ENERGY EFFICIENCY SERVICES LIMITED
A JV of PSUs under the Ministry of Power

MARKET ASSESSMENT FOR **SUPER-EFFICIENT AIR CONDITIONERS**

Knowledge Partner : PricewaterhouseCoopers Private Limited

Acknowledgments

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FOREWORD

The global economy is undergoing a rigorous shift and the ongoing COVID-19 pandemic has been the major contributor inflicting high and rising human costs worldwide. India has also witnessed the impact of this outbreak and although the country is on the path of recovery, the effects of the COVID-19 can be seen on lives and livelihood of millions and multiple sectors have been looking for an uncertain future ahead. The energy sector is also distressed by this upheaval and it has now become imperative to draw a roadmap to rise again and move towards the path of recovery. This would require a collective effort with clear vision, early interventions, targets and timelines.

With the vision of universal access to sustainable energy solutions for all, the Energy Efficiency Services Limited (EESL) has always followed the philosophy of promoting a low carbon future, with significant economic and social impact, particularly in India. EESL has various programs under sustainable energy with an objective to promote energy efficiency and reduce emissions. This includes the Global Environment Facility (GEF) funded, UNEP & ADB supported multi-year project implemented by EESL, supporting innovation in super-efficient technologies especially Super-efficient Air conditioning (SEAC) program, among other. EESL's SEAC program is positioned to transform the market in India towards enhanced energy efficiency and offers highly energy efficient air conditioners with superior technology using low GWP and no Ozone Depleting Potential (ODP) refrigerants.

EESL, with support from GEF, conducted a market assessment study for SEAC in India. The objective of the study was to explore efficient technologies in Room Air Conditioners (RAC) sector which can reduce the energy requirements and environmental impacts associated with cooling sector. The findings of the report would benefit policy makers, economists, planners, domain consultants and other relevant stakeholders.

EESL will continue to promote energy efficiency in the country, and support efforts and interventions towards providing sustainable cooling for all.

(Saurabh Kumar)

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PREFACE

The rapid rise in urbanisation and population growth is making the conventional energy and cooling system increasingly stressed. In India, the energy ecosystem is undergoing an evolution of its own, in terms of energy use, sources, business models and operations. Energy Efficiency Services Limited (EESL) has enabled consumers, industries and governments to effectively manage energy demands through efficient technologies across various sectors such as lighting, buildings, agriculture etc. Its energy efficiency initiatives include Unnat Jyoti by Affordable LEDs for All (UJALA), Street Lighting National Program (SLNP), LED Tube Lights, Energy Efficient Fans, Building Energy Efficiency Program (BEEP), Super-efficient Air-conditioner (SEAC) Program and Smart Meter National Program (SMNP).

India's commitment towards reducing emission intensity of its GDP by 33-35% by 2030 from 2005 level through its Nationally Determined Contribution (NDC), propounds major opportunity for the country. India launched its farsighted roadmap in form of India Cooling Action Plan (ICAP) with an objective to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society. To achieve this ambitious target, energy efficient and climate friendly Room Air Conditioners (RAC) are the need of the hour.

EESL is currently working to promote energy efficiency and reduce direct and indirect emissions due to cooling through Super-Efficient AC program (SEAC) and District Energy Systems (DES). Through SEAC, EESL made a breakthrough initiative that could enhance the level of energy efficiency in space cooling in buildings. To further bolster its energy initiatives, the Global Environment facility (GEF) supported EESL to conduct a market assessment study for SEAC in India. The report provides a comprehensive overview of trends in Indian and global RAC market. The report also covers the barriers and its mitigation measures in the uptake of super-efficient air conditioners.

I am happy to share this document with all relevant stakeholders for kind perusal.

New Delhi
March 2021

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As living standards are improving and electricity reaches more homes in India, the cooling demand is set to rise in future. Air conditioners are now viewed as necessity rather than a luxury and with increased penetration in household and commercial buildings, energy use and use of refrigerants will rise for cooling. It has now become inevitable that coming generation of air conditioners must be climate friendly that are both energy efficient and use climate safe refrigerant gases.

EESL has always been on forefront of taking such initiatives in India by implementing the world's largest non-subsidized energy efficiency portfolio across lighting, buildings, agriculture, etc., at a scale, which no other organization has been able to achieve. Taking this vision forward, EESL launched the Super-Efficient Air-conditioner Program (SEAC). Under this program, EESL intends to supply 50,000 super-efficient and climate friendly five-star 1.5-ton air conditioners. This equipment has an ISEER of 5.4 and have a refrigerant with GWP of 675 which is almost 1/3rd the value of refrigerants prevalent in Indian market and have zero ozone depleting potential. To reach the masses EESL has also developed an online platform (https://eeslmart.in/) to deploy super-efficient and climate friendly air-conditioners at an affordable price. In terms of prices, these AC's are comparable or cheaper than the 5-star AC's available in the market. When compared to the same efficiency levels, these are priced 20-30% less than the market prices.

The program has been a huge success in leap frogging the current energy efficiency levels and use of environment damaging refrigerants used in air conditioners and minimizing the cooling related electricity demand and associated climate threats.

This report on market assessment of super-efficient air conditioners provides a review of trends in India and global air conditioner market and analysing market strategies to scale up the deployment of super-efficient air conditioners.

The report benefited from valuable inputs from Voltas Haier, O.G Heavy Duty, Godrej, MPCL Industries Ltd., Carrier, Trane, Daikin, BSES Yamuna Power Limited (BYPL), Tecumseh, UL, Intertek and acknowledge their support in preparation of this report. I would also like to commend and congratulate the team members from EESL and PwC India for carrying out such a comprehensive study and putting together this report. I look forward to the continued efforts towards achieving our future goals.

(S.P. Garnaik)

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Abbreviations and Acronyms

APF	Annual Performance Factor
ASHRAE	American Society of Heating, Refrigerating and Air conditioning
BEE	Bureau of Energy Efficiency
BIS	Beaurea of Indian Standards
CAGR	Compound Annual Growth Rate
CFC	Chlorofluorocarbon
CSEC	Cooling Seasonal Energy Consumption
CSPF	Cooling Seasonal Performance Factor
CSTL	Cooling Seasonal Total Load
ECBC	Energy Conservation Building Code
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Limited
EMI	Equated Monthly Installment
EMS	Energy Management Systems
ESCO	Energy Service Company
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	HCFC Phase-out Management Plan
HS	Harmonized system
ICAP	India Cooling Action Plan
IoT	Internet of Things
ISEER	Indian Seasonal Energy Efficiency Ratio
MEPS	Minimum Efficiency Performance Standards
MIS	Management Information System
MoEF&CC	Ministry of Environment, Forest & Climate Change
MSME	Micro, Small and Medium Enterprises
NABL	National Accreditation Board for Testing and Calibration Laboratories
ODP	Ozone Depletion Potential
ODS	Ozone Depletion Substances
OEM	Original Equipment Manufacturer
PH	Pressure-Enthalpy
RAC	Room Air Conditioner
RPM	Revolutions Per Minute
S&L	Standards and Labelling
SCOP	Seasonal Coefficient of Performance
SEAC	State Expert Appraisal Committee
SEER	Seasonal Energy Efficiency Ratio
UL	United Laboratories
VFD	Variable Frequency Drive
YOY	Year on Year

Executive Summary

India is the second fastest growing economy in the world. Increasing income levels, urbanization and rising temperatures have led to a growth in demand for room air conditioners (RAC). During the last five years the RAC market has grown at a steep Compound Annual Growth Rate (CAGR) of 18% to touch 7.7 million sales units in 2019-20[1]. This number is expected to exceed the 20 million mark by 2027, with an inevitable surge in the electricity requirement to run this RAC stock. In 2017-18 RAC's constituted around 40% (56 TWh) of total energy consumption in urban homes in India, which is expected to increase to 50% (215 to 385 TWh) by 2037-38 in the reference scenario[2]. The growing RAC market will also raise the peak demand on the already overstressed electricity grids, exacerbating blackouts and brownouts.

To manage the envisaged electricity demand, RAC efficiency has become one of the priority areas for the Government of India (GOI). The Indian Cooling Action Plan (ICAP) estimates that the electricity consumption of the RAC sector can be reduced by 33% (135 to 285 TWh) compared to the 2037-38 reference scenario by suitable interventions.

Several steps have been taken by GOI to regulate the efficiency of the RAC sector. One significant step in this direction was Bureau of Energy Efficiency's (BEE) Standards and Labelling program for RAC. BEE launched its standards and labelling program for RAC in 2007 to regulate and ratchet up efficiency levels in this sector. BEE has periodically revised the RAC efficiency norms resulting in an overall efficiency improvement of ~ 36%[3] compared to the baseline value in 2007. However, there is still a potential for improvement.

Another significant dimension of RAC use is the environmental impact such as Ozone depletion and direct global warming caused by the refrigerants used in them. Although today's RACs use refrigerants which have Zero ODP (ozone depletion potential) and low-GWP (Global warming potential) compared to their older counterparts, there is a further opportunity to transit to natural or HFO's (Hydro-fluoro Olefin) refrigerants with negligible global warming potential.

Given the benefits of promoting efficiency in RAC sector, the Global Environment facility (GEF) is supporting Energy Efficiency Services Limited (EESL) to conduct a market assessment study for such super-efficient air-conditioners (SEAC) in India. The objective of the study is to explore efficient technologies in RAC's which can reduce the energy requirements and environmental impacts associated with RAC use. This is not only paramount for sustainable growth of the Indian economy but also to ensure compliance with international commitments such as Montreal Protocol.

The report provides a comprehensive overview of trends in Indian and global RAC market. Extensive literature review and desk research was done to capture national and international trends on efficiency, refrigerant use and standard labelling programs. This activity was parallelly followed by stakeholder consultations and survey questionnaire for expert opinions and bridging any gaps in data. RAC Component pricing, financing mechanisms, business models and go to market strategies have also been analyzed to scale up the deployment of Super-Efficient air conditioner (SEAC) program in India.

Chapter 1 starts with a brief on air conditioning principles and then gives an overview of Indian air conditioning market, import / export statistics, technology trends in terms of (refrigerant, efficiency). Chapter 1 ends with key insights on the testing standards and labelling program for RACs in India.

[1] As per our stakeholder interactions and analysis
[2] Indian Cooling Action Plan
[3] BEE Star labeled appliances

Chapter 2 and 3 give an overall picture of the demand/ supply scenario in global RAC markets such as China, Japan, Korea, North America and Europe. They also detail the efficiency, refrigerant and technology trends prevalent in these markets. This chapter also provides a comparative of the test standards applicable in China, Korea and Japan.

Chapter 4 gives a snapshot of various policy regulations and programs in place for promotion of efficient AC's in India.

Chapter 5 details the supply chain analysis of major RAC components and domestic manufacturing capability

Chapter 6 gives the regulatory landscape of refrigerant use in RAC's. It summarizes how the refrigerants have transitioned over time from High ODP and GWP to Zero ODP and low GWP under the Montreal protocol and its subsequent amendments.

Chapter 7 gives an insight on the cost components of an RAC and also gives the details of various cost components which contribute to the final cost of the RAC.

Chapter 8 and 9 detail various financing mechanisms and business models for promoting the Super-efficient AC programs.

Chapter 10 gives the barriers in the uptake of super-efficient air conditioners and recommends its mitigation measures

1. Room Air Conditioners – Overview of technology, performance and efficiency trends

1.1. Air-conditioning principles

1.1.1. Thermal Comfort

Air conditioning systems are primarily used for improving thermal comfort of its occupants. American Society of Heating, Refrigerating and Air conditioning (ASHRAE) defines “thermal comfort as a condition of mind that expresses satisfaction with the thermal environment”. Thermal comfort varies from person to person and is broadly dependent on 6 parameters -

1. Metabolic rate;
2. Clothing insulation;
3. Radiant temperature;
4. Air temperature;
5. Humidity limits; and
6. Air speed.

The purpose of air conditioning is to achieve thermal comfort for its occupants by controlling the last 3 parameters (factors 1 and 2 are considered uniform for an application and factor 3 indirectly depends upon the last three factors). Since thermal comfort is relative varying from person to person, ASHRAE’s standard 55 and 62.1 specify the range of these parameters which are acceptable thermal conditions for its occupants (in different applications). The parameter range is as follows –

- Air temperature – Between 67 °F (19.4 Deg.C) to 82 °F (27.7 Deg.C)
- Humidity – 65% Or less
- Air Speed – 0.2 m/s to 1.5 m/s

Depending on the application (office, gym, auditorium etc.), a certain combination of these parameters will provide thermal comfort to its occupants. These parameters are predominantly controlled by air conditioning appliances (such as room air-conditioner (RAC), chillers, VRF/VRV, package DX), all of which work on the principle of vapour compression.

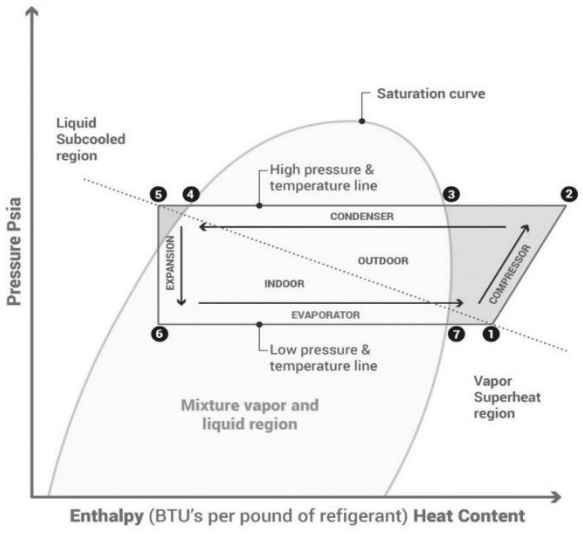


Figure 1:P-H Diagram of a vapor compression cycle

1.1.2. Principle-Vapour compression

Vapour Compression involves circulating a working fluid (refrigerant in this case) that absorbs heat from the place to be conditioned and rejects it elsewhere. The refrigerant goes through 4 stages in a vapor compression cycle for producing the refrigerating effect:

1. Evaporation
2. Compression
3. Condensation
4. Expansion

In each stage of the cycle the refrigerant goes through various thermodynamic state. These thermodynamic states of the refrigerant are depicted on a PH (Pressure-Enthalpy) diagram as shown in figure 1. The saturation curve of the refrigerant gives the demarcation of its 3 states i.e. Liquid, Liquid + Vapor, Vapor.

1. **Evaporation:** Evaporation occurs in the evaporator of an air conditioner. Owning to the low pressure of the refrigerant in the evaporator coils, it boils at a very low temperature. The heat required to boil the refrigerant comes from the space to be cooled. This phenomenon occurs between point 6 and 7 of the PH diagram. As the refrigerant boils, the ratio of vapour in the liquid + vapor mixture of refrigerant increases and it becomes 100% vapor at point 7 (also known as saturated vapor). Super heating occurs between point 7 and 1 and ensures no liquid refrigerant is sent back to the compressor as the liquid can damage it.

2. **Compression:** Compression occurs in the compressor of an air conditioner. On the PH diagram it is depicted between point1 and point 2 in figure 1. It compresses the low-pressure, low temperature refrigerant gas into a high-pressure high temperature superheated gas.

3. **Condensation:** The condenser rejects all the heat absorbed by the refrigerant in the evaporator and compressor. The high pressure and super-heated gas is cooled in the condenser. First the superheat of the gas is removed to bring down the temperature of the vapour to its saturation temperature. The removal of superheat is done in the topmost portion of the condenser coils. This process is shown in point 2 and 3 in the PH diagram. At point 3 the condenser starts changing the phase of refrigerant from vapour, to Liquid + Vapor and finally to saturated liquid by the time it reaches point 4. The refrigerant is then subcooled (as depicted between points 4 and 5) to ensure that only liquid refrigerant enters the expansion device.

3. **Expansion:** The expansion valve reduces the liquid refrigerant under high pressure / high temperature to low pressure / low temperature (as depicted between point 5 and 6 of the figure 1) refrigerant for the evaporator. The temperature/ pressure reduction is achieved by regulating the orifice of the expansion. This cycle is repeated all over again.

At any given condition the heat removed by the evaporator depicted from point 6 to 7 on the PH diagram signifies the cooling capacity of the air conditioner. The work done in compressing the refrigerant from point 1 to 2 signifies the electrical power required by the compressor. The ratio of these, gives the efficiency of the air-conditioning system.

1.2. Overview of Indian RAC market

1.2.1. RAC - Basis type and definition

Room air conditioner (RAC) category in India comprises of Window type and Split type air conditioners up to a cooling capacity of 18 kW. This categorization is as per the standards for air-conditioners laid out by Bureau of Energy Efficiency (BEE). IS 1391 are the Indian standards for RAC. IS 1391 part 1 and part 2 are applicable for window AC and Split AC respectively.

The definitions of window and split AC are as follows:

Window AC: An encased assembly designed as a self-contained unit primarily for mounting in a window or through the wall or as a console. It consists of compressor, heat exchangers and air handling system installed in one cabinet.

Split AC: A split air conditioner consists of an outdoor unit and an indoor unit. The indoor unit is installed inside on the wall or the ceiling, while the outdoor unit is installed on the exterior of the wall. The split AC unit consist of compressor, heat exchangers, fan motors, and air handling system installed in two separate cabinets.

The categorisation based on type of RAC's is depicted in the figure below:

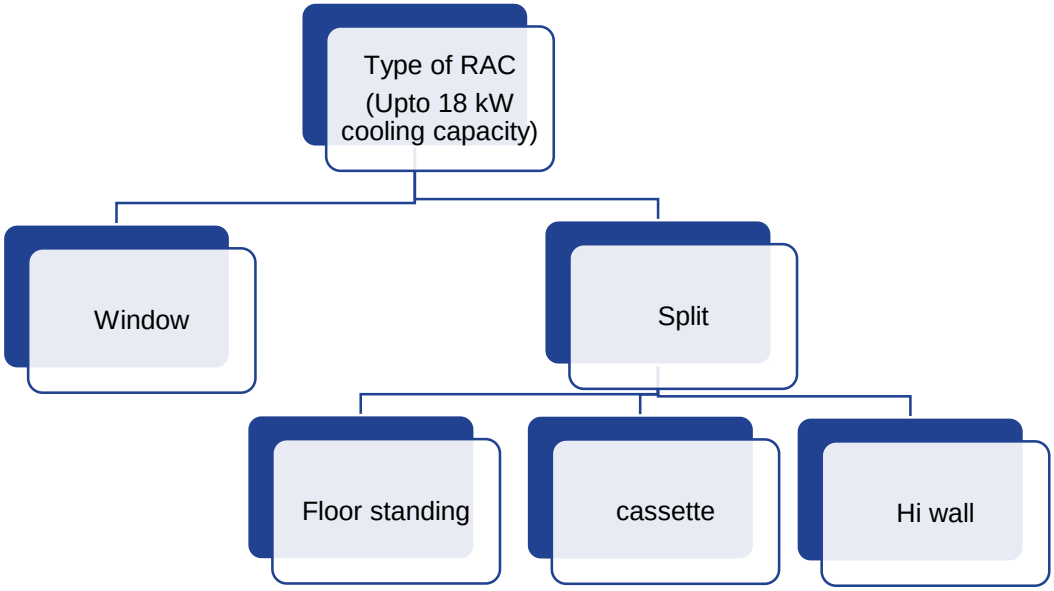


Figure 2: Classification of RAC

Window AC's available in the market are below 7 kW[4] (approx. 2 TR) in cooling capacity, whereas Split AC category extends upto 18 kW (approx. 5.1 TR) with 3 different product types as explained below -

- **Hi-wall Units-** fall below 10.5 kW (approx. 3TR) cooling capacity

- **Cassette AC-** Majority of cassette units sold in the market have cooling capacity between 10.5 kW (approx. 3TR) to 18 kW (approx. 5.1 TR). Very few are sold in less than 10.5 kW cooling capacity size. The indoor units of these AC's are mounted on the ceiling.

  Floor Standing- Majority of floor standing units sold in the market have cooling capacity between 10.5 kW to 18 kW. Very few are sold in less than 10.5 kW cooling capacity size. As the name suggest the indoor units of these AC's are kept on the floor.

Room air conditioners can further be classified based on usage: Cooling only and both heating / cooling.

India, especially north India, experiences extreme weather conditioners. While summers are unimaginable without air conditioners, winters without heaters can be harsh. Manufacturers thus have products that serve the function of both cooling and heating. These products are called **reversible type.**

[4] 1TR = 3.516 kW

The reversible type products are not very common in India with a miniscule market share. However reversible split AC is more common than their reversible window counterpart. There are no standards for heating in India, therefore reversible products are rated based on their cooling efficiency.

1.2.2. Major players and market size

The RAC market in India presents a fragmented scenario with more than 22 players from all over the world and they cater to the diverse needs of the vast Indian customer base. A few dominant players are listed in the figure below:

Figure 3:Key RAC market players in India

The Indian air conditioner market has grown at a CAGR of 19% from FY 14-19. The overall RAC sales across all types of RAC market in India stands close to **6.7 million units (2018-19).**[5]

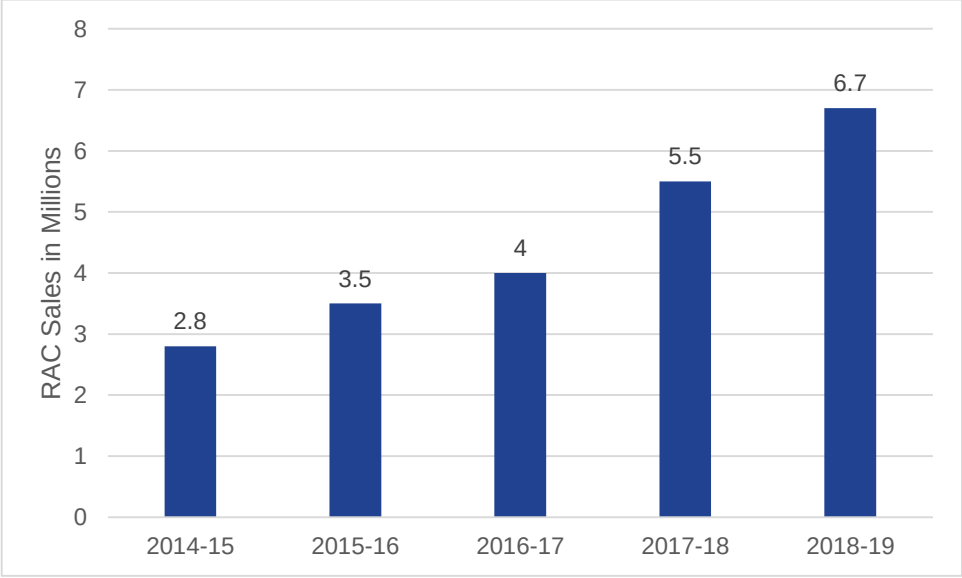


Figure 4: RAC Sales from YOY

[5] Data taken form industry Sources

1.2.3. RAC import / export trend

As per Ministry of Trade & Commerce data, **2.9 million room air conditioners**[6] were imported (the numbers are for complete units) to India FY 18-19. This means that out of 6.7 million units sold in India FY 2018-19, the indigenous manufacture was approximately **3.8 million units**. India exported **0.2 million RAC** in in the same year.

Total units imported (FY 2018-19) - 2.9 million

Major countries of Import
China – 1.9 million
Thailand- 0.6 million
Others- 0.4 million

Total units exported (FY 2018-19) - 0.2 million

Major countries of export
Sri Lanka- 0.028 million
Oman ~ 0.026 million
UAE, Singapore ~ 0.039 million;
Nigeria ~ 0.018 million

The country wise import/export analysis for RACs has been done using Harmonized system[7] (HS) codes from Trademap.org. Trademap.org is a popular source for Import/export data and a lot of businesses use Trademap.org data for Management Information Systems (MIS) and other purposes. To cross check the authenticity of the data, the total import / export quantity for FY 2018-19 (from trademap.org) was validated against data from the Ministry of Commerce and Industry, Govt. of India and Industry experts judgement.

The figure 5 & 6 shows the Import - export trend for complete RAC unit in the last 4 years[8]. The export market has increased at a CAGR of 11.37%, whereas the import has increased from 1.9 million units in FY2015-16 to 2.9 million units in FY2018-19 with a CAGR of 11%.

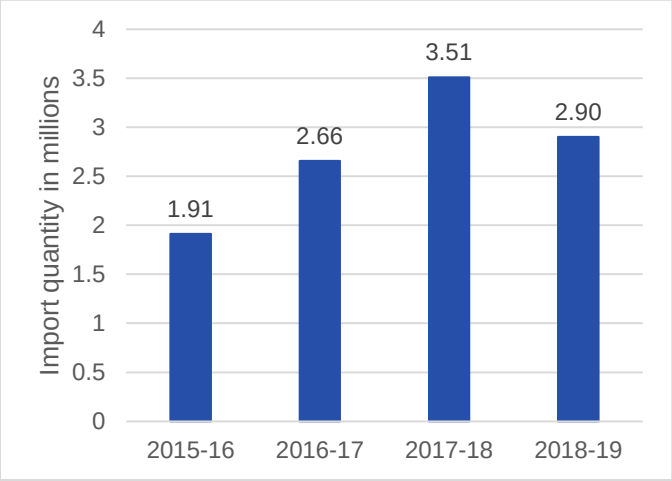


Figure 5: RAC Import

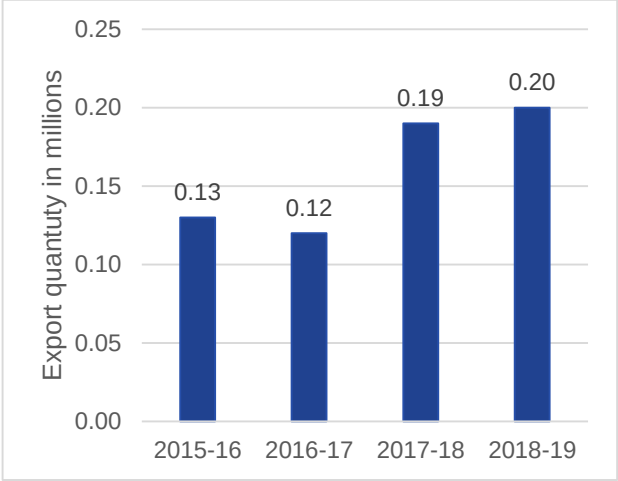


Figure 6: RAC Export

- If we compare the figure 5 i.e. RAC import with figure 4 i.e.RAC market size, there is a clear indication that the indigenous production post 2017-18 has increased

[6] Government of India ministry Of Commerce & Industry. https://commerce-app.gov.in/eidb/default.asp.
[7] The **Harmonized** System classification is a six-digit standardfor classifying globally traded products
[8] Government of India ministry Of Commerce & Industry. https://commerce-app.gov.in/eidb/default.asp

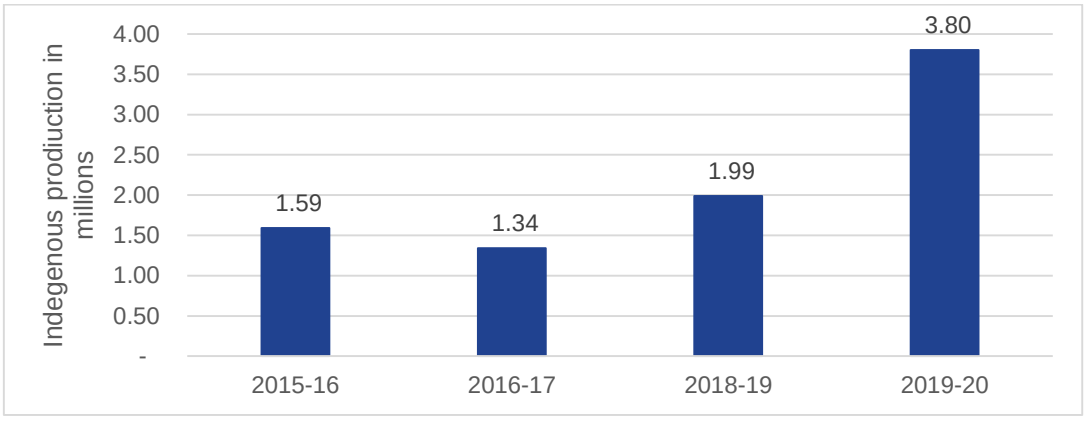


Figure 7 : RAC indegenous production / assembly

1.2.4. Market share – Basis type and technology

The segregation of RACs on the basis of type has been explained in section 1.2.1. The market share of window AC's has decreased by 10% in last five years. Split AC market share is expected to remain constant at approximately 90% in the coming years as the price gap between window and split AC has reduced considerably[9]

Split AC market is expected to transition to inverter technology in the coming years, with inverter ACs projected to account for 50% market share by FY 20 and this transitions is primarily driven by the benefits addressed by the technology such as reduced power consumption, low level of noise, better comfort etc. Manufacturers such as LG have completely transitioned to split inverters.

Based on technology they can be broadly segregated into - fixed speed or inverter. Although both the inverter air conditioner and fixed speed air conditioners have similar functions, the sole difference lies in the compressor technology. The inverter air conditioner can vary the RPM of the compressor by modulating the frequency (Hz) of the electricity supply as per the temperature setpoint. The fixed speed air conditioner, on the other hand, has a regular start/stop compressor once the setpoint is achieved. The figure 8 and 9 depicts the market trend of RAC's basis their type and technology[10].

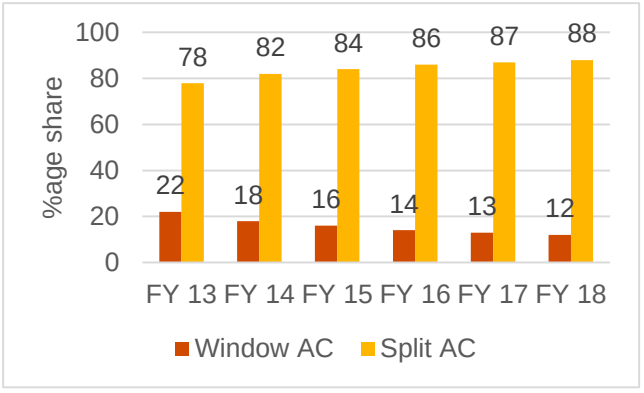


Figure 8: RAC market share by type

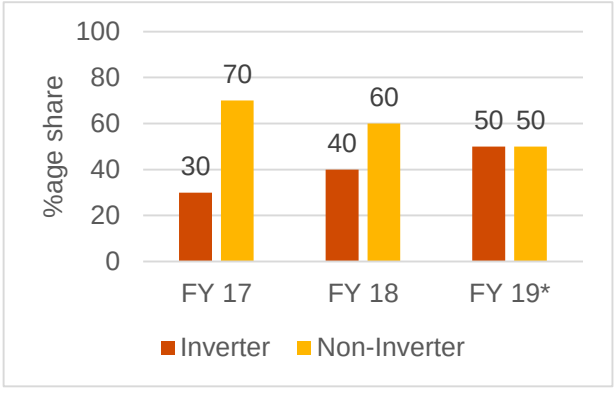


Figure 9: RAC market share by technology

[9] Shift to inverter air conditioners : MOSL report 2017
[10] Data taken form industry sources

1.2.5. Market share – Basis efficiency

The efficiency of RAC's sold in the Indian market is measured in terms of its Indian Seasonal Energy Efficiency Ratio (ISEER) and assigned star ratings as per BEE's star labelling program. The applicable BEE star rating table for both window and split are given in the table 1 and 2.

Table 1 ISEER rating of split AC CY' 18-21

Star Level	Minimum	Maximum
1 Star	3.1	3.29
2 Star	3.3	3.49
3 Star	3.5	3.99
4 Star	4	4.49
5 Star	4.5	

Table 2 ISEER rating of window AC CY' 18-21

Star Level	Minimum	Maximum
1 Star	2.5	2.69
2 Star	2.7	2.89
3 Star	2.9	3.09
4 Star	3.1	3.29
5 Star	3.3	

Figures 10 & 11 shows the market share for all type of star rated RACs in 2017-18 and 2018-19.[11] The 4-5-star market share shifted to lower categories from 2017-18 to 2018-19 due to change in labelling program. As per our interaction with major AC manufacturers, currently (2018-19), the 3-star AC dominates the market with 66% share while low star rating 1 and 2 star have a 11% market share and 5 star has a market share of around 19%.

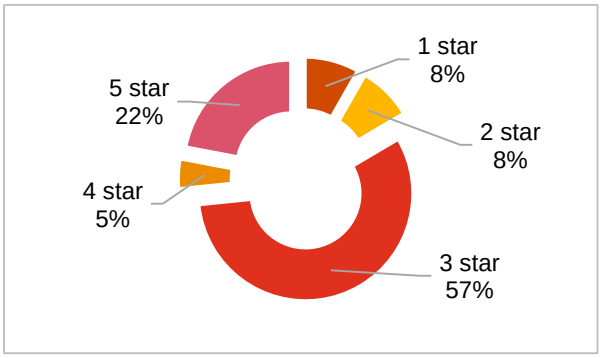


Figure 10: Room AC sales by star rating (2017-18)

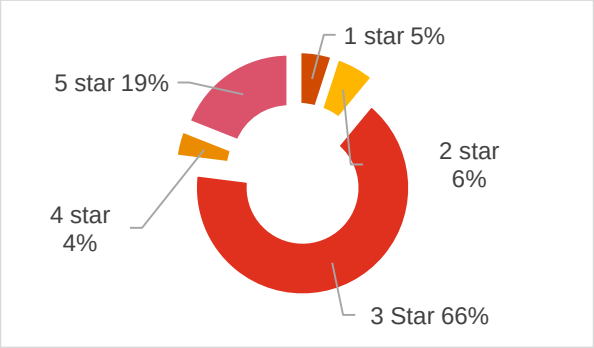


Figure 11: Room AC sales by star rating (2018-19)

1.2.6. Market share – Basis refrigerant

The refrigerants predominant in the current RAC market are R410A, R22, R32 and R290. Refrigerants contained in the RAC's contribute both to the global warming and ozone depletion as per their GWP and ODP values mentioned in the table below:

Table 3:GWP and ODP values of RAC refrigerants

Refrigerant	Category	Global Warming Potential (GWP)	Ozone Depletion Potential (ODP)
R-22	HCFC	1760	0.055
R-410a	HFC	1924	0
R-32	HFC	677	0
R-290	HC	3	0

[11] PwC's internal analysis post stakeholder consultaions

In 2017-18, R-22 was the predominant refrigerant. India is currently implementing phase-out of the HCFCs, as agreed under the accelerated phase-out schedule of the Montreal Protocol on substances that Deplete the Ozone Layer . Due to this phase-out, HFCs are evolving as a default replacement of HCFCs in Indian market.

As per our stakeholder consultation with major AC manufacturers, R-32 and R-410 had a market share of 80% in 2018-19. R-22 and R-290 have approximately 18% and 2% market share respectively.

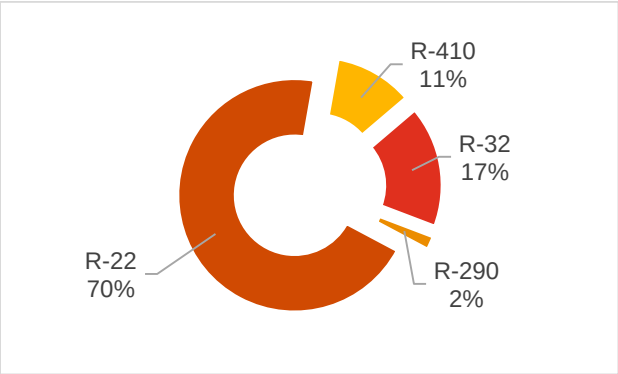


Figure 12: RAC sales by refrigerants (2017-18)

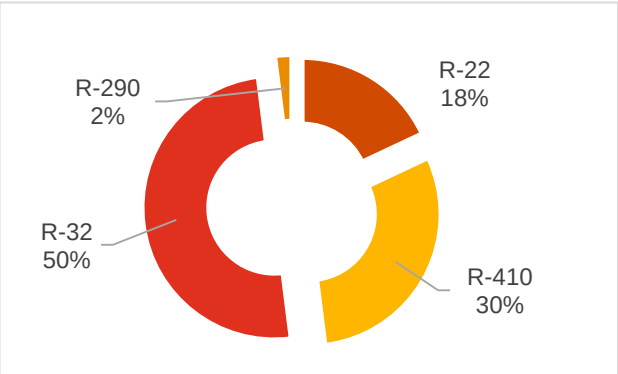


Figure 13: RAC sales by refrigerants (2018-19)

1.2.7. Market Share- Basis tonnage

Major RAC capacities sold in the Indian market vary from 0.75 to 2 TRs. However, products in the 1 and 1.5 TR split category dominate the market. In the present scenario, the market share of 1.5 TR and 1 TR ACs stands close to 90%[12]. 1.5-ton Split AC market is approximately 61% of the total RAC market.

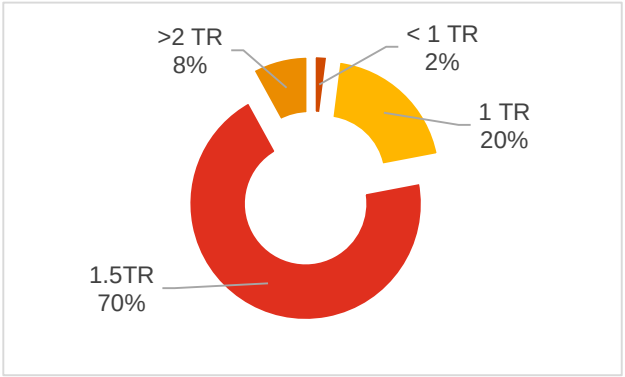


Figure 14: RAC sales by tonnage (FY 16-17)

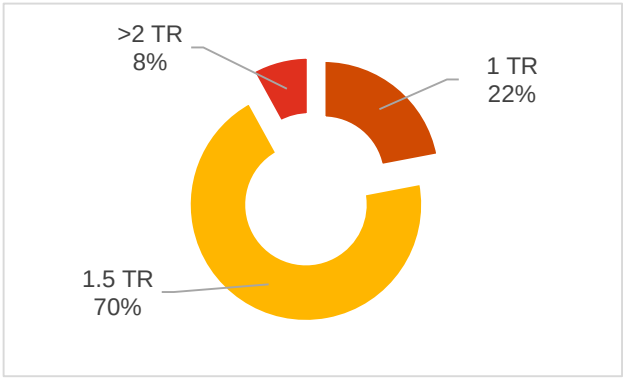


Figure 15: RAC sales by tonnage (FY 17-18)

1.2.8. Energy performance considerations

RAC efficiency is often expressed in:

- **Energy Efficient Ratio (EER)** - measures how efficiently a RAC will operate at a specific outdoor temperature. EER was used for measuring the RAC efficiency till 2015 (became mandatory in 2017), wherein the efficiency was measured at a single temperature of 35℃. The major drawback of EER is that it does not capture the performance of RAC in varying temperature profiles. The EER can be calculated using this equation:

  EER = Output Wattage (or cooling capacity) / Input Wattage.

[12] "A promising, yet stagnant market", March 2019 https://www.tvj.co.in/a-promising-yet-stagnant-market/

In India, **Indian Seasonal Energy Efficiency Ratio (ISEER) is being used as a measure of energy efficiency in air-conditioning units as suggested by BEE star labeling (S&L) programme.**

- **ISSER** - was introduced in voluntary stage from 2015 to 2017 and became mandatory from 2018 onwards. It is a rating methodology that factors in variation of temperature and assigns the efficiency figure accordingly.

  ISEER = Cooling seasonal total load (CSTL) / Cooling seasonal energy consumption (CSEC)

  Where: **Cooling Seasonal Energy Consumption (CSEC)** – Total annual amount of energy (electricity) consumed by the equipment when it is operated for cooling in active mode.

  Cooling Seasonal Total Load (CSTL) – Total annual amount of heat that is removed from the indoor air when the equipment is operated for cooling in active mode.

The method of evaluation of ISEER is based on bin hours of national climatic zone, bin temperature range of 24 - 43°C and 1600 operating hours per annum. Table 4 displays bin hours against each bin temperature.

Table 4: Bin hours against each bin temperature

Temperature (°C)	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Total
Average Annual Hours	527	590	639	660	603	543	451	377	309	240	196	165	130	101	79	59	44	31	20	10	5774
Fraction	9.1	10.2	11.1	11.4	10.4	9.4	7.8	6.5	5.4	4.2	3.4	2.9	2.3	1.7	1.4	1.0	0.8	0.5	0.3	0.2	100
Bin hours	146	163	177	183	167	150	125	104	86	67	54	46	36	28	22	16	12	9	6	3	1600

The higher ISEER value in an AC indicates the higher efficiency of the equipment which corresponds to higher star rating.

1.2.8.1. Fixed speed Vs Variable Frequency Drive (VFD) compressors

As pointed out earlier, the RAC market is shifting towards VFD technology. The main reason for this is:

- Higher efficiency levels (or ISEER) can be achieved by VFD
- Lesser peak load demand / jerk load due to soft start provided by VFD

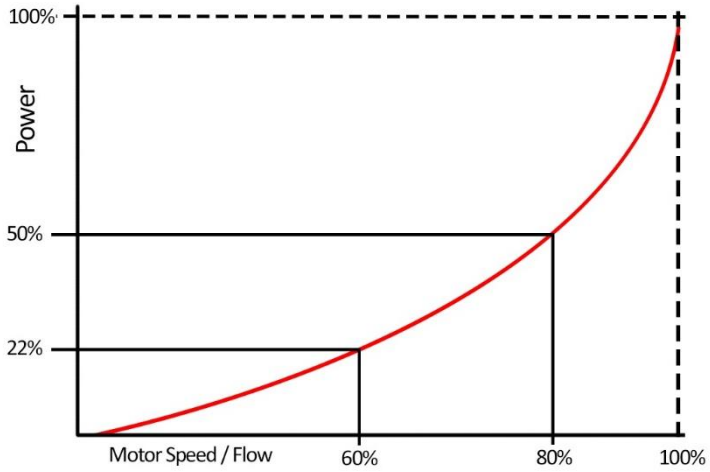


Figure 16: Power and speed relation as per cube law

To understand how higher ISEER levels can be achieved by VFD compressors, it is essential to understand the fan law. The fan law gives the relationship between the speed and power of a fan or a motor. The law states that power consumed by a motor is proportional to its speed cubed. So, if the speed of the motor is reduced by 20%, energy savings of the order of 50% (0.8x0.8x0.8) can be achieved. The speed or the RPM of the motor can be reduced with the help of a Variable Frequency Drive (VFD). The VFD modulates the frequency of electricity supply as per load conditions to reduce the motor RPM. This results in major savings by the virtue of fan law as compared to the fixed RAC.The inverter AC is not only much more energy efficient, but also smoother in operation than the fixed speed air conditioner.

The introduction of ISEER instead of EER and merging of efficiency ratings for fixed and variable speed RAC's has resulted in a market shift towards VFD technology.

1.2.9. Test standards for RAC in India

The energy conservation act of 2001 provides the basis for India's Standards and Labelling (S&L) program. Bureau of Indian Standards (BIS) is the National Standard Body of India, responsible for the standardization, marking and quality certification of various appliances. BIS established IS 1391 for RAC's containing two parts:

- IS 1391 (Part 1): 1992 Room Air Conditioners – Specifications: Part 1 Unitary Air Conditioners (Window)
- IS 1391 (Part 2): 1992 Room Air Conditioners – Specifications: Part 2 Split Air Conditioners

IS 1391 (Part 1 and Part 2) prescribes the constructional and performance requirements of RAC's. It also prescribes the test conditions and corresponding test procedures for determining various performance characteristics of RAC's which operate non-frosting when cooling and dehumidifying at standard rating conditions.

These can be summarized as depicted below in table 5 –

Table 5: Tests under IS 1391

Type tests	Production routine tests (Conducted after production of RAC at manufacturer works)	Acceptance tests (On request of purchaser, production routine tests can be repeated))
• Cooling Capacity test • Power factor test • Maximum operating test • Freeze up test • Enclosure sweat test • Power consumption test • Safety test • Condensate disposal test • Sound Test • Heating capacity test	• General running test • Pressure test or leakage test • Insulation resistance test • High voltage test • Leakage current test • Earthing resistance test	• Dry bulb temperature of return air • Dry bulb temperature of supply air • ISEER current consumption • Total power consumption • Voltage • Leakage test

Out of the above tests, cooling capacity test and power consumption test are key to determine the performance of RAC. They are further elaborated in the next section.

1.2.9.1. Performance tests

Cooling capacity, power consumption and ISEER are some of the major tests that pertain to the performance of RAC's. Cooling capacity is the total amount of sensible and latent heat that can be removed from the conditioned space in a definite time of interval. The test conditions for cooling capacity and power consumption test are given below in table 6:

Table 6: Cooling capacity and power consumption test condition

Test	Temperature	Room air temperature	Outside air temperature
Cooling capacity and power consumption test conditions	Dry Bulb temp	27℃	35℃
	Wet Bulb temp	19℃	24℃

IS 1391 part-2 also specifies the maximum power consumption values which an air-conditioner must not exceed, these values are given in table 7:

Table 7: Maximum power consumption

Rated cooling capacity (kcal/h)	Maximum power consumption (kW)
1500	1
2250	1.2
3000	1.55
3750	1.8

4500	2.2
6000	2.9
7500	3.4
9000	4.2

For calcualting the ISEER value, Cooling Seasonal Performance Factor (CSPF) is determined at various temperature points and bin hours as specified in table 4. CSPF or the ISEER is the ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period.

$$ISEER\ or\ F_{CSP} = {}^{L_{CST}}/_{C_{CSE}}$$

Where, L_{CST} = cooling seasonal total load (CSTL) and

C_{CSE} = cooling seasonal energy consumption (CSEC)

The CSPF calculation requires two sets of test data at -

- full- and half-capacity operation at 35°C
- full- and half-capacity operation at 29°C

Capacity $\emptyset_{ful}(t_j)$ of the equipment when it is operated at outdoor temperature t_j linearly changes depending on outdoor temperature. The capcity and power at 35℃ and 29℃ are measured in the testing facility or the lab.

$$\emptyset_{ful}(t_j) = \emptyset_{ful}(35) + \frac{\emptyset_{ful}(29) - \emptyset_{ful}(35)}{35-29} \times (35 - t_j)$$

Power Input $P_{ful}(t_j)$ of the equipment when it is operated at outdoor temperature t_j linearly changes depending on outdoor temperature

$$P_{ful}(t_j) = P_{ful}(35) + \frac{P_{ful}(29) - P_{ful}(35)}{35-29} \times (35 - t_j)$$

Once the capacity and power consumption test are done at 29°C and 35°C, L_{CST} and C_{CSE} at various points of can be determined from the equations given below.

L_{CST} is determined from the total sum of cooling load at each outdoor temperature t_j multiplied by bin hours

$$L_{CST} = \sum_{j=1}^{m} L_c(t_j) \times n_j + \sum_{j=m+1}^{n} \emptyset_{ful}(t_j) \times n_j$$

Where $L_c(t_j)$ is the defined cooling load at outdoor temperature t_j ,calculated from the bin temperature distribution table:

$$L_c(t_j) = \emptyset_{ful}(t_{100}) \times \frac{t_j - t_0}{t_{100} - t_0}$$

Where:

$\emptyset_{ful}(t_{100})$ is the cooling capacity at t_{100} at full load operating conditioners and

t_{100} is 35℃ and t_0= 23℃

Similarly, C_{CSE} is determined from the total sum of cooling energy consumption at each outdoor temperature t_j

and, $C_{CSE} = \sum_{j=1}^{n} X(t_j) \times P_{ful}(t_j) \times \frac{n_j}{F_{PL}(t_j)}$

Where:

$$X(t_j) = L_c(t_j) / \emptyset_{ful}(t_j)$$

$F_{PL}(t_j)$ - Part load factor

Since the physical measurements at 2 temperature points are interpolated/extrapolated to derive ISEER, this saves both time and cost. The testing requirements to determine ISEER are summarized in the table 8:

Table 8: ISEER Measurement testing conditions

Test	Characteristics	Fixed	Two Stage	Multistage	Variable	Default Value
Standard Cooling Capacity Indoor DB – 27 ℃ WB – 19 ℃ Outdoor DB – 35 ℃	Full Capacity φ (35 ℃)	Compulsory	Compulsory	Compulsory	Compulsory	
	Full Power input P (35 ℃)					
	Half Capacity φ (35 ℃)	-	-	Optional	Compulsory	φ half (29) / 1.077
	Half Power input P (35 ℃)					P half (29) / 0.914

Two methods are specified in the IS 1391 standard for performing cooling capacity and power consumption tests at different temperature conditions, they are as follows:

Room heat balance test method (Calorimeter Test) – A calorimeter can either be balanced ambient type or calibrated type. In the balanced ambient type, two walls separate the inside room chamber from the outside with air between the walls maintained at the same dry bulb temperature as the inside of room, to minimize losses. In calibrated a single wall separates the inside room chamber and outside room.

The calorimeter test method is based on is based on the law of conservation of thermodynamics (the first law of thermodynamics): that is Input Energy = Output Energy;

In calorimeter test, an energy balance is maintained in the inside of the room. The sum of energies given to the room is equal to the cooling capacity of the AC when the dry bulb and wet bulb have remained constant for sufficient time. This method has high accuracy and low risk of error.

Enthalpy difference method (Psychometric Test) – In air enthalpy method, the air enthalpy is measured at the inlet and outlet of the indoor air conditioner. The mass flow rate through the air conditioner is measured as well. The enthalpy difference multiplied with the mass flow gives the capacity of the air conditioner. This method requires less expensive laboratory and shorter time testing.

1.2.9.2. Tolerance limits on performance tests

The following tolerance limits are allowed in the performance testing -

- The measured standard cooling at full capacity shall not be less than 95 percent of the rated value.
- The measured standard cooling at 50% of full capacity shall be ±5% of full load capacity

- The measured power consumption for standard cooling at full capacity shall not be more than 5 percent of the rated value.
- The measured power consumption for standard cooling at 50% of full capacity shall not be more than 10 percent of the rated power consumption at 50% of full capacity.
- The measured energy consumption shall not be more than 5 percent of the rated value.
- For each unit tested, the ISEER shall not be less than 95 percent of the rated value.

1.2.9.3. Testing Infrastructure in India

As per our interactions with manufacturers, majority of them have their own test labs and are testing RAC's as per IS 1391 part 1 and part 2. These labs are NABL accredited. The manufacturers that import RAC's from China or overseas conduct the testing in the country of origin as per IS 1391.

There are third party labs such as Intertek, United laboratories (UL) etc. which have NABL accreditation for conducting performance testing of RAC's as per IS 1391.

As per our discussions with the testing labs, UL has testing facility in China and can test 250~ 270 samples in a year. It has 1 balanced ambient calorimeter up to 3 TR and 1 psychometric chamber to test samples up to 25 TR. Cooling capacity and power consumption test require approx. 8 hours to be completed in their facility. Intertek has its testing facility located in Delhi and can test 800 samples in a year. Intertek has 1 balanced ambient calorimeter and takes approx. 6 to 8 hours for fixed speed AC testing and 12 to 14 hours for inverter AC testing.

2. Key RAC market trends

2.1. RAC market in India

As mentioned in section 1.2.2, the room air conditioner sales have grown to 6.7 million units in 2018-19. The subsequent sections highlight the projected RAC sales trend by refrigerant and technology.

2.1.1. RAC sales projections

Due to the growth factors mentioned in section 2.3 such as per capita income, urbanisation, government subsidies, etc., sales are expected to increase rapidly in the upcoming years. Linear regression on the sales data from 2018-19 has been applied to determine sales projections for the period 2019 - 2027. The sales of room air conditioners are expected to increase around 3 times by 2027-28 from the current year.

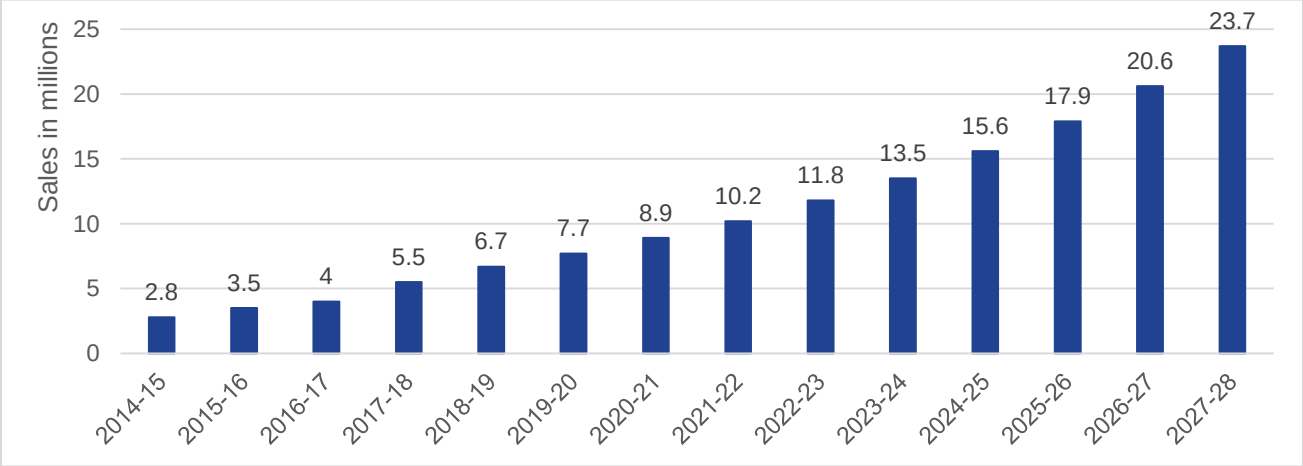


Figure 17: Projected Room AC sales

The air conditioner manufacturers have been adversely affected by the Covid-19 pandemic with sales coming to halt during the peak sale season of summer months. Due to this unprecedented pandemic, 20% decline in AC sales is anticipated in FY 20.

2.1.2. Refrigerant use in RAC

The figures 18 and 19 illustrate the refrigerant mix of the RAC stock in 2017 and 2027 [13]. The installed stock in 2017 was dominated by R-22 refrigerant with a share of 77%, followed by R-32 with 14% share and R-290 with than 1% share.

[13] "Demand Analysis for Cooling by Sector in India in 2027." 2018. Bureau of Energy Efficiency.

The market has also observed a traction for R-290 based RAC's due to its very low GWP. According to the industry experts, R-290 will constitute around 10% share of the total stock by 2027. This refrigerant shift is in line with the global trend and it is expected that it will be primarily driven by India's HCFC phase-out management plan and the HFC phase down under the Montreal protocol.

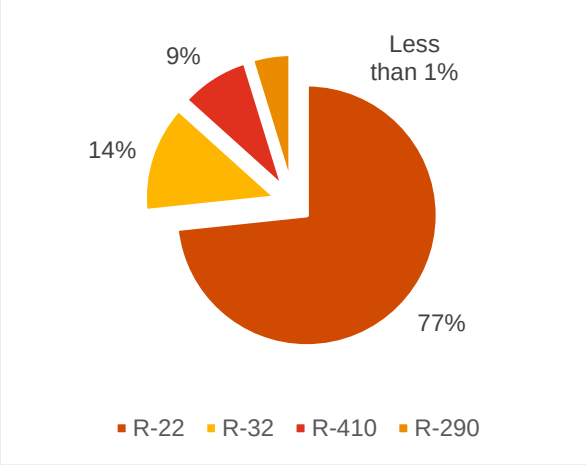


Figure 18 Installed Refrigerant stock in 2017

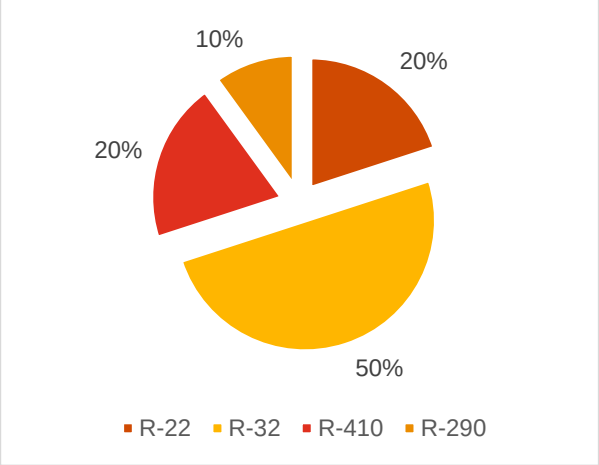


Figure 19: Expected installed refrigerant stock in 2027

2.2. RAC efficiency trends

As discussed in above section 1.2.8, BEE launched a voluntary star labelling plan for fixed speed RAC's in 2006 which became mandatory in 2009. Till 2015, Star rating was assigned based on EER values. However, 2015 onwards, star rating was assigned basis ISEER value (became mandatory in 2018) The tables below show the evolution of BEE's star rating plan for both window and split RAC.

Table 9:Window AC Star Rating Plan CY 09-11

From (12-01-2009- 31-12-2011)		
Star Level	EER (W/W)	
1 Star	2.3	2.49
2 Star	2.5	2.69
3 Star	2.7	2.89
4 Star	2.9	3.09
5 Star	3.1	

Table 10:Split AC Star Rating Plan CY 09-11

From (12-01-2009-31-12-2011)		
Star Level	EER (W/W)	
1 Star	2.3	2.49
2 Star	2.5	2.69
3 Star	2.7	2.89
4 Star	2.9	3.09
5 Star	3.1	

Table 11:Window AC Star Rating Plan CY 12-13

From (01-01-2012- 31-12- 2013)		
Star Level	EER (W/W)	
1 Star	2.3	2.49
2 Star	2.5	2.69
3 Star	2.7	2.89
4 Star	2.9	3.09
5 Star	3.1	

Table 12:Split AC Star Rating Plan CY 12-13

From (01-01-2012- 31-12-2013)		
Star Level	EER (W/W)	
1 Star	2.5	2.69
2 Star	2.7	2.89
3 Star	2.9	3.09
4 Star	3.1	3.29
5 Star	3.3	

Table 13:Window AC Star Rating Plan CY 14-17

From (01-01-2014- 31-12-2017)		
Star Level	EER (W/W)	
1 Star	2.5	2.69
2 Star	2.7	2.89
3 Star	2.9	3.09
4 Star	3.1	3.29
5 Star	3.3	

Table 14:Split AC Star Rating Plan CY 14-17

From (01-01-2014-31-12-2017)		
Star Level	EER (W/W)	
1 Star	2.7	2.89
2 Star	2.9	3.09
3 Star	3.1	3.29
4 Star	3.3	3.49
5 Star	3.5	

Table 15:Window AC Star Rating Plan CY 18-21*

From (01-01-2018- 31-12- 2021)		
Star Level	ISEER (kWh/kWh)	
1 Star	2.5	2.69
2 Star	2.7	2.89
3 Star	2.9	3.09
4 Star	3.1	3.29
5 Star	3.3	

Table 16:Split AC Star Rating Plan CY 18-21*

From (01-01-2018- 31-12-2021)		
Star Level	ISEER (kWh/kWh)	
1 Star	3.1	3.29
2 Star	3.3	3.49
3 Star	3.5	3.99
4 Star	4	4.49
5 Star	4.5	

Table 17:Window AC Star Rating Plan CY 22-24*

From (01-01-2022- 31-12-2024)		
Star Level	ISEER (kWh/kWh)	
1 Star	2.7	2.89
2 Star	2.9	3.09
3 Star	3.1	3.29
4 Star	3.3	3.49
5 Star	3.5	

Table 18:Split AC Star Rating Plan CY 22-24*

From (01-01-2022-31-12-2024)		
Star Level	ISEER (kWh/kWh)	
1 Star	3.3	3.49
2 Star	3.5	3.79
3 Star	3.8	4.39
4 Star	4.4	4.99
5 Star	5	

*As per BEE Amendment dated 27th November 2020

Currently, in India, there are air conditioners with efficiency approximately 30 to 35% above the most stringent threshold. These AC's are pre-dominantly available in 1-ton category and summarized in table 19

Table 19: Best in class RAC in India

S.no	Manufacturer	Capacity	Refrigerant	ISEER	Efficiency above 5-star threshold
1	Godrej	1 Ton	R-290	6.15	36.6%
2	Godrej	1 Ton	R-290	5.8	28.8%
3	Daikin	1 ton	R-32	5.8	28.8%
4	Toshiba	1.5 Ton	R-32	5.6	24.4%
5	EESL Super efficient AC	1.5 Ton	R-32	5.4	20%

2.2.1. Factors effecting RAC efficiency

Manufacturers are incorporating advanced technologies to improve efficiency of RAC's and comply with the constantly evolving BEE thresholds. Below are a few technological changes that have improved the ISEER values in RAC's and helped in transition to energy-efficient system.[14]

Table 20: Technological changes to increase the ISEER in HVAC systems

Technology	Description	Efficiency Gains
Advanced Heat exchangers	Microchannel heat exchangers are an advancement on the traditional finned tube coil type heat exchangers providing superior heat exchange. Micro channel heat exchangers not only improve system efficiency but also reduce refrigerant charge**.**	9.1% to 28.6%
Advanced Compressors	Air conditioner efficiency has substantially increased as manufacturers have leapfrogged from reciprocating compressors to rotary compressors. The latest Dual inverter compressors lower electricity consumption by up to 70% and cool up to 40% faster than a non-inverter RAC[15].	6.5 to 18.7%
Electronic expansion valves	The thermostatic expansion valve is the automatic valve regulates the refrigerant flow in the evaporator as per the load. Newer electronic expansion valves (EEV) provide increased modulation capabilities to match more closely the needs of variable-capacity A/C systems.	5 to 8%
High efficiency motors	Electrically commutated motors (ECM) have higher efficiencies than permanent split capacitor (PSC) motors for A/C. Fan energy consumption has continued to decrease as manufacturers have incorporated aerodynamic component design.	20 to 24.8 %

Some of the other technologies which are globally being used in the super-efficient AC's are given below. These might not have a direct effect on the efficiency gain but improve the product quality and life.

- **Dual Barrier:** The coating material greatly reduces the attachment of dust which is mixed in the conditioned air. This enables the AC to work at full performance. The reduction in the dirt also means the bad smell and odours go down. With less dirt, the necessity of cleaning the air conditioner also reduces.
- **Power Plasma:** Plasma Quad Plus Filter works like an electrical curtain, using an electrical discharge to catch and neutralise even microscopically small particles in the air. It can even capture PM2.5 particles;
- **Low GWP refrigerants –**The world is now looking for the refrigerants which do not contribute to the ozone layer depletion and global warming. Natural refrigerants have no or very low Global Warming Potential (GWP). With the advanced technologies, the most sustainable and low global warming

[14] Shah, Nihar, and Amol Phadke. "Cooling the Planet: Opportunities for Deployment of Superefficient Room Air Conditioners." 2013.
[15] 2019, https://www.lg.com/ae/press-release/lgs-groundbreaking-dualcool-with-inverter-tech-delivers-performance-and-energy-efficiency.

potential gases available to us right now are R290 with GWP of 3.3, R1270 with GWP of 1.8, R744 with GWP of 1, R717 with GWP of 0.

2.3. IoT based applications in RAC's

The Internet of Things (IoT) provides opportunities to control interconnected smart devices via pre-designed scenarios with little or no human involvement. Due to the need for systematic improvement of energy efficiency, the relevance of IoT-based Energy Management Systems (EMS) is constantly increasing. IoT enhanced EMS are created to support the digital transformation for its users across all the sectors (residential, commercial or industrial sector). IOT increases -

- the transparency of energy consumption statistics,
- enhance the personnel awareness of energy losses,
- provide predictive analytics tools for forecasting potential industrial accidents
- future energy demand.

The best way to cut down the operating costs is to consume less energy. IoT systems enables its users to manage their energy demands smartly by aiding them with the above-mentioned functionalities.

Initially EMS was applicable for large AC systems in commercial buildings such as in Chiller and VRF applications. But due to rapid technological advancements it was an inevitable transition towards smart RAC's, Smart RAC offers convenience, easy accessibility, improved energy efficiency and increased ease of control which makes the customer inclined towards purchasing Smart AC's over traditional AC's.

The intelligent RAC control systems utilize the IoT sensors to:

- remotely monitor and control RAC systems from any mobile device.
- IoT assisted EMS platforms can collect weather data and then use both historical and daily energy usage data to predict energy consumption data.
- In smart homes, homeowners can also decide which part of the house can be powered by solar, home battery or electricity enabling them to take smart decisions for managing their energy needs.

Manufacturers are inclined to produce Smart AC's to keep up with the shift in demand in the following way:

- Voltas's 'All Weather Smart ACs' can be operated by a phone using Wifi/GPRS. The air conditioner senses outside temperature and adapts to the weather and keeps a tab on power usage and consumption.

- Hitachi's inverter come with wifi technology to control AC's from anywhere. These Smart ACs offer iClean Plus technology, which automatically cleans the dust in the air filter; iSense technology regulates the temperature as per the person's active body movements; and iSee technology detects faces of people and directs air flow towards them.

- Videocon's 'Aryabot' range of ACs can identify a user's GPS location, switch off the AC when one leaves the house and switch it on before one enters the premises. One can also keep a tab of power consumption through its budgeting feature and can set limits on electricity consumption.

- Llyod has Wifi enabled AC's which enables the user to control the air conditioner through a smartphone.

As per the manufacturers, **upto 35% of the energy consumed by RAC can be saved with the IoT assistance.** IOT applications and smart functions in RAC's are not the key criteria for the consumers in India while making the purchase decision. Although these features give an extra edge to the RAC when compared to another RAC at similar price point.

3. Overview of global SEAC market

3.1. Global RAC landscape

The global RAC demand was estimated to be 96.07 million[16] in 2018-19. Apart from India, the major global RAC markets are China, Europe, Japan, Korea and United States amounting to approximately 70% of the global RAC demand in 2018-19. The RAC demand in Middle East, Africa, and Latin America in 2018 - 19 was estimated to be 12.5 million.

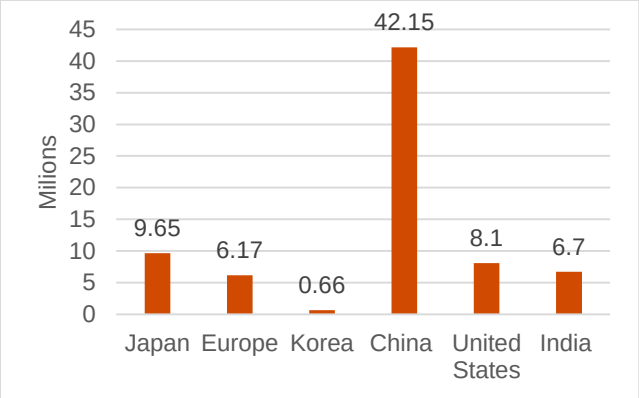


Figure 20: Global RAC Demand in 2018-19

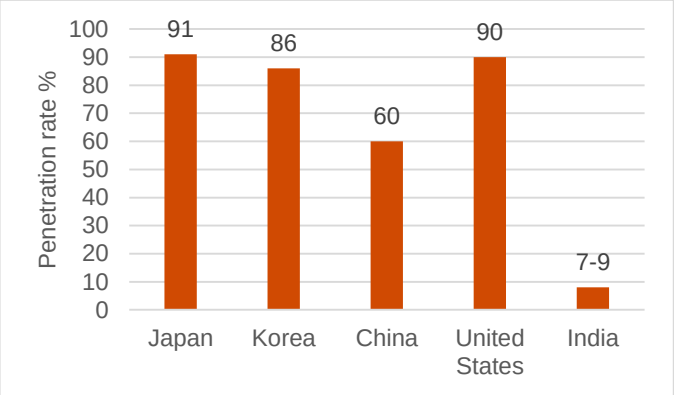


Figure 21: AC Penetration rate in 2018-19

China's RAC demand is 43% of the total global RAC demand, followed by Japan. The demand in Asia (excluding China and Japan) was about 16 million units in 2018.

The AC penetration rates in developed economies such as Japan, Korea and United States are all above 85% whereas India has about only 7 to 9%[17].This shows huge market potential in India in the coming years as market penetration rate is expected to increase to 12.4% in 2026[18].

[16] "World Air Conditioner Demand By Region". Jraia. https://www.jraia.or.jp/english/World_AC_Demand.pdf."
[17] "The future of Cooling", May 2018, IEA
[18] "Penetration rate of the air conditioner market in India from 2005 to 2026". 2019, Statistica

3.1.1. Technology trends

The figure 22 shows the split type RAC demand basis technology type across Japan, China, Europe and North America[19].

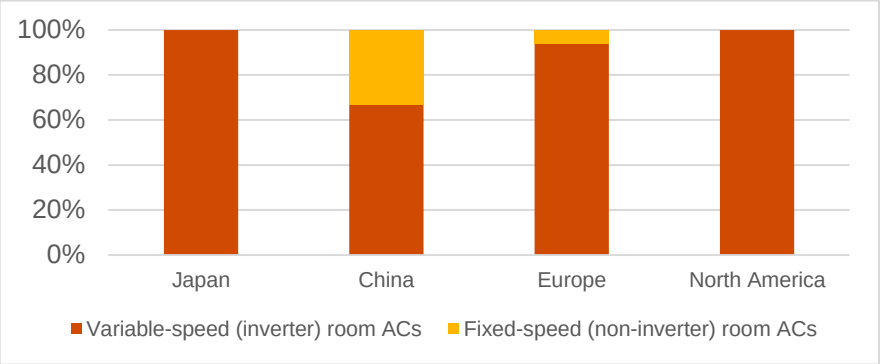


Figure 22: Country wise Fixed speed and Variable speed split type RACs 2017-18

- The market share of inverter RAC's in China and Europe has increased from 7% and 65% in FY 07 to 67% and 94% in FY 17 respectively[20].
- The estimated share of variable-speed RACs in South Korea increased from less than 10% in FY 08 to about 90% in FY15[21].
- Japan and North America have completely transitioned to inverter technology.

3.1.2. Refrigerant trends

HCFC's such as R-22 had always been a dominant and popular choice of refrigerant in the RAC segment. But due to its high ozone depleting potential (ODP), governments around the world are phasing out HCFC's under the Montreal protocol on substances that Deplete the Ozone Layer. HFC's such as R-410a and R-32 are becoming a popular choice of refrigerants in RAC segment and fast replacing the dominant HCFC-22. R-32, an HFC with a GWP of 675 that is positioned to replace R-410A (GWP of 2,088). However, the GWP of R-32 is still on the higher side and with the recent Kigali amendment to the Montreal protocol, HFC's have also come under the category of controlled substances. Therefore, HC's such as R-290 with a GWP of 3 are emerging as a next possible option to HFC's.

Figure 23 and Table 21 highlight the global refrigerant trends in RAC

- Japan, Europe and North America have completely transitioned from HCFC refrigerant to HFC refrigerants in split type RAC'S
- China still has 16% HCFC based split type RAC'22 demand in 2017.

[19] "World Air conditioner demand-Inverter and refrigerant ratio".Jraia https://www.jraia.or.jp/english/statistics/index.html
[20] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017
[21] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017
[22] "World Air conditioner demand-Inverter and refrigerant ratio".Jraia https://www.jraia.or.jp/english/statistics/index.html.

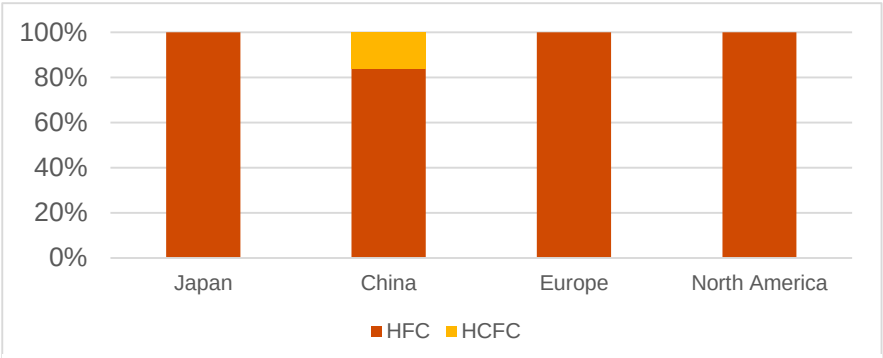


Figure 23: Country wise HFC and HCFC mix for split type RAC FY 17

Table 21: Refrigerant trends in RAC

China:	**Europe:**	**North America:**
• R-410A accounted for approx. 55% share in split RACs (2018) in china[23]. • R-32 has 35% share in 2018**.** • Chinese RAC manufacturers **converted several air conditioner production lines from R-22 to R-290 under Stage I of China's HCFC phaseout management plan**, with a potential to produce 450000 units/ year [24] • Three RAC compressor production lines have also been converted to R290 with a production capacity of 5,400,000 units per year. • Midea R290 based product has obtained over **200 domestic and international patents.** • China is in the process of converting another 20 room AC production lines and another four room AC compressor production lines **to R290 as a**	• R-410A accounted for approx. 63% share in split RACs (2018) in Europe[25]. • R-32 accounted for approx. 20% in 2018. • Europe market is moving towards R290 in portable AC but transition to split AC has not happened yet in Europe. • Effective January 2025, the European Commission will ban refrigerants with GWP greater **than 750 for residential AC**	• Import and production for air-conditioners was banned in North America using HCFC refrigerants in 2010.The sales for HCFC based AC's was banned in 2015. • R-410A accounted for approx. 95% share in split RACs (2018) in North America[26] **Japan:** • To accelerate the adoption of R-32, Daikin offered free access to its patents for R-32 based AC's • Almost 100% RAC products in Japan use R-32 refrigerant **Korea** • R-410 is the dominant refrigerant in Korea.

[23] "BSRIA'S View On Refrigerant Trends In AC And Heat Pump Segments". *Bsria.Com*, 2020, https://www.bsria.com/uk/news/article/bsrias_view_on_refrigerant_trends_in_ac_and_heat_pump_segments/.
[24] "8 major Chinese RAC makers commit to selling 220k R-290 units in 2019" December 2018. hydrocarbons21.com
[25] "BSRIA'S View On Refrigerant Trends In AC And Heat Pump Segments". *Bsria.Com*, 2020, https://www.bsria.com/uk/news/article/bsrias_view_on_refrigerant_trends_in_ac_and_heat_pump_segments/.
[26] I"BSRIA'S View On Refrigerant Trends In AC And Heat Pump Segments". *Bsria.Com*, 2020, https://www.bsria.com/uk/news/article/bsrias_view_on_refrigerant_trends_in_ac_and_heat_pump_segments/.

part of the second stage of China's HPMP until end of 2020.		• The use **of flammable refrigerants in RACs is restricted in Korea**, but transition to mildly flammable R-32 possible in future

Some key observations about global refrigerant trends are -

- R-410a is still the dominant refrigerant for RAC segment in major economies of the world
- The next popular choice after R-410a is R-32
- China which is the major manufacturing hub for RACs' is scaling up the production of R-290 based RAC's

3.1.3. Efficiency trends

Manufacturers are continuously developing innovative technologies to improve the efficiency in the baseline as well as premium products. The energy efficiency of ACs currently in use and for sale around the world has been rising in recent years because of incremental improvements in air-conditioning technology. From 1990 to 2013, U.S. shipment-weighted efficiency for residential split-system ACs increased by 56%[27].

The technological developments which have led to the improvement of efficiency in RACs are advanced compressors, head exchangers, etc. These are explained in detail in section 3.3.

Inverter ACs already dominate global markets in developed nations and continue to increase their market share in developing nations. Along with this trend, SEER which is a better metric for quantifying RAC efficiency (since it captures performance in multiple temperature conditions) has been adopted in many countries. This has boosted the penetration of inverter-based technologies and ratcheting up of efficiency levels.

Table 22 highlights the energy efficiency trends in major economies for RACs'.

Table 22: Efficiency trends in RAC

China	Europe and United States	Japan and Korea
• The Chinese AC efficiency metrics for variable-speed ACs is SEER for cooling-only products and annual performance factor (APF) for reversible-type products (i.e., heat pumps). • The market share (of sales) of variable-speed inverter RACs increased from 7% in 2007 to over 65% in 2017[28]. • For cooling only products, SEER 5.4 and above are labelled grade 1 (most efficient products) and SEER 3.5 represents for grade 3 (least efficient).	• The European efficiency metric for AC's is SEER for cooling only products and seasonal coefficient of performance (SCOP) for heating products. • The market demand for variable speed AC's in Europe is 94%. • Products with SEER 8.5 and above fall under the A+++ category (most efficient) and products with SEER 2.6 and lower fall in the G category (least efficient products) in Europe • In Europe, manufacturers have products of SEER 10.5.	• Due to policy regulations such as top runner program in Japan and energy frontier runner in Korea, room AC efficiency have improved by nearly 100%[29]. • Japanese metric for AC efficiency is Annual performance factor (APF). The top runner standard for cooling capacity between 5 and 6.3 kW is of APF 4.9. Manufacturers have products available in the range of APF 6.8. • For cooling capacities between 4 and 10 kW, CSPF (measure of efficiency such as SEER/ISEER)

[27] Th Goetzler, w. et al. "The Future Of Air Conditioning On For Buildings",2016,
[28] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017
[29] Abhyankar, Nikit et al. "Accelerating Energy Efficiency Improvements In India: Potential, Cost Benefits, Policies". *Ies.Lbl.Gov*, 2017, https://ies.lbl.gov/sites/default/files/lbnl-1005798.pdf.

• China APF of 4.5 and above is considered grade 1(most efficient), APF 3.1 is grade 3 (least efficient) • Manufacturers are selling AC's with APF 5.45.	• IN US SEER is followed for cooling only products and HSPF (Heating Seasonal Performance Factor) is followed for heat pumps. Split AC's with SEER 11.7 is currently available in US market.	greater than 7.2 is the most stringent label. • Manufacturers are selling AC's with CSPF 8 in Korea.

3.2. Applicable international standards

Test standards for any equipment provide an insight on the prevalent efficiency levels (and other market indicators) in the respective country. As discussed in earlier chapters, India follows BEE's star labelling program to regulate the efficiency levels in a RAC. Likewise, various countries have their own labelling programs to regulate the RAC market in their respective countries.

The table below gives a snapshot of RAC standards in Asian countries that have a dominant air conditioning market. The main reason for choosing these countries is that most of the technology/ products are sourced from these countries globally.

Table 23: Standards adopted for RAC labelling by various countries[30]

Country	Standard	Efficiency Matrix	Temp. Range	No. of bins	Operation hrs.	Label
China	• GB 12021.3 for fixed speed AC's • GB 21455 for variable speed AC's	• Seasonal energy efficiency (SEER) ratio is used for cooling only products • Annual performance factor (APF) is used for reversible products	24-38℃	15	1,136	**China energy label** is divided in 3 grades- Grade 1, Grade 2, Grade 3. Grade 1 is the most efficient category
South Korea	KSC 9306	• Cooling seasonal performance factor (CSPF) is used for cooling only products • Average of Cooling seasonal performance factor (CSPF) and Heating seasonal performance	24-38℃	15	941	**Energy Efficiency rating** is a comparative label and has a dial style label with 5 to 1 grade (1 grade being the most efficient) **Energy frontier label** is an endorsement label given to products in addition to the comparative label that achieve efficiency targets 30-50% higher than the current grade 1 level. Products satisfying energy

[30] Shah, Nihar, et al. "Adopting a Seasonal Efficiency Matrix for Room Air Conditioners – A Case Study in Brazil." 2019, http://kigali.org.br/wp-content/uploads/2019/09/Case-Study-in-Brazil_03.pdf.

		factor (HSPF) is used for reversible type products				frontier standard are deemed to be **ultra-highly efficient products.**
Japan	JISC 9612	• Annual performance factor is used to calculate efficiency which is based on both CSPF and HSPF	24-38℃	15	1,569	**Uniform energy saving label** with energy efficiency rating 1 to 5 stars (5 being the most energy efficient) The comparative label indicates the compliance level with the **top runner target** Yellow/Orange to show the appliance has failed to meet the top runner target efficiency level and green for those above efficiency target level
Europe	EN 14511:2013	• Seasonal energy efficiency ratio (SEER) for cooling only product. • Seasonal Coefficient of Performance (SCOP) for heating / cooling products	17-40℃	24	2602	**EU energy efficiency class:** A+++, A++, A+, A, B, C, D, E, F, G based on SEER and SCOP value (A+++ is the most efficient). **The Eco-design Directive** (for ACs with ≤ 12 kW CC) requires different levels of efficiency by refrigerant GWP and capacity
India	IS 1391 part 1 and part 2	• ISEER is used to calculate efficiency levels.	24-43℃	20	1600	**Energy star rating-** 1 star to 5 stars (5-star being most energy efficient)

- The bin hours and bin temperatures used in calculation for SEER (in China, Japan and Korea) are as per their local climatic conditions. These cannot be used for direct correlation with ISEER rating in India.

3.2.1. Efficiency thresholds and most efficient RAC examples in China, South Korea, Japan and Europe

Unlike India, the labelling thresholds in China, Japan and South Korea vary as per the cooling capacities. The tables below give the threshold values of RAC labelling programs along with examples of most efficient RAC's in China, Japan, Korea and Europe.

Table 24: Efficiency Threshold values in China[31]

Type	Cooling capacity in Kw	Grade 1	Grade 2	Grade 3
Fixed Speed (EER)	CC < 4.5	3.6	3.4	3.2
	4.5 < CC < 7.1	3.5	3.3	3.1
	7.1 < CC < 14.0	3.4	3.2	3
Variable speed AC's Cooling only (SEER)	CC < 4.5	5.4	5	4.3
	4.5 < CC < 7.1	5.1	4.4	3.9
	7.1 < CC < 14.0	4.7	4	3.5
Split, Reversible (APF)	CC < 4.5	4.5	4	3.5
	4.5 < CC < 7.1	4	3.5	3.3
	7.1 < CC < 14.0	3.7	3.3	3.1

Table 25: Example of efficient RAC model in China

Country	Make	Cooling Capacity	Refrigerant	Heating and cooling	Efficiency rating
China	Midea	1 Tr	R-32	Yes	APF 5.05
	Midea	1.5 Tr	R-32	Yes	APF 4.51
	Daikin	2 Tr	R-410	Yes	APF 4.43
	Fijutsu General	1 Tr	R-32	Yes	SEER 5.75

The efficiency levels of the super-efficient RAC's are 6 to 12% above grade 1.

Table 26: South Korea's energy efficiency standards and labels for split AC[32]

Cooling Capacity in kW	Energy Frontier	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
CC < 4	6.54<R	5<R	4.59<R<5	4.19<R<4.59	3.78<R<4.19	3.37<R<3.78
4 < CC < 10	9.36<R	7.2<R	6.14<R<7.2	4.4<R<6.14	3.5<R<4.4	2.97<R<3.5
10<CC<17.5	7.54<R	5.8<R	5.04<R<5.8	4.28<R<5.04	3.52<R<4.28	2.76<R<3.52
R is equivalent to CSPF for cooling only products						

Table 27:Example of efficient RAC model in Korea

Country	Make	Cooling Capacity	Refrigerant	Heating and cooling	Efficiency rating
Korea	Samsung	0.75 Tr	R-410	No	CSPF 7.1

[31] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017

[32] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017

	LG	1 Tr	R-410	No	CSPF 7.8
	LG	1.5 Tr	R-410	No	CSPF 8.0

The Efficiency levels of the super efficient RAC's are 42% and 8% and 11% above Grade 1

Table 28: Japan's Top runner program standard in APF for RAC's[33]

Cooling capacity in Kw	APF Value
	Non-Ducted/ Wall mounted
CC < 3.2	5.8 / 6.6[a]
3.2 < CC < 4.0	4.9 / 6.0[a]
4.0 < CC < 5.0	5.4
5.0 < CC < 6.3	4.9
6.3 < CC < 7.1	4.4

Table 29:Example of efficient RAC model in Japan

Country	Make	Cooling Capacity	Refrigerant	Heating and cooling	Efficiency rating
Japan	Mitsubishi	1.5 Tr	R-32	Yes	APF 6.8
	Mitsubishi	2 Tr	R-32	Yes	APF 6.3

The Efficiency levels of the super-efficient RAC's are 38% and 43% above Top runner targets for all cooling capacities

Table 30: EU's energy efficiency classes

Labels	SEER (cooling)
A+++	≥ 8.50
A++	6.10 ≤ SEER < 8.50
A+	5.60 ≤ SEER < 6.10
A	5.10 ≤ SEER < 5.60
B	4.60 ≤ SEER < 5.10
C	4.10 ≤ SEER < 4.60
D	3.60 ≤ SEER < 4.10
E	3.10 ≤ SEER < 3.60
F	2.60 ≤ SEER < 3.10
G	SEER < 2.60

Table 31: Eco Design requirements for RAC's in EU

Eco-design	SEER
GWP > 150 for < 6 kW	4.60
GWP < 150 for < 6 kW	4.14
GWP > 150 for < 6-12 kW	4.30
GWP < 150 for < 6-12 kW	3.87

[33] Park, Won et al. "Assessment Of Commercially Available Energy Efficient Room Air Conditioners Including Model With Low Global Warming Potential" 2017

Table 32:Example of efficient RAC model in Europe

Country	Make	Cooling Capacity	Refrigerant	Heating and cooling	Efficiency rating
Europe	Panasonic	0.75 Tr	R-32	Yes	EU SEER 10.5
	Daikin	1.5 Tr	R-32	Yes	EU SEER 8.6
	Mitsubishi	2 Tr	R-410	Yes	EU SEER 6.8

Manufacturers have products of SEER 10.5 (0.75 TR) which is 23% more efficient than the most stringent label. Most efficient 1.5 ton model has SEER 8.6.

Key observations:

- China, Japan and Korea have different labelling thresholds for different cooling capacities
- Highest efficiency thresholds are observed in less than 5 kW category
- Most widely used refrigerants in super-efficient models are R-32 and R-410.
- All the efficient RAC models are inverter driven and come with advanced features such as WIFI control and occupancy sensors.
- Most of these AC's are also equipped with filters that sieve minute particles and performs self-cleaning.
- For reversible products, APF which considers cooling as well as heating performance of the product is used for classifying the efficiency of air-conditioners
- Japan and Korea have separate labels apart from the mandatory comparative labels which endorse best in class products. This serves as an incentive for the manufacturers to achieve higher efficiency levels (or other sustainable features as low GWP) than specified in the labelling program.
- EU has an Eco design endorsement label which gives weightage to GWP values in assigning SEER targets.

4. Review of National and International policies and programs

4.1. National policies/ programs for promoting energy efficient in RAC

4.1.1. India Cooling Action Plan (ICAP)

India is one of the few countries in the world to develop a comprehensive Cooling Action Plan which has a long-term vision to address the cooling requirement across sectors. ICAP's overall goal is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society.

Priority areas under ICAP are –

Space Cooling in:

- residential and commercial buildings,
- Cold Chain, refrigeration,
- transport air conditioning and refrigeration and
- air conditioning servicing sector.

ICAP provides a 20-year outlook on how cooling demand in India will evolve and highlights strategies to promote sustainable and smart cooling practices across the nation to mitigate its adverse impacts. ICAP has charted out long term, medium term and short-term goals for the cooling sector to accomplish the following goals

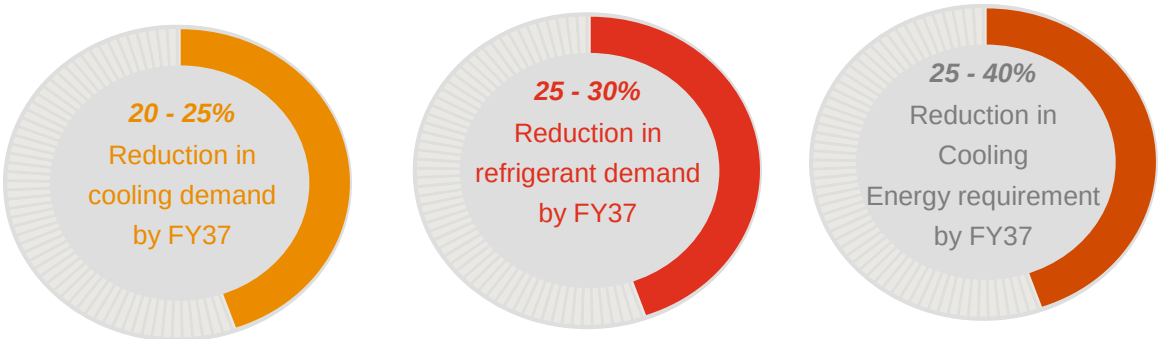


Figure 24: ICAP – Goals for space cooling

4.1.2. BEE's Standard and Labelling program

BEE recognized the impact of increased penetration of air-conditioners and the burden these appliances put on the country's energy resources and therefore, initiated the S&L program for air conditioners. The S&L program in India was launched as a voluntary comparative labelling scheme in 2006-07, which transitioned to a mandatory labelling programme in 2009. The air conditioner labelling program assigned comparative labels ranging from one to five with (1-Star being the minimum efficiency level) to air conditioners as per their efficiency. The evolution of star labelling program for AC's have already been discussed in the section 2.2 of this report.

4.1.3. Energy Conservation Building Code (ECBC)

Considering the vast potential of energy savings and benefits of energy efficiency, the Government of India enacted the Energy Conservation Act, 2001. Five major provisions of Energy Conservation Act relate to

- Designated Consumers;
- Standard and Labelling of Appliances;
- Energy Conservation Building Codes;
- Creation of Institutional Set up (BEE) and
- Establishment of Energy Conservation Fund.

The Energy Conservation Act became effective from March 1, 2002. Energy efficiency institutional practices and programs in India are now mainly being guided through various voluntary and mandatory provisions of the act.

The Energy Conservation Building Code (ECBC), was launched by Ministry of Power, Government of India in May 2007, as a first step towards promoting energy efficiency in the building sector. Initially the compliance of the ECBC was implemented on a voluntary basis. However, BEE has now initiated the task of mandatory implementation of ECBC across the country. Under the 12th five-year Plan, BEE has set up an ambitious goal of 75 per cent ECBC compliant of new commercial buildings

The following are minimum requirements for room air conditioners in ECBC buildings[34]

Table 33: Minimum requirements for RAC in ECBC Buildings

Category	Cooling capacity	Requirement
ECBC	<10.5 kW	BEE 3 star rated
	>10.5 kW	2.8 EER
ECBC Plus	<10.5 kW	BEE 4 star rated
	>10.5 kW	3.2 EER
Super ECBC	<10.5 kW	BEE 5 star rated
	>10.5 kW	3.4 EER

4.1.4. EESL Super-Efficient Air-conditioner Programme

Following the vision of promoting energy efficiency in appliances through innovative business models, Energy Efficiency Service Limited (EESL) has developed an online platform to sell super-efficient and climate friendly air-conditioners at an affordable price for masses. Later the program was almost extended to offline modes as well to facilitate institutional and commercial consumers. EESL invited bids for supplying 50,000 super-efficient and climate friendly five-star 1.5 TR split air conditioners through competitive bidding with the following specifications -

[34] "Energy Conservation Code 2017." 2017, https://beeindia.gov.in/sites/default/files/BEE_ECBC 2017.pdf.

- **5.4 ISEER rated** inverter air conditioners of 1.5 TR capacity. The efficiency level of this AC is –
    - 20% more than the highest star label i.e. 5-star AC's prevalent in India
    - 35% more than the 3-star rated Ac's, which comprised of 65% market share last year

- **Global Warming Potential (GWP) 675** (which is almost 1/3rd the value of refrigerants prevalent in Indian market). The most prevalent refrigerants in the room air conditioner market are R-410a and R-22, which have 2088 and 1810 GWP respectively.

- **Zero Ozone Depletion Potential (ODP),** the project promotes zero ODP based refrigerant. Currently, R22 the dominant refrigerant in the AC market has an ODP of 0.055, which is detrimental for the invaluable Ozone layer.

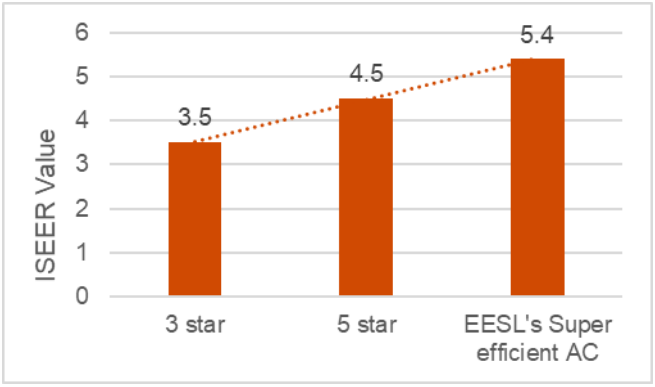


Figure 25: ISEER value comparison in RAC

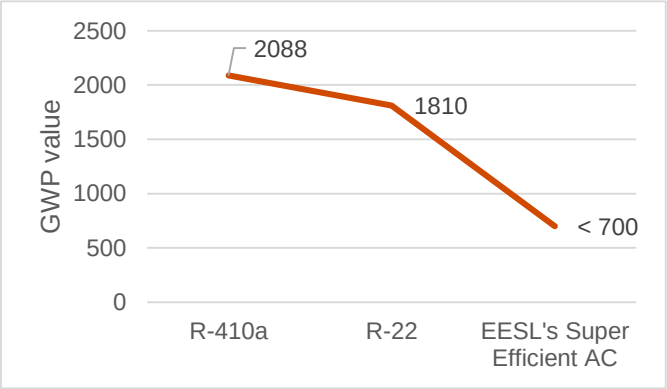


Figure 26: GWP value comparison in RAC

M/s Voltas ltd. was selected as the L1 bidder for supplying these AC's. These AC's are sold through online portal (EESLmart.in) and offline (through Voltas Dealer network) with attractive EMI schemes.

In terms of prices, these AC's are comparable or cheaper than the 5-star AC's available in the market. When compared to the same efficiency levels, these are priced **20-30% less than the market prices** (refer to section 7.2 for detailed payback / analysis).

4.1.5. AC Replacement Scheme by DISCOMS under the DSM program

Demand side management (DSM) aims at the modification of consumer demand for energy through various methods such as financial incentives in adopting energy efficient appliances and behavioural change through awareness. DSM and energy efficiency measures help reduce the end demand, eliminating the need for capacity addition and therefore mitigate carbon emission.

The use of inefficient air conditioners results in high peak demand putting a lot of stress on the Grids. To manage this peak demand load, energy distribution companies (DISCOM) in partnership with air conditioner manufacturers launch 'AC Replacement Schemes' every year. The intent of the schemes is to replace the old inefficient AC's with 5 star rated AC's. Under this programme, upfront rebate is extended to the consumers under the DSM programme. The details of such schemes are as follows:

BSES Yamuna Power Limited

- BSES Yamuna has been running the AC replacement scheme for their consumers for the last 2 – 3 years. Through the scheme, consumers can exchange old, inefficient air-conditioners (upto 3 star in working condition) with BEE 5 star AC's at a discount of up to 64 per cent on MRP.
- BYPL has tied up with Daikin, Hitachi, Voltas, Godrej and LG for the year 2020.
- All the units offered under this scheme conform to BEE 5 star efficiency levels and are available in 1/1.5/2 ton capacity.
- Most of the OEMs are offering R-32 based units under the programme. However, some models also used R-410a and R-22.

BSES Rajdhani Power Limited

- BSES Rajdhani has also been running the AC replacement scheme for their consumers from last 2-3 years. BRPL has also launched limited period AC replacement scheme wherein any BRPL domestic customers can exchangetheir old working ACs with the new energy efficient 5-star rated ACs at a substantial discount of upto 60 on MRP% .
- BRPL has tied up with LG, Godrej, Daikin, Llyod and Voltas for the year 2020
- All the units offered under this scheme conform to BEE 5 star efficiency levels and are 1.5TR in capacity.
- LG, Daikin,Godrej and Llyod are offering R-32 based RAC's, while Voltas has some models with R-410a as well.

TATA Power – DDL Air-conditioner Replacement Scheme

- Tata Power Delhi Distribution Ltd (TPDDL) has been runnung the AC replacement scheme for thier consumers for last 2-3 years. Under this scehme, any TATA power -DDL customers can buy new 1.5 ton BEE 5-star rated AC's at discounts of upto 50% on MRP.
- Consumers can avail additional discount of INR 2500 on replacement of old AC.
- For the year 2020, they have tied up with Voltas and Bluestar.

4.2. International policies/ programs for promoting energy efficient in RAC

4.2.1. HCFC Phase out management plan under Montreal Protocol

On 16 September 1987, the Montreal Protocol (MP) on Substances that Deplete the Ozone Layer was agreed by the international community. The protocol entered into force on 1 January 1989. Since then, this international agreement was signed by 198 developed and developing countries, which are committed to phase-out the consumption and production of Ozone Depleting Substances (ODSs), including inter alia Chlorofluorocarbons (CFCs), halons, Hydrobromofluorocarbons (HBFCs), Hydrochlorofluorocarbons (HCFCs).

The Montreal Protocol provides an step wise timetable to reduce the consumption and production of ODS for both developed (non-Article 5) and developing (Article 5 (A5)) countries. Under this treaty, all parties have specific responsibilities related to the phase out of the different groups of ODS, control of ODS trade, annual reporting of data, national licensing systems to control ODS imports and exports, and other matters. Developing and developed countries have equal but differentiated responsibilities, but most importantly, both groups of

countries have binding, time-targeted and measurable commitments. CFCs and HCFCs have been categorised as controlled substances under this treaty and a phase out plan has been developed as shown below:

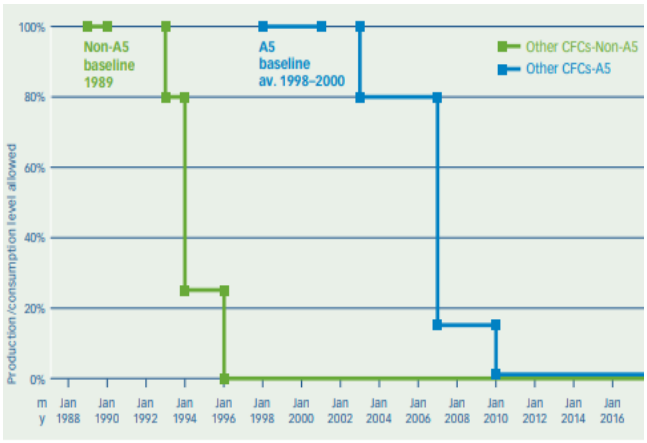


Figure 27: CFC phase out Schedule

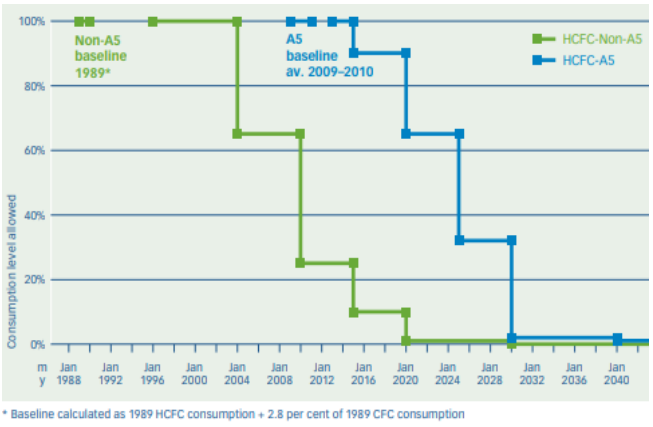


Figure 28: HCFC consumption phase out Schedule

Post this agreement, Montreal Protocol has undergone several amendments as shown in the figure below:

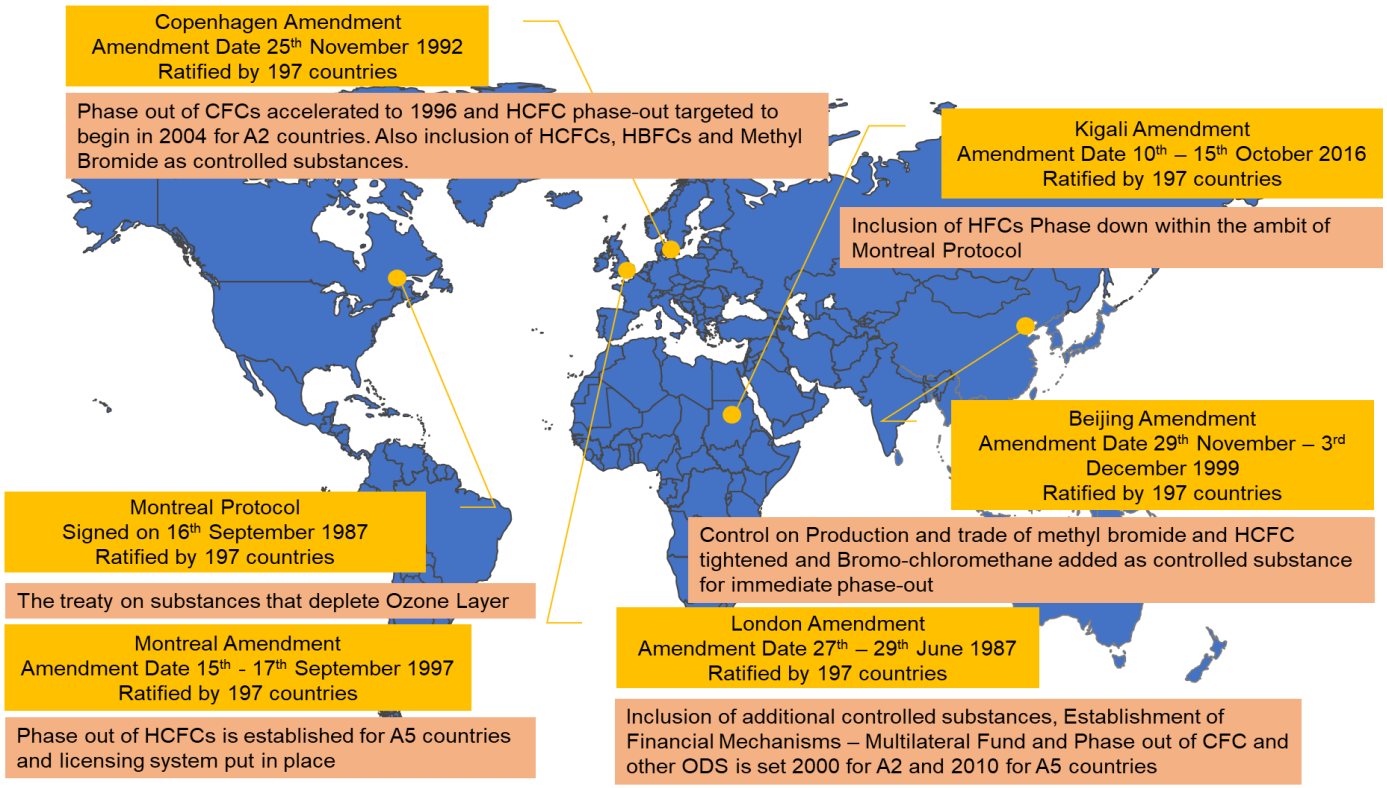


Figure 29: Montreal Protocol and its amendments

Phase-out of HCFCs under Montreal Protocol

HCFCs are gases used worldwide in refrigeration, air-conditioning and foam applications, but due their ozone depleting properties, they are being phased out under the Montreal Protocol. In September 2007, the Parties

decided to accelerate the phase-out schedule for HCFCs by 10 years. Developing countries agreed to start their phase out process in 2013 and are now following a stepwise reduction until the complete phase-out of HCFCs by 2030.

In Article 5 countries, this HCFC phase out is in full swing, with support from the Multilateral Fund (MLF) for the implementation of multi-stage **HCFC Phase out Management Plans (HPMPs),** investment projects and capacity building activities. Throughout this process, countries are encouraging to promote the selection of alternatives to HCFCs that minimize environmental impacts, impacts on climate, as well as meeting other health, safety and economic considerations. For refrigeration and air conditioning, this means optimizing refrigerants, equipment, servicing practices, recovery, recycling and disposal at end of life.

Phase down of HFCs under Montreal Protocol

Hydrofluorocarbons (HFCs), which have zero ODP, are used as an alternative to HCFCs. HFCs were initially considered to be a part of the solution to ozone depletion but turned out to be a very powerful greenhouse gas of high global warming potential. Therefore, on 15th October 2016, the Parties to the Montreal Protocol reached agreement at their 28th Meeting in Kigali, Rwanda to phase-down HFCs. Countries agreed to add HFCs to the list of controlled substances and approved a timeline for their gradual reduction by 80-85 per cent by the late 2040s.

India has already ratified the Montreal Protocol on 19th June 1992 and is classified as a Party operating under Paragraph 1, Article-5 of the Montreal Protocol and therefore qualified for technical and financial assistance from the MLF, established as the financial mechanism of the Montreal Protocol. The country is committed to phase out HCFC in 2030 in accordance to the accelerated phase out schedule under Montreal Protocol and has successfully implemented and achieved the targets set under HPMP Stage I. India is now implementing HPMP stage II with the following objectives:

- To facilitate India's compliance with the Montreal Protocol 2020 control targets for consumption of Annex-C, Group-I substances (HCFCs) through complete phase-out of HCFC-141b consumption by 2020 and phase-out of HCFC-22 in room air conditioner manufacturing and servicing of refrigeration and air conditioning (RAC) sector.
- To achieve sustainable reductions in consumption of Annex-C, Group-I substances (HCFCs) through implementation of a combination of interventions for technology transfer, training and capacity building, awareness, monitoring and management, in HCFC consuming sectors, and policy and regulatory actions.

India has not yet ratified the Kigali Amendment but committed to lower consumption and production of HFCs by freezing the baseline (average of 2024 to 2026) in 2028 and reducing it to 15% of the baseline level in 2047[35].

More details of India HPMP and assessment of refrigerants used in India is provided in Chapter 6 of this report.

[35] HCFC Phase-out and Energy Efficiency in Buildings by UNEP, Ozone Cell and EESL

5. Supply Chain of RAC

The typical bill of materials used to manufacture an RAC are given below

- Compressor (fixed speed / Variable)
- Condenser / ODU (Cu- al, All aluminium, All Copper)
- Sheet metal for the condenser casing
- Evaporator / IDU
- Fan / motor for the evaporator / condenser
- Refrigerant
- Miscellaneous and electronic parts (PCB's, control circuit boards etc).

The figure 30 presents the RAC supply chain of the above bill of materials in India and summarizes its localisation vs. import

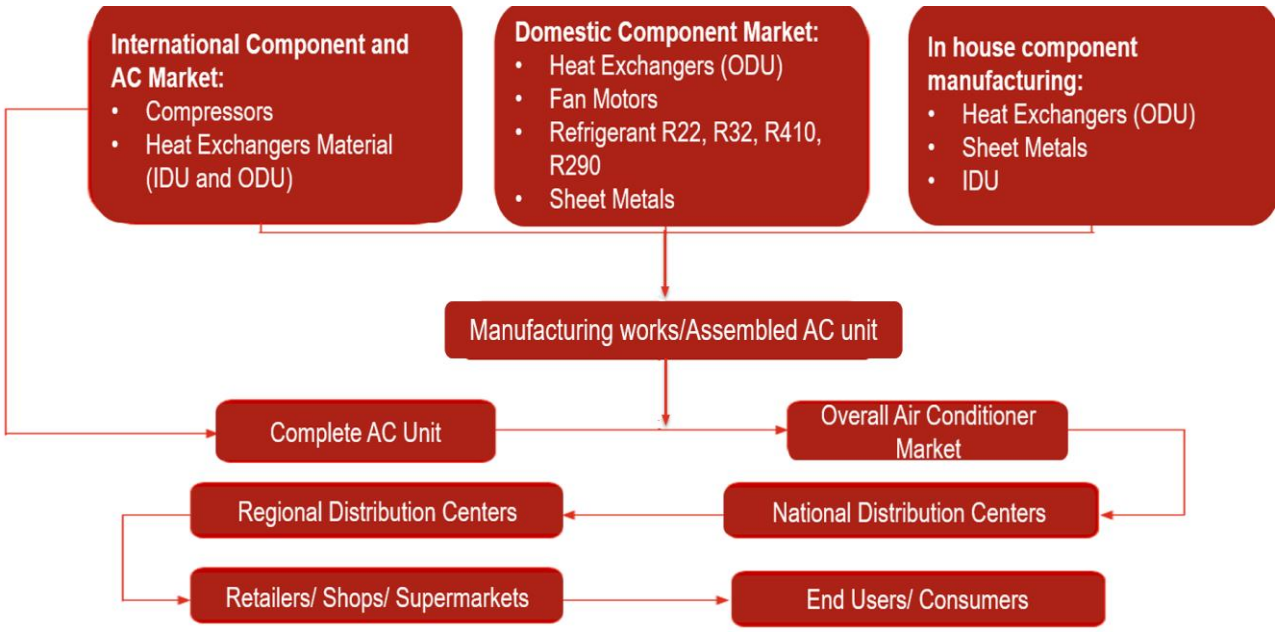


Figure 30: RAC supply chain in India

All the major India OEMs (as mentioned in section 1.2) have established manufacturing facilities in the country where most of the bill of materials are **either manufactured in house or sourced locally through vendors**. Although **compressors and IDU's** are still largely imported due to limited localization in India.

- **Compressors** are majorly imported from China and Thailand.

- IDU's were earlier completely imported from China and Thailand. Some manufacturers such as Bluestar moved from being import dependent for IDU's to producing 250,000 IDU's in 2018 at its Himachal Pradesh facility. Daikin and LG have also started assembling IDU's in their manufacturing facilities in India.

5.1.1. Compressor manufacturing, Import and Export

The compressor is a key component of any air-conditioning system and it is a specialized engineering product with intellectual property rights / trademarks. Globally, the compressor for RAC's is manufactured mainly by 3 countries i.e. China, Japan and Korea. The table 34 summarizes details about compressor manufacturers in different countries–

Table 34: Compressor manufacturing trends FY 17[36]

Country	Total production capacity	Major manufacturers	Manufacturer production	Plants	Major Countries of export
China	200 million	GMCC	65 million	4	Thailand, India, Indonesia, Middle East
		GREE	50 million	5	Brazil, Pakistan, Thailand
		Highly	17 million	3	India, Europe, Unites States, Middle East
		Rechi	21 million	3	Europe, North America, Middle East, South America Japan
Thailand	13 million	Daikin	3.5 million	2	-
		Mitsubishi	4 million	1	-
South Korea	5.5 million	LG	5.5 million	1	Mexico, India, United states, Brazil

China is the largest compressor manufacturer with a capacity of 200 million units followed by Thailand which has a capacity to manufacture around 13 million units. In Thailand, Daikin and Mitsubishi are significant companies with major manufacturing hubs.

China is the biggest exporter of compressors in the world with an estimated **28 million compressor** exports in FY18. Thailand is amongst the biggest importer with an estimated 6.7 million units in FY18. South Korea and Japan have an estimated export of 3 million and 1.9 million respectively in FY18.

The table below shows estimated import export units of RAC compressors by region in FY18.

[36] Nicholson, Scott, and Chuck Booten. "Mapping The Supply Chain For Room Air Conditioning Compressors". 2019, https://www.nrel.gov.

Table 35: Import / Export of RAC compressors by region in 2018-19[37]

Country	Import	Export
China	2.2 million	28.2 million
Thailand	6.7 million	6.5 million
South Korea	3 million	3 million
Japan	3.7 million	1 million

In India, compressor market is import dominated. As mentioned in section 1.2.2, the total RAC sales in India was about 6.7 million units in year 2018-19 and around 6 million compressors were imported to India in the same year[38]. This suggests that domestic requirement of compressors is primarily met through import. There is minimal indigenous manufacturing of compressors in India.

Highly (a JV between Highly China and Hitachi, Japan) has a manufacturing facility in Gujarat with a capacity of 2 million units. The figure 32 illustrates the major countries with which India deals in compressor import.

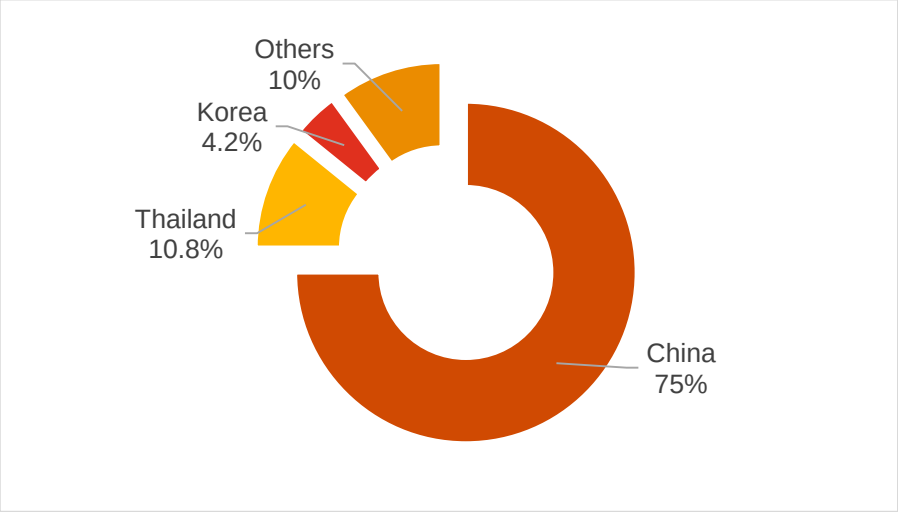


Figure 31: Compressor import in India

India imports 85% of the total compressors from China and Thailand.

The key compressor manufacturers and their involvement in supply (Manufacturing, import and export) in India are summarized in the table 36.

[37] *Trade Map - Trade Statistics For International Business Development*. 2020, https://trademap.org/Index.aspx.
[38] *Trade Map - Trade Statistics For International Business Development*. 2020, https://trademap.org/Index.aspx.

Table 36: Compressor Manufacturers in India

Highly (JV between Highly China and Hitachi, Japan)	GMCC (JV Between Midea and Toshiba)	Others
• Manufacturing facility in Gujarat • Highly India has a capacity to manufacture 2 million units.[39] • Highly plans to expand its capacity to 4 million by 2021.[40] • Plant produces fixed speed compressors for Highly's H&L product lines.	• To enhance the Make in India initiative GMCC is setting up its first manufacturing facility for compressors in India located at the Technology Park at Supa Parner in Maharashtra. The production capacity of this facility would be around 4.5 million and will be operational by end of 2020.	• Landa (Gree), Rechi, Panasonic, Qingan, Mitsubishi Electric, Samsung, and Shenyang Sanyo - 100% import from various countries as mentioned in table 34. • Application with R-22, R410A, R-32, R-290

5.1.2. RAC manufacturing works in India

Daikin, LG, Voltas, Bluestar, Lloyd, Hitachi, Samsung are the manufacturers which have their RAC manufacturing plants in India.

- Daikin's manufacturing plant is situated at Neemrana, Rajasthan is spread across 42000 square meters and has a capacity to manufacture 1.5 million units (per annum) room air-conditioners. The company also has a research and development facility in Neemrana which has three psychrometric labs.

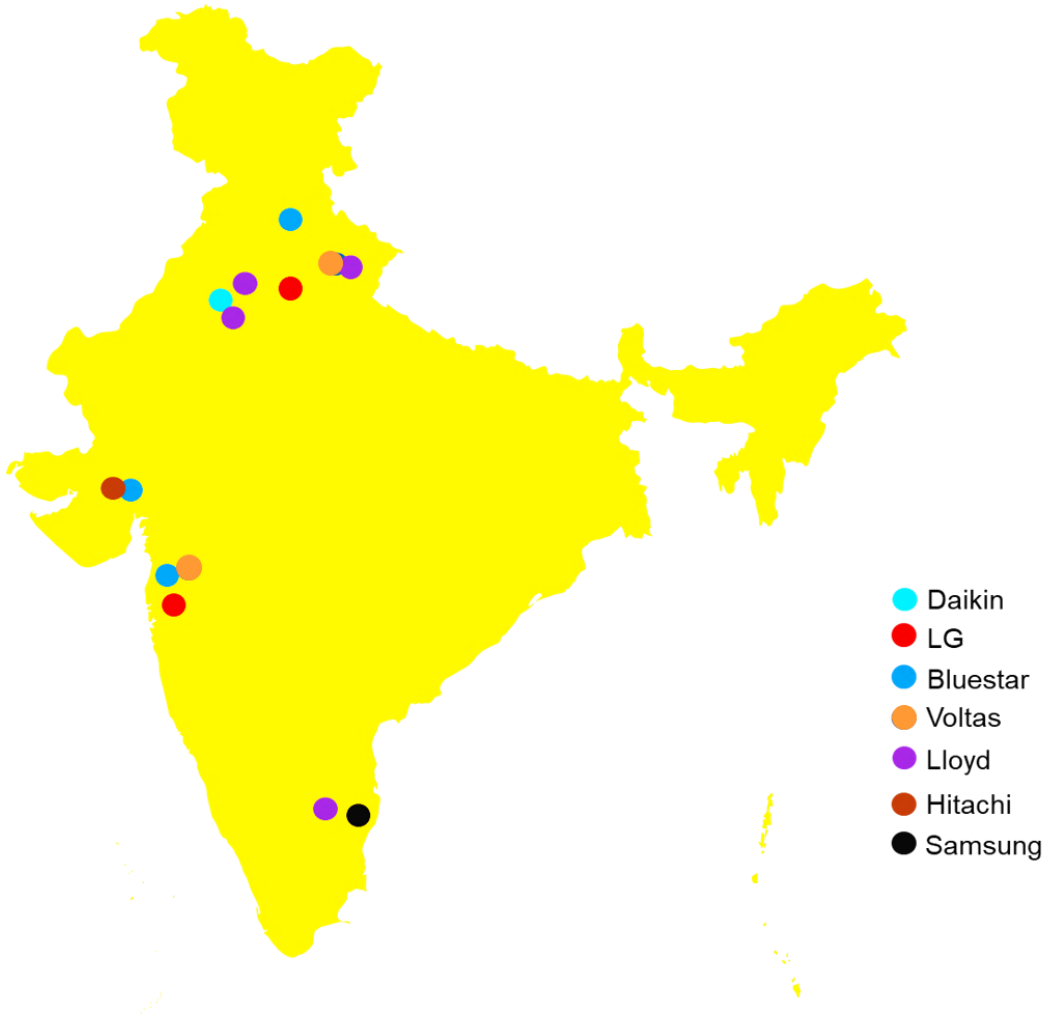
- LG's manufacturing unit is located at Greater Noida and Pune. Currently the company has the capacity to manufacture 1.2 million units annually.

- Blue star has 5 manufacturing facilities located in Wada, Dadra, Ahmedabad and two in Himachal Pradesh and currently have the capacity to produce 0.4 million units annually.

- Voltas Limited – a Tata Group enterprise, has plants in Uttaranchal and Dadra with a capacity of 0.5 million units (per annum) collectively.

- Lloyd has manufacturing facilities in Rajasthan, Haryana, Uttarakhand and Tamil Nadu. Lloyd has the capacity to produce 0.6 million units annually.

[39] http://www.highly.co.in/highly-brand.html.
[40] "Hitachi-Highly Group JV To Expand Production Capacity Of Gujarat Plant". Http://Www.Uniindia.Com/Hitachi-Highly-Group-Jv-To-Expand-Production-Capacity-Of-Gujarat-Plant/Business-Economy/News/1306470.Html, 2018



- Hitachi's manufacturing facility in India is at Kadi near Ahmedabad and has the capacity to manufacture 0.9 million units annually.

- Samsung had a manufacturing plant in Chennai for air-conditioners, but they have shut down their plant due to increase in custom duty on AC compressor, they are now importing air conditioner from Vietnam through the free trade route[41].

5.2. Growth drivers

India currently lags behind other economies in terms of AC penetration. United states, Korea, Japan and China have 90%, 86%, 91% and 60%[42] household penetration respectively compared to India which is 7%-9% as per ICAP, indicating major reliance on fans and air-coolers for cooling.

The following growth factors will have a significant bearing on increasing the penetration rate in India:

[41] After Television, Samsung Now Starts Importing Air-Conditioners." *Economic Times*, 2018, https://m.economictimes.com/industry/cons-products/durables/after-hike-in-customs-duty-samsung-starts-importing-air-conditioners/articleshow/68041110.cms.
[42] Holst, Arne. "Global AC Penetration Rate by Country 2016." *Https://www.statista.com*

- **Growth in per-capita income[43]:** Per capita income is likely to double between 2017 (INR 90,922) and 2027 (INR 178,634) (over the 2017 baseline) and then again double between 2027 and 2037 (INR 361,195) (over the 2027 baseline).
- **Rate of Urbanization:** India is presently 33% urbanized and will be 39% and 45% urbanized in 2027 and 2037, respectively.
- **Competitive market and innovative payment methods:** There are more than 22 players in this segment which results in a competitive market, technology advancement and affordable price range. To top that most of the AC OEM's offer EMI's, cask backs etc. which significantly assists the consumers in the purchase process.
- **Govt. subsidies and program:** Cooling is one of the focus areas for the govt. of India as recognized in the ICAP. To promote energy efficiency and affordability in AC's, Govt. of India does several utility-based replacement and bulk programs, wherein significant discounts and subsidies are offered on AC's. This has an indirect impact on the overall affordability of AC's as high prices are seen as one of the major barriers in low penetration of AC's.

[43] "India Action Cooling Plan",2018

6. Assessment of Refrigerants used in RACs

6.1. Brief overview and history on refrigerants used in RACs

India is the second largest producer and consumer of Ozone depleting substances (ODS) after China. As discussed in section 4.2.1, India ratified the Vienna Convention for the Protection of Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer as early in 1991 and 1992 respectively. The dates of accession by India to the Montreal Protocol and its amendments are shown below:

Table 37: Ratification of various agreement by India

Agreement/ Amendment	Ratification
Vienna Convention	18 March 1991
Montreal Protocol	19 June 1992
London Agreement	19 June 1992
Copenhagen Agreement	3 March 2003
Montreal Amendment	3 March 2003
Beijing Amendment	3 March 2003
Kigali Amendment	Not Yet Ratified

Ministry of Environment, Forest & Climate Change (MoEF&CC) have been entrusted by Government of India to implement Montreal Protocol and has set reduction targets for various substances as per below table.

Table 38: Phase-out schedule of India as per Montreal Protocol

ODS	Baseline Year	2005	2007	2010	2015	2020	2025	2030
CFC	1995-1997	50%	85%	100%	NA	NA	NA	NA
HCFC	2009-2010	-	-	-	10%	35%	67.5%	100%
Halon	1995-1997	50%	-	100%	NA	NA	NA	NA
CTC	1998-2000	85%	-	100%	NA	NA	NA	NA
MCF	1998-2000	30%	-	70%	100%	NA	NA	NA
MeBr	1995-1998	20%	-	-	100%	NA	NA	NA

As discussed in section 4.2.1, India has already implemented and successfully achieved the targets under HPMP stage I approved by the Executive Committee (Ex-Com) of the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol at 66th meeting held in April 2012. The stage I of HPMP was implemented for a period of four years from 2012 to 2015 to achieve 10% phase-out targets of HCFCs by 2015 as per the Montreal Protocol. The HPMP Stage I focused on phase out of HCFC 141-b from foam manufacturing sector and imitated activities in RAC sector also. RAC servicing sector accounts for a significant proportion of

the HCFCs consumed in the country and activities, such as development of training material, training of trainers and technicians etc. related to the servicing sector were initiated to support the HCFC phase-out targets. The HPMP Stage-I trained more than 11,000 technicians across the country. The HPMP Stage-I, has successfully phased-out a total of 341.77 ODP tons of HCFCs including 310.53 OPD tons of HCFC 141b in foam manufacturing and 31.24 ODP tons of HCFC-22 in RAC servicing sector respectively[44]. This has also led to reduction of direct emissions of 3,071,260.5 tCO_2eq per year in terms of GHG.

The HPMP Stage II was launched in February 2017 for meeting compliance targets for 2020. The target is to phaseout HCFC-22 from six major room air-conditioner brands in the country by 2022 and to train about 17,000 refrigeration and air-conditioning (RAC) technicians on alternative technologies and good servicing practices. The HPMP stage II also addressed the capacity building and awareness about harmful effects of HCFC and energy consumption from RAC. The plan also prioritized phase out of HCFC and increasing efficiency in building sector.

Successful implementation of HCFC Stage II will result in 8190 MT or 769.49 ODP tons of HCFC consumption in 2023 with baseline of 1691.25 ODP. In addition, it will also result in reduction of about 8,530,900 MT of CO_2eq in direct GHG emissions from 2023 onwards.

For the RAC sector, the market in India was mostly dominated by HCFC (R22) before 2019, with more than 75% stock of RAC's based on R22. As HCFC are to be phased out under the Montreal Protocol for the ozone depleting properties, the RAC industry is undergoing massive shift from HCFC to HFC.

HFCs are already a widely used popular alternative to HCFCs in India but as discussed above, comes under controlled substance category under the Kigali amendment and therefore calls for its phase down. As per the Montreal Protocol, India must achieve complete phase out of HCFCs by 2030 and simultaneously start phase down of HFCs by 2028.

As discussed above, India has not yet ratified the Kigali Amendment but committed to lower consumption and production of HFCs as per the phase down schedule shown in figure below-

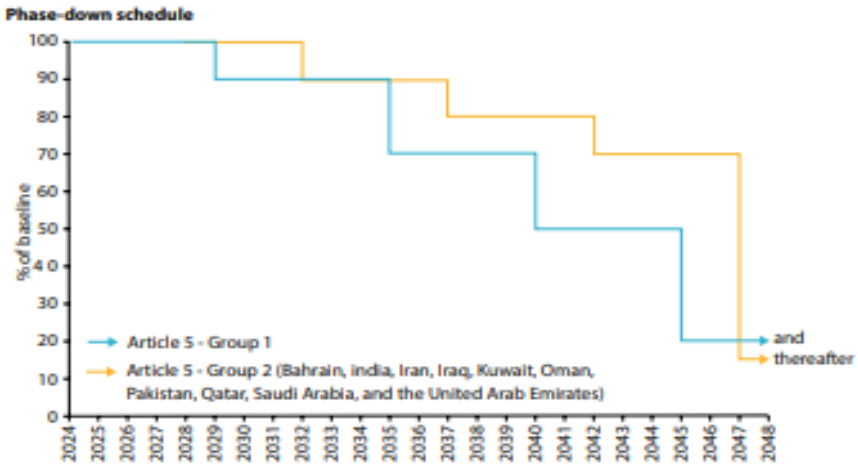


Figure 32:Phase down schedule of HFC for India

[44] Indian HPMP

6.2. Current status of refrigerants used in the Indian RAC market

As discussed in section 1.2.6, the current dominant refrigerant used in RAC is HFC (R410A) which does not have ODP but have high GWP. R32 with GWP lower than R410A, will likely to dominate the market in the coming years and major manufacturers such as Daikin, Bluestar, Voltas, Lloyd, Hitachi, Panasonic and Mitsubishi Electric have mostly shifted to R32 based technology. However, with implementation of Kigali Amendment to phase down HFCs, a shift to low GWP refrigerants such as R290 is expected. R290 is Hydrocarbon (HC) based refrigerant and has a GWP of less than three which is far lower than HCFC and HFCs but is highly flammable.

The table below shows the Ashrae flammability classification of refrigerants.

Table 39: Refrigerant - Ashrae Flammability

Refrigerant	Ashrae Flammability
R-22	Class 1: not flammable
R-410a	Class 1: not flammable
R-32	Class 2L: lower flammability
R-290	Class 3: Higher flammability

6.3. Expected usage and refrigerant transition in the next decade

As discussed in section 2.1.2, the RAC stock of R32 and R290 is envisaged to increase as per the information obtained from consultation with various stakeholders including manufacturers, government agencies etc. These trends have also been validated from the literature survey and secondary sources such as ICAP, BEE Analysis and market reports etc. The below figure showcases the trend of RAC stock and percentage of refrigerant till 2027.

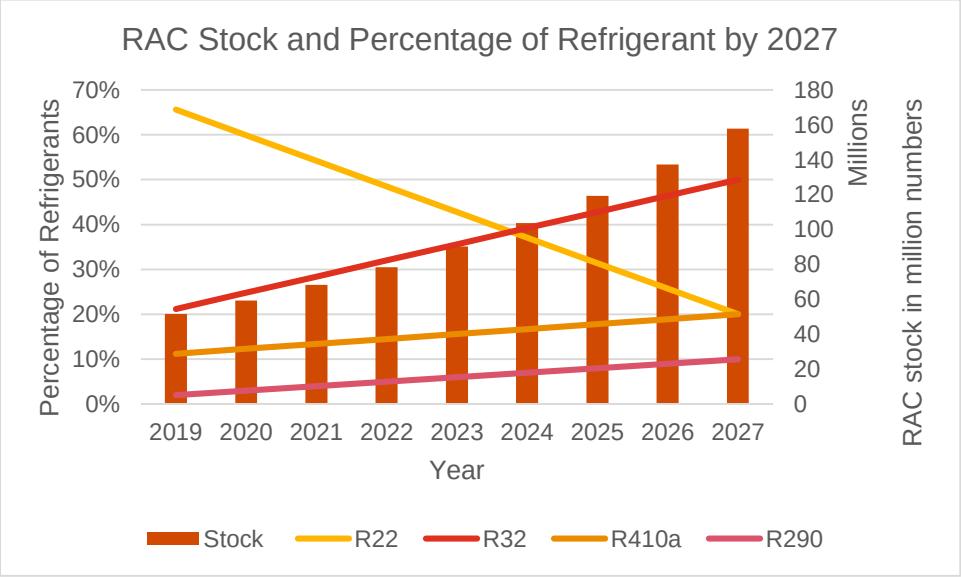


Figure 33: Trend of refrigerant in next five years

6.4. Environmental impacts of the RACs

Refrigerants contained in the RAC's contribute both to the global warming and ozone depletion as per their GWP and ODP values mentioned in section 1.2.6.
These environmental impacts occur via direct or indirect emissions at various stages of RAC Lifecyle as depicted in the figure 34.

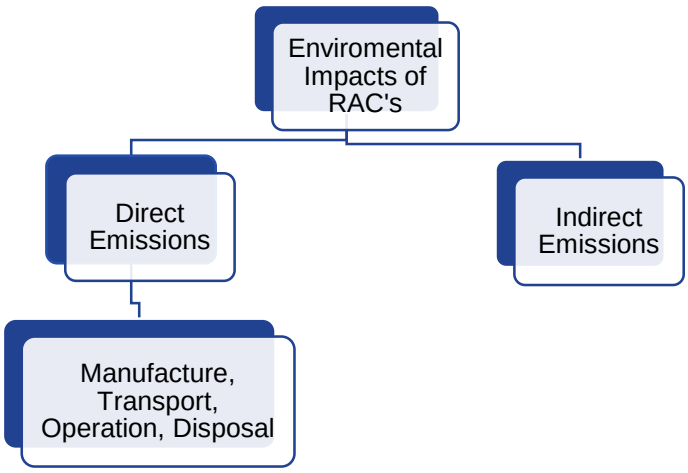


Figure 34: Environmental impacts of RAC'

Direct Emissions
Direct emissions from RAC occur include both fugitive and inadvertent release of refrigerant into atmosphere.

- Fugitive emissions occur during lifetime of equipment when refrigerants leak from equipment during their manufacture, operation and disposal phase.
- Inadvertent releases may occur when equipment is serviced during its operational life.

Servicing emissions are usually high in India due to informal servicing sector that constitutes large part of country's servicing market. Additionally, the equipment in the country are not disposed through manufacturer or certified E-Waste handler and thus emissions from remaining refrigerants are also high at the end-of-life of the equipment. Table 40 presents an overview of refrigerant leakage at different stages of the RAC.

Table 40: Emission during various life stage of refrigerant

Manufacturing	Transport & Distribution	Use	Disposal
Leakage at production site	Leakage due to handling gas containers	Leakage at charging	End of life emissions
-	Atmospheric dispersion	Equipment operation	-
-	-	Servicing	-

Table 41 provides the key results of direct emission for three years (FY17, FY19 and FY27). Refrigerant emissions from different sectors are calculated by emission factors approach where-in generalised assumptions for leakage rates, at different stages for gas-use and disposal at end of appliance and equipment life are used. In absence of national guidelines that exist for calculation of sectoral emissions from HFC end-use, IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) have been used. The information has been

provided by the subject matter experts including OEMs, think-tanks, government agencies etc. and has been validated through different literature available in public domain like India Cooling Action Plan, BEE's Demand Analysis for Cooling Sector in India in FY27 and more. The direct GHG emissions are calculated using equations mentioned in Annexure 1.

Indirect Emissions

Indirect emissions from the RAC equipment occurs due to grid energy consumption during the operations of the equipment. The indirect emissions are calculated using the total energy consumption and grid carbon factor.

Table 41 provides an overview of the direct and indirect emissions from the RAC sector.

Table 41: Overview of emission from RAC sector

Parameter	2017	2019	2027
Stock in (in million units)	39	52	158
Average tonnage of AC (TR)	1.4		
Initial charge in new units (kg)	1.11		
Manufacture emission factor	2%		
Servicing emission factor	10%		
Disposal emission factor	100%		
Average annual usage hour (hr)	1600		
Grid Carbon Factor (tCo_2eq/MWh)	0.82		
Refrigerant Distribution	R22: 77% R32: 14% R410a: 9%	R22: 66% R32: 21% R410a: 11% R290: 2%	R22: 20% R32: 50% R410a: 20% R290: 10%
Direct Emissions ($mtCO_2eq$)	Manufacturing Emission: 0.24 Servicing Emission: 7.89 Disposal Emission: 7.89	Manufacturing Emission: 0.22 Servicing Emission: 8.13 Disposal Emission: 8.13	Manufacturing Emission: 4.68 Servicing Emission: 18.01 Disposal Emission: 18.01
Indirect Emissions ($mtCO_2eq$)	44.1	49.22	118

6.5. Cost comparison analysis of high GWP vs. low GWP

As noted above, all major manufacturers in India are shifting from R-22 to different low GWP alternative refrigerants. Daikin was the first company to introduce R-32 (with GWP 675) in FY12. Almost all major manufacturers such as Hitachi, Blue Star, Carrier, Voltas sell AC's with R-32 refrigerant. Godrej launched R-290 (GWP value of 3) AC in FY12 and have sold more than half a million units in India. Godrej's R-290 is among the most efficient AC's in the market with ISEER 6.15.

Below is a cost comparison of AC's with high GWP and low GWP refrigerants.

Table 42: Cost comparison of various AC models as per refrigerants in INR[45]

[45] Prices taken from online portals such as Amazon, Flipkart, manufacturer website

R-410a			R-32			R-290		
1.5 Ton 5-star Inverter	1 Ton 5-star non-inverter	1.5 Ton 3-star Inverter	1.5 Ton 5-star Inverter	1.5 Ton 3-star inverter	1.5 Ton 3-star non-inverter	1.5 Ton 5-star Inverter	1.5 Ton 3-star non-inverter	1 Ton 3-star non-inverter
44000	34000	34000	43000	35000	35000	53600	41000	35000

- Based on our analysis, the R-290 based AC's are the most expensive amongst the three refrigerant bases.
- The per ton cost of 5-star inverter AC with R-290 refrigerant is INR 35,700 whereas it is INR 28,666 and INR 29,333 for AC's with R-32 and R-410 refrigerant respectively

6.6. Incentives/ subsidies required to migrate to low GWP refrigerants

Migration to low GWP refrigerants involves changes / modifications in the manufacturing lines at works, supply chain, system design etc. Carrying out these changes is as investment intensive activity, which could pose a major challenge for the manufacturers. Incentives / subsidies from the government can aid the manufacturers to make this transition smoothly in the following ways:

- Exemption / reduced import duties on low GWP refrigerant based compressor import and high efficiency DC motors for IDU's. As mentioned in chapter 2.2 compressors is one of the major components in RAC which is still imported from China. Exemption / reduction of customs duty on low GWP refrigerant based compressors / associated parts will help the manufacturers to suitably market the low GWP products in this highly price sensitive market

- Government's support in facilitating easy access of MLF funding, developmental loans, grants and low interest loans to manufacturers for carrying out modifications in their existing manufacturing lines from R-22 to low GWP alternatives such as R-32 and R-290a.

- Endorsement labels from BEE (in addition to comparative star label) for Low GWP refrigerant based AC's can help a create market differentiation for such products. This can act as an incentive for the manufacturers as well as a motivator for consumers

- Encourage localisation of AC components especially compressors and IDU's through joint ventures (with global manufacturers) under the make in India initiative

- To generate demand in the market the government can run awareness campaigns for consumers and rebate/subsidy schemes as highlighted in section 9.3.

7. Cost components of an RAC

Various factors contribute to the total cost of an RAC. The costs incurred to arrive at the final market price of an RAC can be distributed in 3 stages –

- **Stage I – Procurement of material and manufacturing/assembling of the air conditioner inside a factory**
  Costs incurred during this stage are called "**Factory costs**". It includes
  - Material cost of procuring components such as compressor, fan motors, heat exchangers, chassis, refrigerant etc. Customs duty is levied in case of the imported components. GST is applicable on the locally procured components.
  - Factory overheads – Rent, utilities costs, Inventory cost etc.
  - Factory profit margin

  The cost at this stage is called **Factory Transfer Price.** The finished product is transferred to the sales / distribution unit at factory transfer price.

- **Stage II – Transfer of the product from factory to the distribution unit of the company**
  At this stage, the product is transferred from factory to the sales / distribution unit of the company. The additional costs which are added to the Factory Transfer Price are –
  - Warranty
  - Logistics
  - Ware housing
  - Overhead of sales / distribution unit (rent, utilities etc.)
  - Marketing costs
  - R&D, Royalty costs
  - Sales / Distribution margin
  - Dealer Margin

  The cost at this stage is called **Company Realisation Value**.

- **Stage III – Sale of the product by the company to the consumer via distribution channels**
  The air conditioners are sold through various distribution channels such as dealers, retailers, online portals etc. The dealer margins are already factored in the Company realisation value, since this margin is directly paid by the company to its dealers. GST is levied onto the Company Realisation Value to arrive at the **Maximum Retail Price (MRP).** Discount if applicable is applied on the MRP to **cost to consumer.**

7.1. Component wise pricing of super-efficient AC's

This section illustrates the contribution of all the cost components mentioned in the previous section on the final cost to consumer. Like all the other products, the first step in manufacturing of an RAC is procurement of material. The typical bill of materials (BOM) for the RAC are summarized below –

1. Heat exchanger of the evaporator
2. Fan and fan motor for the evaporator
3. Compressor
4. Heat exchanger of the condenser
5. Sheet metal for the condenser casing

6. Fan and fan motor for the condenser
7. Refrigerant
8. Miscellaneous and electronic parts (PCB's, control circuit boards etc.)

For illustration, considering the total material cost to be 100 INR (for local and imported components the **GST / Customs duty** component is included in this cost), the contribution of various components to the total "cost to consumer" is derived. The costing sheet depicting these contributions is illustrated in the table 43.

This costing sheet has been developed based on inputs from various OEM's. The %age contribution of cost components from line item 2 to 13 vary from one OEM to the other.

Table 43 Cost components of an RAC

S.No.	Cost component	Contribution[46]		Value (in INR)
		%	INR	
1	Material cost			100
2	Factory overheads	15%	15.0	115
3	Factory margin	10%	11.5	126.5
4	Warranty (components)	4%	5.1	131.5
5	Logistics	3%	3.9	135.5
6	Warehousing	3%	4.1	139.5
7	Company overheads	10%	14.0	153.5
8	Warranty (services)	4%	6.1	159.6
9	Royalty, Inventory provision	3%	4.8	164.4
10	Research & Development	3%	4.9	169.3
11	Marketing & Advertising	5%	8.5	177.8
12	Profit margin (Sales / Distribution)	10%	17.8	195.6
13	Profit margin (Dealer)	15%	29.3	225
14	GST	28%	63	288
15	Maximum Retail Price (MRP)			**288**
16	**Cost to consumer after discount**	5%	14.4	274

Stage 1 Factory transfer price

Stage 2 Company realisation price

Stage 3 Cost to consumer

For a fixed tonnage or cooling capacity, the cost increases with the increase in efficiency (considering the features and other functions same). The efficiency of a RAC primarily depends on three factors – compressor efficiency, Heat exchange efficiency and type of expansion valve in use.

[46] Values taken from CLASP's "AC challenge program for India 2017" consolidated with the inputs from OEM's

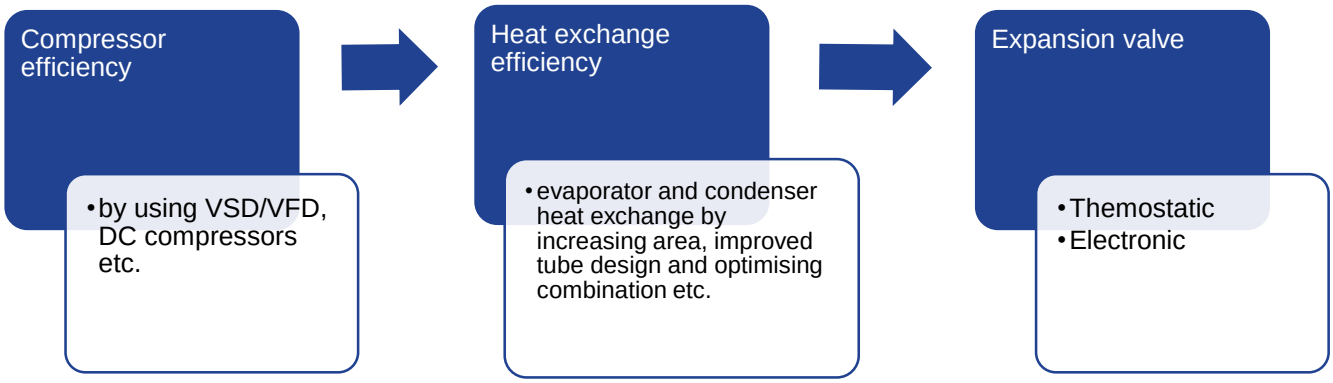


Figure 35: Factors effecting RAC efficiency

The next section presents the relationship between the efficiency and price of an RAC.

7.2. Price – efficiency analysis

The table 44 gives the incremental material cost with the increase in ISEER rating of the RAC. The analysis has been done for 1.5 TR split AC since this is the most dominant RAC category in India

Table 44: Cost - Efficiency analysis of 1.5 TR Split AC

Price – Efficiency analysis					
S.No.	Components	Contribution	3 Star (3.5 ISEER)	5 Star (4.5 ISEER)	5 Star (5.4 ISEER)
		%	INR	INR	INR
1	**Material cost (Approx.)**		**12,100**	**15,410**	**18,300**
2	Factory overheads	15%	13,915	17,722	21,045
3	Factory margin	10%	15,307	19,494	23,150
4	Warranty (components)	4%	15,919	20,273	24,075
5	Logistics	3%	16,396	20,882	24,798
6	Warehousing	3%	16,888	21,508	25,542
7	Company overheads	10%	18,577	23,659	28,096
8	Warranty services	4%	19,320	24,605	29,220
9	Royalty, Inventory provision	3%	19,900	25,343	30,096
10	Research & Development	3%	20,497	26,104	30,999
11	Marketing & Advertising	5%	21,522	27,409	32,549
12	Profit margin (Sales / Distribution)	10%	23,674	30,150	35,804
13	Profit margin (Dealer)	15%	27,225	34,672	41,175
14	GST	28%	34,848	44,380	52,704
15	Maximum Retail Price (MRP)		34,848	44,380	52,704
16	**Cost to consumer after discount**	**-5%**	**33,105**	**42,161**	**50,068**

Factory Margin, warranty (components), marketing and advertising and profit margin (dealer) can be avoided or reduced leading to a reduction of upto 30% on cost to consumer.

In order to validate the cost derived under table 44, price of 3 star and 5-star AC's (for 1.5 TR capacity) from various vendors available online (Amazon, Flipkart, Croma) were studied. The price comparison is shown in table 45.

Table 45: Price discovery of 1.5 TR Split RAC

S.No.	Make	Model	Compressor Warranty (In Years)	Rated ISEER (W/W)	Star rating	Refrigerant	Landed cost with standard warranty on online portals (Amazon , Flipkart) in Rs.
1	Godrej	GIC 18 ETC 5	10 years	4.75	5 Star	R-32	38,900
2		GSC 18 AMINV 3 RWQM	7 years	3.6	3 Star	R-410	34,000
		GIC 18 LAH 5 GWQG	10 years	5.2	5 Star	R-290	53,600
3							
4	Voltas	SAC 185V ADS (R32)	5 years	4.51	5 Star	R-32	38,900
5		183VCZS	5 years	3.8	3 Star	R-32	30,490
6	Blue Star	IC518DBTU	10 years	4.6	5 Star	R32	42,990
7		IC718YCTU	10 years	5.41	5 Star	R32	50,490
8		IC318QATU	10 years	3.6	3 Star	R-32	38,090
9	Lloyd	GLS18I52AV	10 years	4.61	5 Star	R-32	39,990
10		LS18136F	5 years	3.59	3 Star	R-32	31,999
11	Daikin	FTKF50TV	10 years	5.33	5 Star	R-32	46,400
12		ATKL50TV	10 years	3.7	3 Star	R-32	34,900
13	LG	KS-Q18YNXA	10 years	3.68	3 Star	R-32	35,990
14		KS-Q18HNZD	10 years	4.73	5 Star	R-32	39,990

The average price of 3-star, 5 Star and above 5 star (5.2/ 5.33 / 5.4 ISEER) rated 1.5 TR split AC's are **INR 34,259, INR 43,907, INR 50,163** respectively.

It can be established that the table 45 estimates the price of the RAC's with dependable level of accuracy. The relationship is therefore extrapolated in figure 36 by linear regression equations to estimate material cost and cost to consumers of RAC's till 6.2 ISEER for a 1.5 TR capacity AC (since this is the highest efficiency available in Indian market).

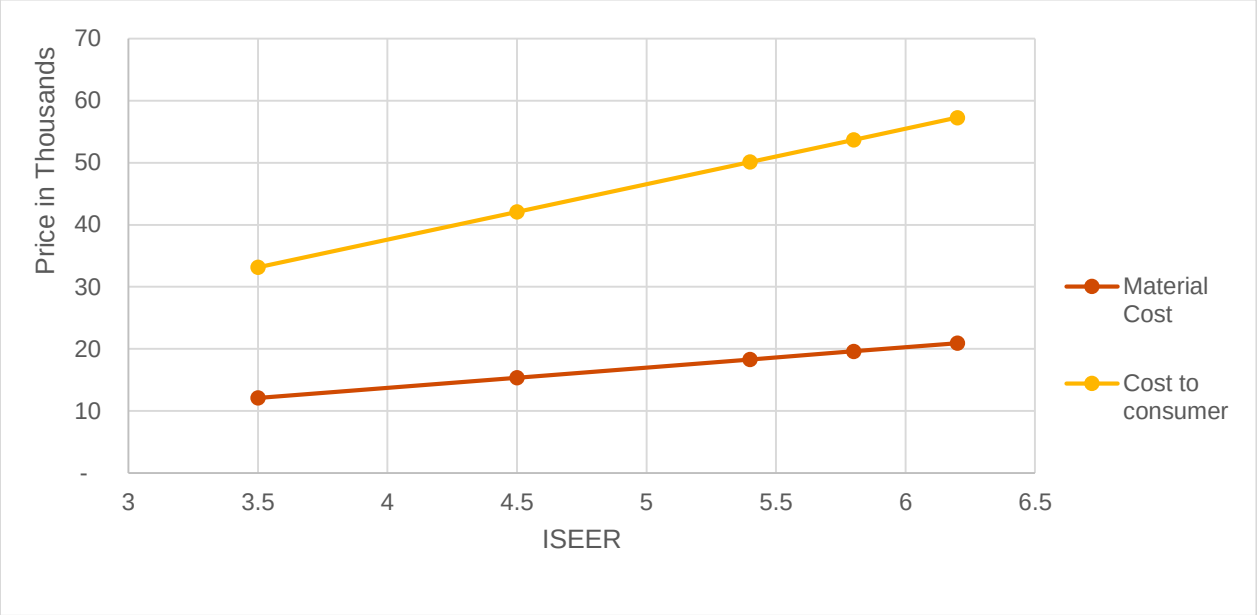


Figure 36: Relationship ISEER, material cost and cost to consumer

7.2.1. Savings / payback analysis of different RAC models

This section provides an overview of the cost, savings and payback of various RAC efficiencies in comparison to the EESL's super-efficient AC . Some of the assumptions used for carrying out the analysis are:

- Since there is no fixed definition of super efficiency, 15-20% higher efficiency than 5-star rating is considered as super-efficient.
- 1.5-ton TR split AC's have considered for comparative purposes as they comprise a dominant market share (70% market share) and have the maximum efficiency levels in the Indian market
- The cost for AC's has been considered after reviewing the most popular AC brands
- For Residential applications: Run hrs.: 1600 hrs. (8 Hrs/ day X 200 days / annum), Electricity Tariff :6 INR/kWh
- For Commercial applications: Run hrs.: 2640 hrs. (12 Hrs/ day X 220 days / annum), Electricity Tariff :8 INR/kWh

Table 46: Savings payback analysis

	Parameters	Units	EESL SEAC	5 Star AC	4 Star AC	3 Star AC
	EER (W/W) & Equivalent ISEER		5.4	4.5	4	3.5
	Cost (Inclusive GST) of 1.5 TR Split	INR	41,300	42,000-45,000	40,000-42,000	35,000-38,000
Residential application	Estimated energy consumption	kWh/Annum	757	876	1,023	1,126
	Estimated energy bill	INR/Annum	4,542	5,256	6,138	6,756

	Savings on Energy Bill	INR/Annum		**714**	**1,596**	**2,214**
	Pay back (on differential cost)	Years		**Immediate**		**1.5 – 2.8**
Commercial applications	Estimated energy consumption	kWh/Annum	1249	1445	1688	1858
	Estimated Energy Bill	INR/Annum	9,992	11,560	13,504	14,864
	Savings in Energy Bill	INR/Annum		**1,568**	**3,512**	**4,872**
	Pay back (on differential cost)	Years		**Immediate**		**0.6 – 1.2**

Some of the key observations are –

- 4- and 5-Star AC's make an immediate case as compared to the EESL's super-efficient AC
- Even for a 3-star AC, the payback period compared to a super-efficient AC is lucrative especially for commercial applications.

8. Financing options for SEAC

Finance is the basic necessity to promote and execute energy efficiency project in any sector. This holds true for the RAC sector as well. The cost of introducing super-efficiency in any appliance over and above the market norm is high due to multiple reasons such as investment for changes / modifications in the manufacturing facilities, R&D costs and high risk for manufacturers due to uncertain / low demand. Financing is therefore required to bridge these barriers.

Broadly financing for any project can be categorized as:

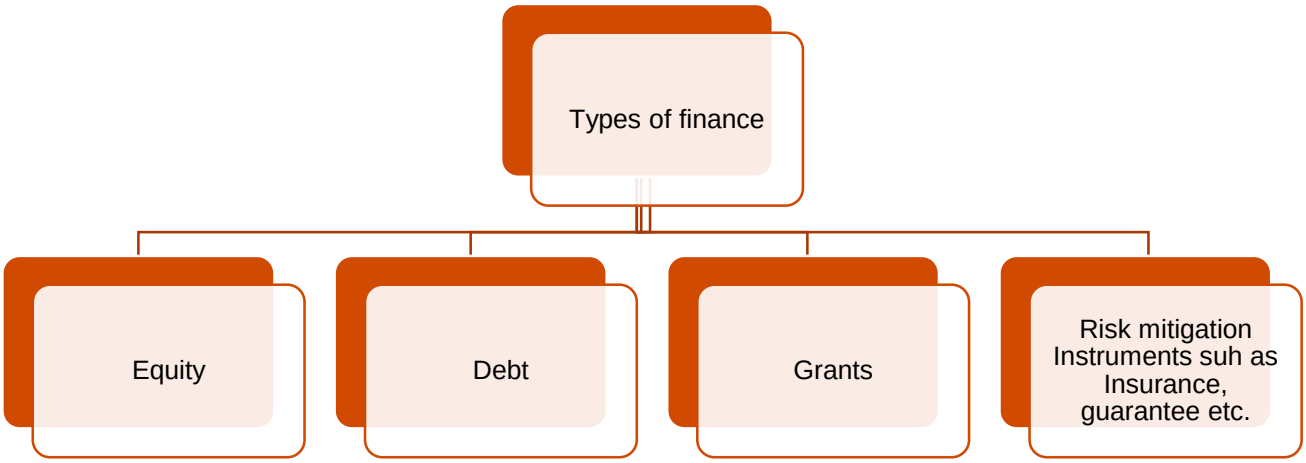


Figure 37: Types of finance

SEAC consumers broadly fall into 3 categories – Residential, Commercial / Institutional. Type of financing required for SEAC programs primarily depends on the type of application / consumers and business model of the program. For instance, the financing (type and source) in large scale ESCO projects is completely different from the Micro level finance required by residential consumers. The type (and source) of finance for super-efficient AC programs is listed in the table 47.

Table 47: Source and type of finance

Source of Finance	Type of finance	Application
Bank	Loans and credits (Debt)	• Residential consumers can avail deferred payment / EMI facility on bank credit / debit cards • Private commercial / institutional projects, public sector projects can avail loan facilities for executing replacement / upgradation of AC's
Non-Banking Finance Company (NBFC)	Loans and credits (Debt)	• Provide financing / loans to residential buyers at a nominal interest fee. NBFC's have tie-ups with major AC OEM's and their dealer networks
Utility financing	On bill financing (Debt)	• Utility may act as a financial institution for its consumers. Mostly applicable in developed countries such as EU, Dubai etc.

		• Facilitate finance through banks at a low rate through NBFC's / banks by acting as a guarantor • Applicable for residential and Institutional consumers
Local / Dealer finance	Loans and credits (Debt)	Applicable for residential consumers of small cities not having access to bank credit/debit cards or organised NBFC's
Private Finance	Company's own Debt / equity	• Applicable for large scale commercial and institutional projects
Multilateral Development Banks	Loans and Grants	• Applicable for funding large-scale public-sector projects • Can also fund private projects but generally a small amount is reserved for private sector
ESCO	Equity, Debt and Risk mitigation instruments	• Can source finance from multiple sources such as its own Debt., equity, Multilateral finance and grants • Applicable for large scale public projects and private commercial/ institutional projects

9. Business models and SWOT analysis

A suitable business model is essential for extending finance and sharing the return on investment amongst various stakeholders involved in the SEAC program. Some of the common business models which are used across the globe for super-efficient appliance programs are as follows -

a. Upfront Model

In the upfront model, the capex investment for the equipment is done by the developer or the building owner. This model is mostly applicable for large scale commercial projects, public sector projects and institutional projects. The sources for finance include private equity funds, loans from private banking Institutions, loans from National development banks (NDB) and Bi/Multilateral development banks (MDB)

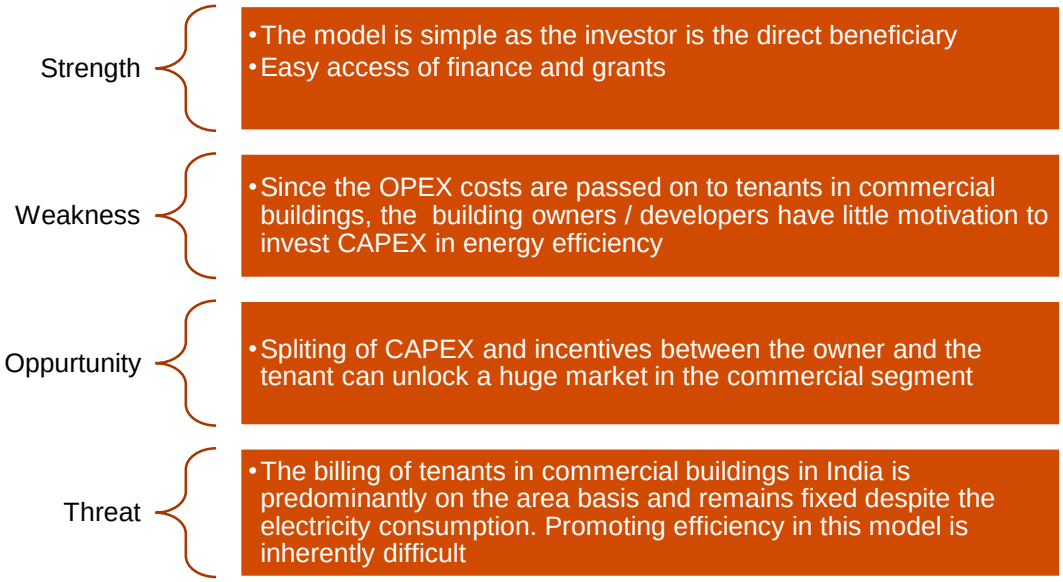


Figure 38: SWOT Analysis of upfront model

b. Deferred Payment

Deferred payment in simple terms means install now and pay later. This is mostly applicable for residential consumers. The total cost of the AC is paid by the consumer over a fixed period in installments. The consumer might have to pay a little extra for availing this scheme, but that depends on the mode of transaction (online, offline) and purchase (Cash, card, digital wallets etc.). In India deferred plans are available through –

- Debit / credit cards of certain banks
- Digital payment wallets such as Paytm
- Non-Banking finance Company's (NBFC) such as Bajaj FinServ which has tie-ups with all the major OEM's and dealer networks

Figure 39: SWOT Analysis deferred payment

c. On bill financing

On bill financing refers to a financing option where in a consumer utilizes his/her utility bill to secure finance / loan for purchasing the energy efficient AC. This is applicable for residential consumers. The sources of finance in this model can be the following –

- The utility takes on the role of financing institution by directly paying for the investment cost of the energy efficient AC's for its consumers
- The utility acts as a facilitator of finance for its consumer. The primary source of finance is an NBFC, public or private financing institution which charges a nominal amount for its services

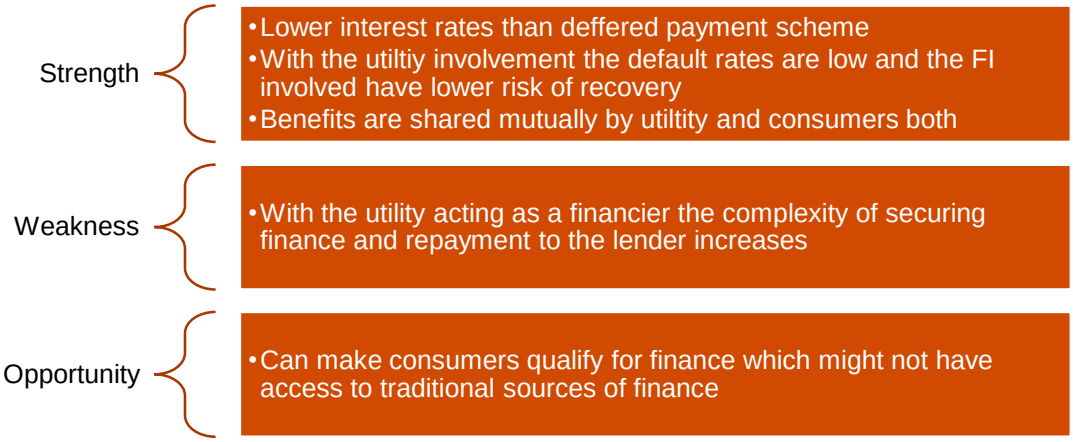


Figure 40: SWOT Analysis on bill financing

d. ESCO

ESCO's are energy service companies which implement energy efficiency projects for a client/owner/end user. The technical, financial and operational risks of the project are taken over by the ESCO and the revenue stream generated out of the savings is split between the project owner and the ESCO. This is mostly applicable for large scale institutional and public sector projects. Since ESCO companies are experienced in energy efficiency projects, they have access to risk mitigation instruments (such as Insurances, credit guarantees) which may decrease the overall risk associated with the project. There are typically two models under which the ESCO's operate, these are –

- Shared savings model – In this model the financing is secured by the ESCO company (and its repayment is also in its scope). The split of savings is mutually agreed in the contract.

- Guaranteed savings model – In this model the client secures finance directly from its preferred financial institution. The repayment on loan is in client's/project owner's scope.

Figure 41: SWOT Analysis of ESCO model

e. Buyback for old less efficient AC

While contemplating of buying an air-conditioner most of the consumers are faced with many dilemmas such as "What do I do with the old AC? Where do I dispose it? It is working, there is still a monetary value to it ".Buyback schemes for old AC's are offered by almost all the OEM's and dealers in India and they assist the consumer in taking the decision to get rid of the old AC by giving a direct discount of certain value on the purchase of a new efficient one. In India most of the OEM's and dealers offer a buy back price of INR 2500 on window AC's and INR 3000 on split AC's.

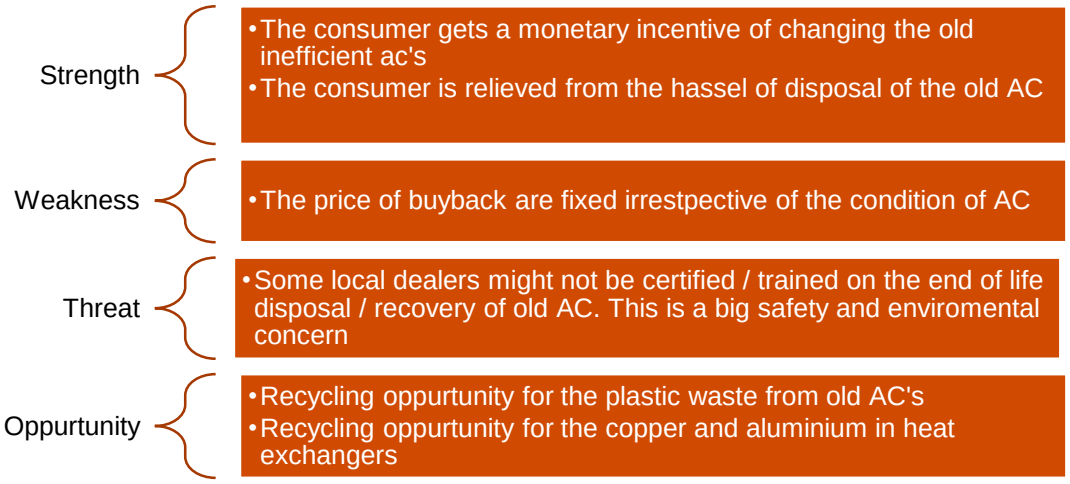


Figure 42: SWOT Analysis buyback of old efficient AC

f. ECO friendly scrapping mechanism

Air conditioner contains a lot of components that may be recycled or reused for example aluminium, steel, copper, plastic, while some components such as refrigerants and PCB's are hazardous. The refrigerants used

in AC's have significant environmental impacts such as global warming and ozone depletion potential as explained in the earlier sections of the report. Apart from the refrigerant, the PCB's used in air conditioner contain substances such as cadmium, antimony, beryllium etc. Therefore, the end of life recovery becomes essential to save environment from the potential adverse effects of these substances. Most of the vendors / OEM's in India offering buy back schemes (as explained in the previous section) also extend e-waste certificates to consumers ensuring proper end of life disposal practices. Eco friendly scrapping mechanism act as a moral incentive for people looking to change their old AC's.

Figure 43: SWOT Analysis ECO friendly scrapping mechanism

10. Gap analysis on Super-Efficient AC programs

10.1. Challenges and barriers in the implementation of Super-Efficient AC program

The challenges and barriers in the implementation of super-efficient AC program / technology are as follows –

a. Traditional selling route for AC's:

90% – 95% of the air conditioners are still sold through the traditional routes such as authorized OEM dealer shops (which may be single brand or multi brand) or big stores such as Croma, Sargam, Vijay sales etc. The Indian consumer stills prefers to get the look and feel of products such as AC and refrigerator before buying it. Even in the evolved consumer base which buys these products online, the main reason for them doing so is because of the trust and confidence acquired by the e-commerce giants over the years.

This traditional selling model for AC's offers a big hurdle for SEAC programs, as the priorities and motivations of these dealer networks / sales points are not aligned with the core agenda of efficiency.

b. Brand preference:

Super-efficient Ac's are generally available with one or two brands. Consumers, whether in India or anywhere around the world have brand preferences and loyalties that are hard to change. Switching from one brand to other, just for efficiency requires a strict resolve on consumers part. It is easier to promote a super-efficient AC program if it is available in multiple brands.

c. Marketing, consumer awareness and market barriers:

The Indian AC market is highly price sensitive. The consumers prioritize first cost over lifecycle cost primarily due to unawareness of the lifecycle cost. Marketing campaigns focusing on lifecycle cost of AC's are lacking in India. OEM's mostly focus their marketing campaigns around smart features, aesthetics and first cost. Although the market trends are shifting towards higher efficiency, the market share of 5-star AC's is still around 20%. OEM's have limited motivation to manufacture anything beyond the regulatory standards as it entails heavy investments and uncertain return on the investment.

d. Product differentiation:

Super-efficient AC's fall in the highest efficiency label applicable for India, even though its efficiency might notionally be 2-3 grades higher as per the existing labelling program. This dilutes the product differentiation in terms of efficiency grading and ultimately the consumers' interest in paying extra for the efficiency.

e. Confirmed Demand and commitment:

Super efficiency comes at an incremental cost of R&D and modifications in the existing manufacturing lines at works, which is a heavy investment. This investment is difficult for the manufacturers to justify if they do not have a visibility of confirmed demand or procurement commitments. This risk factor inadvertently increases the cost, which as explained earlier is a big hurdle in price sensitive market such as India.

f. Split ownerships:

This occurs in commercial buildings or rented accommodations where the entity responsible for using the equipment and paying the electricity tariff does not have any say in the capex decisions. In these kinds of ownerships, the entity responsible for installing the equipment prioritises the first cost and has little incentive to invest extra for the running cost of the equipment.

10.2. External enablers required to advance SEAC penetration

As mentioned in the previous chapter there are many barriers inhibiting the implementation or deployment of super - efficient AC's. Many of these barriers can be overcome with measures such as raising awareness, government incentives /policy push and innovative business models. Some of these measures are discussed below:

a. Special Government Incentives for cost reduction and promotion:

In order to promote super-efficient AC's government support is essential for mitigating 2 barriers of upfront cost and awareness mentioned in the previous section –

- Rebate of Custom duties or tax reversals for AC's manufactured under such programs to bring down the cost.
- Some **special endorsement label on the product** in addition to energy label for awareness and promotion in masses. As mentioned earlier in section 5.2, countries such as Korea, Japan have special endorsement labels for products which exceed best in class efficiency. These labels act as a motivator for the consumers creating demand for such products and on the other hand an incentive for the manufacturers to exceed the efficiency norms.
- Government initiatives in the form of awards or challenge programs encourages healthy competition and innovation amongst air conditioner manufacturers. Such programs can serve as an incentive for the manufacturers / OEMs to showcase their innovation and shape up the market towards a sustainable future. One such initiative is Global Cooling Prize, where the Govt. of India is supporting an incentive program to develop a residential cooling solution that will have at least five times (5X) less climate impact than standard Residential/ Room Air Conditioners (RAC) units in the market today.
- Additional loans in the form of mortgage loans, personal loans etc. may be offered to households to purchase efficient equipment, including energy-efficient air conditioners.

b. Confirmed demand / commitment in government projects

One of the factors that elevates the price of the super-efficient AC's is the risk factor associated with lack of commitments or demand for it. Govt. projects can act as demand centres for such products. This would mitigate the cost escalation related with uncertain demand and encourage healthy competition among manufacturers.

c. Training and Incentives for dealer network and other sales touch points

As mentioned in the previous sections the dealer networks and other stores act as the main source of AC sales in India. The salespeople at these centres should be aligned to the main agenda of efficiency for increasing the sales numbers. This can only be done through **monetary incentives (such as higher dealer margins)** over and above the other AC models.

d. Consumer Awareness:

Consumer awareness can be done through several means by the government –

- Endorsement label on AC to exemplify best in class product
- Behavior change campaigns which make the use of national ambassadors (as detailed in section 12)

e. Access of finance for big projects

The access of financing mechanisms such as Green Climate fund (GCF), Clean development mechanism (CDM) Nationally Appropriate Mitigation Actions (NAMAs) etc. should be made easily accessible for large scale private projects. These sources of finance can even be blended with other domestic / private sources of finance to encourage investment in this sector. The possibility of utilities acting as a financier should also be explored.

f. **Utility DSM programmes offers** –

Utility based appliance replacement programmes are quite popular across the globe. Utilities can play an important role in promoting energy efficient RACs through the following modes

- The utility takes on the role of financing institution by directly paying for the investment cost of the energy efficient AC's for its consumers
- The utility acts as a facilitator of finance for its consumer. The primary source of finance is an NBFC, public or private financing institution which charges a nominal amount for its services
- Provide rebate to consumers for replacing old inefficient ACs with newer efficient ACs. This rebate can be varied according to the ISEER rating, therefore, higher the rating, higher the rebate provided.

10.3. Promotion and educational campaigns for spreading awareness of SEAC

Government policies and awareness campaigns both play an integral role to promote efficiency and sustainability in products / appliances. While the government policies such as appliance labelling programs push the appliances towards better efficiency standards, awareness empowers the consumers to choose efficient products. Awareness amongst the consumers can be spread through:

- **Recognition through Endorsement labels**: A lot of developed countries give endorsement labels to products which are best in class or exceed certain limits set out by the government. Examples of such endorsement labels are Energy star label in USA, Front runner label in japan etc. These kinds of labels not only promote efficiency but also efficient resource use which minimizes the overall impact of a product / appliance on environment. These endorsement labels have proven to be very effective in raising awareness amongst the consumers.

- **Competitions and innovative challenge programs:** Governments can organize competition amongst the AC manufacturers for showcasing their innovative technologies. The award or prize money and exclusive media coverage resulting from winning the competition fosters innovation and healthy competitions amongst manufacturers. The results of such competitions should be disseminated to public for raising awareness.

- **Incentive programs for dealer networks**: Retailers engage directly with customers. Therefore, they should be appropriately incentivised for promoting best in class appliances. Incentives could be in the form of awards, media recognition, cash prizes. The industry representative bodies can play an integral role in designing such a program.

- **Awareness through Utility companies:** Utility companies, such as energy distribution companies (Discoms) can play an important role in educating consumers, and in influencing attitudes towards energy consumption. Their advice is valued by consumers as they are the providers of energy and have no hidden motivations. Discoms are already facing the brunt of the increasing load on the grids. Running a dedicated awareness campaign with through utilities involving an influential ambassador will significantly promote awareness in masses.

- **Awareness campaigns in schools & colleges:** Schools & colleges are key influencers in communities. Specially designed curriculum in schools & colleges for energy efficiency and sustainability will instil responsibility towards environment. The increased awareness at grass root levels will manifest into energy efficient behaviours in Indian homes and help push the society towards smarter choices.

Annexure – 1

Direct emissions calculation

$$E_{Direct,t} = E_{assembly,t} + E_{operation,t} + E_{disposal,t}$$

Where : $E_{assembly,t} = E_{charged,t} \times \left(\frac{k}{100}\right), E_{operation,t} = E_{stock,t} \times \left(\frac{x}{100}\right), \; E_{disposal,t} = Ei_{charge(t-n)} \times Q$

Where,

$E_{assesmbly,t}$ = direct emissions (CO_2eq) of units t during assembly

$E_{operation,t}$ = direct emissions (CO_2eq) of units t during operation

$E_{disposal,t}$ = direct emissions (CO_2eq) of units t during disposal

$E_{charged,t}$ = the amount of refrigerant charged into new systems in year t

k = assembly losses in per cent of the amount charged

$E_{stock,t}$ = amount of refrigerant stocked in existing systems in year t

x = annual leakage rate in per cent of total refrigerant charge in the stock, per cent

$E_{charge(t-n)}$ = amount of refrigerants initially charged into new systems installed in year (t-n)

Q = amount of refrigerants emitted at system disposal in per cent of the quantity of chemical

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