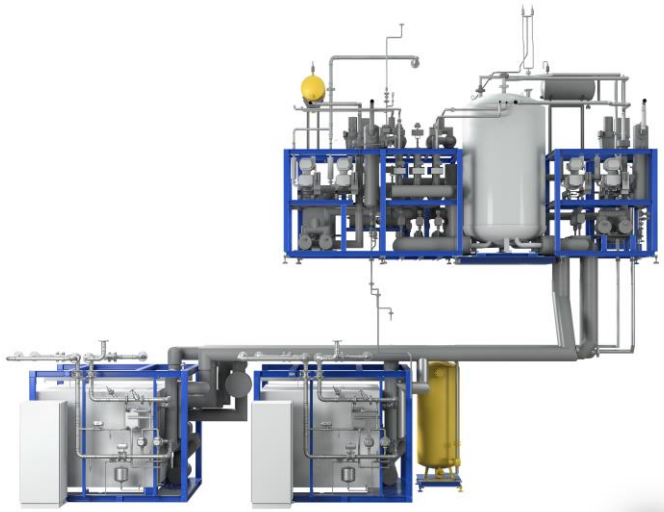
REFOLUTION
Retrofit Solutions

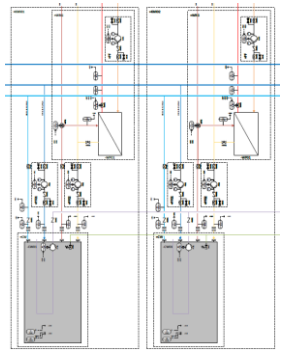
THE ENGINEERING OFFICE FOR SUSTAINABLE REFRIGERATION TECHNOLOGY

Refolution Industriekälte GmbH

The engineering office for sustainable refrigeration

- Consulting
- Planning
- Special plant construction
  - Including Retrofits
- Product development





Thomas Frank
CEO
Germany

Cornelia Schröder
Assistenz
Germany

Jan Zeller
Sales Engineer
Germany

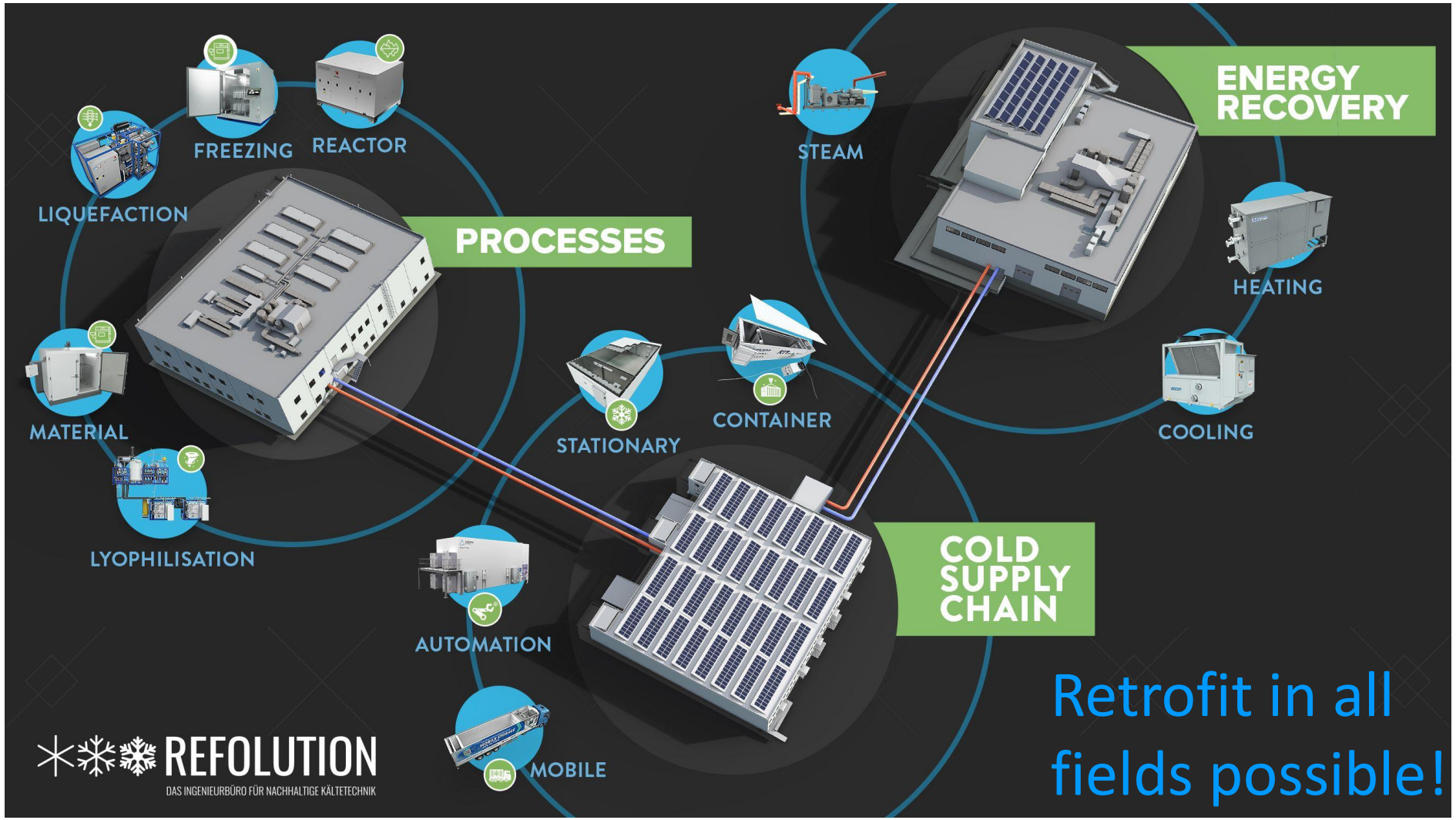
Yannick Pruss
Project Engineer
Germany

Tobias Wurz
Project Engineer
Germany

Thomas Klövekorn
Project Engineer
Germany

Mathias Montfort
Service
France / Lyon

Refolution Portfolio



Reasons for Retrofit

In Germany about 14% to 19% of total electrical power is used in refrigeration & air conditioning processes

- Need for efficient solutions
- High CO_2-footprint of LN2 and High-GWP solutions
- Increasing focus on CO_2-emission / CO_2-pricing / emission goals Scope 1-3

Average life cycle is 15 years and life cycle cost is not counted

- Need for long-lasting solutions

Environmental benefits from natural refrigerants:

- no ODP, low GWP, no PFAS/TFA

- F-Gas-Regulation (EU) 2024/573
  - Strictly limits available amount of F-Gas-refrigerant
  - Price increase inevetible
- PFAS-Restriction proposal (REACH)
  - New Strictly limits available amount of F-Gas-refrigerant

- Freedom of operation only with Use of natural refrigerants
- High impact for **low temperature applications** due to discontinuation of exceptions


Amtsblatt
der Europäischen Union

2024/573 20.2.2024

VERORDNUNG (EU) 2024/573 DES EUROPÄISCHEN PARLAMENTS UND DES RATES

vom 7. Februar 2024

über fluorierte Treibhausgase, zur Änderung der Richtlinie (EU) 2019/1937 und zur Aufhebung der Verordnung (EU) Nr. 517/2014

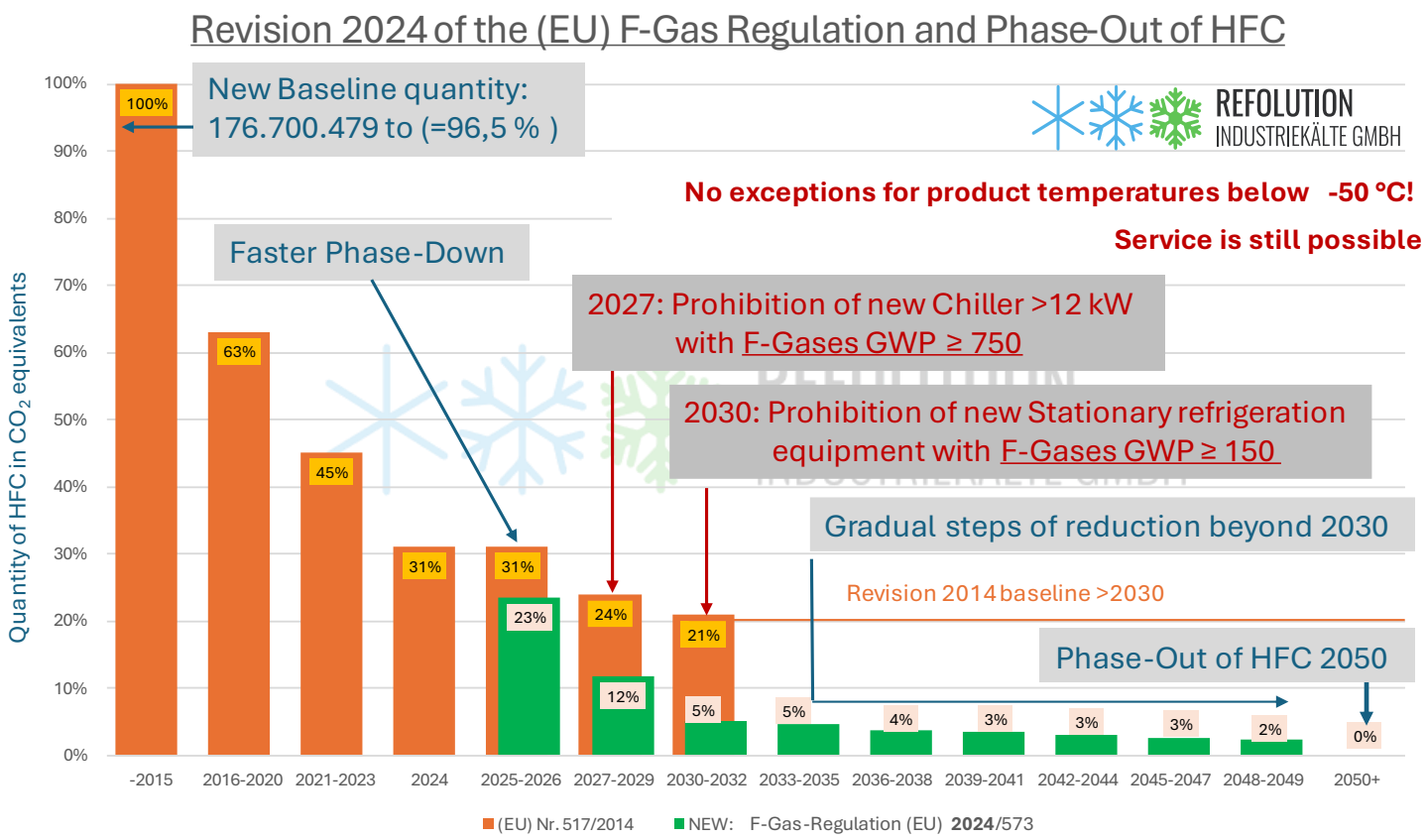
ECHA
EUROPEAN CHEMICALS AGENCY

ANNEX XV RESTRICTION REPORT

PROPOSAL FOR A RESTRICTION

SUBSTANCE NAME(S): Per- and polyfluoroalkyl substances (PFASs)

F-Gas-Regulation – Phase out of GWP



Percentage of maximum allowable quantities of hydrofluorocarbons (HFCs) placed on the market until Full Ban 2050

F-Gas-Regulation (EU) 2024/573 → 11.03.2024

Article 17: Phase-Down for HFC (HFO not in quota)

Distinction between HFC and F-Gases (HFC & HFO)

Additional bans and obligations, NEW: HFO partly included

e.g. Leakage detection of HFO with more than 1 kg

Article 11 - Prohibition of placing products on the market:

(7d) 2027: Chiller with >12 kW with F-Gases GWP ≥750

(5c) 2030: Refrigeration equipment with F-Gases GWP ≥150

Exceptions: Chillers or if required to meet safety requirements at the site of operation.

But no Exceptions for product temperatures below -50 °C!

Article 13 - Control of use of F-Gases

2032: Ban of service with virgin refrigerant GWP ≥750

Exceptions: Chillers or for product temperatures below -50 °C, but will be reviewed 2030

Examples:

R32 – GWP 675 R410A – GWP 2088 R452A – GWP 2140

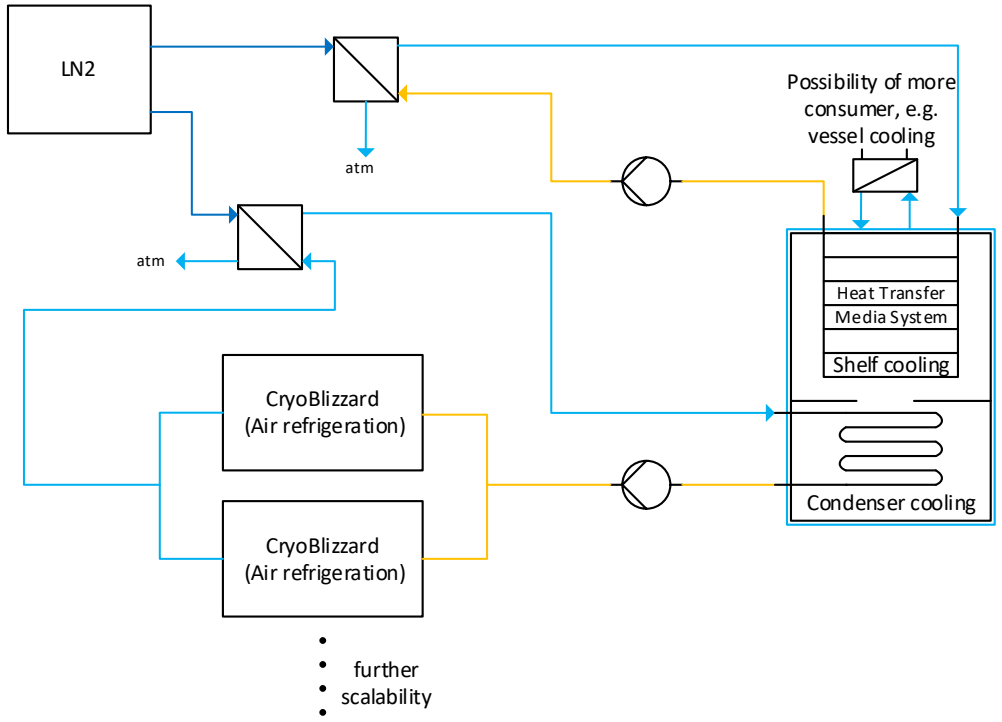
R404A – GWP 3922 R23 - GWP 14800

Retrofit Procedure

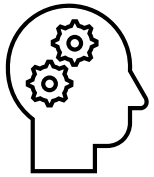
1. Analysis of basis
   - Process demands (Heat, cold)
   - Refrigeration machines and heat exchanger of process
   - Refrigerants (GWP, F-Gas-Regulation)

2. Planning
   - Requirements of customer
     - A1 or A3 refrigerant
     - CO2 reduction goals?
   - Combination of heat and cold possible?
   - Study of possible refrigeration technologies and availabilities
   - Selection of technology
   - Time schedule of retrofit (during operation or during turnaround)

3. Solution (examples)
   - Replacement of refrigeration machine with new one
   - Drop-In with enhanced safety measures
   - Use of thermal oil instead of direct evaporation (no need to replace heat exchanger)
   - Support existing refrigeration machine with sustainable base load machine, e.g. to reduce LN2 consumption

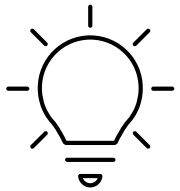


Retrofit Examples



Solution (examples)

- Replacement of refrigeration machine with new one
  - Freeze Dryer, Freeze and Thaw Unit (FTU), reactors
  - Cold air machine can replace F-Gas-Skids for processes that use oil as heat transfer medium

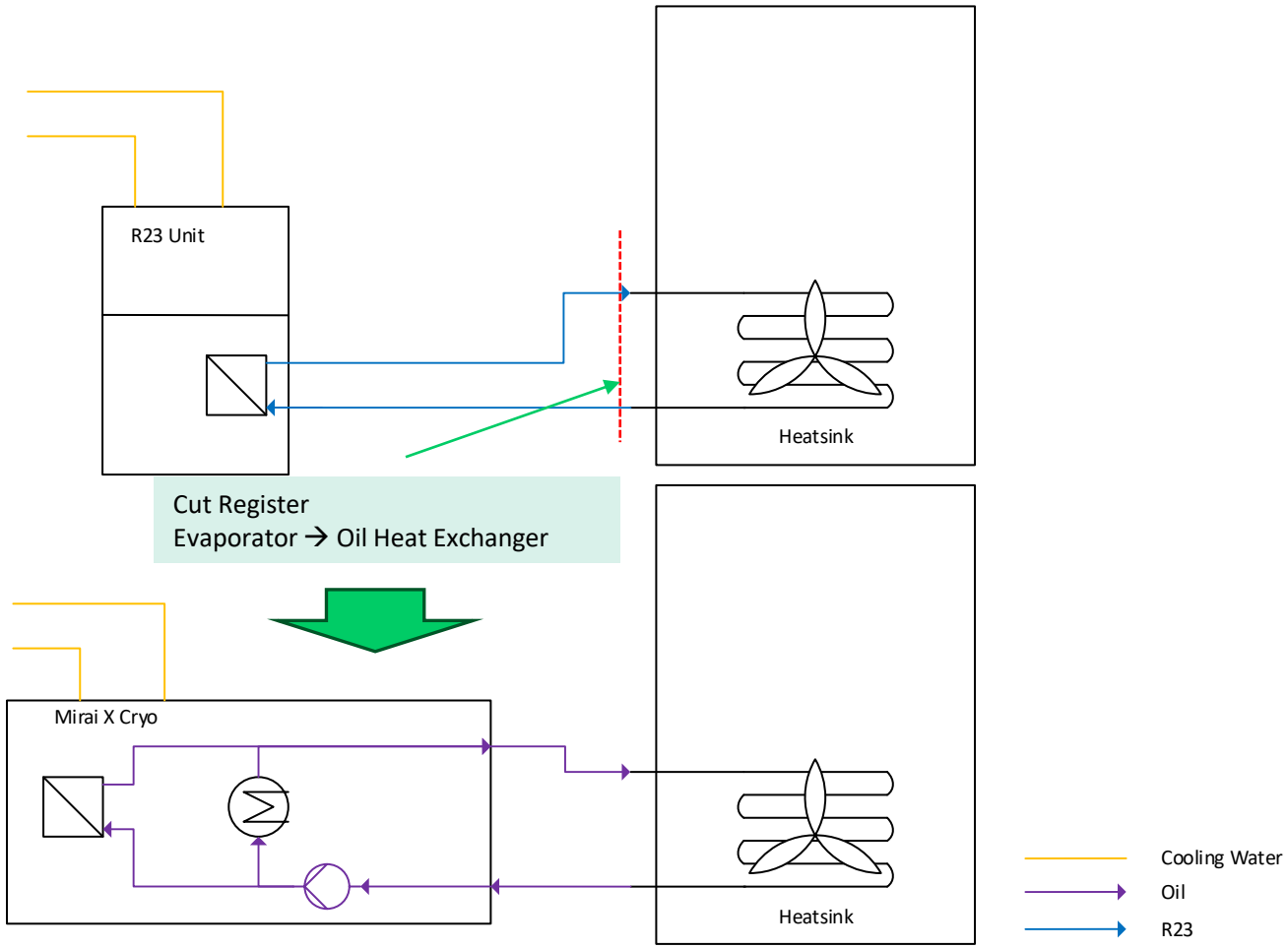


- Use of thermal oil instead of direct evaporation (no need to replace heat exchanger)
  - Freeze Dryer (Ice condenser)

- Support existing refrigeration machine with sustainable base load machine, e.g. to reduce LN2 consumption
  - LN2 Compensation

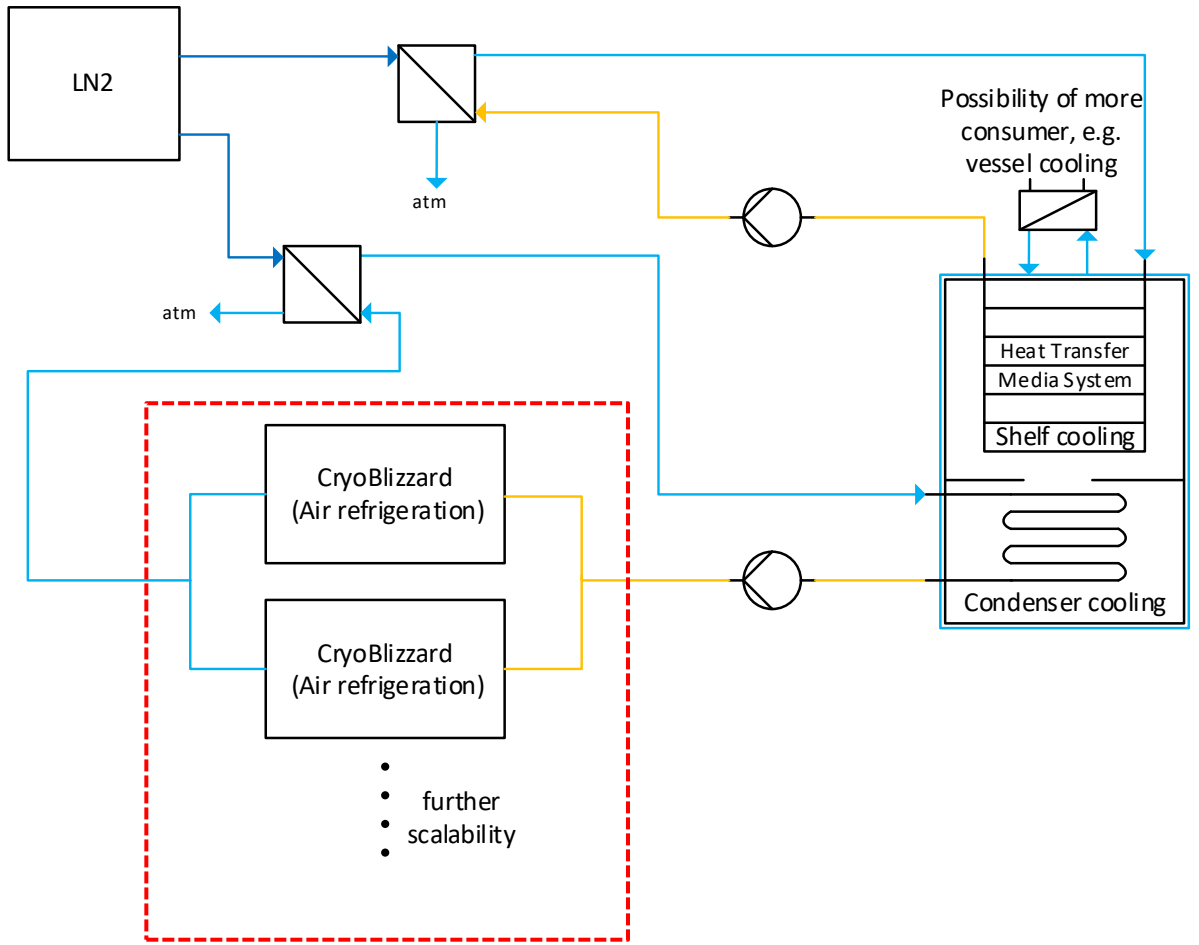
R23 Unit Replacement

- Replacement of R23 Unit with F-Gas-Regulation conform solution: Mirai X Cryo
- Specification:
  - Temperature Control
    - -140 bis +50 °C / +-0,5 K dynamisch
    - In 3 min von -80 °C auf +20 °C
    - In 3 min von +20 °C auf -80 °C
  - Oil Temperature
    - -100 °C up to 45 °C
  - Oil Flow
    - 1350 kg/h
  - Cooling Capacity
    - 5,7 kW @ - 100 °C
  - Size (WxHxD)
    - Ca. 1,6 m x 1,9 m x 1,0 m



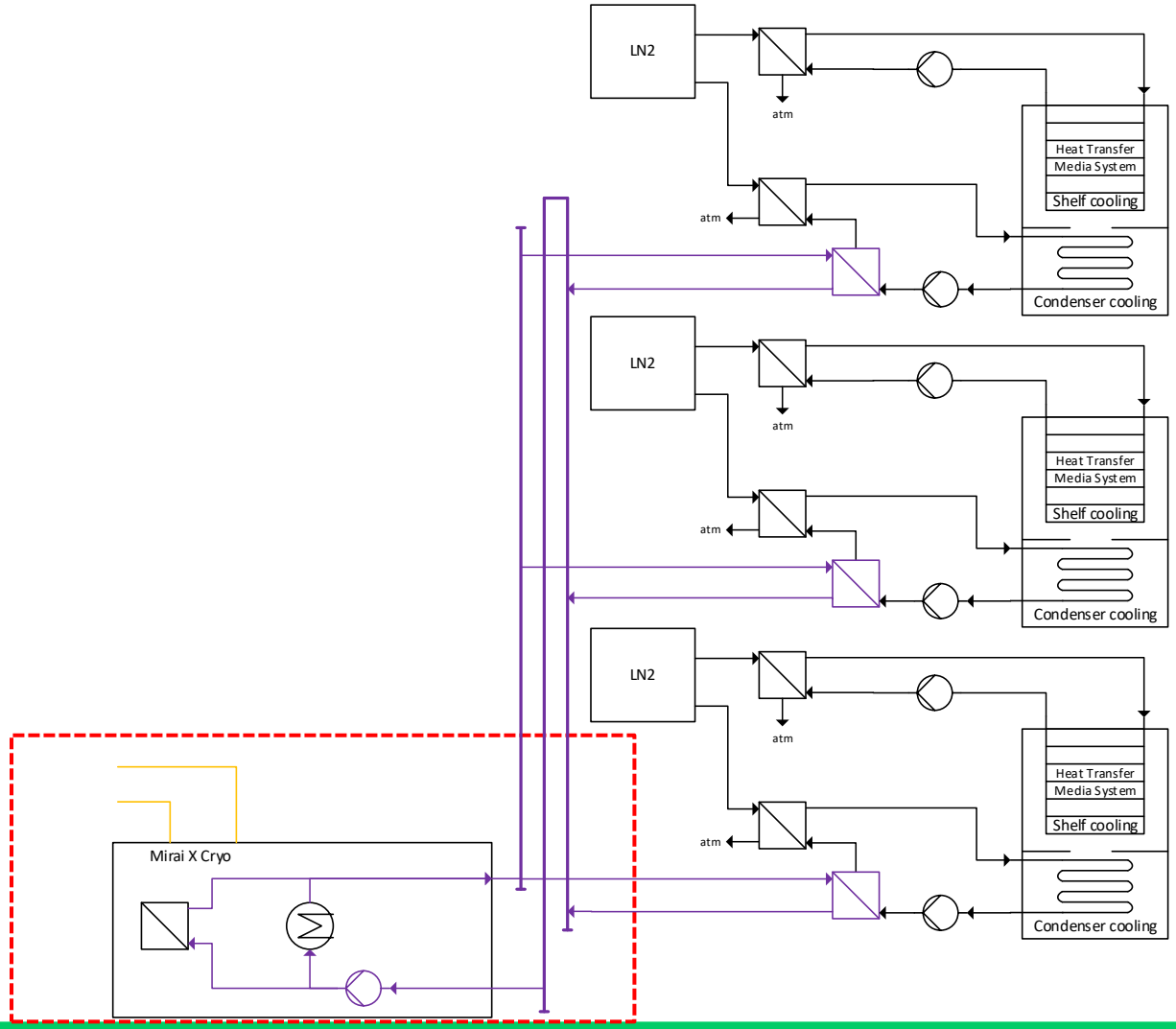
LN2 compensator in installed base

- Reduction of LN2 consumption
  - by integration of air refrigeration
  - cooling capacity in series to LN2 unit
- Use case:
  - Assumptions:
    - MC10 with 5000 h full load operation time (ca. 3,7 kW)
    - 5 days a week with 4 days drying phase
    - Cooling water temperature: 30 °C
    - Oil temperature: -80 °C
    - Cost:
      - Electricity 15 ct/kWh
      - LN2 24 ct/kg
  - Results:
    - Electricity needed:
      - Ca. 64 MWh
    - Savings per year:
      - Ca. 230 t LN2.
      - Ca. 46.000 €
    - ROI in ca. 3,25 years
    - Higher loads and bigger machines decrease the time for ROI



LN2 compensator in installed base

- Reduction of LN2 consumption
  - by integration of air refrigeration
  - cooling capacity in series to LN2 unit
- One Mirai supports multiple freeze driers
  - Advantage:
    - Higher cooling capacity and higher operation time for one machine
    - One big machine sufficient
    - Time for ROI decreases

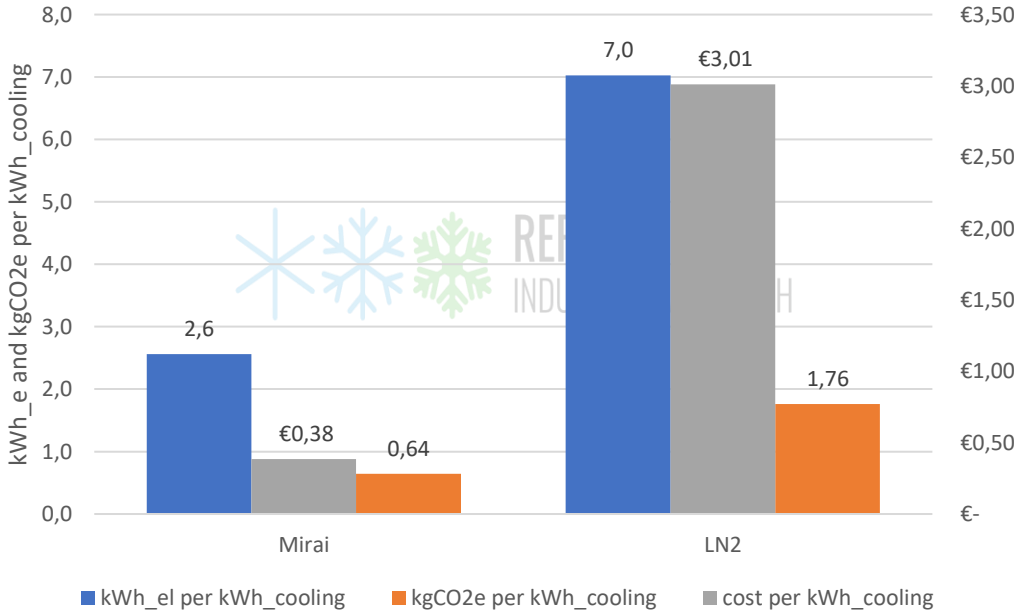


Impact LN2 – CO_2 footprint

- The production of LN2 needs electricity at the air separation and liquefying plant
  - To generate cooling capacity, no electricity is needed at the site of application
- Cold air refrigeration systems need electricity at the site, but specifically much less per kW than LN2
- With the specific CO_2-emissions per kWh in Europe, for each technology a CO_2-footprint per kW of cooling capacity can be calculated

- Results:
  - The cold air technology only needs **2,6 kWh** electricity for 1 kWh cooling capacity, while LN2 needs **7 kWh** electricity
  - The cold air technology has a **>60 % smaller CO_2-footprint** than LN2
  - The cold air technology is **>85% cheaper** in operational costs than LN2

- Assumptions and literature
  - LN2 (0,24 € per kg)
    - Cooling energy in 1 kg LN2: 287 kJ/kg (evaporation from 4 bar storage to 1 bar/-85 °C atm)
    - Necessary energy to produce LN2: 0,56 kWh/kgLN2 (literature: Umweltbundesamt)
    - Transport losses not considered (normally ca. 20 % →20 % higher CO_2-footprint)
  - Cold Air refrigeration/Mirai (0,15 € per kWh_el)
    - EER: 0,39 (MC80, 30 °C cooling water temperature and -80 °C oil temperature at outlet)
  - Facts about carbon footprint of electricity
  - CO2-emissions for 1 kWhel in Europe 251 gCO2e/kWh (2022)
    - https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-14#tab-chart_7



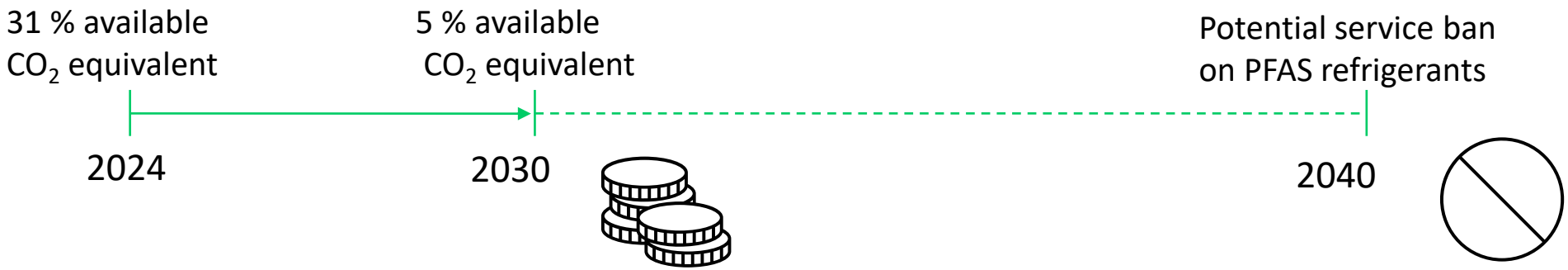
Summary

F-Gase-Regulation (EU) 2024/573

- Sharp price increase for HFC refrigerants with high and medium GWP
- Limited availability of refrigerants with very high GWP
- Obligations & service bans

PFAS-Restriction proposal

- Risk of service bans 12 years after entry into force



Conclusion

Freedom of Operation

Only possible with long-term available and permitted refrigerants

Natural refrigerants without unpredictable risks

For new systems and conversion measures: Check/plan for waste heat utilization

Retrofit Examples for Storage rooms

- Retrofit of existing storage rooms possible
- Temperature stepless from -115 °C to -40 °C
- Procedure:
  - Remove old refrigeration system incl. evaporator
  - Installation of 1+n Air refrigeration machines
    - Attached to side walls with new cuttings
    - Or: Installed on roof with air return collection room
  - Installation of air distribution ducts
  - Installation of air lock cooling system (CO2 or HC-Monoblock)

Advantages and references on the following slides

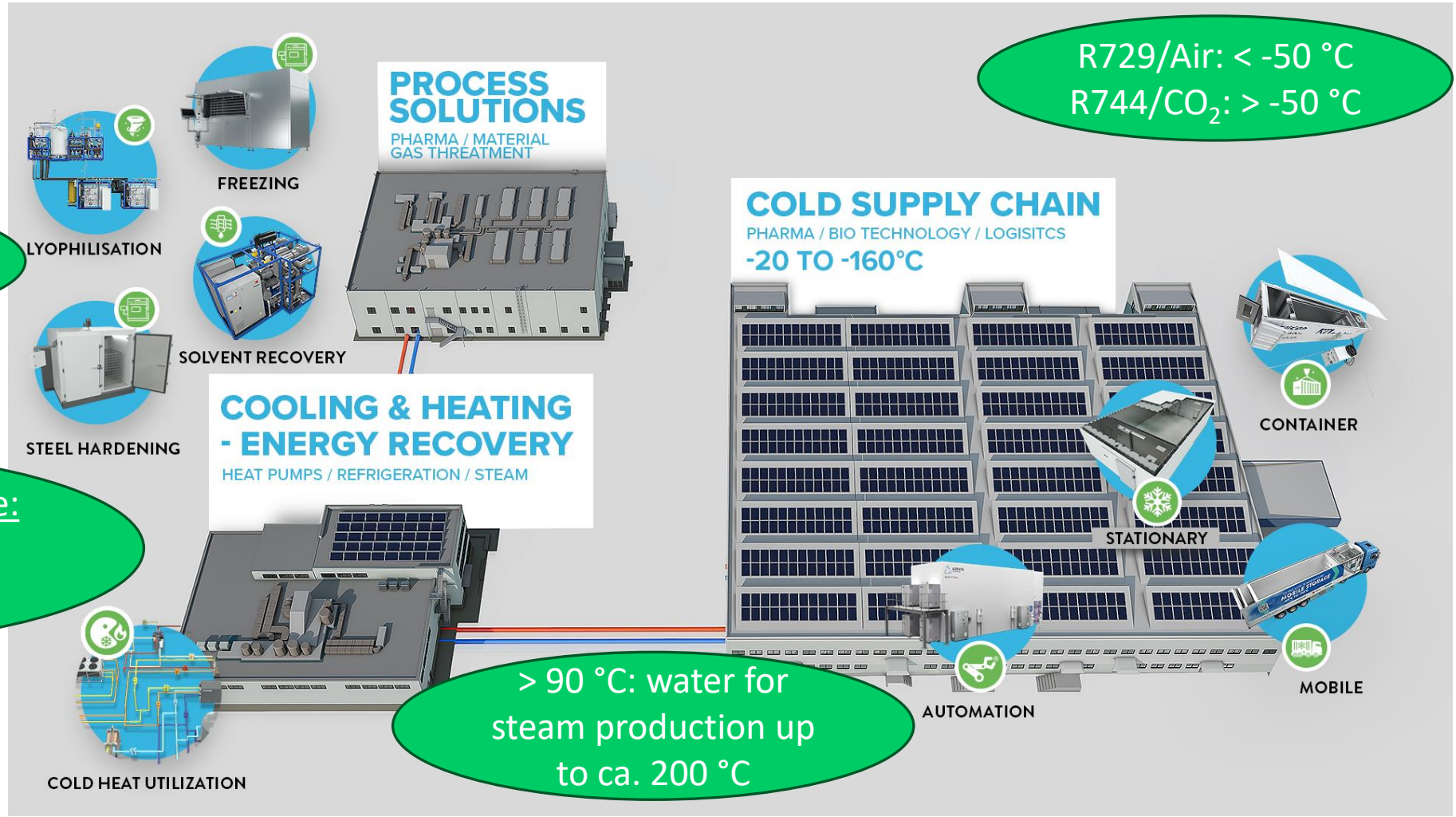
Refolution Portfolio – Recommendation for Refrigerant

< -50 °C: R729/Air

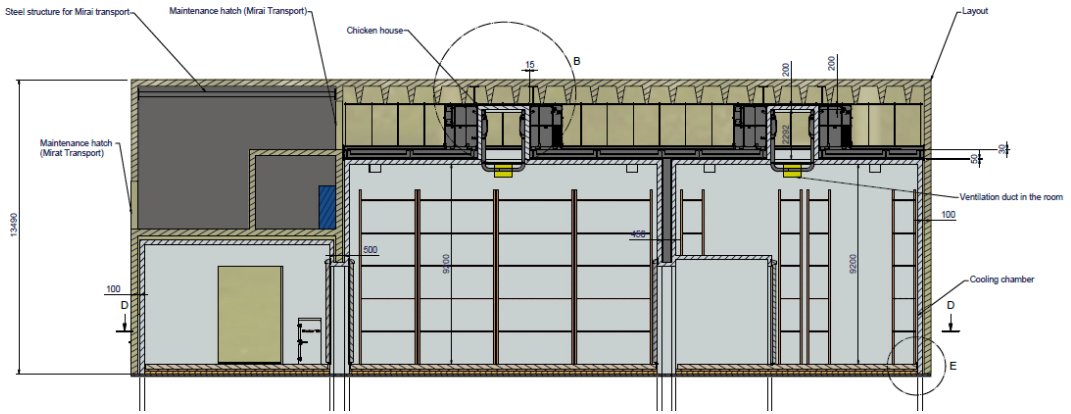
> -40 °C & Large capacity:
Ammonia/R717

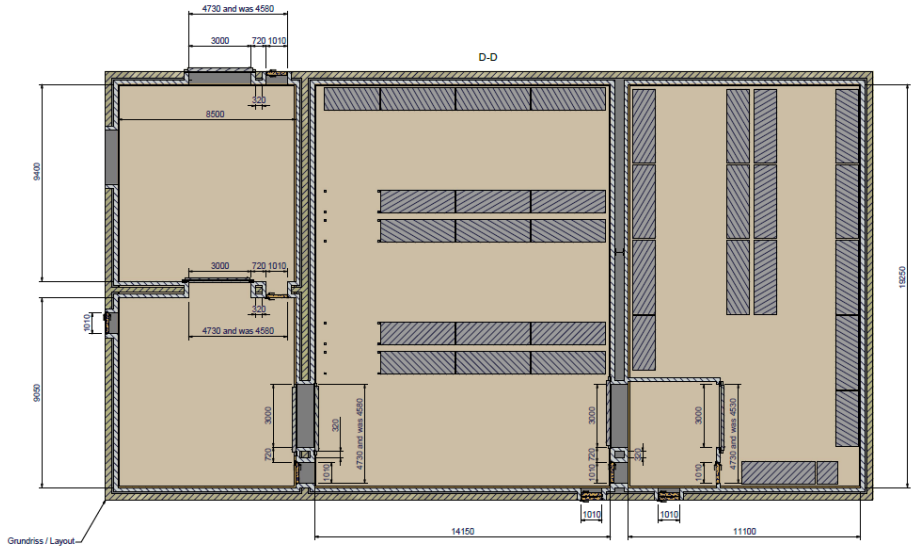
> -50 °C: R744/CO_2

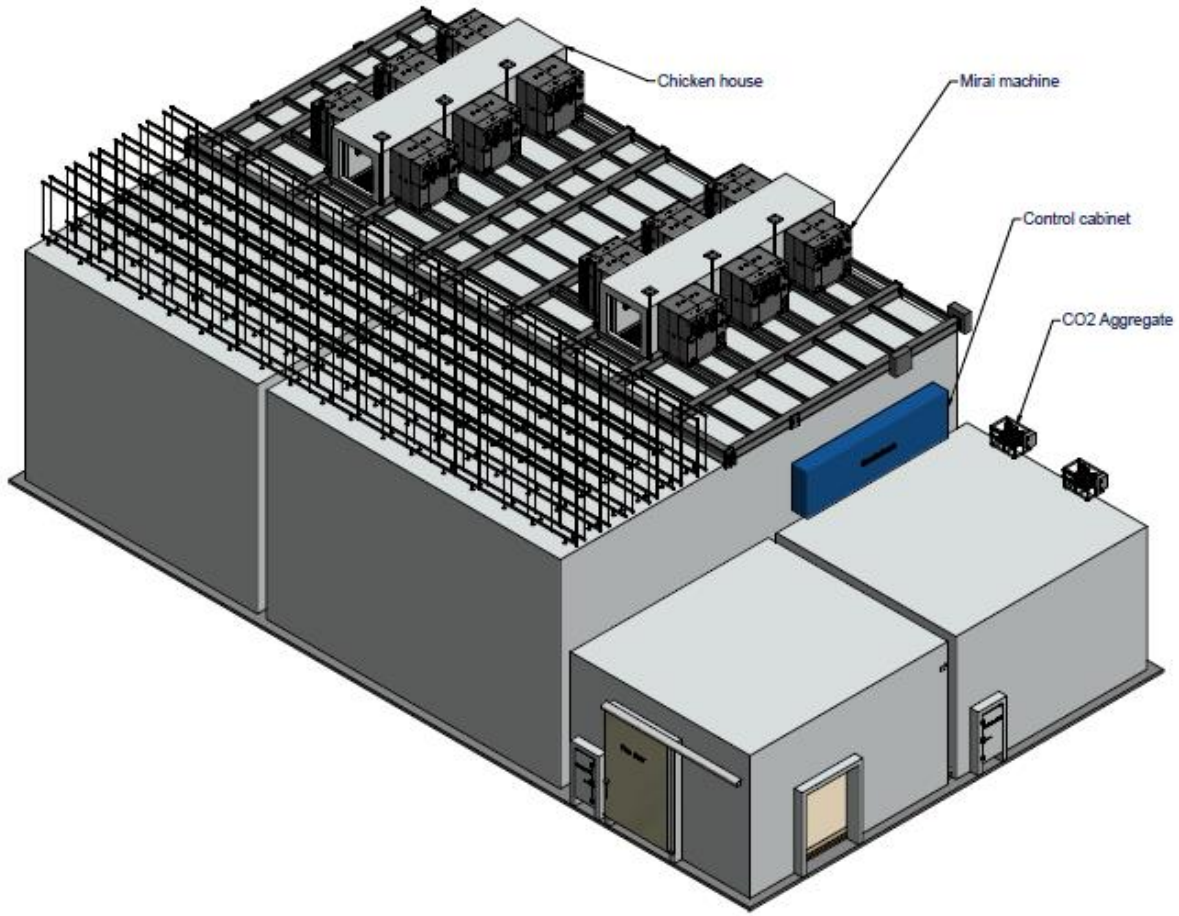
All temperatures & low charge:
Hydrocarbons
R290/ R1270 / R170/R600…



Shelving concept high-bay Storaroom







Automated -80°C Sample Storage System

The BioArc™ Ultra

-80 °C Automated Sample Storage System

77% electricity savings | 73% space savings | 79% lower carbon footprint

compared to the equivalent number of manual freezers when storing 16.92 million 0.9 ml tubes. Please get in touch for more information.

Scan the QR code to access our Savings Calculator and find out how much space, energy, and money you could potentially save with the BioArc™ Ultra compared to a manual freezer collection.

MOST ENERGY-EFFICIENT SYSTEM ON THE MARKET

The lowest power consumption per million tubes

LOWEST CARBON FOOTPRINT ON THE MARKET

The refrigerant gas is natural air, which has 0 Global Warming Potential (GWP) and 0 Ozone Depletion Potential (ODP)

LARGEST SAMPLE STORAGE ON THE MARKET

Can store up to 16.92 million 0.9 ml samples

GxP VALIDATION FOR REGULATED ENVIRONMENTS

IQ, OQ Validation packages and Software supporting CFR21 part 11

FLEXIBLE CHERRY PICKING AND BOX PICKING

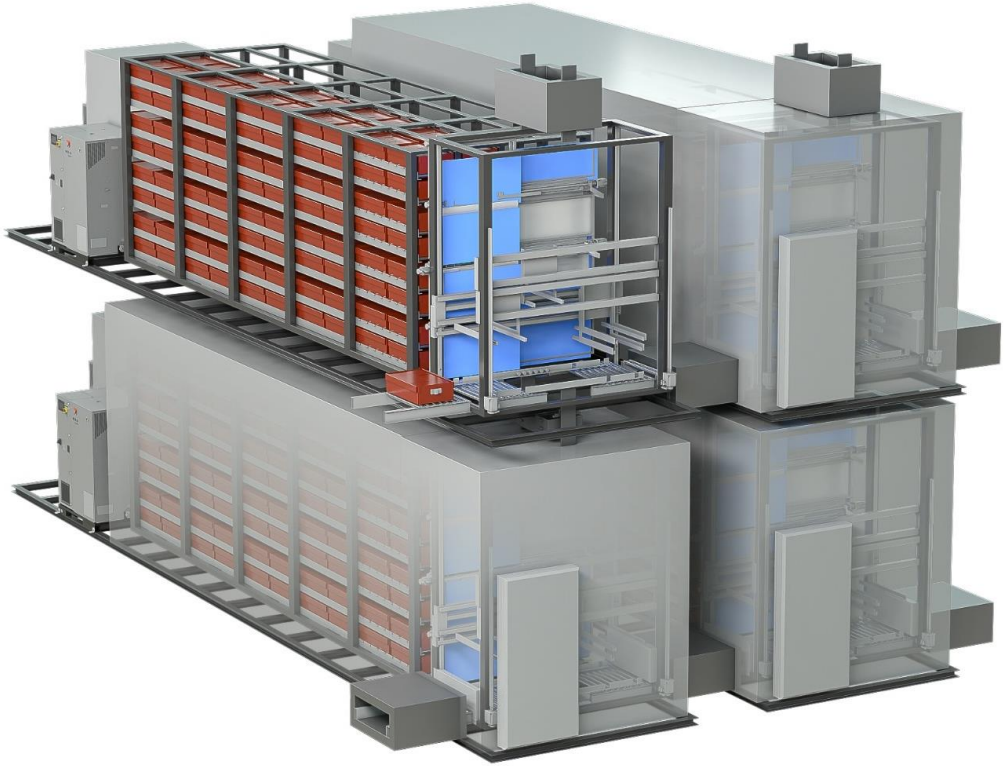
Tubes, cryo-vials, plates, racks, syringes, cryo-boxes, pouches, large bottles, and much more

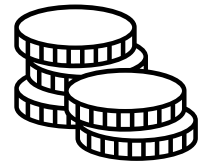
TIME AND LABOUR SAVINGS

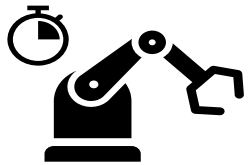
Reduces the amount of time spent locating and moving samples compared to manual freezers

Automated Ultra-Low Temperature High Density storage – ULT HD

The solution is future proof with full flexibility complainant with actual and future regulation to be ready for any kind of medicine that must be frozen, stored and shipped.



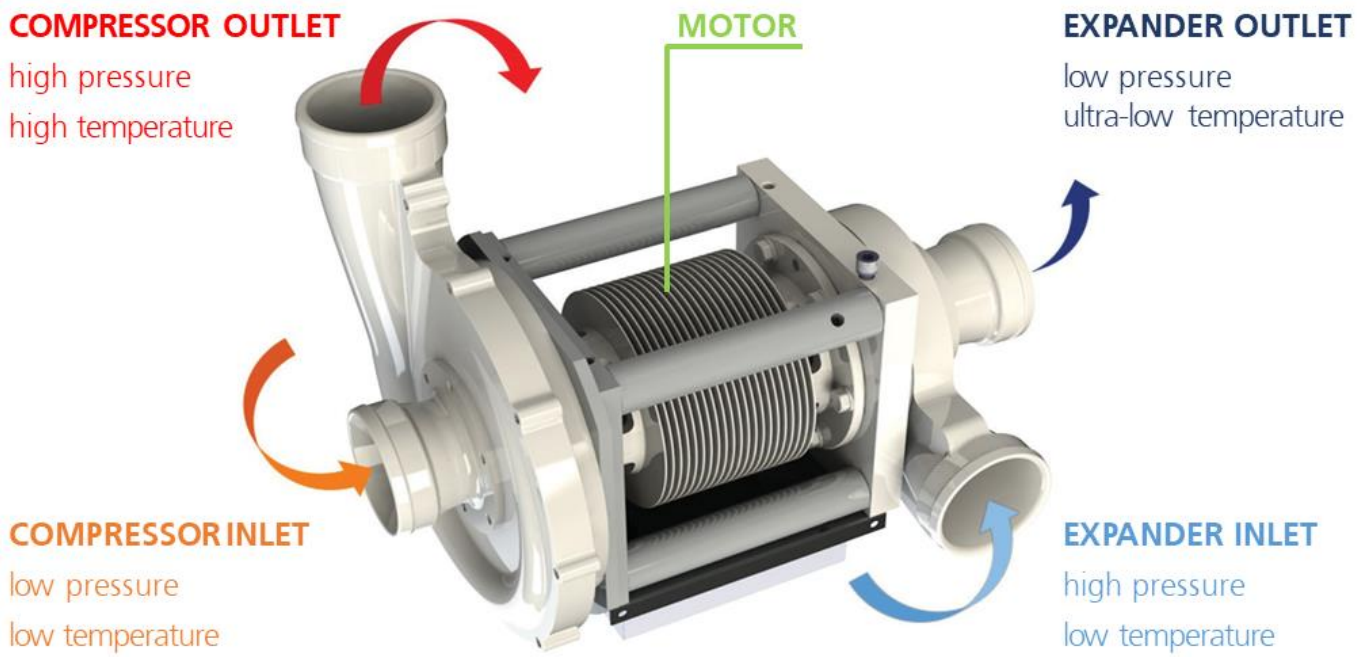


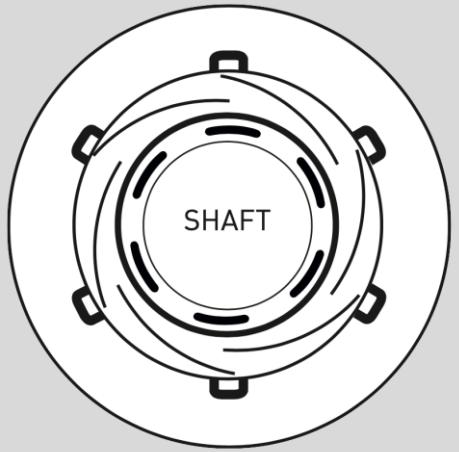


- ✓ Future proof with high flexibility – each module -20°C down to -90°C
- ✓ 70% less space in the building needed
- ✓ 60 % less energy cost and CO2 footprint + reduced labour, qualification and service cost
- ✓ Faster access time
- ✓ Less ice on the product
- ✓ Low maintenance and long-lasting equipment
- ✓ Scalable modular solution also over time

Mirai Turbo-Module

- Compressor and Expander sharing **one shaft**
- Energy **recuperation**
  - Expander → Compressor
  - Up to 30 % of energy savings
- Use of **air bearings**
  - No contacting pairs
  - No oil
  - No wear





Advantages

- **Future-proof**
- **Environmentally friendly**
- **Long lifetime**
- **Fail-Safe**
- **Safe for humans**
- **Maintenance-friendly**
- **Flexible**
- **Efficient**

Open machines

MC10 O/W

MC15 O/A

...

MC22 O/A
02/2021

Closed machines

MC10 C/W/T

MC23 C/W/T

...

MC80 C/W/T
TBA

Retrofit Examples for Heat/ Heat Recovery

180 °C

1. Dampferzeugung
   - Dampferzeugung mit Wärmepumpen auf niedrigem Niveau (ca. 90 - 120 °C)
   - Verdichtung des Dampfs mit Brüdenverdichter (ca. 180 °C)
     - z.B. von Spilling/ Piller Blower
   - Technisch möglich, aber Wirtschaftlichkeit individuell zu prüfen

z.B. Dampfnetze in der Industrie

90 °C

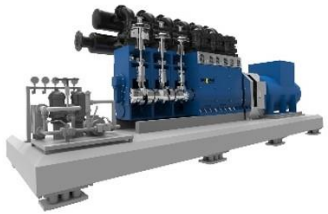
2. Zusätzliche Wärmepumpen
   - Abwärme aus Kälteerzeugung auf höheres Temperaturniveau bringen
   - Aktuell sehr viele Entwicklungen im Bereich Hochtemperaturwärmepumpen

z.B. klassische Heizungen im Bestand

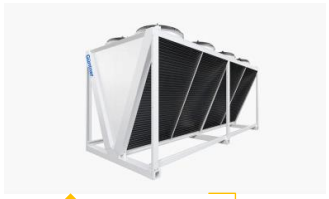
50 °C

3. Vorhandene Kältemaschinen mit höherer Wärmesenkentemperatur nutzen
   - Wärmeübertrager und Anpassung der Regelung

z.B. Niedertemperaturheizungen im Neubau / Renovierter Bestand



Beispiel Warmsolenetz



Rückkühler
(Bestand)

Zusatzwasser
Ṁ = kg/h
p= barg | T = °C

Prozesseitiger
Verbrauch
Dampfnetz

Kondensat
Ṁ = 3575 kg/h
p=1 barg | T = 100°C

Prozessdampf
Ṁ = 3575 kg/h
p=8,5 barg | T = 180 °C

Dampf
Ṁ = 3575 kg/h
p=1 barg | T = 120°C

Speisewasser
Ṁ = 3575 kg/h
p=1 barg | T = °C

Hochtemperatur-
Wärmepumpe
zur Dampferzeugung

Prozess

Prozesswärme
Destillation

Warmwasser
über
Wärmepumpe

Heizwasser
über
Wärmepumpe

Pufferspeicher

NH3 Zentralkälte
(Bestand)

Abwasser-
wärmenutzung
über
Wärmepumpe

Warmsole
Ṁ = kg/h
p= barg | T = +38°C

Legende:

Wärmequelle

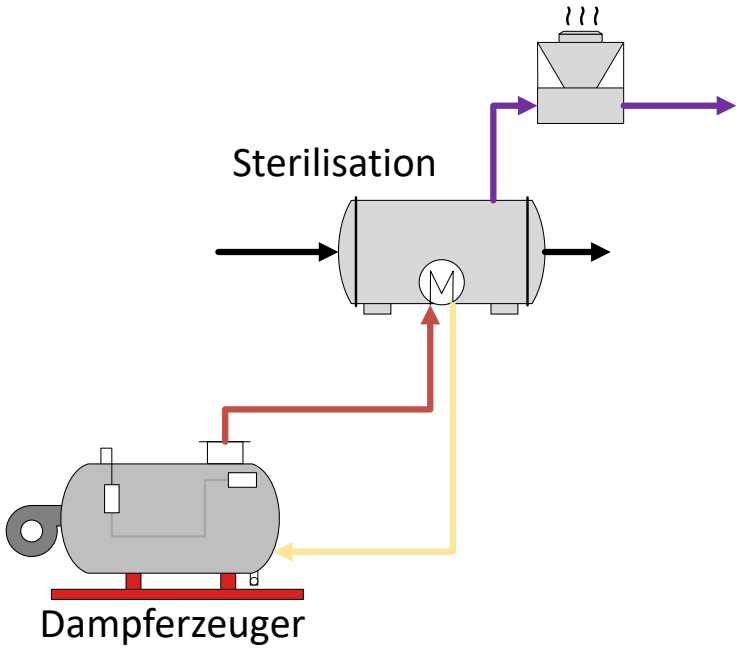
Wärmesenke

Dampf
Kondensat
Zusatzwasser
Speisewasser
Warmsole

Beispiel Sterilisation

Stand der Technik:

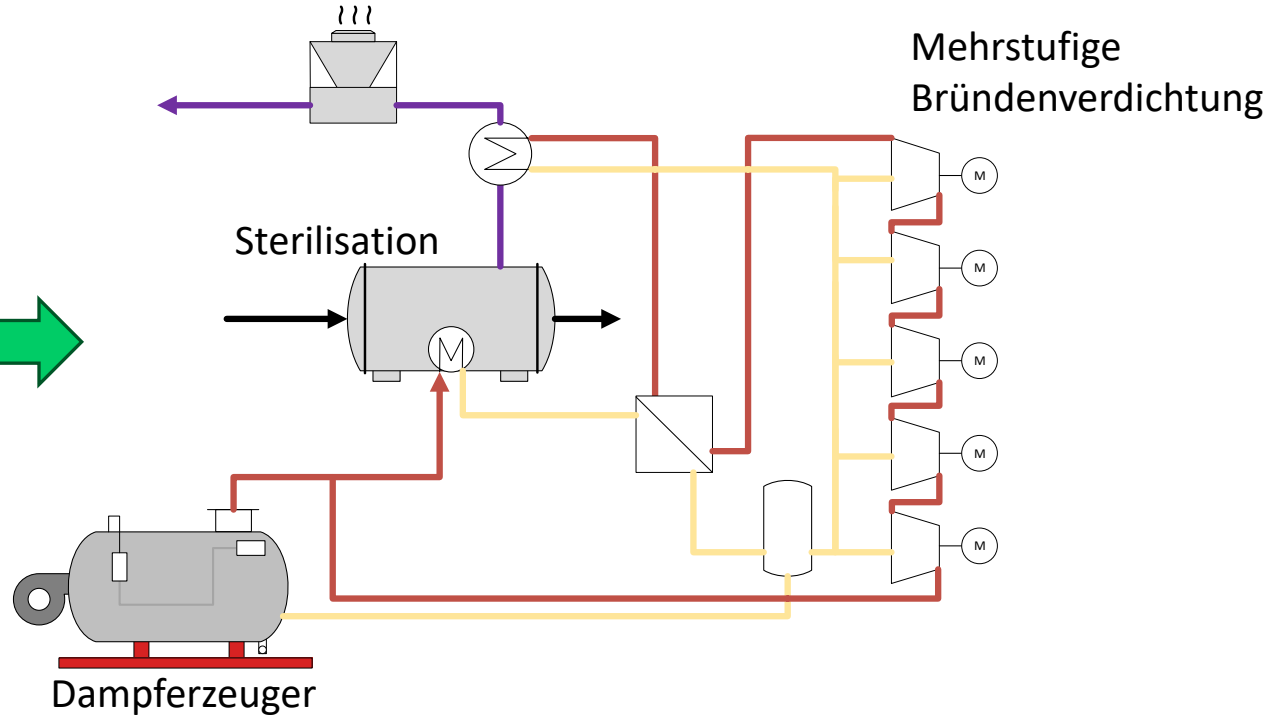
- Erwärmung über fossil erzeugten Dampf
- Abgabe der kompletten Abwärme an Umgebung
- Direkte Nutzung nicht möglich wegen Kontamination



COP = 5

Optimierung:

- Indirekte Erzeugung von Dampf über Abwärme
- Druckerhöhung auf Bedarfsdruck



Kontakt & weitere Angebote

Wir bieten:

- Unternehmensinterne Seminare
  - Vor Ort oder per Online-Schulung
- Beratungen & Planung
  - Unterstützung bei der Einordnung von Bestandsanlagen im Rahmen der F-Gas-Verordnung & PFAS-Thematik
  - Auswahl des Kältemittels
  - Effiziente Neuanlagen und Retrofits angepasst auf Ihren Prozess
  - Konzepte und Potentialanalysen zur Abwärmenutzung
- Sonderanlagenbau & Produktentwicklung
  - Gemeinsame Entwicklung von Produkten, Verfahren und Lösungen
  - Schlüsselfertige Kälteanlagen und Tieftemperaturlagerräumen

Tobias Wurz
Projektingenieur
Refolution Industriekälte GmbH

Tel: +49 17671218755
Tobias.Wurz@refolution.de
www.Refolution.de