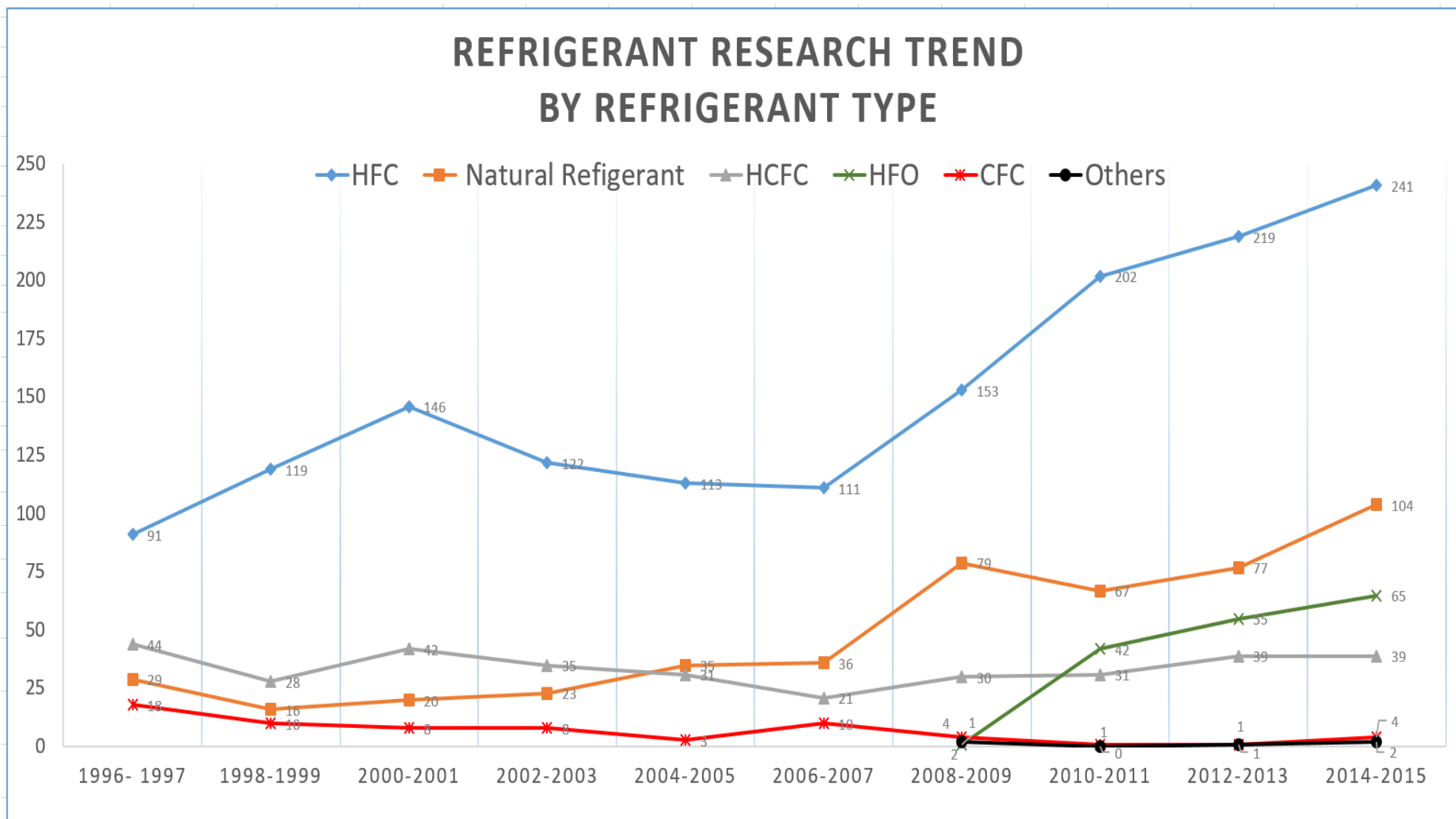
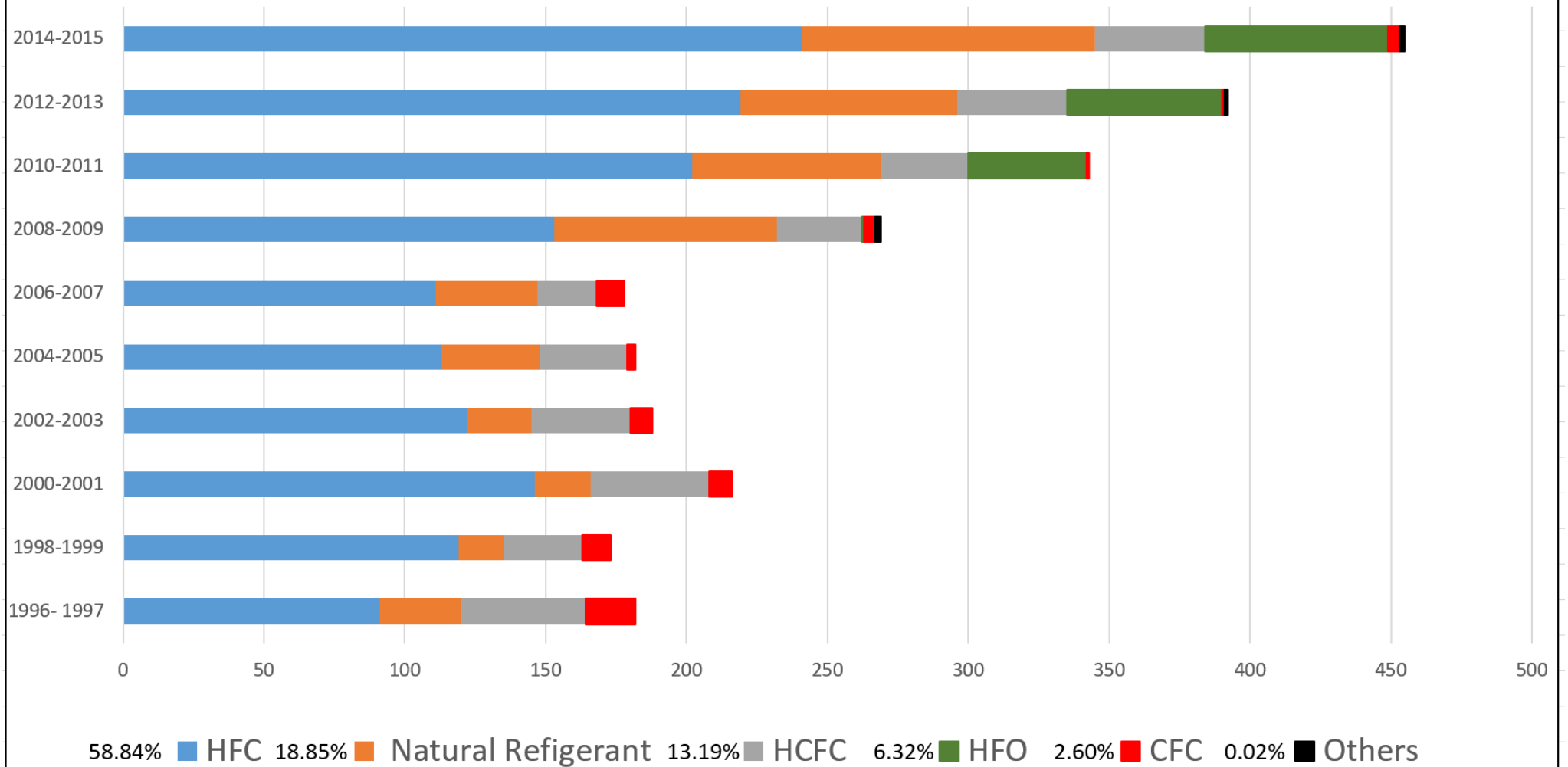


The purpose of this section is to identify publication outputs, and descriptively and quantitatively characterize the popularity of each refrigerant in the academic research through analyses of publication titles over a 20-year-period (1996–2015) and a 5-year-period (2010–2015). Through this analysis, we aim to identify the most popular refrigerant among fellow researchers and provide a clue as to which refrigerant might be the refrigerant of tomorrow.

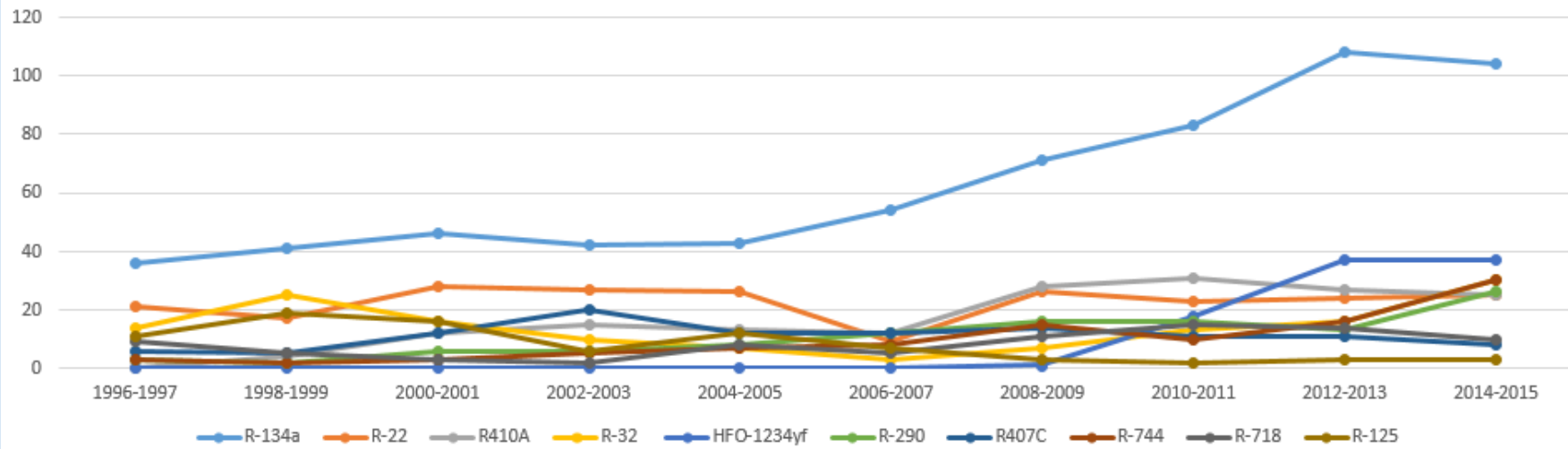


# Refrigerant Research Trend

## Total Number of Publications by Refrigerant Type

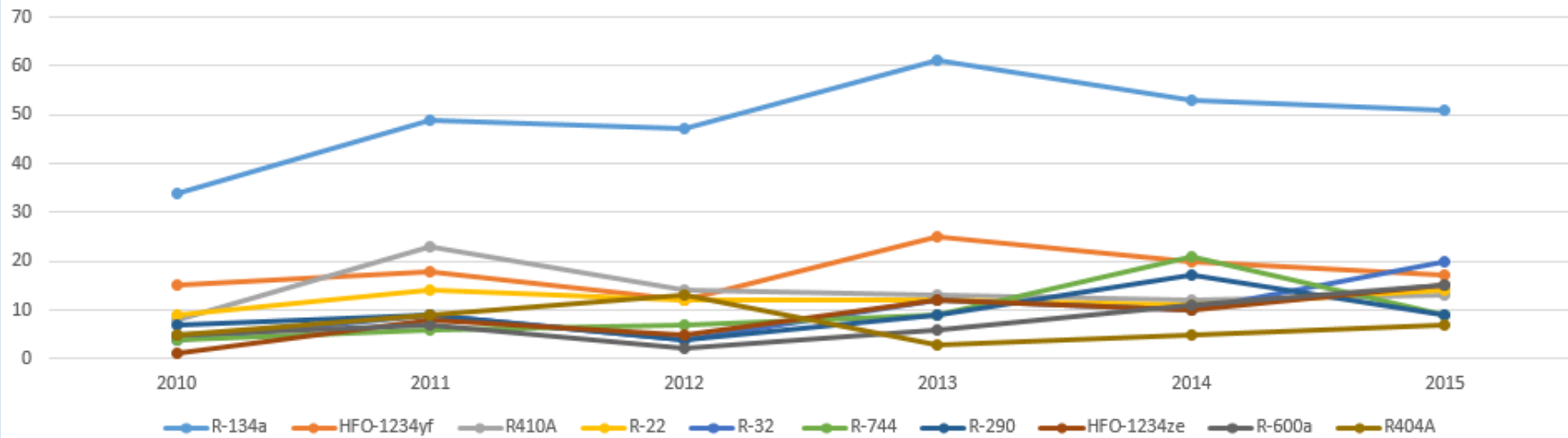


### Refrigerant Literature Trend Top 10 of 20-year-period (1996-2015)



- R-134a
- R-22
- R410A
- R-32
- HFO-1234yf
- R-290
- R407C
- R-744
- R-718
- R-125

### Refrigerant Literature Trend Top 10 of 5-year-period (2010-2015)



- R-134a
- HFO-1234yf
- R410A
- R-22
- R-32
- R-744
- R-290
- HFO-1234ze
- R-600a
- R404A

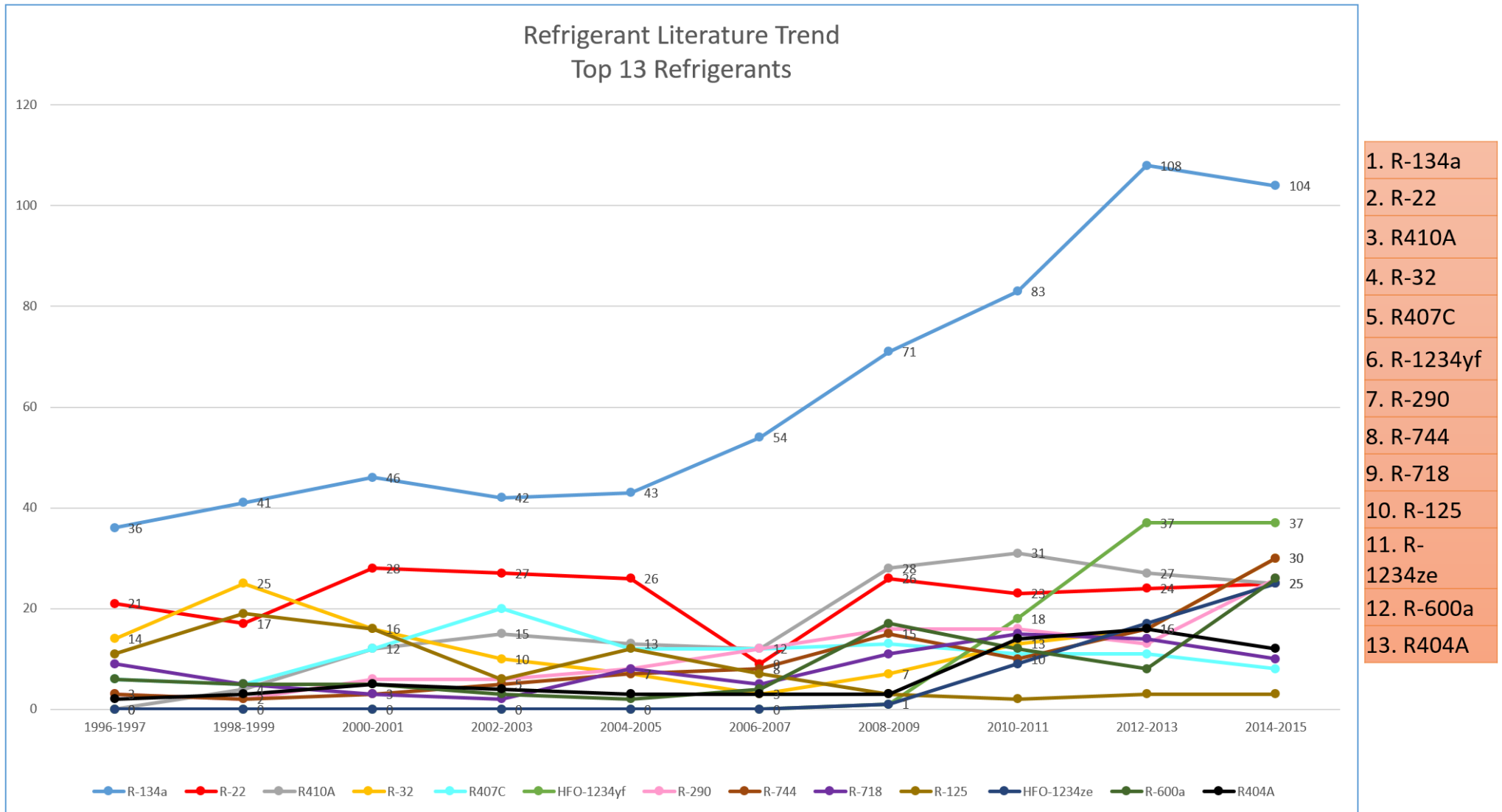


Fig. 1 Merged Refrigerant Literature Trend Results of the 20-year-period and 5-year-period

Table 1. (a) Top 10 Refrigerants of the 20-yr-period

Top 10 20-yr-period (1996–2015)
R-134a (HFC)
R-22 (HCFC)
R410A (HFC)
R-32 (HFC)
R407C (HFC)
HFO-1234yf (HFO)
R-290 (Natural R.)
R-744 (Natural R.)
R-718 (Natural R.)
R-125 (HFC)

Table 1. (b) Top 10 Refrigerants of the 5-yr-period

Top 10 5-yr-period (2010–2015)
R-134a (HFC)
HFO-1234yf (HFO)
R410A (HFC)
R-125 (HFC)
R-290 (Natural R.)
R-718 (Natural R.)
R-744 (Natural R.)
R-22 (HCFC)
R-32 (HFC)
R-125 (HFC)

Disappearing Refrigerant (R-125, R-22, R-32, R-718, R-744)

Table 2. Top 13 Refrigerants to watch

Top 13 Refrigerants to watch (combination)
R-134a (HFC)
R-22 (HCFC)
R410A (HFC)
R-32 (HFC)
R407C (HFC)
HFO-1234yf (HFO)
R-290 (Natural R.)
R-744 (Natural R.)
R-718 (Natural R.)
R-125 (HFC)
HFO-1234ze (HFO)
R-600a (Natural R.)
R404A (HFC)

Emerging Refrigerants (HFO-1234ze, R-600a, R404A)

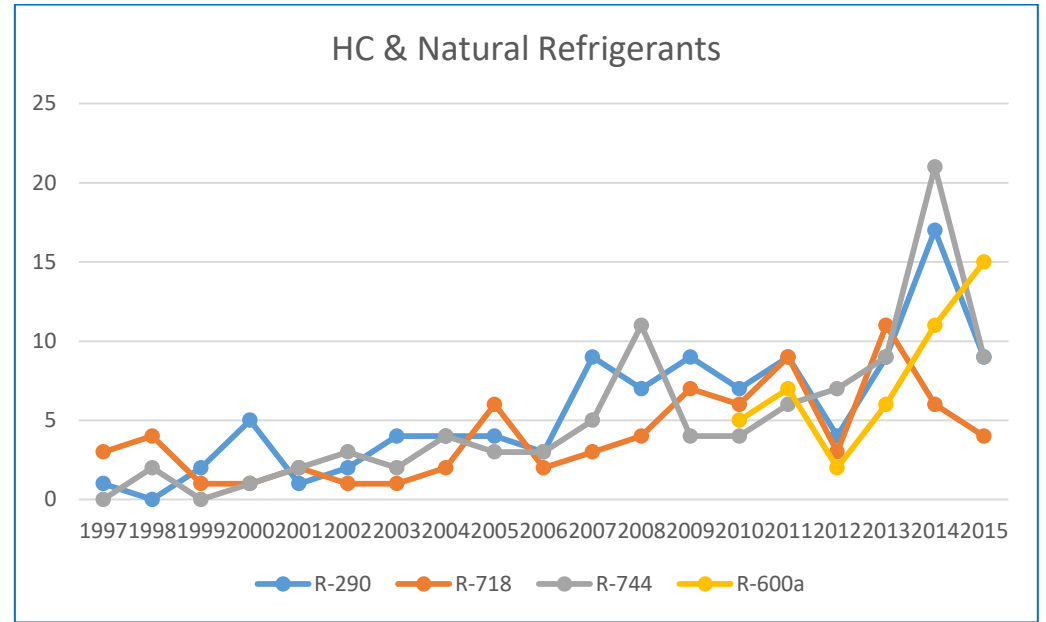
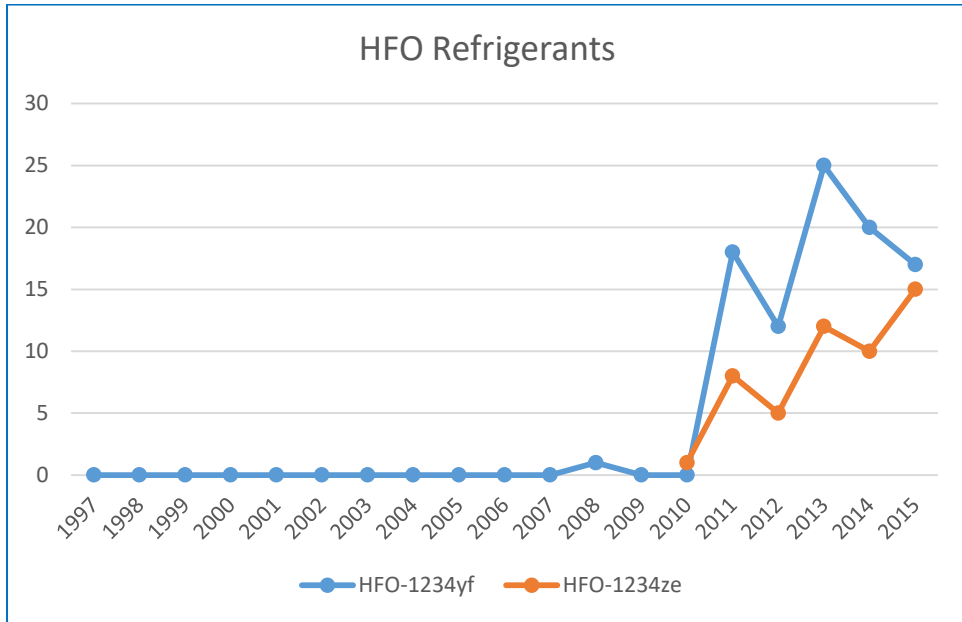
Content analysis of the research article titles in the “Web of Science” was performed. The presence of 340 ASHRAE registered refrigerants in 14 refrigerant types (HFC, HFO, Natural, HCFC, CFC, CFO, HCFO, HCC, HO, PFC, HCO, PFO, PCC, and H) in the research article titles were investigated. 6188 papers were found as the result of the initial screening. By going through procedures to eliminate articles that are irrelevant to heat pump related technologies, 2578 papers were identified. In these 2578 papers, the number of appearances in the title in each year for each of the 340 refrigerants were analyzed. The 13 refrigerants to watch were selected by taking the top 10 refrigerants in the 20-year analysis and adding the refrigerants that were not in the top 10 of the 20-year analysis but were in the top 10 of the 5-year analysis. Trend analysis was conducted for each of these 13 refrigerants and for the rest of the refrigerants.

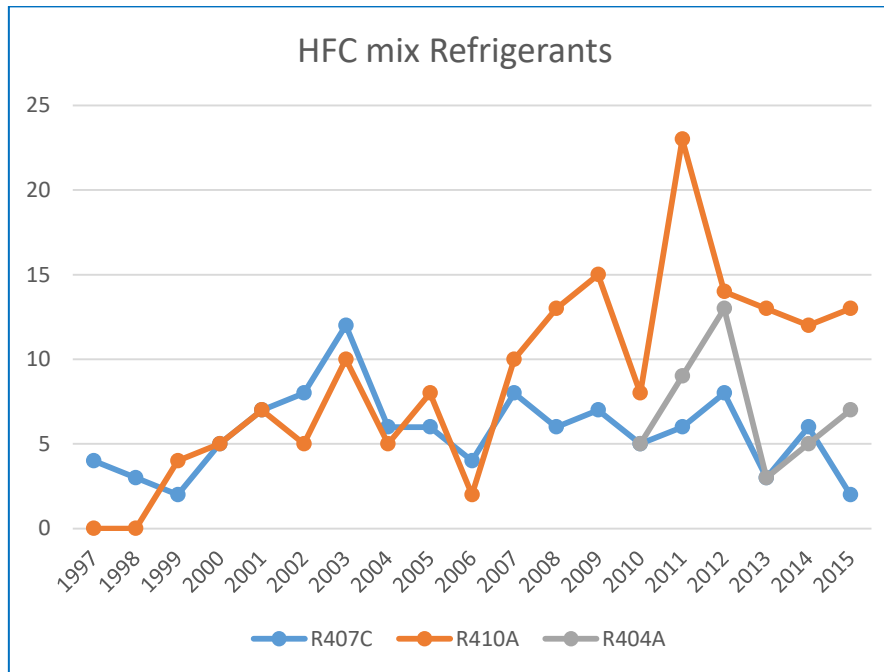
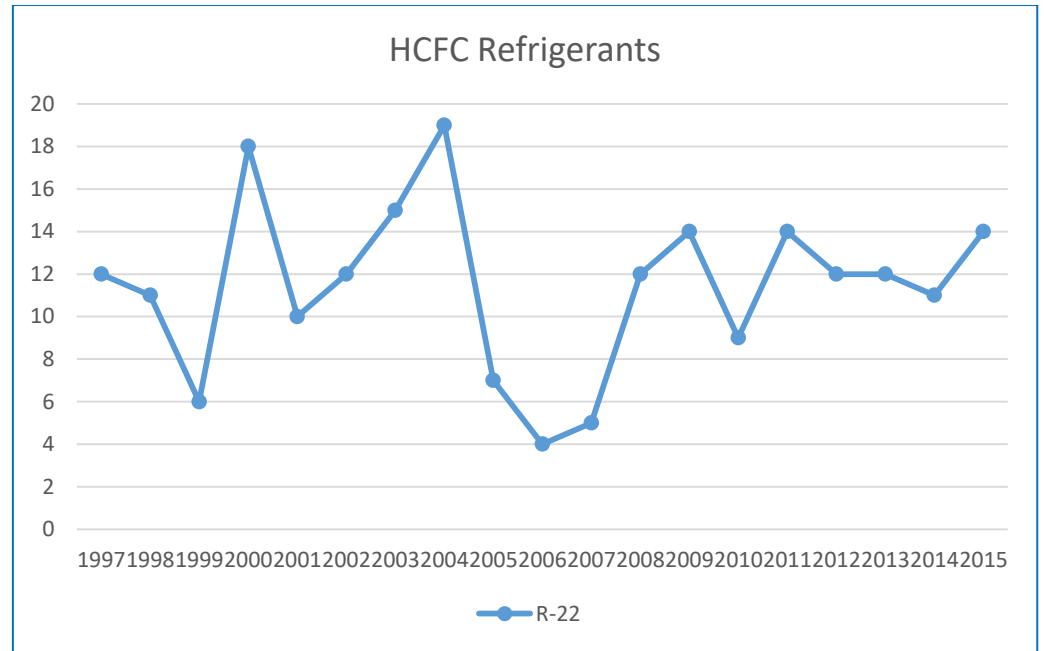
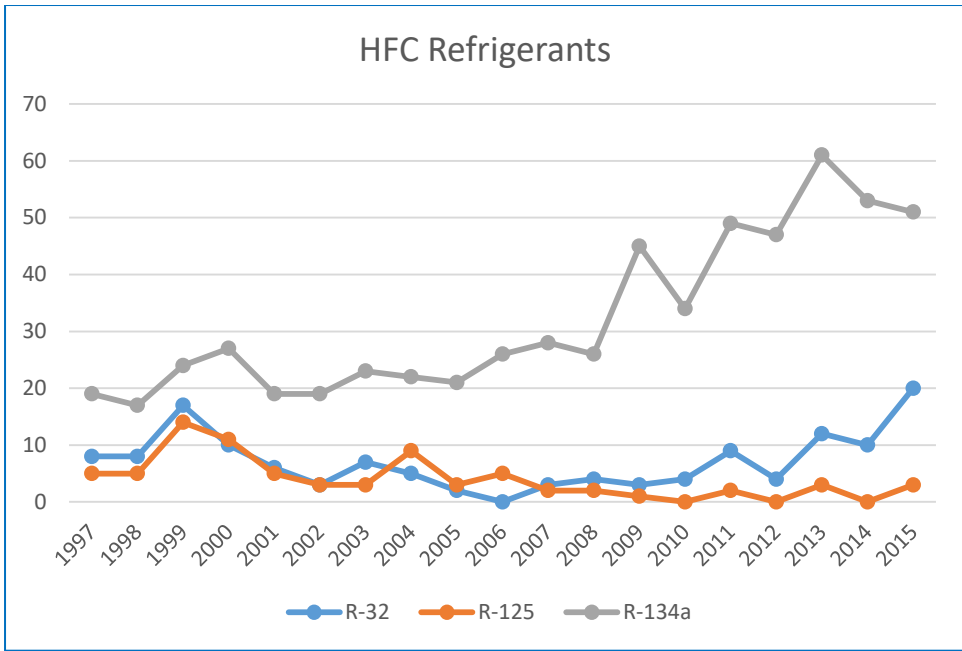
The findings of the analysis in the 20-year-period indicates that the number of refrigerant research articles surged in the 2008-2009 period and continued to rise till 2014-2015 period. In addition, it was found that 58.84% of the refrigerant papers published in the past 20 years were on HFC (hydrofluorocarbon) refrigerants.

The average annual publication growth rate of the refrigerant research articles is 5.60%, while the average annual publication growth rates for each refrigerant type are as follows, (1) 16.95% for HFO, (2) 10.09% for Natural, (3) 5.65% for HFC, (4) 0% for HCFC, (5) 0% for Others, (6) -2.76% for CFC refrigerants.

The top 10 mostly researched refrigerants in the 20- and 5-year-period are shown in Tables 1. (a) & (b). Based on these results, 3 refrigerants from the top 10 refrigerants in the 5-year-period analysis were identified as emerging refrigerants. Combining the top 10 of the 20-year-period and 5-year-period has resulted in the 13 refrigerants to watch as shown in Table 2.

Detailed: TOP 13 refrigerants within its refrigerant type







	Refrigerant Type Name	Total number of refrigerants
HFO's	Hydrofluoroolefin	3 refrigerants
Natural	Natural Refrigerant	32 refrigerants
HFC's	Hydrofluorocarbon	77 refrigerants
HCFC's	Hydrochlorofluorocarbon	162 refrigerants
CFC's	Chlorofluorocarbon	23 refrigerants
Others	CFO, HCFO, HCC, HO, PFC, HCO, PFO, PCC, H and HCFO	43 refrigerants

	Refrigerant Type	Total number of refrigerants
HFOs	Hydrofluoroolefin	3 refrigerants
HCs	Hydrocarbons	26 refrigerants
HFCs	Hydrofluorocarbons - pure	39 refrigerants
HCFCs	hydrochlorofluorocarbon	133 refrigerants
CFCs	chlorofluorocarbons	22 refrigerants
CFO	Chlorofluoroolefin	2 refrigerants
HCFO	Hydrochlorofluoroolefin	1 refrigerants
HCC	Hydrochlorocarbon	11 refrigerants
HO	Hydroolefin (Alkene)	4 refrigerants
PFC	Perfluorocarbon	7 refrigerants

HCs	Hydrocarbons mixture	6 refrigerants
HFCs	Hydrofluorocarbons mixture	38 refrigerants
HCFCs	Hydrochlorofluorocarbon mixture	29 refrigerants
HCO	Hydrochloroolefin	3 refrigerants
PFO	Perfluoroolefin	3 refrigerants
PCC	Perchlorocarbon	2 refrigerants
H	Halon/Halo alkane	7 refrigerants
CFCs	chlorofluorocarbons	1 refrigerants
HCFO	Hydrochlorofluoroolefin	3 refrigerants
	Total Refrigerants	340 Refrigerants

