Technical and Economic Aspects of Designing an Efficient Room Air-Conditioner Program in India

Authors:

Nikit Abhyankar, Nihar Shah, Amol Phadke, Won Young Park

Energy Analysis and Environmental Impacts Division

Lawrence Berkeley National Laboratory

International Energy Studies Group

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Executive Summary

Several studies have projected a massive increase in the demand for air conditioners (ACs) over the next two decades in India. By 2030, room ACs could add 140 GW to the peak load, equivalent to over 30% of the total projected peak load. Therefore, there is significant interest among policymakers, regulators, and utilities in managing room AC demand by enhancing energy efficiency. Building on the historical success of the Indian Bureau of Energy Efficiency's star-labeling program, Energy Efficiency Services Limited recently announced a program to accelerate the sale of efficient room ACs using bulk procurement, similar to their successful UJALA light-emitting diode (LED) bulk procurement program.

This report discusses some of the key considerations in designing a bulk procurement or financial incentive program for enhancing room AC efficiency in India. We draw upon our previous research to demonstrate the overall technical potential and price impact of room AC efficiency improvement and its technical feasibility in India. We also discuss the importance of using low global warming potential (GWP) refrigerants and smart AC equipment that is demand response (DR) ready.

Table ES1 shows a few examples of the room AC builds (1.5-ton capacity) we simulated using more efficient components, their estimated Indian seasonal energy-efficiency ratio (ISEER) values, and estimated retail prices and payback periods.

Table ES1: Technical specifications, estimated retail prices, and payback periods for efficient room ACs (1.5-ton)

Efficiency Level (ISEER)	Technical Specifications	Estimated Retail Price (no bulk discount) (Rupees [Rs])	Simple Payback Period (years) – relative to market average (ISEER = 3.1)		
			No bulk discount	20% bulk discount	40% bulk discount
3.1 (Baseline)	3.0 EER compressor; baseline heat exchanger; capillary tube	35,280	#N/A	#N/A	#N/A
4.6 (5-Star)	3.4 EER compressor with VSD; heat exchanger UA value +20%; thermostatic expansion valve	48,828	3.8	1.7	0
5.2	3.4 EER compressor with VSD; heat exchanger UA value +60%; thermostatic expansion valve	55,404	3.8	1.7	0
5.8	3.4 EER compressor with VSD; heat exchanger UA value +100%; electronic expansion valve	65,940	5.2	3.0	0.7
6.0	3.4 EER direct current compressor & fan with VSD; heat exchanger UA value +100%; electronic expansion valve	72,420	6.1	3.7	1.3

EER = energy-efficiency ratio, UA = Heat transfer coefficient (U) times Area (A), VSD = variable-speed drive.
Assumptions: 1.5 tons of refrigeration (TR) capacity split AC, electricity tariff = Rs 6/kWh increasing at 5% per year, AC life = 7 years, AC use = 1,200 hours/yr.

For an ISEER of 5.2, the simple payback period is estimated to be less than 4 years, even without a bulk discount. With a bulk discount of 20%, the payback period drops to less than 2 years. For ISEER 6.0, the payback period with a 20% bulk discount could be less than 4 years. Note that room ACs with ISEER 5.8 and 6.0 are yet not available in India in 1.5-ton capacity. For institutional consumers (e.g., commercial and office buildings), the payback periods are much shorter because of these consumers' high electricity tariffs and hours of use.

Overall, implementing hydrofluorocarbon (HFC) refrigerant transition and energy-efficiency improvement policies in parallel roughly doubles the greenhouse gas emission reduction from either policy implemented separately. Commercially available low-GWP refrigerants make such HFC transition feasible in a cost-effective manner, especially for the initial phases of a room AC bulk procurement program. A procurement requirement for DR-ready, or "smart," ACs could be used in conjunction with utility DR programs to reduce peak load and integrate variable renewable energy generation. However, merely requiring DR readiness or a smart AC is not sufficient for implementing DR for ACs. A robust regulatory framework is essential, for example, issuing smart grid standards such as communications specifications, setting DR pricing or incentive design, and so forth.

We make the following recommendations for a room AC bulk procurement program in India:

1. The program should help consumers making new room AC purchases buy the most efficient room ACs commercially available in India instead of lower-efficiency products. The most efficient products in India have ISEERs of 5.2 (1.5 ton) and 5.8 (1 ton).
2. If a bulk procurement program reduces the price of an efficient AC by 20%–40%, its cost-effectiveness enhances significantly.
3. Institutional consumers (office/commercial buildings) could be initial participants in the program owing to their high tariffs and hours of use, which further enhance the cost-effectiveness of efficient ACs.
4. The program should give preference to smart ACs and ACs using refrigerants with GWP less than 700, when techno-economic parameters are otherwise equivalent.
5. An efficient AC program would likely reduce a utility's annual revenue requirement and thus consumer tariffs. Therefore, utilities could offer on-bill financing or on-bill repayment programs to increase program participation, as demonstrated successfully in multiple other countries. However, any utility program design should also include regulatory solutions to address the utility cash flow risk.

1 Introduction

India's hot, humid climate creates substantial demand for space cooling, and air conditioner (AC) use is increasing rapidly with the country's rising incomes and increasing urbanization (Phadke, Abhyankar, & Shah, 2013). Several studies have projected a massive increase in peak load and energy demand over the next two decades due to room ACs (Abhyankar, Shah, Park, & Phadke, 2017; Davis & Gertler, 2015; Diddi, 2014; Phadke et al., 2013). Room ACs could add about 140 GW to the peak demand (equivalent to about 300 power plant units of 500 MW each) by 2030 and 300–500 GW by 2050 in India (Phadke et al., 2013; Shah, Wei, Letschert, & Phadke, 2015); these values are equivalent to over 30% of the projected peak loads in 2030 and 2050 (Abhyankar et al., 2013; NITI Aayog, 2015). Even today, ACs have a large peak load impact in areas with significant AC penetration. For example, in New Delhi, space cooling accounts for 40%–60% of the summer peak load (Abhyankar et al., 2017). A holistic strategy is needed to meet sustainably the challenge of growing electricity demand from room ACs in India.

Building on the historical success of the Indian Bureau of Energy Efficiency's (BEE's) star-labeling program, Energy Efficiency Services Limited (EESL) recently announced its intent to accelerate the sale of efficient room ACs using a bulk procurement program similar to their successful UJALA light-emitting diode (LED) program (MoneyControl, 2016; The Hindu, 2017).[1] Bulk procurement can reduce the cost of efficient ACs and address the first-cost barrier, resulting in increased uptake. Such programs will be crucial for supporting the accelerated ratcheting-up of room AC energy performance standards. For example, increasing the market share of highly efficient ACs will facilitate the transition to the same efficiency level being characterized as a two- or three-star level a few years later, because such programs will help efficient products be sold as the norm. Incentive and bulk procurement programs can be used to bring products that are more efficient than today's five-star level to the market.

This report discusses key considerations in designing a bulk procurement or financial incentive program for enhancing room AC efficiency in India. We draw upon our previous research to demonstrate the overall technical potential and price impact of enhancing room AC efficiency and its technical feasibility in India. We also assess the cost-effectiveness of highly efficient room ACs for individual and institutional consumers, and we evaluate the impact of price reduction through a bulk procurement program. We demonstrate how a utility-led efficient-AC program can reduce the utility's overall annual revenue requirement (ARR) and thus consumer tariffs. We discuss the importance of using low global warming potential (GWP)

[1] Unnat Jyoti by Affordable LEDs for All (UJALA) is a national-level LED program started by EESL in 2015. Over the course of 2 years, the UJALA program has distributed more than 230 million LED lamps and reduced the LED price by over 90% through bulk procurement. It is one of the largest and most successful LED programs in the world.

refrigerants and smart AC equipment that is demand response (DR) ready. Finally, we give examples of successful appliance-efficiency programs in other countries, and we conclude with recommendations for a room AC bulk procurement program in India.

2 Room AC Efficiency and Policies in India

The BEE launched a voluntary standards and labeling program in May 2006 to reduce the energy intensity of electrical appliances. The labels use a comparative five-star rating system based on annual or daily energy consumption. The labeling scheme combines the comparative star labels with minimum energy performance standards (MEPS); products that meet the relevant MEPS are awarded one star. Products awarded the five-star level are the most efficient on the market, meeting the most stringent consumption requirements in the program. In 2012, mandatory labeling was introduced for split and window fixed-speed room ACs (BEE, 2012).

Historically, the BEE has revised its efficiency performance criteria and the energy-efficiency ratio (EER) of the star levels every 2 years (Table 1).

Table 1: BEE star rating levels for split ACs effective January 2012 through December 2015

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

	Star Levels for Split ACs (1 Jan 2014 - 31 Dec 2015)	
	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	

Source: BEE (2012, 2014)

In June 2015, the BEE adopted a voluntary label for split inverter ACs with a one-star level of 3.1 and a five-star level of 4.5, using the newly adopted Indian seasonal energy-efficiency ratio (ISEER) metric.[2] Table 2 shows the minimum and maximum ISEER levels for inverter AC labels. 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.

[2] ISEER, the ratio of cooling output to electrical input, measures AC energy efficiency. Higher values imply higher efficiency. ISEER captures the efficiency benefits of part-load operation of room ACs. Inverter ACs, which employ variable-speed drives, can operate at part load, whereas fixed-speed ACs can operate only at full load.

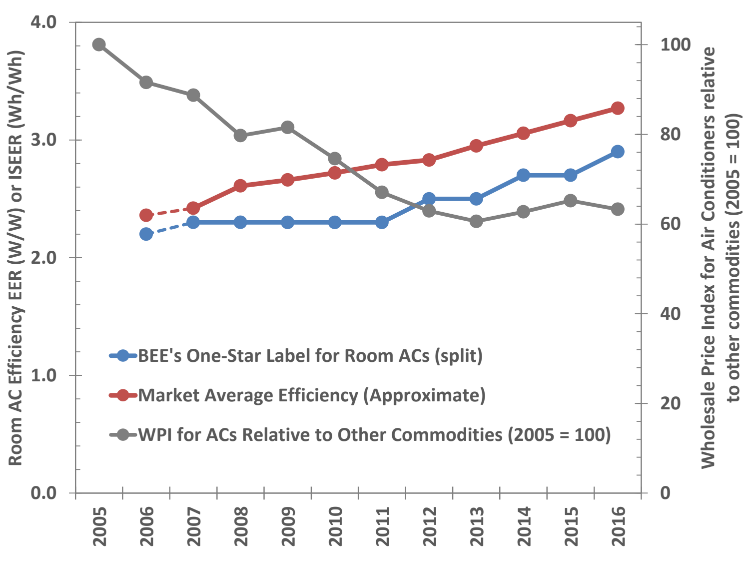
Table 2: BEE star rating levels for inverter ACs effective June 2015 through December 2019

	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	

*Wh = watt-hours

Source: (BEE, 2015)

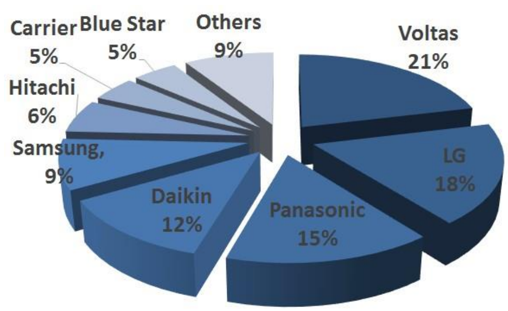
The MEPS (one-star label) for room ACs increased by about 35% from 2006 to 2016, i.e., at about 3% per year (Figure 1). Market-average room AC efficiency has typically been at the two- or three-star level and has improved similarly. Even with these efficiency improvements, inflation-adjusted room AC prices, measured by the wholesale price index (WPI) relative to the basket of all commodities, fell by nearly 35% during the same period.



Note: The one-star or MEPS value for 2007 was proposed, not mandatory. The 2006 value is a notional minimum value, which was used by the BEE to estimate the benefits of the labeling program (BEE, 2008). Similarly, the market average for 2006 is the baseline value used by (McNeil & Iyer, 2008).

Data sources: (BEE, 2008, 2009, 2010, 2012, 2014, OEA, 2015, 2016; McNeil & Iyer, 2008; PWC, 2012, 2015)

Figure 1: Trends in room AC efficiency improvement and decline in AC prices in India (2005–2016)



Total room AC sales (2014) = 3.7 million units
Data source: PWC (2015)

Figure 2: Room AC market shares in India in fiscal year 2014

Figure 2 shows the market shares of key manufacturers in the Indian room AC market in fiscal year 2014. Japanese and Korean brands have more than 60% of the market share. Also, according to PWC (2015), several key room AC components—such as compressors, indoor units, and so forth—are imported by most manufacturers. Some manufacturers also import entire room AC units.

3 Component-Level Technical Details of Enhancing Room AC Efficiency

This section discusses feasible levels of AC efficiency improvement, room AC import prices, and commercially available best technologies.

3.1 Technically Feasible Efficiency Improvement and Incremental Cost

To assess the technically feasible room AC efficiency improvement, we use previous engineering simulations from EuP (2009) and estimate the energy savings for different combinations of room AC components—such as compressors, variable-speed drives, heat exchangers, and so forth—with varying degrees of efficiency. The costs of efficient components are based on surveys of room AC manufacturers in India (PWC, 2012, 2015). For details on the methodology and component cost data, see Shah, et al. (2016) and Abhyankar, et al. (2017).

Table 3 shows a few examples of the simulated room AC builds, their estimated ISEER values, and estimated retail prices. Retail price is estimated assuming a retail markup of 140% based on the actual market prices of one- to two-star products. The markup for five-star or other high-efficiency models on the market may be higher owing to non-efficiency-related features such as air filters and also because these products are marketed as “premium” products, implying other pricing and brand-positioning strategies (Shah et al., 2016). Note that all room ACs presented here are 1.5-ton split units, the most popular size in India (Abhyankar et al., 2017).

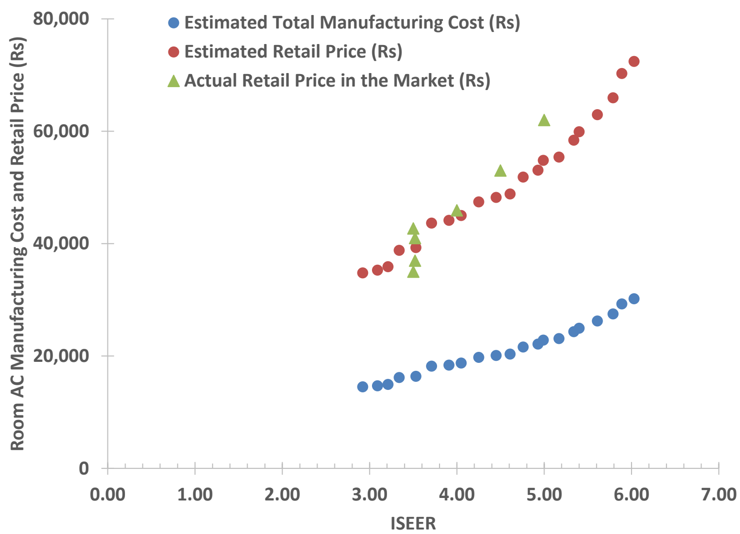
Table 3: Efficient room AC builds (simulated) showing key components, ISEER values, and estimated retail prices

ISEER (Wh/Wh)	Compressor	Variable-Speed Drive (VSD)	Heat Exchanger*	Expansion Valve	Estimated Manufacturing Cost (Rupees [Rs])	Estimated Retail Price (Rs)
6.0	Compressor Efficiency = 3.4 EER	Direct Current (DC) Compressor and Fan with VSD	UA value of both heat exchangers increased by 100%	Electronic Expansion Valve	30,175	72,420
5.9	Compressor Efficiency = 3.4 EER	DC Compressor with VSD	UA value of both heat exchangers increased by 100%	Electronic Expansion Valve	29,275	70,260
5.8	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 100%	Electronic Expansion Valve	27,475	65,940
5.6	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 100%	Thermostatic Expansion Valve	26,225	62,940
5.4	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 80%	Thermostatic Expansion Valve	24,955	59,892
5.3	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 60%	Electronic Expansion Valve	24,335	58,404
5.2	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 60%	Thermostatic Expansion Valve	23,085	55,404
5.0	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 60%	Capillary Tube	22,835	54,804
4.9	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 40%	Thermostatic Expansion Valve	22,115	53,076
4.9	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 20%	Electronic Expansion Valve	21,595	51,828
4.7	Compressor Efficiency = 3.2 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 40%	Thermostatic Expansion Valve	21,990	52,776
4.6	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 20%	Thermostatic Expansion Valve	20,345	48,828
4.5	Compressor Efficiency = 3.4 EER	Alternating Current Compressor with VSD	UA value of both heat exchangers increased by 20%	Capillary Tube	20,095	48,228
3.1 (Market Average, 2015 = Baseline)	Compressor Efficiency = 3.0 EER	#N/A	Baseline Heat Exchangers	Capillary Tube	14,700	35,280
2.9 (MEPS = 1-star)	Compressor Efficiency = 2.8 EER	#N/A	Baseline Heat Exchangers	Capillary Tube	14,500	34,800

*Note: The heat exchanger UA value increase does not necessarily mean increased heat exchanger area (A) alone. There are many ways of enhancing the heat transfer coefficient (U), including developing fin turbulence, better heat exchanger materials, more air or refrigerant flow, and so forth.

To reach a certain ISEER level, there could be multiple possible combinations of these components. Table 3 presents only a few such combinations as examples. The components shown represent the least-cost way of reaching that specific ISEER level. Shah, et al. (2016) elaborate on all the possible design combinations we considered, their respective ISEER levels, and estimated prices (288 combinations in total).

For each design combination considered above, Figure 3 plots estimated manufacturing cost and estimated retail price. Figure 3 also shows the actual retail prices for several models (1.5-ton capacity). The estimated retail prices closely match the actual retail prices observed in the market for low- and medium-efficiency products. For more efficient models, the market price is about 10%–15% higher than our estimates, indicating pricing due to non-efficiency-related factors. For details, see Shah, et al. (2016).



Note: Actual retail price data are only for inverter AC models, from snapdeal.com and amazon.in (last accessed August 23, 2016).

Figure 3: Estimated and actual retail prices and estimated manufacturing costs for efficient room ACs

3.2 Room AC Import Prices

Preliminary assessment of the AC supply chain in India shows that most room AC components by cost, such as compressors and indoor units, are imported for most products (PWC, 2015). Table 4 shows import and retail prices for a few room AC models that are imported as whole units (indoor and outdoor). The import data are from www.zauba.com.

Table 4: Import and retail prices for select room AC models imported as whole units

Date of Import	HS Code	Brand and Model	Cooling Capacity	Origin Country	Port of Discharge	Import Price (Rs)	Retail Price (Rs)	EER/ISEER
11-May-16	84151090	VOLTAS (DC Inverter) Split 18V DYE	1.5 TR	China	Nhava Sheva	14,698	41,770	3-Star ISEER > 3.5
15-Apr-16	84151090	VOLTAS (DC Inverter) Split SAC 183V MY-COOL	1.5 TR	China	Nhava Sheva	16,469	44,990	ISEER 3.60
6-May-16	84151090	VOLTAS (DC Inverter) Split EU 185V CROWN AW	1.5 TR	China	Nhava Sheva	27,170	53,000	ISEER 4.51

11-May-16	84151010	O General (Inverter) Split AOGR12JGC OUTDOOR ASGA12JGC INDOOR	1 TR	China	Tiruvallur-ILP ICD	19,729	42,185	ISEER Not Known 3.4 EER
11-May-16	84151010	O General (Inverter) Split AOGG12JLCA OUTDOOR ASGG12JLCA INDOOR	1 TR	China	Tiruvallur-ILP ICD	18,913	39,900	ISEER Not Known 3.2 EER
28-Apr-16	84151010	KORYO (Inverter) Split WFKSIAO1712A3S W12	1 TR	China	Nagpur	10,569	24,990	ISEER Not Known 3.18 EER
28-Apr-16	84151010	ONIDA (Inverter) Split VERVE - INV12VRV	1 TR	China	Nhava Sheva	14,006	41,590	ISEER Not Known 3.21 EER

TR = ton of refrigeration

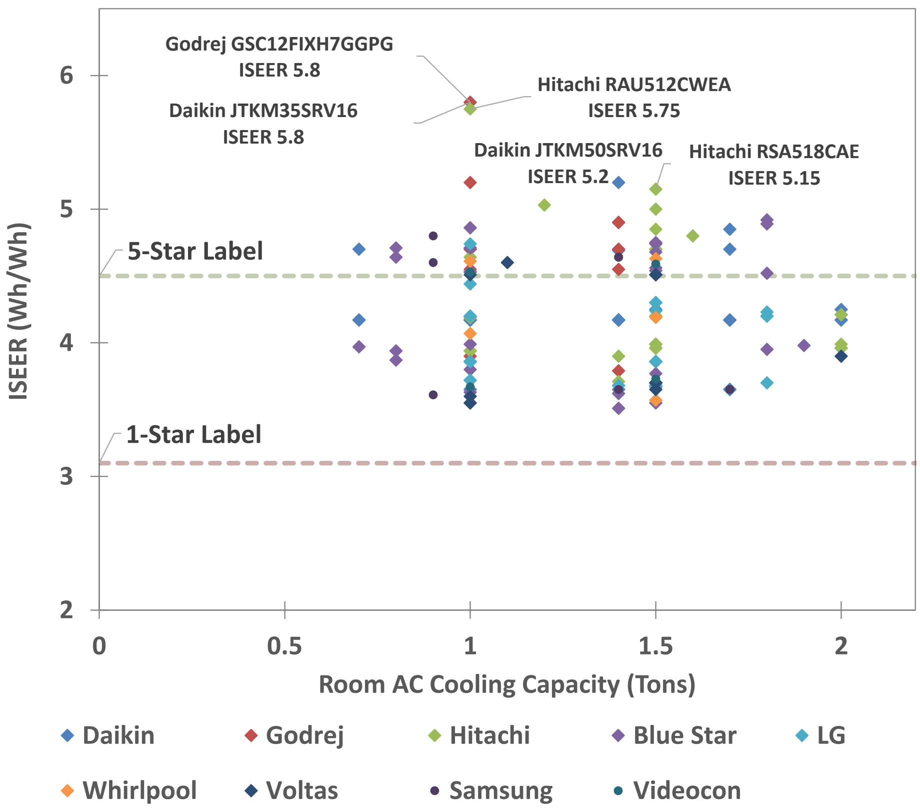
Source: (Zauba, 2016)

The import price estimates roughly match with the manufacturing cost estimates presented earlier. Also, import prices constitute about 40%–50% of the AC retail prices. This implies that, with a volume-purchase guarantee, a significant bulk-purchase discount could be available, as in EESL's UJALA LED program.

3.3 What Is the Commercially Available Best Technology?

In India, the most efficient room ACs sold currently are by Daikin (model #JTKM35SRV16) and Godrej (model #GSC12FIXH7GGPG), with an ISEER of 5.8 and cooling capacity of 1 ton. The most efficient AC in the 1.5-ton room AC category is also by Daikin (model #JTKM50SRV16) with an ISEER of 5.2. Hitachi (model #RSA518CAE) is a close second with ISEER 5.15.[3] Figure 4 shows ISEER levels for all inverter AC models registered with the BEE in 2016, arranged by cooling capacity. It also shows the BEE-specified one- and five-star levels for inverter ACs up to 2019. The inverter AC labels (and thus product registrations) are voluntary until 2018. Note that nearly 50% of the inverter AC models offered in the market (not necessarily sales) already have ISEER beyond the five-star label.

[3] Hitachi model RSA518CAE is priced at Rs 62,000 in the retail market, which is about 15% higher than the retail price we have estimated. (Source: http://www.compareraja.in/hitachi-rau518cwea-1-5-ton-5-star-split-ac-price.html, last accessed on August 22, 2016.)



Note: Each point refers to a room AC model on the market.
Data source: (BEE, 2017)
Figure 4: ISEER spread of inverter room ACs offered by manufacturers, by cooling capacity (as of April 2017)

Globally, commercially available super-efficient room ACs are far more efficient than those available in India. However, note that the efficiency metrics from multiple countries cannot be directly compared with each other owing to differences in country-specific test procedures. Phadke, et al. (2017) find that seasonal efficiency values such as CSPF, when converted to ISEER, typically drop by nearly 15%–20% on average. For example, in Korea, the most efficient room AC is Samsung AF18J9975WWK with a 2-ton cooling capacity and a cooling-seasonal performance factor (CSPF) of 9.4, which translates to ISEER of approximately 7.9 (Abhyankar et al., 2017). In the United States, the most efficient mini-split room AC is sold by TOSOT (model #GWH09YD-D3DNA1A/O) with a 0.75-ton cooling capacity and seasonal energy-efficiency ratio (SEER) of 11.1 (Wh/Wh) (AHRI, 2017). In the European Union (EU), the most efficient room AC model is Panasonic CU-VZ9SKE/CS-VZ9SKE with a cooling capacity of 0.75 tons and cooling SEER of 10.5 (Wh/Wh) (TopTen, 2016).

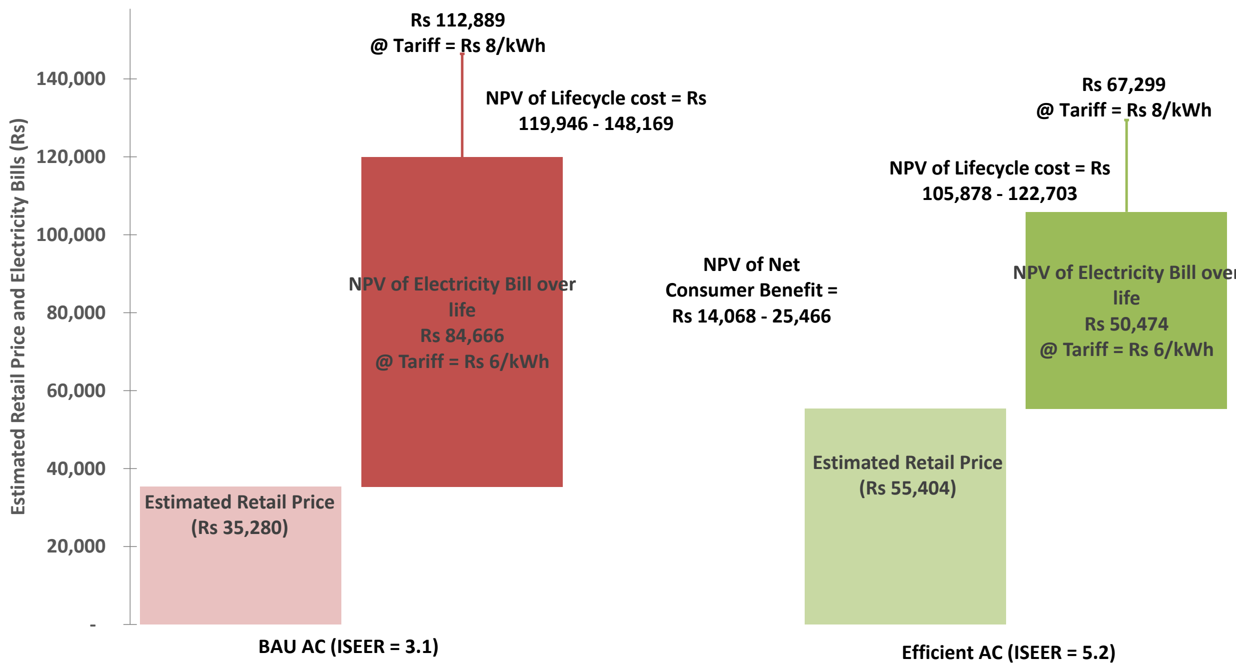
4 Is Room AC Efficiency Improvement Cost-Effective for Consumers?

This section discusses the net consumer benefits and payback periods associated with efficient

ACs as well as the impact of bulk purchase discounts on cost-effectiveness. Individual and institutional consumers are considered.

4.1 What Is the Net Consumer Benefit and Payback?

Figure 5 shows an example of the net consumer benefit for purchasing a new room AC with ISEER 5.2 instead of the current market average ISEER of 3.1 (1.5-ton cooling capacity). Taking the market average as the baseline, the bars show the total estimated retail price of the baseline AC (ISEER 3.1), the incremental price of the efficient AC (ISEER 5.2), and the net present value (NPV) of electricity bill savings over the life of the efficient AC.



Assumptions: Discount rate = 10%, AC life = 7 years, electricity tariff = Rs 6/kWh (or Rs 8/kWh) increasing at 5% per year, and AC use = 1,200 hours/yr.

Figure 5: Estimating the net consumer benefit of purchasing an efficient room AC

The incremental price of the efficient AC is Rs 20,124 (maximum value), while the electricity bill savings would be about Rs 5,000–6,000 per year; that is, consumers could recover the incremental price in about 3–4 years. The NPV of the net consumer benefit is about Rs 14,000–25,000 per consumer. This consumer benefit estimate is highly conservative and should serve as the minimum bound, because: (a) the estimated electricity bill savings are based on conservative assumptions for AC use hours and electricity prices, and (b) we estimate 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. For details on this analysis, see (Shah et al., 2016) and (Abhyankar et al., 2017).

4.2 What Is the Impact of a Bulk Purchase Discount?

If efficient room ACs are procured in bulk quantities, program implementers like EESL may get a significant discount similar to the UJALA LED program's discount. This is especially true for more efficient products, for which the wholesale and retail markups are typically very high.[4] Table 5 shows the impact of bulk purchase discounts (20% and 40% of retail price) on net consumer benefit and payback periods. The analysis considers the same efficiency improvement as shown in Figure 5 (ISEER 3.1 to 5.2). With bulk discounting, the consumer payback improves significantly. In fact, with a 40% bulk discount, the estimated price of the efficient AC (ISEER 5.2) is slightly below that of the baseline AC (ISEER 3.1).

Table 5: Impact of bulk purchase discount on cost-effectiveness of a room AC with ISEER 5.2

	Original	20% bulk discount	40% bulk discount
Price of baseline AC (3.1 ISEER) (Rs)	35,280	#N/A	#N/A
Price of efficient AC (5.2 ISEER) (Rs)	55,404	44,323	33,242
Incremental price of efficient AC (Rs)	20,124	9,043	-2,038
Cost of conserved electricity (Rs/kWh)	4.30	1.93	-0.44
NPV of electricity bill savings over life (Rs)	29,953	29,953	29,953
NPV of consumer benefit over life (Rs)	9,829	20,910	31,990
Simple payback period (years)	3.8	1.7	-0.4

Assumptions: 1.5 TR capacity, discount rate =10%, AC life = 7 years, AC use = 1,200 hours/yr, electricity tariff = Rs 6/kWh increasing at 5% per year.

Table 6 shows the payback periods for purchasing a range of more efficient room ACs (compared with the baseline AC with 3.1 ISEER), with and without a bulk discount of 20% and 40%. The underlying assumptions remain the same as in the previous calculations.

[4] The impact of the Indian government's "Make in India" initiative on potential cost reductions needs to be analyzed further.

Table 6: Impact of bulk purchase discount on cost-effectiveness over a range of ISEER levels

Efficiency Level (ISEER)	Estimated Retail Price (no bulk discount) (Rs)	Simple Payback Period (years) Relative to Market Average (ISEER = 3.1)		
		No bulk discount	20% bulk discount	40% bulk discount
5.0	54,804	3.9	1.7	-0.5
5.2	55,404	3.8	1.7	-0.4
5.4	59,892	4.4	2.3	0.1
5.6	62,940	4.7	2.6	0.4
5.8	65,940	5.0	2.9	0.7
6.0	72,420	5.8	3.6	1.3

Assumptions: 1.5 TR capacity, discount rate =10%, AC life = 7 years, AC use = 1,200 hours/yr, electricity tariff = Rs 6/kWh increasing at 5% per year

The payback period with a bulk discount is about 2–3 years even for highly efficient products (ISEER 5 and beyond) and even under conservative assumptions regarding efficient AC prices, hours of use, and electricity tariffs.

4.3 What Are the Costs and Benefits for Institutional Consumers?

Institutional consumers (mainly private-sector and government office/commercial buildings) likely would be initial participants in a room AC program. Given their high tariff (due to commercial rates) and higher hours of use compared with residential consumers, the cost-benefit analysis shows significantly more favorable results for highly efficient products. Table 7 shows the payback periods for commercial and office buildings (i.e., institutional consumers), with and without a bulk discount of 20% and 40%. The payback period is estimated using the baseline room AC of ISEER 3.1.

Table 7: Cost-effectiveness of efficient room ACs for institutional consumers (higher use and tariff)

Efficiency Level (ISEER)	Estimated Retail Price (no bulk discount) (Rs)	Simple Payback Period (years) Relative to Market Average (ISEER = 3.1)		
		No bulk discount	20% bulk discount	40% bulk discount
5.0	54,804	2.0	0.9	-0.2
5.2	55,404	1.9	0.9	-0.2
5.4	59,892	2.2	1.1	0.1
5.6	62,940	2.4	1.3	0.2
5.8	65,940	2.5	1.4	0.4
6.0	72,420	2.9	1.8	0.6

Assumptions: 1.5 TR capacity, AC life = 7 years, electricity tariff = Rs 9/kWh increasing at 5% per year, and AC use = 1,600 hours/yr.

Without any bulk discount, efficiency improvement up to ISEER 5.2 appears feasible with a simple payback of 1.9 years. With a 20% bulk discount, the simple payback period for the same AC could be as low as 0.9 years, while that for a 6.0 ISEER AC is 1.8 years.

5 What Is the Impact on a Utility's Annual Revenue Requirement?

Participation of the distribution utilities would be crucial for rapid scale-up of the efficient AC program, especially if the program involves on-bill financing or incentives. In this section, we show that room AC efficiency improvement can reduce utility peak load significantly, thus avoiding large power-sector investments and reducing the utility's ARR. Table 8 shows the total peak load saving, avoided investments, reduced utility ARR, and total program cost for a hypothetical on-bill financing program for 1 million new room AC purchases with ISEER of 5.2 (compared with the baseline ISEER of 3.1). Under these assumptions, an on-bill financing program for efficient room ACs can save up to Rs 749 Cr/yr in utility ARR for an incremental cost of Rs 455 Cr/yr.[5] Such a reduction in the ARR may lead to lower average consumer tariffs.

Table 8: Impact of a utility-led program on the utility's ARR

Parameter	Value	Unit
Annual energy savings per AC	816	kWh/yr
Peak load reduction due to an efficient AC	0.42	kW
Program size (assume)	**1 million**	**room ACs**
T&D Loss (approximate)*	15%	%
Total energy savings at bus-bar	961	GWh/yr
Total peak demand reduction at bus-bar	**497**	**MW**
Total avoided generation capacity (assuming 5% forced outage rate, reserves, etc.)	~520	MW
Generation investment per MW	5	Rs Cr/MW
T&D investment per peak MW (approximate and conservative)	~3	Rs Cr/MW
Total avoided power-sector investment	~4,000	Rs Cr
Annualized avoided cost of investment (10% interest rate, life of 25 years)	***461***	***Rs Cr/yr***
Avoided variable (i.e., fuel) cost of generation (weighted for peak coincidence factor)	3.0	Rs/kWh
Avoided fuel cost	***288***	***Rs Cr/yr***
Total avoided cost (investment + fuel) i.e., reduction in utility ARR	***749***	***Rs Cr/yr***
Incremental price of an efficient AC	20,124	Rs
Total cost for the program (incremental price × program size + 10% program management cost)	~2,200	Rs Cr
Annualized cost of efficient AC program (including 10% program management cost)	***455***	***Rs Cr/yr***

Assumptions: 1.5TR capacity, Discount rate =10%, AC life = 7 years, AC use = 1,200 hours/yr, and peak coincidence factor = 0.7.

* T&D (transmission and distribution) loss is taken from the Delhi Electricity Regulatory Commission's tariff orders for the Delhi distribution utilities (Tata Power and BSES) for fiscal years 2014–15 and 2015–16.

[5] Cr stands for Crore. 1 Cr = 10 million.

Although in this example the utility ARR decreases, room AC efficiency programs may affect the utility cash flow negatively and reduce the overall cross-subsidy.[6] Typically, all utilities in India have an inclining block tariff structure, especially for residential and commercial consumers. The marginal tariff in the highest consumption tier, where most room AC consumers would likely fall, is much higher than the cost of supply. When energy consumption declines owing to efficiency programs, utilities lose marginal tariff and thus significant revenue from the participating consumers. At the end of each fiscal year, regulators allow any under-recovery of utility costs as a pass-through to consumers to be recovered through next year's tariffs. Therefore, in a limited sense, Indian utilities are decoupled, because any revenue loss does not result in under-recovery of utility costs. However, the revenue loss may create significant cash flow issues for the utilities, especially because of the high marginal tariffs and cross-subsidy. Given the weak financial condition of most utilities, they may be unwilling to take such cash flow risk and support any large-scale efficiency program targeted at subsidizing consumers. However, several regulatory solutions exist to address this problem, such as sharing of consumer benefits with the utility, treating energy-efficiency expenditures by the utility as capital investments, making more frequent (e.g., monthly) tariff adjustments, and so forth. These issues are explored in Abhyankar and Phadke (2012).

One common concern when assessing the validity of cost-benefit estimates from any appliance efficiency improvement is the rebound effect. The direct rebound effect—higher energy use resulting from the effective rise in consumers' disposable income due to energy-efficiency-induced bill savings—is 8%–12% for most appliance efficiency improvements in developed countries in the short and medium terms (Borenstein, 2013; Gillingham, Rapson, & Wagner, 2016). In emerging economies, direct rebound effects on electricity consumption are higher than in developed countries, varying from 12%–46% (Gillingham et al., 2016). However, consumption patterns in emerging economies change rapidly, and thus estimating the short-term demand elasticities and rebound effect accurately is very difficult. In addition, the rebound effect implies higher consumption of cooling services and thus an overall increase in consumer welfare. In any case, given the large benefits of the AC program (especially with bulk discounting), the financial benefit would still be positive despite rebound effects. Also, the rebound effect will likely have no impact on peak load relative to the business-as-usual scenario given the high peak coincidence of room AC operation. For details on the rebound effect, see Abhyankar et al (2017).

6 Low-GWP Refrigerants

Hydrofluorocarbons (HFCs)—synthetic gases used as refrigerants in air conditioning and

[6] In India, electricity tariffs for commercial and industrial consumers typically are higher than the cost of supply, whereas those for residential (on average) and agricultural consumers are lower than the cost of supply. The difference between tariffs and average cost of supply is known as the cross-subsidy.

refrigeration—are now the fastest-growing greenhouse gases, and they have GWPs thousands of times greater than carbon dioxide's GWP. In India, most manufacturers use R22 and R410A in their room ACs; these HFCs have 100-year GWPs of 1,760 and 1,924, respectively.[7] The Kigali amendment to the Montreal Protocol aims to phase down these high-GWP HFC refrigerants. Therefore, it may be useful to assess whether a low-GWP criterion added to AC procurement requirements can accelerate the transition to low-GWP refrigerants. In addition, low-GWP refrigerants can offer a substantial increase (about 5%–10%) in room AC energy efficiency (Shah, Wei, et al., 2015).

The Air Conditioning, Heating and Refrigeration Institute (AHRI) has extensively tested alternative AC refrigerants under the low-GWP Alternate Refrigerant Evaluation Program (AREP), finding that some refrigerants (e.g., R32 and R452B) are more efficient than the baseline R410A refrigerant (AHRI, 2014). Ingersoll Rand/Trane publicly announced support for developing products using R452B (CoolingPost, 2016). In India, Godrej is selling ACs using R290, while Daikin and several other Japanese manufacturers such as Hitachi, Panasonic, and Fujitsu are selling ACs with R32 (CoolingPost, 2015; EquityBulls, 2016). However, other than those using R32 and R290, ACs with low-GWP refrigerants are not yet commercially available globally or in India. Table 9 shows the relative GWPs and flammability ratings of various refrigerants along with manufacturers of ACs using the refrigerants. More information on the various alternatives, their efficiencies, climate impacts, and peak load impacts can be found in Shah, Wei, et al. (2015).

Table 9: GWPs and flammability ratings of key refrigerants, and manufacturers of ACs using the refrigerants

	100-year GWP	ASHRAE Flammability Rating	Manufacturers	Comments
R22	1,760	A1 (non-flammable)	Many	Ozone depleting, high GWP
R410A	1,924	A1 (non-flammable)	Many	High GWP
R32	677	A2L (mildly flammable)	Daikin, Fujitsu, Panasonic, Hitachi, Mitsubishi	
R452B	676	A2L (mildly flammable)	Ingersoll Rand/Trane (not yet commercial)	
R290	3	A3 (flammable)	Godrej	

ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers

Sources: (Shah, Wei, et al., 2015; Stocker et al., 2013)

In the context of a bulk procurement program for low-GWP ACs, a criterion could be set to allow refrigerants with a GWP of 700 or lower. The EU F-gas regulation has set a requirement banning refrigerants with GWP above 750 from the EU market in 2025 (EU, 2014).

Among highly efficient ACs using low-GWP refrigerants, Daikin's FTKH35RRV16 1-ton inverter

[7] GWP compares the heat trapped by a greenhouse gas in the atmosphere with the heat trapped by similar mass of carbon dioxide (CO_2). CO_2 has a GWP of 1.

AC using R32 is listed at Rs 39,400 and has an ISEER of 4.7, while Godrej's NXW 1-ton inverter AC using R290 is listed at Rs 51,750 and has an ISEER of 5.2. These specifications suggest that manufacturers that have already moved to low-GWP refrigerants can price these models competitively with ACs that use high-GWP R410A. For example LG's BSA12PMZD 1-ton inverter AC using R410A is listed at Rs 48,490 and has an ISEER of 4.7.

For integrating a low-GWP criterion into a room AC program, three potential options exist:

- Eligibility criterion: Only ACs using low-GWP (e.g., GWP < 700) refrigerant are eligible for the program.
- Preference criterion: ACs using low-GWP refrigerant are preferred for the program over ACs using higher-GWP refrigerant if the ACs are otherwise similar in performance, price, and other features.
- Incentive: ACs using low-GWP refrigerant are given a discount (e.g., 5%) on the quoted retail price.

Overall, implementing HFC refrigerant transition and energy-efficiency improvement policies in parallel roughly doubles the greenhouse gas emissions reduction from either policy implemented separately. Commercially available low-GWP refrigerants make such HFC transition feasible and cost-effective, especially for initial phases of a room AC bulk procurement program. Additional evaluation of the supply chain and maintenance constraints would be necessary for wider market transformation and for deeper cuts to refrigerant GWP.

7 Demand-Response-Ready or "Smart" Products

A procurement requirement for DR-ready or "smart" ACs could be used in conjunction with utility DR programs to reduce peak load and integrate variable renewable energy generation. Various countries have adopted or are considering adoption of DR-readiness requirements for various appliances including ACs, as summarized in Table 10.

Table 10: Status of DR-readiness requirements for key appliances (including ACs) in various countries

Country/Body	Standard/Committee	Technology/Appliances	Effective Dates
Japan	Echonet	Meters, appliances, home area networks	Various, 1997–present
USA	Energy Star criteria for connected appliances	Refrigerators	2014
Australia	AS/NZS 4755	ACs, pool pump controllers, water heaters, electric vehicle charge controllers	Various, 2008–2014
South Korea	Korean labeling criteria for ACs and heat pumps	ACs and heat pumps	October 2014
International Electrotechnical Commission (IEC)[8]	TC 59 WG15	Connection of household appliances to smart grids and appliances interaction	Began October 2012

Source: (CEM, 2014)

The specification drafted by the IEC TC 59 WG15 defines a "Customer Energy Manager" (CEM) as "a component or set of functions which has the capability to receive and process Grid Information, Appliance Information and User Instructions and which manages one or more Smart Devices." The CEM could be analogous to a radio-, frequency-, Wi-Fi-, or cellular-controlled chip. The current draft IEC specification requires the CEM to be able to:

- Receive and pass on grid Information to at least one device
- Receive appliance information (e.g., its state or energy-consumption level, etc.)
- Transmit information to the grid (i.e., have bidirectional communication)
- Receive/pass or act on emergency and other types of load-control signals
- Be programmed with preferences (by user, remote agent, or both) and act on them

Information on the relative merits of various types of DR-ready technologies is summarized in Table 11. For more information, see Shah et al. (2015).

[8] IEC is the world's leading organization that prepares international standards for all electrical, electronic, and related technologies.

Table 11: Pros and cons of various types of DR-ready technologies

Technology	Communication Medium	Capabilities	Pros	Cons
Radio-controlled chip that communicates with the appliance microprocessor	Radio signal	Modulate energy consumption (unidirectional communication only)	Lower cost than cell or Wi-Fi	Easier to bypass; actual participation in the program cannot be confirmed and could raise issues for compensation
Frequency-controlled chip that communicates with the appliance microprocessor	Grid frequency	Modulate energy consumption (unidirectional communication only)	Lower cost than cell or Wi-Fi	Unidirectional communication capability; easier to bypass
Wi-Fi chip that communicates with the appliance microprocessor	Wi-Fi network	Modulate energy consumption + report back the status of the device (bidirectional communication)	Hard to bypass; reports back if bypassed/overridden; compensation to consumers can be based on actual participation	Higher cost compared to radio/frequency based switches; costly for retrofit; requires Wi-Fi network; high outage risk; privacy concerns
Cellular chip that communicates with the appliance microprocessor	Cellular network	Modulate energy consumption + report back the status of the device (bidirectional communication)	Hard to bypass; reports back if overridden; consumer compensation can be based on actual participation; availability of cellular network good	Higher costs compared to all options discussed above

All options mentioned in Table 11 are related to requirements on the customer side for implementing an automated DR (ADR) program. This type of AC capability is a prerequisite for implementing an ADR program for ACs. However, merely requiring ADR readiness or a smart AC is not sufficient for implementing DR for ACs. A robust regulatory framework is essential, for example, issuing smart grid standards such as communications specifications, setting DR pricing or incentive design, creating real-time monitoring and verification standards, and so forth. Several institutional arrangements are possible for program implementation, such as the following: (a) the utility communicates to the aggregator for calling the DR event or acts itself as the aggregator;[9] (b) the aggregator bids the DR capacity in the market (real time or ancillary). In the latter case, the regulatory framework would need strengthening, such as by allowing demand-side bidding in power markets, creating markets for more flexible products,

[9] An aggregator, as defined here, is an intermediary between consumers and the utility/grid operator. An aggregator would aggregate the load from multiple consumers (from a few to several thousand) and bid their DR capacity in the wholesale electricity market.

and so forth.

A few utilities in India—such as Tata Power Mumbai and Delhi and Jaipur Vidyut Vitaran Ltd.—have already implemented successful DR pilots, including residential and commercial AC DR. The Jaipur utility, in partnership with the Indian Energy Exchange, has also allowed the demand reductions to bid in the day-ahead electricity market.

For integrating a DR-readiness or smart criterion into a room AC program, three options exist:

- Eligibility criterion: Only DR-ready ACs are allowed to participate in the program.
- Preference criterion: Preference is given to a DR-ready AC if it ties with other ACs on the techno-economic criteria.
- Incentive criteria: DR-ready ACs are given a discount (e.g., 5%) on the quoted retail price.

8 Program Design Examples

This section gives examples of successful appliance efficiency programs from other countries. The examples we describe cover a wide range in terms of their type, funding, and focus.

8.1 Financing Programs

Deason, et al. (2016) offer a comprehensive review of energy-efficiency financing programs in the United States. The report looks at several categories of efficiency programs such as on-bill financing and repayment, utility financing programs (in which loans are not paid back on bills), Property Assessed Clean Energy (PACE) financing, state energy office revolving loan funds, and energy savings performance contracts. In addition to these, several other innovative U.S. programs have enhanced access to capital and financing for efficiency improvement. Zimring, et al. (2012) review such programs. Zimring et al. (2014) discuss a few alternative underwriting mechanisms, such as electricity bill payment history, that reduce consumer rejection as well as default rates significantly. For example, Clean Energy Works Oregon and New York State Energy Research and Development Authority used electricity bill payment history as a proxy for buyer creditworthiness for running their financing programs. Leventis et al. (2016) review several successful PACE programs offered in the United States.

8.2 Complementary Programs such as Demand Response

Several utilities, such as Con Edison of New York and Pacific Gas and Electric in California, offer DR programs in addition to equipment energy efficiency. Con Edison's room AC DR program has been one of the most successful in the United States in recent years. Since 2012, Con Edison's residential AC DR program has had more than 10,000 participants.[10]

[10] More details on Con Edison's DR programs in general as well as their incentive levels can be found at www.coned.com/energyefficiency/demand_response_program_details.asp.

In the Indian context, Shah et al. (2015) give more information on the potential DR programs in India and discuss the communication protocol with the utility grid. The BEE held a workshop on space cooling efficiency improvement and DR in 2014.[11] Clean Energy Ministerial also held a roundtable on cooling DR in 2014.[12] A few urban utilities—such as Tata Power Delhi, Tata Power Mumbai, and Rajasthan distribution companies—have already implemented commercial and industrial DR pilots and are considering residential programs actively.

8.3 Rebates and Incentives

Several countries have successfully implemented incentive programs for efficient appliances. De la Rue du Can et al. (2014) review incentive programs for appliances—including ACs—from multiple countries (Table 12). The most notable downstream (consumer-focused) programs for ACs are from Japan and South Korea; those programs gave consumers "credits" for buying efficient appliances, which could be used to purchase any other merchandise. The programs covered other appliances—such as washing machines and refrigerators—as well and were successful in significantly increasing the penetration of efficient products.

[11] See the agenda and presentations at https://beeindia.gov.in/sites/default/files/ctools/Agenda_CoolingDRworkshop_Delhi_vJun4_2%201.pdf.

[12] The associated presentation, with links to many useful resources on the topic, is at www.cleanenergyministerial.org/Portals/2/pdfs/CEM5-RT-CoolingandDR-Pres.pdf.

Table 12: Examples of appliance efficiency programs from multiple countries

Type of Program	Country	Program	Time Frame	Form	Recipient	Administrator	Funding	Energy-efficient Product
Downstream (Consumer Focused)	**France**	Sustainable Development Tax Credit	2005 to present	Tax credit	Consumers	Government	General budget	Boilers, home insulation, heat pumps, windows, renewable energy
	Italy	Tax Deduction for Energy Savings	2007 to present	Tax deduction replacement	Consumers	Government	General budget	Efficient equipment and home insulation
	United Kingdom	Reduced Value-Added Tax (VAT)	1998 to present	VAT reduction	Consumers	Government	General budget	Insulation material, heating control systems, heat pumps, wood-fueled boilers
	South Korea	Carbon Cashbag	2008 to present	Eco-points	Consumers	Local Government	General and local budget	Home electronics, appliances
	Japan	Eco-point	2009–2011	Eco-points	Consumers	Local Government	Stimulus package	ACs, refrigerators, TVs
	Mexico	PNSEE	2009 to present	Replacement on-bill financing	Consumers	Government	International institution	Refrigerators, ACs
Midstream (Distributor/ Retailer Focused)	**United States (Texas)**	Distributor Air Conditioning Market Transformation	2001–2004	Rebate	Retailers	Utility	Rate funded	Central AC units

	United States (California)	California Business and Consumer Electronics (BCE)	2007 to present	Rebate	Distributors	Utility	Rate funded	Televisions, computer monitors
Upstream (Manufacturer Focused)	**China**	Promotion Products Program	2008 to present	Upstream subsidy	Manufacturers	Government	General budget	Compact fluorescent lamps (CFLs), ACs, TVs, water heaters, washing machines, refrigerators
	Sweden	Ground-source Heat Pumps Technology Procurement Program	1993	Upstream technology procurement	Manufacturers	Government	General budget	Ground-source heat pumps
	United States	Federal Energy-Efficiency Tax Incentives for Manufacturers	2005–2011	Upstream tax credit	Manufacturers	Government	General budget	Residential refrigerators, clothes washers, dishwashers
	United States (California)	California Upstream Lighting Program	2006–2008	Upstream buy down	Manufacturers	Utility	Rate funded	CFLs

Source: (de la Rue du Can et al., 2014)

9 Conclusion and Recommendations

In this report, we have discussed the key technical and economic considerations for designing a room AC bulk procurement/financing program in India, such as the technical feasibility of efficiency improvement and its potential costs, impact of bulk-purchase discounts on consumer (including institutional consumers and utility) costs and benefits, and importance of low-GWP refrigerants and DR readiness. We have also given a few examples of successful appliance programs from other countries.

Table 13 shows a few examples of the room AC builds (1.5-ton capacity) we simulated using more efficient components, their estimated ISEER values, and estimated retail prices. For an ISEER of 5.2, the simple payback period is less than 4 years, even without a bulk discount. With a bulk discount of 20%, the payback period drops to less than 2 years. For ISEER 6.0, the payback period with a 20% bulk discount could be less than 4 years. Note that room ACs with ISEER 5.8 and 6.0 are yet not available in India in 1.5-ton capacity. For institutional consumers (e.g., commercial and office buildings), the payback periods are much shorter because of these consumers' high electricity tariffs and hours of use.

Table 13: Technical specifications, estimated retail prices, and payback periods for efficient room ACs (1.5-ton)

Efficiency Level (ISEER)	Technical Specifications	Estimated Retail Price (no bulk discount) (Rs)	Simple Payback Period (years) – relative to market average (ISEER = 3.1)		
			No bulk discount	20% bulk discount	40% bulk discount
3.1 (Baseline)	3.0 EER compressor; baseline heat exchanger; capillary tube	35,280	#N/A	#N/A	#N/A
4.6 (5-Star)	3.4 EER compressor with VSD; heat exchanger UA value +20%; thermostatic expansion valve	48,828	3.8	1.7	0
5.2	3.4 EER compressor with VSD; heat exchanger UA value +60%; thermostatic expansion valve	55,404	3.8	1.7	0
5.8	3.4 EER compressor with VSD; heat exchanger UA value +100%; electronic expansion valve	65,940	5.2	3.0	0.7
6.0	3.4 EER DC compressor & fan with VSD; heat exchanger UA value +100%; electronic expansion valve	72,420	6.1	3.7	1.3

Assumptions: 1.5 TR capacity split AC, electricity tariff = Rs 6/kWh increasing at 5% per year, AC life = 7 years, AC use = 1,200 hours/yr.

Overall, implementing HFC refrigerant transition and energy-efficiency improvement policies in parallel roughly doubles the greenhouse gas emission reduction from either policy implemented separately. Commercially available low-GWP refrigerants make such HFC transition feasible in a cost-effective manner, especially for the initial phases of a room AC bulk procurement program. A procurement requirement for DR-ready, or “smart,” ACs could be used in conjunction with utility DR programs to reduce peak load and integrate variable renewable energy generation. However, merely requiring DR readiness or a smart AC is not sufficient for implementing DR for ACs. A robust regulatory framework is essential, for example, issuing smart grid standards such as communications specifications, setting DR pricing or incentive design, and so forth.

We make the following recommendations for a room AC bulk procurement program in India:

1. The program should help consumers making new room AC purchases buy the most efficient room ACs commercially available in India instead of lower-efficiency products. The most efficient products in India have ISEERs of 5.2 (1.5 ton) and 5.8 (1 ton sizes).
2. A bulk procurement program can reduce the price of an efficient AC by 20%–40%, significantly enhancing the AC’s cost-effectiveness.
3. Institutional consumers (office/commercial buildings) could be initial participants in the program owing to their high tariffs and hours of use, which further enhance the cost-effectiveness of efficient ACs.
4. The program should give preference to smart ACs and ACs using refrigerants with GWP less than 700, when techno-economic parameters are otherwise equivalent.
5. An efficient AC program would likely reduce a utility’s ARR and thus consumer tariffs. Therefore, utilities could offer on-bill financing or on-bill repayment programs to increase program participation, as demonstrated successfully in multiple other countries. However, any utility program design should also include regulatory solutions to address the utility cash flow risk.

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Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, CA 94720
http://www.lbl.gov/