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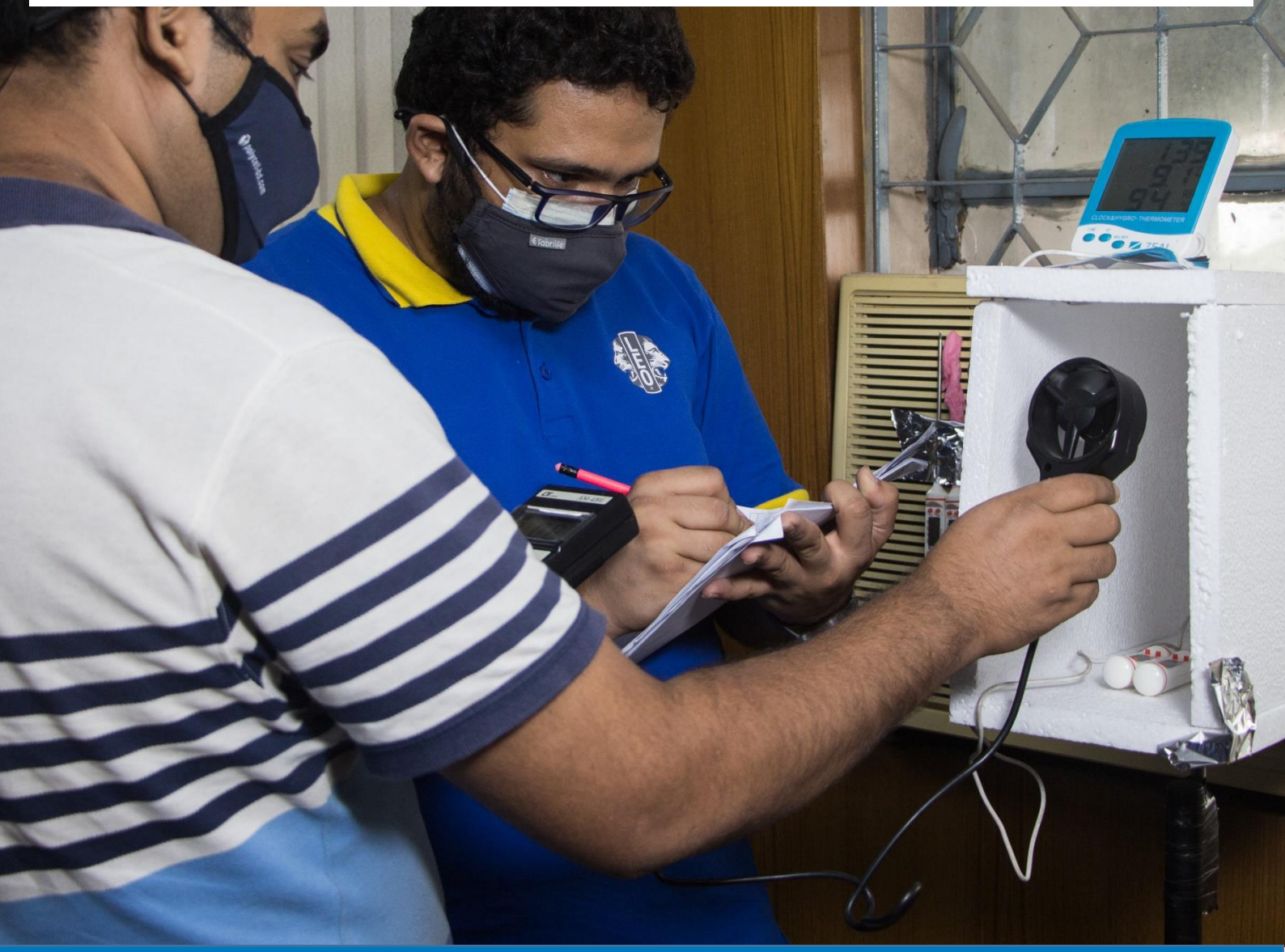

Energy Efficiency in Public Buildings in Bangladesh

Assessment of Best Available Technologies

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The report is mainly based on a desktop survey. Unfortunately, due to the COVID pandemic, no on-site data collection could be conducted. Where brands/products available on the local market were not included in the overall analysis, this was due to a lack of information and was not intentional.

SREDA, as the owner of this initiative on behalf of the Government of Bangladesh, may update the content of this report periodically, with appropriate references provided.

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Abbreviations

AC	Air Conditioner
AC	Alternative Current (starting from p. 45)
BAB	Bangladesh Accreditation Board
BAT	Best Available Technology
BLDC	Brushless Direct Current
BREB	Bangladesh Rural Electrification Board
BRESL	Barrier Removal and Cost-Effective Efficiency Standards and Labelling
BSTI	Bangladesh Standard and Testing Institution
BTU	British Thermal Unit
CAPEX	Capital Expenditures
CBU	Completely Built-Up Unit
CFL	Compact Fluorescent Lamps
CO2	Carbon Dioxide
CO2-EQ	Carbon Dioxide equivalent
CFC	Chlorofluorocarbons
COP	Coefficient of Performance
CRI	Colour Rendering Index
EE&C	Energy Efficiency and Conservation
EEPB	Energy Efficiency in Public Buildings
EER	Energy Efficiency Ratio
ELIB	Efficient Lighting Initiatives of Bangladesh
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	German Corporation for International Cooperation
GOB	Government of Bangladesh
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HVAC	Heating Ventilation and Air Conditioning
IEA	International Energy Agency
K-CEP	Kigali Cooling Efficiency Program
LED	Light Emitting Diode
MEPS	Minimum Energy Performance Standard
MLF	Multilateral Fund
MP	Montreal Protocol
NBR	National Board of Revenue
NCP	National Cooling Plan
NOC	No Objection Certificate

NOU	National Ozone Unit
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substance
OEM	Original Equipment Manufacturer
PA	Paris Agreement
PF	Power Factor
PEEP	Programme for Energy Efficiency in Buildings
PV	Photovoltaic
RAC	Refrigerant and Air Conditioning
SEER	Seasonal Energy Efficiency Ratio
SREDA	Sustainable and Renewable Energy Development Authority
TAPP	Technical Assistance Project Preparation
TR	Ton of Refrigeration
UAC	Unitary Air Conditioning
UNDP	United Nations Development Programme
USD	US Dollar
VRF	Variable Refrigerant Flow

Executive Summary

This report identifies current technologies used in public buildings in Bangladesh and recommends alternative energy-efficient cooling and lighting technology best suited to the country. It also discusses the role of solar photovoltaic (PV) systems in reducing grid electricity use. Finally, the report lists companies providing such climate-friendly equipment, aiming to assist key actors in making an informed decision.

What is the background? This publication was produced as part of the activities of Proklima, a programme within the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), funded by the German Federal Ministry for Economic Cooperation and Development (BMZ). As per the request of the Sustainable and Renewable Energy Development Authority (SREDA), GIZ has received a grant from the Kigali Cooling Efficiency Program (K-CEP) to implement a pilot project on Energy Efficiency in Public Buildings in Bangladesh (EEPB). Under the pilot project, energy audits has been conducted in selected public buildings across Bangladesh.

In what broader context did EEPB originate? The maintenance of buildings requires a high amount of energy. It is no surprise then that, in public discourse, buildings are acknowledged as major sources of greenhouse gas (GHG) emissions. But one particular aspect is often forgotten: cooling. It is essential for residential, commercial and public sectors alike – even more so in countries located in subtropical climate zones such as Bangladesh. The building sector in Bangladesh represents about 35% of the total electricity consumption. With rising temperatures, better standards of living and a growing population, the demand for cooling is ever-increasing. Unsustainable synthetic solutions would not only further accelerate climate change in a country already heavily affected by its adverse impacts; it would also be costly. To single out best available energy-efficient technologies is therefore essential. Among others, this assessment thus highlights synergies between the building sector and the Refrigeration and Air Conditioning (RAC) sector.

What is this report used for? The results will be shared with wider stakeholders. The idea is twofold: to complement the recommendations from the energy audits; and to determine the cost-benefits of promoting nation-wide energy efficiency in public building projects in Bangladesh. Successful implementation of the pilot project could ultimately help grow the energy-efficient appliance market in Bangladesh and garner interest from private sector actors in launching cooling and PV solar projects in residential, commercial and industrial buildings.

1. Introduction and Objective

Buildings are major contributors to climate change. In addressing its adverse impacts, the building sector and a change thereof are crucial. There are two ways in which buildings contribute significantly to greenhouse gas (GHG) emissions. First, through embodied emissions. The production of cement and steel throughout entire building lifecycles accounts for around 10% of the world's annual GHG emissions. Second, through operational emissions. Every day, energy is needed to light, heat, and cool buildings.

The latter is of particular relevance in warmer climates, where cooling accounts for about one-fifth of all electricity used in buildings and thus consumes more than lighting, lifts, or water pumps.[1] The use of energy for space cooling is growing faster than for any other end-use in buildings; it more than tripled between 1990 and 2016. Global sales of air conditioners (ACs) have increased steadily and significantly. Since 1990, annual sales of ACs nearly quadrupled to 135 million units. Globally, there are now about 1.6 billion ACs in use, and they vary enormously in energy efficiency.

In Bangladesh, the building sector is a main driver of economic growth. It is also a significant consumer of energy. Rapid urbanisation, coupled with rising prosperity, will accelerate the construction of buildings, particularly high-rise buildings. Subsequently, the energy used for cooling equipment, lighting, and other electric appliances will also grow.

The discussion on building sector interventions is therefore a timely one. Carefully designed buildings offer great potential for increased energy efficiency and can contribute to replacing substances that are ozone depleting or hazardous to the climate. Building retrofits, a labour-intensive endeavour, can also be an important source of job creation. The contribution of this paper will be to highlight synergies between the building sector and the Refrigeration and Air Conditioning (RAC) sector, and, in so doing, to assess the best available energy-efficient technologies and solar photovoltaic (PV) systems suited for public buildings in Bangladesh.

1.1 Project Idea

With a Gross Domestic Product (GDP) growth of 5.24% in the 2019/2020 fiscal year [2], Bangladesh, at the time of its 50th anniversary, is the fastest growing economy in the Asia-Pacific region. It has gradually evolved from “least developed” to “developing” or “lower middle-income”, according to the World Bank’s country classifications. Energy demand will further surge to achieve its ambition of becoming a fully developed economy by 2041. To sustainably achieve Bangladesh’s development ambition, Energy Efficiency and Conservation (EE&C) Master plan will continue to play a pivotal role. The EE&C Master Plan outlines Bangladesh’s target to achieve a 20% reduction in primary energy consumption per GDP by 2030, compared to the 2013 level.

The commercial and public services sector accounted for 2% of the total energy consumption in 2015 in Bangladesh. According to the EE&C Master Plan, in commercial buildings, approximately 50% of the total energy consumed is caused by air conditioning, followed by 10-30% for lighting. The replacement with energy-efficient inverter type air conditioning and LED lighting system is expected to deliver about 50% electricity savings. The EE&C masterplan also indicates public building retrofits would be cost-effective and deliver a potential annual saving of 5%. If all public buildings in Bangladesh were retrofitted with energy-efficient technology and better insulation, the government would reduce its

1 IEA (2018). The future of cooling
2 Bangladesh Bureau of Statistics

public budget spending substantially, reduce energy consumption and GHG emissions, help establish improved comfort and well-being of public staff, and create an energy efficiency market.

As per the request of Sustainable and Renewable Energy Development Authority (SREDA), GIZ has received a grant from the Kigali Cooling Efficiency Program (K-CEP) to implement a pilot project on Energy Efficiency in Public Buildings in Bangladesh (EEPB). Under the pilot project, energy audits will be conducted in selected public buildings. The project includes a brief assessment of the best suitable and energy-efficient cooling, lighting, and solar PV solutions currently available on the Bangladeshi market and suitable for public buildings. The results of this assessment will be shared with wider stakeholders to complement the recommendations from the energy audits and determine the cost-benefits of implementing nation-wide energy efficiency in public building projects in Bangladesh. Successful implementation of this project could help grow the energy-efficient appliance market in Bangladesh and garner interest from private sector stakeholders in implementing energy efficiency projects in residential and commercial buildings as well as the industrial sector.

1.2 Objectives

The EEPB project aims to determine the potential energy efficiency savings in public buildings to reduce the need for energy used for air conditioning and refrigeration, lighting and other equipment, complemented by the use of solar PV, if viable. In selecting the best available technology (BAT), the objectives of this study are:

i. to identify current technologies used in public buildings for active and passive cooling, lighting and other purposes;
ii. to recommend alternative energy-efficient technology best suited to Bangladesh in terms of climate class, GHG emission reduction, market availability, and cost of the equipment;
iii. to list the companies providing the best energy-efficient equipment, primarily for cooling and lighting in public buildings at an affordable cost and with aftersales services;
iv. to recommend high-performance renewable energy sources such as solar PV solutions suitable for public buildings to reduce the load on grid electricity;
v. and to disseminate the findings of the BAT study with relevant stakeholders of the EEPB project, and to extrapolate the findings of the energy audits to determine the costs and benefits of nationwide energy efficiency in public building projects.

The objectives are interlinked with the output of the EEPB project, and the appointed energy audit firm will conduct an economic analysis of the energy efficiency measures for each of the selected public buildings and consider the technology recommended in this report.

1.3 Scope of Work

The aim of the EEPB project is to determine the potential for improving energy efficiency and reducing the energy used for cooling in public buildings in Bangladesh. The main tasks of the EEPB project include:

i. an inventory of existing public buildings (e.g. building types, floor size, annual energy bills if available, mainly in Dhaka);
ii. an assessment of existing and best available efficient technologies/systems as well as solar technologies (this study);
iii. the facilitation of Energy Audits for at least 12 Public Buildings located in Dhaka, Chittagong, Kushtia, and Rajshahi;
iv. and a technical and economic assessment of a nationwide EEPB project.

This report will cover task ii) and emphasise the building envelope technology, particularly air conditioning, lighting, and solar PV best suitable for public buildings in Bangladesh.

The BAT of the building envelope will largely depend upon the cost, suppliers, and specification on the construction materials (e.g. double-walled and low e-windows, cool roofs, wall insulation) used in the buildings. This includes passive cooling and the use of natural lighting.

Due to the subtropical climate in Bangladesh, there will be a focus on cooling performance of AC systems alone, while heating performance is outside the scope of the project. The energy efficiency data will be based on the specifications declared by the manufacturers. Minimum energy performance standards (MEPS), to date, are not applied to all the electric equipment (especially unitary ACs, Variable Refrigerant Flow (VRF) units, and refrigerators) in Bangladesh. It is currently impossible to compare the energy efficiency performance of all products.

The electric equipment market in Bangladesh is composed of imported as well as locally manufactured products. The BAT assessment will cover both locally produced as well as the imported equipment available on the Bangladeshi market. However, sometimes there is a lack of detailed specifications and technical data sheets of the imported items, as these are imported from the original equipment manufacturer (OEM). Equipment such as ACs with VRF, large chiller-based heating, ventilation and air conditioning (HVAC) system are imported based on the customised need (i.e. commercial buildings, hotels). Therefore, there might be major discrepancies in the prices of possible VRF and HVAC systems in Bangladesh and reported in this study. However, the report will illustrate the current import duty structure of the cooling equipment commonly imported to Bangladesh, which could help to give an estimate of import costs of energy-efficient equipment from the overseas market.

The cost of the energy-efficient equipment provided will be the market price at the retail or online store, and this could vary significantly in the case of large bulk volume orders or orders through the Government tendering process. Therefore, the product costs indicated in this study are likely to be higher than anticipated if procured in bulk for a nationwide EEPB project.

1.4 Methodology

The information on energy-efficient equipment specifications and costs is collected from both primary and secondary sources. The primary sources include bilateral email communication, interviews, and meetings with manufacturers or the association of the equipment manufacturers. Some of the import data will also be collected from the National Board of Revenue (NBR) to cross-verify the market share of the different equipment manufacturers. The secondary sources of data will be collected mainly from the website of the equipment manufacturers. In addition, various research reports, news articles, and similar previous studies by GIZ, SREDA and other institutions will provide secondary data.

The selection of the best suitable refrigerants in the cooling equipment used in Bangladesh will follow the phaseout schedule accepted by the National Ozone Unit (NOU) of Bangladesh as per the agreement with the Multilateral Fund (MLF) secretariat. The report will also incorporate some data from the Ozone Depleting Substances (ODS) alternative survey and the ongoing National Cooling Plan (NCP) in Bangladesh.

2. Background Information

This chapter provides the basic information necessary for a better understanding of the BAT study. For this purpose, a country profile of Bangladesh is presented, including information on the climate and the solar potential. Furthermore, the hydrochlorofluorocarbons (HCFC) phase-out management plan and the justification for energy-efficient technologies are discussed. Finally, measures for reducing cooling loads are presented.

2.1 Climate and Solar Potential

Bangladesh has a subtropical monsoon climate characterised by wide seasonal variations in rainfall, high temperature and humidity. There are three distinct seasons in Bangladesh: a hot humid summer from March to June; a cold rainy monsoon season from June to October; and a cold, dry winter from October to March. In general, maximum summer temperatures range between 30°C and 40°C. April is the warmest month in most parts of the country. January is the coldest month when the average temperature for most of the country is about 10°C. The cool season lasts for 1.5 months, from December 14 to January 31, with an average daily high temperature below 25°C (see Figure 1).

Heavy rainfall is characteristic of Bangladesh. Except for the relatively dry western region of Rajshahi, where the annual rainfall is about 1600 mm, most parts of the country receive at least 2000 mm of rain per year. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the regions in north-eastern Bangladesh receive the most significant average precipitation, sometimes over 4000 mm per year. About 80% of Bangladesh's rain falls during the monsoon season. On average, August is the most humid month in Bangladesh. The average annual percentage of humidity in Dhaka, the capital, is 74%. The weather pattern in Bangladesh explains our focus on cooling appliances as opposed to heating or heating-cooling systems. [3]

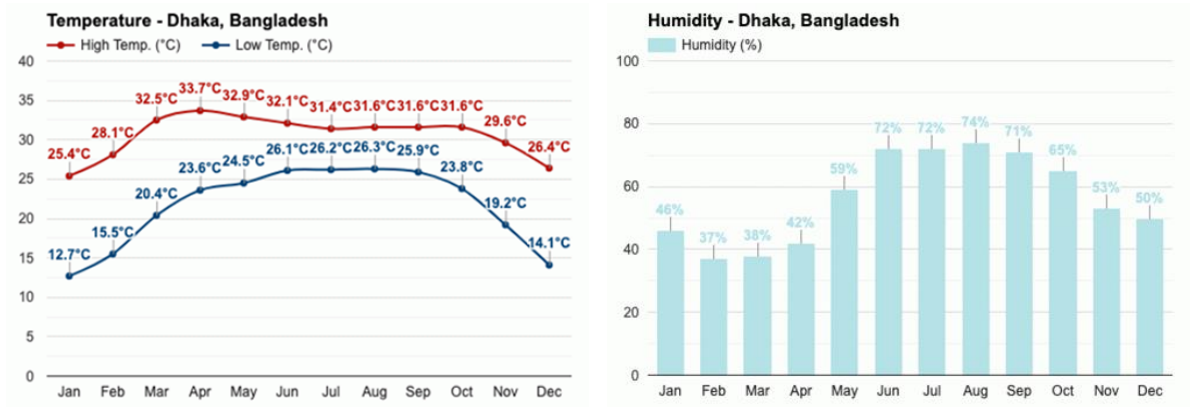


Figure 1. Average temperature and humidity in Dhaka [3]

Furthermore, the climate conditions suggest that the solar potential in Bangladesh is vast. As shown in Figure 2, the specific PV power output ranges between 3.68 – 4.23 kWh/kWp, with the highest potential around Chittagong. The optimum tilt of PV modules ranges between 22-27°C. [4]

3 www.weather-atlas.com
4 World Bank - Global Solar Atlas

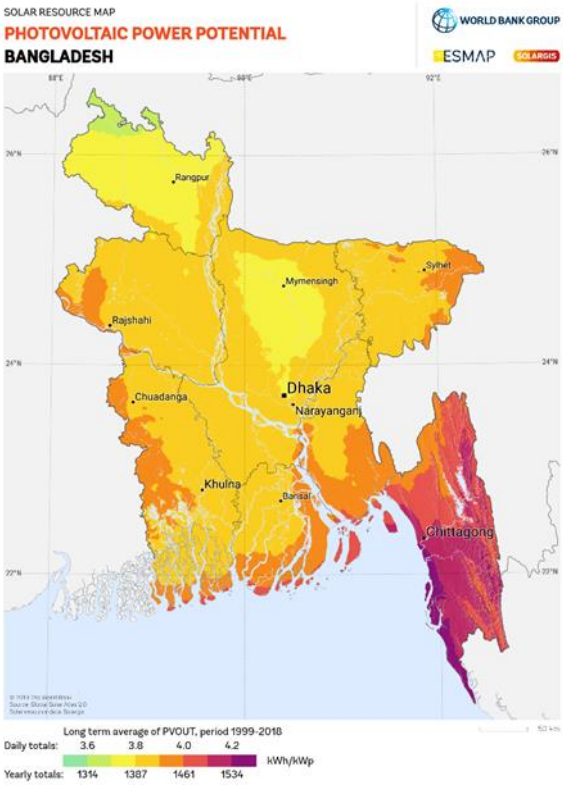


Figure 2. Photovoltaic Power Potential Bangladesh [4]

2.2 HCFC Phase-Out Management Plan (HPMP)

The 81st Meeting of the Executive Committee of the Montreal Protocol (MP) Multilateral Fund approved the HCFC phase-out management plan (HPMP) Stage–II for Bangladesh for the implementation of the MP. The Government of Bangladesh (GoB) proposes to follow the MP schedule and aims to reduce HCFCs consumption by 67.5% of the baseline in 2025. The implementation of Stage-II of the HPMP will help to phase out of 17.09 ozone depletion potential (ODP) tonnes of R22 used in the domestic and commercial AC manufacturing sector. The phase-out of 17.09 ODP tonnes of R22 is equivalent to a net CO2 emission reduction of 1,730,798 CO2-eq tonnes.[5] This will assist Bangladesh in meeting the MP compliance target. During the implementation of the HPMP Stage-II, safety and energy efficiency issues are taken into consideration in line with local and international regulations, standards and guidelines. The project was scheduled to be implemented during 2018-2025 in the National Implementation modality. Still, due to the complex TAPP (Technical Assistance Project Preparation) approval process, the start of the HPMP Stage-II is expected in 2021.

Under HPMP Stage II, the GoB has intended the adoption of non-ODS alternatives, with low global warming potential (GWP), for the AC manufacturing and servicing sectors.[6] The GoB aims to reduce 422.17 MT (24.01 ODP tonnes) of HCFCs by 2025 through the implementation of Stage-II activities. For this purpose, a direct switch to the refrigerants R290 and R32 is planned, which leads to energy savings and a reduction of GHG emissions.

5 Climate impact is calculated as per revised multilateral climate impact indicator (MC II) described at UNEP/OZL.PRO/EXCOM/81/23; 2 June 2018
6 UNEP/OZL.PRO/EXCOM/81/58; 22 June 2018

The following plans are addressable for this project:

a) Implementation of Stage II in an expedited manner, from HCFC-based technologies to lower GWP technologies: R290 in ACs up to 1.5 Ton (18,000 BTU); and R32 in AC equipment larger than 1.5 Ton.
b) Adaptation of direct conversion from R22 to R290 and R32 to maximise the environmental benefits of the phasing out of HCFC and leapfrogging, as feasible, to lower GWP options.
c) Implementation of well-aligned HCFC policies that can help to curb demand for ODS and can foster the need for non-ODS.

The room ACs and chillers are the largest consumers of R22 in the RAC manufacturing sector, accounting for 75% of the total consumption in 2016.[7] R290 and R32 have been selected as alternatives by the AC manufacturing companies. The chillers manufactured will be converted to R32 technology. The residential AC will opt for R290 and R32 based on the cooling capacity size. Given the flammability and still limited component availability of R290 (A3 - highly flammable), R32 (A2L - mildly flammable) is emerging as a widely accepted option for adoption by many industry players across the globe. The Government proposed - adhering to the Kigali Amendment - that the industry should opt, at the maximum extent possible, for R290 for ACs with less than 1.5 Ton capacity, and the air-conditioners which are higher than that capacity would be converted with low GWP. The industry has agreed to such changes during a consultation meeting involving all stakeholders.

The HCFC phase-out strategy in the sector will equip the following enterprises with R290 and R32 conversion technology:

a) Five room AC manufacturers: AC Bazar Industry (one production line), Walton Hi-Tech Industries Ltd (two production lines), Supreme Air-conditioning (one production line), Unitech Products (BD) Limited (one production line), and Elite Hi-Tech Industries Ltd. (one production line)
b) One Chiller manufacturer

This sector plan will be implemented as part of the overall HPMP (Stage-II) for Bangladesh. The Department of Environment (DoE) will coordinate the implementation. United Nations Development Programme (UNDP) is the implementing agency for the RAC Manufacturing Sector. These interventions are expected to result in a phase-out of 310.78 MT (17.09 ODP tonnes) of R22, consisting of 308.636 MT (16.97 ODP tonnes) in room air conditioning and 2.353 MT (0.12 ODP tonnes) in the Chillers.

2.3 Justification for Energy Efficiency Technology

Bangladesh's residential and commercial sectors (including public buildings) represent about 35% of the total electricity consumption, and the demand for housing and offices is ever-increasing.[8] Rising temperatures add further stress on the building sector in the form of higher energy demand and consumption in private and public buildings, as well as increasing GHG emissions. Consequently, the saving of energy and resources during both the construction and consumption process in the building sector should be given high priority to cost-effectively reduce GHG emissions, ensure energy security, promote sustainable growth, and improve comfort of building users.

7 UNEP (2016). ODS survey
8 Energy Efficiency and Conservation Master Plan up to 2030

Public buildings (non-residential buildings) account for most of the energy consumption in the commercial sector. The total construction area of public buildings is 14.27 million square meters connected to 44,650 different types of electric equipment (April 2017).9 Roughly 50-60% of the total energy in a typical commercial building is consumed by air conditioning and 10-30% by lighting systems. At present, 122 central air-conditioners and 23,247 split air conditioners are installed in different public buildings mostly in Dhaka and other cities. Table 1 lists the electric equipment installed in public buildings. 8

Table 1. Electric equipment installed in the public buildings[9]

Sub-station	Lift	Generator	Central AC (With Chiller)	Split/window AC	Solar systems	CC TV	Others
1,034	595	481	122	23,247	303	3,483	15,385

The energy demand for cooling in developing countries is rising by 7% annually until the year 2050[10]. Calculations by GIZ Proklima have shown that equipment with low efficiencies and a high release rate of refrigerants with high GWP account for 10% to 15% of global GHG emissions through the RAC sector. On average, about two-thirds of GHG emissions are caused by energy consumption (indirect emissions) and one-third by the use of refrigerants (direct emissions).[11]

The manufacturing and assembly industry of RAC equipment in Bangladesh is growing at a faster rate due to a significant import tax shield protecting local industries. Over 90% of all types of unitary air conditioners (UACs) are assembled or manufactured locally.[12] According to the Bangladesh Refrigeration and Air Conditioning Manufacturers and Exporters Association, in 2019, around 420,000 units of split ACs were purchased on the Bangladeshi market. Public buildings drive demand for locally manufactured UACs. In light of growing popularity of refrigeration systems, especially of room air conditioning, it is crucial to increase the energy efficiency of the systems and to switch to climate-friendly refrigerants (GWP<10). As mentioned in the previous chapter, this can avoid large amounts of GHG emissions and support the achievement of the MP target and the Paris Agreement. Replacing old AC units with climate-friendly and more energy-efficient ones, especially in public buildings, would contribute to reducing direct and indirect GHG emissions, and raise public awareness.

2.4 Reduction of Cooling Loads

The cooling load of a building is influenced by different heat flows and defines the heat loads that need to be dissipated to reach a required temperature. Here, a distinction between exterior and interior heat loads is made. The cooling load (load that has to be dissipated from the air conditioning system) can be determined by a cooling load calculation (addition of all positive and negative loads).

Interior heat loads include the number of people and their activities as well as the devices used (e.g. lighting, electronic devices, etc.). Depending on the room, the required cooling load is either higher or lower. In order to reduce the interior heat loads, devices which are not in use can be switched off. Furthermore, the choice of lighting also has an impact on the released heat.

The exterior heat loads can be divided into radiation and transmissions heat. The radiation heat is caused by the climatic conditions, such as outdoor temperature, humidity and solar radiation. Transmission heat refers to the heat that passes into a room through the building envelope or adjacent rooms.[13] In order to reduce the exterior heat loads, several measures can be implemented, both by

9 Public Works Department BD (2017). Update of plinth area
10 IEA 2018
11 GIZ Proklima
12 Bangladesh Refrigerator and Air Conditioner Manufacturer and Importers Association
13 Derived from the Cooling Load Calculation

the design and envelope of the building and by the choice of the materials. Table 2 provides an overview of measures for buildings in humid climates, derived by the Programme for Energy Efficiency in Buildings (PEEP). The measures are divided into closed buildings with air conditioning and open buildings without air conditioning. Ideally, the measures are already considered in the architectural planning.

Table 2. Building characteristics in humid climate, statements derived by PEEB [14]

	Closed with air conditioning	Open without air conditioning
Building design		
Orientation	A building should be oriented from east to west along the main path of the sun, exposing only smaller facades to high solar radiation at low angles.	
Shape	• Better air circulation through larger distances between buildings and a green surrounding area • Compact building to reduce the surface area of the building envelope to a minimum to avoid excessive exposure to solar radiation	• Better air circulation through larger distances between buildings and a green surrounding area • The building has an open layout, is not very compact and often with an adjacent or inner courtyard, combining open and closed spaces
Openings	Most openings (doors, windows, vents) should face north or south to reduce sun exposure. The window positions should allow optimal use of daylight, but with a small surface to avoid solar radiation inside. Horizontal glazing should be avoided.	
Window-to-wall ratio	The window-to-wall ratio should be generally low to minimise internal heat gains while allowing for sufficient natural interior lighting. In hot climates, the total window area must not exceed 20% of the total wall area.	
Building envelope		
Walls	The walls are airtight and light to mid-weight with thermal insulation, e.g. materials such as fiberglass insulation, rammed earth walls, ceramic tiles (floor) and stones.	The walls are light and have many openings and vents near the floor and ceiling, creating a pressure difference that causes air circulation and constant ventilation.
Roofs	The roofs are light-coloured with a reflective coating and have thermal insulation Possibilities are cool or green roofs.	
Shading	Generous awnings and roof overhangs and external shading elements (e.g. trees) minimise solar radiation on facades and windows.	
Coatings	Bright and reflective coatings on roofs and facades reflect solar radiation and prevent it from entering the interior. Vegetation can protect facades.	
Windows	The window-to-wall ratio is optimised to allow sufficient natural light to enter while minimising internal heat gains. High-performance and airtight windows with double glazing are used.	Louvre windows or shutter windows are used for continuous air flow.
Cooling	• Earth-air heat exchangers, also called 'earth tubes', can be used for cooling. Outside air flows through a pipe system 1.5 to 3 meters underground, using the nearly constant underground temperature of the earth to cool the outside air. • Concrete core cooling, often called 'concrete core activation', can be used. Cool	Ceiling fans are recommended to increase comfort during temperature peaks and at times when there is no outdoor air movement.

14 Programme for Energy Efficiency in Buildings (2020). Better design for cool buildings – how improved building design can reduce the massive need for space cooling in hot climates

	air passes through holes within concrete slabs to cool the building structure directly, before supplying the air into the interior spaces. • PVs can generate electricity for cooling (and lighting and appliances). • Highly efficient AC units are used in small buildings and central cooling systems with heat exchangers (cooling down exterior air-inflow) in large buildings. Additional dehumidification may be required.	

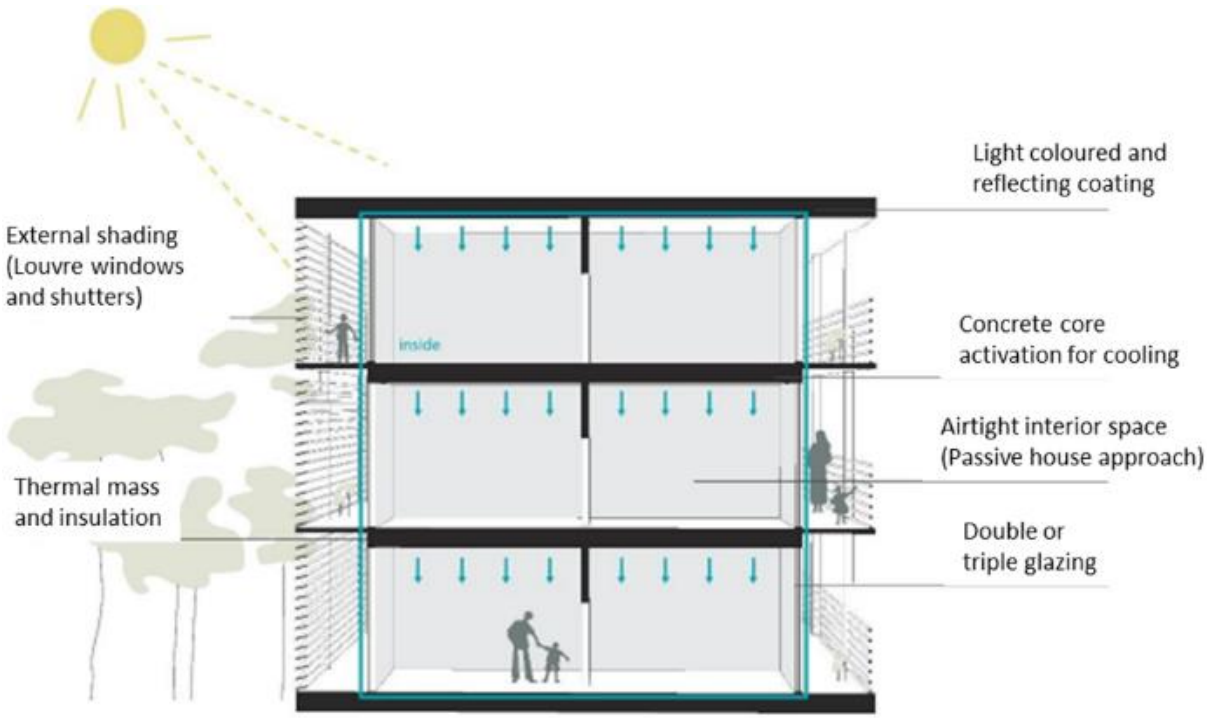


Figure 3. Closed building with air conditioning © GIZ / PEEB

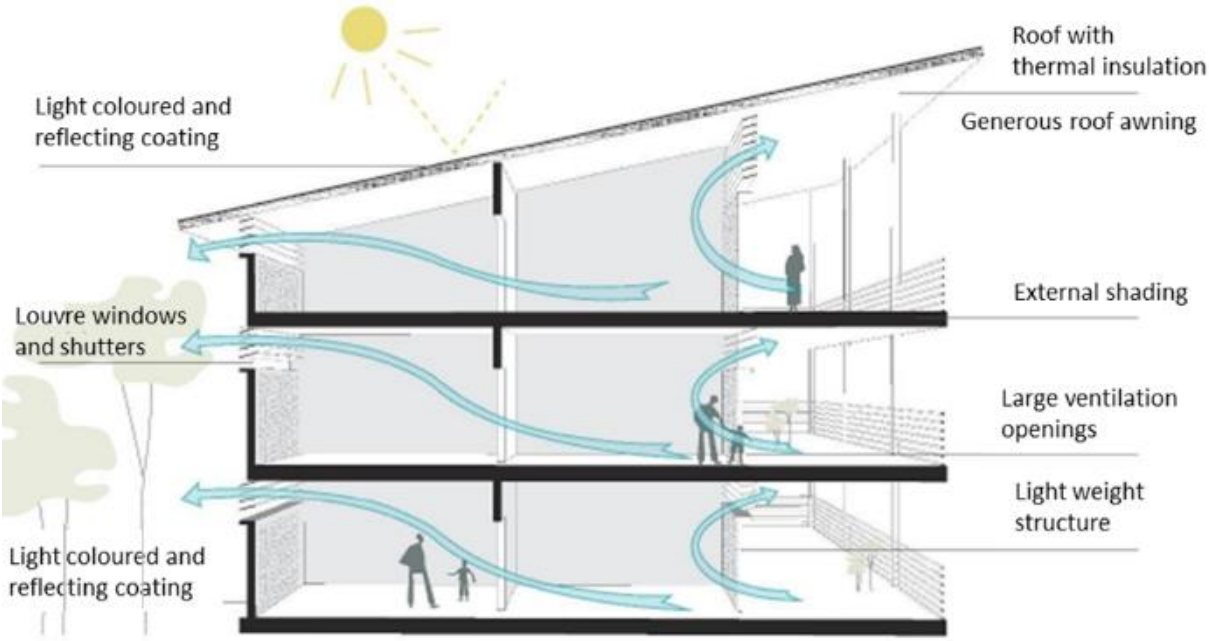


Figure 4. Open building without air conditioning © GIZ / PEEB

In summary, the measures can be grouped into three strategy approaches to reduce climate impact of cooling in buildings: avoid, shift and improve. The first step should always be to avoid cooling loads by adapting the building design to the climate conditions. Ideally, this is already taken into account during the architectural planning. The second strategic approach is to use renewable energies for the electricity demand in order to avoid GHG emissions. In the last approach, the climate impact can be reduced by improving the cooling appliances, for instance through more energy-efficient units or the use of natural refrigerants.[14]

3. Unitary Air Conditioning

This chapter examines the UAC market in Bangladesh in order to provide a recommendation on the best available UAC technologies. UAC includes ductless split, ducted split and rooftop ACs as well as VRFs, which make up 80% of the UAC market[15]. Split residential ACs consist of two units – outdoor and indoor. In cooling mode, air is cooled by blowing over the indoor heat exchanger, which is being used as an evaporator. The modules are connected by refrigerant piping. The basic set-up and operation of a split AC cooling system using vapour compression cycle is shown in Figure 5.

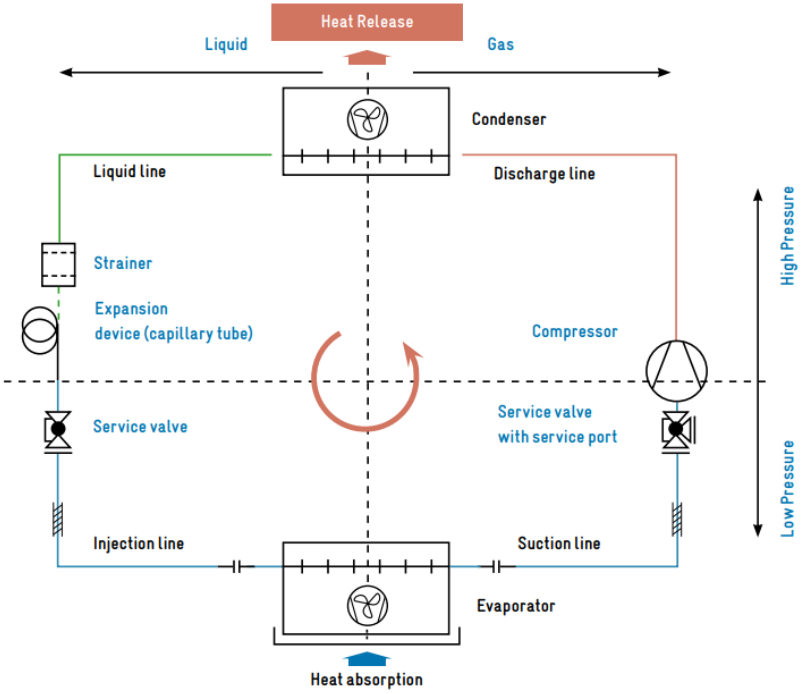


Figure 5. Basic set-up of split AC cooling system vapor compression cycle

VRF was an HVAC innovation created in Japan by Daikin Company in 1982. Resembling ductless mini-split VRFs use the refrigerant as the air conditioning as well as a home heating tool. This cooling agent is conditioned by a single exterior condensing system and is distributed inside the structure to multiple (FCU) fan-coil devices. It has many advantages. The VRF System AC is an innovative technical AC system for commercial buildings which, among others, is characterised by the following features:

1. The cooling agent only, where the refrigerant is the only coolant product in the system (in unlike the cooling water supply, where the cooling agent is used for cooling/heating the water that is distributed throughout the whole system).
2. Inverter compressors that authorise reducing power intake with limited cooling/heating lots.
3. Several air handlers (indoor units) on the same refrigerant ring/route.
4. The capacity of modular growth (particularly suitable for large jobs that can grow in stages).

15 GIZ Proklima (2014). Green cooling technologies-market trends in selected refrigeration and air conditioning subsectors

3.1 Justification of the Best RAC Technology in Bangladesh

The RAC sector is not a homogeneous industry, with products ranging from small split AC units used for domestic purposes to larger chiller systems applied in commercial fields. The best RAC technology can be evaluated using the following criteria.

a) Selection of the refrigerant used (causing direct emissions)
b) Energy Efficiency components and system design (causing indirect emissions)

3.1.1 Selection of Refrigerant

Direct refrigerant emissions can occur during regular operation because of leaks from pipes and components. Though the amount of refrigerant in small units lies in the range of grams to a few kilograms, the high GWP of HCFCs and HFCs implies that direct emissions contribute approximately one-third to total RAC sector emissions. Table 3 lists common refrigerants and their GWP and ODP. In Bangladesh, chlorofluorocarbons (CFC) are banned since 2010. The implementation of the HPMP Stage-II will gradually phase-out 65% of R22 consumption in 2025. So far, Propane (R290), R410A and R32 are the only options for Bangladesh to adopt in its transition to ODS-free alternatives. It was decided to phase out the high-GWP HFC at an accelerated phaseout strategy, which limits the DoE authority to allow the immense quality of R410A import licence from 2023. Considering the future availability, R290 and R32 (for higher filling quantities) are the best available refrigerants for UACs in residential and commercial buildings in Bangladesh.

Typically, the large (5-50kg) gas charging quality required for the VRF system prohibits the use of highly flammable hydrocarbon refrigerants inside the system. The refrigerant leakage rate of the VRF system is also relatively higher than that of smaller split ACs, which ultimately increases the direct emissions caused by the cooling system. Currently, the majority of commercial buildings in Bangladesh use R22- and R410A-based VRF systems.

Table 3. ODP and GWP of the commonly used refrigerants

Type	Gas	GWP	ODP
ODS	CFC-12 (R12)	10,900	1
	HCFC-22 (R22)	1,810	0.055
HFC	R404A	3,922	0
	R410A	2,088	0
	R134a	1,430	0
	R32	675	0
HFO	R1234yf	4	0
Natural	Propane (R290)	3	0
	CO2	1	0

Table 4. ODS-free and low-GWP refrigerant suitable for single and multi-split ACs [16]

Small and medium sized single split air-conditioning	
The single evaporator in a room being cooled connected to an outdoor condensing unit (compressor/condenser) containing 0.5 to 5kg refrigerant. Used for residential and small commercial application (e.g. shops, offices).	
Typical ODS	R22
Typical HFC	R410A
Lower GWP fluoro-carbon	R32 Lower flammability blends e.g. R-454B (GWP 466)
Not in kind	R290 (Propane)
Propane can only safely be used in a small system at the bottom end of the size range. Use of R32 has grown slowly in the market.	

Large-size multi-split, VRF and packaged air-conditioning	
Multiple room evaporators connected to large outdoor condensing units. VRF systems can offer simultaneous heating and cool in different rooms. Packaged units used with ducted air systems. Typically contain 5 to 50kg refrigerant.	
Typical ODS	R22
Typical HFC	R410A
Lower GWP fluoro-carbon	R32 Non-flammable blends e.g. R450A (605) Lower flammability blends e.g. R454B (466)
Not in kind	None
Lower flammability refrigerants (R32 and HFO blends) being used in smaller systems where safety code allows it. Ex-tensive VRF systems currently a problem as they require a non-flammable refrigerator and nothing presently available with a GWP below that of R32. Larger package systems can use non-flammable blends such as R450A.	

3.1.2 Energy Efficiency Component

The possible improvements in energy efficiency depend on the unit under consideration, the already existing Energy Efficiency Ratio (EER), the refrigerant, climatic conditions and cooling capacity. The ideal refrigeration cycle, assuming constant load, infinite-sized heat exchangers and 100% efficient compressors, has a Coefficient of Performance (COP) between 32 and 36 (depending upon the refrigerant used), which of course can never be reached ultimately. This nevertheless leaves a high potential for energy efficiency improvements. The following values are guidelines, and it can be seen that the range is often remarkably high.

- The most important approach is optimised components, such as the compressor, Brushless DC (BLDC) Fan motor, electronic expansion valves and the heat exchanger (Micro Channel condenser).
- Since the majority of AC units are not running at full capacity most of the time, a high energy saving potential in split ACs comes from introducing inverter technology, allowing the units to run at less than maximum capacity.

16 Ozone Action Kigali Amendment Fact Sheet

- AC using HCs as refrigerants have higher efficiencies than CFCs, HCFCs or HFCs. The extent of this is under debate and has been found in experiments to range from 2% to 30%.[17]

In comparison with R22, a thermodynamic cycle analysis of propane (R290) shows a COP loss ranging from -2% to 0%, depending on the evaporating temperature. However, the volumetric capacity of R290 is consistently lower than of R22 by ~14%. Drop-in testing of R290 in R22 equipment revealed a COP improvement of 7% and capacity reduction of 8% compared with R22 at standard rating conditions. This is primarily attributed to the improved transport properties of R290 versus R22. One significant barrier for the use of R290 in room ACs is the flammability rating which currently restricts its usage. With engineering optimisation, R22 alternatives such as R290 can match or exceed the performance of existing R22 units with an efficiency increase of up to 10%.[18] Table 5 summarises efficiency improvements for a range of component design improvements from a "base case" represented by a European MEPS. [19]

Table 5. Efficiency improvement options and corresponding energy savings based on European conditions [19]

Option	Description	% improvement from the base case	
		Min	Max
Efficient heat exchanger	High-efficiency microchannel heat exchanger, large-sized heat exchangers	9%	29%
Efficient compressors	Two-stage rotary compressors, high-efficiency scroll compressor with DC motors	6%	19%
Inverter/Variable speed	AC, AC/DC or DC inverter-driven compressor	20%	>25%
Expansion Valve	Thermostatic and electronic expansion valves	5%	9%

3.2 Best Available UAC Technologies in Bangladesh

In this subchapter, an analysis of the current UAC market situation is conducted, particularly the split AC and VRF market. For both technologies, a general recommendation is given and the best available models on the Bangladeshi market are listed.

3.2.1 Split AC Units

Single split-type ACs are the most widely used UAC in Bangladesh. Among them, ACs with capacities of 12,000, 18,000 and 24,000 BTU-hour are mostly used in residential buildings and offices. According to Bangladesh´s Refrigerator and Air Conditioning Manufacturing and Exporters Association, around 420,000 single split ACs were sold on the local market, where the capacity of 18,000 BTU accounted for more than 60% of the local sales[20]. The growth rate of the UAC market (excluding VRF) is shown in Figure 6.

17 GIZ Proklima (2014). Green Cooling technologies - market trends in selected refrigeration and air conditioning subsectors
18 UNEP (2018). Decision XXIX/10 task force report on issues related to energy efficiency while phasing down Hydrofluorocarbons
19 U4E (2017). Energy-efficient and climate-friendly air conditioners
20 Consultation from the AC manufactures like Walton, Elite

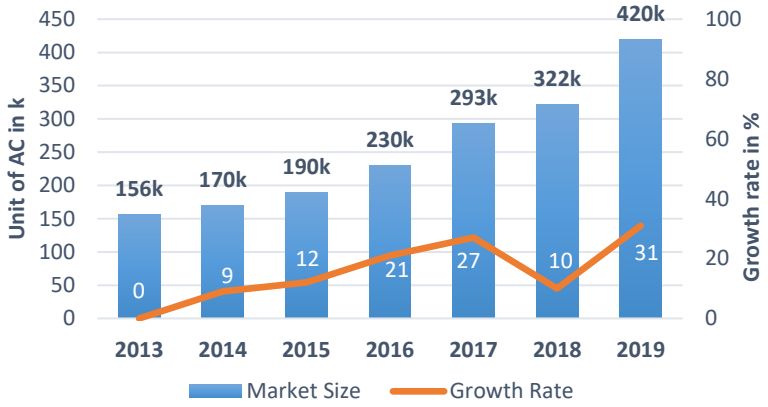


Figure 6. UAC (without VRF) market size and growth rate in Bangladesh [21]

Over 90% of single split ACs (up to 2 Ton) sold on the local market are assembled or manufactured in Bangladesh. Table 6 and

Table 7 lists the most prominent local and international split AC manufacturers and operating brands on the Bangladeshi market. That the share of locally produced ACs is so high is mainly due to the high import taxes of around 160% of the Completely Built-Up Unit (CBU) ACs.[22] Furthermore, the ACs manufactured or imported in Bangladesh must include the energy star rating according to the Bangladesh Standards BDS 1852 set by the Bangladesh Standard and Testing Institution (BSTI).

The MEPS for single split ACs is not enforced, because the local testing laboratory of the BSTI is not adequately equipped and trained to perform the energy performance testing required. Nevertheless, energy efficient ACs are becoming more popular on the local market, although the price is on average 80 to 100 USD higher than the conventional and less efficient induction compressor AC units.

Table 6. List of main local manufactures/providers of air conditioners in Bangladesh

Company Name	Brand	Assembler/ Manufacturer
Walton Hi-Tech Industries Ltd	Walton / Marcel	Manufacturer
Electromart	Gree	Assembler
Singer Bangladesh Limited	Singer	Assembler
Elite Hitech Industries Ltd	Midea/General	Manufacturer
Esquire Heavy Industries Ltd.	General	Assembler
Butterfly Manufacturing Co. Ltd.	Eco Plus/LG	Assembler
AC Bazar Industries Ltd	Chigo	Assembler
Bangladesh Electrical Industries Ltd	Transcom	Assembler
Fair Electronics Ltd (Factory)	Samsung	Assembler
Minister Hi-Tech Park Electronics	Minster	Manufacturer
Hayes & Haier Appliances Co. Ltd	Haier	Assembler
Unitech Products (Bd) Limited	Unitech	Manufacturer
Supreme Air Conditioning	Supreme/Chigo	Assembler

21 Bangladesh Refrigerator and Air Conditioning Manufacturing and Exporters Association
22 http://www.bangladeshcustoms.gov.bd/trade_info/duty_calculator

Table 7. International split AC brand operating in Bangladesh

Brand	Imported /Assembler
Samsung	Imported
LG	Assembled in Bangladesh
General	Assembled in Bangladesh
Daikin	Imported
Panasonic	Imported
Sharp	Imported
Hitachi	Imported
Gree	Import/Assembled in Bangladesh
Midea	Assembled in Bangladesh
Haier	Imported
Chigo	Assembled in Bangladesh

Through a market survey, it was found that AC units using R22 and R410A refrigerants still dominate the Bangladeshi market. However, the trend is moving toward R410A, due to the reduced R22 import quota set by the DoE. Local manufacturers which are the stakeholders of the retrofitting project under MLF projects are working to develop R290-based ACs for capacities of 12,000 BTU and 18,000 BTU. For capacities above 18,000 BTU such as 24,000 BTU, 48,000 BTU and 60,000 BTU, manufacturers are working to develop and establish R32-based ACs due to the (currently) limited charge allowed for R290 flammable refrigerants. R32 has a relatively low GWP (GWP=675) compared to conventional refrigerants but is mildly flammable. UNEP and UNDP facilitate various trainings for local technicians to be able to handle mildly flammable refrigerants in ACs. Currently, the main challenge for local manufacturers is the procurement of R290-based compressors. The rotary compressors for R290 units are currently only manufactured by the Chinese companies GMCC (Guangdong Meizhi Compressor Company) and Highly, offering 1 Ton and 1.5 Ton AC cooling capacities (Nicholson & Booten, 2019).

As there are currently no R290 split AC units available on the Bangladeshi market, it is recommended to temporarily import R290 split AC units until local manufacturers can potentially produce them. Currently, there are three different manufacturers that produce and stock R290 split AC units with 9,000, 12,000 and 18,000 BTU. Table 9 lists the R290 AC units available for import. Since import taxes for ACs are currently very high, importing R290 split ACs is only economically feasible if import taxes for climate-friendly and energy-efficient R290 split ACs were lowered by the GoB. As long as R290 split AC units cannot be imported for this reason, it is recommended to use R32 split AC units. The best technologies available in Bangladesh are listed in Table 10. However, it should be noted that the refrigerant R32 still has a relatively high GWP (GWP=675) compared to R290 and is less energy efficient. For capacities above 18,000 BTU, only R32 split ACs are available, which are also listed in Table 10. Furthermore, for a widespread development towards R290 split ACs, it is recommended to train RAC technicians in handling flammable refrigerants. This is an important prerequisite for a successful market transformation to Green ACs.

4 Ton (48,000BTU) and 5 Ton (60,000BTU) split ACs in the form of cassette- or ceiling-type indoor units are widespread inside commercial buildings. All the brands within the range of 4-6 Ton cooling capacity use R410A or R22. Currently, R290, R32 or HFO based 4 Ton or 5 Ton cooling capacity ACs are not available on the local market. In this context, R410A based inverter compressor ACs are the next best option on the Bangladeshi market and listed in Table 11. Since the high import taxes also apply here, importing, again, is not economical. Therefore, the same recommendation is valid as for ACs with lower cooling capacities: reduction of import taxes for climate-friendly and energy-efficient ACs. Companies like Walton Hi-Tech Industries Ltd and Elite Hi-Tech Industries Ltd are currently developing R32 based 4 Ton and 5 Ton cassette and ceiling type ACs, which will be available by 2024.

3.2.2 VRF Units

VRF is a technology new to Bangladesh but has slowly increased its market share in the last five years. It is in growing demand, as most high-rise buildings, shopping complexes and hospitals are using VRF System Air Conditioners. A rapid increase in the number of commercial buildings and improving electricity quality, then, drive this demand. All VRF ACs are imported from China, Thailand, Malaysia and Korea. In 2019, a total of 27,251,765 tons of refrigeration (TR) VRF units were imported in Bangladesh[23]. The VRF market share of the different companies in 2019 is shown in Table 8. Most of the VRF units imported and installed in Bangladesh are based on R410A and R22 refrigerants with energy-efficient inverters and scroll compressors installed inside the system.

Table 8. VRF market share of different brands in Bangladesh

Brand	Import (tons of refrigeration – cumulative)	Market share
Daikin	3,623,529	13,30%
Samsung	3,450,000	12,66%
York	3,623,529	13.30%
Gree	3,364,706	12.35%
LG	2,360,000	8.66%
Midea	2,030,000	7.45%
Mitsubishi	1,811,765	6.65%
Chigo	1,811,765	6.65%
Dunhum-Bush	1,294,118	4.75%
Panasonic	1,035,294	3.80%
Haier	1,035,294	3.80%
Hitachi	776,471	2.85%
Toshiba	517,647	1.90%
Trane	517,647	1.90%
Total	27,251,765	100%

All the VRF ACs installed in Bangladesh are imported. The import tax is also significantly lower for VRF systems. A local manufacturer, Walton Hi-Tech Industries Ltd, is developing a R410A VRF system to be launched in 2021.[24] All the imported VRF systems use R410A or R22 as refrigerants. Inverter type scroll compressors, being energy-efficient, are used in most VRF systems. The price of the VRF largely varies among the different brands. Multi-split VRF systems connect up to five indoor units to a single outdoor unit without the need for ductwork. It also has indoor units of different styles and capacities in one system for customised solutions unique to each commercial building setting.

Due to the higher filling quantity, as of today, there exists no VRF system based on natural refrigerants. However, there are R32-based VRF systems available on the global market, which are the best available technology in terms of climate-friendly and energy-efficient systems. It is therefore recommended to purchase these systems. Regarding the phase-out of HCFCs and the high GWP and ODP, R22 based VRF systems should no longer be procured. If possible, R410A based VRF systems should no longer be used either. However, in case R32 VRF systems are unavailable, R410A based VRF systems may be considered. Table 12 lists the best options.

23 National Board of Revenue Data, collected from the air condition Manufactures
24 Walton manufacturing VRF technology's Central AC - corporatenews | corporatenews

Table 9. Best available R290 split ACs worldwide, data from manufacturer's website

Brand: Godrej **Devices must be imported** **Split Air conditioning System** **Refrigerant: R290**							
Model Nr	Cooling Capacity BTU	EER (W/W)	SEER (W/W)	Compressor type	Amount of refrigerant (kg)	Price	Source
AC 2T GIC 24ITC3-WTA	24,000 BTU	3.74			-	USD 460	Godrej
AC 1.5T GIC 18NGC5-WUA	18,000 BTU	4.54		Dual rotary	-	USD 420	
AC 1.5T GIC 18IGC5-WUA	18,000 BTU	4.52		Dual rotary	-	USD 380	
AC 1T GIC 12YTC3-WTA	12,000 BTU	3.52			-	USD 370	Godrej
Brand: Midea **Devices must be imported** **Split Air conditioning System** **Refrigerant: R290**							
Model Nr	Cooling Capacity BTU	EER (W/W)	SEER (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
MSAEBU-9HRFN7-QRD6GW	9,000 BTU		7.1	Inverter	0.32	USD 500	
MSAEBU-12HRFN7-QRD6GW	12,000 BTU		7.1	Inverter	0.4		
MSAEC-18CRN7-PC5	18,000 BTU	3.5		Rotary	0.37		
Brand: Appliance Direct **Devices must be imported** **Split Air conditioning System** **Refrigerant: R290**							
Model Nr	Cooling Capacity BTU	EER (W/W)	SEER (W/W)	Compressor type	Amount of refrigerant (kg)	Price	Source
eiQ-9WMINV-V3	9,000 BTU		6.2	Inverter	0.32	USD 430	electriQ
eiQ-12WMINV-V3	12,000 BTU		6.1	Inverter	0.40	USD 450	electriQ

Table 10. Energy efficient split ACs available in Bangladeshi market, data from manufacturer's website

Brand: Daikin **Distributor: Transcom Electronics Ltd/ MK Electronics Ltd** **Split Air conditioning System** **Refrigerant: R32**							
Model Nr	Cooling Capacity Full/Half (Min~Max) BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
JTKJ12TV16UD	12,350/6,175(4,000~13,600)	4.40	4.40	Inverter	0.82	60,280	Daikin
JTKJ18TV16UD	18,016/9,008 (3,412~20,472)	4.09	4.09	Inverter	1.04	95,040	Daikin
JTKJ21TV16UD	20,500/10,240(3,400~23,900)	3.60	3.60	Inverter	1.04	103,840	Daikin
FTL24TV16T1D	24,200/12,113(7,200~25,600)	3.25	3.25	Induction	1.15	92,400	Daikin
FTKL24TV16TD	24,200/12,113(7,200-25,600)		2.95	Inverter	1.05	97,650	Daikin/ Transcom
Brand: Whirlpool **Distributor: Transcom Electronics** **Split Air conditioning System** **Refrigerant: R32**							
Model Nr	Cooling Capacity Full/Half (Min~Max) BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
SAI12K30SC0	1660~3427~3600	3.60	2,79	Inverter	0.85	57,900	Transcom
SAI18K30SC0	5,050 Watt/17,231 BTU	3.60	2,79	Inverter	1.10	76,900	Transcom
Brand: Walton **Manufacturer/Distributor: Walton Hi-Tech Industries Ltd** **Split Air conditioning System** **Refrigerant: R32**							
Model Nr	Cooling Capacity Full/Half (Min~Max) BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
WSI-Riverine-12A	3517 Watt/12,000 BTU	3,27	3.01	Inverter	0.55	47,500	Walton
WSI-Bevelyn-18C	5272.5 Watt/ 17,990 BTU	4.02	3.7	Inverter	0.74	63,000	Walton
WSI-DIAMOND-24C	8034Watt/24,000 BTU		3.44	Inverter	0.83	Upcoming model, price unavailable	Walton

Table 11. Split AC over 24,000 BTU in Bangladeshi Market, data from manufacturer's website

Brand: GREE **Distributor: Electro Mart Limited; Split Air conditioning System (Cassette/Ceiling Type)** **Refrigerant: R410A**							
Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrig-erant (kg)	Price (BDT)	Source
GSH-48TW(H&C) Cassette	48,000	2.99	2.75	Induction		149,000	manufacturer's website
GSH-60TW Cassette	60,000	3.18	2.93	Induction		168,000	
Brand: LG **Distributor: Butterfly Electronics Ltd; Split Air conditioning System (Cassette)** **Refrigerant: R410A**							
Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of re-frigerant (kg)	Price (BDT)	Source
AVUW48LM2S0 (Ceiling) (H&C)	Cooling: 47,000 Heating 52,210	/	Cooling 3.24 Heating 3.41	Inverter Twin Rotary		226,335	manufacturer's web-site
ATUW48LMLS1(Cassette) (H&C)	Cooling: 47,800 Heating: 52,200	/	Cooling 3.20 Heating 3.41	Inverter Twin Rotary		205,465	
Brand: Midea **Manufacturer/Distributor: Elite Hi-Tech Industries Ltd; Split Air conditioning System** **Refrigerant: R410A**							
Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of re-frigerant (kg)	Price (BDT)	Source
MCA-48CR(Cassette)	48,000	2.96	2.73	Scroll/Induc-tion	3.05	115,000	manufacturer's web-site
MCA-60CR(Cassette)	60,000	2.93	2.70	Scroll/Induc-tion	3.05	128,000	
MUB-48CR (Ceiling)	48,000	2.96	2.73	Scroll/Induc-tion	3.05	110,000	
MUB-60CR (Ceiling)	60,000	3.30	2.79	Scroll/Induc-tion	3.05	125,000	

Table 12. Multi-split R410A VRF System in Bangladeshi market

Brand: Daikin **Distributor: Transcom Electronics, AC World, Fresco EME, Teco Cool, Lion Electro-Mechanical Services, ACBazar BD, Penguin Engineering, Confidence Trade** **Multi Split VRF Air conditioning System** **Refrigerant: R410A**							
Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
RXQ6ARY6	54,600	5.14	4.73	Hermetically Sealed Scroll	5.9	100,000~130,000/ Ton of refrigeration	
RXQ8ARY6	76,400	4.70	4.33	Hermetically Sealed Scroll	5.9		
RXQ10ARY6	95,500	4.44	4.09	Hermetically Sealed Scroll	6.7		
RXQ12ARY6	114,000	4.18	3.85	Hermetically Sealed Scroll	6.8		
RXQ14ARY6	136,000	4.06	3.74	Hermetically Sealed Scroll	7.4		
RXQ16ARY6	154,000	3.79	3.49	Hermetically Sealed Scroll	8.2		
RXQ18ARY6	171,000	3.55	3.27	Hermetically Sealed Scroll	8.4		
RXQ20ARY6	191,000	3.43	3.16	Hermetically Sealed Scroll	11.8		
RXQ21ARY6	204,700	3.31	3.05	Hermetically Sealed Scroll	11.8		
Brand: LG **Distributor: MEP Engineering, Tritech Building Services, Butterfly Marketing, Confidence Trade, SAF Engineer** **Multi Split VRF Air conditioning System (Heating & Cooling)** **Refrigerant: R410A**							
Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
ARUN300LTN5	Cooling: 286,620 Heating: 322,400	4.07 4.67	3.75 4.30	Hermetically Sealed Scroll	17.5	60,000~70,000/Ton of refrigeration	
ARUN320LTN5	Cooling: 305,727 Heating: 343,900	3.58 4.40	3.30 4.05	Hermetically Sealed Scroll	17.5		

Brand: Samsung
Distributor: Fair Distribution, Transcom Electronics, Fresco EME, Edison Group
Multi Split VRF Air conditioning System (Heating & Cooling)
Refrigerant: R410A

Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
AM200FXVAGH	Cooling: 191,100 Heating: 215,000	4.44 4,75	4.09 4.38	Inverter/ Scroll	8.4	55,000~65,000/Ton of refrigeration	
AM220FXVAGH	Cooling: 236,500 Heating: 210,200	3.85 4.51	3.55 4.15	Inverter/ Scroll	8.4		
AM240HXVAGH	Cooling:229,300 Heating:258,000	4.27 4.15	3.93 3.82	Inverter/ Scroll	14.30		
AM260HXVAGH	Cooling:248,400 Heating:279,500	4.09 4.08	3.77 3.76	Inverter/ Scroll	14.30		
AM280HXVAGH	Cooling:268,200 Heating:301,000	4.40 4.75	4.05 4.37	Inverter/ Scroll	12.90		
AM300HXVAGH	Cooling:286,600 Heating:322,400	4.40 5.70	4.05 4.37	Inverter/ Scroll	14.20		

Brand: Midea
Distributor: Rangs Electronics, Noor Electronics, Tritec Building Services, Transcom Electronics
Multi Split VRF Air conditioning System (Heating & Cooling)
Refrigerant: R410A

Model Nr	Cooling Capacity BTU	EER (W/W)	COP (W/W)	Compressor type	Amount of refrigerant (kg)	Price (BDT)	Source
MV6-670WV2GN1	Cooling: 228,600 Heating: 228,600	4.02 4.89	3.70 4.50	Inverter/Scroll	22	55,000~60,000/Ton of refrigeration	
MV6-730WV2GN1	Cooling: 249,100 Heating: 249,100	3.79 4.51	3.49 4.15	Inverter/Scroll	22		
MV6-785WV2GN1	Cooling:267,800 Heating:267,800	3.53 4.13	3.25 3.80	Inverter/Scroll	22		
MV6-850WV2GN1	Cooling:290,000 Heating:290,000	3.37 4.02	3.10 3.70	Inverter/Scroll	25		
MV6-900WV2GN1	Cooling:307,100 Heating:307,100	3.15 3.80	2.90 3.50	Inverter/Scroll	25		

3.3 Energy Labelling Programme in Bangladesh

The introduction of an energy efficiency appliance labelling programme is quite effective in promoting EE&C in the commercial and residential sectors. Implementation of Energy Efficiency Standards and Labelling (ES&L) programmes and policies are an effective way of improving energy efficiency and to reduce greenhouse gas (GHG) emissions. In this context, Bangladesh joined the BRESL (Barrier Removal and Cost-Effective Efficiency Standards and Labelling) Programme under UNDP (project timeline: 2009- 2013) with China, Indonesian, Pakistan, Thailand and Vietnam to work together to reduce GHG emission by an estimated 23.4 million metric tons (MMT) per year by the end of the project in 2013[25]. As a follow-up of this project, the GoB nodal agency SREDA decided to establish national energy efficiency labelling programmes, seeking to accelerate EE&C. The Clause 3 under Section 2 of the 2016 EE&C rules provides that the Authority can take assistance from the BSTI for introducing energy efficiency labelling and MEPS of appliances and establishing methods and procedure for testing of such appliances for the purpose of labelling. BSTI standards are in place for some of the appliances covering both MEPS and labelling. These are shown in Table 13.

Table 13. MEPS and Standards

Equipment	Standards No	Description	Coverage	Remarks
Fans	BDS 1860:2012	Minimum allowable and energy efficiency grades for AC fans	All types of fans of different sizes	MEPS for grading only and not sales restriction
ACs	BDS 1853:2012	Performance of close control ACs and MEPS requirement	Excludes some categories such as vapor absorption machines, multi-split systems, etc.	MEPS and star labelling are implemented on a voluntary basis. No sales restriction
Refrigerators	BDS 1850:2012	Specifications for energy efficiency rating of household refrigerators and freezers	For all class categories star labelling	MEPS and star labelling are implemented on a voluntary basis. No sales restriction
LED Lamps	BDS IEC: 62612:2015	Self-ballasted LED lamps for general lighting services with supply voltages >50 Volts and performance requirement	Star labelling	Adopted from IEC standard

However, the label has had limited impact on the market, because elements of the programme like the energy efficiency measurement method, star rating criteria, the energy efficiency verification system, the energy efficiency testing laboratory, or the programme operation body have not yet been sufficiently and suitably prepared. The label designed and adopted by the BSTI has already gone through the market as shown below.

25 Barriers Removal to the cost-effective development of energy Efficiency Standards and Labelling (BRESL) | UNDP in Indonesia

In the draft Standard & Labelling of Appliance Regulations, minimum energy performance standard for ceiling fans, room air conditioners and refrigerators cum freezers are well defined. According to this draft regulation, the star rating plan for appliances models shall be decided in consultation with the technical Committee. Globally, these criteria are continuously reviewed and revised along with the development of energy efficiency technologies.

The Energy Efficiency and Conservation Masterplan highlighted the energy labelling procedure and verification system.

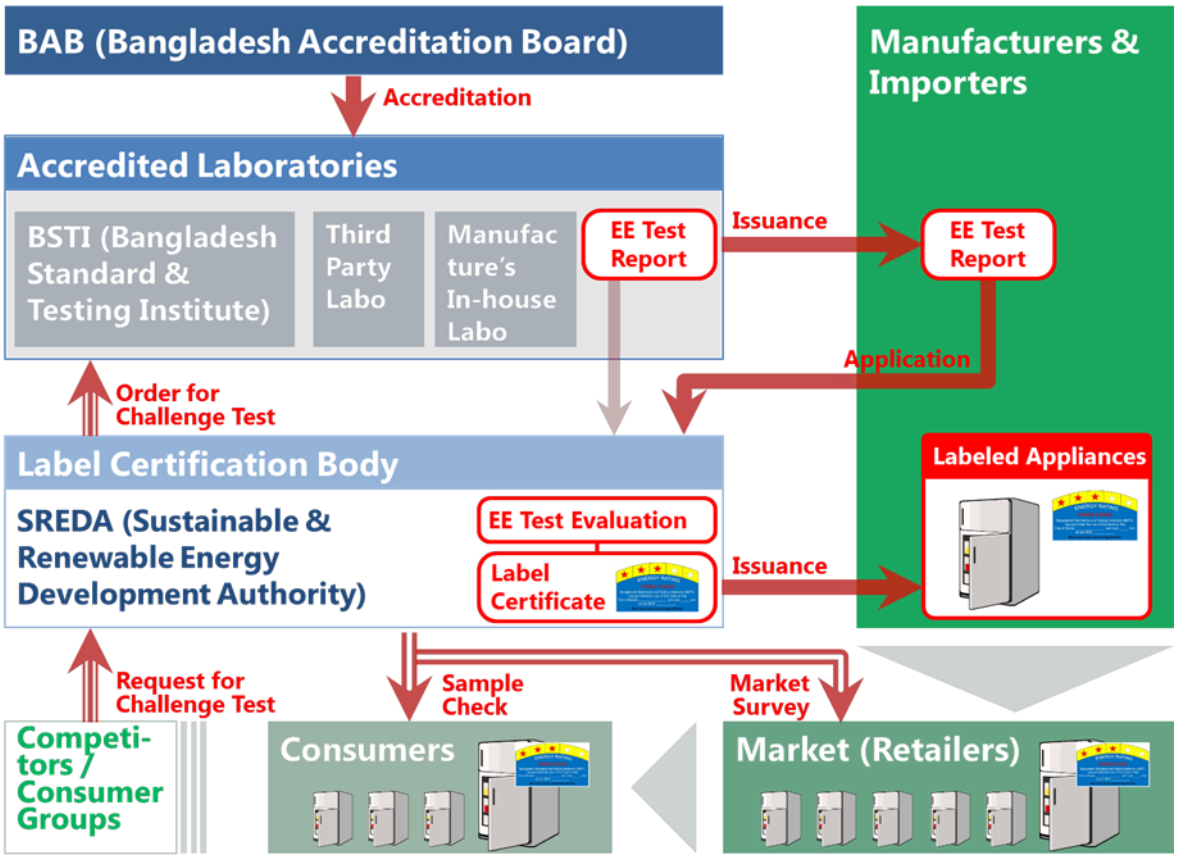


Figure 7. Energy labelling procedures (Source: Bangladesh Energy Efficiency & Conservation Masterplan up to 2030)

The actual procedure is as follows:

1. Manufacturers/importers get the EE test on their products at accredited laboratories.
2. Accredited laboratories must be accredited by BAB through ISO17025.
3. Manufacturers/importers with in-house laboratories can do the EE test at their laboratories, provided these laboratories are accredited by BAB.
4. Label certification body evaluates the EE test report, issues the label certificate on the product with a star rating, and delivers it to the manufacturer/importer.
5. Manufacturers/importers affix the label on the products or their packages and deliver them to the markets.
6. Label certification body carries out an EE check for the products sold on the market and collects samples at random, in order to maintain the label's reliability.
7. Anybody can request to challenge a test before the label certification body, provided the occurring costs are covered by the challenger.

3.4 Comparison Global UAC Market

Globally, the UAC subsector accounts for the highest predicted growth and emissions of the entire RAC sector. In Figure 8, the predicted growth rate (appliances in use) and the emission reduction potential of the UAC sector is displayed.[26]

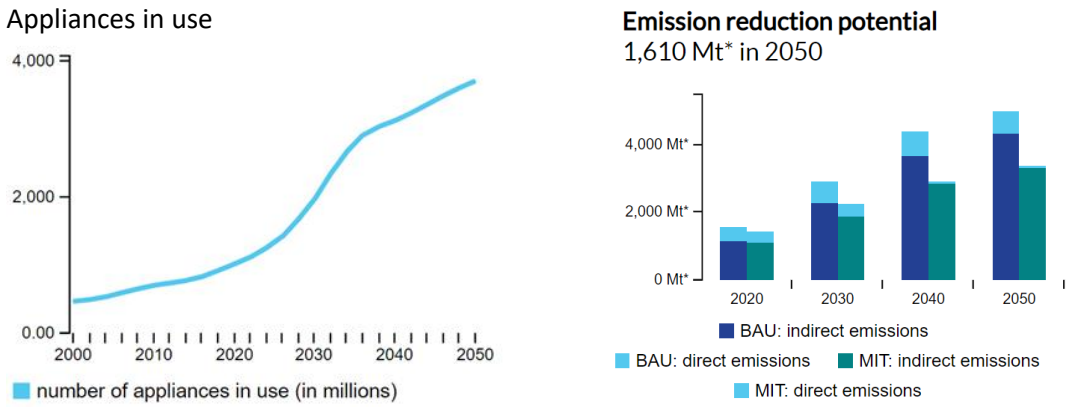
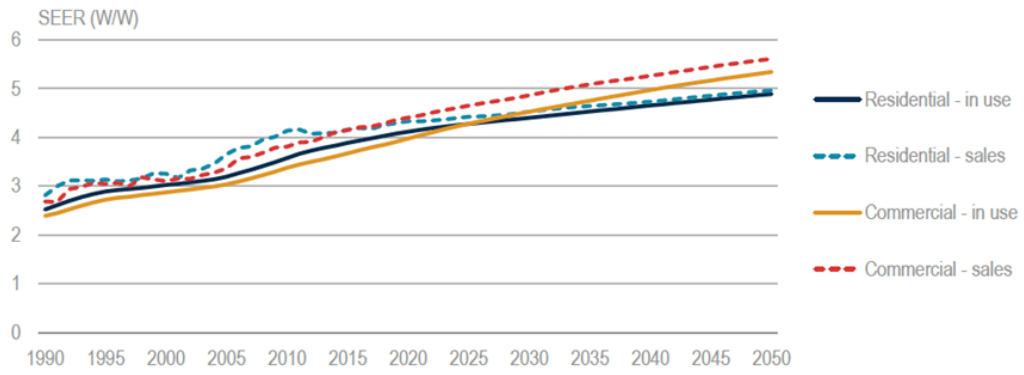


Figure 8. Appliances in use and emission reduction potential of the UAC sector worldwide

As mentioned above, split residential ACs make up the major share of the UAC market with up to 80%. In most developing countries, the refrigerant R22 is mainly used for split residential ACs. While many industrial countries initially adopted R410A as an alternative to HCFCs, more and more countries today promote the use of low-GWP refrigerants such as R32 or, better, natural refrigerants such as R290. Efforts to phase-out HCFCs are also increasing in developing countries for newly produced units. In addition, in many new units, inverter technology is used for improving the energy efficiency during the part load operation. The inverter allows the compressor speed to be controlled according to the cooling demand. This reduces the cycling losses, which occur with on-off control. In general, the energy efficiency of ACs has steadily improved over the last years.[27] In 2016, the average SEER weighted by sales of ACs in the residential sector was around 4.2 and thus 50% higher than in 1990. Commercial ACs have also achieved a SEER average of 4.2. Compared to 1990, it is 57% higher.
According to the International Energy Agency (IEA), the weighted average SEER worldwide of ACs can increase by up to 5.8 (see Figure 9). [28]

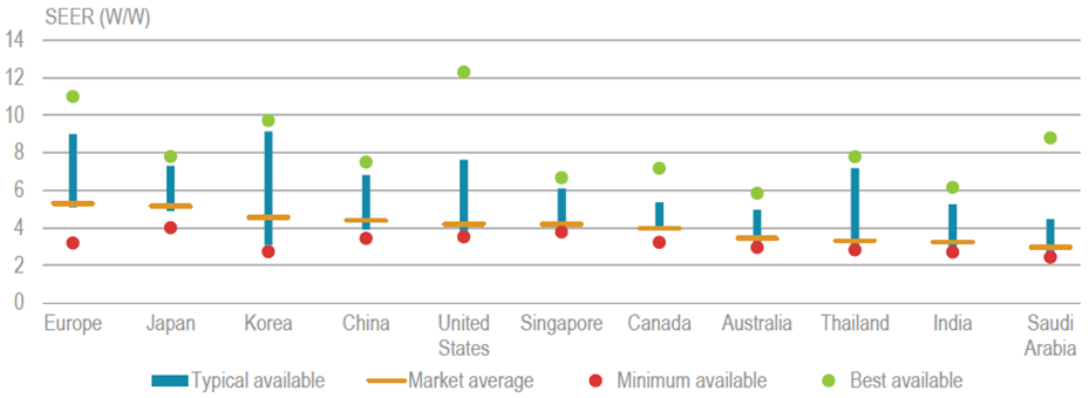
26 Green Cooling Initiative (2014). Country database
27 GIZ Proklima (2014). Green cooling technologies-market trends in selected refrigeration and air conditioning subsectors
28 IEA (2018). The future of Cooling

Figure 9. Weighted average world SEER of ACs in the Baseline Scenario



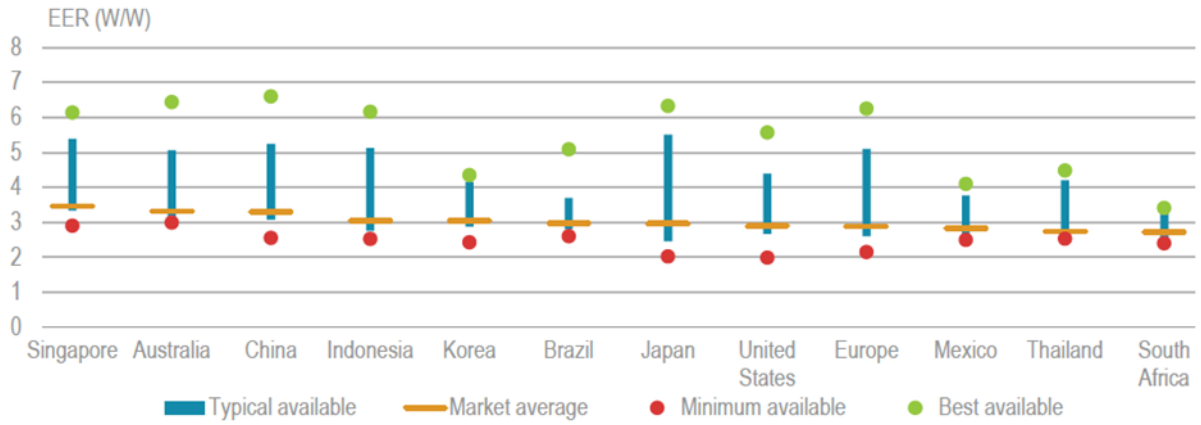
Nevertheless, there are considerable differences in efficiency for the purchaser, depending on the purchaser's location. AC appliances differ from country to country. Figure 10 and Figure 11 show the average SEER and EER of various countries and regions.

Figure 10. SEERs of available residential ACs in selected countries/regions, 2018



Notes: SEER = the ratio of output cooling capacity to electrical energy input, adjusted for the overall performance of the device for the weather over a typical cooling season in each given country; as the test conditions differ across countries, the average ratios are not strictly comparable; W/W = watt per watt.

Figure 11. EERs of available residential ACs in selected countries/regions, 2018



The R290 split ACs listed in Table 9 can achieve an EER between 4 and 5 for cooling capacities of 18,000 BTU and a SEER between 6 and 7 for cooling capacities between 9,000 and 12,000 BTU. Bangladesh's best available R32 split AC appliances achieve an average EER of 3.6, a slightly higher value compared to available AC units in other countries and regions.

Our narrow focus on the best available technologies in Bangladesh helps, explain this discrepancy. Had we included all available units, as opposed to the best available units, the results would have looked different. A quick glance at the global EER and SEER averages illustrates that, in the case of Bangladesh, only R290 split AC units can compete. This highlights once again the advantage in energy efficiency that natural refrigerants, in this case R290, provide.

4. Lighting Systems

Lighting uses more energy in a typical modern commercial office building than in any other sector. As a rule of thumb, 10-15% reduction in cooling energy is possible with more efficient lighting systems. In fact, energy savings of up to 30% are possible if we include the air-conditioning cooling load reduction due to a cutback in heat generation and lighting land.[29]

For a better understanding of lighting technology, the most important basic terms are presented in Table 14.

Table 14. Basic terms of lighting technologies

	Definition
Luminaire	Luminaire is a mechanism which distributes filters or transforms the light emitted by one or more lamps. It protects lamps and prevents glare.
Luminance	Luminance is the light that is reflected off of something else - such as the walls of a room - before it reaches our eyes.
Lumen	This term is used to measure the total light output of a source. Historically, a lumen was the amount of light from one candle which fell on one square foot of area, i.e. one foot away from the candle. The historic "Standard Candle" produces 12.57 lumens. A standard 60-Watt incandescent lamp produces about 900 lumens.
Lux	This term is used to measure the quantity of light striking a surface, which is defined as lumens per square meter (otherwise known as Lux (lx)). Lux measurement is done using a light meter.
Lamp Efficacy	Lamp efficacy is the ratio of the light output from a light source to the power consumed. It is expressed in lumens per Watt (lm/W).
Color Rendering Index (CRI)	CRI expresses the relative ability of lamps to render a full range of subtle colors. Incandescent lamps are used as the reference standard and assigned can index of 100 (highest) and other light sources are judged in comparison with it.
Color Temperatures	Some light sources seem "warm": they are very rich in red light. They mimic light created by a low temperature flame, like a candle. Hence, warm lights are called low color temperature sources. Some light sources seem "cool" or "cold"; they are very rich in blue light. They mimic light created by an intensely hot, blue flame. Hence, "cool" lights are called high color temperature sources.
Lumen Maintenance	Lumen maintenance is an approach of measuring the light output (lumens) of a brand-new light source and comparing that with its light output after a certain period of time. L70 and L50 are examples of lumen maintenance – benchmarks for when 70 or 50 percent of a lamp or fixture's total light output remains. Rated lumen-maintenance life is measured in hours with associated percentage of light output, noted as Lp. For example, L70 of 30,000 hours means that the tested LEDs produce 70% of the initial light output at 30,000 hours. If an LED has L50 of 30,000 hours, its lumen output decays faster than one with L70 of 30,000 hours.

29 Energy audit manual, National Productivity Council India

4.1 Types of lamps Used on Public Buildings

In this subsection, the basic families of common commercial lamp types used in buildings are presented. These include Incandescent lamps, Fluorescent lamps, High-Intensity Discharge (HID) lamps and Light Emitting Diode (LED).

4.1.1 Incandescent Lamp

Electricity flows through a coiled wire called a filament. As it flows, it heats the filament causing it to emit white light. The lamp is filled with an inert gas, usually argon, to prevent oxidation of the filament. The efficacy of an incandescent lamp ranges from 10-20 Lm/W.

4.1.2 Fluorescent Lamp

A fluorescent lamp is a low-pressure mercury electric discharge lamp with a glass tube filled with a mixture of inert gas like argon or krypton gas and mercury vapor at very low pressure. When current flows through the ionised gas between the electrodes, it emits ultra-violate (UV) radiation from the mercury arc which is converted to visible light by a fluorescent coating inside the tube. The combination of minerals or phosphors determines the lamp colour, temperature, and CRI. Fluorescent lamp efficacy is around 60-100 Lm/W and the average life of the lamp is around 8000 hours. The CRI of the fluorescent lamp is greater than 70.

Fluorescent Tube Lamps (FTL)

These are fluorescent lamps with a diameter of 16mm, which is 40% less than the diameter of slim fluorescent lamps. They are designed for higher efficacy and system miniaturisation. The lifespan of T5 lamps is long: around 18,000 hours as compared to 8000 hours for standard fluorescent lamps. In Table 15 different types of fluorescent tube lamps (shapes and diameters) are mentioned.[30]

Table 15. shapes and diameter available of FTLs in the market

Liner Tubes	U-bent tubes	Circular tubes
T12 – 38 mm diameter T8- 25 mm diameter T5 - 16mm diameter T2- 6 mm diameter	T12– 38 mm diameter T8- 25 mm diameter	T9- 38 mm diameter T5 - 16 mm diameter

Among these, different types of FTLs, T5 is the most efficient one. For example, T5 & T8 lamps offer a 5-percent increase in efficacy over a 40-watt T12 lamps. 30

Compact Fluorescent Lamps (CFL)

CFLs are fluorescent lamps, which are small in size and come in both types of ballast-integrated and non-integrated. The life of CFLs is almost ten times that of an incandescent lamp. CFLs are extensively used in landscape lighting, security lighting fixtures, advertisement board lighting, etc. The efficacy of CFC ranges from 40-70 lm/W.

30 Paper 03: Energy efficiency in electrical equipment (portal.gov.bd)

4.1.3 Light Emitting Diode (LED) Lamps and Tubes

Light emitting diode (LED) lamps are the latest type of energy-efficient lamp. LEDs are semiconductor lighting sources. When a diode is forward-biased (switch on), electrons recombine with holes within the device releasing energy in the form of photons.

LED lamps emit visible light in a narrow spectrum and produce 'white light'. LEDs, owing to their very small sizes, are used for a variety of lighting applications such as landscaping, exit signs, or traffic signals. The range of LED technology is rapidly progressing. All types of light used in public buildings could be replaced by LED technology. LEDs offer a significant energy saving of 82-93% and the longest lamp life (40,000 to 100,000 hours). They are also shock- and vibration-resistant. Furthermore, their lifetime is not affected by switching, unlike the CFL.

4.2 Light-regulating Sensors

In the following, three different types of light-regulating sensors are presented which can be used to save energy in buildings.

4.2.1 Occupancy Sensor

Occupancy sensors save energy by turning off lights in unoccupied spaces. The energy saving potential for various areas is as follows[31]:

- Office areas: 20-50%
- Meeting rooms: 45-65%
- Corridors: 30-40%
- Warehouse and storage areas: 50-75%

4.2.2 Motion Sensors

When people come and go at unpredictable schedules in a building, motion sensors can be used to reduce lighting energy consumption. These were originally developed for the security industry, but now are being used in buildings. Motion sensors are normally ceiling-mounted or wall-mounted. There are two basic types of motion sensors:

- Passive infrared sensors
- Ultrasonic sensors

4.2.3 Photosensor Controls

There are several ways to use photosensor controls to save energy:

- Switch exterior lights on during sunset and off at sunrise.
- Switch or dim lights during the day depending on daylight level.
- Dim lights at night in lobbies and transitional areas where people's eyes are adapted to the darkness outside.

31 Energy Management Center Kerala, India Documents

Photosensor control uses a photocell to convert light energy into electricity. The photosensor uses a photocell to generate a continuous signal which is interpreted by a controller to switch or dim lights.

4.3 Best Available Lighting Technologies in Bangladesh

In the following subchapters, a general recommendation on the best available lighting technologies is given.

4.3.1 Sensors

The occupancy and motion sensor-based lighting systems are still in their infancy in Bangladesh. In some privately owned commercial buildings, the use of these sensor-based lighting systems has recently been introduced. These technologies are not widely available in the country. In most cases, they are being imported on project-specific requests. There are only a few selected automation companies in the country which provide such services; thus, the cost becomes even higher. In the public building sector, these technologies are not being implemented. The use of sensors like occupancy, motion and photosensor controllers should be made popular in the building sector of Bangladesh. This would reduce energy consumption and ensure better use of daylight where available.

4.3.2 Lighting

Currently, most of the public buildings in Bangladesh are equipped with Fluorescent Tube Lamps (FTLs), according to a sector expert. Energy audit findings under the EEPB project confirm this. The lighting system in the public building sector is mainly based on FTLs and CFLs. In 2010, a joint initiative called Efficient Lighting Initiatives of Bangladesh (ELIB), administered by the World Bank and the Bangladesh Rural Electrification Board (BREB), distributed CFLs[32] free of cost and contributed to making the technology popular. No such initiatives have been initiated for LED lamps. Still, their use has been increasing in the private building sector of the country. LED lamps are also being manufactured locally. As described above, LED lamps are significantly more energy-efficient and have a longer lifetime. In addition, FTLs are harmful to both health and the environment due to their mercury content. For this reason, these lamps should be disposed properly at the end of their lifetime. Table 16 lists a selection of existing LED lamps of different types and brands available on the Bangladeshi market. The technical specifications and prices vary depending on the manufacturer. Furthermore, the type of a suitable LED lamp depends on the application. It is recommended at this point to check the use of lighting and, on that basis, decide on a suitable LED lamp. Lumen maintenance data like L70, a critical data for the quality of any LED lamp, should be provided by LED lamps manufacturers along with other technical specification and this data should be verified by BSTI or any other accredited testing facility.

32 Bangladesh sets a world record – 5 million CFLs in a day, one bulb at a time! (worldbank.org)

Table 16. Best available lighting in Bangladesh

Brand	Model	Power (Watt)	Lumen (lm)	Power Factor	Colour Rendering Index (CRI)	Efficacy (lm/W)	Temper-ature	View-ing an-gle	Price (BDT)	Source
LED Panel light (Conceal Type)										
Walton	WLED-PL1F1-R24W	24	1800	≥ 0.90	≥ 80	75	6500K	120°	1950	Manu-fac-turer's website
	WLED-PL2F2-R36W	36	2700	≥ 0.90	≥ 80	75	6500k	120°	3800	
	WLED-PL2F2-R48W	48	3600	≥ 0.90	≥ 80	70	6500K	120°	4100	
Eco	48WLAAL185	48	5280	0.96-0.98	≥ 85	110	6500K		3,500	
Super-star	Panelux Downlight (Day Color)	24	2160	0.5	≥ 75	90		210	820	
	Panelux Downlight (Warm Color)	24	2160	0.9	≥ 75	90		210	1050	
ASHA	APT-PLH	20~72		≥ 0.95	≥ 80	85-90				
LED Panel light (Surface Type)										
Ener-gypac	BLSDL	12	960±5%	≥ 0.50	≥ 80	80	6500±500	150±25 %	525	Manu-fac-turer's website
	BLSDL	18	1530±5%	≥ 0.50	≥ 80	85	6500±500	150±25 %	750	
	BLSDL	24	2040±5%	≥ 0.50	≥ 80	85	6500±500	150±25 %	1,050	
Super Star	Panelux Downlight Slim Round Daylight	6	480	0.5	>75	80			420	

Brand	Model	Power (Watt)	Lumen (lm)	Power Factor	Colour Rendering Index (CRI)	Efficacy (lm/W)	Temper-ature	View-ing an-gle	Price (BDT)	Source
	LED Panelux Down-light Slim Square Day-light	6	480	0.5	>75	80			420	
Walton	WLED-SPLS120-UL6W	6	480	≥ 0.90	≥ 80	80	6500K	240°	350	
	WLED-SPLR145-UL9W	9	720	≥ 0.90	≥ 80	80	6500K	240°	390	
	WLED-SPLR170-UL12W	12	840	≥ 0.90	≥ 80	70	6500K	240°	540	
LED Tubes										
Walton	WLED-T5BAT-10W	10	1000	≥ 0.90	≥ 80	≥ 100	6500k	240°	320	Manu-fac-turer's website (Walton)
	WLED-T5BAT-18W	18	1800	≥ 0.90	≥ 80	≥ 100	6500k	240°	485	
	WLED-T5BAT-20W	20	2000	≥ 0.90	≥ 80	≥ 100	6500k	240°	500	
	WLED-T5TUBE-120WMB-20W	20	2000	≥ 0.90	≥ 80	≥ 100	6500k	240°	690	
	WLED-T8TUBE-120WMB-18W	18	1800	≥ 0.90	≥ 80	≥ 100	6500k	240°	650	
Ener-gypac	LED Tube Light	20	2100±10			≥ 100	6500 ± 500K		550	
	LED Slim Batten Light	10	1150 ± 5%	≥ 0.8		≥ 115	6500 ± 500K		425	
LED Bulbs										
Ener-gypac Super Star	EG LED Bulb	12	1200 ± 5%	≥ 0.5	≥80%		6500 ± 500		215	
	LED Prime Day Light B-22(PIN)	9		0.5	80%	100			230	

Brand	Model	Power (Watt)	Lumen (lm)	Power Factor	Colour Rendering Index (CRI)	Efficacy (lm/W)	Temper-ature	View-ing an-gle	Price (BDT)	Source
	LED Prime Day E27(PATCH)	9		0.5	80%	100			230	
Motion Sensor LED Light Bulb										
Super Star	Motion Sensor LED Day Light Bulb E-27 (Patch) [5-8-meter radios motion sense capacity]	9	840						555	
	BLINK motion sensor LED- B22 (Pin)	9	840			90	≥ 6400K	200	585	
Walton	WLED-MW-MSB-10WB22 [5-8-meter radios motion sense capacity with a sens-ing angle up to 360o]	10	900	>0.5	≥ 80		6500K		580	
	WLED-MW-MSB-10WE27 [5-8-meter radios motion sense capacity with a sens-ing angle up to 360o]	10	900	>0.5	≥ 80		6500K		580	

5. Ceiling Fans

Ceiling fans can be divided into two types. AC (alternating current) motor-driven and BLDC (brushless direct current) motor-driven ceiling fans. Nowadays, most ceiling fans are powered by AC motors, since the power grids usually distributed the power through AC. Hence, AC-motored ceiling fans can use the power directly from the power grid. The typical AC motor-based fans have the RPM (revolution per minute) control by the capacitor or resistor-based regulator. However, the regulator itself causes losses, which leads to lower efficiency. In addition, the RPM control is based by controlling the voltage. The voltage fluctuations of the grid make it very challenging to have constant RPM based on the AC grid supply. Furthermore, existing AC motor solutions involve power factor (PF) degradation with no improvement for PF and yield other negative effects such as harmonics injection to the AC mains.
Meanwhile, more and more BLDC motor-based ceiling fans are launched on the markets worldwide, due to their lower energy consumption. In the case of a BLDC motor-driven fan, the alternating current from the power grid must first be converted into a direct current via a transformer. Due to the fixed DC voltage, the ceiling fan has a constant RPM control and therefore a higher efficiency compared to an AC motor-driven fan.

The proposed BLDC motor and the control electronics operate out of 24V DC through a switched mode power supply (SMPS), with an input AC which can vary from 90V to 270V. A comparison between BLDC and conventional ceiling fans is shown below (42" ceiling fan is considered). [33]

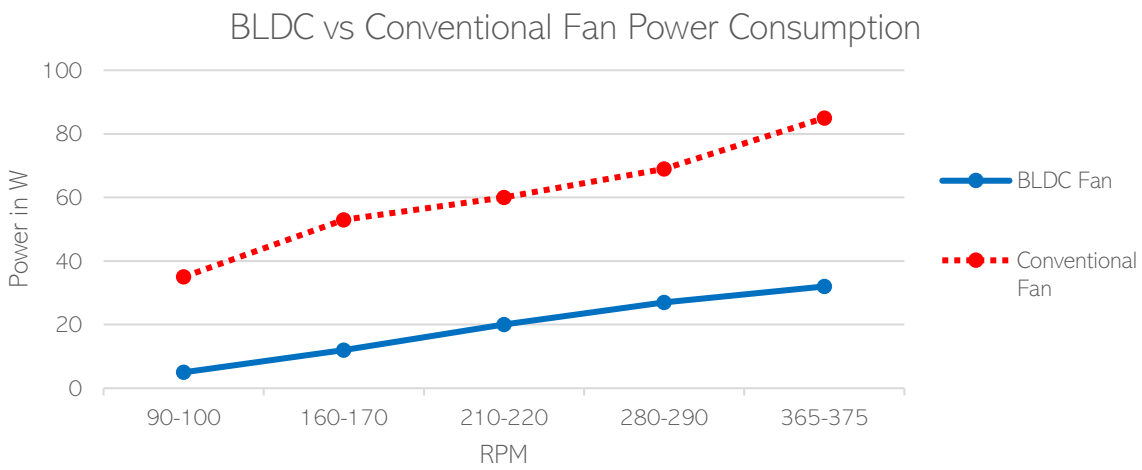


Figure 12. BLDC vs. conventional celling fan (42") power consumption comparison [33]

The power consumption is less than half at full speed and is about 20% at low speed for the BLDC motor compared to the conventional motor-based ceiling fan, as can be seen from the graph above.

In 2018, the Renewable Energy and Energy Efficiency Programme of GIZ Bangladesh sent two sample BLDC ceiling fans, produced by Innoel Technology Ltd, to the Testing Laboratory of the Department of Electrical and Electronic Engineering at Bangladesh University of Engineering and Technology (BUET) to carry out standard electrical tests and routine capacity tests and to provide the test report on two ceiling fans. Table 17 summarises the results of the two test devices.

33 Dr. Mahesh Rao. Energy efficient Ceiling fans using BLDC motors – a practical implementation

Table 17. Full-Load test results for the fans[34]

Parameters	Sample 1	Sample 2
Sweep (mm)	1400	1400
Rated Speed (rpm)	285	285
Minimum Speed (rpm)	98	101
Input Power at Rated Speed (W)	32	34
Input Power at Minimum Speed (W)	5	6
Input Current at Rated Speed (mA)	32	34
Input Power Factor at Rate Speed	0.97	0.94
Input Power Factory at Minimum Speed	0.71	0.80

Air delivery values and service values of the Innoel Technology Ltd fans are listed in Table 18:

Table 18. Air delivery and service value of the fans [34]

	Sample 1	Sample 2
Air Delivery (m3/min)	242	257.46
Service Value (m3/min/Watt)	7.56	7.57

According to the draft Standard and Labelling Appliance (SLA) Regulation, the referred Bangladesh standard for ceiling fan is BDS 1860:2012(Minimum values for energy efficiency and energy efficiency grades for ceiling fans).

The minimum acceptable energy performance values of AC ceiling fans specified under test conditions in the standard BDS 1860:2012 expressed as cubic meter per minute per watt (m3/min/w) of air displacement for qualifying for labelling under draft SLA regulation. MEPS for AC ceiling fans is shown in Table 19.

Table 19. MEPS for Ceiling Fans according to BDS 1860:2012[35]

Fan sweep (mm)	MEPS (m3 /min/w)
700	2.87
1050	2.93
1200	3.08
1400	3.32
1500	3.52
1800	3.67

34 BUET (2018)

35 Schedule VII: Labelling regulation for ceiling fans, Draft Standard & Labelling of Appliance Regulation, SREDA. Retrieved from 2020-06-02-16-42-5e6678ad364e4ff600a17db30d4461cf.pdf (sreda.gov.bd)

5.1 Best Available Energy Efficient Ceiling Fan in Bangladesh

As BLDC motor-based ceiling fans are the most energy-efficient and considered the best technology in this report. Unfortunately, they are not yet widely available on the Bangladeshi market and there is little awareness among the population. Nevertheless, it is recommended that this technology is given priority for new purchases in public buildings. Table 20 lists some of the current available BLDC ceiling fans in Bangladesh. Existing brands include Orient, Panasonic, Innoel, and Atomberg Gorilla. At present, BLDC fans are mostly imported. Some local plants manufacture energy-efficient AC fans which could be a low-cost alternative to the expensive BLDC fans and the cost-benefit comparison is need under a large public procurement programme. Typical AC fans available on the market are in the range of 75-82 watts. The more energy-efficient AC ceiling fans available on the Bangladeshi market are in the range of 52-70 watts and listed in Table 21.

Table 20. Best available BLDC ceiling fan technology in Bangladesh

Brand	Model	Sweep [mm]	RPM	Consumption [W]	Air delivery [cmm]	Price BTD	Source
Innoel	IN56241816CW	1400	290	35	260	4,900	BUET 2016; Innoel
Orient	Orient Aero-quiet BLDC Ceiling Fan	1200	310	35	240	7,965	Orient
	Orient Ecotech Ceiling Fan	1200	320	32	/		Orient
Orient	Orient Eco Quasar Energy Efficient Ceiling Fan	1200	320	32	/	/	
Panasonic	12XDA 48'	1200	355	30	230	15,000	Panasonic
Luminous	Luminous New York Tiffany 48”	1200	330	35	225	16,000	Luminous

Table 21. Best available energy-efficient alternating current fans available in Bangladeshi market

Brand	Model	Sweep [mm]	RPM	Consumption [W]	Air delivery [cmm]	Price BTD	Source
Walton	WCF5601-604 WR	1400	310	70	250	2,940	Walton
Energypac	Energypac Energy Efficient Ceiling Fan	1400	320	65	240	2,500-2,750	Energypac; e-commerce sites
Panasonic	56" Standard Ceiling Fan F-56MZ2	1400	236	52	200-225	5,500-6,400	Panasonic e-commerce sites

6. Solar PV Rooftop

As described in Chapter 2.1, the potential for solar power in Bangladesh is large. Worldwide, the installed power of solar PV energy is increasing, and the costs are still falling. The GoB, for its part, also aims to expand and support PV systems. In this chapter, the current market trends for PV rooftop systems in Bangladesh will be discussed and the best available technologies for PV rooftop systems will be summarised.

6.1 Solar PV Net Metering System Description and Operation Philosophy

A Solar Photovoltaic Power Plant consists of solar modules in series and parallel connections, which convert solar radiations into DC electrical power at the pre-determined range of voltages, whenever sufficient solar radiation is available. The solar module consists of several cells (which are basically semi-conductors), also connected in series and parallel and hermetically sealed, to survive in rugged weather conditions and perform optimally during its long life.

In order to achieve a higher system voltage, modules are installed in a series arrangement, called a string. A higher system voltage has the advantage of reduced installation work, higher efficiency of the entire plant and the usage of smaller cross section cables. The calculated number of strings is connected in parallel by cables in Array Junction Boxes. These Array Junction Box outputs are fed to the Inverter to invert solar-generated DC power into three-phase AC power.

For a grid-connected system, the AC power from the Inverter will be linked with the local LT Power distribution box for local use or export to the grid. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, in case of surplus generation beyond consumption, the grid-connected PV system supplies the excess power to the utility grid. This is achievable through the bi-directional net meter, which records the import and export of energy.

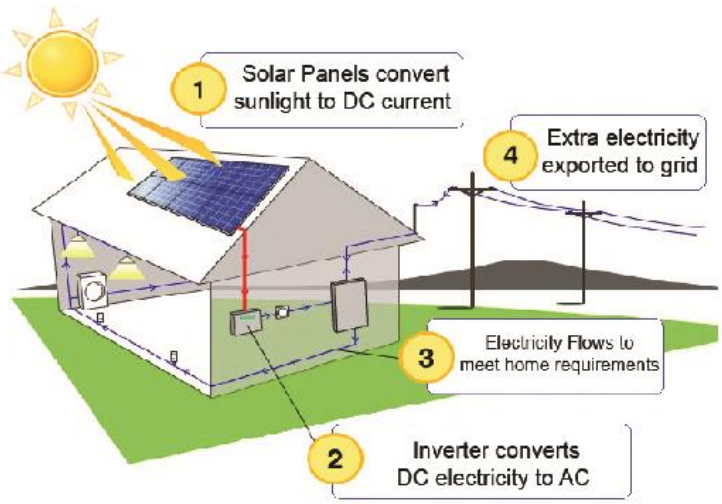


Figure 13. Schematic Diagram of Grid-Tied Solar PV Net Metering System (Courtesy: SREDA)

6.2 The GoB's Initiative to Promote Renewable Energy

Bangladesh is committed to produce 10% of its total electricity from Renewable Energy Sources by 2020. To achieve this objective, both the Cabinet Division[36] and SREDA´s Power Division[37] developed technical and commercial guidelines, which help promote Solar PV grid-tied electricity production and consumption in Bangladesh. SREDA has developed two distinct Implementation Models. One is the capital expenditure (CAPEX) Model and the other is the operational expenditure (OPEX) Model.

1) CAPEX Model: Under this model, the electricity consumer will install the solar PV system by using their own resources or taking on a loan from financial institutions. Here, the consumer will consume grid electricity from the utility and simultaneously produce electricity through the installed PV system. The consumer will pay the bills to the utility only for the net electricity consumption (difference of total consumption and electricity produced from PV system). If the electricity production surpasses its consumption, then the consumer will be paid back by the utility at an agreed rate.

2) OPEX Model: Under this model, a third party will invest for the installation of the whole Solar PV System. The consumer will pay the investor for the consumed renewable electricity at a lower agreed rate than the regular utility tariff. The consumer will pay the utility for additional grid power consumption at the regular tariff. If surplus renewable electricity is exported to grid, the investor will be paid back by the utility for the exported amount. Here, the consumer has no risk at all and both investor and consumer will be benefited.

Thus, a congenial environment will be created to invest for the promotion of Renewable Energy in the country. Simultaneously a new business opportunity will be created. Helpful SREDA information can be found under solar.sreda.gov.bd; www.renewableenergy.gov.bd; and http://www.projukti.net. Under GoB's initiative Solar Net Metering System installed to date (updated regularly) under different utility is shown in Table 22.

Table 22. Solar PV Net Metering System installed to date under different utility

Utility Name	Installed Capacity	Quantity
BPDB	6.788 MW	295
BREB	10.094 MW	204
DPDC	2.158 MW	235
DESCO	2.216 MW	313
WZPDCL	0.903 MW	179
NESCO	0.848 MW	43
TOTAL	**23.007 MW**	**1269**

Courtesy: SREDA

36 Circular No. 04.00.0000.512.82.003.19.298 dated 25.06.2019
37 "Solar PV Net Metering Guidelines-2018" through its Circular No. 27.02.0000.031.22.014.97.2019 dated 11.11.2019

6.3 Factors to be considered for a rooftop solar PV system

Main components of any solar PV system include solar panels/modules, inverters, mounting, battery or energy storage, charge controller, etc. A recent SREDA study reveals the indicative cost sharing among various components of an installed solar PV system. Those are shown in Table 23.

Table 23. Item-wise Indicative Share of Costs based on Total Installed Cost

Sl No	Item Description	Share of Instal-lation Costs
1.	Solar Panel/ Module	53%
2.	Mounting Structure	8%
3.	Grid Tied Inverter	16.66%
4.	Hybrid Fuel Save Controller	5%
5.	Monitoring and communication system	1.5%
6.	Energy Meter (SCM+SGM+NEM)	1.6%
7.	PVC pipe and combiner box	1.67%
8.	Earthing/ Lightning protection, Cable and Maintenance Free Chemical Earthing	2.67%
9.	Cables, Connection and other Equipment	4%
10.	Clearing System: Work way, Handheld Unit Pump	1%
11.	Safety Equipment for O&M: Rapid Shut Down Device,Circuit Breaker, Surge Protector	2.16%
12.	Transportation, Installation and Interconnection Commissioning	1.67%
13.	Design and Consultancy	0.66%
14.	Legal communication and other expenditure	0.17%
15.	Environment Consultancy	0.17%
16.	Total	100%
	Indicative expenditure per Wp (based on a 60 kWp installation = Tk. 50/Wp This sharing will vary depending on capacity, origin of components and site	

Source: SREDA

In a densely populated country like Bangladesh, space is a major challenge for large scale solar PV farms. The objective is to achieve greater efficiency from the installed solar PV panels with less space i.e. rooftop solar PV. Table 24 shows the active area & free area ratio and area/watt peak of three different categories of the solar PV modules.

Table 24. Rooftop Area Requirement per Wp depending on Type of Solar PV Module

Sl No.	Type of Solar PV Module	Active Area: Free Area	Area/Wp
	Monocrystaliline	61% : 39%	7.3 m2
	Polycrystalline	61% : 39%	8.4 m2
	Thin Film	62% : 38%	15.6 m2

Source: SREDA

According to local regulations, the solar accessories available on the Bangladeshi market need to have a NOC (no objection certificate) from SREDA. SREDA follows the below-mentioned standards (Table 25) for providing NOCs to solar PV system providers in the country.

Table 25. Approved Bangladesh Standards (BDS) for Net Metering Solar PV System

SL	Product Name	Name of Standards
1.	Solar Module/Panel	**BDS IEC 61215** Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
		BDS IEC 61730-1:2019 Photovoltaic (PV) module safety qualification part 1: Requirements for Construction
		BDS IEC 61730-2:2019 Photovoltaic (PV) module safety qualification part 2: Requirements for Testing
2.	Grid Tied Inverter	**BDS IEC 62109-1** Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
		BDS IEC 62109-2 Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
		BDS IEC 61727:2020 Photovoltaic (PV) systems - Characteristics of the utility interface
		BDS IEC 62116:2020 Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention
	Besides, any standards certified by any Accredited laboratory are also acceptable	

The standards can be sourced from http://bstibds.com/ online store of BSTI.

6.4 National Database of Service Providers in Installing Rooftop Solar PV Systems and National Solar Help Desk

There are dozens of service providers engaged in designing and implementing solar PV systems in the country. They import solar panels, inverter systems and energy meters from abroad and facilitate their integration. At present, most of the PV panels imported are manufactured in China. However, inverters also come from Europe and other regions. The comprehensive list of the rooftop solar system providers can be found in SREDA's Database of Renewable Energy Stakeholders[38]. GIZ has supported SREDA in establishing the National Solar Help Desk[39]. This help desk has both a physical and an online setup and has been designed to be a 'one-stop' service platform for all relevant stakeholders.

6.5 Best Available Technology for rooftop solar PV system in Bangladesh

It is a challenge to recommend best available technologies for rooftop solar PV systems. The solar PV system is a mix of different components which in collaboration create a system. Change of any of the components like solar panels, inverters, mounting structures, or the angle of the installation can significantly change the output of the system. In Bangladesh, the solar PV system providers set up the whole system on the rooftops of clients; the price is decided on a case-to-case basis. However, it is recommended that installation and maintenance standards for rooftop solar PV systems should be developed to avoid cost reductions at the expense of quality. Some examples of best available solar PV systems in Bangladesh for material supply, installation and commissioning of Rooftop Solar PV net metering system for different capacity are shown in Table 26 through Table 29.

38 https://stdb.sreda.gov.bd/

39 https://nshd.sreda.gov.bd/

Table 26. Budget price of System Provider: Rahimafrooz Renewable Energy Ltd.

SL	Item	Description	Capacity		
1.	Solar PV Module	Brand: Longi/suntech/ Canadian Solar (Tier-1 Listed) Origin: China Certifications: IEC 612215, IEC 61730, UL 61730, ISO 9001:2008, ISO 14001:2004, OHSAS 18001: 2007	5KWp (450Wp x 12	10 KWp (450Wp x 24)	15KWp (450Wp x 36)
2.	Grid Tie Inverter	Model: SSYMO 15.0-3-M Brand: Fronius Origin: Austria Certifications: DIN VDE 0126-1-1/A1, VDE AR N 4105, IEC 62109-1/-2, IEC 62116, IEC 61727, AS 3100, AS 4777-2, AS 4777-3, CER 06-190, G83/2, UNE 206007-1, SI 4777, CEI 0-21, NRS 097	1	1	1
3.	Other related item	Mounting Structure, Protection Devices, Energy Meter, Monitoring system and required accessories	1 lot	1 lot	1 lot
		Package Price	**Tk 4,00,000/**	**Tk. 7,50,000/-**	**Tk.10,80,000/-**
Solar PV Panel Modules Warranty- 5years; Expected life- 20+ years Grid-Tied Inverter Warranty- 5 years; Expected life- 10+ years					

Table 27. Budget Price of System Provider: Energypac Electronic Ltd.

System provider: Energypac Electronics Ltd.			
SL	**Description**	**Brand/Country of Origin**	**Quantity**
1	Tier-1, A Grade Solar PV Module	Astronergyor Equivalent, Engineered in Europe, Manufactured in China	10KWp
2	10KW Solar Grid-tie inverter with Protection Class: IP65	INVT, China	01Set
3	Supply & Installation of rust free solar mounting structure	BSRM /VSL or equivalent	01Set
4	Energy Meter: Three phase	Hosaf, Bangladesh	01 No.
5	Necessary DC cables (1x4rm NYYF)	RR/Partex or equivalent	125 Meter
6	Necessary AC cables (only from Inverter to Inverter AC combiner box)	RR/Partex or equivalent	20 Meter
7	AC Combiner Boxes	Local, Bangladesh	01 Set
8	Necessary Protection Devices & accessories	Legrand or Equivalent	01 Set
11	Supply, Installation & Commissioning with necessary accessories	Energypac, Bangladesh	1 Job
		Total Package Price:	Tk. 6,50,000/-
Solar PV Warranty-12 years' workmanship, Linear Output- 25 years; Grid Tied Warranty- 5years, Meter Warranty- 1year; Other item Warranty- 1 year			

Table 28. Budget Price of System Provider: Super Star Group

System Provider: Super Star Group					
SL	**Item**	**Brand & Origin**	**5 kWp**	**10 kWp**	**15 kWp**
1	Solar PV Module; Monocrystalline	Canadian solar: Manf: China	(440 Wpx 46)	(440 Wpx23)	(440Wpx35)
2	Three Phase Grid Tie Inverter with MPPT-2; 1 Programable	Brand: SMA/ABB Germany/Italy	5 kW	10 kW	15 kW
3	Three Phase Energy Meter (Bi-Directional)	Secure, India or equivalent	1	1	1
4	AC Combiner Box with protection devices	SSG, Bangladesh	1 set	1 set	1 set
5	PV Mounting Structure	BSRM/VSL, Bangladesh	1 lot	1 lot	1 lot
6	DC/AC Cables	BRB/BBS or equivalent	1 lot	1 lot	1 lot
7	PVC pipes & other	Bangladesh	1 lot	1 lot	1 lot
8	Transportation, Installation, Commissioning	SSG, Bangladesh	Whole Job	Whole Job	Whole Job
9	**Budget Price Offer**		**Tk. 3,50,000/-**	**Tk. 7,00,000/-**	**Tk. 10,50,000/-**
All PV modules are of TIER-1 Brand. PV inverters are of Europe Origin. PV module warranty: 12 years' workmanship. Linear power output warranty of 25 Years. Minimum output after 25 years- 82%. Degradation rate-0.72%. Inverter warranty: 5 years. Maximum Inverter efficiency: 98.1%.					

Table 29. Budget price of System Provider: Energypac Electronic Ltd.

System Provider: Energypac Electronic Ltd.			
SL	**Description**	**Brand/Country of Origin**	**Quantity**
1	Tier-1, A Grade Solar PV Module	Astronergy or Equivalent, Engineered in Europe, Manufactured in China	20 kWp
2	20KW Solar Grid-tie inverter with Protection Class: IP65	INVT, China	1 set
3	Supply & Installation of rust-free solar mounting structure	BSRM /VSL or equivalent	1 set
4	Energy Meter: Three phase	Hosaf, Bangladesh	1 No.
5	Necessary DC cables (1x4rm NYYF)	RR/Partex or equivalent	250 Meter
6	Necessary AC cables (only from Inverter	RR/Partex or equivalent	20 Meter
7	AC Combiner Boxes	Local, Bangladesh	1 set
8	Necessary Protection Devices & accessories	Legrand or Equivalent	1 set
11	Supply, Installation & Commissioning with necessary accessories	Energypac, Bangladesh	1 Job
			Total Package Price: Tk. 12,50,000/-

Table 23 (in section 6.3) shows that solar panels and inverters hold the major share of the cost of any solar PV system. Table 30 and Table 31 show the different best available solar panels and grid-tied inverters respectively in Bangladesh.

Table 30. Solar PV Module Specifications (Source: Rahimafrooz solar)

Brand	Model	Effi-ciency	Module Type	Degradation factor	War-ranty period	Coun-try of origin	Local Service Partner
Longi	LR4-72HBD-450M	20.7%	Mono Crystal-line	1st Year -2% 2nd -25 Year-0.5%	25 Years	China	N/A
Suntech	STP450S-B72/Vnh	20.6%	Mono Crystal-line	1st Year -2% 2nd -25 Year-0.5%	25 Years	China	N/A
Canadian Solar	CS3W 450MS	20.37%	Mono Crystal-line	1st Year -2% 2nd -25 Year-0.5%	25 Years	China	N/A

Table 31. Grid-Tied Inverter Specification (Source: Rahimafrooz Solar)

Brand	Model	MPPT Num-ber	Inverter Type	War-ranty period	Country of origin	Local Service Partner
Fronius	SYMO 5.0-3-M	2	Three Phase	05 Years	Austria	Rahimafrooz Solar
Fronius	SYMO 10.0-3-M	2	Three Phase	05 Years	Austria	Rahimafrooz Solar
Fronius	SYMO 15.0-3-M	2	Three Phase	05 Years	Austria	Rahimafrooz Solar
GoodWe	GW5K-DT	2	Three Phase	05 Years	China	Rahimafrooz Solar
GoodWe	GW10KT-DT	2	Three Phase	05 Years	China	Rahimafrooz Solar
GoodWe	GW10KT-DT	2	Three Phase	05 Years	China	Rahimafrooz Solar

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