



COOLING TECHNOLOGY

The Future use of refrigerants under the impact of current regulations

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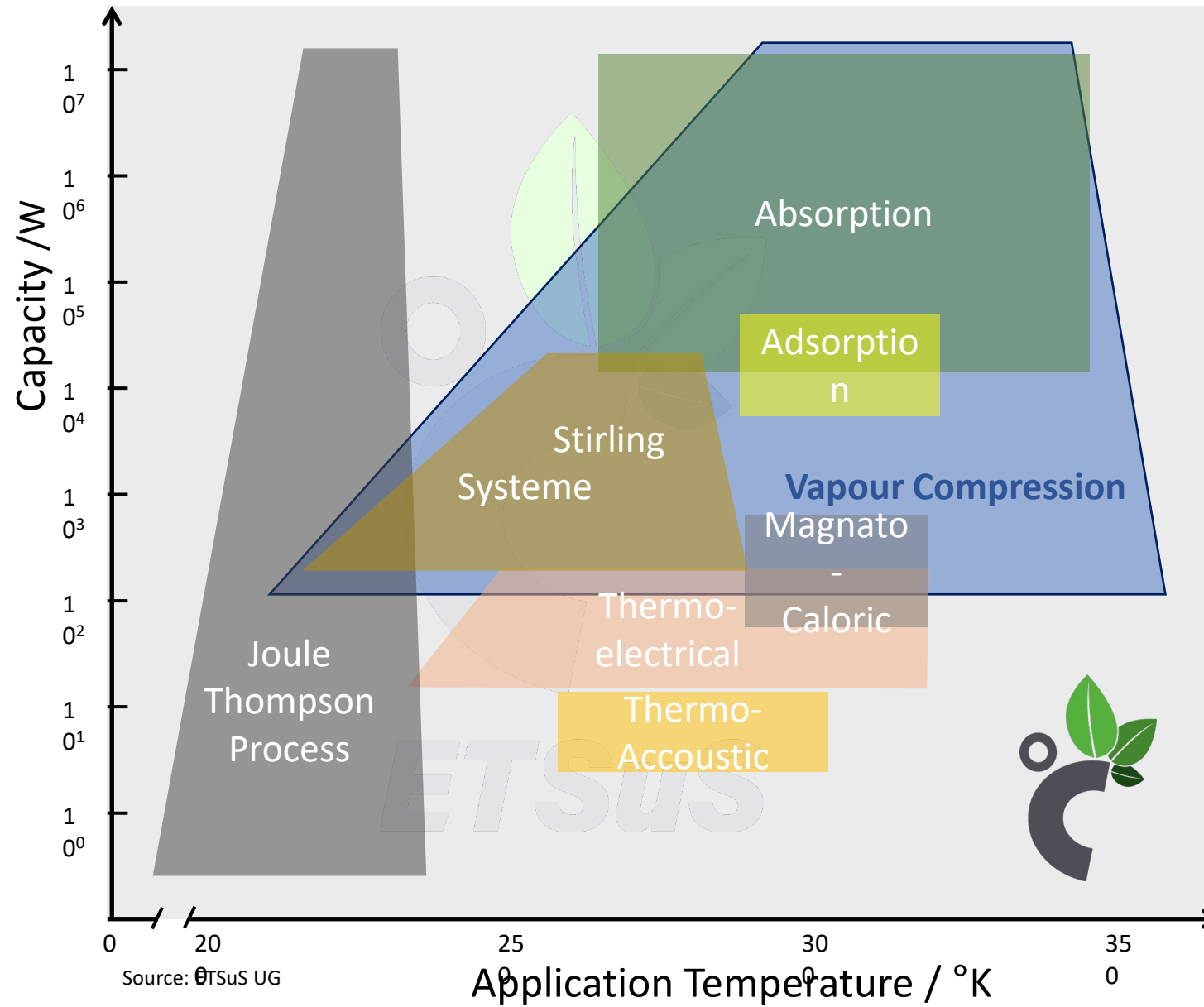


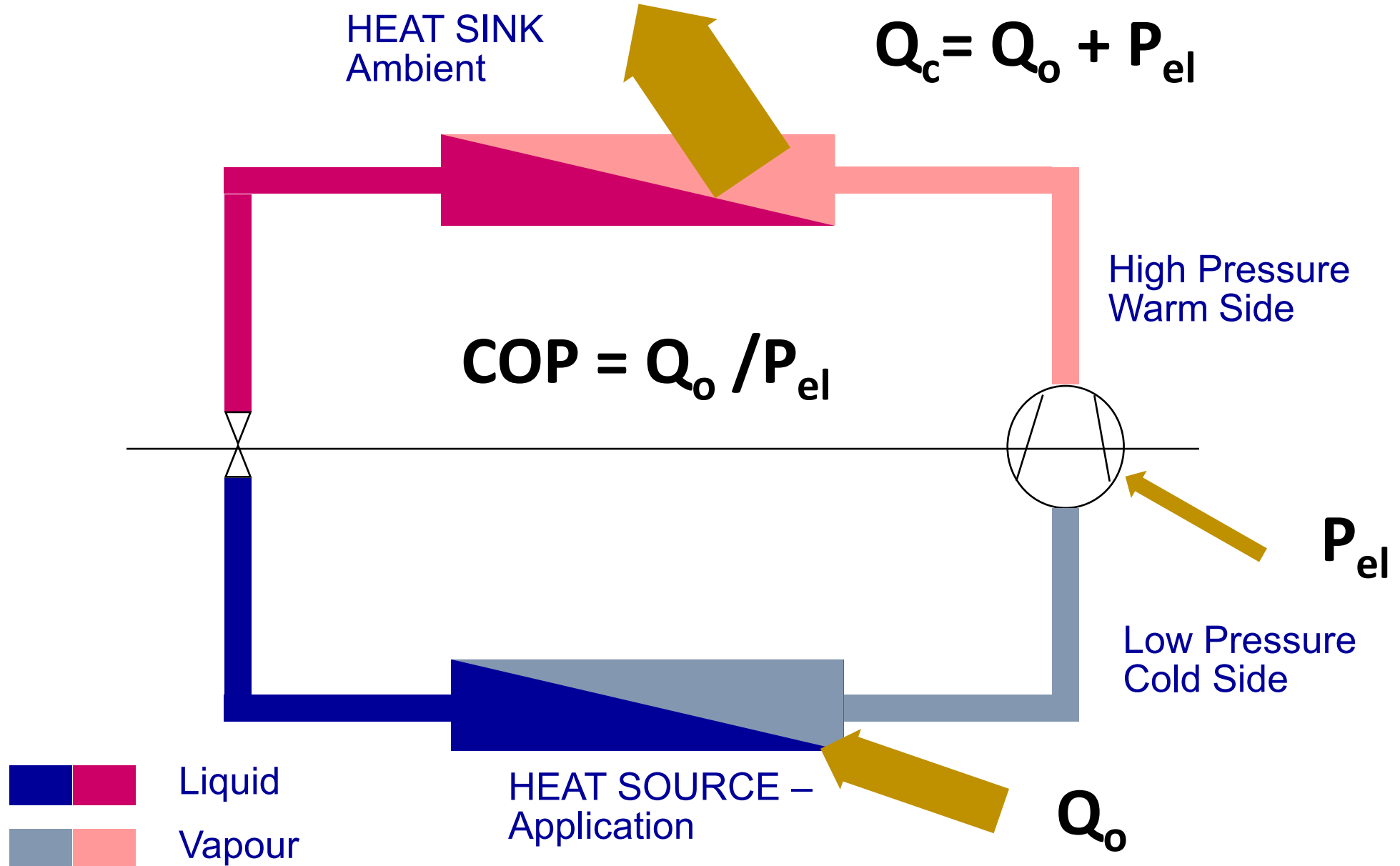
- Introduction
- Cooling technology – a short overview
- Refrigerants legal changes and technical challenges
- Motivation environmental challenge
- The technological challenge: F-Gas Regulation
- Refrigerants – once, now and future
- Summary and outlook

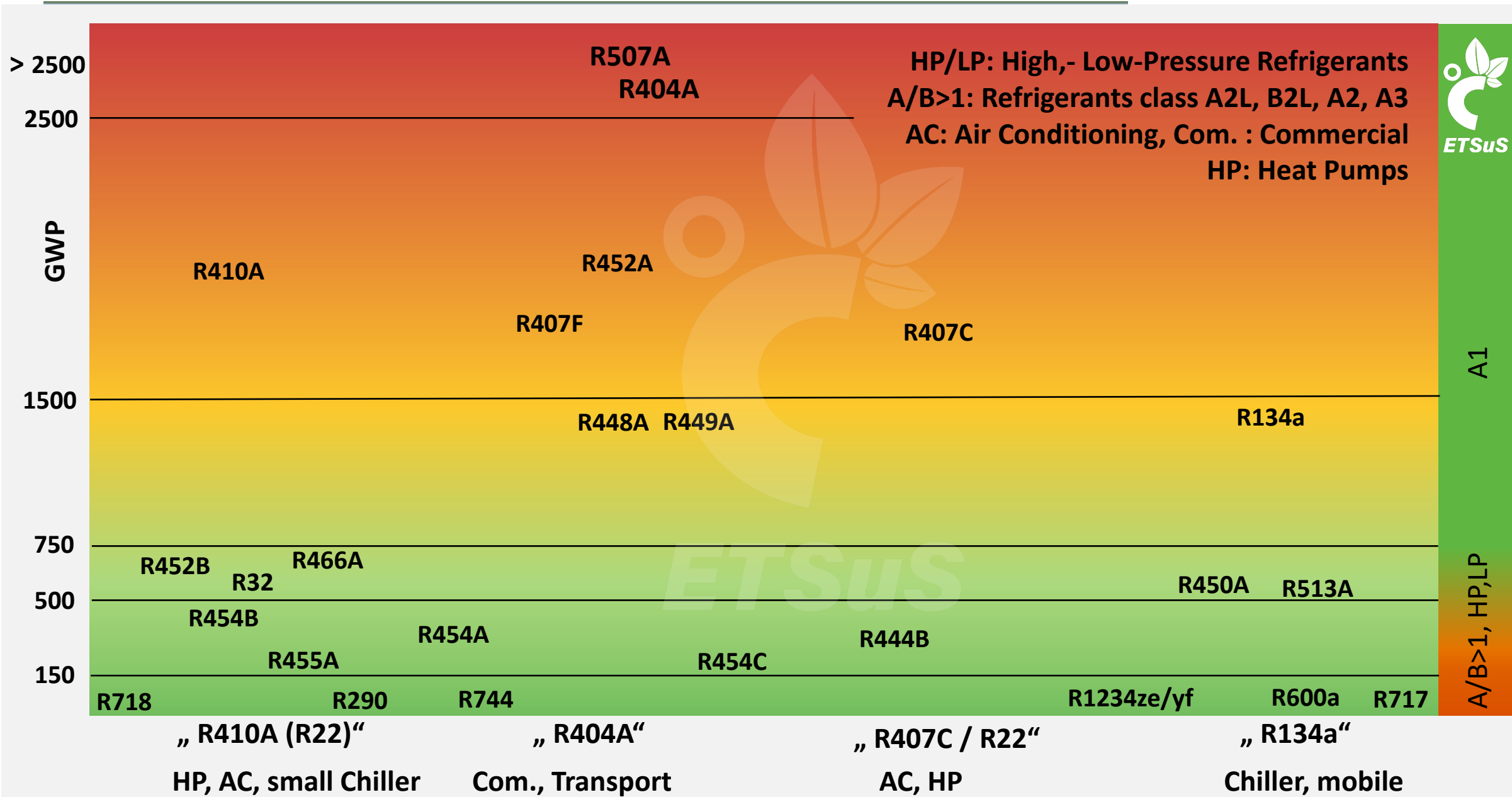


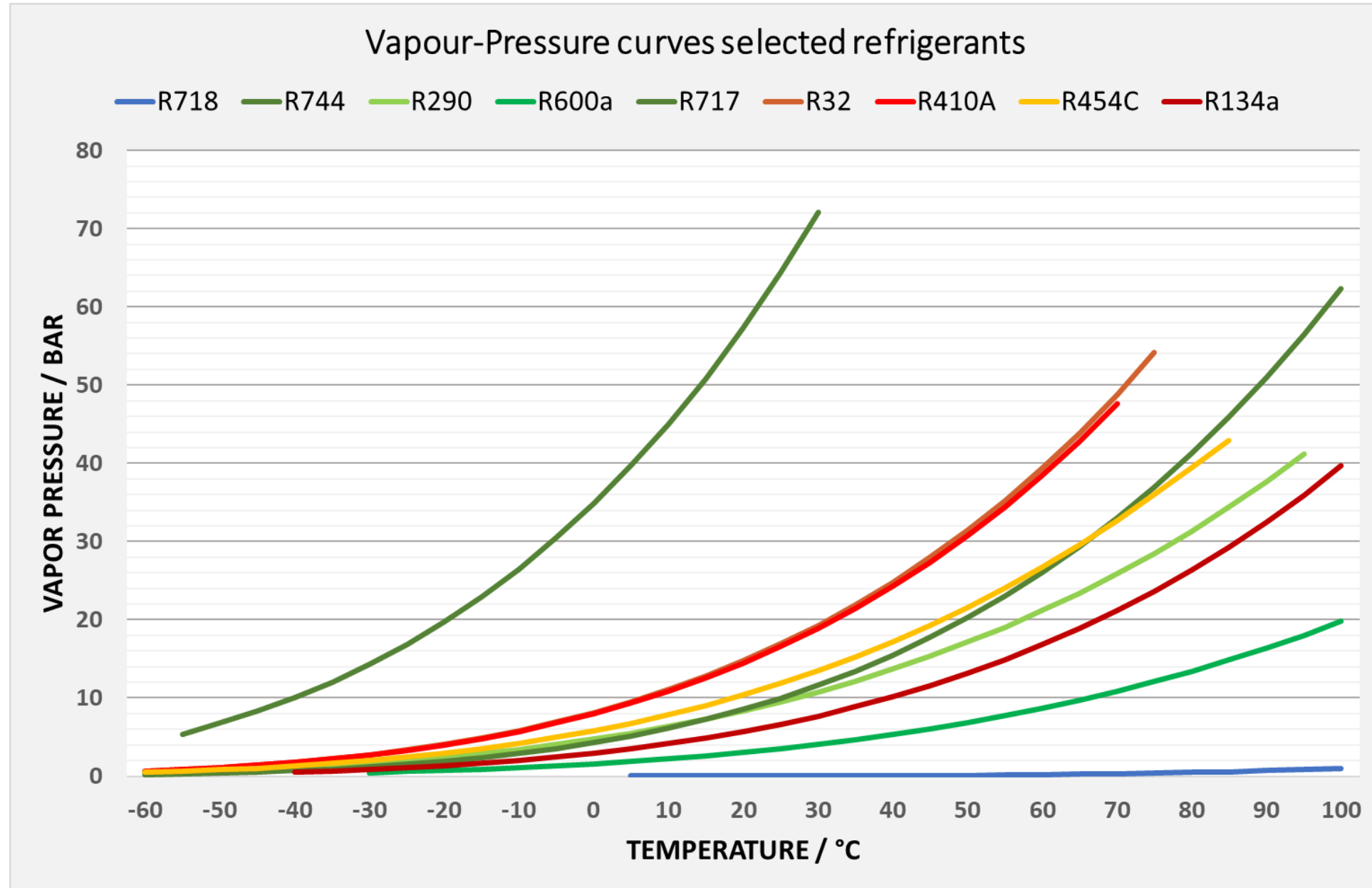
Cooling technology

- Why cooling technology?
- Technology options
- The vapour compression cycle











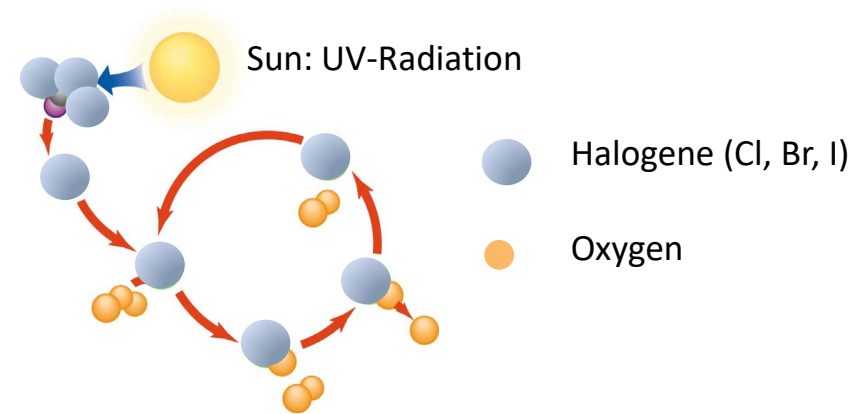
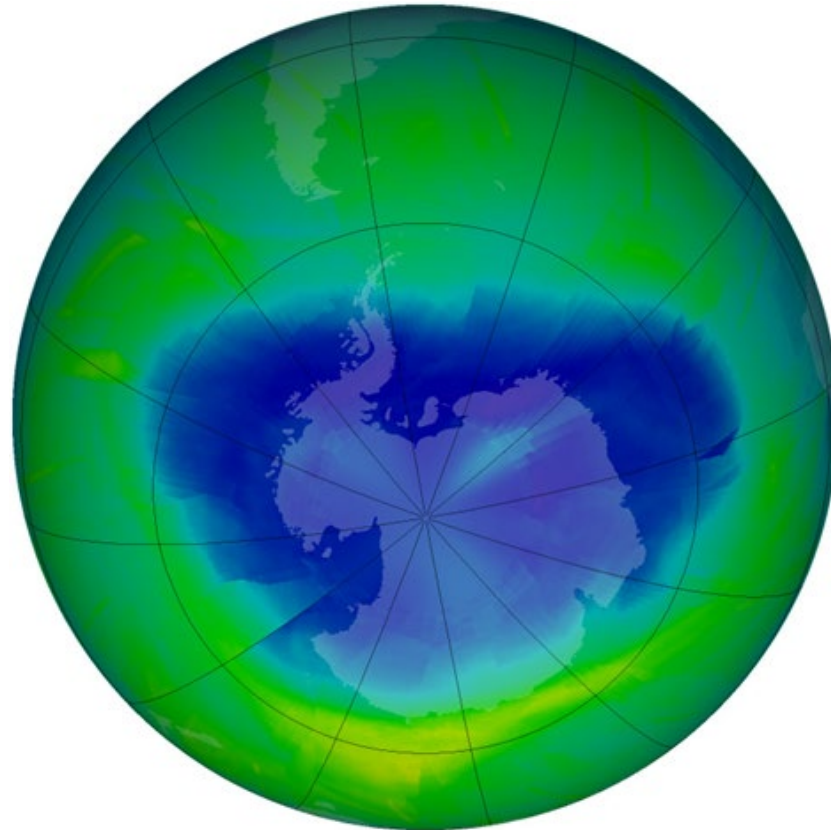
Refrigerants legal changes and technical challenges

- Motivation environmental challenge - Metrics
- The technological challenge: F-Gas Regulation; Reach, Taxaonomy
- Refrigerants – once, now and future
- Summary and outlook



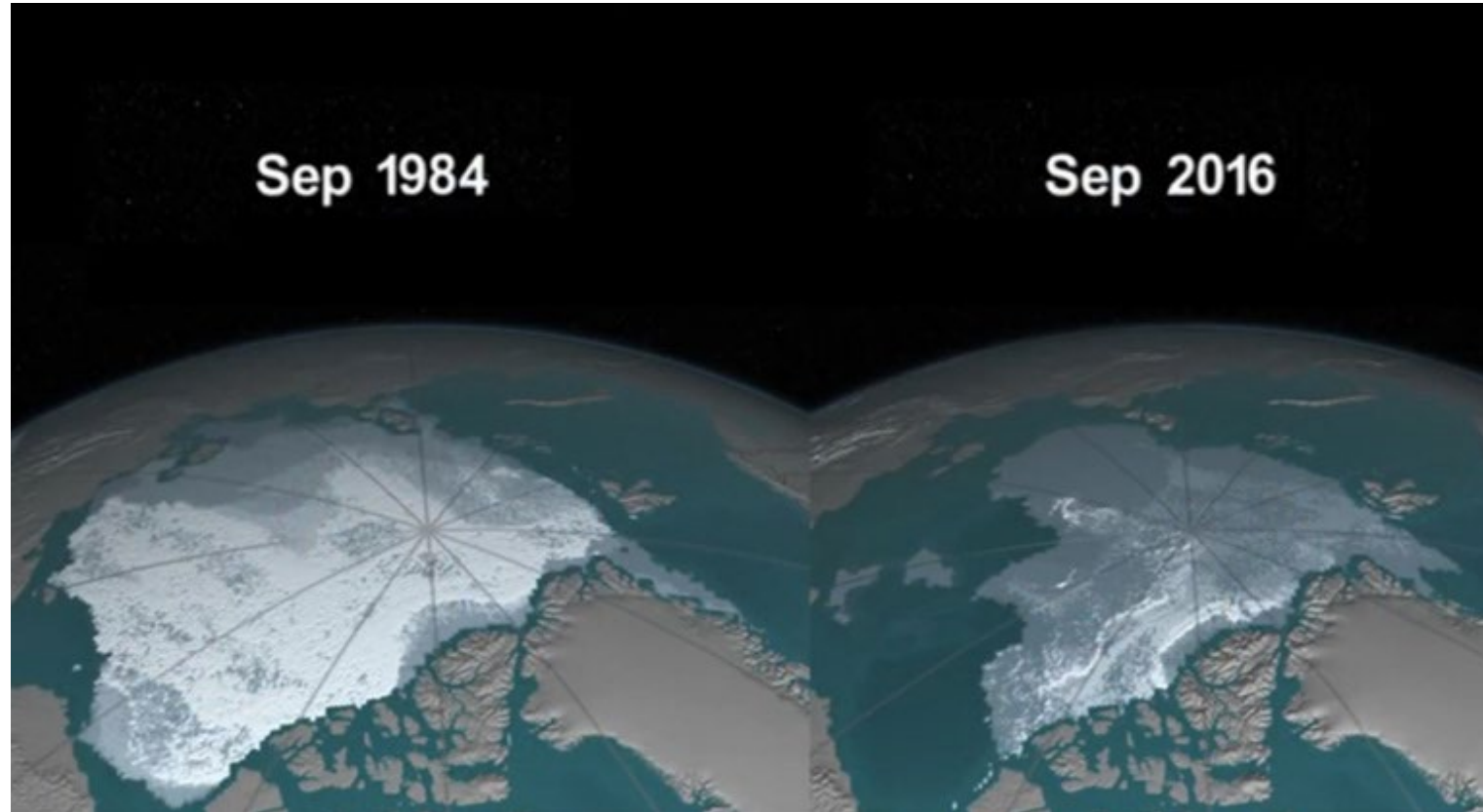
Motivation environmental challenge - Metrics

- ODP – Ozone Depletion Potential
- GWP – Global Warming Potential
- PFAS (Per- and polyfluorinated alkyl substances)
- TFA (Trifluoroacetic Acid)

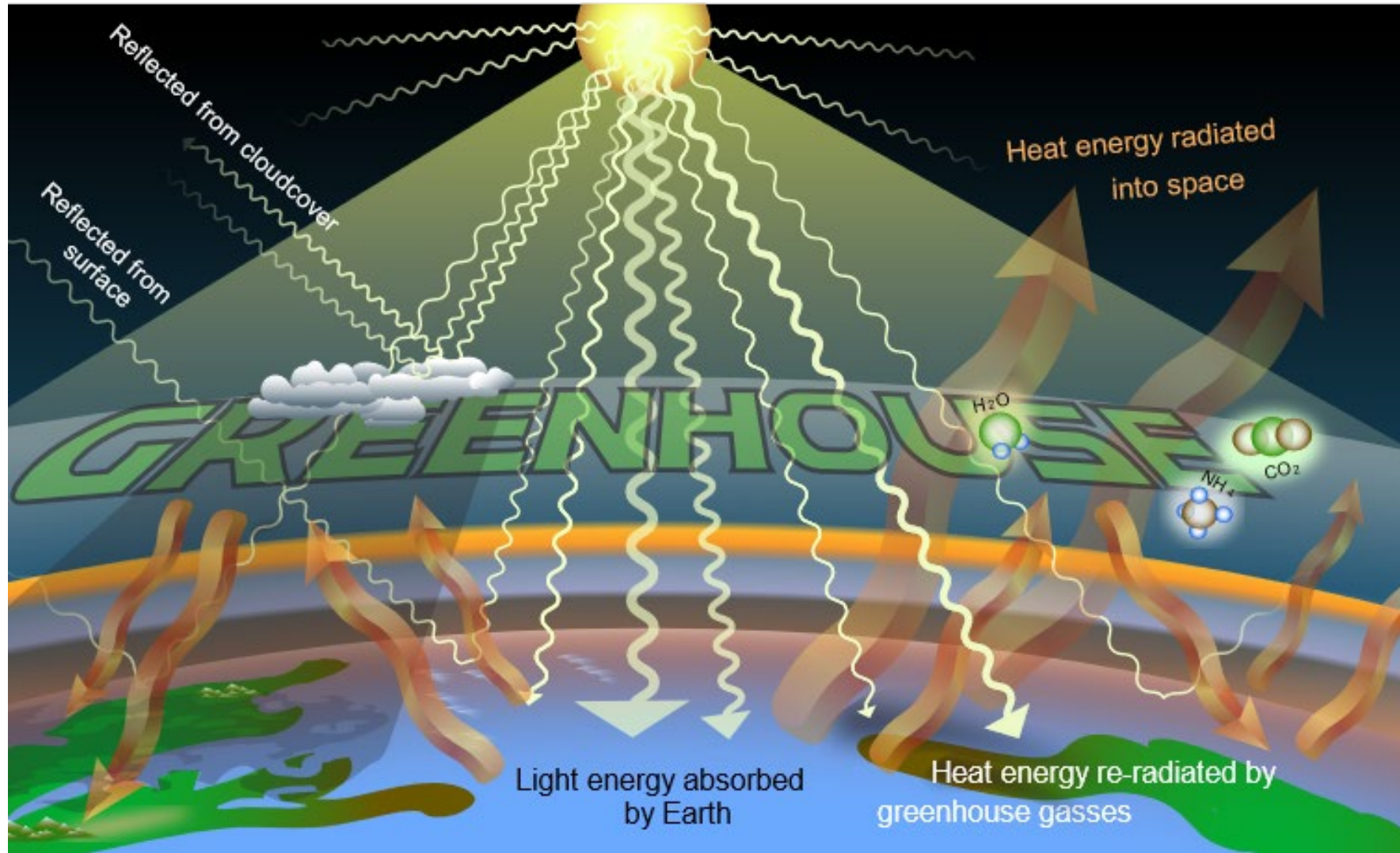


- Ozone Depletion Thesis:
Molina & Rowland & Crutzen 1974
- CFCs as major contributor

Source: NASA Goddard Space Flight Center from Greenbelt, MD, USA - Snapshot of the Antarctic Ozone Hole 2010, Public Domain,
<https://commons.wikimedia.org/w/index.php?curid=69017095>



Quelle: © NASA Goddard Screenshot youtube.com



Source: A loose necktie - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=78336181>



Montreal Protocol (1987) 197 countries as parties (all UN members)

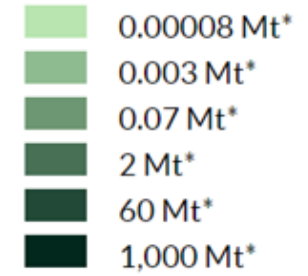
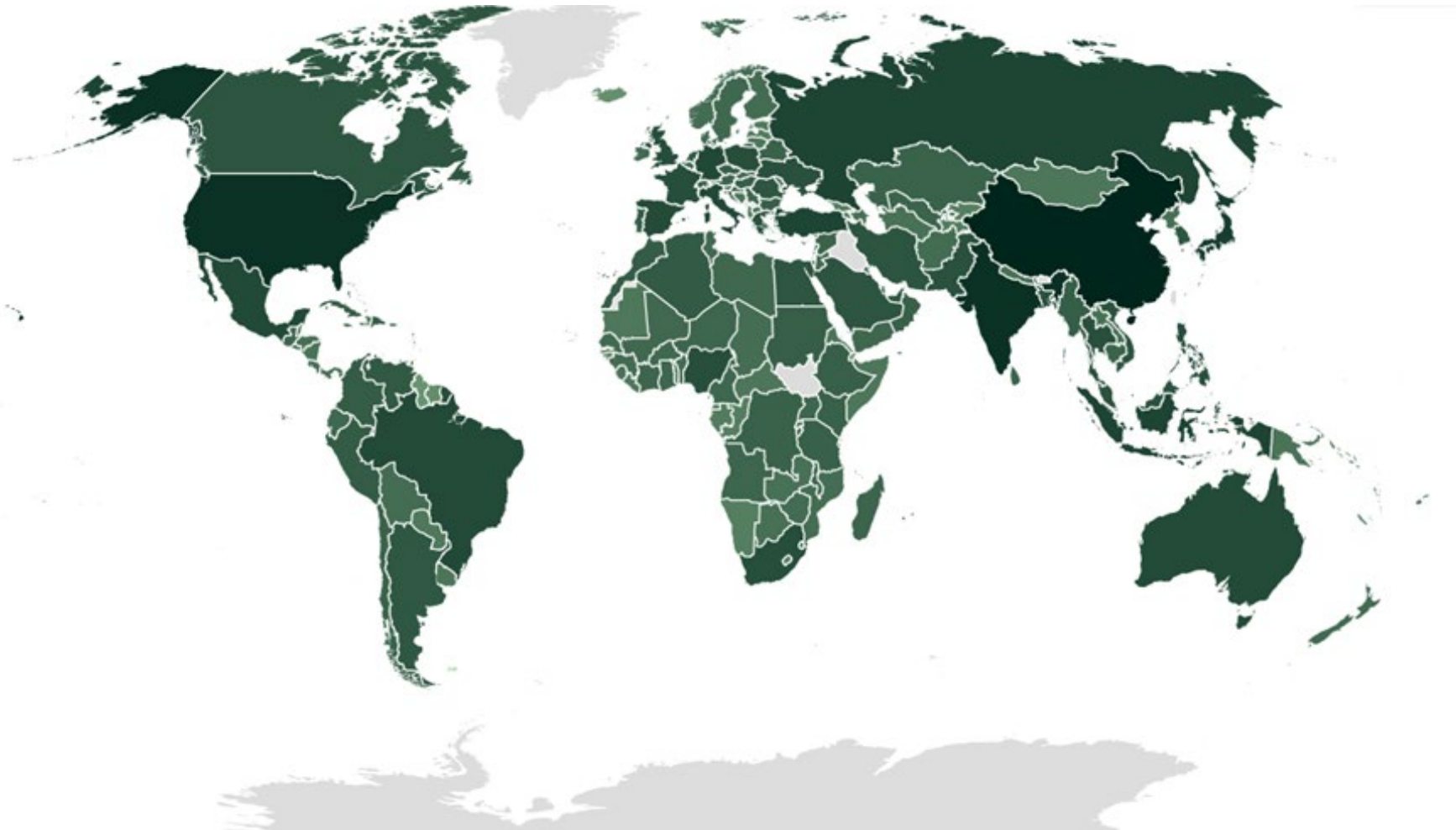
- Based on Vienna Convention (1985)
- Originally focussed on Protection of the Ozone layer
- Phase out/down of ODS (Ozone Depleting Substances)
- Broader approach on GHG (Greenhouse Gases)
- Kigali Amendment (2016):
 - Focussed on phase down of F-Gases (indirect via CO₂- emissions)
 - 15% target value of baseline

Kyoto Protocol (1997) 191 countries + EU ratified

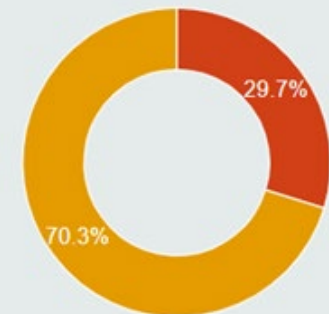
- Focussed on GHG emissions
- Paris Agreement (2015) to limit global warming to 1,5 °C, ratified by 185 nations



- Cooling sector including AC , HP and cryogenics accounts for 7,8 % of global greenhouse gas emissions¹
- Total emissions account to app. 4 Gt CO_{2e} in 2016
- Due to market development – mainly increase of AC sales – total emissions could increase dramatically
- Without counter measures energy demand could triple by 2050 compared to 2016
- With counter measures (mitigation measures) a reduction of 33 – 45 % is achievable in 2050



Total emissions
3,830 Mt*



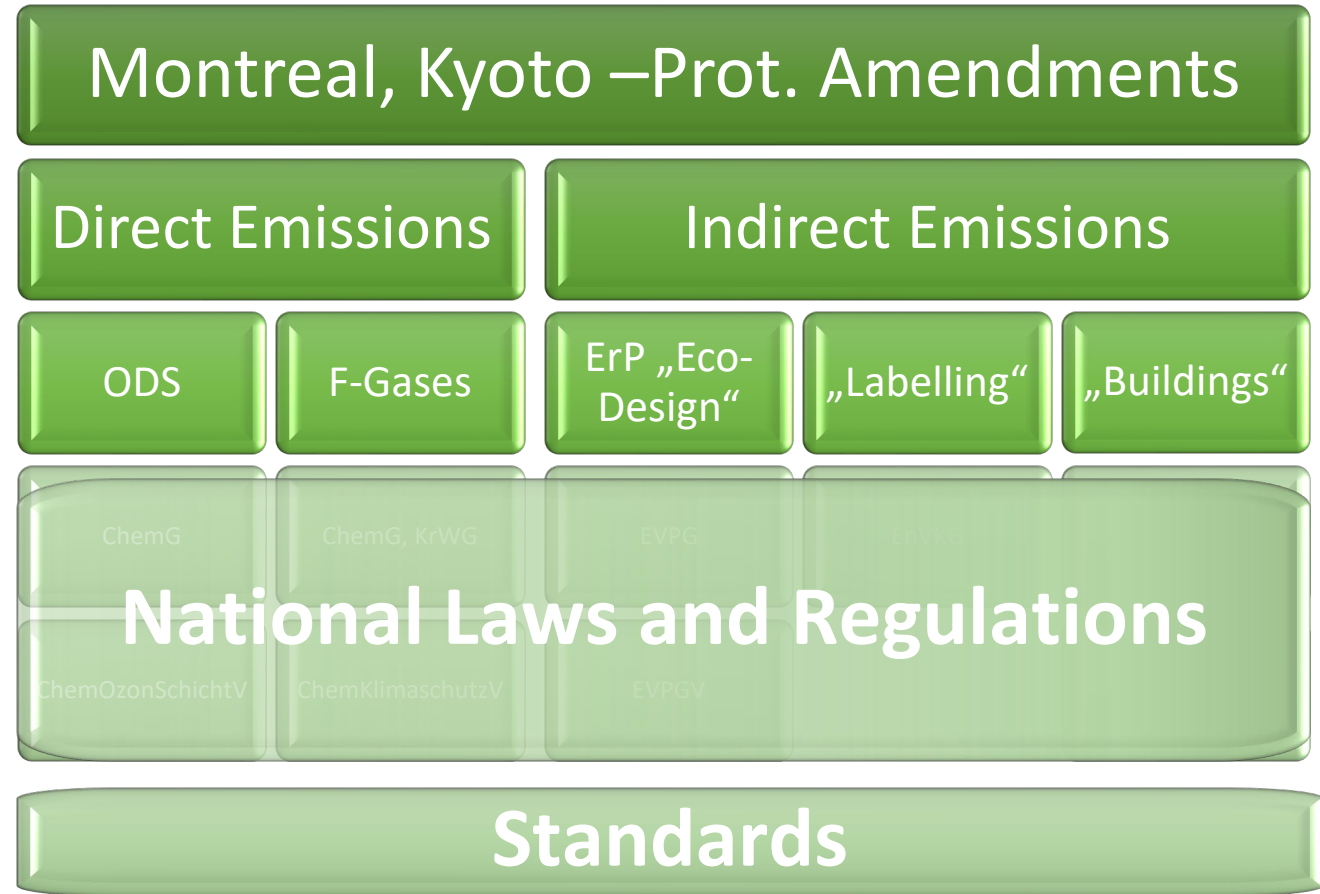
 direct emissions  indirect emissions

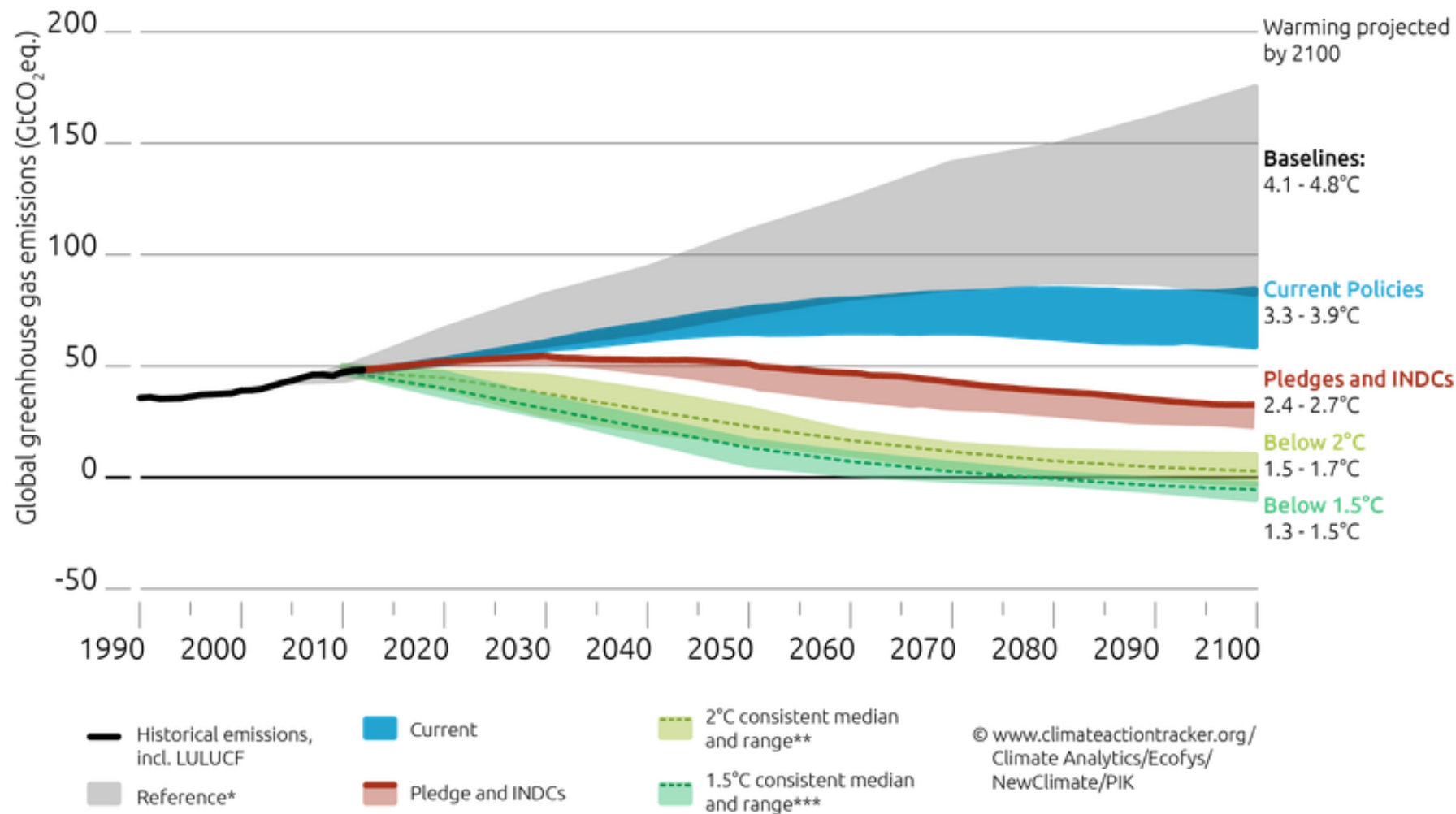


- Global Conventions
- Ratification

- EU Targets
- EU Legal Instruments

- National Laws
- „Standards“



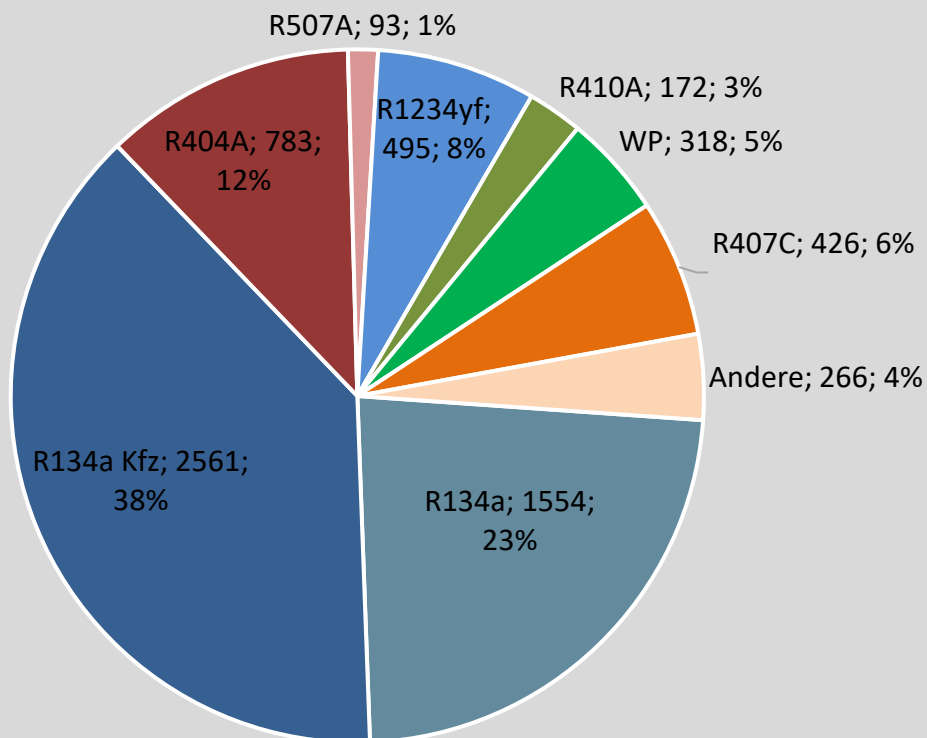




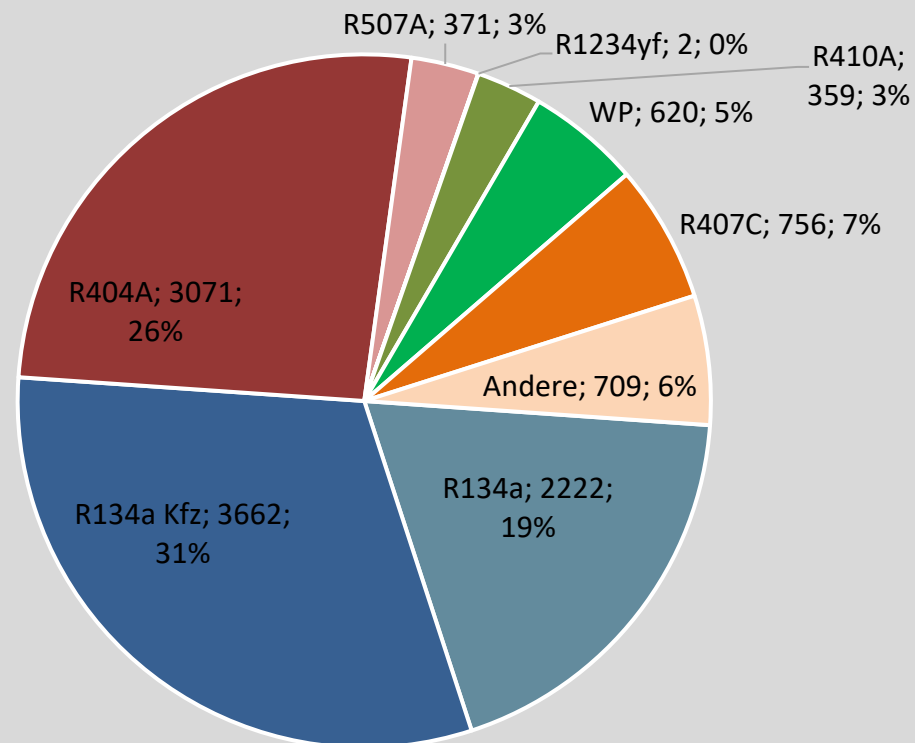
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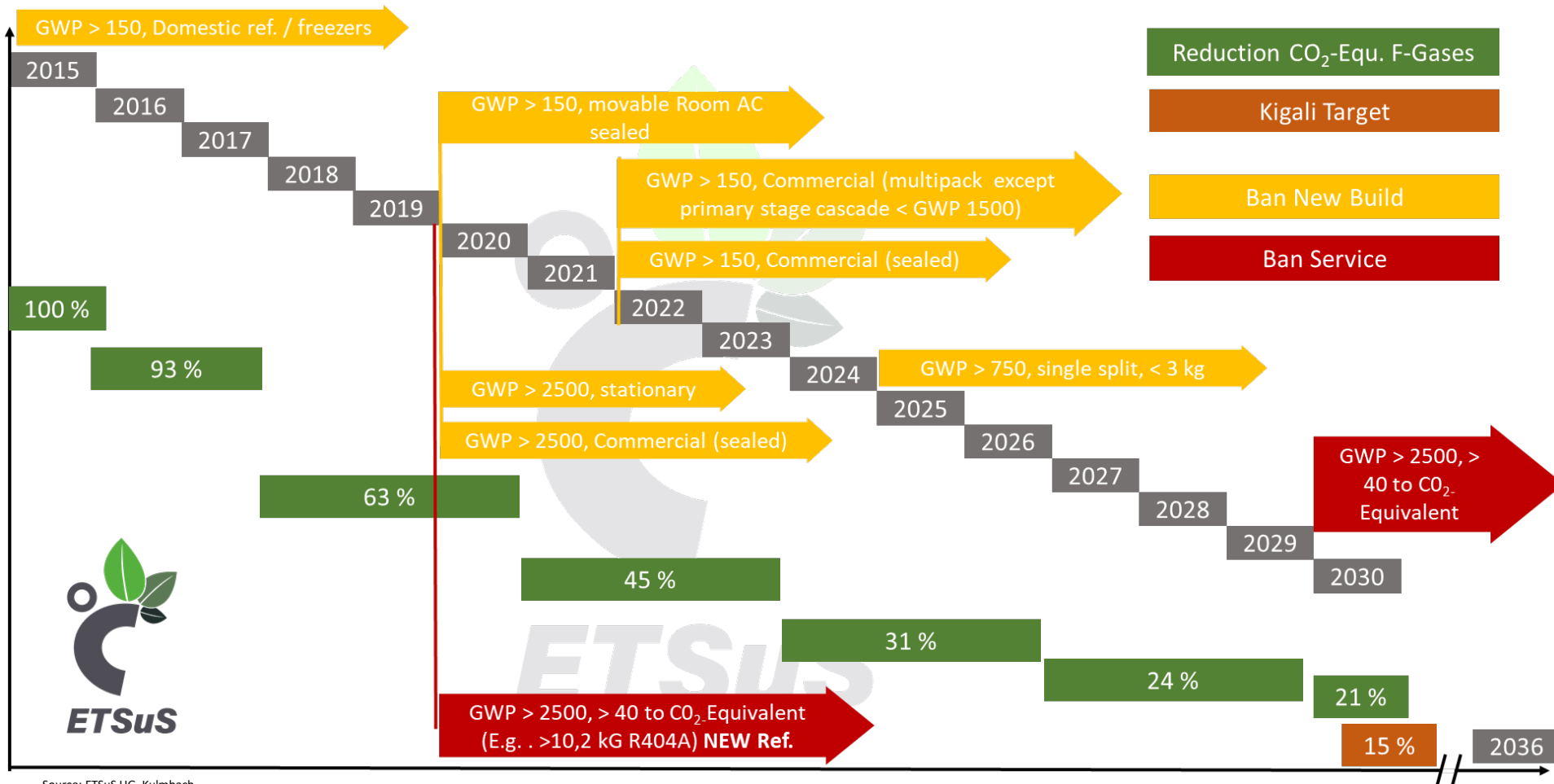
**Share per Ref. / to
Total ca. 6700 to**



**Share per Ref. / 1000 to CO₂-E.
Total ca. 12 Mio. to CO₂-E.**



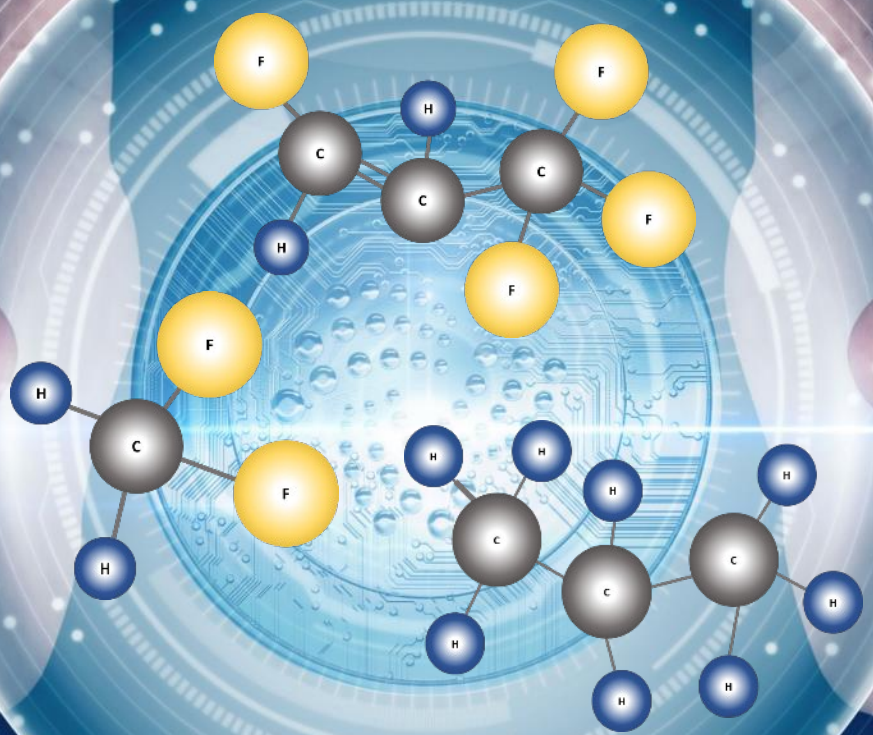
**Average GWP 2016:
1776**

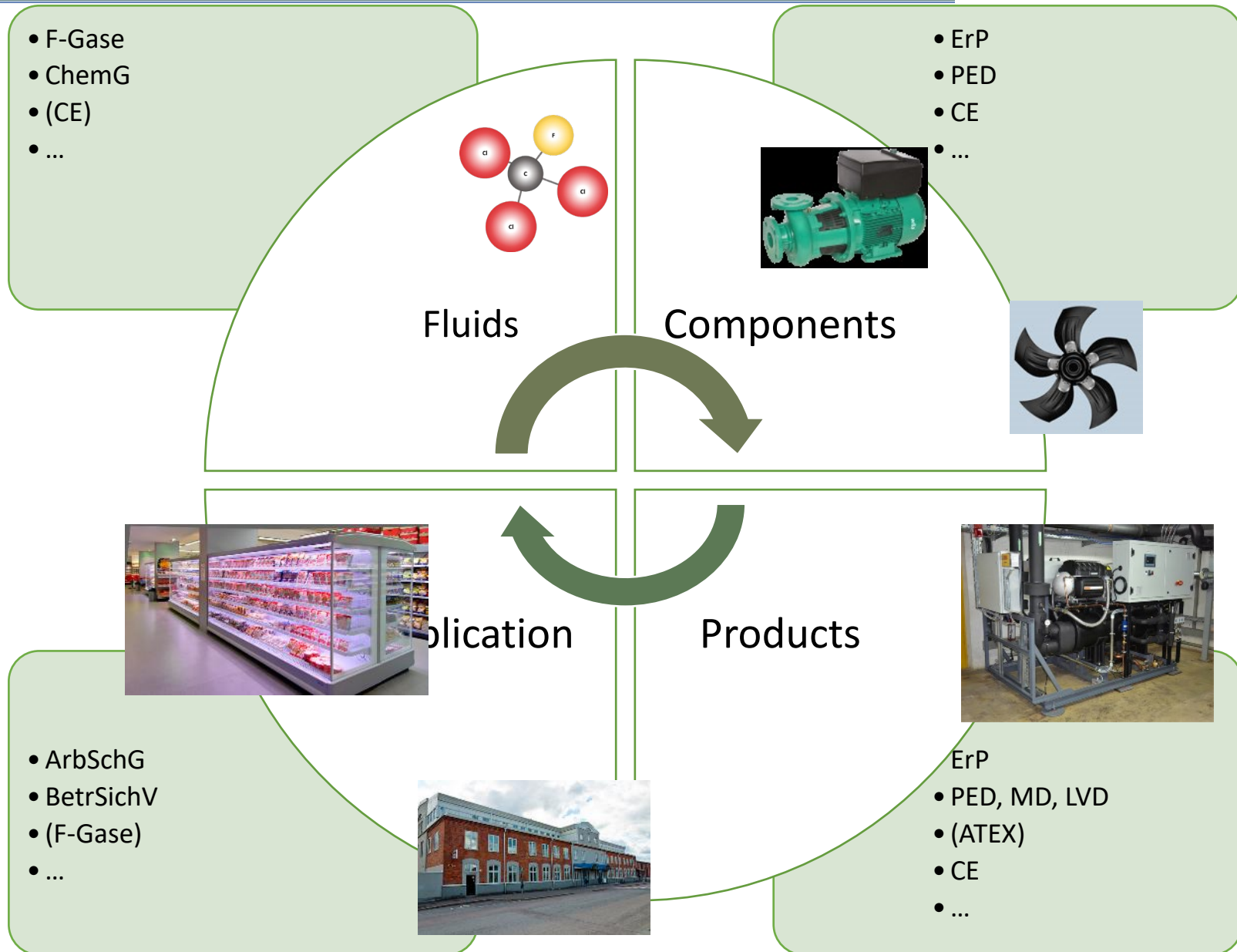
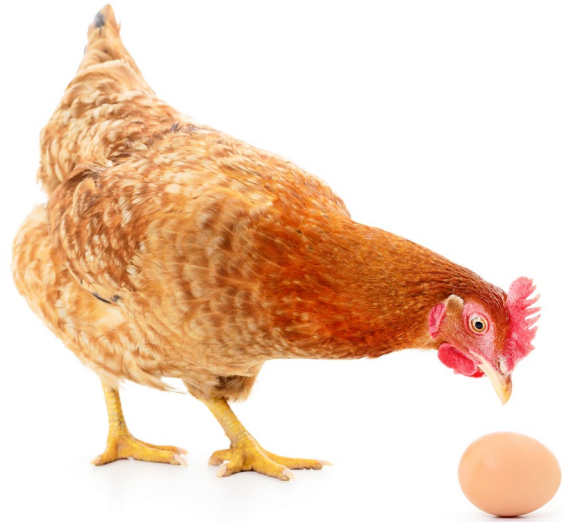


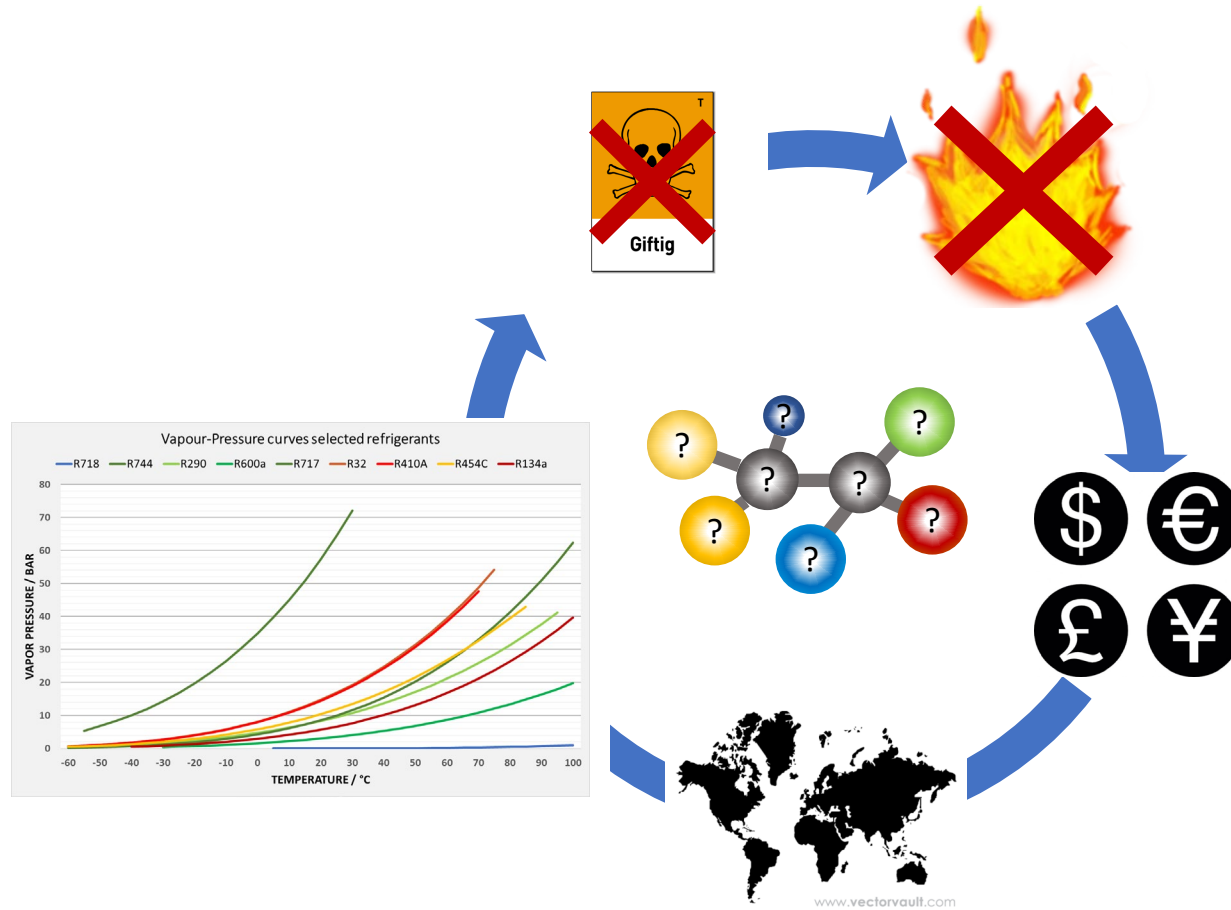
Source: ETSuS UG, Kulmbach

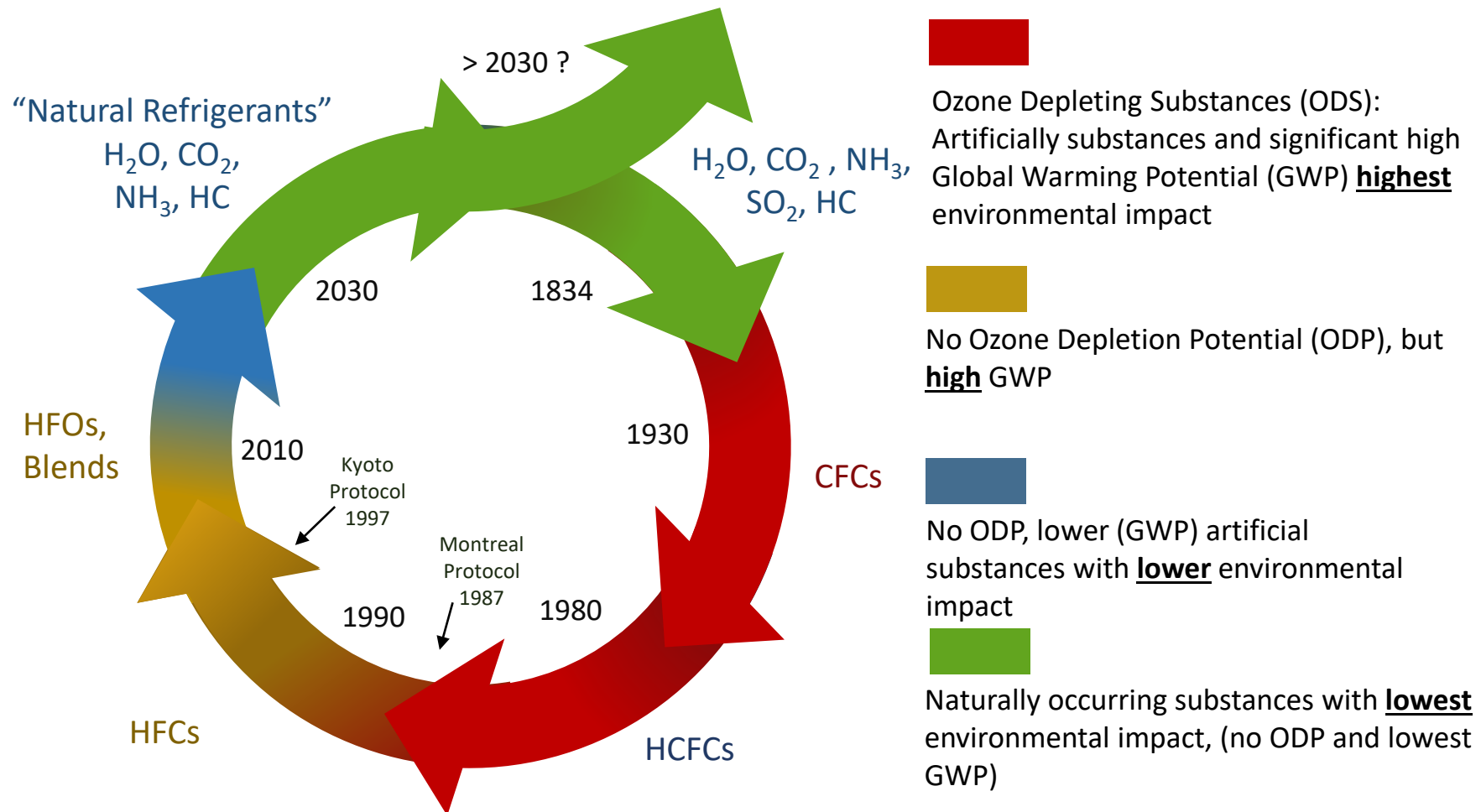


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Product – „CE“

„Manufacturer
„Free Trade..“

GPSD, PED, MD, LVD...

Harmonised Standards
...EN 378, EN 60335

„Humans“

„Employer“

„OHS“

WSD, WPSD;WES,
ATEX-B....

Application

„User“

„Safe Operation“

ErP, F-Gase, EPBD, CPD,
CLP, ADR,



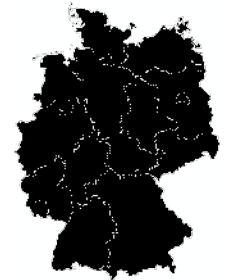
ProdSG, 1., 9., 14. ProdSV
ChemG., GefStoffV
BlmschG,V...

ArbSchG,
15. SozVersG

BlmSchG, -V
EnEV

BetrSichV
ArbStättV.
...

MBO, MVV TB, BRL, MARL



TRBS, TRGS
ASR
DGUV-R

LBO,
VStättV, FeuV,...





**A little refrigerant cooking
cooking session in the
witches kitchen**

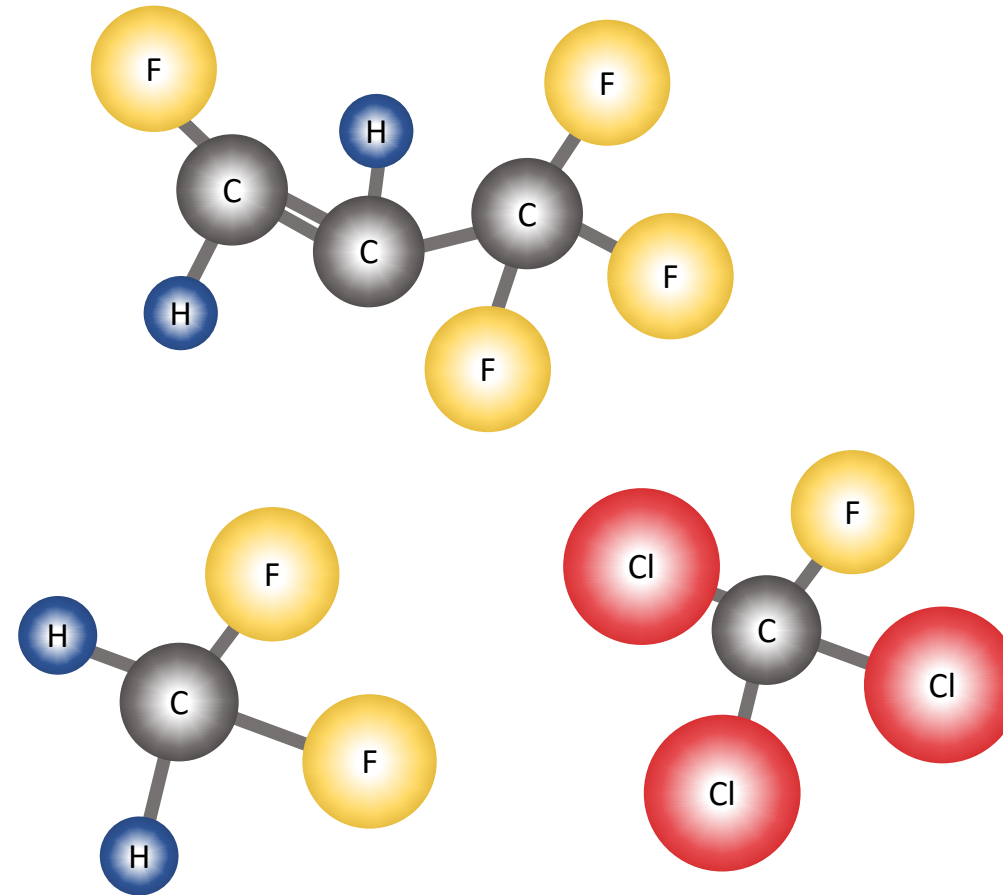


Flammability \ Toxicity	Toxicity	
	Lower Chronic Toxicity	Higher Chronic Toxicity
No Flame Propagation	A1	B1
Lower Flammability	A2L	B2L
Flammable	A2	B2
Higher Flammability	A3	B3

	GWP
Highest GWP	A1
High GWP	A2, A2L
Lower GWP	A2L
Lowest / GDP	A3, B2L, R744



- CFCs, HCFCs, HFCs
 - R11, R22, R134a, R32, R125
- Mixtures
 - Azeotropic
 - R502, R507
 - Non/Azeotropic
 - R410A, R407C
- HFOs
 - HFO1234yf, HFO1234ze,
- Natural Refrigerants”
 - R744, R717, ...
- HCs
 - R290, R170, R600a,





Refrigerant cooking session – the ingredients – What's left?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
I	II											III	IV	V	VI	VII	VIII
1H Wasserstoff 1 20.268 K																	2He Helium - 4.215 K
3Li Lithium 1 1515 K	4Be Beryllium 2 2745 K											5B Bor 3 4275 K	6C Kohlenstoff 4 4470 K	7N Stickstoff 3 77.35 K	8O Sauerstoff 2, -1 90.18 K	9F Fluor -1 84.95 K	10Ne Neon - 27.096 K
11Na Natrium 1156 K	12Mg Magnesium 1363 K											13Al Aluminium 2793 K	14Si Silicium 3540 K	15P Phosphor 550 K	16S Schwefel 717.75 K	17Cl Chlor 239.1 K	18Ar Argon 87.30 K
19K Kalium 1 1032 K	20Ca Calcium 2 1757 K	21Sc Scandium 3 3104 K	22Ti Titan 4, 3 3562 K	23V Vanadium 5, 4, 3, 2 3682 K	24Cr Chrom 6, 3, 2 2945 K	25Mn Mangan 7, 6, 4, 2, 3 2335 K	26Fe Eisen 2, 3 3135 K	27Co Cobalt 2, 3 3201 K	28Ni Nickel 2, 3 3187 K	29Cu Kupfer 2, 1 2836 K	30Zn Zink 2 1180 K	31Ga Gallium 3 2478 K	32Ge Germanium 4 3107 K	33As Arsen ±3, 5 876 K (sub)	34Se Selen -2, 4, 6 958 K	35Br Brom ±1, 5 332.25 K	36Kr Krypton - 119.80 K
37Rb Rubidium 1 961 K	38Sr Strontium 2 1950 K	39Y Yttrium 3 3611 K	40Zr Zirkonium 4 4682 K	41Nb Niob 5, 3 5017 K	42Mo Molybdän 6, 5, 4, 3, 2 4912 K	43Tc Technetium 7 4538 K	44Ru Ruthenium 2, 3, 4, 6, 8 4423 K	45Rh Rhodium 2, 3, 4 3970 K	46Pd Palladium 2, 4 3237 K	47Ag Silber 1 2436 K	48Cd Cadmium 2 1040 K	49In Indium 3 2346 K	50Sn Zinn 4, 2 2876 K	51Sb Antimon ±3, 5 1960 K	52Te Tellur -2, 4, 6 1261 K	53I Iod ±1, 5, 7 458.4 K	54Xe Xenon - 165.03 K
55Cs Cäsium 1 944 K	56Ba Barium 2 2171 K	57La Lanthan 3 3730 K	72Hf Hafnium 4 4876 K	73Ta Tantal 5 5731 K	74W Wolfram 6, 5, 4, 3, 2 5828 K	75Re Rhenium 7, 6, 4, 2, -1 5899 K	76Os Osmium 2, 3, 4, 6, 8 5285 K	77Ir Iridium 2, 3, 4, 6 4701 K	78Pt Platin 2, 4 4100 K	79Au Gold 3, 1 3130 K	80Hg Quecksilber 2, 1 630 K	81Tl Thallium 3, 1 1746 K	82Pb Blei 4, 2 2023 K	83Bi Bismut 3, 5 1837 K	84Po Polonium 4, 2 1235 K	85At Astat ±1, 3, 5, 7 610 K	86Rn Radon - 211 K
87Fr Francium 1 950 K	88Ra Radium 2 1809 K	89Ac Actinium 3 3473 K	104Rf Rutherfordium - -	105Db Dubnium - -	106Sg Seaborgium - -	107Bh Bohrium - -	108Hs Hassium - -	109Mt Meitnerium - -	110Ds Darmstadtium - -	111Rg Roentgenium - -	112Uub Ununbium - -	113Uut Ununtrium - -	114Uuq Ununquadium - -	115Uup Ununpentium - -	116Uuh Ununhexium - -	117Uus Ununseptium - -	118Uuo Ununoctium - -

Do not form gases	Ozone depleting	Remaining candidates
Do not react at all	Greenhouse effect	
	Toxic	

Source: ETSuS UG



Refrigerant cooking session – the ingredients

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
I	II											III	IV	V	VI	VII	VIII	
1 H																	2 He	
	3Li	4Be										5B	6C	7N	8O	9F	10Ne	
	11Na	12Mg									13Al	14Si	15P	16S	17Cl	18Ar		
	19K	20Ca	21Sc	22Ti	23V	24Cr	25Mn	26Fe	27Co	28Ni	29Cu	30Zn	31Ga	32Ge	33As	34Se	35Br	36Kr
	37Rb	38Sr	39Y	40Zr	41Nb	42Mo	43Tc	44Ru	45Rh	46Pd	47Ag	48Cd	49In	50Sn	51Sb	52Te	53I	54Xe
	55Cs	56Ba	57La	72Hf	73Ta	74W	75Re	76Os	77Ir	78Pt	79Au	80Hg	81Tl	82Pb	83Bi	84Po	85At	86Rn
	87Fr	88Ra	89Ac	104Rf	105Db	106Sg	107Bh	108Hs	109Mt	110Ds	111Rg	112Uub	113Uut	114Uuq	115Uup	116Uuh	117Uus	118Uuo

Diagram illustrating the chemical formula $H_n C_m$ formed by connecting the element boxes for Hydrogen (H), Carbon (C), and Nitrogen (N) in the periodic table.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
I	II											III	IV	V	VI	VII	VIII	
1 H																	2 He	
	3Li	4Be										5B	6C	7N	8O	9F	10Ne	
	11Na	12Mg									13Al	14Si	15P	16S	17Cl	18Ar		
	19K	20Ca	21Sc	22Ti	23V	24Cr	25Mn	26Fe	27Co	28Ni	29Cu	30Zn	31Ga	32Ge	33As	34Se	35Br	36Kr
	37Rb	38Sr	39Y	40Zr	41Nb	42Mo	43Tc	44Ru	45Rh	46Pd	47Ag	48Cd	49In	50Sn	51Sb	52Te	53I	54Xe
	55Cs	56Ba	57La	72Hf	73Ta	74W	75Re	76Os	77Ir	78Pt	79Au	80Hg	81Tl	82Pb	83Bi	84Po	85At	86Rn
	87Fr	88Ra	89Ac	104Rf	105Db	106Sg	107Bh	108Hs	109Mt	110Ds	111Rg	112Uub	113Uut	114Uuq	115Uup	116Uuh	117Uus	118Uuo

Diagram illustrating the chemical formula H_2O formed by connecting the element boxes for Hydrogen (H) and Oxygen (O) in the periodic table.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
I	II											III	IV	V	VI	VII	VIII	
1 H																	2 He	
	3Li	4Be										5B	6C	7N	8O	9F	10Ne	
	11Na	12Mg									13Al	14Si	15P	16S	17Cl	18Ar		
	19K	20Ca	21Sc	22Ti	23V	24Cr	25Mn	26Fe	27Co	28Ni	29Cu	30Zn	31Ga	32Ge	33As	34Se	35Br	36Kr
	37Rb	38Sr	39Y	40Zr	41Nb	42Mo	43Tc	44Ru	45Rh	46Pd	47Ag	48Cd	49In	50Sn	51Sb	52Te	53I	54Xe
	55Cs	56Ba	57La	72Hf	73Ta	74W	75Re	76Os	77Ir	78Pt	79Au	80Hg	81Tl	82Pb	83Bi	84Po	85At	86Rn
	87Fr	88Ra	89Ac	104Rf	105Db	106Sg	107Bh	108Hs	109Mt	110Ds	111Rg	112Uub	113Uut	114Uuq	115Uup	116Uuh	117Uus	118Uuo

Diagram illustrating the chemical formula CO_2 formed by connecting the element boxes for Carbon (C) and Oxygen (O) in the periodic table.

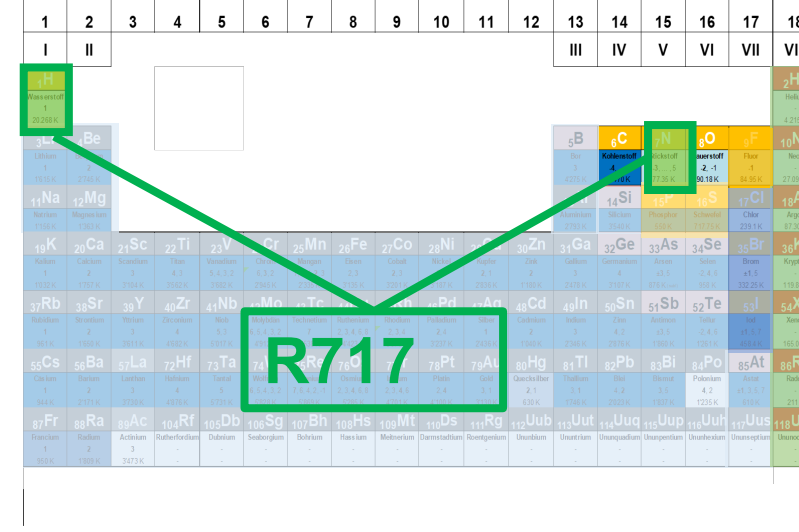
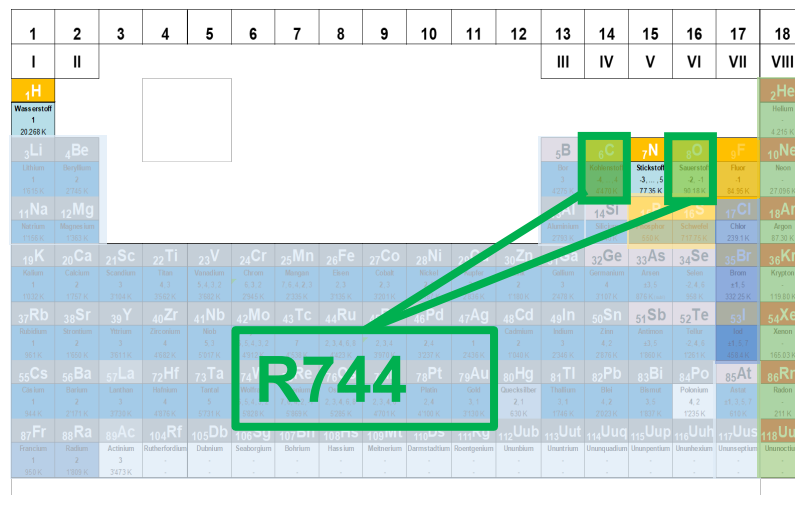
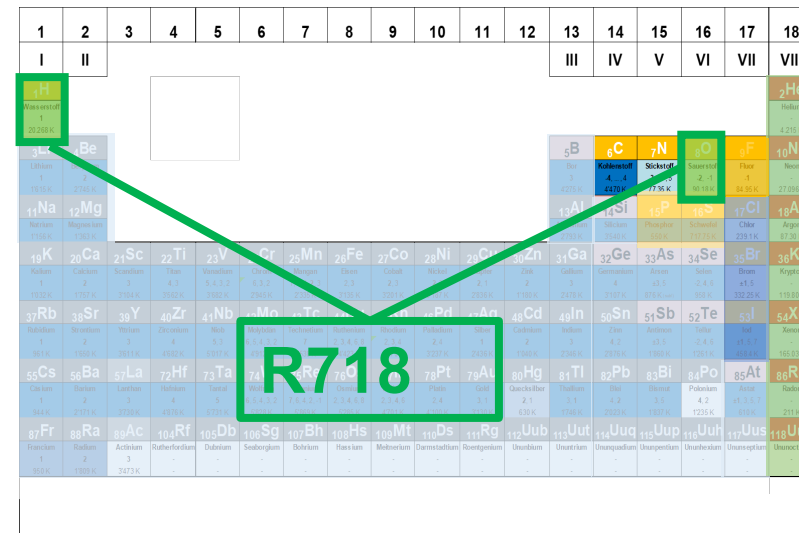
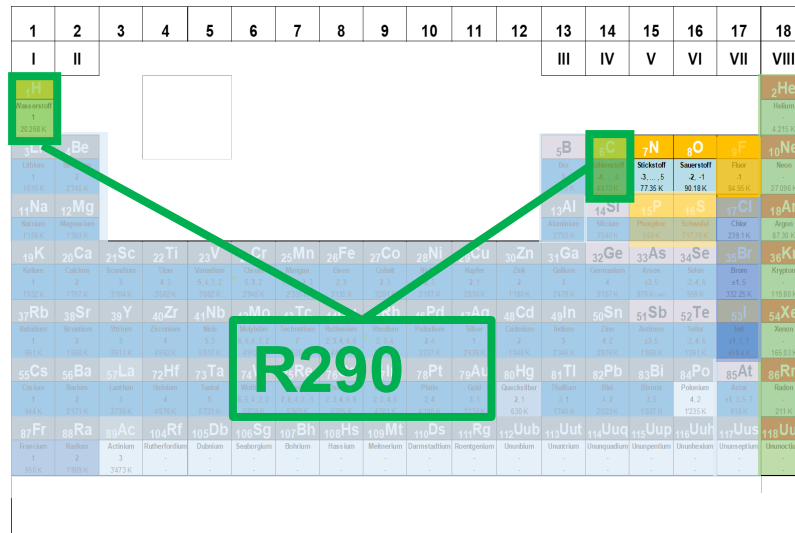
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
I	II											III	IV	V	VI	VII	VIII	
1 H																	2 He	
	3Li	4Be										5B	6C	7N	8O	9F	10Ne	
	11Na	12Mg									13Al	14Si	15P	16S	17Cl	18Ar		
	19K	20Ca	21Sc	22Ti	23V	24Cr	25Mn	26Fe	27Co	28Ni	29Cu	30Zn	31Ga	32Ge	33As	34Se	35Br	36Kr
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	87Fr	88Ra	89Ac	104Rf	105Db	106Sg	107Bh	108Hs	109Mt	110Ds	111Rg	112Uub	113Uut	114Uuq	115Uup	116Uuh	117Uus	118Uuo

Diagram illustrating the chemical formula NH_3 formed by connecting the element boxes for Nitrogen (N) and Hydrogen (H) in the periodic table.

Source: ETSus UG



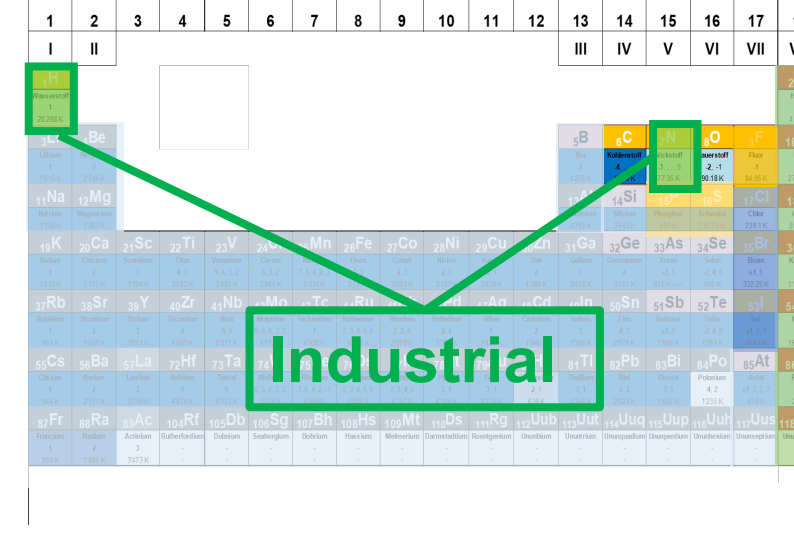
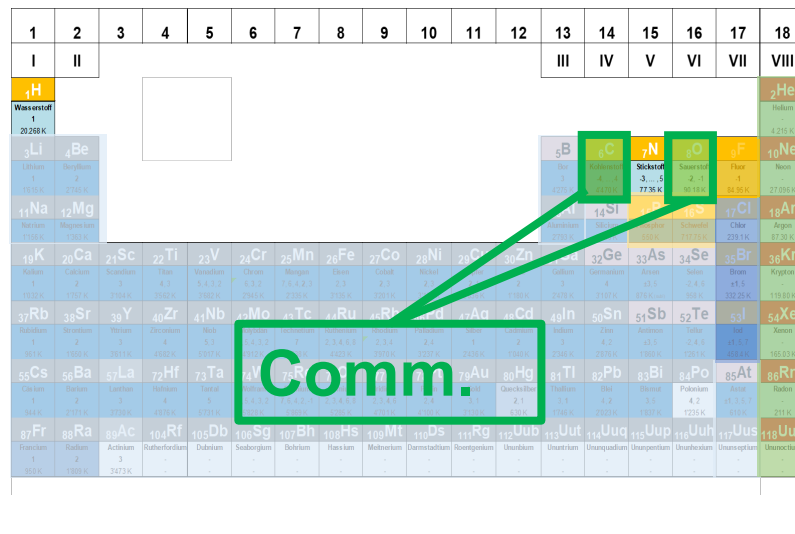
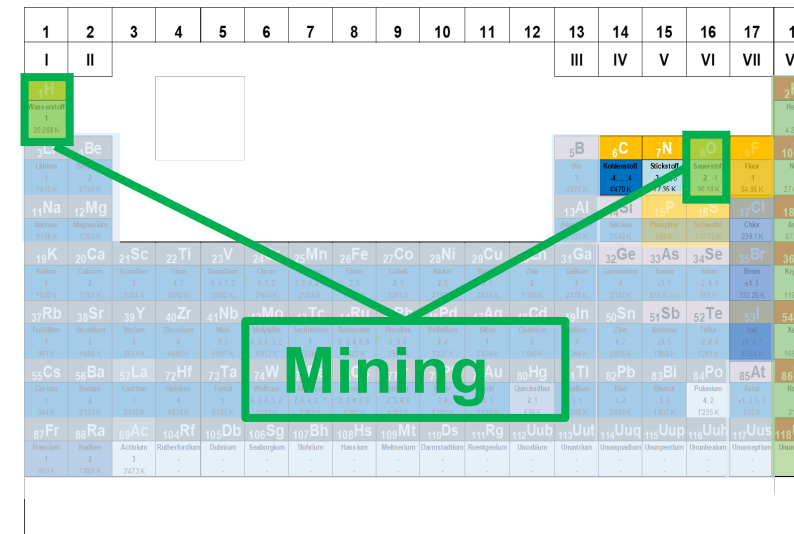
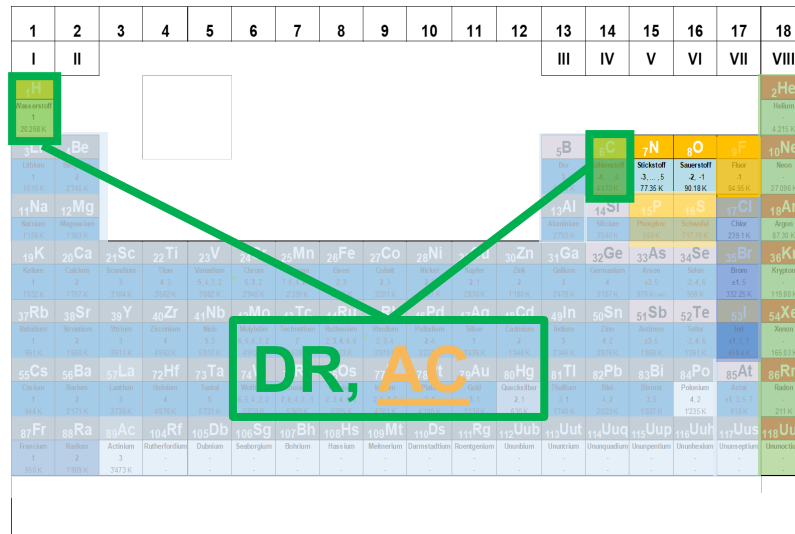
Refrigerant cooking session – the ultimate solution



Source: ETSuS UG



Refrigerant cooking session – the ultimate solution



Source: ETSuS UG



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Thank you for your kind attention.

Contact

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