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THE FUTURE OF TECHNOLOGY RESEARCH AND DEVELOPMENT

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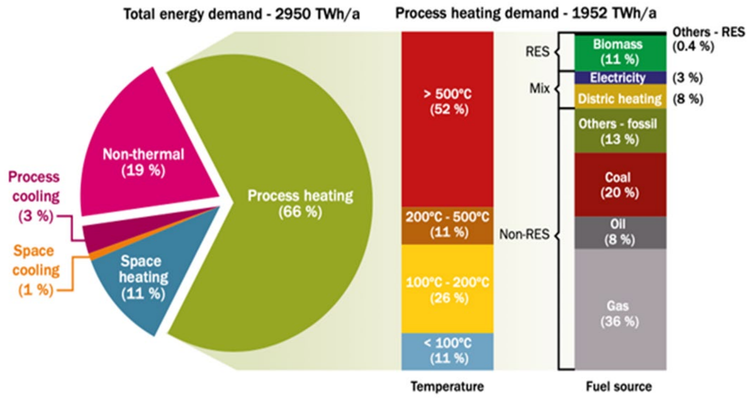
ABSTRACT



If it is assumed that the above graph (de Boer, R. et al., 2022) is correct, to the best knowledge of the authors there is no better information available, space heating represents a much higher potential for the industry than all cooling put together. It is unfortunately not possible to cover all the needs with heat pumps. It is unlikely that temperature levels above 400 °C are achievable, but one may be surprised.

Supply temperatures up to 400 °C, are realistically possible, however, the industry is not quite there yet. Projects are underway to reach the 400 °C level, and field test are in place. The future of high temperature heat pumps will be in systems that are totally environmentally benign, free of all fluorinated compounds, as few mechanical sealing materials as possible and avoiding leaks as much as possible. This will make the systems robust and long lasting thereby reducing the environmental impact on resources of various metal ore and processing. Up time in most cases for these kinds of units is expected to be close to 99% of the time.

In few years, the discussion about PFAS, TFA, ODP and GWP will be topics of the past, in which we put a lot of energy now, just to fight for the right cause. Fluorinated gases will be gone to the history book, where they will just be mentioned as a stress-test of humans if we do the right decisions. We will in this paper not go into further details on this topic. We will look forward at what we believe will be the future and the opportunities in our sector for future generations.

The future systems will be based on technologies that are highly reliable with a minimum of non-recyclable components or materials including working fluids if needed. As far as the current technology goes, the natural five – NH_3, CO_2, HC families, H_2O and air – will have a place. The NH_3 will be green NH_3 derived of water, CO_2 comes naturally from volcano activity or underground but also from breweries and other places where it is recovered from fermentation processes or carbon capture facilities. HC's or hydrocarbons are a large family who will be around for decades. Methane develops in any swamp. Other gases can be derived from the basic gases, which is also being done today. For refrigeration, heat pumps and air-conditioning systems, not many more additional working fluids will be needed, and all of them are already available. They are safe to use for competent staff from design, installation, service etc until decommissioning and recycling.

1. Introduction

After some heated debate, the HFC's with high Global Warming Potential (GWP) were banned by the EU F-gas regulation. Maximum GWP was first limited to 150 for a number of applications, but with a complete ban for all HFC's from 2050 on the horizon, most could see the end of these working fluids coming closer. Nevertheless, several papers were released trying to make the case for the wonderful properties of the latest HFC working fluids and why they should not be regulated and TFE/TFF/TFA being a naturally occurring substance (EFCTC, 2024).

Table 1 Environmental properties of various refrigerants

Environmental Impacts of HVACR&HP Refrigerants				
HVACR&HP Refrigerant	Global Warming Potential*	Ozone Depleting?	Forming PFAS/TFA***	R-23 @ break down**
R-23	**14700**	No	No	**100%**
HFC-134a	**1530**	No	**Yes (7-20%)**	N/A
HCFO-1233ze(E)	3,88	**Yes**	**Yes (2-30%)**	N/A
HCFO-1224yd	N/A	**Yes**	**Yes**	N/A
HFC-1234ze(E)	1,37 (12,5**)	No	**Yes (2-30%)**	**Yes**
HFO-1234yf	0,501	No	**Yes (100%)**	N/A
HFO-1336mzz(Z)	<1**	No	**Yes (4-60%)**	N/A
CO_2 (R-744)	1	No	No	No
NH3 (R-717)	0	No	No	No
*IPCC AR6				
** McGillen et al. 2023				
***https://ozone.unep.org/system/files/documents/EEAP-2022-Assessment-Report-May2023.pdf				

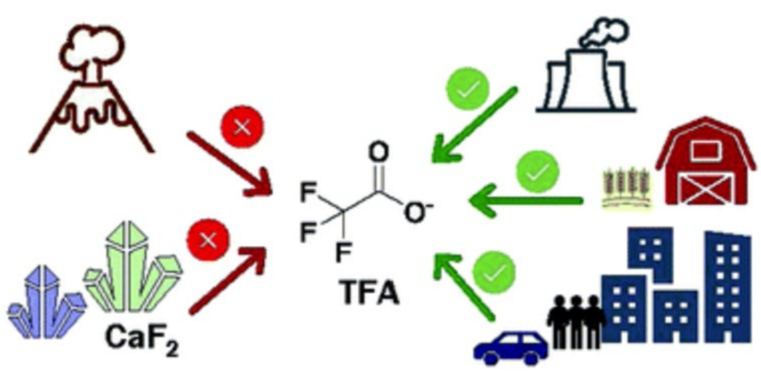


Figure 1 The options for finding the right composition of HF-gas-heat to produce natural PFAS/TFA (Joudan, S., et al, 2021)

It has often been debated if PFAS and TFA could form naturally in nature. The pragmatic answer to this question is that there is no proven place in nature where this could happen (Joudan, S, et al, 2021). The process is very delicate and requires very pure HF acid, acid grade, and heat at a very specific temperature. No known location on earth has been pointed out where these conditions would be present and in quantities needed. In Journal of Fluorine Chemistry[i] it is explained how difficult it was for the pioneers to separate hydrogen fluoride (HF) and other component like sulfur and keep it clean enough to obtain the reactions they wanted. The underestimation of the problem with the huge amounts of TFA found in the pacific, arises because some people (Nielsen, O.J. et al, 2001), (Wallington, T.J. et al, 2015) claim that refrigerants cannot alone be the source. The same people have also acknowledged that TFA does not naturally exist in freshwaters. That can be true, but refrigerants are just one of many sources of PFAS pollution. The amount of fluorinated compounds produced for many different purposes is mind blowing, when you start to look at it, and the 268 million tonnes (Wallington, T.J. et al, 2015) found in the pacific is not enough to explain where and when we will see more – and it is all human made. A paper (Scheurer, M. et al, 2017) has studied sources in Germany showing that undocumented releases into rivers and on soil ends up in the water ways and at the end in oceans. So, when Wallington et al. say it cannot be made by HFO, he is certainly right but what he does not consider is all the other sources of PFAS and TFA but also hydrofluoric acid and from which TFA and PFAS can be produced documented in the German paper. The discussions have been made very controversial for different reasons by industry and science. This makes the message misleading and subjective to being misused for misleading messages (EFCTC, 2024) if not presented very precise.

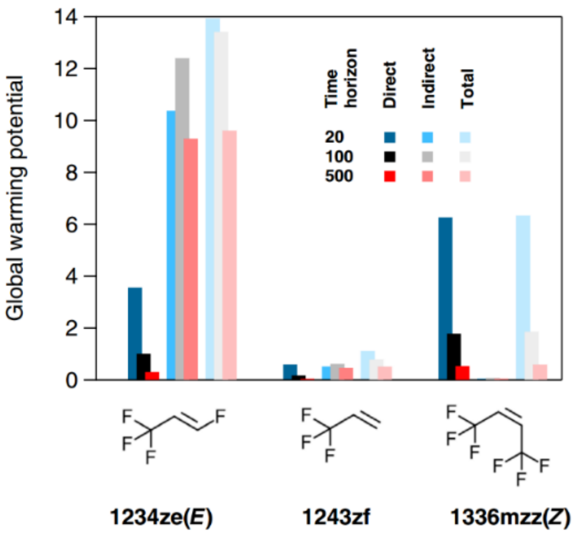


Figure 2 The effect of CF3 formation on the calculated global warming potentials for selected HFO's (McGillen et al, 2015)

The problem with PFAS and TFA is that no natural breakdown path is known in the biosphere. It is estimated that they will at least stay and accumulate in the biosphere for at least 4999 years and possibly much longer. Can be that they can be separated in water for a price possible to pay for everyone, but not for plants and animals drinking all sorts of water. It all ends in human food and finally in our body.
A newer research report (Max R. McGillen et al, 2023) has shown that the reactions under different assumptions than used by Wallington et al., 2015, the HFO can breakdown to R-23 and has a higher GWP than the shown in the IPCC AR6. What is worse is that the GWP remains “nonnegligible over a 500-year time horizon”.

Figure 2 “shows the effects of including ozonolysis upon GWP calculations. For HFO-1234ze(E), which has the largest yield of CHF_3 studied, we find that the GWP associated with CHF_3 production is significantly higher than the primary GWP that is calculated based on radiative efficiency and atmospheric lifetime alone. Furthermore, the production of CHF_3 affects these calculations dramatically over longer time horizons. Although the radiative impacts of HFOs are typically not expected to last far beyond their atmospheric lifetimes (~10 d), when ozonolysis products are accounted for, HFO-1234ze(E) still have a significant GWP even at the 500-y time horizon.” (Max R. McGillen et al, 2023).

It is therefore natural that the industry turns their back on fluorinated working fluids and concentrate development on naturally occurring substances like NH_3, CO_2, HCs, H_2O and air, to participate in the transition and being part of a solution, not the problem. These natural 5 working fluids are well known to the industry. Even they have been used for many years new technologies and ways of applying these fluids, carry the technology forward making the systems more energy efficient at equal or even higher performance.

The problem the HVACR&HP industry is facing is the growing emissions despite all the efforts and regulations put in place to incentivize minimising emissions. The UN Emissions Gap Report 2023 contain the Table2 showing the number of leaks in Giga Tonnes CO_2 equivalents.

Table 2 The UN Emissions Gap Report 2023 shows the importance of F-gas emissions. They are still growing despite the efforts of containing and recycling the same gases. (United Nations Environment Programme, 2023)

$GtCO_2e$	2010–2019 (average)	2020	2021	2022
GHG	54.6 ± 5.55	54.5 ± 5.36	56.8 ± 5.45	57.4 ± 5.48
Fossil CO_2	36.1 ± 2.89	35.9 ± 2.88	38.1 ± 3.05	38.5 ± 3.08
LULUCF CO_2 (global bookkeeping)	4.72 ± 3.3	4.06 ± 2.84	3.94 ± 2.76	3.87 ± 2.71
LULUCF CO_2 (national inventory)*	-2.64 ± -1.85	-2.49 ± -1.74	-2.4 ± -1.68	N/A
CH_4	10.1 ± 3.03	10.4 ± 3.13	10.6 ± 3.18	10.8 ± 3.23
N_2O	2.47 ± 1.48	2.57 ± 1.54	2.63 ± 1.58	2.65 ± 1.59
F-gases	1.17 ± 0.351	1.46 ± 0.439	1.54 ± 0.461	1.62 ± 0.486

Note: * Inventory-based LULUCF CO_2 is excluded from total GHG emissions. Non-CO_2 greenhouse gases are converted to CO_2 equivalents using global warming potentials with a 100-year time horizon from the IPCC WGI AR6 (Forster *et al.* 2021).

If we then assume that the average GWP of used refrigerants is 1300 then we can prepare Figure 3. To this we have the unknown amount of reaction products in the atmosphere which has never been accounted for.

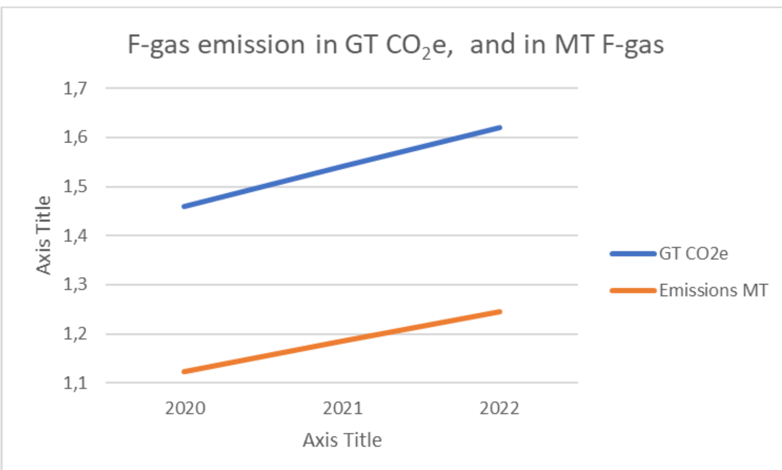


Figure 3 Emissions of F-gas in CO_2e and in tons assuming the average GWP is 1300.

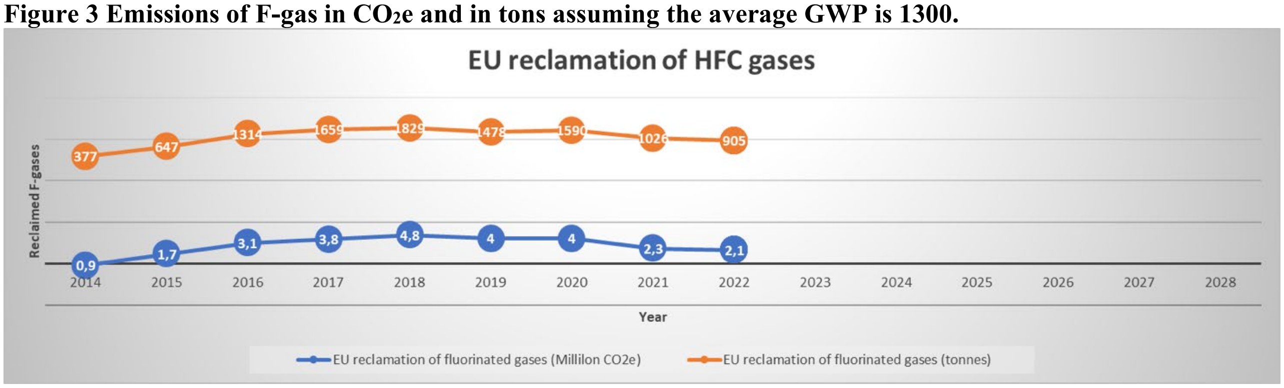


Figure 4 Recycling and reclaim of HFC gases in Europe (Sylvie Ludvig et al, 2023) Note the scale is logarithmic.

The amount of reclaimed refrigerant reported in Europe is only a fraction of the refrigerant sold on the market (POM) even adding uncertainties to the reclaimed numbers, e.g. 10 %.

The growth in emissions of F-gases shows up in the Emissions Gap Report 2023 (United Nations Environment Programme, 2023), and the question is whether the industry and society really need them or if there are alternatives with no or much lower climate or environmental impact in the market already.

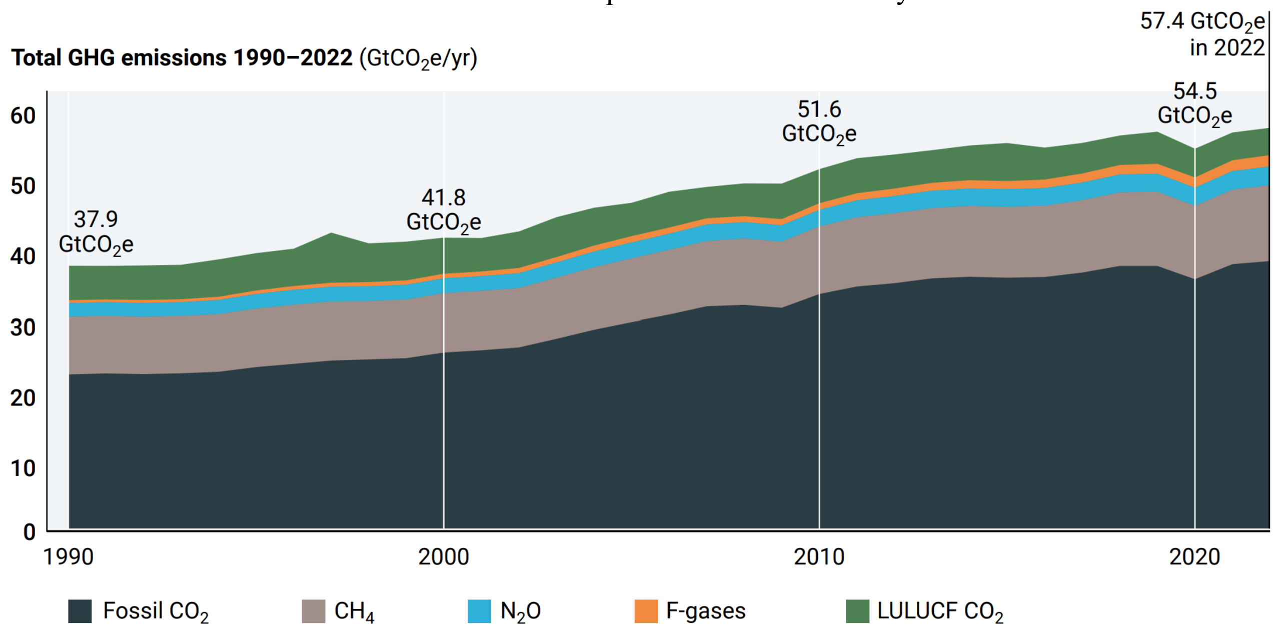


Figure 5 Total net anthropogenic GHG emissions, 1990-2022 (United Nations Environment Programme, 2023)

2. Flammability

Table 3 Flammability properties of some gases.

Refrigerant	ASHRAE Class	LFL [%]	LFL (ISO817) [g/m3]	UFL [%]	UFL [g/m3]	Difference [%]	Stoichiometric concentration in air [%]	Stoichiometric concentration in air (ISO817) [g/m3]	Heat of combustion MJ/kg	Released Energy MJ/KG	Auto Ignition Temperature °C
R-290	A3	2,1	37,8	10,0	179,9	7,9	4	72,0	46,3	3,3	470
R-32	A2L	14,4	306,24	27,50	584,8	13,1	20	425,3	9,4	4,0	648
R-1234yf	A2L	6,2	289,1	12,3	573,5	6,1	7,73	360,4	10,7	3,9	700
R-1234ze(E)	A2L	7	303,0	12,0	559,5	5,0	7,73	360,4	10,7	3,9	368
R-152a	A2L	4,8	129,7	17,3	467,3	12,5	5	135,1	16,5	2,2	440
R-600a	A3	1,7	42,8	8,5	202,0	6,8	3,5	83,2	45,6	3,8	460
R-717	B2L	16	139,0	30,0	208,2	14,0	20	139,0	22,48	3,1	651

The ASHRAE/ISO 817 the A2L classification is among other subjects determined by the flame propagation. If the flame propagation is lower than 10 cm/s, then the gas falls under the 2L classification. However, the 2L classification is misleading because it is determined at the lowest flammable concentration. As shown in Table 3, which is based on standard information, the released energy at the stoichiometric concentration is very similar to the rest of the group selected. It is all about the concentration at which you measure what you want to see. It is interesting to note that R-1234ze[E], in the pressure equipment directive (PED) is classified as A1, but at the same time it is not a secret that it has the lowest auto ignition temperature (AIT) and the energy released is slightly higher than for the hydrocarbons. The question is therefore why the 2L classification.

Flammability is an oxidation process and a degradation process of the gas, which can/will break down to more stable compounds; for the fluorinated gases e.g. such as HF, very toxic or COF_2/CF_2O, which is less stable than HF, but also very toxic. Pubchem says: “Carbonyl fluoride appears as a colorless gas with a pungent odor. Very toxic by inhalation. (PubChem, 2024)” Since hydrocarbons and ammonia contain neither chlorine nor fluorine they cannot contribute to the acidification of the environment. Burning propane produces carbon dioxide and burning ammonia produces nitrogen and water.

Table 4 Overview of properties of various fluids for industrial HTHP. The GWP values for hydrocarbon working fluids are excluding breakdown products so that the values are like for like. (Pachai, A.C., et al., 2021)

Type	R-No	Description	Chemical formula	T_c [°C]	P_c [bar]	ODP [-]	GWP [-]	Safety Class	NBP [°C]	M [g/mol]	Relative price [-]
CFC	**R113**	1,1,2-trichloro-1,2,2-trifloroethane	CCl_2FCCl	214.0	33.9	0.85	5’820	A1	47.6	187.4	Prohibited by Montreal Protocol
	R114	1,2-trichloro-1,1,2,2-tetrafluoroethane	$CClF_2CClF_2$	145.7	32.6	0.58	8’590	A1	3.8	170.9	
HCFC	**R123**	2,2-dichloro-1,1,1-trifluoroethane	$C_2HCl_2F_3$	183.7	36.6	0.03	79	B1	27.8	152.9	
	R21	Dichlorofluoromethane	$CHCl_2F$	178.5	51.7	0.04	148	B1	8.9	102.9	
	R142b	1,1-dichloro-1-fluoroethane	CH_3CCl_2F	137.1	40.6	0.065	782	A2	-10	100.5	
	R124	1-chloro-1,2,2,2-tetrafluoroethane	C_2HClF_4	126.7	37.2	0.03	527	A1	-12	136.5	
HFC	**R365mfc**	1,1,1,3,3-pentafluorobutane	$CF_3CH_2CF_2CH_3$	186.9	32.7	0	804	A2	40.2	148.1	8.9
	SES36	R365mfc/perfluoro-ether	R365mfc/PFPE (65/35)	177.6	28.5	0	3’126	A2	35.6	184.5	10.5
	R245ca	1,1,2,2,3-pentafluoropropane	$CHF_2CF_2CH_2F$	174.4	39.3	0	718	n.a.	25.1	134	n.a.
	R245fa	1,1,2,2,3-pentafluoropropane	$CHF_2CH_2CF_3$	154	36.5	0	858	B1	14.9	134	6.6
	R236fa	1,1,1,3,3,3-hexfluoropropane	$CF_3CH_2CF_3$	124.9	32	0	8’060	A1	-1.4	152	10.2
	R152a	1,1-difluorethane	CH_3CHF_2	113.3	45.2	0	138	A2	-24	66.1	n.a.
	R227ea	1,1,1,2,3,3,3-heptafluoropropane	CF_3CHFCF_3	101.8	29.3	0	3’350	A1	-15.6	170	6.9
	R134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	101.1	40.6	0	1’300	A1	-26.1	102	1.2
	R410A	R32/R125 (50/50% mixture)	CH_2F_2/CHF_2CF_3	72.8	49	0	2’088	A1	-51.5	72.6	2.9
HFO	**R1336mzz(Z)**	1,1,1,4,4,4-hexafluoro-2-butene	$CF_3CH{=}CHCF_3(Z)$	171.3	29	0	2	A1	33.4	164.1	n.a.
	R1234ze(Z)	cis-1,3,3,3-tetrafluoro-1-propene	$CF_3CH{=}CHF(Z)$	150.1	35.3	0	< 1	A2L	9.8	114	n.a.
	R1336mzz(E)	trans-1,1,1,4,4,4-hexafluoro-2-butene	$CF_3CH{=}CHCF_3(E)$	137.7	31.5	0	18	A1	7.5	164.1	n.a.
	R1234ze(E)	trans-1,3,3,3-tetrafluoro-1-propene	$CF_3CH{=}CHF(E)$	109.4	36.4	0	< 1	A2L	-19	114	5.6
	R1234yf	2,3,3,3-tetrafluoro-1-propene	$CF_3CF{=}CH_2$	94.7	33.8	0	< 1	A2L	-29.5	114	13.8
HCFO	**R1233zd(E)**	1-chloro-3,3,3-trifluoro-propene	$CF_3CH{=}CHCl(E)$	166.5	36.2	0.00034	1	A1	18	130.5	6.3
	R1224yd(Z)	1-chloro-2,3,3,3-tetrafluoro-propene	$CF_3CF{=}CHCl(Z)$	155.5	33.3	0.00012	< 1	A1	14	148.5	n.a.
HC	**R601**	Pentane	$CH_3CH_2CH_2CH_2CH_3$	196.6	33.7	0	0.39	A3	36.1	72.2	4.9
	R601a	Iso-pentane	$(CH_3)_2CHCH_2CH_3$	187.2	33.8	0	0.39	A3	27.8	72.15	n.a.
	R600	Butane	$CH_3CH_2CH_2CH_3$	152	38	0	0.09	A3	-0.5	58.1	1.8
	R600a	Isobutane	$CH(CH_3)_2CH_3$	134.7	36.3	0	0.09	A3	-11.8	58.1	1
	R290	Propane	$CH_3CH_2CH_3$	96.7	42.5	0	0.18	A3	-42.1	44.1	1.1
	R1270	Propene	$CH_3CH{=}CH_2$	91.1	45.6	0	0.05	A3	-47.6	42.1	1
	R602	Hexane	$CH_3(CH_2)_4CH_3$	234.7	30.4	0	3	A3	68.7	86.18	n.a.
	n.a.	Benzene	C_6H_6	288.9	43.1	0	n.a.	B3	80.1	78.11	n.a.
	R603	Heptane	$CH_3(CH_2)_5CH_3(C_7H_{16})$	267.1	27.4	0	3	A3	98.4	100.2	n.a.
CF6	Novec 649	Dodecafluoro-2-methyl-3-pentanone	$CF_3CF_2C(O)CF(CF_3)_2$	168.7	18.8	0	< 1	n.a.	49	316	6.8
Ether	E170	Dimethyl ether	CH_3OCH_3	127.2	53.4	0	1	A3	-24.8	46.1	39
Natural	R718	Water	H_2O	373.9	220.6	0	0	A1	100	18	5.6
	R717	Ammonia	NH_3	132.3	113.3	0	0	B2L	-33.3	17	27

At the first glance, the number of non-fluorinated working fluids can seem a little limited but there are more than first meets the eye. In a more recent study, following up on the screening in 2021, a more thorough study examined the possibility of more working fluids enabling heat rejection temperatures of almost 400 °C (Pachai, A.C. et al, 2023). The chemical manufacturing of fluorinated compounds, when under pressure to eliminate the production of C_8F_x went to use C6 which is found in the table 5.

Table 5 Selection of relevant working fluids found in (Refprop 10) (Lemmon, E.W., 2018). There are more fluids available, but fluids mostly used in refrigeration systems are less useful for high and very high- temperature heat pumps. Here is given some specific values

				Critical Point		
	Molar mass	Triple pt. Temp	Normal boiling pt.	Temperature	Pressure	Density
Fluid name	kg/kmol	K	K	K	Mpa	kg/m^3
R-600 (n-Butane) CH3-2(CH2)-CH3	58,122	134,9	272,66	425,13	4	228
R-600a (iso-Butane) CH(CH3)3	58,122	113,73	261,4	407,81	3,629	225,5
R-601 (n-Pentane) CH3-3(CH2)-CH3	72,149	143,47	309,21	469,7	3,37	232
R-601a (iso-Pentane) (CH3)2CHch2CH3	72,149	112,65	300,98	460,35	3,378	236
R-603 (Heptane) CH3-5(CH2)-CH3	100,2	182,55	371,53	540,13	2,736	232
Benzene C6H6	78,112	278,67	353,22	562,02	4,9073	304,71
Methanol CH3OH	32,042	175,61	337,63	512,6	8,1035	275,56
Water H2O	18,015	273,16	373,12	647,1	22,064	322
Ethanol (ethyl alcohol) C2H6O	46,068	159	351,57	514,71	6,268	273,19
Hexane CH3-4(CH2)-CH3	86,175	177,83	341,86	507,82	3,034	233,18
Toluene (methylbenzene) CH3-C6H5	92,138	178	383,75	591,75	4,1263	291,99
p-Xylene (1,4-dimethylbenzene) C8H10	106,17	286,4	411,47	616,17	3,5315	286
m-Xylene (1,3-dimethylbenzene) C8H10	106,17	225,3	412,21	616,89	3,5346	282,93
trans-Butnene (trans-2-Butene) CH3-CH=CH-CH3	56,106	167,6	274,03	428,61	4,0273	236,38
Octane CH3-6(CH2)-CH3	114,23	216,37	398,77	569,32	2,497	234,9
iso-Octane (2,2,4-trimethylpentane) (CH3)2CHCH2C(CH3)3	114,23	165,77	372,36	544	2,572	242,16
Nonane CH3-7(CH2)-CH3	128,26	219,7	423,91	594,55	2,281	232,14
Dodecane CH3-10(CH2)-CH3	170,33	263,6	489,3	658,1	1,817	226,55
Decane CH3-8(CH2)-CH3	142,28	243,5	447,27	617,7	2,103	233,34
Diethyl ether C4H10O	74,122	156,92	307,6	466,7	3,644	264
Cyclohexane cyclo-C6H12	84,159	279,47	353,87	553,6	4,0805	271,33
1-Butene CH3-CH2-CH-CH2	56,106	87,8	266,84	419,29	4,0051	237,89
cis-2-Butene CH3-CH=CH-CH3	56,106	134,3	276,87	435,75	4,2255	238,12
iso-Butene (2-methyl-1-propene) CH2=C(CH3)2	56,106	132,4	266,15	418,09	4,0098	233,96
iso-Hexane (2-methylpentane) (CH3)2CH(CH2)2CH3	86,175	119,6	333,36	497,7	3,04	233,97
Neopentane (2,2-dimethylpropane) C(CH3)4	72,149	256,6	282,65	433,74	3,196	235,93
Propannone (Acetone) (CH3)2CO	58,079	178,5	329,22	508,1	4,7	272,97
Dimethy ether (Metoxymethane) (CH3)2O	46,068	131,66	248,37	400,38	5,3368	273,65
3-Methylpentane (CH3CH2)2CHCH3	86,18		336,38	506	3,1845	239,57
Cyclopentane cyclo-C5H10	70,133	179,7	322,41	511,72	4,5712	267,91
Ethylbezene (Phenylethane) C8H10	106,17	178,2	409,31	617,31	3,6224	291

3. The real barriers for high temperature heat pumps

The real barriers for high temperature heat pumps are simpler than just flammability. Flammability is a matter of proper ventilation of the special machine room, the tighter around the system the better. The tricky part starts at some point, very often overlooked in most research, probably because one would think it is a non-issue: the lubricants. Many lubricants produce soot at about 180 °C +/- and some produce coke in the discharge valves around 200 °C +/-, others are cooked and change properties when getting heated to a level much over 200 °C +/- without using additives. The additives can contain some fluorine, which can break down and contribute to the formation of TFA and other PFAS.

Another obstacle is the sealing materials normally used in valves. Sealing materials between non-moving components are less of a problem than sealing materials like shaft sealing or sealing in valves where the rotation of the valve shaft is essential. They too often contain some amount of fluorine to make the material more heat resistant, but at the end of the service life they must be treated with special care, either at very high temperatures over 1300 °C +/- or special depot as they may otherwise break down to PFAS.

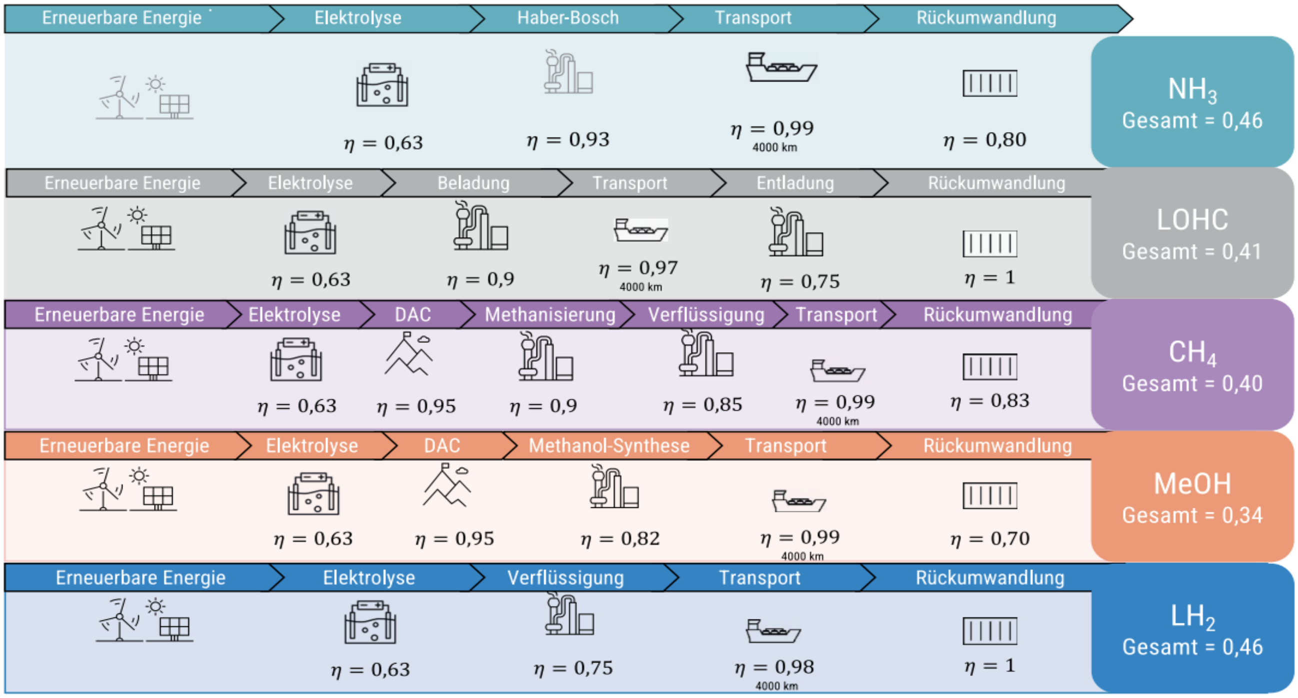


Figure 6 Efficiency from production to use. Ammonia is the most efficient in this report (Ammonia als Energiträger für die Energiewende, 2023)

In a German study/publication we find Figure 6. New technologies are under way making it possible to produce ammonia out of air (Blair, S.J. et al, 2023). Potentially this will enable production onboard the ship or in the car on the go. This is the kind of technologies that is being researched around the world. In the study here it is assumed a transportation on ship over 4000 km. This can of course be reduced to zero if you can produce the fuel out of air at the point of use provided you have some energy to produce ammonia onboard.

4. Conclusions

The future has started and the development of the heat pumps of the future, the next century, will be based on NH_3, CO_2, H_2O, Air, and some other hydrocarbons. The number of hydrocarbons is long but not all are equally suitable for high temperatures. Ethane, ethene and others are for low temperatures, while the longer hydrocarbons can be used with special attention at the properties especially at low temperatures.

The industry is currently being flooded with false claims from the fluorine industry about the society needing F-gases. It is so untrue that it almost incriminating the companies. Therefore, the sender of the messages is hiding behind different names. The messages also brought on Chemours web site say: “Why F-gases are Essential to the World of Today and Tomorrow F-gases make many aspects of our society possible, including green transition, the electrification of heating, the cold chain, advancing new technologies, and much more. (Chemours, 2023)” It is wrong because it can be done with other working fluids which are not containing F components.

The future of R&D within the refrigeration and heat pump industry for the years to come must focus entirely on fluorine free technologies. We already see large international companies asking for fluorine free technologies. Equipment packagers must provide a list of what components in the proposals are containing fluorine and what are the timeline plans for changing is. The era of fluorine in our everyday of refrigeration and heat pumping is coming to an end. To calm down the sceptical elements it is important to send the message, that it will not mean a massive amount of unemployment, just it will create new challenges in our sector. The problem is human made and human must change course and fix the problem.

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