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Government of India

Guidebook for SELECTION OF SUSTAINABLE REFRIGERATION AND AIR CONDITIONING EQUIPMENT

OZONE CELL

Ministry of Environment, Forest and Climate Change (MoEF&CC)

GUIDEBOOK FOR SELECTION OF
SUSTAINABLE REFRIGERATION AND AIR CONDITIONING EQUIPMENT

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भारत सरकार

सत्यमेव जयते

भूपेन्द्र यादव
BHUPENDER YADAV

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA

MESSAGE

Refrigeration and air conditioning systems play a vital role in the modern society and refrigerants used for cooling are integral components of these systems. The Kigali Amendment to the Montreal Protocol has led to the increased need to resolve the environmental impact of conventional refrigerants and development of refrigerants having no ozone depleting potential, low global warming potential, high energy efficiency and required safety considerations.

The use of low Global-warming potential and energy efficient equipment depends on economic factors comprising the cost of alternative refrigerants, equipment upgrades, and system retrofits. To achieve sustainability and economic viability, influencing parameters such as investments needed, long-term operational expenses, accessibility and availability of alternative refrigerants and reliable equipment need to be analysed by the industry. The space cooling in building and refrigeration and air-conditioning technologies thematic area in the India Cooling Action Plan (ICAP) proposes specific action points to address these issues.

The *'Guidebook for Selection of Sustainable Refrigeration and Air Conditioning Equipment"* discusses the parameters that should be considered for making an informed decision regarding selection of refrigeration and air conditioning equipments based on low global warming potential as well as energy efficient refrigerants and offers practical insights that adhere to the highest sustainability standards.

I congratulate the team associated with the development of this Guidebook.

(Bhupender Yadav)

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Message

India is witnessing remarkable growth and development, leading to an increased demand for refrigeration and air-conditioning systems. The refrigerant-based technologies used in these systems is the key factor towards enhancing thermal comfort, preserving food, and ensuring health and well-being for all.

As part of the Montreal Protocol implementation, India has consciously chosen environmentally friendly path using low global warming potential technologies, demonstrating to the global community, its commitment towards protection of the climate and environment.

The India Cooling Action Plan (ICAP) focuses on reducing refrigerant use and energy demand while maximizing environmental and socioeconomic benefits. A comprehensive action plan under the implementation framework of the ICAP promotes use of passive and active cooling strategies including use of energy efficient and low global warming potential alternative refrigerants, development and implementation of safety standards for refrigerants as well as equipment and training and certification of Refrigerants and Air-Conditioning (RAC) service technicians.

The publication of the Guidebook for Selection of Sustainable Refrigeration and Air-conditioning Equipment is very timely and would serve as an important resource material and should be disseminated widely amongst all concerned stakeholders.

I congratulate the team associated with bringing out of this Guidebook.

(Kirti Vardhan Singh)

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MESSAGE

Refrigeration and Air-conditioning (RAC) systems, though important in maintaining comfortable indoor environments, are among the largest energy users. The high energy share of RAC systems not only leads to an increase in costs of the equipment, but also results in greenhouse gas emissions.

The growth of air-conditioning equipment in India in the coming years will be significant due to economic growth, increasing purchasing power, urbanisation trends etc. Developing and promoting use of energy-efficient appliances and systems with low global-warming-potential (GWP) refrigerants, and capacity building in good servicing practices of the RAC equipment including effective handling of alternative low GWP refrigerants will therefore be a critical step for sustainable RAC infrastructure.

The action points relating to RAC technologies in space cooling in buildings and R&D thematic areas underscore the need for development of low GWP refrigerants, formulation of standards, development of norms for testing and calibration of RAC equipment and the importance of R&D in low GWP refrigerants. The implementation of these action points along with the ongoing hydrochlorofluorocarbon (HCFC) phase out and hydrofluorocarbon (HFC) phase down under the Kigali Amendment, will help in developing sustainable RAC infrastructure in the country.

The Guidebook for selection of sustainable refrigeration and air-conditioning equipment will be a useful Reference Document for all concerned stakeholders in this sector.

I take this opportunity to compliment the team associated with the preparation of this Guidebook.

September 6, 2024

(LEENA NANDAN)

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List of **Abbreviations**

AC	Air Conditioners
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CFCs	Chlorofluorocarbons
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
ISEER	Indian Seasonal Energy Efficiency Ratio
LFL	Lower Flammability Limit
MoEF&CC	Ministry of Environment, Forest and Climate Change
ODP	Ozone Depletion Potential
PEL	Permissible Exposure Limit
RAC	Refrigeration and Air Conditioning
UNEP	United Nations Environment Program
VAM	Vapour Absorption Machines
VAV	Variable Air Volume
VRV	Variable Refrigerant Volume
VRF	Variable Refrigerant Flow

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Guidelines for Procuring Refrigeration and Air Conditioning (RAC) Equipment based on Sustainable Cooling Technologies

1.1 Introduction

The ever-evolving landscape of cooling technologies can be overwhelming, especially when navigating towards sustainable solutions. In the contemporary landscape of environmental consciousness and energy conservation, the significance of sustainable cooling equipment cannot be overstated. According to the United Nations Environment Program (UNEP) and the Intergovernmental Panel on Climate Change (IPCC), cooling technologies contribute to about 20% of global greenhouse gas emissions and this figure is projected to reach an even higher value.[1] From residential homes to commercial establishments, there's a growing demand for space cooling solutions that prioritize both comfort and minimal environmental impact. Given these considerations, it becomes imperative to scientifically analyse the parameters that can effectively guide users in procuring cooling equipment that aligns with their specific needs while remaining environmental friendly. Thus, this comprehensive guidebook serves as a valuable tool, aiding users in selecting the most efficient and environmentally responsible cooling systems tailored to their requirements.

1.2 Why a Guidebook is Essential for Procuring Cooling Equipment?

a. *Complexity of Options:* The market offers a plethora of cooling products and solutions using new and evolving technologies with varying specifications and features, making it challenging for users

[1] https://www.unep.org/news-and-stories/press-release/key-measures-could-slash-predicted-2050-emissions-cooling-sector#:~:text=Greenhouse%20gas%20emissions%20from%20power%20consumption%20will,per%20cent%20of%20global%20emissions%20in%202050.

to make informed decisions without guidance.

b. *Sustainability Focus*: Given the global imperative to reduce carbon footprints and mitigate climate change, procurement decisions need to prioritize sustainable options. This guidebook facilitates the selection of environmental friendly cooling solutions.

c. *Economic Benefits:* Energy-efficient technologies not only contribute to environmental sustainability but also offer significant economic advantages. Reduced energy consumption translates to lower utility bills and operational costs over the lifespan of the equipment, resulting in substantial savings for users.

d. *Cost Considerations:* Effective procurement involves not only considering the upfront costs but also the long-term operational expenses. This guidebook assists in evaluating the total cost of ownership, including maintenance and energy consumption.

e. *Performance Optimization:* Appropriate selection of cooling technologies ensures optimal performance, enhancing comfort levels while minimizing energy usage. This guidebook aids users in identifying systems that align with their performance requirements.

1.3 Types of Room Air Conditioners

Room air-conditioning systems encompass a range of options, each designed to meet specific needs and preferences. Window ACs are single-unit systems and are usually fitted in the window, hence the name. They form approximately 12 to 15% of the Room AC market. Window AC units remain a cost-effective and efficient option for cooling smaller rooms or temporary spaces in residential settings, offering simplicity and convenience. Each of these systems cater to specific requirements, ensuring optimal comfort and climate control in diverse environment.

Wall mount Split AC units, consisting of separate indoor and outdoor units, give flexibility in terms of mounting the indoor unit as per the home layout and commonly used in both residential and commercial settings. They provide efficient cooling for individual rooms or zones.

Ceiling suspended units offer discreet cooling solutions without occupying valuable floor or wall space, making them popular choices for retail stores, restaurants, and small offices. Ceiling cassette ACs seamlessly blend into ceilings, delivering even airflow distribution and aesthetic appeal, often found in modern office environments. Ceiling ducted systems, installed above the false ceiling, provide centralized cooling for entire floors or homes, offering uniform temperature control throughout the space.

Variable Refrigerant Volume (VRV) systems have two classifications Mini Variable Refrigerant Flow (VRF) for small commercial requirements and for apartments where all the rooms are air conditioned. Commercial VRF is ideal for larger buildings such as hotels, offices, and shopping centres. These systems allow for precise control over cooling requirements based on the heat load and usage, simultaneously in multiple rooms or areas, maximizing comfort while minimizing energy consumption. VRF comprise of a single or connected modules of Outdoor units connected to multiple and variety of Indoor units such as Wall mount, Cassette, and Ducted units thus giving high flexibility and high

Figure 1 Types of Room Air-Conditioning Systems[2]

efficiency to the end users. Chillers are also used for space cooling in large spaces such as airports, five star hotels, and hospitals.

1.4 The Influencing Parameters for Room Air Conditioners

In the pursuit of sustainability and energy efficiency, the procurement of cooling technologies such as air conditioners, chillers, and refrigerators hold paramount importance. This guidebook aims to provide comprehensive guidelines for procuring sustainable cooling technologies, considering various influencing parameters such as room size, refrigerants, energy-efficient technologies, tonnage, and more. Thus, this guidebook empowers users to make informed decisions when purchasing new cooling technologies, promoting a more sustainable future. By understanding key factors and exploring innovative options, one can achieve optimal cooling performance while minimizing environmental impact and realizing economic benefits. While the purchase of a Window, Split and VRF are made by the individual customers at times with interior designers, the sale of large VRF and Chillers is an informed sale wherein the customer is guided by an appointed consultant or has inhouse competency.

The following are the influencing parameters for room air conditioning:

[2] https://www.indiamart.com/proddetail/acs-amc-services-17448638297.html

1.4.1 Room Size

Accurate measurement of room dimensions is essential for selecting appropriate cooling units. Detailed architectural plans can provide precise space characterization and dimensions, particularly for customized structures. Choosing the appropriate cooling unit is critical to ensure effective cooling without unnecessary energy consumption. To aid in selecting the appropriate cooling unit, the user should do the following:

- Measure the length and width of the space to be cooled. For example, if the room is 10 feet long and 12 feet wide, the area would be 120 square feet.
- Utilize floor plans for large or customized buildings to determine cooling needs accurately.

1.4.2 Refrigerants

Refrigerants play a crucial role in air conditioning and refrigeration systems and their selection is pivotal in determining environmental impact. CFCs like R-11, R-12 and R-502 were once widely used but have been phased out globally due to their high Ozone Depleting Potential (ODP), contributing to the thinning of the ozone layer. HCFCs such as R-22 and R-123 were developed as alternatives with reduced ODP, but they have been phased out due to their significant Global Warming Potential (GWP), contributing to climate change. HFCs like R-134a, R-410A and R-404A are non-ozone depleting but have high GWP. However, the industry is gradually shifting towards more sustainable options. Natural refrigerants, including CO_2, NH_3, and Hydrocarbon (Propane and Isobutane), offer sustainable alternatives with low to zero ODP and low GWP. CO_2 is primarily used in commercial refrigeration and heat pump systems due to its excellent thermodynamic properties and low environmental impact. However, it should also be noted that CO_2 has limitations in application in most of the regions in India due to high ambient temperatures. Ammonia is commonly employed in industrial refrigeration systems due to its high efficiency and low environmental impact, although safety concerns exist due to its toxicity. Propane and isobutane are mostly used in domestic refrigeration and air conditioning units due to their low environmental impact and energy efficiency.

Choosing the right refrigerant is a crucial step in procuring sustainable cooling technology. This decision involves a careful balance between environmental impact, safety considerations, and system performance.

The selection of refrigerants in cooling equipment depends on the following factors:

1. Environmental Impact

GWP: It is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming over a specified period, usually 100 years, compared to carbon dioxide (CO_2).[3] GWP is a relative measure, with CO_2 having a GWP of 1. Therefore, a gas with a GWP of 2 would have twice the warming potential of CO_2

For sustainability, users should look for refrigerants with a low GWP to minimize their contribution to climate change. Considering the market availability and regulation, this guidebook prioritizes refrigerants with significantly lower GWP.

3 https://wedocs.unep.org/bitstream/handle/20.500.11822/28246/7789GWPRef_EN.pdf?sequence=4

Table 1 Types of Refrigerants[4]

Chemical Composition	Examples	Environmental Impact
Chlorofluorocarbons (CFCs)	R-11, R-12, R-502	High ODP, phased out globally
Hydrochlorofluorocarbons (HCFCs)	R-22, R-123	Reduced ODP compared to CFCs Phased out as part of the HCFC Phaseout Management Plan (HPMP) under the Montreal Protocol They also have high GWP
Hydrofluorocarbons (HFCs)	R-32, R-134a, R-410A, R-404A, R-407C	Non-ozone depleting, high GWP
Hydrofluoroolefins (HFOs)	R-1234yf, R-1234ze, R-1233zd	Significantly lower GWP, making them more environment friendly alternatives as compared to HFCs
Hydrocarbons (HCs)	Propane (R-290), Isobutane (R-600a)	Very Low GWP, Flammable, requiring careful handling and appropriate safety measures during use
Natural Refrigerants*	Carbon Dioxide (CO_2), Ammonia (NH_3)	Lowest GWP, Environmentally sustainable alternatives. However, the potential toxicity and flammability of these alternatives require further investigation

* For the safe use of CO_2 and NH_3 as refrigerants, it is essential to comply with the BIS safety standards[5,6]

over the specified period. GWP is commonly used to compare the environmental impact of different greenhouse gases, including refrigerants, in terms of their contribution to climate change.

2. Safety

Understanding the safety classification of a refrigerant is a cornerstone of sustainable cooling practices. These classifications categorize refrigerants based on flammability and toxicity, ensuring the protection of both human health and the environment. Internationally recognized standards like ASHRAE 15, ASHRAE 34, ISO 5149, and ISO 817 provide the foundation for this critical categorization.[7] These international standards, along with national guidelines established by the Bureau of Indian Standards (BIS)[8] and the Ozone Cell, Ministry of Environment, Forest and Climate Change (MoEF&CC), are essential to form a comprehensive framework which can guide user for selecting refrigerants. Concerning safety, this framework prioritizes safety for both personnel and the surrounding environment during the entire lifecycle of a cooling system, from installation and operation to maintenance and eventual decommissioning.

4 https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations
5 https://law.resource.org/pub/in/bis/S02/is.4544.2000.pdf
6 https://law.resource.org/pub/in/bis/S02/is.307.1966.pdf
7 https://ishrae.in/images/ISHRAE-Position-Documents-Refrigerants.pdf
8 https://www.services.bis.gov.in/php/BIS_2.0/bisconnect/pow_new/Pow/download_pow_pdf_dept_commtt/68/290/

2.1) Flammability

ASHRAE Standard 34[9] provides a classification system for refrigerant flammability and toxicity. Designations A and B distinguish between lower and higher toxicity levels, while a numerical scale indicates flammability, ranging from 1 for no flammability to 3 for high flammability. These classifications are integrated to convey the overall safety profile of a refrigerant. For instance, HFC-134a is categorized as A1. In the context of third-generation transitional refrigerants, an additional classification of 2L denotes a marginal level of flammability. Unlike Class 2 refrigerants, 2L substances exhibit slower combustion rates and require more effort to ignite and sustain a flame. Different classes of refrigerants Class 1, 2, 2L and 3 with their description are shown in Figure 2.

2.2) Toxicity

Based on ASHRAE standard 34,[10] Refrigerants are assigned to one of two classes based on long-term allowable exposure known as Permissible Exposure Limit (PEL) which is explained in Figure 3.

Table 2 provides a comprehensive overview of diverse refrigerants, encompassing their ASHRAE designations, GWP, safety classifications, and critical properties including flammability, toxicity, and prevalent applications in cooling equipment. This reference chart serves as a valuable resource for users seeking information about refrigerants in their cooling systems, offering essential insights into safety considerations and suitability for specific cooling applications.

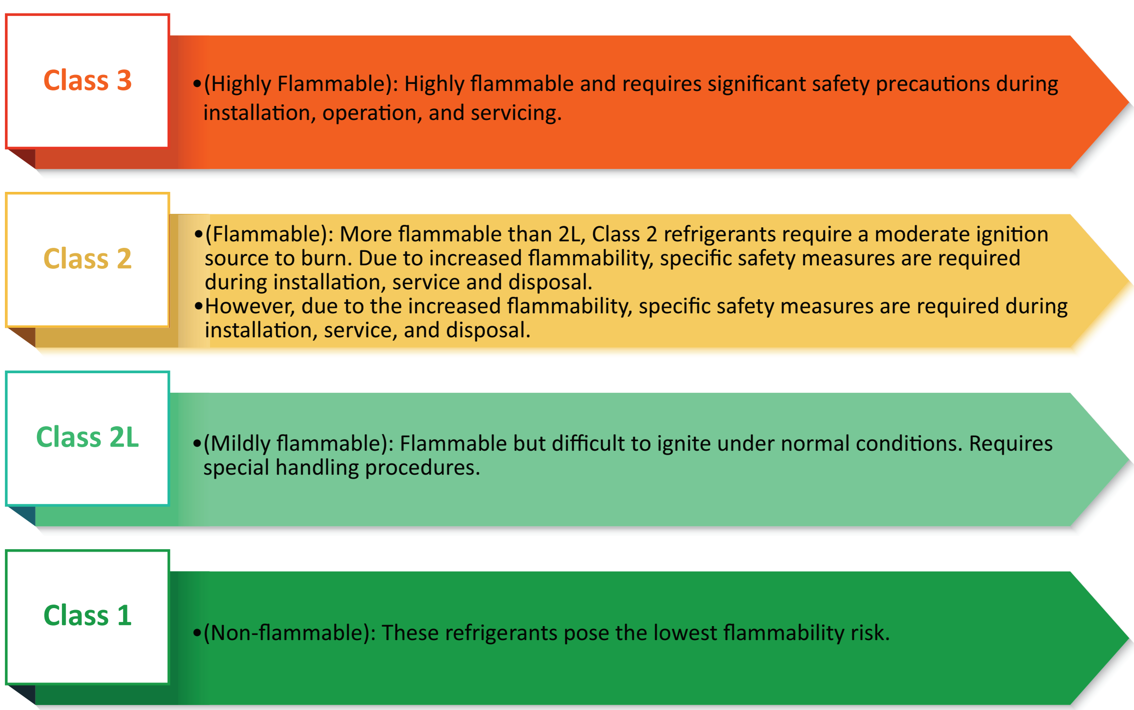

Figure 2 Different Class of Refrigerants

[9] https://www.ashrae.org/file%20library/technical%20resources/refrigeration/unep---ashrae-factsheet--english----april2023.pdf

[10] https://www.ashrae.org/file%20library/technical%20resources/bookstore/factsheet_ashrae_english_november2022.pdf

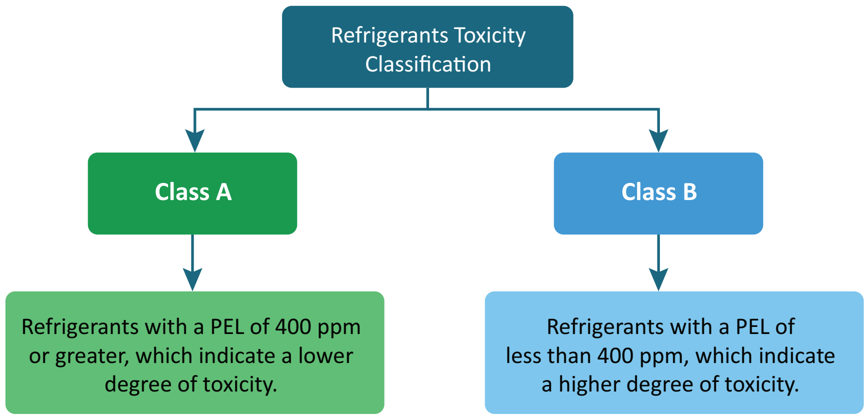

Figure 3 Toxicity Classification of Refrigerants

Table 2 Refrigerant Safety Chart[11]

Refrigerant	ASHRAE Designation	GWP	Safety Classification	Toxicity	Cooling Equipment/Technology
Ammonia	R-717	0	B2 - Toxic	High toxicity	Industrial refrigeration systems
R-32	R-32	675	A2L - Slightly flammable	Low toxicity	Air conditioners, small chillers
R-290 (Propane)	R-290	3	A3 - Flammable	Low toxicity	Domestic refrigerators, Commercial Refrigerators like Deep Freezers, Visi coolers, Water dispensers, Small room air conditioners
R-410A	R-410A	2088	A1 - Non-flammable	Mildly toxic	Room Air conditioners, VRF, Small Chillers
R-407C	R-407C	1973	A1 - Non-flammable	Mildly toxic	Small Chillers, Commercial air conditioners like VRF
R-134a	R-134a	1430	A1 - Non-flammable	Mildly toxic	Large Chillers, Domestic refrigerators, Commercial Refrigerators like Deep Freezers, Visi Coolers, Water Coolers

Ultimately the selection of refrigerant in the cooling system requires a nuanced approach that balances several factors: Performance, Availability, System Needs and serviceability. So, selecting the right air conditioner AC goes beyond just comfort. It's about choosing a system that minimizes environmental impact. Figure 4 highlights three key factors to consider when selecting a refrigerant for an eco-friendly AC.

[11] https://www.ashrae.org/file%20library/technical%20resources/refrigeration/unep---ashrae-factsheet--english----april2023.pdf

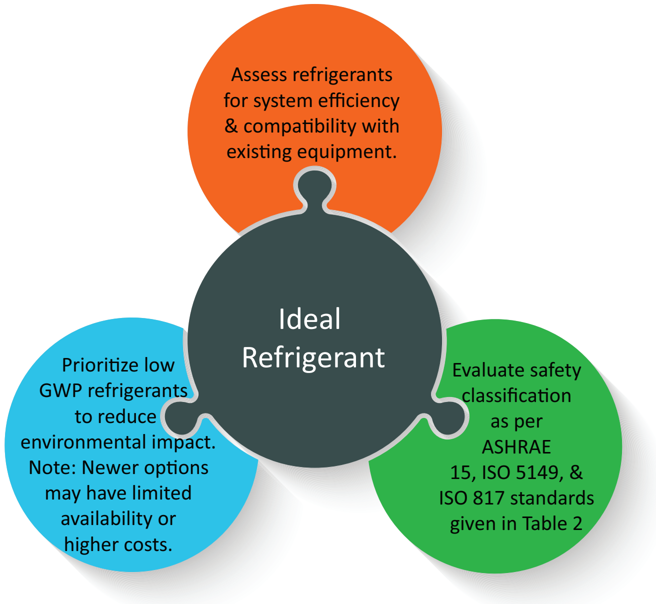

Figure 4 Optimal Refrigerant Selection Triad

By carefully considering these factors, user can make an informed decision that prioritizes both environmental responsibility and long-term system performance, ultimately selecting the best refrigerant for their specific needs. The Refrigerant safety chart in Table 2 presents an overview of different refrigerant's toxicity, flammability and their safety classification. Users installing cooling equipment should refer to this table before making a choice for the procurement of any cooling equipment.

1.4.3 Energy-Efficient Technologies

When selecting cooling devices, it's beneficial to prioritize those with higher star ratings. For air conditioners, focus should be on models with high ISEER ratings (a rating system for ACs that measures the ratio of total annual cooling output to the total annual energy consumption, adjusted for varying seasonal temperatures across different regions of India). These ratings indicate how efficiently the system converts electricity into cooling.

To assist customers in understanding the ISEER values, the Bureau of Energy Efficiency (BEE) has introduced star ratings ranging from 1 Star to 5 Star, with 5 Star denoting the highest efficiency level.

The Star or Energy labelling is based on Standards that prescribe limits on energy performance (usually maximum use or minimum efficiency) based on specified test protocols (BIS standards). The informative labels affixed to products describe energy performance usually in the form of energy use, efficiency, or energy consumption per year as electricity units under standard test conditions. The higher the star rating, the less electricity an appliance consumes. Figure 5 displays a sample of the BEE label that users typically find on their star-rated appliances.

Users must stay informed about BEE's periodic star labeling updates and select cooling equipment based on the latest criteria. Opting for appliances with the highest available star ratings ensures energy efficiency, lowers operating costs, and supports national energy goals. Regularly reviewing BEE updates is essential for making informed choices.

Air conditioners with traditional technology use fixed-speed compressors which operate in a start-stop cycle based on set temperature fixed by the end user, leading to temperature fluctuations and higher power consumption. In inverter technology, the power drive adjusts the compressor speed to match cooling demands and heat load, resulting in lower energy consumption and improved comfort. To understand the core difference, inverter technology can be seen as analogous to the accelerator in a car. If we want to increase speed while driving a vehicle we press on the accelerator pedal, on similar line inverter ACs variable speed compressor draws less power or more power depending on the heat load and set temperature of the room conditions. The inverter is an electronic power component that continuously adjusts the electric supply frequency of an electric motor. Table 3 highlights the advantages of inverter AC technology, including continuous modulation of compressor speed and reduced operating noise.

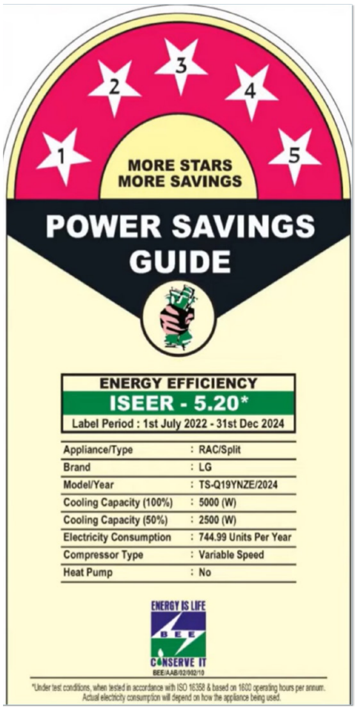

Figure 5 BEE Star Rating Label for Appliances[12]

Table 3 Major Differences between Variable Speed (Inverter) AC and Fixed Speed (Non-Inverter) AC

Parameters	Fixed Speed AC /Non-Inverter AC	Variable Speed/Inverter AC
Technology	Fixed speed compressors	Variable speed compressors
Energy consumption	More	Less
Noise levels	More, due to frequent ON /OFF	Less, due to smooth operation
Thermal Comfort	Less due to frequent ON /OFF cycles	More due to smooth interrupted operation
Cooling Capacity	Fixed	Varies as per cooling load
Usage Recommendation	Buy, if: Normal Daily Usage	Buy, if: 1. Daily usage is large 2. Performance is the priority 3. Flexible Buying budget 4. Electricity Bill Reduction

[12] https://beeindia.gov.in/en/standards-labeling

1.4.4 Cooling Capacity (Cooling Tonnage)

In simpler terms, Cooling Tonnage refers to the cooling capacity of a system, representing the heat removed from the space in an hour under standard test conditions in kilowatts (kW). On any cooling equipment, it is usually mentioned on the label attached on the system. One ton of cooling capacity is roughly equivalent to 3.517 kW. It is important to select the room AC slightly higher than the peak heat load usually at noon on a summer day. Use factors like room size, top floor, and window/wall directions (West wall and Windows and top floor result in higher heat load) to determine the appropriate tonnage. The above-influencing parameters are considered for deciding the appropriate size and capacity of the cooling equipment. Table 4 summarizes the action points for the user based on influencing parameters.

Table 4 User Action for Influencing Parameters

Influencing Parameters	Relevance	User Action Points
Space Assessment	Measure room dimensions for determining cooling capacity. Refer to architectural drawings and plans for estimates Consider the East, West, North and South direction walls of the room and the floor of the room in a building	Measure room dimensions and get floor area Consult architectural plans (if applicable)
Refrigerants	Low GWP refrigerants have a lower impact on climate.	Always select the most preferable refrigerants from the Table In addition to this, user should refer the refrigerant safety chart for their relative toxicity and flammability
Energy Efficiency	Seek high-efficiency equipment with high ISEER	Consider high star (3, 4 and 5) rated air conditioners for energy savings Consult the BEE website and App for regular updates
Efficient Technology	Opt for inverter-based air conditioners which are energy-efficient technologies for reduced energy consumption, consistent comfort, and quieter operation	Refer to the Criteria Tables that prioritize these technologies. User will get their recommended technology after selecting their floor size
System Sizing	Select the right cooling tonnage to avoid inefficient operation	Consult Tables 5 and 6 for appropriate tonnage

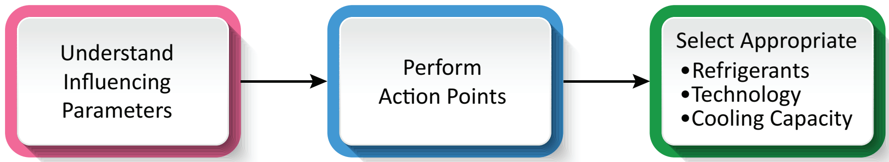

Figure 6 Flowchart for using the Criteria Tables for Sustainable RAC equipment Selection

The sustainable selection process for cooling technologies is outlined in Figure 6 and consists of three key steps: first, identifying the parameters that influence the need for cooling systems; second, addressing the action points associated with each influencing parameter; and third, selecting the appropriate cooling equipment based on refrigerants, technology, and cooling capacity. For ease of use, this procedure is presented in a Criteria Table, simplifying the selection of the most sustainable cooling equipment available in the market.

1.5 Criteria for Selection of Sustainable Air Conditioning Technologies

1.5.1 Residential Buildings

Selecting sustainable cooling equipment for residential settings is crucial for minimizing environmental impact and optimizing energy use. This book introduce Criteria Tables which help users in making informed decisions during the purchasing process.

These Criteria Tables prioritize factors that contribute to long-term environmental and economic benefits. These factors include energy efficiency, measured by star ratings, and refrigerant type, assessed by GWP. Table 5 recommends refrigerants with a low GWP, such as R-32, to minimize their contribution to climate change.

To further enhance the user experience, the Criteria Table is paired with specific recommendations for different building types and sizes. For example, single-room apartments or studio spaces with up to 500 square feet might benefit from a high-efficiency window AC unit or a mini-split system utilizing low GWP refrigerants like R-32.[13] Larger apartments with multiple bedrooms or multi-story buildings can leverage high-efficiency ductless multi-split AC systems for optimal cooling coverage while maintaining environmental responsibility. In selecting between Window and Split type AC check the ISEER values. The Split type of AC has a higher ISEER value as compared to the Window type for a given Star rating category.

[13] https://www.teriin.org/sites/default/files/2019-11/Mapping%20the%20Refrigerant%20Trends%20in%20India%20An%20Assessment%20of%20Room%20AC%20sector.pdf

By utilizing this Criteria Table alongside the accompanying recommendations, homeowners and building managers can make informed choices for their cooling needs. These choices prioritize environmental sustainability while promoting energy efficiency and long-term cost savings. When selecting an appropriate cooling solution, start by assessing the "Built-up Area" of the facility to determine the foundation for your cooling needs. Next, calculate the "Tonnage required" to match the cooling capacity with the space's demands, ensuring optimal performance. Explore the two primary cooling technologies—fixed speed and variable speed—each offering unique advantages depending on the environment. Consider "Suitable Building Types" to ensure the chosen system aligns with the facility's architecture. Finally, prioritize "Refrigerant Used" by opting for eco-friendly options that reduce the carbon footprint and support sustainability efforts.

Table 5 Selection Criteria for Sustainable Cooling Technologies in Residential[14] Buildings

<table>
<tr><th>Room Area[15] (Square feet)</th><th>Required Cooling Capacity (Tonnage)</th><th>Type of Room</th><th>Type of Air Conditioning</th><th>Market Availability[16]</th><th colspan="3">Refrigerants Available</th></tr>
<tr><td>80-120</td><td>1.0</td><td>Small bedroom, Guest room</td><td>Split and Window ACs with variable speeds</td><td>1. BEE Star-rated Unitary Type ACs
2. EESL Super-efficient Air Conditioner</td><td rowspan="5">R-32</td><td rowspan="5">R-290</td><td rowspan="5">R-410A</td></tr>
<tr><td>140-160</td><td>1.5</td><td>Medium bedroom</td><td>Split and Window ACs with variable speeds</td><td>1. BEE Star-rated Unitary Type ACs
2. EESL Super-efficient Air Conditioner</td></tr>
<tr><td>180-200</td><td>2.0</td><td>Large bedroom, Master bedroom</td><td>Split and Window ACs with variable speeds</td><td>BEE Star-rated Unitary Type AC</td></tr>
<tr><td>240-260</td><td>2.5</td><td>Large living room, Open concept living/ dining area</td><td>High-Efficiency Ductless Multi-Split AC System</td><td>BEE Star-rated Multi-Stage Capacity Air Conditioners</td></tr>
<tr><td>290-310</td><td>3.0</td><td>Large living area with high ceilings, Apartments</td><td>High-Efficiency Ductless Multi-Split AC System</td><td>BEE Star-rated Multi-Stage Capacity Air Conditioners</td></tr>
</table>

[14] https://www.hitachiaircon.com/in/magazine/how-to-calculate-the-room-air-conditioner-capacity-requirement-based-on-square-feet

[15] *– (mohua.gov.in)

[16] https://beestarlabel.com/Home/EquipmentSchemes?type=M

Refrigerants	GWP	Preference
R-32	675	Preferable
R-290	3	Preferable
R-410A	1970	**Least Preferable** (Highest GWP)

Note: For top floors and walls and windows facing west, a larger air conditioning unit may be necessary. These areas typically receive more heat from the sun, which can increase cooling demands. Opting for a slightly larger AC unit ensures efficient cooling and maintains comfort during hotter periods.

1.5.2 Commercial Buildings

Criteria Table 6 helps the user choose the most sustainable cooling technology for their commercial space, considering floor size, cooling capacity (tonnage), refrigerant type, and technology. Environmental sustainability is prioritized through the selection of refrigerants with the lowest available GWP refrigerant in the market.

Table 6 Selection Criteria for Sustainable Cooling Technologies in Commercial Buildings

<table>
<tr><th>Built-up Area (Square feet)</th><th>Required Cooling Capacity (Tonnage)</th><th>Type of Air Conditioning</th><th>Suitable Building Types</th><th colspan="2">Refrigerants Available</th></tr>
<tr><td>Less than 5,000</td><td>1- 5 Tons</td><td>Split air conditioning units, packaged air conditioning units</td><td>Small Offices, Retail Stores, Studios</td><td rowspan="2">R-32</td><td rowspan="2">R-410A</td></tr>
<tr><td>5,000 - 20,000</td><td>5-20 Tons</td><td>VRF systems, rooftop units</td><td>Small to Medium Offices, Showrooms, Restaurants, Schools (single floor)</td></tr>
<tr><td>20,000 - 50,000</td><td>20-50 Tons</td><td>Chilled water systems, variable air volume (VAV) systems</td><td>Multi-story Offices, Malls, Schools (multiple floors), Hotels (limited floors)</td><td rowspan="3">HFOs (R-1234yf and R-1234ze)</td><td rowspan="3">R-134-a</td></tr>
<tr><td>50,000 - 100,000</td><td>20-100 Tons</td><td>Chilled water systems, variable air volume (VAV) systems</td><td>High-rise Offices, Large Malls, Convention Centres, Hospitals (multiple floors)</td></tr>
<tr><td>Over 100,000</td><td>More than 100 Tons</td><td>Chilled beam systems, District cooling systems</td><td>Airports, Stadiums, High-rise Hospitals, Large University Complexes, Industrial Complexes</td></tr>
</table>

Refrigerant	GWP	Preference
R-32	675	Most Preferable
HFOs	1	Most Preferable (Lowest GWP)
R-134a	1430	Preferable
R-410A	1970	Least Preferable (Highest GWP)

Note: Users should prioritize high star-rated chillers to achieve improved energy performance for their cooling systems. Users should prioritize transitioning to HFO refrigerants, which have a much lower GWP than HFCs. Stakeholders also need to stay informed on refrigerant advancements to ensure environmental friendliness, commercial viability and regulatory compliance.

Chillers offer a compelling solution for addressing the cooling needs of large buildings due to their scalability, efficiency and reliability. With a wide range of sizes and capacities available, chillers can effectively meet the diverse cooling demands of expansive structures. Their modern designs prioritize energy efficiency, ensuring optimal cooling performance while minimizing operating costs. Additionally, chillers provide centralized cooling, simplified system control and maintenance for large-scale applications. Their robust construction and long service life make them a dependable choice for sustained cooling in commercial and industrial settings.[17]

Air-cooled chillers commonly utilize refrigerants such as R-410A and R-134a. R-32 is widely used in smaller capacity chillers whereas R-134a is used for large capacity systems. Water-cooled chillers utilize different refrigerants and offer distinct advantages. They often use R-134a, valued for its exceptional efficiency and reliability in larger capacity systems, especially where energy conservation is paramount. Water-cooled chillers contribute to sustainability by reducing the demand for freshwater, as they are designed to utilize recycled water in their cooling processes. As chillers are mandatory star-rated cooling appliances under the BEE's Standards and Labeling Program, users should prioritize high star-rated chillers to achieve improved energy performance for their cooling systems. When it comes to safety standards, ISO 5149 and IEC 60335-2-40 are the main regulations governing the use of certain refrigerants, including R-290. For chillers using refrigerant charges above certain thresholds (e.g., more than 4.94 kg of R-290) in applications, national standards, often based on ISO 5149, are recommended to ensure compliance with safety requirements.[18]

For district cooling chillers, the charge of R-290 is often kept below certain thresholds to minimize risk. According to IEC 60335-2-40, systems with a charge exceeding "130 × LFL" (Lower Flammability Limit) must apply national standards. For R-290, the LFL is 0.038 kg/m³, which translates to a maximum charge of around 4.94 kg (130 × 0.038 kg/m³) under certain conditions without additional safety measures. In practice, the actual charge value will depend on the chiller's size, the system's design & implementation of safety features like leak detection, ventilation, and safety shut offs. For large district cooling systems, compliance with national regulations and international standards, such as ISO 5149, is critical when determining the permissible charge of R-290. Future selection strategies for RAC equipment should also prioritize Vapour Absorption Machines (VAMs) as a sustainable alternative to conventional vapour compression systems. VAMs are ideal for industrial and commercial applications, offering significant energy savings by utilizing waste heat, solar thermal energy, or other low-grade heat sources. Users are encouraged to assess the life cycle cost of VAMs, considering their reduced operational costs and environmental benefits. Moreover, the integration of VAMs in district cooling systems, especially in urban planning, should be explored to enhance overall energy efficiency and sustainability.

1.6 How to use the Selection Criteria Tables (Table 5 and Table 6)

To use the Criteria Tables for Residential and Commercial Buildings effectively, the user should follow

[17] https://www.beestarlabel.com/Content/Files/Chillers_schedule_21.pdf

[18] https://ozone.unep.org/sites/default/files/2019-08/application-of-safety-standards-to-RACHP.pdf

these steps: -

1. Identify Building Type

Determine whether the building is residential or commercial. If it is a residential building, refer to Table 5. For commercial buildings, refer to Table 6.

2. Determine Floor Size

Estimate the total square footage of the space to be cooled in the building. The Tables provide ranges for different building sizes.

3. Cooling Capacity (Tonnage)

This refers to the amount of cooling power the room and building needs.

4. Select Recommended Refrigerant

This section prioritizes environment friendly refrigerants based on their GWP. Look for the refrigerant with the lowest GWP number in the recommended range for the building type and size. Lower GWP indicates a more sustainable choice.

5. Choose Recommended Technology

Based on building type, size, and recommended refrigerant, the Tables suggests the most suitable cooling technology. These include options like high-efficiency window AC, mini-split AC, VRF, and secondary loop systems with chillers.

The Tables are designed in such a way that it helps users choose the most suitable sustainable cooling technology for their home, considering floor size, cooling capacity (cooling tonnage), refrigerant type, and technology. Emphasizing sustainability, the Tables prioritize options featuring low GWP refrigerants

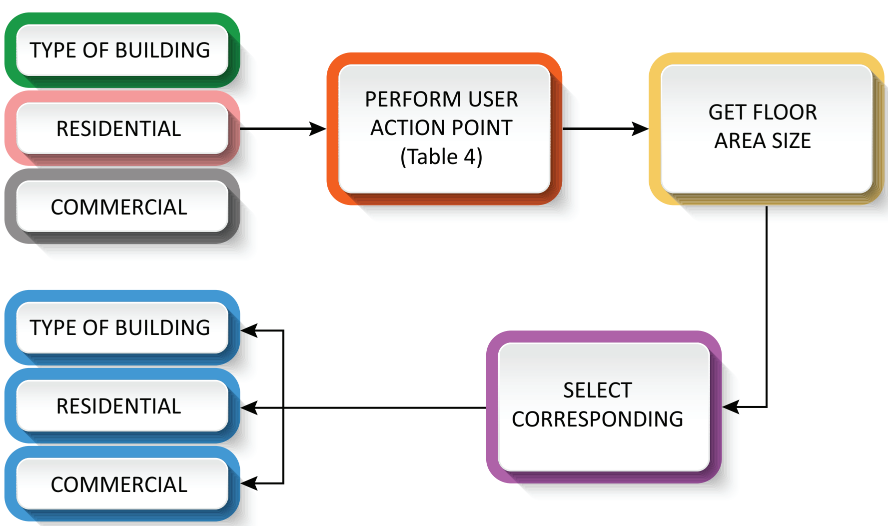

Figure 7 Process Flow Chart for using Criteria Tables for Air Conditioning

and the most efficient technologies currently accessible in the cooling equipment market.

Figure 7 above depicts four-step flowchart which summarises how users must utilise the criteria stepwise. Since the use of technology changes with applications, there are separate tables for residential users Table 5 and Table 6 for commercial users.

1.7 Criteria for Selection of Sustainable Refrigerator Technologies

The refrigerator, or "fridge" as it's commonly called, is more than just a convenient appliance – it's a cornerstone of healthy living. By storing food at cold temperatures (usually just a few degrees above freezing), it prevents spoilage and keeps fruits, vegetables and other perishables fresh. But how these fridges operate and the features they offer can significantly impact both our health and the environment. Here's where understanding refrigerators and their key characteristics becomes crucial. By considering factors that contribute to efficiency and environmental sustainability, the users can make informed choices when selecting a new fridge, ensuring they get the best for their families and the planet.

1.7.1 Different interior parts of Refrigerator/fridge

- Fresh Food Compartment: Maintains a temperature around 37°F (3°C) for storing dairy products, fruits, vegetables and most leftovers.
- Freezer Compartment: Maintains a temperature below 0°F (-18°C) for long-term storage of frozen foods.
- Shelves & Drawers: Adjustable to accommodate different sized items.
- Door Bins: Convenient for storing condiments, beverages and smaller items.
- Crisper Drawers: Maintain a higher humidity level for storing fruits and vegetables.

Installation guidelines to be followed:

- Choose a well-ventilated location with at least 3 inches (7.6 cm) clearance around the back and sides for proper airflow. Avoid direct sunlight and heat sources.
- Ensure the refrigerator is level for optimal performance and to prevent noise.
- Wipe down the interior with a mild soap and water solution before use.
- Allow the refrigerator to reach its desired temperatures (around 2°C for the fresh food compartment and -17°C for the freezer) before adding food. Refer to the manual for specific instructions on adjusting these settings. Don't overload the refrigerator, this reduces airflow and makes the unit work harder.
- Let hot foods cool completely before storing them.
- Regularly defrost manual defrost models to prevent ice buildup, which reduces efficiency.
- Clean the condenser coils on the back of the refrigerator periodically to ensure proper heat

exchange.

- Consider using the "Eco" mode if available, which optimizes energy usage.

1.7.2 Influencing Parameters for Refrigerator Selection

Selecting the ideal refrigerator necessitates a thoughtful evaluation of several key parameters. Key among these is volume capacity, ensuring adequate space to accommodate grocery needs. Beyond size, consider features that enhance both convenience and food preservation. Inverter compressors offer quieter operation and improved energy efficiency, while frost-free technology eliminates the need for manual defrosting. Additional features like smart controls or water dispensers can further elevate the culinary experience. Environmental impact is also crucial. The user should look for models utilizing eco-friendly refrigerants. Finally, prioritize build quality and warranty duration to guarantee long-lasting performance. Understanding these factors empower users to make an informed decision when selecting the perfect refrigerator for their needs.

Various influencing parameters for selecting refrigerator are as follows:

1.7.2.1 Energy Consumption (kWh/year)

This metric reflects the amount of electricity a refrigerator consumes over the course of a year to maintain its specified temperature settings and operate its various features. Refrigerators with higher energy efficiency ratings consume less electricity, resulting in lower energy bills and reduced environmental impact. When selecting a refrigerator, opting for models with lower kWh/year ratings can lead to long-term cost savings and contribute to energy conservation efforts. Energy-efficient refrigerators often feature advanced technologies such as improved insulation, compressor designs and adaptive defrost systems, which help to minimize energy use without compromising performance.

1.7.2.2 Cost

Energy Star-rated fridges typically come with a higher upfront cost; they provide significant savings over their lifespan through reduced energy consumption. These appliances are designed to be more efficient, consuming less electricity to keep food cold. As a result, households can enjoy lower energy bills month after month, ultimately offsetting the initial purchase price. Additionally, Energy Star-rated fridges often come with extended warranties and are built to higher quality standards, reducing the likelihood of repairs and replacement costs down the line. Therefore, while the upfront cost may be higher, the long-term benefits of Energy Star-rated refrigerators make them a cost-effective and environment friendly choice for savvy consumers.

1.7.2.3 Volume Capacity

The volume capacity of a freezer refers to the maximum amount of space available within the freezer compartment to store frozen goods. Families with up to 200 Liter fridge volumes find ample space for essentials, catering to the needs of smaller households or individuals. For slightly larger families or those desiring extra room for perishables, fridge volumes ranging from 250 to 300 Liters offer a comfortable fit. Moving into the 300 to 350 Liter range, households gain additional storage for groceries and condiments, catering to medium-sized families or those with frequent guests. Very larger families can opt for fridge volumes exceeding 400 Liters, ensuring sufficient space for bulk purchases, fresh produce and accommodating various dietary preferences. Thus, aligning fridge volume capacity with family size ensures efficient organisation and meets the diverse needs of modern households.

1.7.2.4 Refrigerants

Refrigerants play a crucial role in the functioning of refrigerators by facilitating the cooling process that preserves food and perishable items. Here's a breakdown of their role and how they influence the selection parameters when purchasing a refrigerator:

1. *Cooling:* Refrigerants are the medium through which heat is absorbed from the interior of the refrigerator, lowering its temperature. They circulate through the refrigeration system, transferring heat from the interior to the exterior environment, thus keeping the contents cool and fresh.
2. *Energy Efficiency:* The choice of refrigerant also impacts the energy efficiency of the refrigerator. Some refrigerants can achieve the desired cooling effect with less energy consumption. Energy-efficient refrigerants contribute to less electricity bills & lower environmental impact.
3. *Environmental Impact:* Refrigerants with high ODP or GWP can harm environment and human health. ODP refrigerant has been already phased out. At present, there are options for low to medium GWP refrigerators. So, selecting refrigerators with refrigerants that have lower GWP values is essential for sustainability. These key factors are presented in form of a flowchart for users below in Figure 8.

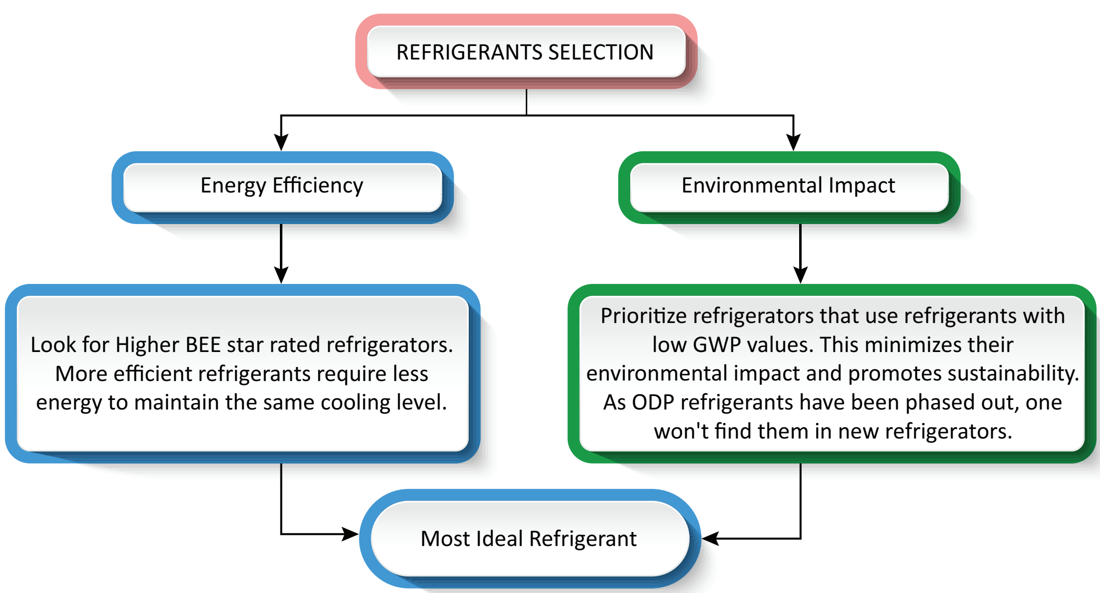

Figure 8 Flowchart Explaining Refrigerant Selection for Refrigerators

1.7.2.5 Technologies

Modern refrigerators boast a range of technologies designed to optimize food preservation and user experience. Common features include a frost-free operation for effortless maintenance and inverter compressors for quiet, energy-efficient cooling. Advanced options like Door-in-Door design, smart controls for remote monitoring and integrated dispensers for water and ice can further elevate the functionality of this essential kitchen appliance. Figure 9 lists the common technologies and advanced technologies available in the refrigerator present in the market so that users can make an informed decision.

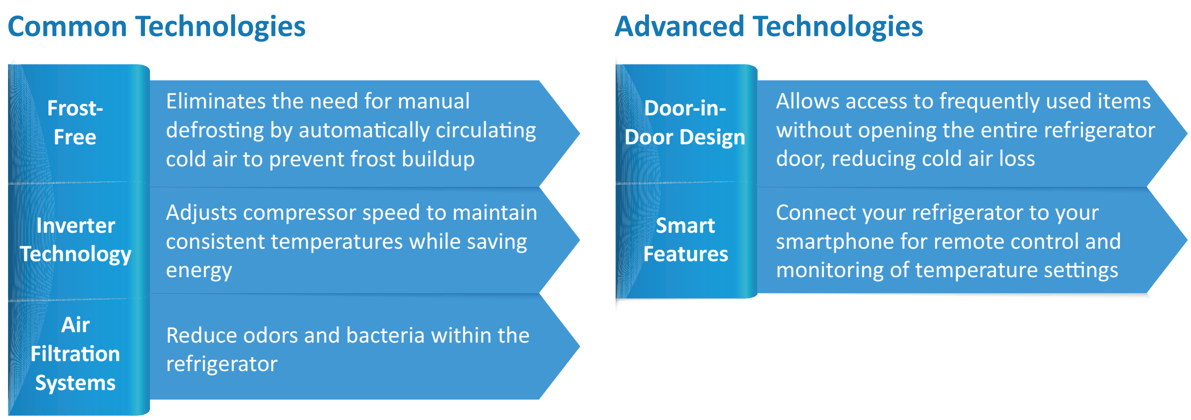

Figure 9 Modern Refrigerator Technologies

1.7.2.6 Durability and Longevity

When selecting a refrigerator, it's essential to consider factors such as the quality of materials used in its construction, the reputation of the brand and user reviews regarding the appliance's reliability. Opting for a refrigerator known for its durability can help avoid frequent repairs or premature breakdowns, ultimately saving both time and money. Additionally, choosing a model with a longer lifespan ensures that the investment in the appliance pays off over time, providing consistent cooling and storage for years to come. Therefore, prioritizing durability and longevity when selecting a refrigerator is essential for making a wise and sustainable investment in household appliances.

1.7.3 Types of Refrigerators

When selecting a refrigerator, it's essential to consider one's lifestyle and kitchen layout to find the best fit. If the user prioritizes easy access to everyday items, a top-mount refrigerator might be ideal, with its freezer conveniently situated at eye level. Conversely, for those who prefer a more ergonomic design, a bottom-mount option places the freezer at the base for effortless retrieval of fresh produce. French door refrigerators offer a balance of spaciousness and style, while side-by-side models provide equal space for both fresh and frozen items. If space is limited, a compact refrigerator could be the perfect solution, offering functionality without compromising on storage capacity. By assessing the needs and preferences, one can judiciously choose the refrigerator type that enhances one's kitchen experience. Figure 10 depicts different types of refrigerators available in the Indian market.

The above important parameters can be constructed into a user-friendly table which guides the user based on sustainability parameters: volume capacity, refrigerants and technology features. While factors like price, warranty and after-sales service are crucial considerations when buying a refrigerator, prioritizing energy efficiency offers significant long-term economic and environmental benefits.

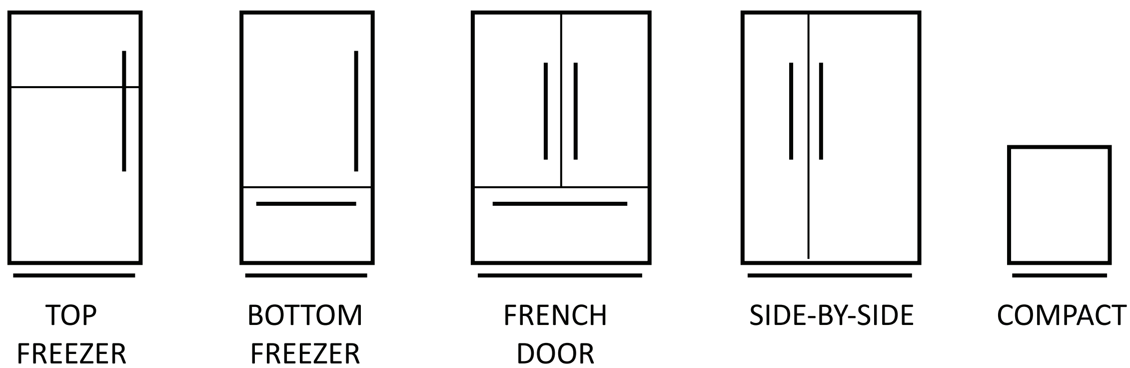

Figure 10 Types of Refrigerator Design

1.8 Refrigerator Sustainability Criteria Tables

To guide sustainable refrigerator selection, two comprehensive Criteria Tables 7 and 8 are constructed based on the key influencing parameters discussed earlier. These tables empower users to choose the most eco-friendly option for their needs, categorized by refrigerator capacity (Liters). A user-friendly flowchart, presented in Figure 11, precedes the Table, guiding users through the decision-making process.

1.8.1 Domestic Refrigerators

Table 7 is the Criteria Table for the residential refrigerators. Before approaching the table, user should follow the steps mentioned in Figure 11.

1.8.2 Commercial Refrigerators

Selecting the appropriate freezer for commercial applications involves considerations of storage capacity, energy performance and environmental impact. Businesses often opt for freezers with varying storage capacities to accommodate their specific needs, whether it be for small-scale retail operations or large-scale food distribution centres. Additionally, the choice of eco-friendly refrigerants is becoming increasingly important in aligning with sustainability goals and regulatory requirements. Refrigerants such as R-600a and R-290 are preferred choices for future use due to their lower

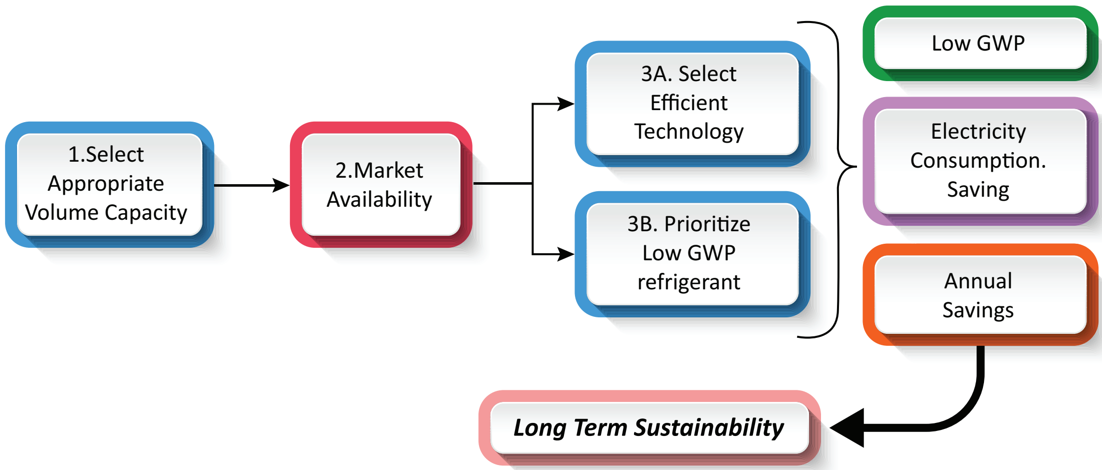

Figure 11 User Action Flow chart for using Refrigerator Criteria Tables

Table 7 Selection Criteria for Sustainable Cooling Technologies in Domestic Refrigerators

Refrigerator Capacity (Litres)	Suitable For	Refrigerator Options*	Energy Efficient Technologies Available	Refrigerant	Pictorial Image
Up to 200	**Suitable for individuals or small households with constrained space** Ideal for apartments, offices, or serving as a secondary refrigerator.	» Mini Fridge » Single-door (Direct Cool) Refrigerator	» Inverter Compressor Technology	R-600a	 
200 to 300	**Suitable for small to medium-sized families of 2-3** Offers sufficient storage for groceries, perishables, and leftovers.	» Double-Door Top-Mounted Freezer » Double-Door Bottom-Mounted Freezer	» Inverter Compressor Technology » Double Door Cooling (separately cooled compartments for optimal temperature control) » Automatic Defrost Systems (reduces energy consumption compared to manual defrosting)	R-600a	 

Refrigerator Capacity (Litres)	Suitable For	Refrigerator Options*	Energy Efficient Technologies Available	Refrigerant	Pictorial Image
300 to 350	**Medium Family of 4-5 members** Provides ample storage for fresh and frozen food.	» Big Capacity Top-Mounted Freezer » Big Capacity Bottom-Mounted Freezer » Side-by-Side Refrigerator (2-door or 3-door)	» Inverter Compressor Technology » Double Door Cooling » Automatic Defrost Systems (reduces energy consumption compared to manual defrosting)	R-600a	 
400 and above	**Family of 6 or more members** Tailored for larger families or households requiring extensive storage. Offers ample room for bulk purchases, larger containers, and diverse food items to meet all needs.	» Side-by-Side Refrigerator (larger capacity options available) » French Door Refrigerator (4-door)	» Inverter Compressor Technology » Triple Door Cooling » Sensor-based technologies for intelligent cooling	R-600a	 

* All of these refrigerators have been star-rated by the BEE, Government of India

environmental impact compared to older refrigerants like R-22. By prioritizing eco-friendly refrigerants, businesses can reduce their carbon footprint and contribute to environmental conservation efforts.

The Criteria Table for commercial refrigerators helps user to select the most suitable and sustainable commercial refrigerators for their needs. Here's how to use it:

1. Identify Storage Needs

- *Storage Volume (Liter):* This column indicates the interior space of the refrigerator in Liters. Choose a size that comfortably meets the user's requirements.

2. Consider Cooling Power

- *Tonnage of Refrigeration:* This refers to the cooling capacity of the refrigerator. A refrigerator with higher cooling tonnage can remove more heat from the stored items within a specific period, enabling it to cool larger volumes of products or maintain lower temperatures in demanding conditions. Refrigeration temperatures for some cooling products are as follows[19]:

[19] ASHRAE Standard 55-1992

Product	Temperature (°C)
Pantries/Groceries	15 to 18
Meat and fish	4 to 6
Fruit and vegetable	6 to 10
Freezing	-18 to -24

3. Match the Application

- *Applications:* This column suggests typical uses for each model, such as home use, small shops, labs, commercial stores, industrial settings, or large-scale storage.

4. Prioritize Sustainability

- *Refrigerant Used:* Different refrigerants have varying environmental impacts. While the table lists several options, here's a breakdown to help choose a more sustainable option:
  - » *Most Sustainable:* R-290 (hydrocarbon), eco-friendly but may not be suitable for all applications (check with the local regulations). R-600a is a good choice available for small-scale applications.
  - » *Good Alternatives:* The user should look for models using R-134a, particularly for large-scale refrigeration. This offers a balance between performance and environmental impact
  - » *Less Sustainable:* R-404A have a higher GWP and may be phased out in the future.

Table 8 is a Criteria Table for commercial refrigerators which will help users to choose a refrigerator based on their needs. It compares different models by storage volume, cooling capacity, typical applications, and the type of refrigerant used.

- The storage volume ranges from 100 Liters for small home use up to 5000 Liters for large scale storage.
- The tonnage of refrigeration indicates the cooling power, with higher tonnage suitable for colder temperatures or larger spaces.
- The table also shows the common applications for each model, such as small shops, laboratories, and commercial stores.
- Finally, the type of refrigerant used in each model is listed.

Table 8 Selection Criteria for Sustainable Cooling Technologies in Commercial Refrigerators

Storage Volume (Liter)	Tonnage of Refrigeration	Applications	Refrigerant Used	Pictorial View
100	0.5	Small Household Enterprise	R-600a	
300	1.2	Small Shops	R-600a	
600	2.5	Laboratory	R-290	
1000	4.0	Commercial Stores	R-290	
2000	7.5	Industrial Use	R-134a/R-404A blend/ R-290 blend	
5000	15.0	Large Scale Storage	R-134a/R-290 blend	

1.9 Conclusion

It is crucial to thoroughly analyse the parameters that guide users in selecting cooling equipment tailored to their specific needs while ensuring environmental friendliness. This guidebook serves as an invaluable resource in this endeavour, offering comprehensive insights into the most efficient and eco-friendly cooling systems available. It addresses key influencing factors such as room size, refrigerant properties (including environmental impact, safety and toxicity), energy-efficient technologies and cooling capacity. The guidebook provides detailed criteria tables that outline various refrigeration and air conditioning technologies, helping users navigate the options based on their unique cooling capacity requirements. These tables are designed to simplify the selection process by presenting clear and actionable information on how different technologies align with both performance and environmental criteria. By utilizing the guidebook's structured approach, users can make well-informed decisions, ensuring that their choice of refrigeration and air conditioning technologies meets both their operational needs and sustainability goals. This balanced approach not only enhances performance and efficiency but also supports broader environmental stewardship, contributing to a more sustainable future in both domestic and commercial settings.

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