



HC-290 AS AN ALTERNATIVE REFRIGERANT FOR SPLIT AIR CONDITIONING SYSTEMS IN HIGH AMBIENT TEMPERATURES

Dilip Rajadhyaksha, Anil Sahu, B. J. Wadia
Godrej & Boyce Mfg. Co. Ltd, Mumbai, India

Daniel Colbourne
c/o GIZ Proklima, Eschborn, Germany



3-4th June, Vienna

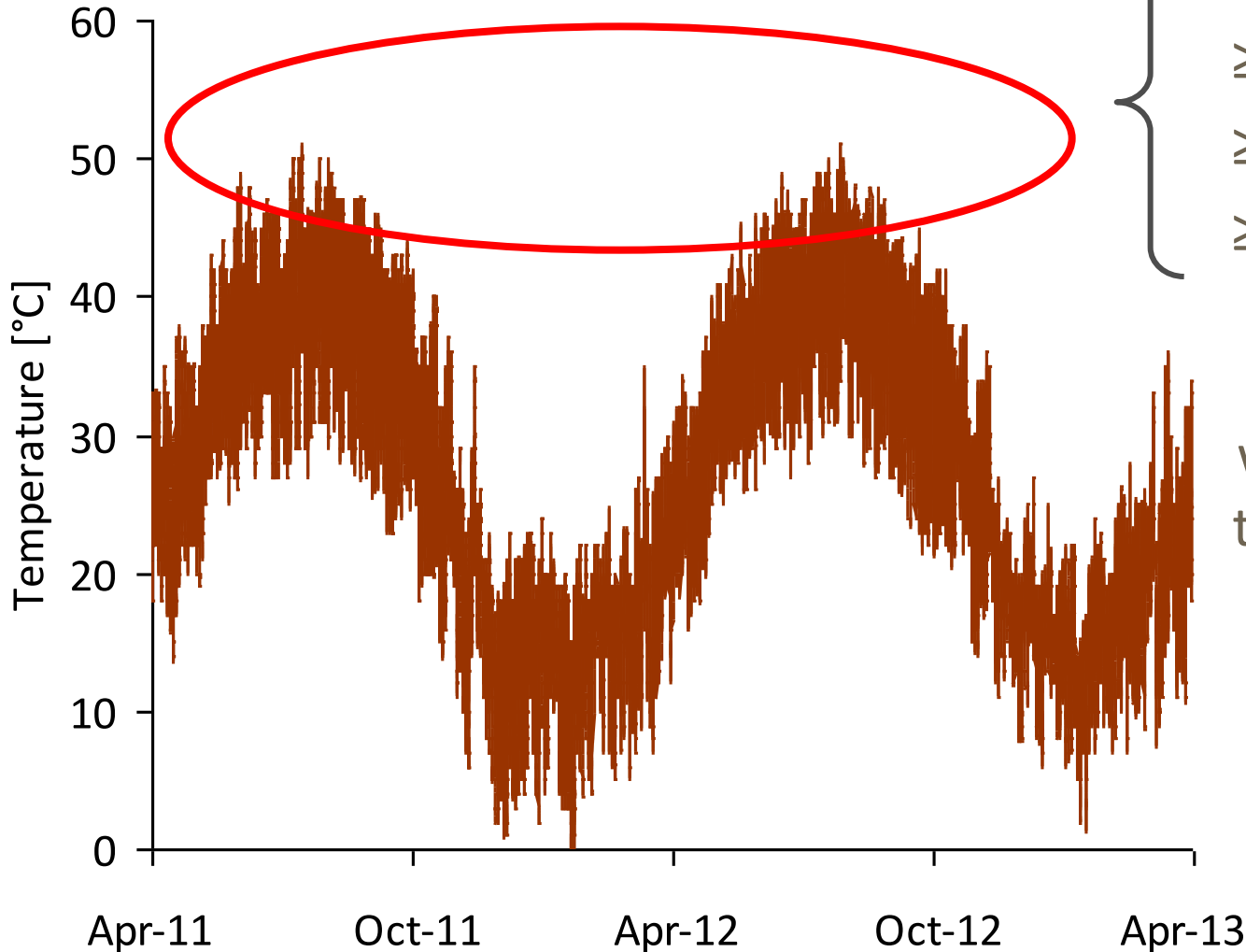


Introduction

- Alternatives to HCFC-22 in ACs...
 - Concern over suitable options for high ambient regions
 - R-410A normally considered to be unsuitable
- Other alternatives include HC-290
 - Normally efficiency in ACs is particularly good and flammability risk is known to be negligible
 - Data on performance at high ambient is very sparse...
- Current work presents results of testing HC-290 and HCFC-22 split ACs at high ambient
 - Variation in COP at high temperature for HC-290 same as with HCFC-22
 - Variation in capacity of HC-290 same as with HCFC-22
 - Consistent with the theoretical calculations, but marginally better results observed
- Evident that HC-290 is well suited to high ambient regions

Introduction

E.g., Kuwait City Airport



$\geq 48^{\circ}\text{C}$: 70 hours/y
 $\geq 49^{\circ}\text{C}$: 31 hours/y
 $\geq 50^{\circ}\text{C}$: 9 hours/y
 $\geq 51^{\circ}\text{C}$: 1 hour/y



ACs demanded to work effectively at these temperature conditions!



Refrigerant selection can be important



Introduction

Volumetric refrigerating capacity of alternatives relative to R-22

Cond T	HCFC-22	R-410A	R-407C	HC-290	HC-1270	HFC-32	HFC-161
40°C	100%	100%	100%	100%	100%	100%	100%
50°C	100%	97%	98%	98%	98%	100%	101%
60°C	100%	93%	96%	96%	96%	99%	102%
70°C	100%	86%	92%	93%	93%	98%	103%

NOTE: Cond s/c = 5 K; evap temp = +10°C; evap exit s/h = 5 K; suction line s/h = 0 K; vol eff = 100%; ref: dew point; Refprop9

Coefficient of Performance alternatives relative to R-22

Cond T	HCFC-22	R-410A	R-407C	HC-290	HC-1270	HFC-32	HFC-161
40°C	100%	100%	100%	100%	100%	100%	100%
50°C	100%	97%	99%	99%	99%	99%	101%
60°C	100%	93%	97%	98%	98%	97%	102%
70°C	100%	86%	94%	96%	95%	95%	103%

NOTE: Cond s/c = 5 K; evap temp = +10°C; evap exit s/h = 5 K; suction line s/h = 0 K; global compr eff = 100%; ref: dew point; Refprop9



Previous studies

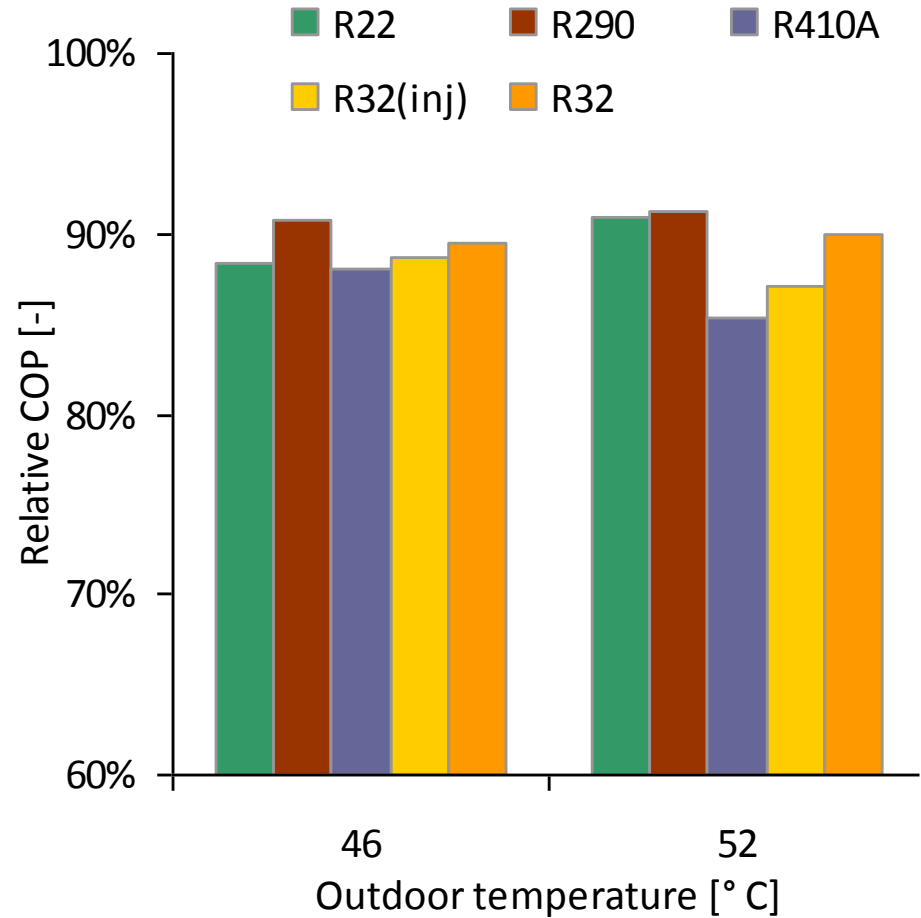
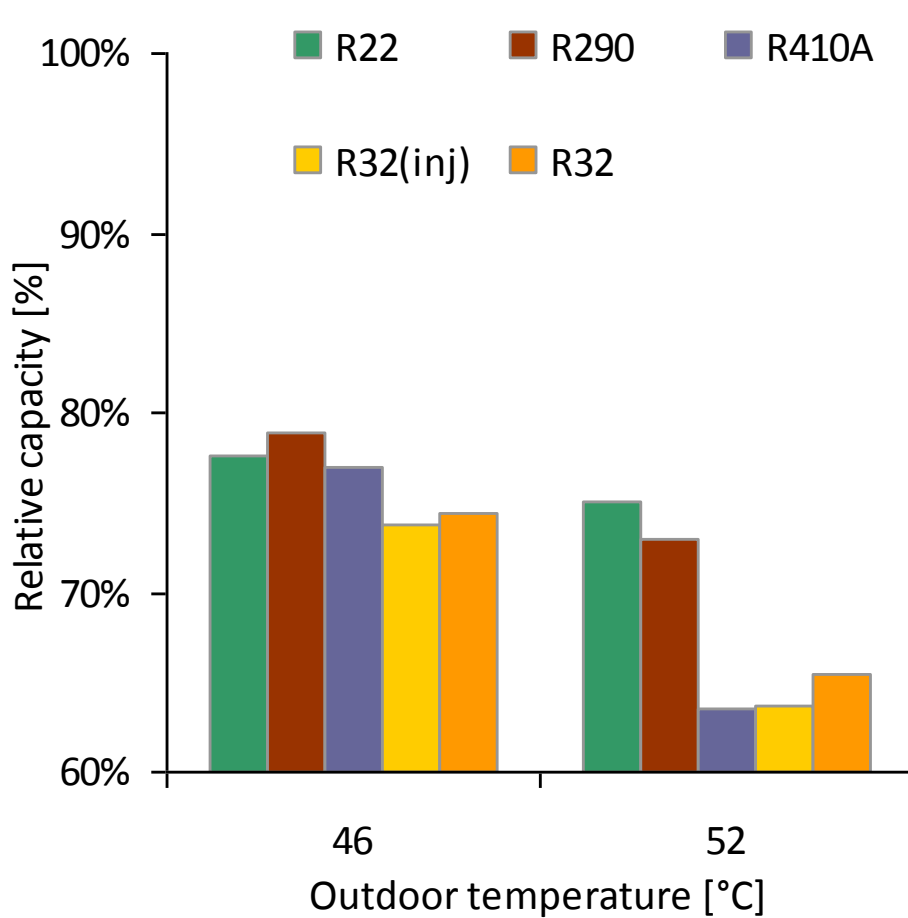
- Surprisingly few published studies on high ambient
 - All indicate R410A performance (relative to R22) declines at higher ambients

Source	Findings
Chin and Spatz (1999)	R410A shows 6% and 7% drop in capacity and COP (simulation)
Motta and Domanski (2000)	R410A shows 5% and 12% drop in capacity and COP (simulation)
Domanski and Payne (2002)	7-8% reduction in capacity at 52° C and around 14 – 20% drop in COP (measurement)
Biswas and Cremaschi (2012)	“DR-4” and “DR-5” show same relative change in COP and capacity at R410A
Chen (2012)	Compared HCFC-22, HC-290, R-410A and HFC-32 (see next)

Previous studies

- From Chen (2012)

- R290 matches R22; R410A and R32 show major degradation





Tested R22 and R290 split ACs

Characteristic	HCFC-22 air conditioner	HC-290 air conditioner
Nominal capacity	5.19 kW	4.83 kW
Nominal COP (cooling)	3.08	3.60
Evaporator type	Finned tube	Finned tube
Evaporator block volume	5.45 litres	5.45 litres
Evap no. tubes, circuits	32, 3	32, 3
Evaporator airflow rate	850 m ³ /h	850 m ³ /h
Condenser type	PFC	PFC
Condenser block volume	6.06 litres	6.03 litres
Condenser no. tubes	52	52
Compr swept volume	5.27 m ³ /h	5.39 m ³ /h
Compressor rated COP	3.10	3.38
Cap tube length, OD	0.8 m, 3.0 mm	0.65 m, 3.2 mm
Refrigerant charge	0.75 kg	0.36 kg

Tested R22 and R290 split ACs



R22 model



R290 model



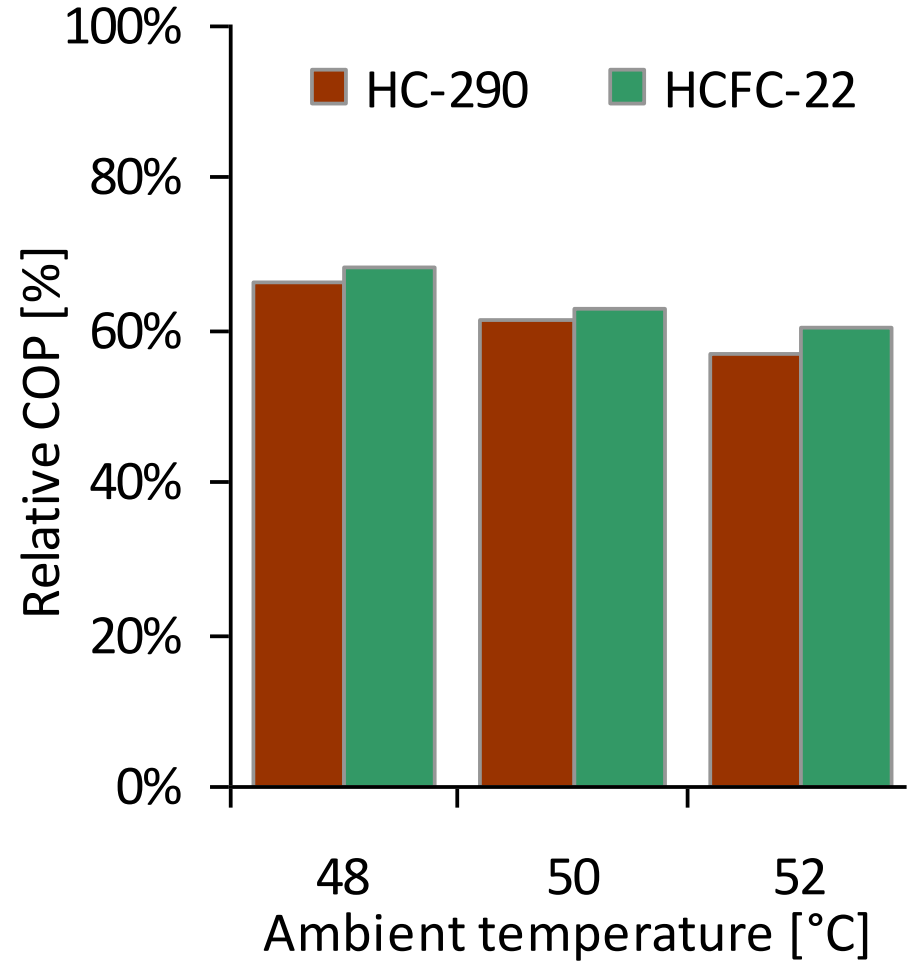
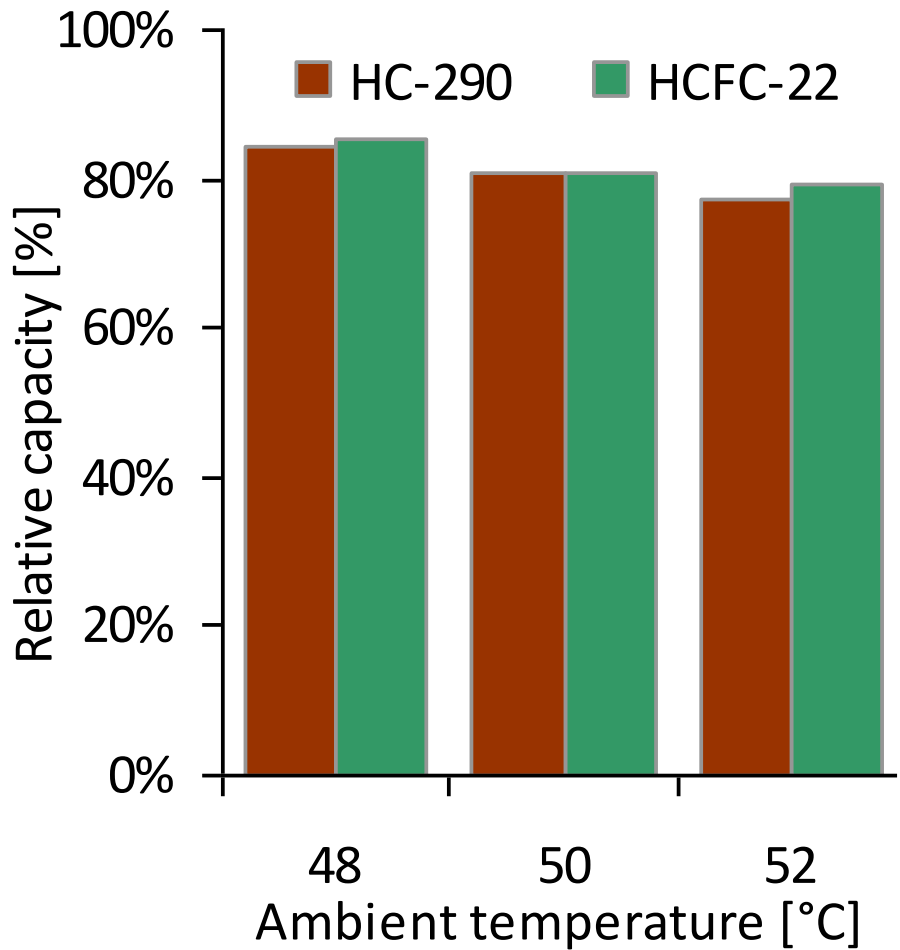


Results; global performance

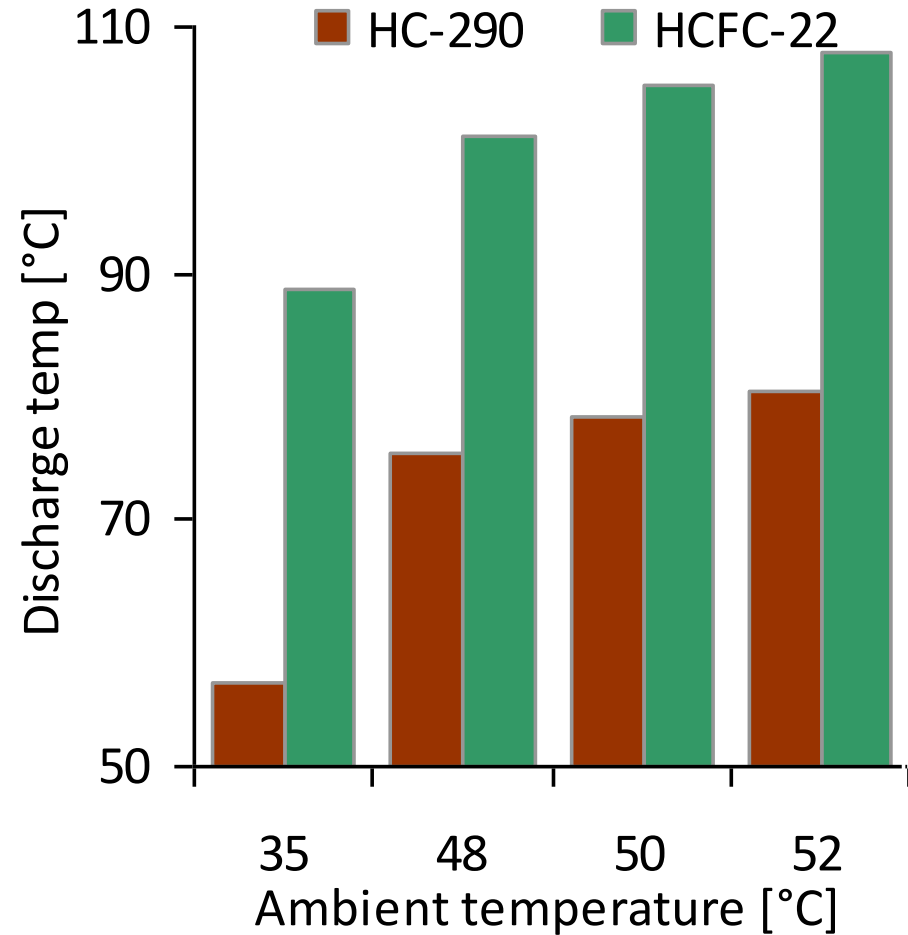
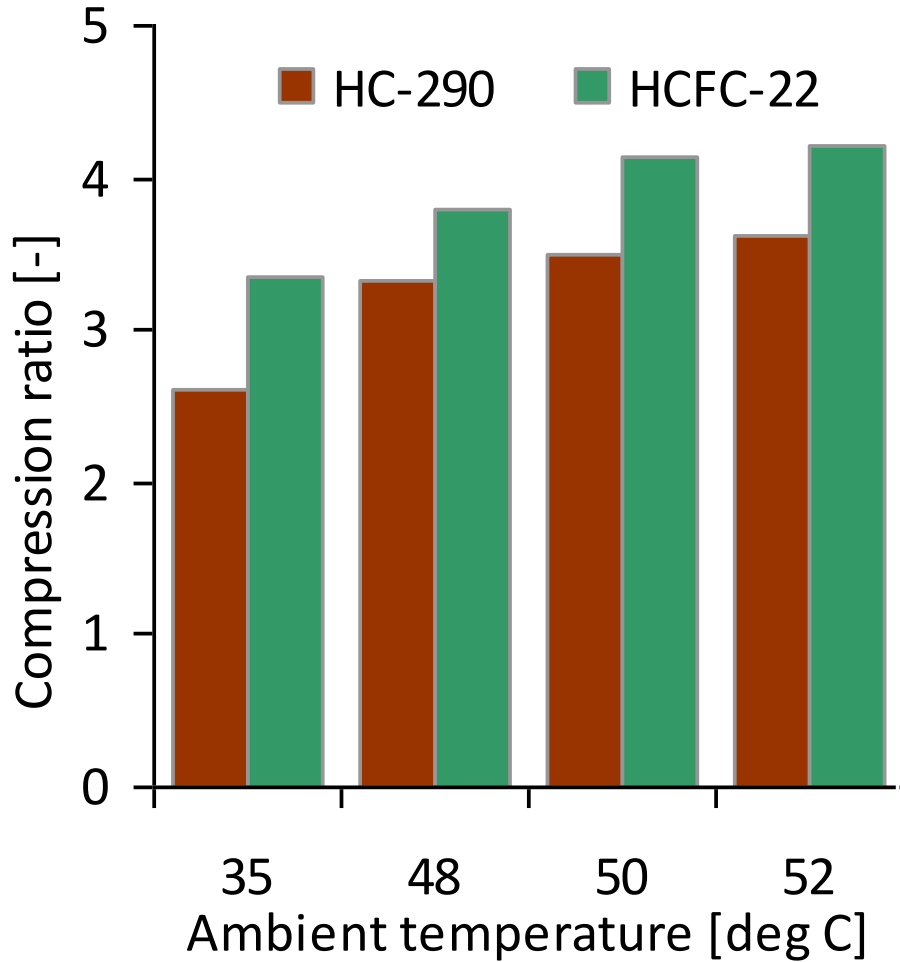
- Global results show
 - Cooling capacity of R-290 model is 7% lower at rating conditions; gets marginally greater at higher temp by 3%
 - Improvement in COP of R-290 over R-22 also declines

Parameter		Outdoor temperature				
		35°C	48°C	50°C	52°C	54°C
Cooling capacity (kW)	HC-290	4.84	4.08	3.90	3.74	3.64
	HCFC-22	5.19	4.43	4.20	4.12	—
	Difference	7%	8%	8%	10%	—
COP (kW/kW)	HC-290	3.60	2.38	2.21	2.04	1.91
	HCFC-22	3.08	2.11	1.93	1.86	—
	Difference	16%	12%	13%	10%	—

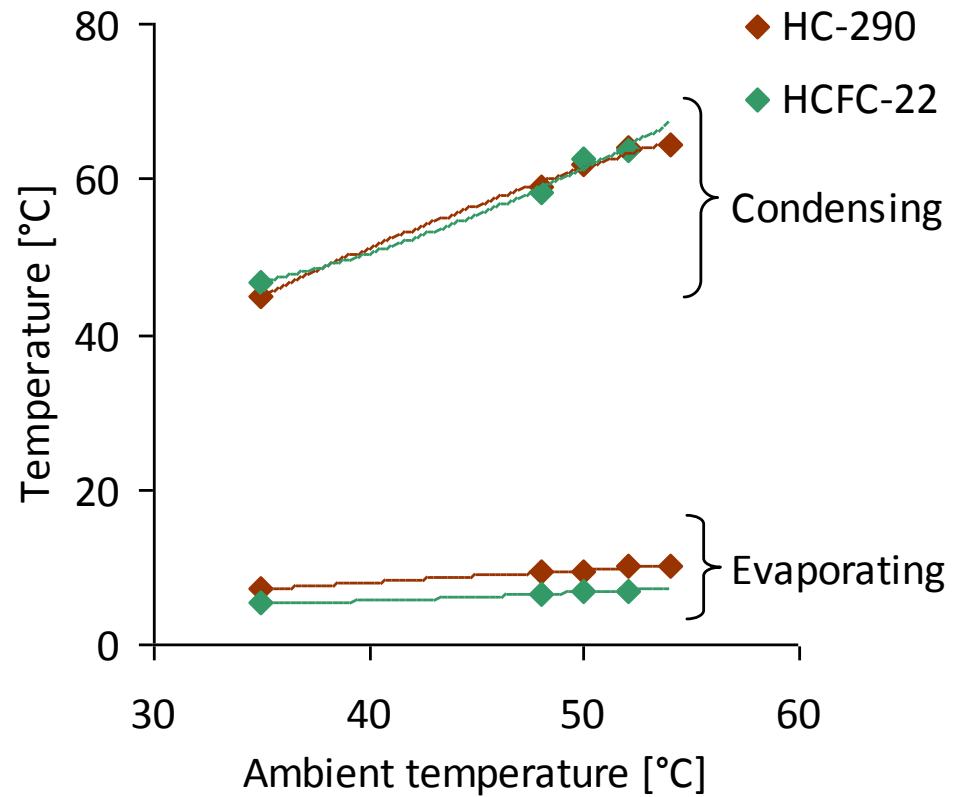
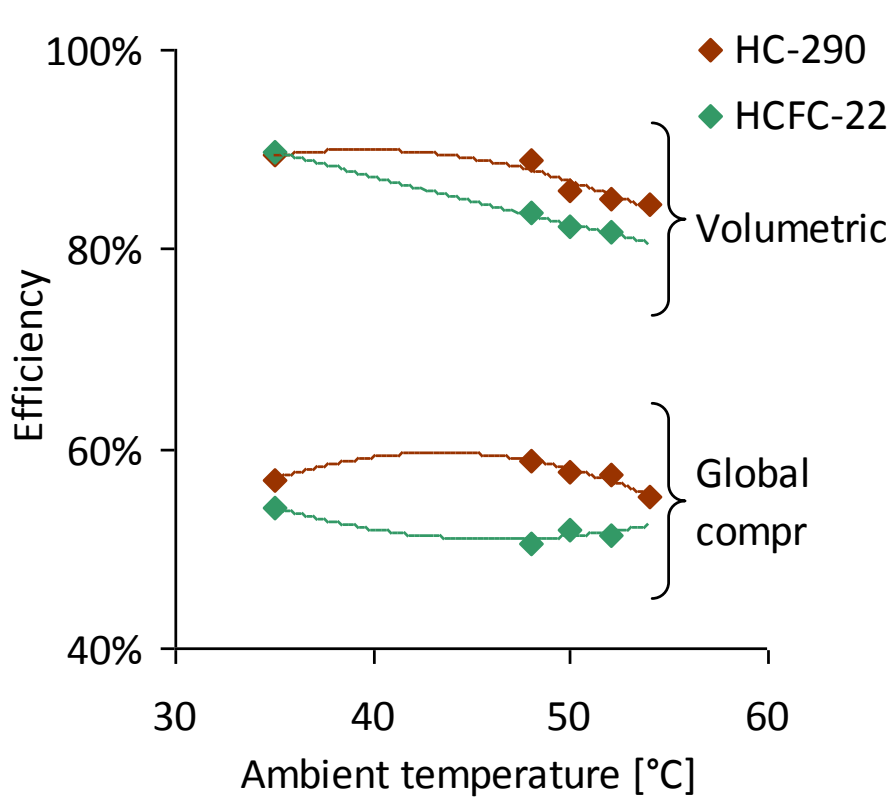
Results; relative capacity and COP



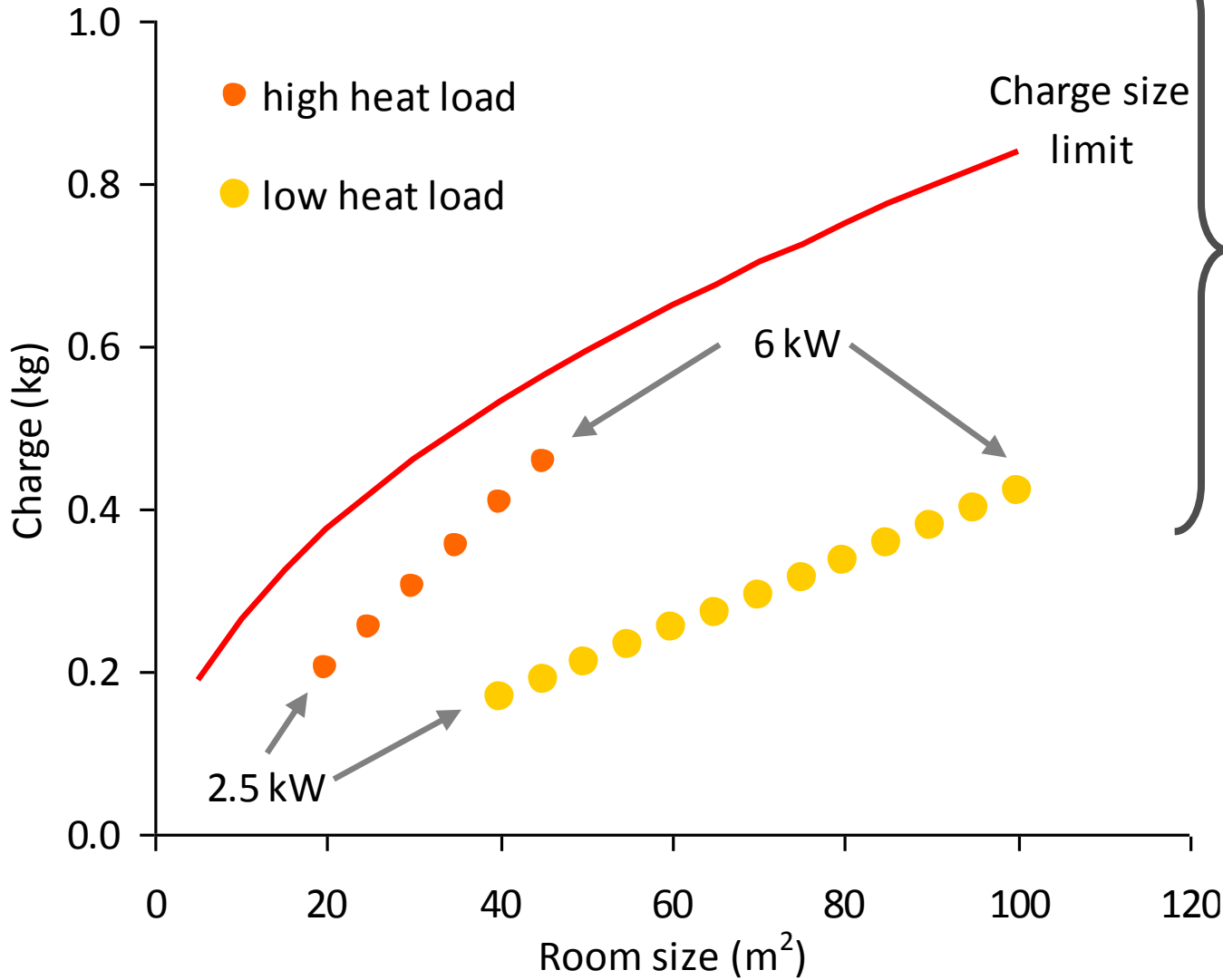
Results; pressure ratio and discharge temp



Results; compressor efficiency and dTs



Remarks on safety



Despite certain obstructive safety standards, HC ACs can still be within limits

[Based on Kuwait Code of Practice for design heat loads; air conditioner charge size as with the tested AC (75 g/kW) but in reality, only ¾ of charge leaks out!]



Final remarks

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Thank you for your attention!

On behalf of



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Environment, Nature Conservation
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