

A Centre for Science and Environment study report

NOT AS COOL

Improving energy performance of air conditioners in India



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Why this study?

Centre for Science and Environment has carried out this study to know how energy efficiency of room air conditioners (RAC) perform when outside ambient temperature is variable and high. Room air conditioner is a cooling device that cools closed environments. The amount of electricity that room air conditioners use to do cooling is one of the critical parameters that decide the energy budget of households as well as that of the country. This appliance is inherently an energy guzzler and therefore a climate rogue. Regulations are shaping up across the world as also in India to set tighter energy efficiency targets for RACs, while passive architectural design is being promoted to improve thermal comforts of buildings to reduce its use.

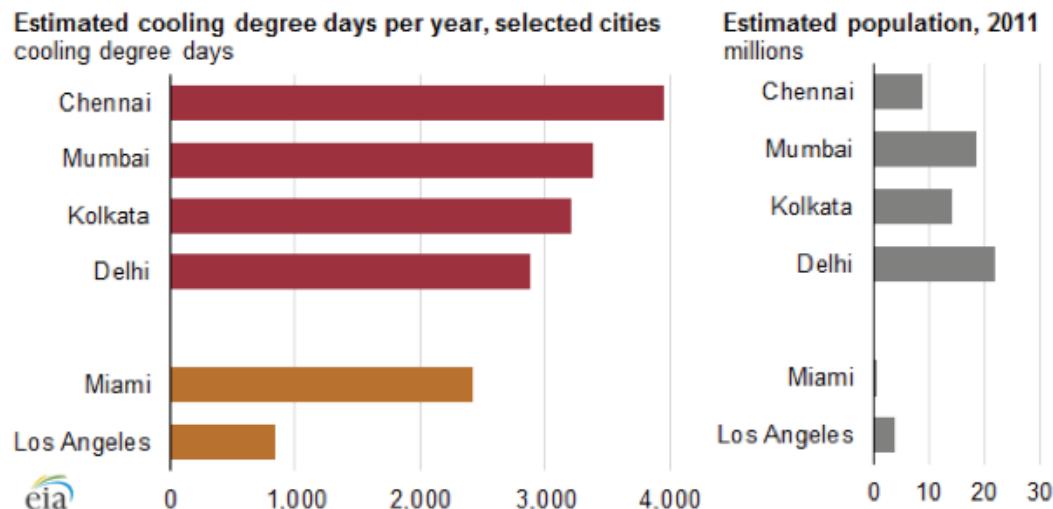
As India has also started to set energy efficiency targets for this appliance it is important to understand the real world energy performance under different operative conditions and if the current benchmark and test parameters are adequately designed to deliver on the intended efficiency targets. It is known that climatic stress affects overall efficiency of these systems. But this is also an important reason to review and address testing parameters and standards of these appliances to minimise deviation and margin of deterioration in the real world to ensure targeted savings.

India needs to take effective steps at the early stages of the market boom. India is still not a big RAC consumer but with growing prosperity, aspirations and changing idea of comfort, the growth rate is skewing already. The increase in demand for cooling is particularly striking in India: at present, the predominant appliance used for space cooling is an evaporative air cooler, which consumes twice the electricity as fan; and RACs consume five-times more electricity than an evaporative air cooler.

India with combination of hot and dry, and warm and humid climate in most parts has a high need for space cooling. India has not officially defined the cooling degree days that require use of air conditioning (an estimate of the energy needed to cool indoor air to a comfortable temperature based on the daily mean external temperature and standard comfort temperature over a year). However, the draft revision of the National Building Code has proposed 23 degree C as the standard cooling degree day temperature. Though this is yet to be finalised, this proposal is not acceptable as in tropical countries comfort expectations are different and people can be comfortable at higher degree. Other tropical countries like China and Hong Kong¹ have defined this at 26 degree C.

In the meantime, the US Energy Information Administration has estimated that Indian cities have more cooling degree days compared to major US cities². But this calculation is based on the assumption of the US standard that temperature above 18 degree C will require artificial cooling. Though this gives an indicative comparison, this can overestimate the cooling need in India as the current adaptive comfort does not require cooling to this extent. (see Graph 1: Estimating number of days that will require cooling in a year in selected cities)

Graph 1: Estimating number of days that will require cooling in a year in selected cities



Source: US Energy Information Administration <http://www.eia.gov/todayinenergy/detail.cfm?id=23512>

Nonetheless, the RAC numbers are growing rapidly. But it is not easy to get real world official estimates of their numbers. The only estimation of the number of RACs in the country comes from India's official submission to the Montreal Protocol that provides financial assistance to phase out ozone-depleting coolants in the machine. This is estimated to be about 17 million RAC units of below-3-tonne capacity in the country in 2008³. This if extrapolated on the basis of 10-year average sales as CSE has done it would be around 30 million units in homes and offices in 2015. Moreover, the sale of RACs was pegged at 4 million units in 2014 and it is projected to grow at about 10 per cent over next five years⁴. The industry hopes to achieve 20 per cent growth rate under right policy impetus⁵.

This growth will have impact on electricity consumption. Centre for Science and Environment (CSE) has projected that electricity consumption by RAC might double by 2024 if the RAC sales continue to grow at 10 per cent annually and Bureau of Energy Efficiency (BEE) used to regulate the sector with four per cent energy efficiency ratcheting every two years with its star labelling programme. BEE last revised the RAC star rating on January 1, 2014. But BEE has subsequently notified on August 21, 2015 stating that the 2014 rating will continue till 31 December 2017⁶. This means the star rating will not be revised until 2018. Thus, the revision which was originally due on January 1, 2016, BEE has deferred this to January 1, 2018. CSE estimates that RACs might be consuming about 96TWh (96 billion units) of electricity if they function as per their efficiency rating (vintage adjusted) and operated for 8 hours a day for 180 days a year. This means that RACs must be responsible for almost third of 295 TWh electricity consumed by homes and offices in 2014-15 as reported by the Central Electricity Authority⁷.

Rapid expansion of air conditioned space will not only upset the energy budget of the households but also that of the country. The BEE estimates that RAC's contribute as much as 20-30 per cent of electricity consumption at the household level⁸. With the demand for space cooling expected to triple between 2010 and 2050, the priority for countries with hot climates should be to reduce the need for cooling with energy efficiency standards, passive architectural design, use of highly reflective external surfaces, and wide adoption of high-performance cost-effective air conditioners.

But technology will have to deliver on the energy saving targets. While full energy efficiency gains and cost recovery from it are made from long term usage, effective real world performance under all operative conditions including short duration climatic stress are important to reduce peak load in cities. If energy performance and cooling capacity deteriorate substantially during hot summer it will undermine overall real energy savings. Policies can address this concern.

Whither policy?

To ease the growth in electricity consumption in the building sector, BEE has initiated a programme of standards and labelling for appliances in 2006. Star rating for air conditioners were made mandatory in 2010, and have been ratcheted in 2012 and 2014. The standards are set in terms of the energy efficiency ratio (EER). The higher the ratio less is the energy use. Currently minimum EER permissible for window AC is 2.5 w/w and for split AC is 2.7 w/w. (see Table 1: Star Rating Band valid from 01 January 2016 to 31 December 2017). Window ACs with EER higher than 3.3 w/w is labelled 5 star. The 5 star split AC is 3.5 w/w or higher⁹.

**Table 1: Star Rating Band valid from 01 January 2016 to 31 December 2017
(for split RAC)**

Star Rating	Minimum EER (W/W)	Maximum EER (W/W)
1 Star *	2.70	2.89
2 Star **	2.90	3.09
3 Star ***	3.10	3.29
4 Star ****	3.30	3.49
5 Star *****	3.50	

Note: There is no tolerance for the Star Rating Bands. All tested products must meet the minimum threshold for each Star Rating Band.
Source: Bureau of Energy Efficiency

These levels are significantly lenient than that of other countries. A rapid review of the energy efficiency standards of different countries including Australia, Brazil, Canada, China, European Union, Japan, Korea, South Africa, USA and India show that minimum EER level allowed and the average EER are among the worst in India. (See Graph 2: Energy efficiency standards in different countries). According to a 2014 Lawrence Berkeley National Laboratory(LBNL) report, “Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges,” India’s average—of all the RAC sold in India—is equivalent to China’s minimum EER requirement¹⁰. China’s highest rated AC has an EER of over 6 and the best commercially available technology currently sold in Japan has higher EER of 6.67. Indian levels are significantly lenient than China and Brazil.

Graph 2: Energy efficiency standards in different countries

Country	Minimum energy efficiency ratio (EER)** allowed	Maximum EER available	Average EER
Australia	2.75	5.75	3.16
Brazil	2.92	4.04	3.19
Canada	2.14	4.33	3.6
China	2.9	6.14	3.23
EU	2.21	5.55	3.22
Japan	2.37	6.67	4.1
Korea	3.05	5.73	3.78
South Africa	2.28	5	2.91
USA	-	4.6	3.04
India	2.7	3.8	2.9

Source: Amol A. Phadke, Nikit Abhyankar, and Nihar Shah 2014, *Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges*, Lawrence Berkeley National Laboratory, Berkeley, USA

The star labelling procedure of BEE requires the manufacturer to submit a self or third party efficiency test report. The testing laboratories are to be accredited with NABL if Indian or with equivalent accreditation agency in the country where the lab is located. The tests are carried out as per Indian standards and BEE protocol. The RAC model is assigned star label based on self reported data from the manufacturer. BEE does not carry out any testing at this stage. But BEE can collect random samples from market anywhere in India and get them tested for compliance. Random sample testing is usually limited to 80-100 units in a year, and a model need not get tested the same year as it is launched in the market. To put things in perspective 1,862 models of RAC have been registered with BEE between 2013 and 2015.

BEE had published names of models which fail its random sampling in 2014 and 2015. The advert released on 23 March 2015 by BEE showed that the models of Samsung, Godrej, Panasonic, O General, Whirlpool, IFB and Videocon had failed the compliance test¹¹. Their 3 star and 4star RAC models could not qualify for 1star rating. Models by Samsung, Panasonic and Godrej were also named in 2014 list. These companies had countered BEE's findings by claiming that the models named by BEE had been discontinued even before the results came out¹². Companies introduce new models every year with some having target of introducing at least 20 in one year. These models in general have a shelf-life of 2 years. It has been noted that companies periodically change the model names by modifying any minor feature, thus escaping BEE scrutiny.

Consumer Voice, a New Delhi based voluntary action group with the Department of Consumer Affairs, Government of India, carried out independent testing of split RACs in 2014 to ascertain their efficiency claims. They tested nine most popular brands for energy efficiency and found that none of the tested models confirmed with their label. Five of the nine brands tested showed lower EER than what they claimed on the label, while four others had slightly higher¹³. The test also reported discrepancy in cooling capacity or tonnage reported by the brands, most of the brands had lower capacity than what they claimed on the product label.

BEE under its (Particulars & Manner of their display on Labels of Room Air Conditioners) Regulation 2009 has provision of penalty and recall if a model is found to be non-compliant but BEE has limited itself to naming and shaming exercise. Further, no reports on compliance have been made public by BEE since the publishing of advert in March 2015.

As BEE will continue with periodic revision of the star rating system of RACs, it is important to inform that process for more robust test procedure to ensure that RACs perform to deliver on their efficiency targets. This concern has led to this study to understand the impact of some of the key operative climatic conditions in the real world where outdoor ambient temperature is a major determinant. Tests have therefore been carried out to see the impact of changing outdoor ambient temperature on the energy efficiency performance of the RACs.

How is policy addressing the connection between outdoor ambient temperature and RAC's energy performance in the real world?

Relationship between outdoor ambient temperature and energy performance of RACs: It is a well known fact that air conditioners are responsible for rise in maximum load (peak) of energy consumption across cities. Their use increase when outside temperature is high. Both residential and commercial space cooling demand has a significant seasonal correlation. The LBNL report has estimated that there is at least 40 per cent difference between summer and winter afternoon peak and 60 per cent difference in the summer and winter evening peak in cities like Delhi because of electricity demand from ACs. The LBNL study says that several load surveys in India have found that the space cooling demand in India is highly coincidental with the peak demand¹⁴. AC's contribution to the peak demand is significant.

The peak electricity demand traditionally coincided with evening hours when the artificial lights are on en masse along with mechanical cooling devices. But this trend has shifted as peak demand is now observed in the afternoon around 3:30 o'clock in cities like Delhi and Kolkata. During afternoon there are a few hours when peaking of residential and commercial demand overlap. Both Mumbai and Delhi experience afternoon peaking during summer. The peak demand in winter drops by nearly 40 per cent and 25 per cent respectively in Mumbai and Delhi. In Delhi, air conditioning now accounts for the highest consumption of electricity during the hottest months, accounting for about 28 per cent of the total monthly electricity consumption. According to an estimate by BEE, ACs also contributes almost 60 per cent of the Delhi's peak electricity demand.

This reflects wider use of AC as primary cooling device in place of desert cooler and fans. Air coolers consume 80-90 per cent less electricity compared to RACs. A 1.5-ton AC consumes about 1.2-1.5 units in an hour, whereas an air cooler consumes just 0.2-0.3 units in an hour. Therefore every air cooler being converted to RAC increases the energy demand six times. Yet another factor impacting electricity peak is mass replacement of energy guzzling incandescent light-bulbs with energy efficient varieties, which has mellowed the impact of switching on of light fixtures in the evening. All this is further worsened by dominant building designs which by the virtue of lack of insulation and shading act as heat magnet making them captive users of artificial means of cooling and also use of artificial lighting during day time.

According to the newly released report of the Central Electricity Authority (CEA) on Load Generation Balance Report 2016-17 India faced a peak load deficit of 3.2 per cent while total electricity availability deficit was about 2.1 per cent in year 2015-16¹⁵. The

report also shows the difference in electricity consumption pattern between urban and rural regions. For instance, Delhi is consuming more electricity than any individual state of Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Chhattisgarh, Goa, Kerala, Bihar, Jharkhand, Odisha, Sikkim and all states of North-east. Delhi's peak demand has doubled in last 10 years, growing faster than the population of the city. Delhi registered all time high peak demand on 1 July, 2016 at 6,260 MW¹⁶. This was the fourth time within the season that record was broken and this demand was higher than CEA projection of 6,100 MW for Delhi's peak in 2016-17 and double of the highest ever peak of Mumbai. CEA estimates Delhi's peak to cross 12,000 MW by 2021¹⁷.

As peak load in cities now coincide and correlate with external temperature conditions, it is critical to understand impact of temperature conditions on energy performance RACs to effectively address growing peak energy crisis in the country.

Current test procedures for testing performance of RACs in different temperature conditions

Testing and certification of RACs are designed to address the energy performance under different temperature conditions. Technically RAC testing standards are defined for two operative conditions -- i) the regular working temperature conditions and ii) the maximum working temperature conditions. Energy performance parameters and cooling capacity are tested under regular working temperature conditions. The maximum temperature conditions are used only to test the reliability of the system under severe climatic stress to provide the minimum comfort. This does not include energy performance test.

Indian standards have been derived from International Standard Organisation. International Standard Organisation's ISO 5151:2010 "Non-ducted air conditioners and heat pumps -- Testing and rating for performance" is the main standard governing RAC ratings internationally. ISO has differentiated weather conditions as T1 (mild), T2 (cold) and T3 (hot). For each climatic condition the ISO has specified the outdoor ambient temperature and indoor temperature and also the maximum level for each climatic condition. In India, BEE has adopted testing code and procedure for air conditioners as per IS1391 Part 2 with all amendments. (See Table 3: ISO classification of outside temperatures).

Table 3: ISO and Indian classification of outside temperatures with corresponding indoor temperature requirement

Classification	Ambient temp. °C	Indoor temp. °C
ISO standard		
ISO-T1 (mild)	35°C (24°C)	27°C (19°C)
ISO-T2(cold)	27°C (19°C)	21°C (15°C)
ISO-T3 (hot)	46°C (24°C)	29°C (19°C)
Indian Standard	35°C (-)	27°C (19°C)

Note: Value in parenthesis is indicative of wet bulb temperature which reflects the humidity level

Source: ISO 5151:2010 "Non-ducted air conditioners and heat pumps -- Testing and rating for performance" and IS 1391 Part 2

Table 4: ISO and Indian Classification of maximum operation conditions with corresponding indoor temperature requirement

Classification	Ambient temperature °C	Indoor temperature °C
ISO standard		
ISO-T1 (mild)	43°C (26°C)	32°C (23°C)
ISO-T2(cold)	35°C (24°C)	27°C (19°C)
ISO-T3 (hot)	52°C (31°C)	32°C (23°C)
Indian Standard	46°C (27°C)	35°C (24°C)

Note: Value in parenthesis is indicative of wet bulb temperature which reflects the humidity level

Source: ISO 5151:2010 "Non-ducted air conditioners and heat pumps -- Testing and rating for performance" and IS 1391 Part 2

India has adopted ISO's T1 or mild climate conditions for all RAC testing in India. Under this the RACs are tested for the range specified for T1 (mild climate) i.e 35 degree C for outdoor and 27 degree C for indoor. The energy efficiency is also tested in this range. For maximum operating condition the ambient temperature considered is 46 degree C and indoor is 35 degree C. This is lower than the ISO's T3 hot climate requirements which for normal working condition specifies 46 degree C external temperature and 29 degree C internal temperature; maximum operating condition is 52 degree C outdoor and 32 degree C indoor.

This study aims to assess what is the energy penalty associated with rating of RAC efficiency as per the current system in India.

About the RAC testing

CSE commissioned an independent National Accreditation for Board for Testing and Calibration Laboratory (NABL)-accredited laboratory to test RAC units and generate information on i) effect of high external temperature; ii) effect of lower internal temperature setting on the real world energy performance and; iii) effect of higher external relative humidity conditions on the real world energy performance. Three popular 5-star RAC models (split RACs) were bought from the market and tested for their energy efficiency and cooling performance using the balanced ambient calorimeter method.

Why Split RAC were selected for the study?

As per the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) the maximum growth has taken place in split RAC segment which is over 61 per cent of AC sales in India. The RAC market has grown from 3.8 million in 2013 to about 4 million in 2014. This includes window ACs (605,000), splits (2,445,000), floor mounted units (15,000), cassettes (80,000), inverter ACs (200,000), ductables and packaged units (90,000), and VRV/VRF (25,000)¹⁸. Therefore, this split RAC segment has been selected for this study.

As per BEE, around 38 brands of air conditioners are registered for star rating. For this study RAC models from Voltas, LG and Godrej were used. These three brands among themselves account for about 50 per cent of Indian RAC market share. According to ISHRAE reports Voltas is biggest RAC brand in India followed by LG. Though Daikin, Panasonic and Samsung have higher market share than Godrej, the company was chosen as it is the second biggest Indian brand.

Further, most popular 5 star rated 1.5 tonne RAC models were used in consideration that this is the most sold category. Popularity was determined by user rating given to the models on online shopping portals Flipkart and Amazon as accessed on 11 March 2016. (See Table 2: details of sample AC model selected for testing).

However, it is stated at the outset the purpose of this study is not to rank the manufacturers or their products but to take popular models that represents large market share to understand performance under climate stress. Results are indicative of the trend.

Table 5: Sample model details

Brand	Volta	LG	Godrej
Model	185 CY	LSA5NP5A	GSC 18 FGA5 WOG
Maximum Retail Price	Rs. 45,590	Rs. 40,990	Rs. 44,450
Star Rating	5	5	5
Capacity (ton)	1.5 ton	1.5 ton	1.5 ton
Capacity (Watt)	5,000 W	5,275 W	5,000 W
Power	1,424 W	1,465 W	1,408 W
EER (w/w)	3.51	3.60	3.55
Refrigerant	R22	R22	R290
Charge Quantity (gram)	690	780	375
Dehumidification	No	Yes	No
Compressor	High EER Rotary	Rotary	Rotary
Dust Filter	Yes	Yes	Yes
Anti-bacteria Filter	Yes	Yes	Yes
Operating Current	6.4 A	6.7 A	6.1 A
Power Requirement	AC 230 V	AC 230 V	AC 230 V

Source: Labels on the tested RAC

About the test

Each sample was operated in defined controlled conditions for 8 hours and their performance was recorded. (See Table 3: Test Conditions).

Table 6: Test conditions

	Indoor temperature	Outdoor temperature	Relative Humidity
Standard test as per IS 1391 Part 2 Standard incorporating Amendment 3 July 2010	27o C	35o C	Humidity not defined
Custom Test A	27o C	40o C	Humidity not defined
Custom Test B	27o C	45o C	Humidity not defined
Custom Test C	27o C	50o C	Humidity not defined
Custom Test D	20o C	35o C	Humidity not defined
Custom Test E	27o C	35o C	55% (maximum achievable in the lab)

Source: CSE

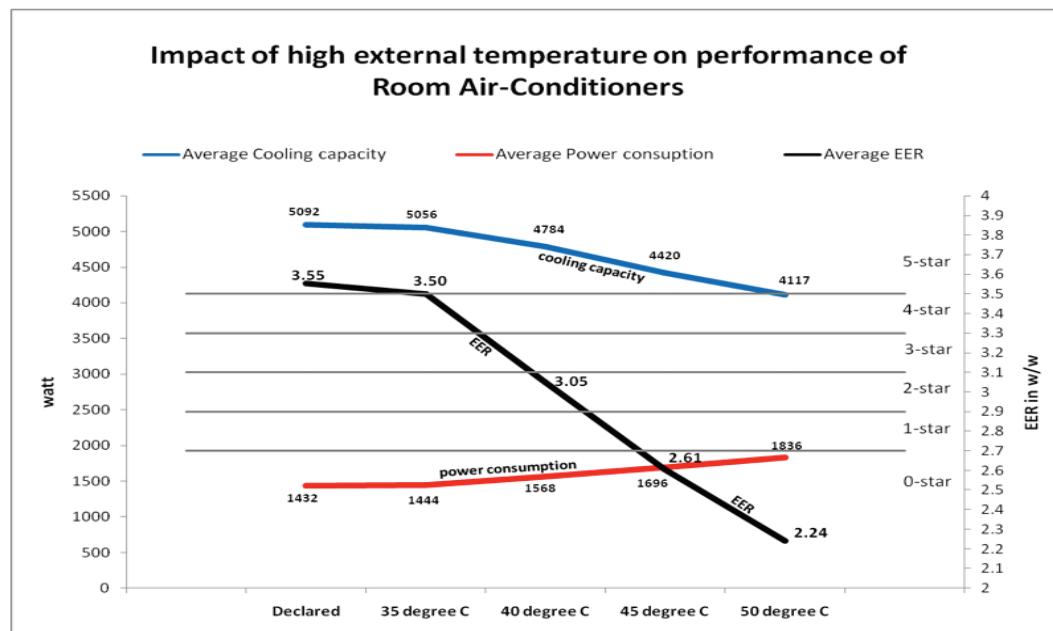
A split air conditioner is made up of two primary parts: the evaporator and the compressor. These elements are common in window air units and wall air conditioners. The difference with a split system is that they are separated into two different and distant components, one being outdoors and one being indoors. The outdoor section is a compressor that initiates the cooling process, while the indoor component consists of an evaporator and fan. The two sections are connected with a set of electrical wires and tubing, also called lines, used to transport air between the two sections. During the test the indoor unit of the air conditioner was mounted on the wall 1 m below the ceiling. The outdoor unit was mounted on the stand 1 m from the wall and the floor. The indoor unit and outdoor unit were connected by 5 m insulated copper pipes. The portion of the wall opening not occupied by the test sample was blocked off with four inch thick PUF insulation panel. The temperature control was positioned at the "Max" (18 Deg C) setting, the fan motor in the "High" position as per manual and the louvers were kept straight.

Findings

The tests have thrown up some significant aspects of real world performance. The RAC makers make several claims regarding energy and power consumption on their label. Companies declare technical specifications of the product on the product packaging. These labelling are governed by BEE regulations and are to be according IS 1391 Part 1 and 2. As mentioned earlier BEE conducts random testing to check compliance with energy label i.e. EER, but not necessarily of other attributes like cooling capacity and power input. It has been possible to verify some of those claims.

The most stark revelation of the test results is that as the outside temperature increases substantially the cooling capacity and energy efficiency ratio decreases and power consumption of RACs increases. (see Graph 3: With increased outdoor temperature power consumption increase while energy efficiency and cooling capacity reduces). The details are as follow.

Graph 3: With increased outdoor temperature power consumption increase while energy efficiency and cooling capacity reduces



Source: CSE

i. Impact of external temperature on the energy performance of room air conditioners

Energy efficiency ratio (EER) of sample units dropped with increase in external temperature conditions. Energy efficiency dropped on an average of 2.5 per cent for every degree rise in external ambient temperature above 35 degree C. This means a 5 star RAC performed like a 2 star RAC and worse than a 1star RAC when external temperature crosses 45 degree C. It continued to deteriorate with rise in temperature. At 50 degree C external ambient temperature the average EER measured was at level which was outlawed in 2010 by BEE. (see Table 7: Difference between declared EER and measured EER (watt/watt)

Table 7: Difference between declared EER and measured EER (watt/watt)

	Declared EER and Star rating	Measured EER @ 35° C (Standard) and Star rating	Measured EER @ 40° C and Star rating	Measured EER @ 45° C and Star rating	Measured EER @ 50° C and Star rating
Voltas	3.51 (5star)	3.51 (5star)	3.04 (2star)	2.56 (0star)	2.23 (0star)
LG	3.60 (5star)	3.56 (5star)	3.15 (3star)	2.73 (1star)	2.36 (0star)
Godrej	3.55 (5star)	3.43 (4star)	2.96 (2star)	2.53 (0star)	2.13 (0star)

Source: CSE

The power input or consumption of sample units went up with increase in external temperature conditions: On an average power input/consumption increased by 1.9 per cent for every degree rise in the external ambient temperature above 35 degree C. At 50 degree C RAC units consumed 28 per cent more power compared to their declared power input. This means in peak summer in composite and hot climate when afternoon external temperatures can hit 40-50 deg C, the RAC unit consumes 10-28 per cent more power, spiking the peak load demand on the electricity grid. It also means consumer is incurring more cost to run these AC during these peak summer times compared to what is advertised by BEE and the manufacturers. (see Table 8: Difference between declared power input and measured power input (in watt)

Table 8: Difference between declared power input and measured power input (in watt)

	Declared Power input	Measured Power input @ 35° C	Measured Power input @ 40° C	Measured Power input @ 45° C	Measured Power input @ 50° C
Voltas	1424	1420	1555	1702	1833
LG	1465	1493	1613	1725	1875
Godrej	1408	1420	1536	1662	1803

Source: CSE

Cooling capacity of sample units dropped with increase in external temperature conditions: On an average the cooling capacity dropped by 1.3 per cent on indoor side and 1.4 per cent on outdoor side from the declared cooling capacity for every degree increase in the external ambient temperature above 35 degree C. Overall 8-21 per cent drop was measured at 40-50 degree C from declared cooling capacity of the models. The drop was highest in Godrej and lowest in LG. Cooling capacity is the amount of heat removed from the room. (see Table 9: Difference between declared cooling capacity and measured capacity outdoor and Table 10: Difference between declared cooling capacity and measured capacity indoor)

Table 9: Difference between declared cooling capacity and measured cooling capacity outdoor (in watt)

	Declared cooling capacity	Measured cooling capacity outdoor @ 35° C	Measured cooling capacity outdoor @ 40° C	Measured cooling capacity outdoor @ 45° C	Measured cooling capacity outdoor @ 50° C
Volta	5000	4922.8	4620.1	4238.1	3978.3
LG	5275	5159.2	5023.5	4659.2	4314.4
Godrej	5000	4749.8	4471.7	4130.9	3734.6

Source: CSE

Table 10: Difference between declared cooling capacity and measured cooling capacity indoor (in watt)

	Declared cooling capacity	Measured cooling capacity indoor @ 35° C	Measured cooling capacity indoor @ 40° C	Measured cooling capacity indoor @ 45° C	Measured cooling capacity indoor @ 50° C
Volta	5000	4978.7	4730.2	4353.8	4082.9
LG	5275	5314.6	5075.8	4704.2	4419.6
Godrej	5000	4875.6	4546.9	4201.6	3847.9

Source: CSE

On an average the Net total sensible cooling effect (NTSCE) was lower: It was noted that under standard conditions the ability of the RACs were on an average about 77 per cent of the rated cooling capacity of the RACs. Net total sensible cooling effect (NTSCE) is a measure of the capacity of the unit for removing sensible heat from the space to be conditioned. When an object is heated, its temperature rises as heat is added. The increase in heat is called sensible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat. Heat that causes a change in temperature in an object is called sensible heat and its removal called sensible cooling effect. It is the actual amount of heat removed from a space so as to affect the indoor temperature as against the total heat removed by the RAC unit -- in other words, a RAC's ability to change room temperature. Tests found LG had best NTSCE at about 81 per cent of the rated capacity; and Volta recorded 74 per cent.

The study found that this went further down with increase in external temperature conditions. On an average NTSCE dropped further by 11 per cent as external temperature rose to 50 degree C and was reduced 69.40 per cent of the declared cooling capacity. (see Table 11: Difference between declared cooling capacity and measured NTSCE capacity)

Table 11: Difference between declared cooling capacity and measured Net total sensible cooling effect (NTSCE) (in watt)

Net total sensible effect (NTSCE)	Declared cooling capacity	Measured NTSCE @ 35° C	Measured NTSCE @ 40° C	Measured NTSCE @ 45° C	Measured NTSCE @ 50° C
Volta	5000	3722	3639	3396	3331
LG	5275	4282	4264	3921	3956
Godrej	5000	3830	3692	3503	3329

Source: CSE

ii. Impact of the internal room temperature on RAC's performance: Energy efficiency ratio (EER) of sample units dropped with lowering of internal room temperature: According to the India's National Building Code of the Bureau of Indian Standards the thermal comfort lies between temperature values of 25°C and 30°C with optimum condition at 27.5°C which is also influenced by age, metabolic rate and clothing and other climatic condition. But as comfort expectations of people are changing users often lowering room temperature to as low as 20 degree C. Average drop in the energy efficiency was measured at 15.31 per cent when the room temperature was lowered from 27 degree C to 20 degree C. This works out to be 2.19 per cent drop in EER for every degree lowering of internal temperature below the standard 27 degree C. This effectively means that performance of a 5star rated AC is equivalent to that of 2-3 star when the internal thermostat setting is lowered to 20 degree C. (see Table 12: Impact of lowering of internal temperature on energy efficiency ratio (in watt/watt)

Table 12: Impact of lowering of internal temperature on energy efficiency ratio (in watt/watt)

	Declared EER	Measured EER @ 27° C (indoor)	Measured EER @ 20° C (indoor)	Difference
Voltas	3.51 (5star)	3.51 (5star)	2.97 (2star)	15.39%
LG	3.60 (5star)	3.56 (5star)	3.13 (3star)	13.06%
Godrej	3.55 (5star)	3.44 (4star)	2.93 (2star)	17.47%

Source: CSE

Cooling capacity of sample units dropped with lowering of internal room temperature: Average drop in the capacity was measured at 20 per cent when the thermostats setting was lowered from the standard 27 degree C to 20 degree C. This works out to be 2.9 per cent drop in EER for every degree lowering of internal temperature below the standard 27 degree C from the declared capacity.

(See Table 13: Difference between declared cooling capacity and measured capacity outdoor based on internal temperature setting and Table 14: Difference between declared cooling capacity and measured capacity indoor based on internal temperature setting)

Table 13: Difference between declared cooling capacity and measured cooling capacity outdoor based on internal temperature setting (in watt)

	Declared cooling capacity	Measured cooling capacity outdoor @ 27° C (internal)	Measured cooling capacity outdoor @ 20° C (internal)	Difference
Voltas	5000	4956	3951.7	20.97%
LG	5275	5190	4324.8	18.01%
Godrej	5000	4782	3896.9	22.06%

Source: CSE

Table 14: Difference between declared cooling capacity and measured cooling capacity indoor based on internal temperature setting (in watt)

	Declared cooling capacity	Measured cooling capacity indoor @ 27° C (internal)	Measured cooling capacity indoor @ 20° C (internal)	Difference
Voltas	5000	4956	4053.1	18.94%
LG	5275	5190	4450.0	15.64%
Godrej	5000	4782	4003.4	19.94%

Source: CSE

The power input or consumption of sample units marginally reduced with lowering of internal room temperature: Average reduction in power input was measured at 3.35 per cent when the thermostat setting was lowered from 27 degree C to 20 degree C. This drop in power consumption is reflective of the drastic drop in the cooling capacity and not of the improved energy performance as the corresponding EER has also dropped. (See Table 15: Impact of lowering of internal temperature setting on power consumption)

Table 15: Impact of lowering of internal temperature setting on power consumption (in watt)

	Declared power input	Measured power input @ 27° C (internal)	Measured power input @ 20° C (internal)	Difference
Volta	1424	1420	1366	4.07%
LG	1465	1493	1420	3.07%
Godrej	1408	1420	1367	2.91%

Source: CSE

On an average Net total sensible cooling effect (NTSCE) or ability to lower the temperature of the room is also lowered: The study found that the NTSCE went further down from an average 77 per cent of declared cooling capacity at 27 degree C to 69.29 per cent of the declared cooling capacity at 20 degree C. This was an average 10.5 percent drop for seven degree lowering of internal thermostat setting from the standard 27 degree C. (See Table 16: Impact on net total sensible effect or effectiveness of the RAC sample)

Table 16: Impact on net total sensible effect or effectiveness of the RAC sample (in watt)

Net total sensible effect (NTSE)	Declared cooling capacity	Measured NTSCE @ 27° C(internal)	Measured NTSCE @ 20° C(internal)	Difference
Volta	5000	3722	3310	11.06%
LG	5275	4282	3866	9.72%
Godrej	5000	3830	3419	10.73%

Source: CSE

iii. Findings on the performance parameters declared on product label against measured performance as per IS 1391 Part 2 Standard incorporating Amendment 3 July 2010. Cooling capacity of the outdoor sub-unit of all the samples were found to be marginally less than claimed on their respective labels: On an average cooling capacity was 2.9 per cent lesser, with Godrej showing highest deviation of about 5 per cent and Volta showing least of about 1.54 per cent.

Tested EER (energy performance ratio) of some RAC samples were found to be inconsistent with their reported EER as on their label: Volta showed same EER while LG and Godrej had lower EER. Godrej's measured EER of 3.43 that fits in with 4star category instead of claimed 5 star of 3.55.

Computed power consumption of all the samples was found to be inconsistent with their reported power consumption as on their label. Volta showed lower power consumption while LG and Godrej consumed more power than claimed. But the deviations were marginal less than 2 per cent. These were marginal variation only, no major significance.

iv. Impact of high humidity on energy performance is uncertain: One of the objectives of the test was also to understand the impact of high humidity level on energy performance of the ACs. However, the maximum humidity that could be achieved under the lab condition was 55 per cent. Under these conditions there was not much impact or variation in the energy performance of the ACs compared to the results of the Standard test as per IS 1391 Part 2. However, the results were lower than the declared specification of energy performance. Marginal drop in EER in all the models noted when compared with EER measured at the standards test. A separate test will be needed to assess the impact of such high humidity as 90 per cent which was not possible to do under the test procedures applied for this study. (See Table 17: Results of Custom Test E (High Relative Humidity)

Table 17: Results of Custom Test E (High Relative Humidity)

	Declared cooling capacity (in watt)	Measured cooling capacity in high relative humidity (55%) (in watt)	Declared EER (watt/watt)	Measured EER in high relative humidity (55%)(watt/watt)	Declared power input(in watt)	Measured power input in high relative humidity (55%)(in watt)	Net total sensible cooling effect in high relative humidity (55%)(in watt)
Voltas	5000	4812	3.51 (5 star)	3.49 (4 star)	1424	1406	3695
LG	5275	5028	3.60 (5 star)	3.54 (5 star)	1465	1458	4151
Godrej	5000	4685	3.55 (5 star)	3.42 (4 star)	1408	1407	3747

Source: CSE

Observations on the findings and next steps

The findings of this study have implications for the way RACs are tested for energy performance and also for the real world energy and monetary savings. A 5-star RAC is supposed to save 20-22 per cent of energy cost compared to a 1-star RAC. But the findings show that in the peak heat of the summer when temperature crosses 40 degree C mark in most of north India, the 5-star RAC can be consuming 10-28 per cent more than their declared rated capacity. Ofcourse, the performance of the 1 star RAC is expected to be even worse.

Moreover, cooling capacity drops by almost 30 per cent, which means a 1.5 ton RAC will act like a 1 ton RAC. This means that there is neither cooling nor saving - if one is running the RAC at 27 degree C setting. Lowering of the internal temperature can further worsen its performance.

Even though the full energy efficiency gains from technology improvement are realised from the overall length of usage over time, the short duration spikes can undermine long term gains and savings. But addressing this is important to manage the peak demand loading. Just to give an indicative idea it may be noted that normally, in monetary terms, running a 5-star RAC for couple of hours of peak afternoon during summer should cost just about Rs. 490 a month. But with worsening of performance it will cost anywhere between Rs 660-780. It will also cool 30 per cent less (based on Delhi's non-subsidized tariff rate of Rs 5.8 per unit). With climate change and more extreme weather conditions this will have serious implications in the longer run.

It is therefore recommended that BEE reviews the critical test parameters to address this

concern. India's star labelling programme for RACs has adopted only T1 requirement of mild climate under the ISO that defines working conditions as 35 degree C external ambient temperature and 27 degree C for indoor temperature, and defines maximum working conditions at 46 degree C external ambient temperature and 35 degree C as internal temperature. Even though the maximum working conditions are defined at 46 degree C for external ambient temperature, this is done only to check reliability of the system under extreme conditions and not to test energy performance.

With climate change more exacting and short duration extreme temperatures can be experienced more frequently during hot summers in northern and western India. It is important therefore that based on the high temperature profiling of different climatic zones and micro climatic conditions BEE and BIS adopts an additional test procedure based on higher temperature representative of Indian conditions.

This is justified based on the observed temperature data in different climatic zones of India. The temperature data available from the Bureau of India Standards for 60 cities in different climatic zones show that 41 out of 60 cities have at least 175 hours in a year when external ambient temperature is above 35 degree C. As many as 22 out of 41 cities that include Delhi-NCR, Jaipur, Ahmedabad, Lucknow and Raipur have temperature around 40 degree C or above according to National Building Code "summary for outdoor design conditions"¹⁹. Based on this it can be safely assumed that almost whole of north Indian plains has at least 175 hours in the year when ambient temperature is above 40 degree C.

Moreover, BEE in its energy conservation building code and BIS in national building code recognise that India has five distinct climatic zones and layouts comfort and heating, ventilation, and air conditioning (HVAC) design guidelines are done according to the climatic peculiarities. It would be advisable to extend the same distinction to space cooling and heating equipments as well as their performance that has high correlation with climatic conditions.

In addition to this, it is important to recognise that even within composite and hot and dry climatic zones there is wide variation in micro climatic conditions that can record much higher temperature than the overall ambient temperature. This is going to get further aggravated in cities expanding concrete space rapidly and falling into the grip of heat islands. A study by IIT Delhi has found that urban centres in India are becoming hot-spots for urban heat island effect. The study has found that dense urban areas and highly commercial areas in Delhi have highest urban heat island effect with maximum hourly magnitude peaks by another 10.7 °C and average daily maximum urban heat island effect by another 8.3 °C.

This means the temperature in the urban cores where most of the RACs are installed have local temperature conditions almost 8-10 degree C higher than the overall ambient air temperature recorded at the weather stations for the city.²⁰ For instance average ambient temperature conditions in Delhi in months of April, May and June is about 38 degree C but micro-climate of Connaught Place, central business district in Delhi, during same time would be 46-48 degree C. Also RACs themselves contribute to the heat island by warming up the immediate environment outside.

In fact, it is not clear why India has adopted 35 degree C internal temperature for maximum range which is not considered comfortable living conditions; 32 degree C is the upper limit for internal comfort temperature range under all national and international comfort standards and guidelines.

It is however to be noted that though India has not adopted ISO's T3 test parameters for products to be sold within India, these conditions are found in the Indian standard (i.e. IS 1391 (Part 2); 1992 Annex - C (Clause 6.1.2.2) Rating Conditions For Units Intended For Export) that are applicable to the units that are meant to be exported.

Yet another significant finding of the study confirms once again that lowering of internal room temperature of the RAC adversely affects the unit's energy efficiency and cooling capacity. This requires widespread consumer awareness programme to sensitise people about the energy penalty of very low room temperature.

There is also the issue of customer misinformation as energy saving claims by RACs are not vetted real time.

International Best Practice

International best practice shows that the countries with harsh summer have adopted both T1 (mild climate) and T3 (hot climate) test parameters of ISO. Saudi Arabia which mandated star rating for RACs in September 2013, has defined energy efficiency benchmarks for both T1 and T3, and every RAC units have to meet both. The minimum EER set for split AC is 2.78 w/w in T1 conditions (India's minimum is 2.70 w/w) and 2.00 w/w in T3 conditions (India has no minimum defined for this condition). Saudi Arabia ratcheted the star rating in 2015 bringing its T1 minimum to 3.37 w/w (4star in India) and T3 minimum to 2.43 w/w²¹. By doing this Saudi Arabia is not only ensuring efficient performance of the RACs during wide range of temperature conditions also during the extreme heat.

Bahrain adopted Saudi model in 2016²².

RAC star rating in Dubai is based on T3 hot climate conditions when ambient dry bulb temperature is 46°C and ambient wet bulb temp is 24°C in hot climate²³.

Australia has 10 star rating system for RACs and with minimum EER mandate of 2.75 w/w. To make the ratings reflect the real world operations the current star rating system is based on an annual efficiency calculation (AEER) which includes non-operational energy consumption such as standby power, and power consumption of crank case heaters (where present). This gives a more accurate representation of energy efficiency across the year. It also acknowledges that the energy efficiency and performance of a certain appliance especially RACs can be impacted by where it is installed (location) and other factors such as usage patterns and climate variations, including air temperature, water temperature, frosting, humidity and cloud cover. Therefore Australia has proposed a move to a zone based energy efficiency labelling system for some products or product categories.²⁴

Other governments intervene to define cooling needs: Without proper policy guidance there is a misconception that drastic lowering of thermostat setting of the RAC to as low as 18-19 degree Celsius will provide the desired comfort. But every degree reduction in thermostat setting of the RAC, there is increased energy consumption of three to ten per cent. But by setting the RAC a couple of degrees higher and using fan to blow cool air uses a lot less electricity than just setting the air conditioner to a lower temperature. Tests in Tokyo indicate that raising the air conditioner's thermostat from 26° C to 28° C and using an electric fan can reduce electricity consumption by up to 22 percent²⁵. After the Fukushima disaster when Japan faced major power crisis, Japanese government mandated that all ACs in the country should not run at temperature setting lower than

28°C. It introduced Bush Shirt rule to relax dress code in work place to encourage comfortable clothing.

In fact the, National Building Code of India (NBC) states that the thermal comfort of a person lies between temperature values of 25°C and 30°C with optimum condition at 27.5°C which is also influenced by age, metabolic rate and clothing and other climatic condition.

The way ahead

In view of the findings of this study it is recommended that the Bureau of Energy Efficiency urgently reviews the current test procedures for energy performance and comfort related parameters for the rating of the RACs and take the following steps to deliver on targeted energy efficiency performance:

- BIS should amend IS 1391 part 2 to incorporate an additional test for testing of energy efficiency ratio based on multiple higher temperature range for different climatic zones for rating and testing of air conditioners.
- BEE should make it mandatory for the manufacturers to declare the tests results carried out based on multiple higher temperature range and declare the results on their product label. Adapt the star rating to this system.
- Manufacturers should declare the annual energy consumption based on cooling capacity tests
- Manufacturers be asked to do detailed and precise labelling indicating exact cooling tonnage etc.
- Ratchet the existing star rating to get best technology in the Indian market.
- Need more aggressive interventions to promote passive architectural features to reduce thermal load of the buildings

Even though this study is limited to split RACs, similar assessment will have to be done for inverter ACs and window ACs. It is desirable that at the next level of review of the star labelling programme all the system should be further modified to make the labelling programme technology neutral and develop more stringent test programme and oversight for monitoring real world performance.

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