

Accelerating Improvements in the Energy Efficiency of Room Air Conditioners (RACs) in India: Potential, Cost-Benefit, and Policies (Interim Assessment)

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Summary

Falling AC prices, increasing incomes, increasing urbanization, and high cooling requirements due to hot climate are all driving increasing uptake of Room Air Conditioners (RACs) in the Indian market. Air conditioning already comprises 40-60% of summer peak load in large metropolitan Indian cities such as Delhi and is likely to contribute 150 GW to the peak demand in 2030. Standards and labeling policies have contributed to improving the efficiency of RACs in India by about 2.5% in the last 10 years (2.5% per year) while inflation adjusted RAC prices have continued to decline. In this paper, we assess the technical feasibility, cost-benefit, and required policy enhancements by further accelerating the efficiency improvement of RACs in India.

We find that there are examples of significantly more accelerated improvements such as those in Japan and Korea where AC efficiency improved by more than 7% per year resulting in almost a doubling of energy efficiency in 7 to 10 years while inflation adjusted AC prices continued to decline. We find that the most efficient RAC sold on the Indian market is almost twice as efficient as the typical AC sold on the market and hence see no technology constraints in a similar acceleration of improvement of efficiency.

If starting 2018, AC efficiency improves at a rate of 6% instead of 3%, 40-60 GW of peak load (equivalent to connected load of 5-6 billion LED bulbs), and over 75 TWh/yr (equivalent to 60 million consumers consuming 100 kWh/month) will be saved by 2030; total peak load reduction would be as high as 50 GW. The net present value (NPV) of the consumer benefit between 2018-2030 will range from Rs 18,000 Cr in the most conservative case (in which prices don't continue to decline and increase based estimates of today's cost of efficiency improvement) to 140,000 Cr in a more realistic case (in which prices are not affected by accelerated efficiency improvement as shown by historical experience). This benefit is achievable by ratcheting up the 1 star level for fixed and inverter ACs to the level of today's five star rating for inverter ACs by 2022. Bulk procurement (similar to the Domestic Efficient Lighting Program) and incentive programs can complement the accelerated ratcheting up of star levels. Similar programs can also be implemented for other types of ACs.

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1 What is at Stake: The Need to Meet Space Cooling Demand Sustainably

Air Conditioner (AC) use is increasing rapidly in India because of the falling AC prices, increasing incomes, increasing urbanization, and high cooling requirements due to hot climate (Phadke et al 2014). The annual sales for room ACs (RACs), which is the most common type of AC, have grown at a Compounded Annual Growth Rate (CAGR) of about 13% per year between 2005 and 2014 (Shah et al, 2013, Phadke et al 2014 and PWC, 2015). An AC is highly electricity intensive; at full load, a typical RAC consumes about 150 times the power of a LED bulb.¹ Given many parts of India routinely experience extremely hot temperatures, increasing availability and affordability of space cooling technologies including fans and ACs in addition to improving building design to provide thermal comfort are opportunities to improve health and economic wellbeing. A recent study by Davis and Gertler (2015) shows that India is the country with the largest AC market growth potential in the world due to its large population and high number of cooling degree days² (Figure 1), low but rising incomes, and rising extreme temperatures due to climate change. The Government of India's Bureau of Energy Efficiency (BEE) has highlighted the nation's concern regarding the already large electricity demand from ACs, which was estimated by BEE to be about 60-80 TWh in 2014.³ In addition, in areas with significant AC penetration, there is a large peak load impact. For example, in New Delhi, cooling represents 40-60% of the summer peak load. In places like Australia with even higher AC penetration (as a percentage of population), the load can triple on hot days (Figure 2).

¹ The most common cooling capacity for an AC in India is 1.5 tons, i.e. roughly 5.25 KW of cooling. At an Indian Seasonal Energy Efficiency Ratio (ISEER) of 3.5, this is roughly 1.5 KW of power consumption which is roughly 150 times the power consumption of a 10-Watt LED bulb.

² Cooling Degree Days: A cooling degree day is a unit used to estimate the need for space cooling based on the daily temperature. Annual cooling degree days are calculated by subtracting 65 from a day's average temperature in Fahrenheit and adding the results over a year.

³ BEE 2014, Workshop on "[Space Cooling Efficiency Enhancement and Demand Response](#)" Presentation on India AC Efficiency Policy Opportunities & Current Activities, Saurabh Diddi, Energy Economist, Bureau of Energy Efficiency, July 2014.

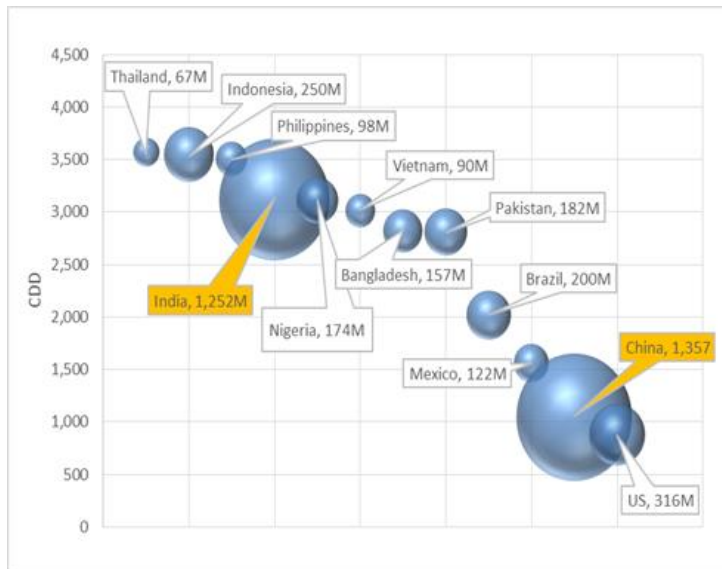


Figure 1: Top 12 countries by air conditioning potential measured in cooling degree days (CDD), the size of the bubble indicates the relative population size (Source: Davis and Gertler, 2015)

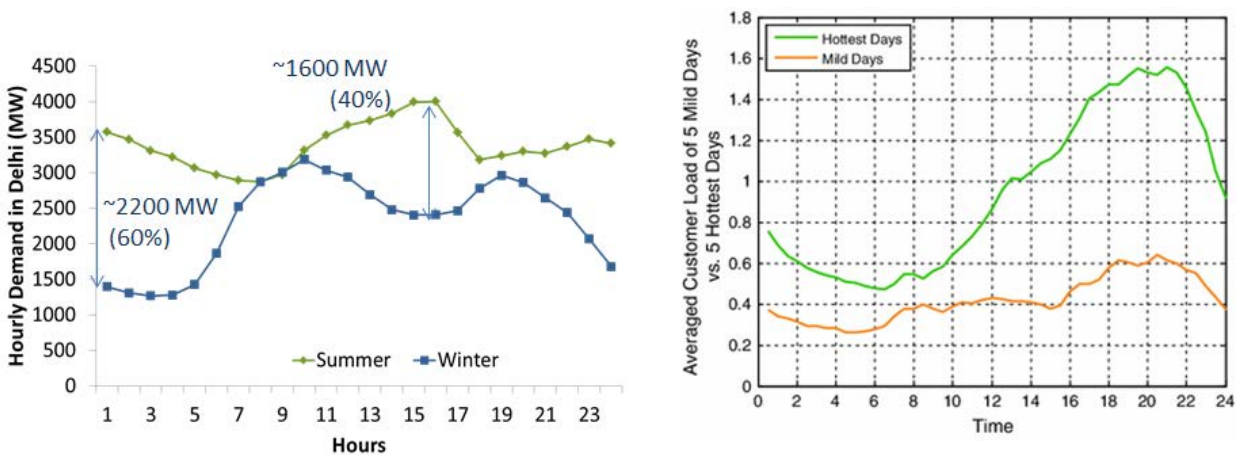


Figure 2: Space cooling load in New Delhi is 40-60% of summer peak load (left), while AC can triple load in the hottest areas e.g. New South Wales, Australia (right)

Data sources: (DSLDC, 2012, Smith et al 2013)

RAC penetration was a little over 5% in urban India in 2011 (NSSO 2012, Phadke et al 2014). RAC penetration in urban China grew from about 5% in 1995 to over 140% in 2015 (Fridley et al, 2012, IBISWorld, 2016). In the absence of additional policy intervention, under a business as usual scenario, room AC penetration is expected to rapidly increase in India and add about 150 GW to the peak demand (equivalent to 300 power plant units of 500 MW each) by 2030 and between 300-500 GW by 2050 (Phadke et al 2013, Shah et al 2015).

A holistic strategy is needed for meeting the challenge of increasing electricity demand from RACs sustainably. This document aims to present a vision for efficient and smart air conditioning equipment in India with a focus on drawing on Indian and international experience in using policies to drive faster adoption of efficient air conditioning, mainly focused on mini-split RACs. We recognize that efficient and smart air conditioning is only one of the strategies to meet cooling demand sustainably and needs to be complemented by other strategies, such as cool roofs, better building design, and energy management systems.

In Section 2, we review the current status and trends of RAC efficiency in India and summarize the policies that have been used to drive RAC efficiency. In section 3, we summarize similar experience in Japan and Korea where RAC efficiency has almost doubled in a span of about ten years and draw insights that are relevant for future policies to accelerate RAC efficiency improvements in India. In section 4, we assess technical feasibility and cost-benefit of scenarios of faster improvement in AC efficiency in India and discuss potential policies that can be used to achieve the same. In Section 5, we provide recommendations for additional research and policies.

2 RAC Efficiency and Policies in India

The Energy Conservation (EC) Act 2001 provides the legal and institutional framework for the Government of India to promote energy efficiency across all sectors of the economy. The Bureau of Energy Efficiency (BEE) was created under the Ministry of Power to implement the EC Act.⁴ The Standards and Labelling (S&L) Program was launched by BEE in May 2006 as a voluntary scheme with an overarching agenda to reduce the energy intensity of electrical appliances used in the country. The label provides a comparative 5-star rating system based on annual or daily energy consumption. The star labelling scheme combines comparative star labels with Minimum Energy Performance Standard (MEPS) such that products that pass the minimum energy efficiency requirements specified by BEE are awarded 1-star while the consumption norm specified by the five star level is the most stringent efficiency criteria, typically awarded to some of the most efficient products available on the market. BEE typically revises the rating criteria every few years. Since 2010, mandatory labelling was introduced for Room Air Conditioners (split and window) under this scheme⁵.

Historically, BEE has been revising the efficiency performance criteria and the energy efficiency ratio (EER) for star levels every two years (see Table 1), and has done so about two years in advance of implementation to give the AC industry time to adjust their supply.

⁴ EC Act amended in 2010 to empower BEE to accredit energy auditors and to hire its own staff, and the Central Government to issue energy savings certificate

⁵ Standards and Labeling, BEE, <http://beeindia.in/content.php?page=schemes/schemes.php?id=2>

Table 1: BEE star rating levels for split ACs effective January 2012 and January 2014 (Source: BEE)

	Star Levels for Split ACs (1 Jan 2012 - 31 Dec 2013)			Star Levels for Split ACs (1 Jan 2014 - 31 Dec 2015)	
	Minimum EER (W/W)	Maximum EER (W/W)		Minimum EER (W/W)	Maximum EER (W/W)
1-Star	2.50	2.69	1-Star	2.70	2.89
2-Star	2.70	2.89	2-Star	2.90	3.09
3-Star	2.90	3.09	3-Star	3.10	3.29
4-Star	3.10	3.29	4-Star	3.30	3.49
5-Star	3.30		5-Star	3.50	

Since June 2015, BEE adopted a voluntary label for split inverter ACs with a one-star level of 3.1 and a 5-star level of 4.5 in the newly adopted Indian Seasonal Energy Efficiency Ratio (ISEER) metric, based on the ISO 16358 standard with an India-specific temperature distribution.⁶ This is shown in Table 2.

Table 2: BEE star rating levels for inverter ACs effective June 2015 through December 2019 (Source: BEE)

	Star Levels for Inverter ACs (29 June 2015 - 31 Dec 2019)	
	Minimum ISEER (Wh/Wh)	Maximum ISEER (Wh/Wh)
1-Star	3.1	3.29
2-Star	3.3	3.49
3-Star	3.5	3.99
4-Star	4.0	4.49
5-Star	4.5	

⁶ ISO 16358 was adopted by the ISO in 2013 to provide an international standard to rate fixed-speed and inverter (or variable speed) ACs under the same metric. This metric (Cooling Season Performance Factor/Heating Season Performance Factor or Annual Performance Factor) allows a weighted average to be calculated based on a country or region-specific temperature bin, but has the added advantage of using the same test points as ISO 5151 rating standard for ACs, thus making for a smoother transition to rating of inverter and fixed speed ACs under the same metric while also capturing the benefits of the part load savings available under a seasonal metric. For cooling only operation, this metric is known as the cooling season performance factor (CSPF). In 2015, BEE has adopted ISO 16358 but modified the temperature bin distribution to account for the hotter weather in India to calculate the Indian SEER (ISEER) metric for fixed speed and inverter ACs. BEE has adopted the ISEER metric to measure the performance of Room ACs in India in the future (Shah et al 2016).

Note that the ISEER metric credits the efficiency improvement to a variable speed drive used in RACs, known as inverter ACs. The ISEER metric and the star labels shown in Table 2 are due to become mandatory for all ACs (fixed-speed and inverter ACs) in 2018.

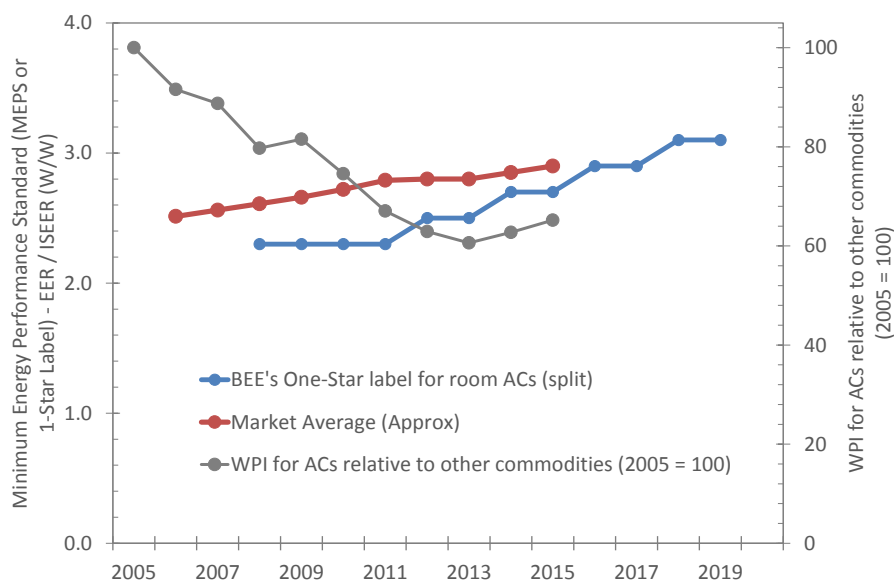


Figure 3: Trends in improvement of AC efficiency and fall in AC prices in India (2005-present) (Source: BEE (2010, 2012, 2014), PWC (2015) and OEA (2016))

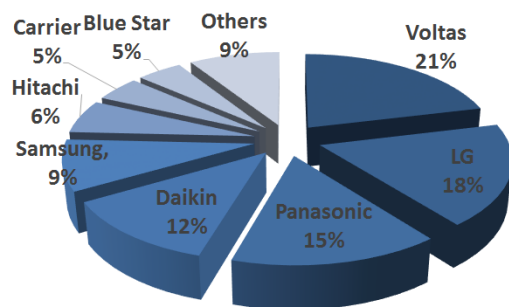
Minimum Energy Performance Standard (one-star label) for room ACs has been increased by about 30% between 2006 and 2016, i.e. about 3% per year (Figure 3). Market average RAC efficiency has typically been slightly higher than the one star level and has improved similarly. Between 2005 and 2015, despite such efficiency improvements, the inflation adjusted RAC prices, measured by the Wholesale Price Index (WPI) relative to the basket of all commodities, have fallen by over 35%.

Although the MEPS and the five-star level for the inverter AC efficiency in India up to 2019 is ISEER 3.1 and ISEER 4.5 respectively, the most efficient commercially available AC in India has an efficiency of ISEER 5.75; moreover, several brands have models with efficiency between ISEER 4.5 and 5 (see Figure 7). If, going forward, the BAU efficiency trend of about 30% improvement in 10 years continues, the market average efficiency of ACs in 2026 will be ISEER 4.0, well below the efficiency of most efficient RAC sold in India in 2016. If India takes an accelerated efficiency improvement pathway, where today's most efficient technology becomes the market average in 10 years, it would imply an efficiency improvement of nearly 100% by 2026.

In the next section, we describe experience in Japan and Korea where such accelerated improvements in RAC efficiency have occurred.

3 AC Efficiency in Japan and Korea: Examples of Accelerated Efficiency Improvement Driven by Policy

Japan and Korea have seen a rapid improvement in RAC efficiency. We summarize the policies aimed at increasing RAC efficiency and its impact on efficiency and prices and draw insights for increasing the rate of improvement of RAC efficiency in India. Japanese and Korean brands hold more than 60% of the market share in the Indian RAC market (see Figure 4) and hence the experience of AC improvement in these countries might be particularly relevant for India.



Total room AC sales (2014) = 3.7 million units

Data source: PWC (2015)

Figure 4: Room AC market shares in India in 2014

3.1 Japan

Figure 4 shows trends in RAC efficiency reported as Coefficient of Performance (COP) and Annual Performance Factor (APF), and room AC prices represented by inflation adjusted Consumer Price Index (CPI) for RACs. We also show relevant details on the timing and targets of efficiency policies.

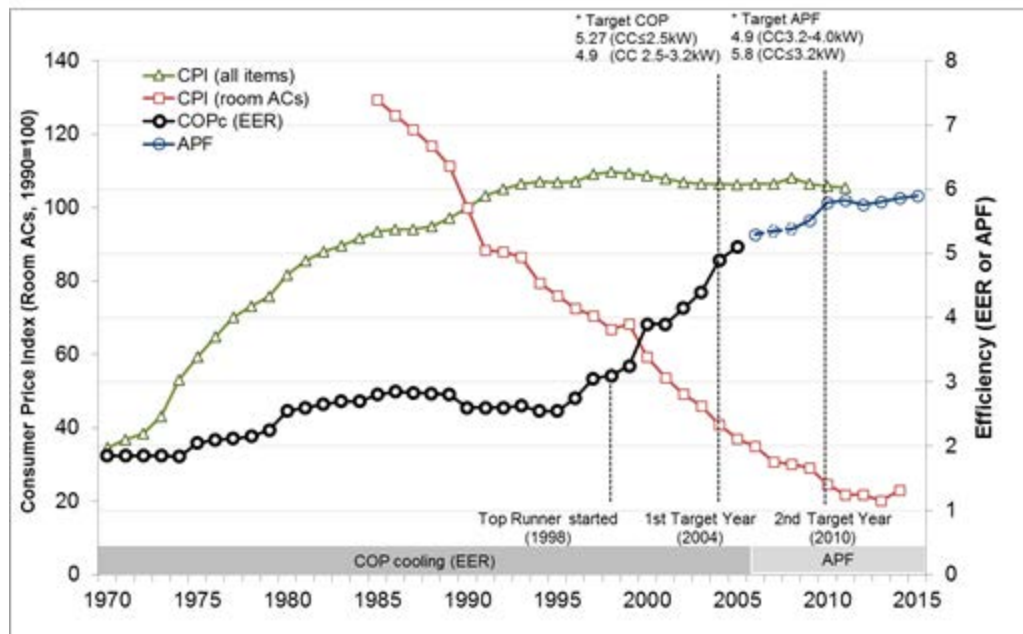


Figure 4: Room AC efficiency trend and price indices in Japan

Sources: Kimura (2010) for COPs (EERs) for 1970-2005. Japan's Annual Performance Factor (APF) for 2006-2015 are product-weighted average estimated based on the Energy Conservation Center Japan (ECCJ)'s database. CPIs are from the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan. Dotted-lines are author's estimates.

One of the main policies to promote energy efficiency of RACs in Japan is the Top Runner program launched in 1997. When the program was launched, it mandated that by 2004, all AC manufacturers must have a sales weighted fleet average COP of 5.3 (W/W) for small ACs and 4.9 (W/W) for larger ACs, which was over 60% more efficient than the market average efficiency in 1997 (improvement of over 7.5%/year). This target COP was informed by the COP of the most efficient AC model available on the market. Industry met this target by producing more efficient ACs and discontinuing the sale of inefficient ACs. They used several strategies to improve efficiency including variable speed compressors, microchannel heat exchangers, and electronic expansion valves. Significant efficiency improvements were also achieved by increasing the size of the heat exchanger and increasing the refrigerant flow. In 2003, a new target was established for 2010 which required a further improvement of about 20%. The efficiency metric was changed to an "annual performance factor" (APF) to more accurately credit the savings achieved by variable speed/inverter ACs and performance in both cooling and heating mode. This target was also met by the industry. From 1998 to 2010, efficiency improved by over 90% (a rate of 7.7%/year).

Before the Top Runner program, efficiency improved only marginally and improved substantially after the program was initiated. The rate of reduction in prices did not change significantly even as efficiency improved substantially. Since 1996, the efficiency improved by over 90% and

inflation adjusted prices declined by over 80%. Further, given that there is no clear trend of increasing electricity prices while efficiency was improving, it appears that changes in electricity prices does not appear to be a driver for accelerating efficiency improvement.

3.2 South Korea

The Korean government has implemented the Energy Efficiency Label and Standard Program (EELSP) since 1992 to improve energy efficiency of key products including appliances and vehicles which account for majority of energy consumption (Lee, 2010). Mandatory MEPS regulations were published in 2002 and became effective in 2004 for window and split AC units up to 23 kW cooling capacity. In September 2011, the government launched the Energy Frontier Program, which sets energy efficiency criteria in key appliances at 30-50% more efficient than Grade 1 (most efficient criteria in 2011). The first phase of the program has included four major appliances; TVs, refrigerators, ACs, and clothes washers (Lee 2010).

Box 1: Comparing ISEER and Other Efficiency Metrics like Japanese APF and Korean CSPF

Please note that the Indian ISEER metric may not be directly comparable with the Japanese APF or Korean SEER levels presented here. This is primarily because of the differences in the AC efficiency test points used in these countries. For example, India SEER calculation requires testing only at full load and half load operation at 35°C and at 29°C (i.e. measured capacity and power input at full and half load operations at 35°C and ISO 16358 determined default coefficients for capacity and power input at full and half load operations at 29°C). Korea or Japan CSPF calculations require test points at full, half, and minimum load operations at 35°C and at 29°C (Phadke et al 2016). Korean or Japanese metrics may be able to capture the savings due to variable speed drives in operations below half load, which would not be the case with ISEER. However, given climate conditions and usage patterns in India, ACs are unlikely to operate below half load for significant amount of time and hence such savings may not be significant in Indian conditions. In general, the efficiency of an AC unit measured in ISEER would be lower than that measured in the Korean CSPF or Japanese APF. Further, Japanese APF also considers efficiency performance in the heating mode. Phadke et al 2016 find that if the Japanese and Korean ACs were tested under the ISEER test conditions, their Japanese APF and Korean CSPF values would lower by 10% and 13% on average when converted to ISEER; for some of the most efficient models, ISEER values would be as much as 20% lower than Japanese APF and Korean CSPF values.

Samsung and LG together comprise more than 80% of the Korean market share. Industry experts indicate that both brands want most of their models to qualify under the Grade 1 or the Frontier

criteria to be competitive in the market and hence these requirements, despite being a voluntary, drive overall efficiency improvement in the market.

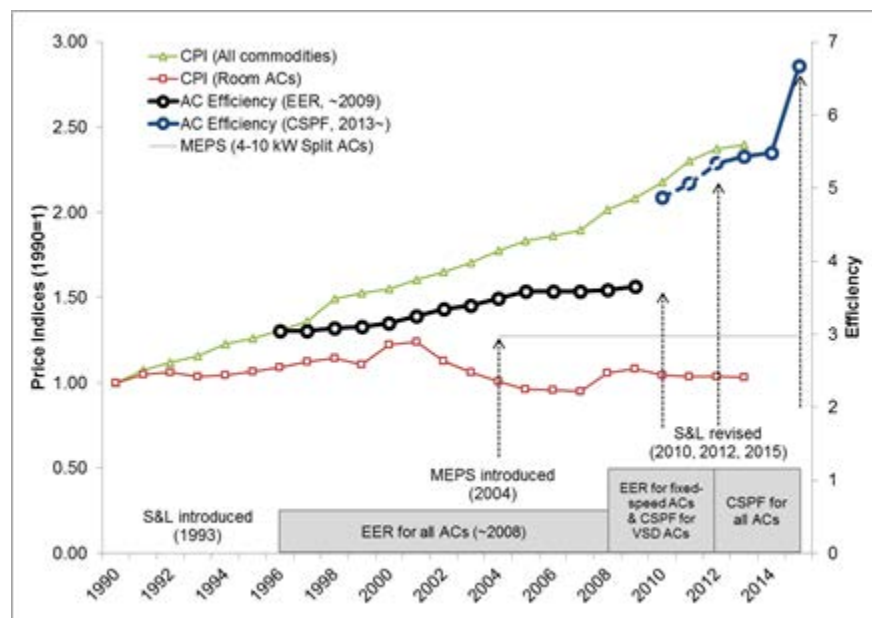


Figure 5: Trends in room AC efficiency and price indices in Korea

Sources: EERs for 1996-2008 are sales-weighted average estimated by the Korean Energy Agency (KEA). Mixed efficiency with EER and CSPF for 2009-2010 and CSPF for 2013-2015 are product-weighted average estimated based on KEA's database. CPIs are from the Statistical Database of Korean Statistical Information Service. VSD (inverter) ACs are estimated to account for more than 85% of the AC sales in the market in 2013 and more than 90% of AC sales in 2015. The dotted-lines are author's estimates.

Figure 5 shows that the Grade 1 efficiency criteria has increased efficiency requirements by over 100% since 2008 and most new models by LG and Samsung meet either the Grade 1 or the Frontier criteria resulting in significant improvement in average AC efficiency (see Figure 5). Share of inverter/variable speed ACs increased from less than 10% to over 90% within a span of 8 years and efficiency improved by over 100% (~12% per year). During this period, inflation adjusted RAC prices (CPI) continued to decline.

Given the experience in Japan and Korea, we assess the technical feasibility, impact, and cost benefit of accelerated AC efficiency improvement in India.

4 Technical Feasibility, Impact, and Cost Benefit of Accelerated AC Efficiency Improvement in India

We assess the technical feasibility, peak demand and electricity consumption impact, and cost-benefit of a scenario of accelerated efficiency improvement over a business as usual (BAU) scenario. In the BAU scenario, we take the BEE specified star levels up to 2019 and assume that

one star level is ratcheted up at the historical rate of 3.0% per annum reaching an ISEER of 4.2 by 2030. The accelerated efficiency improvement scenario can be viewed as a target to be achieved by enhanced policy interventions. In that scenario, we assume that the room AC MEPS is revised to ISEER 3.5 in 2018 (against 3.1 specified by BEE) and it is ratcheted up at double the historical rate (6.0% p.a.) thereafter. Over the next six years, the five star AC efficiency level in 2016 (ISEER 4.5) becomes the MEPS (one-star level) by 2022. Over the next 10 years, i.e. by 2026, the room AC MEPS will nearly double the current level (from ISEER 2.9 to 5.7); by 2030 the room AC MEPS reaches an ISEER of 7.1, an improvement in the MEPS of about 140% in 15 years. Figure 6 shows the room AC MEPS (one-star levels) up to 2030 for the two scenarios - BAU and Accelerated Efficiency Improvement.

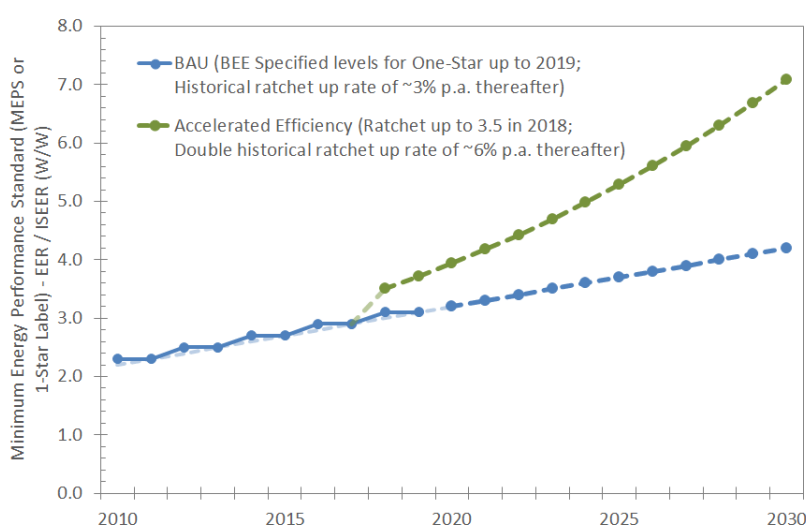


Figure 6: Alternative trajectories for room AC minimum standard (1-Star Level) improvement

As discussed in the previous section, there is evidence from Japan and Korea of such aggressive efficiency improvements. In Japan, during a ten year period between 1995 and 2005, the RAC efficiency improved by nearly 100%. In Korea, between 2009 and 2015, the RAC efficiency improved by over 80%.

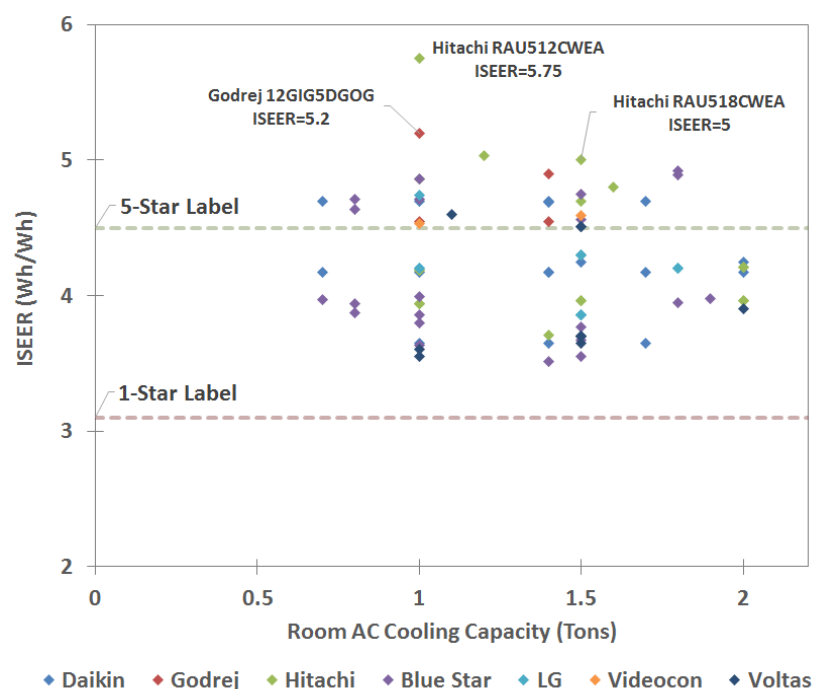
4.1 Technical Feasibility of the Accelerated Efficiency Improvement Scenario

The accelerated efficiency improvement scenario implies that the most efficient RAC sold on the Indian market today (ISEER of 5.75)⁷ will become the market average efficiency level in 2026,

⁷ Hitachi RAU512CWEA with 1 ton cooling capacity

whereas one of the most efficient RAC on the global market today (Korean CSPF of 9.4; about 15-20% lower when converted to ISEER)⁸ will be the market average efficiency in 2030.

Figure 7 shows ISEER levels of all the inverter AC models that are sold in India in 2016 arranged by cooling capacity. The figure also shows the BEE specified 1-star and 5-star levels for inverter ACs up to 2019.



Note: Each point refers to a room AC model on the market. The most efficient model, offered by Hitachi (model # RAU512CWEA), has an ISEER of 5.75 for cooling capacity of 1 Ton.

Data source: BEE (2016)

Figure 7: Spread of the inverter room AC products offered by each manufacturer by cooling capacity (as of June 2016)

As shown in Figure 7, most brands in India have RAC models with ISEER >4.5, which is an indicative one star level by 2022 in the accelerated efficiency improvement scenario, i.e. the manufacturers appear to have the technology to meet the mandatory one star requirement in the accelerated efficiency improvement scenario. Note that the ISEER of 5.75 (as well as 7.5) has been achieved for capacities less than 1.5 tons, which are the most commonly used models in India. Anecdotal interviews with industry experts indicate that there should not be any technical constraints in achieving similar ISEER in 1.5 ton models as well. Improving efficiency beyond 7.5 ISEER for 1.5

⁸ Samsung AF18J9975WWK with 2 ton cooling capacity

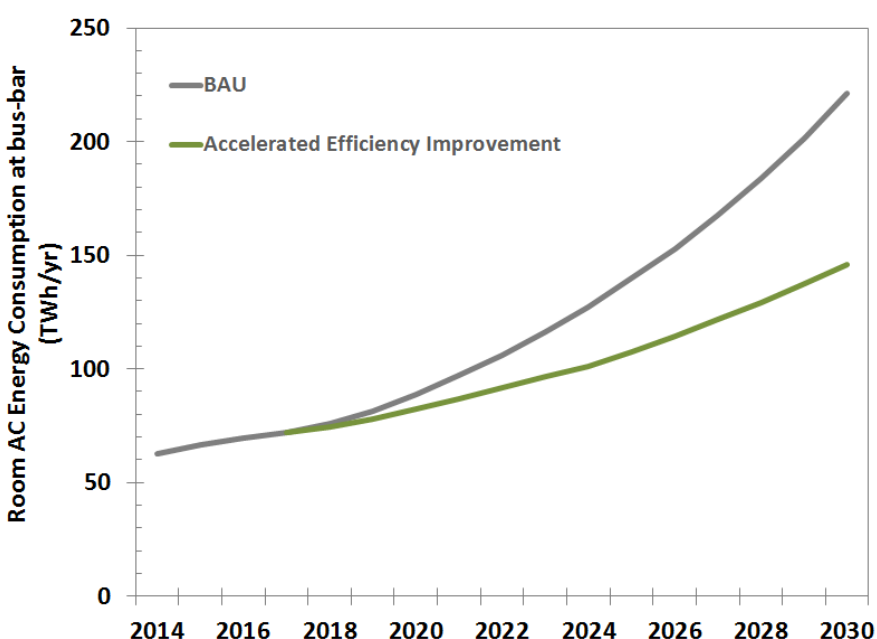
ton models will require additional R&D. Some future directions to improve efficiency include separate sensible and latent cooling(dehumidification), evaporative pre-cooling, desiccant-based dehumidification, M-cycle based evaporative cooling, absorption and adsorption cooling, solar cooling, thermoelectric, magnetocaloric and elastocaloric cooling.

4.2 Impact of the accelerated improvement in AC efficiency

See annexure for data, methodology, and assumptions used to estimate the impact of the accelerated efficiency improvement scenario.

4.2.1 Reduction in Electricity Consumption and Peak Load

Figure 7 shows the total energy consumption due to room ACs at bus-bar for both scenarios. By 2030, with accelerated efficiency improvement, room AC consumption could be reduced by nearly 75 TWh at bus-bar without compromising any cooling service provided by room ACs. This is equivalent to the total energy generation from more than 40 GW of solar PV capacity, and is in line with that estimated by BEE.⁹



Note: The energy consumption projections are preliminary estimates and we believe are conservative.

Figure 8: Energy consumption for alternative trajectories for room AC efficiency improvement

⁹ BEE 2014, Workshop on “[Space Cooling Efficiency Enhancement and Demand Response](#)” Presentation on India AC Efficiency Policy Opportunities & Current Activities, Saurabh Diddi, Energy Economist, Bureau of Energy Efficiency, July 2014 showed a similar 60GW savings from aggressive AC efficiency improvement.

One of the common concerns of any appliance efficiency improvement is the rebound effect. The direct rebound effect (increase in the energy use as a result of the effective rise in the disposable income of consumers due to increased energy efficiency) is found to be 20 to 40% for most appliance efficiency improvements (Gillingham et al 2015, Borenstein et al 2014). However, this estimate is highly dependent on the energy demand elasticity assumptions; in developing countries, estimating such elasticities and thus the rebound effect accurately is very hard and is outside the scope of this paper. Also, rebound effect implies an increase in the cooling services and thus an overall increase in the consumer welfare. The Indirect rebound effect (increase in the consumption of other commodities due to the reduction in the energy expenditure) is hard to predict and typically small (Gillingham et al 2015, Borenstein et al 2014).

As mentioned previously, room ACs are already a major contributor to the peak load in major urban areas. In the BAU trajectory, we project that by 2030, the peak load due to room ACs would be about 150 GW at bus-bar. Please refer to the annexure for more details on the projection. Room AC efficiency improvement would result in significant peak load savings as shown in the following chart.

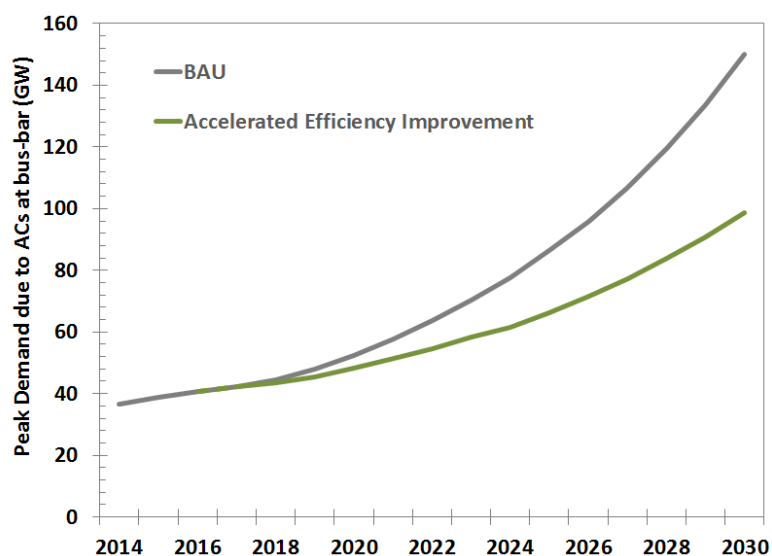


Figure 9: Peak load for alternative trajectories for room AC minimum standard (1-star level) improvement

By 2030, with accelerated efficiency improvement, peak demand could be reduced by over 50 GW. This is equivalent to avoiding building 100 large coal fired power plants of 500MW each. Note that the rebound effect is not applicable in case of peak load.

4.2.2 Net Consumer Benefit

We estimate the net consumer benefit for a given level of cooling service is the net present value (NPV) of the electricity bill savings due to efficiency minus the incremental price paid for the

efficiency gain. To know the incremental price paid by the consumers, we first have to estimate what the price would have been in the absence of efficiency improvement (counterfactual price). Examples in Japan and Korea discussed above and examples in several other countries for several other appliances and equipment (see Buskirk et al 2015) indicate that efficiency policies and efficiency improvements do not increase inflation adjusted prices over time and may in fact reduce prices compared to the counterfactual prices. However, at any given point in time, prices of efficient ACs appear to be higher and engineering estimates also indicate that at any given point in time, it costs more to produce efficient ACs which may create the possibility of ACs prices increasing with efficiency if there is no technological change, economies of scale, or supply side responses. To represent both these possibilities, we consider two scenarios. The first is a realistic consumer benefit scenario where we assume that accelerating efficiency improvements will have no impact prices in line with the historical experience, and a highly conservative consumer benefit scenario where we assume that the prices will go up with efficiency improvements considering today's cost of efficiency improvement. Cost of efficiency improvement are based on engineering estimates of efficiency improvement and corresponding cost data provided by the Indian manufacturers (see Shah et al, forthcoming and the annexure for details). This approach is used in the US and EU regulatory process to set the minimum energy performance standards. Studies have shown that, this approach is likely to underestimate consumer benefits because ex-post empirical assessments show that prices continue to decline at the same rate after the policy intervention and increase in efficiency (Buskirk et al, 2015).

We find that the accelerated efficiency improvement of room ACs is cost-effective from the consumers' perspective even in the conservative benefits case, i.e. the electricity bill savings are much higher than the incremental price of the efficient AC. An example of estimating the net consumer benefit for an individual consumer in 2018 is shown in Figure 10. In the BAU trajectory, the one-star level in 2018 is expected to be ISEER 3.1 (specified by BEE); the market average ISEER would be about 3.3. In the accelerated efficiency improvement scenario, the one-star level is assumed to be ratcheted up to ISEER 3.5 in 2018; the market average efficiency would be ISEER 3.7. Figure 10 shows the incremental price of an AC with ISEER 3.7 over an AC with ISEER 3.3 (BAU); it also shows the NPV of electricity bill savings over the life of the AC assuming a discount rate of 10%, AC life of 7 years, electricity tariff of Rs 6/kWh and AC usage of 1200 hours/yr.

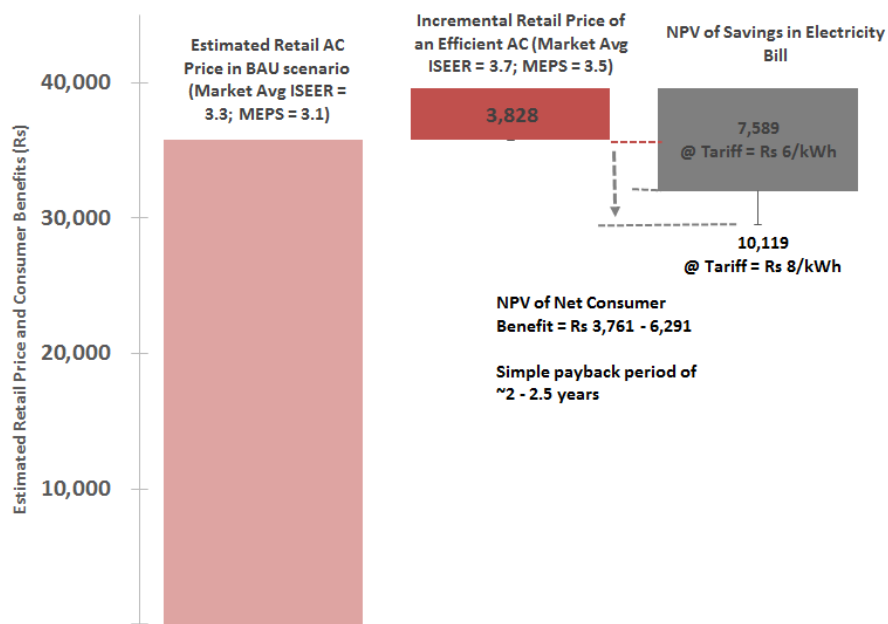
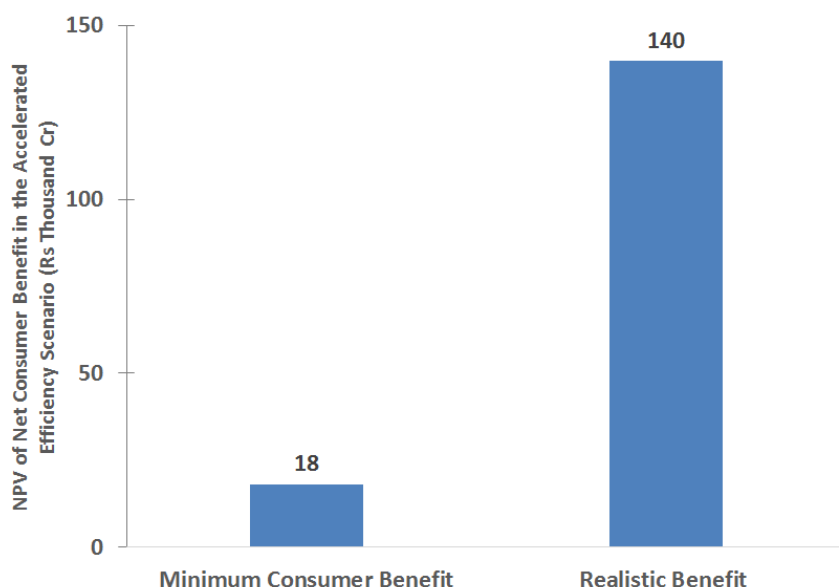


Figure 10: Estimating the net consumer benefit for an individual consumer in 2018

We find that despite the aggressive ratchet in 2018, consumers still benefit. The incremental price of an efficient AC is estimated at Rs 3,828 (maximum value) while the electricity bill saving would be over Rs 1,500 per year, i.e. the consumers can recover the incremental price in about 2-3 years. NPV of the consumer benefit is in the range of Rs 4,000-6,000 per consumer. Note that this consumer benefit estimation is highly conservative and should serve as the minimum bound. This is because: (a) the estimated electricity bill savings are based on conservative assumptions of AC usage hours and electricity prices, and (b) we have estimated the incremental retail price of the efficient AC based on the current technology costs, assuming no subsequent technology innovation, economies of scale or supply side response in the future.

The following chart shows the NPV of the net consumer benefit in the accelerated efficiency improvement scenario when the benefits are added over all consumers and discounted up to 2030.



Key Assumptions: Hour of room AC use: 1200 hours/yr; electricity price of Rs 6/kWh in 2016 increasing at 5% p.a.; discount rate of 10% for estimating the NPV; life of the AC of 7 years. Note that the net benefits estimates are indicative only since the assumptions on electricity prices and hours of use are hard to predict in the future.

Figure 11: NPV of the net consumer benefits due to the accelerated efficiency improvement

The NPV of the net consumer benefit between 2018 (first year of the proposed aggressive ratchet) and 2030 would range between Rs. 18,000 Cr at the minimum to Rs. 140,000 Cr in a more realistic case. In addition, AC efficiency improvement will have significant benefits for the utility due to the reduction in the peak load.

5 Policies and Programs to Accelerate Room AC Efficiency Improvement

Examples in Japan and Korea show that EE policies have a significant role in accelerating AC efficiency with no significant impact on prices. Examples in Japan and Korea in particular show that efficiency can be improved at a rate that is significantly higher than achieved historically. Further, we show that accelerated improvement in AC efficiency will have enormous benefits for India, including but not limited to strengthening the capacity of Indian manufacturers to compete in the global market. For example, if efficiency is improved at 6% per year instead of the historical rate of 3% per year, 40 GW of additional power will be available on peak. For supplying the same amount of peak power, an investment of 250,000 Cr. would be needed in transmission and generation. This means that 250,000 Cr. of additional supply side investment will be needed if the BAU efficiency trajectory continues instead of the accelerated efficiency improvement trajectory. Further, the net consumer savings from the accelerated efficiency trajectory will range from Rs 18,000 Cr to Rs 140,000 Cr.

5.1 Accelerated Ratcheting Up of BEE Star Rating Levels

Experience in India and several other countries have shown that efficiency is significantly driven by the minimum energy performance standard (e.g. 1-star) and related energy efficiency labeling levels. For example, in India, 2 and 3-star labeled ACs dominate the market; the weighted average market efficiency approximately equals the 2 star level even with increasing stringency of the star labels.

Hence, accelerating the ratcheting up of star levels is one strategy to accelerate the efficiency. Note that this does not mean that the revisions need to be made more frequently but just requires that more stringent levels are specified compared to the historical trajectory.

5.2 Providing Policy Direction with a Medium Term and Long Term Target for Star Levels

Similar to Japan's Top Runner program, a long term target can provide a broader policy direction, which informs setting and revision of the interim targets, i.e. today's best available technology in India can be the target for market average (2-3 star level) by 2022. This means that today's five star level (4.5 ISEER) should be the 1-star level in 2022. Note that several brands (Bluestar, Godrej, Hitachi, Voltas) already sell models with efficiency of ISEER 4.5 and higher. A 2-star level of ISEER 5 in 2022 will achieve an efficiency improvement at the rate that was achieved in Japan and Korea historically. An additional long term target could be making today's globally available best commercial technology the market average by 2030 (implying the one-star label to be about 7.1). Once such long term targets are specified, BEE may ratchet up MEPS in the interim years. The standard practice so far has been that every two years, all star levels increase by one star, i.e. an efficiency improvement CAGR of ~3% per year. One of the options for an accelerated ratchet up is widening the spread of the star labels which incentivizes more efficient products to be sold on the market; then ratchet up the star levels every two years by two stars instead of one. For example, within 3 revisions (up to 2022), the current five-star label becomes the MEPS (one-star label).

Figure 12 shows one such potential schedule of ratchets to achieve the accelerated efficiency improvement trajectory with the two long term goals in mind - (a) today's five star becomes the one-star label in 2022 (ISEER 4.5), and (b) today's globally available best commercial technology becomes the one-star label in 2030 (ISEER 7.2).

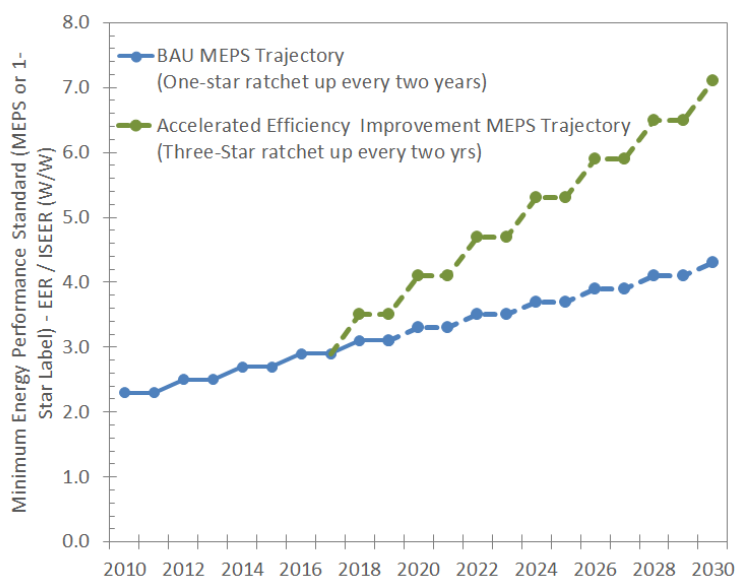


Figure 12: Potential schedule of ratcheted levels for alternative trajectories for room AC minimum standard (1-star level) improvement

Note that this is one possible pathway of ratcheting up of star levels. The most appropriate pathway can be identified based on inputs from several stakeholders.

5.3 Bulk Procurement & Incentives to Support Accelerated Ratcheting Up of S&L Levels

Building on the historical success of the BEE star-labeling program, the Indian government has recently announced its intent to accelerate the sale of efficient air conditioners using a program design similar to the successfully implemented Domestic Efficient Lighting Program (DELP), for LEDs.¹⁰

Bulk procurement and incentives can reduce the cost of efficient air conditioners and increase their uptake. Such programs will support accelerated ratcheting up of star levels. For example, increasing the market share of today's five star AC will allow an easier transition to the same efficiency level being characterized as a two or three star level few years down the line because such programs will help efficient products to be sold as the norm. Incentive and bulk procurement programs can be used in bringing even more efficient products (more efficient than today's five star) to the market.

¹⁰ Announcement by Shri Piyush Goyal, Minister of State for Power, Coal, and New and Renewable Energy, March 2, 2016. See: http://www.moneycontrol.com/news/wire-news/govt-to-sell-energy-efficient-ac-fan-at-lower-price-goyal_5736361.html

5.4 Star Rating for Other Types of Space Cooling Equipment (Chillers, VRFs, Ducted Splits, and Rooftop ACs)

A similar accelerated trajectory based on the most efficient commercially available models can be followed for other types of space cooling equipment including chillers, Variable Refrigerant Flow (VRF) multi-split ACs, ducted split ACs and rooftop ACs as their penetration also increases in the Indian market. Note that such development of star rating for different equipment types will need a number of related interventions such as test procedure development, capacity building of test labs, development of appropriate efficiency metrics for other equipment types, integration with building codes and standards.

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Annexure: Assumptions on AC Efficiency Improvement, Prices, Sales, and Consumer Cost-Benefit

AC Efficiency Trajectory

We have created two scenarios for how the AC MEPS (1-star level) would be revised in the future: Business As Usual (BAU) and Accelerated Efficiency Improvement. In the BAU case, we take the BEE specified levels up to 2019 and assume that the MEPS are ratcheted up at the historical rate of 3.0% p.a.; by 2030, the room AC MEPS reaches an ISEER of 4.2. The accelerated efficiency improvement scenario can be viewed as a target to be achieved by enhanced policy interventions. We assume that the room AC MEPS is revised to 3.5 in 2018 (against 3.1 specified by BEE) and it is ratcheted up at double the historical rate (6.0% p.a.) thereafter; over the next 10 years, i.e. by 2026 the room AC MEPS will nearly double current level (from ISEER 2.9 to 5.7), and by 2030 the room AC MEPS reaches to an ISEER of 7.1. The following table shows the room AC MEPS (one-star levels) up to 2030 for the two scenarios - BAU and Accelerated Efficiency Improvement.

	2010	2015	2018	2020	2022	2025	2030
BAU	2.3	2.7	3.1	3.2	3.4	3.7	4.2
Accelerated Efficiency Improvement	#N/A		3.5	3.9	4.4	5.3	7.1

AC Prices

To know the incremental price paid by the consumers, we first have to estimate what the price would have been in the absence of efficiency improvement (counterfactual price). We base it on the engineering estimates of the incremental manufacturing costs of efficiency improvement from Shah et al (2016). On top of these manufacturing costs, we add 140% markup for wholesale and retail costs and profits; this markup is also taken from Shah et al (2016). We then use the same methodology to estimate the retail AC prices in case of the accelerated efficiency improvement scenario. The following table shows the estimated retail AC prices for a range of ISEER levels.

ISEER (Wh/Wh)	Equivalent EER (W/W)*	Estimated Retail Price Rs.
3.5	3.4	39,288

3.6	3.4	36,660
3.7	3.5	39,588
3.8	3.5	42,888
3.9	3.5	40,188
4.0	3.6	43,188
4.1	3.6	44,436
4.2	3.6	44,700
4.3	3.6	46,764
4.4	3.6	45,300
4.6	4.4	48,228
4.9	4.6	51,828
5.2	4.8	56,076
5.5	5.0	59,311
5.8	5.2	62,546
6.1	5.3	65,781
6.5	5.5	70,095
6.9	5.7	74,409
7.3	5.9	78,722

*Note: A particular value of ISEER could be achieved by multiple combinations of efficient components such as efficient compressors, better UA heat exchangers, variable speed drives, etc. Our engineering economic model chooses the efficient components in order to minimize the total manufacturing cost for reaching an ISEER level. Therefore, depending on the components chosen, same ISEER level may have multiple EERs or vice versa.

Net Consumer Benefit

Net consumer benefit for a given level of cooling service is the NPV of the electricity bill savings due to efficiency minus the incremental price paid for efficiency gain. The electricity bill savings are estimated by multiplying the energy saving due to efficient ACs by the electricity price for each year in the life of the AC. The net consumer benefits of all ACs added up to 2030 are then discounted to 2016 in order to estimate the NPV of the net consumer benefit.

The following table shows our assumptions.

Parameter	Assumption
AC size	1.5 Tons (5.25 kW)
Hours of use	1200 hours/yr
Electricity price	6 Rs/kWh in 2016 increasing at 5% p.a.
Discount rate	10%
Life of the AC	7 years

AC Sales, Stock, Total Energy Consumption, and Peak Load

Room AC sales have been growing at a CAGR of over 10 over the last 10-15 years. In the future, due to rising incomes, urbanization, and falling appliance prices, we expect the same trend to continue. We assume that between 2016 and 2030, the room AC sales grow at a CAGR of 10% p.a. Assuming an average life of about 7 years (conservative), we then estimate the total stock of room ACs in India. For estimating the total energy consumption at the bus-bar, we assume the T&D loss to be 15%. Since ISEER is a seasonal energy efficiency metric, it cannot be directly used for estimating the kW rating of an AC and thus its peak load contribution. Based on the temperature distribution and seasonal test conditions in India, and the engineering options available for efficiency improvement, we estimate the equivalent EER level (Shah et al 2016). This EER value (W/W) is then used to estimate the kW input rating of the AC. Based on Phadke et al (2013), we use a peak coincidence factor of 0.7 and T&D loss of 15% to assess the concurrent AC peak load at bus-bar. The key assumptions and results are summarized in the following tables.

Parameter	Assumption
CAGR of AC sales growth	12.5% p.a.
Life of the AC	7 years

Hours of use	1200 hours/yr
T&D loss	15%
Peak coincidence factor	0.7
AC Peak Load (bus-bar)	AC input rating (kW) * Peak Coincidence Factor/(1 - T&D Loss)

Summary of sales, stock, energy, and peak load projections:

	2015	2020	2025	2030
Room AC sales (millions/yr)	4	8	14	24
Room AC live stock (millions)	24	38	69	124
Total Room AC Consumption at bus-bar (BAU Scenario) TWh/yr	67	89	140	221
Total room AC Peak Load at bus-bar (BAU scenario) GW	39	52	86	150

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