Renewable Energy for Food Storage in SAARC Countries

SAARC Energy Centre

December 2021

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Foreword

Agriculture is regarded as the backbone of most SAARC Member States. Most of the regions' population lives in rural areas and depend on agriculture as the main source of income and employment. In most Member States, food grains are the staple and most cultivated crop, contributing to food and nutritional security. However, these crops are produced on a seasonal basis and are harvested once or twice a year. This means that the crops could be held in storage for a long time, varying from a month to a year, until the next harvest. Shortage of storage options near the farm area is a big constraint for farmers as they may feel pressured to sell their crops to aggregators or contractors prior to crop maturity, reducing their bargaining power.

Storage is becoming a significant component of the food industry. One of the main functions of food storage, apart from preservation, is to decrease the variability of food supply during times of uncertainty caused by natural and manmade calamities. The challenge is that all the SAARC Member States are facing a range of issues pertaining to food storage at the farm-level and central level which affect food security. Inadequate storage techniques can lead to food wastage and this has a cascading effect on the income of farmers and the cost of purchase for consumers. Growth and technological advancement in this sector can prompt income security, reduce hunger, eradicate poverty and promote sustainable growth in each country. One of the ways through which growth can be encouraged is by utilizing renewable energy solutions to address certain food storage problems.

The research study prepared based on the latest data for renewable energy usage in food storage technologies, lists out the potential areas for development like technical, operational, financial, organizational for the large-scale deployment of viable solutions. The study will run as a guidebook for key stakeholders in the SAARC region to formulate conducive policies and provide organizational support in the regions and technologies identified. The study is expected to facilitate the SAARC Member States in minimizing food wastage, reducing GHG emissions, poverty and improving the quality of life of rural communities through increased earnings.

Acknowledgements

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List of Abbreviations

Acronym	Definition
C&I	Commercial & Industrial
CERC	Central Electricity Regulatory Commission
CUF	Capacity Utilization Factor
CWC	Central Warehouse Corporation
FCBL	Food Corporation of Bhutan Limited
FCI	Food Corporation of India
FMCG	Fast Moving Consumer Goods
FMTC	Food Management and Trade Company Limited
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPPP	Government Paddy Purchasing Program
HPS	Husk Power Systems
kWh	Kilo Watt Hours
MDB	Multilateral Development Banks
MEA	Maldives Energy Authority
MMT	Million Metric Tonne
MNRE	Ministry of New and Renewable Energy
MT	Metric Tonne
MW	Mega Watts
MWh	Mega Watt Hours
NEPRA	National Electric Power Regulatory Authority

Acronym	Definition
NCCCD	National Centre for Cold Chain Development
OA	Open Access
PASSO	Pakistan Agricultural Storage and Services Corporation Ltd
PHL	Post-Harvest Losses
PMB	Paddy Marketing Board
RE	Renewable Energy
RPO	Renewable Power Obligation
RTC	Round the Clock
SERC	State Electricity Regulatory Commission
SIP	Solar Irrigation Pumps
SWC	State Warehouse Corporation
TJ	Tera joules
T&D	Transmission & Distribution

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Executive Summary

The SAARC Region is highly dependent on agriculture as the primary source of income and employment. Growth and technological advancement in this sector can prompt income security, reduce hunger, eradicate poverty and promote sustainable growth in each SAARC country. The SAARC Region faces many challenges related to the agricultural sector, specifically in the post harvesting stages. One major challenge is associated with the lack of adequate food storage facilities, which results in avoidable food loss. Post-harvest loss (PHL) is the food lost along the agricultural supply chain, from harvest until consumption. Proper storage protects the quality of perishable and non-perishable foods and prevents untimely deterioration. Inadequate storage techniques can lead to food wastage and this has a cascading effect on the income of farmers and the cost of purchase for consumers. Food loss can occur at all stages of agro-value chain. For the SAARC Member States, post-harvest losses are the highest during the storage stage. Figure 1 below illustrations the main stages of the post-harvest value chain.

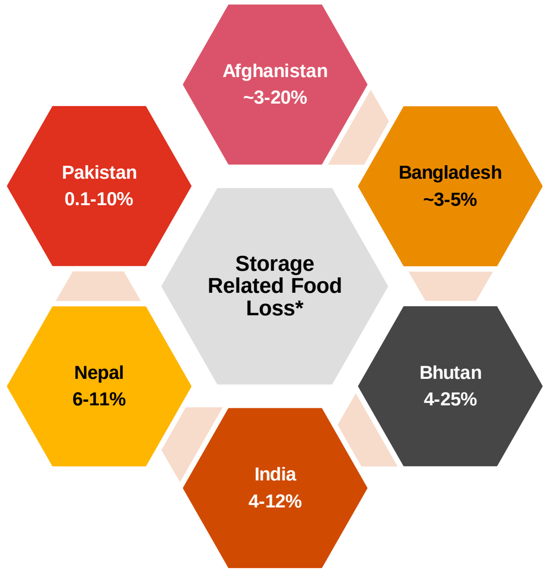
Figure 1 - Post Harvesting Value Chain

After an agricultural sector analysis on a country wise basis, it was observed that post-harvest losses could be attributed to:

- Improperly managed storage facilities
- Inadequate central storage capacity
- No awareness on extent of storage related losses
- Poor storage infrastructure
- Insects, rodents, moisture

Figure 2 – Annual Storage Related LossesFigure 2 below outlines the annual storage related losses incurred by each SAARC Member State.

Figure 2 – Annual Storage Related Losses



*Maldives does not have data available to quantify this loss

The relationship between food production and energy has evolved due to the reliance on irrigation and mechanization. High costs of energy have a negative impact on production costs in the agricultural sector. The integration of RE into the agricultural value chain could be one of the best ways to improve national food and energy security in a sustainable manner. RE based solutions can help overcome the barriers arising from lack of electricity and different solutions can help minimize the food wastage and increase the efficiency of existing food storage methods. This can cascade into other positive aspects such as reducing poverty in rural areas, reduce GHG emissions and provide a business case for RE suppliers/solution providers by increasing the demand beyond traditional consumption of energy for industrial, commercial and agricultural users.

Renewable Energy based solutions for food storage can be centralized (on-grid) or decentralized (off-grid). The report explores successfully implemented centralized and decentralized solutions for food storage in the form of case studies. To promote the use of RE solutions for reducing food storage related losses, factors such as national polices, government incentives and access to finance also play a major role. Existing RE policies for each SAARC Member State which have propagated numerous successful projects in the agricultural sector are also explored. The policies have even positively impacted the RE tariff structures in few countries. A review of policies and existing examples in the SAARC Member States have also revealed similar barriers to the successful deployment of RE based solutions in the agricultural sector, as shown in Figure 3.

Figure 3 – Barriers to Implementation of RE Based Solutions for Food Storage

Based on the barriers to implementation of RE based solutions for food storage, the general recommendations for all SAARC Member States are -

- Develop and implement incentive mechanisms, subsidies and tax breaks to promote the uptake of renewable energy across the agricultural -value chains
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop and implement well defined agricultural policies which details how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing, if required, to deploy decentralized RE storage solutions.

Based on the analysis of the barriers to implementing RE based solutions in the Agriculture and Power Sectors for each Member State, tailored recommendations have been detailed in the last chapter. To effectively drive the implementation of RE based solutions for food storage at a large scale, it is imperative to address each of the barriers keeping in mind the Member State's current agricultural, energy and regulatory situation.

Chapter 1: Introduction & Scope

1 Chapter 1: Introduction & Scope

The aim of this chapter is to introduce the reader to the role of agriculture in the SAARC Member States and the consequences of food loss along the agricultural value chain. In addition to outlining the objective, scope, approach and limitations of the study; the chapter will also introduce the benefits of incorporating renewable energy-based solutions to agricultural activities, mainly food storage.

1.1 Background and Introduction

Agriculture has been defined as the practice of cultivating and producing crops and livestock for economic development as it requires skill of operation, utilizes technologies based on scientific principles and aims to maximize returns from management of its value chain. It involves all aspects of crop production from pre-harvesting to post harvesting for horticulture, food grain, oilseeds, livestock rearing, forestry, and fisheries.

The SAARC Region, classified as low income and high poverty, has high dependency on agriculture as a primary occupation. Most of the regions' population lives in rural areas and depend on agriculture as the main source of income and employment. Agriculture is considered a predominant sector of the member countries' economy as it contributes towards approximately 16.5 - 40%[1] of the regions total Gross domestic product (GDP) (excluding Maldives). Growth and technological advancement in this sector can prompt income security, reduce hunger, eradicate poverty and promote sustainable growth in each SAARC country.

Food wastage occurs at every stage of the supply chain for reasons that are dependent on the local conditions of each region and country. Inadequate storage can lead to food wastage and loss of income. It is estimated that in low-income countries, particularly the SAARC Member States, ~250 million metric tonnes (MMT) of food is wasted annually. Of this, 30-40%[2] of the food loss occurs in the post-harvest and storage stages of the supply chain. This translates to ~USD 300 billion[2] of losses annually, primarily due to inadequate refrigeration and unreliable and expensive energy supply. Furthermore, this loss has a cascading effect on the income of farmers and the cost of purchase for consumers. This food wastage also contributes to the GHG emissions and is the third largest emitter of CO_2 globally[3].

There are many challenges prevalent in the agricultural sector of the SAARC region such as lack of mechanization, irrigation, scarcity of capital and inadequate & outdated food storage facilities – this report will focus on the existing food storage situation and how renewable energy-based solutions could help resolve certain issues faced at this stage. Food storage is an important part of the agri-

[1] World Bank Group. (2021); Indian Council of Agricultural Research (ICAR). (2016); Dorjin et. Al (2021); GC, A., & Ghimire, K. (2019)
[2] Ridolfi, R., & Dubois, O. (2019)
[3] Promoting Sustainable Lifestyles, (2021)

business function that involves stowing and preserving the food grain from the time they are harvested till they are required for consumption. Storage protects the perishable and non-perishable items from deterioration and external threats such as weather and pests. Another function of food storage is to help even out fluctuations in market supply, both from one season to the next and from one year to the next, by taking produce off the market during surplus season, and releasing it back onto the market during lean seasons – thus leveling out the variations in market prices and achieving food security.

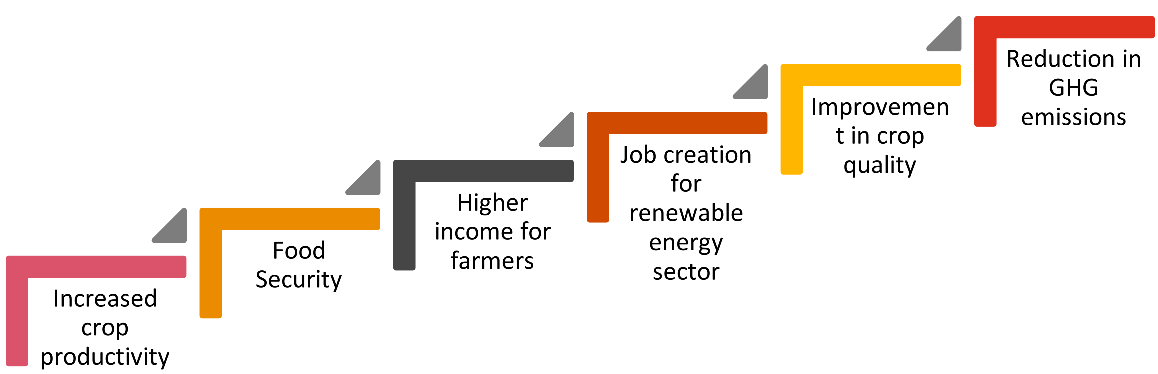
For this multifaceted issue, the report will take a deep dive into, inter-alia, agricultural value chain issues and energy scenarios for each of the SAARC Member States.

1.2 Rationale and Objective of Study

Most farmers, agents and other middlemen use traditional methods of food storage, which are neither temperature controlled nor have adequate protection against pests, rodents and other natural elements. These methods also contribute largely towards spillage and mishandling of waste. Without access to modern food storage infrastructure, it is challenging to enable the economic transformation for small land holders, who bear the brunt of food wastage and are most vulnerable to climate change.

The objective of the study is to understand critical issue pertaining to food preservation in the SAARC Member States and then provide country specific recommendations to each State. The recommendations will focus on how RE based solutions can be deployed to alleviate these food preservation issues. This will depend heavily on factors such as existing and future RE policies, feasible technologies, financing options and general awareness of these solutions. Deployment of renewable energy-based storage solutions will not only contribute to reduction in food wastage, but also reduce GHG emissions and provide a business case for energy suppliers/ developers by increasing the demand beyond traditional consumption of energy for industrial, commercial and agricultural use. The overall outcome of such food storage solutions is listed in Figure 4.

Figure 4 - Benefits of improved food storage methods



1.3 Scope of Study

The scope of study below describes the specific areas of research for this study:

a. **Current Scenario in SAARC Member States**: This section will cover the production quantity of main crops in the Member States, along with their storage requirements and current methods of storage. Emphasis will be laid on the wastage occurring at each stage of the value chain, from post-harvest till end-consumption.

b. **Energy Use in Food Storage & Related Activities**: This section will cover the types of energy required in Agricultural Sector. Then it will outline the current energy scenario in each SAARC Member State. The focus of this chapter will be to quantify what storage capacity would need to be added by each Member State to reduce food loss and the energy required to power these facilities.

c. **Application of Renewable Technologies**: The section will study different renewable technologies available for food storage to reduce dependency on conventional energy sources. It will also highlight different technologies available, operational parameters, business model of the technology and incentives provided by governments. The section will present the most technically and commercially viable solutions for the SAARC Region.

d. **Challenges and barriers**: This section will focus on the barriers and challenges faced by stakeholders in deployment of such solutions and their localized and large-scale penetration. The barriers will holistically include financial, political, regulatory, technical and operational challenges faced by stakeholders in successful deployment.

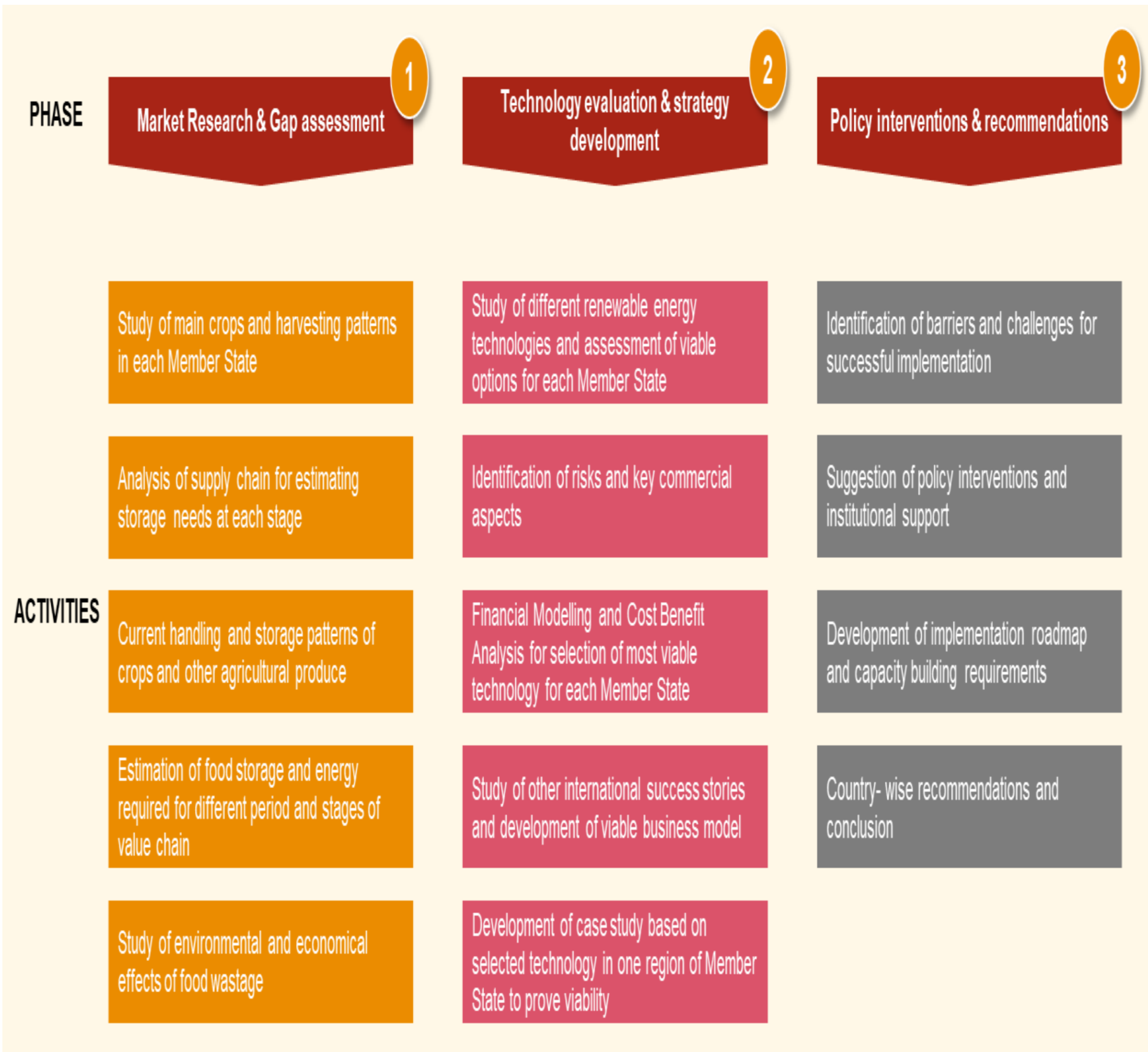
e. **Recommendations**: This section will cover the Member State-wise recommendations to overcome the barriers and challenges identified previously. It will include the detailed assessment of changes required to the policy and regulatory framework, availability of suitable technologies, financial instruments and incentives required, and technical capacity building of stakeholders (among others) for successful deployment of renewable energy usage for food storage.

1.4 Approach and Methodology

The proposed methodology for this report is to professionally develop a range of activities, methodically divided in coherent phases, which would lead to the realization of the desired outcomes. The detailed approach and workplan are provided in

Figure 5.

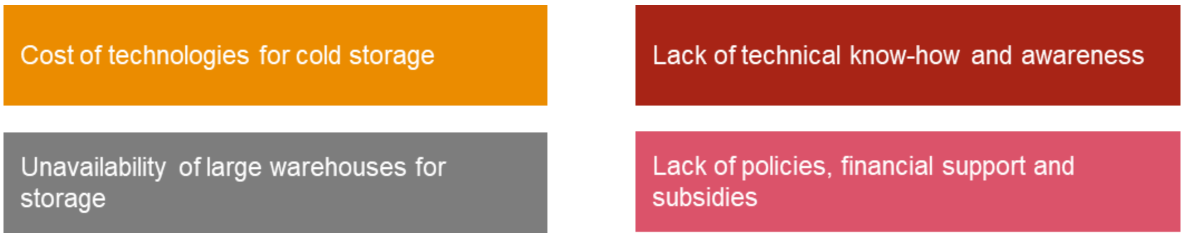
Figure 5 - Phase wise approach



1.5 Limitations and Assumptions

The main issues faced by the deployment of efficient renewable energy technologies for food storage can be categorized broadly into technical, financial, operational and political challenges as shown in Figure 6.

Figure 6 - Main Issues for Deployment



While private companies offer standalone drying and storage systems to farmers and aggregators, most farmers in SAARC regions are small landowners and are unable to afford and bear the cost of these systems. Moreover, the solutions are only available in towns and cities and are yet to make inroads in the countryside. Most small farmers are also reluctant to use these systems due to lack of technical know-how and awareness of such solutions.

Warehouse storage systems are generally used by traders and aggregators using traditional methods. Bangladesh and India have organized central warehousing facilities across their respective countries. Most other storage systems are small and decentralized and use electricity from the grid for cooling or drying purposes. Only Bangladesh, India and Nepal have implemented renewable energy-powered cold storage facilities, however these facilities are small scale and unique.

Lastly, each of the Member States lacks targeted central policies and regulations for the use of renewable energy for food storage systems. In the absence of such policies and incentives it is challenging for successful deployment and large-scale penetration of technological solutions.

The report has the following limitations:

- Data collection and analysis is based on verified public sources of information such as industry studies, journals, publications and various research databases.
- Relevant data/statistics/information/reports shared by SEC for the study has been used.
- The report is limited to verified and authentic secondary sources of information and discussion only. No primary research has been undertaken for the assignment.
- During analysis and benchmarking, widely acceptable norms have been utilized in case actual information is unavailable.

- Some relevant data used is a few years old, as up to date information is unavailable due to lack of studies carried out on relevant topics
- Relevant data pertaining to crop production, food storage and current energy scenario in Maldives is unavailable

This report is made on the following assumptions:

- Traditional methods of storage are inefficient.
- Renewable energy-based food storage methods will be reliable.
- Renewable energy-based food storage methods will not face the same issues as traditional storage methods such as pest and insect infestation.
- End users of the renewable energy food storage methods will accept the transition from known traditional methods of storage.

1.6 Value Addition

With close to 50-60% of the population in the SAARC Member States is dependent on agriculture for livelihood, the project can aim to not only increase the annual income of these farmers, but also improve their quality of life. By using these storage solutions, farmers will not be obligated to sell their produce right after harvest at low prices but can retain their produce for sale during the lean seasons when the demand and prices are both high. Another indirect benefit of such projects will be to reduce the GHG emissions caused by food wastage and aid towards food security and environmental benefits. Other than this, decentralised renewable energy solutions will also create job opportunities for renewable energy service providers and developers by increasing the demand beyond traditional consumption of energy for industrial, commercial and agricultural use. The findings and recommendations of the report could be useful for policy makers, national & regional entities and various leaders in updating policies and implementing relevant interventions for the promotion and uptake of the RE based solutions for food storage.

Current Scenario in SAARC Member States

2 Current Scenario in SAARC Member States

Chapter 2 will focus on the key crops cultivated and outline the crop value chain on a country-to-country basis. The chapter will also explore the post-harvest losses that occur along the crop value chain for certain main crops to understand the root causes of these losses.

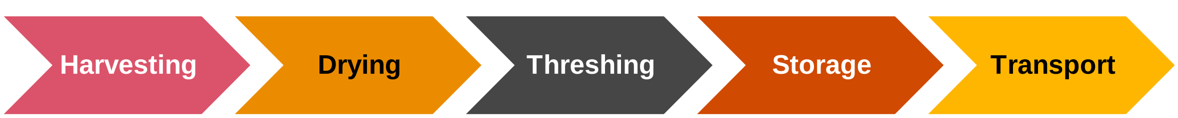
2.1 Broad Overview of Current Scenario

The SAARC Region comprises of 8 countries – Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The agriculture sector accounts for a substantial portion of total GDP throughout the region and has grown at a remarkable rate during the past 30 years because of the Green Revolution/ Third Agricultural Revolution. Nonetheless, the region has a greater number of undernourished and poor people compared to any other developing region, and more than two-thirds of these people reside in rural and remote areas. They remain largely dependent on agriculture for their livelihood and employment. Agriculture remains the predominant occupation for 50-60%[4] of the workforce. Most of the poor people live in rural areas and are particularly more vulnerable to droughts, floods, and other natural calamities. Continuous and sustained growth of the agriculture sector is vital for the eradication of poverty, livelihood security, reduction in hunger and promotion of sustainable and inclusive growth of the regional economies.

2.2 Country wise Agricultural Value Chain Analysis

This section will identify the main crops, food storage methods and post-harvest value chain on a country-to-country basis. Once the value chains have been identified, shortcomings at each stage can be investigated. Input will vary on a country-to-country basis as information is dependent on data being available from studies, publications and national investigations. The general post-harvest system has been categorized below in Figure 7.

Figure 7 - General Post Harvesting Value Chain



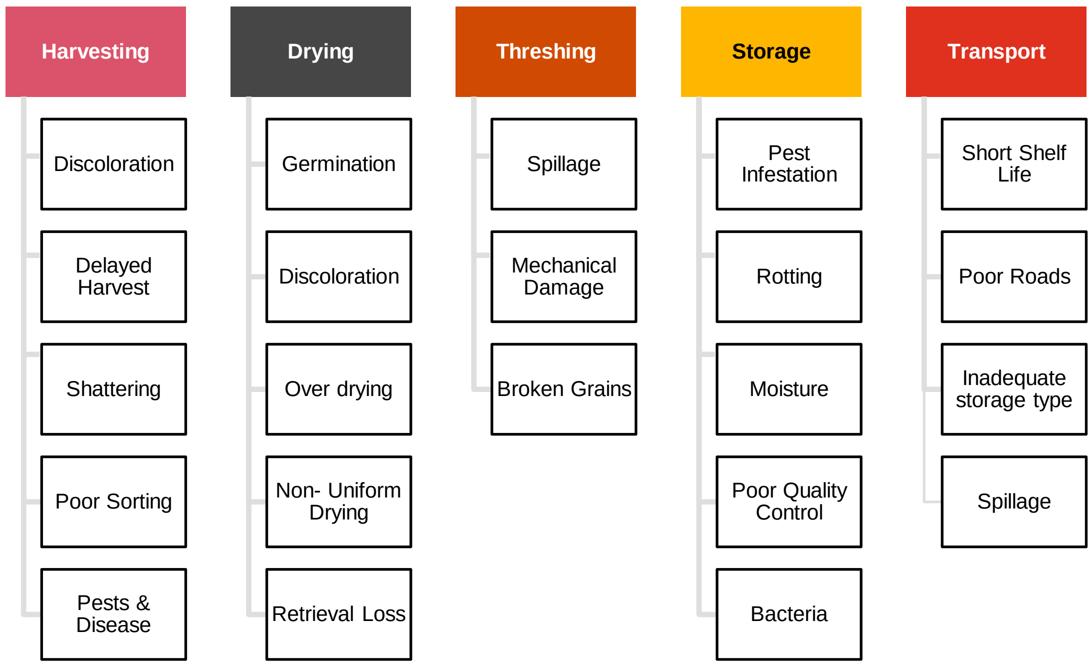
Post-harvest loss (PHL) is the food lost along the agricultural supply chain, from harvest till consumption. The magnitude of PHL varies from country to country based on their economic development state. Food storage is an important function in the agricultural value chain and plays a vital role towards country's food security agenda. Food storage involves holding and preserving goods

[4] Roser, 2017

from the time they are produced until they are ready for consumption. Proper storage protects the quality of food and prevents untimely deterioration. It also ensures a continuous flow of goods into the market.

Food loss can occur at all stages of the value chain. A few reasons are outlined in Figure 8 below.

Figure 8 - Potential Reasons for Post Harvesting Losses



Apart from the agricultural supply chain, there are various conditions which can influence the value chain of crops. Macro influences such as physical conditions, socioeconomical, biological and operational factors can severely impact the quality of crops. The conditions that impact the crop value chain are listed in Figure 9.

Figure 9 - Conditions that directly impact the Value Chain of Crop

Physical Conditions	Biological	Socioeconomic	Operational
• Temperature	• Insect	• Family size	• Harvesting Technology
• Moisture	• Rodents	• Income	• Storage Technology
• Oxygen level	• Germs	• Land size	• Building Infrastructure
• Quantity Stored	• Mold	• Storage duration	• Equipment Type
• Duration of storage		• Road accessibility	
		• Market prices	
		• Crop safety	

It is estimated that post-harvest loss accounts for 20%[5] of global food loss. Therefore, it is very important to understand the value chain of the main crops. The sections below will outline what factors affect the crop production in each SAARC Member State.

The country wise analysis will include – introduction to the agriculture sector, main crop produced, post-harvest losses for selected main crops, loss percentage at each stage and current methods of storage for the main crops. For high crop producing countries such as India, Nepal and Pakistan, the drivers of PHL at each stage of the value chain have been summarized and generalized for all categories of produce. For the remaining SAARC Member States, the drivers of PHL have been included alongside the PHL % at each stage for the identified main crops of that region.

2.2.1 Afghanistan

The agricultural sector of Afghanistan supports the livelihood of ~75% of the population and contributes ~28% of the total GDP[6]. Over 20% of the population experience food insecurity and malnourishment due to fluctuating food prices, poverty, conflict driven displacement, lack of quality basic services and weak institutional policies. Progress in this sector is imperative for ensuring growth in the economy and safeguarding national food security. Afghanistan produces organic fruits, nuts, grains, vegetables with a substantial amount of these commodities moving towards the export market. Although wheat accounts for over 50% of the cereal production, the country faces cereal deficit even during periods of good harvest.

Farms in Afghanistan are small and their productivity is low as they mainly seek to satisfy the food requirements of their households. The agricultural sector is dominated by private entities including farmers, livestock herders, cooperatives, suppliers, processors and exporters. Wheat is considered as the nation's major crop and staple, followed by grapes which greatly contribute towards their exports. The most substantial crop production details of the country are outlined below in

Table 1.

Table 1 - Afghanistan's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	5,583,461
Horticulture	Fruit	2,872,161
	Vegetable	1,273,847
Commercial Plants	Oil Seeds	89,021
	Other	196,156
Total Production		10,014,646

[5] GC & Ghimire, 2019
[6] Muradi, A., & Boz, I., 2018
[7] Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

As per small scale studies, post-harvest losses for horticulture crops range from 10-40% at the farm-level. Table 2 below outlines the loss percentages and associated reasons for each stage of the post-harvest value chain. Studies carried out on grapes and apples report that storage losses account for 2.67% and 19.1% of the total post-harvest loss respectively (refer Table 2). Grapes are stored at the farm-level in small airtight mud containers while apples are stored in wooden crates – both fruits are then stored in on-site sheds.

Table 2 - PHL for Horticulture Crops in Afghanistan[8,9]

Crop	Category	PHL %	Drivers for PHL
Grapes[8]	Handling & Packing	1.90%	Lack of knowledge
	Loading & Unloading	2.10%	Mishandling of produce
	Storage	2.67%	Faulty Storage
	Transportation	2.43%	Poor transportation methods, poor roads and no access to specialized vehicles
	Other	1.33%	
Apples[9]	Harvesting, Sorting & Packaging	14.1%	Physical + Mechanical damage, improper packing materials, unavailability of knowledgeable labor
	Storage (4 months)	19.1%	Pests, decay, rotting, sunburn
	Transportation	7.5%	Long distance, weather, no access to cool storage

At a central level, Afghanistan has 17 Strategic Grain Reserves around the country with a total capacity of 240,000 MT10. However, these storage facilities are only used during emergency situations. The Government of Afghanistan's, Ministry of Agriculture, Irrigation, and Livestock (MAIL) owns 5 silos in Kabul, Kandahar, Herat, Baghlan, and Balkh Provinces with a combined storage of 170,000 MT[11]. The government also owns numerous small warehouses with a combined capacity of 65,000MT[11] to store wheat. Unfortunately, only 25% of this capacity is used due to lack of modern stock management practices, skilled maintenance, and available spare parts. The outdated operating practices and poor conditions of these storage facilities reduce the quality of wheat available. This leads to large fluctuations in wheat prices and effectively disables these facilities from being useful food reserves during times of emergency.

It is estimated that the post-harvest losses for wheat range from 15-20%[12]. In 2006, the Rebuilding Agricultural Markets Program supplied 21 cold storage facilities to 10 provinces; however, farmers lacked the technical know-how and financial resources to maintain these assets. The Government of

[8] Mirwais & Yamada, 2017
[9] Masood, 2011
[10] Afghanistan Food Suppliers, 2017
[11] The World Bank Afghanistan Strategic Grain Reserve Project, 2017
[12] Ministry of Agriculture, Irrigation and Livestock (MAIL), 2013

India also supplied a 5000 MT cold storage facility in 2006[13]. Table 3 includes the main storage methods in Afghanistan.

Table 3 - Storage Methods for crops in Afghanistan[10,11,14,15]

Storage Type	Description	Capacity[10, 11,14,15]
Silo's	Metal structures	20,000 – 50,000 MT. Total Capacity 170,000 MT
Warehouses	Basic storage complex	1000 – 22,000 MT. Total Capacity 65,000 MT
Cold Storage	• 21 Cold Rooms from Rebuilding Agricultural Markets Program • 1 cold storage facility from the Government of India • Commercial Cold Storage • ~3000 active farm cold storage units using evaporative cooling (no energy)	• 2000 MT • 5000 MT • 50-5000 MT each, total 24,000 MT • 5-50 MT each, total capacity 95,000 MT
Village Type Storage	• Kangina - two layered earthen clay containers • Jute bags, crates	1 kg – Variable

Due to the lack of managed centralized storage options in Afghanistan, the crops are predominantly stored at the farm-level. Traditional methods of storage invite moisture, pests, microbes and rotting. Improved methods of storing horticulture crops can lead to lower levels of food loss and higher income for farmers.

2.2.2 Bangladesh

Agriculture is the main source of livelihood for over 80% of Bangladesh's rural population and contributes towards 17% of the total GDP[16]. Rice, wheat and maize are the major food crops, though the crop sector is dominated by rice. The total food grain production in 2019-2020 was 37.64 MMT, of which 36.61 MMT[17] was rice production. Rice farming is one of the main sources of income for the rural population. The most substantial crop production details of the country are outlined below in Table 4.

[13] India News, 2006
[14] USAID, 2006
[15] MAIL Cold Storage Industry Afghanistan, 2017
[16] CIAT; World Bank. 2017
[17] Food Planning and Monitoring Unit of the Ministry of Food, 2021

Table 4 - Bangladesh's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	5,917,2720
	Pulses	385,988
Horticulture	Fruit	3,135,571
	Vegetable	16,457,560
Commercial Plants	Oil Seeds	522,586
	Other	6,098,782
Total Production		85,773,207

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

The level of avoidable post-harvest storage losses of major stored cereal such as rice, maize and wheat vary from 10-25%[18]. The level of post-harvest losses for horticulture crops such as fruits and vegetables ranges from 24 – 44%[19]. Post-Harvest Losses have major ramifications on food security and nutrition. Post-Harvest losses in Bangladesh are higher than global averages and the reasons can be attributed to - inaccessibility to food processing technologies for farmers, climatic conditions and adverse weather conditions (floods, droughts, heavy rains). Table 5 below outlines the loss percentages for each stage of the post-harvest value chain for the main crops.

Table 5 - Cereal Post Harvesting Losses in Bangladesh[20]

Crop	Post-Harvest Stage	Loss in %[20]	Loss in Tonnes
Wheat Loss	Harvesting Loss	0.77	7,829
	Drying Loss	0.62	6,304
	Threshing Loss	0.65	6,609
	Storage Loss	1.54	15,659
	Transporting Loss	0.09	915
	Total Loss	3.67	37,317
Maize Loss	Harvesting Loss	0.33	11,779
	Drying Loss	0.62	22,130
	Threshing Loss	0.55	19,631
	Storage Loss	2.5	89,233
	Transporting Loss	0.12	4,283
	Total Loss	4.12	147,056
Rice Loss	Harvesting Loss	1.62	884,299
	Drying Loss	2.43	1,326,448

[18] Grain Storage - Banglapedia, n.d.
[19] National Food Policy Capacity Strengthening Programme, 2010 [Provide the updated references throughout the report. Use all the references no later than 2018]
[20] 'Bari MD, 2015

Crop	Post-Harvest Stage	Loss in %[20]	Loss in Tonnes
	Threshing Loss	1.25	682,329
	Storage Loss	4.15	2,265,333
	Transporting Loss	0.95	518,570
	Total Loss	10.4	5,676,980

Looking at Table 5, crop loss due to storage is 1.54%, 2.5% and 4.15% for wheat, maize and rice respectively. Rice has larger storage loss percentage as it is stored for a longer duration compared to wheat and maize. Approximately, 80% of crops are stored on the farm in 5 types of traditional storage methods (Motka, Bags, Dole, Steel and Plastic drums) while the rest are stored in national warehouses and silos. The local and central storage depots are used for short term storage as these contents are procured from farmers only during harvesting season. Table 6 lists the storage methods used in Bangladesh.

Table 6 - Storage Methods for Cereals in Bangladesh[21]

Storage Type	Description	Capacity
Motka	Earthen container	80-200kg
Plastic Bags	Poly Propylene bags	40-50 kg
Dole	Oval bamboo container with open top	180-1000 kg
Steel Drum	Steel Cylinder with lid	20-200 kg
Plastic Drum	Plastic Cylinder with lid	20-40kg
Cold Storage	400 cold storage facilities	6,000,000 MT
Local Storage Depot	633 Warehouses, aged 40 to 60 years old	2,137,234 MT[21]
Central Storage Depot	13 Warehouses, aged 40 to 60 years old	
Silos	6 silos for bulk material storage	
Multistoried Warehouse	Solar Powered temperature-controlled warehouse	25,000 MT

The inefficient crop storage method in Bangladesh leads to the highest post-harvest losses. The traditional storage methods invite high levels of insect infestation and germination while the national warehouses are timeworn, in poor conditions and lacks technologically for the evolving food quantities.

2.2.3 Bhutan

Agriculture is the dominant source of income and employment in Bhutan as over 60%[22] of the

[21] Kabir, Yunus, Hossain & Rashid, 2019
[22] Tobgay et al, 2019

population resides in rural areas and over 40% of the total population is employed in the agricultural sector[23]. Maize is the staple crop of Bhutan, followed by rice, vegetables and fruits. Maize accounts for over 45% of the total cereal production and is generally cultivated in small quantities by famers for personal consumption. The most substantial crop production details of the country are outlined below in Table 7.

Table 7 - Bhutan's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	102,100
	Pulses	407
Horticulture	Fruit	41,054
	Vegetable	84,456
Commercial Plants	Oil Seeds	803
	Other	18,172
Total Production		246,992

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

Bhutan has a range of agricultural ecological zones and climates which provides a good opportunity to cultivate a wide variety of crops. Horticultural crops such as quinoa, apples and mandarin were introduced to the country in the 1960's. Unfortunately, due to the uneven geographical spread of the country, only 8% of land can be cultivated. Further, farmlands are scattered and fragmented across different and challenging terrains making farming a labor-intensive profession. Farmers face issues such as inaccessibility to main roads and markets, resulting in high transportation costs.

Poor post harvesting techniques account for 20% food loss, which in 2017 amounted to Nu 180 million (approx. USD 2.5 million)[24]. Bhutan farmers have adopted few improvement techniques which has resulted in higher crop yields, however the quality of post-harvest management such as storage, is low. Bhutan does not have enough data to validate the storage loss numbers; however, small-scale studies have been conducted on the post-harvest losses for major crops such as maize, mandarin, quinoa, and apples. The loss percentages and associated reasons are outlined in Table 8 below.

Table 8 - PHL Loss & Reasons in Bhutan[25]

Crop	Post-Harvest Method	Loss %[25]	Drivers for PHL
Maize	Storing cobs on attic floor	Average loss 26.1%	

[23] CIAT; World Bank, 2017
[24] Dorji, Tshering & Lhami, 2020
[25] Bhutan Journal of Agriculture 2019, 2020 & 2021

Crop	Post-Harvest Method	Loss %[25]	Drivers for PHL
	Hanging cobs from house ceilings	Average loss 23.3%	• Average Loss due to Insect Infestation 17.5% • Average Loss due to fungal infection 8.5%
Quinoa	Field Drying	Loss 5.0%	• Total Post Handling Loss 9.4% • Loss due to harvesting before crop reaches maturity • Farmer's knowledge of newly introduced crops is low
	Storage	Loss 4.4%	
	Threshing	Loss 4.4%	
Mandarin	Post-Harvest Operations (Transport)	Partial Damage 25.57% Loss 5.63% Damage during handling operations 31.20%	• Partial damage - bruising, shrinkage, or peeling • Loss - the fruit having no economic value • Transport Loss – long distance, rough handling of fruits, poor road conditions • 14.08% of damage and loss from disease, birds, insects • Nu 77.33 million economic loss
Apple	Post-Harvest Operations (Transport)	Partial Damage 37.76% Loss 5.18% Damage during handling operations 42.94%	• Partial damage - bruising, shrinkage, or peeling • 30.16% of Damage and losses due to birds, insects and natural causes • Combined Total Damage (Damage due to birds, insects + Damage during operations) is 73.10% • Nu 26.72 million economic loss

Maize is traditionally stored in open sheds on the farm. An article published in 2021 suggest that these traditional methods of post-harvest storage were responsible for damaging 78%[26] of maize produce. Mandarins and apples are stored in crates and containers on the farms for a short duration. The fruits are then transported to the markets for domestic and export purposes. The transportation vehicle can be considered as a portable storage method for these fruits and contributes heavily towards storage related PHL as they are unable to maintain the crops at their optimum conditions.

[26] Wangmo, 2021

Food Corporation of Bhutan Ltd. (FCBL) provides centralized storage in Bhutan. Unfortunately, the warehouse network consists of low volume storage facilities and is grossly inadequate for domestic crop storage. FCBL has 47 warehouses and transit stores across 20 districts of Bhutan with total storage capacity of 19,000 MT including 4 commercial warehouses with a capacity of 2200 MT[27]. FCBL also plans to complete the construction of 3 cold storage warehouses by August 2021.

Crop loss and damage have a heavy economic impact on the farmers and overall value chain. The small-scale studies identified that the crop value chains in Bhutan are complex and therefore correctly quantifying losses at each stage may not be accurate. It was evident that the losses occur mostly due to lack of knowledge and awareness, unavailability of technology and poor infrastructure and equipment.

2.2.4 India

Agriculture is the main source of income for 58% of the population and contributes about 16% towards the total GDP[28]. In 2019-2020, India's food grain production was 296 MMT[28]. The most substantial crop production details of the country are outlined below in Table 9.

Table 9 - India's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	324,300,640
	Pulses	19,791,250
Horticulture	Fruit	94,556,000
	Vegetable	188,927,690
Commercial Plants	Oil Seeds	31,518,350
	Other	433,147,220
Total Production		1,092,241,150

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

India lost INR 926 bn (USD 14.33 bn)[29] due to post-harvest losses in 2018, averaging a daily loss of USD 19.4 million due to rejection of produce at the farm gates and delays in distribution. Post harvesting process in India can be divided into four categories as shown in Figure 10, and each contribute towards the compounding inefficiencies which result in crop loss and food wastage.

Figure 10 – Drivers of Post-Harvest Losses in India

Harvesting	• Improper care during harvesting • Lack of primary processing post harvesting leads to reduced shelf life

[27] Bhutan Storage Assessment, 2019
[28] IBEF, 2021
[29] Intellecap, 2018

Storage	• Poor crop protection and storage facilities leads to crop spoilage • Lack of cold storage facilities and pack houses leads to waste • Rough handling of produce • Poor methods of cleaning, drying and storage
Processing	• Only 2% of produced food is processed • Inadequate food processing capabilities near farms
Transportation	• Farmers unable to receive optimal price for produce • Lack of market information available to farmers • Poor road connectivity, quality and network • Poor transportation capabilities

Post-harvest losses affect small and marginal farmers the most. Poor and inefficient storage techniques forces farmers to sell their produce at low prices post-harvest. Moreover, quality and quantity losses due to poor storage facilities contributes towards seasonal food shortages and low farmer income. Food Corporation of India (FCI) estimates the food loss and wastage to be about 15%. Improper storage and inadequate food protection invite decay, pests, diseases and leads to losses. Table 10 below outlines the loss percentages for each stage of the post-harvest value chain for India's main crops.

Table 10 – PHL range in % for Main Crops Categories in India[30,31]

Crop Category	PHL Loss %[30]	PHL Loss % at Each Stage[31]
Cereal	3.9-6%	Harvesting 1.15% – 2.08%
		Threshing 1.20% - 2.15%
		Storage 0.75% - 1.21%
		Transport 0.09% - 0.15%
Pulses	4.3-6.1%	Harvesting 1.18 – 2.00%
		Threshing 1.54% - 1.19%
		Storage 1.18% - 1.67%
		Transport 0.14% - 0.35%
Fruits	5.8-18.1%	Harvesting 0.98% – 5.33%
		Sorting 1.46% - 4.95%
		Storage 1.31% - 3.98%
		Transport 0.42% - 1.91%
Vegetables	6.9-13%	Harvesting 0.99% – 3.16%
		Sorting 0.04% - 0.52%
		Storage 0.78% - 3.03%
		Transport 0.61% - 1.75%
Oil Seeds	2.8-10.1%	Harvesting 0.9% – 5.45%
		Threshing 0.49% - 1.78%
		Storage 0.22% - 1.61%

[30] Bahri, 2019
[31] ICAR, 2016

Crop Category	PHL Loss %[30]	PHL Loss % at Each Stage[31]
		Transport 0.07% - 0.14%

Table 10 outlines the loss percentages for each stage of the post-harvest value chain for India's main crops where losses from storage for each crop range from 0.22% to 4%. This amounts to roughly 2.5 – 43 MMT of food loss due to inefficient storage methods for different crops. A large share of the crops produced are retained for personal consumption and are stored in traditional and warehouse storage facilities at the farm-level. The remaining marketable crops are stored at trader levels or central storage pools operated by the Food Corporation of India or State Warehouse Corporate (SWC).

FCI is responsible for the procurement of crops, movement of crops to deficit areas, national distribution, and maintenance of excess capacity. FCI utilizes the help of Central Warehouse Corporation (CWC), State Warehouse Corporation (SWC) and other private entities for storage of food grains. The total food storage capacity of FCI – CWC's and SWC's - is 81,796,000 MT[32] as of 2021, with an average utilization percentage of 85%. The managed storage methods used are outlined in Table 11.

Table 11 - Storage Methods for Cereals in India[32,33]

Storage Type	Description	Capacity[32,33]
Covered Storage	Grains stored in Jute bags and piled into warehouses	5000 MT to 50,000 MT each, 74,000,000 MT total
Cover and Plinth Method	Food grains are stored in the open and protected using polythene covers	5000 MT each, 12,200,000 MT total
Cold Storage	Cold storage facilities for perishable horticulture crops	37,500,000 MT[33]
Silos	Metal tower structures for grain storage	50,000 MT each
Silo bag technique	Hermetic type storage made from plastic bags and are weatherproof	200 MT each

Vast amount of food loss occurs due to inadequate storage, and this directly affects the farmers across India. Many farmers lack necessary food storage facilities at the farm-level, leading to damage of crops by pests, rodents and insects. At the central level, India's storage capacity is grossly inadequate for the current production levels. Further, the existing storage infrastructure is poorly maintained and lacks necessary conditions to keep grains free from moisture and varying temperatures. Improved storage methods can help farmers supply crop produce at a profitable price when there is a demand and protect the produce when demand is low.

32 FCI Storage & Contract, 2021
33 Press Information Bureau Delhi, 2020

2.2.5 Maldives

Agriculture is the third most important sector after tourism and fisheries in Maldives. Tourism accounts for 28% of the total GDP[34] and revenues from this sector play a significant role towards livelihood, employment and the food import bill. Agriculture contributes towards less than 5% to the total GDP and accounts for a meagre 8%[35] of livelihood for the population of Maldives. Agriculture is lagging due to a series of challenges such as limited land for cultivation, unavailability of technology to enhance and improve production and difficult market access. 95% of the food consumed in Maldives is imported, making the country extremely vulnerable to changes in the global food supply.

Agriculture is predominantly focused on horticulture crops such as watermelon, papayas, bananas, mango, mangosteen, chilies etc.; the country does not cultivate cereals or pulses. The most substantial crop production details of the country are outlined below in Table 12.

Table 12 - Maldives Top Crop Production[7]

Crop Type	Category	Value (MT)
Horticulture	Fruit	3,528
	Vegetable	64
Plantation Crops (Coconut)	Other	272
Total Production		3,864

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

A major constraint for the sector is transportation of goods along the agricultural value chain. Post-harvest losses in Maldives can be attributed to untimely transportation to relevant markets and suboptimal storage infrastructure, though there is not enough data available to amount the losses. Maldives imports all staple crops such as rice, wheat, flour, fruits, and vegetables. Food imports are maintained in 3 main warehouses and 10 smaller warehouses; however, this is not adequate as a national food reserve. Maldives has insufficient data for research to quantify the post-harvest losses for their main horticulture crops.

2.2.6 Nepal

The agriculture sector accounts for 64%[36] of the livelihood for the population of Nepal and contributes towards 34% of the total GDP. Approximately 30% of the land is used towards agricultural activities. The nation's major crops are – rice, maize, wheat and barley. The cash crops are – oilseeds, tobacco,

[34] World Resources Institute - Maldives
[35] Employment in agriculture (% of total employment) (modeled ILO estimate) | Data, 2021
[36] Employment in agriculture (% of total employment) (modeled ILO estimate) | Data, 2021

jute, and sugarcane. The most substantial crop production details of the country are outlined below in Table 13.

Table 13 - Nepal's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	10,625,158
	Pulses	350,420
Horticulture	Fruit	1,417,398
	Vegetable	7,794,551
Commercial Plants	Oil Seeds	313,798
	Other	3,617,255
Total Production		24,118,580

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

Compared to other SAARC Member States, Nepal has a competitive advantage in the agricultural sector due to its varied geography, abundant water resources and ample labor. Despite that, the nation faces low agricultural productivity rate due to fragmented farming, poor technical knowledge, unpredictable weather, lack of market opportunities and biological issues. This low productivity has led to depressed rural economies, increase in urban migration and widespread hunger. Nepal's agricultural imports from India have increased at a rate of 40%[37] annually over the past 7 years. The main drivers of post-harvest losses are detailed in Figure 11.

Figure 11 - Drivers of Post-Harvest Losses in Nepal

Harvesting	• Manual harvesting • Improper care during harvesting
Threshing	• Inefficient means of threshing (manual) • Lack of power operated threshers • Delayed threshing (delay causes pest infestation)
Transportation	• Grains transferred in sacks on peoples back, bullock cart or mules • Loss due to grains spilling over during transportation
Drying	• Sun drying is the only option • Highly dependent on weather • Grains dried in the open field, unprotected from natural elements
Storage	• Traditional methods of storage used • Prone to pest infestations • Vary with local customs and climate

[37] Agriculture - Federation of Nepalese Chambers of Commerce and Industry [FNCCI], 2021

PHL losses for fruits range from 20-35% and 15-30%[38] for vegetables. Table 14 details the PHL losses at each stage for Nepal's main crops.

Table 14 - Cereal Post Harvesting Losses in Nepal[39]

Crop	Post-Harvest Stage	Loss in %[39]	Loss in Tonnes
Rice	Harvesting	1.6	90,508
	Transporting	1.2	65,263
	Threshing	1.2	69,377
	Drying	1.5	85,646
	Storage	6.2	348,943
	Total Loss	11.8	659,737
Wheat	Harvesting	1.5	30,486
	Transporting	4.1	81,497
	Threshing	1.9	37,172
	Drying	1.1	22,463
	Storage	10.2	204,578
	Total Loss	18.8	376,196
Maize	Harvesting	0.4	11,586
	Transporting	0.2	5,306
	Threshing	0.5	14,328
	Drying	0.9	22,641
	Storage	7.6	201,646
	Total Loss	9.6	255,507

Storage contributes towards the largest percentage of food loss. The Food Management and Trade Company Limited (previously Nepal Food Corporation), a government entity, is the primary provider for centralized and commercial public sector food storage. FMTC has 147 warehouses across Nepal with a total storage capacity of 160,000 MT[40]. The Association of Cold Storage of Nepal states that the country has 35 cold storage facilities with a capacity of approximately 105,000 MT. Table 15 below describes the types of storage used for the major crops.

Table 15 – Storage Methods for Cereals in Nepal[40,41]

Storage Type	Description	Capacity
Warehouse	Commercial Food Storage	100 MT – 40,000MT[40]
Cold Storage	35 cold storage facilities	3000 MT each, 105,000 MT[41] total

[38] Bhattarai, 2018
[39] Shrestha, n.d [What is n.d, Correct this reference and provide all required information]
[40] Nepal Storage Assessment, 2019
[41] Federation of Nepalese Chambers of Commerce and Industry (FNCCI), n.d.

Village Level Storage	• Bamboo Structure (Beri) • Wooden Structure (Kath-ko-Bhakari) • Outdoor Structures (Thangro) • Mud Bin (Dehari) • Earthen Structure (Ghyampo)	Variable

Nepal has an array of low volume storage options. Village level storage vary by size and capacity, depending on the socioeconomic status of the farmers and ecological situation. Storage related post-harvest losses are high because of rodents and pests. The existing traditional storage method are inefficient in providing safety to the crops against rodents, birds, insects and mold. The current centralized food storage network has insufficient capacity to meet the production yield.

2.2.7 Pakistan

Agriculture is the largest sector of Pakistan's economy, contributing towards 24% of the total GDP[42]. 39% of the population is involved in the agricultural business. Major crops include wheat, cotton, rice, sugarcane, fruits, and vegetables. Pakistan is a major rice exporter, suppling about 10% of the global rice requirement. Wheat is also considered to be an important crop in Pakistan and is grown by over 80%[43] of the farmers. In 2019, Pakistan produced 24 MMT of wheat, which accounts for 50% of the total cereal production. Wheat plays a vital role in the nation's economy and thus any losses from deterioration of wheat quality due to inadequate handling and storage would bear heavy financial consequences. The most substantial crop production details of the country are outlined below in Table 16.

Table 16 - Pakistan's Top Crop Production7

Crop Type	Category	Value (MT)
Food Grain	Cereal	43,260,318
	Pulses	591,691
Horticulture	Fruit	5,538,213
	Vegetable	10,554,084
Commercial Plants	Oil Seeds	635,119
	Other	71,629,489
Total Production		132,208,914

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

[42] Agriculture Statistics | Pakistan Bureau of Statistics, 2021
[43] USDA Foreign Agricultural Service - Grain and Feed Annual, 2020

Studies have quantified that Pakistan loses about USD 1 billion due to post-harvest losses every year[44]. These losses are predominantly due to mishandling of perishable goods, poor transportation, inadequate storage facilities and poor market infrastructure. Pakistan's PHL value is estimated to be nearly USD 343 million[45] per annum for their major crops – wheat, paddy, and maize. This is due to poor drying methods and inadequate storage. The PHL losses for horticulture crops range vary between 35-40%[46], of which 10%[47] can be attributed to poor storage conditions. While there are plenty of qualitative reasons for losses along the crop value chain, there are no recent studies or publications that have quantified the losses at each stage. The drivers of PHL in Pakistan are detailed in

Figure 12.

Figure 12 – Drivers for PHL in Pakistan

Harvesting	• Manual harvesting • Delayed harvesting • Mechanical harvesting yields high immature grains
Threshing	• Inefficient means of threshing (manual) • Lack of power operated threshers • Poor maintenance of mechanical threshers
Transportation	• Grains transferred in low quality sacks, prone to tears • Loss is due to grains spilling from too much handling • Sacks are heavy to carry
Drying	• Sun drying is the only option • Highly dependent on weather • Grains dried in the open, unprotected
Storage	• Traditional methods of storage used on farms for 60-75% of crop • Poor Infrastructure of government storage facilities • Temporarily stored in rail carriages or open piles

There is little information available from secondary sources regarding storage and warehousing in Pakistan. Known storage methods in Pakistan include farm level storage and storage beyond the farm gate. Farm level storage equates to traditional methods of storage which include mud bins, plastic and jute bags or even compact crop heaps within the farm compound. Grain storage beyond the farm gate is taken care of by the public sector, Pakistan Agricultural Storage and Services Corporation Ltd (PASSCO), Ministry of National Food Security & Research and other provincial departments. Public sector storage includes storage of grain in jute bags in godowns, open air storage, concrete or metal silos. Pakistan has 5 government agencies for wheat procurement and management of which PASSO is the largest and maintains wheat stocks on behalf of the federal government. Other public sector storage entities include Punjab, Sindh, Khyber Pakhtunkwa and Balochistan Food Departments

[44] Ahmed, 2019
[45] United States Agency for International Development (USAID), 2020
[46] Abbas, 2018
[47] Ahmed, 2021

Cold storage in Pakistan consists of godown style facilities which use industrial style refrigeration equipment with ammonia compressors. The cold storage facilities in Pakistan are stand-alone operations in major cities. The various storage methods are detailed in Table 17 below.

Table 17 - Storage Methods for Cereals in Pakistan[48,49]

Storage Type[48]	Description	Capacity[49]
Godowns (PASSCO Warehouses)	304 Horizontal or flat-shed storage facility	1500 – 50,000 MT, total ~3,000,000 MT
Cold Storage	Low volume, independent cold storerooms	Quantifiable data not readily available
Open Air Ganji	Open storage with tarp cover	Variable
Silos (PASSCO)	28 Concrete and Metal Structures	5000 – 50,000 MT
Binishells	Reinforced concrete Dome Shaped Structures	1,500 MT
Village Level Storage	Gunny bags, earthen and metallic bins and pots of various sizes, pallies, kharas, bakharies	Variable

The losses for different types of storage methods range from 0.1% to 10%[48], depending on the size, quantity and storage period of the wheat. Losses from covered storage is estimated to be an average of 2.5%, however it can be as high as 15% due to insect infestations from prolonged storage duration. Losses from open air storage range from 3-8% depending on how many months the bags are stored outside. IFC estimates that Pakistan loses PKR 3900/tonne[48] of economic losses due to wheat quality deterioration annually.

The Government of Pakistan has laws that prevent most private entities from procuring and storing large quantities of wheat. The government bears all costs of procurement, storage and sale of wheat by using commercial loans and this has contributed towards significant losses to the economy. Financing efficient storage infrastructure for wheat is expensive, however, not having proper storage facilities costs the country nearly USD 343 million per annum in post-harvest losses.

2.2.8 Sri Lanka

Agriculture is an important sector for Sri Lanka, contributing towards 7% of the total GDP. This sector also provides employment to over 25% of the population[50]. Agriculture has been an important driver for alleviating poverty in the country. Poverty reduction was motivated by increase in agricultural

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[48] Food and Agriculture Organization of the United Nations (FAO), 2013
[49] Khushk et al., 2017
[50] Sri Lanka - Agricultural Sector, 2019

wages between 2006-2013. While this was a helpful motive, sustained efforts would need to be maintained in improving agricultural productivity. Improved technology, better post-harvest management and organized value chain would drive productivity.

Rice is the major crop and rice cultivation occupies approximately 35% of the total cultivated area. Rice cultivation is done by small scale farmers. The country also produces cash crops such as tea, rubber, coconut and high value fruits and vegetables – these crops are the basis for the high foreign exchange earnings. The most substantial crop production details of the country are outlined below Table 18.

Table 18 - Sri Lanka's Top Crop Production[7]

Crop Type	Category	Value (MT)
Food Grain	Cereal	4,837,907
Horticulture	Fruit	707,250
	Vegetable	963,655
Commercial Plants	Oil Seeds	35,355
	Other	3,964,935
Total Production		10,509,102

Source: Food and Agriculture Organization of the United Nations Crop Statistics (Official Data), 2019

A recent article stated that post-harvest losses in fruits and vegetables are estimated to be 30-40% and roughly 270,000 MT annually, which amounts to Rs. 20 billion (~USD 100 million)[51]. Rice, the staple of Sri Lanka, also faces post-harvest losses. The crop is predominantly cultivated by small to medium size farmers. Fragmented and small-scale studies have identified that post-harvest losses of paddy are about 15% of total production. Out of this, 24%[52] can be attributed to threshing and cleaning. 4-6% can be contributed to improper Paddy storage at the farm-level. Paddy is stored on the farms level invites rodent & pest infestations. Paddy is generally stored using unscientific methods until sold to 'Collectors' or to government and/or private paddy millers. Storage methods for rice are detailed in Table 19.

Table 19 – Storage Methods for Paddy in Sri Lanka[53,54]

Storage Type	Description	Capacity
Warehouses	323 paddy warehouses	323,700 MT[53]
Cold Storage	1 facility with 7 cold rooms	1000 MT[54]
Village Type Storage	• Jute & gunny bags • Temporary huts	Variable

[51] Daily FT, 2021
[52] Prasanna et al., 2011
[53] Gunaratna, 2021
[54] Sri Lanka Storage Assessment, n.d

	• Rooms inside/outside the house	

Paddy is also stored in central warehouses maintained by the Paddy Marketing Board (PMB). The total paddy capacity maintained by PMB cannot accommodate the quantity of crop produced annually. The PMB carries out purchase, sales and supply of grain products and maintains distribution activities to ensure food security. As of 2020, 52%[55] of the farmers in Sri Lanka felt incentivized to use the Government Paddy Purchasing Program (GPPP) while the remaining farmers sold their crops to private sector paddy purchasing schemes. The PMB does have restrictions and conditions such as maintaining a certain level of moisture and having a purchasing limit of 2500 kg/farmer[55]. There are many farmers that lack safe storage facilities to dry their paddy and thus finds it arduous to meet the PMB's 14% moisture content requirement. Inaccessibility to safe storage forces farmers to either sell 'wet paddy' to private buyers or store their paddy at the farm-level and face high PHL and in turn receive an unfavorable rate from the GPPP.

Storage related losses in Sri Lanka can be attributed to unscientific farm-level storage and disparities between paddy channel choice for farmers.

2.3 Chapter Conclusion

This chapter has studied the agricultural value chain for the main crops for each SAARC Member State and identified storage as the key problem area. The common issues across all 8 countries are the low-quality existing storage infrastructure, improper and scarce facilities, poor market access and lack of proper storage knowledge. Poor storage infrastructure is not a stand-alone issue – it could be propagated by lack of other basic facilities. Access to clean, reliable and affordable energy is the major proponent for proper storage. Food storage is largely required at the farm-level so that farmers can store and market the crops during lean seasons. Clean and reliable food storage solutions could help farmers preserve their produce at the source for relatively longer period and prevent avoidable post-harvest loss. Horticulture crops require cold storage facilities to maintain good quality produce and, cereal and pulses require modern temperature and moisture-controlled facilities.

Two classes of storage have been prominent – traditional storage at the farm-level and centralized storage at a national level. Traditional methods of storage are experience based and unscientific, these low volume storage options cannot protect crops from natural elements. Central level storage is limited to large urban areas and the facilities are outdated and insufficient in volume.

The losses can be mainly attributed to:

- Improperly managed storage facilities

[55] Wijesooriya, 2020

- Inadequate central storage capacity
- Lack of awareness of the extent of storage related losses
- Poor storage infrastructure
- Insects, rodents, moisture

Table 20 summarizes the total post-harvest losses and storage losses for each SAARC Member State.

Table 20 – Summary Table of Total PHL and Storage Losses for each SAARC Member State

Country	Crop Category	Total Post Harvest Losses %	Total Post-Harvest Loss due to Storage %
Afghanistan	Fruits	10-40	~3 to 20
Bangladesh	Cereals	3 – 11	~3 – 5
Bhutan	Cereals & Fruits	9 -43	4-25
India	All	23 – 54	4 – 12
Nepal	Cereals	9 – 12	6 – 11
Maldives	-	-	-
Pakistan	Cereal	-	0.1 – 10
	Horticulture Crops	35-40	10
Sri Lanka	Cereal	15	4 - 6

* Where blank, specific data is unavailable

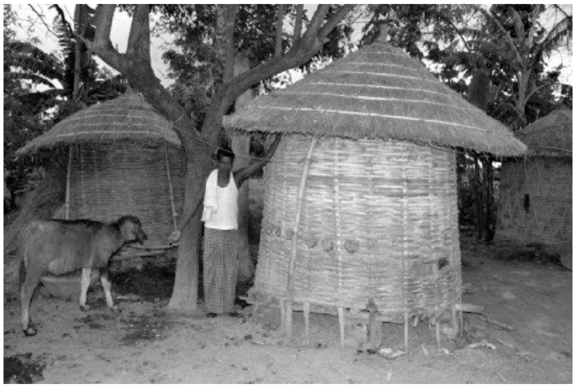
It can be quantitatively derived that post-harvest loss due to storage is a major issue for SAARC Member States as it directly influences pressing issues such as food security, sustainable livelihood, and food wastage. Storage loss can be avoided to a certain extent with proper education, access to technology, changes to policy and institutional and government aid. The images below, in Table 21, show some of the storage techniques discussed in the section above.

Table 21 - Images of Select Storage Options across the SAARC Member States

	Kangina, Afghanistan Source: www.fooddnk.com Accessed: December 2, 2021

	Kabul Silo, Afghanistan Source: https://benbruges.medium.com/ Accessed: December 2, 2021
	Left to Right – Dole, Plastic Bag, Motka Bangladesh Source: https://en.banglapedia.org/index.php/Grain_Storage Accessed: December 2, 2021
	Silo, Bangladesh Source: https://www.world-grain.com/ Accessed: December 2, 2021
	Cover & Plinth Storage Method, India Source: https://www.indiamart.com/ Accessed: December 2, 2021

	**Silo Bag Technique, India** Source: https://www.forbesindia.com/blog/enterprise/in-madhya-pradesh-a-different-kind-of-cloud-storage/ Accessed: December 2, 2021
	**Godown, India** Source: https://economictimes.indiatimes.com/industry/cons-products/food/sufficient-food-grain-in-godowns-fci/articleshow/82150388.cms Accessed: December 2, 2021
	**Cold Storage Facility, India** Source: *www.sinsoonvegetable.com* Accessed: December 2, 2021

	Beri (Bamboo Structure), Nepal Source: Integrated Pest Management by Uma Shankar Accessed: December 2, 2021
	Wheat Silo, Pakistan Source: https://agriplan.nl/6843/ Accessed: December 6, 2021
	Paddy Storage Silo, Sri Lanka Source: https://siloscordoba.com/ Accessed: December 6, 2021

	Vee Bissa (Traditional Paddy Storage), Sri Lanka Source: https://www.dilmahconservation.org/ Accessed: December 6, 2021

Chapter 3: Energy Use in Food Storage and Related Activities

3 Chapter 3: Energy Use in Food Storage and Related Activities

Chapter 2 identified storage related issues as the foremost post-harvest problem for all SAARC Member States. This chapter focusses on the energy landscape of each country and energy usage for centralized storage systems. It will also investigate the energy input required to manage storage and identify the energy required for each type of food storage and related activities in each of SAARC Member States.

3.1 Energy and Agriculture

A wide range of agricultural activities uses energy as an important input towards effective production and efficient storage. This sector uses energy directly from fuel or electricity to operate machinery and equipment, temperature control buildings and for lighting the farm area. Energy is also used for manufacturing pesticides and fertilizers. Agricultural activities require 3 broad sources of power for operations as shown in Figure 13.

Figure 13 - Three sources of power for Agriculture

This chapter will focus on the Machinery Efforts such as fuel-based technologies and electricity applications for post-harvest operations. Agriculture is considered an energy intensive sector; however, accessibility and affordability of energy are major issues for farmers. Energy consumption can be bifurcated into energy consumption from electricity and thermal (combustion of fuel). Thermal power such as petrol and diesel are predominantly consumed by the agricultural sector. This consumption has been increasing over the years and can be attributed towards the transportation of goods to and from markets as can be seen in

Table 22.

Table 22 below shows the energy used towards agricultural activities. Fuel based technologies are used towards machinery for water pumping, harvesting, drying, threshing, tractors and transportation. Electricity is utilized for lighting, heating and cooling of homes and possibly towards storage facilities.

These operations require fuels such as: i) Coal, ii) Natural Gas, iii) Gas/Diesel Oil, iv) Gasoline, v) Liquefied Petroleum Gas (LPG), vi) Fuel Oil; and vii) electricity. Energy availability and price volatility can influence choice of crop harvested, cultivation methods, irrigation and post-harvest strategies such as storage options.

Table 22 - Energy Used in Agriculture (Terajoules)[56]

Country	2016	2017	2018	2019
Afghanistan	2,778	2,130	2,152	1,964
Bangladesh	45,294	49,982	51,665	51,973
Bhutan	208	215	238	244
India	857,412	865,091	863,574	843,003
Maldives	1,174	1,125	1,275	1,332
Nepal	10,186	11,813	12,808	13,872
Pakistan	47,849	48,557	50,550	51,984
Sri Lanka	3,836	3,636	3,722	3,701

To narrow down the study, the identified main crops from Chapter 2 will be bifurcated and categorized into horticulture crops and food grain crops. Horticulture crops should ideally be stored in cold storage facilities whereas food grains are best stored in temperature and moisture-controlled warehouse facilities. While the traditional and unscientific methods of storage do not require fuel-based energy or electricity, centralized and/or managed storage systems such as cold storage facilities and warehouses require electricity to maintain crops at optimum levels.

3.2 Country wise Energy Landscape

Energy is crucial for economic growth and plays a key role towards developing the health and welfare of a nation. This section will cover the energy landscape of SAARC Member State and assess the adequacy to meet the agricultural needs through existing infrastructure.

Afghanistan

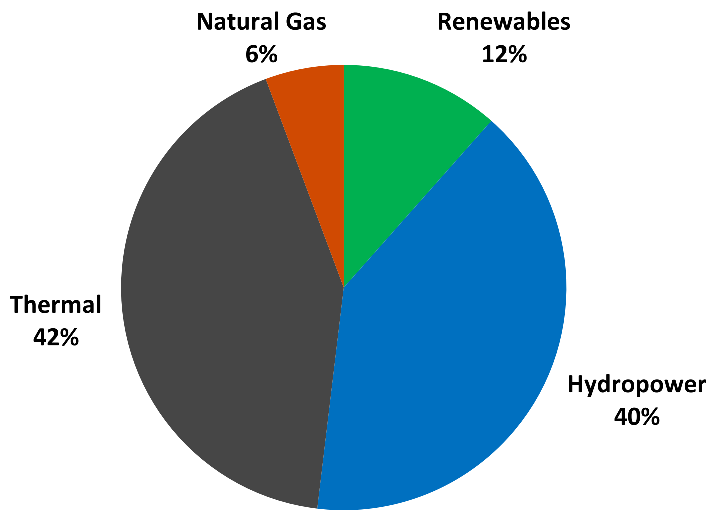
Afghanistan's energy industry is in a poor state due to continuous years of conflict and negligence. The energy infrastructure, generation, transmission and distribution of network are in poor conditions. The country has no universal access to power and relies on neighboring countries for electricity to meet the country's growing energy demands. The energy demand doubled from 1500 MW in 2010 to 3000 MW[57] in 2019, and this demand increase trend is expected to continue. Afghanistan's domestic transmission of power is very limited and unreliable. This means that residents suffer from unstable

[56] FAO Energy Usage Data, 2019
[57] Assessment of solar energy potential and development in Afghanistan, 2021

power supply and frequent power outages. Afghanistan has approximately 737 MW[57]of installed capacity as of 2021.

Figure 14 below details the energy mix of the country.

Figure 14 –Afghanistan's Energy Mix



Source: E3S Web of Conferences 239, 00012 (2021)

In Afghanistan, 98%[58] of the urban population have access to grid-based electricity and only roughly 13% of rural households have access to the grid. Energy use towards agricultural activities has been limited and decreasing. The reliance of electrical energy from imports increases the electricity tariffs which in turn causes financial burdens on the Afghan society. Electricity is an unviable resource for rural farmers.

Bangladesh

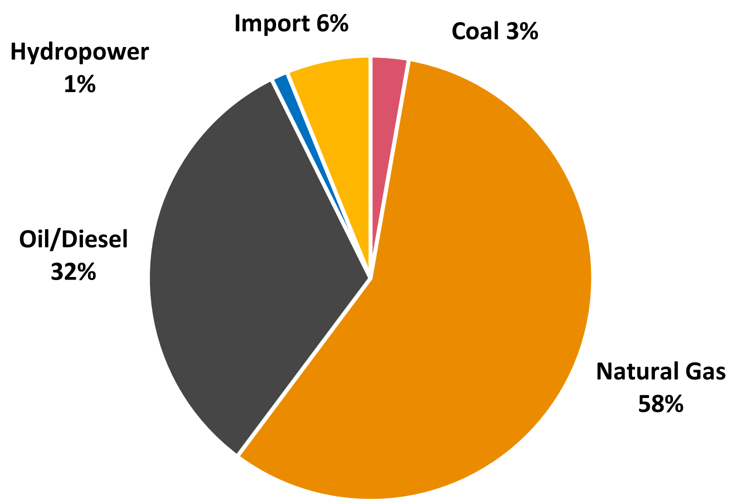
Bangladesh has been experiencing a rapidly increasing demand for energy and power sector has been unable to meet system demands for over a decade. The gap between energy supply and consumption stands at 26%[59]. The country is facing an energy crisis whereby they are overly dependent on natural gas to fuel majority of their energy needs. US based companies supply over 50%[60] of Bangladesh's domestic natural gas production and are dominant investors for their power plants. The State-owned utility companies are suffering financially because they have failed to attract private investors due to poor pricing models – this has further expanded the energy crisis. Despite grid expansions, the existing substandard grid infrastructure leads to unreliable power supply and frequent power cuts.

[58] IRENA Statistics, 2019
[59] Energy Profile Bangladesh, 2019
[60] Bangladesh - Power and Energy, 2021

Approximately 97 million people don't have access to electricity or to a nearby electrified city and only 10-15%[61] of the rural population have partial access to electricity which barely meets basic usage requirements.

The country is in process of installing new liquified natural gas (LNG) and coal-based power plants to meet its growing demand. Bangladesh has an installed capacity of 21,617 MW[60] as of 2019. Figure 15 below details the energy mix of the country.

Figure 15 – Bangladesh's Energy Mix



Source: Energypedia – Bangladesh Energy Situation, 2019

Agricultural activities account for only 5%[60] of the total energy demand, however this number has been rapidly increasing. This is a positive sign as increase in demand of energy in agricultural sector leads towards increased productivity.

Bhutan

Despite being one of the smallest countries in South Asia, Bhutan has one of the fastest growing economies in the world. This economic growth has been accompanied by raised standards of living and increase in levels of energy consumption. Bhutan's power generation is completely reliant on hydropower plants. This overdependence renders the country vulnerable to climate change and weather impacts which has the potential to negatively impact the country's energy security. Furthermore, weather and climate change are serious environmental threats and can have huge impacts on agricultural productivity on a country already challenged with limited cultivable land due

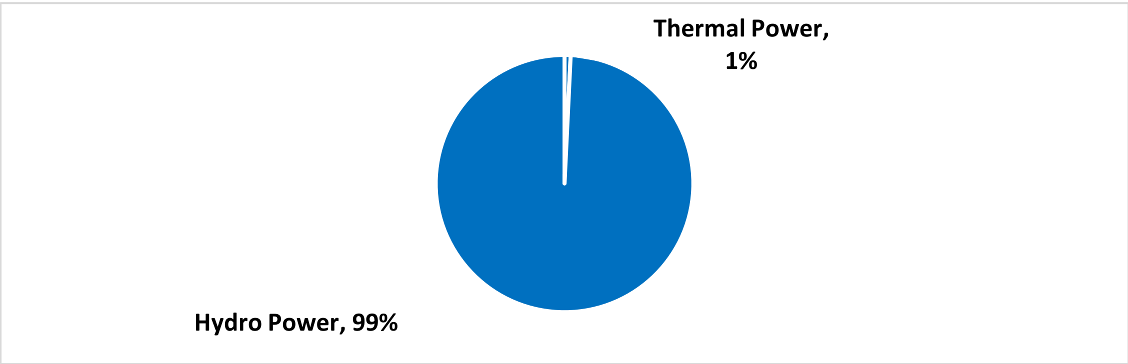
[61] Taheruzzaman, M, 2016

to geographical and topographical variations. Bhutan is working towards diversifying the renewable energy mix to reduce dependency on a single technology.

During monsoons, the country has the capacity to export surplus energy to India. However, during winter, Bhutan imports fossil fuel energy as hydropower capacity drops by over 75%[62] due to low flow in the rivers. As of 2019, Bhutan's total installed capacity was 2353 MW[62], of which 2335 MW (99%) is from Hydropower.

Figure 16 below details the energy mix of the country.

Figure 16 – Bhutan's Energy Mix



Source: International Hydropower Association (IHA) – Bhutan 2019

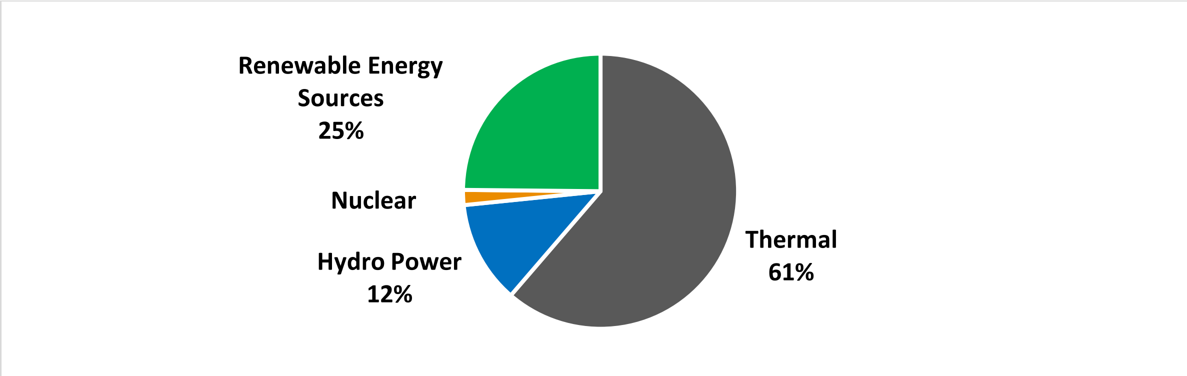
Bhutan has achieved access to electricity for 100% of its population. The use of electricity towards agricultural activities is still low at ~3%[63].

India

India's power sector is one of the most diverse in the world as its energy portfolio includes conventional sources of power generation such as coal, natural gas, hydropower and nuclear along with renewable sources of power such as wind and solar. As of 2021, India's total installed capacity is 382,820 MW[64]. Figure 17 below details the energy mix of the country.

Figure 17 – India's Energy Mix

[62] Energy Profile Bhutan, 2019
[63] IRENA RRA Kingdom of Bhutan, 2019
[64] Power Sector at a Glance ALL INDIA, 2021



Source: Government of India Ministry of Power, 2021

In India, 97% of the population have access to electricity and is connected to the grid while less than 1%[65] rely on off grid electricity sources. The remaining 2% of the population is unelectrified – citing inability to afford grid connection. Agriculture accounts for 20%[66] of the national energy consumption. This suggests that the farming community in the country is actively using mechanized and modern agricultural practices.

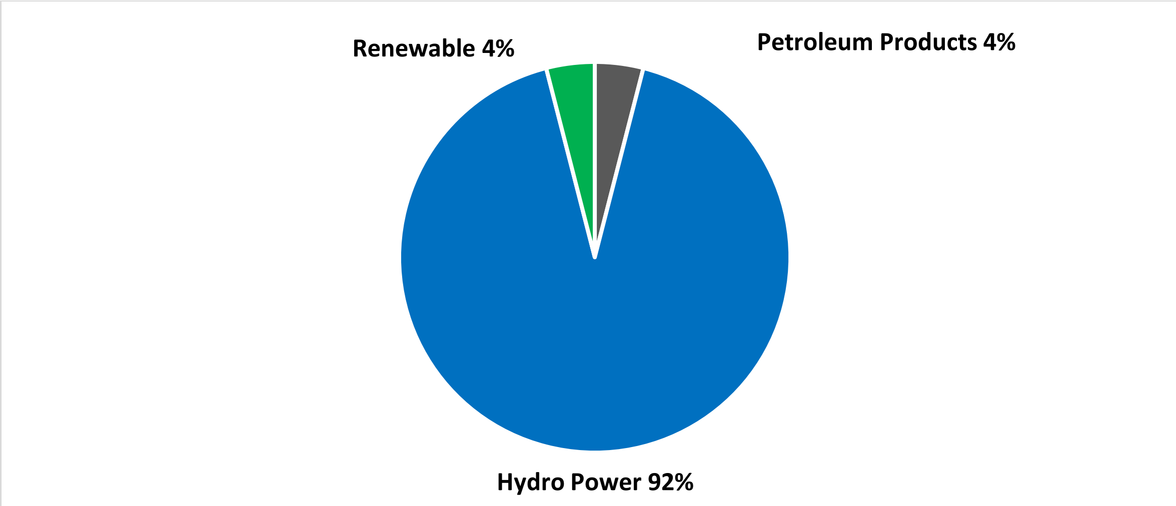
Nepal

Nepal has been facing energy crisis for over 10 years despite its energy usage per capita being the lowest among South Asian countries. A predominant factor is the geographical spread of the country and its population. Over 80%[36] of the population of Nepal lives in the rural areas with agriculture as the mainstay. Having no fossil fuel reserves, biomass is the primary source of fuel in Nepal for much of the rural community. Biomass fuel consists of wood, agricultural residue and dung, and is used towards cooking and household heating purposes.

For the urban cities, electricity is generated through hydropower or is imported from neighboring countries. Nepal has a vast untapped hydropower potential; however, the incentives for private investment towards these power plants are inadequate to attract investors. 91%[67] of the population has access to electricity; however, the grid infrastructure of the country is in poor shape as the Nepal faces long and frequent power outages. Nepal has a total installed capacity of 1,290 MW of which 1,182 MW[68] is hydro power capacity as of 2019. Figure 18 below details the contribution of hydropower in the country.

Figure 18 – Nepal's Energy Mix

[65] Agarwala 2020
[66] Kumar, 2018
[67] Ritchie, 2016
[68] International Hydropower Association (IHA) – Nepal 2019



Source: IRENA Energy Profile Nepal, 2019

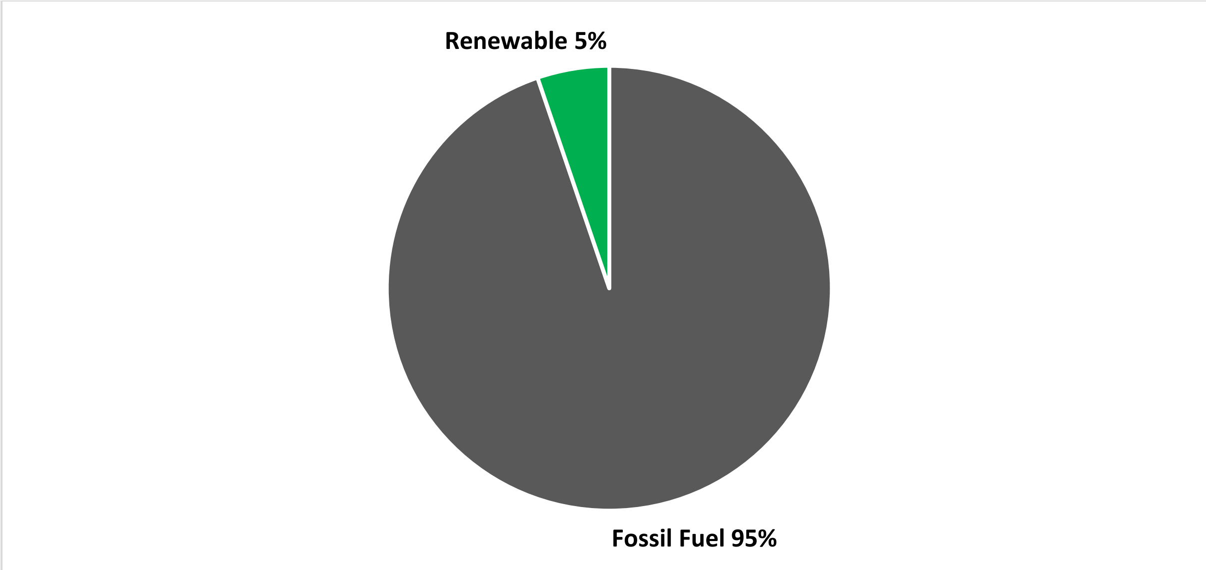
In Nepal, the agriculture sector accounts for only 1% of the total energy demand and 2%[67] of the electricity consumed.

Maldives

Maldives, like Nepal, does not have any fossil fuel reserves. The country is entirely dependent on imports like diesel, petrol, aviation fuel and LPG. In 2018, the Maldives imported 643,900 MT[69] of fuel, the expenditure to which accounted for approximately 7% of the total GDP. Due to its dispersed geographical spread, the country operates on stand-alone grid and power generation systems like generator sets. Maldives has an installed diesel generator capacity of 287 MW[70] as of 2019. Figure 19 below details the energy mix of the country.

Figure 19 – Maldives Energy Mix

[69] Revi, 2021
[70] IRENA Energy Profile Maldives, 2019



Source: IRENA Energy Profile Maldives, 2019

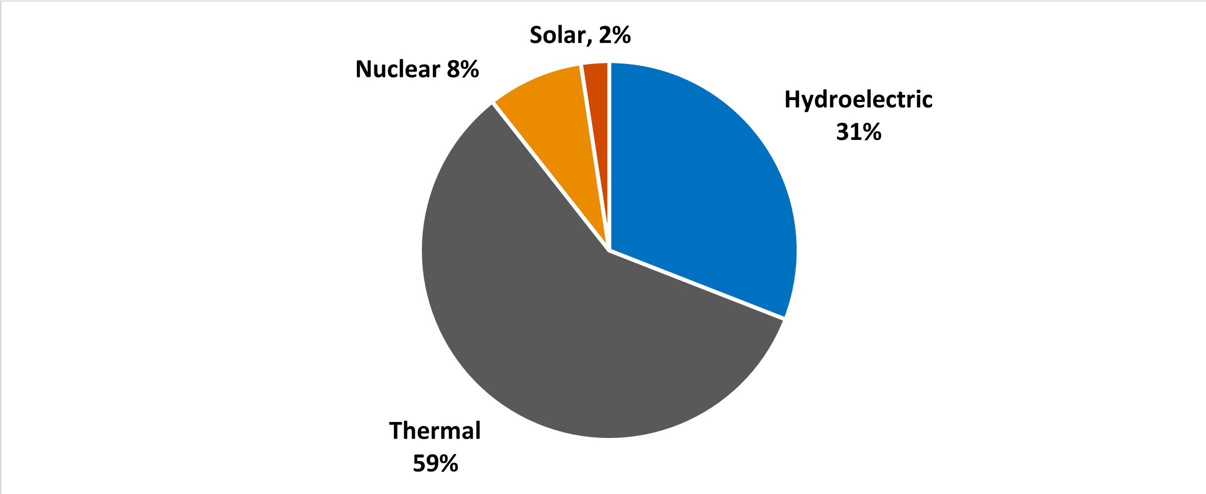
The greater Male region has rooftop solar panel installations. Maldives is rich in natural resources like solar, wind, ocean energy which could help lead the country away from its overdependency on imported fossil fuels. There is no available data to quantify the energy used by the agricultural sector in the Maldives. Most of the energy is used to power the storage of food that is imported.

Pakistan

The dominant sources of fuel in Pakistan are oil and natural gas, followed by hydropower. The country's reliance on imported and local fossil fuels has been decreasing over the years, primarily due to depletion of natural gas reserves and the introduction of LNG. The country currently has 40 million[71] unelectrified users and has a total installed capacity of 35,792 MW as of 2020[72]. Figure 20 below details the range of energy sources of the country.

Figure 20 – Pakistan's Energy Mix

[71] Pakistan - Countries & Regions - IEA, 2021
[72] Ministry of Finance | Government of Pakistan, 2021



Source: Ministry of Finance | Government of Pakistan, 2021

The agriculture sector consumes about 10%[72] of the total energy consumption.

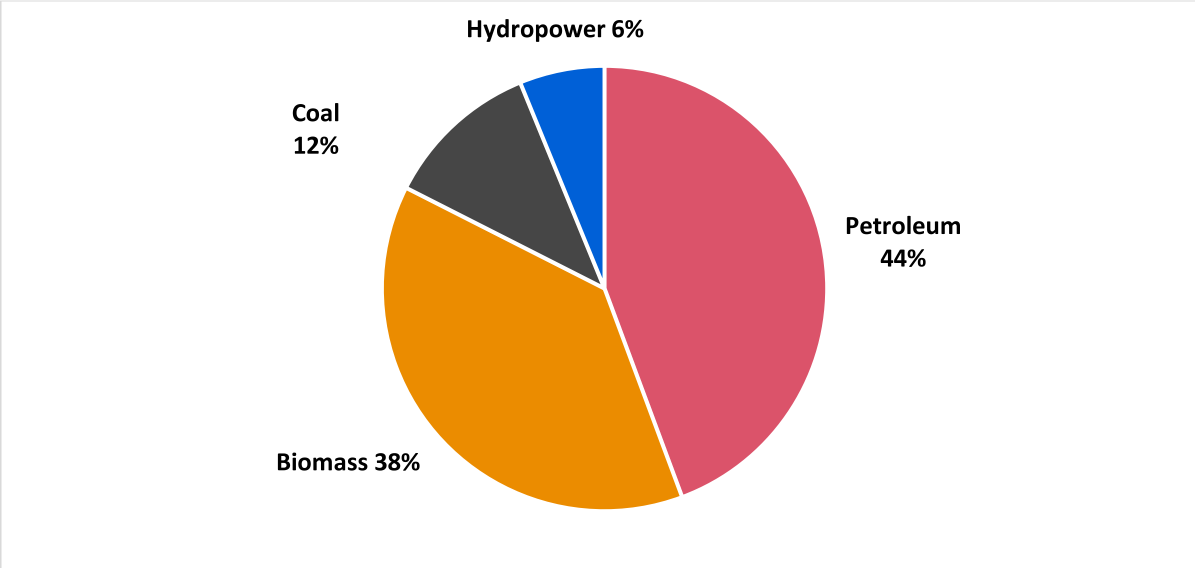
Sri Lanka

Sri Lanka has moved from 100% hydropower regime in 1995[73] to incorporate other reliable sources of energy. Coal and petroleum are imported to Sri Lanka – these fuels are used to supplement power generation during peak demand periods and when hydropower generation drops. Biomass is an important fuel source for household and commercial sectors as its used for heating and cooking. Sri Lanka reports access to electricity for 100% of the population.

Sri Lanka experienced numerous electricity blackouts in the last 3 years. This was caused by unpredictable weather patterns having a direct effect on the water availability to the nations hydro plant fleet. Sri Lanka's existing capacity is extremely susceptible to adverse climate change patterns and is insufficient to meet the current energy demands. Sri Lanka has an installed capacity of 4233 MW[73] as of 2019. Figure 21 below details the range of energy sources of the country.

Figure 21 - Sri Lanka's Energy Mix

[73] IRENA Energy Profile Sri Lanka, 2019



Source: IRENA Energy Profile Sri Lanka, 2019

Fuel based energy use in the agricultural sector is low as the sector is heavily reliant on labor intensive endowments.

3.3 Energy and food Storage

Large share of crops are stored at the farm-level and farmers use traditional and unscientific methods of storage. The marketable crops are stored in centrally managed warehouses. There are significant gaps between the total crop production quantity and existing storage facilities. To minimize these gaps, additional storage facilities are required. Depending on the level of perishability, different crops require various types of storage Horticulture crops are more perishable and require energy intensive storage facilities such as Cold Storage Warehouses to maintain and prolong the shelf life of produce. Food grains are less perishable and can be stored for short, medium and long term in temperature and moisture-controlled warehouses and godowns.

Table 23 - Ideal Conditions for Crop Storage Facilities[74,75]

Crop Type	Crop Category	Ideal Storage Type	Optimum Conditions
Fruits	Horticulture	Cold Storage	Temperature Range: -1 to 5°C[74] Relative Humidity Range: 85 – 95%[74]
Vegetables	Horticulture	Cold Storage	Temperature Range: 0 to 15°C[74] Relative Humidity: 90-100%[74]
Cereals	Food Grain	Warehouse	Safe moisture content (%): 10-12%[75]
Pulses	Food Grain	Warehouse	Safe moisture content (%): 14-15%[75]

[74] Ali, S., 2008
[75] Indian Grain Storage Management and Research Institute – Moisture, 2021

Table 23 above describes the ideal storage conditions for the main crop categories. As cold storage facilities need to maintain low temperatures using refrigeration equipment such as compressors, these facilities would consume significantly more energy compared to warehouses. To quantify the minimum storage capacity required to avoid current storage related losses, the quantum of food loss has been calculated using the crop data from Chapter 2. The following parameters in Table 24 have been used and extrapolated linearly for empirical calculations in Table 25 and Table 26:

Table 24 – Parameters for Storage Capacity Energy Load Calculations

	Power Required	Components	Data Source
Cold Storage	120 kW (Connected Load)	• 5 storage chambers • Rack Type refrigeration System	Mission for Integrated Development of Horticulture (MIDH) India – Engineering Specifications for 5000 MT Cold Storage Facility
Warehouse	2.5 kW	• 20 no. of 36 W LED Lights • 36 Turbo Fans (No electricity needed) • Misc. Electrical Load	Central Warehousing Corporation India – Engineering Specifications 1000 MT Godown

Table 25 has quantified the storage losses for each SAARC Member State for Food Grains and Horticulture crops, as they encompass the largest share of crop production. It also displays the additional required cold storage and warehouse capacity along with the energy load that each State could plan to reduce crop wastage. The energy load has been calculated as follows:

Cold Storage Facility -

$$Energy\ Load\ Required\ (kW) = \left(\frac{Capacity\ to\ Avoid\ Storage\ Lost\ (MT)}{5000\ MT}\right) x\ 120\ kW$$

Warehouse Facility -

$$Energy\ Load\ Required\ (kW) = \left(\frac{Capacity\ to\ Avoid\ Storage\ Lost\ (MT)}{1000\ MT}\right) x\ 2.5\ kW$$

Table 25 - Storage Loss Quantified to Capture Minimum Additional Capacity and Energy Load

SAARC Member State	Crop Category	Storage Type	Storage Related Loss (MT)	Capacity to Avoid Storage Loss (MT)	Energy Load Required (kW)*
Afghanistan	Horticulture	Cold Storage	77,527	80,000	1,920
	Food Grain	Warehouse	978,000	980,000	2,450
Bangladesh	Horticulture	Cold Storage	8,542,605	8,550,000	205,200
	Food Grain	Warehouse	2,370,225	2,380,000	5,950
Bhutan	Horticulture	Cold Storage	10,444	11,000	264
	Food Grain	Warehouse	12,067	15,000	38
India	Horticulture	Cold Storage	9,487,838	9,490,000	227,760
	Food Grain	Warehouse	4,254,552	4,260,000	10,650
Maldives	Horticulture	Cold Storage		NA	NA
Nepal	Horticulture	Cold Storage	2,834,455	2,840,000	68,160
	Food Grain	Warehouse	755,167	760,000	1,900
Pakistan	Horticulture	Cold Storage	6,436,919	6,440,000	154,560
	Food Grain	Warehouse	2,434,898	2,440,000	6,100
Sri Lanka	Horticulture	Cold Storage	668,362	670,000	16,080
	Food Grain	Warehouse	275,523	280,000	700

*Empirical Calculations for energy load required for Cold Storage has been based on the energy load for a 5000MT cold storage facility in India and extrapolated. ** Empirical Calculations for energy load required for warehouses has been based on the energy load for lighting and fans of a typical warehouse and extrapolated.
*** Where blank, data is unavailable

Table 25 calculated the storage capacity required to avoid storage related losses based on static current data. Storage related losses will increase annually if not adequately addressed. Table 26 has calculated the additional storage capacity required for a SAARC Member State to effectively store 20% of its total crop production. An ideal storage capacity of 20% have been assumed based on discussions with government bodies, such as National Centre for Cold Chain Development India (NCCCD) and Food Corporation India (FCI), and the technical experience of industry experts and private players. Further, post-harvest, crops are sent for processing, marketed immediately (locally or exported) or even bought by large FMCG companies directly from the farmers. Building a capacity beyond this would be counterproductive as money would be utilized to build capacity which would go unused.

Looking at Table 26 below, only Bangladesh and India have been able to reach the 20% cold storage and warehouse storage capacity respectively.

Table 26 – Storage Capacity Quantified to Capture Adequate Additional Capacity and Energy Load

SAARC Member State	Crop Type	Ideal Storage Type	Existing Capacity (MT)	Total Production (MT)	Existing Storage Capacity vs. Total Production	Capacity to meet 20% storage (MT)	Energy Load (kW)
Afghanistan	Horticulture	Cold Storage	31,000	4,146,008	0.75%	798,202	19,157
	Food Grain	Warehouse	305,000	5,583,461	5.46%	811,692	2,029
Bangladesh	Horticulture	Cold Storage	6,000,000	19,593,131	30.62%	NA	NA
	Food Grain	Warehouse	2,162,234	59,558,708	3.63%	9,749,508	24,374
Bhutan	Horticulture	Cold Storage	NIL	125,510	0.00%	25,102	602
	Food Grain	Warehouse	19,000	102,507	18.54%	1,501	4
India	Horticulture	Cold Storage	37,500,000	283,483,690	13.23%	19,196,738	460,722
	Food Grain	Warehouse	81,796,000	344,091,890	23.77%	NA	NA
Maldives	Horticulture	Cold Storage		3,592	0.00%	718	17
Nepal	Horticulture	Cold Storage	105,000	9,211,949	1.14%	1,737,390	41,697
	Food Grain	Warehouse	160,000	10,975,578	1.46%	2,035,116	5,088
Pakistan	Horticulture	Cold Storage		16,092,297	0.00%	3,218,459	77,243
	Food Grain	Warehouse	2,980,000	43,852,009	6.80%	5,790,402	14,476
Sri Lanka	Horticulture	Cold Storage	1,000	1,670,905	0.06%	333,181	7,996
	Food Grain	Warehouse	323,700	4,837,907	6.69%	643,881	1,610

Each country would need to invest in additional storage capacity to work towards reducing the food wastage due to storage related crop losses. Countries like Bhutan and Maldives would need to introduce affordable commercial cold storage options into the crop value chains as these countries do not have these facilities available. There is little information available from secondary sources regarding storage and warehousing in Pakistan. Major cities in Pakistan such as Lahore, Islamabad and Karachi have numerous low volume stand-alone cold rooms – the exact number of facilities and capacities of these cold rooms is not readily available.

Creating additional storage capacity and efficiently powering each storage facility can seem challenging, especially for rural farmers who can't access or afford these resources. The next chapter will investigate how the SAARC Member States can accommodate the new storage capacities as well as the added energy load in a way which will benefit all stakeholders.

Chapter 4: Application of Renewable Energy Technologies for Food Storage

4 Chapter 4: Application of Renewable Energy Technologies for Food Storage

This chapter will introduce the distinctions of renewable power technologies along with their economic and environmental benefits. The existing RE policies, financial institutions, and incentives that each SAARC Member State has implemented to encourage RE based solutions, specifically in the Agricultural sector will also be explored. Further, viable centralized and decentralized RE solutions will be investigated in detail.

4.1 Introduction

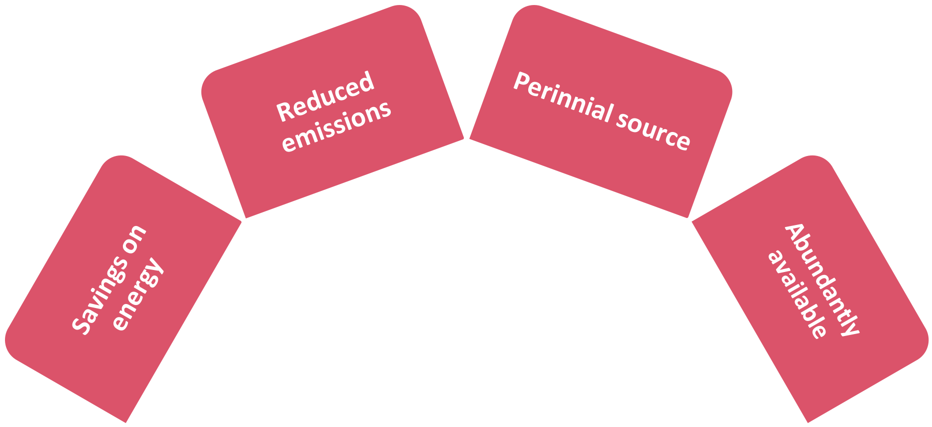
Rural communities in the SAARC Member States lack access and affordability to basic resources such as electricity, which directly affect the type of food storage options available to them. Traditional methods of storage do not require electricity; however, they have proven to be very inefficient. Modern storage solutions, which are efficient, require electricity and can be expensive for rural communities to set up and use without necessary technical and financial support.

High costs of electricity supply, poor grid networks and tariff fluctuations can trap rural farmers in a poverty loop, which affects food security of the community and the nation. The relationship between food production and energy has evolved and become stronger due to the reliance on irrigation and mechanization. Further, high costs of energy have negative impacts on production costs in the agricultural sector. The integration of RE into the agricultural value chain could be one of the best ways to improve national food and energy security in a climate safe way. This can cascade into other positive aspects such as reducing poverty in rural areas and income generation through increased productivity.

Chapter 2 concluded that storage related issues contribute towards the highest post-harvest losses. Renewable based storage methods can help farmers extend the shelf life of perishable produce and keep them in good condition. Harnessing and utilizing RE power has direct environmental benefits such as reducing pollution levels and lower carbon emissions. Renewable energy costs have been and will continue to fall, making them a more cost-effective source of power compared to conventional sources of power. This can result in increased market output and reduction of food wastage through better storage solutions.

At macro level, the socio-economic benefits of renewable energy solutions in the agro- value chain are outlined in Figure 22.

Figure 22 - Benefits of Renewable Energy in Agricultural Activities



4.2 Renewable Sources of Power

Renewable energy can be described as sources of power fueled by infinite natural resources such as solar, wind, water and heat from the earth. Types of renewable energy are listed in Figure 23.

Figure 23 - Main Types of Renewable Energy

Solar Power	Wind Power	Hydro Power	Bioenergy	Geothermal Power

Solar Power - Solar power utilizes the energy of the sun's radiation to produce electricity using photovoltaic (PV) cells. The technology for solar power is relatively matured and applications include heating & cooling, thermal energy, and electricity for modular and large-scale users. Existing applications in the agricultural sector include – solar heat collectors and solar dryers for drying crops, solar irrigation pumps, solar powered cold storage and solar power systems for water pumping and more.

Wind Power – Wind energy binds the kinetic energy of wind flow. Wind turbines can be used to generate electricity on a modular and large-scale basis. Existing applications in the agricultural sector include – wind pumps, wind power to grind grain and pump water from wells.

Hydro Power – Hydropower harnesses the kinetic energy of flowing or falling water. The differential created by water moving from a high elevation to a lower elevation can propel a turbine. It's a mature technology which can be used for centralized and decentralized energy needs. Existing applications in the agricultural sector include – powering agricultural operations in flour mills by using the flow of water to turn a waterwheel and mechanically drive flour grinders. Micro-hydro systems can even be a local source of power generation.

Bioenergy – Bioenergy can be used from various fuels such as agricultural residue, wood, plants, crops and compost. The technology maturity level varies for different users, but it can be used at a modular or large-scale purpose. Existing applications in the agricultural sector include – burning biofuel for heating, crop drying and dairy operations. It can also be used for transportation as it is the only alternative renewable fuel compatible with combustion engines.

Geothermal Power – Geothermal energy is renewable energy taken from below the Earth's surface. The heat is carried by water and/or steam to the surface and can be used for heating and power generation. The technology maturity level varies by type of usage. Existing applications in the agricultural sector include – heating greenhouses for certain horticulture produce, drying crops & grains and even dehydrating certain horticulture produce.

RE Power generation costs are not simply competing with conventional sources of fuel, they are challenging them as well. The International Energy Agency (IEA), in their World Energy Report 2020, has declared solar power as the cheapest electricity source in the history.

Table 27 compares various factors such as capital costs, capacity utilization factor, fuel and O&M costs as well as levelized cost of electricity (LCOE) for existing power generation technologies in India, as an example. The data shows that not only are the associated costs lower for RE's, but they are also projected to drop further in the next 20 years. Renewable energy has become more viable and feasible given the growing concern for climate change.

Data from

Table 27 is helpful as it details that RE sources of power will continue to be economical power sources for applications in all sectors, including the agricultural sector – at a centralized or decentralized level.

Table 27 - Comparing Technology Costs in India

India	Capital costs (USD Million /MW)		Capacity factor (%)		Fuel and O&M (USD /MWh)		LCOE (USD /MWh)	
	2019	2040	2019	2040	2019	2040	2019	2040
Nuclear	2.8	2.8	80	80	30	30	70	70
Coal	1.2	1.2	60	60	30	35	55	55
Gas CCGT	0.7	0.7	50	50	50	70	60	85
Solar PV	0.61	0.35	20	21	5	5	35	20
Wind on shore	1.1	1.0	26	29	10	10	55	50
Wind offshore	3.1	1.7	29	38	25	15	135	60

Source: IEA World Energy Model Document 2020

Renewable Energy can supply thermal and mechanical energy to satisfy the energy needs of different stakeholders. Some of the major applications of RE are mentioned in Table 28. This can be helpful to gauge which type of RE source would be best suited for food storage facilities in the agricultural sector. For example, Solar PV technology can be designed to supply utility scale power to numerous stakeholders such as a network of warehouses and can also be designed as a decentralized source of power to a designated stakeholder such as a standalone cold storage facility.

Table 28 – Type of RE Technologies and Relevant Applications

Technology	Market	Application
Solar PV	Solar Parks	Utility Scale
	Solar IPP	Utility Scale
	Concentrating Solar	Utility Scale
	Rooftop with Net Marketing	Captive Consumption/ export to grid
	PV for Personal Use	Off-grid/ decentralized
	Solar + Diesel	Off-grid/decentralized
	Solar Power Cold Storage	Off-grid/decentralized
	Solar Dryers	Off-grid/decentralized
	Solar Irrigation Pumps	Off-grid/decentralized
	Solar Tube Well Pumps	Off-grid/decentralized
Hydro	Large scale power plants	Utility Scale
	Small/medium hydro plants	Captive or exported to grid
	Hydro + Diesel	Off-grid/decentralized
Wind	Wind IPP	Utility Scale
	Wind + Diesel	Off-grid/decentralized
	Wind Pump	Off-grid/decentralized
	Wind Powered Grain Grinding	Utility Scale & Off-grid/decentralized
Bioenergy	Power generation from agri waste	Utility Scale
	Biomass + Diesel	Off-grid/decentralized
Geothermal	Electricity generation	Utility Scale
	Greenhouse Heating	Off-grid/decentralized

RE Technologies can be centralized (on-grid) or decentralized (off-grid). Centralized energy systems are traditional power management systems whereby large-scale power plants (usually thermal) supply energy to multiple end users through a grid network. The infrastructure of the system such as the grid network and transmission lines are centrally controlled.

Decentralized renewable energy sources are not connected to the grid and are usually standalone sources of power generation. These sources play a crucial role in transforming energy access by providing electricity production, heating and cooling capabilities and mechanical power in a clean and affordable manner. These applications can be used along the entire agro-value chain, but this chapter will investigate the options of renewable energy solutions for post harvesting activities such as food preservation and storage.

4.3 Renewable Sources of Energy in SAARC Member States

This section outlines the RE sources already available and feasible for implementation in each Member State. Based on data in Chapter 3, significant capacity will need to be created to accommodate the increase in storage related energy sources. The clean energy potential is substantial in the SAARC Member States. Trends show that the countries have initiated utility scale projects for proven RE's such as solar, wind and hydro power. In Table 29, the tentative deployment of these proven RE's over the next 10 years have been estimated based on the following factors:

- ***Current Installed Capacity*** – The current and operational RE capacity by source in each SAARC Member State
- ***Historical growth/ Year on Year Run Rate*** – The Year over Year RE capacity installed over a period of 5 years by source in each SAARC Member State
- ***Identified targets*** – The identified source wise RE targets set by each SAARC Member State
- ***Potential*** – The RE potential that can be materialized in each SAARC Member State

Table 29 - Existing and Expected Capacity Additions for Renewable Energy Sources[76]

Country	Renewable Energy (MW)			
	Hydro	Solar	Wind	Bioenergy
Afghanistan Existing Capacity	333	85	NA	NA
Afghanistan Estimated Capacity Addition by 2030	2863	1450	1200	NA
Bangladesh Existing Capacity	230	284	3	5
Bangladesh Estimated Capacity Addition by 2030	60	1913	1370	NA
Bhutan Existing Capacity	2,334	NA	1	NA
Bhutan Estimated Capacity Addition by 2030	7600	12	9	NA
India Existing Capacity	46,367	40,100	39,250	10,145
India Estimated Capacity Addition by 2030	23,030	147,933	127,307	NA
Maldives Existing Capacity	NA	14	1	NA
Maldives Estimated Capacity Addition by 2030	NA	26	NA	NA
Nepal Existing Capacity	1,182	54	NA	NA
Nepal Estimated Capacity Addition by 2030	14,000	892	NA	NA
Pakistan Existing Capacity	11,151	1,329	1,236	432
Pakistan Estimated Capacity Addition by 2030	22,748	12,800	12,700	NA
Sri Lanka Existing Capacity	1,798	215	128	54
Sri Lanka Estimated Capacity Addition by 2030	431	1735	2185	NA

*Where blank, data is not publicly available

Afghanistan, Bangladesh, India, Pakistan and Sri Lanka have strong solar, wind, and hydro potential. Further based on existing and planned projects along with the positive country wise RE policies, the estimated capacity additions for these RE sources projected to be significant. Nepal and Bhutan are heavily reliant on hydropower and have high potential for the addition of more hydropower plants. Both SAARC Member States are less inclined and have low potential for solar and wind power, which is why even the estimated capacity addition for these sources is minimal.

The existing installed capacity is predominantly used for commercial electricity purposes except for bioenergy which is mainly used for residential purposes such as personal cooking and heating. There is a strong growth potential for RE sources across the SAARC Member States. However, for this potential to materialize, it needs to be supported by favorable macro factors such as strong RE policy, willingness of financial institutions to provide support and ability for projects to attract investment.

[76] PwC Internal Analysis using 5-Year Growth (% CAGR) of RE Implementation for SAARC Member States (2015-2019) and respective Member States Power Ministries

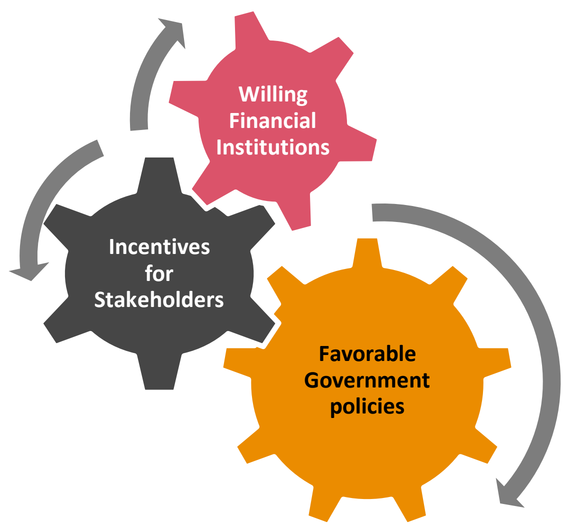
4.4 Existing Policies in SAARC Member States

Policies provide guidance, accountability and clarity on how a process should function. Policies for RE technologies are important as they help integrate these technologies into the overall power sector. Additionally, they lead to benefits for all involved stakeholders and help nations meet specific national and international environmental goals by penning discussed agendas into actionable targets. Incentives stemming from policies attract investors which can propagate financing options for RE based solutions.

Financial Institutions play an important role for the development of RE based solutions. Large scale projects need the support of national banks, international financial institutions and international grants to finance projects. Project financing is a critical step towards the commercialization of RE technology. Projects supported by lenders, guarantee's, power purchase agreements (PPA) or other contractual agreements that are further supported by multilateral agencies help mitigate risks associated with new RE technologies. This is also an incentive for private project investors.

To implement renewable energy sources to avoid storage related food losses at such a vast scale – the following aspects, listed in Figure 24, are of primary importance.

Figure 24 – Key Aspects to Ensure Success of Renewable Energy Projects



The tables below will briefly describe the policy landscape in each of the SAARC Member States. Understanding the existing regulatory, financial and policy climate can help determine a State's willingness towards the use of renewable energy for future activities – such as the agricultural value chain.

Table 30 – Existing Policies in Afghanistan[77,78,79]

Afghanistan	
Financial Institutions	Projects have been largely funded by the Government of Afghanistan credit lines offered by multilateral and foreign development funds. Over the years, Afghanistan has been receiving aid from multilaterals, such as International Bank for Reconstruction and Development (IBRD) and International Development Association (IDA) lending[77].
Policies & Incentives	The 2015 Afghanistan Renewable Energy Policy (RENP)[78] offers financial incentives to different stakeholders: • Upfront Capital Support in the form of Subsidies • Preferential Tariffs and Performance linked incentives for using RE technology • Debt Moratorium for RE projects • Customs tax and Sales tax duty exemptions • Income tax exemption for first 5 years of operations • Land acquisition will be done by Government • Security will be provided during project implementation
Existing RE Initiatives in Agricultural Sector	RENP has set targets to deploy 4500+ MW[78] of RE in the country. The Afghan government (with the support of the international community) has set viable targets in the RE sector. To achieve these targets, policies and incentives have been detailed to attract domestic and international investors to participate in generation, transmission, and distribution of RE. In 2020, Afghanistan signed a USD 160 million[79] RE deal with Turkey and India to install 110 MW of solar power. This project will reduce the quantum of imported energy and will help to propagate improvements in other sectors as well. Improving access to energy is a major step towards enabling development. Reducing the quantum of imported energy will also reduce the cost of electricity, making it more affordable for the rural farming communities.

Table 31 - Existing Policies in Bangladesh[21,80,81,82,83,84,85]

Bangladesh	
Financial Institutions	Institutions such as ADB[80], IFC and the World Bank[81] have a significant presence in increasing the investment towards the power sector in Bangladesh. The World Bank has also extended Multilateral Investment

[77] The Renewable Energy Roadmap for Afghanistan, 2017
[78] Ministry Of Energy and Water – Renewable Energy Policy 2015
[79] Salahuddin, 2020
[80] Spectra Solar Power Project: FAST Report, 2019
[81] Bangladesh Investment Promotion and Financing Facility Project II, 2017

Bangladesh	
	Guarantee Authority (MIGA) facility to private firms. This has improved the financial attractiveness of private sector projects. Furthermore, Bangladesh Infrastructure Finance Fund Ltd. (BIFFL) and Investment Development Company Limited (IDCOL), provide low-cost debt financing to large infrastructure and power projects[82].
Policies & Incentives	Bangladesh has introduced the Power System Master Plan (2016) which aims to increase the total RE installed capacity to 2,470 MW by 2021, and 3,864 MW by 2041[83]. The Government has introduced various incentives for private investors[84]: • The Government has declared power generation as an industry. Therefore, any company in this sector will be eligible for all concessions available to industrial projects. • Exemption from Corporate income tax for private power producers for 15 years • Exemption from income tax for foreign lenders lending to private power producers • Import of plant, equipment, and spare parts up to 10% of the original value of total plant and equipment is permitted within a period of 12 years of commercial operation without any customs duties and other surcharges. • Private power companies can buy insurance of their choice as per the requirements of the lenders and the utilities and not be limited to National Insurance Company (Sadharan Bima Corporation (SBC)). • Foreign companies registered in Bangladesh will be treated as local companies to borrowing facilities. • Power generation companies, starting operation before 31st December 2022, can enjoy full tax exemption on income from their power generation business till 2034. • Foreign employees in power generation business will be given tax exemption on their salaries for three years from their first date of arrival into the country • Bangladesh has also introduced policies to purchase unconsumed or surplus energy from rooftop solar producers under 'net metering' scheme'; and purchase unconsumed energy from solar irrigation pumps (SIP)
Existing RE Initiatives in Agricultural Sector	A working paper by ADB studied the impact of solar irrigation pumps on the wellbeing on farmers in 2020. The paper concluded that solar irrigation pumps provide an opportunity to irrigate a larger amount of land due to reliability, affordability, and accessibility[85]. Further, during the off-season, farmers can use solar electricity for other income-generating purposes as well as to supply electricity back to the grid. The government policy of purchasing surplus energy from SIP's can positively contribute towards

[82] Transforming the power sector in Bangladesh, PwC 2018
[83] Power System Master Plan 2016 Final Report
[84] Rapid Assessment GAP analysis Bangladesh, n.d
[85] Asian Development Bank Institute, 2020

Bangladesh	
	farmers income. Using SIP's also offsets the use of diesel pumps which emit 7.5 kg of carbon dioxide, amounting to 22.34 kg per acre annually[85]. In 2017, the Bangladesh Prime Minister inaugurated a 25,000 MT multistory 100% solar powered food grain warehouse in the city of Santahar[21].

Table 32 - Existing Policies in Bhutan63,[86,87,88]

Bhutan	
Financial Institutions	Major investments in power sector happen predominantly in hydropower projects. Large hydropower projects are funded by a combination of debt and grants by partner governments[63,86].
Policies	Bhutan Sustainable Hydropower Development Policy 2008 encompasses all aspects of hydropower development, including institutional structure, project solicitation, fiscal incentives and project investment. The policy aims to attract public and private investment in the hydropower sector. The Alternative Renewable Energy Policy, 2013 (AREP), aims to develop renewable energy in the country. The policy has defined energy targets of 20 MW by 2025 of which there must be 5 MW of solar PV, wind and biomass each. The Government of Bhutan also has a Renewable Energy Master Plan (2016), which is a succession of national economic development tactics. Key incentives offered in Bhutan are[87] • Investments in large hydropower projects (150 MW to 1,000 MW) can form joint ventures with Bhutanese companies or can be eligible for 100% FDI. • Private companies are exempt from paying corporate income tax for 10 years from date of operation of the hydropower plant. Developers who develop projects in remote areas are eligible for an additional 5 years' tax holiday. • Project developers are exempted from payment of all import duties and sales taxes on the import of plant and equipment during the construction period. Further, no sales tax or duty will be charged on the export of electricity. • Investors in the manufacturing sector of RE based products in Bhutan are exempted from income tax for a period of 10 years.
Existing RE Initiatives in Agricultural Sector	ADB and the Government of Bhutan have signed a USD 3 million deal with Japan Fund for Poverty Reduction in 2020[88]. The project aim is to provide rural households with sustainable reliable energy via solar PV systems. This

[86] An Assessment of Financial Sector Development in Bhutan, 2016
[87] Rapid Assessment GAP analysis Bhutan
[88] Asian Development Bank, 2020

Bhutan	
	would help farmers mechanize crop production processes and avoid using gas-based fuels.

Table 33 - Existing Policies in India[89,90,91,92,93,94]

India	
Financial Institutions	The Indian government has played a key role in rallying funds for RE projects. Efforts include initiating a body of funds—the National Clean Energy Fund, now known as the National Clean Energy and Environment Fund (NCEEF)—from the proceeds of coal cess (cess is the carbon tax on coal)[89]. Institutions that provide development capital include – National Investment & Infrastructure Fund, MDB's (World Bank, ADB, IFC, KfW), Development Finance Institutions and Indian Power Billionaires (Adani Green Enegry, Tata Power)[90] Various private equity, sovereign wealth funds, global pensions, infrastructure funds are also refinancing existing RE power projects[90]. Domestic national banks, non-banking financial companies (NBFCs) and debt funds are the major sources of funding for RE projects
Policies & Incentives	Important policies responsible for RE growth are National Electricity Policy, 2005; National Tariff Policy, 2006; Integrated Energy Policy, 2006 along with subsequent amendments; Proposed Electricity (Amendment) Act, National Solar Mission 2015, Tariff Policy 2016 and the 2019 PM KUSUM (Kisan Urja Suraksha Evam Utthaan Mahaabhiyan) Incentives for the new projects being implemented include: • Ministry of Power has waived inter-state transmission charges for solar and wind power projects commissioned before 30th June 2023 for a period of 25 years[91]. • Renewable power benefit from must-run status while scheduling the electricity supply to match the demand. Historically, when receiving injection requests into the grid from generators, transmission operators follow the merit order principle and prioritize the lowest-cost sources for dispatch. However, RE power is exempted from such priority and injection of electricity is scheduled when requested by RE generators[92]. • Renewable energy equipment and parts for manufacturing fall under a lower GST rate of 5%[93], while inputs to thermal generation are charged between 5% to 18%.

[89] Ministry of Finance, Government of India Union Budget 2010-2011
[90] IEEFA Capital Flows Underpinning India's Energy Transformation, 2021
[91] Ministry of Power, Government of India Order, 2021
[92] Indian Electricity Grid Code 2010
[93] LiveMint - Solar panel equipment to attract lowest GST rate of 5%

India	
Existing RE Initiatives in Agricultural Sector	The Ministry of New and Renewable Energy (MNRE) launched the PM KUSUM program in 2019 offering INR 34,422 Crore[94] (USD 4.62 billion) of financial assistance. This entails assisting in: • Setting up 10 GW of decentralized grid connected RE plants by individual farmers, cooperatives, unions or farmer organizations. Unused power will be bought by DISCOMS at a pre-determined tariff. • Providing 1.75 million standalone solar pumps to replace diesel pumps • Solarization of 1 million agricultural pumps • 1.75 million solar pumps and 1 million agricultural pumps will avoid 27 million tons of CO_2 emissions annually

Table 34 - Existing Policies in Maldives[95,96,97]

Maldives	
Financial Institutions	The RE projects have so far been funded by a combination of Climate Investment Funds (CIF) from multilaterals agencies in the form of grants and loans, and co-financing from government and private equity investors[95]. World Bank has authorized USD 107 million under the project for Accelerating Renewable Energy Integration and Sustainable Energy (ASPIRE)[96]. The funds will be used to increase the Solar PV capacity with the help of private sector participation from independent power producers.
Policies & Incentives	The 2016 Maldives Energy Policy and Strategy intends to promote renewable energy sources, but it is inadequate in defining clear quantifiable targets for RE. Moreover, the policy does not provide any specific incentives but has a provision to introduce innovative financing mechanism to promote RE's in the country. Electricity supplied from powerhouses registered with Maldives Inland Revenue Authority are exempted from the payment of GST of 12% on value of services provided[97]. The Ministry of Economic Development encourages foreign investment in projects that promote the use of renewable energy in Maldives

[94] Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahaabhiyan, 2019
[95] Climate Investment Funds – Investment Plan for Maldives 2013-2017
[96] World Bank Press Release - World Bank Supports Maldives to Accelerate Renewable Energy Transition, 2020
[97] Maldives Inland Revenue Authority – Guide to Except Goods & Services, 2015

Table 35 - Existing Policies in Nepal[98,99,100,101,102,103]

Nepal	
Financial Institutions	Apart from the Government of Nepal, funding is received from ADB, the government of Denmark and Norway, the European Commission, the European Investment Bank, the Japan International Cooperation Agency (JICA), KfW, the Netherlands Development Organization, the United Nations Development Programme and the World Bank[98]
Policies & Incentives	Important energy policies in Nepal include - 1992 Nepal Electricity Act, 2001 Hydropower Development Policy, 2008 National Electricity Crisis Resolution Action Plan in 2008 ADB has been an important partner in improving Nepal's power sector, propagating on-grid support for the NEA's expansion of generation, transmission, and distribution capacity, with 6 loans and 1 grant amounting to USD 521 million. ADB has also provided 21 technical assistance projects amounting to USD 13.7 million since 1999[99] Private companies holding a license to generate, transmit or distribute electricity will be granted concessions, provided commercial operation commences before April 2024. Electricity generated from solar, wind or organic material (biomass) would be allowed 100% tax exemption up to 10 years and 50% rebate for the following 5 years[100,101].
Existing RE Initiatives in Agricultural Sector	The Government of Nepal is actively supporting RE in agriculture. With the help of NGO's and international financiers such as Alternative Energy Promotion Centre (AEPC), 1600 SIP's have been installed for irrigation and drinking water[102]. Clean Energy Development Bank (CEBD) and SNV Netherlands have developed pico (<5kW) hydro power plants[103] for remote farmer communities in Nepal to improve food processing capacity and reduce cost of production.

Table 36 - Existing Policies in Pakistan[104,105,106,107,108,109,110,111]

Pakistan	
Financial Institutions	MDB's such as World Bank[104], IFC[105], KfW, ADB[106] and DEG (Deutsche Investitions- und Entwicklungsgesellschaft) actively fund RE projects in Pakistan. State Bank of Pakistan, JS Bank, Bank of Khyber, Habib Bank, Faysal Bank, Meezan Bank and Bank Alfalah have introduced schemes to support and finance RE projects in the country
Policies & Incentives	Pakistan's Alternative and Renewable Energy Policy was launched in 2006 and revised in 2019 National Electric Power Regulatory Authority Net Metering Policy 2015 allows solar and wind generators under 1MW to sell back electricity to the grid[107] Incentives for all stakeholders include: • Profit from any RE power projects are exempted from tax[108] • First-year allowance of 90% of the cost of plant, machinery and equipment are available to encourage private investment in RE projects[109] • Imported Solar PV manufacturing materials will enjoy duty free benefits[110]
Existing RE Initiatives in Agricultural Sector	The On-Farm Water Management wing of the Agricultural Department provides a subsidy of 50% of the total cost of agricultural solar energy irrigation pumps. Local companies such as EBR Energy have installed the following high efficiency irrigation systems[111] – • 459 kWp Solar PV Pump in Sukkur Barrage • 1.27 MW Solar PV Pump in Pano Hill • 1.16 MW Solar PV Pumping System in Sindh

Table 37 - Existing Policies in Sri Lanka[112,113,114,115,116]

Sri Lanka	
Financial Institutions	Commercial banks like HNB and DFCC have helped finance small scale RE projects. Most RE projects are funded by domestic lenders and equity investors due to projects being small scale[112].

[104] World Bank Press Release – WB Supports Clean and Green Power in Pakistan, 2020
[105] IFC Supports Largest Wind Power Plant in Pakistan to Help Address Power Deficits, 2017
[106] ADB Pakistan: Access to Clean Energy Investment Program, 2021
[107] IEA Renewables Policies Database, 2015
[108] PwC Tax Analysis
[109] Deloitte International Tax Pakistan Highlights 2020
[110] Government of Pakistan Power Policy, 2019
[111] EBR Energy - How Can Farms Benefit from Becoming Solar-Powered in Pakistan?
[112] Accelerating Renewable Energy Investments in Sri Lanka, 2020

Sri Lanka	
	RE projects are also funded by MDB's like JICA, KfW, the World Bank, ADB and the USAID[113]
Policies & Incentives	Important energy policies in Sri Lanka include - National Energy Policy and Strategies 2019, 'Soorya Bala Sangramaya' program 2016, Sri Lanka Carbon Crediting Scheme (SLCCS) Incentives for stakeholders include: • Companies generating clean power from RE sources can earn Sri Lanka Certified Emission Reduction Units (SCERs). This can be used to offset their own emissions using these units or trade their carbon credits with other companies[114] • Electricity generation companies using RE technology can enjoy a 7-year tax holiday[115]
Existing RE Initiatives in Agricultural Sector	Sri Lanka's Ministry of Agriculture along with Australian company BP Solar, implemented the Sustainable Agricultural Water Management Project (SAWMP) for installing low-cost solar powered drip irrigation technology for the efficient management of water in dry zones. Over 5000+ units have been installed in dry zones across the country. The government has also set up subsidized and affordable payment procedures for small and mid-level farmers to ensure the installation is economical for the end users.[116]

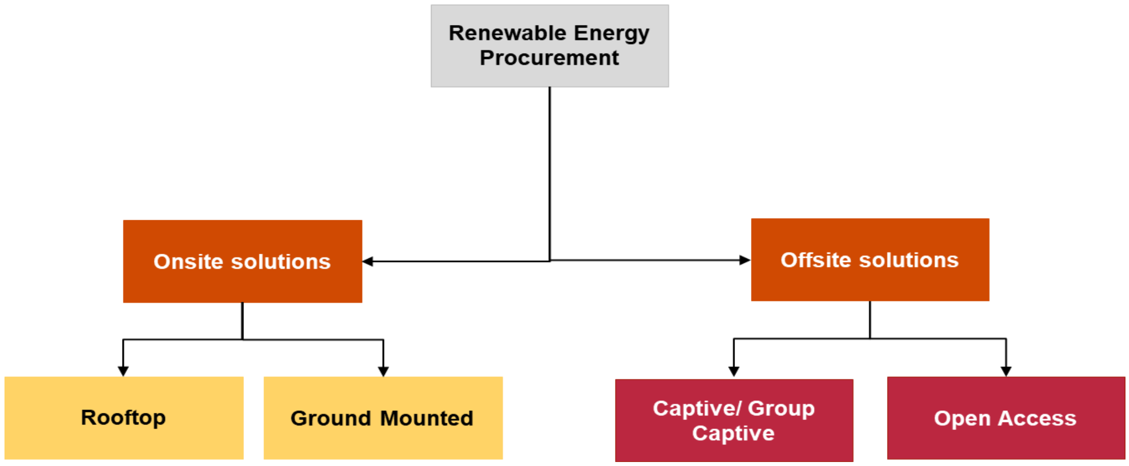
4.5 Power Distribution

Renewable sources of power can be centralized (grid connected) or decentralized (off-grid/standalone). This section will detail the options available for centralized sources of RE, specifically in the urban areas of the SAARC Member States. This is relevant as food storage facilities, such as warehouses and cold storage rooms, in many Member States are government owned and operated. These facilities likely draw power from centralized power sources using conventional fuel.

Figure 25 below breaks down the different ways RE technologies can be implemented in urban cities of SAARC Member States.

[113] Renewable for Rural Electrification in Sri Lanka
[114] World Bank Blog - Sri Lanka catches the low carbon development train 2019
[115] BDO Sri Lanka Annual Budget, 2021
[116] Sri Lanka Ministry of Agriculture - Sustainable Agricultural Water Management Project (SAWMP)

Figure 25 - Contracting Models for RE Technologies



Onsite solutions can be centralized or decentralized; the important factor is that the power generation source is located closest to the immediate end user. Offsite solutions typically are larger scale power generators located at a distance from the end user. These generators can supply energy to the grid via Power Purchase Agreements (PPA).

PPA's include details such as amount of electricity to be supplied, tariffs, fixed and variable charges, and penalties for non-compliance. It can reduce market price risks and provide the power supplier with financial stability. The supplier can accurately predict energy expenses over short- and long-term period.

Open Access to the Transmission and Distribution (T&D) network enables heavy energy users connect to the grid to purchase power from the open market. The idea is to give consumers the option to purchase power from several competitive power generation sources as opposed to purchasing power from an assigned source. Open Access allows renewable power sources to compete with conventional sources of power. It can also help industries and companies (heavy energy users) to improve their Renewable Purchase Obligations (RPO's).

The SAARC Member States are experiencing a rapid increase in energy demand because of rapid transformation and growth. Open Access to the power grid can be indispensable to introducing and improving competition in the electricity market. It increases opportunities for all stakeholders to buy and sell electricity at cost reflective prices leading to more efficient operations and improved quality of power as well. It's an excellent avenue for new renewable sources of power to integrate into the energy systems. Table 38 details the OA landscape in each SAARC Member State.

Table 38 - Existing Systems in SAARC Member States

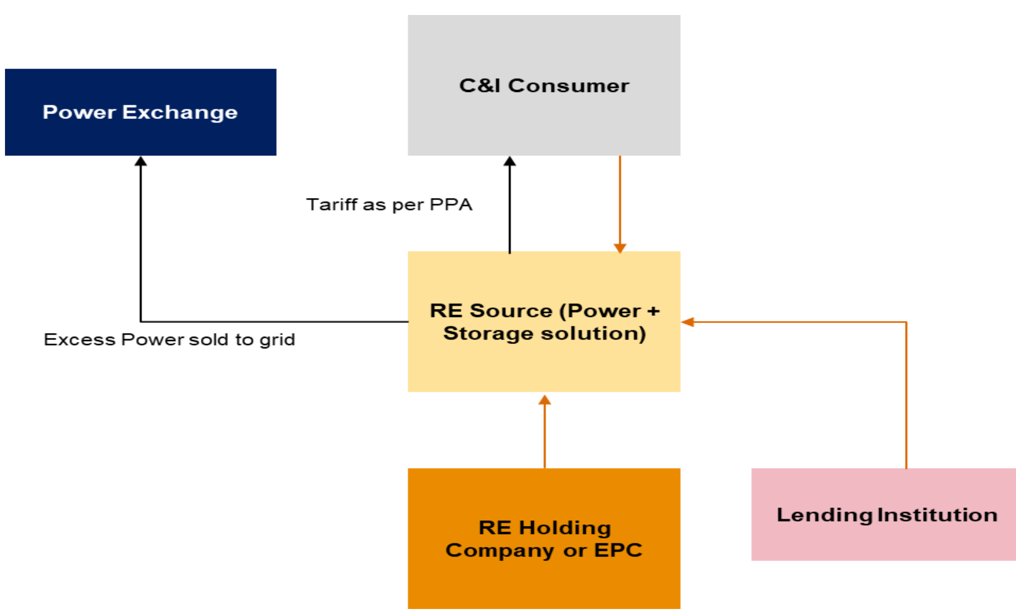
Country	Independent Regulator	Open Access Policy	Open Access Regulations	Open Access Pricing Frameowork	Net Metering Policy
Afghanistan	No	No	No	No	No

Country	Independent Regulator	Open Access Policy	Open Access Regulations	Open Access Pricing Frameowork	Net Metering Policy
Bangladesh	Yes	Yes	No	Yes	Yes
Bhutan	Yes	No	No	No	No
India	Yes	Yes	Yes	Yes	Yes
Maldives	Yes	No	No	No	No
Nepal	Partial	No	No	No	No
Pakistan	Yes	Yes	No	No	Yes
Sri Lanka	Yes	No	No	No	Yes

Source: Framework & Guidelines For Non-discriminatory Open Access in Transmission for Facilitating Cross Border Electricity Trade in South Asia, 2017

Captive Power Sources are electricity generation sources used and managed by commercial & industrial (C&I) users for their own consumption. Historically, this would be utilized by industrial users that require a continuous source of energy such as chemical or steel plants. However, given the drastic cost decline of RE sources, less energy intensive C&I users can economically install solar PV, wind or even solar-wind hybrid power generation sources coupled with battery systems to avail clean and sustainable round the clock power. A basic overview of captive power generation is shown in Figure 26 where an RE source designed by a third-party company will supply power to a single user. A lending institution can help finance the project. Excess power generated can be sold to the grid network for additional revenue. Captive Power Sources can be beneficial for powering large scale central cold storage facilities which require round the clock power.

Figure 26 - Captive Power Generation Model



4.6 Tariff Comparison

The generation, transmission and distribution of power is governed by policy and regulatory frameworks across the SAARC Member States. Each country has a separate regulatory authority to oversee the tariff determination process. Further, each Member State has taken efforts to introduce reforms in the electricity sector to improve the quality and reliability of supply to its end users. Tariffs are determined by power procurement guidelines and presently only India and Sri Lanka have separate guidelines. The remaining 6 Member States have vertically integrated power utilities where power procurement from independent power producers (IPP's) is determined through negotiations. There are different types of tariffs for the various types of end users. The broad categories include – residential, commercial, industrial and agricultural.

Table 39 includes the average tariffs for end-users such as commercial and industrial consumers for 6 of the SAARC Member States from conventional sources of power.

Table 39 - Commercial and Industrial (C&I) Electricity Tariffs[117,118]

	Bangladesh	Bhutan	India	Nepal	Pakistan[118]	Sri Lanka
Commercial Tariff (US Cents/kWh)	15.81-19.45	7.58 – 9.32	21.21–23.06*	16.80-18.39	11.59-13.93	21.73-23.65
Industrial Tariff (US Cents/kWh)	15.1 – 15.55	6.30 – 9.32	16.35-18.98*	11.87-14.77	10.01-12.01	12.24-15.19

*State of Tamil Nadu

Table 40 below includes the agricultural electricity tariffs for 5 SAARC Member States. The Agricultural sector usually receives electricity with low tariffs or sometimes receives electricity for free. This has played a key role in utilization of irrigation systems and is important for agricultural growth. However, these subsidies have a negative consequence – poor electricity supply and service quality due to low tariffs. Low tariff revenues from this sector often discourage DISCOMS from investing into improvements towards supply and metering. To offset the subsidies provided to the agricultural sector, C&I consumers must bear the costs in terms of higher tariff rates. This encourages C&I end users to relocate their businesses to areas where tariffs are more affordable.

Providing farmers with the means to use clean and sustainable solutions along the agricultural value chain can help reduce the dependency on conventional sources of power and ease the high tariff burden that C&I consumers must carry.

117 Karunathilake, 2018
118 NEPRA Consumer-End Applicable Tariff, 2020

Table 40 - Agricultural Electricity Tariffs[118,119,120,121]

Agricultural Tariffs	
Bangladesh[119]	• Agricultural Pumping 4.5 US cents/kWh (3.82 BDT/kWh)
Bhutan[120]	• 100% subsidy for Low voltage Rural power up to 200 kWh
India[121]	• Agricultural Power is free for the following States – Andhra Pradesh, Karnataka, Punjab, Tamil Nadu, Telangana • Metered Agricultural Power Ranges from 1.2 to 7.6 US cents/kWh (INR 0.87 – 5.64/kWh) • Unmetered agricultural supply tariff is at a fixed rate ranging from 14 to 19.19 US cents/kWh (INR 10/HP/Month to INR 1415/HP/Month) • Unmetered agricultural supply tariff is dependent on HP, land size and zonal area
Pakistan[118]	• Agricultural Tube wells 5.5 US cents/kWh (PKR 9.50/kWh) • Agricultural Residential/Lighting/Other – 11 to 13 US cents/kWh (PKR 19.16 to PKR 23.14/kWh)
Sri Lanka[122]	• Does not offer subsidies for Agriculture

Compared to the other SAARC Member States, India has well established guidelines for power procurement and tariff determination. Further, the Central Energy Regulatory Commission (CERC) has a framework for determining the generic or basic tariff for each type of RE generation. Each State Electricity Regulatory Commission (SERC) also publishes a framework for basic tariff guidelines. As the RE market and RE regulatory frameworks in India are so well established, a basic tariff calculation has been performed below to highlight the differences in tariffs between conventional sources of power and RE sources of power.

Table 41 shows the calculated range of tariffs for new solar and wind power generated in Tamil Nadu, India for a C&I consumer using Open Access. The range of tariffs has been calculated using the MNRE approved range of Capacity Utilization Factors (CUF) – 17% to 21% for solar power and 26% to 32% for wind power. CUF is the ratio of actual production to the plant production capacity in a year. A low CUF translates to a higher tariff and a high CUF translates to a lower tariff. Using a range of CUF values provides realistic tariff prices.

Table 39 detailed that tariffs for commercial users in India (Tamil Nadu) ranged from US Cents/kWh 21.21– 23.06 while tariffs for industrial users ranged from US Cents/kWh 16.35-18.98. Table 41 shows that tariffs from RE sources in Tamil Nadu ranges from US Cents/kWh 4.4 - 8.3. The difference is tariffs is significant. The landed tariffs are over 50% lower than the tariffs for conventional sources of power for the state as RE sources benefit from government subsidies and lower charges. The following

[119] Dhaka Power Distribution Company Limited (DPDC), 2021
[120] Bhutan Power Corporation Limited (BPC) Electricity Tariff, 2021
[121] Electricity Tariff & Duty and Average Rates of electricity supply in India, 2019
[122] Electricity Tariffs and Charges – Public Utilities Commission of Sri Lanka

charges are also subsidized for solar and wind generators by 50% - wheeling charges, scheduling charges, cross subsidy charges, operating charges and transmission charges.

Table 41 - Calculated Tariffs for RE Technologies using Third Party Open Access (Tamil Nadu)[123]

	Solar PV (10 MW)		Wind (50 MW)	
Levelized Tariff (US Cents/kWh)	4.2	5.2	4.4	5.5
OA Charges (US Cents/kWh)	3.0	3.1	2.7	2.8
Landed tariff (levelized tariff + OA charges + Electricity Tax) (US Cents/kWh)	7.2	8.3	7.2	8.3

Renewable energy is a more economical option compared to conventional sources of power as shown in Table 39 and Table 41. Central food storage facilities, such as warehouse and cold storerooms, in major cities in SAARC Member States would be considered C&I users. Changing these facilities source of power from predominantly conventional fuels to RE based fuels would save energy consumption costs. C&I users switching to RE supplied power can benefit from lower tariff rates as due to government subsidies and lower distribution charges. Investors for greenfield RE projects can also benefit from the encouraging policies and incentives initiated by the SAARC Member States, which will lead to lower costs in the short and long term. Food storage facilities can greatly benefit from a clean and affordable source of power towards their electricity needs.

4.7 Case Study for Grid Connected Renewable Energy Sources

Installation of rooftop solar can be a viable RE solution for food storage warehouses and cold storage facilities. The rooftop solar market is rapidly expanding in India and it is being led by the Commercial and Industrial (C&I) sector. The C&I segment accounts for 75% of the rooftop solar market in 2020 with over 6000MW[124] installation in the sector. The solar energy market is picking up because entities are looking to reduce costs and improve their sustainability perceptions. Rooftop solar installations not only reduce the electricity costs, but they also help companies achieve their RPO targets.

Rooftop installations follow two business models – Capital Expenditure (CAPEX) and Operations Expenditure (OPEX). In the CAPEX model, the solar installation is owned and financed by the rooftop or property owner. For OPEX, the installation is designed, financed and developed by a third-party company and the energy generated is sold through a tariff determined between the energy service provider and consumer.

[123] PwC Internal Model Calculation
[124] JMK Research & Analytics, 2021

The table below shows the technical details of an Industrial user in Maharashtra, India using rooftop solar installation to power their operations:

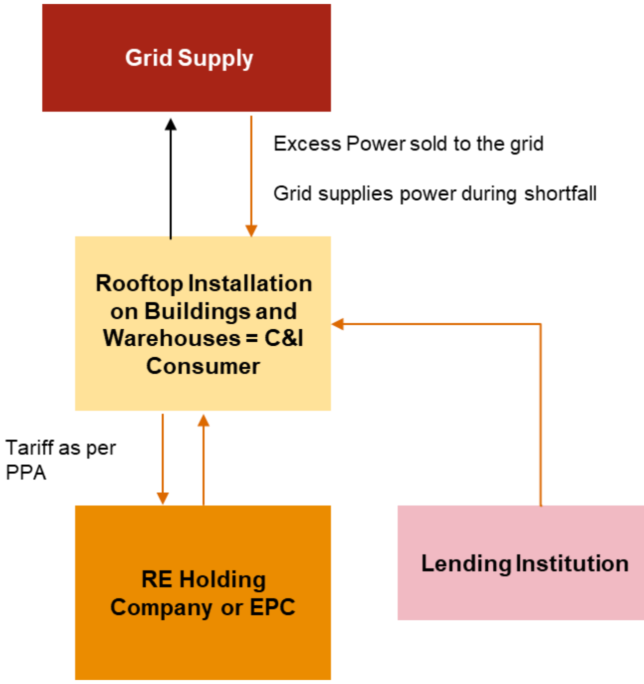
Rooftop Solution for Chiplun[124] – India	
Technology	Solar PV Installation
Structure	Rooftop + Ground Mounted Installation
Status	Operational (2021)
Capacity	828 kWp
Costs	• Installation Costs (pre-tax): INR 38,000 (USD 506) – INR 41,000 (USD 546) per kW • Payback period (CAPEX): 3 – 3.5 years • OPEX Tariff: INR 3.4 – 3.7/kWh (US cents/kWh 4.5 to 4.9) for 10-12 years • Estimated energy cost savings: 35-40% per year
Construction Time	6 months
Net Metering	Yes
Savings	INR 260,000/month (USD 3,464/month)

Further, the user availed the Net metering facility which allows the C&I user to export power to the grid from the rooftop solar installation when the facility has unutilized power and earn additional revenue from this source. The user is also able to draw electricity from the grid during times of electricity generation shortfall. The net power consumed or exported is calculated using a net meter – the user is either paid or charged for the units consumed. This allows a user to recover the investment costs of the installation by selling surplus power. Bangladesh, India, Pakistan and Sri Lanka have approved Net Metering programs for renewable sources of power. The image below shows the ground mounted solar panel installed by Cleantech Solar.

Source: Energy world, June 30, 2021. Accessed on October 28, 2021.

Figure 27 below explains the process of an OPEX Business Model where the installation is designed and developed by a third-party company and the energy generated is sold through a tariff determined between the energy service provider and consumer. A lending institution can help the C&I user finance the capital costs of the project. Any excess power can be sold to the grid while grid power can be used during times of shortfall.

Figure 27 - Net Metering for Rooftop Solar Installations



A standard cold storage facility is approximately 5000MT. According to a study from the Central Power Research Institute in India, a 5000 MT cold storage facility would require a 573-kW solar PV plant[125]. The Solar PV plant would roughly produce 4000 kWh/day for running the cold storage facility including the thermal ice storage and cold liquid ammonia at low pressure. Solutions such as the rooftop solar installations by CleanTech Solutions could power a cold storage facility and generate income from the sale of excess or unused power.

4.8 Decentralized Renewable Energy Solutions

This section will explore the different types of low-cost off grid renewable technologies available, outside the realm of traditional renewable energy power generation. These solutions are still nascent technologies and can only accommodate very small volumes. It can still be useful in identifying technologies that would be most suitable for different actors involved in the agro-value chain across the SAARC Member States.

The agricultural value chain requires energy input at each stage, especially as the sector has become more industrialized to meet the growing demands. Energy is required for optimized and efficient storage, processing, transport, animal comforts, lighting etc. Unfortunately, many rural communities don't have access to modern energy services or connectivity to the national grid. Creating provisions of modern sustainable energy technologies is essential in these scenarios. A sustainable and efficient value chain, using renewable energy solutions can help farmers achieve a higher output by using less energy. Table 42 to Table 46 have outlined the various technologies available.

[125] Powering Cold Storage Plants | Cooling India Monthly Business Magazine on the HVACR Business, 2016

Table 42 - Evaporative Cooling Technology Information

Technology	Description
Evaporative Cooling[126]	It is a pot in pot system where the smaller pot is placed inside the bigger pot and the gap is filled with sand, creating insulation. The sand is kept damp by pouring water over it regularly. The evaporation of water creates a cooling effect. It is a no-energy alternative storage solution that can aid in introducing farmers to the concept of cold storage.
Financing	• Building 12 kg worth of storage costs USD 2 to produce • No external funding required
Purpose	• Economical and extends the life of fruits and vegetables by 2 weeks which leads to increase in profit for the farmer by 25-30%. • Can be used by rural farmers that cannot yet afford advanced RE cold storage solutions
Disadvantages	Low volume and temporary solutions at farm-level
Examples	• Zeer Pot Cooling in Nigeria • Zero Energy Cool Chamber (ZECC) in India and Afghanistan

Table 43 - Solar Thermal Refrigeration Technology Information

Technology	Description
Solar Thermal refrigerators[126]	Uses solar heat to evaporate a refrigerant mix of water, ammonia and silicagel to generate a cooling effect. The system includes a solar collector, a tank for thermal storage, a thermal air conditioning unit and a heat exchanger
Financing	Solar Ice Company in partnership with NGO Heifer Project International. Project was funded by the World Bank.
Purpose	Suitable for low volume cold storage of fruits and vegetables in areas with lack of grid electricity access and high solar radiation
Disadvantages	Complex, medium cost and still in pilot stage
Example	ISAAC (Intermittent Solar Ammonia Absorption Cycle) solar-powered icemaker was pilot tested in Kenya

126 IRENA – Renewable Energy Benefits; Decentralized Solutions in the Agri-food Chain, 2016

Table 44 - Solar Electrification Technology Information

Technology	Description
Solar Electrification[126]	Using solar technologies to power cold storage rooms and/or refrigerators. The system includes solar panels and lead batteries as a backup during overcast days and during power outages.
Purpose	Extends shelf life of fruits and vegetables and is self-sustained as it is not grid connected
Disadvantages	Batteries significantly add to installation and maintenance costs
Example	Pilot solar powered cold rooms for horticulture crops installed in Nigeria for USD 88,728

Table 45 - Day Light Harvesting Technology Information

Technology	Description
Day Light Harvesting	A lighting control technology to maximize the use of natural light to offset the use of electric lighting in enclosed spaces. The controls can adjust the level of lighting in response to availability or intensity of natural sunlight.
Purpose	• Energy consumption reduction of 40-50% for buildings operating 24 hours and roughly 70% for buildings operating 10-12 hours • Can be used for existing and future warehouses and godowns to reduce energy consumption and costs
Disadvantages	Highly dependent on sensors
Example	The Chennai International Airport has been installed with sun tracking and electric lighting system[127]

Table 46 - Ice Battery Technology Information

Technology	Description
Ice Battery Technology[128]	Uses passive cooling technology to maintain and extend the duration of constant temperatures needed for horticulture crops. Solutions range from ice packs, 1000L containers, freight containers to hybrid trucks. No repair and maintenance costs, ice batteries are reusable
Purpose	Can be used to extend the quality of fruits and vegetables during transportation from farm to market

[127] Net Zero Energy Buildings – Daylight Technologies
[128] IceBattery® in Media – Icebattery, 2021

Technology	Description
Disadvantages	Ice Battery needs proper charging (freezing) for 12 hours before deployment
Example	Container Corporation of India Limited (CONCOR) has partnered with Innovation Through Energy (ITE) to supply IceBatteries to the Indian market

4.9 Case Studies for Decentralized Renewable Energy Sources

This section will detail companies that have successfully implemented renewable sources of energy for food storage – EcoFrost by Ecozen, Inspirafarms Cold Storage and Husk Power System. The SAARC Member States have numerous smallholder farmers who face trials towards their productivity and sustainability such as lack of access to finance, limited knowledge of smart technology and broken links along the agro-value chain.

Ecozen and InspiraFarms are private players trying to address the gaps for these smallholder famers by not only providing agricultural cold storage solutions, but also providing financial solutions that address their needs and requirements. Private and public investors along with various programs of the World Bank, FAO, USAID and more, support Ecozen and Inspira farms. They make their cold storage solutions accessible and affordable to small holder farmers by involving global and local financial institutions and CSR departments of corporations to help facilitate loans to their customers.

Husk Power System (HPS) is a private player trying to provide access to electricity to rural villages in India. Lack of electricity has also been identified as a major challenge for farmers productivity in Chapter 3. Like Ecozen and InspiraFarms, HPS is also supported by investors and subsidies. However, HPS has working business models which have enabled the company to earn profits from the sale of electricity as well, as the case study will detail.

EcoFrost

Table 47 – EcoFrost Case Study

EcoFrost by Ecozen[129] – India **EcoFrost is a standalone and portable solar powered micro cold storage room which can help extend the shelf life of fruit and vegetables. It is a 5 MT capacity cold room container which operates using decentralized solar energy. Alternatively, it can utilize grid or generator power during times of unfavourable weather. The system takes 5-6 hours to fully charge and can operate for 30 hours with the help of battery-less thermal plates.**	
Technology	Solar powered micro cold storage room

[129] Ecofrost - Solar Powered Cold Storage Room Manufacturer in India, 2021

Status	Operational
Capacity	2 MT, 5MT, 8 MT
Costs	The EcoFrost costs depend on the equipment specification. However, with government subsidy the costs can be drastically lower. Below are the available costs breakdown. As provided by a representative of EcoZen: Installation Cost – INR 20,000 – 30,000 (USD 270 – 400) Transportation Cost – INR 10,000 – 100,000 (USD 130 – 1330) O&M Cost – 40,000 (Optional and first year is free) (USD 530) Equipment Cost ~ INR 1,000,000 to INR 1,80,000 (USD 13,356 to USD 24,000)
Financing	Approved subsidy schemes for Ecozen[130]: 1. Ministry of New and Renewable Energy (MNRE), the Government of India, 30% subsidy is provided from the central government for the micro-cold storage facility. 2. 40% subsidy each from Chhattisgarh state & central government 3. National Bank for Agriculture and Rural Development (NABARD) approved a 40% subsidy scheme for Madhya Pradesh, Chhattisgarh, Maharashtra and Bihar
Purpose	• Selling produce at peak season • Extending shelf life of produce • Reducing post-harvest losses from 15% to 2%[131]

The image below shows the portable cold storage unit by EcoZen.

[130] The Innovation Policy Platform: Case Study – Ecozen, 2018

Source: https://www.ecozensolutions.com/ecofrost , accessed on November 29, 2021

The breakeven depends on the type of commodity being preserved – exotic plant growers achieve turnover within a year whereas vegetable famers can take 3 to 4 years on average. A basic cost-benefit analysis has been calculated as an example in

Table 48 and Table 49 to understand how marginal farmers can afford this technology. Using the range of average earnings on a popular vegetable, the earnings from using the 5 MT EcoFrost have been extrapolated. Further, as stated in Table 47, the EcoFrost reduces PHL from 15% to 2%. Based on this figure, annual savings can be derived assuming the crop cycle is 3 months, and this crop can be harvested 4 times a year.

Table 48 – Example of Annual Savings from Utilizing EcoFrost

Range of Farmer Earnings for crop (INR/kg)	Earnings per MT (INR)	Earnings for 5 MT (INR)	Earnings lost from 15% PHL (INR)	Earnings lost from 2% PHL (INR)	Earnings saved using EcoFrost (INR)	Earnings saved using EcoFrost (USD)	Earnings saved annually using EcoFrost (USD)
17.5	17,500	87,500	13125	1,750	11,375	152	608
22.5	22,500	112,500	16875	2,250	14,625	195	780

Marginal farmers can save USD 608-780, or more, annually from utilizing the 5MT EcoFrost, depending on the crop. Table 49 below provides the breakeven points for utilizing the EcoFrost with and without subsidies. Subsidies in India range from 30% to 80%.

Table 49 – Example of Cost of EcoFrost and the Breakeven Point

	Basic Equipment Cost (USD)	Equipment Costs With 30% Government Subsidy (USD)	Equipment Costs With 70% Government Subsidy (USD)	Equipment Costs With 80% Subsidy from Bank and Government (USD)
Equipment Cost	13,356	9,349	4,007	2,671
Breakeven Period	19 years	13 years	6 years	4 years

Without subsidies, a marginal farmer will take almost 20 years to breakeven, though the time reduces to 4 years with the help of subsides.

Due to poor market connectivity and lack of electricity access, Indian farmers have struggled with reducing food waste. Cold storage rooms have also been unattainable due to unreliable electricity access and high energy costs. A farmer in the state of Maharashtra, India procured the EcoFrost to help relieve him of the financial burdens caused by avoidable crop decay. His area was drought-prone and only received 8 hours of electricity per day. Without access to continuous electricity, it was difficult to store his harvest of fruits and vegetables in a cold room, causing a significant portion of it to decay and become un-sellable. The cost of the 5MT EcoFrost was INR 1.2 million (~USD 16,000)[131], however he was able to avail the central government subsidy of INR 540,000 (USD 7200) (refer Table 47) and procure the container for ~INR 650,000 (USD 8,800). He managed to break even in 2 years by storing crops and selling them at opportune times.

In February 2018, tomato prices fell to INR 2-3 per kg. Rather than immediately selling his crop, the farmer stored 5 MT of tomatoes in the EcoFrost and sold them the following month for INR 25/ kg earning him INR 125,000 (USD 1683). He earned 8x more profit by keeping the tomatoes in the EcoFrost and selling them during a time of high demand.

Table 50 - SWOT Analysis for EcoFrost

Strengths	Weaknesses
• Portable • Decentralized solar solution • Humidity control • Internet-of-Things module to monitor and report issues in real time • Options to finance to ownership • Effective crop storge during periods of low demand	• Weather dependent • Expensive without subsidy • Limited storage capacity • Temperature range 4^{o}C and over only limits the range of horticulture crops for storage

[131] Chaudhary, 2018

Opportunities	Threats
• Larger capacity rooms • Could provide Sub-zero temperature cold storage options	• Growing list of competitors • Administrative red tapes and obstacles for farmers when trying to avail subsidies

InspiraFarms

InspiraFarms provides cold storage solutions like Ecozen in India, to small holder farmers in East Africa. Apart from supporting farmers, the company provides solutions for larger agrobusinesses, exporters and food distributers.

Table 51 – InspiraFarms Case Study

InspiraFarms[132] – East Africa InspiraFarms provides modular, energy efficient pre-cooling rooms, cold storage rooms and pack houses for agribusinesses. The lightweight structures are shipped as turn-key solutions and are easy to install and relocate as needed. These facilities can be operated for 18-24 hours with full charge, during power outage. These facilties are available as off-grid or hybrid model solutions.	
Technology	Solar Powered micro cold storage room
Status	Operational
Capacity	1 – 100 MT
Financing	1. Long term loans to customers supported by financial institutions and impact investors 2. Partnerships with banks to facilitate consumer finance; the risk is shared between InspiraFarms and partnered banks
Purpose	• Reduce horticulture food losses • Extend shelf life of produce • Reduce expenditure on energy and diesel • Creates ~30 jobs in each community

InspiraFarms designs and installs modular, crop specific cold storage and packhouse solutions in East Africa and Latin America. Their range of products are helpful in preserving and extending the shelf life of horticulture crops.

GreenPath Food is one of the few organic farming business in Africa that exports organic produce to Europe and the Middle East. Located in Ethiopia, this community of 241 smallholder farmers exported 20 MT of herbs, peppers and avocados per week. The issue they faced was poor cold storage

[132] Cold Room Units for Agribusinesses| InspiraFarms 2021

infrastructure at the farm to maintain export quality produce. InspiraFarms installed two 240 m^2 packhouses with inbuilt cold storage rooms as a solution to this farmer community. GreenPath Foods increased their export volume and export frequency to 3-4 times a week[133]. The image below shows InspiraFarms' cold room facility.

Source: https://www.inspirafarms.com/products/cold_room/ , accessed on October 28, 2021

Table 52 - SWOT Analysis for InspiraFarms

Strengths	Weaknesses
• Specialized for cold chain for fruits and vegetables • Modular • Customized and crop specific • Delivered as turnkey • Energy efficient in any climactic condition • Flexible location (indoor or outdoor)	• Powered by electric power from either grid, or mix of grid, solar or generator – all of which can be unreliable at different times • Access to roads is required to deliver the product • Access to grid is required • Farmer to provide concrete foundation which can be expensive
Opportunities	**Threats**
• Could be completely off-grid, powered by solar with battery storage • Could provide financing options which don't rely on loans from institutions	• Growing list of competitors • Cutbacks from corporations CSR departments • Reduced funding from institutions could lead to inability to provide loans to customers

[133] GreenPath Food Case Study | InspiraFarms 2021

• Could seek to obtain subsidies from governments of clients	

Husk Power Systems

Although the first two examples, EcoFrost and InspiraFarms are RE based cold storage facilities, a good alternative solution is a mini power plant by Husk Power Systems which provides electricity using agricultural waste. This can be used to power warehouses and cold storage facilities in areas where the solar potential is low. The case of HPS is different as the aim of this private company is to electrify rural villages across India. The company has a few working business models to power remote villages as outlined in Table 53.

A community having clean and sustainable access to electricity can be a steppingstone towards implementing food storage solutions which require electricity such as cold storage options. Further, the farmers can earn good profit from the sale of their produce and agricultural waste as a fuel source.

Table 53 – Husk Power Systems Case Study

Husk Power Systems[134] – Bihar, India Husk Power Systems (HPS) has installed over 70 mini-power plants that use biomass gasifiers to power rural villages in India, Nigeria and Tanzania. These mini power plants are for off-grid villages or those areas that experience negligible or unreliable power supply. Villagers can make use of the available biomass to generate power. The Power plants are set up using financial subsidies from the Ministry of New and Renewable Energy.	
Technology	Biomass gasifiers using rice husk as fuel
Status	Operational
Capacity	25kW (~400 households)
Costs	Capital cost – USD 25,000[134] HPS charges each household Rs.100 (USD 1.33) for installation charges and charges monthly tariff based on actual usage (for lighting, charging mobile, printing etc.)
Financing	HPS models of operation include: 1. HPS receives a subsidy of USD 7100 to USD 16500[135] for each power plant from MNRE 2. Each household and/or small business pays INR 100 monthly as electricity fees

[134] Ashden Winners – Husk Power Systems
[135] Acumen – Husk Power Systems

	3. BOOM (Build, Own, Operate and Maintain) Model where HPS owns 100% of the plant while doing the entire O&M 4. BOM (Build, Own and Maintain) – HPS installs and owns plant, while a local entrepreneur manages day to day operations and sale of electricity. Local entrepreneur invests INR 200,000 (USD 2600) up front and INR 15,000 (USD 200) per month as maintenance charge for 6 years, post which ownership is transferred to the local entrepreneur.
Purpose	• Famers are compensated for sale of agricultural waste. This additional source of income will deter them from burning crop residue • Having a 25 kW plant replaces the need for 42,000 L of kerosene and 18,000 L of diesel per year. • Employment for local community for O&M activities

The image below shows a typical HPS powerplant -

Source: https://medium.com , accessed on November 29, 2021

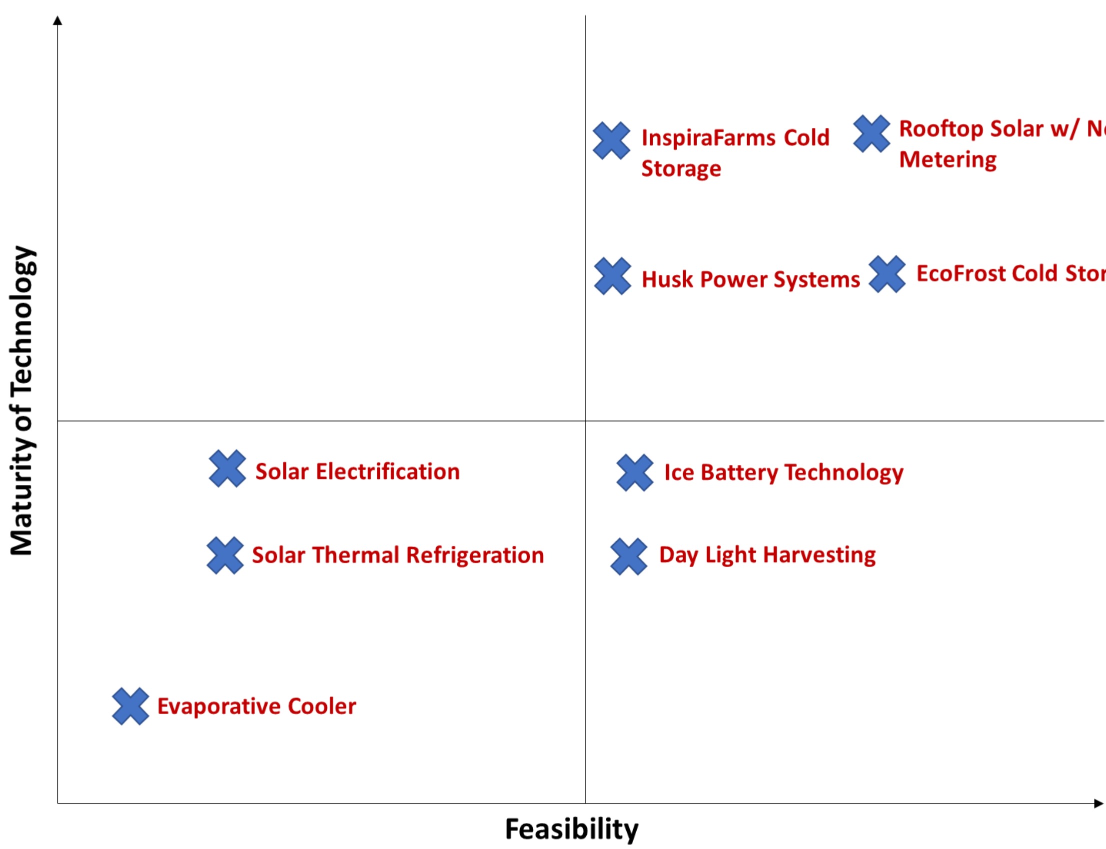
Table 54 - SWOT Analysis for HPS

Strengths	Weaknesses
• Uses agricultural waste and rice husks to power off the shelf turbine to generate electricity	• Risk of electricity theft

• Provides employment to local community • Allows community to be stakeholders in the power plant • Diverts community from burning crop residue • Decentralized power source backed by private company to offer assistance and training	• Risk of community being unable to afford monthly electricity charges
Opportunities	Threats
• Expand into more states • Appeal for more subsidies • Appeal for subsidies which can help HPS power cold storage facilities	• Dependent on agricultural waste

This chapter has discussed numerous centralized and decentralized RE technologies and solutions. These solutions had been detailed keeping in mind the feasibility and benefits for the individual farmer or farmer community. Figure 28 below compares all the technologies based on their feasibility and level of maturity. The layout will be useful for determining which solution would be ideal for a given individual or community in the SAARC Member States.

Figure 28 – Maturity of Technology vs. Feasibility



Each technology has been mapped according to its feasibility and maturity. Feasibility entails both cost and ease of implementation whereas maturity entails how long a technology has been available such that its major faults or problems have been reduced by further development. Decentralized technologies such as InspiraFarms, EcoFrost, CleanTech (Rooftop Solar w/ Net Metering) and Husk Power Systems can be categorized as high maturity and high feasibility. This is because these companies have not only successfully implemented solutions for clients but can also help clients finance these projects based on their needs. Further, these companies have dedicated teams to help clients from enquiry stage to final implementation. InspiraFarms, EcoFrost, CleanTech and HPS offer long-term solutions which help alleviate specific client pain points. Storage related losses are addressed by cold storage solutions (InspiraFarms, EcoFrost) that result in reduced crop wastage and higher profits for farmers. CleanTech and Husk Power Systems provide captive and clean access to electricity in remote locations. Clean tech and HPS solutions can be used for providing access to energy for food storage facilities in villages that don't have grid access. These solutions are ideal for rural farming communities in Afghanistan, Bangladesh, India, Maldives and Pakistan because these Member States produce large quantities of Horticulture crops. Protecting valuable horticulture crops can ensure quality crops reach the market and farmers don't lose profits due to avoidable crop damage and loss.

IceBattery and Daylight Harvesting are relatively newer technologies that have not been implemented as widely as InspiraFarms, EcoFrost, CleanTech and HPS – and therefore are categorized as less mature. These technologies can be considered as reasonably feasible as solutions are easy to implement and the costs vary by the type of requirement. IceBattery solutions range from portable insulation boxes to transportation carts. These would be ideal for rural farmers in Bhutan, Nepal and Maldives to use during transport of fruits and vegetables to the market to reduce food wastage during transportation. Due to the varying geographical spread of these countries, transportation of horticulture crops also leads to high PHL as the vehicles are ill equipped and road connectivity to the market is poor – causing crop damage and loss. Daylight Harvesting technologies will help reduce energy consumption if installed or retrofitted on all food grain warehouses. SAARC Member States with centralized warehouse networks such as Bangladesh, India, Pakistan and Sri Lanka could implement this technology across their existing warehouses along with rooftop solar installations. This could be a positive step towards modernizing the warehousing infrastructure.

Evaporative Coolers, Solar Electrification and Solar Thermal Refrigeration technologies are still in nascent stages – therefore they are all considered the least mature and feasible. Evaporative cooling techniques are economical solutions to keep horticulture crops cool for a few extra days. Evaporative coolers can be made on the farm site using 2 differently sized clay pots or double walled brick layers to create larger chambers to hold larger capacities of crops. These techniques are already being used in India and Afghanistan as they are low-cost solutions to farmers that cannot afford or easily access cold storage facilities. However, evaporative cooling techniques cannot replace cold storage solutions as they are open-air and cannot protect produce from deterioration caused by natural elements. Solar Electrification and Solar Thermal Refrigeration are still in pilot stages as described in Table 43 and Table 44 – while these technologies are not commercial yet, they are viable and have strong potential to be implemented in rural communities with no reliable access to electricity.

This chapter explored the distinctions of renewable power and investigated examples of available and viable centralized and decentralized solutions. RE power sources are an economical and clean source of energy and can positively impact the agricultural sector. Each SAARC Member State has initiated policies and incentives to make RE more affordable and sustainable. The next chapter will consider which types of RE solutions can be applied across each SAARC Member State taking into consideration the country's main crop losses, energy scenario and feasibility of particular RE solutions.

Chapter 5: Conclusion & Recommendations

5 Chapter 5: Conclusion & Recommendations

5.1 Conclusion of Findings

This section will summarize the main findings from each chapter:

Chapter 1 – This chapter introduced the topic and scope of study - the importance of food storage and how renewable energy sources can contribute towards clean and sustainable energy for storage facilities. Annually, ~250 MMT of food is wasted and 30-40% (amounting to ~USD 300 billion) of this food loss occurs in the post-harvest storage stage of the agricultural value chain. The storage related losses primarily stem from inadequate refrigeration and unreliable & expensive energy supply. Moreover, food loss due to inadequate storage has a cascading effect on the income of farmers and the cost of purchase for consumers. Food wastage also heavily contributes to the GHG emissions, which can be curtailed with proper storage solutions.

Chapter 2 – This Chapter focused on the key crops cultivated and main crop storage methods in each SAARC Member State. It was derived that all Member States utilize traditional methods of food storage at the farm-level and managed methods of storage – such as warehouses and cold storage facilities at the central level. The storage related losses can mainly be attributed to:

- Improperly managed storage facilities
- Inadequate central storage capacity
- Lack of awareness of the extent of storage related losses
- Poor storage infrastructure
- Insects, rodents, moisture

Chapter 3 – This chapter introduced the use of energy in agriculture and the energy mix of each SAARC Member State. The Agricultural Sector uses energy directly from fuel or electricity to operate machinery and equipment, temperature control buildings and for lighting the farm area. Horticulture crops should ideally be stored in cold storage facilities whereas, food grains are best stored in temperature and moisture-controlled warehouse facilities. Centralized and/or managed storage systems such as cold storage facilities and warehouses require electricity to maintain crops at optimum levels. Chapter 3's aim was to explain what quantum of storage capacity is needed to avoid food loss in each Member State and how much subsequent energy is required for these facilities.

Chapter 4 – This chapter introduced the distinctions of renewable energy. The chapter briefly described the main types of renewable energy technologies and quantitatively displayed their benefits compared to conventional sources of energy. However, understanding the benefits of RE would be in vain unless other macro factors were taken into consideration such as a Member States policy, incentives and financing options for RE technologies. These are key indicators of how proactively solutions could be considered. Additionally, the electricity tariffs of certain C&I consumers and Agricultural consumers connected to the grid were compared to captive RE users in order to demonstrate how RE technologies can be more affordable. Keeping in mind that most of the population in the SAARC Member States reside in rural areas, alternate decentralized RE technologies were also detailed in Chapter 4.

Chapter 5 will first categorize key areas of intervention for deployment of RE generation for food storage into 4 broad buckets and then provide country wise recommendations based on the specific learnings from chapters 2, 3 and 4.

5.2 Areas of Intervention

This section will detail specific areas that would need to be explored and addressed to implement RE based solutions for food storage in the SAARC Member States. The 4 main categories are elaborated below in Figure 29.

Figure 29 - Main Areas of Intervention

Policy & Regulations: National Policy and Government support are vital in deploying RE based solutions for food storage. A well-designed policy framework can help accelerate the implementation of commercial RE technologies. As identified in Chapter 4, SAARC Member States do have policies and government incentives in place to push renewable energy generation; however, the push for RE in the Agriculture sector is limited.

Each SAARC Member State can identify and establish central and regional policies with clear guidelines and approval paths for each RE technology. More beneficial would be a single central entity for each Member State that can introduce, implement and support existing policies that favor centralized and decentralized RE technologies for the agricultural value chain specifically. The dedicated agencies can also work with the Agricultural and Power Sector to make these sectors more attractive for investors and improve ease of business. Strengthening these sectors and establishing clear policies specifically aimed at the agricultural value chain will help interested parties navigate bureaucratic procedures and obtain necessary approvals from required authorities in an effective manner.

To improve ease of business, tax incentives for involved stakeholders such as financial institutions, corporates, public and private investors, and end consumers can be further developed for RE technologies in the Agricultural Sector. Further, dis-incentivizing or increasing tax on conventional sources of power could also be introduced, as this would promote investment towards RE and discourage investment towards fossil fuels.

The 5 SAARC Member States can also work with countries such as India, Nepal and Bangladesh to understand and implement Net Metering and Open Access policies. This would involve collaboration with the Power Sector of each country to understand the generation, transmission and distribution scenarios and the subsequent tariff structures. Creating a regulatory framework for Net Metering and Open Access can even lead to cross border open access for SAARC Member States. It would greatly benefit nations like Afghanistan and Nepal, that depend on energy imports, by making electricity more accessible and affordable.

SAARC Member States could also introduce policies to remove Agricultural Tariffs, which are heavily subsidized electricity charges for farmers and rural communities that negatively impact the entire power sector. The Agricultural sector receives low quality erratic power supply during odd hours of the day and therefore are charged less than the cost of supply. Further, C&I users must bear the costs to reduce the burden on the utilities. Providing RE based solutions to farmers to meet their electricity requirements can positively impact both sectors. It would also provide farmers with electricity at the time of need.

Lastly, as all SAARC Member States have poor grid infrastructures which result in unreliable power supply to end users, policies to encourage RE technology captive power generation and Open Access mechanisms can be promoted. This will help reduce the tariff burden on C&I consumers.

Energy Transition Solutions for Power Requirement: Most centralized RE technologies such as solar, wind and biomass power projects are relatively mature in terms of R&D and commercialization. Decentralized RE technologies are still nascent and are either not well recognized or remain uneconomical. Most farmers in the SAARC Member States do not have access to reliable electricity and continue to use traditional techniques for farming and post harvesting activities. They might also be unaware of the technological advancements available to ensure efficient farming and crop storage.

The Government could initiate programs to raise awareness and promote modern RE technologies that would enable farmers to store crops more efficiently. Presently only India offers capital subsidies on decentralized RE equipment. Even then, these options are not well known by rural farmers due to lack of awareness or fear of income loss due to adopting a new equipment.

Operational Support: Implementing and operating centralized RE based solutions for food storage such as roof top solar or solar-wind hybrid solutions or decentralized RE based cold storage facilities would be a new venture for many stakeholders. Farmers may not be aware of the social, economicor environmental benefits of using RE based solutions towards agri-based activities. They would also be unaware of how to efficiently use these technologies. Many cold storage facilities have been left unused or underutilized because users are not able to maintain the upkeep and associated costs.

SAARC Member State Government should offer aid for the lifecycle of these RE projects. Assistance could be in the form of regional and local trainers that could help train rural communities to understand the importance of RE based storage facilities and how to efficiently use these facilities. These trainers could help raise awareness, provide operational training, offer financial advice, and troubleshoot issues which could arise before, during and after operation. This would help increase the community's knowledge towards agricultural advancements, provide employment and build community capabilities. This platform could promote knowledge exchange for ideas on new best practices for food storage and preservation.

Financing: There are three models for financing RE projects, as shown in Figure 30.

Figure 30 - Models for Financing a Power Project

Public	Private	Public Private Partnership
• The power project is owned and operated by a government entity. • The project is developed on government owned land. • The project is financed using government funds, grants and subsidies	• The power project is owned and operated by a private company for the entire lifecycle of the project • The project is financed without government investment	• The power project is built and operated by a private company; however, the ownership lies with the government. • The private company leases the power plant from the government and performs the O&M activities • Once the agreement ends, the private company can either renew or relinquish the contract

The three best ways of financing RE projects are 1) private investment 2) SAARC Development Fund 3) Enablers. The goal is to reduce the dependency from government funding and grants.

Despite infrastructure finance investors increasing their investment towards RE, RE projects in developing countries such as the SAARC Member States can be perceived as high-risk investments. Private investors either avoid investments in these countries or ask for high premiums and additional safeguards to protect their interests – issues less prevalent in developed nations. Further, while large scale centralized RE projects can attract private investors and banks to provide financing and credit lines, decentralized RE projects have limited scope to attract these finance options. Given the maturity and proven success of centralized RE technologies for various uses, investors and local companies are more inclined to fund these projects.

As outlined in Chapter 4 Section 4.4, there are numerous international financing agencies such as ADB, WB, IFC etc. that provide loans and grants for RE based projects. The SAARC Development Fund (SDF) could collaborate with these financial institutions to create a fund specifically for RE based solutions for food storage in the SAARC region. This fund could help cover research costs, costs of projects and resource capability building for communities ready to adopt RE based solutions for their food storage needs. Having an internationally backed specialized fund can also accelerate new business models which can activate different types of investors that could finance different stages of the RE projects. Decentralized RE solutions can benefit from business models such as pay-to-use or corporate sponsorship for small-scale RE solutions.

To further de-risk the large-scale investments and make them more bankable, SAARC Member States could offer Sovereign Guarantees[136] to investors. Sovereign Guarantees is an assurance by the government to cover payments in case the primary investor defaults. Achieving financial closure requires risks to be allocated and mitigated in a manner where all stakeholders are happy. In developing countries there are many risks which could arise such as tax, policy or government changes over time or sudden tariff changes. A Sovereign Guarantee is a great way to cover such major risks, however, might be difficult to obtain. Companies such as GuarantCo are funded by the European government and provide credit solutions and structured guarantees to infrastructure projects facing difficulty in obtaining debt financing. GuarantCo primarily operates in Asia and Africa.

The recommendations above are most suitable for large scale RE based solutions. Decentralized RE based solutions provided by InspiraFarms and EcoFrost are funded by private and public investors along with various programs of the World Bank, FAO, USAID and more. They involve global and local financial institutions and CSR departments of corporations to help facilitate loans to their customers. A major hindrance for farmers continues to be navigating the bureaucratic procedures to avail the available subsidies. These companies could also use the help of local and national NGO's and microfinancing institutions to help farmers avail subsidies in a seamless manner by educating them and acting as their knowledgeable proxy when navigating administrative processes.

5.3 Recommendations

This section has country wise recommendations for each SAARC Member State based on the findings from Chapters 2, 3 and 4.

5.3.1 Afghanistan

Table 55 – Recommendations for Afghanistan

	Cold Storage	Warehouse
Existing Storage Capacity	31,000 MT	305,000 MT
Additional Storage Capacity to Avoid Loss	80,000 MT	980,000 MT
Additional Energy Required	1920 kW	2450 kW
Additional Storage Capacity to Meet 20% Storage Target	822,202 MT	876,692 MT
Additional Energy Required	19,733 kW	2192 kW

136 IRENA Renewable Energy Finance: Sovereign Guarantees, 2020

Recommendations:

- Expand cold storage and warehouse capacity on a central level as the current capacity is too low for the existing food production level
- Raise awareness about solar powered cold storage solutions such as Ecozen and Inspirafarms for village communities as Afghanistan exports large quantities of grapes globally. Traditional storage methods such as Kangina's provide limited protection against natural elements. Solar power cold storage rooms can keep the grapes at export quality for long.
- Create centralized warehouse infrastructure for wheat using daylight harvesting technology and decentralized rooftop solar panels, as the grid infrastructure is poor. Current warehouses are only used for emergency purposes and more infrastructure needs to be built to improve food security. Afghanistan has a high solar power potential, so new storage infrastructure should include rooftop or ground mounted solar panels for electricity generation.
- Develop policies for Open Access and Net Metering for commercial, industrial and agricultural end users, as the country does not have these policies in place. These policies can help attract private sector participation to set up RE based power projects in the country.
- Develop and implement incentive mechanisms, subsidies and tax breaks to promote private participation in the power sector. Fiscal incentives to lower equipment and operational costs are crucial for private participation. Current projects, which have been financed by donors, have not been able to run independently.
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

5.3.2 Bangladesh

Table 56 - Recommendations for Bangladesh

	Cold Storage	Warehouse
Existing Storage Capacity	6,000,000 MT	2,162,234 MT
Additional Storage Capacity to Avoid Loss	8,550,000 MT	2,380,000 MT
Additional Energy Required	205,200 kW	5,950 kW
Additional Storage Capacity to Meet 20% Storage Target	Target Achieved	9,749,508 MT
Additional Energy Required	Not Applicable	24,374 kW
Recommendation:		

	Cold Storage	Warehouse

- Educate farmers on how to efficiently store pulse crops at the farm-level, as current methods are inefficient and lead to food loss.
- Upgrade the quality of existing and outdated central warehouses to prevent avoidable food loss and install net-metered rooftop solar panels.
- Create new warehouse infrastructure using net-metered rooftop solar panels and retrofit existing warehouses. Bangladesh has Open Access polices which means unused electricity from the rooftop solar panels can be sold to the grid for additional revenue.
- Install new net-metered solar power cold storage facilities at the central level, as the current storage fleet will not be able to accommodate the growing food production supply.
- With the high number of planned RE projects; Bangladesh can work towards modernizing existing grid network to main grid stability. Further, Bangladesh can work towards expanding the grid infrastructure across the country so that 97 million people can have access to reliable electricity.
- Promote decentralized mini biomass fueled power plants, such as the HPS power plants, for those rural areas without grid connectivity and high agricultural waste. While the grid infrastructure expansion is underway, communities will still have access to electricity from the mini power plant.
- Initiate and implement improved tariff structures/ tariff models for all sources of power including hydro, solar and wind power to attract private investors to set up RE projects. State owned utility companies are suffering financially, and the energy sector has failed to attract private investors due to poor pricing models – this has further expanded the ongoing energy crisis.
- Advance existing policies for Open Access and Net Metering for commercial, industrial and agricultural end users. This along with well-defined tariff structures will promote private investment into RE based projects, including ones aimed for agriculture.
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions

5.3.3 Bhutan

Table 57 - Recommendations for Bhutan

	Cold Storage	Warehouse
Existing Storage Capacity	-	19,000 MT
Additional Storage Capacity to Avoid Loss	11,000 MT	15,000 MT
Additional Energy Required	264 kW	38 kW
Additional Storage Capacity to Meet 20% Storage Target	25,102 MT	1,501 MT

Additional Energy Required	602 kW	4 kW

Recommendation:

- Build cold storage facilities on a central level, as the country has no known cold storage facilities.
- Develop community wise warehouses for groups of farmers to store Maize efficiently. Since the country has an uneven geographical spread – decentralized solar or small hydropower warehouses can be built to power these storage facilities.
- Promote solar refrigerators and solar powered cold storage for horticulture crops for farmers in remote locations to preserve mandarin and apples effectively.
- Promote the installation of modular biomass power plants for small rural communities where solar potential is low and agricultural waste is high. Biomass power plants can power cold storage facilities and warehouses.
- Promote Ice Battery technology that can be used when transporting fruits from the farms to the markets as poor transport vehicles contribute to avoidable food loss in the fruits.
- Merge Bhutan Sustainable Hydropower Development Policy 2008, Alternative Renewable Energy Policy, 2013 and 5-year renewable energy master plan to develop a single comprehensive RE master plan with actionable targets and clear policies and incentives.
- Develop policies for Open Access and Net Metering for commercial, industrial and agricultural end users. This will attract private investors to set up RE based solutions, including solutions for agriculture.
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

5.3.4 India

Table 58 - Recommendations for India

	Cold Storage	Warehouse
Existing Storage Capacity	37,500,000 MT	81,796,000 MT
Additional Storage Capacity to Avoid Loss	9,490,000 MT	4,260,000 MT
Additional Energy Required	227,760 kW	10,650 kW
Additional Storage Capacity to Meet 20% Storage Target	19,196,738 MT	Target Achieved
Additional Energy Required	460,722 kW	Not Applicable

	Cold Storage	Warehouse
Recommendation: • Collaborate with FCI to implement RE based solutions towards existing and future warehouses across the country. Daylight harvesting technology can be retrofitted into existing warehouses to reduce current energy consumption. Net-metering rooftop solar can be installed on planned warehouses. • Collaborate with NCCCD to implement RE based solutions towards existing and future cold storage facilities. Cold Storage facilities consume a large amount of energy as they operate round the clock. RE based solutions will be economical and sustainable. • Promote captive RE powered warehouses in areas where warehouses are planned or located in remote locations. Captive power generation can supply power to a cluster of warehouses and cold storage facilities in a clean and sustainable manner. Any excess power can also be sold back to the grid, generating additional revenue. • Aggressively push towards educating horticulture farmers on solar powered cold storage. India has different capacity cold storage rooms by Ecozen, which can benefit one farm or a group of farms. EcoFrost is economical as users can avail a series of government (central and state) approved subsidies. However, administrative barriers when trying to avail government subsidies need to be streamlined so that farmers are not discouraged from trying to use new technology. • Increase spends towards R&D or initiate incentives for the advancement of decentralized renewable energy solutions in the agricultural sector and modernize existing grid infrastructure to accommodate planned RE projects • Increase efforts towards public private collaborations for solutions in the agricultural sector. India can reduce dependency on international financier programs and develop traction for corporate investment • Update Net Metering polices to remove limitations on user categories (some states only allow residential and agricultural users) and remove grid support charges • Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain • Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale. • Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.		

5.3.5 Maldives

Table 59 - Recommendations for Maldives

	Cold Storage	Warehouse
Existing Storage Capacity	-	-
Additional Storage Capacity to Avoid Loss	-	-
Additional Energy Required	-	-
Additional Storage Capacity to Meet 20% Storage Target	718 MT	-
Additional Energy Required	17 kW	-

Recommendation:

- Educate farmers on modern farming methods and RE based storage solutions. Farmers continue to use traditional methods of farming due to lack of knowledge and inaccessibility to modern farming technologies.
- Promote RE based solar solutions on islands leased for agricultural purpose. Decentralized solar powered cold storage rooms can be used for preserving horticulture crops.
- Promote decentralized mini biomass fueled power plants for islands leased for agriculture so that farmers can mechanize their farming processes.
- Promote Ice Battery Technology for transporting horticulture crops from leased agriculture island to the markets. Most horticulture crops deteriorate in quality during transportation.
- 2016 Maldives Energy Policy and Strategy does not have clear quantifiable targets or incentives. Develop a comprehensive policy for decentralized RE solutions for various sector needs. RE policies should be detailed sector and technology wise.
- Develop policies and well- defined incentives for private investors to enter and improve the power sector. Detail a clear process path for private companies entering the market to avoid inefficiencies when seeking government approvals.
- Collaborate with international financiers or other private sector companies to develop RE based solutions for assigned agricultural islands
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

5.3.6 Nepal

Table 60 - Recommendations for Nepal

	Cold Storage	Warehouse
Existing Storage Capacity	105,000 MT	160,000 MT
Additional Storage Capacity to Avoid Loss	2,840,000 MT	760,000 MT
Additional Energy Required	68,160 kW	1,900 kW
Additional Storage Capacity to Meet 20% Storage Target	1,737,390 MT	2,035,116 MT
Additional Energy Required	41,697 kW	5,088 kW

Recommendation:

- Build additional warehouse and cold storage capacity to accommodate growing food production demand. The current capacity for both facilities is very low.
- Promote solar powered cold storage facilities at the central level and community level where solar potential is high. Village level storage for horticulture is extremely inefficient and leads to high storage related losses. In areas where solar potential is low, mini hydro power plants can be built to generate electricity for cold storage facilities.
- Promote modular biomass power plants for rural communities with poor grid network access and high agricultural waste. Biomass power plants can power cold storage facilities and warehouses.
- Develop policies for Open Access and Net Metering for commercial, industrial and agricultural end users. Cross Border Open Access policies should be developed as Nepal imports electricity to meet the nation's energy demands.
- Develop well defined policies and incentives for the private sector to invest in hydropower as Nepal has vast untapped hydro power potential
- Invest in R&D projects for pico (upto 100 kW) and small (<2 MW) hydropower plants for the rural community and small farmer holders to provide them with access to electricity
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

5.3.7 Pakistan

Table 61 - Recommendations for Pakistan

	Cold Storage	Warehouse
Existing Storage Capacity	Not Quantified	2,980,000 MT
Additional Storage Capacity to Avoid Loss	6,440,000 MT	2,440,000 MT
Additional Energy Required	154,560 kW	6,100 kW
Additional Storage Capacity to Meet 20% Storage Target	3,218,459 MT	5,790,402 MT
Additional Energy Required	77,243 kW	14,476 kW

Recommendation:

- Build additional warehouse capacity for wheat, and install net-metered rooftop solar panels and day light harvesting sensors to reduce the energy consumption
- Build large capacity central cold storage facilities as the country numerous stand-alone low capacity facilities in major cities. Horticulture crops face high post-harvest losses due to lack of efficient and nearby storage solutions.
- Encourage rural farming communities to use RE based cold storage solutions, such as InspiraFarms and EcoFrost for their horticulture crops to avoid food loss. Small land holders unable to afford these storage solutions despite subsidies can be made aware of evaporative cooling technology solutions or IceBattery Solutions.
- Educate farmers on efficient storage methods of wheat at the farm-level to prevent avoidable losses. Wheat is a cash crop for the nation and predominantly stored at the farm-level. Loss due to poor storage can affect the income of farmers.
- Fit new or planned wheat warehouses with net-metered rooftop solar installations and have daylight harvesting technology to reduce energy consumption/ maximize the use of natural light.
- Develop policies for Open Access for commercial, industrial, and agricultural end users.
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

5.3.8 Sri Lanka

Table 62 - Recommendations for Sri Lanka

	Cold Storage	Warehouse
Existing Storage Capacity	1,000 MT	323,700 MT
Additional Storage Capacity to Avoid Loss	670,000 MT	280,000 MT
Additional Energy Required	16,080 kW	700 kW
Additional Storage Capacity to Meet 20% Storage Target	333,181 MT	643,881 MT
Additional Energy Required	7,996 kW	1,610 kW

Recommendation:

- Build additional warehouse and cold storage capacity to accommodate growing food demand. The country has negligible cold storage facilities to properly store horticulture crops. Village storage methods lead to high avoidable horticulture losses.
- Collaborate with central storage facilities such as PMB to integrate RE based technologies and net-metered rooftop solar installations for their storage facilities. Due to adverse weather conditions that create unpredictable water availability for hydro plants, Sri Lanka can actively work towards a diverse RE technology portfolio.
- Promote solar powered cold storage facilities at the central level and community level. Sri Lanka has been facing numerous energy crisis scenarios; therefore, food storage facilities should be decentralized. Captive RE power generation sources can generate power for large-scale storage facilities round the clock.
- Modernize and weatherproof the existing grid infrastructure to avoid long lasting electricity blackouts
- Promote modular biomass power plants for rural communities that have poor access to the grid network. Through this they are not dependent on unreliable power supply.
- Develop policies for Open Access and Net Metering for commercial, industrial and agricultural end users. These policies will help Sri Lanka import power during grid inefficiencies and attract private investors to help set up RE based solutions across sectors, specifically for the agricultural sector.
- Formulate and deliver effective awareness campaigns to educate the agricultural sector about RE based solutions along the agricultural value chain
- Develop well-defined agricultural policies, which detail how to increase food storage capacity for Horticulture and Food Grain crops in a cost effective, sustainable and environmentally friendly manner on a national scale.
- Collaborate with private companies or investors to develop nodal agencies that can educate farmers on efficient and sustainable storage methods at the farm-level. These agencies can further help farmers on how to avail financing if required to deploy decentralized RE storage solutions.

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Thank You

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