Ministry of Climate Change and Environmental Coordination

Government of Pakistan

Pakistan's Cooling Needs Assessment Report

SEPTEMBER 2022

clasp Efficient Appliances for People & the Planet

SAMA^Verte

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ACKNOWLEDGEMENTS

The authors would like to thank Pakistan's manufacturers and National Energy Efficiency and Conservation Agency for providing the consultative support and data for this report.

REPORT REVISION

The report was revised in 2023 to include additional analysis on cooling access and direct emissions.

Contents

Executive Summary

Pakistan has the 5th highest total cooling demand of any country, estimated at 646 billion Person Cooling Degree Days per annum*, but access to cooling and penetration of cooling appliances† is low. *Chilling Prospects: Tracking Sustainable Cooling for All (SEforAll) 2022* lists Pakistan among the 54 high impact countries and the 9 critical countries which have the greatest number of people at high risk from inadequate cooling.[1]

The country regularly experiences some of the highest temperatures in the world, with an average of around 29°C during the summer months.[2,‡] Further, the Intergovernmental Panel on Climate Change (IPCC) projects a global average temperature increase of 3.7°C by 2081–2100, whilst a 5.3°C increase is projected for Pakistan under the highest emissions pathway scenario.[3] As temperatures in the country rise, cooling technologies will become increasingly critical for health and productivity.

The cooling demand, while growing, does not account for the households without access to space cooling or refrigeration or the wider unmet cooling demand§. In Pakistan, fans and air conditioners are used for space cooling, and a variety of refrigerating appliances are used for food storage in the domestic sector, commercial cold chain, and pharmaceutical sector. Nearly all households own an electric fan, but only 11% of them own an air conditioner as they are still considered a luxury item by a majority of the population. About 57% of households own refrigerators, which are necessary for preserving food during the prolonged summer season. However, due to limited use of cold chain technology, 40-70% of the food is wasted at various stages of the supply chain.[4]

The current **demand for cooling and refrigerating appliances** has mostly been driven by:

- **Rising temperatures and heatwaves.** Most of Pakistan, especially the Punjab and Sindh provinces, experience long and hot summers with temperatures consistently exceeding 40°C.[5] In 2022, Pakistan experienced an unprecedented heatwave with recorded temperatures as high as 49°C in some parts of the country and extreme heat affecting about a third of the land area.**
- **Increasing income levels.** In 2022, Pakistan recorded a GDP growth rate of 5.97%[6] with GDP in real terms of around USD 383 billion placing the Pakistani economy at the 44th rank globally in terms of nominal GDP and 24th in terms of purchasing power

* This is the product of population and Cooling Degree Days per year (230M x 2,810 CDDs), as described by the US Department of Energy in The Future of Air Conditioning For Buildings (2016)

† In this report cooling appliances encompass both space cooling and refrigerating appliances.

‡ June through August

§ NCAP Methodology - Percentage of households that do not own any cooling appliances, Lack of access to electricity

** Carbon Brief, Climate change made India and Pakistan's 2022 early heatwave '30 times more likely', 2022 https://www.carbonbrief.org/climate-change-made-india-and-pakistans-2022-early-heatwave-30-times-more-likely%EF%BF%BC/

parity[7]. According to *The World in 2050*,[8] Pakistan could become the 20th largest economy by 2030, potentially rising to 16th position by 2050.[9]

- **Increasing population and urbanization**. With over 230 million inhabitants, Pakistan is the fifth most populated country in the world.[10] Growing at an estimated rate of 2% annually, Pakistan's population is projected to reach 245 million by 2025 and cross 350 million by 2050.[11] Currently, about 32.5% of the population live in urban areas[12]. However, the United Nations estimates that by 2050, nearly half the country's inhabitants will live in the cities.
- **An expanded grid**. The number of households with access to electricity increased rapidly in recent years reaching 74% in 2021.[13]

Almost 22%[14] of the population in Pakistan lives below the poverty line. The two main barriers hindering access to cooling in the country include access to a steady supply of electricity and affordability of cooling appliances and operation. With 26% of the population not connected to the grid,*[15] affordable solar solutions and off-grid appliances will play a key role in bridging the gap to meet this cooling demand.

In 2021, the total electric power generation in Pakistan was about 143 TWh.[16] According to analysis by CLASP and SAMA^Verte, cooling appliances consumed an estimated 46% of this total, rising to 84% of the domestic sector's total electricty consumption and 78% that of the commercial sector. As more people are able to purchase cooling appliances, dramatic increases in energy demand on an already overburdened grid and associated greenhouse gas emissions are expected outcomes.

RATIONALE FOR A PAKISTAN COOLING ACTION PLAN

Pakistan does not have a national strategy to prioritize and coordinate activities in the cooling sector yet, nor a mechanism to effectively identify cooling gaps. As Pakistan's population is at high risk of heat-related incidents due to inadequate cooling, it is imperative to develop a plan that:

1. manages current and future cooling demands,
2. reduces the gap in access to cooling, and
3. decreases emissions from cooling sectors.

Currently, the Government of Pakistan, with technical support from CLASP and SAMA^Verte (formerly known as HIMA^Verte), and financial support from Clean Cooling Collaborative (CCC), is developing the country's first integrated cooling strategy; the Pakistan Cooling Action Plan (PCAP). In line with the revised 2021 Nationally Determined Contributions (NDC) commitments and other national climate ambitions, the PCAP will establish a baseline for priority cooling sectors, identify paths for timely action, and

* There is a wide variation in electricity access rate in Pakistan quoted by various sources, ranging from 70% to 97%. However, based on census data and number of connections reported by distribution companies, it is estimated that 74% of the population has access to grid electricity.

outline concrete interventions to effectively manage the growing cooling demand while reducing associated emissions. The PCAP will be developed by the Ministry of Climate Change (MoCC), in collaboration with National Energy Efficiency and Conservation Authority (NEECA), other federal and provincial departments, and industry associations.

This data-driven cooling demand needs assessment was conducted to inform the PCAP, including the existing cooling landscape, where cooling is most needed and used, and areas of expected growth. The assessment focuses on the domestic and commercial refrigeration sectors, and the domestic air conditioning and electric comfort fans used for space cooling. This sector prioritization was agreed upon by government stakeholders as it focuses assessment resources on the cooling sectors with the highest energy consumption and emissions. The assessment also includes a baseline for cooling access, a brief overview of the wider cold chain and servicing sectors, informed through stakeholder consultations. This assessment only covers met cooling demand due to the added complexity and limited resources and scope of this project.

COOLING NEEDS ASSESSMENT - MAIN FINDINGS

POLICY LANDSCAPE. Pakistan's revised 2021 NDC submission sets an ambitious target to reduce 50% of the country's projected emissions by 2030, modified from 20% in the 2016 NDC submission. The document calls for the development of a Pakistan Cooling Action Plan (PCAP) and refrigeration and air conditioning standards and labels to help achieve overall emissions reduction targets. However, the NDCs do not include any reduction targets associated with the cooling sector.

NEECA's Strategic Plan 2020-2023 identifies the development of Minimum Energy Performance Standards (MEPS) and labels for cooling appliances including fans, air conditioners, and refrigerators with expected savings of up to 0.2 Mtoe by 2023. Currently, MEPS and labeling policies for the following seven cooling appliances are in different stages of approval and pending implementation:

- **Electric fans:** mandatory MEPS and 5-star labeling scheme for fans including ceiling, table, pedestal, wall, and exhaust fans expected to come into force in 2023.
- **Air conditioners:** mandatory MEPS and 5-star labeling scheme for domestic air conditioners officially approved but yet to be formally adopted.
- **Refrigerators:** mandatory MEPS and 5-star labeling scheme for domestic upright refrigerator-freezer finalized and approved but yet to be formally adopted.
- **Visi-coolers:** MEPS for visi-coolers are under review by Pakistan Standards & Quality Control Authority (PSQCA) and NEECA.
- **Horizontal beverage coolers, horizontal chest freezers and horizontal refrigerator-freezers.** MEPS for these cooling appliances which were submitted to PSQCA and NEECA in 2022, are currently under review for approval.

COOLING DEMAND ASSESSMENT. This cooling assessment analyzes and sets a baseline for the following cooling appliance sectors:

- **Domestic space cooling including air conditioners used for indoor cooling in homes and smaller buildings, and electric fans. For household and smaller commercial establishments, space cooling has traditionally been dominated by ceiling fans and evaporative coolers. Over the last decade, demand for air conditioners increased with a gradual shift to split-type air conditioning units.** Nevertheless, electric fans are still the most common source of cooling for households in Pakistan.
- **Domestic refrigeration** including upright and horizontal refrigerators and refrigerator-freezers used by households and sometimes in small retail establishments.
- **Commercial refrigeration** including visi-coolers, display cabinets, and freezers used in retail outlets, restaurants, and other commercial establishments. The importance of this sector is increasing as disposable incomes rise and consumers purchase more processed foods and drinks.
- **Off-grid cooling appliances** primarily focusing on Direct Current (DC) only fans used in off-grid and weak-grid areas. The 18-inch DC pedestal fan is the most popular appliance which is typically operated by directly connecting to a solar photovoltaic (PV) panel but is also used as part of a solar home system with batteries.

These cooling appliance sectors have been prioritized as they are integral to meeting the growing need for space cooling and refrigeration in Pakistan. They also have significant potential for emissions reduction in the short to medium term in comparison with other cooling appliances and equipment and increasing cooling access, as shown by this cooling needs assessment (CNA). Table 1 below provides estimated stock, sales, and the projected annual sales growth through 2030 for the selected appliances.

TABLE 1: SUMMARY OF STOCK, SALES, AND PROJECTED RATE OF SALES GROWTH FOR COOLING SUB-SECTORS

APPLIANCE SUB-SECTOR	APPLIANCE	2022 STOCK (MILLION UNITS)	2022 SALES (MILLION UNITS)	ANNUAL SALES GROWTH (%)
Space Cooling	Air Conditioners	11.3	1.2	7%
	Alternate Current (AC) and AC/DC Hybrid Fans	146.9	9.3	4%
	DC-only Fans*	1.5	0.2	-
Domestic Refrigeration	Upright Refrigerator-Freezers	16.6	1.6	5%
	Horizontal Refrigerator-Freezers	1.3	0.16	5%
	Horizontal Freezers	0.5	0.07	5%
Commercial Refrigeration	Visi-Coolers	1.4	0.13	5%
	Horizontal Beverage Coolers	0.2	0.05	5%
	Horizontal Food Freezers	0.02	0.005	5%
	Horizontal Ice Cream Freezers	0.09	0.02	5%

* Stock and sales data for DC-only fans is available only for the formal sector. The off-grid market is mostly served through a large informal sector, estimated to be around 3 to 4 times greater than the formal one, for which there is very little data available.

ASSESSMENT OF FUTURE COOLING NEEDS. Several scenarios were developed to project and assess future cooling needs (met demand*) and associated stock, energy consumption, and emissions (direct† and indirect‡) from priority cooling sectors in Pakistan. The modeling was done using a combination of CLASP's Mepsy: The Appliance & Equipment Climate Impact Calculator and SAMA^Verte's in-house modeling. Four policy scenarios were modeled across the selected cooling sectors for energy consumption and indirect emissions:

- **Business as Usual (BAU) scenario,** which represents expected market development with no policies and other interventions.
- **Minimum Energy Performance Standards (MEPS) scenario**, which represents market response to introduction of the policies that are pending adoption or being developed.
- **United for Efficiency (U4E) MEPS scenario**, which represents the market response to policies being introduced, which follows the U4E model regulation guidelines.§
- **Best Available Technology (BAT)** represents market impact of immediate adoption of the highest efficiency technology available in the world. Wherever the global highest efficiency figures were not available, BAT represents U4E's "High Ambition" scenario from their *Pakistan's Country Savings Assessment***.

Five policy scenarios in addition to BAU were modeled across the priority cooling sectors for direct emissions:

- **Business as Usual (BAU) scenario,** which represents expected market development with no policies and other interventions.
- **Reduced refrigerant charge scenario**, which represents market response to a potential policy to be developed for reducing the charge in cooling appliances.
- **Reduced annual leakage scenario**, which represents market response to a potential policy to be developed for reducing the annual leakage rate in cooling appliances.
- **Reduced service venting scenario**, which represents market response to a potential policy to be developed for reducing the emissions from service venting in cooling appliances.
- **Reduced end-of-life losses scenario**, which represents market response to a potential policy to be developed for reducing end-of-life emissions in cooling appliances.
- **Accelerated refrigerant transition scenario**, which represents market response to a potential policy to be developed for accelerating the refrigerant transition to a lower Global Warming Potential (GWP) refrigerant in cooling appliances.

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* The cooling demand that will be delivered or "met"

† Greenhouse gas emissions from leakage of refrigerants in the atmosphere

‡ Emissions associated with consumption of energy for running cooling appliances

§ U4E Model Regulation Guidelines: https://united4efficiency.org/resources/model-regulation-guidelines/

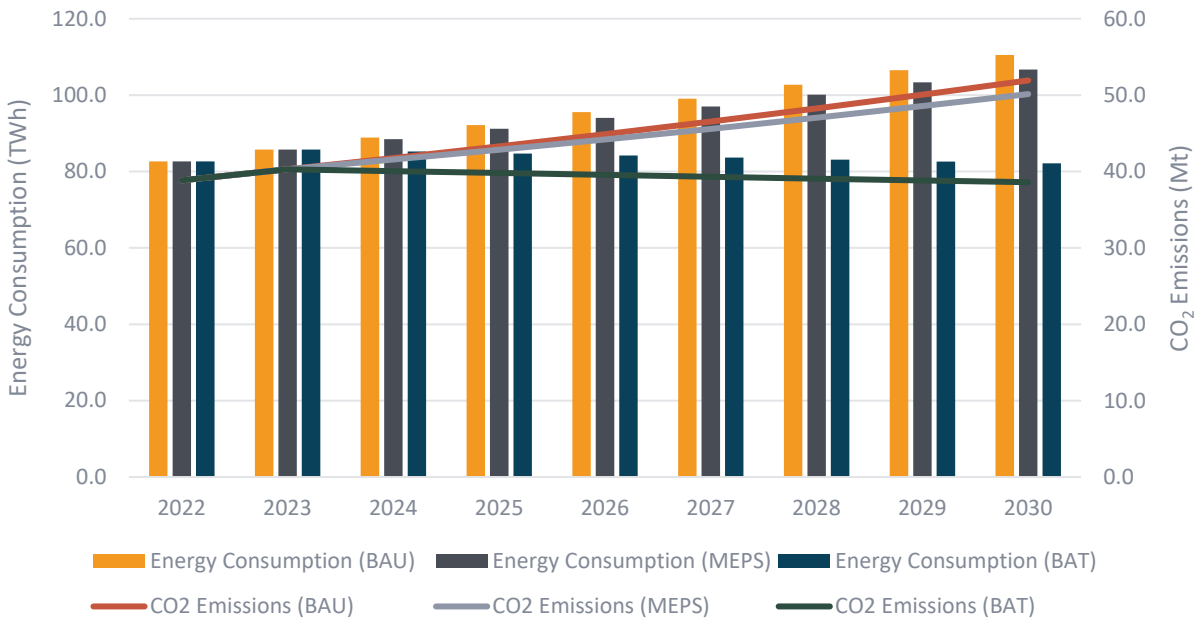
** U4E Country Savings Assessments: https://united4efficiency.org/countries/country-assessments/

According to 2022 BAU projections, indirect emissions are responsible for 86% of the total emissions, while direct emissions contribute around 14% amongst the priority cooling appliances. Fans dominate the cooling appliances in indirect emissions with 54% share, while air conditioners emit 93% of the direct emissions.

Energy consumption and associated CO_2 emissions under the BAU scenario are projected to increase substantially from 2023 to 2030 (Graph 1). **Without mandatory standards and labels interventions, Pakistan's BAU cumulative energy consumption and CO_2 emissions are projected to reach 695.4 TWh and 326.8 Mt, respectively, from 2024-2030.** This will add significant strain to Pakistan's power grids and further exacerbate climate change.

Relative to the BAU scenario, the **MEPS scenario is projected to provide cumulative energy consumption and CO_2 emissions reductions of 14.5 TWh and 6.8 Mt, respectively**. The **BAT scenario** has the potential to provide about **7 times the reductions of the MEPS** scenario, with **cumulative reductions of 109.7 TWh and 51.6 Mt**, respectively.

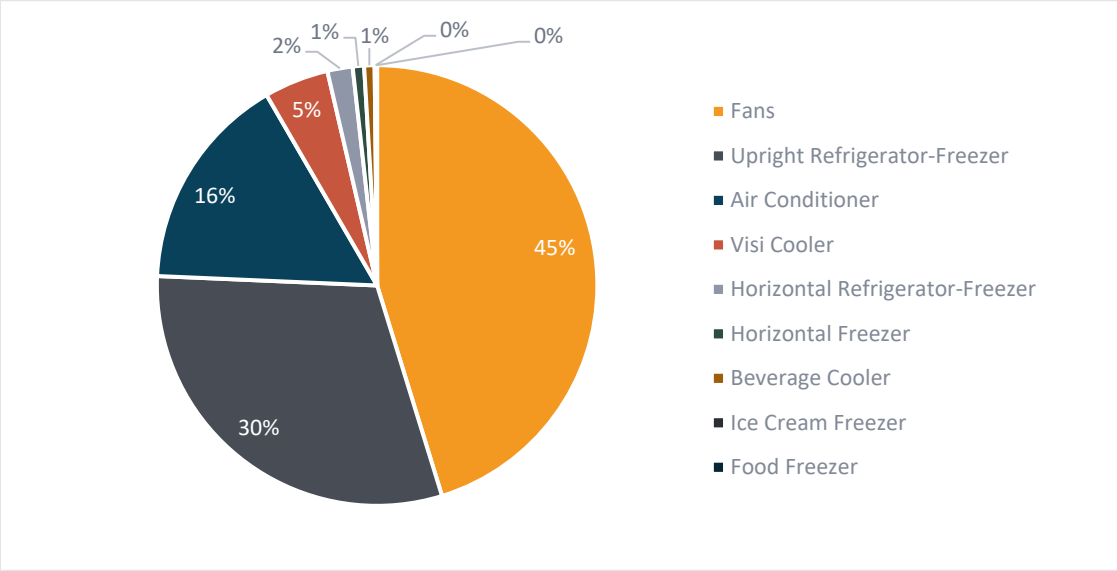
GRAPH 1: ANNUAL AGGREGATE ENERGY CONSUMPTION AND ASSOCIATED CO2 EMISSIONS FOR ALL MODELED PRODUCTS, BY POLICY SCENARIO



Fans, domestic air conditioners, and domestic and commercial refrigeration all offer significant potential to reduce energy consumption and associated CO_2 emissions by 2030 (Graph 2). As fans consume about 27% of national electricity*, they have the most substantial potential for impact amongst the cooling sectors in reducing energy consumption and indirect emissions and should be the focus for interventions.

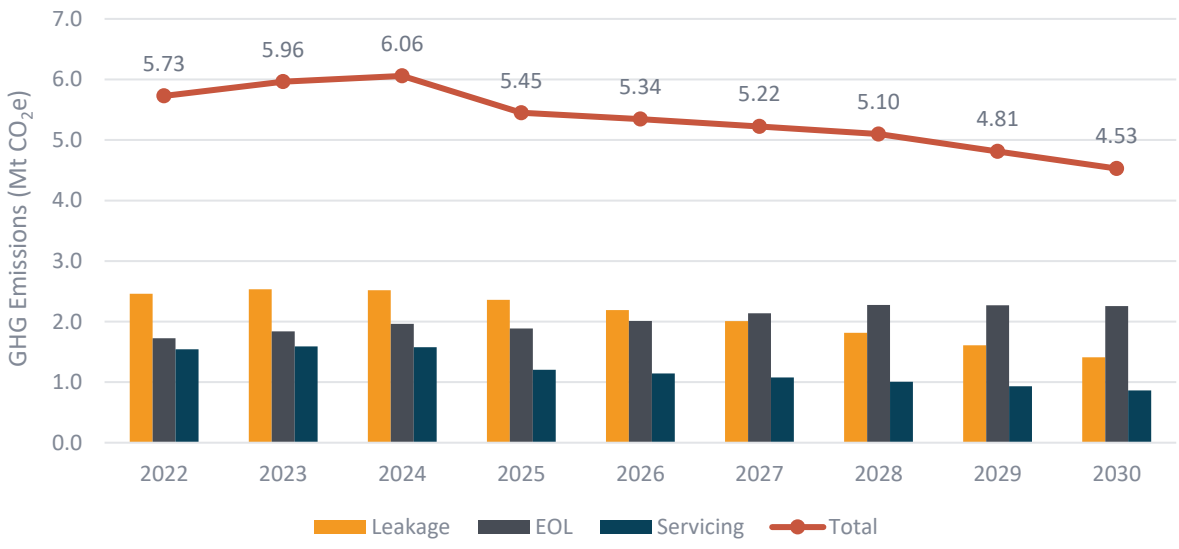
* CLASP/SAMA^Verte calculation

GRAPH 2: 2030 BAU ENERGY CONSUMPTION AND ASSOCIATED CO2 EMISSIONS, BY PRODUCT



Without policy intervention, Pakistan's cumulative direct emissions are projected to total 38.4 Mt CO_2e from 2025-2030. This will further contribute to climate change and its negative impacts. All the policy scenarios (combined) are projected to lead to a reduction in direct emissions of around 7.9 Mt CO_2e from 2025-2030, as compared to BAU. Amongst the five modelled policies, the **accelerated refrigerant transition** in cooling appliances is projected to provide the most significant reduction in cumulative emissions and should be prioritized to curb direct emissions. Air conditioners emit over 90% of the direct emissions amongst the priority cooling appliance sectors. A regulation which mandates a lower-GWP value for refrigerants in manufacturing of air conditioners and an accelerated transition alone can lead to a cumulative reduction of 4.4 Mt CO_2e from 2025-2030.

GRAPH 3: PROJECTED EMISSIONS FROM COMBINED POLICIES IN PRIORITY COOLING APPLIANCES



Given that cooling accounts for a large part of electricity use in residential and commercial sectors, and the projected substantial growth in cooling appliance sales (on average 5%), increasing ambition of current policies and implementing market transformation initiatives are essential in curbing energy consumption and emissions, as well as reduce the need for building additional generation capacity to meet future energy demand.

The off-grid market is largely served through DC-only fans. Almost all the households located in high heat stress regions of the country have access to at least one basic cooling appliance such as a DC fan, as it is impossible to survive in these areas without some form of cooling. However, access to cooling may be limited due to the poor quality (efficiency, durability and operating hours) of DC fans being sold through the informal sector. In addition, the number of people that can be cooled by a single DC fan may be exceeded by household composition in poorer communities, contributing to the unmet demand and lack of cooling access in off-grid and weak grid communities.

THE WAY FORWARD. This CNA document will serve as a basis for identifying priority interventions to sustainably address cooling growth in Pakistan and recommendations for the PCAP. The initial recommendations for the PCAP encompass the following categories:

- **Policy and regulatory interventions, which include developing or revising MEPS and l**abels for cooling appliances to accelerate market transition to more efficient appliances. CNA's projections and analysis will help inform priority interventions for PCAP. Ensuring the policy implementation through robust processes and infrastructure such as product registration system and testing facilities will be essential. Other potential policy interventions may include a review and revision of building codes and vehicle emissions standards.
- **Technology interventions**, that may include enhancing the efficiency of existing cooling technologies through industry support such as "know how," technology transfer programs, and improved supply chains. Other solutions may include adoption of alternative refrigerants with lower-GWP and increased uptake of sustainable cooling solutions for off-grid and weak-grid areas.
- **Interventions for market enablement**, which may include financing instruments to promote sustainable cooling, innovative business models to deliver and scale up sustainable cooling, public procurement of cooling appliances, strengthening institutional and professional capacities (including training technicians), and enhancing consumer and stakeholder awareness.
- **Affordable solutions for off-grid and weak-grid communities,** facilitating provision of high energy efficiency DC pedestal fans, focusing on geographies with high average annual temperatures and large off-grid population, and introducing financial and policy instruments to promote and increase uptake of solar solutions and high-quality energy efficient off-grid appliances.

The PCAP Working Group will lead the PCAP development over the next 12 months driven by a heavily consultative process. The next steps for developing the PCAP include:

- **Presenting the Cooling Needs Assessment insights and results to the PCAP Working Group and stakeholders** including industry through consultations to gather their feedback and input into PCAP.
- **PCAP development**, which will include consultations and identification of interventions. The Working Group will prioritize the areas of focus for the PCAP, assess the robustness of the recommendations against the Pakistan's national targets and their alignment with existing policies and programs, and seek government buy-in. The CLASP/SAMA^Verte team will provide support thorough prioritization of the recommendations and development of the plan.

1 Introduction

Pakistan has the 5th highest total cooling demand of any country, estimated at 646 billion Person Cooling Degree Days per Annum,* but access to cooling and penetration of cooling appliances† is low. *Chilling Prospects: Tracking Sustainable Cooling for All (SEforAll) 2022* report lists Pakistan among the 54 high impact countries and the 9 critical countries which have the greatest number of people at high risk for inadequate cooling.[17]

Pakistan lies in a temperate zone and its climate is as varied as the country's topography—generally dry and hot near the coast and along the lowland plains of the Indus River, and progressively cooler in the northern uplands and Himalayas. While mean annual temperature of the country is around 21°C, Pakistan regularly experiences some of the highest temperatures in the world, with an average of around 29°C during the summer months.[18,‡]

Between 2014 to 2018, some regions in the Punjab and Sindh provinces (where over 70% of the country's population resides) experienced temperatures exceeding 40°C, putting the population at extreme risk given insufficient access to cooling in both provinces[19] (Figure 1). The heat wave in 2022, resulting in record temperatures as high as 49°C[20] in some parts of the country, emphasized the need to accelerate adaptation and mitigation actions.

There are also some regions classified under the category of "Extreme Danger" according to Pakistan Journal of Meteorology§, which represent areas with heat index** exceeding 54 Degrees Centigrade or more. Seventeen districts of the Sindh province with population of 25 million, partial areas of 2 districts of the Punjab province and a small sparsely populated part of the Baluchistan province falls in this region. This whole region of high heat index is also characterized by weak or no grid connectivity and high incidence of poverty and is therefore most critical for access to cooling.

The Intergovernmental Panel on Climate Change (IPCC) projects a global average temperature increase of 3.7°C by 2081–2100, while a 5.3°C increase is projected for Pakistan under the highest emissions pathway scenario.[21] The IPCC also predicts that under the higher emissions pathway scenario, the number of days per year exceeding 35ºC in Pakistan will increase from 120 to 150 by 2050. [22] These temperature changes will place significant strain on urban environments, resources, and energy systems, especially as the need for cooling is expected to increase.[23]

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* This is the product of population and Cooling Degree Days (CDDs) per year (230M x 2,810 CDDs). The Person CDDs methodology has been described by the US Department of Energy in The Future of Air Conditioning For Buildings (2016), which uses the 2016 population figure of 182M. This has been updated using population of 230M in 2022. The 646-billion-person CDDs still ranks Pakistan in 5th place behind India, China, Indonesia and Nigeria.

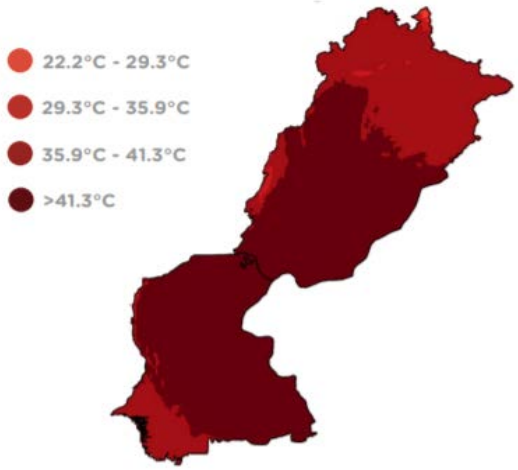
† In this report cooling appliances encompass both space cooling and refrigerating appliances.

‡ June through August

§ Pakistan Journal of Meteorology, 2010

** The term "*heat index*" refers to the perceived temperature for the human body taking into account the combined effect of high ambient temperature and ambient humidity, calculated in degrees centigrade

FIGURE 1: AVERAGE MAXIMUM TEMPERATURES FROM 2014 TO 2018



Electric fans are the most common affordable cooling appliance in Pakistan, with nearly all households owning at least one,* whereas the penetration of higher-end cooling appliances (refrigerators and air conditioners) is lower. The Pakistan Demographic and Health survey[24] suggests that 77% of urban households own a refrigerator and 22% an air conditioner, compared to 42% of rural households that own a refrigerator and 4% an air conditioner (57% refrigerator and 11% air conditioner ownership for all households).† The higher number of refrigerators is likely due to their role in preserving food during the prolonged Pakistan summer season, while air conditioners are still largely considered a luxury item.

SEforAll identifies the largest segment in Pakistan at risk due to insufficient cooling is the lower-middle income population. This group has over 174 million people‡ making it the 4th biggest lower-middle income population at risk in the world.[25] Lower-middle includes the increasingly affluent lower-middle class on the brink of purchasing the most affordable air conditioner or refrigerator on the market.[26] As more and more people are able to purchase cooling appliances, those that have a lower upfront cost and are likely less efficient will grow in ownership, potentially causing a dramatic increase in energy demand and associated greenhouse gas (GHG) emissions.

Over 26 million urban poor are also at risk due to lack of access to cooling in Pakistan. Urban poor is defined by SE4All as those who may have access to electricity, but the quality of their housing is likely very poor, and their income may not be sufficient to purchase or run a fan.[27] They may own or have access to a refrigerator, but an intermittent electricity supply may cause frequent food spoilage and a high risk of poor nutrition or food poisoning.[28] For example, in Karachi, the largest city in Pakistan,

* Estimated stock of 147 million fans in the country in 2022.

† The Pakistan Demographic and Health Survey 2017-2018. There are other numbers given in the 2018-19 Social and Living Measurement Survey which puts air conditioner ownership figure at 8% of households or 2.4 million and refrigerators at 55%.

‡ The lower-middle income population is the estimated segment of the population outside of rural and urban poverty living on less than USD 10.01 per day.

approximately 62% of its population (nearly 10 million) lives in informal settlements with limited access to clean water and uninterrupted electricity.[29] These poor urban households also have limited access to indoor cooling and typically live in houses with poor ventilation and construction that is usually incompatible with certain cooling technologies and therefore make residents more vulnerable to extreme heat. Additionally, according to Pakistan's regulatory authority for low-cost urban housing, there is an estimated shortage of around 10 million housing units in Pakistan.[30]

Cooling technologies are not only important for human health and well-being but also for economic development, as refrigeration is necessary for industrial production and cold chain food and medicine storage. According to the SEforAll report, among the 54 high-risk countries lacking access to cooling, those in Asia have the highest food loss, at 48%. The average food loss in Pakistan is 50-60 kg per capita, the highest among all high-risk countries, which average 35 kg per person per year.[31] Pakistan's Cold Chain Development Company also estimates that 40-70% of the food is wasted at various stages of the supply chain between farm and consumer.

CLIMATE MITIGATION. In 2015, Pakistan emitted 2.4 tonnes of CO_2e per capita, ranking 19th globally and 3rd regionally for emissions. If the country continues with business as usual, emissions are projected to increase to 2.9 and 5.4 tonnes of CO_2e per capita by 2025 and 2050 respectively.[32]

During 2021, total electric power generation in Pakistan was approximately 143 TWh, with the priority cooling sectors consuming 46 of the total electricity.[33]

The lack of a cooling sector baseline means there is no specific identification of overall energy consumption and emissions related to cooling products. Further, Pakistan's GHG inventory does not include data on refrigerants (or F-gases) and, consequently, there is no existing national cooling sector baseline CO_2 equivalent for refrigerant emissions.

National cooling strategy. Pakistan does not yet have a national strategy to prioritize and coordinate activities in cooling sectors, nor a mechanism to effectively identify cooling gaps. Considering that Pakistan is among the countries whose population is most at risk from a lack of access to cooling, it is imperative for them to develop a policy that has a plan for:

- Managing current and future cooling demand,
- Reducing the gap in access to cooling, and
- Decreasing the emissions from cooling sectors.

Currently, the Government of Pakistan (with support from CLASP and SAMA^Verte*) is developing the country's first integrated national level cooling strategy, i.e., the Pakistan Cooling Action Plan (PCAP). National Cooling Action Plans support countries in achieving

* Funded by Clean Cooling Collaborative

national priorities and international commitments (e.g., the Paris Climate Agreement, the Sustainable Development Goals, and the Kigali Amendment to the Montreal Protocol).

In line with Pakistan's 2021 National Determined Contributions (NDC) commitments and other national targets, the PCAP will establish a baseline for priority cooling sectors, identify priorities, and outline concrete interventions to effectively meet growing cooling demand while reducing emissions from the cooling sector. The PCAP is being developed by the Ministry of Climate Change (MoCC) in collaboration with National Energy Efficiency and Conservation Authority (NEECA) and federal and provincial departments.

Pakistan is committed to developing the PCAP as evidenced by its inclusion in Pakistan's revised NDCs 2021 submission:
'Developing a Pakistan Cooling Action Plan (PCAP) which will identify the key cooling needs and prioritize actions for addressing current and future cooling demands with the minimum possible impact on the environment'.

NEEDS ASSESSMENT. A data-driven needs assessment of cooling demand is a prerequisite for developing an effective National Cooling Action Plan. A comprehensive assessment includes mapping the existing cooling landscape in a country to understand where cooling is most needed and used, and to predict areas of expected growth.

The cooling sector in Pakistan can be divided in the following sectors:

- *Domestic space cooling*: air conditioners and electric fans used for indoor cooling in homes and smaller buildings.
- *Domestic refrigeration*: refrigerators, refrigerator-freezers and freezers used in households.
- *Commercial refrigeration*: various types of refrigerating appliances such as beverage coolers, display cabinets and freezers used in retail outlets, restaurants and other commercial establishments.
- *Commercial air conditioning*: air conditioning used for cooling large building complexes.
- *Mobile air conditioning*: air conditioners used in cars and other transport vehicles.
- *Cold chain and transport refrigeration*: large refrigeration units or cold storage used for food, beverage, and pharmaceuticals; refrigerated (reefer) trucks and other transport vehicles that transport perishable goods in cold temperatures.

In preparation for the development of the PCAP, this cooling needs assessment focuses on the domestic and commercial refrigeration sectors, and the domestic air conditioning and electric fans space cooling sectors. This sector prioritization was agreed upon by government stakeholders as it focuses assessment resources on the cooling sectors with the highest energy consumption and emissions.

A preliminary baseline for DC fans and population without access to cooling is also included in the assessment. The document also includes a brief overview of the wider

cold chain sector, refrigerants and the servicing sectors informed by stakeholder consultations. However, sector (including mobile and commercial air conditioning) assessment is not performed as there are little or no data available, and undertaking the necessary substantive data collection is not an effective use of resources.

2 . Country Context Mapping

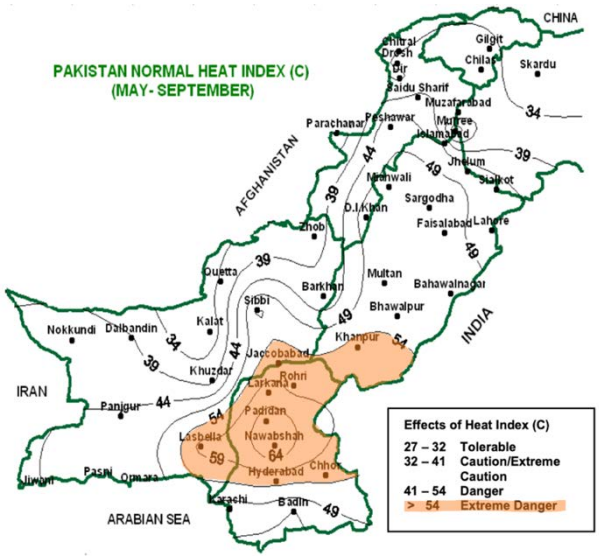
2.1 FACTORS DRIVING GROWTH IN COOLING DEMAND

Met cooling demand i.e., the cooling demand that is delivered, is driven by environmental, demographic, and socio-economic factors. In recent years the demand for cooling and refrigerating appliances has grown due to rising temperatures and heat waves, increased economic activity, and a growing population:*

- **Climate and environmental factors.** Most of Pakistan, especially in the Punjab and Sindh provinces, experiences long and hot summers with temperatures consistently exceeding 40°C.[34] In 2022, Pakistan experienced an unprecedented heatwave with recorded temperatures as high as 49°C and extreme heat effects on about a third of the land area.[35] As temperatures in the country rise, cooling technologies will become increasingly critical for health and productivity.

  The map in Figure 2 shows the regions of Pakistan with the highest heat index. The term "heat index" refers to the perceived temperature for the human body taking into account the combined effect of high ambient temperature and ambient humidity, calculated in degrees centigrade. The regions classified under the category of "Extreme Danger" represent the region with heat index exceeding 54°C or more. Seventeen districts of the Sindh province with a population of 25 million, partial areas of 2 districts of the Punjab province and a small sparsely populated part of the Baluchistan province falls in this region. This region of high heat index is also characterized by weak or no grid connectivity and high incidence of poverty and is therefore most critical for access to cooling.

  FIGURE 2: HIGH HEAT INDEX AREAS IN PAKISTAN

  In Pakistan, fans and air conditioners are used primarily for space cooling in grid-connected areas and DC-only fans in off-grid areas, while refrigerating appliances are essential for food storage in the domestic sector as well as in cold chain for commercial food and beverage and in the pharmaceutical sector.

- **Through additional grid connections, more people can access a wider variety of appliances.** Recently, there has been a rapid increase in the number of households with access to electricity, from 70.8 %[36] of the population in 2017 to 74% in 2021, in comparison to only an additional 0.1% of households gaining access annually during

* UNDP Greenhouse gas emissions from refrigeration and air conditioning sector – case of Pakistan 2021

2000–2016.[37] More households gaining access to electricity also means an increase in sales and use of cooling appliances.

- **Increasing income levels.** This allows more people to 1) own more space cooling appliances such as air conditioners or fans, 2) buy their first refrigerator or replace the one they own with a bigger one, or buy a second refrigerator or freezer, and 3) purchase more convenience items (soft drinks, milk, processed food), driving commercial (and supply chain) refrigeration needs. In 2022, Pakistan recorded a GDP growth rate of 5.97%[6], with GDP in real terms of approximately USD 383 billion ranking the Pakistan economy as 44th in size globally in terms of nominal GDP and 24th in terms of purchasing power parity[7]. According to The World in 2050 report,[8] Pakistan could become the 20th largest economy by 2030 and reach as high as 16th by 2050.
- **Population growth and rural-to-urban migration.** At over 230 million inhabitants, Pakistan is the fifth most populated country in the world[10]. Growing at an estimated 2% annually, Pakistan's population is projected to reach 245 million by 2025 and over 350 million by 2050.[11] Currently, about 32.5% of the population live in urban areas,[38] however, the United Nations estimates that by 2050, nearly half the country's inhabitants will live in cities. Urban households own more cooling appliances relative to rural households; 77% of urban households having access to refrigerators and nearly 22% owning air conditioners, compared to only 42% of rural households own refrigerators and about 4% own air conditioners.[39,40] Accordingly, growing urbanization will drive the demand for cooling appliances.

However, the met demand for cooling appliances does not include the gap in cooling access. The cooling demand, while growing, does not take into account households without access to space cooling or refrigeration, or unmet cooling demand.* Currently, an estimated 89% of the households do not have access to air conditioning, while 43% do not have access to a refrigerator. Almost 22%[41] of the population lives below the poverty line. The two main factors hindering the access to cooling in Pakistan are access to /a steady supply of electricity and affordability of cooling appliances and their operation:

- **Non-grid connection is still an issue for 26% of the population, which limits access to cooling.** Even though the country is making steady progress in increasing overall electricity generation capacity, due to persistent issues in transmission and distribution, underserved communities located away from grid infrastructure are unlikely to receive reliable electricity access in the near future. Currently, there is prolonged load shedding because of rising petrol prices and a shortage of natural gas, as thermal (fossil fuel) is responsible for almost 61%[42] of the current electricity supply impacting households which have a grid connection. Hence, solar solutions and off-grid appliances such as DC fans will play a key role in bridging the cooling demand gap in both the areas with and without electricity access.†

* NCAP Methodology - Unmet cooling demand is the percentage of households that lack access to cooling, lack access to electricity or cooling appliances. The cooling demand growth to bridge the lack of access to cooling is referred to as the 'unmet' cooling demand.

† The Alternative and Renewable Energy Policy (2019) targets to achieve 20% share of renewables by 2025 and 30% by 2030.

Overall, income levels have been rising, but many cooling products are still largely unaffordable to purchase and/or operate. For example, affordability of purchasing and running an air conditioner is a major reason for low AC penetration in the country (less than 11 % of grid-connected households). In contrast, almost all households own at least one fan, which is a go-to space cooling appliance due to its low upfront and operational costs but is not sufficient for enduring the summer heat. The increasing prices of cooling appliances because of the Pakistan rupee's devaluation against the dollar in recent years has also negatively impacted market growth. This has caused consumers to shift toward buying smaller-sized ACs and refrigerators[43] and away from purchasing larger units which may be needed to meet the household needs.

Electricity tariffs in Pakistan have also grown at an alarming rate over the past few years, increasing by 300%* over the 2017–2022 period. Electricity bills are now a major burden, causing people to limit their use of cooling appliances. On average, 31% - 41% of a household's annual energy consumption is from air conditioners, 11 - 14% from refrigerators, and 10% - 22% from fans[44] (in houses without air conditioning, fans consumed most of annual electricity at 22%, while refrigerators consumed 14%†). Lower income households have been significantly affected, prompting them to shift to alternative solutions such as solar home systems and use appliances that consume less electricity. Overall, domestic consumption is the highest in Pakistan, consuming 45% of the country's electricity during 2021-22[16].

Cooling demand growth also depends on industry capacity and energy infrastructure. When projecting unmet needs for cooling in Pakistan and associated growth of cooling product markets, the current infrastructure should be taken into consideration, i.e., whether it can support further pressure of additional cooling demand. While it is critical to assess the unmet cooling demand, this assessment only covers met cooling demand due to the added complexity and limited resources and scope of this project.

2.2 EXISTING DATA ON GHG EMISSIONS FROM THE COOLING SECTOR

Prior to the inclusion of the Pakistan Cooling Action Plan in their 2021 NDC submission, the Government of Pakistan did not consider the climate impact from cooling a national priority. Consequently, there is relatively scarce literature, studies, and assessments for quantifying GHG emissions from the cooling sector in Pakistan. The two main studies on this subject are a 2021 UNDP study *Greenhouse Gas Emissions from Refrigeration and Air Conditioning Sector – Case of Pakistan* and a 2016 Green Cooling Initiative data for GHG emissions from Pakistan's cooling sector.

The United Nations Development Programme (UNDP) 2020 study was a first data-driven attempt to comprehensively review cooling applications in the country and estimate associated GHG emissions. This study categorizes cooling sectors as follows:

* Estimated based on the tariff rates.

† The peak energy consumption was during the month of June.

1. **Domestic refrigeration**;
2. **Commercial refrigeration** including equipment ranging from automatic vending machines, to centralized refrigeration systems in supermarkets, and refrigerated display cases;
3. **Industrial processes** including chillers, cold storage, and heat pumps used in the food, petrochemical and other industries;
4. **Refrigerated transport**, including equipment and systems used in refrigerated trucks, containers, and wagons;
5. **Stationary air conditioning**, including compact systems, heat pumps and chillers for residential and commercial applications; and
6. **Vehicle air conditioning systems**, used in passenger cars, truck cabins, buses, and trains.

Of these six categories, the UNDP study focused on four: stationary air conditioning (domestic and commercial), vehicle air conditioning, domestic refrigeration, and commercial refrigeration. Table 2 summarizes the hydrofluorocarbon (HFC) or direct emissions, indirect emissions, and total emissions for these sectors.

TABLE 2: COOLING SUB-SECTORS AND TOTAL EMISSIONS (DIRECT AND INDIRECT) IN 2020 (UNDP STUDY)*

COOLING SUB-SECTOR	EMISSIONS IN 2020 (Mt CO_2e)		
	DIRECT	INDIRECT	TOTAL
Domestic air conditioning	0.485	0.735	1.22
Commercial air conditioning	0.003	0.357	0.36
Domestic refrigeration	0.017	1.580	1.60
Commercial refrigeration	0.358	2.320	2.68
Total	**0.863**	**4.992**	**5.86**

Note: The indirect emissions for 2020 were estimated based on average future growth rate provided in UNDP report.

The UNDP data suggests both direct and indirect emissions from air conditioning are dominated by the use of domestic style split air conditioners in residential and commercial applications, with very little penetration of centralized systems. For refrigeration, most emissions are associated with standard refrigerators and freezers, typically used in households and standalone coolers/freezers in retail outlets.

In the domestic sector, indirect emissions from refrigeration (1.58 Mt CO_2e) are more than double the emissions from air conditioning (0.735 Mt). This indicates higher market penetration for refrigerators as compared to air conditioners. However, direct emissions from refrigeration (0.017 Mt CO_2e) are much lower than air conditioning (0.485 Mt CO_2e).

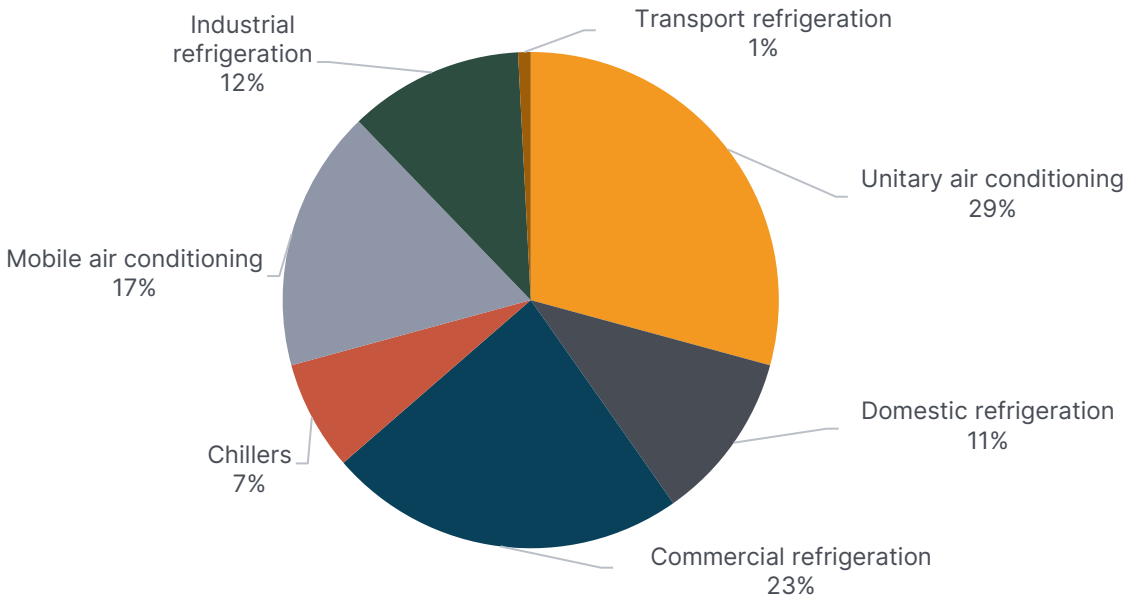
* The table does not include vehicle air conditioning emissions that have been presented in the UNDP study but are significantly overestimated as the methodology used calculates emissions based on total fuel used in cars, buses, etc. (excluding motorcycles and 3 wheelers) and not specifically from energy required for air conditioning in vehicles.

The UNDP study does not explain higher direct emissions from domestic air conditioning despite having lower sales and stock figures. Based on stakeholder consultations conducted by SAMA^Verte and feedback on market practices, air conditioners typically undergo more frequent servicing, which includes recharge of refrigerants. Most service providers in Pakistan do not have the proper servicing equipment, resulting in high refrigerant leakage/venting (air conditioners also have a higher refrigerant charge as compared to refrigerators), which can explain the higher direct emissions from this sector.

In the commercial sector, there is a greater disparity between emissions from refrigeration (2.68 Mt CO_2e) and air conditioning (0.36 Mt CO_2e). The results can be interpreted to mean that the commercial air conditioning market is relatively small and can therefore be considered a low-priority sector.

The Green Cooling Initiative (GCI)* 2016 study was the first and only source of GHG emissions from Pakistan's cooling sector prior to UNDP 2021 study. The GCI developed cooling sector emissions database for almost all countries, based on existing knowledge and estimates. Graph 4 shows Pakistan's total GHG emissions, including both direct and indirect, from each of the seven cooling sectors defined in the study. Table 3 provides emissions in megatons of carbon dioxide equivalent (Mt CO_2e) from each sector for the year 2016. Commercial and domestic refrigeration along with unitary air conditioning† collectively constitute the highest share of emissions, accounting for about 63% from all cooling sectors.

GRAPH 4: SHARE OF EMISSIONS (DIRECT AND INDIRECT) FROM THE COOLING SECTORS IN PAKISTAN IN 2016 (GCI)



Source: Green Cooling Initiative

* GCI is a union of various global projects and partners, funded by the German government and coordinated by GIZ.

† Unitary air conditioning includes ductless split, ducted split and rooftop ACs as well as variable refrigerant flow (VRF) systems and self-contained units, which are movable ACs and window/through-the-wall units.

TABLE 3: DIRECT AND INDIRECT EMISSIONS FROM COOLING SUB-SECTORS IN PAKISTAN IN 2016 (GCI)

COOLING SUB-SECTOR	EMISSIONS IN 2016 ($MTCO_2E$)		
	DIRECT	INDIRECT	TOTAL
Unitary Air conditioning	3.74	4.48	8.22
Domestic refrigeration	0.201	2.90	3.10
Commercial refrigeration	3.06	3.51	6.57
Chillers	0.98	1.03	2.01
Mobile air conditioning	2.02	2.77	4.79
Industrial refrigeration	2.16	1.04	3.20
Transport refrigeration	0.0964	0.130	0.226
TOTAL	**12.26**	**15.86**	**28.12**

Source: Green Cooling Initiative

Data comparison. There is significant variance in the UNDP and GCI emission estimates and uncertainties in the data collection and analysis methodologies used. Clearly, this raises concerns related to the accuracy of existing data and the baselines they create. The UNDP study provides more recent figures and references data sources and states assumptions for some of their estimates, and therefore can be considered more reliable among the two data sources. However, some inconsistencies such as unrealistic vehicle cooling emission figures underline the need for additional study and detailed data-driven assessments of the cooling sector in Pakistan.

Section 4 of this report covers future emissions projections by CLASP and SAMA^Verte for selected cooling appliances.

The variance between the emissions estimates by CLASP/SAMA^Verte and UNDP and GCI projections can be attributed to the difference in specific products represented by the cooling sub-sectors. For example, for commercial refrigeration, both UNDP and GCI represent centralized systems in their scope of products whereas the CLASP and SAMA^Verte model only represents the four stand-alone products described in Section 3.3. For air conditioning, both UNDP and GCI represent ducted and commercial split systems whereas the CLASP and SAMA^Verte model only represents residential non-ducted units. Domestic refrigeration cannot be evaluated because neither UNDP nor GCI list the specific products represented within this sector. Secondly, stock is a difficult variable to accurately estimate and has a substantial impact on projections, thus is a probable cause for discrepancies between the figures. However, accepting the potential shortcomings of the two data sets, based on the information presented, the priority sectors are domestic cooling and domestic and commercial refrigeration, which substantiates our selection of the same sectors (fans have not been covered in either of the earlier studies).

2.3 COOLING REGULATORY FRAMEWORK REVIEW

INTERNATIONAL COMMITMENTS. Pakistan has acceded to several international treaties and commitments which target ozone-depleting substances (including the Montreal Protocol) and call for the phase-out of refrigerants but has had limited impact on improving efficiencies and reducing indirect emissions from the cooling sector. Pakistan is in the process of ratifying the Kigali Amendment to the Montreal Protocol, which is the international treaty addressing climate impact from refrigerants.

Pakistan is also a signatory to the 2015 Paris Agreement and submitted their first NDCs in 2016. The NDC 2016 document covered the main GHG-emitting sources but did not recognize the emission reduction potential from the cooling sector. In October 2021, the Government of Pakistan submitted revised NDCs to the UNFCCC. This revised submission sets an ambitious goal to reduce 50% of Pakistan's projected emissions by 2030, up from 20% in 2016 NDC submission. Out of the 50% reduction, the Pakistani government commits to achieving 15% by its own means, and the remaining 35% is contingent on foreign aid and grants. The strategy to achieve this target is to shift to 60% renewable energy and 30% electric vehicles by 2030 and completely ban imported coal. In addition, about 500 Mt CO_2e emissions are planned to be offset by afforestation.

The 2021 revised NDC included a reference to the "*development of a Pakistan Cooling Action Plan (PCAP) to prioritize actions for addressing current and future cooling demands with the minimum possible impact on the environment*", and refrigeration and air conditioning standards and labels developed by NEECA to help achieve overall emission reduction targets. This was a significant achievement made possible because of the efforts of the project team and implementation partners. However, the cooling sector is not addressed adequately, as the GHG emissions do not include quantification of emission reduction from the cooling sector, nor any reduction targets associated with the cooling sector.

Table 4 lists the international treaties signed by Pakistan relevant to environmental and climate impacts from the cooling sector.

TABLE 4: STATUS OF RATIFICATION OF COOLING RELATED GLOBAL TREATIES BY PAKISTAN

STATUS OF RATIFICATION BY PAKISTAN	
Vienna Convention	Accession (18 December 1992)
Montreal Protocol (MP)	Accession (18 December 1992)
London Amendment to MP	Accession (18 December 1992)
Copenhagen Amendment to MP	Ratification (17 February 1995)
Montreal Amendment to MP	Ratification (2 September 2005)
Beijing Amendment to MP	Ratification (2 September 2005)

UNFCCC	Ratification (1 June 1994)
Kyoto Protocol	Ratification (10 January 2005)
Paris Agreement	Ratification (10 November 2016)
Kigali Amendment	In process

Source: National Ozone Unit and Ministry of Climate Change

NATIONAL POLICIES. The focus on cooling is very limited in Pakistan's existing national policies and plans, indicating that it has previously not been a priority sector for the government. The only national-level policy that addresses efficiency improvement and emissions reduction in the cooling sector is NEECA's Strategic Plan 2020–2023. The Plan targets 3 Mtoe energy savings from primary energy supply by 2023 (leading to 6.4 Mt CO_2e emissions reductions) by focusing on interventions across various sectors including industry, buildings, transport, energy, and agriculture.

The NEECA Strategic Plan 2020-2023 breaks down the sectoral objectives into activities, outputs, and key performance indicators (KPIs). With reference to cooling, the Plan aims to achieve energy use reduction through development/implementation of:

- Minimum Energy Performance Standards (MEPS) and labels for cooling products including fans, air conditioners, and refrigerators. These developments are expected during the third phase of Plan implementation with anticipated energy savings up to 0.2 Mtoe **by 2023 (current status of MEPS and labels is detailed below)**.
- Building codes which cover the energy efficiency standards for building heating, ventilation, and air-conditioning (HVAC) equipment; development of building energy management systems; and a mandatory appliance labeling regime in the buildings. The savings target is up to 0.5 Mtoe by 2023.

While NEECA's strategic plan indicates specific strategies such as developing MEPS and labeling scheme for cooling appliances, it has not identified sector-level strategies for 'cooling' or emphasized promoting efficiency of cooling appliances or access to cooling.

MINIMUM ENERGY PERFORMANCE STANDARDS AND LABELING SCHEMES FOR COOLING PRODUCTS. The first voluntary MEPS and labelling for ceiling fans was introduced by NEECA in 2016. This was revised in 2017 through a collaboration with CLASP, including the development of a compliance and enforcement strategy. Since then, 24 large- and medium-sized fan manufacturers have registered 43 fan models under the voluntary scheme, and over 500,000 energy-labeled fans have been sold. If mandatory labelling regulations are enforced, about 388 GWh per year of electricity use can be reduced which translates to 200,000 tonnes of CO_2 emissions avoided and cost savings of USD 25 million per year.*

The successful introduction of the fan voluntary labeling program provided evidence for possible implementation of a standards and labeling scheme in Pakistan. Currently,

* Based on estimates from NEECA Energy Efficiency & Conservation National Action Plan 2023 - 2030

seven* MEPS and labeling policies for cooling products are with NEECA and pending implementation while several others are in the process of review and approval as follows (summary in Table 5):

- **Electric fans.** Mandatory MEPS and 5-star labeling scheme for electric fans including ceiling, table, pedestal, wall, and exhaust fans is expected to be enforced from 1st July 2023.
- **Air Conditioners.** NEECA developed mandatory MEPS and labeling scheme for domestic air conditioners in 2021 in coordination with Japan International Development Co-operation (JICA) and Pakistan Standards and Quality Control Authority (PSQCA). These performance requirements have been officially approved but have yet to be formally adopted. The scope of the requirements covers inverter and non-inverter type wall-mounted split room air conditioners. Requirements (including the 5-star label thresholds) are based on cooling seasonal performance factor (CSPF) range.
- **Refrigerators.** Similarly, JICA supported the development of MEPS and labeling scheme for domestic refrigerators, which was finalized and approved by NEECA and PSQCA in 2021 but not yet implemented. The scope is limited, covering only vertical two-door domestic refrigerator-freezers. Performance requirements are internationally aligned based on the current IEC energy performance tests.
- **Visi coolers.** In 2021/2022, CLASP/SAMA^Verte with support from Clean Cooling Collaborative developed MEPS for visi coolers. The final policy proposal for commercial glass-fronted beverage display cabinets, known locally as visi coolers, was submitted to PSQCA and NEECA in March 2022, where it is currently under review for approval.
- **Horizontal beverage coolers, horizontal chest freezers and horizontal refrigerator-freezers.** CLASP/SAMA^Verte with support from Clean Cooling Collaborative developed MEPS for these cooling appliances which were submitted to PSQCA and NEECA in 2022, where they are currently under review for approval.

There have been delays in NEECA rolling out MEPS and initiating implementation of policies initially due to the COVID-19 pandemic and later due to the lack of an online product registration system (PRS) and availability of accredited, independent test laboratories to provide reliable product performance data to underpin the MEPS. The PRS is essential to efforts by the Pakistan Government to improve the energy efficiency of products available on the local market. It will provide an initial compliance gateway wherein manufacturers will need to register their products with NEECA prior to market entry and will support monitoring, verification, and enforcement (MVE) activities.

*There are two other polices for non-cooling products: 1) Mandatory electric motor MEPS, developed by CLASP/SAMA^Verte in 2019, which have been submitted to and approved by NEECA and PSQCA in 2020 but yet to be implemented; 2) mandatory MEPS and labels for LED Lights developed by UNEP/GEF in collaboration with NEECA which were approved in 2019 and came into force in 2020.

TABLE 5: PRODUCTS WITH STANDARDS AND/OR LABELING POLICIES IN PLACE OR IN PROGRESS

PRODUCT	POLICY TYPE	POLICY STATUS	COME INTO FORCE
Fans (ceiling, pedestal, desk, and exhaust)	Voluntary label	In force	2016 (revised 2017)
	Mandatory MEPS and labeling scheme	MEPS approved but not rolled out	2023
Air conditioners	Mandatory MEPS and labeling scheme	MEPS approved but not rolled out	2024
Refrigerators	Mandatory MEPS and labeling scheme	MEPS approved but not rolled out	2024
Visi Coolers	Mandatory MEPS	Draft prepared, under review by PSQCA and NEECA	2024
Horizontal beverage coolers	Mandatory MEPS	Draft prepared, under review by PSQCA and NEECA	2024
Horizontal refrigerator-freezers	Mandatory MEPS	Draft prepared, under review by PSQCA and NEECA	2024
Horizontal chest freezers	Mandatory MEPS	Draft prepared, under review by PSQCA and NEECA	2024

2.4 KEY STAKEHOLDERS IN THE COOLING SECTOR

The Ministry of Climate Change is guiding the process of PCAP development through the PCAP Working Group (for which they are the notifying body as well as the Chair). Key stakeholders involved in Pakistan's cooling sector expected to contribute to development of the PCAP are divided into three broad groups: Public/Governmental Sector, Private Sector, and Other Stakeholders.

PUBLIC/GOVERNMENT SECTOR. Pakistan consists of four provinces, two autonomous territories, and one federal territory, all operating under a federal system. Both the federal and provincial ministries are further divided into departments, Authorities, and/or Agencies operating below them.

Typically, Provincial Government structure broadly mirrors that of the federal level but with an elected *Chief Minister* in the place of the Federal Prime Minister. Historically, Provincial Government had relatively limited formal powers to operate independently. However, following the 18th Amendment to the Constitution in 2010, authority has been delegated to the provinces across several key areas, providing direct control of, or influence over, strategic issues such as energy policy and implementation.

Such a devolved federal system has many strengths but can lead to challenges in coordinated strategic policy development and implementation, particularly during periods when the federal and regional government are led by competing political parties. These challenges are further complicated by the somewhat turbulent nature of Pakistani politics, with relatively frequent changes to federal and regional government, movements of responsibilities within and between ministries/departments at each level, and changes to the leading personnel (and hence priorities) within the respective ministries/ departments.

Key Ministries and associated Departments, Agencies, and Authorities relevant to cooling:

- **Ministry of Climate Change and Environmental Coordination (MoCC)**: MoCC is the federal authority responsible for all environment and climate-change-related policy and sets the NDC targets (and hence were responsible for the inclusion of cooling as a separate item within Pakistan's most recent NDC submission). The Ministry is responsible for monitoring implementation of Multilateral Environment Agreements to which Pakistan is a signatory, monitoring and compliance of National Environment Quality Standards, and implementation of all environmental-related policies. MoCC is the Chair of the PCAP Working Group, leading and facilitating development of the PCAP and coordination with other relevant stakeholders.
- The **Global Change Impact Study Centre** (GCISC) sits under the MoCC. The GCISC is a dedicated research institute for climate change studies in Pakistan. It acts as the secretariat for NDCs in Pakistan and is responsible for data collection related to GHG emissions.
- Also sitting under the MoCC is the **National Ozone Unit (NOU)**. The NOU was established to monitor and ensure the implementation of the Montreal Protocol in Pakistan. The Unit also supports local industry's conversion to ozone/climate-friendly technologies through implementing agencies (UNDP, UNEP, UNIDO, and World Bank).
- **Ministry of Science and Technology (MoST):** The primary aim of the MoST is to enhance technological and intellectual capacity of Pakistan for development. While this mandate is wide, it has relevance to the PCAP in several areas. The following three institutions which operate under MoST are of relevance.
    - The **National Energy Efficiency and Conservation Authority** [*] which has recently moved from Ministry of Energy and Power to MoST, is the federal authority at the forefront of all energy efficiency measures including buildings, and appliances. For appliances, NEECA is responsible for setting energy labelling thresholds and managing implementation of the labelling program.[†] As part of this appliance regulatory program, NEECA may also be able to set refrigerant requirements, as is the case with the pending label for vertical beverage coolers, although this legality is yet to be tested in court. Supported by CLASP/SAMA^Verte and JICA,

[*] Prior to 2016 known as National Energy Conservation Centre (ENERCON)

[†] PSQCA is technically responsible for the setting the MEPS for these products, but this is often a formal procedure with NEECA developing both MEPS and labelling thresholds.

NEECA has developed MEPS and labelling for several cooling products discussed in the preceding sub-section. However, implementation is pending development of supporting compliance infrastructure.

- The **Pakistan Council of Scientific and Industrial Research (PCSIR)** is tasked with promoting research and development in manufacturing and processing. While these activities are generally not of direct relevance to the PCAP, PCSIR is responsible for the establishment of National Laboratories, accredited through the **Pakistan National Accreditation Council (PNAC)** which also sits under MoST. PCSIR has existing fan testing facilities and a test laboratory for refrigerators. However, capacity in these laboratories is limited (e.g., only one refrigerator may be tested at a time).
- The **Pakistan Standard and Quality Control Authority** holds the responsibility for standards and conformity assessment. PSQCA is responsible for issuing mandatory or voluntary standards (test methods and performance requirements) for goods and appliances including MEPS. PSQCA is responsible for regular market monitoring to ensure that products conform to the approved standards, and have the authority to cancel product licenses, though this function is very weak (mainly focused on critical health-related issues such as food and drug safety) due to lack of resources.

- **Pakistan Customs** is responsible for all border regulations and control of import and export across the country's borders. Customs is a key source of information on the import of cooling products and refrigerants. Further, given their border gatekeeper role, customs has the potential to form a key pillar of any product-related efficiency regulation, as they currently do with PSQCA conformity certificate requirements.
- **The Ministry of Industries and Production** (MoIP) is responsible for industrial development, setting up industrial zones, skill development for industrial sector, and promotion of SMEs and traditional crafts of Pakistan. The role of MoIP may be beneficial in supporting changes in manufacturing to promote cooling and energy efficiency and developing vocational training or skill development programs for the cooling servicing industry.
- **Provincial Energy Departments.** Following the 18th Amendment, provincial governments were empowered with policy formulation for energy/power within their respective provinces. This resulted in formation of provincial energy departments that are mandated to develop and implement power projects, as well as energy-efficiency-related initiatives. The **Punjab Energy Efficiency and Conservation Agency** (PEECA), which sits under the **Punjab Energy Department,** is the provincial body responsible for implementing energy efficiency policy and standards in Punjab and are increasingly active in developing and implementing efficiency-related initiatives. PEECA have already guided the inclusion of NEECA's 3-star energy-labelled fans into the Provincial Government's procurement guidelines (management of which sits under the **Punjab Finance Department**). High-efficiency requirements for air conditioners have also been submitted to PEECA, and they are activity seeking legal routes to include similar high-efficiency requirements for other cooling products. The Sindh Energy Efficiency and Conservation Agency (SEECA) was notified in August 2022 and is in the process of becoming functional under the **Sindh Energy**

Department. Other provincial energy departments include the **Balochistan Energy Department, and Khyber Pakhtunkhwa Energy & Power Department,** while the two semi-autonomous regions Gilgit-Baltistan (GB) and Azad Jammu and Kashmir (AJK) also each have a water and power department. However, apart from the Punjab government, all other provincial energy departments have had limited activity related to energy efficiency and are more focused on power generation.

PRIVATE SECTOR. There are two major industry associations with relevance to the cooling sector:

- **Pakistan Electric Fan Manufacturers Association (PEFMA)** which is an elected body representing fan manufacturers. There are approximately 200 fan manufacturers, of which 150 are registered with PEFMA.
- **Pakistan Electronics Manufacturers Association (PEMA)** is the elected body that represents electric goods manufacturers. Members produce a variety of cooling products including commercial display cabinet refrigerators, ice freezers, air conditioners, domestic and commercial refrigerators.

In both cases, participation of the associations in the PCAP development process brings the opportunity for data access, increases the likelihood of the PCAP being accurate, and any resulting recommendations being implemented. However, it should be recognised that:

- Not all manufacturers are affiliated with the associations; in some cases, major suppliers to the sector(s) are not members.
- Both the associations and individual member and non-member companies have strong political connections, all with the potential to influence the ultimate implementation of the PCAP. Thus, engagement with the full sector is required to achieve successful outcomes.

Other Stakeholders. There are several other relevant stakeholders:

- **Service sector (vocational training centres)** which train technicians in the basics of electronic products (cooling included). Potential appears to exist for improving the training of technicians in installation and maintenance of cooling products for better performance, especially in refilling refrigerants and end-of-life disposal.
- **Other associations, societies and organizations** representing private companies and experts providing cooling products and services for commercial buildings and cold chains. These include the Pakistan HVACR (Heating, Ventilation, Air conditioning and Refrigeration) Society, ASHRAE (American society of heating, refrigerating and air conditioning engineers) Pakistan and the Pakistan Cold Chain Development Company.
- **International Organisations.** Most notable and relevant among the donor organisations are the World Bank, AfD (France), GIZ (Germany) and various United Nations Agencies. While they will be informed of progress in PCAP development, their participation could support the implementation phase.

3. Cooling Demand Assessment

In recent years, there has been a rising cooling and refrigeration demand in Pakistan due to the increase in population, rising temperatures and heat waves, and increased economic activity. A large proportion of the space cooling and refrigerating appliances satisfying this growing demand are produced domestically. The indigenous appliances industry has grown steadily over the past few years, driven by a combination of the market growth and a tax system that favors indigenous production over import (import tax on components is typically 10% compared with 80% on finished products).

This section provides a market overview of the key sectors covered by this cooling needs assessment.

3.1 KEY COOLING SECTORS

As is clear from previous sections, the cooling appliance sectors addressed in this assessment (and the subsequent PCAP) are a subset of the entire cooling environment. These appliances have been prioritized as they are integral to meeting the growing need for space cooling and refrigeration in Pakistan and are widely used in the domestic and commercial sectors. Further, these appliance sectors are high emitters in themselves and have significant potential for emission reduction in the short to medium term in comparison with other cooling appliances and equipment.

The sectors prioritized, and the associated rationale, are as follows:

- **Domestic space cooling** including air conditioners used for indoor cooling in homes and smaller buildings, and electric comfort fans (subsequently referred to only as fans). For household and smaller commercial establishments, space cooling has traditionally been dominated by ceiling fans and evaporative coolers, with little penetration of air conditioners. Fans are still the main source of cooling for most households as they are the most affordable cooling appliance available, but they do not provide sufficient cooling during peak summer temperatures. Fans are also the largest energy consumer and indirect emissions emitter amongst the priority cooling appliances. Over the last decade, demand for air conditioners has gradually increased, and there has been a shift from the traditional window units towards split type air conditioning units. This switch appears to be driven by the increasing cost of electricity and the perception that variable speed units will result in reductions in electricity consumption, combined with the ability to provide heating (the latter resulting from a steep increase in the price of and irregularity of natural gas which has been traditionally used as the primary fuel source for domestic space heating).
- **Domestic refrigeration** includes the refrigerators (upright) refrigerator-freezers (upright and horizontal) and deep freezers used by households and, in some cases, in small retail establishments. Domestic refrigeration is one of the higher emitting cooling sectors in Pakistan.

- **Commercial refrigeration** includes various types of refrigerators and freezers such as visi coolers and display cabinets and freezers used in retail outlets, restaurants, and other commercial establishments. This is a sector of increasing importance as disposable income rises and more processed food and drink are purchased.
- **Cold chain** is primarily used for agricultural produce and food, as well as in the health sector. Limited data is available on cold storage and cold chain applications in Pakistan. Cold storage capacity for post-harvest food storage is estimated at around 6%, mostly concentrated in main cities and potato-growing areas.[45] Given the limited data available, this sector is not covered in detail. However, an estimated 40-70% of the total fruit and vegetable produce is wasted, in part due to inadequate cold chain infrastructure.[46] The economic impact of this sector requires inclusion to initiate debate and future data collection in this important field.
- **Off-grid cooling appliances** include DC-only fans. DC-only fans have gained market share in Pakistan over recent years, mainly due to their use in off-grid and weak-grid areas of the country. The large appliances in off-grid sectors are just emerging; high costs and a lack of awareness stifle the markets for larger appliances such as refrigerators.

3.2 DATA COLLECTION METHODOLOGY

Given the limited data available for the development of the cooling needs assessment, and the disparate sources of the information that is available, a variety of primary and secondary data collection strategies were deployed. The varying methodologies are summarized below.

- **Residential air conditioning and refrigeration.** The team used three approaches to collect data for the air conditioning and refrigerating appliance markets in Pakistan:
  - Meetings with industry. One-on-one meetings with major manufacturers and wider industry/sector consultative meetings.
  - Retail surveys. SAMA^Verte team developed the questionnaires for each appliance group based on similar research projects done by CLASP in other countries to collect information including size, power consumption, energy efficiency, price, and refrigerants. The team, with support from WWF-Pakistan, collected the data in 2022 through retail surveys from 45 stores across six Pakistani cities (three large cities: Lahore, Karachi, Islamabad and three medium sized cities: Multan, Faisalabad, Sialkot). Data was collected from ten retail outlets in each of the larger cities and five retail outlets in each of the smaller cities. Because only a limited number of shops were visited (each city market consisted of hundreds of shops), the methodology used covered a cross-sectoral market from outlets specializing in electronic products to larger home stores in different parts of the city (new high-end areas to older areas). The survey consisted of two parts: the first part involved collecting qualitative data about sales patterns, popular brands, consumer priorities when buying appliances; and the second part

collected gathered quantitative data on appliances such as power consumption, refrigerants, appliance size, price, etc.

- Online data scraping. Data was collected from approximately 25 manufacturer websites and online retail outlets. The quantitative data questionnaire from the retail survey was used for the online data scraping.

The dataset from retail surveys and online data scraping included data for 368 air conditioner models and 428 refrigerator models, with both appliances consisting of approximately 75% unique models. However, some of the desired product and performance criteria were missing for some models, including energy efficiency information. There were a variety of labels found in the surveyed appliances and different brands display different information on the labels.

- **Electric fans.** The data for electric fans were collected during the stakeholder consultative meetings. The team held individual meetings with several manufacturers both in person and over the phone. The team also met with PEFMA to collect annual sales and stock data.

  Additionally, the team tested select fans in-house in Lahore. PCSIR lab also shared some fan test data from the tests that they had conducted. The team also shared the fans sale and stock estimates with one of the largest fans manufacturers who validated the data used for policy scenario analysis.

- **Commercial refrigeration**. The team collected data for commercial refrigeration using the following means:
  - Online data scraping from 5 manufacturer websites and 10 online retail outlets. A detailed template sheet was used to extract data from the websites.
  - Meetings with the big buyers and major manufacturers who shared product specifications and details.
  - Testing several purchased models at the Government accredited lab as well as carrying out in-situ testing of appliances installed in the market to gather energy consumption data.

  The collected market and product data was shared with and validated by the industry experts and multinational byers.

- **Off-grid cooling appliances.** The data for off-grid fans was gathered in the following manner:
  - Desk study. A comprehensive desk review conducted in collaboration with WWF-Pakistan, to determine the baseline for cooling access by analyzing number of people without access to grid electricity, with solar home systems or other off-grid energy sources to power electric fans.
  - Data was collected from previous studies and projects which were focused on off-grid appliances particularly DC fans to determine the production of DC fans, sale of DC fans, number of households using off grid appliances etc.

- The team conducted a small household and retail survey in areas with large off-grid populations (Multan district in South Punjab and Sukkur district in Northern Sindh) to collect data on the type and quality of DC fans typically used in off-grid communities and to assess field conditions.
    - Household Survey. A questionnaire was developed to collect data from a sample of off-grid households on their off- grid fans and other appliances usage. Fifty off-grid households were identified through the support of WWF-Pakistan in two districts in Punjab (15 households) and Sindh (35 households) and data was collected during November – December 2022. The survey consisted of two parts: first, the team collected quantitative data for DC fans such as consumption, size etc. The team also physically checked the fans basic parameters using a standard clamp ampere meter for power consumption and anemometer for air flow. Secondly, the team collected qualitative data about appliance brands, method of purchase for off-grid appliances, usage patterns etc.
    - Retail survey. The SAMA^Verte team also developed a questionnaire for collecting data from retail shops which sold off- grid appliances to collect information including size, power consumption, energy efficiency and price. The team collected the data in 2022 from over 20 stores in 3 cities/areas (Lahore, Multan and its surrounding areas and rural areas around Sukkur) to assess availability and type of DC fans available in the market.
    - Testing of DC fans. The team brought a sample of fans from the field (used fans from households as well as new fans from retail stores) and had 8 of them tested at the PCSIR laboratory. Six out of the eight fans selected for testing were unbranded whereas the other two were manufactured by well-known manufacturers (one from Tier one and the second from Tier 2 manufacturers). The purpose of this sample selection was to assess and compare performance of the unbranded fans with those produced by the large and well-known fan manufacturers.
- SAMA^Verte knowledge and data collected through other projects. The team has been involved in two past and one ongoing project which enabled some data availability of off-grid community appliance use, in particular: a) Pakistan Microfinance Investment Company solar home system project, b) Sindh solar home system appliance needs assessment, funded by the UK government, and c) Provision of clean energy solutions for rural off-grid/weak-grid communities of Punjab, in partnership with Pilio UK, funded by the UK government Innovate UK Energy Catalyst Fund.
- CLASP Low Energy Inclusive Appliances. Review of data gathering by the project for the Pakistan component.
- Stakeholder consultations. One on one meetings were held with the known leading manufacturers of DC fans including Royal Fans, Tamoor Fans and Khurshid Fans as well as wider discussions through stakeholder workshops and meetings.

- Verasol database. Analysis of the products in Verasol quality assurance database to assess the relative performance of Pakistani DC fans.
- DC fan procurement standards. Analysis of DC fan procurement standards as part of solar home system solutions listed by organizations such as PMIC, the National Rural Support Programme.

- **Cold chain.** Limited information on cold chain was collected through desktop research, meetings and workshops with cold chain stakeholders such as the Pakistan Cold Chain Development Company and a few cold storage manufacturers and service providers including Koldkraft Refrigeration, Thermoworx and P.Pulsometer Co. However, sector-level data has not been readily available.

Note: All stock projections shared in section 3.3 for all cooling products are sales-based

3.3 COOLING SECTOR OVERVIEW

3.3.1 AIR CONDITIONING

In Pakistan, three types of units constitute most of the domestic air conditioner market:

- **Window air conditioners,** which has all the components (including compressor, condenser, expansion valve, cooling unit) enclosed in one box.
- **Split air conditioners** which have indoor and outdoor units. The indoor unit has the evaporator and cooling fan. The outdoor unit has compressor, condenser, and expansion valve. The split air conditioner market is dominated by the inverter-type models.
- **Central air conditioners,** which has all the components (including the compressor, condenser, and expansion value) housed in one single box. The cool air is transferred to rooms through ducts.

Traditionally in Pakistan, air conditioning in domestic sector was dominated by window air conditioning units. However, around 15 years ago, there was a rapid switch to fixed-speed, cooling-only split systems. Further, in 2014-2016, inverter units entered Pakistan's air conditioning market with rapid uptake due to increased electricity prices. Later, in response to the increasingly intermittent supply of gas, the uptake of reverse cycle units increased which provided an option for space heating.

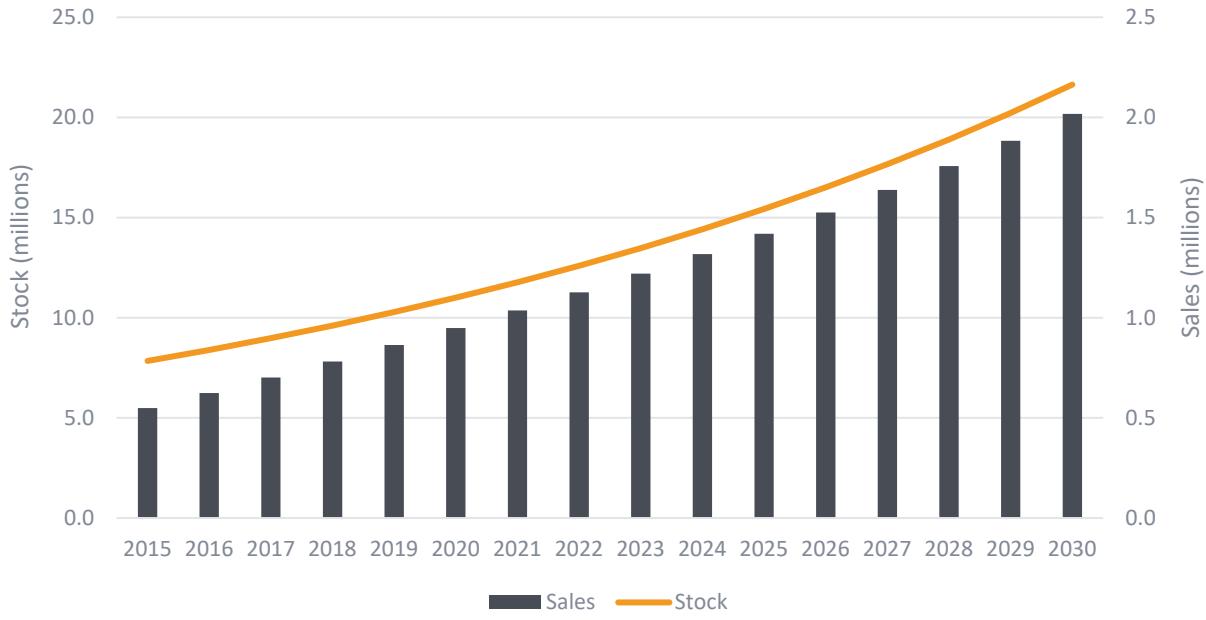
At present, the central air conditioner market is quite nascent with applications primarily in the commercial and industrial sectors. As the focus of this assessment is the domestic sector, central units are not analyzed. However, central air conditioners (particularly Variable Refrigerant Flow type) are expected to grow in the commercial sector with potential significant penetration in apartment buildings.[47]

MARKET SIZE AND STOCK. In 2022, about 1.3 million air conditioning units were sold in the Pakistani market with an estimated annual growth rate of 7% (Graph 5). About 70% of

the retail respondents reported a slowdown in sales over the last two years. Surprisingly, the respondents reported that inflation, rather than COVID-19, was the main reason behind the drop in sales. The retailers who saw an increase in air conditioner sales reported increased temperature as a main reason for it. The manufacturing industry also reported a slight slowdown in sales during the COVID-19 pandemic, which has now bounced back to normal and has returned to the steady growth estimated at 7%. Split air conditioners dominate the market and are expected to remain dominant in the coming years.[48]

Based on an industry estimate of an average unit lifetime of ten years, domestic air conditioner stock in Pakistan is estimated at almost 11.3 million units in 2022 (Graph 5). Stock is expected to grow to about 20.2 million units by 2030 (almost double the current stock) with annual sales close to 2.2 million units by 2030 at current growth rates.

GRAPH 5: ESTIMATED SALES AND STOCK FOR DOMESTIC AIR CONDITIONERS IN PAKISTAN



SECOND HAND MARKET. Pakistan has a secondhand market for air conditioners, but it is small and fragmented. Secondhand air conditioners can be found in smaller shops in large cities or rural cities. They are typically older split or window type units which have been replaced with newer inverter air conditioners.

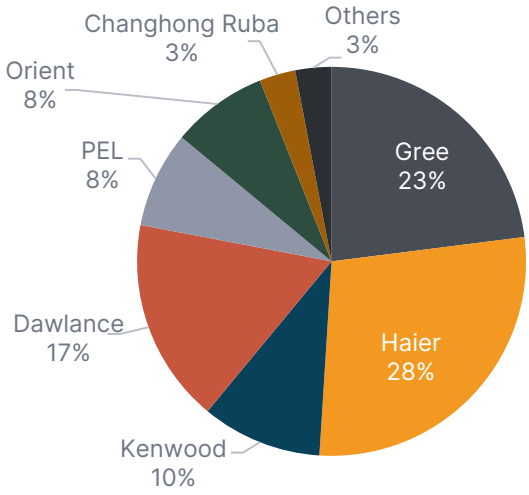
SUPPLY SIDE. About 95% of split air conditioners are produced locally and the remaining 5% are imported. The imported air conditioners consist mostly of larger-sized units (3-4 tons), although some foreign brands such as Samsung and Mitsubishi also sell smaller size units.

Local production essentially refers to assembly of air conditioners as most companies import “completely knocked down” (CKD) packages from international suppliers, sourced primarily from China, and reassemble them locally. The main reason is that import duties

for completely manufactured products such as air conditioners are higher than for import of separate parts which are then assembled locally. In recent years, the industry has been increasing local procurement of material for parts, with about 30% of the material used for air conditioners now being manufactured in Pakistan, primarily plastic and metal sheets.[49]

Graph 6 shows that the air conditioner market is dominated by a few companies: Haier, Gree, and Dawlance.* Until recently, Gree (DWP) led the Pakistan air conditioner market. Currently Haier (Haier Pakistan Pvt Ltd) is the market leader with a 28% share and Gree has approximately 23%, followed by Dawlance with around 19%.† Other companies with smaller market shares are Orient (Orient Electronics), Kenwood (R&I Electrical Appliances, a subsidiary of British company Kenwood Limited), PEL (Pak Elektron Limited), and Changhong Ruba. Newer companies such as Hisense have also set up their plants in Pakistan and are successfully marketing their reverse cycle models. Other companies with a presence in the market include Ecostar, TCL, Electrolux, and Homage.

GRAPH 6: APPROXIMATE BRAND MARKET SHARE FOR AIR CONDITIONERS (2021)

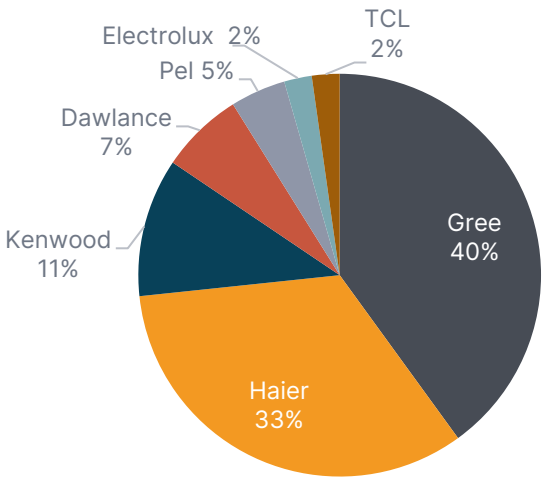


This supplier view is supported by the retailer survey, in which 40% of surveyed retailers stated that Gree was their bestselling air conditioner brand, followed closely by Haier at 33% (Graph 7). Other popular brands were Orient, Kenwood, Dawlance, PEL, and TCL. Retailers promote Gree and Haier the most in their sales pitches to customers as, in their opinion, they have the best quality.

* Gree and Haier are Chinese subsidiary companies, and Dawlance is subsidiary of the Turkish company Arcelik

† Market share numbers were provided by industry.

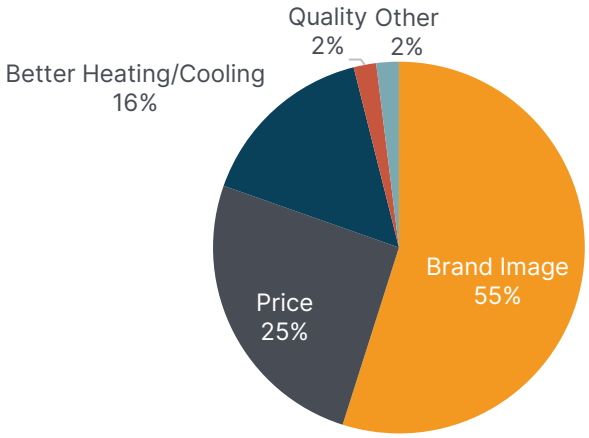
GRAPH 7: BESTSELLING AIR CONDITIONER BRAND ACCORDING TO RETAILERS



DEMAND SIDE. Around 11%[50] of households in Pakistan own air conditioners, which are still considered a luxury item not affordable for the lower-income households, the largest population segment. However, with rising temperatures, the expanding middle-income class is showing an increasing desire for cooling beyond comfort fans.

About 55% of surveyed retailers indicated that brand trust/image was the main determining factor for consumers to buy a particular product (Graph 8). Price surprisingly ranked second in importance (25%) when the consumer is making an air conditioner purchase decision.

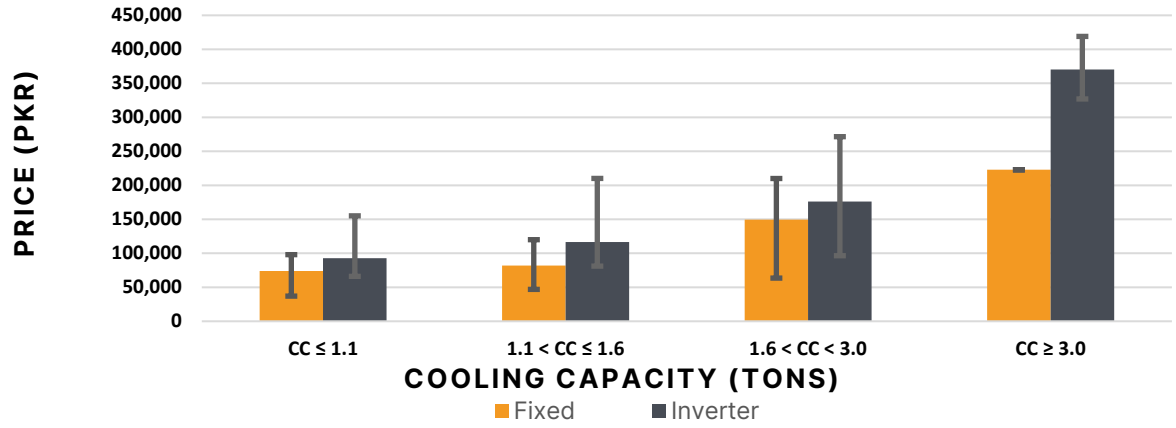
GRAPH 8: CONSUMER PREFERENCES WHEN PURCHASING AIR CONDITIONERS



The price range for domestic air conditioners varies by different brands and models. In 2022, at the time of the survey, the average price for a 1.5-ton inverter split air conditioner was about PKR 115,000 (USD 503),* which was almost a 20% increase from the previous year, mainly due to the devaluation of Pakistani rupee. Some imported models are priced at over PKR 200,000 (USD 875) (Graph 9).

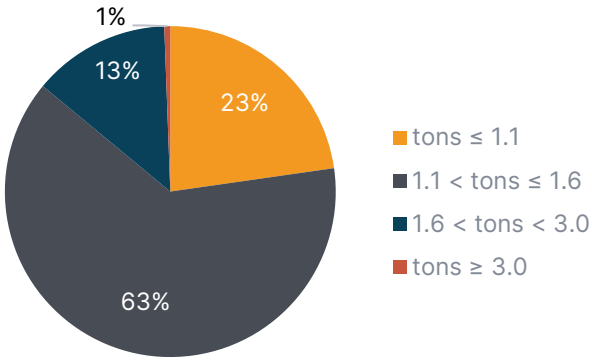
* The data was collected earlier in the year, - during months of April, May, and June 2022, - when the exchange rate was USD 1 = PKR 186. Current AC prices may be even higher as the exchange rate has gone up to over PKR 300.

GRAPH 9: PRICE RANGE FOR DIFFERENT AIR CONDITIONER SIZE (CAPACITY)



PRODUCT CHARACTERISTICS. The 1.5-ton air conditioners are the most commonly sold in Pakistani market, currently constituting about 80% of the market share.[51] However, due to the significant price increases over the last year, the cheaper 1-ton air conditioners are increasing in popularity.[52] The retail survey data showed that about 64% of ACs available on the market are 1.5 ton, while 23% are 1-ton units.*

GRAPH 10: PROPORTION OF AIR CONDITIONER MODELS AVAILABLE IN THE MARKET BY COOLING CAPACITIES



According to surveyed retailers, the air conditioner market has shifted from mainly fixed-speed to inverter type air conditioners in the last few years. Only 8% of surveyed models were fixed-speed compared with 92% had inverter/variable control compressors. As noted in the section introduction, the demand for reverse cycle models, which provide both cooling and heating, has increased significantly in the last 2-3 years. This demand for reverse cycle models is driven by the shortage of natural gas, which in domestic households is used for gas heaters (amongst other uses) during the limited winter season. In the retail survey, almost 78% of the models were reverse cycle models, confirming that the demand for these models is higher.

REFRIGERANTS. R-410A has traditionally been the most commonly used refrigerant by all local manufacturers for inverter air conditioners models in Pakistan. Some

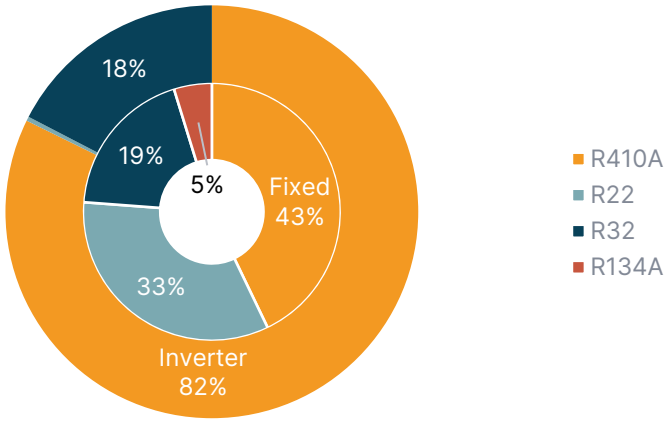
* The availability of models and sizes indicates the market preference.

manufacturers have partially switched to the more efficient R-32 or are in the process of transition. Other manufacturers plan to shift to R-32 from R-410A in the next few years. In the retail survey, almost 80% of air conditioner models use R-410A refrigerant (GWP* of 1,923.50), while only 18% use R-32 (GWP of 677†) and 3% use R-22 (GWP of 1,760‡). As shown in Graph 11, about 33% of fixed-speed air conditioners still available on the market use R-22 refrigerant (HCFC§), compared to almost no inverter units. Older air conditioner models installed in houses also use R-22 refrigerant, which is still available through repair shops for servicing those ACs.

Shifting to hydrocarbon refrigerants such as R-290 does not seem possible in the near future as the capacity for its production, handling, and after-sales service is currently not available in Pakistan.

According to industry consultations a transition to R-32 from R-410A began in 2019, with R-410A being used in almost 45% of all newly produced AC units.

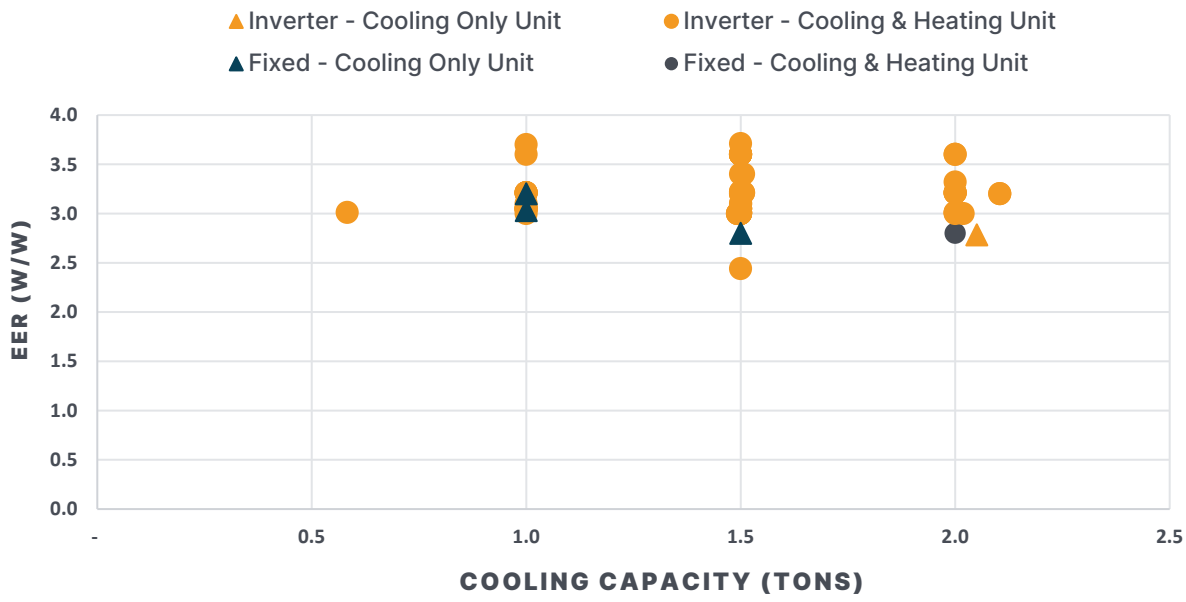
GRAPH 11: MARKET RETAIL SURVEY DATA ON REFRIGERANTS, BY COMPRESSOR TYPE



PRODUCT PERFORMANCE. A 2021 research study[53] found that in households that own air conditioner units, 41% of a household's annual electricity consumption is from air conditioners. A typical household in Pakistan consumes 24 kWh/m^2/year of electricity,[54] so approximately 10 kWh/m^2/year is consumed by a household with air conditioners according to the study. According to Karachi Electric,** daily usage for an average 1.5-ton inverter air conditioner is 12 kWh.

* Global warming potential, 100-year figure as defined by IPCC AR5 report, 2014
† 100-year GWP of 677 (IPCC AR5)
‡ 100-year GWP of 1760 (IPCC AR5)
§ Hydrochlorofluorocarbon
** Company which serves about 2.5 million customers in south Sindh and Balochistan

GRAPH 12: COOLING CAPACITY AND EFFICIENCY LEVELS FROM MARKET SURVEY



There is currently no requirement to display a unit's energy efficiency level on the unit itself or on a label, although this requirement will be enforced when MEPS are introduced. The data collected show an average energy efficiency ratio (EER) of 3.16 W/W (where a higher EER indicates greater efficiency) in 88 of the models that had the information displayed on their labels. EERs for fixed-speed units (4 of the 88) was between 2.8 W/W and 3.2 W/W, while inverter units (84 of the 88) had a greater range of EERs, between 2.44 W/W and 3.71 W/W.* None of the surveyed models had a Cooling Seasonal Performance Factor (CSPF) listed, which will be the efficiency metric in Pakistan's AC regulations.

According to industry, most of the current models being manufactured would meet 2- or 3-star rating with some meeting even a 4-star requirement in soon-to-be adopted MEPS and labeling scheme for air conditioners. Only the fixed-speed models would fall in 1-star category or below.

REGULATIONS AND CURRENT STATUS. NEECA and the Japanese International Cooperation Agency (JICA) developed *Minimum Energy Performance Standard and Labeling Requirements for Room Air Conditioner.* These regulations were formally approved by PSQCA and NEECA in 2021, but their implementation is still pending. Barriers to implementation include awaiting the development of an online Product Registration System at NEECA and the absence of a certified air conditioner testing laboratory in Pakistan (although, at the time of writing, the registration system and a laboratory† are under development).

*The efficiency metrics are displayed on voluntary basis and may have some errors.

† Some of the larger manufacturers have state of the art air conditioner labs but they are not accredited and are used for testing their own products

Summary details of the regulations are as follows:

- The scope: non-ducted wall mounted split room ACs with cooling capacity up to 10.5 kW
- Ambient temperature: T1 zone
- MEPS set at CSPF 3.2 Wh/Wh
- 1-5 Star rating labeling scheme

The test standards to be used are:

- PS: ISO 16358-1 Air-cooled air conditioners and air-to-air heat pumps—Testing and calculating methods for seasonal performance factors—Part 1: Cooling seasonal performance factor
- PS: ISO 16358-1 Amendment 1 Air-cooled air conditioners and air-to-air heat pumps—Testing and calculating methods for seasonal performance factors—Part 1: Cooling seasonal performance factor Amendment 1
- PS: ISO5151/2013 Non-ducted air conditioners and heat pumps—Testing and rating for performance

Options and/or need to modify policy. The air conditioner MEPS were developed based on 2018–2019 data collection and consultations. Consequently, the MEPS in the new regulation may not be ambitious enough given the market's rapid evolution in recent years. The market is likely ready for MEPS set at 3-star rating, as most of the air conditioners on the market may already be above the proposed MEPS (1-star) level. Given that the current regulations are yet to be implemented, there may be an opportunity to include a rapidly revised MEPS schedule (e.g., an increase in the MEPS level in the near future to the 3-star MEPS level), with a mandated review of the MEPS/star rating levels at that point (based on the product performance data that will be available at that time from the registration system), with further incremental MEPS increases from that point onward.

3.3.2 ELECTRIC FANS

Most of Pakistan's population still relies heavily on comfort fans as their first line of defense against the heat, as air conditioners can only be afforded by a small segment of the population. Severe heat has necessitated the need for robust fans with high airflow, which Pakistani fans are regionally known for. However, as fan technology improved, the industry has not prioritized energy efficiency, and the government has only taken interest in that aspect recently.

Two types of fans technologies are covered in this section:

- **AC fans**, which are driven by a standard AC central stator motor operating (almost exclusively) from grid-connected mains supply. Tolerance to grid voltage fluctuations varies by specific design. These include ceiling fans, pedestal fans, exhaust fans and bracket fans.

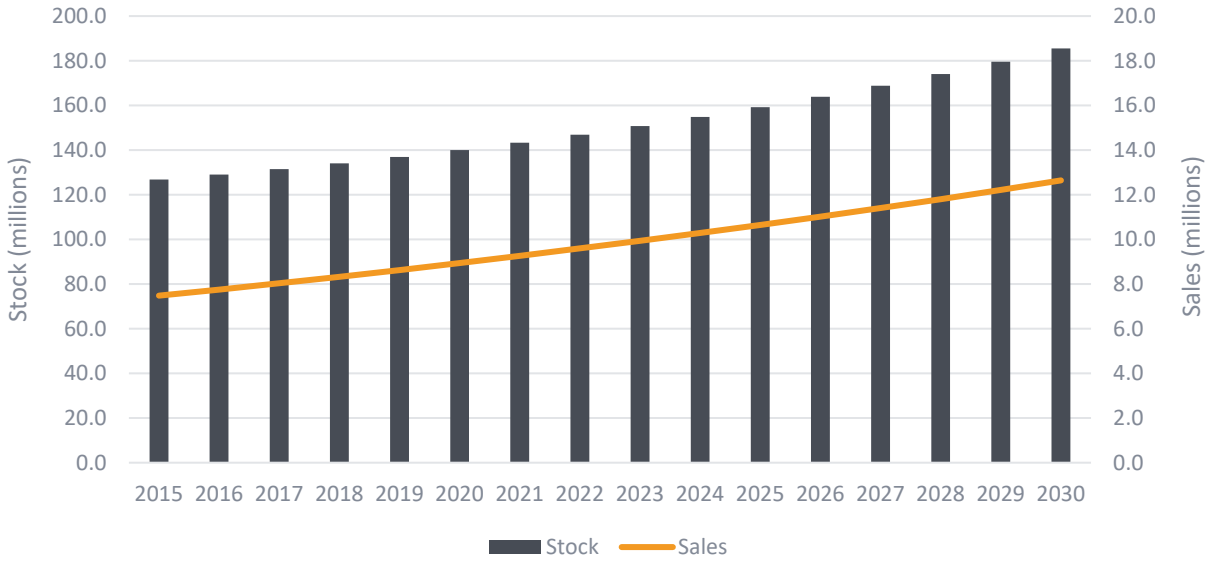
- **AC/DC hybrid fans**, which can be used both on- and off-grid. Hybrid-type fans have DC permanent magnet motors and an internal or external inverter that allows them to switch between AC and DC power supply. They are also able to respond to voltage variation.

Off-grid (DC only) fans are covered separately in Section 3.3.8.1.

MARKET CHARACTERISTICS AND STOCK. Ceiling fans dominate the on-grid fan market in Pakistan with an 85% share. The remaining market is distributed between pedestal fans with 8-10% and exhaust and bracket fans with 5-7%. Within the ceiling fan segment, more than 90% of the market is comprised of 56-inch fans (1400 mm). Thus, the analysis in this section focuses primarily on ceiling fans as their use is by far the most common.

Over 9 million fans were sold in 2022, and annual sales are expected to grow steadily, reaching over 12 million by 2030. The majority of ceiling fans sold in Pakistan are manufactured locally. Fans are the most widespread cooling technology in Pakistan with an estimated 147 million units in stock in 2022. Fans stock is expected to grow to 186 million by 2030, driven by increasing population, household income levels and grid connections (Graph 13).

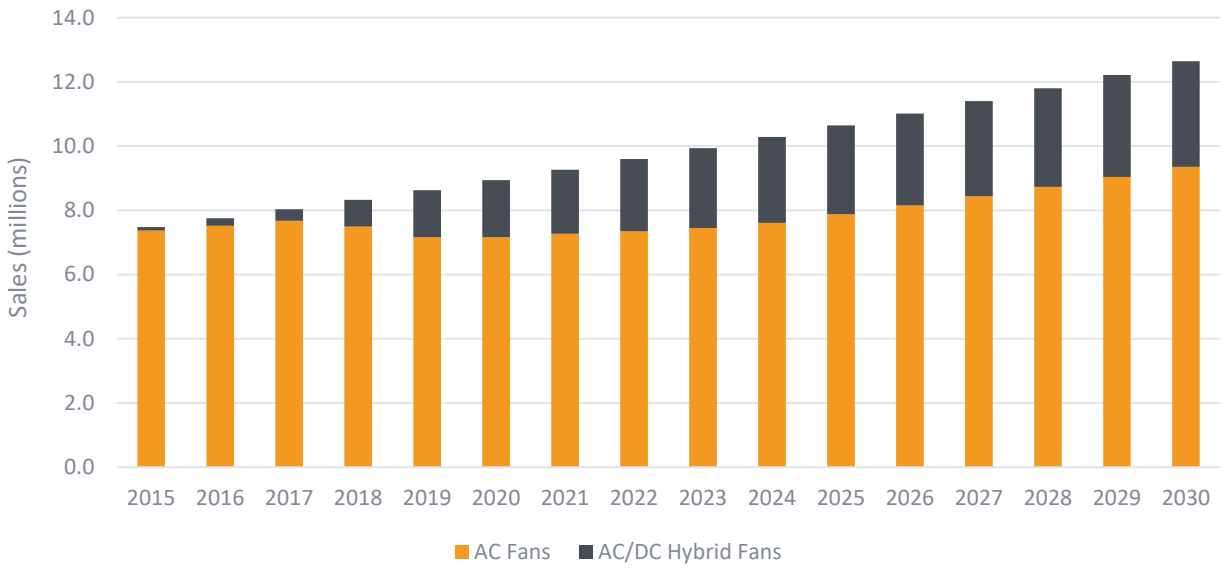
GRAPH 13: HISTORIC AND FORECASTED FANS STOCK AND SALES



Decades of status quo production of the standard AC (central stator) motor fans continued until 2018, when the AC/DC hybrid fan was introduced by two Tier 2* manufacturers (Taimoor Fans and Khursheed Fans) and much of the market followed, introducing AC/DC fans into their range. In 2022, 24% of all fans sales were AC/DC hybrid fans. Due to their resilience to voltage fluctuations, AC/DC fans have good penetration in poor grid areas and smaller cities (Graph 14).

* See below for definition of Tier 2 manufacturers.

GRAPH 14: ANNUAL FANS SALES BY TYPE



SUPPLY SIDE. Pakistan has a strong fan manufacturing industry with about 225 local manufacturers producing over 1,000 fan models. Nearly 95% of locally sold fans are produced in two central Punjab cities, Gujrat and Gujranwala. The industry can be divided into four tiers based on product quality and technology:

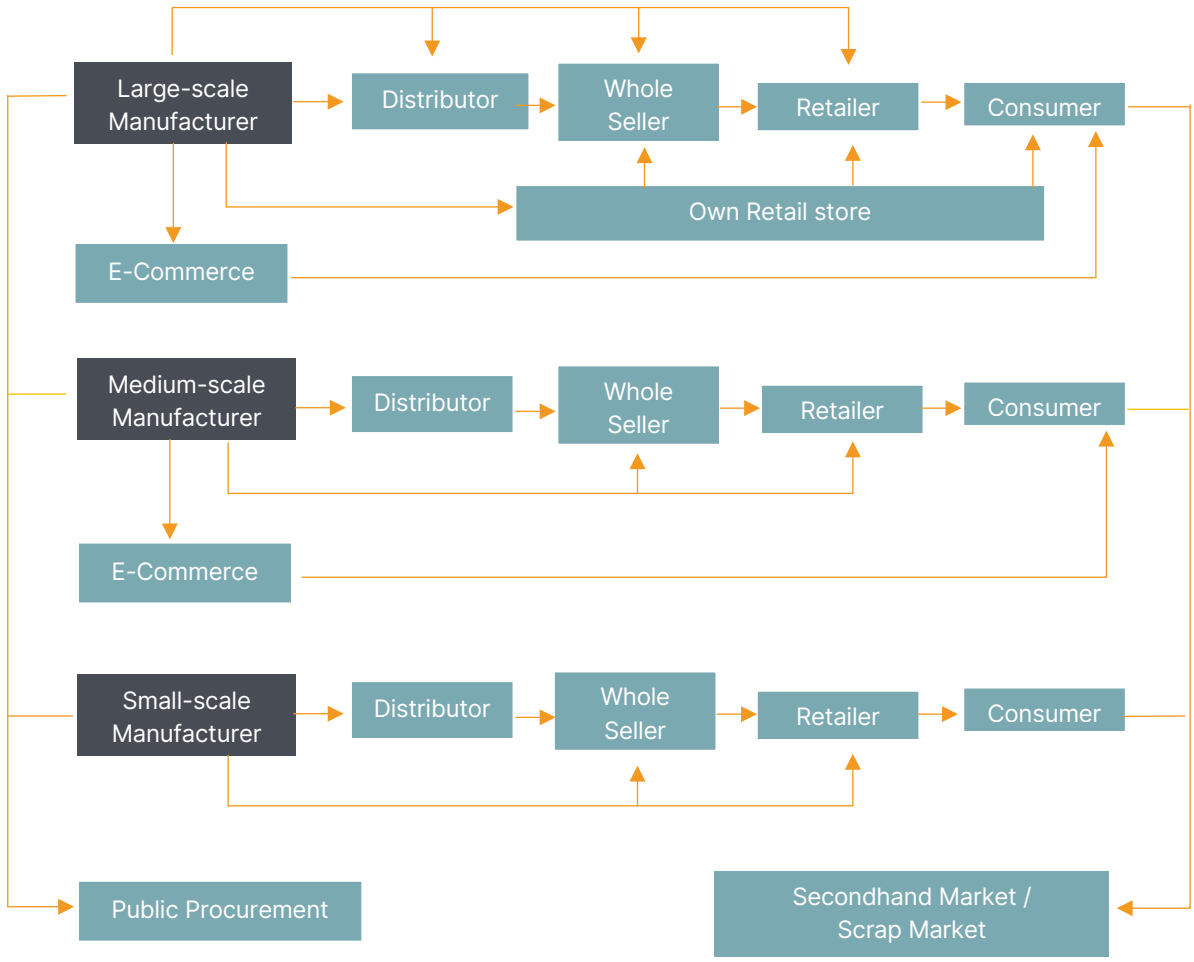
- **Tier 1** group includes four nationally recognized large manufacturers ("Big Four": GFC, PAK Fan, Royal Fan, Super Asia) with relatively advanced technical design and production facilities. They make high-quality fans which are both sold in the country and exported and are capable of competing with the best fans in the world. Tier 1 manufacturers supply approximately 48% of the fans market.
- **Tier 2** group includes about 20 manufacturers with ranging technological capabilities and varying degrees of in-house component production. They have high capability and make quality fans but are not as large as Tier 1 companies. Tier 2 producers supply approximately 24% of the fans market.
- **Tier 3** manufacturers include companies of varying sizes and capability. Most of these companies are long established, some being household names. They make fans that may be durable and give high airflow but consume a lot of energy (usually above 110 W for a 56-inch fan). There are 76 manufacturers in Tier 3 who supply approximately 18% of the fan market.
- **Tier 4** is comprised of the cottage industry. The fans they produce are not very durable. The air flow is usually acceptable, but energy consumption is above 125 W even for a new fan. There are 125 Tier 4 producers that supply about 10% of the market.

After production of fans, mainly in the cities of Gujrat and Gujranwala, distributors then supply to rural and urban areas (Figure 3). For rural areas, distributors usually supply fans to a small town in the center of a large rural population. For urban areas, large distributors

supply fans to warehouses that act as second distributors based in large cities such as Karachi, Lahore and Faisalabad, who then onward distribute to retailers.

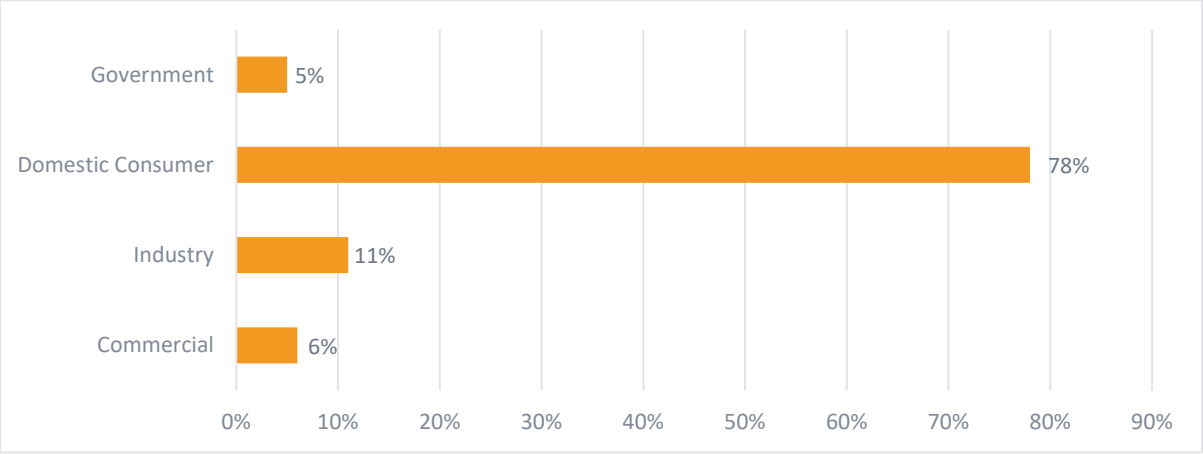
After a useful average life of about 15–20 years, most fans are sold for scrap. The copper winding (some have aluminum) is valuable and thus a used fan fetches 25% of the price of a new fan when sold for scrap. Very few fans are fixed and re-sold to enter the secondhand market.

FIGURE 3: FANS SUPPLY CHAIN IN PAKISTAN



DEMAND SIDE. An estimated 147 million fans are installed in Pakistan, of which 60% are installed in the Punjab province. Graph 15 illustrates that ownership (and purchasing) is dominated by the domestic sector. In 2019, about 78% of ceiling fans were used by households, 11% by industry, and 6% by commercial entities and 5% are installed in regional and provincial government buildings.

GRAPH 15: INSTALLED CEILING FANS STOCK BY SECTOR (2019)



Consumer purchasing decisions are driven by multiple factors including: 1) brand allegiance, 2) air flow, 3) price, 4) regional preferences for air flow direction and noise, 5) energy saving feature (priority fluctuates), 6) appearance, and 7) remote control.[55]

GEOGRAPHICAL PREFERENCES. Fans run for almost 11 months of the year in Karachi, a city of approximately 20 million. In the central and northern parts of the country, fans run for 8 to 9 months. Regional preferences include air flow, direction, fan noise and preference for two of the 3-blade designs. Consumers in larger cities such as Lahore and Karachi prefer a column airflow blade design while Southern Punjab, Northern Sindh, and other rural/semi-urban areas prefer blades that induce well-spread air flow. The latter also prefer noisy fans as compared to buyers in large urban cities of Lahore, Islamabad, or Karachi.

The hybrid fans have strong penetration in poor grid areas where consumers use such fans in both AC and DC modes depending on grid and solar power availability. These types of fans also run well on low voltage which is a problem in weak grid regions.

PRODUCT PERFORMANCE. Despite the increasing focus on fan efficiency and energy consumption, and the small improvements made in efficiency across different fan models in the last 20 years, the average rated consumption of a ceiling fan still varies dramatically between models. Table 6 shows the average rated consumption of fans produced by Tier 3 suppliers is over 50% greater than the average produced by Tier 1 suppliers, and for some Tier 3 models, rated consumption can be twice that of Tier 1 products.

TABLE 6. AVERAGE RATED ENERGY CONSUMPTION OF CURRENT FAN SALES BY MANUFACTURER TYPE

MANUFACTURING TIER	MARKET SHARE	AVERAGE RATING
Tier 1	48%	75 W and above
Tier 2	24%	95 W and above
Tier 3	18%	110 W and above
Tier 4	10%	125 W and above

Note: 3 Star (Voluntary) level & AC/DC hybrid average rating are 60W

Fan airflows are generally high, with most fans delivering air flow greater than 260m^3/min (some fans consume less than 70 W with an airflow of over 250m^3/min, thus meeting the 3-star voluntary energy label level*).

Since the AC/DC hybrid fan was introduced in the market in 2018, fan manufacturers have strived to produce fans with lower energy consumption. Fans consuming as little as 40 W are also available on the market but have poor airflows.

Mandatory regulation and current status. In 2016, fans were the first product for which MEPS were developed, and a voluntary labeling program for fans was introduced with a 3-star label. A total of 24 manufacturers have obtained the 3-star voluntary label (for a total of 43 ceiling fan models). Due to some political hindrances, the scheme remains voluntary to date. The mandatory MEPS and labeling requirements (Table 7) for 56-inch ceiling fans were put in place in early 2022 and implemented is expected to start mid-2023.

AC/DC HYBRID FAN TECHNOLOGY

Electronic kits installed in this type of fan allow for switching between AC and DC supplies and, within limits, is able to provide voltage control in poor grid areas. These kits are almost all imported, with the permanent magnet motors required for AC/DC hybrid application either imported or manufactured locally.

Electronic kits are installed in the canopy which covers the part of the fan attached to the ceiling. If the fan becomes faulty only this needs to be replaced while the rest of the fan does not need to be dismounted.

The advantages of hybrid fan are: 1) less noise, 2) uses less energy, 3) runs well on low voltage which is a problem in weak grid regions 4) comes with a remote control, 5) price is only USD 1.5 higher than high quality tier 1 AC fan, and 6) when fan breaks down manufacturers can send just the electronic kit which is replaceable on site.

Despite high growth rates for hybrid fans, some of the key drawbacks include: 1) permanent magnet supply via "unorthodox" routes, 2) unreliability of voltage controllers, 3) 15% price premium, and 4) current maximum penetration expected at about 35% due to import dependency.

TABLE 7: MANDATORY MEPS AND LABELING REQUIREMENTS FOR 56-INCH CEILING FANS (2022 REVISION)

SWEEP (MM)	MAXIMUM RATED POWER INPUT (W)	MINIMUM RATED AIR DELIVERY (M^3/MIN)	SERVICE VALUE [M^3/MIN/W] BASED STAR RATING FOR GRANT OF NEECA'S PAKISTAN ENERGY LABEL				
			1 Star	2 Star	3 Star	4 Star	5 Star
900	55	110	2.75	2.87	2.95	4.25	5
1050	60	150	2.79	2.93	3.10	4.10	5.10
1200	70	190	2.93	3.08	3.22	4.20	5.13
1400	80	230-250	3.15	3.32	3.45	4.45	5.15
1500	90	300	3.33	3.52	3.68	4.50	5.25

* Manufacturers who were first to get 3-star voluntary label complied with the minimum air flow requirement of 225m3/min set by NEECA. However, when actual supply started this air flow was insufficient in the Pakistani environment and consumers complained. Manufacturers worked on improving airflow while still meeting the 3.45 service value ratio.

As per market research, over 70% of the fan market (by production) comprised of the top 25 manufacturers can meet MEPS levels, with many of them meeting 3-star level or better.

Some barriers and challenges delaying adoption of MEPS for fans include:

- Delay in launching the online registration system for registering fans and other regulated products.
- Political issues: Lack of strong political will to enforce mandatory MEPS and labels (with the resulting business failures/employment issues created by companies who are incapable of producing products meeting MEPS).
- Technology issues: electrical steel sheet import duties* and availability of presses† are challenges for small manufacturers.
- Testing and compliance: lack of testing capacity as there is only one accredited laboratory, the Pakistan Council of Scientific & Industrial Research (PCSIR) laboratory in Lahore, which can conduct 2 to 3 fan tests a day. Given that there are around 1000 models available in the market, it is not feasible to test all models currently on sale taking no account of new annual product launches. The Ministry of Science and Technology recently (early 2022) pledged to improve and upgrade the existing lab at PEFMA Gujrat. This was originally run by Intertek for a few years; however, it has not been functional since 2021.
- Supply chain issues: because of the limited capability of Pakistani industry to locally produce the electronic kits for AC/DC hybrid fans, the industry is dependent on imported parts. The quality of imported electronic kits varies from shipment to shipment, and manufacturers do not have control over the supply chain to resolve quality fluctuation issues.

Options and/or need to modify policy. NEECA announced a mandatory MEPS and labeling scheme in early 2022, but the implementation was deferred to 2024 due to political pressure from the industry association. However, there has been recent momentum and push by the government to roll out mandatory fan MEPS from 1st July 2023‡. If the growth in the AC/DC hybrid fans continues, the market will naturally continue moving towards energy-efficient fans which may result in less resistance from the association towards a mandatory fan policy. Once the mandatory policy comes into force with 1-star MEPS level in 2024 and are fully complied with, further revision of the levels can be considered.

3.3.3 DOMESTIC REFRIGERATION

Local refrigerator manufacturing in Pakistan started back in the 1980s and is now well established, reaching a level of maturity and quality necessary to tap into regional export markets. It contributed about 2.5% to Pakistan's GDP in 2018-19.[56] The main types of refrigerating appliances for domestic use include:

* Custom duty on the import of electric silicon steel sheet

† Machinery to press/bend sheet to make rotor and stator for fan motor

‡ However, it's expected that enforcement will probably begin in 2024

- **Upright refrigerator-freezer or Top freezer, w**ith top compartment serving as a freezer and refrigerator at the bottom. These are the most common refrigerators in Pakistani households.
- **Refrigerator only***,* which are upright single-door refrigerators without a freezer.
- **Bottom freezer refrigerator**, which are similar to the top freezer models but have the freezer located in the bottom compartment while the top compartment is the refrigerator.
- **Side-by-side refrigerator–freezer**, which are vertically oriented two-door models, with the refrigerator and freezer compartments located side by side.
- **French door refrigerator-freezer** (latest trend in refrigerator design), which have two refrigerator doors that open outward, with a split in the middle. The freezer is located in a separate bottom compartment.
- **Deep freezer,**[*] which are horizontal freezers that have a lid that opens from above. These are further divided into two categories: side-by-side horizontal fridge-freezers and horizontal freezers only. Horizontal freezers are also used in commercial retail shops, but for the purpose of this analysis, deep freezers pertain to domestic refrigeration only.

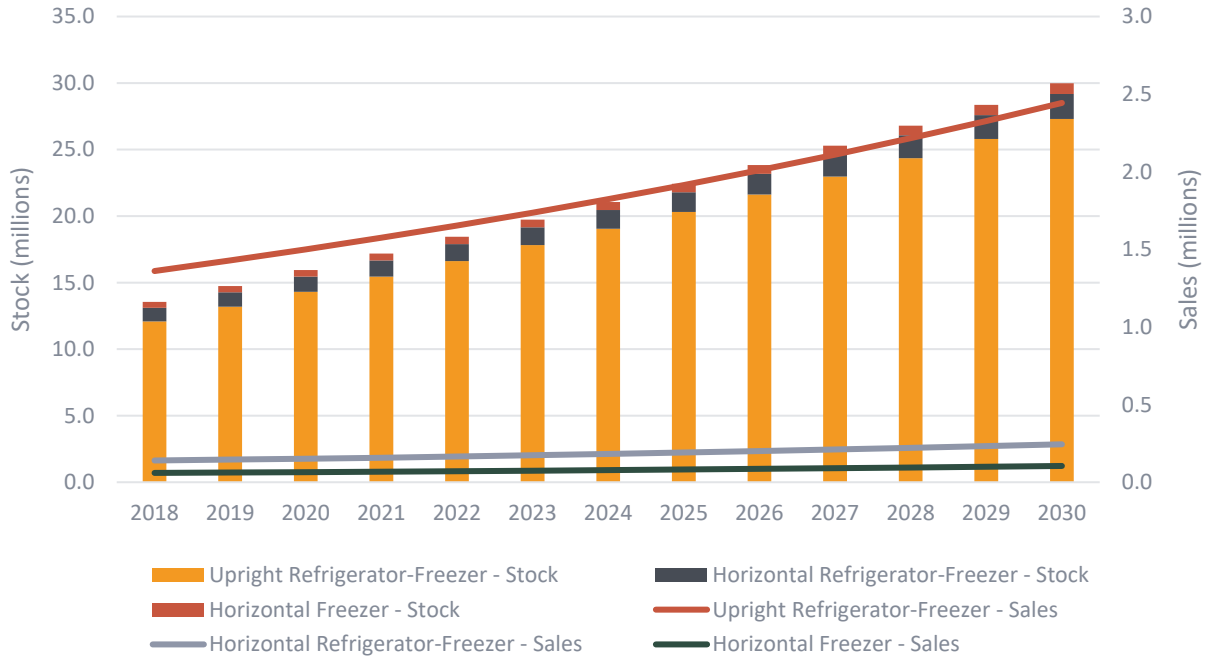
MARKET SIZE AND STOCK. The upright refrigerator-freezer stock was estimated at 16.6 million units in 2022, with top freezer refrigerators being the most common type used in the domestic sector. While there is demand for horizontal refrigerator-freezers and deep freezers, their market is relatively small with a combined estimated 1.8 million units currently installed across the country.[†]

Annual production of refrigerators over the last decade varied from 1 million to 1.8 million, with steady annual growth seen in the early part of the decade driven by an increase in demand because of high rural-urban migration and greater electricity access. Production of deep freezers was about 236,000 units per year in 2022, of which about 70% (165,00 units/year) are horizontal fridge-freezers and 30% (71,000 units/year) are horizontal freezers only. The average life of refrigerators manufactured domestically averages 11 years depending on the type. Production has declined since 2017 due to a general slowdown of the economy and COVID-19's impact on sales during 2020-2021. However, as noted in the air-conditioner section, the growing wealth of sections of society is making appliance ownership more common, and given their critical household function, refrigerators are one of the first appliances purchased, and hence growth is projected to return to 5% for the rest of the decade. Graph 16 shows historic and projected stock until 2030.

[*] These are also commonly referred as chest freezers but for clarity we refer to them in this report as deep freezers.

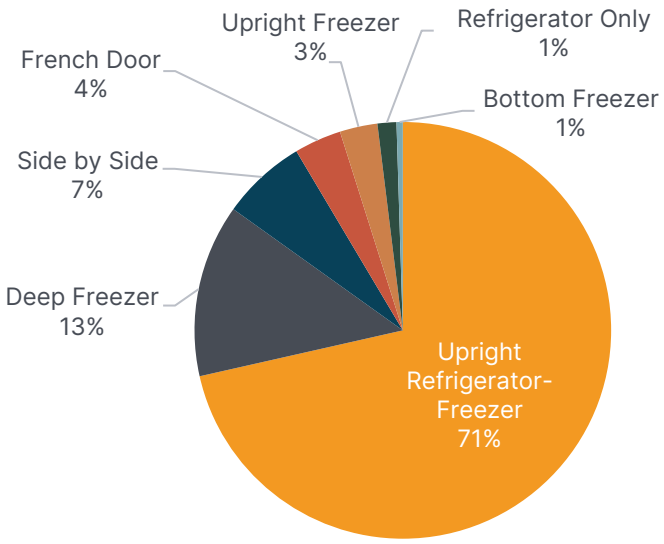
[†] Estimated figure based on SAMA^Verte's consultations with manufacturers.

GRAPH 16: DOMESTIC REFRIGERATION HISTORIC AND PROJECTED STOCK AND SALES



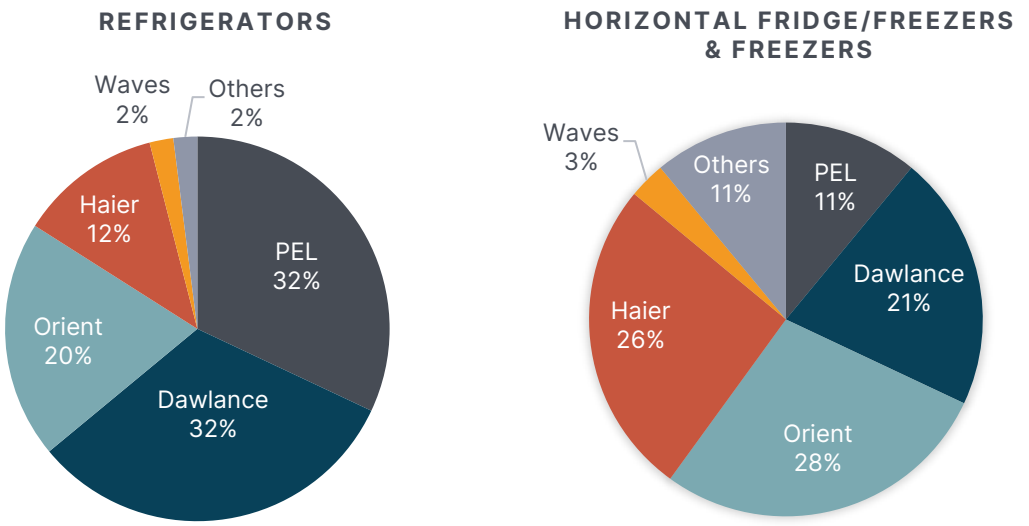
From the SAMA^Verte retail survey, 71% of the products were upright refrigerator-freezer models, 13% were horizontal/deep freezers and the remaining 14% included side-by-side refrigerator-freezer, French door, bottom freezer, upright freezer and refrigerator only (Graph 17).

GRAPH 17: TYPES OF SURVEYED REFRIGERATING APPLIANCES



SUPPLY SIDE. The refrigerator and deep freezer market in Pakistan is dominated by a few large domestic manufacturers; Dawlance (a wholly owned subsidiary of Arcelik, Turkey), PEL, Orient, Waves Singer Limited, and Haier. Collectively they constitute over 98% of refrigerator production and about 89% of local deep freezer manufacturing (Graph 18).

GRAPH 18: APPROXIMATE MARKET SHARE OF LOCAL REFRIGERATOR (LEFT) AND DEEP FREEZER (RIGHT) PRODUCTION (2018)

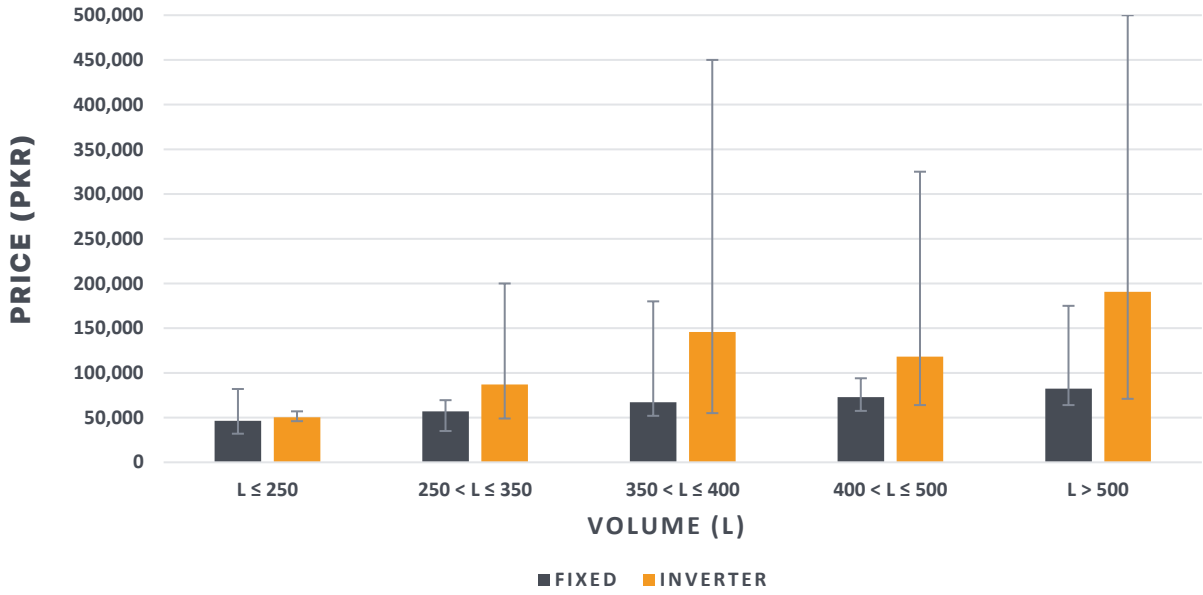


Source: CLASP/SAMA^Verte market analysis[57]

While locally produced refrigerators and deep freezers dominate the market, around 85% of the raw materials required for production are imported.[58] In recent years, manufacturers have been gradually procuring more raw materials locally. Despite the high dependence on imported raw material, Pakistani refrigerators are competitively priced and are generally lower in price than similar products in other countries in the region. The market structure is non-competitive, with few manufacturers that dominate the market offering refrigerators that are similar in specifications and performance.[59.] Manufacturers are operating at an average capacity rate of around 75-80%, which implies that there is capacity to cater to higher demand with likely little impact on price.

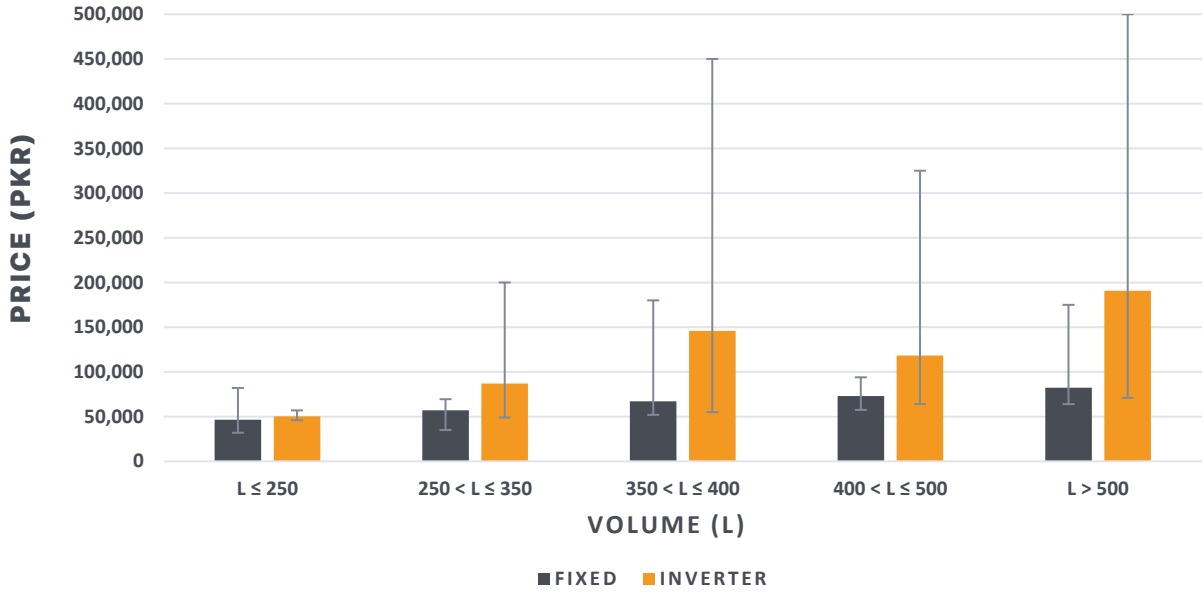
The retail survey findings show prices of refrigerators vary between PKR 41,000 (USD 179) and 500,000 (USD 2,189) and generally increase with storage volume for both inverter and fixed-speed units, as shown in Graph 19.

GRAPH 20: PRICE RANGES FOR DIFFERENT VOLUMES OF REFRIGERATORS CATEGORIZED BY COMPRESSOR TYPE



The average price for inverter units in the 400 L to 500 L category is lower than that of inverter units in the 350 L – 400 L range, which may be due to the latter group including a large proportion of more expensive, imported models.

GRAPH 19: PRICE RANGES FOR DIFFERENT VOLUMES OF REFRIGERATORS CATEGORIZED BY COMPRESSOR TYPE



DEMAND SIDE. Market penetration rate of refrigerators for domestic use is estimated in the range of 57%[60] which indicates a significant untapped potential and scope for market growth. Demand for refrigerators in Pakistan has traditionally been restricted due to various factors including erratic grid power supply, prolonged hours of electricity load shedding, high prices and inefficiency of products consuming more energy and therefore higher operating cost. However, a steady growth rate is projected due to improved

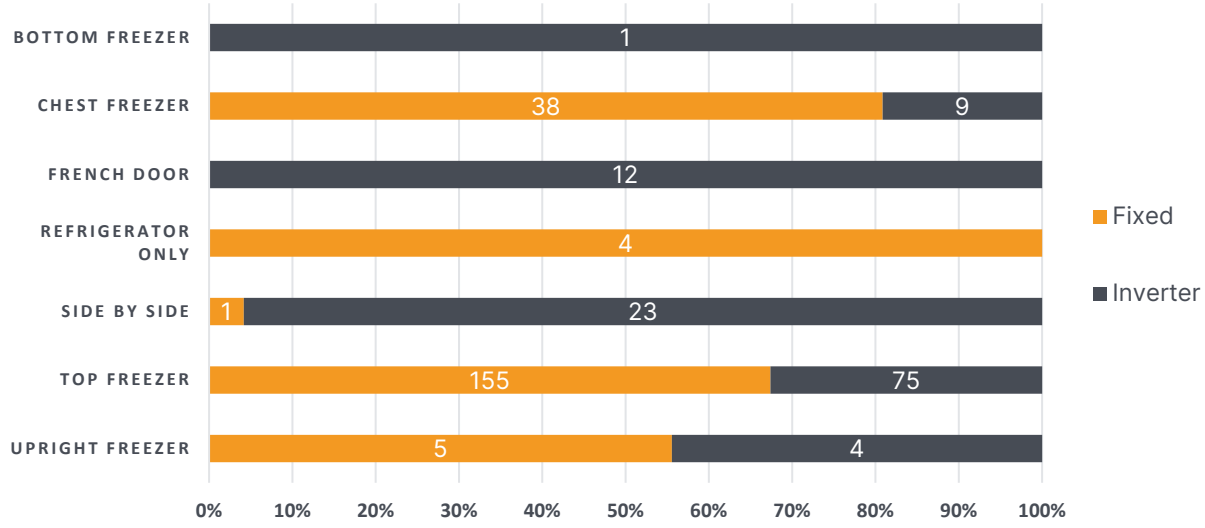
electricity access, increase in urban population, growth in per capita income and increased cooling demand due to climate change.

PRODUCT CHARACTERISTICS. Refrigerator size or capacity ranges from 100 L to over 500 L with 300-400 L upright refrigerator-freezers being the most popular among domestic consumers. The top freezer model captures over 97% of market share of vertical refrigerator-freezers.[61] Consultations with manufacturers indicates that market share of 300-400 L refrigerators has declined from about 44% in 2015 to 37% in 2019, whereas the market share of 200-300 L models has increased slightly. Manufacturers suggest this can be attributed to an increase in prices of the refrigerators.

The refrigerating appliances sold in Pakistan almost exclusively use direct cooling technology (95-98%).[62] Direct cooling refrigerators are preferred as they have lower energy consumption as compared to frost-free models, and in areas with excessive power outages, ice formation in the freezer compartment provides the benefit of longer cooling periods without power. Demand for frost-free refrigerators is very low, roughly estimated at around 15,000–20,000 units per annum, primarily met through imports.[63]

The market has transitioned towards variable speed inverter technology from fixed-speed compressors. Inverter type refrigerators are more energy efficient as the compressor power reacts directly to the specific load. However, unlike the air conditioner market, not all manufacturers have fully transitioned to inverter refrigerators, and fixed-speed models are still being produced and are dominant in sales. Based on the data collected from the retail survey for all domestic refrigerator products, 62% of units were fixed-speed and 38% were inverter. Of the Upright refrigerator-freezers, 67% were fixed-speed and 33% were inverter (Graph 21). In the case of deep freezers, 81% were fixed-speed and 19% were inverters. This indicates that the popular domestic refrigerating appliances still predominantly use the fixed-speed technology. Newer models, on the other hand, (French door and side-by-side refrigerators) mostly have inverter technology.

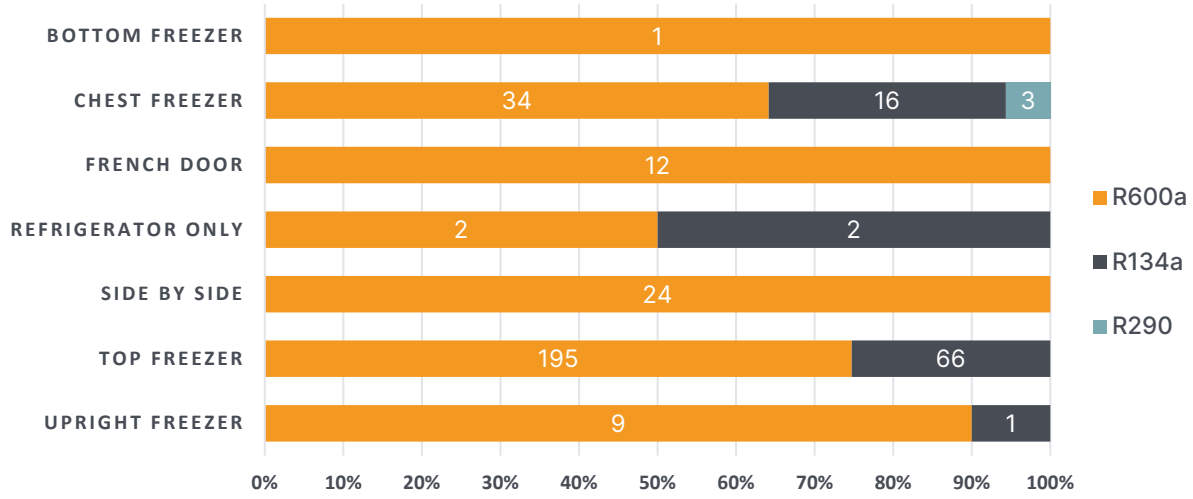
GRAPH 20: COMPRESSOR TECHNOLOGY BY REFRIGERATOR TYPE RETAIL SURVEY



REFRIGERANTS. R-134A (100-year GWP of 1,300) has traditionally been the most commonly used refrigerant by all local manufacturers for domestic refrigerators. Some manufacturers including Haier and Dawlance have fully transitioned to R-600A, while others such as PEL and Waves are still using R-134A, though they have a transition plan in place to shift to R-600a. The transition to R-600A started in 2018, and currently 37% of the new top freezer refrigerator models and 73% of the new horizontal refrigerator models are using R-600A, which is an organic hydrocarbon commonly known as isobutane, with a very low GWP and no ozone depleting properties. R-600a has roughly 0.1% of the GWP of R-134a.[64]

Out of the retail survey sample, 93% of inverter refrigerators and 73% of fixed-speed refrigerators used R-600A, while R-134A was observed in 6% of inverter units and 26% of the fixed-speed units surveyed. The breakdown of refrigerant use by type of refrigerator is demonstrated in Graph 22. About 75% of top freezer models surveyed had R-600A as most of the surveyed units were Haier and Dawlance products that have transitioned most of their products to R-600A. The remaining 25% from other manufacturers were using the traditional R-134A. In the case of chest freezers, about 64% of the surveyed units had R-600A and 3 out of the 53 surveyed deep freezers were using R-290.

GRAPH 21: REFRIGERANT USE BY REFRIGERATOR TYPE



PRODUCT PERFORMANCE. The only source of performance data for refrigerators is from the manufacturers themselves as there is no published data from third party accredited labs in Pakistan. The SAMA^Verte team approached a number of manufacturers to obtain data for the Unit Energy Consumption (UEC) for their most common refrigerator models. Average UECs are summarized in Table 8 and compared to performance values specified in draft MEPS. The current average daily UEC of 400 L refrigerators is about 3.1 kWh/day, which is slightly higher than the level specified in the draft MEPS (2.91 kWh/day).

TABLE 8: REFRIGERATOR PRODUCT PERFORMANCE CLAIMED BY MANUFACTURERS AND IN DRAFT MEPS

	PERFORMANCE PER TESTS CONDUCTED BY PROJECT TEAM	PERFORMANCE SPECIFIED IN DRAFT MEPS
PRODUCT SIZE/CAPACITY	400 Liters	400 Liters
AVERAGE DAILY UEC KWH/DAY	3.1	2.91
AVERAGE ANNUAL UEC KWH/YEAR	1,131.5	1,063

Since labeling requirements for refrigerators are not yet enforced in Pakistan, efficiency rating information was available only for about a quarter of the recorded units from the retail survey, primarily the imported units. Roughly 40% of the units with efficiency rating information have a European Union efficiency rating (old notation: A+++ through D); most (61%) of these units have an A+ rating, 34% have an A++ rating, and only 5% have the highest rating of A+++. Refrigeration equipment larger than 400 L have more high-rated (A++ or A+++) units than equipment at or below 400 L.

REGULATIONS AND CURRENT STATUS. NEECA, with the support of JICA, developed MEPS and the mandatory labeling scheme for domestic refrigerators simultaneously with those for air conditioners in 2021. Similar to the case of air conditioners, the draft MEPS for domestic refrigerators were approved by the government in 2021 and are expected to be implemented in 2023. Key features of the MEPS and labels include:

- The scope: domestic two-door top freezer refrigerators only.
- The MEPS requirement cut-off level is a function of the adjusted volume of refrigerator (Vadj), calculated by adding the volume of each compartment and applying the volume adjustment factor, as per the formula: MEPS cut-off level = 0.576 x Vadj + 420
- The labeling requirement specifies a star rating band ranging from 1 to 5 stars based on comparative energy consumption.
- The testing standards applied are:
  - PS: IEC62552-1/2018 Household Refrigerating Appliances – Characteristics and Test Methods - Part1: General requirements)
  - PS: IEC62552-2/2018 Household Refrigerating Appliances – Characteristics and Test Methods - Part2: Performance requirements)
  - PS: IEC62552-3/2016 Household Refrigerating Appliances – Characteristics and Test Methods - Part3: Energy consumption and volume)

3.3.4 COMMERCIAL REFRIGERATION

In Pakistan, there are four main types of refrigerating appliances used in the commercial sector:

- **Visi Coolers**, which are glass-fronted vertical beverage cooling and display cabinets used to display soft drinks, fruit juices, and milk.* The cabin temperature of these coolers ranges from 0^{o}C-7^{o}C (test method: ISO 22044).
- **Horizontal Beverage Coolers**, which are chest-shaped horizontal cooling cabinets with a cooling function similar to visi coolers but without a display function (test method: ISO 22044).
- **Horizontal Freezers**, which are mostly single-door freezers used by ice cream manufacturers (test method: ISO 22043) and companies selling frozen foods (test method: ISO 23953). This appliance is also used by domestic consumers (deep freezers), but in commercial application, typically a glass top variant of horizontal freezers is used which is reviewed in this section.
- **Horizontal Side-by-side Fridge-Freezers**, which is largely a domestic product (test method: IEC 62552) that is also used by some shops selling yogurt and related products, and by small rural shops where it is used for both commercial and domestic purposes. In this analysis, this product is covered in the domestic refrigeration section.

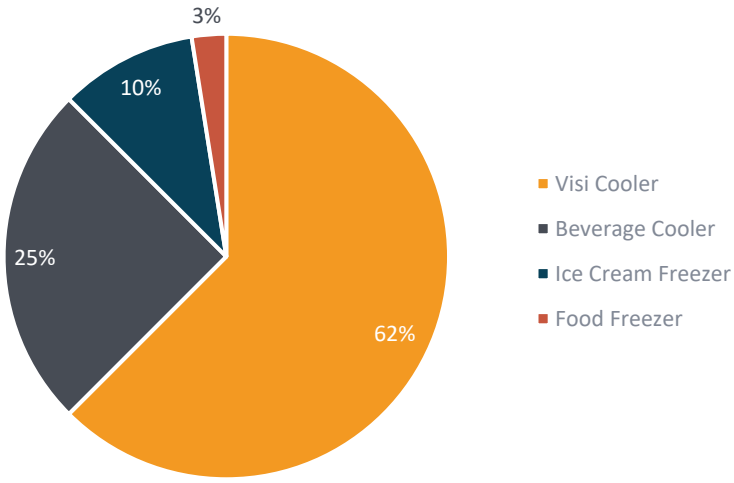
A very small number of larger supermarkets (e.g., Carrefour) located in large cities use remote chiller and freezer units and open display cabinets. However, these have been excluded from the analysis because this type of refrigeration is used in only 40–50 such stores nationwide. All commercial refrigerating appliances covered in this chapter are

* Common types of containers are glass bottles, cans, and plastic bottles for soft drinks and cartons for juices and fresh milk.

stand-alone, plug-in units with integral condensers (remote condenser packaged units are yet to enter the market).

MARKET SIZE AND STOCK. In 2022, the sales of visi coolers were estimated at around 131,000,* with an expected growth rate of 5%. In the same year, around 53,000 units of horizontal beverage coolers were sold with a projected growth rate of 5% per annum. The sales of ice cream freezers and frozen food freezers were lower, at about 21,000 and 5,000 units respectively (Graph 22). However, ice cream freezer and frozen food freezer markets are growing steadily with an expected growth rate of 4–5% per annum (Graph 24).

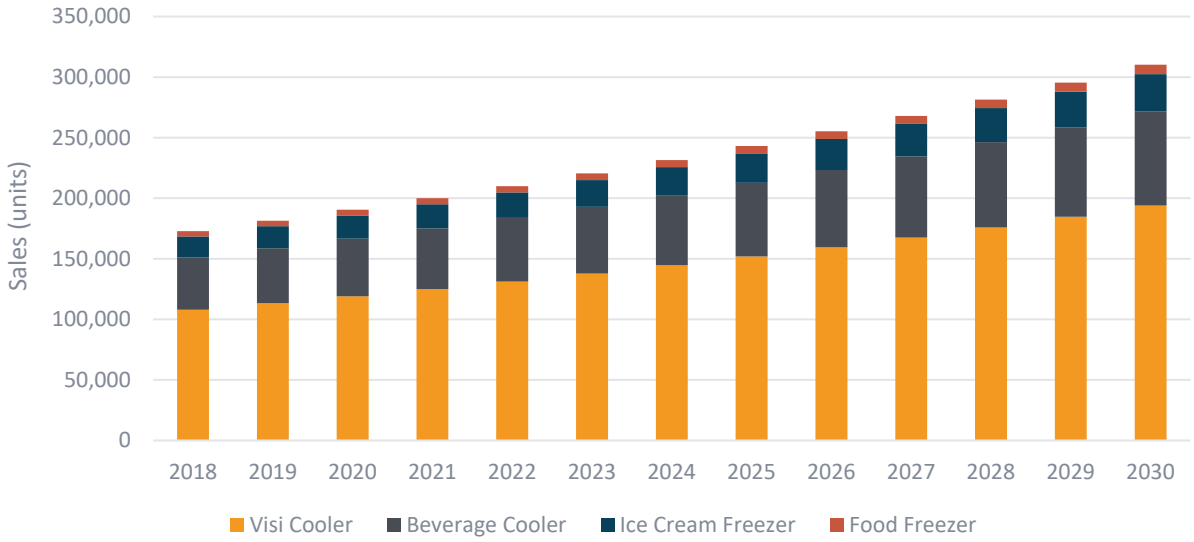
GRAPH 22: MARKET SIZE (SALES, IN UNITS) FOR COMMERCIAL REFRIGERATING APPLIANCES, 2022



During the COVID-19 pandemic (2020–2021), there was a lull in beverage and ice cream sales, but refrigerating appliances continued operating. Beverage, ice cream, and food companies ordered additional refrigerating appliances during the pandemic year despite low food and beverage sales. Their strategy was to have enough coolers/freezers deployed in the market to take advantage of sales growth post-COVID. The market has recovered, and the growth has returned to pre-COVID levels.

* Based on interviews of procurement managers from large beverage companies, frozen food, and ice cream manufacturing companies.

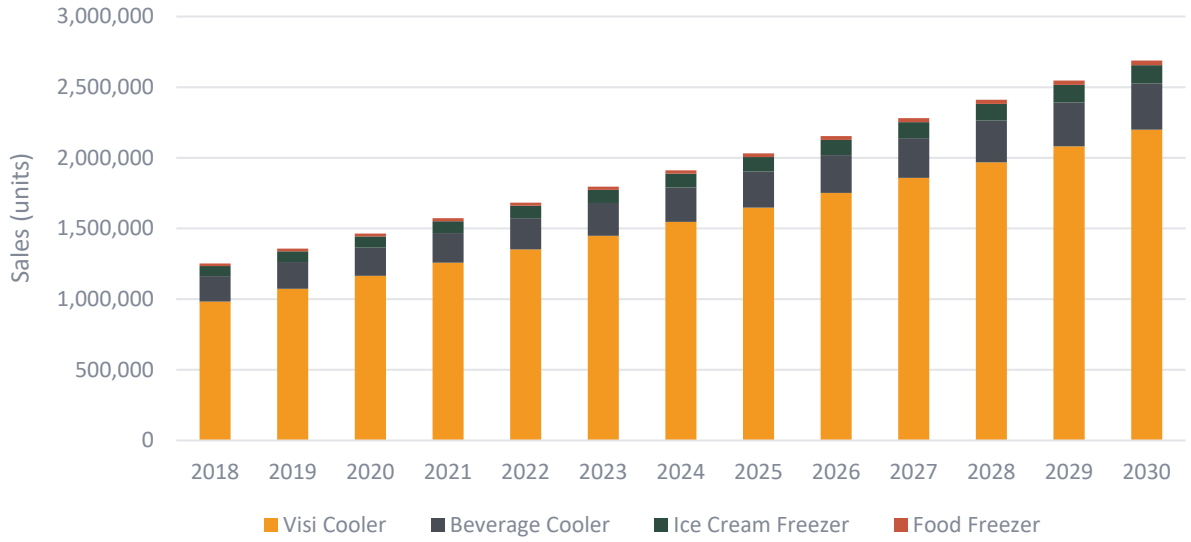
GRAPH 23: HISTORICAL AND PROJECTED SALES OF FOUR REFRIGERATING APPLIANCES, 2018-2030



Graph 24 shows that installed stock in 2022 was around 1.7 million with about 1.4 million visi coolers, over 200,000 horizontal beverage coolers, and about 100,000 horizontal freezers in use. Commercial refrigerating appliances have a relatively short lifetime of 5 years for horizontal beverage coolers and horizontal freezers, and 12 years for visi coolers.

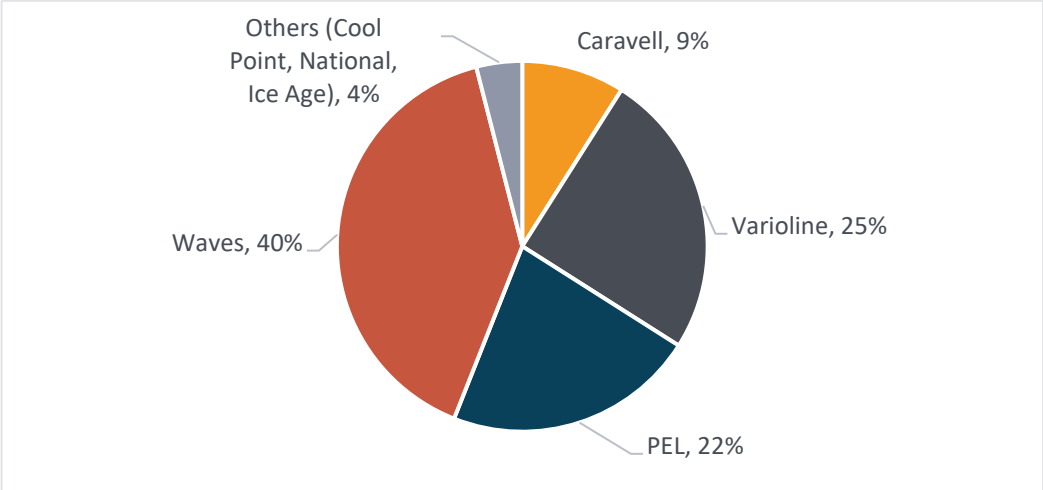
Beverage companies have been pushing for the uptake of visi coolers rather than horizontal beverage cooler as these allow for more brand/beverage visibility and occupy less space. The glass door of the visi coolers also prevents shop owners from misusing the branded appliance by placing food items and drinks from other brands in it. Visi coolers are also more accessible to the consumer and effectively trigger impulse buying, through which most soft drink sales are based in hotter climates. A complete shift from horizontal beverage coolers has not happened yet due to cultural issues. The shopkeepers in mostly rural settings, as well as small corner shops in cities, regularly use the appliance to house miscellaneous items while some use it as the front counter in their small shop. Therefore, despite the desire of beverage manufacturers to phase out the horizontal beverage cooler, many manufacturers believe that it is here to stay and will experience slow growth.

GRAPH 24: COMMERCIAL REFRIGERATORS INSTALLED STOCK 2018-2030



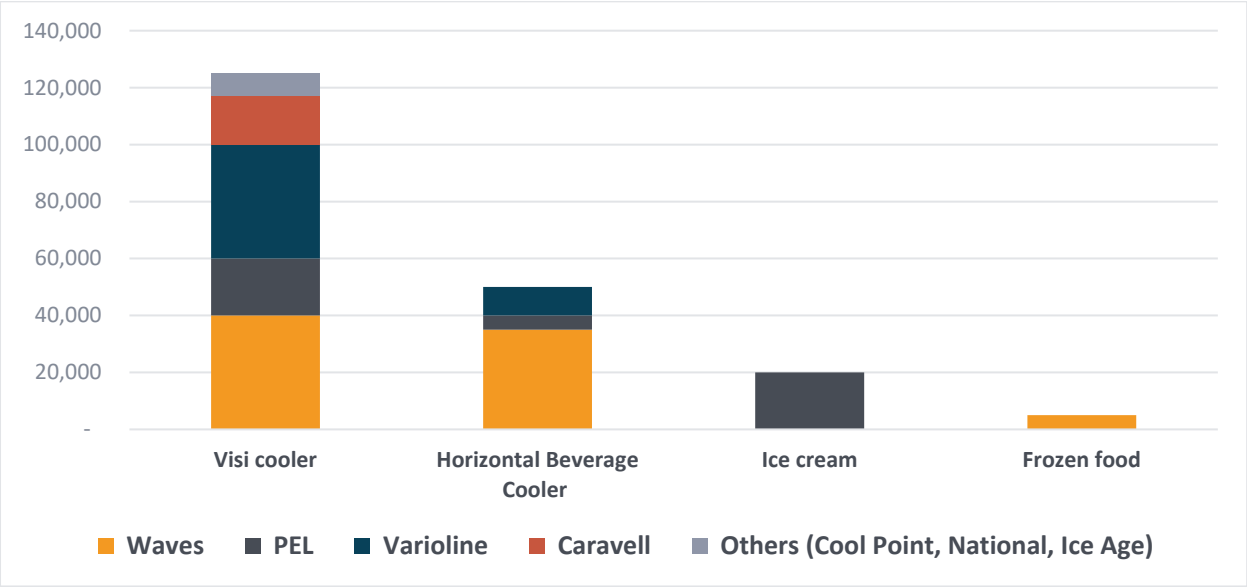
SUPPLY SIDE. All integrated refrigerating cabinets are produced nationally by 6 suppliers. Although it changes every year, approximate market share for 2021 is shown in Graph 25. Waves, Varioline, and PEL have the largest market shares, estimated at 40%, 25%, and 22%, respectively.

GRAPH 25: BRAND MARKET SHARES FOR COMMERCIAL REFRIGERATING APPLIANCES



Six primary manufacturers are engaged in the production of visi coolers. Some of these are relatively small companies like Caravell, National (MEGA), and Ice Age. Large companies such as PEL and Waves, who are leaders in domestic refrigeration, also lead visi cooler manufacturing. The ice cream freezer market is dominated by PEL, whereas the frozen food freezer market is led by Waves. The latter is also the leading visi cooler manufacturer in Pakistan. All current visi cooler manufacturers are based around Lahore. Dawlance (Arçelik) will be the only Karachi-based manufacturer once it starts producing the coolers.

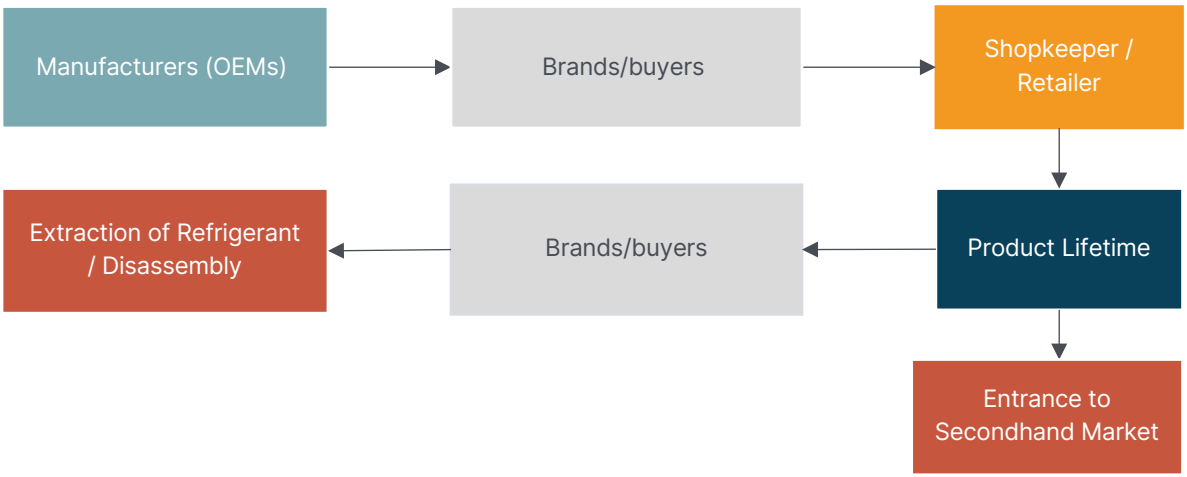
GRAPH 26: BRAND SALES FOR DIFFERENT TYPES OF COMMERCIAL REFRIGERATING APPLIANCES (2021)



Compressors and some critical control equipment (electronics and valves) are imported, mainly from China. Cooler and freezer production is usually based on a semi-automated assembly, but technological advancement is increasing in Pakistan with some components being sourced locally. Manufacturing practices are improving quite fast with Arcelik and Haier operating locally in the market.

The market may be characterized as an oligopolistic market as products are rarely sold directly to end users but rather to large commercial entities which then deploy them to retail outlets around the country. In some cases, the secondhand market also ends up receiving some of these products. During research conducted by SAMA^Verte, it was determined that the stock was larger than the declared sales coupled with lifetime, which points to the possibility of a secondhand market. Some evidence of this was also observed on site. This market, however, is quite fragmented and exists in small pockets, so it has been difficult to track and document.

FIGURE 4: SUPPLY CHAIN FOR COMMERCIAL REFRIGERATION



OPERATING CONDITIONS. Generally, operating conditions for commercial appliances in Pakistan are far from optimal and their handling is rough. These refrigerating appliances are often placed in dusty environments, indoors in corridors and outside in alleyways with temperatures over 40^{o}C. They are often branded, overloaded, and frequently moved around to enhance or decrease visibility based on popularity of the products they display. The hinges on coolers are frequently loosened due to rough use such as, harsh slamming of the doors. As the shop owners do not own the appliances (they are owned by the brand supplying their products), their maintenance is poor, with minimal floor cleaning of horizontal cabinets which results in floor damage in the appliance. The harsh ambient conditions and poor handling leads to shorter lifetimes for these appliances. Servicing of these appliances is rare, and they are only repaired when they stop working. Since the brand owns the appliance, they replace it if it breaks. Brand owners may not be concerned with energy consumption, as electricity costs are borne by the shop owners.

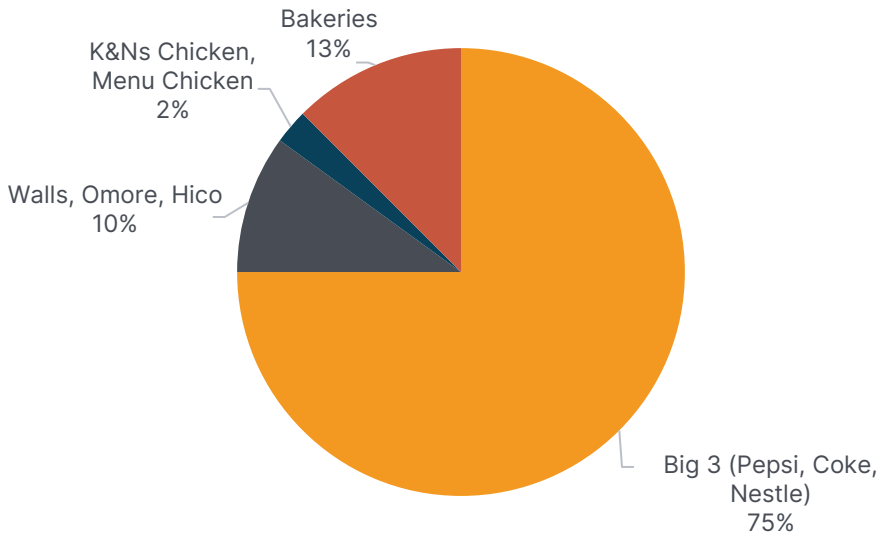
DEMAND SIDE. The demand side for visi coolers and horizontal beverage coolers is dominated by multinational corporations. Over 95% of the appliances are supplied (for first use) by corporations from the primary beverage (Coca-Cola, Pepsi, Nestle) and ice-cream brands (Walls, Omore, Hico). These companies than supply the units to retail outlets for retail storage/display of their products. All multinational corporations buy the appliance per their internationally defined specifications, which have varying degrees of rigidity. Products are normally procured to meet CC2 climate class (32^{o}C)[*] and KK1 (Avg 3.5^{o}C).[†]

The frozen food market is mainly comprised of 4– 5 players retailing frozen chicken products, with the main ones being K&N, Menu Chicken, and Sabroso, whereas the ice cream market is dominated by Walls at almost 60%; the rest of the 40% share is mostly made up of Omore and Hico ice cream brands. Overall, the buying market is dominated by 3 big multinational companies, followed by bakeries and ice cream companies (Graph 27).

[*] Commercial refrigerators are designed to work under certain climate conditions which are rated by climate classes. It indicates the minimum and maximum temperature limits, within which the refrigerators are able to operate effectively.

[†] Storage temperature of cabinet compartment; For KK1 class the average storage temperature is 3.5^{o}C

GRAPH 27: BUYERS OF COMMERCIAL REFRIGERATING APPLIANCES (2022)



RETAILERS. A large number of small, independent retailers operate across the country, which are typically 7-11 style multiproduct shops. There are also formal stores that are a part of a network or chain of stores dotted around cities, as well as corner shops. It is estimated that in large urban centers, there is a retailer for every 500 individuals. The vast majority of these retailers have one or two beverage cabinets (vertical and/or horizontal), which are often also used to store other items susceptible to temperature (e.g., dairy, chocolate). A smaller number of shops also have horizontal ice cream freezers and even fewer have horizontal or vertical glass-topped frozen food cabinets. A few chain outlets, which typically sell raw or preprocessed meat products, have multiple freezer units. Similarly, a small number of (typically) chain bakery outlets use chilled open horizontal and vertical display cabinets. The appliances are primarily located inside the store, but a number (about 20%) are placed outdoors, often in full sun for promotional purposes or, more often, due to the limited space inside the shop.

As the vast majority of appliances are supplied directly by the large beverage and ice-cream brands, the store owner has little control over the product provided and the associated energy consumption. However, shop owners are acutely aware of the high energy consumption of the units and often employ mitigation strategies to reduce consumption such as turning units off overnight or during peak hours in the evening. This allows thermal mass to limit excessive temperature rises, with “on” periods used to pull down the temperature of newly added products.

PRODUCT CHARACTERISTICS. As shown in Table 9, the most common size for all commercial refrigeration products is 400 L. Visi coolers range in size from 250–1000 L, and all horizontal coolers and freezers have a smaller range of 250–550 L. Estimated product lifetimes are 12 years for visi coolers and 5 years for horizontal coolers and freezers.

TABLE 9: TYPICAL REFRIGERATING APPLIANCE VOLUMES AND LIFETIMES

TYPE OF APPLIANCE	MIN VOLUME (L)	MAX VOLUME (L)	MOST COMMON (L)	LIFETIME (YEARS)
Visi Cooler	250	1000	400	12
Horizontal Beverage Cooler, Ice Cream Freezer, Frozen Food Freezer	250	550	400	5

REFRIGERANTS. The visi beverage coolers and ice cream freezers, which form the bulk of the commercial cooling market, are rapidly transitioning from R-134A to R-290 refrigerant. In 2022, almost 70% of newly produced visi coolers, 75% new beverage coolers and 100% new ice cream freezers used R-290[65]. As the stock life is 5–12 years and as more and more manufacturers shift to R-290, a complete transition is expected to take place within the next decade. However, currently the majority of the stock (visi coolers and freezers) still uses R-134A refrigerant.

PRODUCT PERFORMANCE. There is very limited performance data available across refrigerating appliance groups, as Pakistan currently has only one accredited test lab for refrigerators/freezers. To obtain performance data, we tested a select number of products in the accredited test lab, with additional tests conducted in operational settings by affixing test meters on appliances in real market conditions.

Initially, the energy consumption by the most common visi cooler, a 400 L unit, was estimated to be 5.84 kWh per day after testing in simulated lab conditions. This was confirmed by lab results from a government and a manufacturer's lab which produced consumption results of 6.00 kWh and 5.95 kWh per day respectively. The horizontal beverage cooler energy use estimate is 6 kWh per day, which is yet to be confirmed through laboratory testing. Test UEC values were observed to be much lower than those running in the market as there were no door openings during the test, machines were brand new, and ambient temperature was maintained at the CC2 level (Table 10). In-situ testing conditions with loaded refrigerators yielded energy consumption values that were much higher, as they often operate above average ambient temperatures. Secondly, frequent door opening (often above once per minute) play a big role in the energy consumption being high under field conditions.

TABLE 10: COOLER AND FREEZER TESTING RESULTS FROM LABS AND SAMA^VERTE IN-HOUSE TESTING

TYPE OF CABINET	TESTING AT NATIONAL LAB KWH/DAY	TESTING WITH EFERGY (IN-HOUSE) KWH/DAY	IN-SITU TESTING AT SHOPS KWH/DAY
Visi Cooler	6	7	12
Horizontal Beverage Cooler	-	6	11-12
Chest Freezer (ice cream and frozen food)	2.83	2.25	4-6

Consumption at some stores was observed to be unusually low despite high ambient temperature, rough usage, veranda and corridor placements, and frequent door openings. This was mainly due to the way shop owners managed the units by switching them off for some time during peak tariff hours or when the store was closed.

Typical temperatures which various types of cabinets are expected to operate are shown in Table 11.

TABLE 11: TYPICAL OPERATION TEMPERATURES FOR REFRIGERATING APPLIANCES

TYPE OF APPLIANCE	STORAGE TEMP (°C)
Visi Cooler	0-7
Horizontal Beverage Cooler	0-7
Ice Cream Freezer	-28
Frozen Food Freezer	-18

REGULATIONS AND CURRENT STATUS. Mandatory regulation (MEPS and labels) for visi coolers has been developed by CLASP and SAMA^Verte and is pending approvals by PSQCA and NEECA. Regulations for three types of horizontal cooling chest cabinets have also been developed by CLASP and SAMA^Verte and submitted to PSQCA and NEECA for approval. In all cases, these regulations have increasing defined increases in stringency over time. MEPS for ice cream freezers and food freezers have not yet been prioritized for development due to their smaller numbers in comparison to domestic products.

Summary details of the regulation for visi coolers and horizontal beverage coolers are as follows:

- *The scope:* integral vertical commercial beverage coolers between 0.5m and 2.2m in height and horizontal commercial beverage coolers of all sizes
- *MEPS* set at EEI max 100 through 31 December 2024 and at EEI max 80 from 1 January 2025
- Reference standard:
  - ISO 22044:2021: Commercial Beverage Coolers - Classification, requirements, and test conditions

NEECA plans to take all the cooling cabinets regulations to the federal cabinet for final approval. However, this is likely to be somewhat delayed as the Pakistan's regulator is still struggling with the rollout of the online registration system to register regulated products for which policy work is already in place. Lack of high-quality accredited test labs also hinders policy implementation.

MARKET READINESS TO ADOPT REGULATIONS. Given the limited number of suppliers, oligopolistic purchasers (with global sustainability objectives), and other smaller users, regulatory intervention to improve efficiency should be relatively easy to implement once NEECA has the right infrastructure in place and approvals received.

OPTIONS AND/OR NEED TO MODIFY POLICY. MEPS and labels for visi coolers and horizontal chest coolers were finalized in 2022 and recommend incremental increase in levels periodically as part of the regulations. As such, no upgrade or modification of MEPS and label policy is warranted for these products.

3.3.5 COLD STORAGE AND COLD CHAIN

Cold chain is a low-temperature controlled supply chain network for perishable products that need refrigerated temperatures to maintain quality and safety from point of production to point of consumption. There is very little data available on the cold chain applications in Pakistan, therefore, in this report we provide only a brief overview of this sector.

AGRICULTURAL PRODUCE AND FOOD COLD CHAINS. The process in Pakistan for perishable food items typically comprises of cold storage, transportation (reefer or refrigerated containers), and ripening chambers (for some fruits).

The concept of cold chain in Pakistan is not fully understood, and services are provided in parts rather than as a whole chain. People who accept a certain level of food loss as normal would require a change of mindset to understand that the cold chain needs to start as soon as possible after harvest and continue without a break throughout cooling, storage, grading, transport, and finally to the foodservice or retail outlet.[66]

Cold storage capacity for post-harvest food storage in Pakistan is estimated at around 6% and mostly concentrated in Punjab (over 95%) and other main cities and potato growing areas.[67] Most of these cold storage facilities for fresh produce were constructed at the lowest capital cost possible, using energy inefficient compressors with no backup from generators and insulation, and degrading with age, incurring heavy losses. An estimated 30–40% of the total fruit and vegetable produce is wasted, in part, due to inadequate cold chain infrastructure in Pakistan.[68] Overall food loss in Pakistan is estimated at 50-60 kg per capita, which is amongst the highest in the world.[69]

Challenges and Constraints in Pakistan's Cold Storage Sector

- Losses up to 30-40% in post-harvest processing are considered acceptable and do not drive the demand for increase in cold storage capacity
- Lack of awareness and limited appreciation of factors affecting the stability of perishables (temperature, handling, hygiene, humidity)
- Misconceptions and lack of awareness of start-to-end cold chains, resulting in fragmented cold storage applications
- Lack of technological advancements, and limited services providers
- Lack of expertise for operation and maintenance of cold chain facilities
- Low electricity access and frequent power cuts limit the viability of investing in cold storage infrastructure

One of the main factors for setting up cold storage is economic viability. For example, in the case of potatoes, setting up a cold storage infrastructure would drive up the cost of potatoes which makes it uncompetitive as the main variety grown in Pakistan is not considered of high value. Thus, investment in high end storage facilities is not a feasible venture for potatoes and instead traditional methods of underground storage prevail.

The cold storage construction and infrastructure market is dominated by a single company "Koldkraft" that has been operating in the sector for over 3 decades (estimated 80% market share). They are manufacturing Polyutherane (PU)/polyisocyanurate (PIR) insulation panels which provide -40°C cold storage, as well as reefer containers and cold storage specialized equipment for a variety of products. There are other companies which provide similar services but are new entrants in in this sector and as yet have a small market share.

FISH AND AQUACULTURE COLD CHAIN

The World Bank conducted a study titled *Pakistan's resource efficient fish and aquaculture cold chain* as part of its initiative to advance a blue economy agenda for sustainable growth in Pakistan. The study, completed in May 2023, analyzes the fish value chain in Pakistan and proposes recommendations for energy efficiency and climate friendly solutions to improve the cold storage infrastructure and reduce losses. The scope of the study includes identifying market barriers, policy and regulatory issues and providing recommendations in line with the objective of Pakistan's National Food Security Policy, the 2021 revised NDCs, as well as aligning with the Kigali implementation plan for HFC phase-down.

The study estimates 15-35% losses in fisheries sector due to inadequate cold chain infrastructure and lack of awareness on benefits and availability of cold storage technologies. Existing cold storage for fish products relies almost exclusively on ice blocks. Use of mechanical refrigeration systems such as cold stores or refrigerators, is very limited and only observed in conjunction with fish export (25% of the catch is exported, the remaining 75% consumed locally). The study finds that there is no refrigeration system used on board fishing vessels. Refrigerated transport for fish products is also almost non-existent, the catch is typically transported openly from source until it reaches distribution centers or stores. Use of reefer trucks and refrigerated containers is mainly observed for processed export products. At the end of the supply chain, barring a few large supermarkets, the fish products are simply displayed for sale openly or on ice, which is inadequate for their preservation.

The high energy use and emissions from the fisheries sector is attributed to inefficiencies in the block ice plants. There are about 4,000 ice block plants in Pakistan that are highly inefficient, using outdated technology under unhygienic conditions. The refrigerant typically used in block ice plants is ammonia, which has a low GWP so does not have high direct emission contribution. However, the energy use in these plants is very high since the equipment used works at full capacity irrespective of refrigeration load. The study included site assessment of 82 block ice plants and concluded that on average, these plants only operate at about 20% capacity. The overcapacity of these plants further contributes to energy waste. The study finds that 17,000 to 39,000 tonnes of CO_2e can be reduced through energy efficiency improvements in fish processing plants while a further 320,000 to 952,000 tonnes of CO_2e emissions can be reduced through energy efficient refrigeration in the ice block plants.

Some of the recommendations for technological improvements provided by the study include:

- Use of variable speed drives as to improve energy efficiency of existing ice block plants
- Facilitate transition from use of ice blocks to refrigerated equipment
- Use of wall insulation inside cold stores
- Renovating vessels by adding on board refrigeration equipment
- Introducing use of refrigerated trucks and reefers for inland transport
- Introducing appropriate commercial refrigeration technologies

The main form of cold storage used in Pakistan is refrigerated transportation which transports the goods in reefer containers from the ports to various destinations inland or from main production centers to different cities. The main products that are transported include ice cream, meat, fruits, and vegetables.

There are no standards or regulations for the cold chain market, except for the pharmaceutical sector. For example, in the dairy sector, a key requirement before transportation is minimum pasteurization and storage at 4ºC. The Punjab government drafted a minimum pasteurization law, but it could not be passed due to vested interests such as opposition from 'gawalas' who are sellers of unpackaged and unprocessed milk, and other challenges. Currently, packaged milk only captures about 5% (2.5 million tonnes)[*] of the total dairy market of 50 million tonnes.[†]

PHARMACEUTICAL COLD CHAINS. A cold chain for the storage and transportation of temperature-controlled medicines and vaccines exists as the pharmaceutical sector is heavily regulated by Drug Regulatory Authority Pakistan (DRAP). The authority regularly visits storage facilities and checks the transportation containers to ensure that the cold chain process is being maintained.

REFRIGERANTS. Refrigerants used in cold storage applications include both fluorinated and natural refrigerants. Fluorinated refrigerants commonly used are R-134a, R-404A, R-407, and R-410A, whereas natural refrigerants include ammonia, carbon dioxide, and other hydrocarbons. Ammonia is the most common refrigerant used in cold storages in Pakistan, and there is no immediate phaseout plan for it. Fluorinated refrigerants including R-134a and R-410A have a phaseout plan in line with the Kigali Amendment.

3.3.6 COOLING SUPPORT SERVICES AND INDUSTRIES

It is important to consider the composition and capacity of the service industry when projecting the growth of the cooling sectors. Manufacturers of refrigerators, air conditioners, and fans typically provide after-sales support for servicing and maintenance of their products. However, their geographic outreach is limited, and most consumers consider the service charges high. A large informal servicing market has evolved, mostly comprising of untrained technicians providing repair and maintenance services for the appliances. Most technicians do not possess the requisite knowledge, skillset, and equipment for servicing and maintaining cooling appliances such as air conditioners and refrigerators.

This lack of capacity is also a major contributing factor for direct emissions from the cooling sector. Because technicians are not equipped with the right tools, quite often refrigerants are released into the atmosphere when air conditioners and refrigerators are being serviced. There are currently no standards or regulations for capturing refrigerants at end of product life. Consequently, all refrigerants in air conditioners and refrigerators

[*] Pakistan Cold Chain Development Company

[†] Trade Development Authority Pakistan 2022

are leaked into the atmosphere when these products are discarded. Furthermore, the training facilities for disseminating knowledge and educating the servicing sector on handling of new refrigerants are limited. This has also created safety risks because, unlike traditionally used refrigerants like R-134A and R-410A, new refrigerants such as R-32, R-600A, and R-290 are highly flammable. Inclusivity of the servicing sector is therefore an important factor to consider in the phaseout and transition plan for refrigerants.

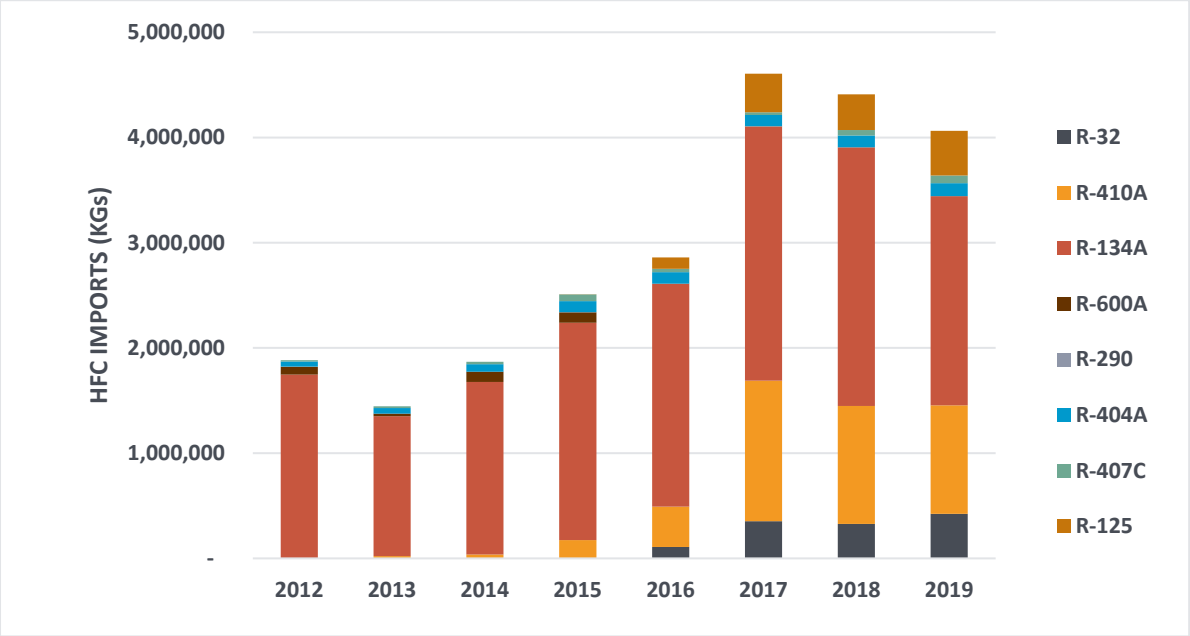
In addition to domestic air conditioners, refrigerators, and fans, the servicing sector also provides services for cold chains; commercial and industrial cooling including construction, repair, and maintenance of cold stores; refrigerated transport; and controlled atmosphere stores. Because the demand for cold chains is low, there are very few qualified companies or individuals offering these services.

3.3.7 REFRIGERANTS

Pakistan imports all refrigerants used in the cooling sector. There are several refrigerant importing companies who forward the fluids to distributors, refrigeration component stores, the retail market, or in some cases, directly to companies operating in the maintenance and technical servicing sector. Graph 28 presents the HFC and hydrocarbon (HC) refrigerants imports in Pakistan.

The most common refrigerant in air conditioners is R-410A, though some manufacturers have switched to R-32, which has a lower GWP. For refrigerators, while the lower-GWP R-600A has been adopted by most manufacturers, R-134A is still being used by some of the industry, but there is a transition plan in place to adopt R-600A in the next few years while some companies have shifted to the more climate friendly R-290 in manufacturing of deep freezers. Graph 28 from a UNDP study shows the import of low GWP refrigerants such as R-600A and R-290 was negligible until 2019, while R-32 gradually increased from 2017 to 2019. However, with most manufacturers now transitioning to these refrigerants, data from 2020 onwards (when available) is expected to show higher volumes of lower GWP refrigerant import.

GRAPH 28: PAKISTAN HFC IMPORTS 2012-2019 (UNDP)



3.3.8 OFF-GRID COOLING APPLIANCES

3.3.8.1 DC ELECTRIC FANS

This section covers DC electric fans, as AC and AC/DC hybrid fans have been covered in Section 3.3.2. There are three main types of DC fans found in Pakistani markets:

- Stand fan or pedestal fan,
- Ceiling fan, and
- Table fan

DC motor technology, which uses permanent magnet (brushless) motors, is more efficient than AC motor technology, which uses conventional motors.* In recent years, DC fans have gained market share in Pakistan, mainly due to their use in off-grid and weak-grid areas. There are a number of contributing factors that favor the adoption of DC fans. In particular:

- *The off-grid and weak-grid population* in Pakistan remains significant, relying on backup power due to lack of availability of utility power. Only 74% of the population is connected to the electricity grid in Pakistan.[70]
- *Climate change* is creating unprecedented heat waves in the country, affecting most of the off-grid and weak-grid populations mentioned above.
- *Solar solutions* are now more affordable due to reduced prices of solar panels globally. The GOGLA 2018[71] off-grid market survey noted that Pakistan imported about 4.7 million solar panels in the price range of USD 10-150 per watt, which corresponds to small scale solar solutions. In 2021, it was estimated that around 20% of rural households[72] had a solar solution, which translated to around 22 million installed units.

* Appliances using permanent magnet motors use between 22-42% less energy than those using conventional motors; https://efficiencyforaccess.org/publications/the-benefits-of-permanent-magnet-motors

The SAMA^Verte field survey, as well as key stakeholder consultations, concluded that almost all off-grid households have some sort of off-grid solution such as DC fan and associated solar panels. According to the survey, 74% of households had a 150-watt solar panel, while the remaining households had solar panels with higher wattage, going up to a maximum of 330-watt rating.

The SAMA^Verte field study found that the main appliance used to relieve heat stress in rural communities is the DC pedestal fan, which runs on solar panels and/or batteries. This section will thus focus on understanding the existing use of these fans, and associated energy performance and procurement standards.

MARKET CHARACTERISTICS AND STOCK. According to PEFMA, there are around 150 manufacturers of DC fans in Pakistan, which collectively produced 2 million units in 2021. Out of these, about 90% were AC/DC hybrid fans and the remaining 10% were DC fans (about 200,000 units in 2021). [73]

Formal sector DC fan manufacturing in Pakistan began in 2013. Based on available production figures, an estimated 200,000 DC fans are sold through the 'formal' market in Pakistan annually. There are also a large number 'informal' manufacturers in the country, but there is no accurate estimate available for the number of fans produced or sold by the informal market. However, according to stakeholder consultations, the size of informal market may be three to four times that of the 'formal' market.

According to the retail and household surveys conducted for the Cooling Needs Assessment, the most popular fan model is the 18-inch DC pedestal fan. It is operated by directly connecting to a solar PV panel.

SUPPLY SIDE. The 150 DC fan manufacturers in Pakistan include the companies registered with PEFMA and are part of the 'formal' market. The well-known DC-only fans manufacturers include large companies that also manufacture AC fans including G.F.C., Royal Fans, Super Asia, and Pak Fans as well as some smaller companies that specialize in DC and AC/DC, hybrid fans such as Khurshid Fans, Tamoor Fans, Starco, Belvin and Harness Energy. According to recent stakeholder consultation*, large manufacturers have restricted the sale of DC only fans in the open market and produce only on bulk orders. This indicates that while there is a large market of DC fans, it is mostly being served through the informal sector for households buying from the market directly.

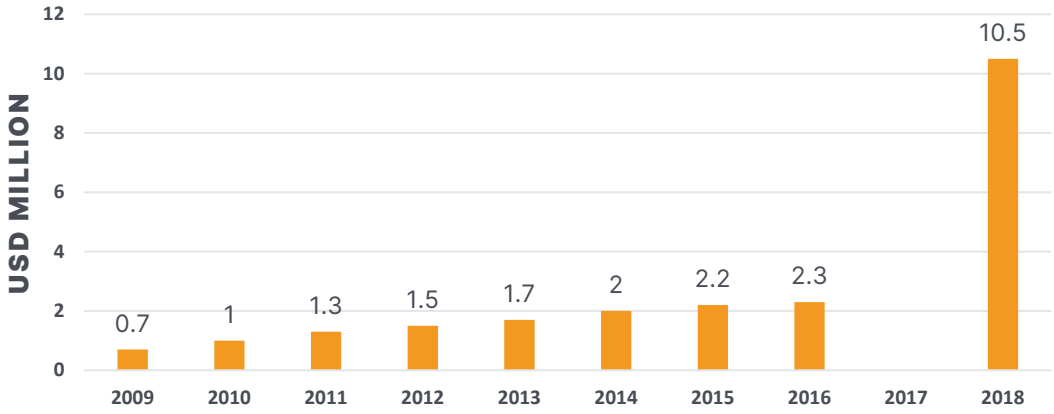
The number and names of small manufacturers who form the 'informal' market is difficult to identify, as these fan producers don't have registered addresses and include those operating in and near off-grid areas where they assemble and sell fans within their shops. Fans produced by these informal manufacturers are typically sold without any product labels, packaging or printed information regarding the fan's specifications and performance. From the SAMA^Verte market survey, it was observed that in Lahore, DC

* PCAP Stakeholder Workshop 2023

fans were not available off-the-shelf, though shopkeepers said they could be arranged. In the Multan market, DC and AC/DC hybrid fans were more readily available, though the more popular or recognized brands were not found.* A wide range of DC fans, mostly produced by the informal sector, were available in the rural markets surveyed around Sukkur as they were located in or around off-grid communities where demand is highest for these fans.

The Brushless DC Motor (BLDC) and electronic kit have until recently been imported from China for the production of both AC/DC hybrid and DC-only fans.[74] The steady increase in imports of the small DC motors over the past eight years, with a jump in 2018 as shown in Figure 5, also indicates increasing sales of DC motor fans. Since early 2022 some of the manufacturers have started producing DC motors in Pakistan, but all the magnets are still being imported from China. There is no import data available after 2018 to determine recent market trend. However, stakeholder consultations indicated that many large DC fan manufacturers have halted production of DC only fans (apart from bulk orders) and have mostly shifted their production towards AC/DC hybrid fans. Further feedback from various stakeholders and from observations through the SAMA^Verte field survey indicates that the demand for DC only fans in the off-grid market is still quite substantial. As branded, good quality DC fans supply in the market has been scaled back, most of the current demand is being met through inefficient fans produced by the informal sector.

FIGURE 5: DC MOTOR IMPORTS FROM CHINA 2009 - 2018

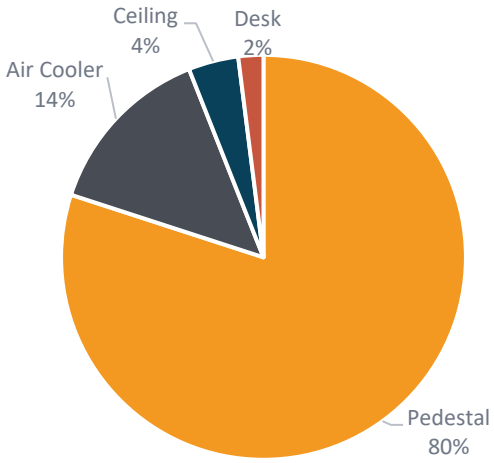


Note: no data on imports in 2017

DEMAND SIDE. All households surveyed as part of CNA were using DC cooling appliances, with a majority of households (80%) owning a DC pedestal fan as shown in Graph 29. All households surveyed reported operating fans only during daytime when sunlight was available by directly plugging the DC fans with a solar panel. The survey did not report any households that use batteries to run the fans during the night.

* Market visits were conducted in the markets of Lahore, the capital of Punjab, and Multan, a town in the south of Punjab, closer to the off-grid, weak-grid areas.

GRAPH 29: DC FANS BY TYPE FROM SAMA^VERTE FIELD SURVEY



On average, households reported paying PKR 3,750 for the DC 18-inch pedestal fan, with the most expensive reported as costing PKR 8,000. The 20-inch DC pedestal fan prices were in the range of PKR 5500 – 6000.

FUTURE PROSPECTS FOR DC FAN SALES. Due to limited data availability and most of the demand met by the informal sector, it is difficult to accurately project growth of the DC fans market. DC fans produced by recognized manufacturers are primarily produced only for bulk orders received through off-grid energy access programs. Some of these programs include:

- Pakistan Microfinance Investment Company (PMIC) and German Development Bank (KfW) renewable energy initiative through microfinance (PRIME), 2019 – 2025. The program launched in August 2019 with a target to provide 200,000 households with high quality Solar Home Solutions (SHS). To date, approximately 20% of the target has been achieved according to PMIC. The program design includes specifications for DC fans. Each SHS must include a DC pedestal, table or ceiling fan capable of running for at least 8 hours per day (when used in combination with lighting and smartphone charging). Minimum air delivery rates specified for each type of DC fan are Pedestal: 50 m3/min; Table: 30 m3/min; Ceiling: 200 m3/min. To qualify, DC fans must undergo the following tests to evaluate product performance:
    - A procedure to measure air delivery, power input, and energy efficiency value adapted from IEC 60879:1986: Performance and Construction of Electric Circulating Fans and Regulators;
    - A procedure for evaluating drop resistance and physical ingress protection adapted from IEC TS 62257-9-5:2018: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-6: Integrated system – Selection of stand-alone lighting kits for rural electrification;
    - A procedure for inspecting fan blades and guards adapted from IEC 60335-2-80: Household and similar electrical appliances. Safety. Particular requirements for fans.

- Sindh Solar Energy Project (SSEP), 2018 – 2023. With a total budget of around USD 30 million, the project aims to provide solar home systems (SHS) with DC fans to about 1.2 million people (200,000 houses) in underprivileged areas of Sindh. The program specifies requirements for lighting, ventilation (air circulation) and mobile phone charging, at a minimum. The minimum system requirements for DC fans are as follows:
    - System includes at least one DC fan (table, pedestal or ceiling) that has a metal body and base.
    - After one day of solar charging, the system is capable of powering, including a DC fan for at least 8 hours per day.
    - Minimum service value for DC fans: Pedestal: 2.27 m3/min/W +/- 5percent, Table: 2.8 m3/min/W +/- 5percent, Ceiling: 6.66 m3/min/W +/- 5percent (when used in combination with lighting and smartphone charging)
    - The minimum warranty period from the time of purchase by the end-user is at least 2 years for all lighting appliances that include their own batteries (including pico-power lights), all non-lighting appliances such as DC fans.
- Pakhtunkhwa Energy Development Organization (PEDO) Solar Home Systems project, Phase 1 and 2, 2014 – 2025. The provincial government of Khyber Pakhtunkhwa is undertaking a SHS project for rural communities that include DC fans. Procurement specifications for DC fans as part of the project include:
    - DC Ceiling Fans: 48-inch size with maximum power rating of 36 W and air delivery of 9.54 m^3/min/Watt
    - DC Pedestal Fans: 18-inch size with maximum power rating of 30 W and air delivery of 5.22 m^3/min/Watt
- Southern Punjab Poverty Alleviation Project (SPPAP), 2013 – 2028. The project aims to provide 5087 Solar Home Systems (SHS) along with DC fans in villages of Muzaffargarh, D.G. Khan, Rajanpur, Bahawalpur, Bahawalnagar, Khushab, Bhakkar, Mianwali, R.Y. Khan, Layyah. The project was initiated in 2013 and is expected to complete its target by 2023. After this, a next phase aims to target another 3000 houses in the same areas from 2023 to 2028. The SHS will provide LED bulbs, DC fans & mobile charging facility in each house. The program provides procurement specifications for ceiling DC fans only which include a maximum power rating of 35 Watts and air delivery of 1200 m^3/min.

Collectively these projects aim to provide DC fans to over 2.5 million people living in rural communities. An estimated 350,000 people have been reached to date.

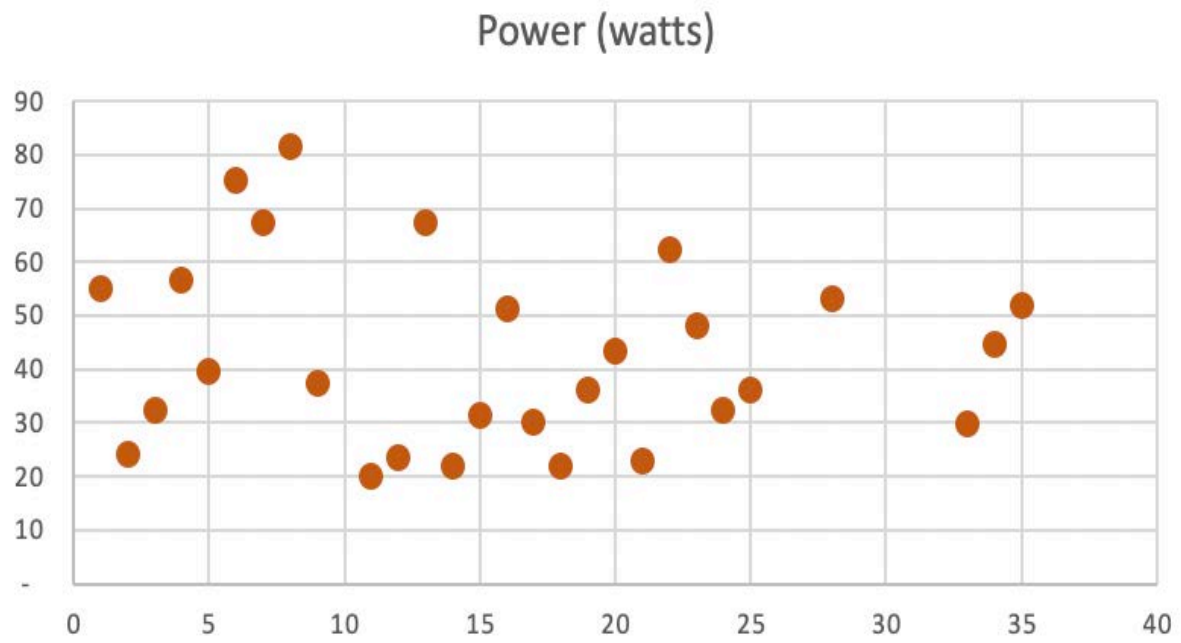
USER OPERATING CONDITIONS. The operating conditions for DC ceiling fans and DC pedestal fans are significantly different. The ceiling fan remains fixed in a household and there is very low risk of it being knocked down or injuring a user. The pedestal fan, however, is “portable” and can be used inside a room during the day and brought outdoors in the evening where rural populations like to sleep, as it is cooler outdoors at nighttime.

The SAMA^Verte field survey found that 30% households reported problems with their fans, of which 67% were locally repaired and the remaining 33% were replaced with new fans. The main complaint was the motor burning out, sometimes due to moisture ingress. None of the households from the survey sample used batteries for night use, they all

plugged in the DC fans directly to solar panels and only used the fans during sunlight hours.

PRODUCT CHARACTERISTICS AND PERFORMANCE. As previously mentioned, the 18-inch DC pedestal fan is the most popular for use in the off-grid market. Of the 40 pedestal fans checked during the SAMA^Verte field survey, 38 were 18-inch, while only 2 were 20-inch. Only 4 fans were manufactured by known brands, and the rest came from the 'informal' market and either had no brand name or carried the name of the local distributor.

FIGURE 6: POWER CONSUMPTION OF 18-INCH DC PEDESTAL FANS FROM FIELD TESTING



The survey included testing the power consumption of fans using a multimeter, measuring the actual voltage and current. A wide variation in power consumption was recorded, as shown in the Figure 6. It was observed that the four fans produced by recognized brands consumed lower power, in the range of 22 to 24 watts. In contrast, there was a wide variation in unbranded fans, consuming as high 82 watts, with most fans in the range of 30 to 70 watts. With regards to air flow, the survey team used a handheld anemometer to measure air flow, attempting to replicate standard test conditions used by PCSIR. However, there was a wide variation and inconsistencies in measuring air flow. It was therefore concluded that air flow measurements in the field did not provide any meaningful data to determine product performance.

Selected fans were tested from the PCSIR laboratory to provide more accurate energy consumption and air flow under lab conditions (some were fans taken from the households in the off-grid areas and some were new fans purchased from markets surrounding the surveyed areas). The three key parameters tested were peak power consumption in Watts (W), air flow in cubic meters per minutes (m^3/min) and service value in cubic meters per minute per Watt (m^3/min/W). Results are summarized in Table 12.

TABLE 12: PCSIR LABORATORY FAN TEST RESULTS SUMMARY

FAN DESCRIPTION	POWER CONSUMPTION (W)	AIR FLOW (m^3/min)	SERVICE VALUE (m^3/min/w)
18" unbranded DC fan	63.3	70	1.11
18" unbranded DC fan	63.4	65.78	1.04
18" unbranded DC fan	61.5	86.7	1.41
18" unbranded DC fan	46.2	57.32	1.24
20" unbranded DC fan	60.7	74.79	1.23
20" unbranded DC fan	65.5	94.6	1.44
18" DC Fan (branded)	20.5	53.53	2.61

The test results indicate that there is a significant difference between performance of branded and unbranded fans. Power consumption of five unbranded fans ranges between 61.5 to 65.5 W, with just one fan having relatively lower consumption of 46.2 W. In comparison, the one branded fan tested consumes only 20.5 Watts. Though the branded fan has lower air flow as compared to the unbranded fans, it provides the best service value of 2.61 m^3/min/W amongst the fans tested.

The low power consumption and high service value offered by the branded fans offer a more economical option when paired with solar PV panels or batteries. Due to lower power rating, a lower capacity solar PV panel is required to operate the fan during daytime. At night these fans can run on batteries for 2 to 3 times longer.

Pakistani fan manufacturers have the capacity to produce high quality DC fans. Some of them are listed in the VeraSol Product Database, managed by CLASP. The database now includes several Pakistani fans tested by the VeraSol program (Table 13). In the stand fan category, Pakistani fans are prominent as having 6 of the 10 best models, in terms of air flow, the most important attribute for the end user.

TABLE 13: VERASOL TESTED DC STAND FANS LISTED BASED ON THE HIGHEST AIR FLOW

S No	Brand	Air flow (m3/min)	Peak Watt	Service value	AC/DC	Country
1	Superfan	66	28	2.4	DC	India
2	Tamoor	65	17.5	3.7	DC	Pakistan
3	GFC	56	24	2.3	DC	Pakistan
4	Tamoor	56	35	1.6	DC	Pakistan
5	GFC	56	17	3.3	DC	Pakistan
6	Royal	53	35	1.5	DC	Pakistan
7	Maks	51	13	3.9	DC	Bangladesh
8	Sunshine	50	11	4.5	DC	Unknown
9	Starco	48	29	1.7	DC	Pakistan
10	Saachi	46	15	3.1	DC	China

REGULATIONS AND CURRENT STATUS. The new mandatory MEPS and labeling scheme issued by PSQCA and NEECA* also includes DC fans. The Federal Cabinet has approved these and announced the date of 1st July 2023† for effectiveness of the new MEPS. While the MEPS document scope mentions both AC and DC fans, the thresholds for MEPS and Standards & Labels for 5-Star levels have only been given for the AC fan category, and not yet defined for DC fans. The rating values for DC fans must be developed and approved by the government to ensure Pakistani consumers can access high-quality, energy-efficient fans.

3.3.8.2 OFF-GRID REFRIGERATORS

The off-grid refrigerator market in Pakistan is nascent‡ and there is little to no data stock and sales data available. High prices and lack of awareness may hinder the penetration of off-grid refrigerators in Pakistan.

The Efficiency for Access (EforA) survey in 2018 and 2022 found only 2 brands of DC refrigerators in Pakistan.§ Both manufacturers offered a full line of refrigerator types and sizes. Distributors noted that it is difficult to keep the stock and sell DC refrigerators because of their high prices and low demand.

The 2022 survey found refrigerators ranging from 60-550 L with units greater than 250 L being most common. The refrigerators-freezers were the most commonly available type of off-grid refrigerator. EforA noted that there are several large commercial DC deep freezers on the market, but they were not captured in the 2022 survey. Prices for

* PSQCA PS-1:/2021 Rev (5). https://www.psqca.com.pk/Electrotechinal/PS%201%202021%20Rev%203%202021%20Final.pdf

† Tribune 2 March 2023. https://tribune.com.pk/story/2403993/plan-to-ban-production-of-traditional-fans

‡ Sales volumes of off-grid refrigerators in Pakistan have not been high enough where GOGLA can report them.

§ In 2018 4 models (from single manufacturer) and in 2022 9 models from 2 brands were surveyed.

surveyed refrigerators range from 131 to 360 USD, increasing with size. Regarding performance, the power of surveyed DC refrigerators increases with volume from 60 W for 60 L refrigerator to 120 W for 550 L refrigerator.[75]

4 Assessment of Future Cooling Needs

4.1 INDIRECT EMISSIONS

4.1.1 INTRODUCTION AND METHODOLOGY

Having established the current state of priority cooling appliance sectors and their likely future growth, this chapter projects and analyses the related energy consumption and emissions. This chapter is estimating the energy consumption and emissions abatement potential from the priority cooling sectors under different regulatory and best available technology scenarios. Details are also provided below for the adopted modeling approach, inputs and assumptions.

The modeling was done using a combination of CLASP's Mepsy: The Appliance & Equipment Climate Impact Calculator (Mepsy) and SAMA^Verte in-house model (Table 14).

Both **Mepsy** and **SAMA^Verte models** are based on a bottom-up stock accounting method that accumulates unit sales and retirements to estimate the number of appliances in use (i.e., stock). Final energy consumption is estimated by summing, over lifetime, the product of 1) annual sales and 2) average unit energy consumption factors of a given sales-year's units. Unit energy consumption reflects the efficiency and usage of appliances, which is used to distinguish between policy scenarios. Indirect CO_2 emissions are determined by multiplying energy consumption by grid emission factor, provided in the assumptions section below. The models use product survival/retirement curves based on the appliances they model. The SAMA^Verte model was selected to model fans as it was developed specifically for the complex Pakistan fan market, including accounting for the market shift to AC/DC hybrid technology.

TABLE 14: COOLING SUB-SECTORS AND RESPECTIVE PRODUCTS MODELED, AND MODEL USED

COOLING SUB-SECTOR	PRODUCTS	MODEL USED
Commercial Refrigeration	Visi coolers, horizontal beverage coolers, horizontal ice cream freezers, horizontal food freezers	Mepsy model
Domestic Air Conditioning	Split-type air conditioners	Mepsy model
Domestic Refrigeration	Upright refrigerator-freezers, horizontal refrigerator-freezers, horizontal deep freezers	Mepsy model
Electric Fans	Ceiling fans	SAMA^Verte model

4.1.2 POLICY SCENARIOS, ASSUMPTIONS, AND INPUTS

Four policy scenarios are modeled across the selected cooling sectors: business as usual (BAU), minimum energy performance standards (MEPS), United for Efficiency (U4E) MEPS, and best available technology (BAT). These scenarios are characterized as follows:

- **BAU scenario** represents expected market development with no policies and other interventions in place.
- **MEPS scenario** represents market response to introduction of the policies that are pending adoption or are being developed.
- **U4E MEPS scenario** which represents market response should policies be introduced which follow the U4E model regulation guidelines.
- **BAT scenario** represents market impact of immediate adoption of the highest efficiency technology available in the world. Where global highest efficiency figures were not available, BAT represents U4E "High Ambition" scenario from the *Pakistan's Country Savings Assessment*[*].

Detailed assumptions of the scenarios for analyzed cooling appliances are:

- **BAU scenario:**
  - Average efficiency of units currently on the market with no efficiency policy interventions.
  - All other scenarios are modeled as adjustments to this baseline, from a given policy implementation year.
- **MEPS scenario**:
  - Air conditioning: the MEPS levels are approved levels in the regulation developed by NEECA with support from JICA.[†]
  - Domestic refrigeration: 1) for upright refrigerator-freezers, the MEPS levels are approved levels in the regulation developed by NEECA with support from JICA;[‡] 2) for horizontal refrigerator-freezers and horizontal freezers, the MEPS levels used in the modeling are proposed levels by CLASP/SAMA^Verte in the regulation that was submitted to NEECA and PSQCA for approval in 2022.
  - Commercial refrigeration: 1) for visi coolers, the MEPS levels proposed by CLASP/SAMA^Verte are from the regulation submitted to PSQCA and NEECA for approval; 2) for horizontal beverage coolers, the MEPS levels are proposed levels by CLASP/SAMA^Verte in the regulation that was developed and shared with NEECA and PSQCA for approval in 2022; 3) for horizontal food freezers and ice cream freezers, the MEPS levels are extrapolated from those of chest freezers, given the former will not be regulated in the near future.
  - Electric fans: MEPS levels for AC, AC/DC hybrid fans are the approved levels (PS: 1/2021 5th (Revision) by PSQCA in coordination with NEECA.

[*] U4E, Country Savings Assessments, https://united4efficiency.org/countries/country-assessments/

† NEECA, Draft final Minimum Energy Performance Standard and Labeling requirements for Room Air Conditioner.

‡ NEECA, Draft final Minimum Energy Performance Standard and Labeling requirements for Household Refrigerating Appliances.

- **U4E MEPS scenario** is applied only for air conditioners and domestic refrigeration. There are no model regulation guidelines for fans, and the scope of the U4E guidelines for commercial refrigeration is not representative of the appliances analyzed in this assessment.* The assumptions for air conditioning and domestic refrigeration are:
  - Air conditioning: an average CSPF of Pakistan's two secondary climate groups (0B and 1B) with cooling capacity and a Pakistan-specific temperature constant to determine annual unit energy consumption.
  - Domestic refrigeration: manual defrost was used in the annual energy consumption calculation for upright refrigerator-freezers, and freezers, as the majority of surveyed units were of manual defrost type. The U4E Guidelines do not cover horizontal refrigerator-freezers (Pakistan-specific) within the scope, therefore annual unit energy consumption was estimated based on that of upright refrigerator-freezers by scaling it down 13%, which is the ratio of energy consumption between the two products in the BAU scenario.
- **BAT scenario:**
  - Air conditioners: the U4E country savings assessment "High Ambition Scenario" UEC is used as the best available technology.†
  - Domestic refrigeration: the UECs of top 10 European units (from Liebherr, Electrolux, Samsung) represent the best available technology for refrigerators (0.65 kWh/daily) and freezers (0.6 kWh/daily).
  - Commercial visi coolers: UEC is that of Heineken brand and commercial horizontal beverage coolers are assumed to have the same BAT UEC.
  - Electric fans: the best available fan unit in Pakistan that consumes 45 Watts.

Other assumptions include:

- Both models assume efficiency policies will take one year from adoption to be fully implemented, thus reductions begin one year after any listed policy adoption year.
  - For air conditioning, domestic and commercial refrigeration: projected reductions begin in 2024, given the adoption of the approved policies are in 2023.
  - For fans: projected reductions begin in 2024, given the adoption of the approved policy will be mid-2023.
- Annual efficiency improvement rate: 1% for all policy scenarios (BAU, MEPS, U4E, BAT) and all products, except for fans. The annual efficiency improvement rate for fans varies by each Tier and is different for AC fans and Hybrid fans. For Tier 1 products, improvement rate of 0.8% is assumed in AC fans, and 1% in Hybrid fans for all policy scenarios (BAU, MEPS, BAT). For Tier 2 products, annual efficiency improvement is 0.8% in AC fans and 0.5% in Hybrid fans. For Tier 3 products, it is 0.8% in AC fans and 0% in Hybrid fans for all policy scenarios (BAU, MEPS, BAT). For the U4E scenario, an annual efficiency improvement rate of 1% was applied across all applicable products

* U4E Model Regulation Guidelines: https://united4efficiency.org/resources/model-regulation-guidelines/

† U4E Country Savings Assessment for Pakistan: https://united4efficiency.org/wp-content/uploads/2022/08/PAK_U4E-Country-Saving-Assessment_Jul-22.pdf

(excluding fans) for consistency, as it is not provided in the model regulation guidelines.

- Pakistan's grid emission factor: both models use a consistent emission factor of 0.39 kg/kWh across all policy scenarios and years modeled. Since CO_2 emissions are calculated from the product of energy consumption and an emission factor, the proportions of consumption and emissions for a matched comparison will be the same for any given product.
- Transmission and distribution losses: the Mepsy model and SAMA^Verte fans model factors in 17% T&D losses to the calculation of national CO_2 emissions.
- Air conditioner usage factor: a 35% usage factor was applied to estimating energy consumption and emissions. This is the result of consultations with industry experts which suggest high electricity prices and the installation of products in low use areas such as guest bedrooms affect energy consumption, so that consumption is the equivalent of only 30-40% of the air conditioner stock running at the annual operating hours specified in Table 15.

Table 15 provides a summary of the inputs used in the scenario modeling. The data was collected from a variety of sources, including stakeholder consultative meetings (with manufacturers, multinational procurers, industry experts, etc.), retail surveys across 45 stores in 6 cities, and online data scraping (refer to Section 3.2 for more information).

Sales data sources are the same for all products. Sales figures have been collected through consultations with manufactures, matching the sales figure with the production figure of a given appliance for the manufacturers to validate. Limited surveys of the market and discussion with relevant senior officials of large manufacturers were also considered when finalizing the sales figures.

Table 16 and Table 17 provide the UECs used for each of the above-described scenarios.

TABLE 15: SPECIFIC INPUTS USED IN THE MODELING, BY PRODUCT.

APPLIANCE SUB-SECTOR	APPLIANCE	REPRESENTATIVE SIZE	AVERAGE LIFETIME (YRS)	ANNUAL OPERATING HOURS	POLICY IMPACT YEAR
SPACE COOLING	Air Conditioners	1.5 tons	10	1395	2024
	Fans	56 in	20	3240	2024
COMMERCIAL REFRIGERATION	Horizontal Beverage Coolers	400 L	5	8760	2024
	Horizontal Food Freezers	400 L	5	8760	2024
	Horizontal Ice Cream Freezers	400 L	5	8760	2024

APPLIANCE SUB-SECTOR	APPLIANCE	REPRESENTATIVE SIZE	AVERAGE LIFETIME (YRS)	ANNUAL OPERATING HOURS	POLICY IMPACT YEAR
	Visi Coolers	400 L	12	8760	2024
DOMESTIC REFRIGERATION	Horizontal Freezers	400 L	9	8760	2024
	Horizontal Refrigerator-Freezers	400 L	9	8760	2024
	Upright Refrigerator-Freezers	400 L	15	8760	2024

TABLE 16: 2024 UNIT ENERGY CONSUMPTIONS (UEC) USED FOR MODELING, BY PRODUCT AND SCENARIO

APPLIANCE SUB-SECTOR	APPLIANCE	UNIT ENERGY CONSUMPTION (kWh/yr) (2024)			
		BAU	MEPS	U4E	BAT
SPACE COOLING	Air Conditioners	2238	2512*	1793	1369
	Fans	283	236.52	N/A	145.8
COMMERCIAL REFRIGERATION	Horizontal Beverage Coolers	2147	613.2 - 1755.65**	N/A	693.5
	Horizontal Food Freezers	1013	569.4 - 876**	N/A	237.25
	Horizontal Ice Cream Freezers	1013	569.4 - 876**	N/A	237.25
	Visi Coolers	2147	613.2 - 1755.65**	N/A	693.5
DOMESTIC REFRIGERATION	Horizontal Freezers	1013	876	318.75	219
	Horizontal Refrigerator-Freezers	966	740.95	221.09	237.25
	Upright Refrigerator-Freezers	1109	1063	254.13	237.25

** The proposed MEPS for air conditioners is less efficient than the current baseline of the market.*
***Commercial refrigeration products were modeled with tiered MEPS at staggered implementation years; the Policy Implementation Year listed for commercial refrigeration products refers to the implementation year of the first MEPS tier. See Table 17below for details on tiered implementation years and associated unit energy consumptions.*

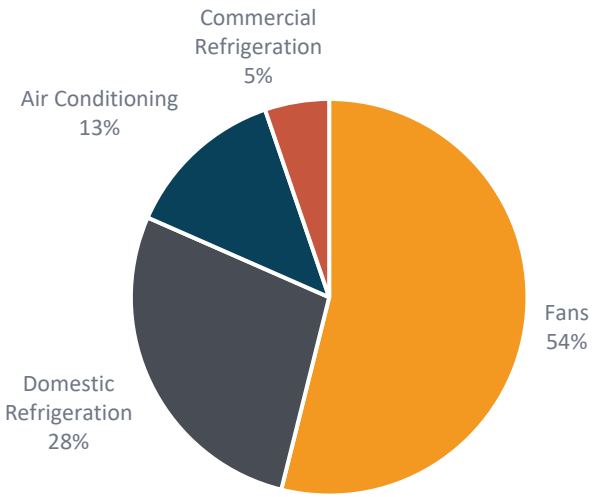
TABLE 17: TIERED MEPS ADOPTION YEAR AND UNIT ENERGY CONSUMPTIONS (UEC) USED IN THE MODELING FOR PRODUCTS WITHIN THE COMMERCIAL REFRIGERATION SUB-SECTOR

SCENARIO	BAU*	MEPS TIER 1	MEPS TIER 2	MEPS TIER 3	BAT
POLICY IMPACT YEAR	N/A	2024	2025	2030	2024
Horizontal Beverage Coolers	2190	1755.65	1405.25	1142.45	693.5
Horizontal Food Freezers	1032.95	876	770.15	660.65	237.25
Horizontal Ice Cream Freezers	1032.95	876	770.15	660.65	237.25
Visi Coolers	2190	1755.65	1405.25	1142.45	693.5

4.1.3 FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO_2 EMISSIONS FROM PRIORITY COOLING APPLIANCES/SECTORS

This section discusses modeling results and abatement potential for energy consumption and associated CO_2 emissions for the scenarios described above. Graph 30 shows the share of indirect emissions from each of the cooling sectors for the year 2022. Fans are the highest contributor, accounting for 54% of the total indirect emissions from the four priority sectors, followed by domestic refrigeration (28%) and air conditioning (13%). Commercial refrigeration has a relatively smaller contribution of 5%.

GRAPH 30: INDIRECT EMISSIONS FROM THE PRIORITY COOLING APPLIANCES (2022)



* For the BAU scenario, represented UECs are for 2022.

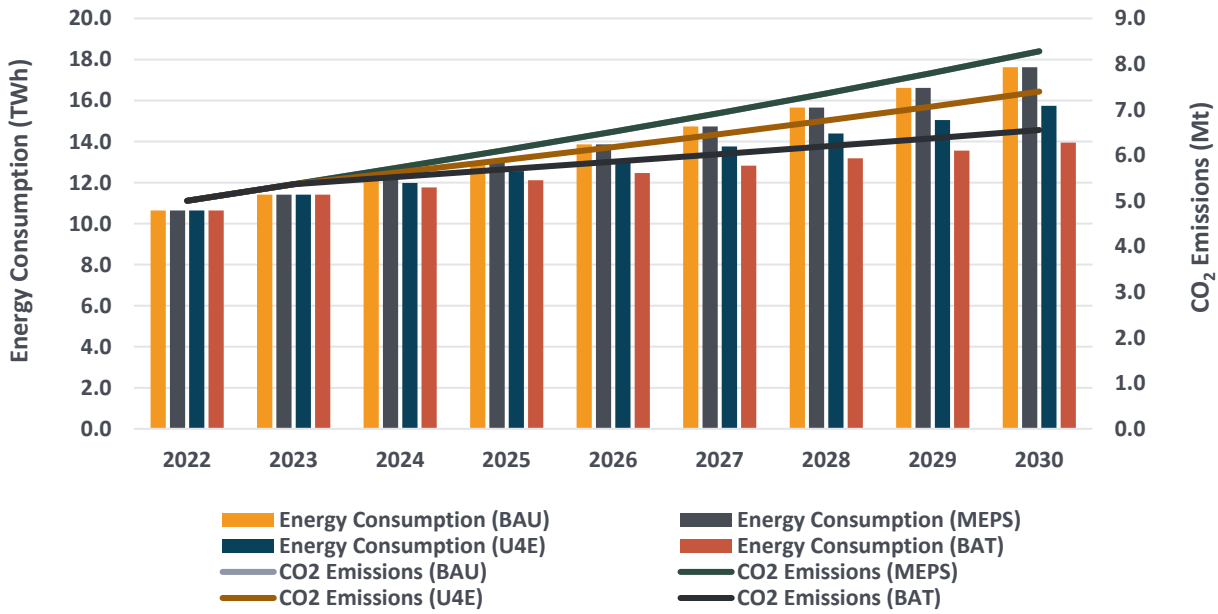
4.1.3.1 FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO_2 EMISSIONS FROM AIR CONDITIONING

Most air conditioners currently on the market are inverter type with better efficiencies than the air conditioning appliances sold previously. However, the current low penetration of air conditioners (11%) and anticipated growth of 7% (from installed stock of 11.3 million in 2022 to 20.2 million units in 2030) will result in a significant increase in energy consumption and emissions. Graph 31 shows projected energy consumption and CO_2 emissions from air conditioning through 2030, along with the potential energy and CO_2 reduction opportunities from the various efficiency policy scenarios.

Both the BAU and MEPS scenarios project energy consumption and CO_2 emissions will increase from baseline to 2030. The MEPS policy scenario exactly matches the BAU scenario for the duration of the analysis period because the average air conditioning unit in the current market is already more efficient than the MEPS level in the approved regulation, therefore no reductions are expected. In the **BAU scenario, air conditioning cumulative energy consumption and CO_2 emissions from 2024-2030 are projected to be 103.7 TWh and 48.7 Mt, respectively.**

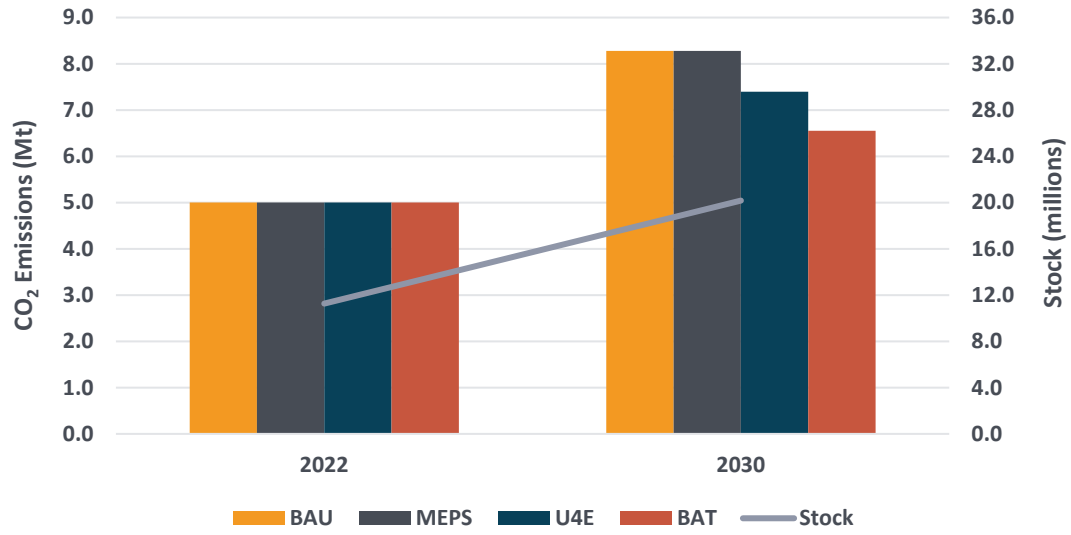
Increasing the stringency of current MEPS to match the **U4E level or BAT level could result in cumulative energy reductions from 2024 through 2030 of 7.1 TWh or 13.9 TWh, respectively, or CO_2 reductions of 3.3 Mt or 6.5 Mt, respectively.** While air conditioner stock is projected to grow by 78% by 2030, a transition to BAT would effectively curb CO_2 emissions, keeping 2030 emissions (6.6 Mt) below the 2022 baseline (8.3 Mt) (Graph 32). Hence, an increase in ambition of the current proposed MEPS must occur to materialize significant policy impacts.

GRAPH 31: DOMESTIC AIR CONDITIONING ANNUAL ENERGY CONSUMPTION (TWh) AND CO_2 EMISSIONS (Mt) 2022-2030, BY POLICY SCENARIO



Note: Since the unit energy consumption of the proposed MEPS level is higher than that of the current market baseline, the CO_2 emissions line for MEPS scenario exactly matches the BAU line (does not project reductions) and thus is not visible on the graph.

GRAPH 32: DOMESTIC AIR CONDITIONING ANNUAL CO_2 EMISSIONS AND STOCK IN 2022 AND 2030, BY POLICY SCENARIO



4.1.3.2 FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO2 EMISSIONS FROM ELECTRIC FANS

In 2022, about 9.6 million fans were produced, with 77% of the market still comprised of the less efficient standard AC non-labelled* and non-hybrid fans. Thus, there is much room for improving fan energy efficiency in Pakistan.

Fans are the largest consumer of energy amongst the priority cooling appliances as well as the biggest emitters of indirect emissions (54% of indirect emissions from priority cooling appliances in 2022). Graph 33 shows that, under the BAU scenario, the annual energy consumption of fans will increase by 5.2 TWh from 2024 to 2030, reaching nearly 50 TWh in 2030. CO_2 emissions under the BAU scenario will increase by 2.5 Mt from 2024 to 2030, reaching nearly 24 Mt in 2030. Cumulatively, energy consumption and CO_2 emissions in the **BAU scenario are projected to be 330.5 TWh and 155.3 Mt from 2024-2030**. Over that same period, the **MEPS scenario is projected to provide cumulative energy and CO_2 emissions reductions of 6.4 TWh and 3.0 Mt**, respectively.

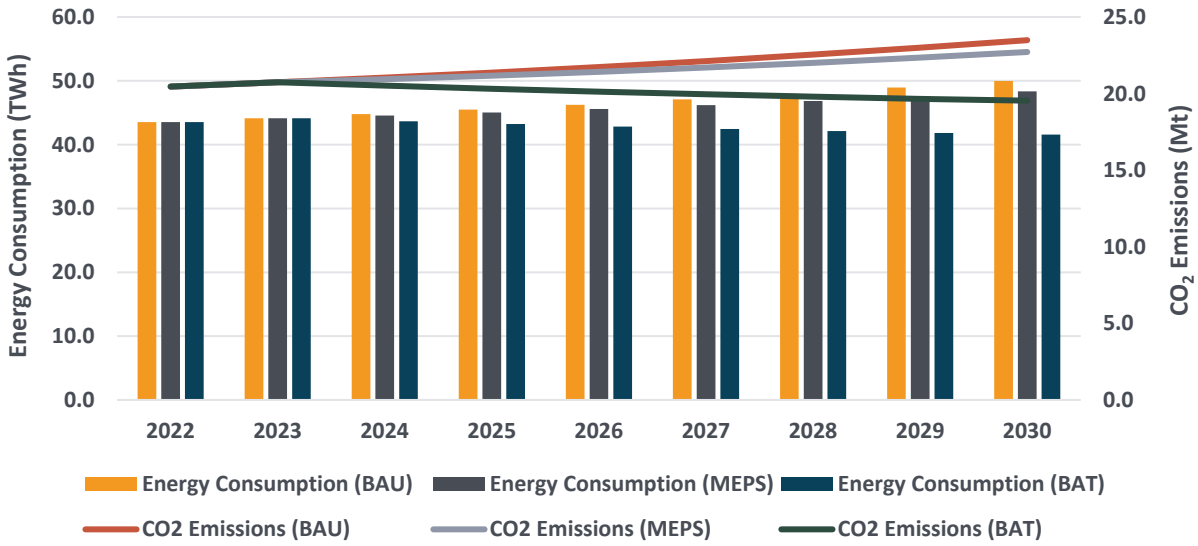
Tier 1 manufacturers (48% market share) will likely aim for 4-star or 5-star efficiency and the rest of the industry will try to meet mandatory MEPS (1-star), resulting in the new fan market exceeding the projected MEPS reductions and realizing energy and CO_2 reductions between 9-21 TWh and 4-8 Mt, respectively, through 2030.

BAT is the only scenario projected to reduce annual consumption and emissions below 2023 levels by 2030. Cumulatively, the **BAT scenario is projected to provide energy consumption and CO_2 emissions reductions of 32.8 TWh and 15.4 Mt,** respectively, **from 2024-2030**. The policy interventions that are in line with BAT will help accelerate

* About 100,000 of the voluntary labelled fans are procured each year.

the transition of the market to more efficient technologies such as AC/DC hybrid fans and improving the efficiencies of the remaining 52% of the products striving to meet mandatory MEPS.

GRAPH 33: ELECTRIC FANS ANNUAL ENERGY CONSUMPTION (TWh) AND CO_2 EMISSIONS (Mt) 2022-2030, BY POLICY SCENARIO

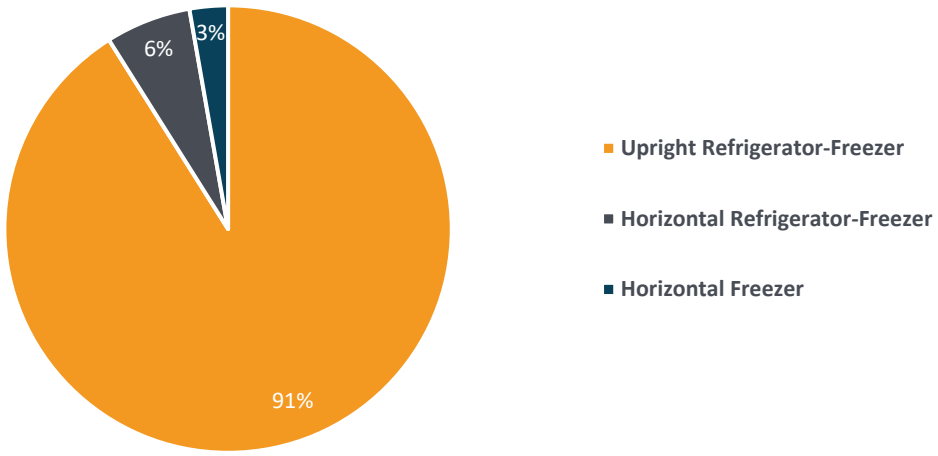


Note: There is no U4E data represented because there are no model regulation guidelines for fans.

4.1.3.3 FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO2 EMISSIONS FROM DOMESTIC REFRIGERATION

Amongst appliances evaluated under the domestic refrigeration sector (upright refrigerator-freezers, horizontal refrigerator-freezers, and horizontal freezers), upright refrigerator-freezers consumed the majority of energy (91%) in 2022 and consequently had the highest CO_2 emissions (Graph 34).

GRAPH 34: DOMESTIC REFRIGERATION ENERGY CONSUMPTION AND CO_2 EMISSIONS PROPORTIONS BY PRODUCT, 2022

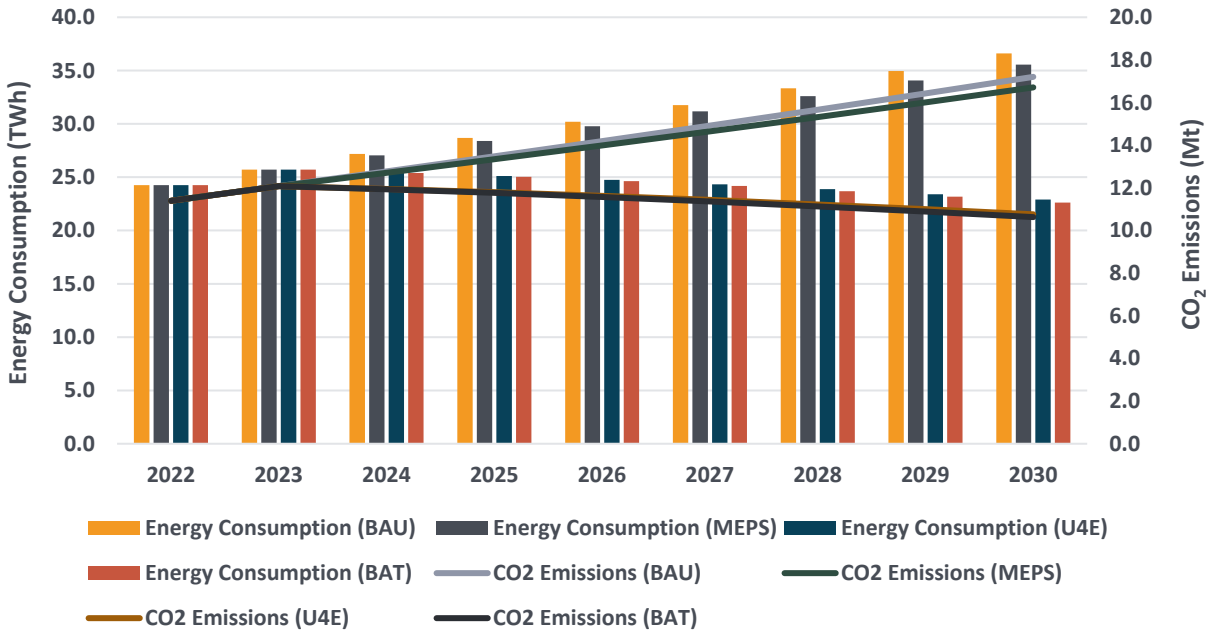


Graph 35 shows that for both energy consumption and CO_2 emissions, the BAU and MEPS scenarios align closely to each other, while the U4E and BAT scenarios align closely to one another and are much more ambitious. The U4E levels (and corresponding UECs in Table 16) are close to the top 10 European refrigerating unit efficiency levels that are used to represent best available technologies for refrigerators and freezers in this analysis. The proposed MEPS policy level is only 14% more efficient than the current market baseline (as an average across the three products), whereas the U4E and BAT policies are an average of 74% and 77% more efficient, respectively.

In the **BAU scenario, domestic refrigeration cumulative energy consumption and CO_2 emissions are projected to be 206.8 TWh and 97.2 Mt, respectively, from 2024-2030**. Over that same period, **the MEPS scenario could provide cumulative energy reductions of 3.4 TWh and cumulative CO_2 reduction of 1.6 Mt.** This compares with the much larger reductions available from the **U4E and BAT scenarios, which are projected to provide cumulative energy reductions of 40.6 TWh and 41.5 TWh**, respectively, and associated **cumulative CO_2 reductions of 19.1 Mt and 19.5 Mt**, respectively.

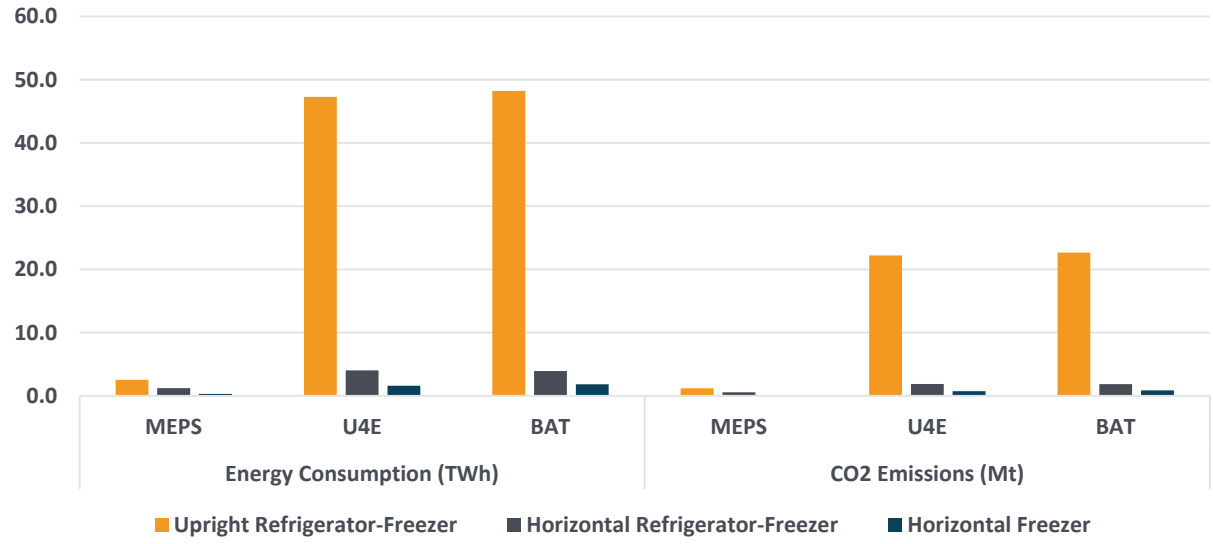
An increase in ambition of the proposed MEPS should occur to have substantive impacts and help realize consumption and emissions mitigation goals. Adopting the U4E levels over the proposed MEPS would increase reductions by a factor of 12.

GRAPH 35: DOMESTIC REFRIGERATION ANNUAL ENERGY CONSUMPTION (TWh) AND CO_2 EMISSIONS (Mt) 2022-2030, BY POLICY SCENARIO



Graph 36 depicts the proportion of reductions from each product, for a given policy scenario. Under all scenarios, most reductions come from upright refrigerator-freezers, a reflection of their popularity and thus large stock. Hence, achieving an increased ambition MEPS policy even for upright refrigerator-freezers alone would result in substantial impacts.

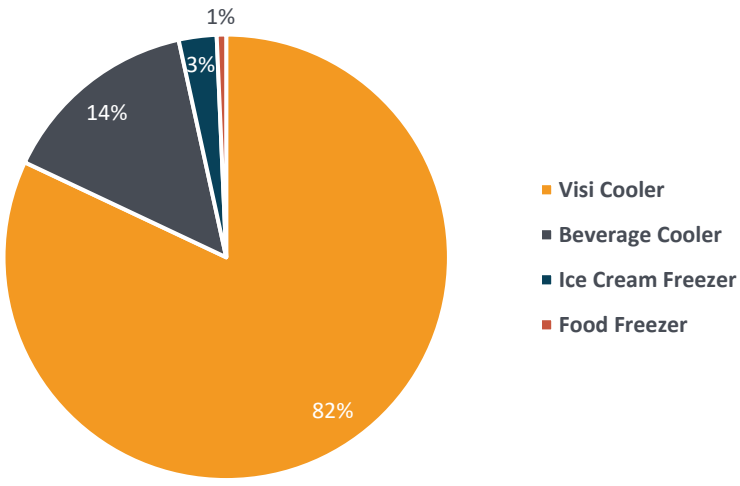
GRAPH 36: DOMESTIC REFRIGERATION CUMULATIVE REDUCTIONS (2024-2050) FOR ENERGY CONSUMPTION AND CO_2 EMISSIONS, BY PRODUCT AND POLICY SCENARIO



4.1.3.4 FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO2 EMISSIONS FROM COMMERCIAL REFRIGERATION

The commercial refrigeration appliances evaluated in this analysis are visi coolers, horizontal beverage coolers, ice cream freezers, and horizontal food freezers. Visi coolers are the most popular commercial refrigeration appliance among those modeled and therefore comprise the majority of energy consumption and CO_2 emissions in 2022, at 82% as shown in Graph 37.

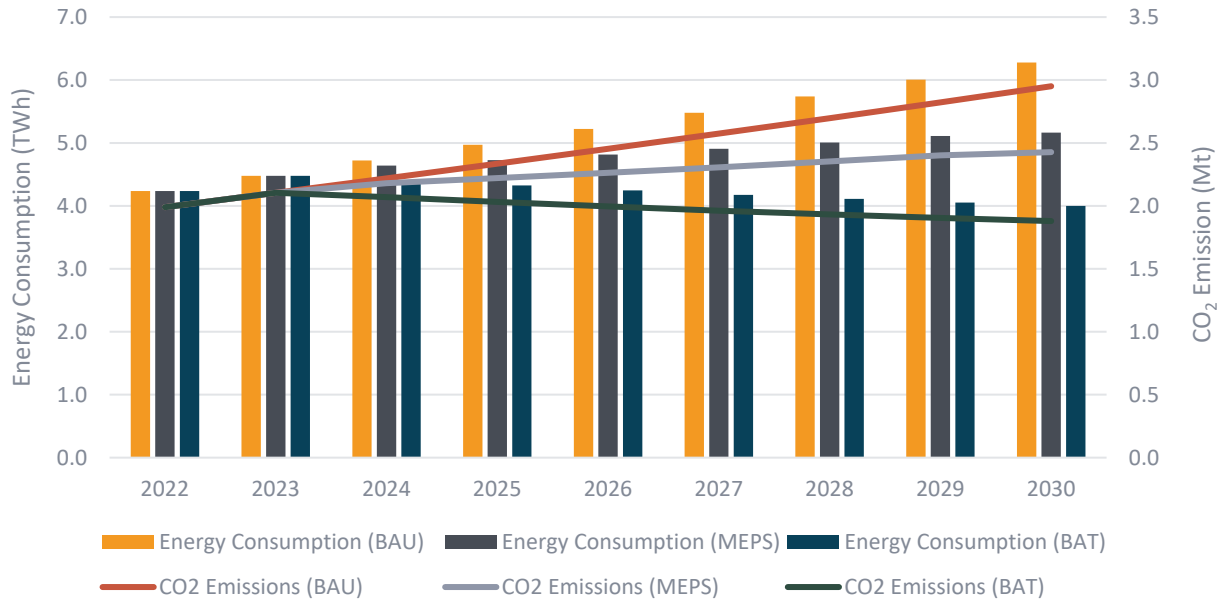
GRAPH 37: COMMERCIAL REFRIGERATION ENERGY CONSUMPTION AND CO_2 EMISSIONS IN 2022, BY PRODUCT



Commercial refrigerators emit the smallest proportion of indirect CO_2 among the priority cooling products (5%). Graph 38 shows that in the **BAU scenario, commercial refrigeration cumulative energy consumption and CO_2 emissions are projected to be 38.4 TWh and 18.1 Mt, respectively, from 2024-2030**. Over that same period, **MEPS*** **and BAT scenarios are projected to provide cumulative energy reductions of 4.1 TWh and 9.1 TWh**, respectively**; cumulative CO_2 reductions for those scenarios over the same period are projected at 1.9 Mt and 4.3 Mt**, respectively.

The MEPS policy for commercial refrigeration is projected to provide reductions from BAU that is about 21% larger than reductions projected for domestic refrigeration, even though there are far more domestic refrigeration units than commercial. This is largely due to the tiered MEPS for commercial refrigeration providing two efficiency increases (2024 and 2025) over the same analysis period as compared to domestic refrigeration's single-year MEPS efficiency increase.

GRAPH 38: COMMERCIAL REFRIGERATION ANNUAL ENERGY CONSUMPTION (TWh) AND CO_2 EMISSIONS (Mt) 2022-2030, BY POLICY SCENARIO

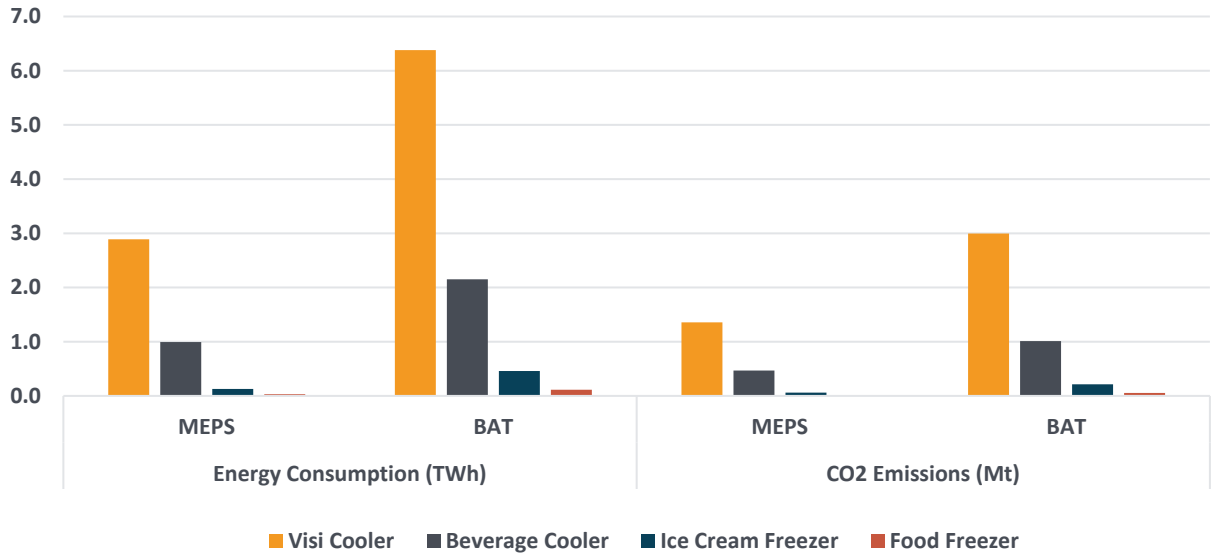


Note: There is no U4E data represented because the scope of the U4E guidelines for commercial refrigeration is not representative of the appliances analyzed in this assessment. Additionally, the full impact of all four MEPS tiers will not be represented on the graph because the analysis timeframe is kept to 2030 and earlier for consistency in comparison across other modeled cooling sub-sectors.

Graph 39 depicts the proportion of reductions from each product, for a given policy scenario. Most reductions come from visi coolers, as they constitute the majority of the market and represent the greatest reduction potential as compared to other commercial refrigeration appliances.

* The proposed commercial refrigeration policy has tiered MEPS, with the last tier implemented in 2035; however, for analysis comparability across cooling sub-sectors the analysis time period for commercial refrigeration only goes through 2030 and not reflect the full impact of the policy.

GRAPH 39: COMMERCIAL REFRIGERATION CUMULATIVE REDUCTIONS (2024-2030) FOR ENERGY CONSUMPTION AND CO2 EMISSIONS, BY PRODUCT AND POLICY SCENARIO



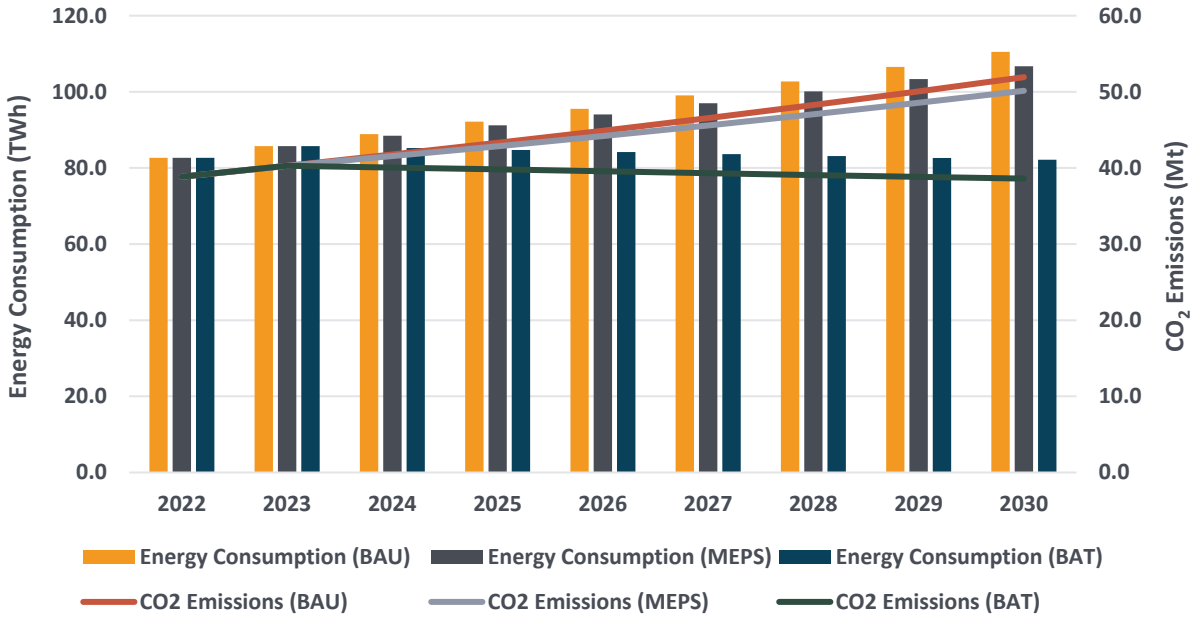
4.1.4 SUMMARY FUTURE PROJECTIONS OF ENERGY CONSUMPTION AND ASSOCIATED CO_2 EMISSIONS FROM PRIORITY COOLING SECTORS

This section summarizes the overall energy consumption and emissions reduction potential from the four analyzed cooling appliance sectors.

Graph 40 shows that energy consumption and CO_2 emissions are projected to increase from 2024 to 2030 for BAU and MEPS scenarios, but not the BAT scenario. **Without mandatory standards and labels interventions, Pakistan's cumulative energy consumption and CO_2 emissions are projected to total 695.4 TWh and 326.8 Mt, respectively, from 2024-2030.** This will add significant strain to Pakistan's power grid and further contribute to climate change and its negative impacts.

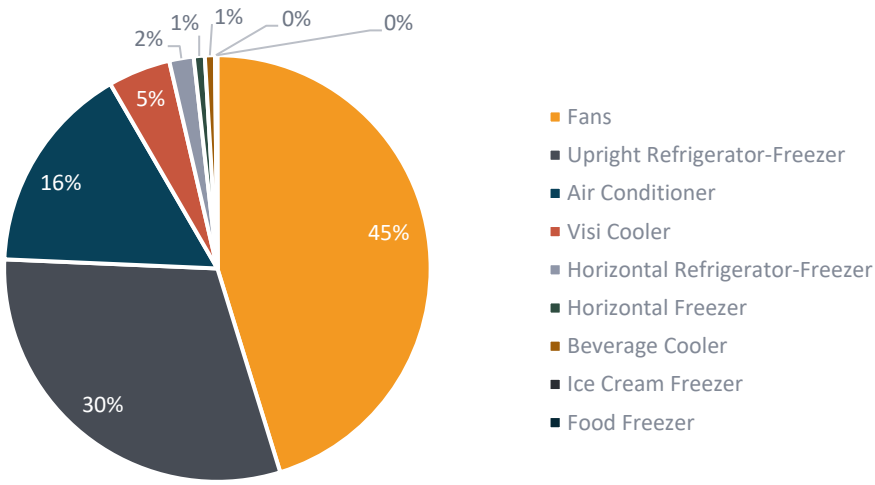
The current planned MEPS for all products are projected to provide cumulative energy consumption and CO_2 emissions reductions of just 14.5 TWh and 6.8 Mt, respectively. This compares with the 7 times greater savings potential available (represented by the BAT scenario) which would yield cumulative reductions of 109.7 TWh and 51.6 Mt, respectively.

GRAPH 40: ANNUAL AGGREGATED ENERGY CONSUMPTION AND CO_2 EMISSIONS FOR ALL MODELED PRODUCTS, BY POLICY SCENARIO, 2022-2030



Fans, domestic and commercial refrigeration offer significant potential to reduce energy consumption and CO_2 emissions by 2030 (Graph 40). Fans, the most common space cooling appliance, is expected to have higher energy consumption and CO_2 emissions in 2030, at 45%, as compared to other analyzed cooling appliances. As fans consumed 27% of national electricity in 2021, they have significant potential for climate mitigation impact. As for air conditioners, their sales are expected to grow faster (7%) than sales growth of other analyzed appliances (5% or less), thus air conditioning also has a significant potential to help reduce future energy consumption and associated emissions. The current air conditioner MEPS are set at a level below the current market baseline and should be strengthened as soon as possible to realize the mitigation potential of this appliance.

GRAPH 41: 2030 BAU ENERGY CONSUMPTION AND CO_2 EMISSIONS, BY PRODUCT



In 2022, Pakistan's domestic sector consumed 48%, and commercial sector about 7%, of total generated electricity. Of the total electricity produced, analysis shows that about 46% of electricity is used by cooling appliances, with cooling accounting for 84 % of electricity consumed by the domestic sector, and 78% of that consumed by the commercial sector. Without policy intervention, energy consumption of these sectors is estimated to increase at an average of 4% annually from 2024-2030. Even with adoption of the proposed and/or approved policies (MEPS scenario), the average annual growth in assessed appliance energy consumption is projected to be 3% for the same period.

Given the projected substantial growth in cooling appliance sales (on average 5%) and associated energy use, current policies are insufficiently ambitous to slow the growth of energy consumption and associated emissions from cooling. **It is imperative for Pakistan to adopt ambitious policies with MEPS levels close to BAT levels to reduce energy consumption and emission while the demand for appliances grows**. This in turn will reduce the need for Pakistan to build additional power generation capacity.

4.2 DIRECT EMISSIONS

4.2.1 INTRODUCTION AND METHODOLOGY

This section provides an explanation of the model and assumptions used to project refrigerant-based emissions (direct emissions) from cooling appliances, as well as provide a more detailed examination of the policy options for reducing direct emissions.

Unlike indirect emissions, which occur at power generation plants and are a byproduct of electricity generation required to power cooling appliances, direct emissions come from the appliance itself. The direct emissions in this assessment refer to the refrigerants (e.g., R-410A, R-134A) that escaped containment from within the appliance at some point during its lifecycle. Although emissions released directly from appliances are quite small in comparison to indirect CO_2 emissions, refrigerant chemicals, particularly those

developed years ago, have significantly higher global warming potential than CO_2, as seen in Table 18. Reducing direct emissions is essential to mitigate climate impacts from cooling appliances.

TABLE 18: REFRIGERANTS USED WITHIN THE MODELED PAKISTAN COOLING APPLIANCES AND THEIR ASSOCIATED GLOBAL WARMING POTENTIALS (GWP)

REFRIGERANT	GWP	APPLICABLE APPLIANCE
R-410A	1,923.5	Air conditioner
R-134a	1,300	Domestic and commercial refrigeration units
R-32	677	Air conditioner
R-290	0.036	Domestic refrigeration units
R-600a	0.006	Commercial refrigeration units

Note: for reference, CO_2 has a GWP of 1

4.2.2 POLICY SCENARIOS, ASSUMPTIONS, AND INPUTS

The cooling appliances analyzed mirror those in the indirect emissions section, excluding fans which contain no refrigerant. In addition to the BAU assumptions used in indirect emissions for each of these products (refer to section 4.1.2) the additional assumptions used for the business-as-usual (BAU) modeling of direct emissions are detailed in Table 19.

TABLE 19: BUSINESS-AS-USUAL (BAU) SCENARIO ASSUMPTIONS FOR MODELING DIRECT EMISSIONS FROM SELECT PAKISTAN COOLING APPLIANCES

PRODUCT	LIFETIME	EXISTING REFRIGERANT (1ST REFRIGERANT)	TRANSITION REFRIGERANT (2ND REFRIGERANT)	TRANSITION TIMELINE (1ST TO 2ND REFRIGERANT)	ANNUAL LEAKAGE RATE	TOTAL LIFETIME SERVICES
Domestic Air Conditioner	10	R-410A	R-32	2020-2030	9.8%*	2
Domestic Upright Refrigerator-Freezer	15	R-134a	R-600a	2019-2028	2%	1
Domestic Horizontal Refrigerator-Freezer	9	R-134a	R-600a	2019-2028	2%	1
Domestic Horizontal Freezer	9	R-134a	R-600a	2019-2028	2%	1
Commercial Visi Cooler	12	R-134a	R-290	2023-2024	2%	3
Commercial Beverage Cooler	5	R-134a	R-290	2023-2024	2%	1

* This leakage rate is a weighted average, assuming the modeled air conditioner is serviced on the fourth and eighth years of its 10-year life, and servicing the air conditioner increases leakage, thus leaking 2% before first servicing and leaking 15% after first servicing.

Commercial Ice Cream Freezer	5	R-134a	R-290	2012-2013	2%	1
Commercial Frozen Food Freezer	5	R-134a	R-290	2019-2028	2%	1

Detailed assumptions of the BAU and Policy scenarios for analyzed cooling appliances are:

BAU:

- It is assumed that 100% of all cooling appliances are leaking (i.e., have annual leakage rates applied in modeling) and when serviced, are refilled to total charge.
- For domestic refrigeration appliances (excluding air conditioners), it is assumed only one in five units (20%) require service during their lifetime. For commercial refrigeration appliances it is assumed that half (50%) of all units get serviced during their lifetime. All (100%) air conditioners are assumed to be serviced.
- The amount of remaining (not yet leaked) gas vented at a servicing event is assumed to be 100% for domestic refrigeration appliances, excluding air conditioners; for air conditioners and commercial refrigeration this figure is assumed to be 50%.
- For all modeled cooling appliances, in the BAU scenario it is assumed that 100% of refrigerant gas is released (not captured) at end-of-life.

Policy Scenarios:

Six potential policy scenarios have been modelled to reduce direct emissions from cooling appliances. The policies are listed in Table 20, along with the appliances on which the policies impact, and at what point in their lifecycle this impact occurs.

TABLE 20: ACTIONS TO REDUCE DIRECT EMISSIONS FROM COOLING APPLIANCES

	ACTION	APPLICABLE APPLIANCES	MARKET IMPACT
1	Reduce Refrigerant Charge	All modeled appliances	Only new products
2	Reduce Annual Leakage	All modeled appliances	Only new products
3	Reduce Service Venting	Only air conditioners and commercial refrigeration	All stock
4	Reduce End-of-Life Losses	All modeled appliances	All stock
5	Accelerate Refrigerant Transition	All modeled appliances	Only new products

The policy, assumptions and impact of each emission reduction action are detailed below:

1. **Reduce refrigerant charge.** This refers to reducing the total mass (charge) of refrigerant utilized in cooling appliances. This is only possible at the point of

manufacture, and typically requires changes to the fundamental product design. When this action is applied to a business-as-usual scenario, there is a resultant reduction in refrigerant losses, and in losses at the end of product life. Since cooling appliances are manufactured with a specific calibration of charge to function properly, this policy action could only apply to and reduce emissions for newly sold products.

2. **Reduce annual leakage.** Leakage of refrigerant from the appliance happens continuously over its lifetime and this loss is often approximated by an annual figure. This leakage occurs due to deficiencies in original product design/construction, in life deterioration of, for example, pipework joints, or following service where inadequate unit sealing occurs. Reducing leakage either via improved product manufacturer and/or servicing, would not only reduce the amount of refrigerant emitted each year, but it would also contain the refrigerant so end-of-life recovery programs could be most effective. Since, for most products, leakage is a byproduct of the manufacture of an appliance, and because repairs to reduce or eradicate leakage would be cost ineffective, this policy action would only reduce emissions for newly sold products. As noted, air conditioners differ slightly, and better servicing techniques (see following action), should result in reduced refrigerant leakage loss.
3. **Reduce service venting.** In Pakistan, cooling appliances are serviced by technicians as needed over their lifetimes. When servicing occurs, some technicians vent all of the refrigerant gas within the refrigerating system in order to execute repairs, then they refill the system with more refrigerant. A potential policy intervention is for a technician training program to educate workers on how to seal the refrigerant elsewhere within the system to make repairs, rather than vent it, and to reseal the system appropriately after service to prevent excess leakage. This particular policy action is only applicable to air conditioners and commercial refrigeration units (visi coolers, horizontal beverage coolers, ice cream freezers, and frozen food freezers) because the structure of their refrigerating pipework allows for the refrigerant gas to be contained elsewhere within the system without leaking while repairs are done, whereas this is not possible with domestic refrigeration units. Favorably, this policy could impact all existing units in use, not just newly sold units.
4. **Reduce end-of-life (EOL) losses.** Once an appliance is discarded or reaches the end of its operational life, the refrigerant remaining within the system (i.e., the amount after leakage following manufacture/the last service) will either be released into the atmosphere or be partially to fully captured for recycling. At present, there is effectively no end-of-life refrigerant capture from cooling appliances in Pakistan. A policy option for reducing end-of-life emissions is implementing a partial or total refrigerant capture mandate for processors of appliance waste. Since a refrigerant capture program can be applied to any existing unit before its end-of-life, this policy would apply to all existing units in use, not just newly sold units.
5. **Accelerate refrigerant transition.** All cooling appliances modeled have, or are currently undergoing, a transition to lower-GWP refrigerants. The market proportion of newly sold units containing a lower-GWP refrigerant is greater than older, obsolete high-GWP using appliances. Accelerating the timeline of either a market- or policy-led refrigerant transition would reduce CO_2 equivalent emissions

substantially sooner than the BAU scenario, primarily through reducing the impact of all other refrigerant related direct refrigerant losses. While retrofitting some products with a lower GWP refrigerant is technically possible, in practice, this policy would really only be applicable to newly sold products.

These policy scenarios were evaluated individually and in combination, in terms of emissions reduction potential, cost, market and industry readiness, and policy feasibility. With these factors specific to Pakistan in mind, the modelling assumptions for each policy scenario are listed in Table 21.

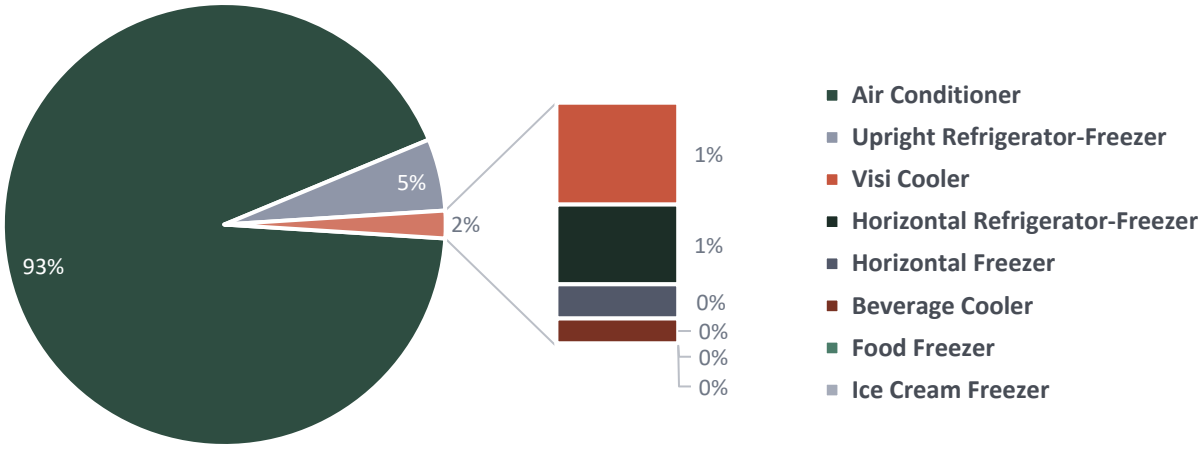
TABLE 21: MODELING ASSUMPTIONS FOR POLICY ACTIONS, FOR ALL COOLING APPLIANCES

	ACTION	ACTION ASSUMPTION
1	Reduce Refrigerant Charge	10% reduction
2	Reduce Annual Leakage	33% reduction
3	Reduce Service Venting	20% reduction
4	Reduce End-of-Life Losses	10% reduction
5	Accelerate Refrigerant Transition	From current 2023 market proportions to full transition by 2025

4.2.3 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM PRIORITY COOLING APPLIANCES/SECTORS

In 2022, direct emissions from cooling products totalled 5.7 Mt CO2e. Of these, over 90% of the direct GHG emissions from the Pakistan cooling sectors are from split-system air conditioning. Upright refrigerator-freezers have the second highest BAU emissions, constituting 5% of projected emissions.

GRAPH 42: DIRECT EMISSIONS FROM PRIORITY COOLING SECTORS UNDER BAU IN 2022

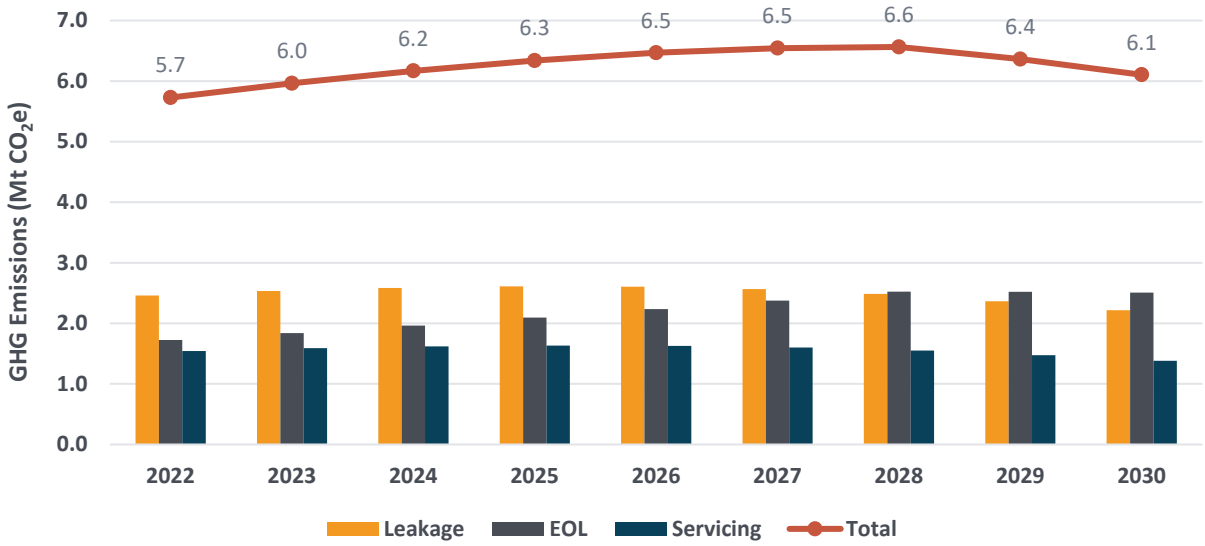


Under the BAU scenario, between 2020 and 2030, air conditioners average approximately 13 times the combined emissions of other cooling appliances. This is a direct result of the large refrigerant charge of air conditioners relative to the other products, the high GWP of the refrigerants being used in air conditioners, venting of refrigerant during service, and their high rate of leakage. Another contributing factor as to why air conditioners have by far the largest emissions in the BAU scenario is because air conditioner's refrigerant in transition (R-32) still has a GWP of 677 whereas the other refrigeration products have a second refrigerant with 100-year GWPs of less than one.

4.2.3.1 FUTURE PROJECTIONS OF DIRECT EMISSIONS UNDER BAU SCENARIO

Graph 43 shows a peak in BAU emissions in 2028 (6.6 Mt CO_2e), with a reduction in direct emissions beginning in 2029. This is because, in 2029, most of the cooling appliances would have fully transitioned to their lower GWP refrigerant (apart from air conditioners). Under the BAU scenario, all new air-conditioners are expected to have transitioned to R-32 by 2029, meaning emissions from air conditioners starts falling from that point as older R-410A units exit the market.

GRAPH 43: BAU DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS, BY EMISSION SOURCE, 2022-2030

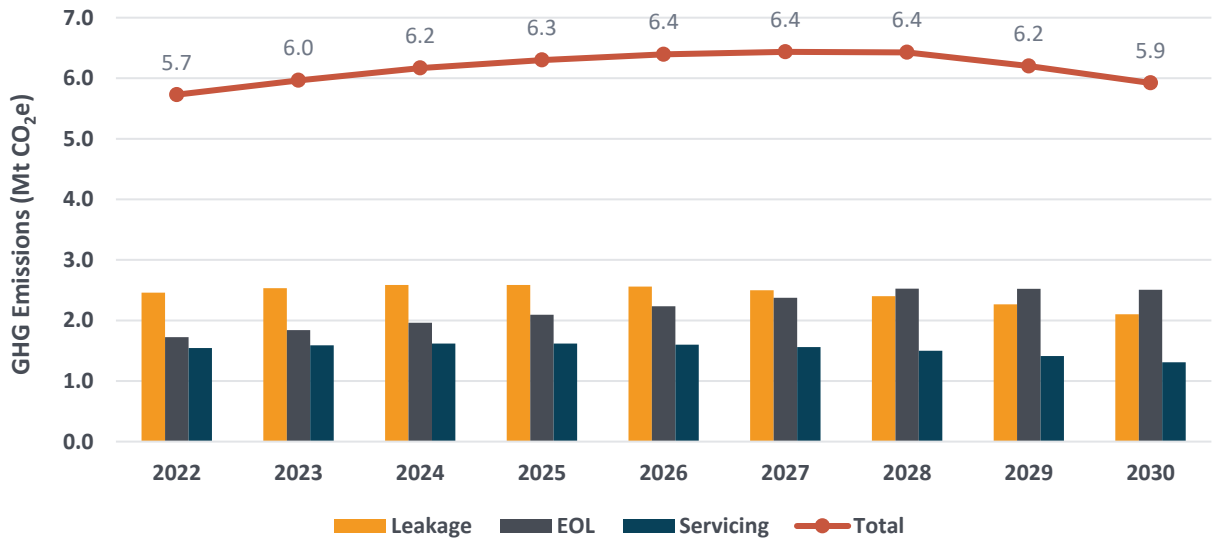


Graph 43 shows that under the BAU scenario, the leakage will peak in 2025 (2.6 Mt CO_2e) and will reduce to 2.2 Mt CO_2e by 2030. The service venting emissions will also peak in 2025 (1.6 Mt CO2e) and will reduce to 1.4 Mt CO_2e by 2030. End of life direct emissions will peak in 2028 (2.5 Mt CO_2e) and will then start reducing. **Cumulative direct emissions from the cooling appliances are projected to be 38.4 Mt CO_2e from 2025 through 2030**.

4.2.3.2 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM REDUCING REFRIGERANT CHARGE OF PRIORITY COOLING APPLIANCES

The policy scenario assumes a reduction of 10% in refrigerant charge for all new products impacting from 2025. The reduction in charge is projected to lead to a slight reduction in emissions from leakage and service venting but will not impact EOL emissions within the timeframe being used for the assessment (by 2030) as the appliances being changed (reduced refrigerant charge) will not yet be retired within this timeframe. The combined direct emissions under this policy scenario are projected to peak in 2027 (6.4 Mt CO_2e) and then start reducing. Cumulatively, direct emissions in the **BAU scenario are projected to be 38.4 Mt CO_2e from 2025-2030**. Over that same period, the reduced refrigerant charge **scenario is projected to reduce direct emissions by around 0.7 Mt**.

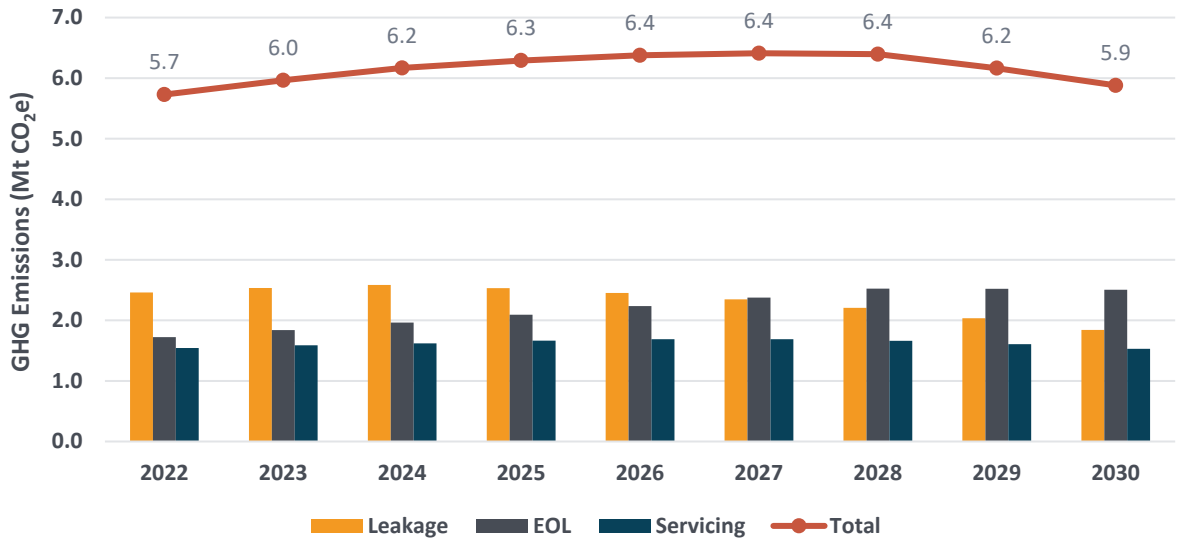
GRAPH 44: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROM REDUCING REFRIGERANT CHARGE, 2022-2030



4.2.3.3 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM REDUCING ANNUAL LEAKAGE RATE OF PRIORITY COOLING APPLIANCES

The policy scenario assumes a reduction of 33% in annual leakage charge for all new products impacting from 2025. The combined direct emissions under this policy scenario are projected to peak in 2027 (6.4 Mt CO_2e) and then start reducing. Cumulatively, direct emissions in the **BAU scenario are projected to be 38.4 Mt CO_2e from 2025-2030**. Over that same period, the reduced annual leakage rate **scenario is projected to reduce direct emissions of 0.9 Mt**.

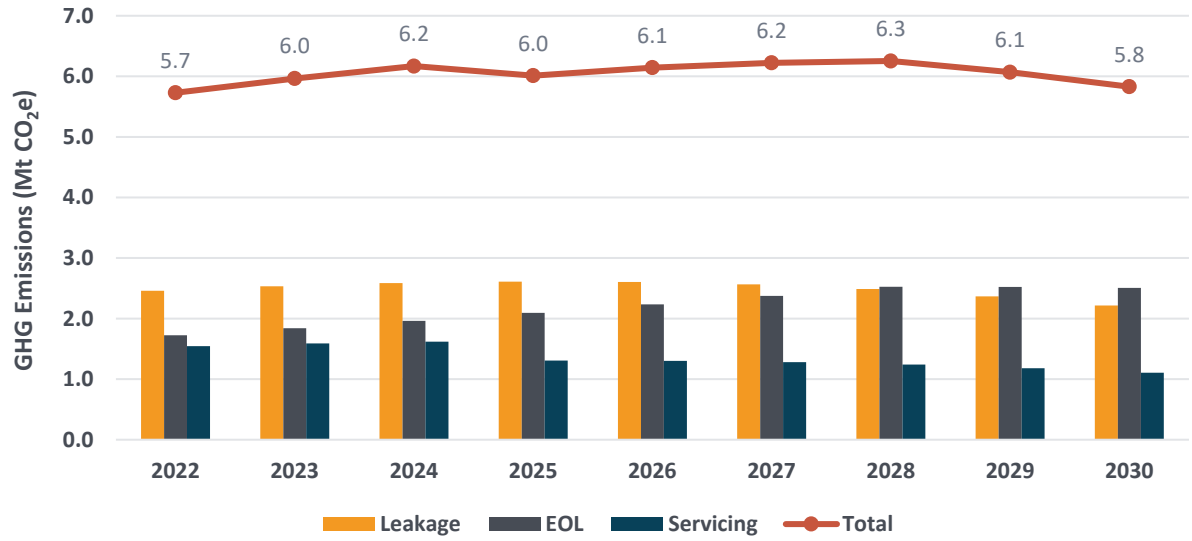
GRAPH 45: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROM REDUCING ANNUAL LEAKAGE RATE, 2022-2030



4.2.3.4 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM REDUCING SERVICE VENTING OF PRIORITY COOLING APPLIANCES

This scenario is focused on reducing service venting by 20% for all new products impacting from 2025. The reduction in service venting has a direct impact on the emissions during servicing but, due to the construction of the scenarios, has no impact on EOL or leakage during the timeframe under consideration. The combined direct emissions from the policy scenario can be seen in Graph 46. The reduced service venting **is projected to cumulatively reduce direct emissions by 1.9 Mt from 2025-2030 as compared to BAU scenario**.

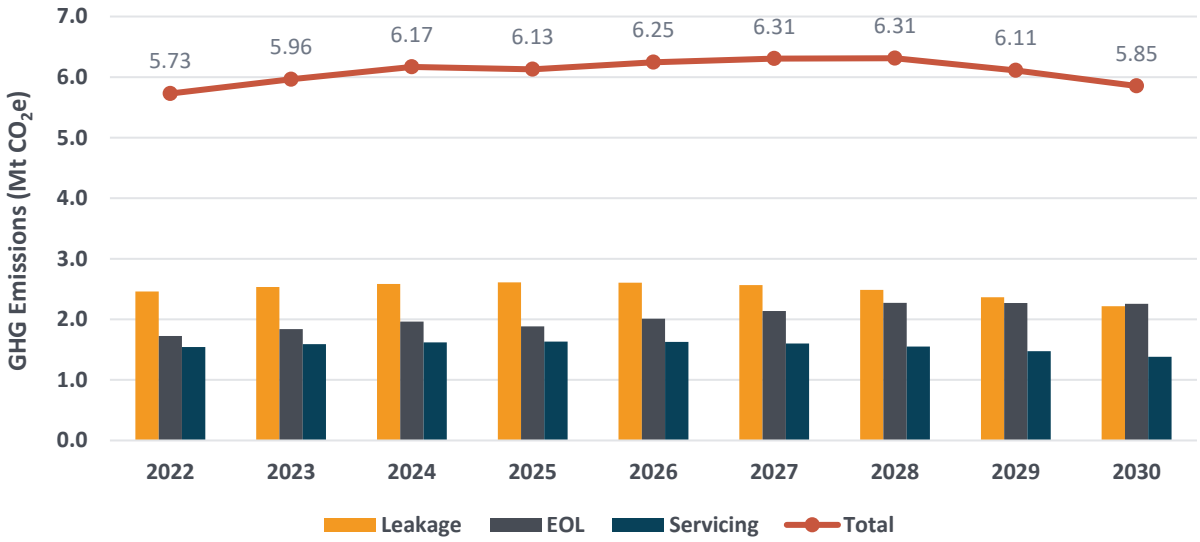
GRAPH 46: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROMREDUCING SERVICE VENTING, 2022-2030



4.2.3.5 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM REDUCING END-OF-LIFE LOSSES OF PRIORITY COOLING APPLIANCES

The policy scenario assumes a reduction of 10% in emissions in end-of-life losses for all products impacting from 2025. This policy will result in cumulative emissions of 37.0 Mt CO_2e from 2025-2030, as compared to 38.4 Mt CO_2e under the BAU scenario. In this case, there is no impact on refrigerant losses during the product use period. The reduction in end-of-life emissions **is projected to cumulatively reduce direct emissions by 1.4 Mt CO_2e from 2025 -2030 as compared to BAU scenario**.

GRAPH 47: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROM REDUCING EOL LOSSES, 2022-2030



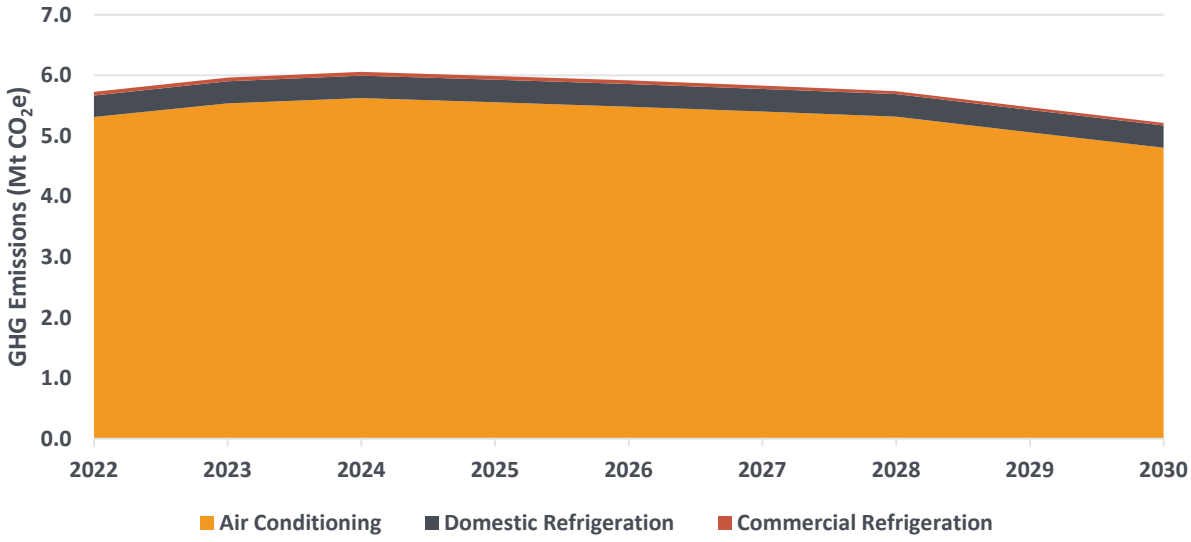
4.2.3.6 FUTURE PROJECTIONS OF DIRECT EMISSIONS FROM ACCELERATED REFRIGERANT TRANSITION OF PRIORITY COOLING APPLIANCES

The policy scenario assumes that all the new cooling appliances in the market in 2025 will have shifted to the lower GWP refrigerant (R-32 for air conditioners, R-600a for domestic refrigerators and R-290 for commercial cooling appliances). This policy has the most significant reductions amongst the modelled policies as the accelerated transition of refrigerants in air conditioners, currently the largest contributor to emissions, will lead to:

- A refrigerant which has almost one-third the GWP of the current refrigerant (677 GWP compared to 1923.5 GWP),
- A lower refrigerant charge requirement (890g instead of 1400g) which consequentially results in reduced emissions during servicing and annual leakage.

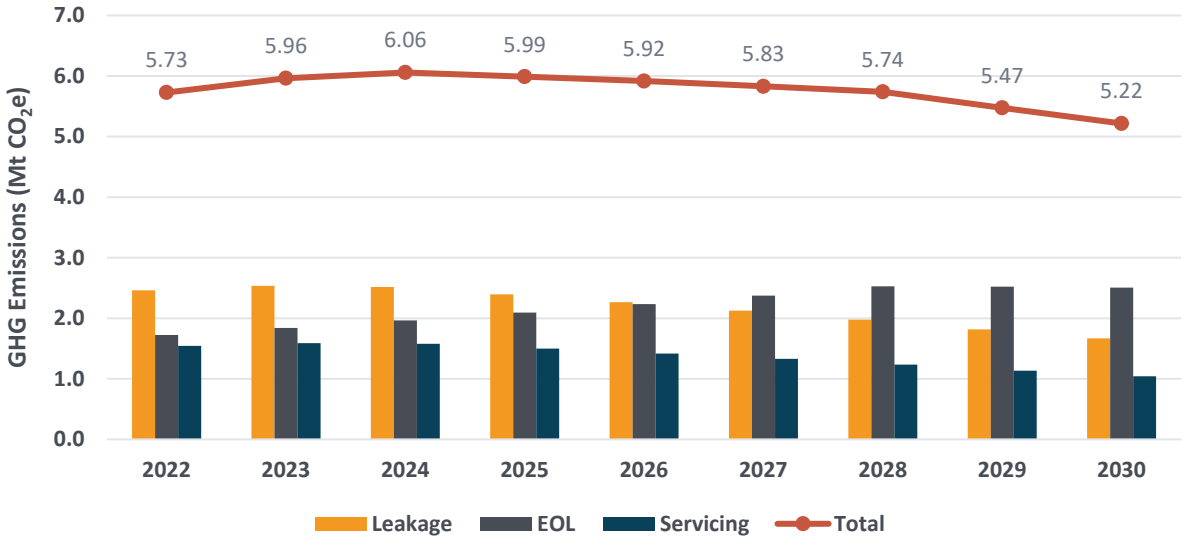
There will also be reduced emissions from most of the other cooling appliances but, due to the dominance of air conditioners, these other reductions are less visible (Graph 48).

GRAPH 48: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROM ACCELERATED REFRIGERANT TRANSITION, BY COOLING APPLIANCE SECTOR, 2022-2030



The accelerated transition in refrigerants is projected to lead to reduction in emissions from leakage and service venting but will not impact EOL emissions within the timeframe being used for the projections (until 2030). **The cumulative reductions in direct emissions from this policy scenario are projected to be 4.2 Mt CO_2e between 2025-2030**.

GRAPH 49: DIRECT EMISSIONS FOR ALL AGGREGATED PRODUCTS FROM ACCELERATED REFRIGERANT TRANSITION, BY EMISSION SOURCE, 2022-2030

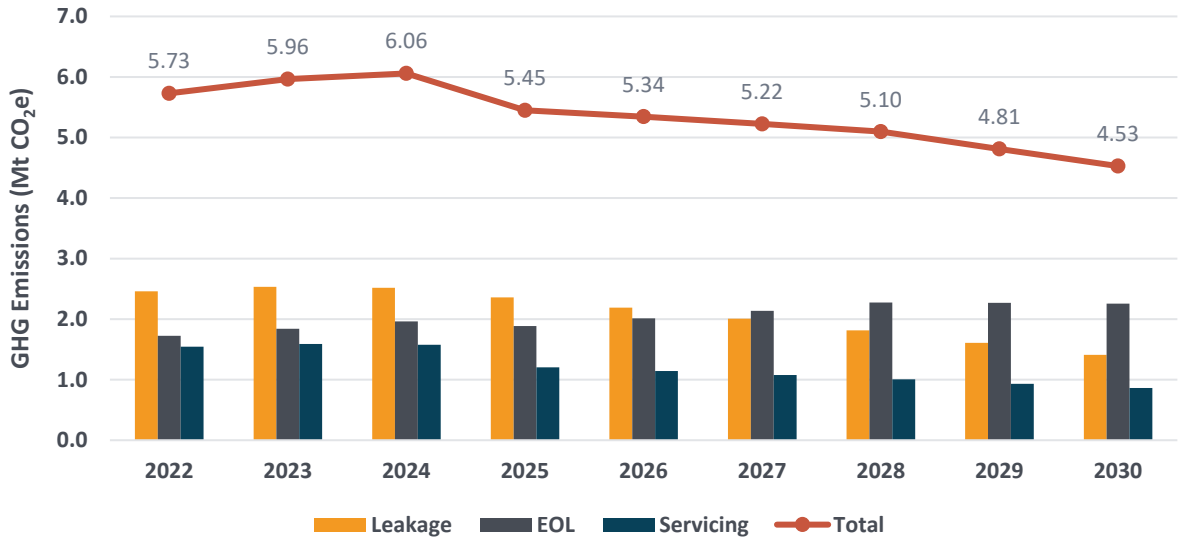


4.2.4 SUMMARY MEDIUM- AND LONG-TERM PROJECTIONS OF EMISSIONS FROM COOLING SECTORS

This section summarizes the overall direct emissions reduction potential from the analyzed cooling appliance sectors. **Without any policy interventions, Pakistan's cumulative direct emissions are projected to total 38.4 Mt CO_2e, from 2025 to 2030.** This will further contribute to climate change and its negative impacts.

Implementation of all policies developed within the scenarios above are projected to lead to a reduction in emissions of around 7.9 Mt CO_2e from 2025-2030 as compared to BAU. Amongst the five modelled policies, the accelerated **refrigerant transition policy scenario** in cooling appliances (most of which is contributable to air conditioners) alone is projected would provide the most significant reduction in cumulative emissions of 4.2 Mt CO_2e from 2025-2030.

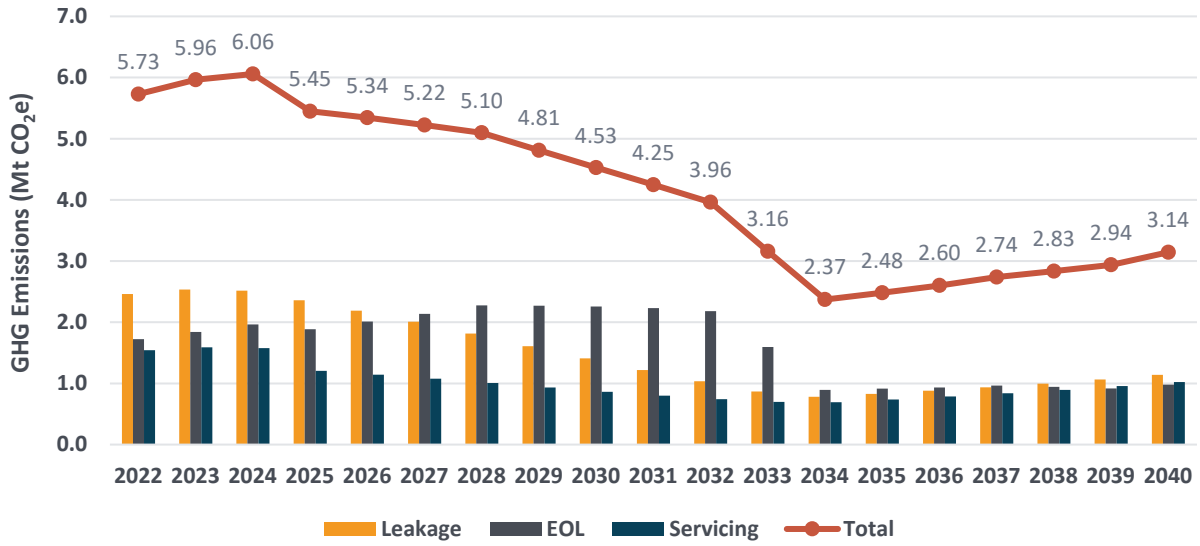
GRAPH 50: PROJECTED EMISSIONS FROM COMBINED POLICIES IN PRIORITY COOLING APPLIANCES



Graph 51 is projected through 2040 to better detail the long-term impact of policies and show that emissions will continue to reduce beyond 2030. In 2034, all R-410A refrigerant air conditioning units will have left the stock, resulting in this year being the lowest annual direct emissions (2.4 Mt CO_2e). From this point onward, emissions begin to rise as the direct emissions from increases in number of units installed outweigh the reductions from the policies introduced.

Further, it is important to note the impact of the policies on end-of-life emissions in the longer term. Primarily, the introduction of end-of-life policies in the late 2020s would appear to yield relatively high savings. However, Graph 51 shows that as products with high GWP refrigerants transition from the market, the value of end-of-life capture falls dramatically (from 2.2 Mt in 2032 to 0.9 Mt in 2034). Hence, heavy investment in end-of-life processing facilities, and the extensive infrastructure required to capture and transport the units to the facilities at end of life, may result in stranded assets by the early 2030s.

GRAPH 51: PROJECTED EMISSIONS FROM THE PRIORITY COOLING APPLIANCE SECTORS



Air conditioners offer the most significant potential to reduce direct emissions by 2030 amongst the priority cooling appliances. Although, air conditioners have a low penetration of 11% among households, they have the potential to reduce cumulative 7.6 Mt CO_2e emissions (all policies combined) from 2025-2030 as compared to other analyzed cooling appliances from the total projected cumulative reduction of 7.9 Mt CO_2e emissions. Thus, air conditioners alone have a significant potential for climate mitigation impact. Domestic refrigerators have the potential to only reduce direct emissions by 0.3 Mt CO_2e by 2030 through all the policy options and commercial refrigerators can reduce direct emissions by 0.03 Mt CO_2e by 2030. The main reason for this is that the direct emissions being emitted from these appliances are limited (7% of the total direct emissions in 2022) as refrigerator systems have a closed system which doesn't allow for significant leakage or service venting.

4.3 COOLING ACCESS

The population without access to grid electricity also has access to cooling, having some type of cooling appliances in their homes. The population without access to grid electricity is further analyzed to determine the proportion without any cooling appliance. The estimated number of people living in off-grid areas by province is shown in Table 22. The figures are based upon the 2017 census data of the Pakistan Bureau of Statistics and extrapolated using average growth rates for the respective provinces. The table shows that there are currently over 64.5 million people without grid electricity access in Pakistan.

TABLE 22: POPULATION LIVING IN OFF-GRID AREAS OF PAKISTAN

PROVINCE	POPULATION 2022	POPULATION WITH GRID ELECTRICITY ACCESS (2022)	POPULATION WITHOUT ACCESS TO GRID ELECTRICITY (2022)	PERCENTAGE OF POPULATION WITH ELECTRICITY ACCESS (2022)	PERCENTAGE OF POPULATION WITHOUT ACCESS TO ELECTRICITY (2022)
Sindh	54,028,331	32,386,527	21,641,803	59.94	40.06
Punjab	122,665,064	95,697,939	26,967,125	78.02	21.98
Baluchistan	14,708,144	8,367,549	6,340,595	56.89	43.11
KPK	35,253,389	25,573,928	9,679,461	72.54	27.46
Pakistan	**226,654,928**	**162,025,943**	**64,628,985**	**71.49**	**28.51**

Given the limited data available, it is difficult to establish a preliminary baseline for people without access to cooling. There are some assumptions and facts which need to be considered when drawing a conclusion about the population without access to cooling:

- The various projects being undertaken to provide solar home systems and off-grid appliances were assessed and their progress to date based upon information gathered from interviews concludes that about 350,000 people have access to cooling through DC fans produced by a recognized manufacturer from the formal sector (assuming an average household size of 6 persons).
- The total stock of DC pedestal fans sold through formal sector is estimated to be around 1.5 million. Assuming each fan delivers cooling access to an average household size of 6 persons, about 9 million people have cooling access through the purchase of branded DC pedestal fans over the last 10 years.
- There is a significant market share of unbranded DC fans sold through the informal sector for which production and sales figures are not available. This could be 3 to 4 times higher than the formal sector. However, the quality, performance and durability of these fans is comparatively low, and they therefore may not provide the same level of cooling access as compared to a DC pedestal fan from an established manufacturer.
- There is a growing demand for off-grid appliances such as DC fans (given the rapidly increasing population of Pakistan). PEFMA has estimated a growth rate of 10% for the coming years for DC fans but given that there is no comprehensive data available on total production and sales (which includes the 'informal' market), it is not possible to determine the growth rate for DC fans.
- The off-grid household survey indicated that at least a proportion of off-grid households* already have some form of off grid cooling appliance such as DC pedestal fan which has been purchased directly from the local market.
- According to stakeholder consultation with fan manufacturers, government, rural support organizations and other key experts in off-grid appliances, almost all the households located in the warmer regions of Pakistan would have access to some

* All the sample off-grid households from the off-grid survey had DC fans already installed

basic cooling appliance such as a DC fan, as it would be impossible to survive without access to some form of cooling in such areas during the summer season. In addition, the number of people a single DC fan can provide cooling for is probably exceeded by household composition in poorer communities, so there would be 'unmet' demand which is not being catered for by the current installed stock.

Based on the available data, above assumptions and facts, it can be concluded that while off-grid households located in hot climate zones where space cooling is a necessity do have access to a cooling appliance to meet their most basic cooling need. Their overall access to cooling is still limited due to the off-grid appliance's quality, efficiency, durability, operating hours and/or due to insufficient number of appliances per household.

Mapping of off-grid areas is essential for identifying specific areas where access to cooling is critical, focusing on the geographical clusters that have the largest off-grid population and highest heat index. The most vulnerable are the estimated 25 million people living in regions of heat index of 54 Degrees C and above. To meet these critical needs, the following interventions are recommended:

a) Facilitate the provision of high energy efficiency DC pedestal fans of 18-inch sweep size, which could easily provide the minimum air flow required by the user with a power consumption of 30 watts or less through the notification of MEPS for DC fans. This will provide a much better service compared to the wide range of power consumption and air flow observed during the SAMA^Verte small scale field survey.

Figure 7 shows the results from testing air flow and power consumption of 18-inch and 20-inch DC fans and comparing with AC fans of equal size. The 18-inch AC pedestal fan delivered an air flow of 70 m^3/min while 65 Watts power. In comparison, the 18-inch DC pedestal fan produced an air flow of 50 m^3/min, that provides optimal level of cooling, while consuming only 26 watts. While the NEECA/PSQCA MEPS only apply to AC fans at present, they can be applied to benchmark performance of DC fans. This analysis shows that this high-quality DC fan has a service value superior to the 5-Star threshold for an AC 18-inch pedestal fan equivalent. Similarly, a high-quality 20-inch DC pedestal fan provides a service value of 1.98 m^3/min/W which is higher than the 5-star threshold for AC fan of same size.

FIGURE 7: SAMPLE TEST RESULT OF HIGH-QUALITY DC FANS IN COMPARISON WITH AC FANS

AC Pedestal Fan:

Fan Size (Sweep)		MEPS		Aligned Standards & Label				
mm	Inch	Min Air Delivery (m3/min)	Max Watts	1 Star*	2 Star	3 Star	4 Star	5 Star
450	18	70	65	1.1	1.19	1.42	1.46	1.8
500	20	100	90	1.13	1.25	1.45	1.5	1.81

**NEECA 1-Star aligns with the PSQCA PS-1 MEPS*

Sample of one of the best DC Pedestal fan tested from PCSIR:								
450	18	53.6	26					2.09
500	20	73	37					1.98

b) Inclusion of DC fans in the MEPS and Labelling policy for fans will help in removing inefficient off-grid fans from the market. The population in weak- and off-grid areas will get access to reliable cooling products, requiring significantly lower power, enabling users to purchase smaller solar solutions or increase operating hours if used with a battery, thereby improving cooling access.

c) Focus on the geography of rural Sindh, where over 25 million of the most vulnerable people live within the zone of heat index of 54 Degrees Centigrade and above.

Conclusion and Way Forward

This Cooling Needs Assessment (CNA) report was prepared to inform the development of PCAP, a macro-level policy document to guide and accelerate the country's transition towards sustainable cooling. The CNA report provides a comprehensive assessment of the priority cooling sub-sectors in Pakistan, including domestic and commercial refrigeration, and domestic space cooling. It delivers insights and comparative assessment of future pathways for these sub-sectors to address anticipated cooling demand and associated impacts. Lastly, it highlights the most critical cooling needs and challenges to be considered when developing the PCAP.

The major CNA outcome is establishing a baseline for met cooling demand, population with access to cooling, energy consumption, as well as indirect and direct emissions for the priority cooling sectors. The energy consumption and indirect projections* include BAU growth, MEPS, U4E, and BAT scenarios that estimate how the cooling demand will evolve based on varying efforts across policy, technology, and market enablers. The projections for direct emissions include BAU growth, reducing refrigerant charge, reducing annual leakage rate, reducing service venting, reducing end-of-life losses, and accelerating refrigerant transition to estimate how direct emissions will be impacted by these policies.

Under BAU scenario, Pakistan's cumulative energy consumption and CO_2 emissions from 2023-2030 are estimated at 695.4 TWh and 326.8 Mt CO_2 indirect emissions and 44.6 Mt CO_2e direct emissions.

The MEPS scenario is projected to provide cumulative energy consumption and associated CO_2 indirect emissions reductions through 2030 of 14.5 TWh and 6.8 Mt, respectively. The BAT scenario has the potential to provide about seven times the reductions of the MEPS scenario. Given such small impact of current policies (MEPS scenario) and that the assessed cooling appliances use estimated 46% of total electricity, robust and ambitious policies and market transformation initiatives are essential to curb energy consumption and emissions. These interventions can also reduce the need to build additional generation capacity to meet the future cooling demand.

All the combined policies targeting direct emissions have the potential to reduce emissions by 7.9 Mt CO_2e from 2025-2030. To curb direct emissions, air conditioners should be prioritized based on the analysed data and policy projections. They emit over 90% of the direct emissions amongst the priority cooling appliance sectors. A regulation which mandates a lower GWP value for refrigerants in manufacturing of air conditioners and an accelerated transition alone can lead to a cumulative reduction of 4.4 Mt CO_2e between 2025-2030.

* At the present time, this document has only included policies linked to minimum energy performance standards.

This comparative sectoral and policy assessment will serve as a basis for identifying priority interventions to sustainably address cooling growth in Pakistan and recommendations for the PCAP. The initial recommendations for the PCAP encompass the following categories:

- *Policy and regulatory interventions*, which may include developing or revising MEPS and labels for cooling appliances to accelerate market transition to more efficient appliances. CNA will inform these interventions. Ensuring policy implementation through robust processes and infrastructure such as product registration system and testing facilities will be essential. Other potential policy interventions may include review and revision of building codes and vehicle emission standards.
- *Technology interventions*, that may include enhancing the efficiency of existing cooling technologies through industry support such as "know how" and technology transfer programs, and improved supply chain. Other solutions may include adoption of alternative refrigerants with lower GWP and increased uptake of sustainable cooling solutions for off-grid and weak-grid areas.
- *Interventions for market enablement*, which may include financing instruments to promote sustainable cooling, innovative business models to deliver and scale-up sustainable cooling, public procurement, strengthening institutional and professional capacities (including training of technicians), and enhancing consumer and stakeholder awareness.
- *Affordable solutions for off-grid and weak-grid communities*, that may include financial and policy instruments to promote and increase uptake of solar solutions and high-quality energy efficient off-grid appliances.

PCAP Working Group will lead the PCAP development over the next 12 months through a heavy consultative process. The next steps for developing the PCAP include:

- Presenting the CNA insights and results to the PCAP Working Group and stakeholders, including industry, through consultations to gather their feedback and input into PCAP.
- PCAP development, which will include consultations and identification of interventions. The Working Group will prioritize the areas of focus for the PCAP, assess the robustness of the recommendations against Pakistan's national targets and their alignment with existing policies and programs, and seek government buy-in. CLASP/SAMA^Verte team will support careful prioritization of the recommendations and development of the plan.

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