

ENGINEERING
TOMORROW

Solutions for **Energy Efficient Air Conditioning Systems**

Rupesh Patil, Business Development Manager – APA

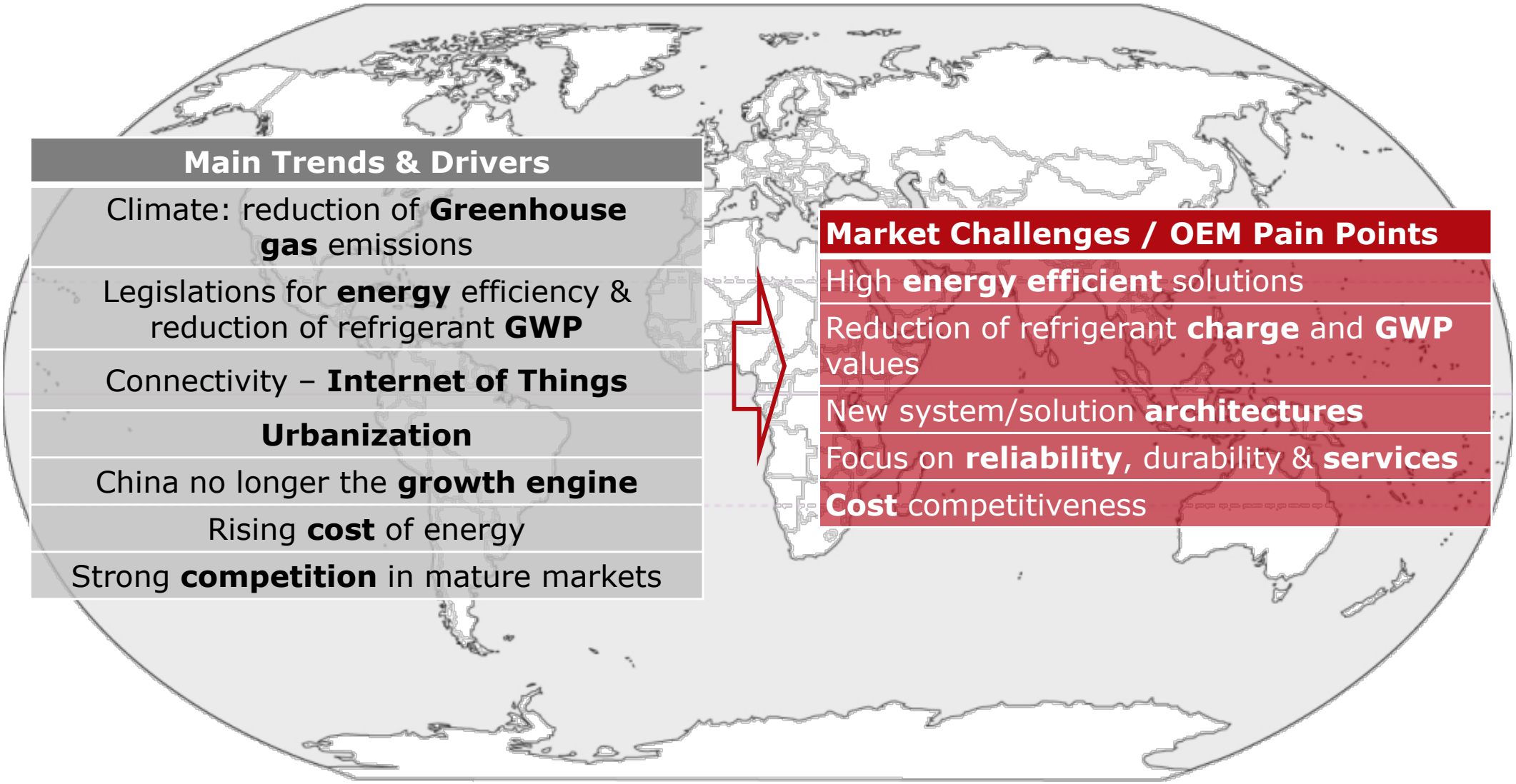
www.danfoss.com



Content

- HVAC global trends and drivers
- HVAC legislations
- Refrigerants trends
- Solutions for superior part load efficiency
  - Manifolding
  - Intermediate Discharge Valve technology
  - Inverter scroll technology
- Scroll chiller V/s Screw chiller in medium size capacity

HVAC/R Main Trends & Drivers

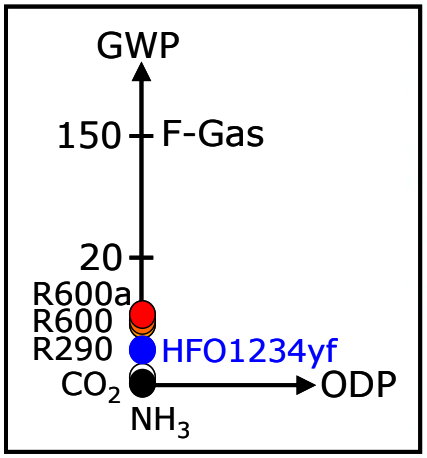


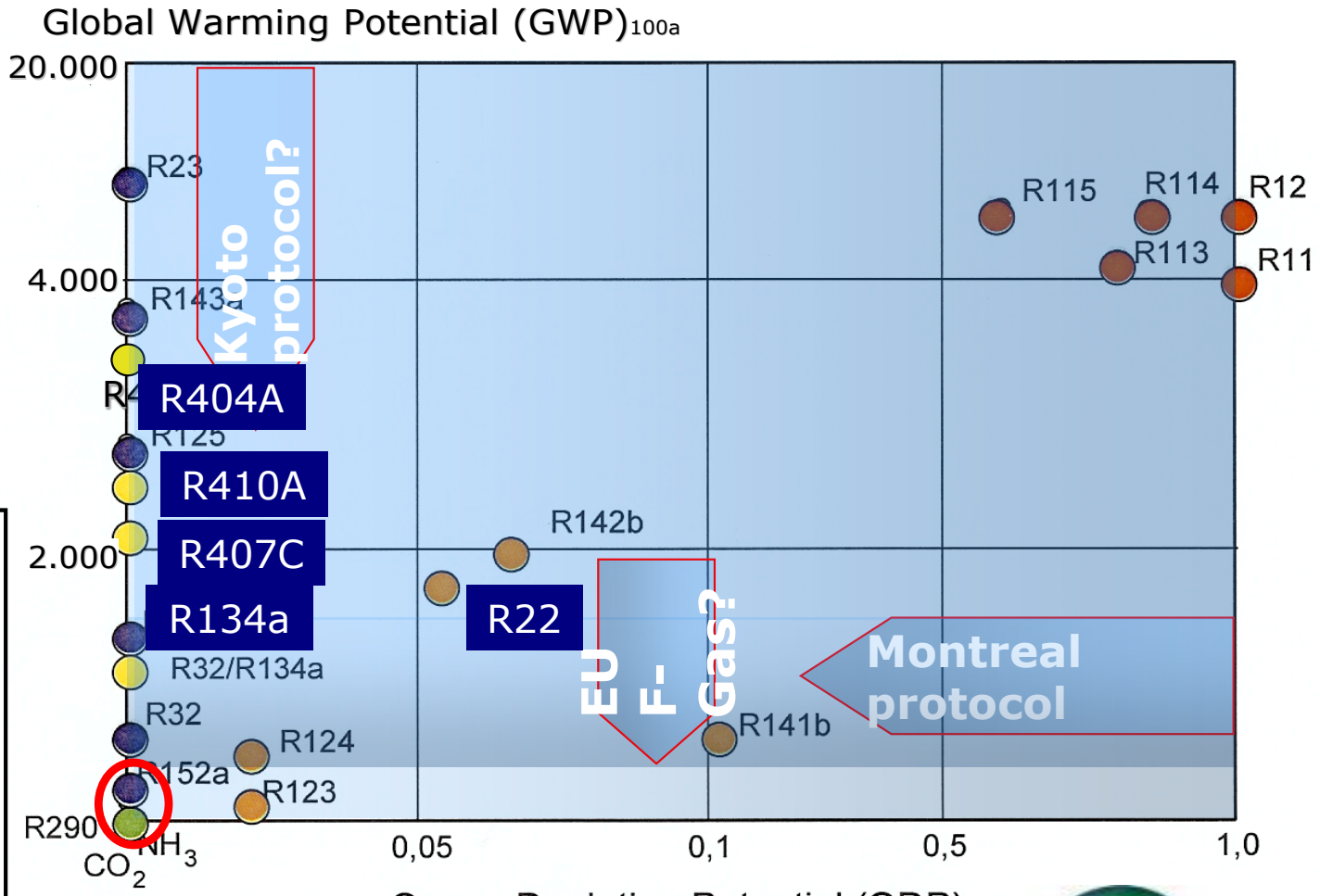
Main Trends & Drivers
Climate: reduction of **Greenhouse gas** emissions
Legislations for **energy** efficiency & reduction of refrigerant **GWP**
Connectivity – **Internet of Things**
Urbanization
China no longer the **growth engine**
Rising **cost** of energy
Strong **competition** in mature markets

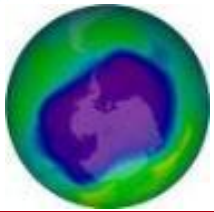
Market Challenges / OEM Pain Points
High **energy efficient** solutions
Reduction of refrigerant **charge** and **GWP** values
New system/solution **architectures**
Focus on **reliability**, durability & **services**
Cost competitiveness

HVAC Legislations









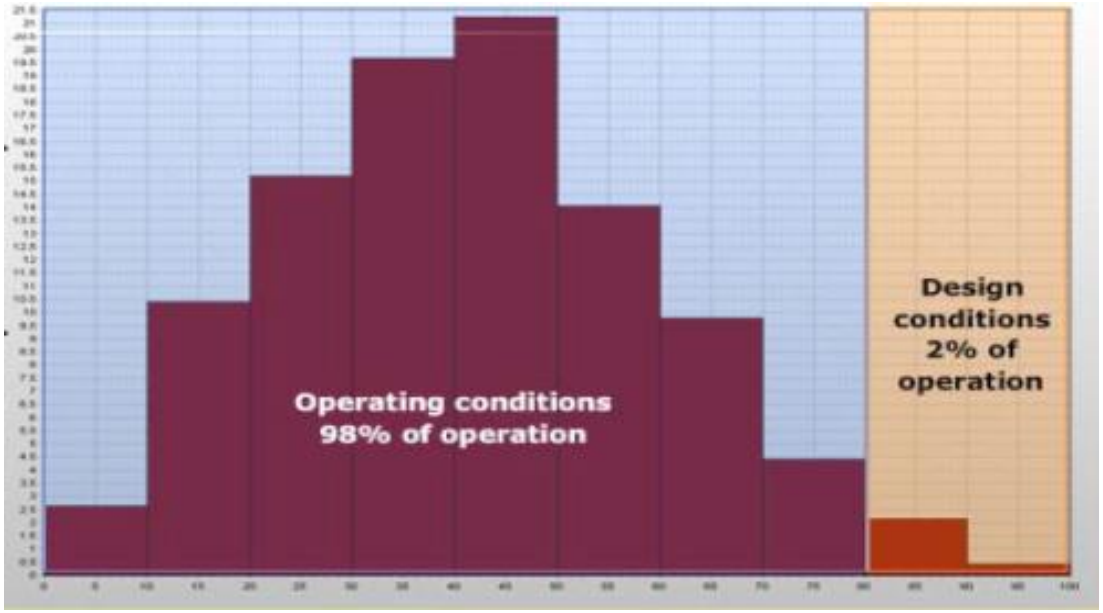
Focus on Part-Load Efficiency

Factors Impacting Building Load

- Daily & seasonal ambient temperature variations
- Indoor loads constantly changing
- Operation of different building types

Air-conditioning system needs to adjust cooling capacity to match the changing load.

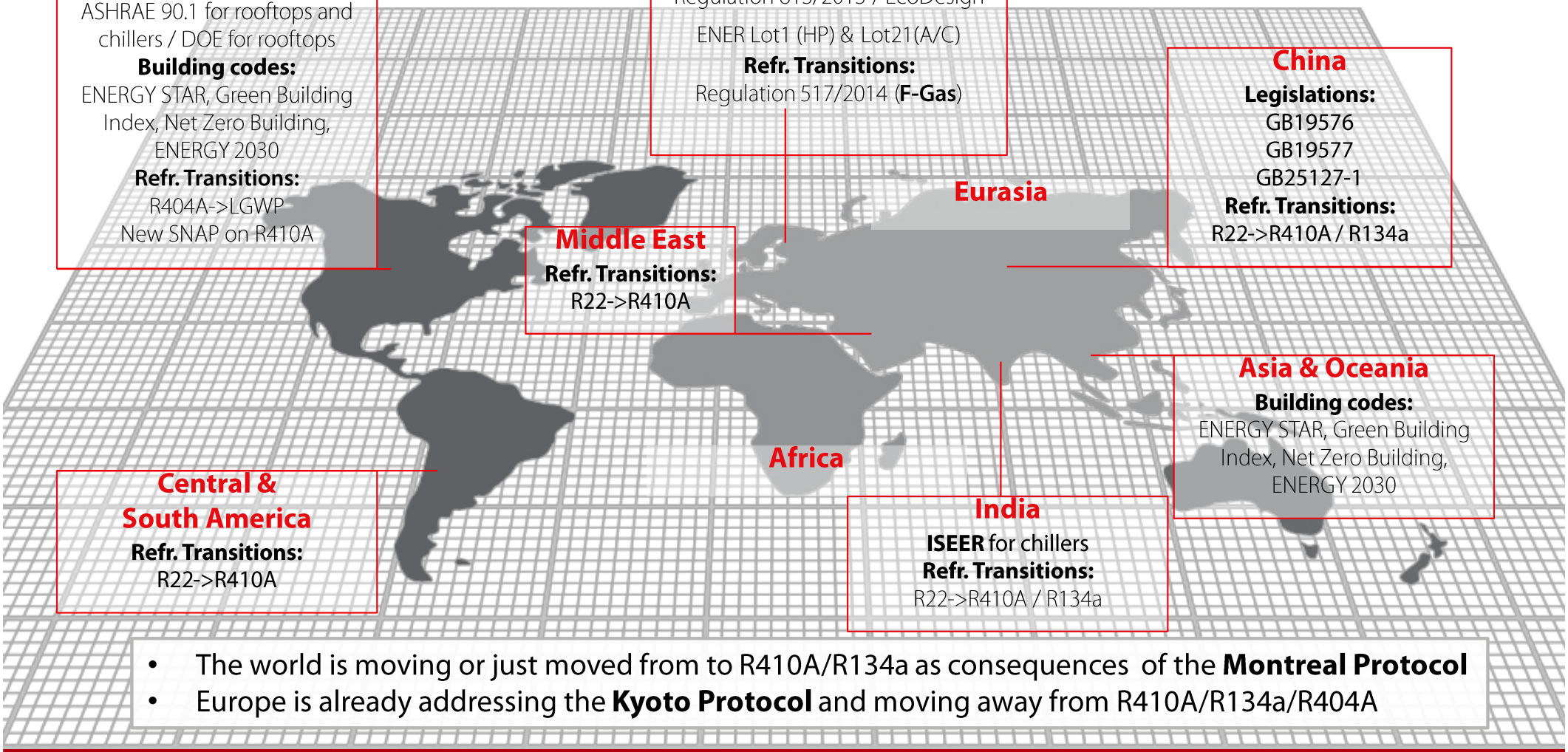
Typical Air Conditioning System Operation / day



Full load Full load

Today, HVAC systems are designed for peak conditions (right side), instead of where systems operate 98% of the time

A global overview of regulations impacting HVAC industry



USA

Legislations:
ASHRAE 90.1 for rooftops and chillers / DOE for rooftops
Building codes:
ENERGY STAR, Green Building Index, Net Zero Building, ENERGY 2030
Refr. Transitions:
R404A->LGWP
New SNAP on R410A

Europe

Legislations:
Regulation 813/2013 / EcoDesign
ENER Lot1 (HP) & Lot21(A/C)
Refr. Transitions:
Regulation 517/2014 (**F-Gas**)

China

Legislations:
GB19576
GB19577
GB25127-1
Refr. Transitions:
R22->R410A / R134a

Middle East

Refr. Transitions:
R22->R410A

Eurasia

Asia & Oceania

Building codes:
ENERGY STAR, Green Building Index, Net Zero Building, ENERGY 2030

Africa

Central & South America

Refr. Transitions:
R22->R410A

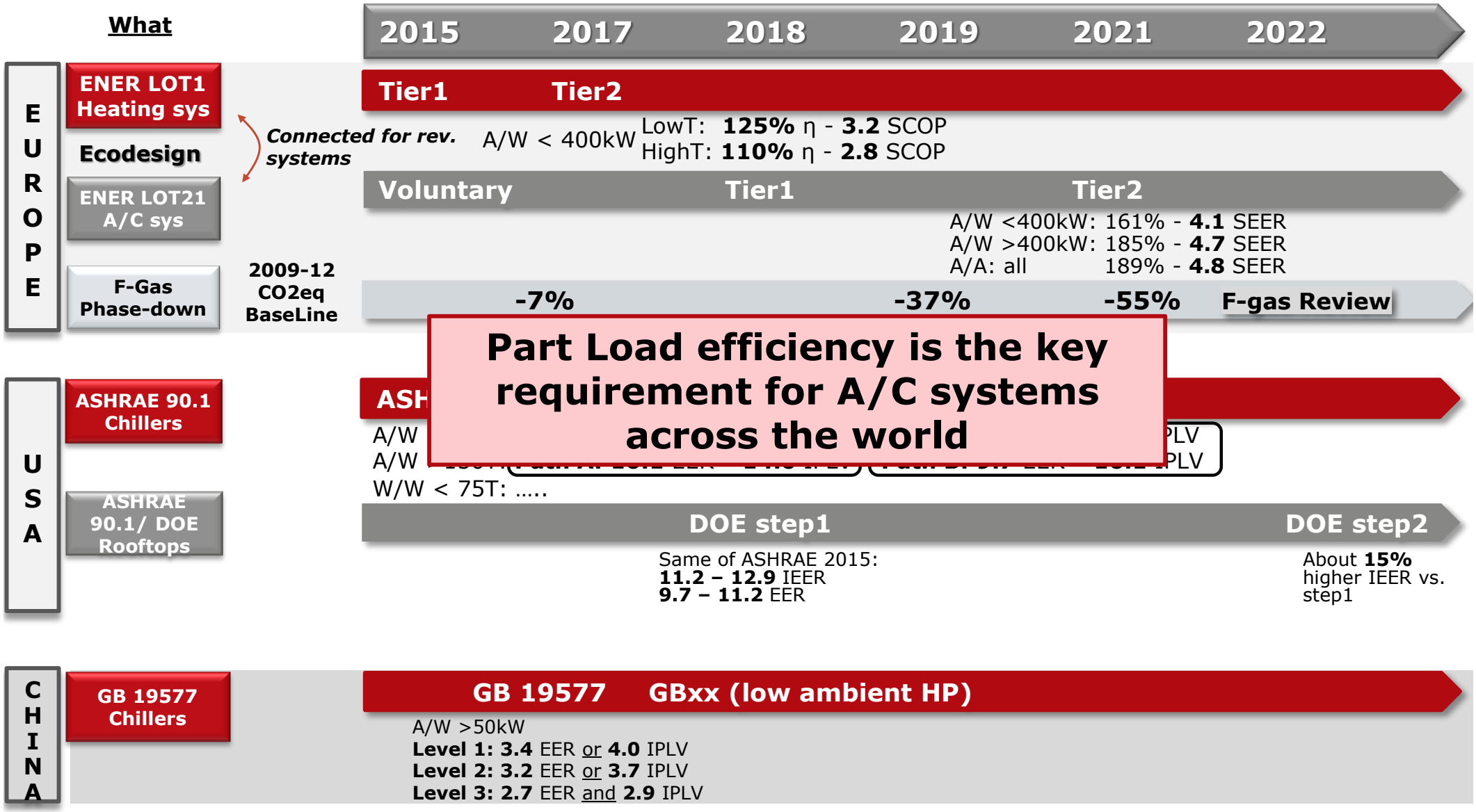
India

ISEER for chillers
Refr. Transitions:
R22->R410A / R134a

- The world is moving or just moved from to R410A/R134a as consequences of the **Montreal Protocol**
- Europe is already addressing the **Kyoto Protocol** and moving away from R410A/R134a/R404A

A/C Worldwide Legislations

Efficiency Directives & Fluorinated Gases



Seasonal Efficiency Ratings: 4 point measure

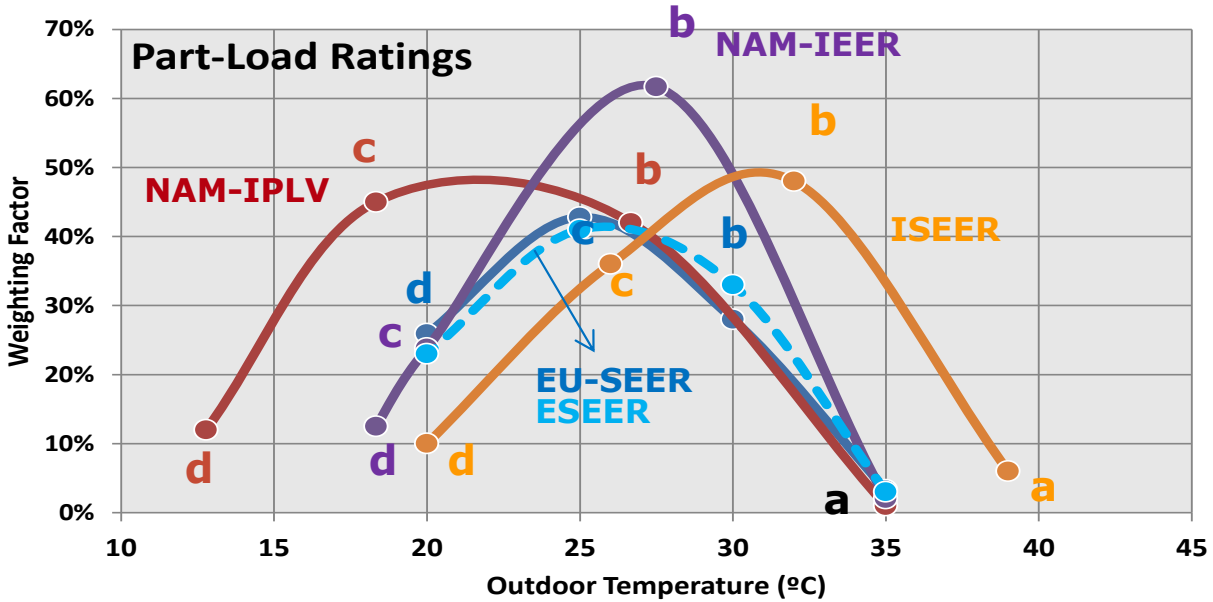
More representative of system real application & use than full load EER/COP ratings

- **Europe, only seasonal:**
  - **SEER** -> **S**easonal **E**nergy **E**fficiency **R**atio (all A/C systems) (currently still **ESEER**)
- **North America, seasonal and full load:**
  - **IPLV** -> **I**ntegrated **P**art **L**oad **V**alue (all Chiller systems)
  - **IEER** -> **I**ntegrated **E**nergy **E**fficiency **R**atio (Unitary A/C, Rooftops)
- **India, only seasonal:**
  - **ISEER** -> **I**ndian **S**easonal **E**nergy **E**fficiency **R**atio (all chiller systems)

Seasonal Eff. Rating: a*EER**@100%**load **+ b***EER**@75%**load **+ c***EER**@50%**load **+ d***EER**@25%**load
European SEER rating has no weighting factor: it is based on temp. BINs of European average climate

a, b, c, d*: load profile weighting factors relevant to the specific rating @ different* ***outdoor*** *temperatures*

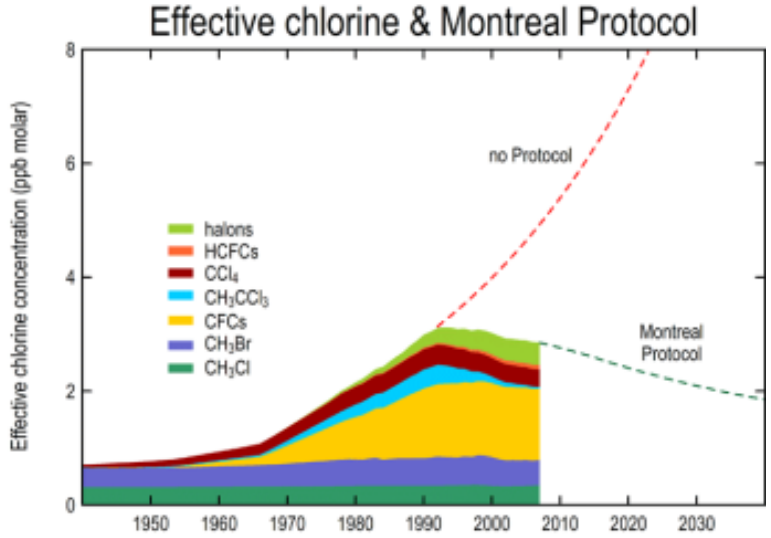
Each rating is different in weight and operating conditions and potentially drives different system and compressor optimisations

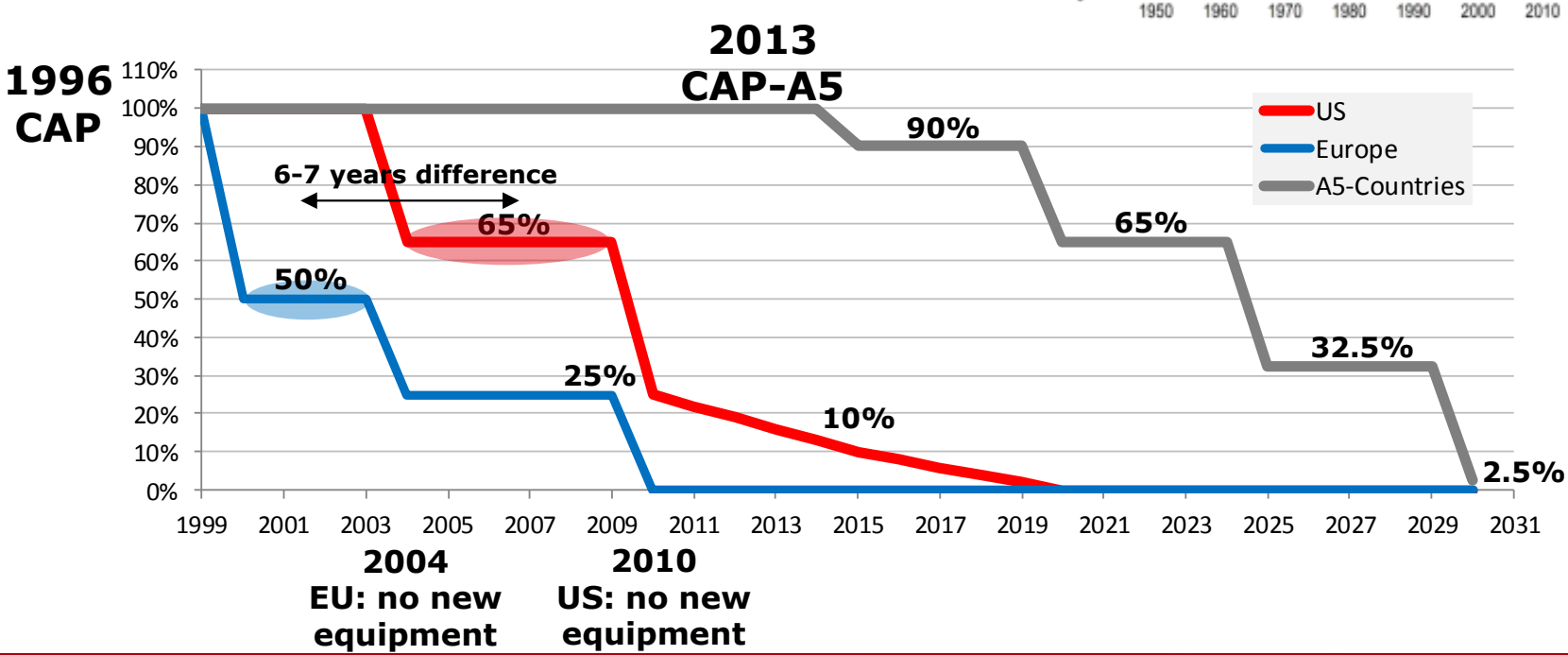


Refrigerants Trends

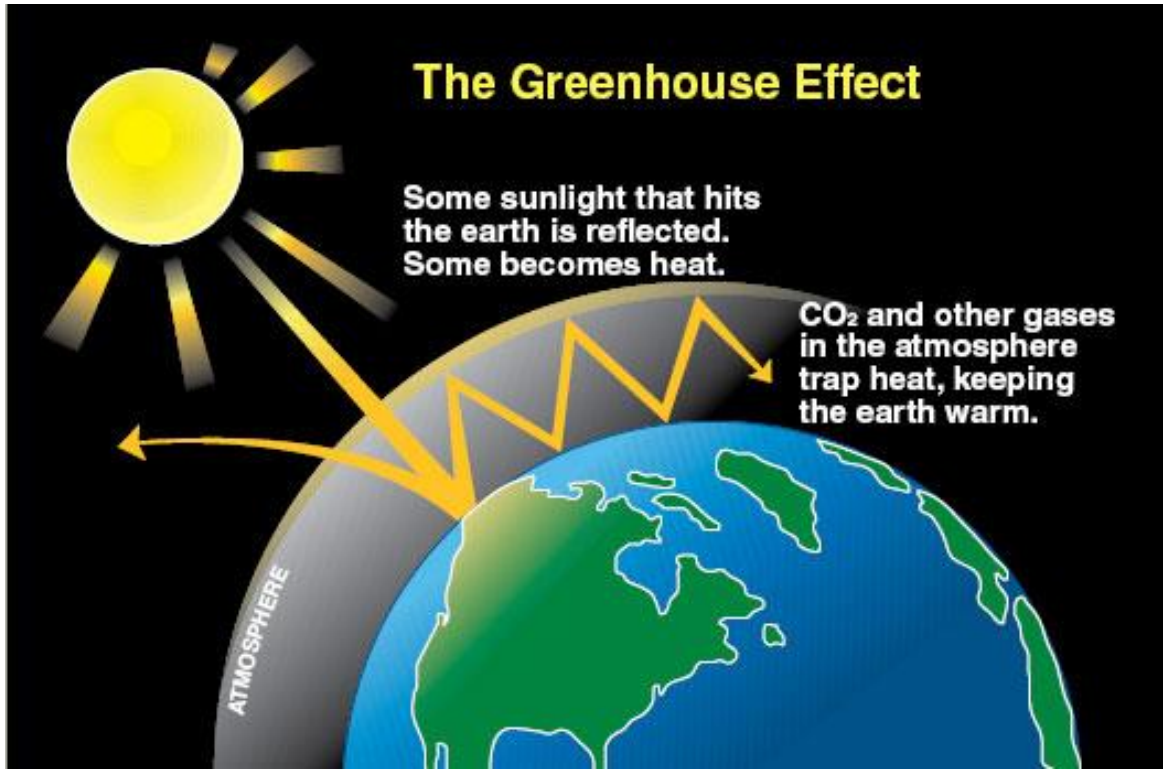
Montreal Protocol agreement to reduce ODP substances

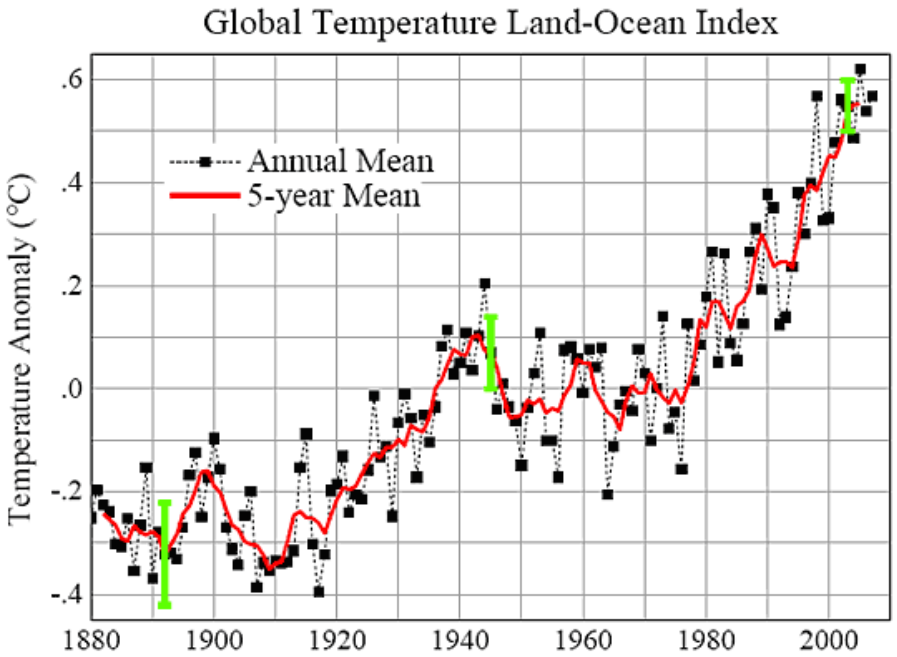
- Developing A5 Countries are only now beginning to phase-down R22





Kyoto Protocol - Greenhouse Effect & Climate Change





From an HVAC perspective, **CO2 reduction** can be achieved in 2 ways

- Reduction of **direct** emissions -> F-gas regulation: **alternative low GWP refrigerants**
- Reduction of **indirect** emissions -> Ecodesign: ENER Lot1 & Lot21 for **energy efficiency**

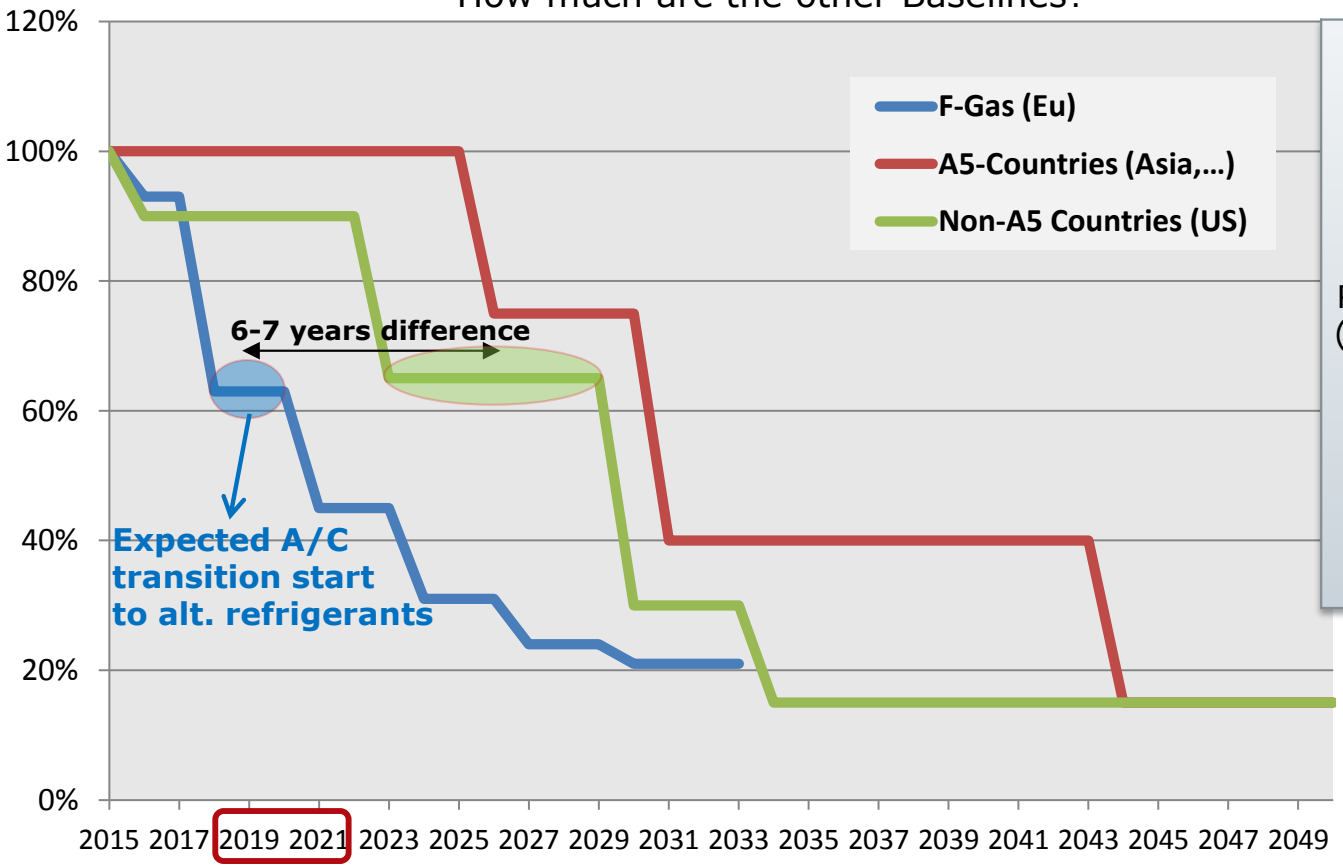
Alternative refrigerant options available in the next future

Gas	Supplier	Composition	Alt. to	GWP	Safety Class
R404A	All	R125 (44%) / R143A (52%) / R134a (4%)		**3922**	**A1**
R407A	All	R32 (20%) / R125 (40%) / R134a (40%)	R404A	**2107**	**A1**
R407F	Honeywell	R32 (30%) / R125 (30%) / R134a (40%%)	R404A	**1824**	**A1**
R448A	Honeywell (N40)	R32(26%) / R125(26%) / yf(20%) / R134a(21%) / ze(7%)	R404A	**1273**	**A1**
R449A	Dupont (XP40)	R32(24.3%) / R125(24.7%) / yf(25.3%) / R134a(25.7%)	R404A	**1397**	**A1**
L40	Honeywell	R32(40%) / R152a (10%) / R1234yf(20%) / R1234ze(30%)	R404A	**285**	**A2L**
DR7	Dupont	R32(36%) / R1234yf(64%)	R404A	**250**	**A2L**
R290	All		R404A	**3.3**	**A3**
R134a	**All**			**1430**	**A1**
R450A	Honeywell (N13)	R134a (42%) / ze (58%)	R134a	**601**	**A1**
R513A	Dupont (XP10)	R134a (44%) / yf (56%)	R134a	**573**	**A1**
R1234yf	Honeywell/Dupont		R134a	**4**	**A2L**
R1234ze	All		R134a	**6**	**A2L**
R410A	**All**	**R32(50%) / R125 (50%)**		**2088**	**A1**
R32	All	R32 (100%)	R410A	**675**	**A2L**
L41	Honeywell	R32 (68%) / ze (32%)	R410A	**461**	**A2L**
DR5	Dupont	R32 (68.9%) / yf (31.1%)	R410A	**466**	**A2L**

European F-Gas Phase-Down & North American Proposal

CO2eq vs. Baseline

Eu baseline: **183 Mtonnes CO2eq**
How much are the other Baselines?



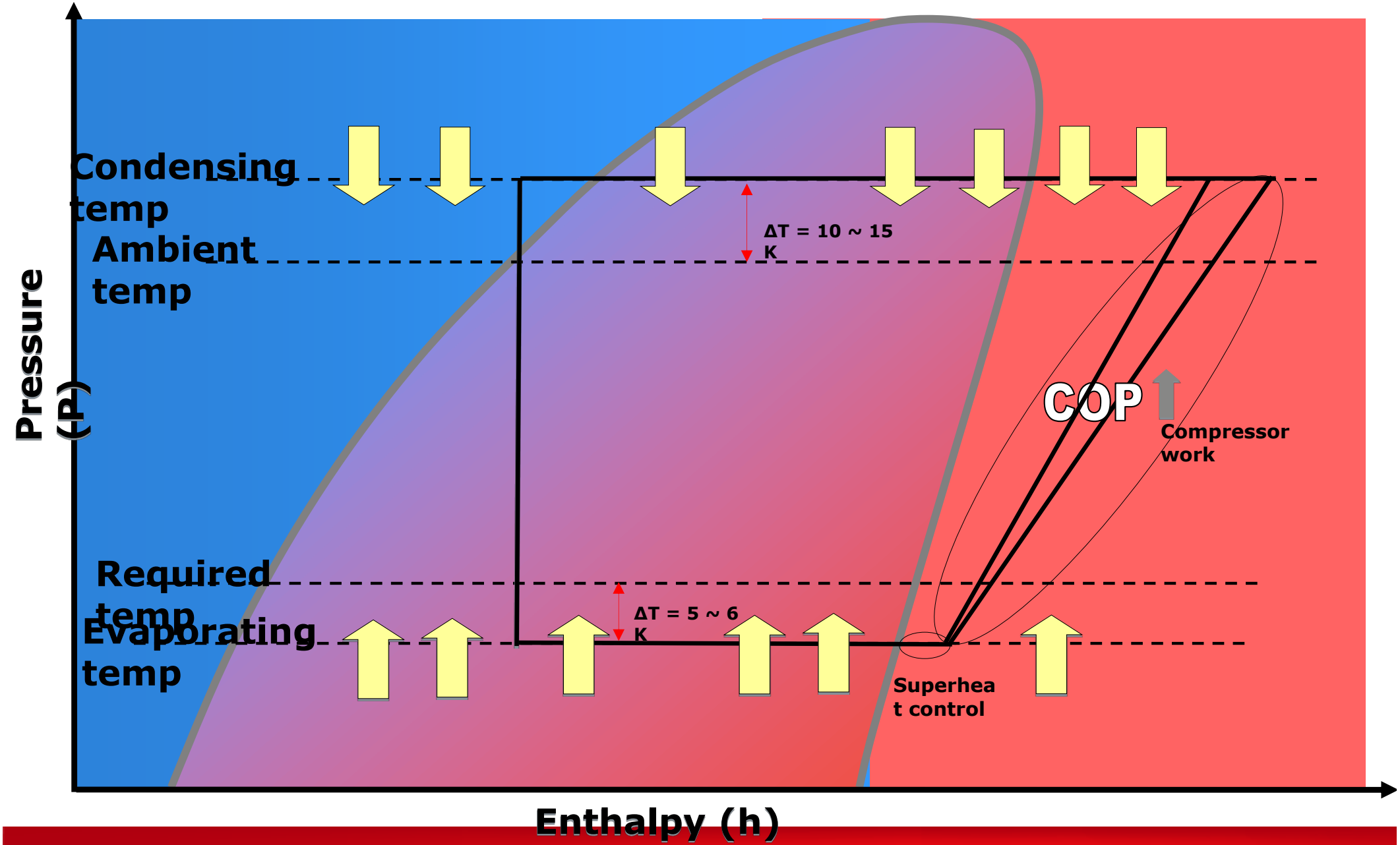
Alternatives to R410A

R410A (2088)	**DR5A** (490) **DR55** (676)	Chemours	R32/1234yf (68/32) R32/1234yf/125 (67/26/7)	A2L & high density
	L41-2 (572) **L41-y** (676)	Honeywell	R-32/1234ze/125 (68/28,5/3,5) R-32/??	
	R32 (675)	All	R32 (100)	

Europe going ahead first, R410A likely to stay several more years outside Europe. In any case alternatives are all high density and back-ward compatible with R410A

Solutions for superior part load efficiency

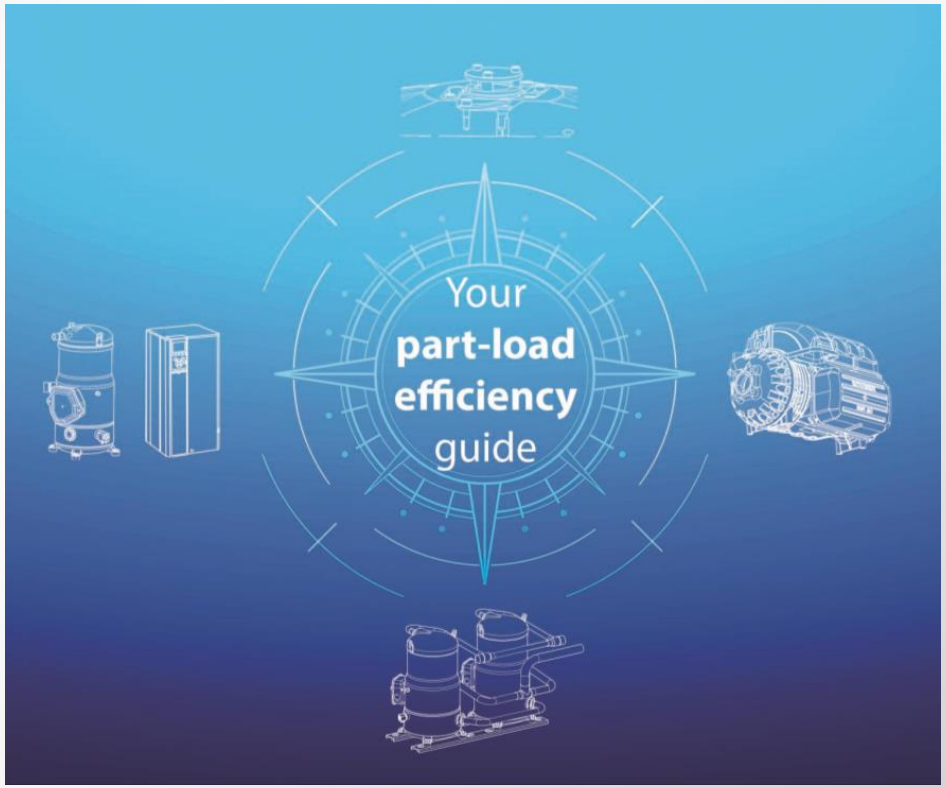
Scope for Energy Efficiency



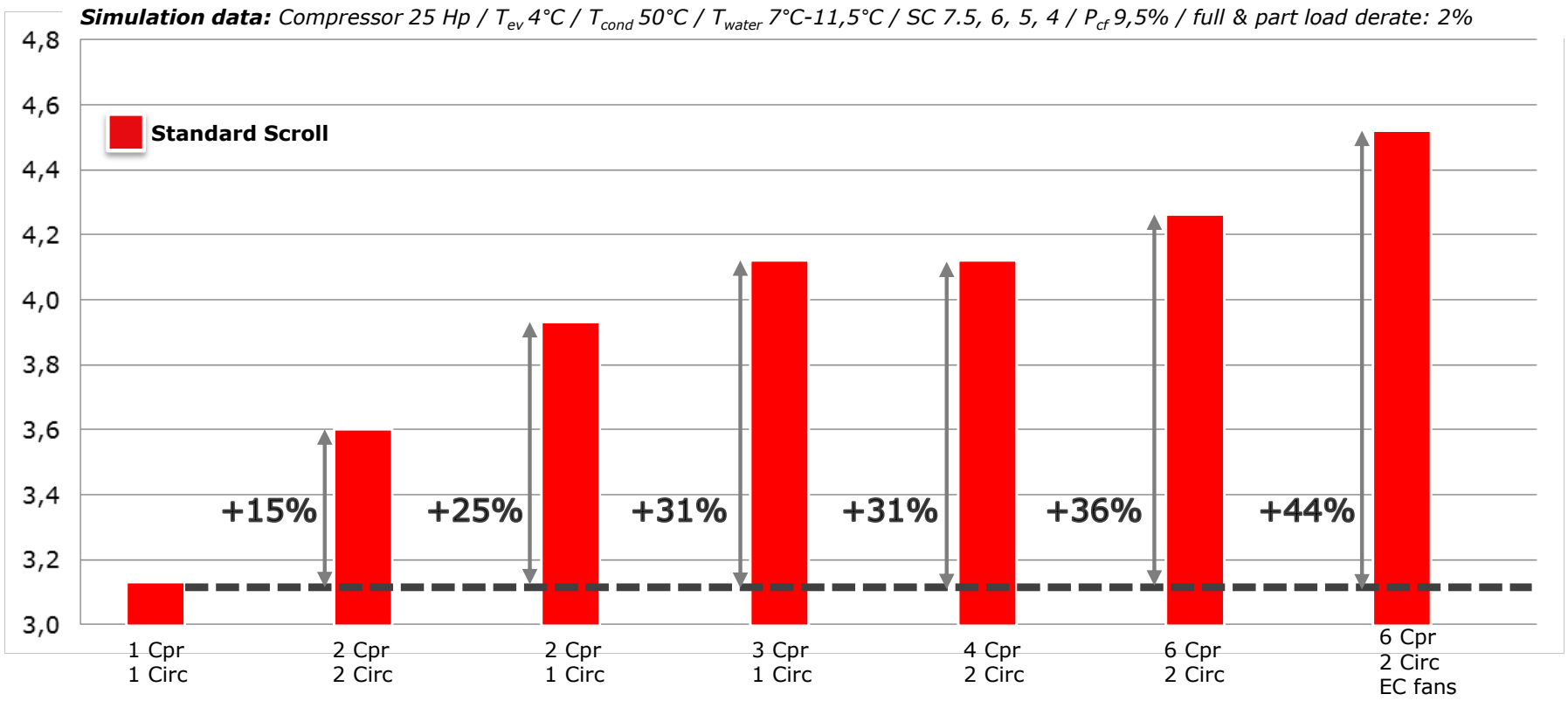
Solutions for superior **part-load efficiency** and comfort

Market most extended range of solutions for system capacity modulation:

1. **Manifold Scrolls**
   wide offering from 5 to 120T / circuit
2. **Intermediate Discharge Valve (IDV)**
   Enhancing scrolls, manifolds and inverter scrolls efficiency
3. **Inverter Scrolls**
   Extended range from 4 to 26T / up to 52T in hybrid tandem conf.
4. **Turbocor**
   Inverter, Oil-Free, Magnetic Bearing Centrifugal
   Extended range from 60 to 350T (single)



Scroll manifolding effect on seasonal performance (SEER) for A/W chiller

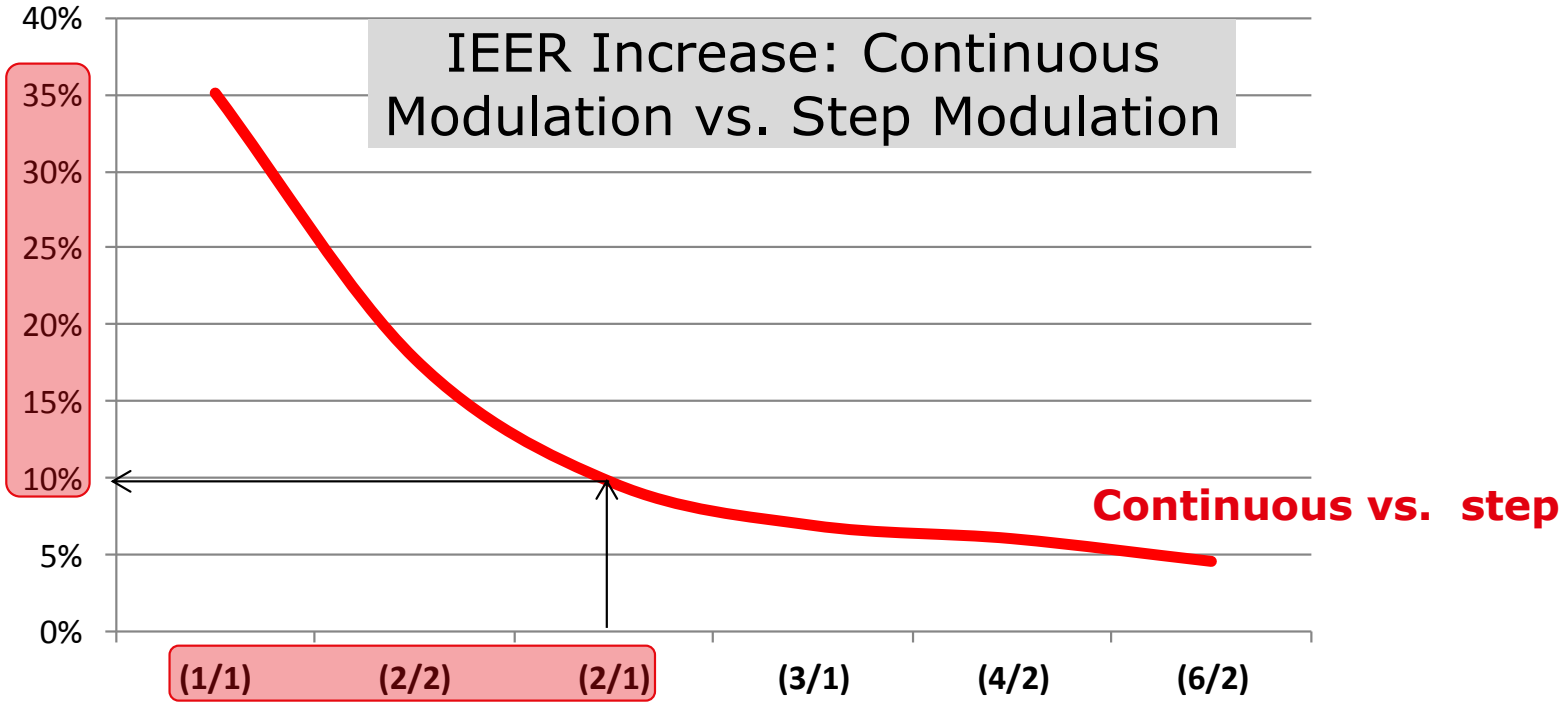


SEER improvement due to capacity modulation

Mechanical improvement of efficiency at part load conditions

Part-Load Efficiency: benefit with Variable Speed vs. Multi-scroll in Rooftops

- VS technology provides strong IEER improvements when compared to systems using fixed-speed compressors and manifolding up to 2 capacity steps



- VS technology offers additional advantages in terms of:
  - **Comfort:** Humidity & supply-air temperature control
  - Capable of meeting the min **25% modulation** capacity as per VAV system requirements (elimination of hot-gas bypass)

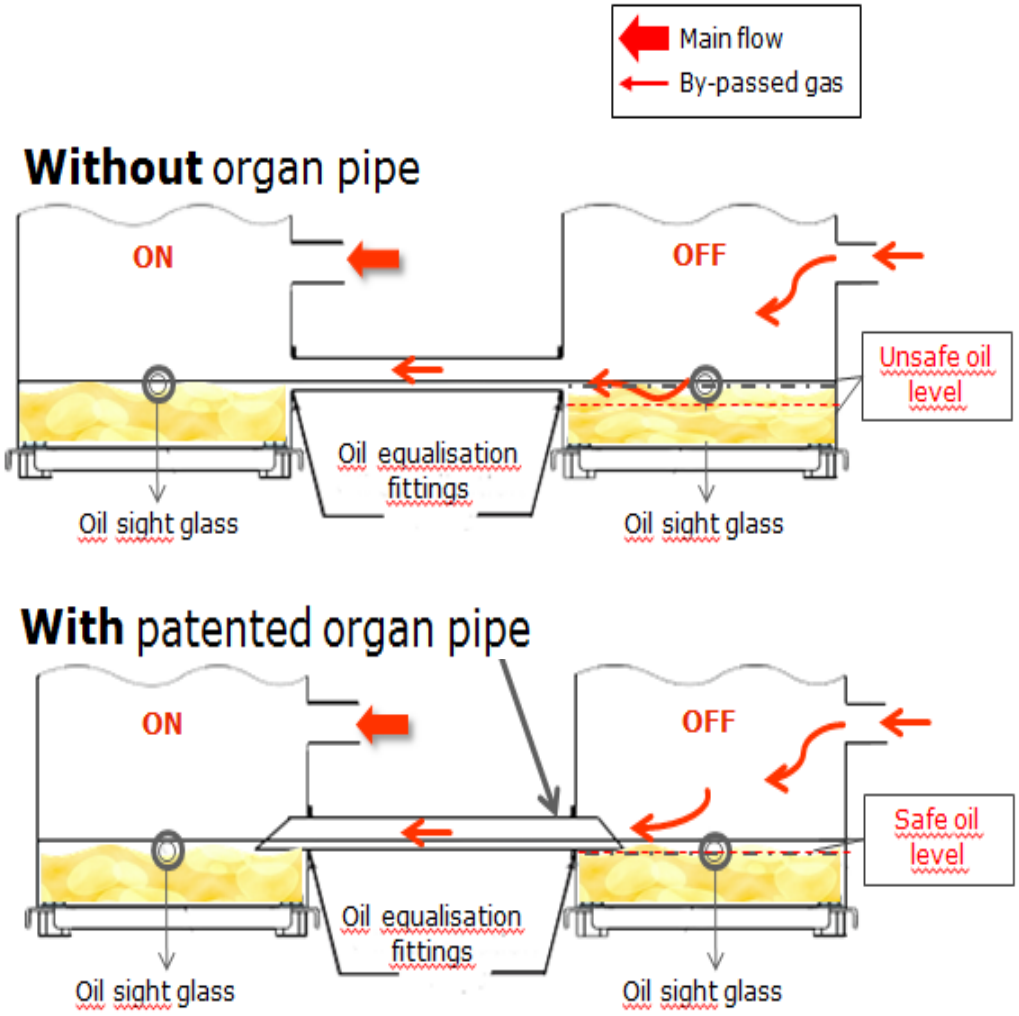
Manifold scrolls

Enhancing Part-Load Efficiency with staged modulation



- Wide range of even and uneven combinations
- From **15 to 120T** (in one circuit) for:
  - Up to **10 modulation steps** (in 2 circuits) and
    Better outlet-air / -water temperature control and hence **comfort**
  - Less compressor models for a complete system lineup:
    increased **stock flexibility**
  - OEM **flexibility**

Manifolding technology : “organ pipe”



Description:

- “organ pipe” in compressor oil equalization fitting
- Available for all large fixed and inverter scroll range

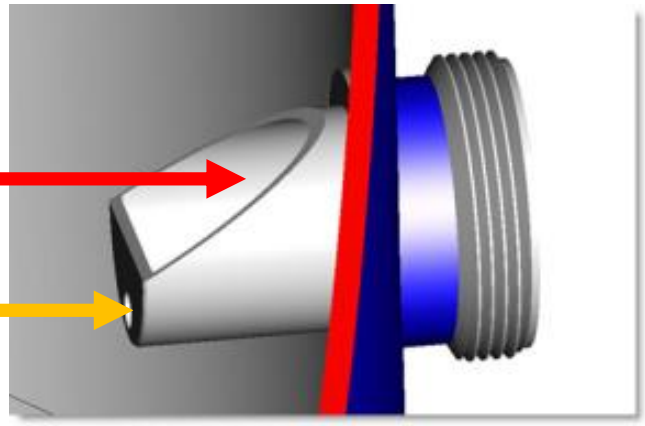
Main Benefits:

- Avoids oil emptying in part load conditions on idle compressors
- Oil levels remain visible in the oil sight glass of idle compressors
- Significant OCR reduction in part load

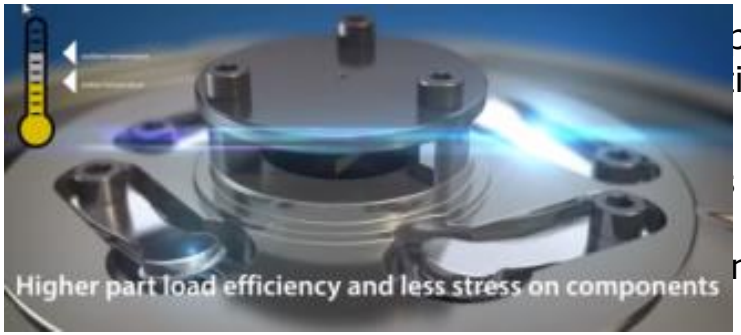
Inside Look:

Refrigerant gas flow between compressors

Oil flow between compressors. Wall helps to avoid excessive oil migration



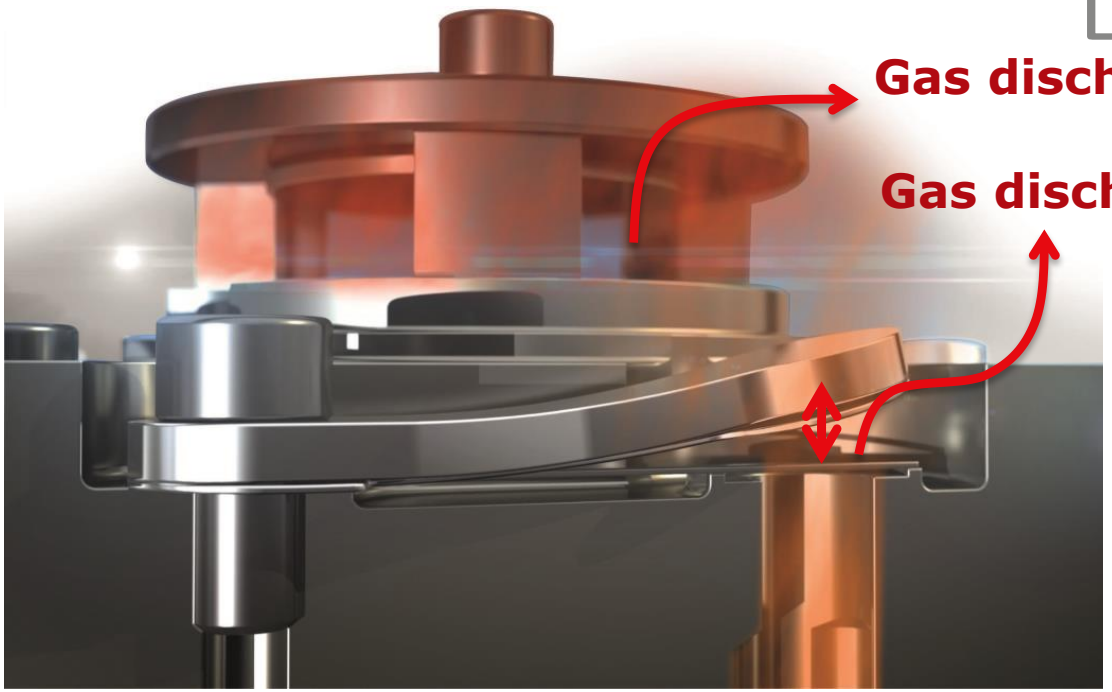
Intermediate Discharge Valves
Enhanced Part-Load Efficiency

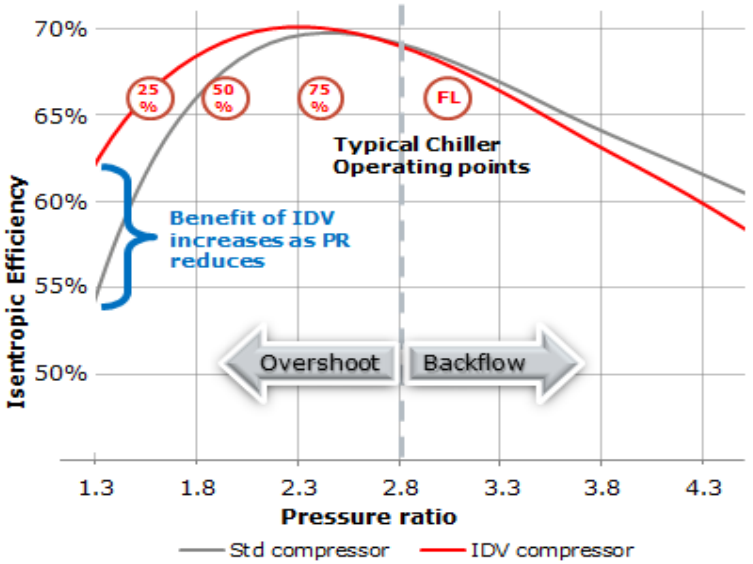


pts the motor effort to the pressure conditions in the system to
ioning systems

nical parts

High Pressure Ratio: IDV closes

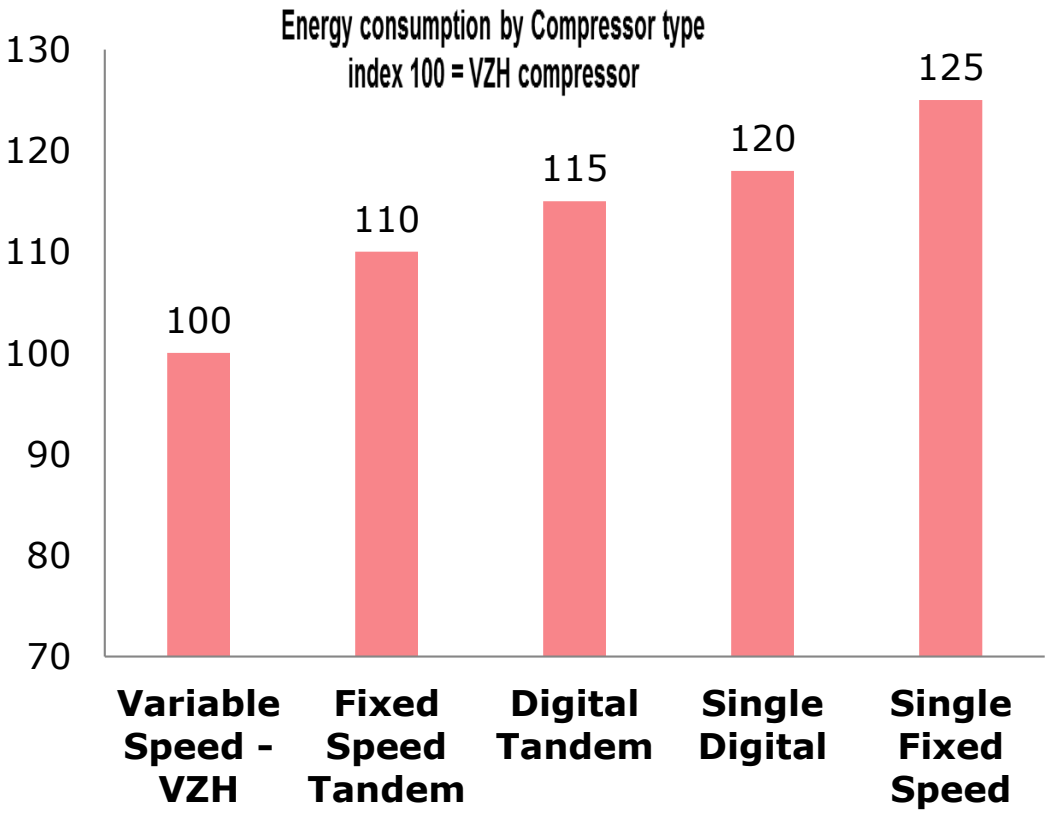




Inverter scrolls: benefits and values

- **Energy efficiency (end-user)**
- **Power grid benefits (end-user)**
- **Precise temperature control (end-user)**
- **Implementation (OEM & contractor)**

Unmatched energy efficiency



Thanks to a smart design:

1. Inverter scroll technology: load matching principle
2. Two models dedicated to different Pressure Ratios Systems
3. High Efficiency Permanent Magnet Motor

Benefits:

Annual Energy Savings with inverter scroll

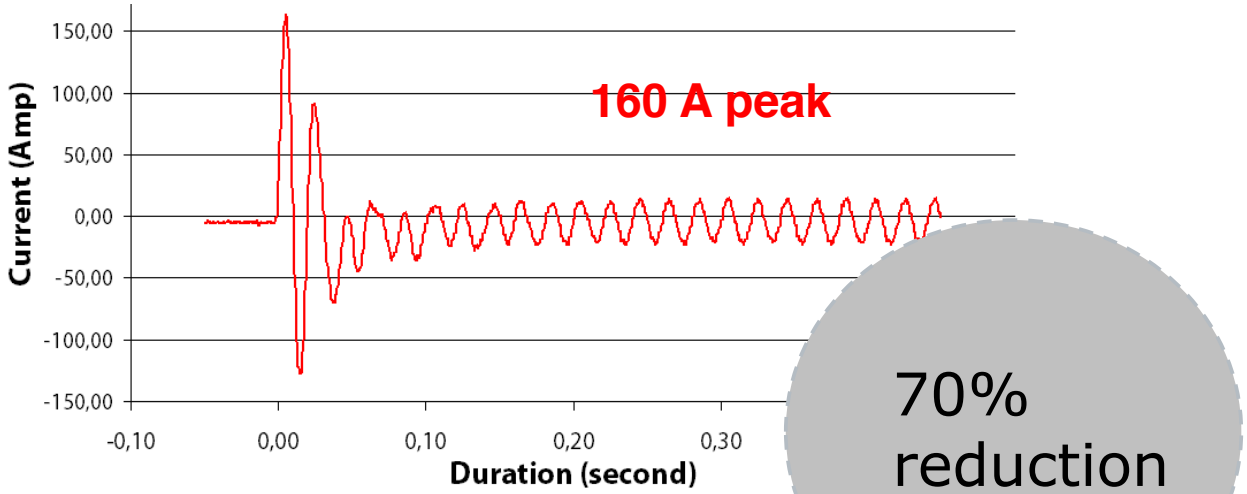
- 10-15% vs tandems
- 20-25% vs digital
- 25-30%+ vs fixed-speed comp

Power grid benefits

Reduced Demand on Power Grid

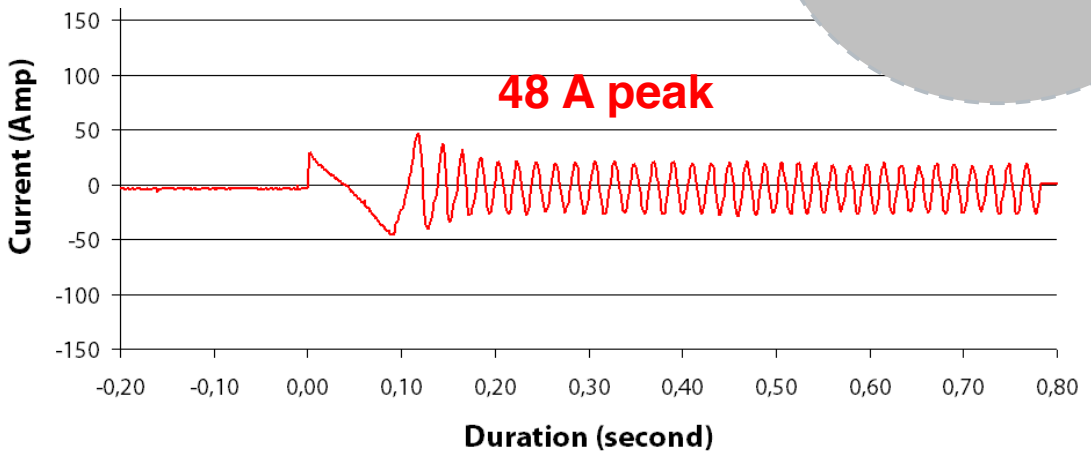
Near zero in-rush current with variable speed technology

Starting Current 10TR Fixed Speed Compressor



70% reduction

Starting Current 12TR Variable Speed Compressor

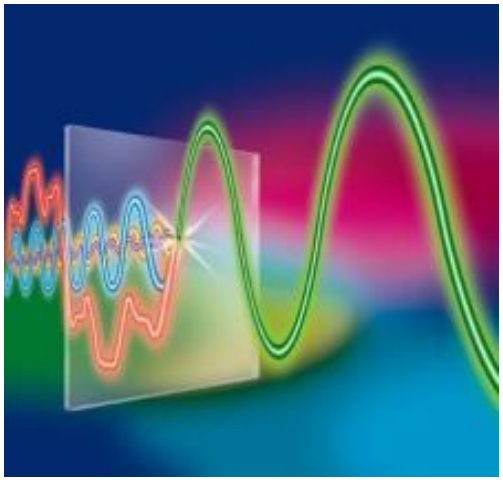


Power grid benefits

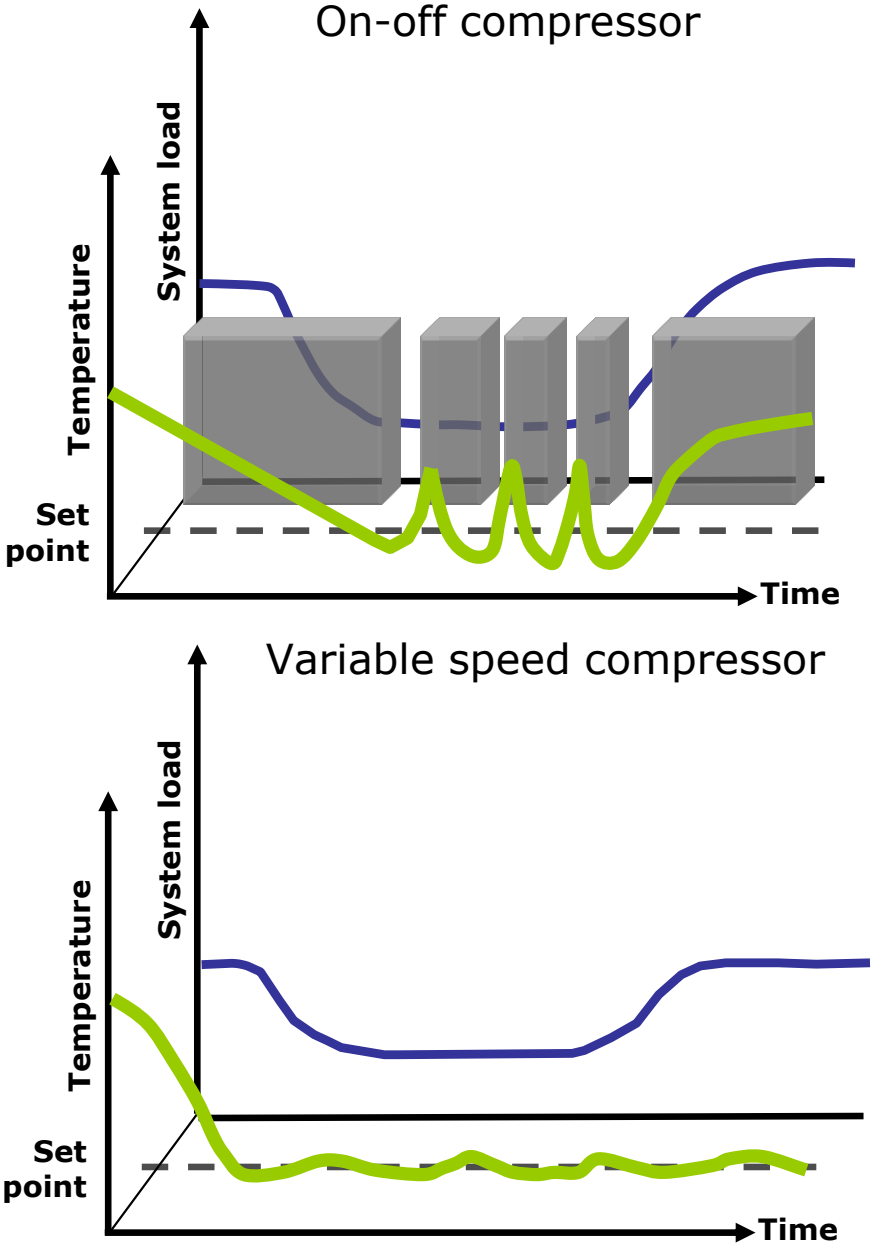
High Power Factor with VZH

Reduces losses and increases efficiency

- Integrated power factor correction
- Harmonic suppression : Power Factor ~ 1
- Avoids interference with the mains with **reduced losses and higher efficiency**
- Avoids heavy **energy bill penalties** at some utilities
- No need for additional harmonic suppression devices



Smooth & Precise Temperature Control



With Inverter Scroll, temperature is maintained more precisely compared to on-off compressors.

Temperature control of +/- 0.3°C is achievable with VZH

Benefits:

- Increased comfort in air-to-air units
- Data Center cooling energy saving: 1°C shift from the operating set-point can be 0.5% on the energy bill (*In-Row cooling – source APC Schneider*)
- Chiller water tank down-sizing
- Waste reduction in process cooling

Simplified maintenance & service

Increased unit up-time

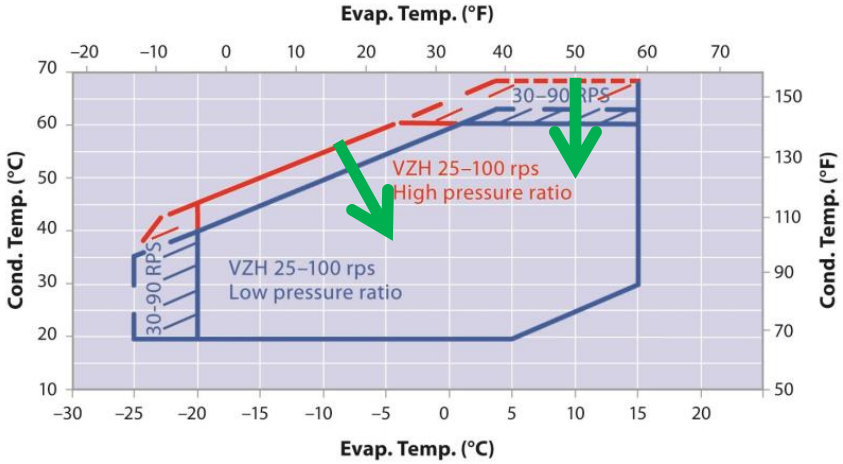




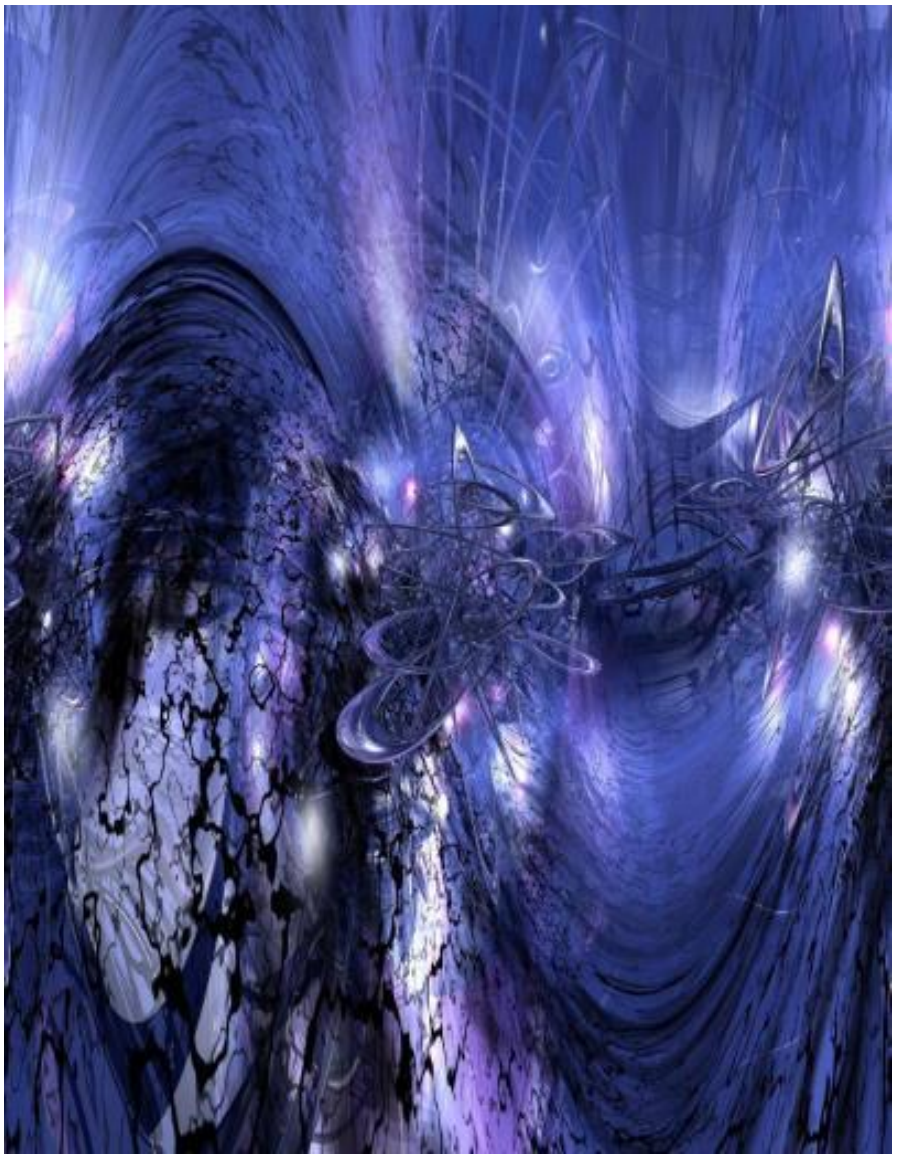
- **Safe and continuous compressor running**
  - Current monitoring & motor overload protection
  - Discharge temperature monitoring

Service made simple and quick

- Hand-held LCP : user-friendly quick access
- Software tools for diagnostics
- Modbus / data access: remote monitoring



EMC Compliance



Feature:

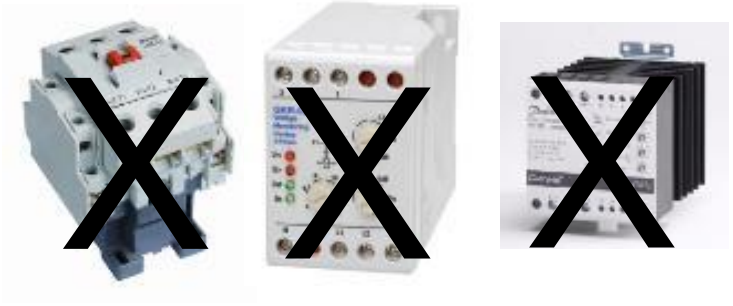
- 2 levels of EMC filter provided as standard option

Benefits:

- Compliance with regulations
- Reduce EMC qualification time for the whole system
- No need for special EMC filter adding
- No risk to use the drive in EMC sensitive application (data center, telecommunication…)

Simplified unit design
Reduced applied costs

- Smooth start-up & reduced peak current : removal of soft-starters *(down-sizing of UPS in data-centre cooling)*
- No need for contactors
- Phase monitoring : no need for phase controller devices
- Integrated EMC filters
- Power factor correction





Compressor protection functions from inverter drive

- Oil return management
- Oil injection control
- Current monitoring and overload protection
- Integrated mains & motor phase loss protection
- Reverse rotation protection
- Short cycling protection : less stop - starts
- Discharge temperature monitoring
- Compressor start-up logic
- Compressor safe stop

Inverter scroll made simple with VZH

Differentiate through innovation

Reduced energy bill
Energy Saving

- *25-30% over Fixed speed*
- *20-25% over digital*
- *10-15% over Fixed tandem*



Reduced applied cost

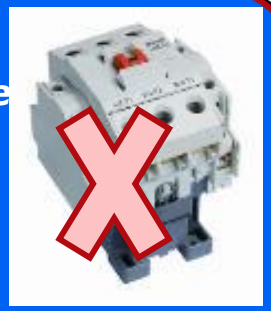
No need of electrical safety device

Contactor,

Phase monitoring devices,

Overload replay,

over/under voltage safety



Simplified maintenance, assembly & commissioning

- *Fully tested, pre-qualified compressor + drive package*



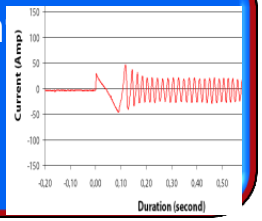
Smooth & precise temperature control

- *± 0.3 deg C accuracy*
- *Chiller water tank downsizing*



70% reduction in Inrush curren

- *No need for soft starter*
- *Downsizing of UPS / Back up*



Enhanced Reliability

- *Compressor protection functions from inverter drive*



Power grid benefits

- *High power factor, PF = 0.9 to 1*
- *EMC compliance*



VRF & Chillers Have Strengths
in different segments



VRF Focus
Systems < 200kW
New but especially Retrofit
Mainly Installer / HVAC designer

Installer Value Preference
- Strong support from supplier
- Ease of installation
- Installation cost



Chiller Focus
Systems up to several MW
New & Replacement
Consultants / HVAC designer

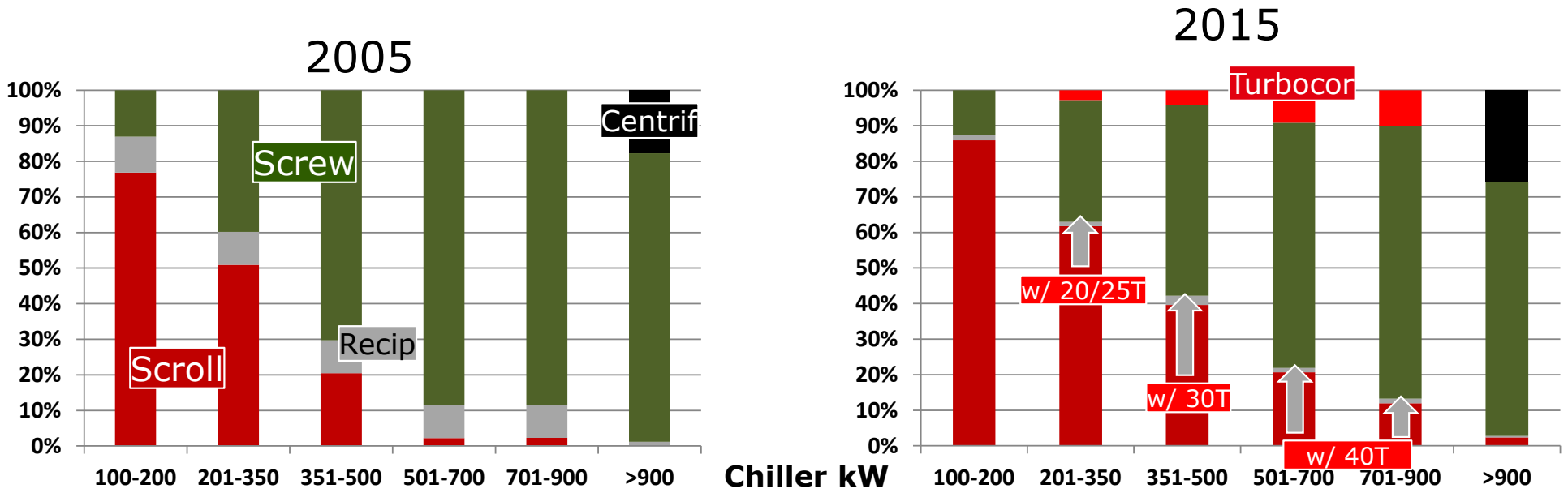
Consultant Value Preference
- Comfort (air quality)
- Ease of maintenance
- Open system architecture
- Operating costs

- VRF WW foreseen CAGR around **10%** (still regions with low penetration)
  - But serious challenges arising from focus on GWP / flammability of alt. refrigerants
- Chillers WW foreseen CAGR around **3%** (a more mature application)
  - But better positioned to be seen as „greener" systems

Scroll chillers vs. **Screw chillers**

Scroll Chillers winning market shares from Screw Chillers - Europe

- With the transition from R22/R407C to R410A for scrolls and to R134a for screws, multi-scroll commercial chillers have gained large parts of market share up to 600-700 kW



Scroll: from 21% to 30% penetration – CAGR **4%**
Screw: from 66% to 57% penetration – CAGR **-1%**
Centrifugal: from 6% to 12% - CAGR **7%** (thanks to Turbocor)
In a flat chiller market

Source: BSRIA European data + Danfoss Market Intelligence Projections

Benefits of
Scroll Chillers vs. Screw Chillers

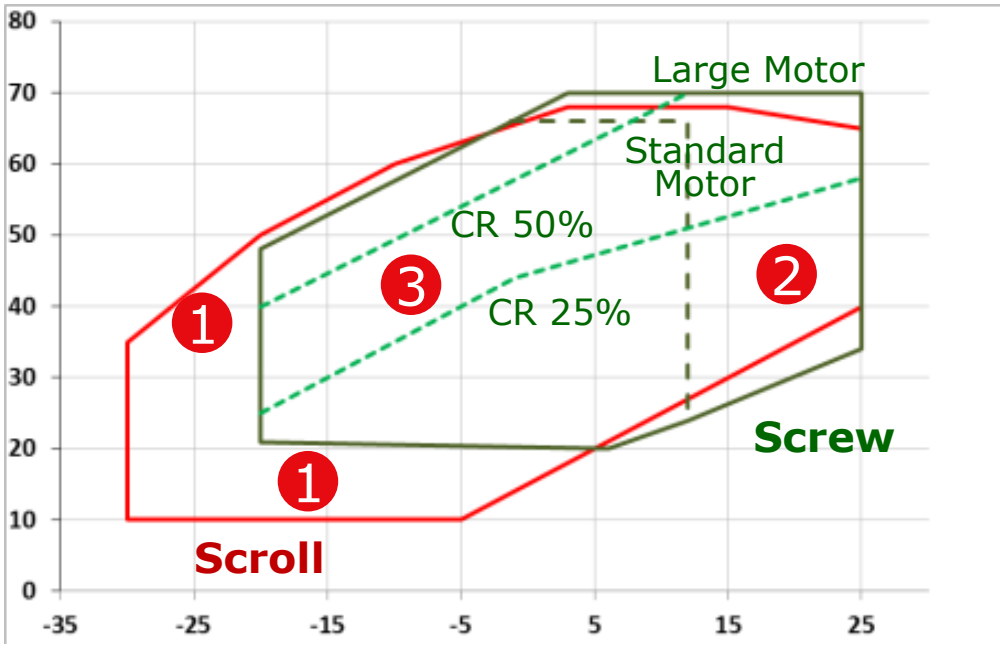
- Smaller footprint
- Chillers service clearance
- Sound power level and quality
- Larger operating envelope
- Better liquid handling capabilities for HP operations
- Lower complexity, higher stock velocity
- Higher seasonal / part-load performance
- Lower system cost
- Lower maintenance costs

Benefits of Scroll Chillers vs. Screw Chillers

Simplicity & Flexibility

Large Operating Envelope

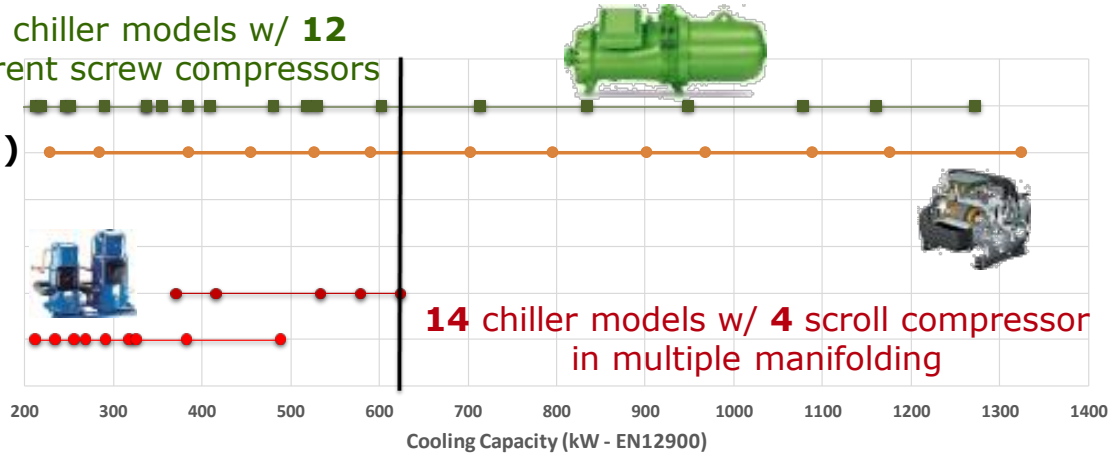
1. HP operations / Process chillers
2. Data Server cooling chillers
3. No envelope variation in part load conditions



Reduced complexity & stock velocity

Screw (2 circ.)
TT300-350 (1 & 2 circ.)

Scroll
30 & 40T(2 circ.)
20,25 & 30T (2 circ.)



A/W Chiller Lineup

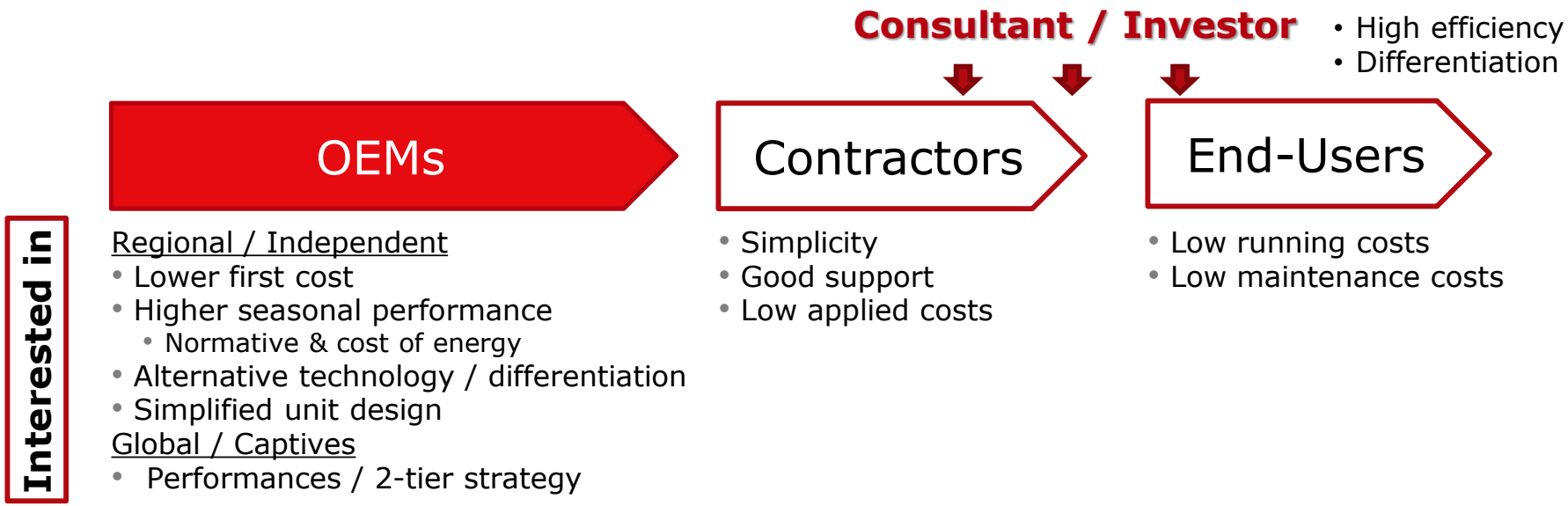
Benefits of Scroll Chillers vs. Screw Chillers

Lower System / Applied Costs & Channel to Market

Refrigerant transition:
R22 -> R410A for scrolls (compactness)
R22 -> R134a for screws (larger size)

and latest tech **scroll optimized for high density refrigerant**

Offers opportunity for cost competitive large size scroll chillers

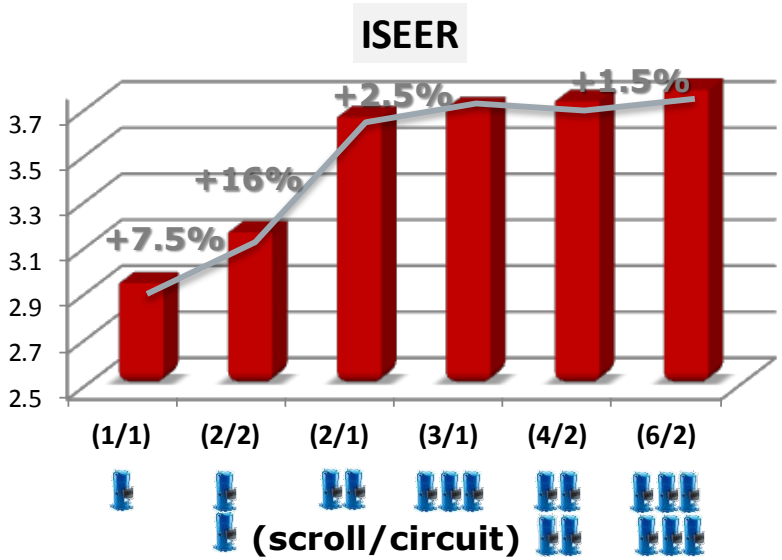


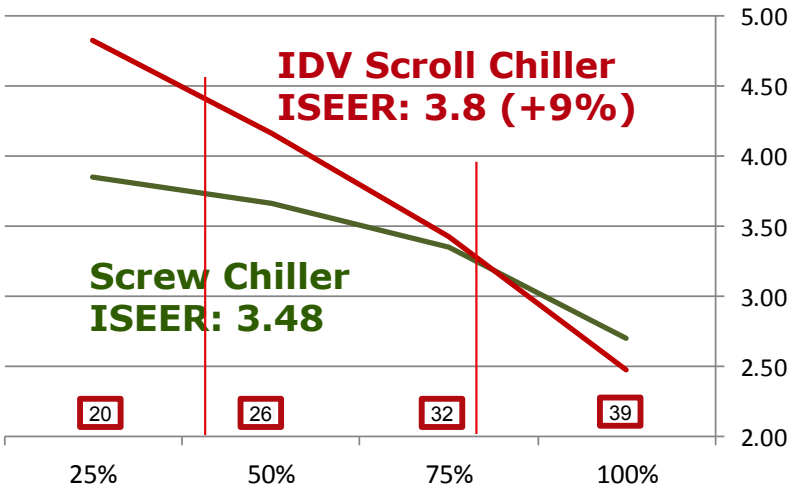
Benefits of Scroll Chillers vs. Screw Chillers

Efficiency & Lower Running Costs

A/W Chiller
360kW

A/W, 2 circuit, chiller
DTC:15K
DTE:3.5K
2 x trio 25T Scrolls V/s 2 Screw
Office building application: 2892 hours x year





- Higher seasonal **efficiency**
- Reduction of **CO2** emission
- Reduction of **running costs**

Thank You