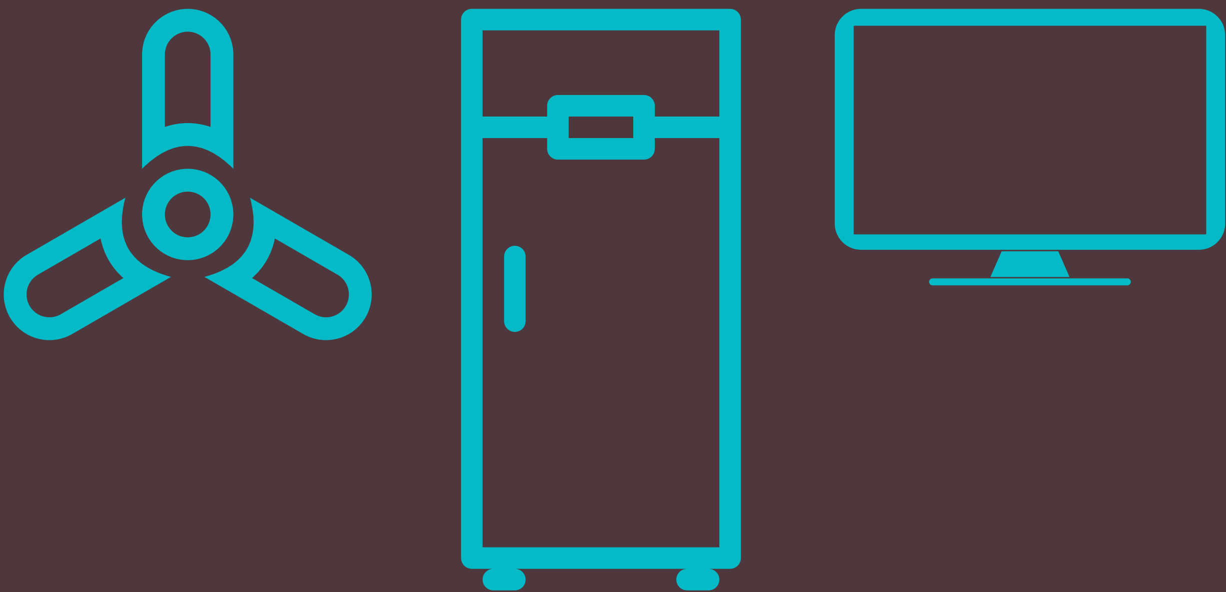
ACEEE
American Council for an Energy-Efficient Economy

Alliance for an Energy Efficient Economy

MAINSTREAMING SUPER-EFFICIENT APPLIANCES IN INDIA



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Disclaimer

This report is based on data collected by Alliance for an Energy Efficient Economy (AEEE) and American Council for an Energy-Efficient Economy (ACEEE) from government and other databases for energy-efficient appliances and from product specifications provided by manufacturers. Every attempt has been made to ensure the correctness of data. However, AEEE does not guarantee the accuracy of the data or accept responsibility for the consequences of the use of such data.

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Last but not least, we are grateful to our own in-house support teams.

EXECUTIVE SUMMARY

The appliance and consumer electronics market in India was pegged at INR 2050 billion in 2017 and is projected to grow to INR 3150 billion in 2022 (PwC, 2017). This growth in appliance ownership, while improving the quality of life and standard of living for a growing and aspirational Indian middle class, will significantly increase energy demand. By how much is a crucial question.

Consumer appliance market in India is projected to grow to
INR 3150bn
in 2022

Electricity consumption in the residential sector is projected to grow from 259 TWh in 2016-2017 (MoSPI, 2018) to 533 TWh in 2027 (CEA, 2017), putting pressure on energy supply and the environment due to increased GHG emissions. However, there is a cleaner and more energy-efficient path. A case in point is the UJALA programme for LED bulbs by Energy Efficiency Services Limited (EESL), which completely transformed the lighting sector and, as of June 2019, resulted in annual energy savings of 45,866 million kWh and CO_2 reduction of 37 million tons per year. Ceiling fans, refrigerators and televisions, which are among the top four appliances in energy consumption, could make a similar step change in energy efficiency by mainstreaming some of the most energy-efficient technologies.

UJALA programme for LED bulbs by Energy Efficiency Services Limited (EESL) resulted in annual energy savings of
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and CO_2 reduction of 37 million tons per year

The good news is that the technology is already available in the market. Yet, cost barriers deter these super-efficient appliances from forming the bulk of the market, as evidenced by the much smaller share of 4-star and 5-star appliances in the market. For example, 5-star rated ceiling fans constituted only 9% of the ceiling fan market in 2017-2018. This report is based on a study of the most energy-efficient product models among ceiling fans, refrigerators and TVs in Indian and global markets. The study examines the energy performance of the selected models and technologies that differentiate the most energy-efficient models from the rest. Inputs from manufacturers on barriers they face in mainstreaming super-efficient technologies as well as their recommendations to transform the market for energy-efficient appliances are presented in this report. The concluding section suggests pathways to mainstream super-efficient appliances.

Cost barriers
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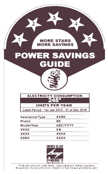
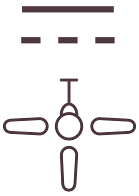


5-star ceiling fans with energy-efficient AC induction motors consume about

50w compared to 70-75w

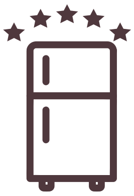
for fans with no star rating.



BLDC ceiling fans consume on average

32 w

36% less than 5-star fans with AC induction motors.



5-star refrigerators consume

30-35% less

energy compared to 3-star refrigerators.

India Cooling Action Plan is an expedient opportunity to mainstream BLDC fans & make a step change in the energy efficiency of refrigerators.

Fans are a low-cost means of providing thermal comfort for all in India and are the 2nd most common appliance in homes after lighting. 5-star ceiling fans with energy-efficient AC induction motors consume about 50 watts compared to 70-75 watts for fans with no star rating. The most energy-efficient ceiling fans in the market use Brushless DC (BLDC) motors and consume on average 32 watts, 36% less than 5-star fans with AC induction motors. Unfortunately, BLDC ceiling fans are about 80% more expensive than 5-star ceiling fans with AC induction motors, the main reason being the cost of BLDC motors. Building a robust local eco-system for BLDC motors and bringing down their cost, possibly through bulk procurement/import of critical components (magnets, control circuits) will result in energy-efficiency dividends for ceiling fans and a range of other household appliances driven by motors. Given the importance of ceiling fans in providing thermal comfort for all at low cost, the India Cooling Action Plan (ICAP) is an expedient opportunity to mainstream BLDC fans.

5-star refrigerators that consume 30-35% less energy compared to 3-star refrigerators are already available in the market. Yet, their higher cost is a deterrent to the widespread adoption of 5-star refrigerators. For refrigerators too, the lack of local availability of some technologies, such as highly efficient compressors and the latest insulation technology, is a barrier to widely deploying the best available energy-efficient technologies at a competitive price. India Cooling Action Plan (ICAP) is an opportunity to invest in a robust 'Make In India' ecosystem for critical components and make a step change in the energy efficiency of refrigerators.

Correlating the energy performance of TVs with the best available energy-efficient technologies was a challenge. It would be worthwhile to conduct a comprehensive technical analysis on the most energy-efficient display technologies and power management features used in a range of electronic devices - TVs, commercial displays, desktop monitors, laptops and mobiles. Examining the applicability of the most energy-efficient technologies could spur improvement in the energy performance of all such electronic devices, not just TVs.

ABBREVIATIONS

ABC	Automatic Brightness Control
AC	Alternating Current
AEC	Annual Energy Consumption
BAU	Business As Usual
BEE	Bureau of Energy Efficiency
BI	Built-In
BLDC	Brushless DC
CC	Climate Class
CCFL	Cold Cathode Fluorescent Light
CEA	Central Electricity Authority
CEC	Comparative Energy Consumption
CRT	Cathode Ray Tube
DC	Direct Current
ECBC	Energy Conservation Building Code
EE	Energy Efficiency, Energy-Efficient
EESL	Energy Efficiency Services Limited
GHG	Greenhouse Gases
GWP	Global Warming Potential
HD	High Definition
HFC	Hydrofluorocarbon
HVAC	Heating, Ventilation and Air conditioning
ICAP	India Cooling Action Plan
INR	Indian Rupees
kVA	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt-hour
LBA	Liquid Blowing Agent
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPG	Liquified Petroleum Gas
MEPS	Minimum Energy Performance Standard
MoSPI	Ministry of Statistics and Programme Implementation
ODP	Ozone Depleting Potential
OLED	Organic LED
PUF	Polyurethane Foam
QLED	Quantum-dot LED
TWh	Terawatt-hour
UHD	Ultra-High Definition
VIP	Vacuum Insulation Panel
w,W	Watts

CONTENTS

Residential buildings accounted for

24% of total electricity consumption

in India for the year 2016-2017

Estimated number of households in India (year/households)

2017
272 million

2027
328 million

2037
386 million

Estimated growth in residential electricity consumption

2016-2017
259 TWh

2027
533 TWh

1 INTRODUCTION

Residential Buildings accounted for 24% of total electricity consumption in India for the year 2016-2017, second only to industry (MoSPI, 2018). As of 2017, the estimated number of households in India was approximately 272 million, which is expected to increase to 328 and 386 million by 2027 and 2037 respectively (NITI Aayog, 2015). With the increase in households and growing demand for consumer appliances, electricity consumption in the residential sector is estimated to grow from 259 TWh in 2016-2017 (MoSPI, 2018) to 533 TWh in 2027 (CEA, 2017). A recent study by Brookings India 'The Future of Electricity Demand in India' estimates that in the year 2030 the top four appliances in terms of electricity consumption will be room air conditioners, refrigerators, fans and colour televisions.

The growth in ownership of fans, refrigerators and TVs spells a significantly improved quality of life for more Indians, especially in terms of healthier and more comfortable living. Mainstreaming the best available energy-efficient technologies will enhance this quality of life by reducing carbon emissions and will also directly benefit the consumer by lowering his/her annual electricity consumption. Further, reducing the demand for electricity will help achieve India's goals towards 24x7 energy access, energy security and climate change.

Table 1 illustrates the energy savings potential from improved energy efficiency in ceiling fans, domestic refrigerators and colour televisions (AEEE, 2018 and Brookings India, 2018).

TABLE 1. APPLIANCE ENERGY CONSUMPTION

Appliance	Total Annual Energy Consumption in India (TWh)			Energy Savings Potential 2027 (TWh)	Energy Savings Potential 2027 (%)
	2017	2027 (BAU)	2027 (Improved EE)		
Fans	41	52	46	6	12%
Refrigerators	51	87	73	14	16%
Colour TVs	23.6[1]	46.1[2]	36.2[2]	9.9	21.5%[2]

Source: Demand Analysis for Cooling by Sector in India in 2027 (AEEE, 2018); The Future of Indian Electricity Demand (Brookings India, 2018); [1]Year 2015, [2]Year 2030

The Bureau of Energy Efficiency (BEE) in India has developed two programmes to reduce energy intensity in buildings, the Energy Conservation Building Code (ECBC) for commercial and residential buildings, and a Standards and Labelling programme for appliances and equipment. ECBC for commercial buildings was first launched in 2007. ECBC 2017, the latest edition of the code for commercial buildings, applies to commercial buildings with connected load of 100 kW and above or 120 kVA and above and focuses on building envelope, mechanical systems and equipment including heating, ventilating and air conditioning (HVAC) systems, interior and exterior lighting systems, electrical systems and renewable energy. Eco Niwas Samhita Part 1 - Building Envelope, the first part of the Energy Conservation Building Code for residential buildings was launched in December 2018. Eco Niwas Samhita Part 1 addresses only the building envelope and not the whole building, in that it does not cover electrical and mechanical systems and equipment and other aspects of energy conservation for buildings.

BEE's Standards and Labelling was launched in 2006 and currently covers twenty-three appliances and equipment, of which ten are included in the mandatory labelling scheme, and thirteen are included in the voluntary labelling scheme, as indicated in Table 2.

TABLE 2. APPLIANCES IN BEE STANDARDS AND LABELLING PROGRAMME

MANDATORY LABELLING SCHEME	VOLUNTARY LABELLING SCHEME	
ROOM AIR CONDITIONER • Window & Split, non-inverter • Cassettes, Floor standing • Variable Capacity Inverter	CEILING FAN	DIESEL ENGINE DRIVEN MONOSET PUMP
REFRIGERATOR • Frost Free • Direct Cool	LPG COOKSTOVE	PUMP SET
LAMPS • Tubular Fluorescent • LED	WASHING MACHINE	INDUCTION MOTOR
COLOUR TV	MICROWAVE OVEN	SOLID STATE INVERTER
ELECTRIC GEYSER	COMPUTER (LAPTOP, NOTEBOOK)	DIESEL GENERATOR
DISTRIBUTION TRANSFORMER	OFFICE EQUIPMENT (PRINTER, COPIER, SCANNER)	CHILLER
	BALLAST (ELECTRONIC, MAGNETIC)	

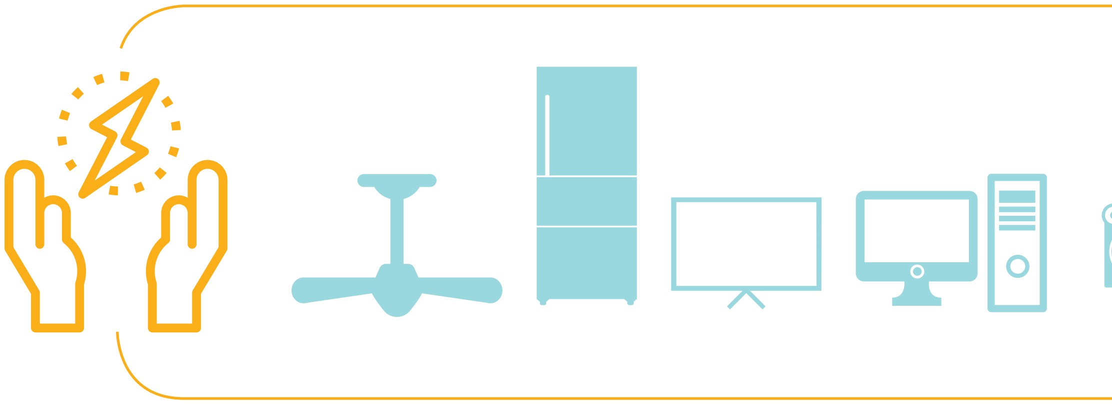
OBJECTIVE OF THIS STUDY

The objective of this study is to research the most energy-efficient product models among ceiling fans, refrigerators and TVs in Indian and global markets, identify technologies that differentiate the most energy-efficient models from the rest and suggest pathways for mainstreaming these super-efficient technologies.

The expected mid-term to long-term outcomes of this study are

- Policies and programmes to increase market penetration of super-efficient appliances
- Higher stringency in the national standards and labelling programme

2 APPROACH

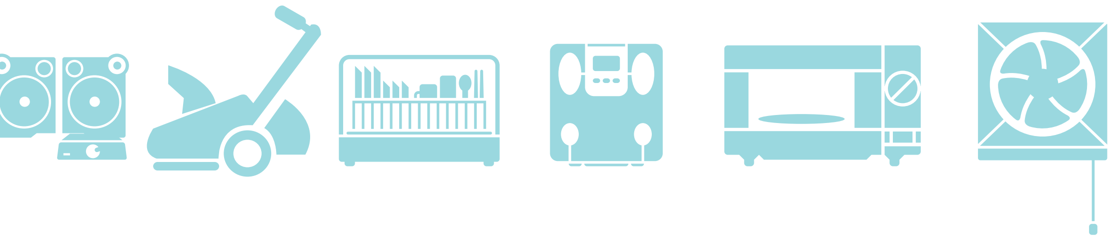


1. IDENTIFY THE MOST ENERGY-EFFICIENT MODELS IN INDIAN AND GLOBAL MARKETS

A range of models was selected in the following product categories: 1200mm ceiling fans, single door and double door direct cool and frost-free refrigerators, and 32-inch LED TVs in Indian and global markets. These product models were chosen because they are the most common or among the most common models sold in India, and because these models are often the choice for those first acquiring these appliances. The high-efficiency Indian models examined are those rated 4-star and 5-star as per BEE's Standards and Labelling Programme. The product models examined from global markets are mostly from the top two energy-efficiency labels in those markets.

2. ANALYSE ENERGY CONSUMPTION VIS-À-VIS THE TECHNOLOGIES USED

The energy performance for the selected models was compared based on the capacity and features, energy consumption and power specifications for each model. For Indian products that were examined, the components and technologies that differentiate the most energy-efficient models from other models were reviewed. The energy consumption and power specifications for each model have been taken from the energy label for the product and information available on the manufacturer's website. The energy performance for ceiling fans is measured as *'air delivery in cubic metres per minute/input power in watts'*. The energy performance for refrigerators is taken as *'Annual Energy Consumption in kWh/Adjusted Volume in litres'*, where the adjusted volume is calculated according to the test specification for the specific country's standards & labelling regulation. The energy performance for TVs is taken as *'screen area in square inches/active power in watts'*. While the particulars of these metrics might be subject to debate, they were chosen because they provide a measure of energy performance based on the data that is publicly available, and therefore could be obtained, for the selected models.



3. SEEK INPUTS FROM MANUFACTURERS

Inputs were sought from manufacturers of energy-efficient appliances in India. The purpose of the survey was to obtain data on

- differentiating technologies used in 5-star and 4-star models compared to 3-star models in India
- barriers to widely deploying the most energy-efficient technologies
- suggestions for driving market penetration of the most energy-efficient technologies in India

4. DEVELOP POLICY RECOMMENDATIONS

Based on AEEE's research and inputs received from manufacturers, suggestions to mainstream the most energy-efficient technologies are presented in this report. These include but are not limited to, recommendations related to the availability and cost of technologies, market conditions and consumer awareness.

The total fan market for 2017-2018 was approximately

55 million units

39 million (72%)

were ceiling fans

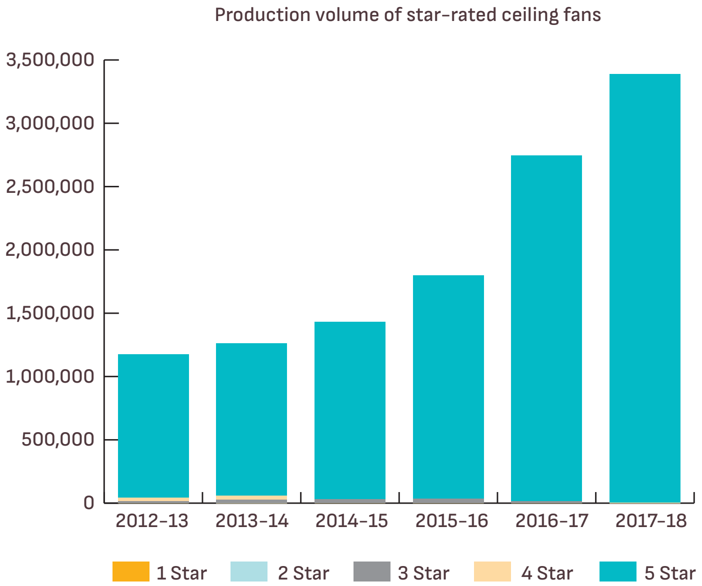
3.39 million (9%)

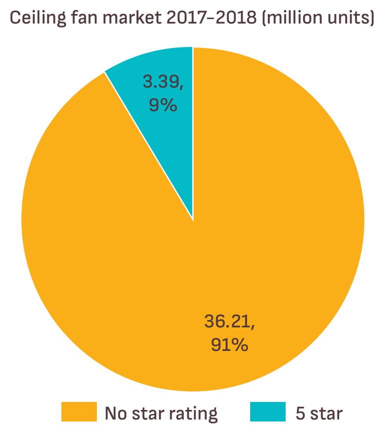
fans were labelled as 5-star in 2017-2018

3 CEILING FANS

The total fan market for 2017-2018 was approximately fifty-five million units, of which thirty-nine million (72%) were ceiling fans (Frost & Sullivan, 2018). Figure 1 illustrates the production data for ceiling fans. Only 3.39 million fans were labelled as 5-star in 2017-2018, barely 9% of the overall market for ceiling fans.

FIGURE 1. CEILING FAN PRODUCTION





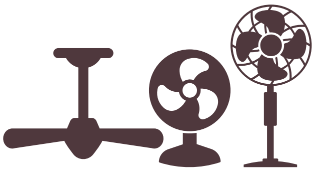
Source: BEE, Frost & Sullivan

Energy labelling for ceiling fans is covered under BEE's voluntary labelling scheme. The energy performance or 'service value' of ceiling fans is defined as *'air delivery in cubic metres per minute / input power in watts'*. Table 3 provides the service value range applicable for each star rating for 1200mm ceiling fans.

TABLE 3. BEE STAR RATING FOR 1200MM CEILING FANS

Service Value for 1200mm Ceiling Fans		
Star rating	1-Jan-2016 to 30-Jun-2019	1-Jul-2019 to 30-Jun-2022
1 Star	≥ 3.2 to < 3.4	≥ 4.0 to < 4.5
2 Star	≥ 3.4 to < 3.6	≥ 4.5 to < 5.0
3 Star	≥ 3.6 to < 3.8	≥ 5.0 to < 5.5
4 Star	≥ 3.8 to < 4.0	≥ 5.5 to < 6.0
5 Star	≥ 4.0	≥ 6.0

Source: BEE



Fans of all types – ceiling, table, pedestal – are probably among the most widely used home appliances after lighting.

Fans are a low-cost means of thermal comfort in India. Fans of all types – ceiling, table, pedestal – are probably among the most widely used home appliances after lighting. So much so, Energy Efficiency Service Limited (EESL) launched the UJALA Fan scheme to make energy-efficient ceiling fans affordable to a broader population. Fans per household are projected to increase to 2.05 in 2030 from 1.18 in 2012 (Brookings India, 2018).

REVIEW OF SELECTED MODELS

The energy performance of ten ceiling fan models sized 1200mm manufactured prior to 1 July 2019, was examined. The energy performance, or service value, is based on the air delivery in cubic metres per minute and input power as indicated on the manufacturer's website or catalogue for these models. Table 4 provides the energy performance (referred to as service value), annual energy consumption and annual electricity cost assuming ten hours of use per day. The domestic electricity tariff varies widely across India, from as low as INR 1/kWh to as high as INR 12/kWh. An electricity tariff of INR 5/kWh has been used in this report.

TABLE 4. ENERGY PERFORMANCE OF CEILING FANS

Air Delivery (m^3/minute)	Service Value (m^3/minute/watt)			AEC (kWh) for 10 hours usage/day			Annual Electricity Cost (INR) for 10 hours usage/day		
	5-star BLDC Motor	5-star AC Induction Motor	No star rating	5-star BLDC Motor	5-star AC Induction Motor	No star rating	5-star BLDC Motor	5-star AC Induction Motor	No star rating
200 – 210	-	4.20 - 5.25	4.0	-	146 - 183	183	-	730 - 915	915
215 – 220	6.88	4.11 - 4.58	-	117	175 - 193	-	585	875 - 965	-
230	6.57–8.21	-	-	102 - 128	-	-	510 - 640	-	-

Sample size - 10; Air Delivery: 200-210 - 3 models, 215-220 - 5 models, 230 - 2 models
Source: Manufacturer product specifications

With BLDC fans costing on average 80% more than 5-star AC induction motor fans, the payback period from energy savings by using a BLDC fan versus a 5-star AC induction motor fan is about 4-6 years.

For the models reviewed in Table 4, the price of a fan without a star rating is about INR 1600, whereas the price of a 5-star AC induction motor fan is about INR 1800-2800 and that of a Brushless DC (BLDC) motor fan is about INR 3600-5000. With BLDC fans costing on average 80% more than 5-star AC induction motor fans, the payback period from energy savings by using a BLDC fan versus a 5-star AC induction motor fan is about 4-6 years.

The annual domestic electricity consumption per capita is 200 kWh (CEA, 2018) and that per connected domestic consumer is 1234 kWh (CEA, 2018), resulting in an annual electricity bill of INR 6170 per domestic connection/household at a tariff of INR 5/kWh. In smaller lower-income households the annual consumption and bill would be much less than the above stated average, with lighting, fans and a TV being the only electrical loads. Switching to the most energy-efficient fans will have a proportionately higher impact for such households, but the much higher cost of a BLDC fan is likely to make most consumers opt for less efficient lower-cost fans.

TECHNOLOGY OVERVIEW

The technologies available for the main components of a ceiling fan are listed in Table 5.

TABLE 5. CEILING FAN TECHNOLOGY

Component	Technology options impacting energy performance
Motor	The motor is the component that most impacts the energy performance of a ceiling fan. The best technology in the market is the brushless DC motor (BLDC), which improves energy performance (service value) by 50-60% compared to an AC induction motor based on the models that we reviewed, as given in Table 4. Even for AC induction motors, there is a range of efficiency levels available in the market. The efficiency of AC induction motors can be improved through design and materials, e.g. increasing the length and cross-section of copper wiring within the motor.
Blade design	Blade design impacts air delivery and drag and therefore affects energy performance. Blade design, e.g. bevelled, twisted or curved, should be chosen to provide optimal air delivery.
Blade material	Blade material has some impact on energy performance. Aluminium is relatively widely used in the Indian ceiling fan market because it's low weight and durable.
Controls	Controls such as occupancy sensors and sleep mode timers help in reducing energy consumption by automatically reducing hours of operation and/or reducing fan speed.

Based on inputs we received from manufacturers, the critical technology differentiator in the most energy-efficient fans is the brushless DC motor. However, BLDC fans are about 80% more expensive than even the most efficient AC induction motor fan. AC induction motor efficiency too is a crucial determinant of the difference in energy performance between 5-star fans and fans with no star rating. Blade design has some impact on energy performance as well as on comfort factors such as reduced noise level. Higher-end fans come with controls such as timer mode and sleep mode.

BLDC motors have an efficiency of 80% compared to 40-60% for single-phase AC induction motors.

BLDC MOTORS

BLDC motors have an efficiency of 80% compared to 40-60% for single-phase AC induction motors. Further, BLDC motors are smaller, less noisy and have a wider speed range. For these reasons, they are highly suitable for consumer/home appliances like ceiling fans, air conditioners, washing machines, dishwashers and smaller appliances. Small BLDC motors can also be used for the evaporator & condenser fans in refrigerators, improving their energy efficiency. Therefore, any programme to vastly improve the BLDC motor ecosystem and reduce the cost of BLDC motors, such as bulk procurement of BLDC motors or the critical components for BLDC motors, would make a step change in energy efficiency for many widely used consumer appliances – fans, air conditioners, refrigerators, washing machines – at fairly competitive prices.

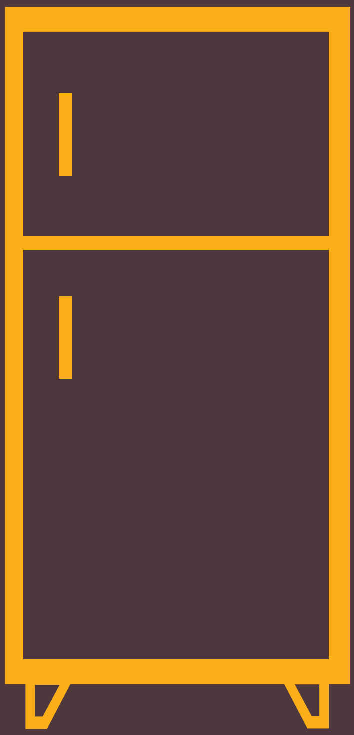
BARRIERS

Manufacturers indicated that the main barrier to making the most energy-efficient fans accessible and affordable is the cost of the BLDC motor. Manufacturers of BLDC ceiling fans typically produce the BLDC motors themselves. However, magnets and control circuits for BLDC motors are generally imported from China, and the vendor ecosystem for BLDC motor components is not that well developed in India.

RECOMMENDATIONS

- Developing the ecosystem for BLDC motor components in India will help reduce the cost of production of these motors, which in turn would reduce the cost of BLDC ceiling fans and other consumer appliances that would be more energy-efficient with BLDC motors. Given that ceiling fans are a low-cost means of providing thermal comfort, the India Cooling Action Plan is an expedient opportunity to develop a robust ‘Make In India’ ecosystem to bring down the cost of BLDC ceiling fans.
- Bulk procurement of BLDC motors or bulk import of critical components (magnets, control circuits) for BLDC motors would help bring down costs.
- Preferential tax or duty for imported components required for BDLC motors could be considered since it will help develop the vendor ecosystem in India.

- Mandating minimum energy performance standards (e.g. 5-star BLDC fans) for appliances and equipment procured in government organisations will help in developing and growing the market for super-efficient appliances.
- Bringing ceiling fans under the mandatory Standards and Labelling scheme is essential to differentiate and promote energy-efficient fans.
- The government could establish R&D programmes on super-efficient technologies such as BLDC motors and their application in consumer appliances.
- Consumer incentives such as subsidy, on-bill financing and differential tax rates for super-efficient appliances could be considered for demand side management programmes.



Projected growth of refrigerators per household

2012
0.18

2030
0.64

90 %

of the market share is accounted for by single-door and double-door Direct Cool and Frost-Free refrigerators

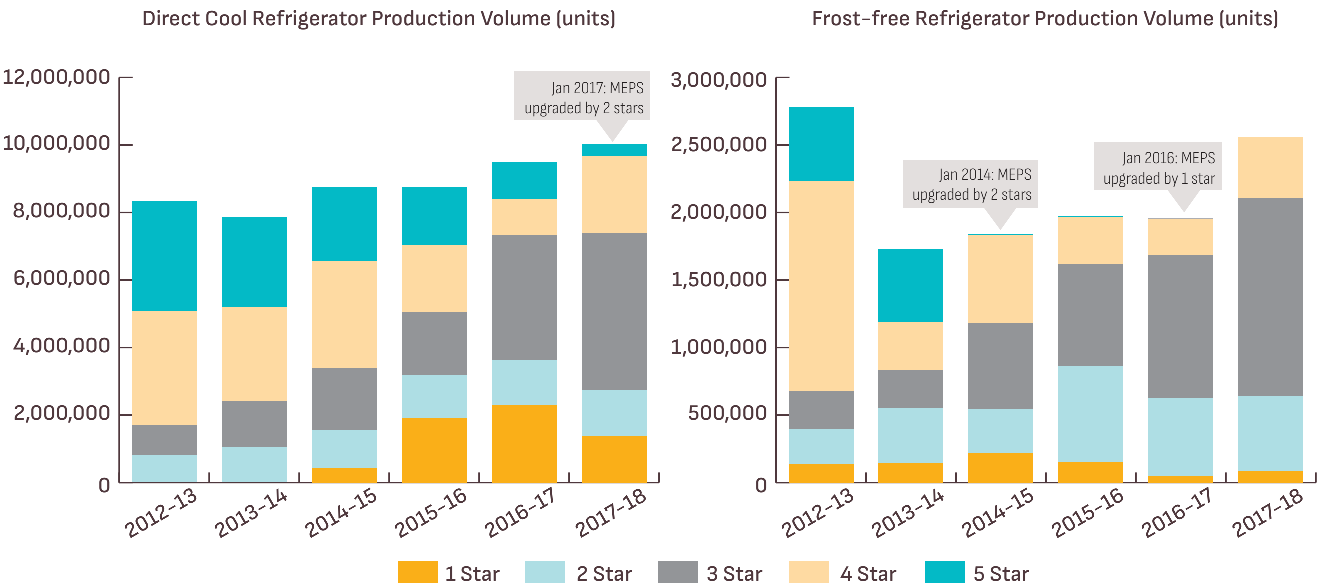
4 REFRIGERATORS

Refrigerator ownership is projected to grow to 0.64 per household in 2030 from 0.18 per household in 2012 (Brookings India, 2018). Single-door and double-door Direct Cool and Frost-Free refrigerators account for more than 90% of the market. Multi-door and side-by-side refrigerators have a very small market share.

Figure 2 shows the production trend for refrigerators. Bureau of Energy Efficiency (BEE) data for 2017-2018 indicates that models rated 1-star to 3-star dominate the market for direct cool refrigerators (74%) and frost-free refrigerators (82%). The MEPS for direct cool refrigerators was upgraded by two stars (two levels) in January 2017, and that for frost-free refrigerators was improved by two stars (two levels) in January 2014 and by one star (one level) in January 2016.

Models rated 1-star to 3-star dominate the market for direct cool refrigerators (74%) and frost-free refrigerators (82%).

FIGURE 2. PRODUCTION VOLUME FOR REFRIGERATORS



Source: BEE

BEE mandates energy efficiency standards and labelling for single-door and double-door direct cool and frost-free refrigerators, but multi-door and side-by-side refrigerators are not yet included in the mandatory labelling scheme.

Table 6 provides the energy performance bands for direct cool refrigerators valid till 31 December 2019, with 1-star being the least efficient and 5-star being the most efficient.

TABLE 6. BEE STAR RATING FOR DIRECT COOL REFRIGERATORS

Star Rating Band for Direct Cool Refrigerators valid till 31 December 2019	
Star rating	Comparative Energy Consumption (CEC) Criteria
1 Star	$(0.264 * V_{adj\_tot\_dc} + 221) \leq CEC < (0.33 * V_{adj\_tot\_dc} + 277)$
2 Star	$(0.211 * V_{adj\_tot\_dc} + 177) \leq CEC < (0.264 * V_{adj\_tot\_dc} + 221)$
3 Star	$(0.169 * V_{adj\_tot\_dc} + 141) \leq CEC < (0.211 * V_{adj\_tot\_dc} + 177)$
4 Star	$(0.135 * V_{adj\_tot\_dc} + 113) \leq CEC < (0.169 * V_{adj\_tot\_dc} + 141)$
5 Star	$CEC < (0.135 * V_{adj\_tot\_dc} + 113)$

Source: BEE

Comparative Energy Consumption (CEC) is the estimated annual energy consumption in kWh. $V_{adj\_tot\_dc}$ is the total adjusted volume of the refrigerator and is calculated as follows:

$$V_{adj\_tot\_dc} = \text{(fresh food chamber storage volume in litres)} + 1.31 \times \text{(freezer chamber storage volume in litres)}$$

The energy performance range for a Direct Cool refrigerator of net volume 180 litres, with a fresh food storage capacity of 165 litres net and a freezer capacity of 15 litres net is indicated in Table 7.

TABLE 7. ANNUAL ENERGY CONSUMPTION FOR 180 LITRE DIRECT COOL REFRIGERATOR

Example: 180-litre net Direct Cool refrigerator, 165-litre fresh food + 15-litre freezer	
Star rating	Energy Consumption Range (kWh/year)
1 Star	270 - 338
2 Star	216 - 269
3 Star	172 - 215
4 Star	138 - 171
5 Star	< 138

Table 8 provides the energy performance bands for frost-free refrigerators valid till 31 December 2019, with 1-star being the least efficient and 5-star being the most efficient.

TABLE 8. BEE STAR RATING FOR FROST FREE REFRIGERATORS

Star Rating Band for Frost-free Refrigerators valid till 31 December 2019	
Star rating	Comparative Energy Consumption (CEC) Criteria
1 Star	$(0.286 * V_{adj\_tot\_nf} + 249) \leq CEC < (0.357 * V_{adj\_tot\_nf} + 311)$
2 Star	$(0.228 * V_{adj\_tot\_nf} + 199) \leq CEC < (0.286 * V_{adj\_tot\_nf} + 249)$
3 Star	$(0.183 * V_{adj\_tot\_nf} + 159) \leq CEC < (0.228 * V_{adj\_tot\_nf} + 199)$
4 Star	$(0.146 * V_{adj\_tot\_nf} + 127) \leq CEC < (0.183 * V_{adj\_tot\_nf} + 159)$
5 Star	$CEC < (0.146 * V_{adj\_tot\_nf} + 127)$

Source: BEE

Comparative Energy Consumption (CEC) is the estimated annual energy consumption in kWh. $V_{adj\_tot\_nf}$ is the total adjusted volume of the refrigerator and is calculated as follows:

$V_{adj\_tot\_nf}$ = (fresh food chamber storage volume in litres)

+ 1.62 x (freezer chamber storage volume in litres)

The energy performance range for a Frost-Free refrigerator of net volume 255 litres, with a fresh food storage capacity of 202 litres net and a freezer capacity of 53 litres net is indicated in table 9.

TABLE 9. ANNUAL ENERGY CONSUMPTION FOR 255-LITRE FROST FREE REFRIGERATOR

Example: 255-litre net Frost-free refrigerator with 202-litre fresh food + 53-litre freezer	
Star rating	Energy Consumption Range (kWh/year)
1 Star	331 - 413
2 Star	265 - 330
3 Star	212 - 264
4 Star	169 - 211
5 Star	< 169

REVIEW OF SELECTED MODELS

The models that were reviewed include eleven direct cool models from India with net volumes in the range 182-205 litres and twelve frost-free models from India with net volumes in the range 234-267 litres. Also included in the review were thirty-six models from other countries - China, Sweden and the USA. Of these, four are direct cool refrigerators from China with net volumes in the range 171-203 litres. Of the thirty-two frost-free refrigerators from other countries, three are from China and eighteen are from Sweden with net volumes in the range of 179-311 litres, and eleven are from the USA with a gross volume of 266-521 litres. Comparing the energy performance of refrigerators across countries with different energy efficiency standards and diverse climates is not that straightforward. Nevertheless, it helps in identifying refrigerators that may be worth analysing further to mainstream the best available technologies for India.

Tables 10 and 11 depict the energy performance of selected Indian direct cool and frost-free refrigerators that were reviewed for this study. Annual Energy Consumption (AEC) is as displayed on the BEE star label for these models. '*AEC in kWh/litre of adjusted volume*' has been used as the energy performance indicator, where AEC in kWh is as displayed on the BEE star label for the model and adjusted volume is calculated as given in BEE Standards and Labelling notifications for Direct Cool refrigerators and Frost Free refrigerators. The values for total net volume, fresh food compartment net volume and freezer compartment net volume were taken from product specifications on the manufacturer's website, where available. Where these are not available, the volume was approximated based on the fresh food net volume and freezer net volume for similar capacity models in the market. The electricity tariff is taken as INR 5/kWh.

TABLE 10. ENERGY PERFORMANCE OF DIRECT COOL REFRIGERATORS IN INDIA

Net volume (litres)	Freezer capacity (% net volume)	Annual Energy Consumption (AEC) (kWh)			AEC / adj. vol. (kWh/litre)			Annual Electricity Cost (INR)		
		5-star	4-star	3-star	5-star	4-star	3-star	5-star	4-star	3-star
182	9.9%	120 - 131	162 - 170	200	0.64 - 0.70	0.86 - 0.91	1.07	600 - 655	810 - 850	1000
205	8.9%	133	166 - 167	-	0.63	0.79	-	665	830 - 835	-

Sample size – 11; 182-litre models - 8 (5-star – 3, 4-star – 4, 3-star – 1); 205-litre models - 3 (5-star 1, 4-star – 2)
Source: Manufacturers' product specification, BEE star label

TABLE 11. ENERGY PERFORMANCE OF FROST-FREE REFRIGERATORS IN INDIA

Net volume (litres)	Freezer capacity (% net volume)	Annual Energy Consumption (AEC) (kWh)			AEC / adj. vol. (kWh/litre)			Annual Electricity Cost (INR)		
		5-star	4-star	3-star	5-star	4-star	3-star	5-star	4-star	3-star
234 - 240	22.6%	-	190 - 204	243 - 254	-	0.70 - 0.75	0.89 - 0.93	-	950 - 1020	1215 - 1270
255	20.8%	159	199	248	0.55	0.69	0.86	795	995	1240
263 - 267	20.8%	-	194 - 208	-	-	0.65 - 0.69	-	-	970 - 1040	-

Sample size – 12; 234-240 litre models - 7 (4-star – 5, 3-star – 2); 255 litre models - 3 (5-star 1, 4-star – 1, 3-star – 1) 263-267 litre models - 2 (4-star – 2)
Source: Manufacturers' product specification, BEE star label

For Direct Cool refrigerators in the capacity range listed in table 10, the incremental cost of a 4-star refrigerator compared to a 3-star model is approximately INR 1500-2300, and the incremental cost for a 5-star refrigerator is approximately INR 2200-3000. At these prices, the payback period based on energy savings is in the range of 6-10 years, based on an electricity tariff of INR 5/kWh. For frost-free refrigerators like those listed in table 11 the incremental cost of 4-star and 5-star refrigerators compared to 3-star models is INR 5000-6000, resulting in a payback period of more than ten years.

ENERGY PERFORMANCE OF REFRIGERATORS IN SELECT COUNTRIES

An accurate, comprehensive comparison of refrigerators across countries would be possible only if the models from each country are tested using the same test procedure and conditions. Nevertheless, a comparison of models of similar size and features based on the annual energy consumption and annual energy consumption per unit of volume provides some indication of the energy performance of refrigerators across countries. The energy performance of similar sized refrigerators in China, Sweden and the USA have been examined for this study. Tables 12 and 13 provide the energy labelling scheme and an overview of the main criteria in the test specifications for refrigerators in India, China, Sweden and the USA.

TABLE 12. ENERGY LABELS FOR REFRIGERATORS IN SELECT COUNTRIES

Country	Most Efficient Rating	2nd Most Efficient Rating	3rd Most Efficient Rating
India	5-star	4-star	3-star
China	Level 1	Level 2	Level 3
Sweden	A+++	A++	A+
USA	Energy Star Most Efficient	Energy Star[1]	

TABLE 13. OVERVIEW OF MAIN CRITERIA IN TEST SPECIFICATIONS FOR REFRIGERATORS IN SELECT COUNTRIES

Country	Refrigerator Type	Adjusted Volume	Ambient Temperature (°C)	Fresh Food Temperature (°C)	Freezer Temperature (°C)
India	Direct Cool	(fresh-food-compartment-net-vol) + (1.31*freezer-net-vol)	32	3	-6
India	Frost Free	(fresh-food-compartment-net-vol) + (1.62*freezer-net-vol)	32	3	-15
China	Direct Cool	[(fresh-food-compartment-net-vol) + (2.15*freezer-net-vol)] * BI * CC	25	5	-18

1 Energy Star represents a range of energy performance levels, not just the 2nd most energy-efficient.

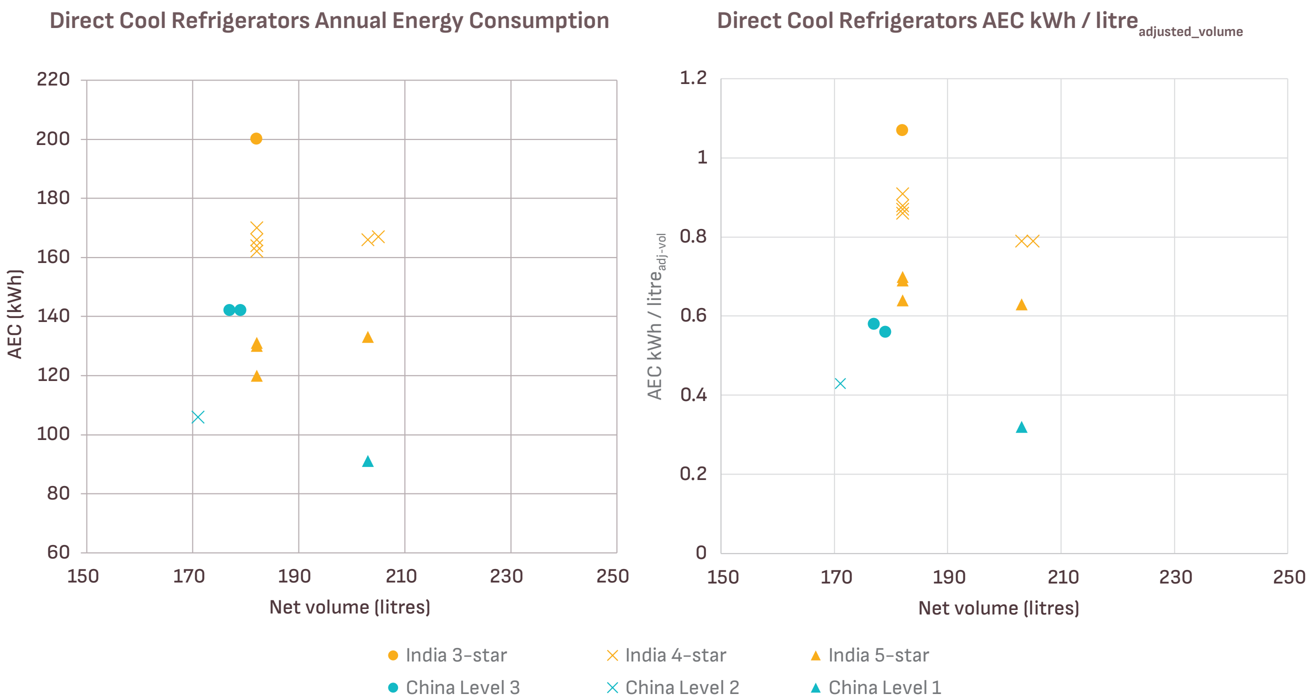
Country	Refrigerator Type	Adjusted Volume	Ambient Temperature (°C)	Fresh Food Temperature (°C)	Freezer Temperature (°C)
China	Frost Free	1.5*[(fresh-food-compartment-net-vol) + (2.15*freezer-net-vol)] * BI * CC	25	5	-18
Sweden	Frost Free	1.2*[(fresh-food-compartment-net-vol) + (2.15*freezer-net-vol)] * BI * CC	25	5	-18
USA	Frost Free	(fresh-food-compartment-net-vol) + (1.63*freezer-net-vol)	32	3	-15

BI: Built-in factor (built-in = 1.2; free-standing = 1); CC: Climate Class (Temperate = 1, Tropical = 1.2)
Source: (bigEE, 2012), BEE Schedule 5, BEE Schedule 1, (EU) No 1060/2010, China GB 12021.2-2015, USA 10 CFR 430

Figures 3 to 5 depict the energy performance of refrigerator models selected from different countries. The graphs depict the annual energy consumption (kWh) against the net volume (or gross volume) of the refrigerator and the annual energy consumption (kWh) per litre of adjusted volume of the refrigerator. The annual energy consumption and refrigerator volume were taken from the energy rating data for that model as given in government databases for energy-efficient appliances and the product specifications provided on manufacturers' websites. The adjusted volume of the refrigerator is based on the size of the freezer compartment and the fresh food compartment and has been calculated using the standard test specification in each country, as summarised in Table 13. The models selected from China and Sweden are free-standing refrigerators and therefore the value of BI is taken as 1 (free-standing model), and the value of CC is taken as 1 (Temperate climate) in the calculation for adjusted volume.

Figure 3 depicts the energy consumption of select direct cool refrigerators in India and China. There are eleven models from India with total net volume in the range 182-205 litres, of which four are rated 5-star (most energy-efficient), six are 4-star, and one is 3-star. There are four models from China

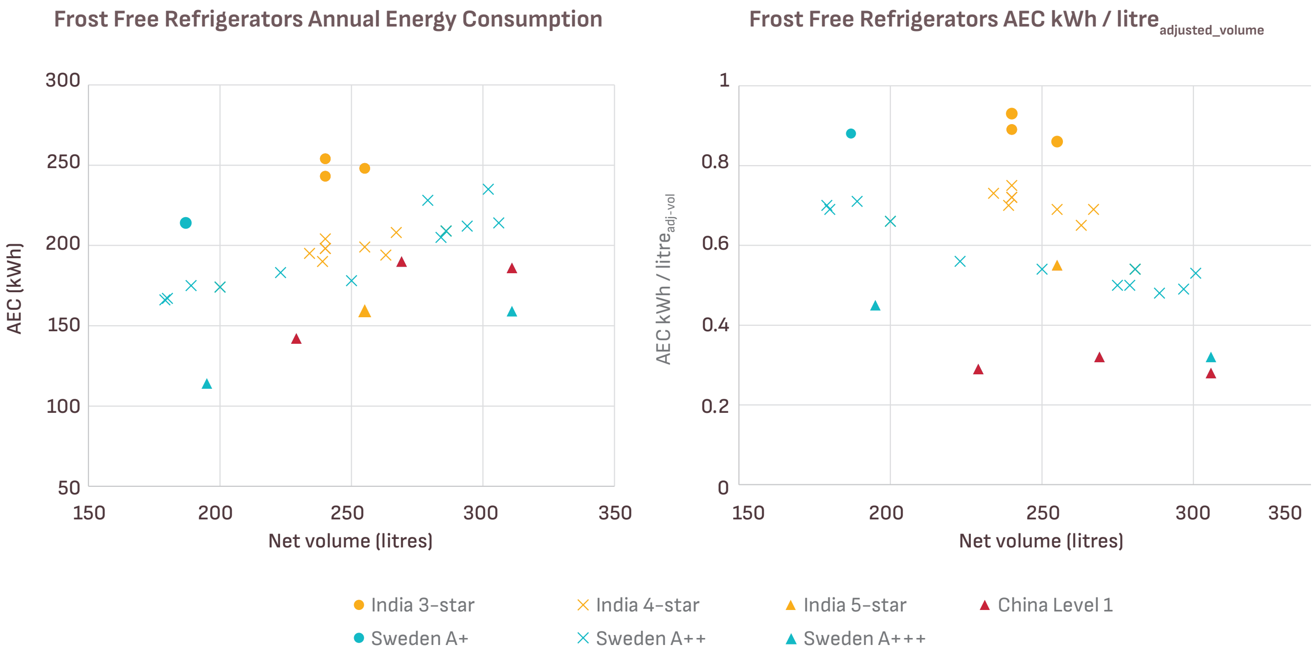
FIGURE 3. ENERGY PERFORMANCE OF DIRECT COOL REFRIGERATORS – INDIA AND CHINA



Source: Product specifications and energy labels with total net volume in the range 171-203 litres, of which one is rated Level 1 (most energy-efficient), one is Level 2 and two are Level 3. The freezer volume for the selected Indian models is about 10% of the total net volume, whereas it is 33-37% of the total net volume for the selected Chinese models.

Figure 4 below depicts the energy consumption of select frost-free refrigerators in India, China and Sweden. There are twelve models from India with total net volume in the range 234-267 litres, of which one is rated 5-star (most energy-efficient), eight are 4-star, and three are 3-star. There are three models from China with total net volume in the range 229-311 litres, all of which are rated Level 1 (most energy-efficient). There are eighteen models from Sweden, of which two are rated A+++ (most energy-efficient), fifteen are rated A++, and one is rated A+. The freezer volume for the selected Indian models is about 20-23% of the total net volume, whereas

FIGURE 4. ENERGY PERFORMANCE OF FROST-FREE REFRIGERATORS — INDIA, CHINA, SWEDEN



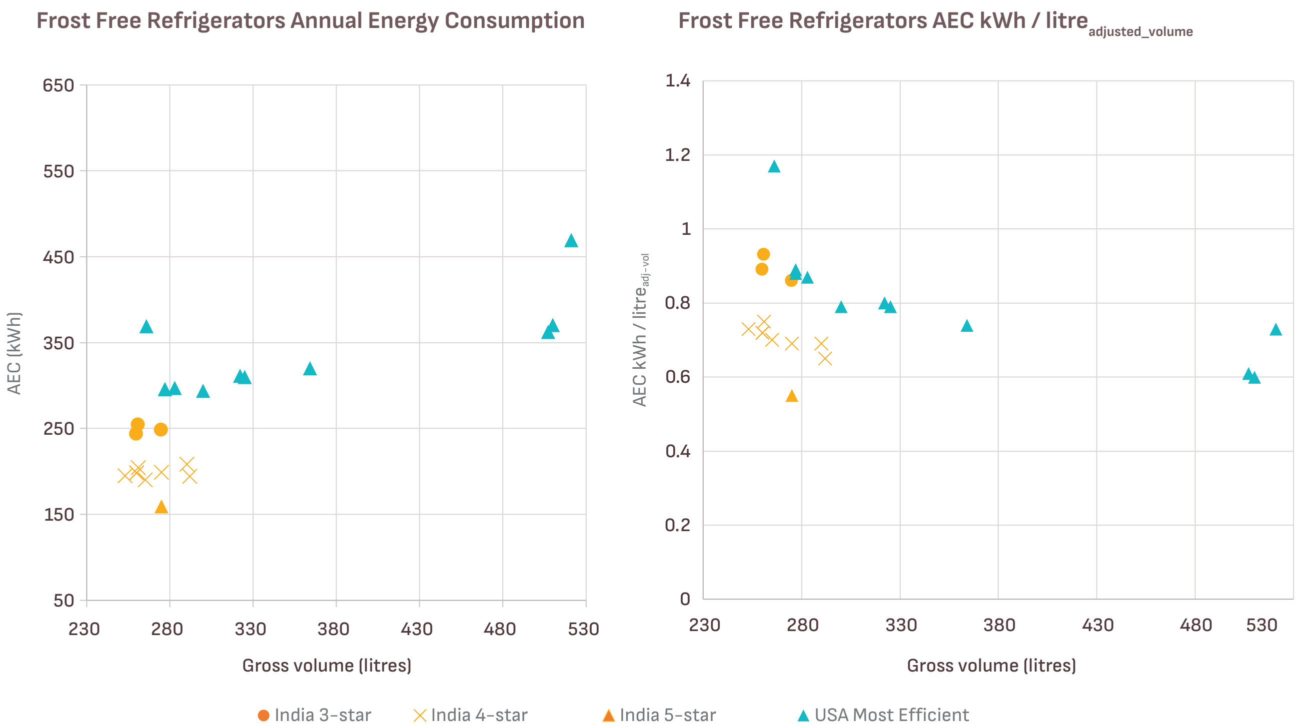
Source: Product specifications and energy labels

for the Chinese models it is 35-39% of total net volume, and for the Swedish models the freezer volume is in the range 7-31% of total net volume.

Figure 5 below depicts the energy consumption of the same frost-free refrigerator models in India with a few selected models from the USA, based on gross volume. The twelve models from India have a total gross volume in the range 253-292 litres, of which one is rated 5-star (most energy-efficient), eight are 4-star, and three are 3-star. There are eleven models from the USA with total gross volume in the range 266-521 litres, all of which are rated Energy Star Most Efficient.

Based on the selected frost-free refrigerator models, it appears that higher capacity models are generally more energy-efficient in terms of annual kWh / $\text{litre}_{\text{adjusted\_volume}}$. For the frost-free refrigerator models that we reviewed, Chinese refrigerators and some Swedish models appear more energy-efficient than models in India, especially when considering the size of the freezer

FIGURE 5. ENERGY PERFORMANCE OF FROST-FREE REFRIGERATORS — INDIA AND USA



Source: Product specifications and energy labels

compartment, which is larger in Chinese models and in some Swedish models. As stated earlier, a true comprehensive comparison of energy performance of refrigerators across countries would be possible only if the models from each country are tested using the same test procedure and conditions, especially since the testing specifications for each country are very different. In particular, the ambient temperature setting in Chinese and Swedish test procedures is much lower (25 °C) compared to that for US and India (32 °C), the temperature for the fresh-food compartment is higher in Chinese and Swedish test procedures and the method for calculating the adjusted volume is also different in each country. These conditions could have a significant impact on test results and the specified annual energy consumption and energy rating assigned to the model. Testing these models under the same test procedure and analysing the components of these refrigerators, i.e. compressor, insulation, heat exchangers, etc. would provide more meaningful insights into actionable pathways to improve the energy efficiency of Indian refrigerators.

TECHNOLOGY OVERVIEW

The technologies available for the main components of a refrigerator are listed in Table 14.

TABLE 14. REFRIGERATOR TECHNOLOGY

Component	Technology options impacting energy performance
Compressor	Compressor efficiency is a crucial determinant of energy performance in refrigerators. The most common type of compressor used in domestic refrigerators is the reciprocating compressor. Linear compressors, which are more efficient than even BLDC reciprocating compressors, have been introduced by some manufacturers, and are found to reduce energy consumption by 10%.

<table>
<tr><th>Component</th><th>Technology options impacting energy performance</th></tr>
<tr><td>Variable Speed Drive</td><td>Variable speed drive (inverter) compressors are deployed in some domestic refrigerators. However, these have not yet become mainstream since they cost more.</td></tr>
<tr><td>Insulation</td><td>The most common type of insulation is Polyurethane foam (PUF) with different blowing agents. With a push to phase out HFCs and switch to zero-ODP and low-GWP blowing agents, cyclopentane is now commonly used as the blowing agent for PUF insulation. Vacuum Insulation Panels (VIP) are used in higher-end refrigerators, but these are much more expensive than PUF. Other insulation materials in the market are listed below, with the best one (lowest thermal conductivity) listed first:
<table>
<tr><th>Insulation</th><th>Thermal Conductivity (W/m/K)</th></tr>
<tr><td>PU Foam with Solstice Liquid Blowing Agent (LBA) from Honeywell</td><td>0.000026</td></tr>
<tr><td>Vacuum Insulation Panels (VIP)</td><td>0.0024 – 0.0097</td></tr>
<tr><td>Aerogel panels</td><td>0.016</td></tr>
<tr><td>PU Foam with Cyclopentane</td><td>0.020</td></tr>
<tr><td>PU Foam with HFC-134a blowing agent</td><td>0.020-0.021</td></tr>
</table>
Insulation thickness can be increased as well. However, this will generally impact net volume or the overall size of the refrigerator.</td></tr>
<tr><td>Heat Exchangers – Evaporator and Condenser</td><td>The surface area and heat transfer capability (thermal conductivity) of heat exchangers have an impact on energy performance. Increasing the surface area can improve the efficiency of heat transfer.

Additionally, using lower power fans, e.g. BLDC fans, to improve heat transfer capacity for heat exchangers can improve the energy performance of the refrigerator.</td></tr>
<tr><td>Refrigerant</td><td>With the push to drive out HFCs, R600a has replaced R134a in newer refrigerators and is equal to or better than R134a when it comes to energy efficiency.</td></tr>
</table>

Source: Technology Roadmap on Ecodesign requirements for household refrigeration appliances (VHK, ARMINES, et al., March 2016); Honeywell; ENERGY STAR Residential Refrigerators and Freezers, Version 5.0 Specification Framework Document; UNEP Information Paper on Cyclopentane Blowing Agent for PUF

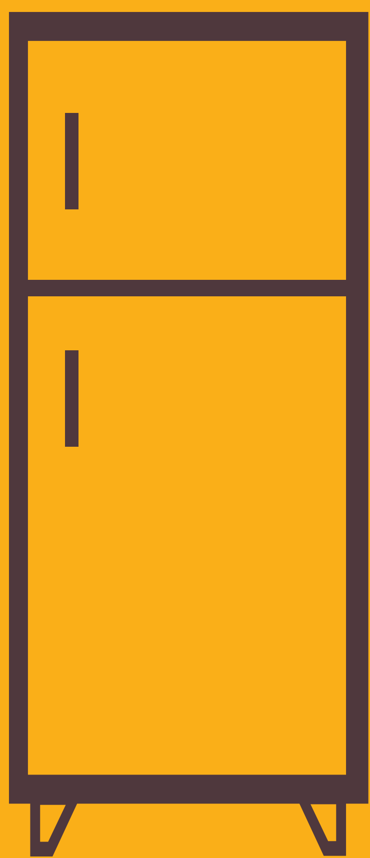
Based on inputs received from manufacturers, the main differentiators between 3-star models and 4-star and 5-star models in India are the compressor efficiency, use of variable speed drive, type of insulation and heat exchanger improvements. Compressors in 4-star and 5-star models are about 10-25% more efficient than those in 3-star models. Further, most 4-star and 5-star models are equipped with variable speed drives. The most common insulation is Cyclopentane PU foam, with some 5-star models also incorporating vacuum insulation panels (VIP). Other technologies used in 5-star models are high-efficiency fan motors, dual evaporator and forced condenser.

BARRIERS

Manufacturers indicated that the topmost barrier to mainstreaming the most energy-efficient technologies for refrigerators, i.e. using 5-star technologies in all models in the market, is the much higher cost of these technologies. The lack of local availability of some technologies, such as highly efficient compressors and the latest insulation technology, is a related barrier, increasing cost and making it more difficult to obtain supplies. Consumer interest and awareness about energy-efficient models has improved with the introduction of the BEE star rating. However, there is scope to enhance consumer awareness and access to information on the energy performance of the products in the market.

RECOMMENDATIONS

- The technology used in the most energy-efficient products already exists but is currently more expensive. Government policies and initiatives to spur local production and to create a well-developed eco-system for super-efficient technologies and components used in refrigeration – highly efficient compressors, fan motors, vacuum insulation panels, etc., will help bring down the price of super-efficient technologies.
- The government could consider setting up R&D programmes for the development of energy-efficient heat exchanger technology and super-efficient design technology for small compressors and motors.
- The India Cooling Action Plan is a timely opportunity to act on the above recommendations and make a step change in the energy efficiency of domestic refrigerators in India. ICAP provides an opportunity to mainstream the most energy-efficient technologies and thereby increase standards and labelling stringency.
- Consumer incentives such as subsidy, on-bill financing and differential tax rates for super-efficient appliances (5-star rated) could be considered for Demand Side Management programmes.
- The actual operational energy consumption of refrigerators depends a lot on consumer usage. Adding a display panel to show actual energy consumption and input power for a refrigerator, along with “Quick Tips” could prompt consumers to maintain and use their refrigerators to get optimal energy performance.
- Manufacturers’ websites & online retail platforms should necessarily include the BEE star label in the technical specs for each model so that the consumer can view all energy performance information online as well.
- BEE’s website and mobile app for appliances should be comprehensive and up to date to include information on all models in the market.



Projected growth of TVs per household

2012

0.48

2030

1.05

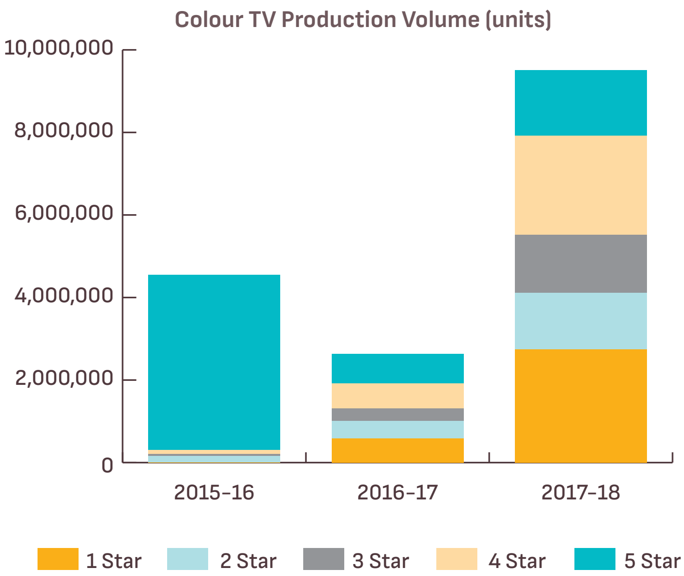
58%

is the market share for models rated 1-star to 3-star

5 TELEVISIONS

Television ownership, which was 0.48 per household in 2012, is projected to grow to 1.05 per household in 2030 (Brookings India, 2018). BEE data for 2017-2018 indicates that models rated 1-star to 3-star constitute more than half the TV market (58%).

FIGURE 6. TV PRODUCTION VOLUME IN INDIA



Source: BEE

BEE mandates energy efficiency standards and labelling for colour televisions with resolutions up to 1920x1080. Table 15 provides the energy performance range for LED-backlit LCD televisions, commonly referred to as LED televisions, with resolutions up to 1920x1080, where 'A' is the screen area in square centimetres.

TABLE 15. BEE STAR RATING FOR LED TELEVISIONS

Annual Energy Consumption (AEC) in kWh		
Star rating	26-May-2016 to 31-Dec-2018	1-Jan-2019 to 31-Dec-2020
1 Star	(0.027 x A) + 2.63 ≤ AEC < (0.030 x A) + 2.63	(0.024 x A) + 2.63 < AEC ≤ (0.027 x A) + 2.63
2 Star	(0.024 x A) + 2.63 ≤ AEC < (0.027 x A) + 2.63	(0.022 x A) + 2.63 < AEC ≤ (0.024 x A) + 2.63
3 Star	(0.022 x A) + 2.63 ≤ AEC < (0.024 x A) + 2.63	(0.019 x A) + 2.63 < AEC ≤ (0.022 x A) + 2.63
4 Star	(0.019 x A) + 2.63 ≤ AEC < (0.022 x A) + 2.63	(0.016 x A) + 2.63 < AEC ≤ (0.019 x A) + 2.63
5 Star	AEC < (0.019 x A) + 2.63	AEC ≤ (0.016 x A) + 2.63

Source: BEE

The annual energy consumption (AEC) estimate is based on a daily usage pattern of six hours in active mode, twelve hours in standby mode and six hours switched off at the mains.

As per BEE's standards and labelling, the annual energy consumption range for a 32-inch LED television with aspect ratio 16:9 is indicated in Table 16.

TABLE 16. ANNUAL ENERGY CONSUMPTION FOR A 32-INCH LED TELEVISION

Example: Annual Energy Consumption (AEC) Range in kWh for a 32-inch TV (aspect ratio 16:9)		
Star rating	BEE Standard 26-May-2016 to 31-Dec-2018	BEE Standard 1-Jan-2019 to 31-Dec-2020
1 Star	79 - 86	70 - 78
2 Star	70 - 78	65 – 69
3 Star	65 - 69	56 – 64
4 Star	56 - 64	48 – 55
5 Star	< 56	< 48

Energy labelling for colour televisions was made mandatory from May 2016 and was upgraded by one star (one level) in January 2019. Television display technology has improved dramatically in the last fifteen years, with Cathode Ray Tube (CRT) being replaced by Liquid Crystal Display (LCD) with Cold Cathode Fluorescent Light (CCFL) backlight, and subsequently by LCD with LED backlight. A 32-inch LED television consumes much less energy than other household appliances such as air conditioners and refrigerators, and the difference in energy consumption between a 3-star and 5-star 32-inch television (8-16 kWh per year) may not seem much when compared to overall electricity consumption for a single household. However, the high penetration of televisions in Indian homes and other buildings make televisions the fourth most significant contributor to total household energy consumption in India. Further, there is an increasing trend towards buying larger TVs with better resolution and features, as well as having more than one TV in the same household. Ultra-High Definition TVs are already available at competitive prices for 43-inch models, but these are not included in the current BEE standard.

REVIEW OF SELECTED MODELS

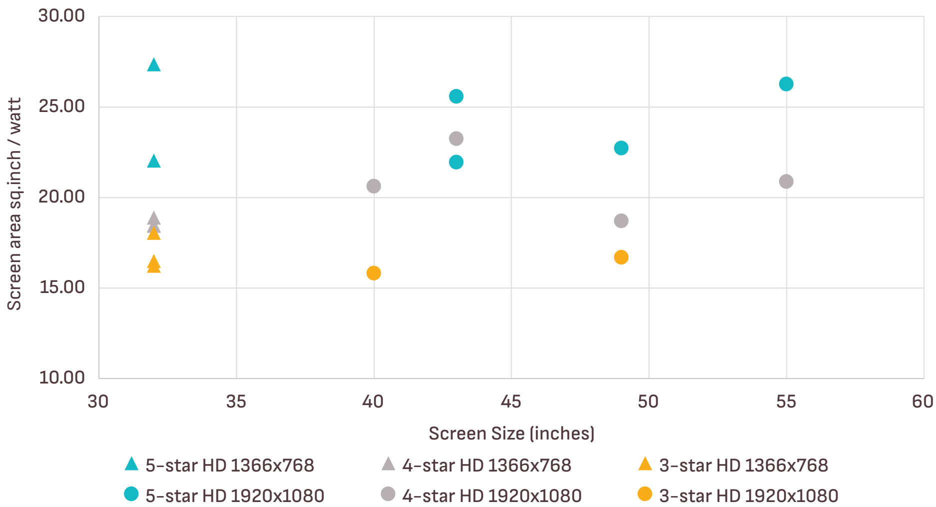
The eighteen Indian LED TV models that were reviewed are in the size range 32-55 inches, with energy efficiency ratings of 3-star, 4-star and 5-star. International models that were reviewed include fourteen models from the United States, all listed as "Energy Star Most Efficient", and eleven models from the European Union's TopTen.eu list, four rated A+ and seven rated A++.

TABLE 17. ENERGY LABELS FOR TVS IN SELECT COUNTRIES

Country	Most Efficient Rating	2nd Most Efficient Rating	3rd Most Efficient Rating
India	5-star	4-star	3-star
EU	A+++	A++	A+
USA	Energy Star Most Efficient	Energy Star	

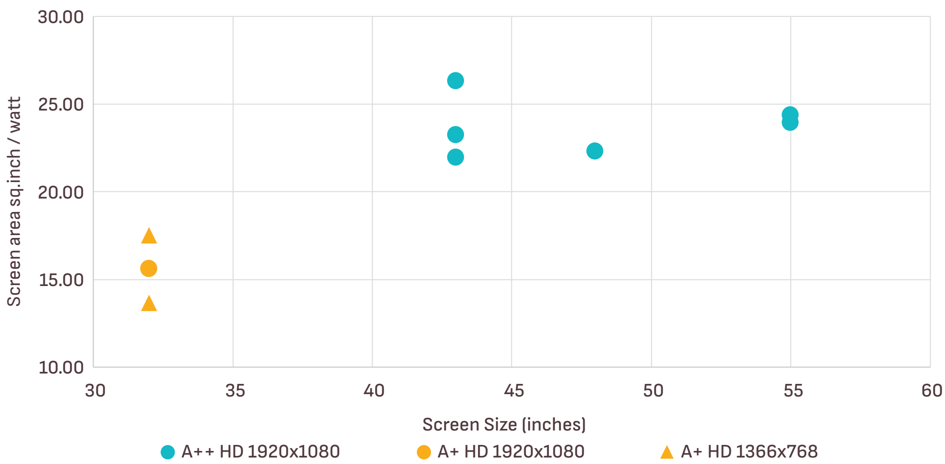
The energy performance indicator (EPI) of *'screen size in square inches/ typical active power in watts'* (sq. inch/watt) has been used to compare models, with higher values indicating more energy-efficient models. The screen area and typical active power have been taken from the certified energy rating for the model. The actual energy consumption depends on several usage-related parameters such as lux levels, audio levels, wi-fi and smart features. Figures 7, 8, 9 indicate the EPI for the selected models in India, the European Union and the United States, respectively. In India, when compared to 3-star TVs, 4-star TVs are on average 19% more energy-efficient, and 5-star TVs are on average 45% more energy-efficient. In the EU and US, higher-end TVs (larger screen, higher resolution) appear to be more energy-efficient than lower-end TVs. Energy performance of the reviewed A++ rated models in the EU appear to be more energy-efficient than 4-star models in India. However, as with refrigerators, a true comparison of energy performance of various TV models requires that all the models are tested using the same test specifications.

FIGURE 7. ENERGY PERFORMANCE OF INDIAN TVs



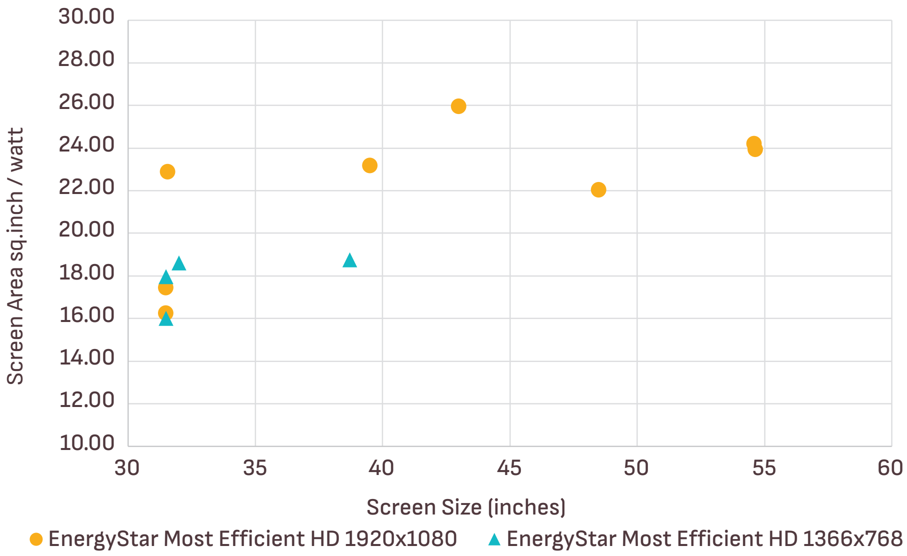
Source: BEE, product specifications

FIGURE 8. ENERGY PERFORMANCE OF EU TVs



Source: TopTen.eu

FIGURE 9. ENERGY PERFORMANCE OF US TVs



Source: Energy Star Most Efficient

TECHNOLOGY OVERVIEW

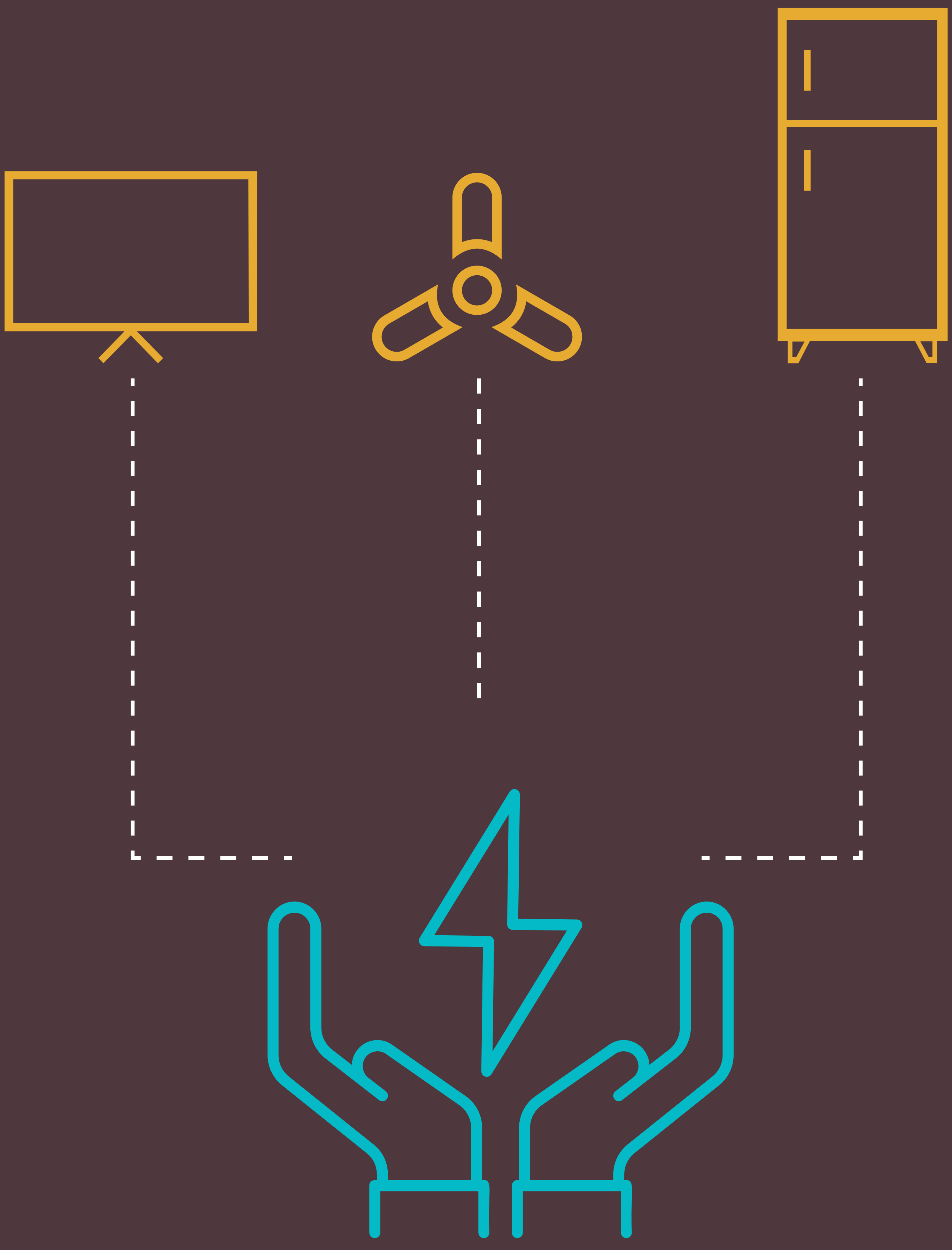
The component that has the most significant impact on the energy performance of televisions is the display. Display technology was revolutionised through the replacement of CRT's by LCDs and plasma displays and, subsequently, by the introduction of LED-backlit LCDs in the last ten years. LED TVs (LED-backlit LCD) have now taken over the market in India. OLED TVs were introduced into the Indian market in 2015 but have negligible share due to their very high price.

TABLE 18. TV TECHNOLOGY

Component/Feature	Technology options impacting energy performance
Display	**LED back-lit or LED edge-lit Liquid Crystal Display (LCD):** The display panel is lit by LEDs along the back of the panel (backlit) or along the edge of the panel (edge lit). **Organic LED (OLED):** The display panel is made up of LEDs which provide light and control colour and brightness. These displays are brighter and thinner than LED-backlit LCDs. **Quantum-dot LED (QLED):** Samsung has introduced this technology for higher-end TVs. OLED and QLED TVs provide much better picture quality than LED-backlit LCD TVs. OLED TVs are considered more energy-efficient than LED-backlit LCD TVs. However, a more detailed analysis of the energy consumption of LED-backlit vs OLED vs QLED TVs of the same size and features should be done to find out how they compare.
Resolution	**High Definition (HD):** HD TVs have a resolution of 1366x768 pixels and 1920x1080 pixels (Full HD). **Ultra-High Definition (UHD) / 4K / 8K:** A 4K display has 3840x2160 pixels or 4096x2160 pixels, and an 8K display has 7680x4320 pixels. A study of US UHD 4K TVs found that they typically consume 30% more energy compared to a Full HD TV of the same size (NRDC, 2015).
"Smart" features	Internet connectivity to enable on-demand streaming content and the capability to run apps have become standard features for most residential TVs. These capabilities add to energy consumption. Additionally, if these "smart features" delay the start-up of a TV from switched off mode to on mode, consumers are more likely to use "Quick Start" options and leave their TVs in standby mode when not in use, rather than turning them off completely, resulting in more energy consumption compared to a completely switched off TV. These features could be designed or engineered to improve energy performance.
Backlight Control	Automatic brightness control (ABC) allows for the backlight to be decreased or increased based on the ambient light/brightness in the room. Backlight Dimming controls the amount of backlight based on the video scene being viewed, i.e. turning off or dimming backlight for black or dark pixels. These features help in reducing energy consumption by reducing the amount of backlight in real time, rather than having the same brightness level always.
Power management and Standby power	Standby power is the power used when the TV is not in use but has not been switched off from the mains. Standby power is used to keep electronics on to receive remote signals, device status displays, and functions to enable "quick start" for smart TVs. The best way to do away with this is to switch off the TV at the mains. However, consumers may not do that if TV start-up takes time. Using technologies to improve the efficiency of power supplies and status displays can reduce standby power.

RECOMMENDATIONS

- Comprehensive testing and comparison of TVs with various technologies and features would be needed to better understand which technologies and features could significantly improve energy efficiency in TVs at a moderate cost. Similarly, and potentially more likely, are display technologies and power management features being used in laptops and mobiles that could be useful for efficiency improvements in TVs and desktop monitors, since efficient power management is critical to consumer satisfaction with battery-powered mobile devices. Identifying and mainstreaming the most energy-efficient display and power management technologies will benefit a whole range of electronic devices that use similar technologies, e.g. TVs, laptops, desktop monitors, commercial displays, etc.
- UHD TVs should be included in BEE's standards and labelling since there are already 43-inch UHD TVs in the market that are very competitively priced.
- The BEE standard could be updated to include specifications that require manufacturers to make the energy-saving mode as the default setting for all TVs
- Manufacturers' websites & online retail platforms should include the BEE star label in the technical specs for each model so that consumers can get energy performance information online as well, not just in retail outlets.
- BEE's website and mobile app for appliances should be comprehensive and up to date to include information on all models in the market.



6 CONCLUSION AND KEY TAKE AWAYS

This study has identified key super-efficient technologies for ceiling fans, refrigerators and to some extent televisions. Mainstreaming these super-efficient technologies that are already in the market, but are currently restricted to a few select expensive models, could result in higher energy savings.

BLDC ceiling fans are already available in the market and consume 36% less power than 5-star ceiling fans with AC induction motors. In the case of refrigerators, 5-star models that consume 30-35% less energy compared to 3-star refrigerators are already available in the market and can be mainstreamed in the next 2-3 years. Doing so could result in higher energy savings by 2027 than the 16% estimated in the study 'Demand Analysis for Cooling by Sector in India in 2027'.

Government policies and initiatives can transform the market for super-efficient appliances. Comprehensive testing and technical analysis of the best available technologies and upcoming technologies can help identify super-efficient technologies for the Indian market.

GOVERNMENT POLICIES AND INITIATIVES

1. Developing a robust ecosystem for BLDC motors in India will help reduce the cost of production. To start with, bulk procurement or bulk import of components such as magnets and control circuits for BLDC motors could potentially bring down the cost of manufacturing BLDC motors, and thereby the cost of appliances. Preferential tax or duty for imported parts for BDLC motors could be considered as well. It's important to note that investing in a robust 'Make In India' ecosystem for BLDC motors will produce energy efficiency dividends for a range of consumer appliances, not just ceiling fans.

2. The India Cooling Action Plan is a timely opportunity to make a step change in the energy efficiency of domestic refrigerators in India. These include initiatives to enable a well-developed eco-system for super-efficient technologies and components used in refrigeration – highly efficient compressors, BLDC fan motors, vacuum insulation panels. ICAP also provides an opportunity to invest in R&D for the development of energy-efficient heat exchanger technology and super-efficient design technology for small compressors and motors.

3. Energy performance of an appliance should be "advertised" as much as the features of the appliance, in the same way that vehicle mileage is advertised as much as features of the vehicle. To that extent, the information available on energy labels for appliances should be consistently available and clearly visible on all sales platforms – retail outlets, online retailers, manufacturers' website. Similarly, BEE's website and mobile app for appliances should be comprehensive and up to date to include information on all models in the market.

4. Mandating standards and labelling for ceiling fans will help differentiate and promote energy-efficient fans. Further, improving standards stringency for refrigerators, TVs and other appliances included in BEE's standards and labelling programme will push the market to steadily move towards more energy-efficient products.

COMPREHENSIVE TESTING AND DETAILED TECHNICAL ANALYSIS

1. For refrigerators and TVs especially, testing the most energy-efficient models from a few representative countries using the same test specifications would help in analysing the energy performance of various technical components and energy-saving features. Doing so will help in identifying the best available energy-efficient technologies to mainstream in India.

2. A survey of households to determine the usage patterns of refrigerators and TVs would complement the in-depth testing and technical analysis and contribute to developing more comprehensive programmes for improving appliance energy efficiency and consumption behaviour.

By implementing these recommendations, India can capture substantial energy savings and other benefits of super-efficient appliances.

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