Tunca Sekban
Sébastien Casterman
16th October 2018

LONG-TERM SOLUTIONS FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS

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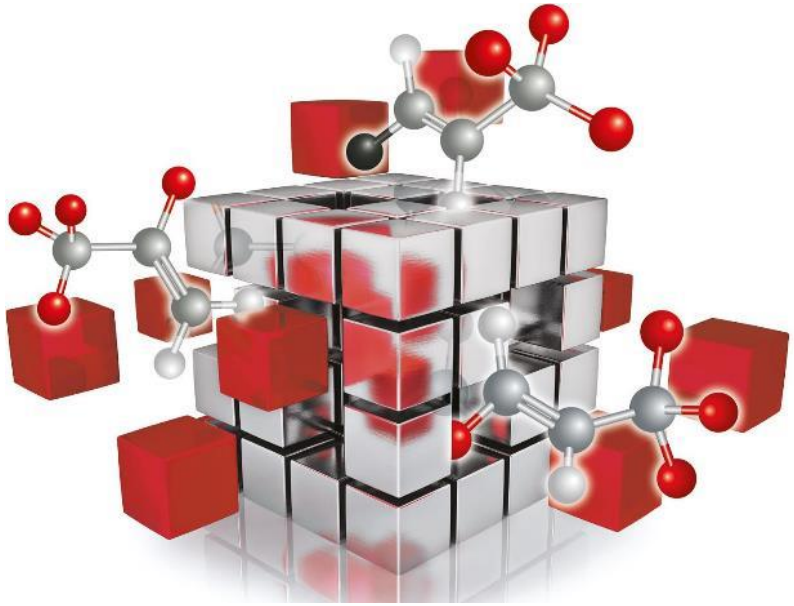
Long-Term Solutions for Refrigeration & AC Systems



Agenda

- **Air-Conditioning**
  - Heat Pumps
  - Split Air-Conditioning
  - VRF & Rooftop Units
  - Chillers
- **Refrigeration**
  - Assessment of Refrigeration Systems
  - Food Service, Cold Rooms
  - Convenience & Forecourt Stores
  - Small/Medium-Size Supermarkets
  - Large Supermarkets
  - Industry
- **Summary**

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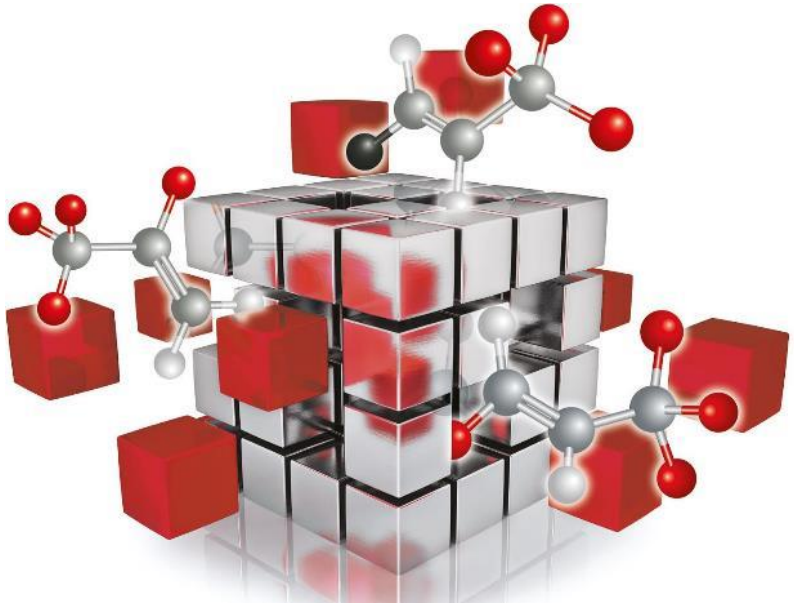

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Solstice® Stationary Platform (Interim <750 GWP)

Air-Conditioning & Heat Pumps

Application	Market Solution	HON Interim Solution	Reason for Refrigerant Choice	Compressor	System Image
Heat Pump Tumble Dryers	**R-134a** GWP = 1430	**Solstice® N13 (R-450A)** GWP = 604	Reduced GWP Lower cost than R-134a Matching performance vs. R-134a	Rotary	
Heat Pumps Water Heaters	**R-134a** GWP = 1430	**Solstice® N13 (R-450A)** GWP = 604	Reduced GWP Lower cost than R-134a Matching performance vs. R-134a	Rotary/Scroll	
Heat Pumps Space Heaters	**R-410A** GWP = 2088	**Solstice® L41y (R-452B)** GWP = 698	Reduced GWP Lower cost than R-410A and N41 Matching performance vs. R-410A Better performance vs. R-32 in heating	Rotary/Scroll	
	R-407C GWP = 1774	**N/A**			
Air-Conditioning (Split)	**R-410A** GWP = 2088	**Solstice® N41 (R-466A)** GWP = 733	Reduced GWP Non-flammability Matching performance vs. R-410A	Rotary/Scroll	
Air-Conditioning (VRF/Rooftop)	**R-410A** GWP = 2088	**Solstice® N41 (R-466A)** GWP = 733	Reduced GWP Non-flammability Matching performance vs. R-410A	Rotary/Scroll	

Compressors currently available

Compressors pending

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Solstice® Stationary Platform (Interim <750 GWP)

Chillers & ORC

Application	Market Solution	HON Interim Solution	Reason for Refrigerant Choice	Compressor	System Image
Chiller Low Pressure (Indoor/Outdoor)	**N/A**	**Solstice® zd (R-1233zd)** GWP = 1	Ultra low GWP Non-flammability Higher efficiency vs. R-1234ze	Centrifugal	
Chiller Mid Pressure (Outdoor)	**R-134a** GWP = 1430	**Solstice® ze (R-1234ze)** GWP < 1	Ultra low GWP Higher efficiency vs. R-134a	Screw	
Chiller Mid Pressure (Indoor)	**R-134a** GWP = 1430	**Solstice® R-515B** GWP = 293	Reduced GWP Non-flammability Higher efficiency vs. R-134a	Screw	
Chiller High Pressure (Outdoor)	**R-410A** GWP = 2088	**Solstice® L41y (R-452B)** GWP = 698	Reduced GWP Lower cost than R-410A and N41 Matching performance vs. R-410A	Scroll	
	R-407C GWP = 1774	**N/A**	**N/A**		
Chiller High Pressure (Indoor)	**R-410A** GWP = 2088	**Solstice® N41 (R-466A)** GWP = 733	Reduced GWP Non-flammability Matching performance vs. R-410A	Scroll	
	R-407C GWP = 1774	**N/A**	**N/A**		
ORC	**R-245fa** GWP = 1030	**Solstice® zd (R-1233zd)** GWP = 1	Ultra low GWP Higher efficiency vs. R-1234ze Non-toxicity	Turbine/Expander	

Compressors currently available

Compressors pending

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Solstice® Stationary Platform

AC, Heat Pumps & Chillers

Solstice® N13 (R-450A)

- HON solution replacing R-134a in heat pump and chillers
- ~60% reduction in GWP (GWP=604)
- Matching properties with R-134a
- Favourable price vs. R-134a
- Compressors available for different applications

Solstice® L41y (R-452B)

- HON solution replacing R-410A in heat pump and chillers
- ~65% reduction in GWP (GWP=698)
- Matching properties with R-410A
- Favourable price vs. R-410A
- Compressors available for different applications

Heat pump / Chiller Applications

Heat Pumps & Chillers

Chillers with Solstice® L41y (R-452B)

Heat Pump Tumble Dryers with Solstice® N13 (R-450A)

Solstice® Stationary Platform (Long Term <150 GWP*)

Air-Conditioning & Heat Pumps

Application	Market Solution	HON Long Term Solution	Reason for Refrigerant Choice	Compressor	System Image
Heat Pump Tumble Dryers	**R-134a** GWP = 1430	**Solstice® R-515B** GWP = 293	Non-flammability Very low GWP Higher efficiency vs. R-134a	Rotary	
Heat Pumps Water Heaters	**R-134a** GWP = 1430	**Solstice® L40X (R-455A)** GWP = 148	Ultra low GWP Higher capacity/efficiency vs. R-134a Higher water temperature vs. R-134a	Rotary/Scroll	
Heat Pumps Space Heaters	**R-410A** GWP = 2088	**Solstice® L40X (R-455A)** GWP = 148	Ultra low GWP Higher efficiency vs. R-410A and R-32 Higher water temperature vs. R-410A and R-32	Rotary/Scroll	
	R-407C GWP = 1774	**Solstice® L40X (R-455A)** GWP = 148	Ultra low GWP Higher efficiency vs. R-407C Higher water temperature vs. R-407C		
Air-Conditioning (Split)	**R-410A** GWP = 2088	**Solstice® yf (R-1234yf)** GWP = 1	Ultra low GWP Higher capacity vs. R-1234ze	Rotary/Scroll	
Air-Conditioning (VRF/Rooftop)	**R-410A** GWP = 2088	**Solstice® ze (R-1234ze)** GWP < 1	Ultra low GWP Lower cost vs. R-1234yf	Rotary/Scroll	

*Where regulations do not allow A2L, an A1 <300 GWP solution is offered

GWP of zd/ze (exempt from F-Gas) has been shown according to AR5

Compressors currently available

Compressors pending

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Solstice® Stationary Platform (Long Term <150 GWP*)

Chillers & ORC

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GWP of zd/ze (exempt from F-Gas) has been shown according to AR5

Compressors currently available

Compressors pending

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First HFO Chiller

- Developed by Geoclima in 2010
- Using R-1234ze(E) to replace R-134a
- Used for a water loop in a UK supermarket
- In operation since 2011 and no issues reported
- Geoclima reported 3.5% better COP on average vs equivalent R-134a chiller
- More efficient than the HC version used by the same supermarket chain
- Geoclima has optimized HFO based chiller designs, now offering a full range of chillers using R-1234ze

GVAF Air Cooled Chillers R-134a vs R-1234ze(E)

Model Name	GVAF XP 245 LN	GVAF XPG 245 LN	
Refrigerant	R-134a	R-1234ze	
GWP	1300	<1	-99.9%
Cooling Capacity (kW)	878	878	
EER	3.48	3.72	+6.9%
ESEER	5.30	5.65	+6.6%
Power Consumption (kW)	252	236	

Source: www.eurovent-certification.com

- Efficiency, an important criteria in chiller selection

Channel Tunnel Application

The largest HFO chiller installation of its kind in the world, Trane CenTraVac's using R-1233zd(E) replace the existing R-22 chillers serving the Channel Tunnel.*

- R-1233zd(E) chosen for the renovation of the channel tunnel refrigeration system
- 4 New R-1233zd(E) Chillers replaced R-22 old system
- Each chiller providing 14MW cooling load, to maintain tunnel temperature below 25°C
- 33% drop in energy usage – 500.000€ savings in 2017

* http://www.coolingpost.com/world-news/hfo-chillers-to-cool-the-channel-tunnel/

Eurocontrol Application

The Quantum ‘G’ Water cooled chiller

- Eurocontrol’s headquarters, flight management and data center facilities in Brussels was equipped lately with a new cooling system based on R-1234ze(E) technology
- Quantum® cooling systems produced by ENGIE Axima are designed with oil-free, magnetic-bearing centrifugal compressors replacing an older R-22 system
- The first results indicate that the cooling system’s design helps achieve annual energy savings up to 1,500 MWh and reduce EUROCONTROL’s total annual consumption by more than 12 percent, helping EUROCONTROL save up to €150,000 per year on energy costs.

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Kirloskar HFO Chiller

Kirloskar water cooled R-1234ze(E) chiller

Kirloskar initial test results

- Kirloskar is one of the leaders in chiller technology in India and has developed a new chiller based on R-1234ze(E)
- Equipped with screw compressor, water-cooled condenser and flooded shell & tube evaporator. It chills water at delta t of 5 K
- Chiller is little less on capacity but matches the efficiency of R-134a chiller with significant reduction in compressor power

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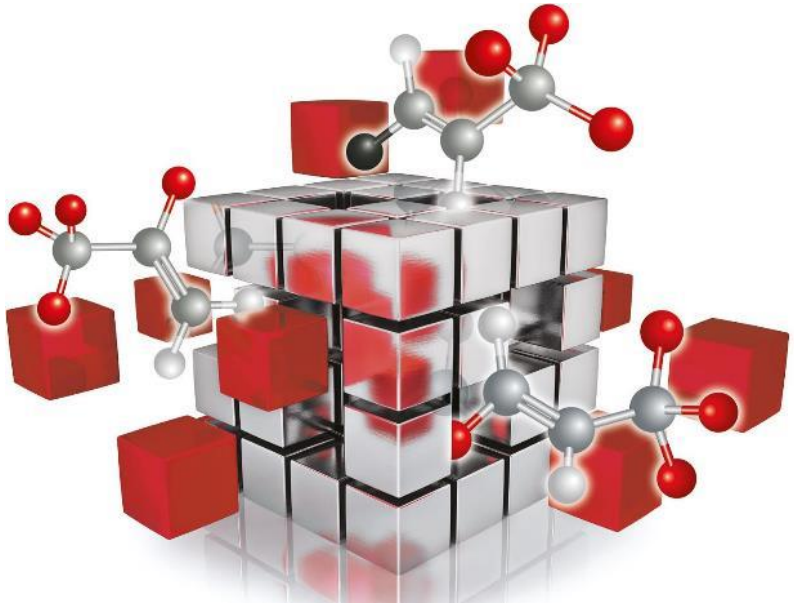
Long-Term Solutions for Refrigeration & AC Systems



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Assessment of Refrigeration Systems

- There is no single refrigerant solution for all applications
- The focus needs to shift away from the refrigerant only, towards the combination system + refrigerant
- Systems are evolving based on the possibilities and opportunities offered by each refrigerant
- What aspects should be considered to assess impact of any refrigeration system or installation?
  - **Environmental parameters**
    - Direct emissions (coming from leaks) expressed in ton of CO_2 eq. throughout life span of the refrigeration installation
    - Indirect emissions, coming from CO_2 emissions through the energy production necessary for the installation to be operated, expressed in tons of CO_2 throughout life span of the refrigeration installation
  - **Financial parameters (for the end user of the installation)**
    - CAPEX
    - OPEX (including maintenance, refrigerant top-off, repairs throughout life span of refrigeration installation)
  - **Safety Risk**

		% of capture of impact	
	Metric type	Environmental	Financial
GWP	1 dimension	up to 35%	0%
TEWI	1 dimension	up to 95%	0%
LCCP	1 dimension	up to 100%	0%
Eco-Efficiency	2 dimensions	up to 95%	up to 100%

Make sure to use the most eco-efficient „system + refrigerant“

Food Service, Cold Rooms

Typical Examples of Systems

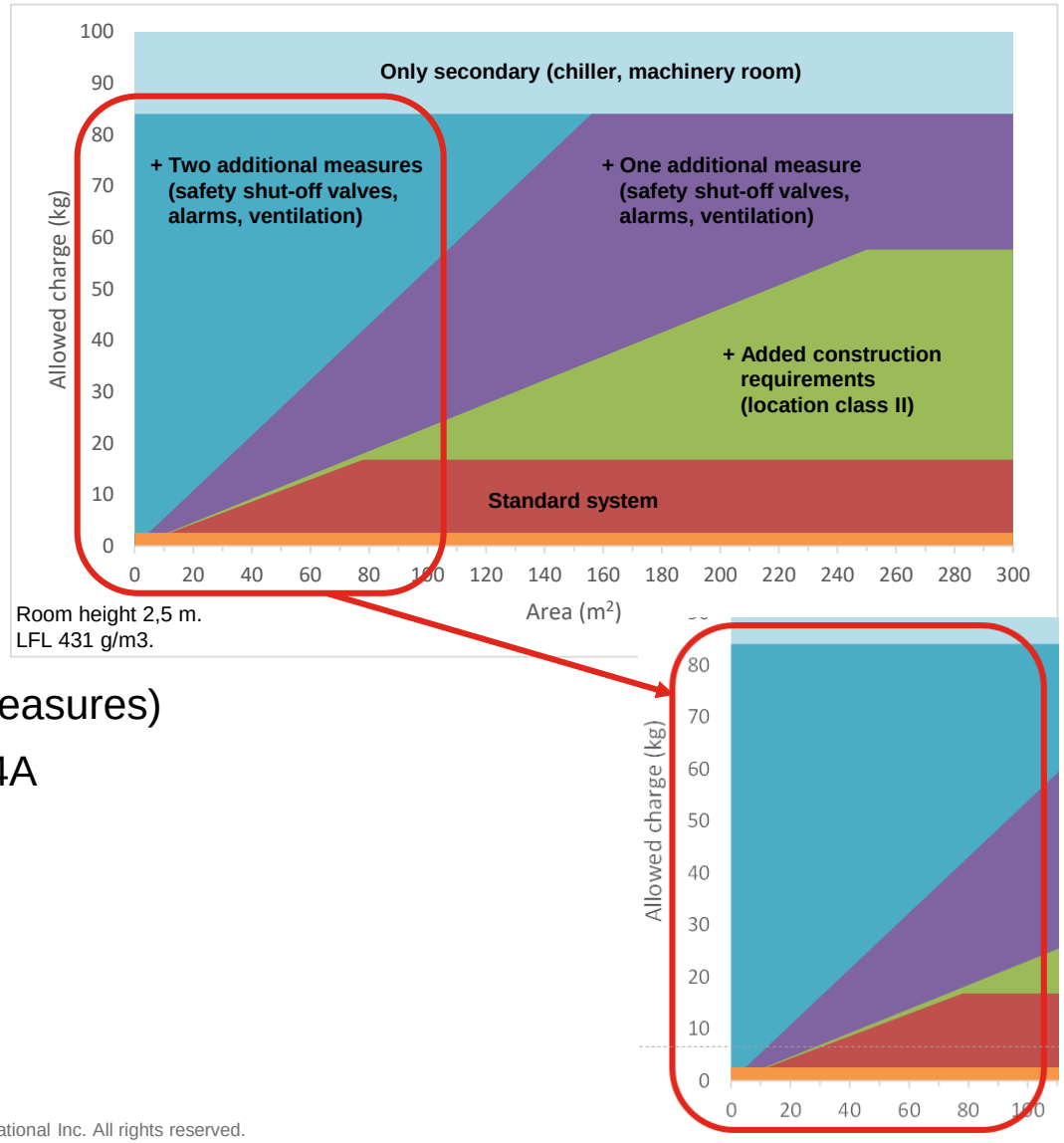
- **Condensing Units**
- **Monoblock Systems**

Recommended Refrigerant Solution

Solstice® L40X (R-455A)

Key Benefits System + Refrigerant

- EN 378: Direct expansion possible in public buildings with up to 84 kg of R-455A per circuit (with 2 additional safety measures)
- High efficiency in medium- & low-temp, comparable with R-404A
- Higher capacity per circuit vs. R-290 and lower safety risk
- Cost comparison vs. R-744 condensing units (MT) result in:
  - ca. 46% lower CAPEX
  - ca. 36% lower OPEX (calculated for 15 years life span for average European ambient temperatures)
- Eco-Design: GWP<150 gives access to reduction of MEPS

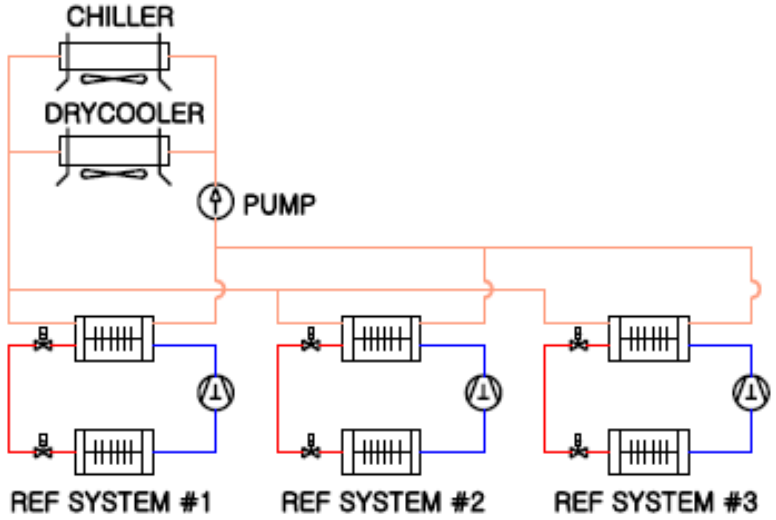


Solstice L40X (R-455A) covers most capacity requirements

Convenience & Forecourt Stores

Example of System/Architecture

Waterloop-cooled stand-alone units with heat recovery



Recommended Refrigerant Solution

Solstice® L40X (R-455A)

Key Benefits System + Refrigerant

- EN 378: Charge up to 2,6 kg possible in public buildings without room size constraints nor additional measures
- Higher capacity per circuit vs. R-290 and lower safety risk
- Simplicity & speed of system construction vs. R-744 systems (reduced store downtime: faster store opening)
- Simplicity, safety & speed of maintenance vs. R-744 and R-290 systems
- Smaller systems allow for significantly reduced power consumption peaks & lower price per kWh for the operator
- R-455A is versatile and covers whole temperature range: low-temp, medium-temp and AC/heating chiller
- Evacuation of condensation heat from stand-alone systems i.e., lower load on AC system in warm periods, and lower load on heating system in cold periods (lower OPEX)

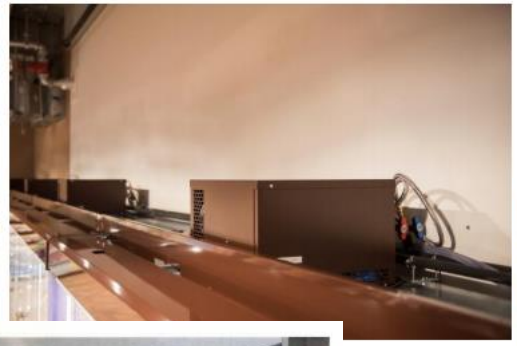
Safe, simple, flexible and cost-effective solution

Convenience & Forecourt Stores

FINALIST

References

- **KMW Limburg:** Available (**booth 6-126**)



KMW KÜHLMÖBELWERK Qualität aus Deutschland

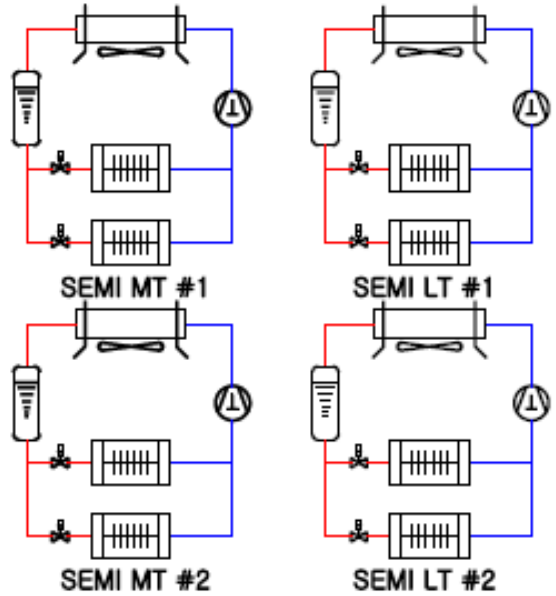
proKlima

Several retailers and forecourt stores confirmed implementation

Small/Medium-Size Supermarkets

Example of System/Architecture

Distributed architecture based on condensing units



Recommended Refrigerant Solution

- **Solstice® L40X (R-455A)**
- **Solstice® N40 (R-448A) / N13 (R-450A)**

Key Benefits System + Refrigerant (R-455A)

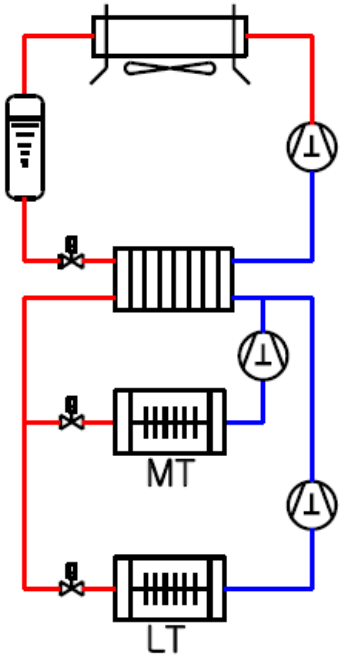
- Covers both low- & medium-temp with GWP<150 (similar to R-448A)
- EN 378: Charge up to 57,7 kg possible in public buildings if outdoor condensing units (min. 625 m^3 room volume) or up to 84 kg per circuit (with 2 additional safety measures) - this reduces the number of circuits to be built (lower CAPEX & OPEX)
- Higher capacity per circuit vs. R-290 and lower safety risk
- Lower cost & higher efficiency vs. centralized R-744 systems (specific set point for each cluster of cabinets allow for optimized working conditions hence efficiency)
- Architecture allows for higher flexibility vs. centralized system architectures (store set-up configuration, replacement of failing units, potential food loss)

Solstice L40X (R-455A) enables optimization of system decentralisation

Large Supermarkets

Recommended System/Architecture

Cascade architecture



Recommended Refrigerant Solution

Solstice® ze & R-744

Key Benefits System + Refrigerant

- Full coverage of refrigeration, heating, AC and hot water through properties of R-1234ze
- R-1234ze: PED Group 2 & higher COP than R-134a
- Better efficiency in medium & high ambient conditions when compared with transcritical R-744 systems
- Subcritial installation: simplicity & lower cost of system construction and maintenance vs. transcritical R-744 systems
- GWP<1, no F-Gas constraints (R-1234ze is not GHG)
- Risk assessments ongoing to determine max. allowed charge of R-1234ze in DX (no charge limitation if in machinery room)

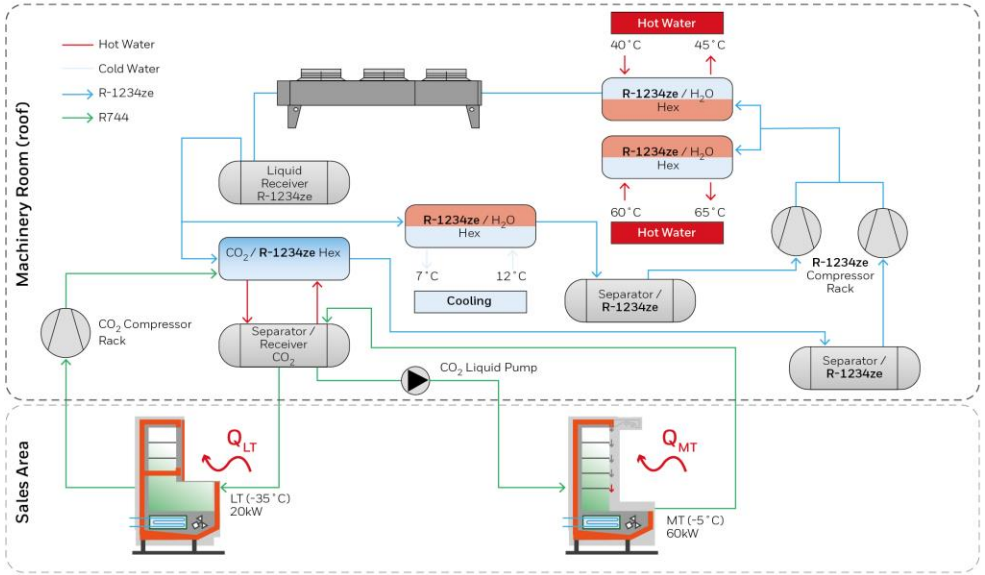
Simplicity and maximum efficiency for large centralized systems

Large Supermarkets

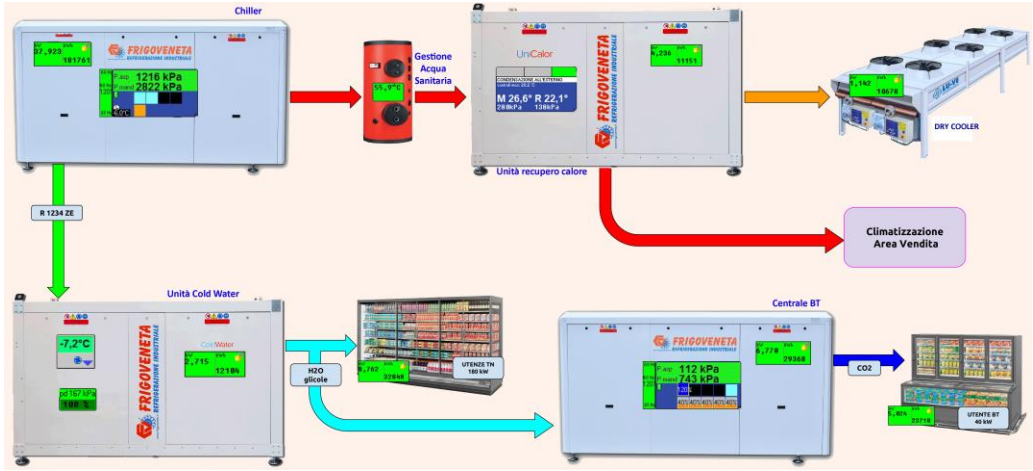
References

- **U2/UNES Supermarket (Parma, Italy)**
  - Commissioned Dec 2014
  - Operating & maintenance costs reduced by ~15,000 €/year *
  - Energy consumption reduced by ~35% *
  - Compact system design: Increase sales floor area

  * *When compared to standard 3-system architecture (Ref DX + HVAC + Gas HW)*



- **Famila & Mega Supermarkets (Italy)**
  - 4 stores commissioned in Sep 2018 by Frigoveneta
  - Chiller R-1234ze (ca. 80 kg)
  - Glycol for medium-temp (180 kW) / R-744 for low-temp (40 kW)
  - Energy consumption optimization thru :
    - Recovery of waste heat from cooling (AC + sanitary hot water)
    - Central regulation of all HVAC loads (heat pump, air treatment, fans)
    - Central management of lighting loads & FM



ALFA PROJEKT

FRIGOVENETA REFRIGERAZIONE INDUSTRIALE

Industry

Example of System/Architecture

Process Chiller

Recommended Refrigerant Solution

Solstice® ze

Key Benefits System + Refrigerant

- More compact system design vs. R-717 chillers: Lighter & lower CAPEX
- Simplicity & lower cost of system construction, operation and maintenance
- Efficiency comparable with R-717 systems
- Lower safety risk vs. R-717 chillers
- GWP<1, no F-Gas constraints (R-1234ze is not GHG), PED group 2
- EN 378: No charge limitations in most cases (room occupancy/access & system location)

HFO refrigerants offer more options for industrial applications

Industry

References

- **Zimavi Vegetable Processing (Alicante, Spain)**
  - 2 cold rooms (@1ºC) + 1 refrigeration tunnel (from 25ºC to 2ºC) / 250 kW
  - Chiller R-1234ze from Geoclima + heat transfer fluid Temper
  - Consultancy/Contracting: Frimavi
  - 20% lower investment & 70% lower operation cost than for a corresponding R-717 installation
  - COP similar to corresponding R-717 installation (similar operating conditions)

- **Quercy Refrigeration (South-West France)**
  - Fruit storage & processing
  - COP higher than for the R-717 chillers, through the use of air-cooled DX condensers (upwards waste heat recovery)
  - 50% lower CAPEX vs. similar R-717 chillers
  - Lower noise level
  - Compressors for R-1234ze are tight compared with compressors for R-717 systems

Lower safety risk and costs with long-term refrigerant solution

Honeywell Solutions for New Refrigeration Systems

<table>
<tr><th colspan="2"></th><th>Food Service, Cold Rooms</th><th>Convenience & Forecourt Stores</th><th>Small/Medium-Size Supermarkets</th><th>Large Supermarkets</th><th>Large Industrial</th><th>Refrigerated Transport</th></tr>
<tr><td colspan="2">Self-contained, integral systems Low- & Medium-Temp (Plug-ins)</td><td colspan="4">Solstice® L40X (R-455A)</td><td></td><td></td></tr>
<tr><td rowspan="3">Condensing Units</td><td>Compressor below 2 HP</td><td colspan="2">Solstice® L40X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Compressor between 2 and 10 HP</td><td></td><td colspan="2">Solstice® L40X
(if charge size allowed by EN378 and/or risk assessment)
Otherwise: Solstice® N40 or Solstice® N13</td><td></td><td>Solstice® L40X</td><td></td></tr>
<tr><td>Compressor above 10 HP</td><td></td><td></td><td></td><td></td><td>Solstice® L40X</td><td></td></tr>
<tr><td colspan="2">Waterloop Systems</td><td></td><td colspan="2">Solstice® L40X</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Monoblock Systems</td><td colspan="2">Solstice® L40X</td><td></td><td></td><td>Solstice® L40X</td><td>Solstice® L40X</td></tr>
<tr><td>Centralized systems</td><td>System cooling capacity above 40 kW</td><td></td><td></td><td colspan="2">Today: cascade
Solstice® ze/R-744
Tomorrow: “Solstice® zd loop / Solstice® L40X”</td><td>Process chillers:
Solstice® ze/zd</td><td></td></tr>
</table>

Solstice refrigerants for all systems and segments

Summary

- HFO solutions represent an optimum in terms of efficiency (TEWI), capacity, safety risk & total cost of ownership in many applications and systems
- Honeywell has developed interim and long-term refrigerants which can cover most systems and applications
- **Solstice N13 & Solstice L41y:**
  - Used in various heat pump and chiller applications today
  - Provide interim solutions for R-134a and R-410A equipment to reduce their GWP without significant design changes
- **Solstice® L40X (R-455A):** F-Gas compliant refrigerant for Low-, Medium- & High-Temp in refrigeration, heat pumps and chillers
  - Its extremely low flammability is a key differentiator vs. hydrocarbons; the high LFL enables higher max. charges according to EN 378 and is a key differentiator vs. other A2L's
  - Its high efficiency in Medium- & Low-Temp, also in small capacities, is a key differentiator vs. R-744
- **Solstice ze & Solstice zd:**
  - Widely used in chiller applications today; optimal & safe solutions for cascade in retail & industrial refrigeration
  - A1 Solstice zd provides an ideal solution for centrifugal chillers with high EUR/kWh
  - PED 1 category of Solstice ze (nonflammable below 30°C) reduce the equipment design cost significantly

Solstice refrigerants with GWP<150: the future of AC & refrigeration… now!

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