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Energy Efficiency –
A Global Challenge

Schaffhausen, 28th / 29th June, 2018

Contents

Initial Situation

Initial Situation

- **Climate Change / Global Warming** is a world-wide threat and challenge
  ⇨ Issue: increasing direct and indirect CO_2 emissions

Resulting programs (1)

➢ **Paris Climate Accord*** − international agreement

Key aim ⇨ CO_2 emission reduction by:

Holding the increase in global average temperature well below 2°C above pre-industrial levels and pursue efforts to limit temperature increase to 1.5°C

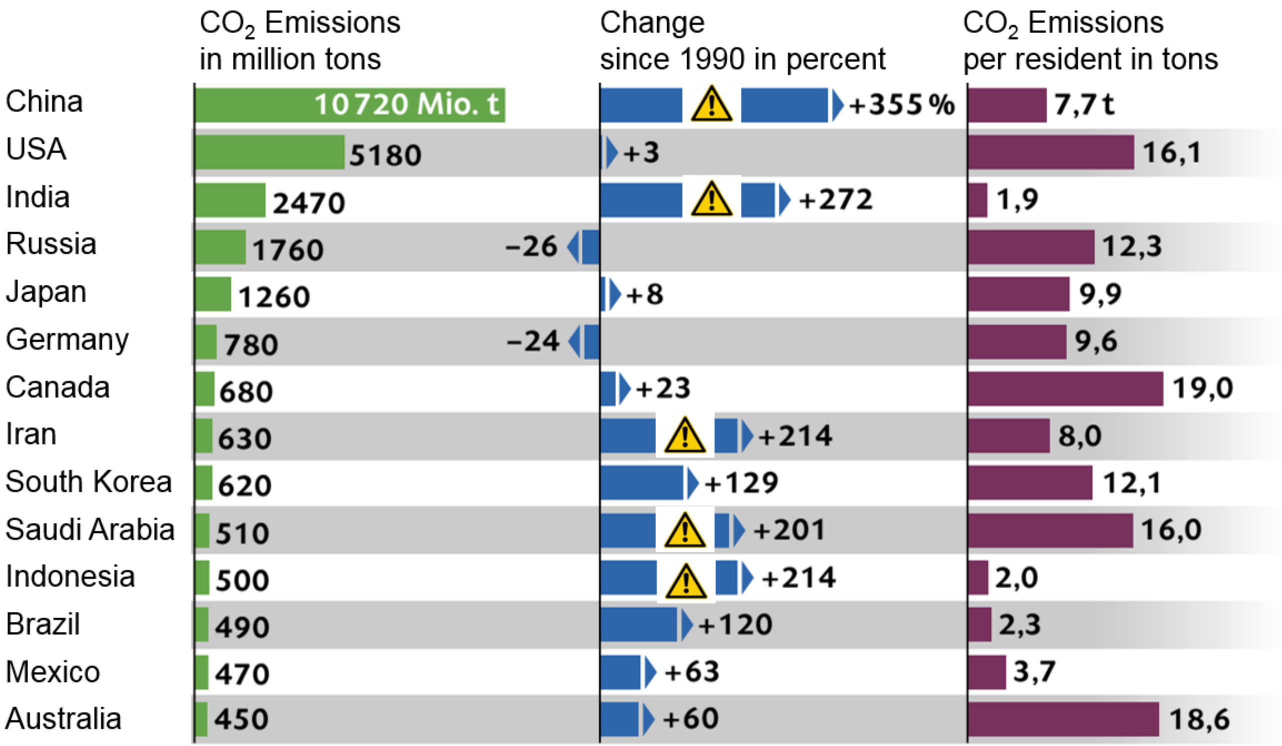
Note! Manufacture and use of (H)FCs are regulated separately:

EU: **F-Gas Reg. 517/2014** (e.g. Phase-down by 79% until 2030)

International: **Kigali Agreement** (80..85% reduction until 2045)

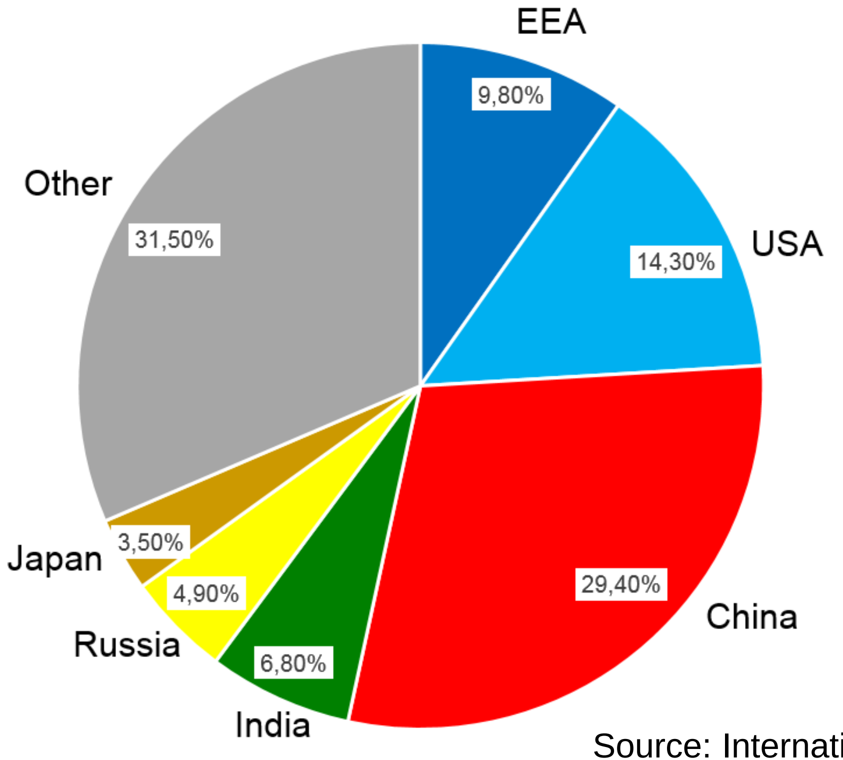
* Supported by national and regional Climate Protection Programs

Countries with High CO_2 Emissions (2015)



Source: European Commission (EC)

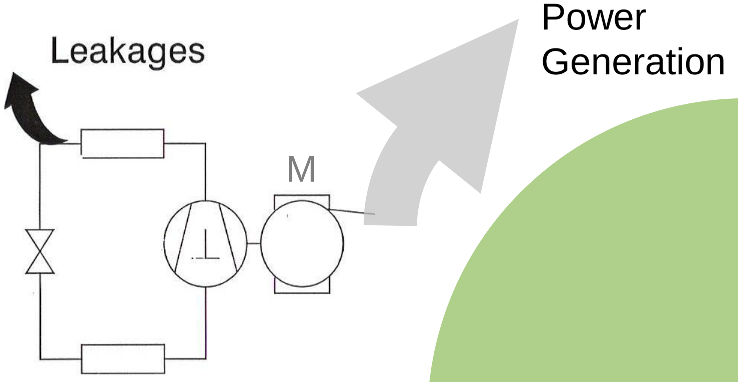
Global CO_2 Emissions by Country / Region



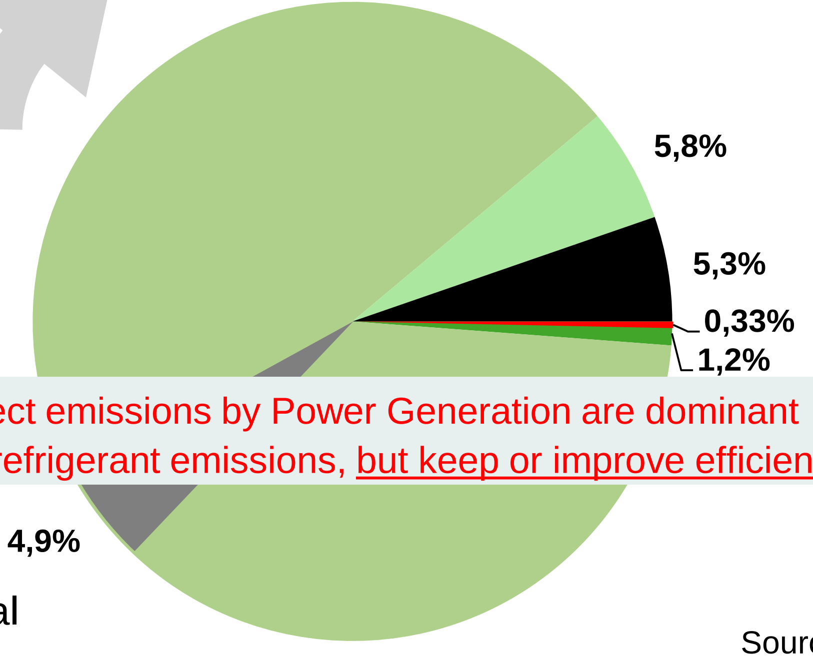
Source: International Energy Agency (IEA)

Programs and Standards on Energy Efficiency of RACHP Equipment and Systems

Relation of Direct and Indirect Emissions



Example Germany 2010



Indirect emissions by Power Generation are dominant

Reduce refrigerant emissions, but keep or improve efficiency!

- F gases
- CO_2 (Carbon Dioxide)
- N_2O (Nitros Oxide)
- CH_4 (Methane)

- Emissions from stationary refrigeration systems
- Emissions from power consumption of stationary refrigeration systems

Electrical consumption for RACHP ≈ 15% of total

Source: Federal Environmental Agency (UBA)

Examples of Programs and Standards for Efficiency Improvement (1)

- EU: Ecodesign Directive 2009/125/EC − Improved energy efficiency of energy-related Products

  EU: Directive 2010/31/EU − Energy Performance of Buildings (EPBD)

  - Including associated Standards and Certification Schemes

- USA: EPA National Action Plan for Energy Efficiency

  - Including e.g. Energy Star Program, ASHRAE 90.1 Standard, AHRI 550/590 Standard and Certification Schemes, …

Examples of Programs and Standards for Efficiency Improvement (2)

- Japan: Ministry of Economy, Trade and Industry (METI)
  - Energy Efficiency “Top Runner Program“
- China: Minimum Energy Performance Standards
  - e.g. GB19577-2015 Efficiency Grades for Chillers
- India: National Mission for Enhanced Energy Efficiency (NMEEE)
  - e.g. ISHRAE Standard for Chillers

Example EU: Projects (Lots) / Regulations within the Ecodesign Framework Directive 2009/125/EC

Commissions Energy (ENER) and Enterprise (ENTR)

ENER Lot .			ENTR Lot .
1. Boilers ☒ - under revision	10. Air con < 12 kW ☒ - under revision	20. Local room heating	1. Refrigeration ☒
2. Water heaters	11. Motors, fans, .. ☒ - under revision	21. Central heating, cooling products ☒	2 ransformers
3. PC	. Com. Refrigerators	....	3. media
4. C	mestic Refrig	.....	4. furnaces
5. T	sh washers	30. Motors / Drives	
6. Stand-by losses	15. Fossil fuel	31. Compressors	
7. Battery charger	16.		
8. Office lights	17.		8. Power cables
9. Street lights	18.		9. Enterprise servers
	19. Domestic lighting	.....	

- Axial fans with motor

- HT Process Chillers
- Comfort A/C Chillers
- Air Heating Heat Pumps

- Condensing Units
- MT & LT Process Chillers

RACHP Involvement

☒ Current main work items for RACHP

EU Major Projects for RACHP

Current Major Focus

ENTR Lot 1 — (EU) No. 2015/1095 – in application since July 2016
Tier-2 as of July 2018

Professional Storage Cabinets, Blast Cabinets, Condensing Units and MT/LT Process Chillers

ENER Lot 21 — (EU) No. 2016/2281 – in application since Jan. 2018
Tier-2 as of Jan. 2021

Air Heating Products (incl. "Air" HP), Cooling Products (incl. A/C Chillers) and High Temp Process Chillers

Requirements for Placing Products on the Market (1)

COP or EER evaluation at one reference condition is history with larger condensing units and liquid chillers

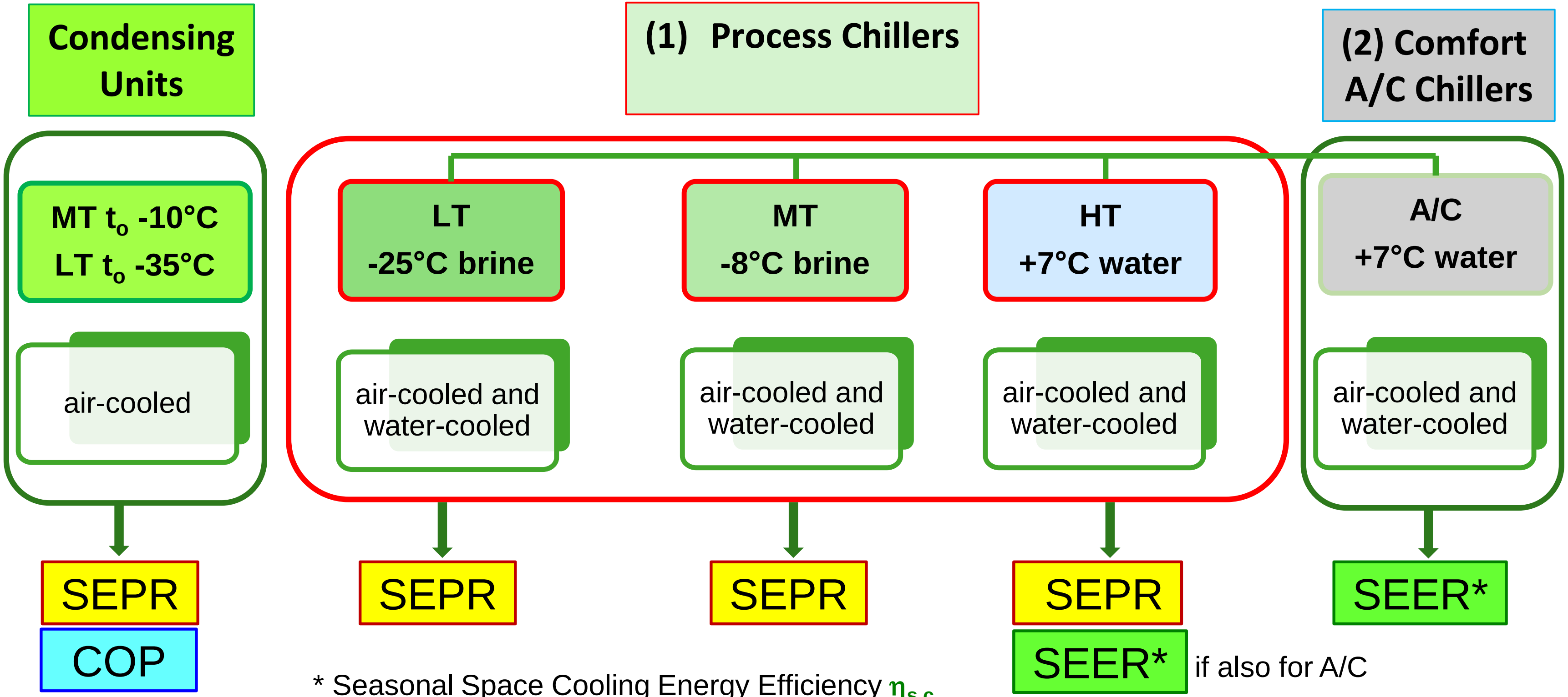
- Condensing Units (> 5 kW (MT) / 2 kW (LT)*
  - **SEPR** „**S**easonal **E**nergy **P**erformance **R**atio“
    based on **COP** at 4 reference points ⇨ Annual temperature profile
- Process Chillers
  - **SEPR „S**easonal **E**nergy **P**erformance **R**atio**“**
    based on **EER** at 4 reference points ⇨ Annual temperature profile

* COP declaration only with smaller CU (“indoor” application)

Requirements for Placing Products on the Market (2)

- Comfort A/C Chillers (HT Process chillers – if also for A/C)
  - Seasonal Space Cooling Energy Efficiency [%] – calculated from:
  - **SEER** „**S**easonal **E**nergy **E**fficiency **R**atio“
    based on **EER** at 4 reference points ⇨ Summer temperature profile

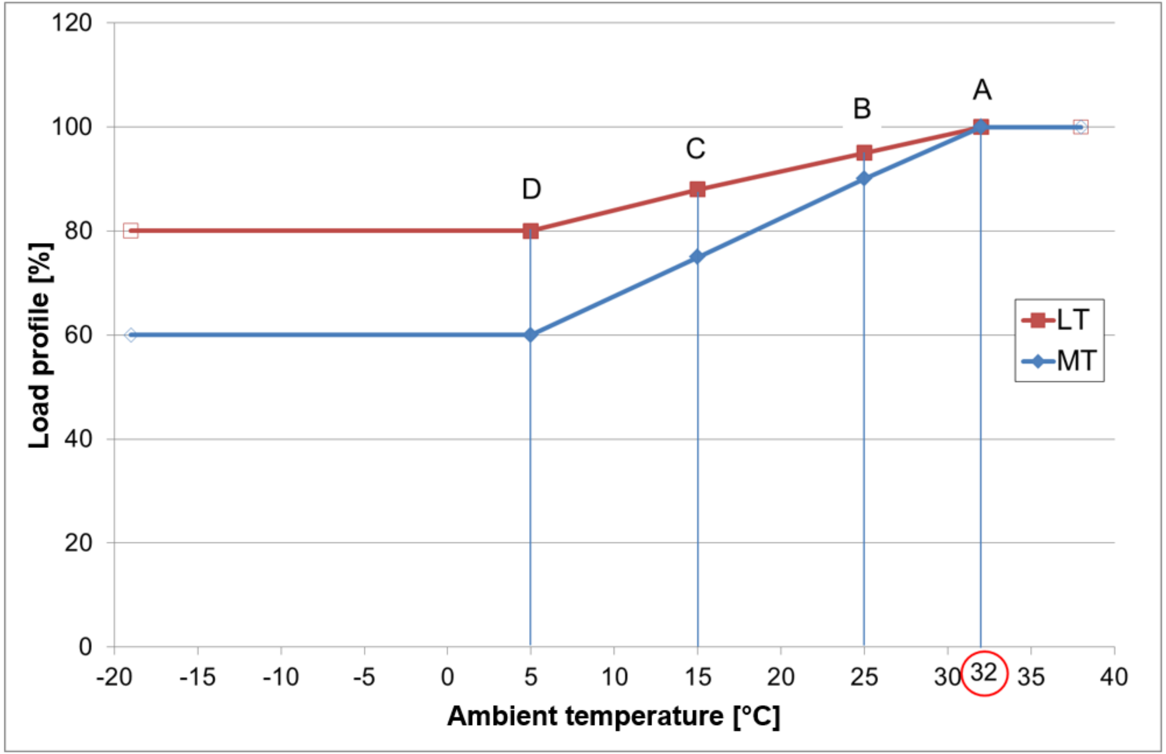
Summary – Methods for Efficiency Evaluation



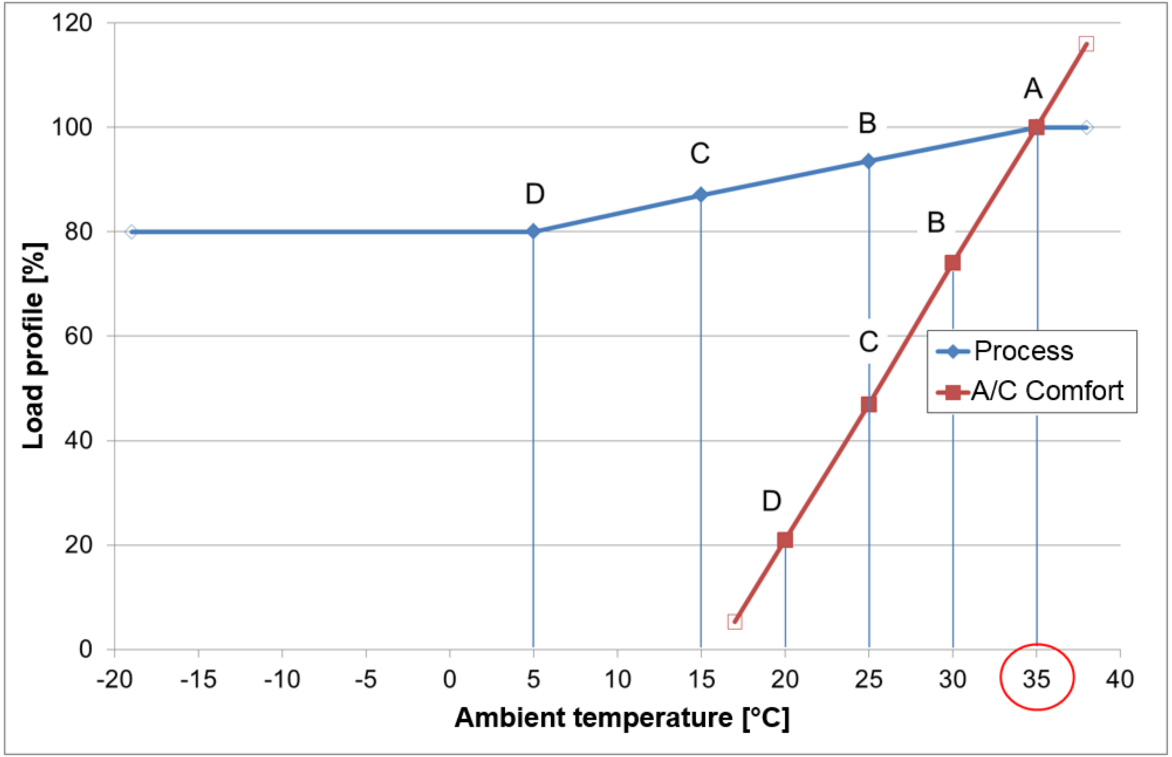
* Seasonal Space Cooling Energy Efficiency $\eta_{s,c}$

Calculation Methods
Load and Temperature Profiles

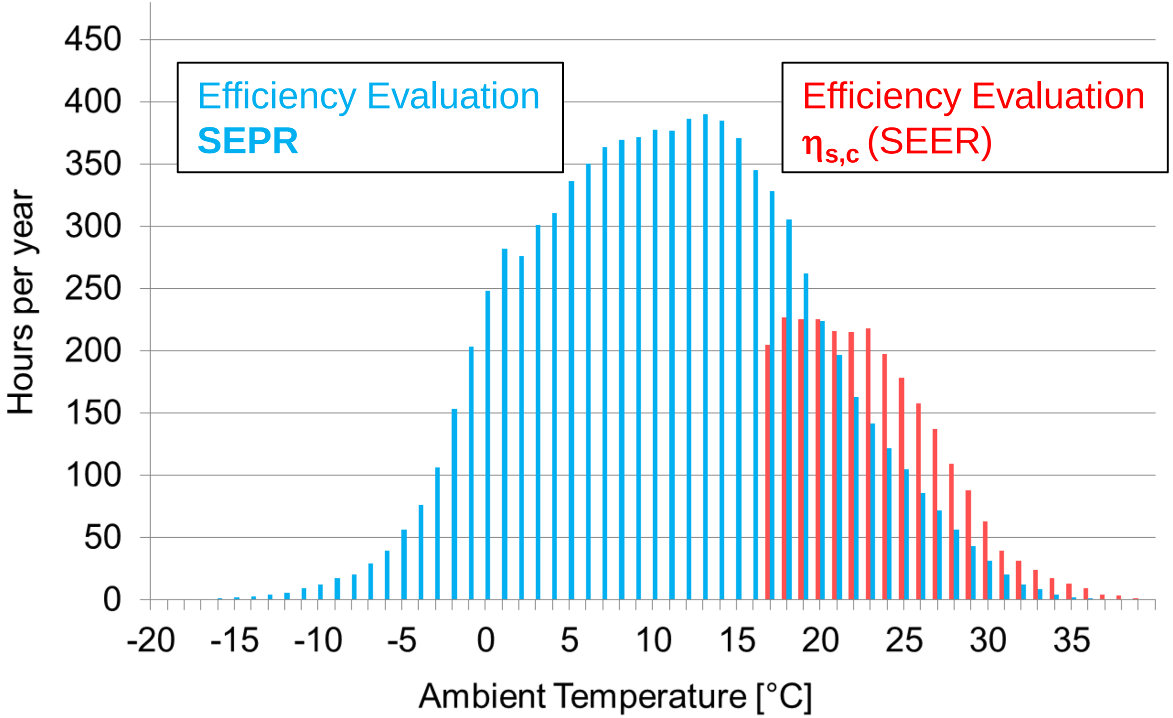
Condensing Units > 5 kW (MT) / 2 kW (LT)
Load Profile vs. Ambient Temperature



Liquid Chillers – Load Profile vs. Ambient Temperature



Temperature Profile (EN 14825) for A/C Chillers vs. Temperature Profile for Process Chillers and CU



Calculation Methods for Evaluation of SEPR and $\eta_{s,c}$ (SEER)

SEPR Calculation Method – CU and Process Chillers

Seasonal **E**nergy **Performance** **R**atio

$$\text{SEPR} = \frac{\sum_{j=1}^{n} h_j \cdot P_R(T_j)}{\sum_{j=1}^{n} h_j \cdot \left(\frac{P_R(T_j)}{COP_{PL}(T_j)} \right)}$$

$EER_{PL(Chiller)}$

$$\text{SEPR} = \frac{\text{annual cooling demand (kWh)}}{\text{annual electricity consumption (kWh)*}}$$

$COP_{PL}(T_j)$ = COP values of the condensing unit for the corresponding BIN temperature T_j

EER_{PL} = EER values of the chiller for the corresponding BIN temperatur T_j

SEER Calculation Method (EN14825) – A/C Chillers

Seasonal **E**nergy **Efficiency** **R**atio

$$SEER = \frac{Q_C}{Q_{CE}}$$ calculated by $$SEERon = \frac{\sum_{j=1}^{n} h_j \times P_c(T_j)}{\sum_{j=1}^{n} h_j \left(\frac{P_c(T_j)}{EER_{bin}(T_j)} \right)}$$

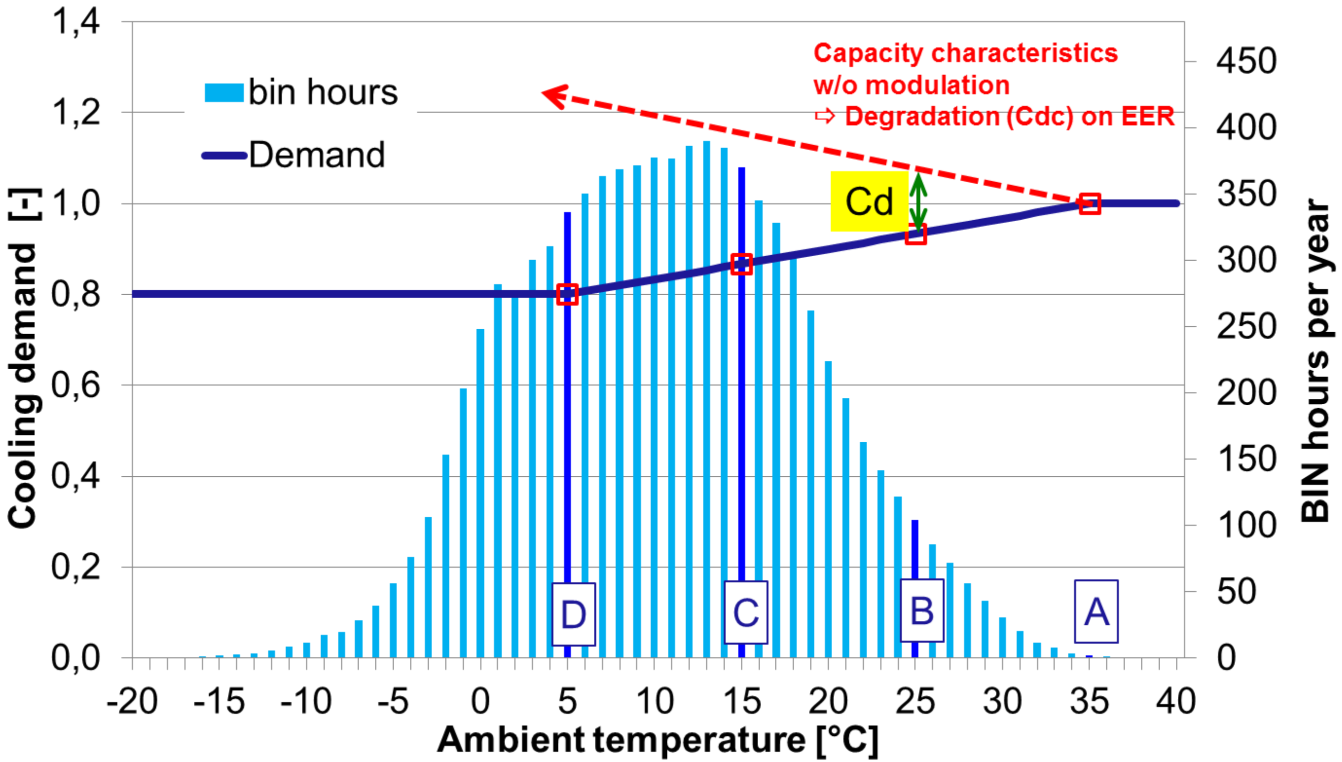
+ Electr. consumpt. (kWh)
  - thermostat-off and standby modes,
  - oil heater mode etc.

$$SEER = \frac{\text{reference annual cooling demand } Q_C \text{ (kWh)}}{\text{reference annual electricity consumption } Q_{CE} \text{ (kWh)}}$$

$EER_{bin}(T_j)$ = EER values for the corresponding BIN temperature T_j

Q_{CE} = Annual electricity consumption incl. thermostat-off mode, oil heater etc.

Degradation Coefficients for EER Correction – Example: Process Chiller w/o Capacity Modulation



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A/C Chillers – Conversion of SEER to Seasonal Space Cooling Energy Efficiency $\eta_{s,c}$

$$\eta_{s,c}\ [\%] = \frac{1}{CC} \cdot SEER\ [\%] - \Sigma F_{(i)}\ [\%]$$

$$\eta_{s,c}\ [\%] = \frac{SEER \cdot 100}{2{,}5} - 3$$

$$\eta_{s,c}\ [\%] = (SEER \cdot 40) - 3$$

- **Conversion Coefficient CC = 2.5 (PEF)** ⇨ currently in discussion (2.0 .. 2.3?)

  reflecting the estimated 40% average efficiency for generating electrical energy within the EU – acc. to Directive 2012/27/EU, Annex IV

- **Summation of Corrections $\Sigma F_{(i)}$ = 3%**

  accounts for the “negative contribution due to adjusted contributions of temperature controls”

Excel Sheet for SEPR Calculation – Example: Process Chillers

Industrial Process Chiller (HT / MT / LT) – Fix Capacity or Stepless Capacity Control | Tool version 1.5.3 | 2013-09-01

Declared cooling capacity at full load i.e. Point A (DC, in kW)	593,00

DC = declared cooling capacity at temperatures A, B, C and D

DC at rating points B, C and D s... of the cooling demand (P_R) – CR...

	EER	Cooling demand (P_R) (=DC(full load)*Partload)	DC in kW (measured or calculated)	EER at this DC (measured or calculated)	Degradation Calculation: Degradation coefficient Cc	Capacity Ratio CR (=P_R/DC)	EER at Part Load EER(PL) (=EER@full cap)*CR/(Cc*CR+(1-Cc))
EER A	2,41	593,00	593,00	2,41	-	1,00	2,41
EER B	3,05	553,47	620,00	3,05	0,90	0,89	3,01
EER C	3,66	513,93	660,00	3,66	0,90	0,78	3,56
EER D	4,24	474,40	710,00	4,24	0,90	0,67	4,04

Please consider: Selection of EERA, EERB, EERC, EERD depends on different ambient temp conditions, load profile and application temperature (HT, MT, LT)

If Cc is not determined by test then the default degradation coefficient Cc shall be 0.9

Ratio between cooling demand and declared capacity (CR=1, in case of a continuous capacity adjustment)

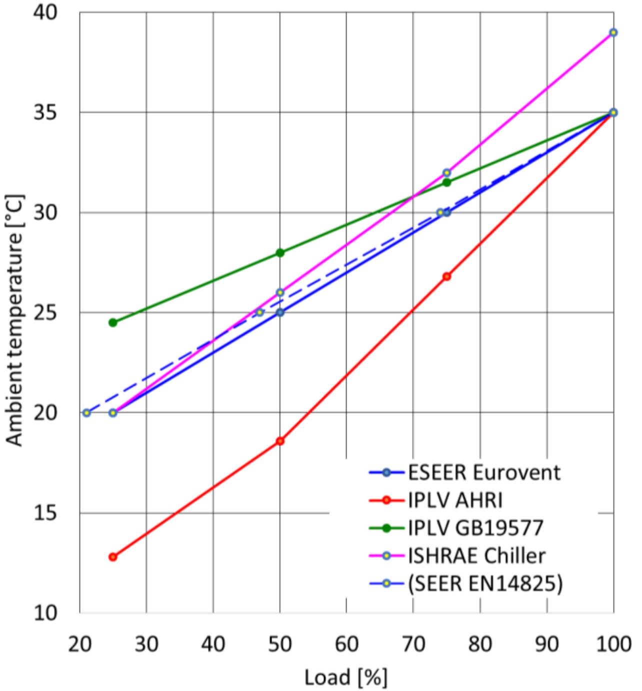
	j	Tj (°C)	hj	part load %	cooling demand	EERPL	Ph*Tj	PH*Tj/EERDC
	1	-19	0,1	80%	474,40	4,04	40	10
	2	-18	0,4	80%	474,40	4,04	193	48
	3	-17	0,6	80%	474,40	4,04	307	76
	54	34	3,8	99%	589,05	2,47	2.256	913
A	55	35	2,1	100%	593,00	2,41	1.240	515
	56	36	1,2	100%	593,00	2,41	716	297
	57	37	0,5	100%	593,00	2,41	309	128
	58	38	0,4	100%	593,00	2,41	238	99
						total	4.393.752	1.205.605

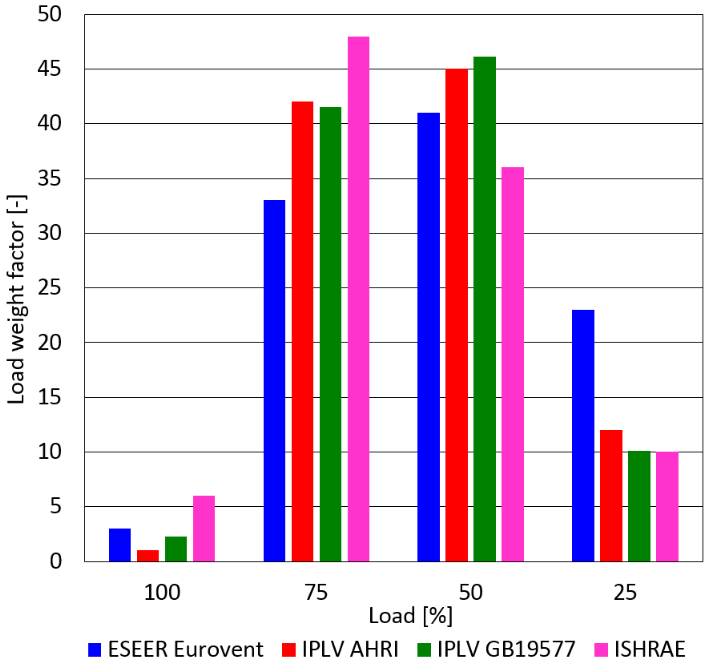
SEPR	3,64

Temperature range for SEPR calculation – from -19°C to 38°C in 1 K increments

4 Reference Conditions:
35°, 25°, 15°, 5°C ambient

Other Programs / Calculation Methods for A/C Chillers





Load and weighting profiles very different
⇨ Programs not comparable

(E)SEER / IPLV = LWF **A** x EER **A** + LWF **B** x EER **B** + LWF **C** x EER **C** + LWF **D** x EER **D**

Efficiency Requirements

Reg. 2015/1095: MEPS Requirements for Condensing Units

Minimum **E**nergy **P**erformance **S**tandards “**MEPS**“

Very ambitious − especially Tier-2
> 35% of products to be dropped or redesigned

Bonus GWP < 150 ⇨ Tier-1: 15% // Tier-2: 10%

	Refrigerating capacity	MEPS Tier-1	MEPS Tier-2
Medium Temperature	5 .. ≤ 20 kW 20 kW .. ≤ 50 kW	2,25 2,35	2,55 2,65
Low Temperature	2 .. ≤ 8 kW 8 kW .. ≤ 20 kW	1,5 1,6	1,6 1,7

up to + 13%

Reg. 2016/2281: MEPS Requirements for A/C Chillers

Minimum **E**nergy
Performance **S**tandards “**MEPS**“

Very ambitious − especially Tier-2
Large proportion to be dropped or redesigned

Comfort A/C Chillers – $\eta_{s,c}$ / (SEER) **Analysis – $\eta_{s,c}$** based on PEF 2.5

	Cooling capacity	$\eta_{s,c}$ (SEER) Tier-1	$\eta_{s,c}$ (SEER) Tier-2
air-cooled	< 400 kW	149% (3,8)	161% (4,1)
	≥ 400 kW	161% (4,1)	179% (4,6)
water-cooled	< 400 kW	196% (5,0)	200% (5,1)
	≥ 400 kW	227% (5,8)	252% (6,4)
	≥ 1500 kW	245% (6,2)	272% (6,9)

up to
+ 11%

Efficiency Improvement Options
Example: Compressors

Efficiency Improvement Options with Compressors

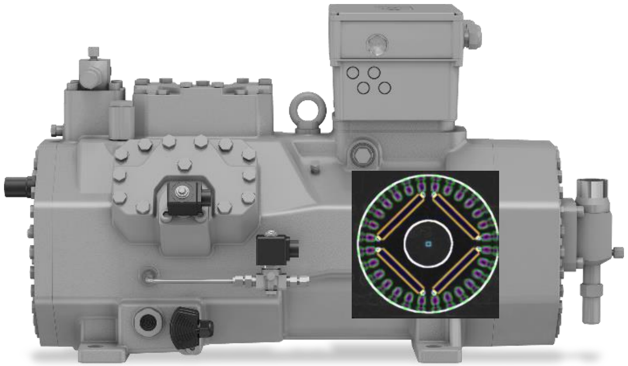
Main challenges with regard to system load and temperature profiles

- Majority of operating time is at part load conditions
  - Requires compressor optimisation for highest part load efficiency
- Quick load variations lead to pressure fluctuation and instable operating behavior ⇨ negative impact on system efficiency
  - Requires close step or stepless capacity modulation
- Improved capacity & efficiency at high lift conditions − e.g. heat pumps, LT appl.
  - Potential for “Economiser” operation with screw and scroll compressors
- Reliable operation and high availability
  - Requires “intelligent” monitoring and control of integrated functions

Efficiency Improvement Options with Recip' Compressors

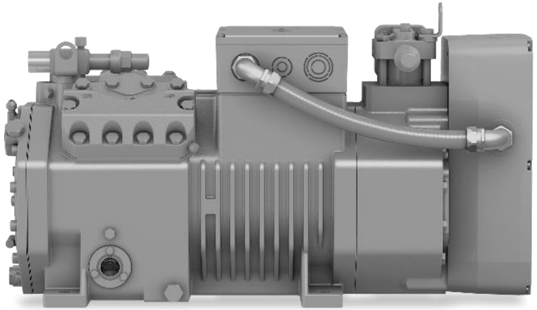
Semi-hermetic recip' (CO_2)

- **LS**PM motor / DOL or VSD
- Quasi stepless mech. CR
- Module for control of functions



Semi-hermetic recip'

- Integrated FI (VSD)
- FI refrigerant cooled
- Stepless CR

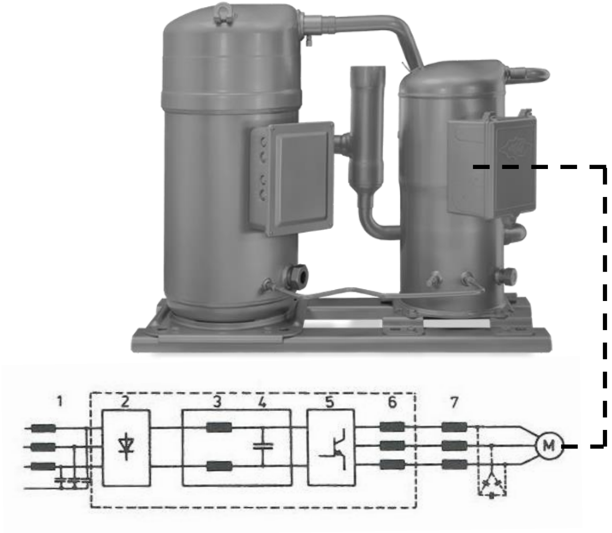


Efficiency Improvement Options with Scroll Compressors

Scroll Multi Packs
- VSD of lead compressor
- Oil equalising system

Single Scroll
- **LS**PM motor
- DOL or VSD

Single Scroll
- Economiser
- e.g. Heat Pump

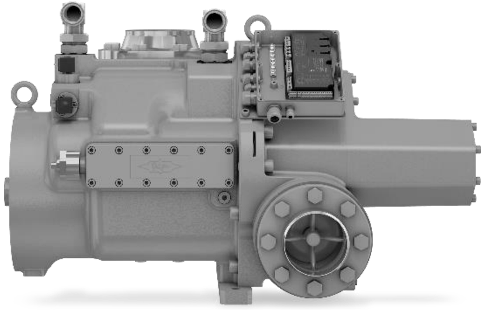


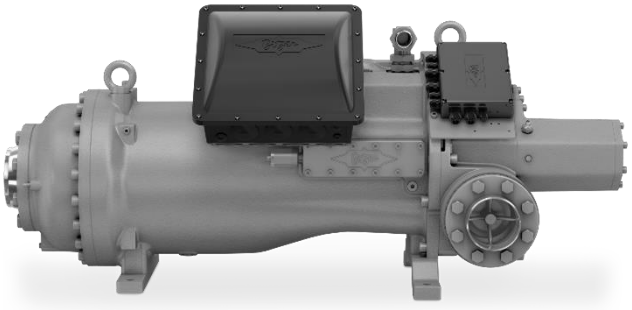
Efficiency Improvement Options with Screw Compressors

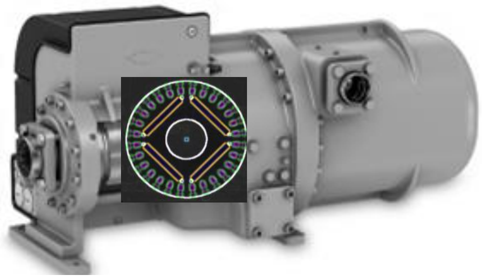
Open drive screw (NH_3)
- Slider cap control or VSD
- Slider Vi control
- Economiser
- Module for control of functions

Semi-hermetic screw
- Slider cap control or VSD
- Slider Vi control
- Economiser
- Module for control of functions

SH Compact screw
- Integrated FI for VSD
- PM motor
- Slider Vi control
- Economiser
- Module for control of functions







Summary

- Global warming and progressing shortage of resources are initiating worldwide legal measures in order to …
  - ➢ improve the energy efficiency of RACHP equipment
  - ➢ reduce energy consumption of buildings
- Different Programs and Standards − mostly <u>not</u> harmonised on international level
- MEPS requirements are very ambitious − often require a modification of equipment or even a new design
- One possible approach ⇨ High efficiency compressors with optimised capacity modulation techniques and motor design

eurammon is always available as a sparring partner for questions on refrigeration with natural refrigerants.

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