Standard and labelling for evaporative air coolers: a roadmap to affordable & sustainable space cooling solutions in India

Srishti Sharma
Alliance for an Energy Efficient Economy
37 Link Road, Ground Floor
Lajpat Nagar III
New Delhi 110024
India,
srishti@aeee.in

Tarun Garg
Alliance for an Energy Efficient Economy
37 Link Road, Ground Floor
Lajpat Nagar III
New Delhi 110024
India,
tarun@aeee.in

Akhil Singhal
Alliance for an Energy Efficient Economy
37 Link Road, Ground Floor
Lajpat Nagar III
New Delhi 110024
India,
akhil@aeee.in

Keywords

evaporative air coolers, cooling, affordability, efficiency standards, minimum energy efficiency standards, energy standards, appliances, non-GWP refrigerant based space cooling solution

Abstract

India has around 3,000 cooling degree days per year[1]. However, it is one of the countries with the lowest access to cooling with per capita space cooling energy consumption at 69 kWh compared to the world's average of 272 kWh. India being one of the fastest growing economies in the world, will result in an increase in demand for a better quality of life and enhanced thermal comfort in the coming future. On the other hand, it has been estimated that a significant share of households will not have the purchasing power for room air conditioners (RACs) for attaining thermal comfort in the coming decade. RACs, despite their low penetration (~9 %), accounts for ~42 % of the space cooling energy consumption (~135 TWh) in 2017–18 in India. In addition, RACs are not climate-friendly as they use refrigerants with high Global Warming Potential (GWP) that contribute to ozone layer depletion and carbon emissions to a large extent. It has also been projected that the affordable housing sector will add another 360 million sq.m. by 2022 to the building footprint. This will lead to an increase in demand for affordable space cooling solutions, which in turn will require the deployment of affordable and sustainable space cooling solutions such as evaporative air coolers (EACs). EACs can effectively provide thermal comfort by evaporation of water to cool and humidify the supply air in residential and commercial settings under India's hot-dry and composite climatic zones. The current penetration rate of EACs in Indian households stands at 15 %. In addition to that, India's EAC market is projected to grow at a Compound Annual Growth Rate (CAGR) of 14.2 % during 2019–25. However, their market is majorly unorganised, and there is an absence of a Standard and Labelling (S&L) program for EACs in India. In contrast, the RAC market is organised and regulated by the S&L program. Thus, the development of the S&L program for EACs shall lead to market organisation. This paper provides an overview of India's policy, regulatory and institutional landscape concerning the S&L program. It establishes a comparative assessment between standards adopted nationally and internationally for EACs. This paper aims to bridge the information gap and act as a catalyst in facilitating the key decision makers to develop the S&L program and create a market for energy efficient EACs in India.

Introduction

Thermal comfort is defined as a state where an individual is satisfied with the thermal conditions of the surrounding environment. As the human body is adaptable to the local surroundings, the thermal comfort of an individual usually varies by region and is influenced by social/cultural acceptability. Thus, what is comfortable for an individual who is used to live in a hot and humid climate, may differ for an individual from a cold and dry climate. Thermal comfort is determined and affected by various factors such as the microclimatic conditions, which includes temperature, relative humidity and air temperature, an individual's clothing insulation and metabolic rate, etc.(Ameri-

1. A cooling degree day is a measurement to estimate the demand for energy needed to cool a building.

Table 1. Key Specifications of different types of EACs (Amer, Boukhanouf, and Ibrahim 2015; Sarkar 2020).

Parameters	DEC	IEC	IDEC
Technology Description	In a DEC, the air passes through the cooling pad of the EAC, leading to direct contact between air and water. DEC help reduce the air temperature through evaporation of water along with the conversion of sensible heat into latent heat.	An IEC helps in reducing the air temperature through heat exchange without adding specific humidity in the supply air. In an IEC, with the help of Heat exchangers (HE), there is no direct contact between air and water.	An IDEC is also known as a two-stage evaporative air cooler. During the first stage, the air is cooled through IEC, followed by DEC in the second stage. Air from secondary and primary air stream doesn't come in direct contact.
Cooling medium	Cooling pad	Heat transfer through HE	Both cooling pad and HE
Performance	More efficient than IEC	Less efficient than DEC (Least efficient)	Most efficient
Added specific humidity content in supplied air	Yes	No	Yes, but less than DEC
Applications (most optimal)	Residential	Large-scale commercial and industrial spaces where specific humidity in the supply air has to be avoided	Large-scale commercial and industrial spaces where there is a significant temperature drop requirement and the ambient air has low humidity content
Climate zone applicability	Hot-dry	Composite/Hot-dry/Warm-humid	Composite/Hot-dry

can Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) 2020; Sustainable and Smart Space Cooling Coalition 2017). Access to cooling for attaining thermal comfort is no longer a luxury but has become a necessity to ensure the overall quality of life, health and well-being. Thus an exponential upward trend is expected in the space cooling energy consumption by appliances such as ~11 TWh to ~76 TWh by EAC and ~57 TWh to ~304 TWh by RACs from 2017–18 to 2037–38 respectively (Ministry of Environment Forest & Climate Change (MoEF&CC) 2019).

India has around 3,000 cooling degree days per year, as per a recent study done by Rocky Mountain Institute (RMI) (Lalit and Kalanki 2019). However, it is one of the countries with the lowest access to cooling with per capita space cooling energy consumption at 69 kWh compared to the world's average of 272 kWh (MOEF&CC 2019). India being one of the fastest growing economies, would result in an increased demand for a better quality of life, and access to thermal comfort in the coming future. On the other hand, it has been estimated that a significant share of households will not have the purchasing power for RAC for attaining thermal comfort in the coming decade (MoEF&CC 2019). Despite having low penetration of ~ 9 % in Indian households, RACs accounts for a significant share of space cooling energy consumption (MoEF&CC 2019). Also, RACs accounts for ~32 million tCO_2e of carbon emissions in the residential sector, which is expected to increase to around 180 million tCO_2e of carbon emissions by 2027, in a business-as-usual and moderate growth scenario (Sachar, Goenka, and Kumar 2018). In addition, RACs are not climate-friendly as they use refrigerants with high GWP that contribute to ozone layer depletion and carbon emissions to a large extent. It has also been projected that the affordable housing sector will add another 360 million sq.m. by 2022 to the building footprint (Pathak, Garg, and Kumar 2020). This will lead to an increase in demand for affordable space cooling solutions, which in turn will require the deployment of affordable and sustainable space cooling solutions such as EACs.

EVAPORATIVE AIR COOLERS

EACs are also known as swamp or desert coolers and can be used in residential and commercial settings. These appliances use water, a natural refrigerant (R718), and are used to cool the air through the fundamental principle of evaporation of water. Thus, EACs are a Non-GWP refrigerant based space cooling technology. Further, EACs provide cooled air with added specific humidity and can effectively provide thermal comfort under India's hot-dry and composite climatic zones (Jain and Hindoliya 2016; Govekar, N., Bhosale, A. & Yadav 2015; Sarkar 2020). There are three types of EACs: 1) Direct Evaporative air Cooler (DEC), 2) Indirect Evaporative air Cooler (IEC), and 3) Indirect-Direct Evaporative air Cooler (IDEC). Table 1 shows the difference between different types of EACs based on select parameters.

EACs are an affordable and sustainable space cooling technology alternative. They are 85 % cheaper and, on average, consumes ~56 % less energy than a conventional RAC (Grand View Research 2019; Jain and Hindoliya 2016). Further, EACs, if installed with energy efficient fans and pumps, have an energy saving potential of around 20 % in the coming decade compared to business as usual. The current penetration rate of EACs in Indian households is 15 % (Agrawal et al. 2020). In addition to that, India's EAC market is projected to grow at a CAGR of 14.2 % during 2019–25 (6Wresearch 2019). However, 70 % of the EAC market is unorganised and is usually 'made-to-order', which does not fall under the purview of any regulation, whereas the remaining 30 % is organised, comprising of major EAC manufacturers such as HMX, Symphony Limited, Bajaj Electricals Limited, etc. These major players manufacture EACs, compliant with appliance declaration requirements, wherever applicable. On contrary, the RAC market is organised and regulated by the S&L program since 2006. India's S&L program implements the 'push' & 'pull' strategy in the appliance market for bringing market transformation. The 'push' for the elimination of less energy efficient models from the market by the prohibition of their sale is created by establishing Minimum Energy Performance Standards (MEPS) and a 'pull' for consumers to opt for and purchase a highly efficient appliance or equipment is created by the application of informative energy performance labels (Bureau of Energy Efficiency (BEE) 2020). Thus, the development of the S&L program for EACs shall lead to the market organisation by eliminating low-performing EACs that do not comply with the S&L norms. This paper provides an overview of India's policy, regulatory and institutional landscape for the S&L programme. It establishes a comparative assessment between standards adopted nationally and internationally for EACs. This paper aims to bridge the information gap and act as a catalyst in facilitating the key decision makers to develop the S&L program and create a market for energy efficient EACs in India.

National Policy, Regulatory and Institutional Framework for Appliances

This section will provide an understanding of 1) India's S&L program, which is commonly known as the Star Labelling Program of Bureau of Energy Efficiency (BEE) and its standard development process, and 2) national institutional landscape governing energy efficiency in appliances.

BEE STAR LABELLING PROGRAM

BEE's S&L program, known as the 'Star Labelling program', was established in May 2006 by BEE, Ministry of Power (MoP) under the Energy Conservation (EC) Act, 2001. This program aims to provide clear information to the consumers about the energy savings potential of an appliance to make an informed decision (BEE 2020).

There are two components to this program as described below:

- **Standards:** They prescribe a limit on energy consumption or minimum level of the energy efficiency of an appliance. They mean defined test protocols to obtain an accurate estimate of the energy performance of an appliance or a set cap/target limit for an appliance's energy performance.
- **Labels:** They are informative labels affixed to products and give consumers the necessary information to make informed purchases such as appliance type, star rating, energy use, etc.

Types of Energy Performance Labels and MEPS for Appliances

BEE has classified the energy performance label into two categories: comparative label and endorsement label. The comparative label helps compare similar appliance based on energy consumption and other criteria. Whereas an endorsement label confirms to the prospective buyer that the appliance is highly energy efficient and suitable for purchase/usage. (BEE 2019b)

The energy performance labels range from 1-star to 5-star, 1-star stands for minimum energy performance level, which is given to the least efficient models, and 5-star for maximum efficiency, which is given to the most efficient models. The labels and MEPS are periodically upgraded, ~2–3 years, by BEE to maintain the efficiency of appliances, as per the development in technology. The program focuses on market transformation by improving the average energy performance of appliances in the market by mandating the MEPS for various energy intensive appliances.

Mandatory and Voluntary Schemes for Appliances

BEE has established energy performance standards for 26 appliances, as mentioned below in Table 2 (BEE 2020). Ten appliances are under the mandatory scheme, and the other sixteen are under a voluntary scheme. It shall be noted that India reviews its standards every 2–3 years.

The voluntary scheme includes Induction Motors, Pump Sets, Ceiling Fans, Cooking Stoves, Washing Machine, Computer, Ballast, Office equipment, Diesel Engine Driven Monoset Pumps, Solid State Inverter, DG Sets, Chillers, Microwave Oven, Solar Water Heater, Light Commercial Air Conditioner and Deep freezers.

Table 2. BEE Standards & Labelling Program: Mandatory Schemes for Appliances.

Mandatory appliances	Units measured	Latest notification – valid up-to	Review cycle
1. Room Air Conditioners	Indian Seasonal Energy Efficiency Ratio (ISEER) (kWh/kWh)	2020–2024	After every 2 years
2. Frost Free Refrigerators	Comparative Energy Consumption (CEC) kWh/litre/year	2018–2021	After every 2 years
3. Tubular Florescent Lamp	Lumen per Watt (lm/W)	2020–2023	After every 3 years
4. Distribution Transformer	Standard losses in watts	2020–2022	After every 3 years
5. Room Air Conditioner (Cassette, Floor Standing)	ISEER (kWh/kWh)	2020-2024	After every 2 years
6. Direct Cool Refrigerator	CEC kWh/litre/year	2018–2021	After every 2 years
7. Colour TV	Annual Energy Consumption(kWh/annum)	2020–2021	After every 2 years
8. Electric Geysers	Standing Losses (kWh/24 hour/45 °C)	2020–2021	After 2021
9. Variable Capacity Inverter Air conditioners	ISEER (kWh/kWh)	2020–2024	After every 2 years
10. LED Lamps	Luminous Efficacy (Lumen/Watt)	2019–2023	After every 3 years

Source: (Author's analysis based on data extracted from BEE 2020).

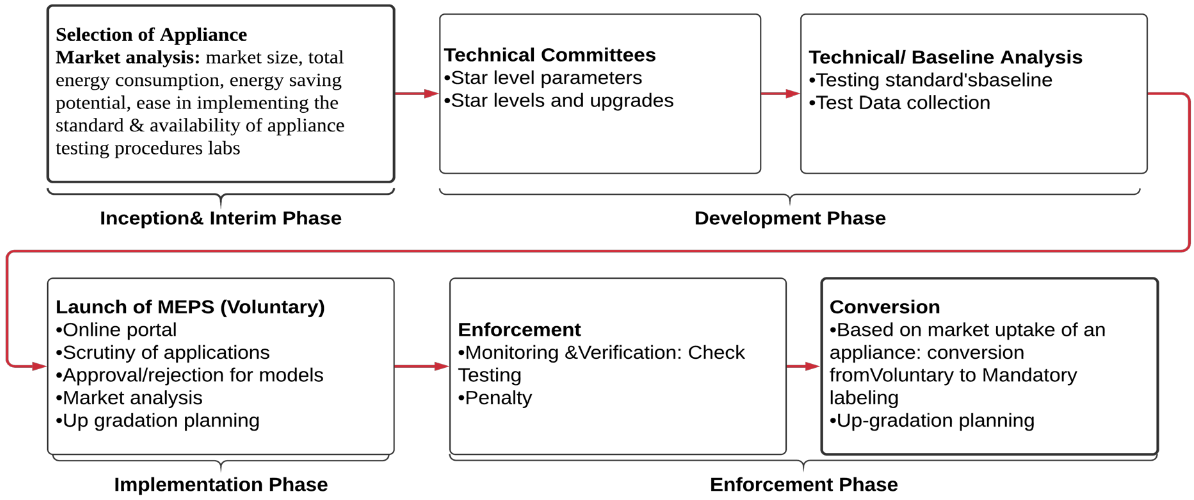


Figure 1. BEE's S&L Process: A typical cycle for each appliance under S&L. Source: Author's analysis based on data extracted from BEE 2020.

BEE follows a typical process for each appliance under S&L, as shown in Figure 1. The phases under this process are specified below in detail.

Inception & Interim Phase: The appliance selection criteria depends on the market size of the appliance, the share of organised & unorganised market, total energy consumption, energy saving potential, ease in implementing the standard, and availability of appliance testing procedures and test labs.

Development Phase: For each appliance, BEE establishes separate appliance specific technical committees comprising of key experts and stakeholders, which play a significant role in establishing MEPS. This committee guides to conduct a baseline estimation study to finalise the inclusion of a particular appliance in the S&L program. Identification and analysis of the international labelling programs and best practices that can be adopted under Indian climatic conditions is also taken up. A draft schedule is then developed for the submission to MoP.

Implementation Phase: The permittee/applicant/manufacturer has to register themselves on BEE's S&L web portal and submit the required documentation along with the application form. This is followed by model registration. The Independent Agency for Monitoring and Evaluation (IAME) and State Designated Agencies (SDA) will evaluate and verify whether the energy performance of the labelled appliance under conditions mentioned in the appliance regulations matches its performance claims assess the application. After their approval, BEE will allow the applicant to add a BEE star label to the registered product.

Enforcement Phase: Monitoring and verification, check and challenge testing of the labelled appliances will be conducted by BEE or its designated agencies such as Central Power Research Institute (CPRI) and SDA to evaluate and verify whether the energy performance of the labelled appliance under conditions mentioned in the appliance regulations are matching its performance claims.

Compliance Mechanism: The SDA appoints an inspection officer for ensuring compliance with the regulations. In case of non-compliance by the permittee, the SDA informs BEE to disqualify such appliances/equipment for retail sales and informs the State Electricity Regulatory Commission (SERC). The SERC appoints an adjudicating officer who follows the final adjudication process and then proposes the final verdict. Therefore, SDAs and SERC are part of S&L's enforcement mechanism, and BEE along with CPRI are the part of S&L administration, as shown in Figure 2 (BEE 2019a).

NATIONAL INSTITUTIONAL LANDSCAPE

India's institutional landscape governing the appliance sector is inclusive of various ministries, central and state level nodal agencies, as shown in Figure 2.

As shown in Figure 2, the S&L scheme is majorly administered under the umbrella of MoP and is supported by the Ministry of Consumer Affairs Food and Public Distribution. BEE is majorly responsible for rolling out new appliances under the S&L and its overall administration. CPRI provides technical support and provides expertise for the development of performance testing procedures and protocols. The SERC and SDA support the enforcement of S&L within the respective states. The Bureau of Indian Standards (BIS) provides pivotal support to the S&L scheme by supporting the development of testing methods and overall quality standards of various products, which are then referred back through the S&L regulations. On the other hand, the Ozone Cell under the umbrella of MoEF&CC had launched ICAP. ICAP is inclusive of a long-term integrated 20 year (2017–18 to 2037–38) outlook across sectors on India's cooling demand, technology options, refrigerant use and energy consumption. ICAP's space cooling in buildings has specified a short-term recommendation that deliberates upon the development of MEPS for EACs. ICAP has also identified a steering committee inclusive of BEE for the implementation of ICAP. However, Ozone Cell is not a part of the overall S&L administration and can only recommend to take up actions as climate change mitigation measures.

Review of EAC Standards

This section highlights information about the standards or regulations or MEPS adopted nationally and internationally for improving the energy performance of EACs.

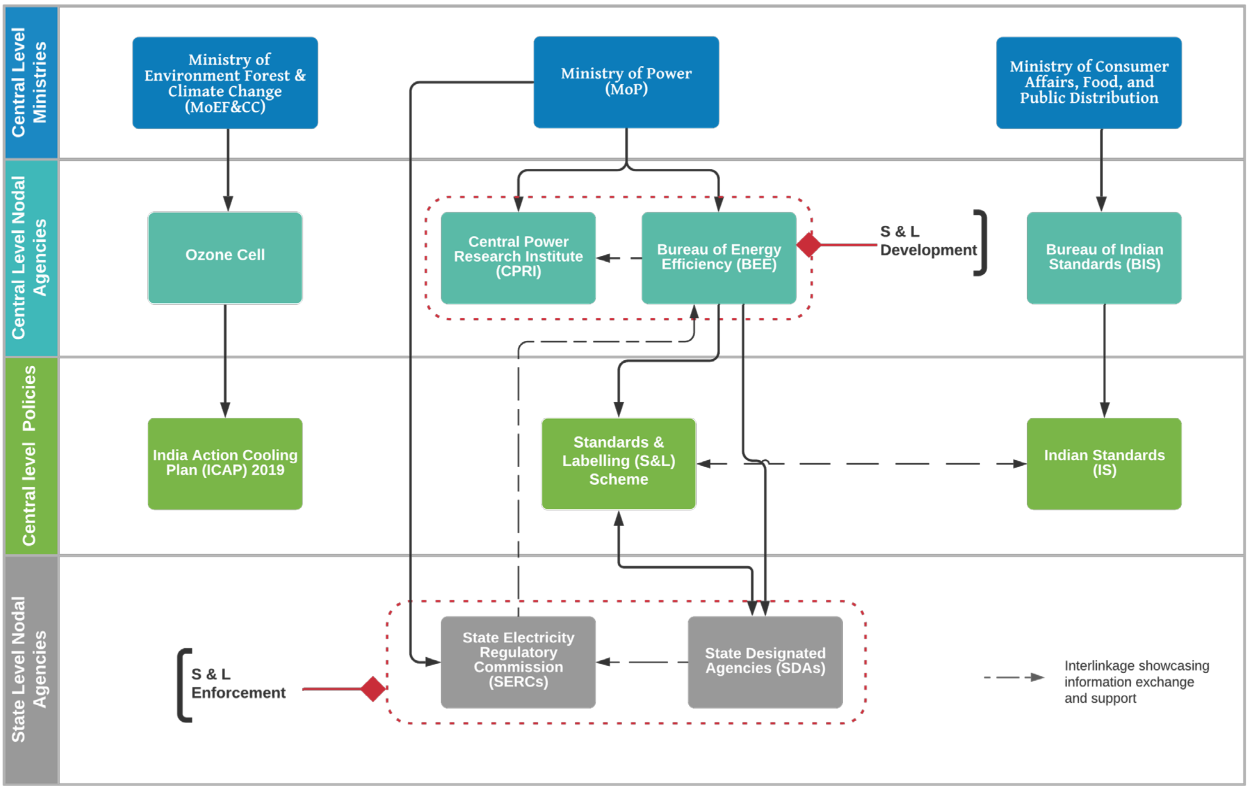


Figure 2. India's Institutional Landscape governing energy efficiency in Appliance. Source: Author's analysis based on the data extracted from BEE 2019a; MOEF&CC 2019; Bureau of Indian Standards (BIS) 2016.

INDIA: IS 3315:2019 QUALITY AND TESTING STANDARD FOR EACS

The Indian Standards (IS) standard notified by BIS is an overall quality and testing standard for the EAC and looks at several components such as construction material, testing and performance. Whereas the S&L program only focuses on energy consumption parameters such as energy efficiency ratios or annual energy consumption, which are then categorised into different star label categories. The S&L then builds upon and refers back to IS for testing procedures. The latest IS 3315: 2019 for EACs is a comprehensive version, prepared under the Refrigeration and Air Conditioning Sectional Committee under Mechanical Engineering Division Council MED 03 (Bureau of Indian Standards (BIS) 2019). The key highlights from the latest version of this standard are mentioned in Table 3.

In addition to the above-mentioned specifications, the manufacturer shall provide an operating & maintenance manual that shall cover the suitability of coolers; which capacity of cooler is suitable for with which room size. The standard has also specified that the nameplate shall be inclusive of information, namely name of the manufacturer type or model number, year of manufacturing and serial number, minimum air capacity at zero static pressure, total current and voltage, power input, sump tank capacity and cooling efficiency of the unit). The appliance following all the conditions mentioned above shall be given IS 3315: 2019 mark under the provisions of the Bureau of Indian Standards Act, 2016. Thus, as per the latest BIS standard of an EAC, the material of the outer structure, airflow, noise levels, fan motor, evaporative cooling pads, and water pump efficiency are the most critical parameters for evaluating the overall cooling efficiency of an EAC. However, the standard does not focus on water consumption levels (BIS 2019).

AUSTRALIA: AS/NZS 2913-2000 TESTING STANDARDS FOR EACS

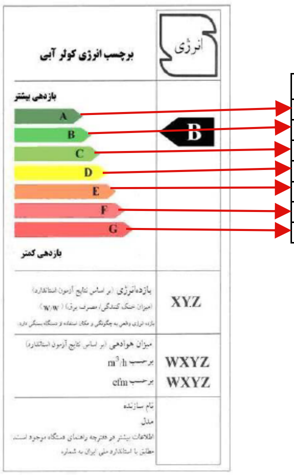
Australia has a tropical climate with the majority of the demand for direct evaporative air coolers. Australia has established AS/NZS 2913-2000 testing standards for evaporative air-conditioning equipment. This standard has been prepared by Standards Australia Committee ME-062, Ventilation and Air conditioning under Manufacturing & Processing sector of Standards Australia, which is an independent body and a non-government standard-setting organisation. Australia doesn't have MEPS and labelling for evaporative air coolers. The first version of this testing standard came in 1987 and then the latest version in 2000, which got reconfirmed in 2016. The standard focuses on parameters, namely airflow, evaporation efficiency, sound power measurements, power consumption and operating conditions. It includes temperature conditions required for evaluating and rating cooling performance of inlet dry and wet-bulb temperatures of 38 °C and 21 °C, respectively and supply dry-bulb temperature of 27.4 °C. However, energy ratings are not mentioned. It also focuses upon construction requirement. This standard does not inform about indirect or two-stage evaporative air coolers, and there is no focus on evaluating water consumption (Saman, Bruno, and Tay 2010; Standards Australia 2000).

IRAN: 4910-2 MEPS & LABEL FOR EAC

Iran majorly has a dry climate with a high demand for EACs. Institute of Standards and Industrial Research of Iran (ISIRI), under the supervision of the Ministry of Industry, Mines and Trade, Islamic Republic of Iran have established a mandatory comparative labelling program and MEPS 4910-2 for EACs in 1999 (Harrington and Damnics 2004; ISIRI – Institute of Standards and Industrial Research of Iran 2010). This got revised in

Table 3. Details of the latest version of the IS 3315 (BIS 2019).

S.No.	Parameters	Key Specifications
1	Air capacity	750–8,000 m^3/h are the specified air capacities based on air delivery at 'Zero' static pressure.
2	Manufacturing and Construction	Under 'design and built', the standard specifies the specifications for outer body structure, fan, pump and cooling pads. The details relevant to energy performance are mentioned below: **Fan Material:** Sheet metal or plastic. **Fan testing protocols:** IS 2312 certified. **Fan motor:** IS 996 certified. **Pump Testing protocols:** IS 11951 certified. **Cooling pad Material:** Wood wool/honeycomb or environment-friendly material to be used.
3	Performance	Under performance, the focus is on noise level and power consumption, as shown below: **Noise Testing protocols:** The decibel level should not be more than 65 dBA when measured at a 1 m distance from the cooler when in an anechoic room setting. The appliance shall pass the sound test as per IS 1391 (Part 2). **Air delivery:** Shall be as per the minimum air capacities mentioned in point 1 above and shall not be less than the declared minimum capacity. **Cooling effectiveness:** Shall be either greater than or equal to 65 %. **Power consumption**: The standard has specified power consumption as per the air capacities and ranges between 95–500 W.
4	Tests	Manufacturers need to conduct both type (mainly cooling efficiency, air delivery, power consumption) and routine test (mainly high voltage, power consumption, current leakage).
5	Rating	The rated voltage shall be 230~240 volts at a rated frequency of 50 Hz.
6	Eco-mark	The EAC shall conform to the requirement of safety, quality and performance as per the points mentioned above (2–4). EAC to be sold with the proper usage instruction for maximising the performance along with the packaging of biodegradable materials. Noise levels as per the Environment (Protection) Act, 1986. Power consumption shall be less than 5 % of the maximum power consumption as specified in point 3.



Rating	EER Value
1	EER ≥ 65
2	58 ≤ EER < 65
3	50 ≤ EER < 58
4	42 ≤ EER < 50
5	34 ≤ EER < 42
6	26 ≤ EER < 34
7	EER < 26

Figure 3. Iranian energy label and energy efficiency thresholds adapted from (Effatnejad and Salehian 2009; Saman, Bruno, and Tay 2010).

2009 (CLASP 2020). The aim of this mandatory labelling program was to encourage manufacturers to produce energy efficient coolers complying with the standard performance criteria (Saman, Bruno, and Tay 2010). The testing is as per Iranian test standards No. 4910 and No. 4911, which uses the Indian Standard IS3315-1974 and Australia Standard AS 2913-2000 as their base test standards (Effatnejad and Salehian 2009). The Iran energy label displays efficiency levels from A to G, as shown in Figure 3, these levels are as per the energy efficiency threshold values defined in terms of Energy Efficiency Ratio (EER), where seven is the least efficient and most used, and one is the most efficient with minimum consumption. Therefore, as shown in Figure 3, one is denoted as A, which is the most efficient and the shortest bar in green and seven is denoted as G, which is the least efficient and the longest bar in red, in the label.

The EER is used as an energy labelling parameter for comparing products, as shown in Figure 3. EER is the sensible cooling capacity of the cooler to the total electricity/power input (Saman, Bruno, and Tay 2010).

EER = Sensible cooling capacity (kW)/Total input electrical power (kW)

The cooling capacity of an EAC can be defined as (Saman, Bruno, and Tay 2010):

$$S = \rho\, q_v\, C_p\, (t_r - t_{in})$$

Where,
S: cooling capacity (kW)
ρ: density of standard air (1.20 kg/m^3 for standard air)
q_v: air volume flow rate corrected to standard temperature and pressure (m^3/s)
C_p: Specific heat capacity of moist air at constant pressure
t_{in}: air inlet dry-bulb temperature to the conditioned space (°C)
t_r: air outlet temperature from the conditioned space (°C)

During the pre-label design stage for EACs, the efficiency of fans and motors, evaporative cooling pad density, and water circulation rate were identified as the critical parameters affecting the energy consumption by EACs. Iran is the only county with a set MEPS and mandatory comparative labelling program for EACs (Energy Efficient Strategies 2014). Iran's critical review reflected that the standard does not focus upon water efficiency as a parameter.

USA (CALIFORNIA): CEC-410-2017-002 APPLIANCE EFFICIENCY REGULATION

California, USA, majorly has a Mediterranean climate, with hot and dry summers, making evaporative air coolers feasible for achieving thermal comfort. The California Energy Commission established appliance efficiency regulation (California Code of Regulations, Title 20) in 1976. Currently, the latest version of this regulation, 'CEC-410-2017-002', is dated January 2016, which is inclusive of a process for evaluating and rating the energy performance of evaporative air coolers. Twenty-one appliance categories are currently included in this appliance efficiency regulation, and evaporative air coolers are one of the appliances (Saman, Bruno, and Tay 2010; Baez et al. 2017).

Evaporative Cooler Efficiency Ratio (ECER) is used as a parameter for evaluating energy performance and evaporation efficiency and is calculated by using below mentioned equation (Saman, Bruno, and Tay 2010):

$$ECER = 1.08\ (t_{room} - (t_{db} - E \times (t_{db} - t_{wb}))) \times Q/W$$

Where,
t_{room} = room dry-bulb temperature, °C
t_{db}= outdoor dry-bulb temperature, °C
t_{wb} = outdoor dry-bulb temperature, °C
E= saturation effectiveness/100
Q = air flow rate, cfm
W = total power, W

The specified conditions for calculating ECER inlet dry and wet-bulb temperatures of 32.8 and 20.6 °C respectively, and assumed room outlet air temperature of 26.7 °C. The regulation focused upon airflow, Evaporative Media Saturation Effectiveness (%) for DEC, Media Type (for DEC) and Cooling Effectiveness (for IEC), Total Power (Watts) and Airflow Rate (CFM). They have considered ASHRAE's test standard for testing both direct and indirect evaporative air coolers (Saman, Bruno, and Tay 2010; Baez et al. 2017).

From the review of California's appliance efficiency regulation, it has been observed that, like Australia, California has not focused upon including water consumption as a parameter for evaluating evaporative air cooler's performance and energy efficiency levels. Most importantly, they have used ECER as the parameter to assess performance. However, this regulation has only specified the testing methods for evaporative air coolers and haven't included their MEPS.

ASHRAE TESTING STANDARD 133-2015

ASHRAE has established Standard 133, the international standard for direct evaporative air coolers (DECs), which includes the lab testing procedures for calculating the overall cooling effectiveness of a DECs, for obtaining related ratings. The first version of this standard came in 2001, followed by 2008 and then the latest one came in 2015, which included the following key details required for testing DECs: air flow rate, water flow rate, water quality, standard airflow rate, standard static pressure differential, fan standard power, standard power input, fan speed and saturation effectiveness (ASHRAE 2015a). The test conditions are: Inlet air dry-bulb temperature (maximum): 46 °C (115 °F), Wet-bulb temperature (minimum): 5 °C (41 °F) and Wet-bulb depression (minimum): 11 °C (20 °F).

ASHRAE TESTING STANDARD 143-2015

ASHRAE has established standard 143, an international standard for indirect evaporative air coolers (IECs), which includes the lab testing procedures for calculating the cooling effectiveness and power requirement of an IEC for obtaining related ratings. Compliance with this standard is voluntary. The first version of this standard came in 2000, and then it got revised with the latest one in 2015 (ASHRAE 2015b), which has the following key highlights:

- Under this testing standard, the IECs are sub-divided into the following four categories as per their construction style, namely component IECs, semi-packaged secondary indirect evaporative coolers, semi-packaged primary IECs and packaged IECs. This standard is designed to estimate the key parameters such as airflow, temperature (inlet and outlet) to calculate the pressure drop for achieving evaporative air cooling.
- The test report shall include the data related to barometric pressure, primary and secondary air temperature, primary and secondary air flow rate, electric power input, and primary and secondary air static pressure drop. Performance curves of electricity inputs and cooling capacity shall be included. In IECs who do not have air-moving devices, their static pressure drop curve shall also be included.

ASHRAE's testing standards focused on airflow rate, water flow, dry and wet-bulb temperature, water quality, water entrainment, power requirement, saturation effectiveness, and static pressure. Nevertheless, these standards do not talk about testing for the noise levels, the material used in the outer structure, and evaporative cooling pads' effectiveness (ASHRAE 2015b).

EUROVENT CERTITA CERTIFICATION'S RATING STANDARD FOR EACS

Eurovent Certita Certification (ECC) is an international-private organisation which have established the voluntary rating standards along with its operating manual for certifying EACs, both DECs and IECs along with Evaporative Cooling Equipment (ECE) (Eurovent Certita Certification (ECC) 2018a), as highlighted below:

RS/9/C/004-2018: DECs (ECC 2018b)

Key Performance Data: Cooling Capacity (kW), Air Flow [m^3/hr], Evaporation Efficiency [%], EER and Water Consumption [l/hr] as per the ASHRAE 133-2015 section 6.5.

For Testing:

AS 2913-2000 standard and ASHRAE 133-2015 are considered to calculate: airflow, power consumption, water consumption & evaporation efficiency.

Operating conditions: Inlet dry-bulb temperature: 38 °C, Inlet wet-bulb temperature: 21 °C and Room dry-bulb temperature: 27.4 °C.

Water quality specifications: The in-let water temperature shall not be less than 10 °C, and its readings by sensors shall be as per the EN 14511-3:2013 and manufacturers have to provide the details of the water being supplied to the water distributor, namely Range of Conductivity, Total Hardness, PH and Total Salt Content (TSC) or Total Dissolved Solids (TDS).

Rating requirements: The standard air density shall be considered at 1.20 kg/m^3, and a test check shall be conducted for re-evaluating the performance under the standard test operating conditions with the help of selection software.

RS/9/C/005-2018: IECs (ECC 2018d)

Case A: Where an indirect evaporative cooler has air-moving devices for both primary and secondary air passages. The key performance data considered is namely Total Cooling Capacity [kW], Room Cooling Capacity [kW], Airflow [m^3/hr], Cooling Effectiveness [%], Water Consumption [l/hr] as per the ASHRAE 133-2015 section 6.5. and EER.

Case B: Where a packaged indirect evaporative cooler has air-moving devices for both primary and secondary air passages. The key performance data considered is namely Total Cooling Capacity [kW], Airflow [m^3/hr], Wet-bulb approach effectiveness [%], Dry-bulb approach effectiveness [%], Water Consumption [l/hr] as per the ASHRAE 133-2015 section 6.5. and EER. The rating requirements are the same as those of DECs.

RS/9/C/006-2018: Evaporative cooling equipment (ECE) (ECC 2018c)

Water spray system, cooling pads/media and ultrasonic units (The unit with which fine mist is generated by converting an electronic signal into a mechanical oscillation) are the types of evaporating media considered under this rating standard. The key performance data considered is namely Cooling Capacity [kW], Evaporation Efficiency [%], EER, Water Consumption [l/hr] as per the ASHRAE 133-2015 section 6.5., Wet Pressure drop [Pa] and Dry Pressure drop [Pa].

ECC evaporative cooling certification program does not talk about the noise level and water wastage as parameters under their standards for EACs.

Discussion: Comparative Analysis of National & International Standards for EACs

Comparison of parameters covered with respect to the performance of EACs under India: IS 3315:2019 Quality and Testing Standard, Australia: AS/NZS 2913-2000 Testing Standards, Iran: 4910-2 MEPS & Label, USA (California): CEC-410-2017-002 Appliance Efficiency Regulation, ASHRAE Testing Standards (133&143) and ECC Rating Standard for EAC has been covered in Figure 4.

The standards compared in Figure 4 are based on four broad categories, namely “water consumption & quality”, “performance”, “testing protocols & MEPS” and “other details” such as instructions for manufacturers, specification related to different types of EACs and information pertaining to eco-mark.

Water Consumption and Quality: It can be observed that most of the standards adopted by the countries do not give much weightage to water consumption and quality. The “water quality” parameter is adopted within the ASHRAE and ECC testing standards. The “water flow rate” has been used by ASHRAE testing standard 133-2015 to notify the water flow to the header of the EAC. ECC testing standard used “water consumption” interchangeably to ASHRAE’s testing standards “water flow rate” terminology under section 6.5. However, the ECC testing standard does not capture the water consumption by the EACs as such. Thus, it can be said that though efforts have been made to monitor the water flow rate, water consumption is not

	Water Consumption & Quality		Performance						Testing Protocols & MEPS		Other Details		
Parameters	Water Consumption & Water Flow Rate	Water Quality	Energy Performance and Power Consumption	Noise/ Sound Level	Safety, Exterior structure /design & build	Air Flow	Evaporative cooling pad and rate of evaporation/ Evaporative effectiveness/ cooling effectiveness/ Saturation effectiveness	Static pressure/ Pressure drop	Testing Protocols	MEPS & Label	Guidance & Instructions for Manufacturers	Eco-mark	Detailed specifications w.r.t. types of EACs
India: IS 3315:2019			✔	✔	✔	✔	✔	✔	✔		✔	✔	
Australia: AS/NZS 2913-2000			✔	✔		✔	✔	Not Specified	✔				
Iran: 4910-2			✔			✔	✔	Not Specified	✔	✔			
USA (California): CEC-410-2017-002			✔			✔	✔	Not Specified	✔				
ASHRAE Testing Standards (133 & 143-2015)	✔	✔	✔			✔	✔	✔	✔				✔
ECC rating standard for EAC	✔	✔	✔			✔	✔	✔	✔				✔

** Grey Box: Parameter NOT covered and ✔ : Parameter Covered*

Figure 4. Comparative Analysis: National & international Standards for EACs. Source: Author’s analysis.

Table 4. Gaps & Recommendations for India's EAC sector.

S.No.	Gaps at National & State Level	Recommendations
	Absence of MEPS & label for EACs at the national level.	The Seasonal Energy Efficiency Ratio (SEER) would be an ideal parameter to evaluate the energy performance of an EAC annually. For the development of the performance label of EACs in India, a comprehensive comparative assessment of different labelling programs available globally could be undertaken, which will facilitate in providing recommendations specific to the Indian climatic conditions for the label development. The central level nodal agencies can take up this recommendation.
	Lack of "ecosystem" for EACs.	There is a requirement to build an "ecosystem" around EACs in India, including testing infrastructure, operation & maintenance services, training & development, and integration with academia. For the development of this ecosystem, financing will be an essential parameter. The central level nodal agencies can take up this recommendation.
	Lack of testing standards or protocols for different types of EACs.	State level Nodal Agencies with support from civil society organisations (CSOs) or any other association working in appliance energy efficiency could be appointed as the knowledge partners that could support the S&L program in framing set energy performance testing standards for different types of EACs.
	The IS for EACs do not consider water efficiency as a parameter	IS for EACs could also focus on water consumption and its efficiency levels as a critical parameter to cover the overall performance of EACs.
	Lack of trained experts.	A limited number of trained sectoral experts in the field of evaporative air cooling are available in India. Capacity buildings workshops could be conducted by CSOs and State level Nodal Agencies for increasing the number of trained sectoral experts and technicians.
	Unavailability of concrete research on the potential of the EACs and their market potential.	CSOs can carry out an in-depth market transformation potential study to identify the exact potential of EACs in the commercial segment.

yet captured within any of the standards reviewed. Water being a precious resource and depleting with each passing day shall be one of the key parameters to be measured and standardised to avoid excessive water use within an EACs.

Performance Parameters: "Energy performance and power consumption" has been covered by all the reviewed regulations/standards and MEPS, nationally and internationally. India's IS 3315:2019 quality, and testing standard states that the power consumption at zero static pressure shall not exceed the specified range of 95–500 W. Iran's 4910-2 MEPS & Label and ECC testing standard have specified energy performance in terms of EER values. California's CEC-410-2017-002 appliance efficiency regulation have specified ECER as the parameter for evaluating energy performance. ASHRAE testing standards have specified the power input testing requirements. There shall be a common metric like EER that can be used to compare and quantify the performance of products from different countries. Monitoring the energy consumption leads to enabling an implicit mechanism to reduce the energy consumption. The "noise level" of an EAC has only been covered under IS 3315: 2019 and Australia's AS/NZS 2913-2000 testing standards. The requirement for "safety, exterior structure/design & build" of an EAC has only been covered under IS 3315: 2019. Other important parameters, namely "airflow" and "evaporative cooling pad and rate of evaporation/evaporative effectiveness", has been covered by all the above-mentioned standards and MEPS. Whereas the "static pressure" has also been covered by all, except it was not specified under AS/NZS 2913-2000, CEC-410-2017-002 and 4910-2.

Testing Protocols & MEPS: All the above-mentioned standards and MEPS have provided the information regarding the testing protocols for EACs. However, MEPS for EACs have only been defined by Iran's 4910-2. In addition to these important parameters, the "guidance & instructions for manufacturers" and information regarding "eco-mark" has only been covered by IS 3315: 2019. The details or parameters concerning "different types of EACs" have only been specified under ASHRAE and ECC Testing Standards.

Gaps & Recommendations

From the review of MEPS and testing standards for EACs adopted or developed internationally and nationally, the following gaps have been identified, and recommendations have been suggested in Table 4 for the current national level institutional and regulatory framework, which will facilitate the development of the S&L framework for EACs in India.

Conclusion

Achieving thermal comfort is a necessity to ensure the overall quality of life, health, and well-being. India has around 3,000 cooling degree days per year and is one of the countries with the lowest access to cooling. However, India's RACs sector still accounts for a significant share (~42 %) in space cooling energy consumption and carbon emissions. These factors, along with the rising temperatures and the projected increase in the affordable housing sector, will increase demand for affordable space cooling solutions such as EACs. EACs is a Non-GWP refrigerant based space cooling technology that is affordable and sustainable compared to a conventional RAC. In addition, the increasing purchasing power and affordable rates of EACs, will make ECAs the preferred solution for achieving thermal comfort. Furthermore, the EAC market in India is projected to grow at a CAGR of 14.2 % during 2019–25 and is mainly unorganised. Thus, EACs might contribute to increased energy demand and severe environmental effects if left unchecked. Therefore, prevailing conditions postulate an opportunity to develop mechanisms such as the S&L program to minimise the impact of EACs on the environment and stay ahead of the demand curve. It was observed that EACs are predominantly of three types depending on the type of cooling medium used, their application and performance. It was also observed that water consumption by an EAC had not been adequately covered under any standard, and energy performance specifications for an EAC have been only covered by Iran 4910-2. Therefore, India shall focus on both water and energy performance as mandatory regulations under the S&L program to support the climate change actions. While there is no S&L program for EACs in India, developing it could bring about market standardisation, as it will mandate the sale and purchase of certified products 'only'. This will also aid in evidence based policy research that can be utilised later to develop quantified results and to assess the contribution of EAC towards 'climate change action' in India. Therefore, EAC's quality and performance can already be leapfrogged by mandating the specifications and MEPS at par with the international standards. In addition, it is essential to create an "Ecosystem" including relevant stakeholders at different stages of the push and pull strategies of the S&L program and to enhance service technicians and test lab capacity, which will together facilitate market organisation and standardisation of appliances.

Henceforth, it can be concluded that the roadmap for an effective transition to EACs, an affordable, sustainable, and Non-GWP refrigerant based space cooling technology in India can be cruised through the implementation of the S&L program; for deployment of this energy efficient and sustainable technology. This will facilitate transformation towards a sustainable and energy efficient appliances market and also unlock significant economic, social and environmental benefits with affordable, sustainable, higher performance products and modern energy systems.

References

6Wresearch. 2019. "India Air Cooler Market (2019-2025)." 6Wresearch. September 2019. https://www.6wresearch.com/industry-report/india-air-cooler-market-2019-2025.

Agrawal, Shalu, Sunil Mani, Dhruvak Aggarwal, Chetna Hareesh, Karthik Ganesan, and Abhishek Jain. 2020. "Awareness and Adoption of Energy Efficiency in Indian Homes: Insights from the India Residential Energy Survey (IRES) 2020."

Amer, O., R. Boukhanouf, and H. G. Ibrahim. 2015. "A Review of Evaporative Cooling Technologies." *International Journal of Environmental Science and Development* 6 (2): 111–17. https://doi.org/10.7763/ijesd.2015.v6.571.

American Society of Heating Refrigerating and Air-Conditioning Engineers. 2015a. "ANSI/ASHRAE Standard 133-2015 Method of Testing Direct Evaporative Air Coolers." Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

American Society of Heating Refrigerating and Air-Conditioning Engineers. 2015b. "ANSI/ASHRAE Standard 143-2015 Method of Test for Rating Indirect Evaporative Coolers." Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). 2020. "Standard 55 – Thermal Environmental Conditions for Human Occupancy." 2020. https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy.

Baez, Carlos, Ben Fischel, Betty Chrisman, and Jared Babula. 2017. "2016 Appliance Efficiency Regulations."

Bureau of Energy Efficiency. 2019a. "Enforcement Machinery under Energy Conservation Act, 2001." https://www.beeindia.gov.in/sites/default/files/Draft Enforcement Manual - Version 1.0.pdf.

Bureau of Energy Efficiency. 2019b. "Impact of Energy Efficiency Measures for the Year 2017-18." www.beeindia.gov.in.

Bureau of Energy Efficiency. 2020. "Lab Capacity Building." 2020. https://beeindia.gov.in/content/lab-capacity-building.

Bureau of Energy Efficiency (BEE). 2020. "Standards & Labeling." 2020. https://beeindia.gov.in/content/standards-labeling.

Bureau of Indian Standards. 2019. "Evaporative Air Coolers (Desert Coolers) – Specification (Third Revision) IS 3315 : 2019." BUREAU OF INDIAN STANDARDS. https://www.sylvane.com/evaporative-swamp-coolers.html?f[1253]=Indoor&pg=1&nidx=true&fbclid=IwAR1VzFcaS_APSSiiD-6sW8ISZGtA5QBxkPhdJc8M-x1TekbwKSpPSLYC7mUg.

Bureau of Indian Standards (BIS). 2016. "About BIS." Webpage. 2016. https://bis.gov.in/index.php/the-bureau/about-bis/.

CLASP. 2020. "Policy Details." 2020. https://www.clasp.ngo/policies/iran-meps11.

Effatnejad, R, and A B Salehian. 2009. "Standard of Energy Consumption and Energy Labeling in Evaporative Air Cooler in Iran." *International Journal on "Technical and Physical Problems of Engineering" (IJTPE) Issue* 1: 54–57. www.iotpe.com.

Energy Efficient Strategies. 2014. "Energy Standards And Labelling Programs Throughout The World In 2013." Australia. https://www.iea-4e.org/wp-content/uploads/publications/2014/07/NEW_Int-Label-2013-desktop-v7b.pdf.

Eurovent Certita Certification. 2018a. "Evaporative Cooling." 2018. https://www.eurovent-certification.com/en/third-party-certification/certification-programs/ec-evaporative-cooling.

Eurovent Certita Certification. 2018b. "Rating Standard for the Certification of Direct Evaporative Cooling RS / 9 / C / 004-2018." Paris.

Eurovent Certita Certification. 2018c. "Rating Standards for the Certification of Evaporative Cooling Equipment RS / 9 / C / 006-2018." Paris.

Eurovent Certita Certification. 2018d. "Rating Standards for the Certification of Indirect Evaporative Cooling RS / 9 / C / 005-2018." Paris.

Govekar, N., Bhosale, A. & Yadav, A. 2015. "Modern Evaporative Cooler." *International Journal of Innovations in Engineering Research and Technology [IJIERT]* 2 (4): 1–8.

Grand View Research. 2019. "Air Coolers Market Size, Share, Industry Report, 2019-2025." 2019. https://www.grandviewresearch.com/industry-analysis/air-coolers-market.

Harrington, Lloyd, and Melissa Damnics. 2004. "Energy Labelling And Standards Programs Throughout The World." Australia Report. www.clasponline.org.

ISIRI – Institute of Standards and Industrial Research of Iran. 2010. "Introduction." 2010. http://www.isiri.com/about.htm.

Jain, J.K., and D.A. A. Hindoliya. 2016. "Energy Saving Potential of Indirect Evaporative Cooler under Indian Climates." *International Journal of Low-Carbon Technologies* 11 (2): 193–98. https://doi.org/10.1093/ijlct/ctt076.

Lalit, Radhika, and Ankit Kalanki. 2019. "How India Is Solving Its Cooling Challenge." World Economic Forum. 2019. https://www.weforum.org/agenda/2019/05/india-heat-cooling-challenge-temperature-air-conditioning/.

Ministry of Environment Forest & Climate Change (MoEF&CC). 2019. "India Cooling Action Plan." http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

Pathak, Anukriti, Tarun Garg, and Satish Kumar. 2020. "A Policy Strategy for Decarbonising the Building Sector: Facilitating ENS Implementation in Affordable Housing." https://aeee.in/our_publications/a-policy-strategy-for-decarbonising-the-building-sector/.

Sachar, Sneha, Akash Goenka, and Satish Kumar. 2018. "Leveraging an Understanding of RAC Usage in the Residential Sector to Support India ' s Climate Change Commitment." *ACEEE Summer Study on Energy Efficiency in Buildings*, 1–12.

Saman, Wasim, Frank; Bruno, and Steven Tay. 2010. "Technical Background Research on Evaporative Air Conditioners and Feasibility of Rating Their Energy Performance." *Institute for Sustainable Systems and Technologies*, no. March.

Sarkar, Jahar. 2020. "Evaporative Cooling Technologies for Buildings." Cooling India. 2020. https://www.coolingindia.in/evaporative-cooling-technologies-for-buildings/.

Standards Australia. 2000. "AS 2913-2000 (R2016) Evaporative Air-Conditioning Equipment." 2000. https://infostore.saiglobal.com/en-au/standards/as-2913-2000-r2016--123494_saig_as_as_259449/.

Sustainable and Smart Space Cooling Coalition. 2017. "Thermal Comfort for All – Sustainable and Smart Space Cooling." https://aeee.in/wp-content/uploads/2020/07/2017-Thermal-Comfort-for-All-1.pdf.