of the high stage compressors. Most compressors are capable of 2-stage compression and possess this port, which usually is simply **sealed off for non-economised** operation.

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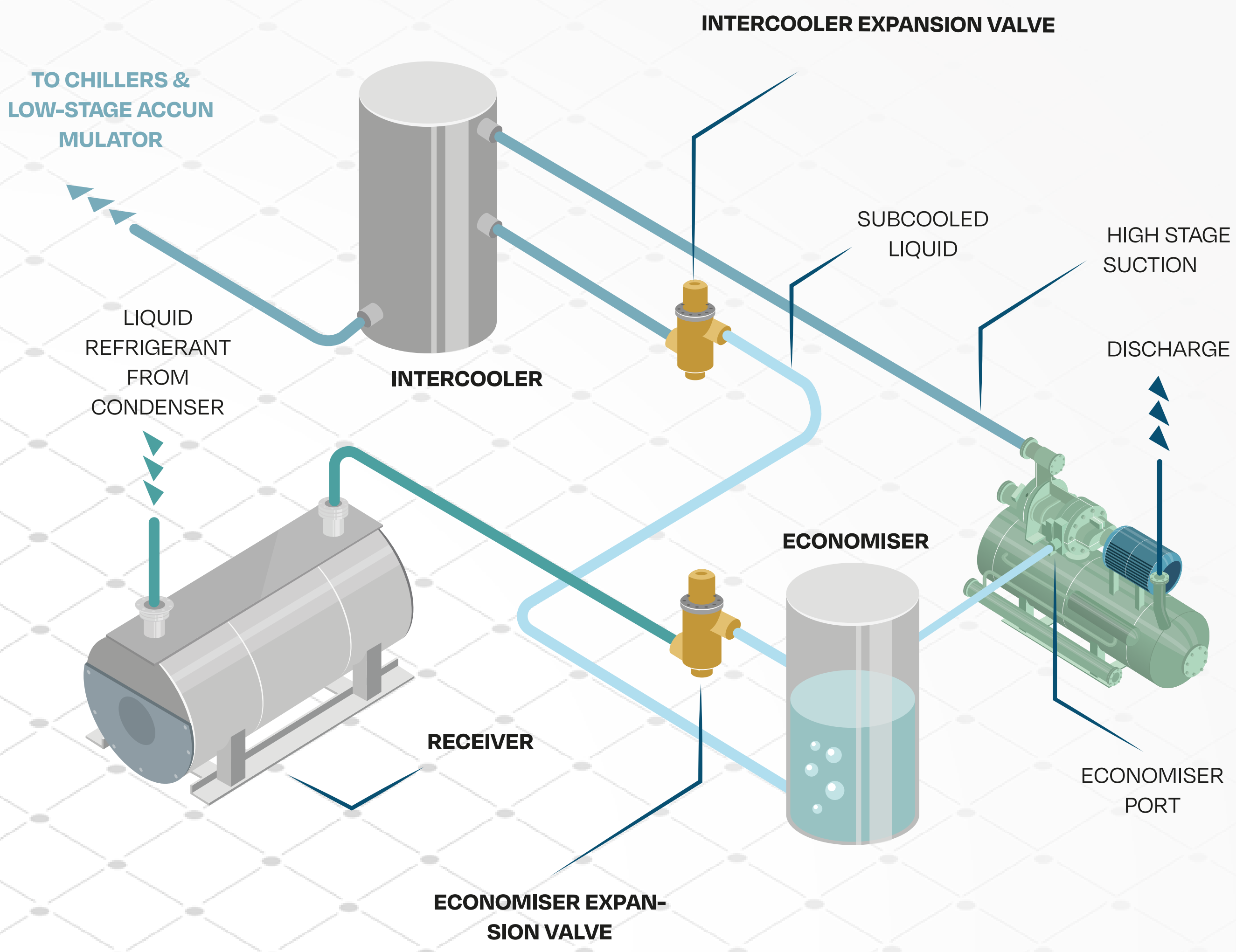



## THE BENEFITS ③

Economisers which are operated correctly save about **7 % of high stage compressor energy consumption**, which can translate into large financial savings depending on the size of your plant.

Due to the higher pressure the suction gas at this level is **denser** than in the intercooler, **increasing compressor capacity.**

**Increased capacity** makes plant **more resilient** on hotter days.

# ④ DOES THIS WORK FOR ME?

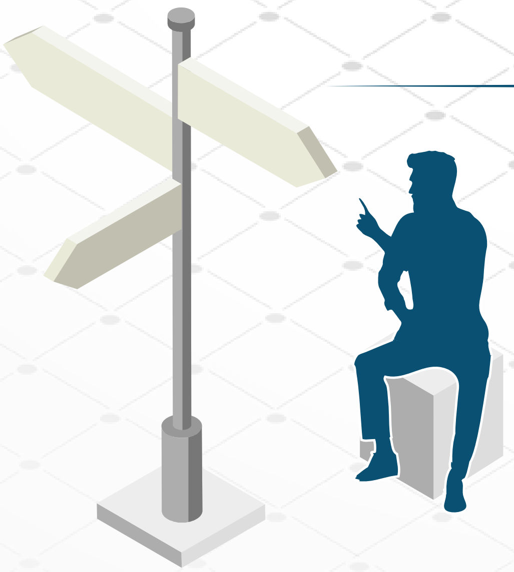
Do you have a screw compressor that runs on a **variable speed drive**? Mechanical unloading and economiser operation do not go together.

Other than capital cost & minimal higher plant complexity there is no reason not to use an economiser from an energy efficiency and even a plant capacity perspective.

# ⑤ SYNERGIES

**Follows:**

- **Control & Monitoring Upgrade** – sensors and measurements concerning economiser operation need to be implemented into the monitoring system.
- **Plant Stabilisation** – Economiser pressure adjusts to condensing and high stage suction pressures. If these pressures constantly fluctuate efficiency gain from economiser is reduced.
- **Compressor Speed Control & Staging** – It is essential for an economiser that the connected compressors do not slide-valve unload. This would open the economiser suction to the intercooler suction and render the economiser useless! Compressors need to run fully mechanically loaded which can be achieved through speed control via VSD.



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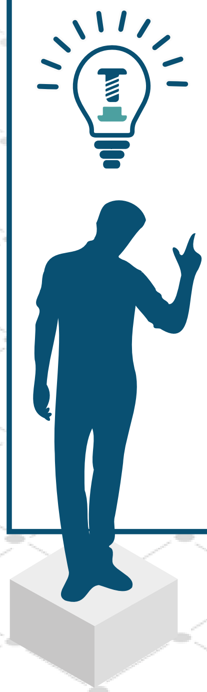
# ⑥ GOOD TO KNOW



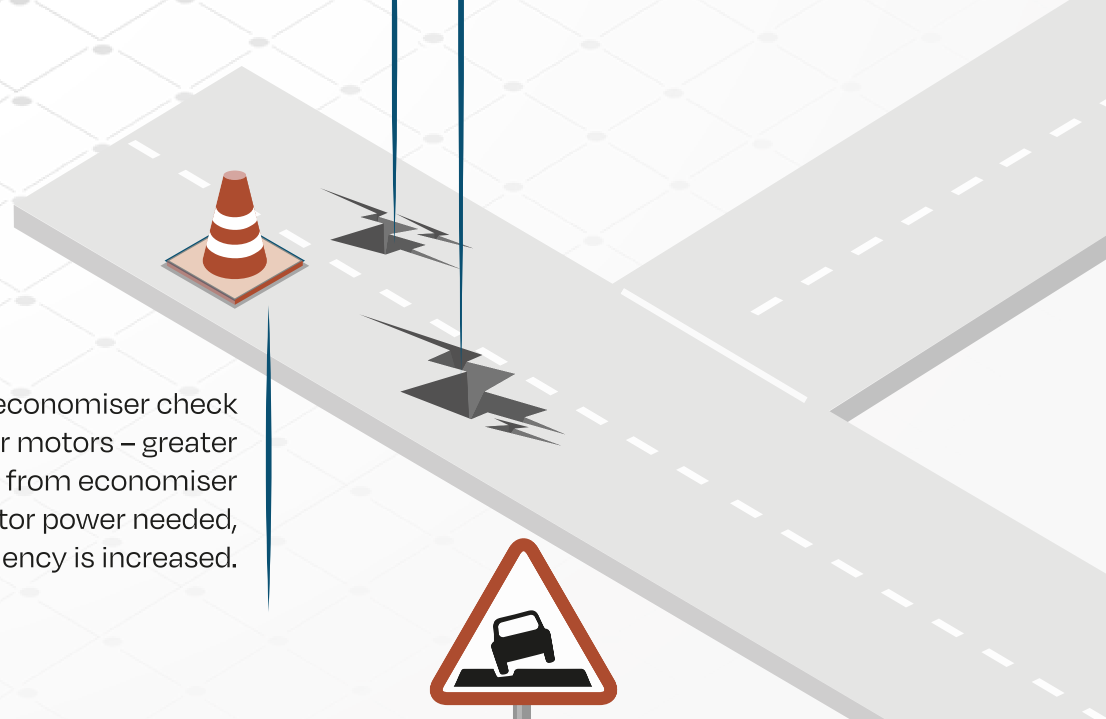
- Do not bother installing economisers, if you have not figured out Plant Stabilisation and Compressor Speed Control before. Compared to other EEOs they are capital intensive, and their benefits are compromised without prior resolution of the issues which are addressed by these EEOs.
- There are two different economiser types, open or closed. Refer to the How-To Manual.
- Most screw compressors as used in industrial plants are capable of 2-stage compression required for economiser operation and come with an economiser port.
- Consider an additional cooling load (side load) via the economiser port – often this is a great way to accommodate air-conditioning loads (e.g. adjacent admin building).

# ⑦ POSSIBLE POTHOLES

If compressors do **slide-valve unloading**, economiser port opens to suction and renders the economiser **useless.**

→ Avoid slide valve unloading through compressor speed control.

Be careful with **valve selection** for the economiser port on the compressor and its **location** due to possible issues with **gas pulsation.**



When retrofitting an economiser check size of compressor motors – greater cooling capacity from economiser means greater motor power needed, even if efficiency is increased.

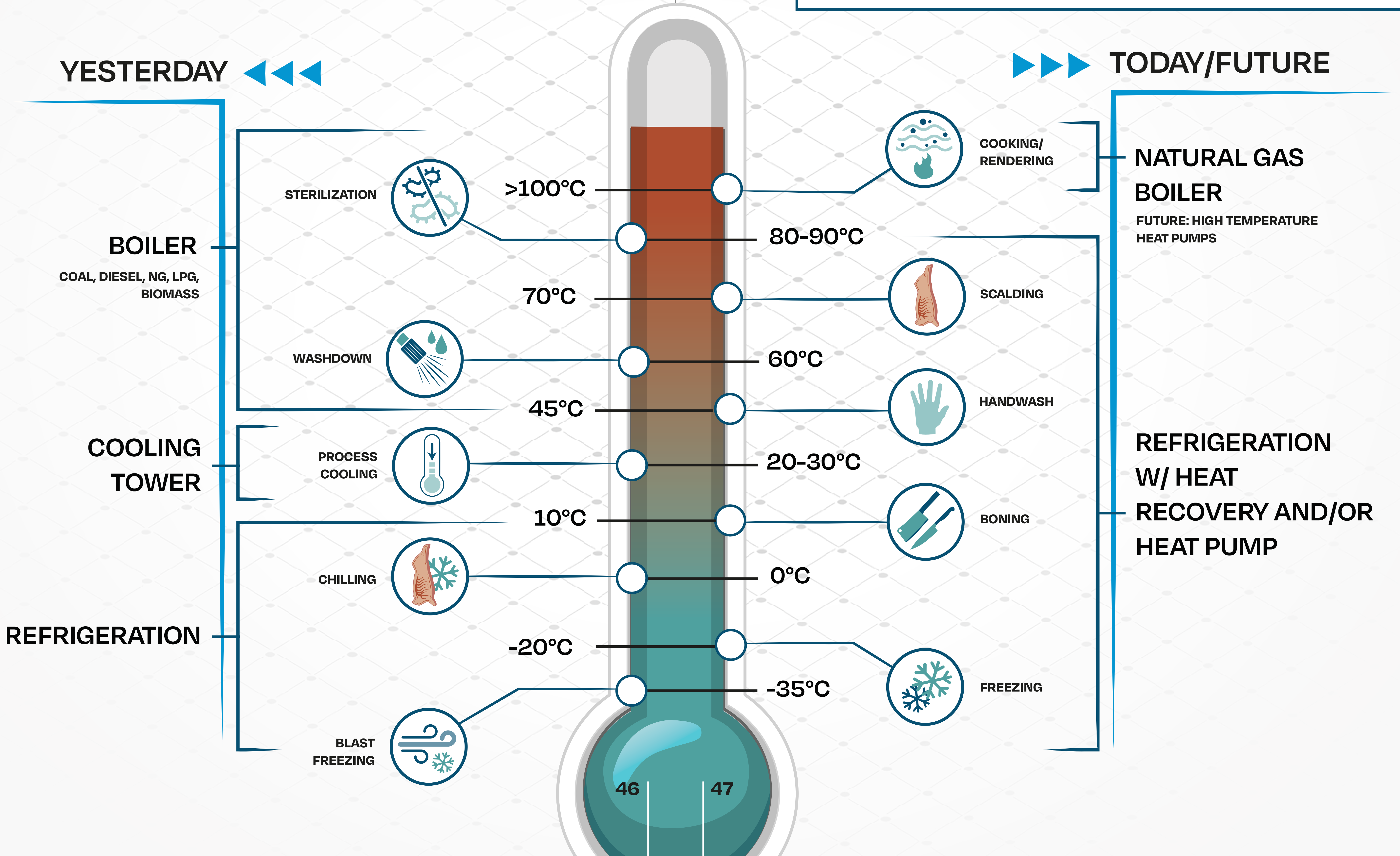
# INTEGRATION

## MORE THAN JUST COOLING

Most heating needs of an abattoir can be provided by refrigeration if integrated into the refrigeration plant. Waste heat that would otherwise be disposed of can be used to generate hot water either directly or after it is upgraded to higher temperature via heat pumps.

# TEMPERATURE NEEDS IN AN ABATTOIR

This graphic shows the different **process temperatures** inside an abattoir. Up until now cooling and heating were provided by **two different systems.** Most cooling is done by the **refrigeration plant** while heat comes from **boilers.** Incentivised by **higher fuel costs** and the need to **lower $CO_2$ emissions** most **heating needs can be covered by the refrigeration plant through integration.** At this moment in time only **steam for rendering** must still be provided by a boilers, but **high temperature heat pumps** could relieve them in the near future.

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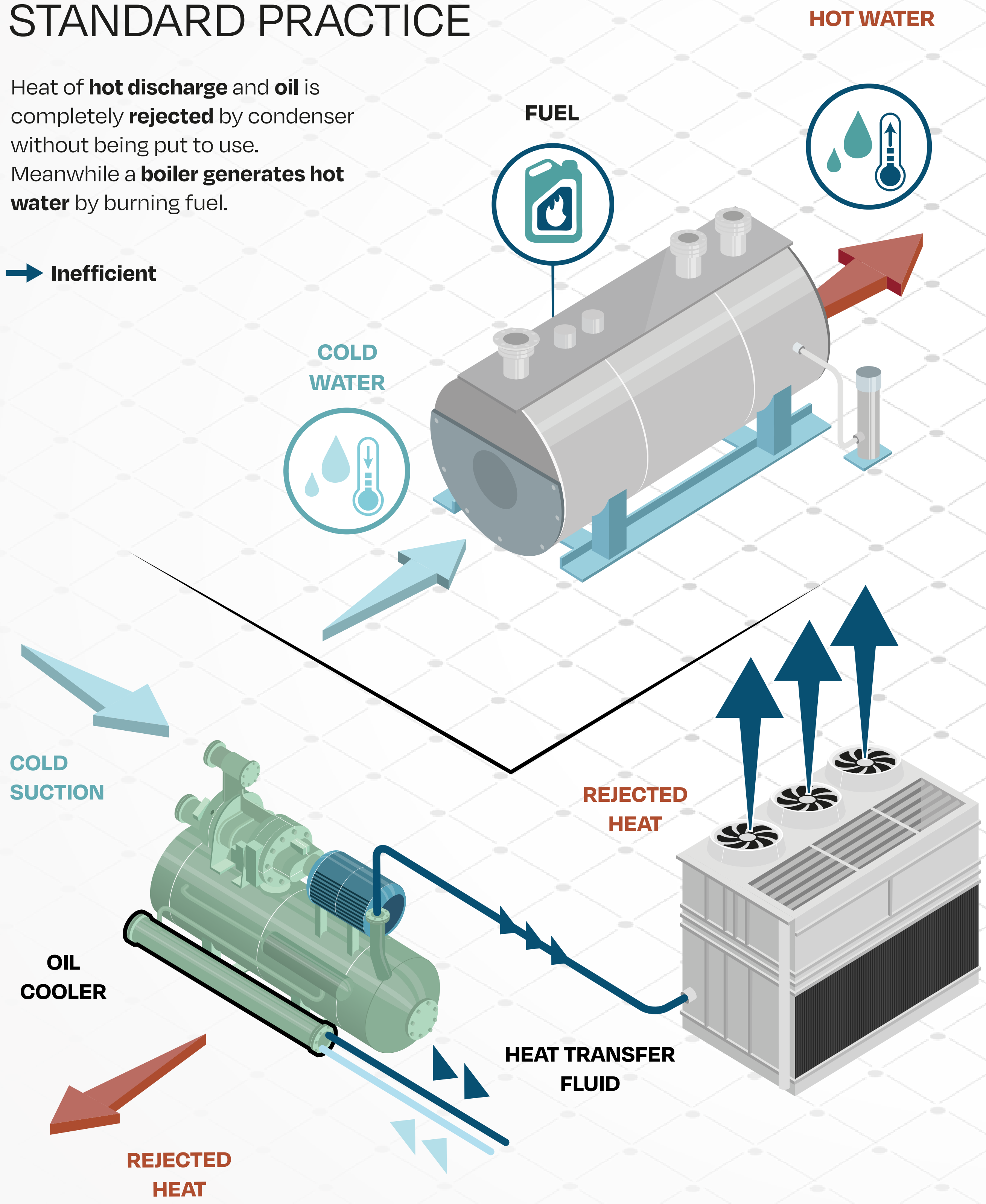
# HEAT RECOVERY

FOR WASHDOWN

## ① STANDARD PRACTICE

Heat of **hot discharge** and **oil** is completely **rejected** by condenser without being put to use. Meanwhile a **boiler generates hot water** by burning fuel.

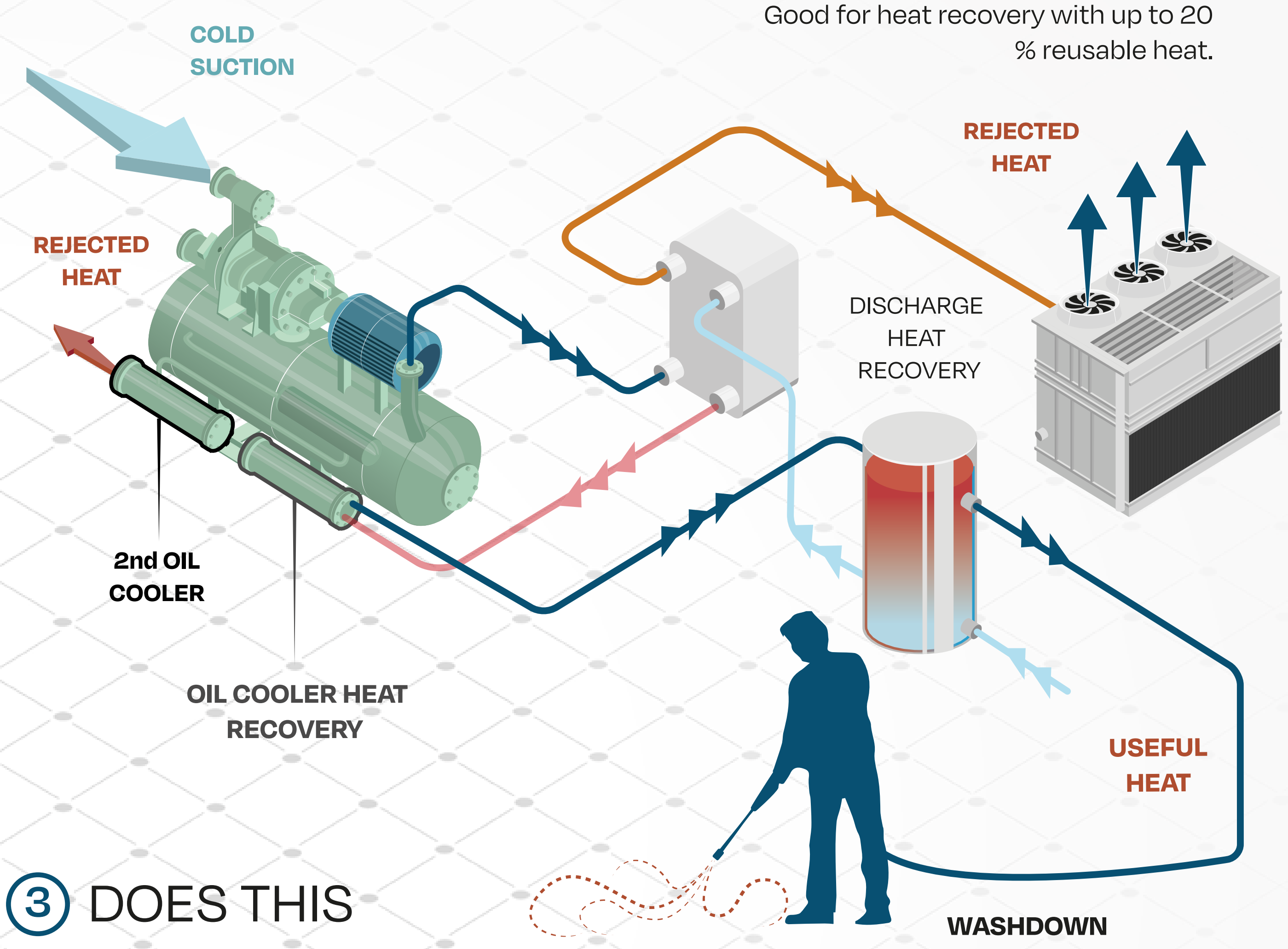
→ **Inefficient**




## TURN WASTE TO PROFIT ②

$NH_3$ has **high discharge temperature**

Good for heat recovery with up to 20 % reusable heat.




## ③ DOES THIS WORK FOR ME?

**CHECKLIST**

- [ ] Do you need **hot water** to wash down your processing areas? ▶▶▶ Heat recovery can provide large amounts of 60 °C hot water.
- [ ] Are you using **LPG or even diesel** for heating fuel? ▶▶▶ The more you spend on expensive fuel, the more attractive heat recovery becomes.
- [ ] Is your hot water or steam boiler **inefficient** or due for replacement? ▶▶▶ If you are due to replace a boiler, this is the perfect opportunity to make a switch to a heat recovery system.

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## ④ SYNERGIES

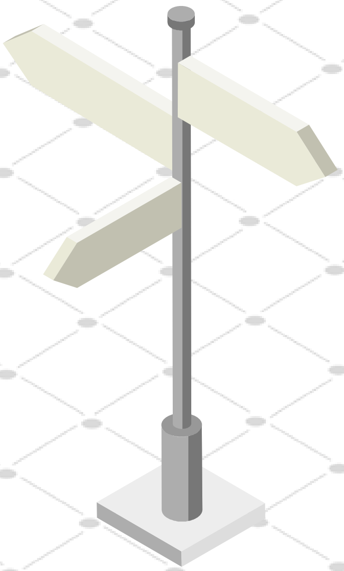
**Follows:**

**Oil Injection Optimisation** - should be done to avoid over injection which would reduce oil and discharge temperatures needed for heat recovery.

**Compressor Staging** - To reduce pipe work needed, only lead compressors would be used for heat recovery.

**Enables:**

**Fan Speed Control** - Using waste heat that would otherwise be disposed of via the condensers, relieves the latter. Hence condenser fans do not need to run as hard and more energy can be saved.

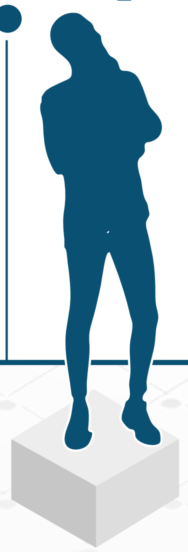


## ⑤ GOOD TO KNOW

Stratified storage tanks **steadily heated up all day.**

Ammonia can provide large amounts of **washdown water (60-70 °C).**

Sites with rendering possess big boilers, often burning cheap fuel which makes heat recovery **less feasible**. However, there might be a niche for it. E.g. hot water demand and rendering facilities are located far away from each other. Long steam piping required which comes with heat losses and a safety hazard. Can be avoided by using heat recovery from refrigeration plant next to **location of hot water demand.**



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A hidden bonus which could be of great value: **Amount of heat rejected** by condensers and their **water use** go hand in hand. By recovering heat instead of rejecting it via condensers, the latter are relieved and consume **less water.**

## ⑥ POSSIBLE POTHOLES

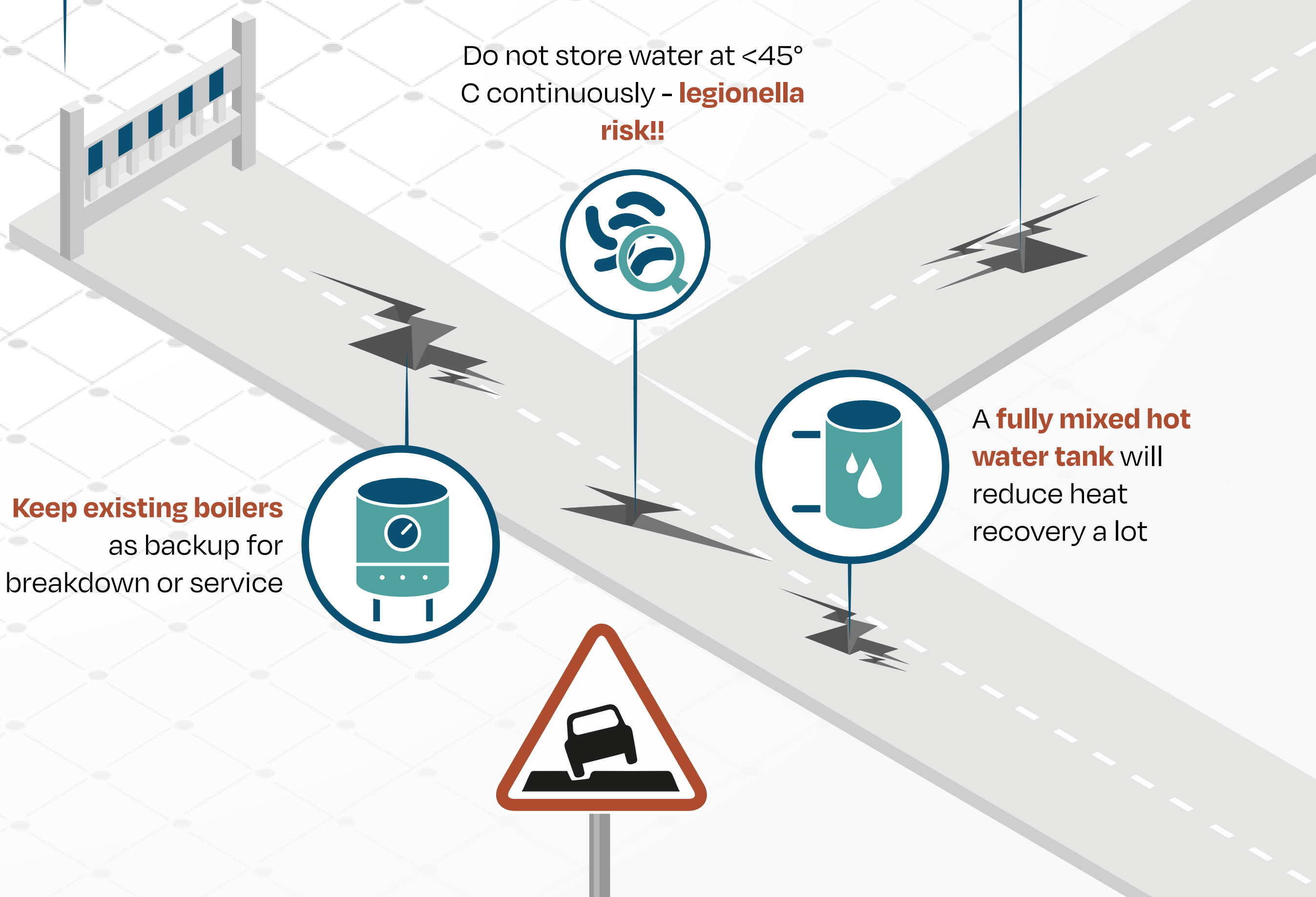
Reducing condensing temperature with **Variable Head Pressure Control** (see pg. 20 - 25) could be counterproductive for heat recovery during cooler weather. Depending on your heating costs, it may be economical to limit variable headpressure, to benefit heat recovery – this needs analysis.

Fit VSDs and good controls to water pumps to control temperatures **even at part load,** otherwise you will lose temperature.

Do not store water at <45° C continuously - **legionella risk!!**

**Keep existing boilers** as backup for breakdown or service

A **fully mixed hot water tank** will reduce heat recovery a lot

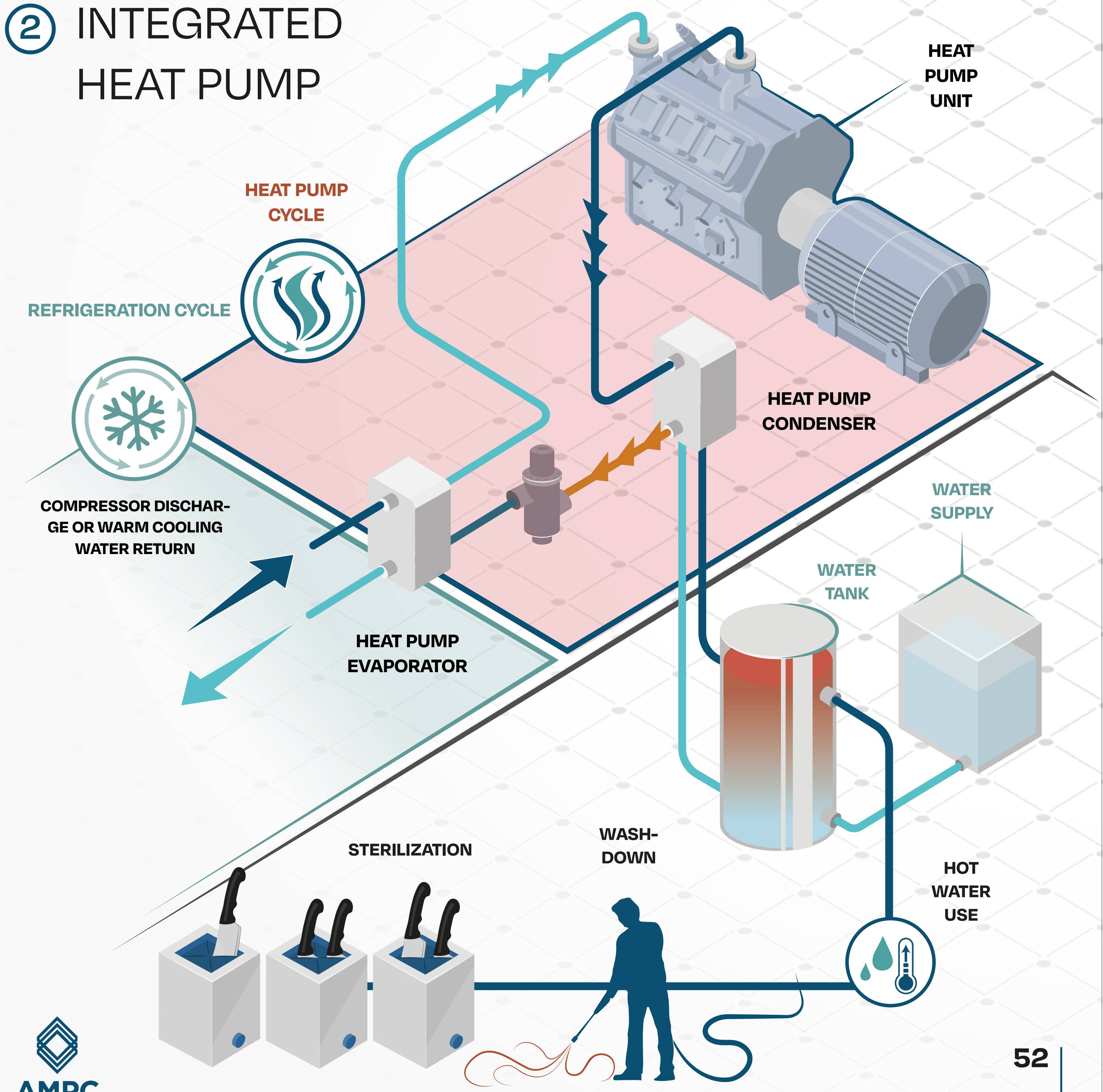


# INTEGRATED HEAT PUMP

## ① HOW DOES IT WORK?

A heat pump works **like a refrigeration plant.** But with a different focus. Instead of creating low temperatures in the evaporator the aim is to produce useable high temperature heat in the condenser. Absorbed heat from the evaporator together with the compression energy is used at high temperature to heat water for hot water uses such as **wash down** of the plant & **sterilisation.**

## ② INTEGRATED HEAT PUMP




The evaporator of an **integrated** heat pump is a heat exchanger that takes **waste heat** from the refrigeration cycle. This heat would otherwise be disposed of, but instead is upcycled. The heat pump cycle is **directly connected to the refrigeration plant and expands it.** We speak of **integration.**

A compressor then raises the vapour from the heat pump evaporator to such high pressures that it can heat water to temperatures as high as **95 °C** for **sterilisation** or **60 °C** for **wash down** (the latter could also be achieved with direct heat recovery).

## THE BENEFITS ③

High coefficient of performance (COP) & high discharge temperatures result in large amounts of heat at high temperatures by using only **a fraction of that in electricity**

**Save money** on **fuel & investment** for boiler

**If you have Solar:**

Electric power used by heat pumps can be generated by **solar.**

Hot water can easily be stored.

Counteract daytime dependent availabilty of solar power.

**More savings** from solar.

## ④ DOES THIS WORK FOR ME?

- ☐ Are you using **considerable amounts** of hot water to wash down your plant and for sterilizers?
- ☐ Do you spend a lot of money or are **dependent on fuel**?

**Fuel costs** for wash down and sterilisation hot water can be **completely offset** by heat pumps. In return, electricity costs will rise due to heat pump power consumption. But due to high efficiency of heat pumps their electricity should cost less than the fuel for boilers. The **difference** and therefore the **savings** will depend on your fuel and electricity costs (heat pumps work well with solar).

**High fuel prices.**

**Cheap electricity or solar.**

**More savings** from heat pumps compared to fuel boilers.

Is your steam boiler **inefficient or old?**

If an investment for a new boiler is due, this is the perfect time to replace it with a heat pump.

Are you **not** rendering on site and run a steam boiler **for knife sterilisation only?**

If you do not use steam for rendering, heat pumps allow you to cover all temperature needs of an abattoir without need for a steam boiler.


Unfortunately, heat pumps do not yet allow for temperatures high enough to generate **steam for rendering.** Most facilities that use rendering possess large steam boilers and use heat recovery from the cooker condensate for 60 °C wash down water and top up with steam to generate 90 °C sterilisation water. In this case heat pumps are most likely not financially feasible due to the excess waste heat from rendering.

## 5 SYNERGIES

**Enables:**

**Condenser Fan Speed Control** – will benefit from heat pumps which, by absorbing waste heat, relieve condensers. Hence, fans can run more slowly and save more energy. This is a bonus, not a necessity.

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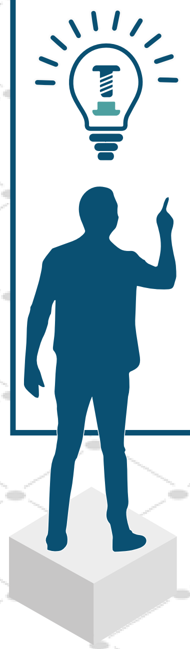
**Complements:**

**Heat Recovery –** and heat pumps should be considered in combination. This could reduce heat pump size and cost.

## 6 GOOD TO KNOW

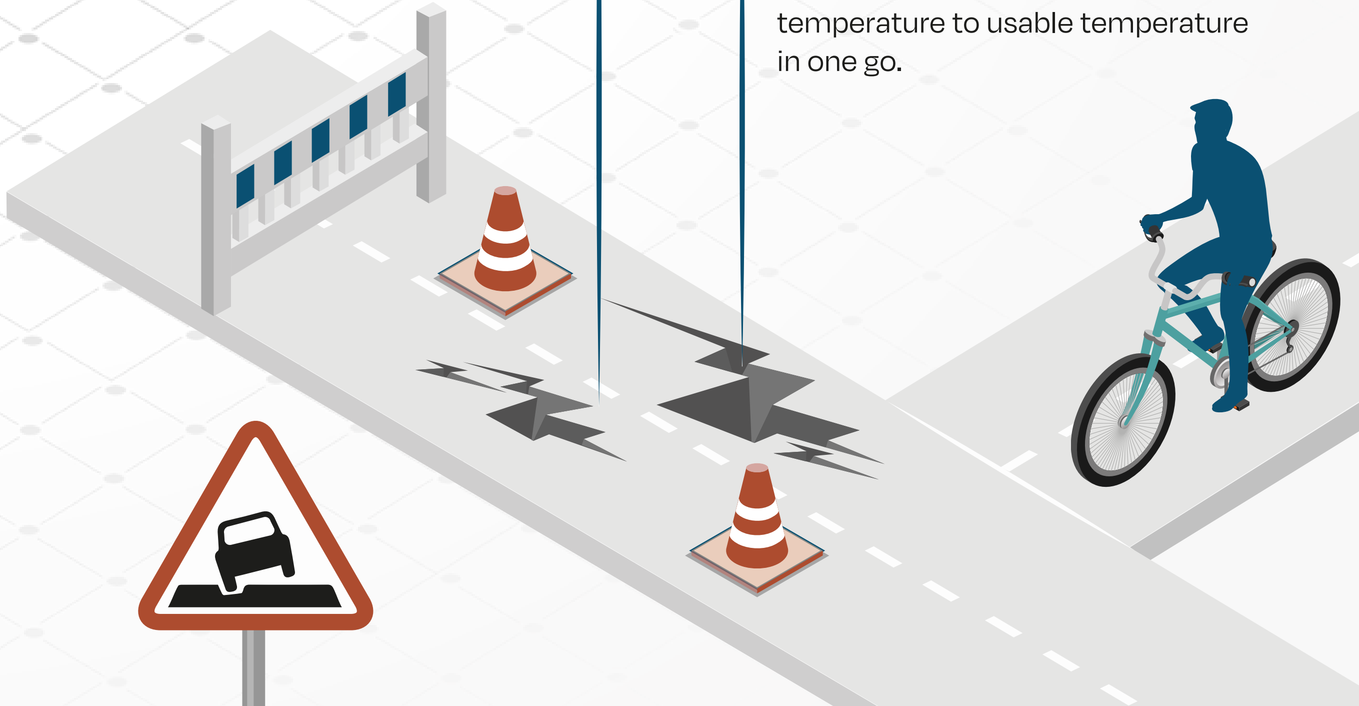


- In addition to money savings, heat pumps allow you to lessen your $CO_2$ footprint by **not burning fuel.**
- **No boiler inspections** required for these heat pumps.
- Both $NH_3$ and $CO_2$ heat pumps are capable of producing water to 95 °C, hence good for sterilizing.
- Always use stratified hot water storage tanks – cold at the bottom, hot at the top – and speed controlled pumps to maintain temperatures.

## POSSIBLE POTHOLES 7

**Do not** oversize heat pumps or size for peak demand, size for average demand and use storage tanks.

Heat pumps are not efficient for **"topping up" hot water** as in a ringmain, but are best to liftwater from low temperature to usable temperature in one go.

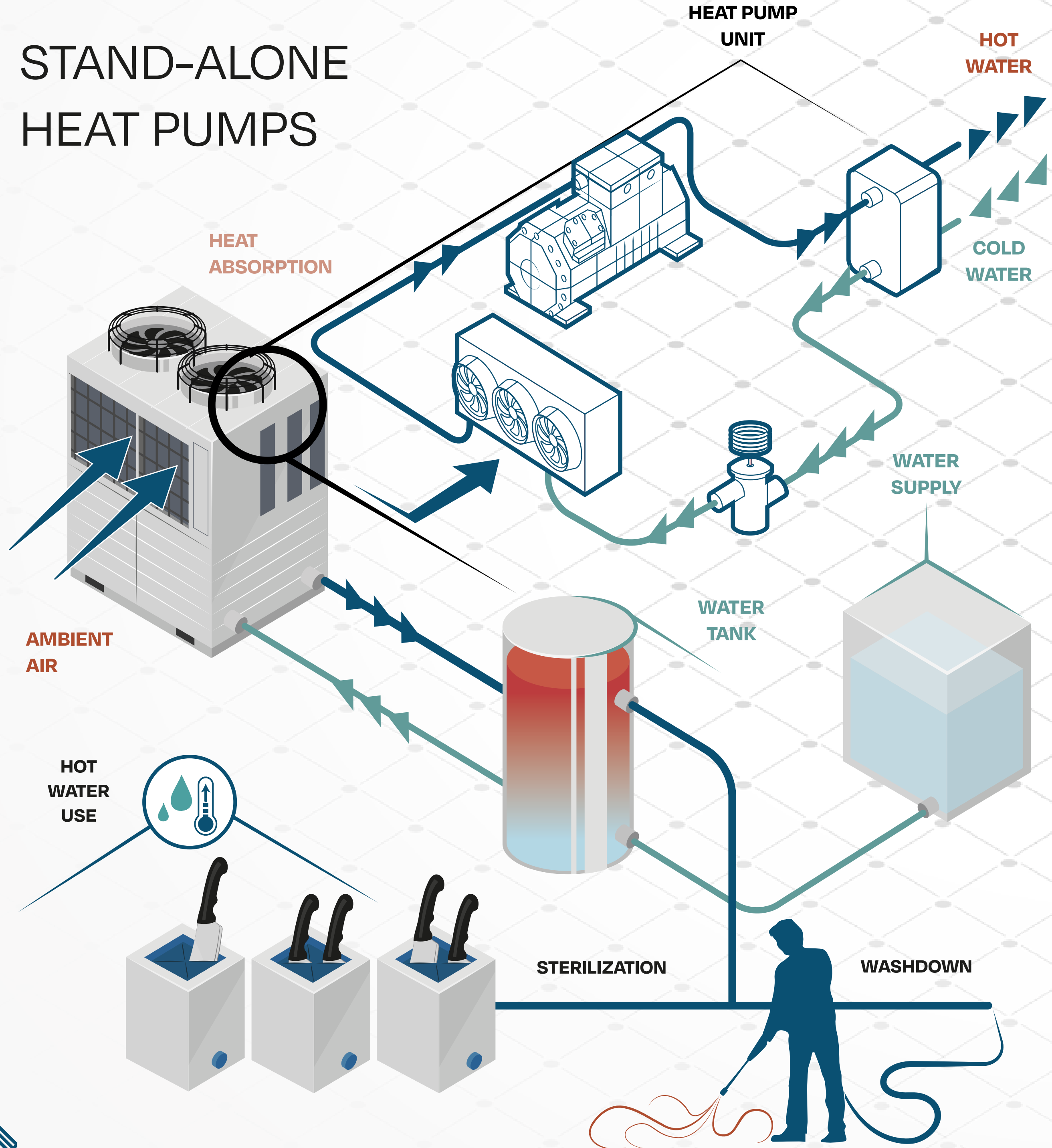


# AIR SOURCE HEAT PUMPS

## ① HOW DOES IT WORK?

An air-source heat pump is **stand-alone** and draws heat from the ambient air. This allows you to generate hot water at point of use, rather than pump it from a remote plant room. Most air-source heat pumps use $CO_2$ as refrigerant, but ammonia is also plausible for large units.

## ② STAND-ALONE HEAT PUMPS




The evaporator of an air source heat pump takes **heat** from the **ambient air.** This allows for small decentralized stand-alone units. These units can be installed at various locations, away from the main plant, directly where the hot water demand is, saving pump power.

A compressor then raises the vapour from the heat pump evaporator to such high pressures that it can heat water to temperatures as high as **95 °C** for **sterilisation** or **60 °C** for **wash down.**

## THE BENEFITS ③

High coefficient of performance (COP) & high discharge temperatures result in large amounts of heat at high temperatures by using only **a fraction of that in electricity**

Reduce piping and pumping costs by locating the heat pump close to point of use.

**If you have Solar:**

Electric power used by heat pumps can be generated by **solar.**

Hot water can easily be stored.

Counteract daytime dependent availabilty of solar power.

**More savings** from solar.

## ④ DOES THIS WORK FOR ME?

- [ ] Are you using **considerable amounts** of hot water to wash down your plant and for sterilizers?
- [ ] Do you spend a lot of money or are **depen-dent on fuel**?

**Fuel costs** for wash down and sterilisation hot water can be **completely offset** by heat pumps. In return, electricity costs will rise due to heat pump power consumption. But due to high efficiency of heat pumps their electricity should cost less than the fuel for boilers. The **difference** and therefore the **savings** will depend on your fuel and electricity costs (heat pumps work well with solar).

**High fuel prices.**

**Cheap electricity or solar.**

**More savings** from heat pumps compared to fuel boilers.

Is your steam boiler **inefficient or old?**

If an investment for a new boiler is due, this is the perfect time to replace it with a heat pump.

Are you **not** rendering on site and run a steam boiler **for knife sterilisation only?**

Do you need hot water a long distance from the plant room?

If you do not use steam for rendering, heat pumps allow you to cover all temperature needs of an abattoir without need for a steam boiler.

Also, by generating the hot water close to point of use, less heat is wasted and pumping power consumed.

## 5 SYNERGIES

As these air sourced heat pump units are decentralized stand-alone units, they do not have any effect on the rest of the plant and therefore **no synergies** with other EEOs, which all evolve around the central ammonia plant.

## GOOD TO KNOW 5

- In additionto money savings, heat pumps allow you to lessen your $CO_2$ footprint by **not burning fuel.**
- **No boiler inspections** required for these heat pumps.

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- Both $NH_3$ and $CO_2$ heat pumps are capable of producing water to 95 °C, hence good for sterilizing.
- Always use stratified hot water storage tanks – cold at the bottom, hot at the top – and speed controlled pumps to maintain temperatures.
- $CO_2$ heat pumps work well even under v**ery cold winter conditions (<<0°c).**
- Heat pumps can be located **close to** where you **need sterilizer water** - adja-cent to the boning room.

## POSSIBLE POTHOLES 6

$CO_2$ heat pumps require a **specialist to repair**

→ Best to manifold several together and have a backup unit on site.

$CO_2$ heat pumps especially are **not good for "topping up"** hot water as in a ring-main, but need to lift water from low temperature to usable temperature in one go.

**Do not** oversize heat pumps or size for peak demand, size for average demand and use storage tanks.

This Guidebook is one of five developed during the "Refrigeration Plant Energy Improvement" research project by the Australian Meat Processor Corporation (AMPC). The series aims to help plant personnel and stakeholders of meat processing facilities to identify energy efficiency opportunities within their refrigeration systems.

This Guidebook subtitled "COMMERCIAL FREON SYSTEMS" is aimed at small-sized meat works which use commercial type freon refrigeration systems.

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