THE KIGALI COOLING PLAN STRATEGY FOR SRI LANKA

Ministry of Environment

Government of Sri Lanka

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For
National Ozone Unit
Ministry of Environment
Government of Sri Lanka
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List of Acronyms

AC	-	Air Condition
AHU	-	Air Handling Unit
ASHRAE	-	Association of Heating Refrigeration and Air Condition Engineers
BAU	-	Business As Usual
BMS	-	Building Management System
CBSL	-	Central Bank of Sri Lanka

CBD	-	Convention of Biological Diversity
CEA	-	Central Environment Authority
CEB	-	Ceylon Electricity Board
CFC	-	Chlorofluorocarbon
CR	-	Commercial Refrigeration
DX	-	Direct Expansion
EO	-	Environment Officer
EPL	-	Environment Protection License
EV	-	Electric Vehicle
FAO	-	Food and Agriculture Organization
FCU	-	Fan Coil Unit
GDP	-	Gross Domestic Product
GHG	-	Greenhouse Gas
GWP	-	Global Warming Potential
HC	-	Hydrocarbon
HCFC	-	Hydrochlorofluorocarbon
HFC	-	Hydrofluorocarbon
HFO	-	Hydrofluoroolefin
HVAC	-	Heating Ventilation and Air Conditioning
IOT	-	Internet of Things
K-CEP	-	Kigali - Cooling Energy Programme
MAC	-	Mobile Air Conditioning
MLF	-	Multilateral Fund of the Montreal Protocol
MP	-	Montreal Protocol
NCP	-	National Cooling Plan

NDC	-	Nationally Determined Contributions
NIK	-	Not in Kind
NOU	-	National Ozone Unit
NVQ	-	National Vocational Qualification
ODP	-	Ozone Depleting Potential
ODS	-	Ozone Depleting Substances
PA	-	Paris Agreement
PCM	-	Phase Change Material
PEC	-	Presidential Expert Committee
RAC	-	Refrigeration and Air Conditioning
Ref.	-	Refrigeration
RPL	-	Recognition of Prior Learning
SDG	-	Sustainable Development Goals
SEA	-	Sustainable Energy Authority
SLTDA	-	Sri Lanka Tourism Development Authority
TOT	-	Training of Trainers
TR	-	Tonnes of Refrigeration
TVEC	-	Tertiary Vocational Education Training
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
UNIVOTEC	-	University of Vocational Technology
USD	-	United States Dollar
VRF	-	Variable Refrigerant Flow
VRV	-	Variable Refrigerant Volume

Executive Summary

Context

Development of the Kigali Cooling Plan Strategy for Sri Lanka has been a multi-stakeholder consultative process that addresses cooling demand and energy efficiency improvements in Sri Lanka linking all relevant sectors. An action plan integrated with recommendations has been developed to address current and future cooling demands through refrigerant transition, energy efficiency improvement, use of renewable energy sources and improved regulatory framework. The cooling plan provides a set of recommendations with a time frame to achieve energy targets related to the cooling sector in Sri Lanka. The sector-wise cooling demand for 18 years (2020-2038) has been projected considering the growth of population, the economy and the other driving factors.

The reference scenario of cooling demand for the period of 2020-2038 is projected assuming that the current trend will continue to be affected by the main driving factors including income level, population growth and Gross Domestic Production (GDP). The intervention scenario is explored assuming that future cooling demand will be impacted by policy interventions, energy efficient strategies and energy saving refrigerant transitioning systems aligned with Kigali amendments of the HFC phase down programme.

The population growth in Sri Lanka is on the rise. Industrial and service sectors have considerably been contributing to the growth of GDP over the recent years. The following figure indicates the sector-wise share of total energy consumption over the period from 2012-2017. The share of industry has been steadily increasing over the period.

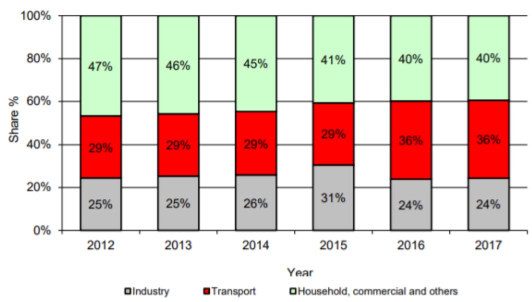


***Figure A*. Share of energy consumption 2012-2017 (Draft CEB generation plan, 2019)**

Consumption of refrigeration and air-conditioning equipment in Sri Lanka has been increasing progressively, leading to substantial growth in energy demand. The cooling related energy demand is projected to increase due to population growth, urbanization, enhanced income level and increasing ambient air temperature. The action plan encompasses ways and means to guide the use of energy in a sustainable manner. Moreover, in order to provide sustainable cooling and thermal comfort the following strategies are emphasized: short (1-3 year), medium

(3-5 years) and long (more than 5 years) term recommendations are made to achieve sustainable cooling objectives via these cooling efficiency strategies.

1. Recognition of cooling related sectors and sector-wise cooling demand.
2. Reduction of cooling related energy demand via energy efficiency measures, low energy cooling technologies and renewable energy based applications.
3. Policy interventions to enhance the use of renewable energy to address cooling related energy demand and technological and market transition to energy efficient, low Global Warming Potential (GWP) Refrigeration and Air-conditioning (RAC) equipment and refrigerants.
4. Training of technicians on energy efficient alternatives and good refrigeration practices, minimizing energy loss.
5. Focusing on research and development and identification of knowledge gaps pertaining to use of indigenous knowledge in cooling related processes, especially in designing buildings and food conservation.
6. Identification of policy gaps related to sustainable use of energy. These include policy issues that address synergistic actions to achieve cooling targets linking all sectors including food, agriculture, health, transport, electricity *etc*.

Cooling demand: Sector Highlights

The growth of cooling demand is explored sector-wise using the reference and intervention scenario. The projection is made up to 2038 and pro-active measures are recommended to achieve cooling related energy reduction targets.

Space Cooling

Space cooling is a major sector in the total cooling requirement of Sri Lanka. Details of heat transferring into buildings, space cooling technologies, Sri Lankan building stock, cooling demand and strategies to energy saving are discussed in this chapter.

Unitary type air conditioners constituted the dominant share of the Sri Lankan space cooling sector. Of all the residential buildings, around 5% - 7% use air conditioners. The residential sector is likely to be the leading driver for growth of air conditioners in Sri Lanka due to economic growth, global warming and heat island effect *etc*.

Optimization of the cooling demand in the space cooling sector of new buildings is the best practice because a large portion of cooling demand is yet to come. Designing buildings with passive cooling technologies, improvement of cooling equipment efficiency, and improvement of operations and maintenance practices can save more than 30% of future energy consumption.

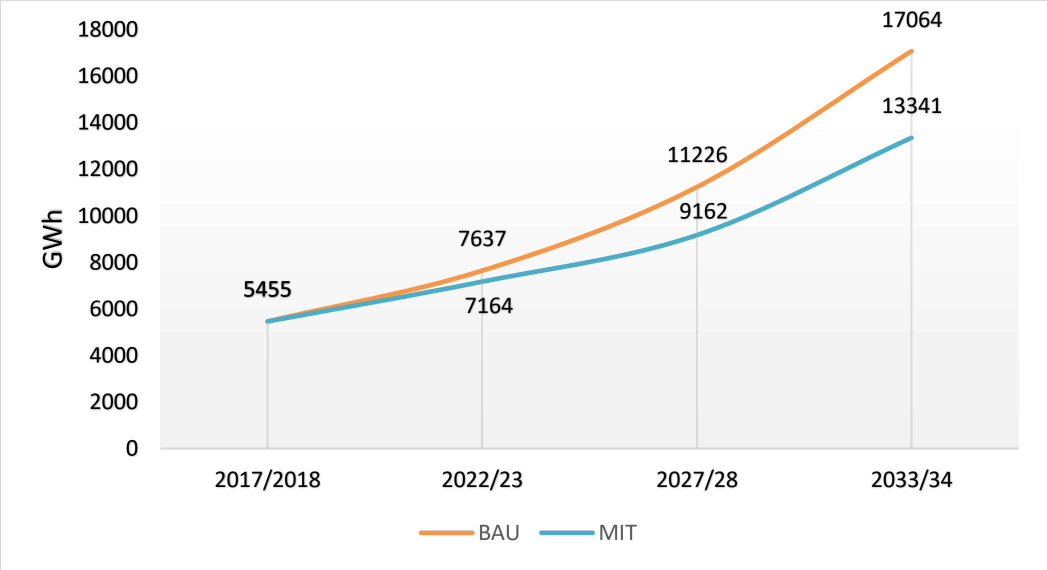


Figure B. **Projected annual energy consumption BAU and Intervention scenario in space cooling in buildings. (Source: Annex 2 Table F)**

Cold Chain & Refrigeration

The cold chain industry in Sri Lanka is still at a developing stage. Despite the large production of perishable produce, the cold chain potential remains untapped due to high initial capital investment for land, cold storages, and auxiliary refrigeration facilities. High cost of electricity, unavailability of skilled manpower, inefficient handling of perishables and financing options impact the industry adversely. Cold chain refrigeration is a highly fragmented industry and needs urgent attention to develop a national policy on cold chain. Sri Lanka has a fairly large number of cold storages or refrigerated warehouses for dairy, fisheries, poultry, and meat, but the other elements that make up an uninterrupted cold chain, such as pack houses and ripening chambers, are largely missing. However, the increase in demand for fresh produce, meat and perishable packaged foods is leading to a significant growth in this sector, which is increasingly relying on sustainable cold chain networks.

Projection shows that active intervention can reduce cooling energy requirement by 5-12% in year 2032-2033 for dairy, fisheries, and poultry over the current baseline. However, in the retail sector, the energy saving potential would be around 10– 15% during the same period. Energy consumption scenarios are highlighted in Figures C and D.

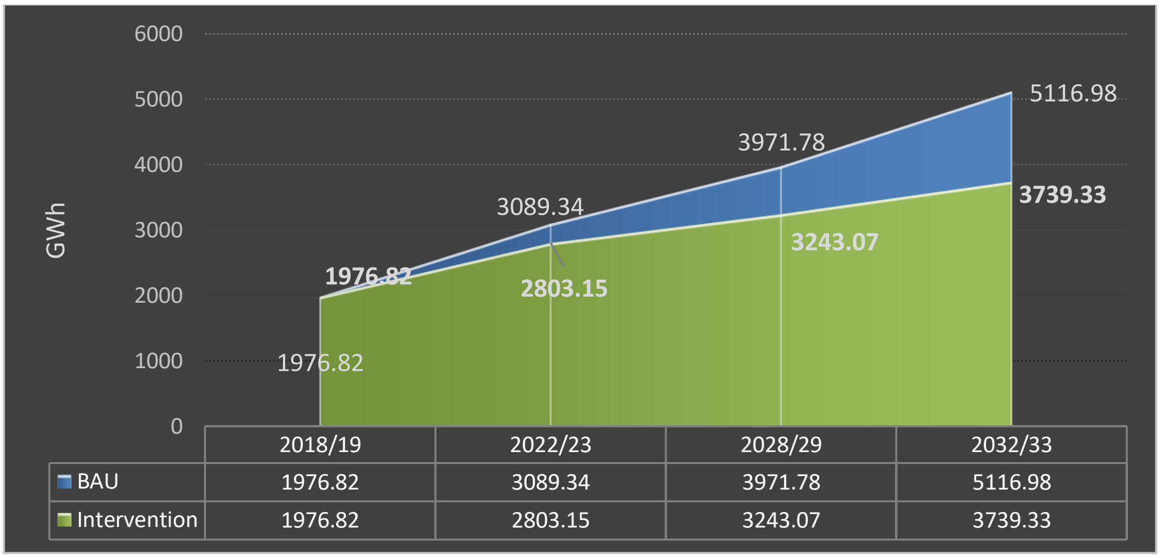


Figure C. **Annual Energy Consumption BAU and scenario intervention**

In this context, appropriate policy and regulatory measures are recommended to improve equipment energy efficiency and replace outdated refrigeration systems with new energy efficient refrigeration systems.

Transport Sector

The vehicle population in Sri Lanka over the last few years has considerably increased mainly due to the influence of economic growth, increase of individual income, population growth and rapid growth of highway road systems. Scenarios indicate that the projected motor car, bus, dual purpose vehicles population of Sri Lanka will reach up to nearly 2.2, 0.3 and 1.2 million respectively by 2037-38.

The main refrigerants used for mobile air conditioners and transport refrigeration include HCFC-22, HFC-134a, R-404A and R-507A.The reference scenario indicates that the total refrigerant demand in the transport sector is expected to increase, and the intervention scenario suggests that, through pro-active measures, the total demand can be reduced. These measures include implementing good practices, enhancing awareness/training programmes for technicians in the RAC sector and introducing improved technological interventions.

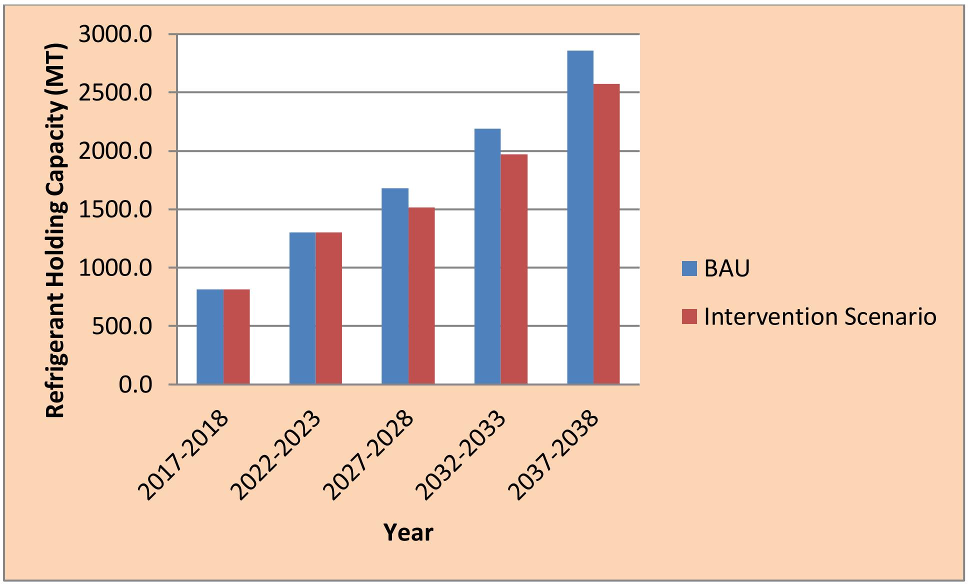


***Figure D*. Projected refrigerant holding capacity in transport sector** [*]

**Projections were reached, analysing each category of vehicle in number and related holding capacity as per the vehicle manufacturers manual.*

Refrigeration and Air-conditioning (RAC) sector

RAC service sector plays a leading role in development of any country. National cooling plan has to address a high portion of energy consumed by RAC sector in residential and commercial buildings. Sri Lanka has been using HFC-134a and HCFC-141b in refrigerator manufacturing sector. However, HC based refrigerant (HC-600a) and Cyclopentane are used at present in domestic refrigerator manufacture sector. AC demand in Sri Lanka is met by imports which are working with refrigerant R-410A, HFC-32. The higher capacity RAC equipment imported to the country are working with refrigerants such as HFC-134a, R-410A, R-507, R-407C, R-404A, *etc*. Technicians needed for the service sector are trained at the institutes regulated by the Tertiary Vocational Education Commission (TVEC). RAC service sector workshops are operating throughout the country (around 100 in the formal sector and 3000 in the informal sector).

As the economy of the country is growing, it is imperative that the air-conditioning and refrigeration servicing sector also grow and needs to strengthen its quality of delivery. This in turn implies that the mean performance of technicians ought to grow to deliver higher quality service. An understanding of current status is useful for better planning for the future.

Refrigeration and air conditioning servicing sub-sector is mainly responsible for the refrigerant consumption in Sri Lanka. Therefore, skilled personnel are needed for installation and servicing RAC equipment and thus training of RAC service technicians are so important. The new alternative refrigerants will be coming into the market while phasing out HCFCs. Most of them are either mildly flammable or flammable and the technicians need to be trained on their safe handling. At present around 40-50% of the service technicians are in the informal sector. Future training of informal RAC technicians on Good Practices in Refrigeration is essential to avoid occupational hazard as well as for customer safety. Therefore, the future trend of the RAC service sector will be based on safety and enhanced work performance.

Indigenous Knowledge and Research: Cooling and Refrigeration

Indigenous concepts respect the principals of sustainability leading to the gaining of socio-economic and environmental benefits, while minimizing potential consequences. Sri Lanka has a long history of indigenous knowledge evolved over the centuries. Traditional methods have widely been used in sound decision making in the use of natural resources and ecosystem management.

Ancient farmers in Sri Lanka have been using traditional practices of food production and preservation methods, which have been tested over the long period. Sri Lanka has had long architectural traditions in harmony with nature, dating back from the period of ancient kings, which have been steadily influenced by different cultural aspects. During the past few years, professionals in Sri Lanka involved in building construction have considerably focused on sustainable issues pertaining to energy efficiency, climate benefits, and sustainable use of resources and minimizing waste generation, holistically based on green building principles. Most of the conventional buildings consume significant amounts of energy. This has been recognized by the modern architecture, and therefore, sustainable energy measures are considered in designing new buildings and renovation of old buildings. Natural lighting and ventilation are the most important aspects of traditional or vernacular architecture that need to be learned from history in designing energy efficient buildings utilising modern architecture.

Although the demand for green building is on the rise, field –based evidence to prove their feasibility is poorly understood. This emphasizes the necessity of multi-disciplinary research focused on natural ventilation, use of natural materials, use of renewable energy *etc*. The cooling plan provides recommendations pertaining to the use of indigenous knowledge to achieve energy consumption reduction targets in a sustainable manner. More research is needed to analyze the traditional or vernacular architecture that existed in the past, and the future use of these techniques to achieve sustainable energy benefits. Even though Sri Lanka is blessed with multiple renewable energy sources, which are largely used, their application for energy generation has not been harnessed to their full potential. Therefore, further research is encouraged to explore their technical and socio-economic feasibility.

Chapter 1

1. Introduction

1.1. Background

Sri Lanka is an island located in the northern Hemisphere between 6^0-10^0 North Latitudes and between 80^0-82^0 East Longitudes with a land area of about 65,000 sq. km (6.5 million hectares), and is positioned on the far southern edge of the Indian subcontinent in south-central Asia. Based on the elevation and salient landforms, the country can be divided into five topographical regions. These are: central highlands, South-West lowlands, East and South-East lowlands, North and North-Central lowlands, and the coastal fringe lowlands. Since its geographical positioning is closer to the Equator, the country receives ample sunlight throughout the year resulting in hot and humid climate conditions.

The average yearly temperature of the country ranges from 28°C to 32°C. The mean annual temperature manifests largely homogeneous in the lowlands but rapidly decreases with elevation resulting in colder climates in the highlands. Higher temperatures are experienced generally in the Northern, North-Central and Eastern regions of the Island, ranging from 33.3°C to 34.7OC. The average pattern of climate in a given local area could be determined by the variations in precipitation via South-West monsoon, North-East monsoon and two inter-monsoons in between. Sri Lanka's mean annual rainfall was reported to be 1850 mm that would range from 900 mm to 5000 mm.

The Sri Lankan history dates back more than 2500 years in coexistence with nature, where utilization of natural resources was sustainable. Population of Sri Lanka consists of different ethnic groups with diverse cultural and religious backgrounds.

Sri Lanka is a democratic socialist republic and a unitary state governed by the Central Government. For administrative purposes, the country is divided into 25 districts. The Government's district administration is coordinated via district secretariat. This structure has been further divided into 328 divisions managed through respective divisional secretariats. The smallest unit of government's representation has been the aggregation of a few villages into *Grama Niladari* divisions administrated at the divisional secretariat level. The 13th amendment adopted in 1987 established 09 provinces with specific administrative powers that are generally composed of 2 to 4 districts. These provinces have been subdivided into local governments that comprises of 12 municipal councils, 51 urban councils and 257 divisional councils (*Pradeshiya Sabha*) in order to maintain public utilities in respective localities.

A total population of 21,670,000 has been reported during 2018, where, Urban, Rural and Estate population have been represented by 18.2 %, 77.4% and 4.4% respectively (Department of census and statistics 2018)

The country's economy: Gross Domestic Product (GDP) grew to its peak by 9.1% in 2012 since Independence and to the most recent low at 3.2% in 2018. The per capita GDP grew from USD 3,351 of 2012 to USD 4,102 of 2018. The Central Bank of Sri Lanka (2018) reported that the GDP was contributed to by 7.0% agriculture, 26.1% industry, 57.7% services, and 9.2% taxes less subsidies on products.

The income increase is correlated to urbanization. The household average per capita income of Rs.11,819 in 2012 grew to Rs.16,377 per month in 2016 with an increase by 39% with the change of lifestyle and pattern (Central Bank of Sri Lanka 2018).

The economy of Sri Lanka has been transitioning from a rural-based agrarian economy to a manufacturing and service oriented urbanized economy. Industrial export has shown a steady growth over the last few years and is expected to accelerate further. Industries and related service sectors have increasingly become a viable source of employment and income in both urban and rural areas. There has also been progress in promoting industrial and service sectors while improving environmental management, urban development, and natural resource management. With regard to GDP by economic activities, contribution by industries and service sectors have been represented considerably higher over the recent past (Central Bank 2018).

The change in lifestyle and growth of both industrial and service sectors require more cooling of the living, working and manufacturing spaces. Refrigeration and Air Conditioning demand in Sri Lanka is driven by population growth and socio-economic and environmental factors. Since Sri Lanka is a country with hot and humid climatic conditions, the popularity for use of air conditioning equipment is on the rise. The trend for higher air conditioning demand is triggered due to growth of the population and rise in income level.

1.1.1 Overview of Refrigerant Import and Consumption in Sri Lanka.

Sri Lanka does not produce refrigerants and therefore consumption relies only on imports. With regard to Ozone Depleting Substances (ODS) consuming sectors in Sri Lanka, the majority is contributed by refrigeration and air-conditioning while foam and aerosol sectors represent considerably less. The types of air-conditioners include, room (residential) air-conditioning, commercial air-conditioning, central air-conditioning, variable refrigerant flow (VRF) systems and mobile air-conditioning. With the phasing out of Chlorofluorocarbons (CFCs) in the early 2000s, Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) have been increasingly consumed in domestic and commercial cooling. These have low or zero Ozone Depleting Potentials (ODP) but significantly contribute to global warming by acting as Greenhouse Gases (GHGs). The most widely used HFCs in Sri Lanka include HFC-134a, R-404A, R-407C, R-410A, R-407C, HFC-152a. These are found to be having a higher Global Warming Potential (GWP) over the 100-year life cycle of the chemical.

Table 1.1. Widely used refrigerants, and their Global Warming Potentials (GWPs)

Refrigerant	GWP	Application
HFCs		
HFC-134a	1430	Domestic, commercial and industrial refrigeration, Mobile Air conditioning, Central AC, Transport refrigeration
R-404 A	3922	Commercial and industrial refrigeration
R-4O7C	1770	Commercial and industrial refrigeration
R-410A	2088	Unitary Air conditioners
R-507	3985	Industrial and transport refrigeration
HFC-125	2800	Fire suppressor
HCFC-22	1810	Domestic, commercial and industrial refrigeration, Mobile Air conditioning, Central AC, Transport refrigeration
Ammonia (R 717)	0	Extensively used in ice production plants, food processing, freezing and cold storages.
HC-600a	Very low	Domestic Refrigerant

1.1.2. Overview of Sri Lanka future power generation

The Sri Lankan government is aiming for an energy self-sufficient nation by 2030. The objective is to increase the power generation capacity of the country from the existing 4,043 MW to 6,900 MW by 2025 with a significant increase in renewable energy. Sri Lanka has already achieved a grid connectivity of 98 percent, which is relatively high by South Asian standards.

Electricity in Sri Lanka is generated using three primary sources: thermal power (which includes coal and fuel oil), hydropower, and other non-conventional renewable energy sources (solar power and wind power etc.). From 2018- 2037, Sri Lana's plans to add power generation is presented in Fig 1.1.

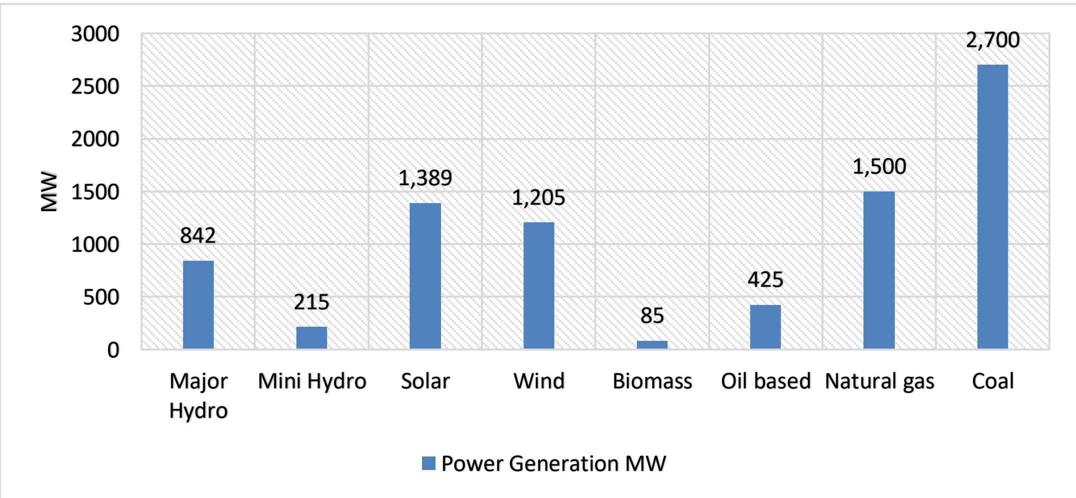


Figure 1. 1. **Power generation plan 2018-2037 (Source : http://www.ceb.lk)**

Having pledged to use only renewable energy resources by the year 2050 at the 22nd UNFCCC Conference of Parties in Marrakech, Morocco, as part of the Climate Vulnerable Forum, Sri Lanka is slowly yet steadily navigating towards introducing renewable energy resources other than hydropower to its energy landscape.

When electrical energy is generated in thermal power stations, there is an emission of CO_2. Hence, it is estimated that the implementation of these programs will allow the generation of more than 1,350 GWh of renewable energy avoiding more than 1.08 million MT of CO_2 emission to the atmosphere.

1.2. Addressing Cooling Demand

Increasing global temperature associated with global factors and rapid urbanization combined with economic growth is greatly expected to enhance the cooling demand. Ambient temperature rise, population growth, urbanization and increase of income levels are the main influencing factors that cause the increase in cooling demand and high energy consumption. UNEP (2018) reported that the number of air conditioners used in the world will increase 1.5 billion to 5.5 billion units between 2015 and 2050. As cooling demand grows further, Refrigeration and Air Conditioning (RAC) equipment consumption puts a considerable stress on the power sector. It is expected that an increase of cooling demand in hot, populous countries would tremendously impact peak electricity demand.

Refrigeration and air conditioning equipment and services are widely used in the country ranging from household (refrigerators and room air conditioners) to commercial and industrial operations (building air conditioners /chillers) that cumulatively represent a considerable segment of energy consumption. RAC equipment population has increased drastically during the recent past, leading to a substantial increase in energy demand (Sri Lanka Customs 2016). The cooling demand of a country highly depends on ambient temperature and humidity level; therefore, a significant increase in cooling demand is expected in Sri Lanka as well.

The Global demand for energy is rapidly increasing and the world faces twin challenges related to energy generation and consumption: expanding energy generation opportunities to meet increasing demand and addressing environmental related pressure. Global warming is intrinsically correlated with global energy consumption, mainly produced by fossil fuel base. Therefore, energy generation strategies are vital in terms of securing environmental benefits and in the fight against global warming.

Energy consumption for RAC sector shows a significant increase in compliance with rapid growth of economic sectors and associated social and lifestyle changes in the society. On the other hand, the energy requirement in the country is expected to increase drastically in future due to rapid growth in tourism and accommodation units, housing and construction industry building condominiums, industries catering manufacturing and provisions of services.

Refrigeration and air conditioning are cooling related energy consuming sectors that are significantly demanding a considerable portion of energy generation. Typical air conditioning units use fluorocarbon refrigerants as a coolant, which can have a direct negative impact on the environment if the coolant is leaked during maintenance and repairing or at the end of usage. The RAC equipment considerably utilizes high energy and significantly contributes to global warming as a source of greenhouse gas, when HFCs are leaked into the atmosphere, due to its Global Warming Potential (GWP). Indirect contributions include atmospheric GHG emissions during the process of electricity generation, where fossil fuel combustion led to eventual CO_2 emissions to the atmosphere. Both direct and indirect contributions can have significant impacts on increasing emissions of GHGs that could consequently add to the warming of the atmosphere.

1.3. National Cooling Plan (NCP)

The specific objective of developing a national cooling plan for Sri Lanka is to achieve energy efficiency, and to succeed in HCFC phase out and HFC phase-down strategies, thereby reducing direct and indirect GHG emission. Moreover, the cooling will integrate with existing climate resilient energy generation and sustainable development plans of the country. The NCP can benefit the country via improved energy efficiency for businesses and consumers.

The NCP will explore more sustainable energy systems, clean air opportunities and other additional benefits in terms of food waste, improving health, and increasing productivity through improved access to cooling aligned with Sustainable Development Goals (SDG) Good health well-being (SDG- 3), Decent work and Economic growth (SDG- 8), Sustainable cities and communities (SDG-11), Climate action (SDG-13) and, especially, on Affordable and clean energy (SDG-7), ensuring the access to affordable, reliable and modern energy for all. Sri Lanka has to identify and prioritize energy efficiency measures, particularly based on renewable and indigenous resources of the country to meet energy supply, to be responsive to increasing demand while enhancing climate benefits. The NCP provides an overview of the cooling requirement of the country in current context, future perspectives, and recommendations towards achieving sustainable cooling solutions.

1.4. Need of Cooling Plan for Sri Lanka

Statistical analysis reveals that the air temperature over a period of more than 100 years has shown a significant increase over the entire Island, particularly during the period of 1961 - 1990. This increase corresponds to approximately 0.16 ^{0}C per decade. Temperature scenarios indicate that the increasing trend is continued with anticipated GHG emission projections. Ambient temperature rise is one of the significant driving factors causing increased cooling related energy consumption in Sri Lanka. Despite Sri Lanka's RAC sector related energy consumption, currently, being comparatively low, significant rise in demand will be expected with the ambient temperature increase. The positive recommendations on energy efficiency improvement need to be adopted. This emphasizes the importance of energy improvement related strategies to meet future demands, while securing social, environmental, and economic benefits in the energy sector.

Population growth, food production and sustainability are significant factors that drive energy consumption for domestic and commercial cooling in Sri Lanka. Rise of population would result in increased energy and cooling demand, consequently leading to an energy crisis and a range of enviromental consequences associated with additional energy generation. The NCP will serve as a holistic approach to meet the cooling demand of the growing population, while optimizing socio-economic and environmental benefits.

Energy is a fundamental input to economic growth. As population grows energy demand increases, therefore the energy sector in Sri Lanka must evolve further to be responsive to the socio-economic and environmental challenges. Sri Lanka has achieved nearly 100% electrical energy to households. As such, energy improvement systems are vital to meet increasing demand with the rise of population and economic development, while minimizing negative consequences to the environment. NCP will identify the trend of energy consumption with future driving factors that will be beneficial in adopting energy efficiency strategies in advance to meet anticipated challenges. Energy transition will boost the growing economy of the country, opening numerous beneficial opportunities. Energy improvement strategies need to be consistent with economic, social, and environmental goals of the country to achieve sustainable development objectives.

1.5. Objectives of NCP

- Assessment of overall current cooling demands of the country and analysis of future demand based on projected scenarios.
- Identification of sectorial demands and analysis of future variations in correlation with driving factors.
- Prioritizing vulnerable sectors with high cooling demand
- Present RAC equipment demand and future projections with socio-economic development and environmental considerations.
- Support NDC by setting up recommendations for energy efficient transformation.
- Promotion of recommended alternative refrigerants to achieve climate and economic benefits.
- Focus on policy and legislations that might be needed.

The NCP provide an overview of following thematic sections:

- Synergistic actions to address energy and cooling demand
- Space cooling: Current and future view
- Cold chain and refrigeration
- Refrigeration and air conditioning for service sector

- Transport air conditioning and refrigeration
- Alternative technologies to secure environmental and socio-economic benefits.
- Research and development

1.6. Survey Data collection and Analysis

The data for preparing National Cooling Plan (NCP) was collected from primary and secondary sources. The following activities were carried out to obtain information for completing the relevant chapters and assessments:

- A national kick-off workshop in Colombo on May 27, 2019. It was organized by the Ministry of Environment (MOE) in collaboration with UNDP and UNEP. Relevant stakeholders were participated, and their views and comments were recorded.
- Primary data was gathered through a detailed survey performed using questionnaires, online and field visits.
- Secondary data were obtained from statistical outputs of government departments, reviewing previous surveys data, custom data for imported equipment and refrigerants, annual reports of equipment manufacturers and expert opinions.

The following challenges were encountered during the data collection work from the primary data sources:

- Difficulties in completely filling out questionnaires or reluctance to provide information by certain establishments.
- Questionnaires had to be explained during personal visits to get the needed information.
- Collect data on equipment and appliances was difficult, because of reluctance to provide inventory of equipment, capacities, and production data.
- Contradicting information was provided in some questionnaires, reducing the confidence level in some results.

For two key subsectors, namely space cooling and cold chain, representing the majority of total cooling demand, a survey was carried out to form the base of the recommendations. The largest buildings for space cooling, food & agriculture (fruit& vegetables, dairy, fisheries and meat), commercial (supermarkets and retails), health services and domestic refrigeration that are offering refrigeration and air-conditioning were surveyed to cover the biggest possible share of the cooling demand in the country. The survey was done through extensive field visits conducted by the project team.

For each of the subsectors and their respective appliance types, the methodology estimates an inventory of historic and future unit sales and stocks. From this, energy and refrigerant demand were estimated. Finally, assessed potential gains from the introduction of improved technologies. The approach considers the gradual replacement of the stock through replacement with new energy efficient appliances.

1.7. Synergistic actions for NCP and securing sustainable deve lopment

1.7.1. Local Initiatives

Several policy measures have been adopted by the Government of Sri Lanka with respect to energy efficiency, air quality, transport, building and health and implementation, in coordination with state and private stakeholders aligned with sustainable development goals. Each policy focuses on strategies and actions that may synergize to achieve multiple objectives.

The National Energy policy and Strategies, specifically introducing energy labelling on equipment by Sustainable Energy Authority (SEA) of Sri Lanka in Sri Lanka are important energy efficiency related roadmaps. The primary objective of the energy policy is to ensure that energy is available through economically viable supplies that are clean, secure, sustainable, and reliable, to provide convenient, affordable energy services that support socially equitable development in Sri Lanka. The policy presents Sri Lanka plans, in terms of managing and developing the energy sector to ensure delivery of a cost-effective energy service from diversified sources. Furthermore, strategies mainly emphasize the transition to diversified sources of energy generation, particularly based on renewable resources. This policy founded on ten pillars, rooted in the broad areas impacting society, economy, and the environment.

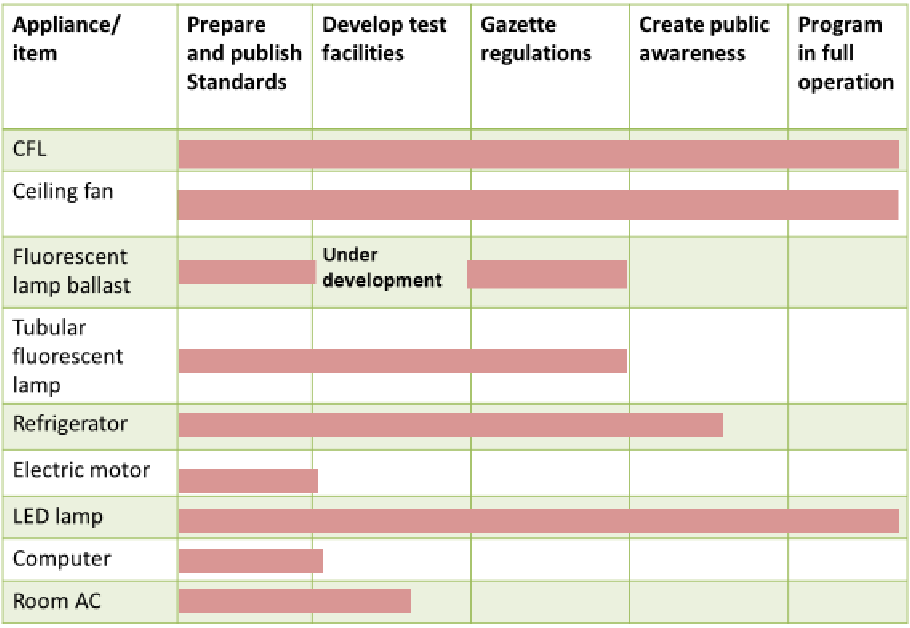
Greater use of RAC equipment would create a significant pressure on peak electricity demand in countries like Sri Lanka. As cooling demand increases, the country needs to consider additional power generation and distribution systems to cater to the demand. Prevailing background and future projections provide a general overview leading to concerns regarding energy-related feedback effects on climate change. The National Energy Policy and Strategy aims to increase the share of renewable energy in combination with conventional sources. According to Ceylon Electricity Board (CEB) generation plan, the renewable energy share is to increase to 30% by 2030 and 50% by 2050 (CEB generation plan).

Minimum Energy Performance Standards (MEPS)

One of the ways to reduce the electrical energy consumption of RAC equipment is the use of more efficient equipment. Minimum Energy Performance Standards (MEPS) at the national level are established to eliminate inefficient products from the market; this is an element that forces local manufacturers to produce more efficient equipment, and importers to bring more efficient products to the national market. MEPS are also an important tool for developing countries to avoid being the dumping ground for inefficient technologies discarded by developed countries.

The present situation of adaptation to minimum energy efficiency is presented below.

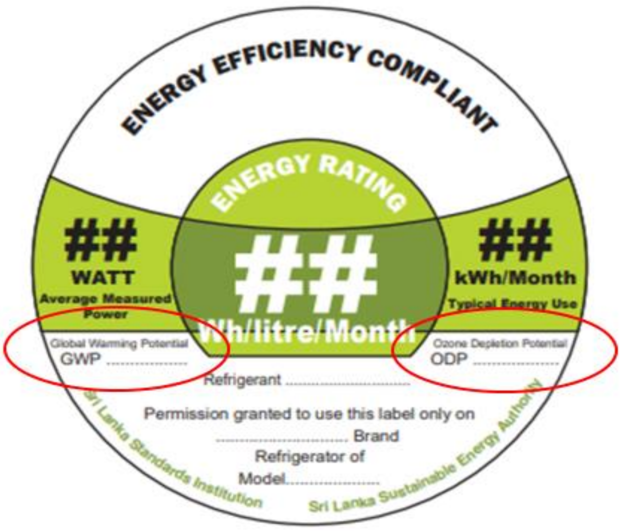
Present Status



Source: Presentation by Sustainable Energy Authority of Sri Lanka

The penetration in the market of any equipment requires the technical acceptance by the Sri Lanka Standard Institute (SLSI); the first step is the application to the National Testing Laboratories to verify compliance with the MEPS.

Energy and environmental performance labels have been developed allowing consumers to identify the most efficient products. Valuable partnership from the business community is expected to provide incentive programmes to encourage consumers to prefer more energy-efficient products. In Sri Lanka, it will be mandatory in the future to attach the energy-efficiency label (shown below) for all equipment in order to place them in the market.



Source: Presentation by Sustainable Energy Authority of Sri Lanka

The MEPS label for refrigerators will have the following information,

- Name or trademark of the manufacturer/responsible vendor
- The model number and the serial number of the refrigerator
- The rated volume in liters
- Control type (inverter control or non- inverter control)
- Defrosting system (no-frost/ automatic defrost/ manual)
- Rated voltage & rated power input in Watt.
- Information on the Refrigerant used
- Global Warming Potential (GWP) value and Ozone Depleting Potential (ODP) value
- Weight of the refrigerant used.

The Sri Lanka Sustainable Energy Authority has formulated a long-term Demand Side Management (DSM) Programme to cope with the demand growth. Through this DSM, 1,895 GWh of Electricity will be saved during a five-year span by avoiding 471 MW electricity generation capacity for domestic, Commercial, and industrial sectors.

To achieve these targets, A Presidential Task Force on Energy Demand Side Management (PTF on EDSM) was established by the Ministry of Power in 2015. This PTF on EDSM intends to phase out the inefficient refrigerators in homes by replacing them with efficient refrigerators. The annual saving is estimated to be 161 GWh per annum, after replacing 100,000 refrigerators per annum for 5 yrs. The PTF has proposed to introduce a 'trade-in' scheme with the involvement of vendors, lenders (Participating Financial Institutions) such as banks, leasing companies, micro credit companies etc., and consumers with the Ceylon Electricity Board (CEB) /Lanka Electricity Company (LECO)

National Missions under the *Haritha (*Green*) Lanka Programme-2009* focus on cleaner air, energy efficiency, GHG emission reduction, greening industries, and meeting challenges of climate change. A separate mission on greening the industries (Mission: 09) directs industries to exercise environmental care and social responsibility, promoting energy use efficiency, and switching to renewable energy use where possible.

Apart from the above-mentioned regulatory measures, codes and guidelines are in place in the area of RAC for the promotion of minimum energy performance formulated by SEA in collaboration with NOU. In addition, several gazette notifications have been introduced under the import and export control act to control the import of ODS into Sri Lanka. A gazette has been issued for the collection of import data and for defining the baseline consumption of HFCs in order to comply with Kigali amendment.

The readiness plan has been adopted for the implementation of Nationally Determined Contributions (NDC) to achieve GHG emission reduction targets under the Paris agreement of UNFCCC. As a signatory to the Paris agreement, the country is setting up national initiatives in addressing adverse climate change impacts. Key objectives include reduction of 20% of GHG emission against the business as usual (BAU) scenario in the energy sector and 10% reduction on transportation, industry, waste and forestry sectors. With the implementation of recommendations in the NCP, reduction in electrical energy use in RAC sector (use of energy efficient refrigerants, modern methods in space cooling and housing development etc.) is expected. This will help achieve targets in energy sector NDC. Adaptation strategies focus on human health, food production (agriculture, livestock, and fisheries), water and irrigation, coastal and marine, biodiversity, infra-structure structure and human settlement, tourism *etc*.

After agreeing with the Paris agreement, the document has been prepared by the Presidential Expert Committee (PEC) on Sustainable Sri Lanka Vision, and Strategic Path 2030 has given an in-depth analysis of current status and further recommends future actions covering social, economic, environment and governance. It especially focuses on strategies and actions to achieve Sustainable Development Goals (SDGs) by 2030.

1.7.2. Contribution to Global Initiatives

At the 28th meeting of the Parties to the Montreal Protocol held in Kigali in 2016, the refrigeration and air-conditioning sectors were identified to represent a substantial percentage of global electricity demand (decision XXVIII/3), which is projected to be increasing. Under the Kigali Amendment, 197 countries committed to cut the production and consumption of HFCs used in the refrigeration and air conditioning sector by more than 80% over the next 30 years. Kigali - Cooling Energy Programme (K-CEP) supports the Kigali amendment to enhance energy efficiency of cooling to achieve climatic benefits, while increasing development benefits during HFC phasing down.

It is expected that the intended HFC phase down has the potential to avoid up to 0.4° C of global warming by the end of the century, and up to 0.5° C if the phase-down is accelerated. The parties agreed that improvements in energy efficiency via a multi-national agreement could deliver a range of benefits towards sustainable development, in terms of climate change mitigation and ozone protection. The decision recognizes the importance of enhancing energy efficiency while transitioning from high GWP HFCs to low GWP alternatives in the RAC sector.

The Kigali amendment addresses the issues related to energy efficiency while phasing down HFCs. Parties expect to achieve energy benefits via the Kigali cooling plan aligning with environmental, social, and economic elements of the sustainable development framework of the United Nations. As a party to the Montreal protocol on controlling ozone depleting substances and Kyoto Protocol on Greenhouse Gas emission reduction, Sri Lanka is obliged to implement Kigali amendments to achieve HFC phase-down targets. Further, it is expected that

Sri Lanka's initiatives on energy efficiency strategies are in line with Kigali targets that could benefit energy related sustainable development goals (SDGs) of the United Nations as well.

The phase-down schedules applicable for both developed and developing countries are shown below.

Table 1. 2. HFC phase down schedule of the Montreal Protocol

	Developed countries	Developing countries Group 1 (Middle Ambient Temp)	Developing countries Group 2(High Ambient Temp)
Baseline Years	2011-2013	2020, 2021 &2022	2024, 2025 & 2026
Formula	Average HFC consumption	Average HFC consumption + 65% of HCFC Baseline production/consumption	Average HFC consumption+ 65% of HCFC Baseline production/consumption
Freeze		2024	2028
1st Step	2019-10%	2029-10%	2032-10%
2nd Step	2024-40%	2035-30%	2037-20%
3rd Step	2029-70%	2040-50%	2042-30%
4th Step	2034-80%	2045-80%	2047-85%
Plateau	2036	2045	2047

Since the ratification, Sri Lanka has progressively achieved important milestones of ODS phase out targets in compliance with the time targets of the Montreal Protocol. It was remarkable that the country achieved CFC phase out in 2008, two years before the deadline for developing countries. In the meantime, shifting to chemicals such as HCFCs and HFCs as transitional substitutes were actively encouraged and financially supported as listed below:

- **HCFC Phase-out Management Plan**: Global concern of the dual threats posed by HCFCs prompted the parties to decide to speed up phase-out of HCFCs in 2007. Initiatives have been by taken by the National Ozone Unit (NOU) of Sri Lanka to accelerate HCFC phase out in compliance with the decision XIX /6 of Executive Committee of the Montreal Protocol. **Kyoto Protocol/ UNFCCC**: Increased consumption of HFCs has become a significant threat owing to its powerful warming potential leading to negative consequences to the climate. Although, HFCs have no ozone destruction potential, Montreal protocol provides leadership to implement HFC phase-down plan integrated with Kigali amendments addressing global climate effects. HFCs are found to be a powerful greenhouse gas in the basket addressed by the Kyoto Protocol. Sri Lanka has ratified UNFCCC and Kyoto Protocol and is obliged to implement GHG emission related strategies to achieve climate change mitigation targets.
- **Paris Agreement**: The Paris Agreement aims to keep global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (UNFCCC). Moreover, the agreement aims to strengthen the capacity of parties to address the climate change impacts, and to build resilience of vulnerable communities. The country has been a strong advocate of Paris Agreement during COP 21 and has ratified the Agreement and submitted its Nationally Determined Contributions to the UNFCCC

Secretariat in 2016. The agreement requires that all Parties report regularly on their emissions and on their implementation efforts.

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Chapter 2

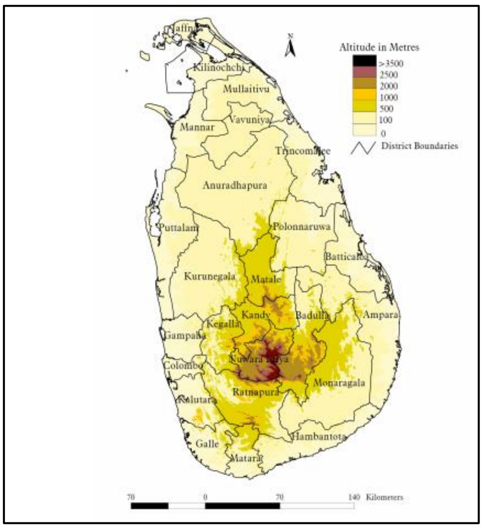
Space Cooling

2. Space Cooling in Buildings

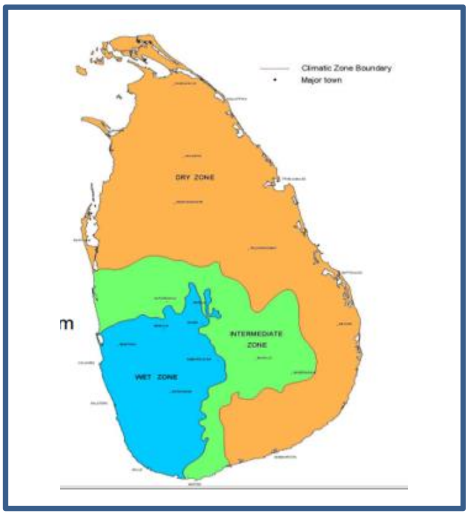
2.1. Introduction

Cooling for Human Comfort is the major component of Space Cooling in the island country due to its warm and humid tropical climatic conditions throughout the year except for a relatively small upcountry area. The technologies used for cooling are predominantly refrigerant based. Non-refrigerant based technologies currently used for cooling in the country are mostly fan and limited number of Air Coolers.

The mean annual temperature in Sri Lanka manifests largely homogeneous temperatures in the lowlands and rapidly decreasing temperatures in the highlands. In the lowlands, up to an altitude of 100 m to 150 m, the mean annual temperature varies between 26.5 °C to 28.5 °C, with an annual average of 27.5 °C. In the highlands, the temperature falls quickly as the altitude increases. The mean annual temperature of Nuwara-Eliya, at 1800 m above sea level, is 15.9 °C. The coldest month with respect to mean monthly temperature is generally January, and the warmest months are April and August.



Topography



Average temperature
Dry zone → 28 ⁰C
Intermediate zone → 24 - 26 ⁰C
Wet zone → 24 ⁰C

Figure 2. 1. **Topography Map and Climate zones of Sri Lanka (Source: Meteorological Department)**

The island is humid, where the relative humidity is recorded more than 65% under normal conditions. In the coasts, it rises to 90% during wetter seasons. There are dry dehydrating effects in the leeward side of the country due to the mountain effect during the period May – September and the humidity drops in the eastern region from June to September. Mean relative humidity for an average year is recorded as 79.8% and on a monthly basis it ranges from 75% in January to 83% in October.

Overview of Space cooling Technologies

The space cooling technologies for providing thermal cooling in buildings fall within three broad categories: refrigerant based, non-refrigerant based, and not-in-kind technologies.

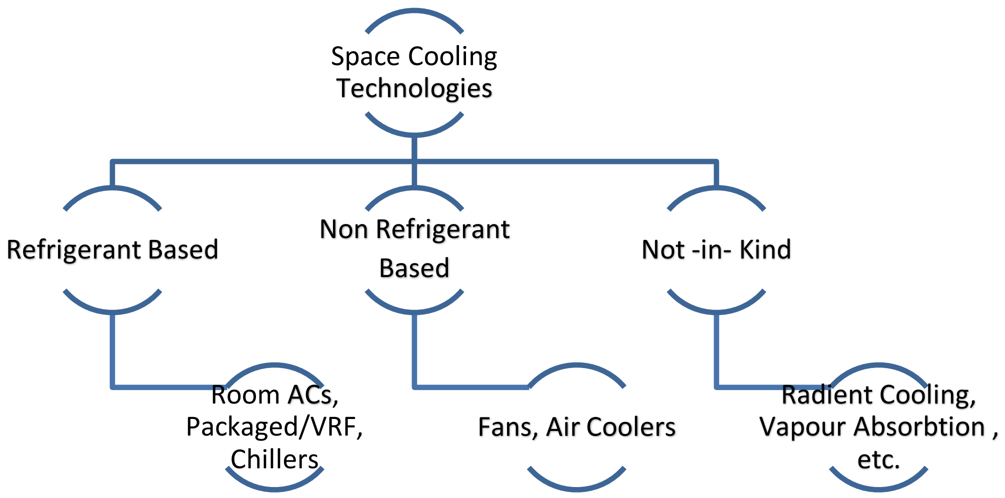


Figure 2. 2. **Space cooling segments**

Among the refrigerant-based systems, room air conditioner finds predominant application in the residential sector. Air conditioning systems utilised in commercial buildings, excluding room air conditioners, can be classified into three major types – chiller system, packaged direct expansion (DX), and variable refrigerant flow (VRF) system. The non-refrigerant based cooling technologies like fans and coolers are significantly pervasive in the residential sector, as well as in the small to medium commercial, and in commercial applications such as warehouses.

Refrigerant-based Cooling Technologies

Room (Residential) Air Conditioning system

Room air conditioners are the key appliances used for space cooling in domestic as well as the commercial sector. There are several configurations including mini/multi Split, window and non-ducted unitary systems. Currently, the room air conditioners stock comprising mainly of fixed speed types and inverter types is gaining popularity due to energy efficiency ratio.

Variable Refrigerant Flow (VRF) System:

Variable Refrigerant Flow, or VRF HVAC systems, have been the HVAC system of choice for quite some time. VRF systems are typically used in medium-size commercial buildings and high-income group residential units that have varying exposure and cooling loads and has ability to control the amount of refrigerant flowing to each of the small air handlers. In spite of its higher initial costs as compared to other comparable systems, VRF systems have been gaining popularity and strong market share, due to the advantage of energy efficiency, quick installation, ease of operation and the flexibility of choosing from a range of indoor units.

Packaged DX System

Packages DX, also known as unitary and light commercial systems typically cater to small-to-medium commercial buildings to avoid the complexities associated with chiller systems. A packaged DX system also contains all components of the system in a single unit, but in some packaged systems, the evaporator, compressor, and condenser are located outside the building, and the unit pumps cooled air into the building through ducts.

Another key feature of DX Packaged units is the advantage of having the entire cooling system self-contained in one unit. This allows for the installation on top of or alongside a building without too large of a footprint and is generally less expensive to install.

Chiller System:

Chiller systems (central chilled-water air conditioning systems) are the preferred choice for large commercial buildings. Chiller systems range vastly in size and design and are available as small, localized or portable chiller units for smaller applications or large central chillers designed to provide cooling for entire processes. Chiller systems are installed in commercial buildings to achieve proper temperature control. There are two types: water cooled chillers and air-cooled chillers. Both are refrigeration systems used to cool fluids or dehumidify air in both commercial and industrial facilities.

Chiller is better than DX package units as its higher efficiency and ability to cover larger areas for cooling. But chillers require more maintenance than DX package units. Therefore, DX package units are used in some areas mainly for it’s low maintenance cost.

2.2. Space Cooling in Building and Cooling Demand

The demand for RAC appliances in Sri Lanka is continuously growing. The current and future drivers of demand are namely: growing population and number of households, increasing urbanization and economic growth.

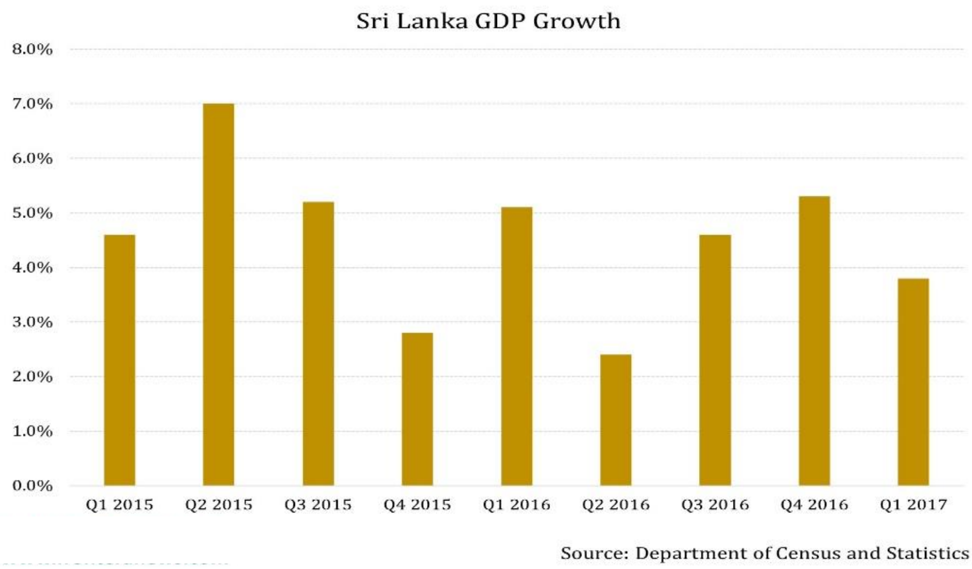


Figure 2. 3. **Sri Lanka GDP Growth (Source: Department of Census and Statistics)**

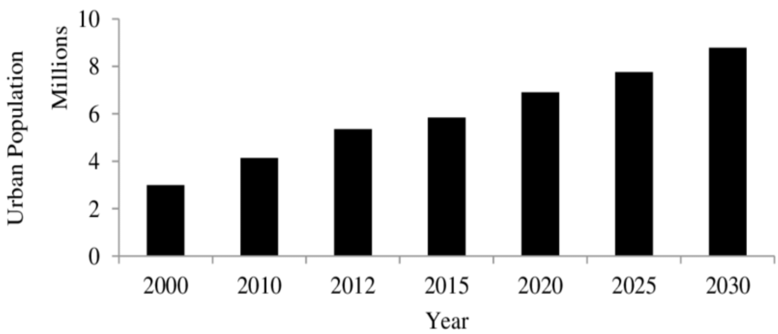


Figure 2. 4. **Sri Lanka Urban Population growth (Source: Department of Census and Statistics)**

Sri Lanka is experiencing fast construction growth in commercial and residential condominiums. In view of the rapid increase in building stock and the associated air-conditioned area, it becomes increasingly important to formulate strategies and more interventions to reduce the need for active cooling of buildings. High-performance buildings on average reduce the energy consumption substantially (consume less energy as compared to than that of conventional conditioned buildings). Therefore, incorporating energy efficient design and construction strategies for buildings can inherently reduce the energy consumption footprint over its operating lifetime. Hence, in the country thermal comfort can be predominantly linked to space cooling in buildings using refrigerant-based air conditioning and non-refrigerant-based cooling through fans and air coolers.

2.2.1. Residential Sector Current Stock and Future Projections

Economic growth of the country is closely related with real estate development. The residential real estate sector in Sri Lanka includes different types of properties; h single houses, storied houses, annexes, twin houses, lined houses, condo/apartment units etc. Condominiums are a convenient type of residence that attracts the upper income urban population.

Single Houses

The entire country has approximately 5.5 million of occupied housing units and among them 85% belong to single house category. Balance 15% is in the category of condominium (Prathapasinghe et al, 2018). Figure 2.5 shows the projection of single housing units in the country, considering the population growth, 1.1% (Department of Census and Statistics, 2018) and the economic growth 4.1% (Central Bank of Sri Lanka, 2018).

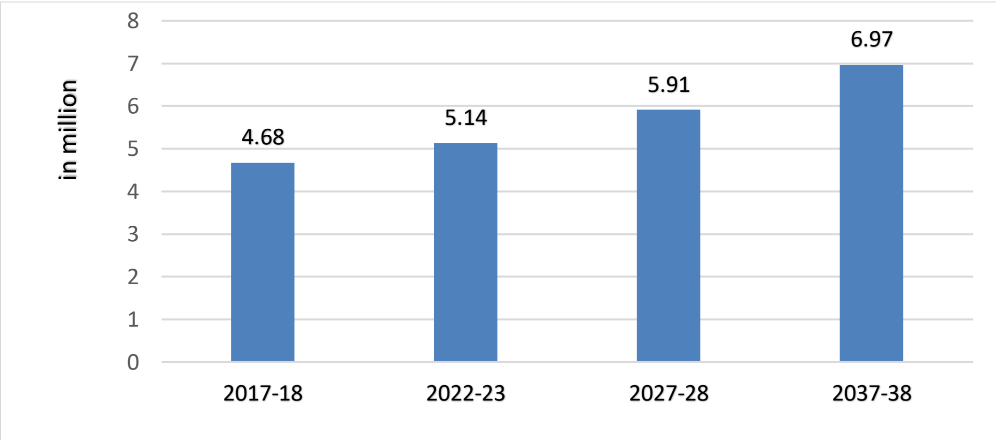


Figure 2. 5. **Single housing units (Source: Based on Department of Statistics and research sources - Prathapasinghe, et al, 2018)**

Multi-storied Houses and Condominium

The current upward trend in residential condominium sector took a long period of evolution. In 1960's and 1970's the government launched apartment housing projects as a strategic measure to solve the burning housing issues of low and middle-income communities in Colombo where lands are limited. During the last few decades, apartments/flats/high-rise housing projects are observed to be increasing. The estimated number in the category of condominium is approximately 15% of total housing population in Sri Lanka (Prathapasinghe et al, 2018).

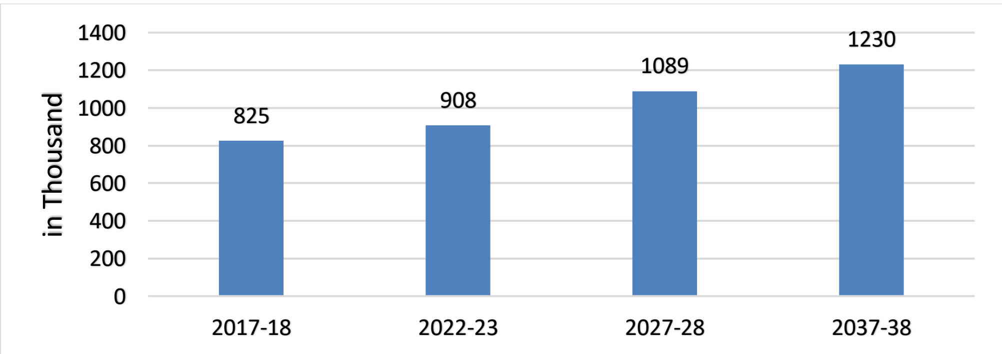


Figure 2. 6. **Multi-storied and Condominium (Source: Based on Department of Statistics and research sources -Prathapasinghe, et al, 2018)**

Currently, there are over 900 apartment complexes in the country having approximately 13,000 residential units therein. It is estimated around 100 condominium new projects are in the pipeline adding over 4,000 residential units and these are to be completed soon.

2.2.2. Cooling Demand from Residential sector (Single housing, Multi-storied / Condominium)

This section provides the cooling equipment of residential building (housing units), current stock and its growth trajectory over the next decade to comprehend the upcoming cooling demand from these sectors. The cooling demand approximate numbers have been presented here to provide trends and are based upon building industry information, surveys and research conducted by various organizations.

Room (Residential) Air Conditioners:

Room Air Conditioning Unit Stock.

The current penetration of room air conditioners in country and stock were estimated based on Customs data (Country Assessment Report 2019) and HCFC survey conducted in 2019 as shown in Table 2.2 and the projection in Figure 2.7.

Table 2. 1. Total number of new RAC equipment imported, 2012 – 2018.

RAC equipment	2012	2013	2014	2015	2016	2017	2018
Room Air-conditioners	98,780	112,555	108,888	111,051	167,152	183,072	159,941

Source: Country Assessment Report 2019 and HCFC survey

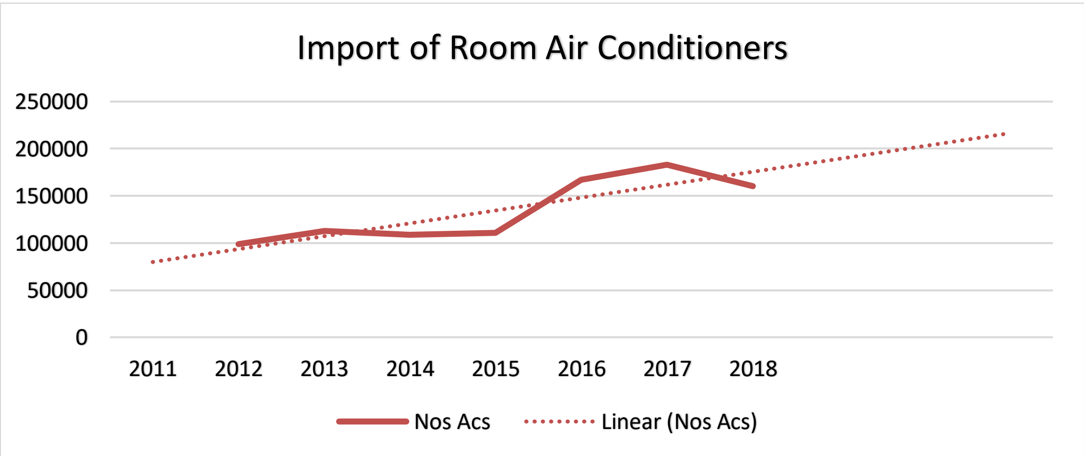


Figure 2. 7. **Import of Residential Air Conditioners (Source – Country Assessment Report and HCFC Survey 2019)**

Use of residential air conditioners is limited in single housing units, because owners are in lower or middle-income group. It is apprehended by the experts in this sector that around 4 to 5% household now have access to room air conditioner facilities. Around 70% of them have one unit of AC and the rest possess more than one air conditioner. The demand for residential ACs is growing significantly with the rise of the economy which offers a tremendous opportunity for this sector to grow. The residential sector is likely to be the leading driver for the growth of air-conditioning in Sri Lanka in the next twenty years because of urbanisation trends.

Further it is estimated that 10% of multi-storied houses and 90% of apartments in condominium are installed with split type air conditioners. The stock of air conditioners in 2018 in the domestic sector can be estimated as 429,850 units and approximate cooling capacity was calculated assuming cooling capacity of one unit AC as 1.0 TR. The results are presented below in Table2.2

Table 2. 2 Estimated Residential AC stock and Cooling Capacity

Description	Nos of houses	% of AC	Number of houses with AC	Minimum number of AC per house	Number of ACs	Cooling capacity per house, TR	Approximate Total Cooling Capacity. TR
Single Houses	4,675,000	5	233,750	01	233,750	1.0	233,750
Multistoried houses	812,000	10	81,200	02	162,400	2.5	406,000
Apartment houses	13,000	90	11,700	03	35,100	3.5	105,300
Total	**5,500,000**		**326,650**		**431,250**		**745,050**

Source: Department of Census and Statistic -2018 and market information.

[Note: 1TR = 12,000 Btu/h or 3.5 kW]

Projections on Growth of Room (Residential) Air Conditioners in households

It has been assumed that from 2010 till 2015, the majority of households purchased their first residential air conditioner. However, based on the expert's analysis and interactions with various stakeholders it is likely that in next 15 to 20 years, many households, especially those in the urban areas, would buy their second or third air conditioners. The future residential air conditioner stock has been estimated using historical installed base and current trend of sales along with the following underlying assumptions:

- Room air conditioner life is around 10 years,
- The market of room AC is almost doubled in every 6 years. (from import data analysis)

According to the survey results and market analysis, approximately 5% of the current households have room air conditioners. This is anticipated to rise to 10% and 15% in 2027-28 and 2033-34 respectively (Figure 2.8)

(The available data was extrapolated to arrive at the current and future built-up stock within each category of households mentioned in Table 2.2).

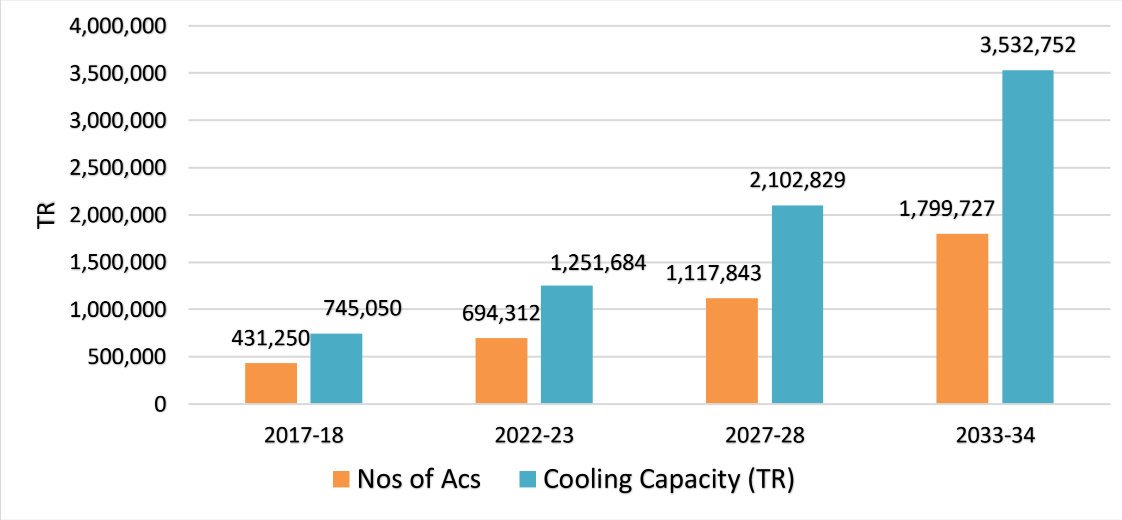


Figure 2. 8. **Projection of the growth of Residential ACs and relevant Cooling capacities. (Source: Survey results and market analysis)**

Energy Consumption of Residential Air Conditioning in housing sector.

Energy consumption of Air Conditioners varies depending on the energy efficiency of Air Conditioning equipment and ranges from 0.81 to 1.25 kW/TR. For the calculation of AC equipment, it is considered the energy consumption per 1TR is equal to 1.1 kW. Annex 2 – Space Cooling shows the calculation and Figure 2.9 below present the energy consumption for ACs in housing units.

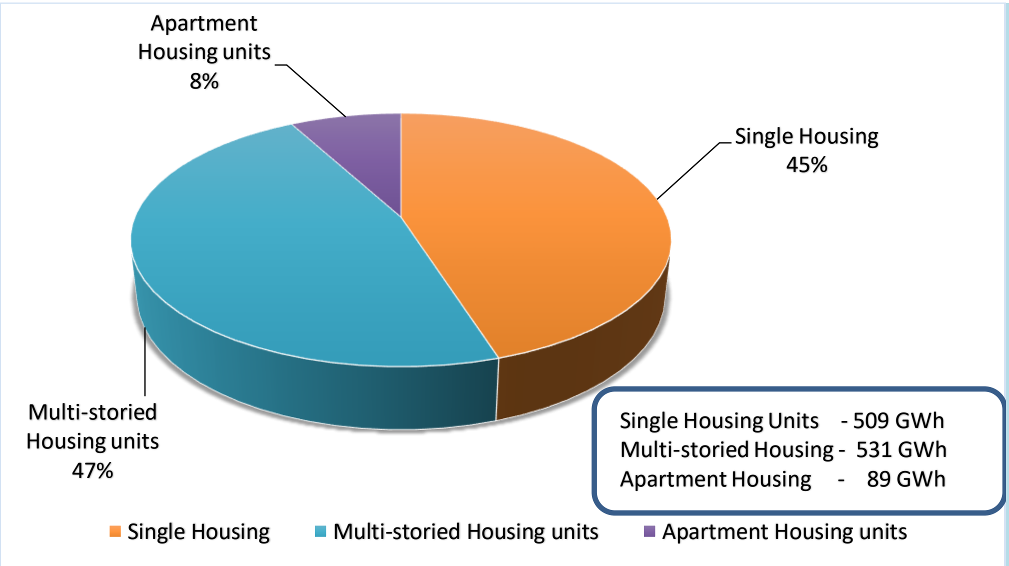


Figure 2. 9. **Energy consumption in Space cooling Housing (Residents) sector (Source: Market and sector analysis)**

2.2.3. Commercial Building Air Conditioning Sector

The commercial sector building comprises of office buildings, shopping malls, hotels and restaurants, hospital, supermarket & retail outlets, educational institutions, convention halls, airports, and warehouses. Different types of air-conditioners are used in commercial building air conditioning, such as splits ACs, Package units, Variable Refrigerant Flow (VRF) systems and chillers. In general, chillers are used to cool space above 50 TR refrigeration capacity and range up to thousands.

Every segment of the commercial building space has experienced a significant growth during last decade and the trend is continuing. However, data on current stock of commercial space, how much of the space has cooling access and stock of AC equipment are not available. In this scenario, a sample survey was carried out with the determination of historical installed base data and current sales data of chillers system and variable refrigerant flow (VRF) system with their respective capacities from the importers of these equipment and consulting firms. Details of Space Cooling equipment, Cooling Capacities and Energy Consumption are furnished in Annex 1– Space Cooling Table A, B and C

Room Air conditioners

Use of room air conditioners in commercial buildings has been increased tremendously during last ten years owing to rapid increase of demand for new commercial entities. Based on the survey data during 2015-2018 (Country Assessment Report, 2019) growth of unitary ACs is graphically presented in Figure.2.7

As per the Figure 2.5, residential air-conditioners stock in 2018 was estimated as 950,000 units. As previously mentioned, 429,850 ACs in housing units are included to the total estimated units. Accordingly, for commercial space cooling 515,000 unitary air conditioners are employed. Assuming average cooling capacity of an air conditioner is 1.5 TR (18,000 Btu/h), the approximate total installed cooling capacity is around 475,950 TR.

Variable Refrigerant Flow (VRF) System

According to ASHRAE and building engineering experts, VRF systems are typically used in medium-size commercial buildings and is getting popular from the management level. It is predicted that the VRF market will grow at an average rate of at least 10 to15% in the next decade. VRF systems have been gaining popularity due to various advantages such as energy efficiency, quick installation, ease of operation and the flexibility of choosing from a range of indoor units. The energy saving is achieved through diversity, and variable capacity, to meet the indoor heat load. However, no data is available on current stock of VRF systems in 2017-18, but HVAC industry experts suggest the installed capacity is around 60,000 TR.

Package Direct Expansion Systems (Unitary and light commercial systems)

In the commercial air conditioning segment, the Packages DX covers ducted and packaged systems including rooftop and indoor packaged units. These systems are installed in small-to-medium commercial buildings, because they are not as complicated as chiller systems. According to sales inputs received from importers, these systems start from 3 TR and are available up to 20 TR using single or multiple compressors depending on the cooling capacity. HVAC industry experts suggest the installed capacity is around 70,000 TR.

Chillers systems

Chiller systems are the preferred choice for large commercial building and are the largest consumer of energy. Chillers are either air-cooled or water-cooled and are sub-categorized into scroll chillers from 10 to 150 TR, Screw chillers from 50 to 500 TR and centrifugal chillers from 300 to 2500 TR. Chiller system consist of pumps, condenser fans, Air Handling Units (AHU) and to operate these auxiliary items, a considerable amount of additional energy is consumed. The existing chiller stock information has been arrived at by gathering chiller sales data and the estimate of the historical installations based on consultations with industry experts. As per the ASHRAE information, 70-75% of chillers installed are in commercial buildings and the rest is installed in industrial buildings. According to HVAC industry experts total installed chillers have been estimated as around 2400 units and capacity is around 0.73 million TR.

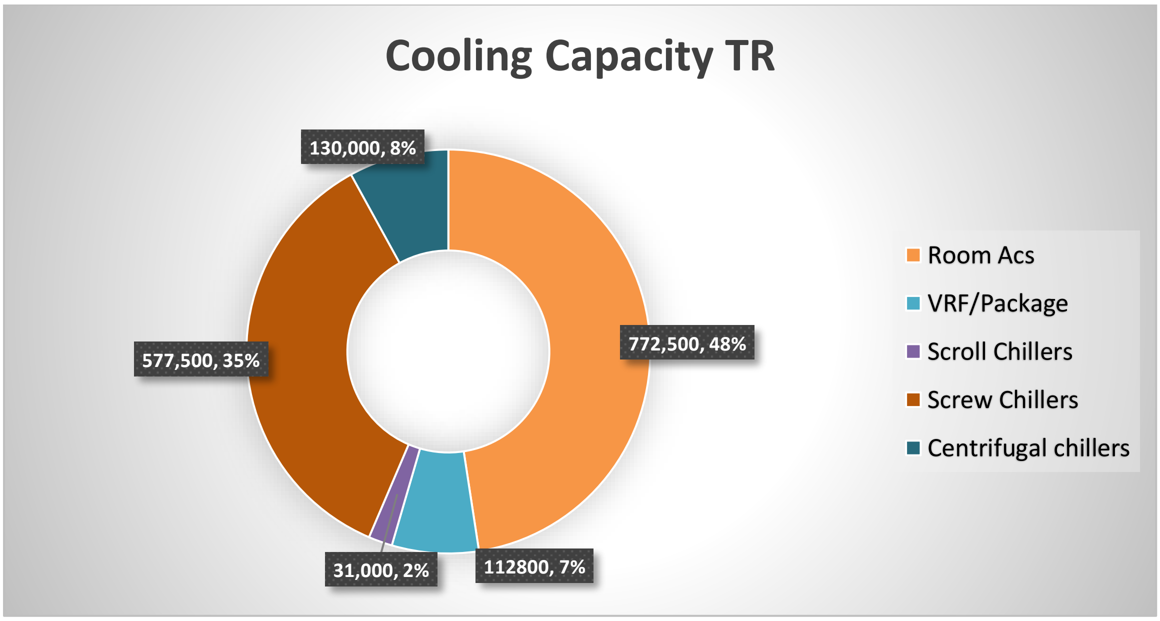


Figure 2. 10. **Cooling capacities in Commercial buildings**

2.2.4 Non-refrigerant-based Cooling Technologies

Fans and Air Coolers

Fans are widely used across all income categories both in rural and urban homes and even homes that utilize room air conditioner for thermal comfort, tend to use fans simultaneously. This appliance category covers ceiling, pedestal, table and wall-mounted fans. Fans are also widely utilized in the small to mid-commercial segment. According to the Annual Report of Central Bank of Sri Lanka 2019, the percentage of the availability of fans in the domestic sector was 61.5%. (approximately 3.5 million). Despite a rise in using room air conditioner in households, majority of the population will still not be able to afford air conditioning in the next two decades and will continue to rely on fan-assisted ventilation or natural ventilation for their thermal comfort. In Commercial and Industrial Sectors, fans are heavily used. Therefore, the quantity of fans may exceed 8-9 million.

Air coolers are not very popular in Sri Lanka, because the cooling effectiveness of air coolers is constrained by the humidity content of the ambient air. Air coolers need adequate ventilation to function well in humid conditions. However, it is assumed that there may be 15,000 – 20,000 Air Coolers in Sri Lanka.

2.2.5. Annual Energy Consumption in Space Cooling in all Sectors.

The relative share of energy demand for cooling for all sectors (Domestic and Commercial) is presented in Fig.2.11. Within space cooling, room air conditioners constitute the dominant share of the sector's cooling energy consumption – at around 46% in 2017-18. Fans as a non-refrigerant-based space cooling technology are also widely utilized in the small to mid-commercial segment. The total annual energy consumption of fans is currently around 18%.

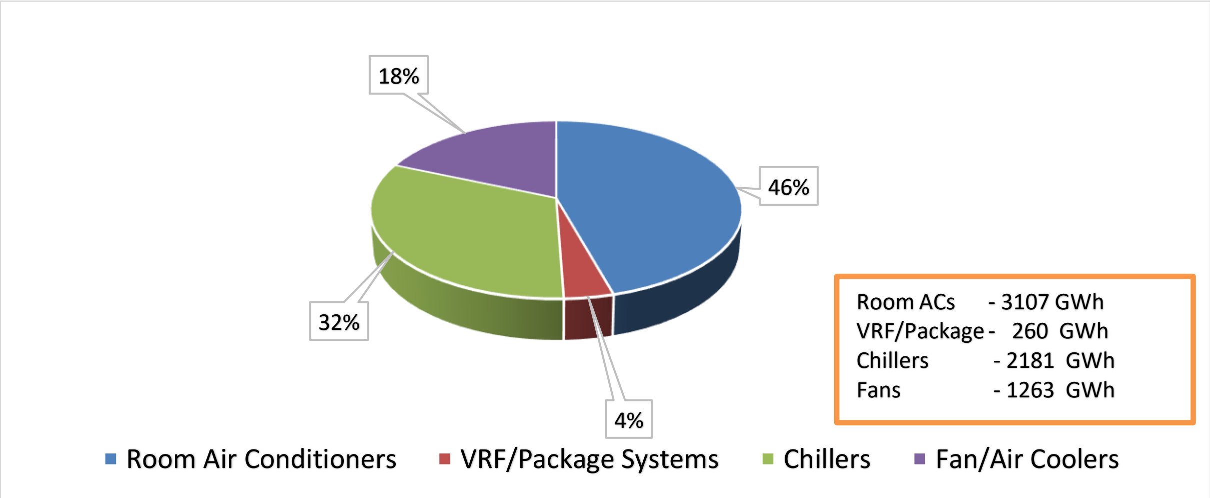


Figure 2. 11. **Share of Annual Energy Consumption for Space Cooling (Source: calculation result)**

2.2.6. GHG Emission in Spacing Cooling Sector

The GHG emissions in the RAC sector result from direct, refrigerant-related GHG emissions and indirect energy generation-related. Most of Sri Lanka's energy is still generated from fossil fuels which is rated as 63% in 2018. The RAC sector is a significant driver for the growing demand for energy and will further increase Sri Lanka's GHG emissions. Therefore, a substantial amount of reduction of the GHG emissions from the RAC sector could be achieved through technologically and economically feasible mitigation actions.

Electricity consumption by space cooling equipment contributes to indirect greenhouse gas emissions. Figure 2.11 shows the annual total energy consumption in Space Cooling sector is 6,811 GWh. Accordingly, the indirect GHG emission is equivalent to 3.5 million MT CO_2 eq. Figure 2.12 illustrates the indirect GHG emission from using equipment and appliances in Domestic, Commercial and Fans/Air Coolers sub sectors.

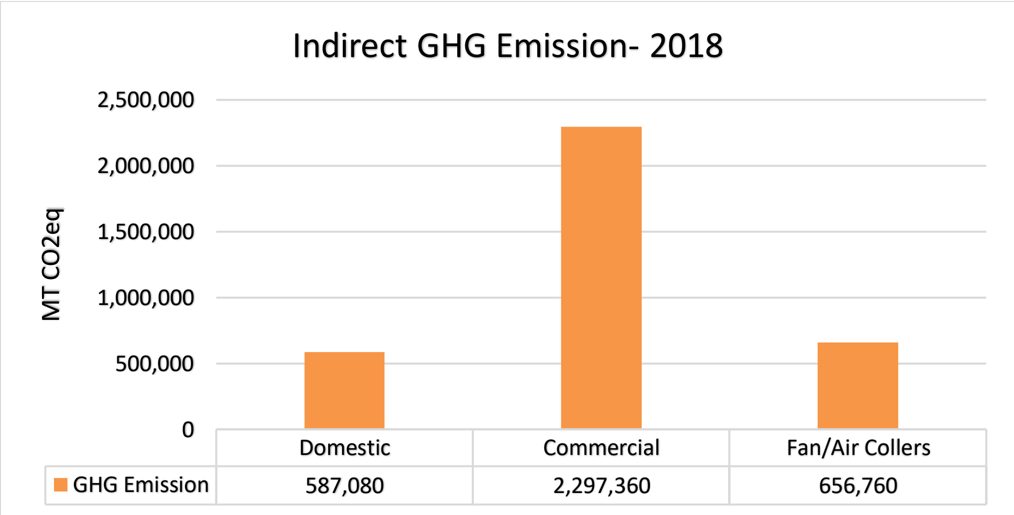


Figure 2. 12. **Indirect GHG emission of Space cooling (Source: Calculation Annex 1. Table A)**

Direct Emission in Space Cooling Sector

Direct GHG emissions in the RAC sector result from the manufacturing process, from leakage and service over the operational life of the equipment and from disposal at the end of the useful life of the equipment. These gases have 100-year global warming potentials (GWPs), which are typically greater than 1,000 times that of CO2, so their potential impact on climate change can be significant. . By the same token, any reductions of these gases have a large potential for climate benefit.

The data on potential emission levels and sources of emissions are missing to track the details associated with GHG emission of equipment. However, modelling parameters mentioned in Table 2.3 below were taken from http://www.green-cooling-initiative.org and modified according to stakeholder/industry consultation. For the calculation of GHG emission from refrigerant/ equipment, the following assumptions were considered.

- Room air conditioners - R -134 A (GWP -1450)
- Package/VRF – R 410 A (GWP -2088)
- Scroll Chillers – R 410 A (GWP -2088)
- Screw/Centrifugal Chillers – R 134 A (GWP -1450)

Direct GHG emission from Commercial Space Cooling is illustrated in Fig: 2.13 and Total GHG emission (Direct+ Indirect) is shown in Fig: 2.14.

Table 2. 3. Direct GHG Emission from Domestic Air Conditioning

Applications	Estimated Equipment Stock	Average charge (kg)	Refrigerant Stock (kg)	Leakage rate (%)	Emission (kg)	GHG Emission MT CO_2eq
Room air-conditioner	431,250	1.2	517,500	10	51,750	75,037

Table 2. 4. Equipment Stock, Refrigerant Stock and Direct GHG Emission in Commercial buildings.

Applications	Estimated Equipment Stock	Average charge (kg)	Refrigerant Stock (kg)	Leakage rate (%)	Emission (kg)	GHG Emission MT CO_2eq
Room air-conditioner	515,000	1.2	618,000	10	61,800	89,610.0
Package and VRF System	9400	16	150,400	20	30,080	64,310.4
Scroll Chillers	620	40	24,800	10	2,480	3,432.0
Screw Chillers	1650	320	528,000	20	105,600	151,008.0
Centrifugal Chillers	130	600	78,000	20	15,600	22,308.0
Total	526,800		1,399,200		215,560	330,668.4

Source: http://www.green-cooling-initiative.org and modified according to stakeholder/industry consultation

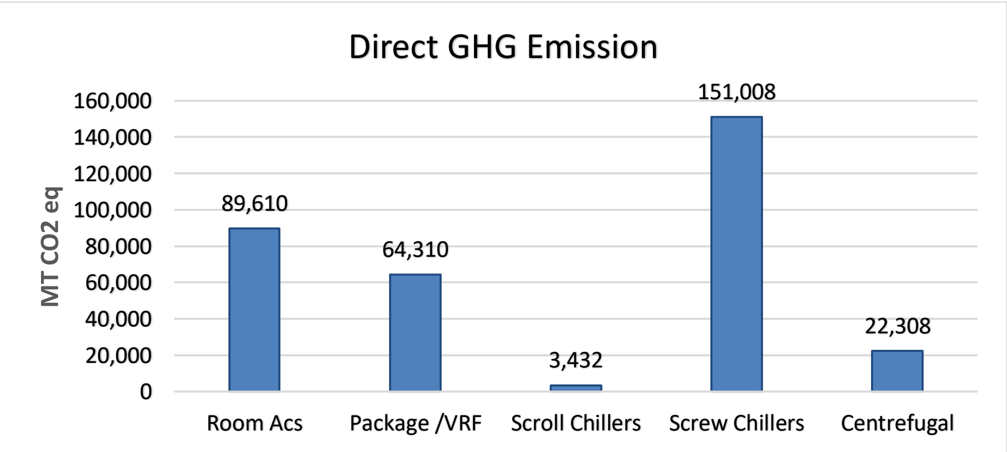


Figure 2. 13. Current Direct GHG emission in Commercial building space cooling

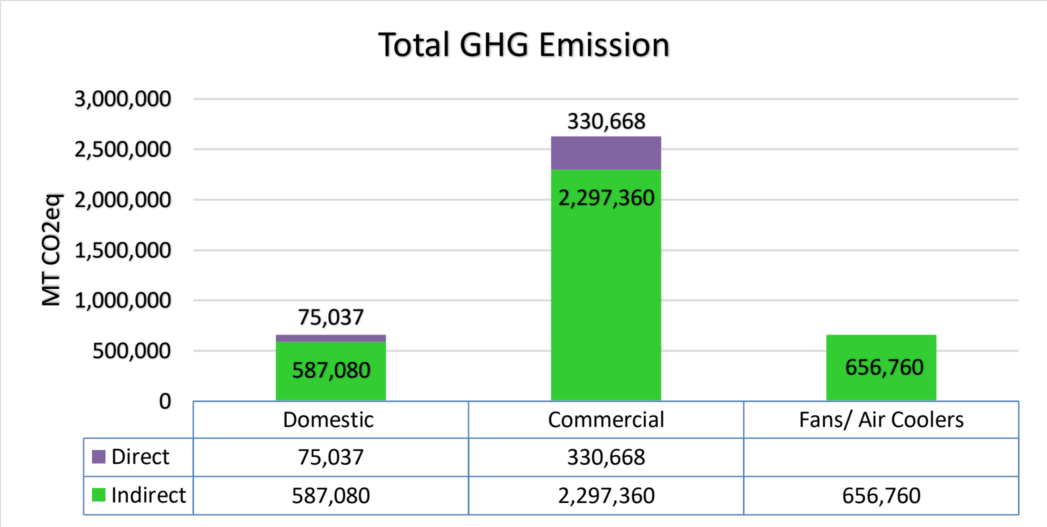


Figure 2. 14. **Total Current GHG Emission of Space Cooling from Domestic and Commercial Space cooling**

2.2.7. Not-in-Kind Technologies in Space Cooling

'Not-in-kind' technologies are those that break away from the traditional refrigeration and air conditioning systems that rely on a vapor compression cycle using a gaseous refrigerant. Since not-in-kind systems do not require a gaseous refrigerant, they are usually HFC-free and therefore climate-friendly technologies.

Not-in-kind' includes a number of different types of cooling systems, some of which have been in use for centuries, such as evaporative cooling. District cooling is another not-in kind technology which delivers cooled water to an entire district either using cold water from the ocean or deep lake or using a central cooling facility with ammonia or other refrigerant to cool the water delivered. Another not-in-kind technology is adsorption cooling systems, which are driven by heat and utilize a solid 'sorption' material in combination with a refrigerant, usually water or ammonia. Others like magnetocaloric refrigeration which relies on a magnetic field to create a cooling effect, and electrochemical compression, which uses electricity, water, and a proton-exchange-membrane technology, are on the cutting edge and have been demonstrated but yet to be commercialized. Whether already commercially developed or still in the early stages of technical demonstration, 'not-in-kind' solutions are likely to play a big role in the future of climate-friendly HFC-free cooling.

The most climate-friendly systems reduce or eliminate the need for electricity consumption by being paired with a solar thermal or waste heat energy source, for example in solar adsorption chillers for cooling, or waste heat driven adsorption heat pumps.

2.2.8. Projection of cooling demand Business as Usual (BAU)

The growth in cooling requirements (in TR) under Reference Scenario is presented in Figure 2.15. The analysis projects a range for growth, dependent on variables such as economic growth, leading to continued growth in building construction, rate of urbanisation, and improved lifestyle and aspirations. To forecast the growth in cooling demand, the HVAC experts were consulted and referred RAC assessments in regional countries (India and Bangladesh) where an almost similar economic and social index exist. Accordingly, the housing building sector (Domestic) shows the most significant growth in TR, at nearly 11% as compared to the current baseline and Commercial building cooling demand shows the growth of nearly 8%.

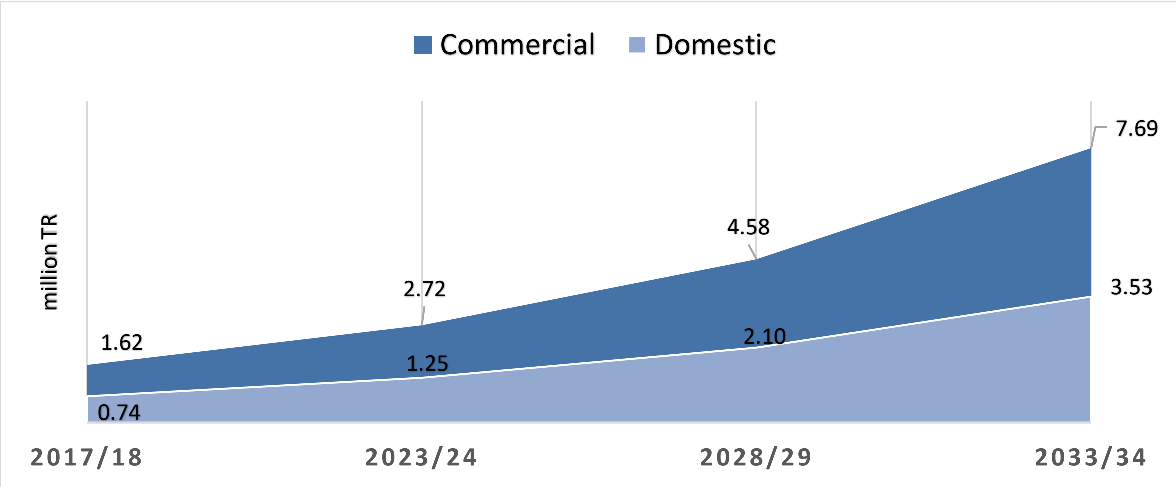


Figure 2. 15. **Projection growth of cooling demand (BAU) (Source: Annex 1- Table E)**

2.2.9. Projection of Energy Consumption in Business as Usual (BAU) and Intervention Scenario.

The Intervention scenarios were developed assuming the future development of equipment/appliances in line with the overall technical performance, the use of alternative low-GWP refrigerants, energy efficient technologies, and the expected energy-saving potential. For example, using a variable speed compressor, inverter technologies, modifications to reduce compressor friction losses and high-performance heat insulation will increase energy efficiency rate. With a transition to ozone-friendly, climate-friendly, and energy-efficient appliances, direct and indirect GHG emissions can be reduced by reducing demand for power supply.

To forecast the intervention scenario for the energy efficiency ratio against BAU scenario, as usual the energy experts were consulted and referred to similar RAC assessments in other regional countries. Table 2.5 lists the refrigerant and assumed energy performance improvements for new appliances in the Intervention Scenario.

Table 2. 5. Energy efficiency ratios; BAU and Mitigation (intervention) scenarios

Subsector	Refrigerants				Expected increase of Energy Efficiency ratios		
Category	**Current (2018)**	**2023/24**	**2028/29, 2032/33**	**Current**	**2023/24 (INT)**	**2028/29 (INT)**	**2032/33 (INT)**
Domestic	R -22, R-32 R-410 A,	R-410A, R-32, R-290	R-32, R-290 HFC Blends	2.1	2.2	2.4	3.3
Commercial	R -134a, R-22 R- 410 A,	R-134a, R-290, R-717 HFOs	R-290, R-717, R -744, HFOs	2.1	2.4	2.6	3.5

Source: A Guide to Energy Efficiency in Cooling & Heating, 2016

Accordingly, assuming significant improvement of energy efficiencies and general movement towards the use of natural refrigerants, overall, 50% of energy efficiency could be expected in 15 years. The improved efficiencies result in an overall reduction of CO_2 from indirect emissions (i.e., a reduction in electricity demand)

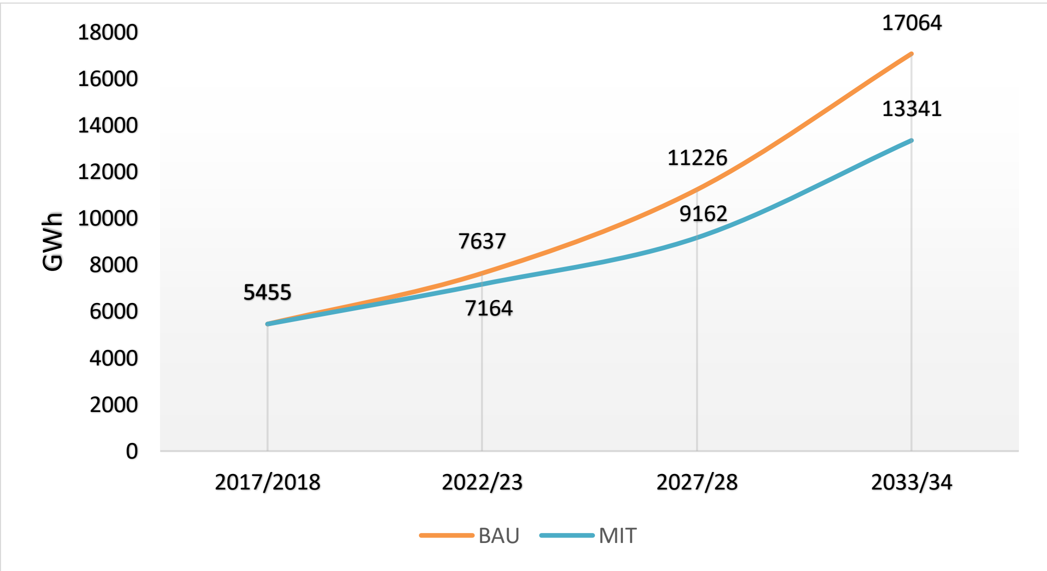


Figure 2. 16. **Projection of Energy Consumption BAU and Intervention scenario (Annex 1- Table F)**

2.2.10. Projection of GHG Emission in Business as Usual (BAU) and Intervention Scenario

Integration of recommendations of the NCP into NDC, whereas climate friendly and energy efficiency cooling can contribute with a mitigation effort by up to 2.0 million MT CO2-eq or up to about 21% of GHG emissions from BAU in 15 years.

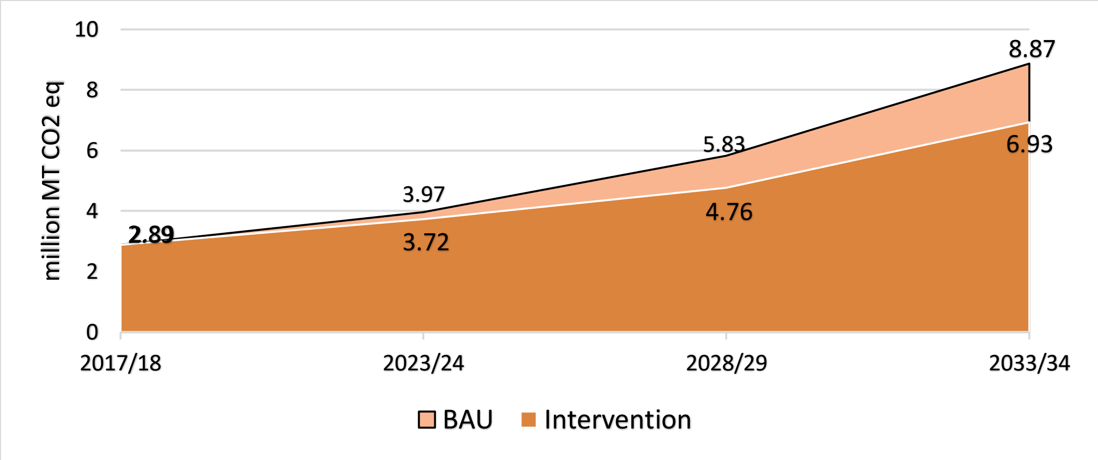


Figure 2. 17. **Projection of GHG emission in BAU and Intervention scenario (Source Annex 1 Table G)**

2.3. Passive cooling designs

Passive cooling designs are methods of improving indoor thermal comfort and thereby reducing energy use, without using an active system such as electrical fans, cooling/heating-based air conditioning systems, which are energy intensive. There are four key passive strategies to reduce energy use and electricity demand.

- Understanding the neighborhood: Buildings cannot stand alone without its context. The city is a fabric of numerous buildings and vegetation around the land. Therefore, understanding of such a context; both physical and climatic, is essential in order to build an energy efficient home.
- Apply shading to avoid sun: Minimizing solar radiative heat gain can improve thermal comfort for building occupants. This helps reduce the demand for cooling, improving energy efficiency. Solar heat gain can be reduced by sensible building orientation, proper window design and adequate shading solutions. It is important to avoid direct solar radiation into the house.
- Apply proper ventilation: Passive ventilation strategies use natural airflow patterns around and within a building. For natural ventilation and natural air conditioning, wind and buoyancy caused by air temperature differences between the two spaces need to be created. Buildings can be designed in such a way to enhance natural airflow and take advantage of them, thus enhancing thermal comfort and reducing energy use.
- Select proper materials: Thermal insulation is a barrier to heat flow through material and helps reduce heat gain to interiors. Thus, insulation will also help to prevent cooled air from warming up. Insulation can reduce the cooling load on a building by preventing heat gain. Because less heat passes into the living space, less energy is required to provide thermal comfort for occupants. Insulation can be installed in the roof, ceiling, or walls.

Natural Ventilation

Natural ventilation relies on the wind and the “chimney effect” to keep a home cool. The wind will naturally ventilate the home by entering or leaving through windows, depending on their orientation to the wind. Heat accumulated in the home during the day is replaced by the cold air entering from outside during the night. Natural ventilation can be improved by proper designing and locating of buildings by considering the wind direction. Wind moving along a wall creates a vacuum that pulls air out of the windows. The chimney effect occurs when cool air enters a home on the first floor or basement, absorbs heat in the room, rises, and exits through openings at upper levels. This creates a partial vacuum, which pulls more air in through lower-level openings. Natural ventilation works best in climates with cool summers or cool nights and regular breezes.

2.4. Strategies to Reduce Energy Consumption for Space Cooling

To develop strategies to reduce energy consumption for space cooling in buildings, the buildings can be categorized into two categories such as:

1. Existing buildings
2. New buildings

2.4.1. Strategies for Existing Buildings

The total heat load of a building can be divided in to two categories as internal and external heat gains. Not considering the internal heat gains generated by occupants, both internal and external heat gains are high due to unscientific orientation of building, substandard material selection, unsatisfactory operating practices in most existing buildings in Sri Lanka. For example, the external heat gain will be high if they are more windows which are directly oriented to east and west. In this Scenario, energy consumption of air conditioner will be higher. Material use for windows and walls with higher U value (overall heat transfer coefficient) are considered as substandard material. Unsatisfactory operating practices in buildings of Sri Lanka by unrealistic low value is causing higher energy consumption. It is advisable to follow comfort zone temperature as per ASHRAE standard 55.

In existing buildings, a comprehensive study such as a detailed energy audit would reveal the opportunities to save substantial amount of energy by way of:

1. Eliminating or minimizing energy wastage
2. Improving energy efficiency

Energy wastage can be eliminated or minimized by:

- Proper operation practices

- Educating the users on proper actions to be taken on operating the controls/switches and on preventive measures for excessive heat gain to the space
- Providing training on proper practices for operation, servicing, and maintenance personnel

Reduction on energy consumption and improvement of energy efficiency can be achieved by:

- Reduction of heat gain via external sources
- Reduction of heat gain via internal sources
- Efficient usage and operation of cooling systems with optimized control
- Efficient servicing and maintenance of equipment and components using properly recognized practices.
- Proper execution of regular servicing and maintenance
- Repair or retrofit energy inefficient system components, equipment and accessories or replacing (if found more feasible) using appropriate and energy efficient items.
- System retrofit, upgrading, or replacing systems (if found more feasible) using appropriate and energy efficient systems.

2.4.2. Strategies for New Buildings

Global warming and related adverse climate changes are significant all over the world. Temperature increases and erratic weather events are leading to many disasters such as droughts, floods, landslides etc. In addition, the surrounding temperature of cities are increased due to the heat island effect in urban areas. The above facts must be considered when designing new buildings. Increasing outdoor temperature leads to increased heat gain in the buildings and energy consumption. These effects can be minimized by using passive cooling methods such as shading, chimney effect and good material selection.

In new buildings, a substantial amount of energy can be saved by way of:

- Good building/ space design practices (Green Buildings)
- Energy efficient cooling system design with due consideration to efficient servicing and maintenance
- servicing and Energy efficient selection of equipment and components with due consideration to efficient servicing and maintenance
- Installation of equipment, components and systems using properly recognized practices with due consideration to efficient maintenance.

2.4.3. Energy Efficient Building Envelope for Lower Energy Consumption.

The Building Envelope element which is the physical separator of unconditioned environment (outside) and conditioned environment (inside) contributes to a substantial share of the cooling or heating load. The Heating, Ventilating and Air-conditioning (HVAC) system has to cater to this load as well in order to maintain the comfort and/or process conditions. Thus, the building envelop element plays an important role with respect to energy consumed and the cost of energy in its operating phase during the entire life of the building facility.

Minimizing the solar heat infiltration through the building envelope is a primary consideration within the tropical region. Hence, siting and orientation of the building with its long axis in line with east-west, avoiding openings in east and west directions. Use of light-coloured walls and roof surfaces, appropriate internal and external shading, moderate window to wall ratios, minimum air infiltration into the occupied space and economic utilization of building envelope insulation are good practices in designs.

2.4.4. Low GWP refrigerants with Energy Saving Potential

The following refrigerant based space cooling technologies have the potential for energy saving in the country.

- Vapour Adsorption – This technology uses water as the refrigerant. The main feature is, the energy source to drive it uses low grade heat such as hot water from 60°C to 90°C produced from Waste Heat or from Solar Water Heaters and does not need Electricity. The advantages are low costs of operation and maintenance with zero Carbon Dioxide (CO2) emissions.
- Technologies based on Ammonia (NH_3), Carbon Dioxide (CO_2), Hydrocarbon (HC) and combined systems of NH_3 and CO_2.

2.5. Recommendation

Short Term

1.

- Promote passive Cooling during nighttime, where the outdoor conditions are comfortable, by using proper materials, good orientation, natural ventilation, etc. instead of room air conditioners.
- Reduce Cooling load of the building by selecting the proper orientation, using passive designs and envelope improvements.

2.

- Regulations, Labelling and Awareness for fulfilling Minimum Energy Performance (MEP)
- New regulations/codes of building design need to be introduced for local authorities.
- Awareness programs should be conducted for the general public on new regulations/codes of building design.

- Develop procedures to permit import of star rated air conditioners only.
- Establish testing facilities and certification mechanisms for air conditioners.

3.

Design and equipment/components selection

- In selecting proper system design and equipment, following points need to be taken into consideration.
- Devise a method to promote accurate load calculation when designing and selecting HVAC systems in order to ensure the indoor air quality.
- Promote Building Management System (BMS), Internet of Things (IOT), sensors and dampers for efficient air conditioning systems.
- Encourage star labelled fans and room air conditioners in new and existing buildings.

4.

Good maintenance practices

- Enhance standardized training programs and certification systems.
- Follow the green procurement guidelines for procuring HVAC equipment and systems.

Medium and Long Term

1. Initiate the national policy for advising buildings owners to maintain the internal temperature between 24-26 ^{0}C with recommended humidity and airflow to conserve energy and achieve healthy living for occupants.
2. Research and development mechanism for designing comfortable and habitable spaces in housing units and commercial buildings need to be established.
3. Research and development activities including indigenous methods need to be promoted for air conditioning throughout the country at appropriate institutes to achieve national needs and objectives.
4. Promote technologies such as ice bank systems, and district cooling systems where applicable.
5. Promote retrofitting and retro commissioning of AC systems in existing buildings, which are of 10 years or above to reduce cooling requirement and energy consumption based on the assessment.

2.6. References

1. Department of Meteorology web site (www. meteo.gov.lk)

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5. Department of Census and Statistics, 2018. Annual report (http://www.statistics.gov.lk/)

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7. Country Assessment Report on Kigali Amendment, Ministry of Environment, 2019

Chapter 3

Cold Chain and Refrigeration in Sri Lanka

3. Cold Chain & Refrigeration in Sri Lanka

3.1. Introduction

A cold chain is a temperature-controlled supply chain, which consists of an uninterrupted series of refrigerated production, storage, and distribution activities, along with associated equipment and logistics that maintains a desired low-temperature range. The cold chain ensures that perishable products are safe and of a high quality at the point of consumption. Effective management of the cold chain maintains the quality of a product, which leads to a satisfied customer, greater demand, and overall protection of public health. A recent FAO report estimates that roughly one-third of food produced globally for human consumption is lost or wasted (Gustavsson et al., 2011).

Typically, a cold-chain is made of 4 links: pack-house or source point, reefer transport, cold storages, ripening chambers or retail. Refrigeration forms an important and significant part of the food and beverage retail market. It ensures optimal preservation of perishable food. Domestic refrigeration and commercial / industrial refrigeration are also the important elements of the cold chain.

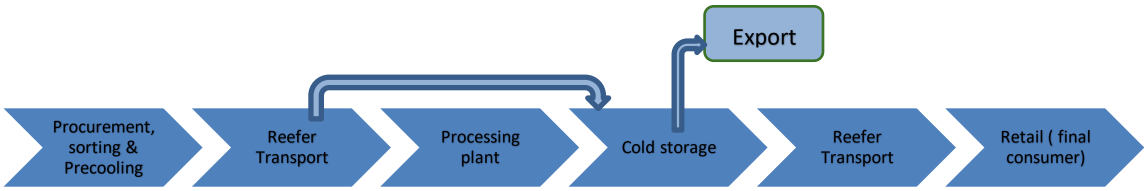


Figure 3. 1. **Cold chain links**

Reducing food loss and waste is critical to creating a Zero Hunger world and reaching the world's Sustainable Development Goals (SDGs), especially **SDG 2** (End Hunger) and **SDG 12** (Ensure sustainable consumption and production patterns)

It is estimated that in Sri Lanka, the post-harvest loss due to inadequate cold storage facilities is as high as 30 percent of the total output (Industry capability report, 2017). The quality of remaining 70% is also affected by inadequate cold chain facilities. The demand for proper refrigeration facilities in view of the growing food needs of the ever-growing population thus signifies the need for interventions.

3.2. Overview of Cold Chain infrastructure in Sri Lanka

Cold chain refrigeration is another big emerging sector which is expanding rapidly for the preservation of perishable foods like fruits, vegetables, dairy products, fish, and meat. There are scopes for enhancing the energy efficiency of the cold-chain sector whilst selecting new refrigerants which are economically viable and environmentally sustainable. The challenge for the industry is to move towards energy-efficient and environment friendly technologies.

Cold-chain infrastructure in the country consists predominantly of refrigerated warehouses. However, a significant part of the infrastructure (packhouses, ripening chambers, etc.) for handling of fruits and vegetables is yet to be developed. The cold chain for frozen products originating from postproduction at manufacturing / processing factories captures most of the refrigerated storage capacities and transport facilities. The majority of cold storages are single temperature storage, but distribution and end of the supply chain maintains a small percentage of multiple temperature storages.

The current state of the cold chain market integrally covers Food & Agriculture (fruits, vegetables, dairy, and meat) and fisheries, Commercial, Health services, and domestic. The development of cold chain refrigeration has been progressively discussed on a national level as an opportunity to close the gap between food losses and wastes and carbon emissions, highlighting the social and environmental benefits of doing so.

Sri Lanka has limited post-harvest storage infrastructure such as cold storage. Current capacity of Cold storages is estimated as 43,000 MT (Field survey, 2019). Figure 3.2 shows the composition of cold storage in food & agriculture and commercial sectors.

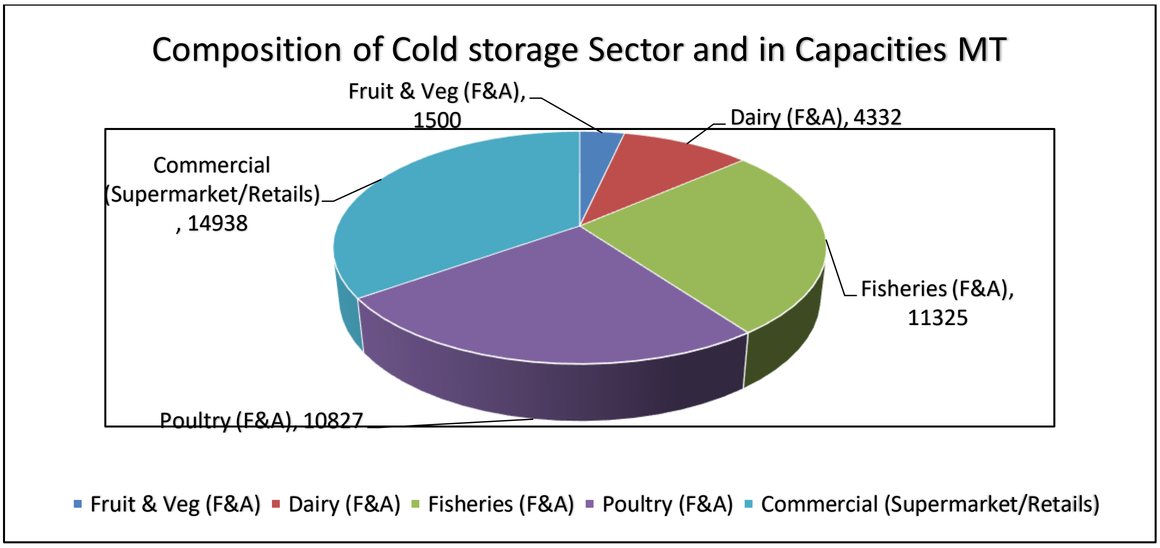


Figure 3. 2. **Cold storage distribution (Source: Survey Data, 2019)**

With the increase of urbanization and growth of GDP, the cold chain industry in Sri Lanka is developing, especially domestic and commercial refrigeration. The trend is now shifting towards establishing multipurpose cold storages and providing end to end services to control parameters throughout the value chain.

Most of the cold storages are in the Western province of Sri Lanka, where the main port and airport are situated. According to the survey approximately 70% of the cold storage capacity is concentrated within this province, 17% in the North -Western province and the rest is in other provinces.

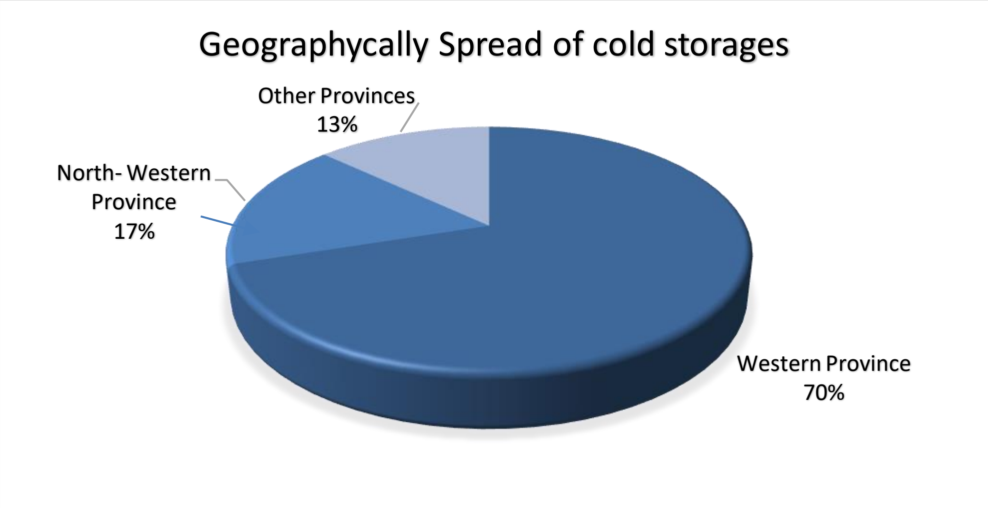


Figure 3. 3. **Spread of cold storages on provincial basis (Survey Analysis, 2019)**

Presently Sri Lanka has approximately 10-15 pack-houses operated by fruit and vegetable exporters and supermarket chains. However, the percentage of Seasonal Cold storage and Ripening Chambers is extremely low, and a great potential exists for growth.

3.2.1 Cold chain market in Sri Lanka

The private sector currently represents the largest segment of cold chain in Sri Lanka and it is followed by the corporative and public sector. Based on the product type, the market has been segmented as fruit and vegetables, meat and fish, dairy products, and healthcare products.

Dairy Sector: The marketing of milk in Sri Lanka is complex and varied. There are individual farmers who sell direct to processors, consumers, hotels, cafeterias, and canteens. Cooperatives are organized primarily for the purpose of collecting and selling milk to either hotels or processors. The formal, or processed dairy market consists of small dairy cooperatives, larger local cooperatives, district dairy cooperatives, dairy cooperative unions and networks of collection points and milk chilling centres operated by cooperatives or the main dairy processors.

Milk is a very affordable source of protein to the large vegetarian population in the country. The growing trend in demand is expected to continue in the short and medium term. The Government has major involvement in the state-owned milk processing company MILCO. Availability of cold-chain facilities is in short supply in rural areas and needs expansion.

Processed Food Sector: There has been a marked improvement in the consumer demand for processed foods. Private sector entrepreneurs have indicated the intent of establishing several food courts in main cities. This is a good opportunity for the development of the cold chain industry in the country.

Supermarket and Retail: this sector is expected to be amongst the biggest drivers of the cold chain market in Sri Lanka. Consumers easily access a large variety of fresh fruits and vegetables, dairy products, fish, meat and poultry products and a number of other temperature sensitive commodities. The supermarket and retail sector has already acknowledged that setting up of a strong cold chain infrastructure is a key step in efficiently managing their supply chains.

Healthcare Sector: A number of healthcare products such as vaccines, are heat sensitive and must be stored at temperatures ranging from $2^{O}C$ - $8^{O}C$. With Sri Lanka's pharmaceutical market expected to grow, a strong and efficient cold chain facility will be developed in the coming years.

Government assistance for cold chain projects.

There are low interest loan schemes introduced by the national budget aiming to facilitate the establishment of a strong cold chain facility for agricultural, horticultural, dairy, fish & marine, poultry and meat products by establishing linkage from the farm gate to the consumer to reduce losses through efficient storage, transportation, and processing.

3.3. Overview of refrigeration in cold chain

Industrial cold chain refrigeration is identified as refrigeration equipment involved in processing and storage of fruits, vegetables, milk, meat, fish, ice-cream manufacturing and storage, storage of pharmaceutical including vaccination. In large industrial systems, such as fish/meat freezers, cold storage mainly uses ammonia (R-717), HCFC-22 and R- 404A which are accepted as the preferred refrigerant. For pre-cooling systems and small/medium cold storages HCFC-22 and HFC 134a are used.

The penetration rates of cold chains in Sri Lanka sector-wise is not recorded. However, this chapter covers Food and agriculture (fruits, vegetables, dairy, meat), fisheries, Commercial (supermarkets and retail groceries), Health Services (Pharmaceutical), and domestic refrigeration. The data on other industrial refrigeration facilities such as industries that are not food related were not included in the survey and thus not included in this document.

The required data was collected through the reports published by relevant authorities, and from the field survey using questionnaires as well as through online interviews with HVAC

Consultants, equipment importers and cold room installers. Data on refrigeration facilities that are used by other sectors such as hotels, hospitals, *etc*., were not included in the survey.

3.4. Cold chain in Food and Agriculture

3.4.1. Food and Agricultural Sectors

3.4.1.1. Fruit & Vegetable Sector

Agricultural statistics indicate that Sri Lanka has produced 2,962,000 MT of vegetables and 1,096,000 MT of fruits in 2017(Industry capability report, Export Development Board, December 2019). However, the lack of infrastructure for cold chain management caused post-harvest loss of fruit and vegetables, which is estimated at 30 - 40 %. A limited number of companies engage in import/export of fruit & vegetables and supermarket chains play an important role in fruit & vegetable collection as well as distribution. They have in -built effective cold chain facilities including sorting and grading facilities. The fruit and vegetable processors use mainly ambient temperature-controlled spaces for short time storage. The inbuilt cold storages as well as reefer containers converted to cold storages are used for long-term storing. All these are medium in size and have a refrigeration capacity range from 0.75 to 2.0 TR. HCFC-22 and HFC-134a are used as refrigerants. The total estimated refrigeration capacity and total estimated daily energy consumption is shown in Annex 2 Table A.

3.4.1.2. Dairy Sector

The dairy industry is one of the most important industries with the potential to develop the economy of the county. At present, Sri Lanka produces 40% (domestic sources) of milk products and imports the balance 60% of milk products to fulfill domestic requirements. Sri Lanka has produced 374,015,943 million liters of cow's milk in 2019 (Department of census and statistics, 2019).

The country has an extensive network of approximately 300 milk collecting centers island-wide under 14 Milk Processing factories. Milk cooling tanks are mainly used in preserving and storing fresh raw milk. The cooled raw milk rapidly reaches the needed temperature of 4-5°C and is kept constant, which prevents the generation of bacteria. The capacity range of milk chilling tanks is 2,500 -10,000 liters.

The availability of refrigeration facilities in both government and private sectors is around 80% of production. Smallholder dairy farmers usually sell milk collected directly to consumers as fresh milk, as well as to processing companies.

Table 3. 1. Milk production and chilling facilities in 2019

Total Milk Production, liters/day	Milk chilling facilities available liters/day*
1,226,252	981,000

Source: Key Statistics of Dairy Industry 2015 – 2019, Department of Census and Statistics and* field survey 2019

The primary business of the formal private sector stakeholders, mainly multinational companies run substantial milk powder-processing operations. Fresh milk is processed as liquid milk, pasteurized and sterilized milk, flavoured drinks, ice cream, and yogurt. According to the diary expert information, annual ice-cream production is approximately 44 million liters or approximately 120,000 l/day (2019, Statement of Corporate Intent – MILCO Pvt. Ltd), which is approximately 10% of daily supply of milk. It was a complicated process to calculate the exact refrigeration and energy requirements since multiple factors and parameters which are different to each other are applicable. The best possible estimation is given in consultation with experts and analysis of survey data.

Further, there are chilled and frozen cold storages in the dairy industry as per the survey data collected in 2019. It is estimated that there are 205 Chilled storages (+ 5^{0}C) and 73 Frozen storages (- 20 ^{0}C) dedicated for storing chilled and frozen dairy products, respectively. HFC-134a, R-404A and HCFC -22 are the predominant refrigerant in this sub-sector in the country. The total estimated refrigeration capacity and energy consumption is shown in Annex 2 Table A.

3.4.1.3. Poultry/meat sector

The poultry and meat industry in Sri Lanka has shown a phenomenal growth over the recent past. According to the National Livestock Statistics 2019, Annual production of poultry and meat products was recorded as 263,410 MT (Average daily production 721 MT). It was revealed that the wastage in the poultry/meat sector is insignificant. According to the market and survey information, approximately 30% of total daily production of poultry and meat (216.5 MT) is sold as fresh meat without processing. The remaining 70% (505 MT) is processed to make various products and stored in cold storages.

Ammonia is widely used as a refrigerant for blast freezing and for cold storage. R-404 A and HCFC-22 are used in cold storages and chilled water systems. However, the use of HCFC-22 equipment is becoming less year by year.

Table 3. 2. Poultry and meat production

Description	Quantity MT
Average daily production of Poultry and meat	721
The estimated quantity of freezing and storing per day. (Estimated percentage of freezing and storing per day is approximately 70%).	505

Source: Key Statistics 2008-2017. Department of Animal Production & Health

All processors are equipped with chilling and blast freezing facilities. After the blast, freezing products are stored in the cold rooms which maintain -18 ^{0}C to -25 ^{0}C.

It is difficult to calculate exact refrigeration load and power consumption since these values are dependent on various parameters and factors. The total estimated refrigeration capacity and energy consumption is shown in Annex 2 Table A.

3.4.1.4. Fisheries sector

The fisheries sector in Sri Lanka plays a vital role in economic and social lifestyle development by providing direct and indirect employment opportunities for about 560,000 people and livelihoods for more than 2.7 million coastal communities. The fishery industry comprised of costal, offshore/deep-sea, and inland sub sectors. In 2017, the share of fisheries to the Gross Domestic Production (GDP) of the country was 1.3% (Central Bank of Sri Lanka, 2018). Annual fish production in 2017 was 531,310 MT. Importantly, it provides more than 60% of animal protein requirement to people in the country (Fisheries Industry outlook, 2017). The wastage level of fish caught by fishermen is significantly high due to inadequate post-harvest technologies. Therefore, more intervention to enhance refrigeration facilities is expected, especially in multi-day fishing trawlers.

According to the market information, nearly 50% of the total fish catch is sold as fresh fish at wholesale and retail fish markets for internal consumption and 20% for making dry fish and animal feed. The balance 30% of the harvest is processed by the fish processing companies using refrigeration facilities. Ammonia (R- 717) is used in all ice plants for manufacturing ice blocks and HCFC-22 is used in refrigeration systems for ice storage. However, the HCFC 22 based equipment are gradually being replaced with new equipment working with other refrigerants. Table 3.3 demonstrates the average production of fish and seafood, and the quantity of processing in 2017.

Table 3. 3. Production of Fish and Seafood

Description	Quantity MT
Average production of fish per day	1455.0
Average production of Seafood per day	82.0
Total production per day	1537.0
Estimated quantity of processing, freezing, and storing per day (approximately 30% of daily production)*	461.0

Source: Fisheries Statistics 2018, Ministry of Fisheries and *industry experts' information

All major fish and seafood processing facilities are equipped with chilling, blast freezing and storing facilities. The survey has identified that there are approximately 85 frozen fish and seafood storages having a total storing capacity of 11,335 MT. The total estimated refrigeration capacity and power consumption for this sector is shown in Annex 2 Table A

3.4.2. Commercial Refrigeration sector (supermarket and retail outlets)

One of the most important segments in commercial refrigeration is retail stores and supermarkets. Commercial refrigeration (CR) in supermarkets and retail stores have large areas dedicated to perishable products that require refrigeration from frozen to cold, including dairy products, meat, beverages, and fruit juices, among others and it is one of the most relevant energy consuming sectors.

According to the market survey the size of commercial refrigeration combining deep freezers, island freezers, bottle coolers, remote condensing units, and walk-in coolers in the base year 2018, including the historically installed base, sourced from importers and various market reports across different types of technologies has been estimated to be around 50,000 TR. The Market experts believe that different kinds of commercial refrigeration units shall witness a steady Combined Annual Growth Rate (CAGR) of around CAGR 10% increase over 10 to 15 year as outlined in Figure 3.9.

There were 573 supermarket outlets operating under 5 supermarket chains as of December 2018 (2019, field survey). The supermarkets are categorized according to the floor area, trade volume and available services. Refrigeration is widely used in all supermarkets and the number of refrigeration applications vary according to the size of the supermarkets. In addition, there are approximately 100 mini supermarkets all over the island, and most of them are installed with at least one mini cold storage for frozen products, island freezers and wall cabinets for diary, fruit, and vegetable products. The refrigerants in these units are typically R-134a and R-600a in the standalone units and R-404A and R-22 in the condensing units. All supermarkets were categorized according to the minimum number of refrigeration units/items available at the supermarket as shown in Annex 2 Table B-1. A summary of the estimated refrigeration capacity and annual energy requirement is shown in Annex 2 Table B-2.

3.4.3 Health Services (Medical/Pharmaceutical)

Pharmaceutical cold chain management is an important aspect of the supply chain in the healthcare industry. Cold chain logistic services assist the pharmaceutical and healthcare industries maintain a continual stock of drugs from suppliers and distributors across varied locations.

Most of the Pharma product storage and activities are done at room temperature at 20 ^{0}C to 25 ^{0}C, as Ambient Temperature-Controlled Storages. Available floor area in this kind of facility is approximately estimated at 30,000 m^2 and total available capacity is approximately 700 MT in 2018.

Some drugs degrade at room temperature and these drugs are stored in cold storage conditions. Popularly known cold storage conditions are 2 ^{0}C to 15 ^{0}C. (approximately 5000 m^3 of the storage volume belongs to ten leading pharmaceutical companies). Some importers have storages that could be converted to below zero (-5 ^{0}C to -20 ^{0}C) to store vaccines, but the total capacity such cold storages is approximately 50 MT.

The Sri Lankan pharmaceutical industry consists of both government and private sectors. It is expected to grow due to the start of manufacturing some medicines that have previously been imported to Sri Lanka. With this initiative, a strong demand of efficient cold chain facilities in the coming years could be visible. Therefore, demand for large warehousing facilities is set to increase. Further, a greater cold chain and cold storage capacity may also be necessary for the health sector, in particular for storing COVID-19 vaccines. The total estimated refrigeration capacity and energy requirement for this sector has been calculated and is shown in Annex 2, Table C

3.4.4. Domestic Refrigeration

As refrigeration is a basic need of people of this era, the permanent demand of refrigerators is increasing continuously in Sri Lanka. According to the Annual report 2019 issued by the Central Bank of Sri Lanka, 52.2% of homes in Sri Lanka had a refrigerator in 2016 and among them 69% were in urban areas. Currently in the country there are about 3.5 million domestic refrigerators, including those in the service sector, most of them based on HFC-134a and penetration ofC-600a technology was started from 2015. It is estimated that there will be a growth in the purchase of refrigerators. Below Table 3.4 shows the number of households and the percentage of ownership of refrigerators.

Table 3. 4. Population of Household domestic refrigerators

	2009	2013	2016
No. of Households	4.7 million	4.9 million	5.0 million
% of refrigerators	39.6	46.2	52.9
Number of refrigerators	1,861,200	2,263,000	2,645,000

Source: Annual Report-2019, Central Bank of Sri Lanka

Domestic refrigerator sales witnessed a steady rate of growth of around 15% in the last decade. It is thought that this trend shall continue for another 10 to 12 years and it may reach a saturation point in 2030-32. Three factors accounted for a steady increase in the sale of refrigerators since 2010. First is the steady and higher economic growth i.e., per capita income, second, the penetration of electricity in rural areas and the third is the availability of refrigerators at an affordable and competitive price from local manufacturers.

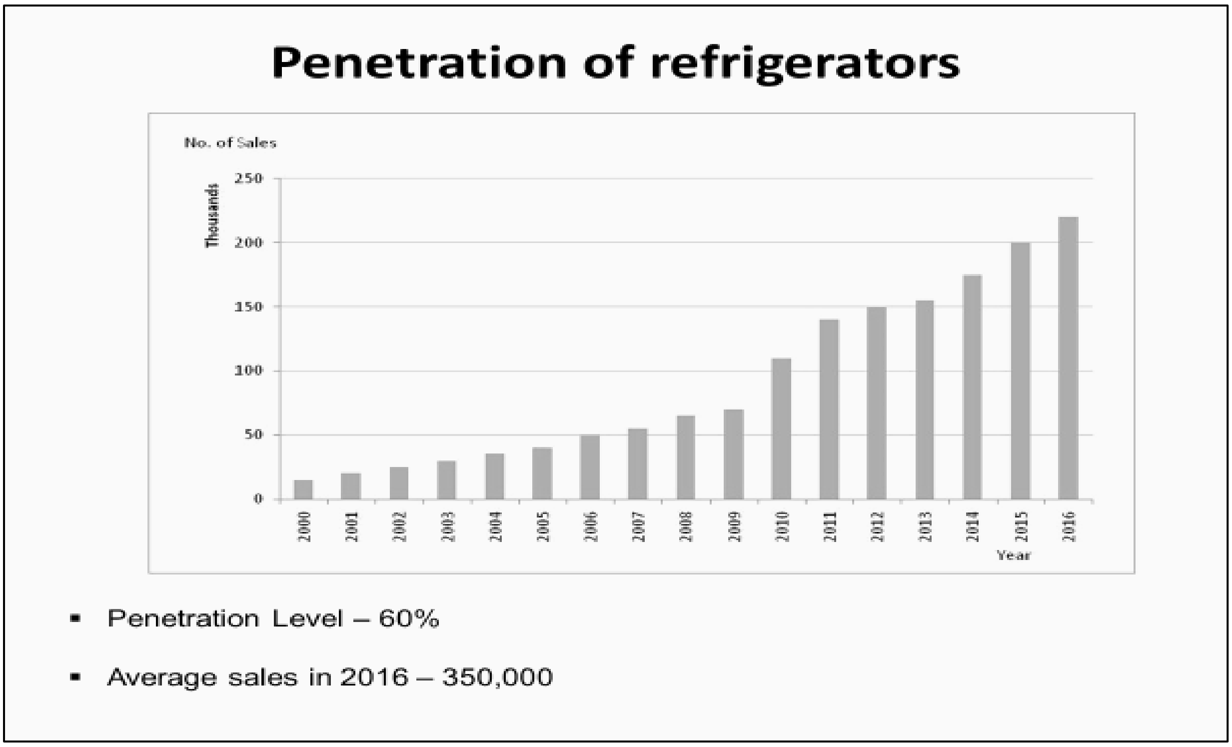


Figure 3. 4. **Penetration of refrigerators. (Source: Sustainable Energy Authority presentation 2019)**

The total estimated refrigeration capacity and energy consumption for the domestic refrigeration sector has been calculated and is shown in Annex 2 Table D.

The production of domestic refrigerators by two manufacturers has grown in addition to the import by several importers. It may further be noted that local manufacturing companies can now cater to 65 -70% of the market demand in Sri Lanka and the balance requirement is catered by imports.

[Production details of refrigerators in Sri Lanka appeared in Chapter 5 – RAC Service sector].

3.5. Summary of estimated refrigeration capacities and energy consumption.

The summary of the estimated refrigeration capacities and energy consumption calculated with data collected through survey, reports and best of assumption is shown in Table. 3.5

Table 3. 5. Summary of refrigeration capacity and Energy consumption of all sectors as of 2018

Sector	refrigeration capacity, kW	Energy consumption, kWh/day	Annual Energy Requirement, GWh
1. Food and Agriculture	117,415	659,627	240.74
2.Commercial refrigeration	173,080	321,720	117.43
3. Health Services	2,400	48,000	17.52
4. Domestic refrigeration	522,000	4,369,863	1,595.00
Total	**814,895**	**5,399,210**	**1,970.69**

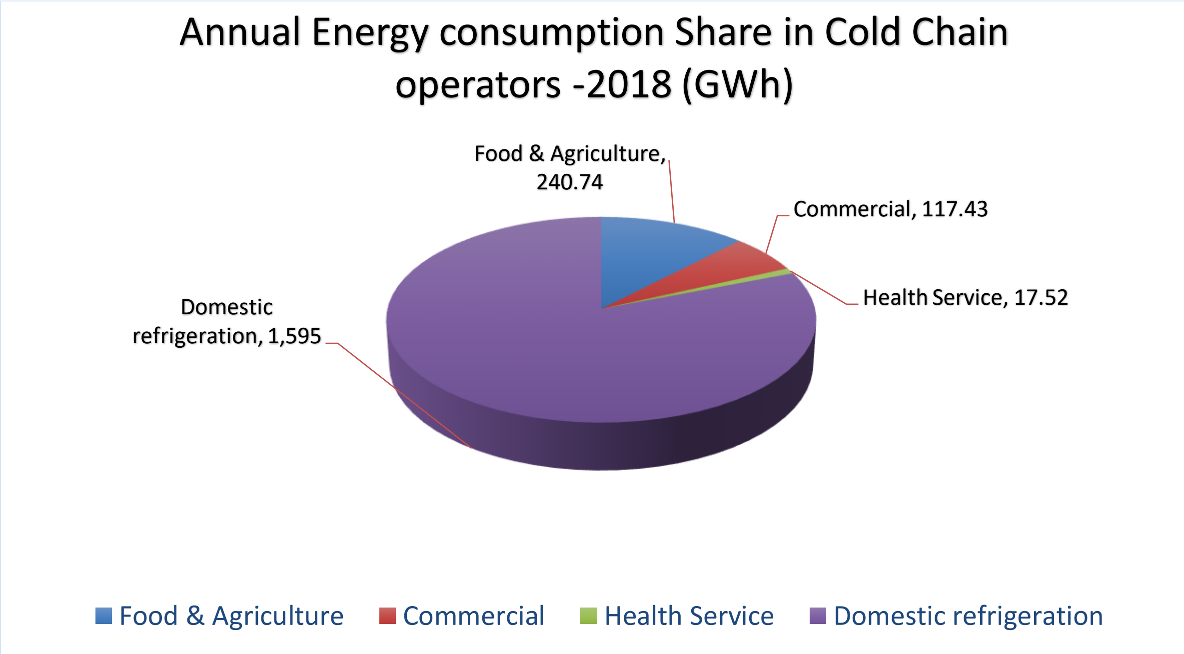


Figure 3. 5. **Annual Energy requirement for Cold chain sector in 2018 (Refer Annex 2,Table A-F)**

Summary:

Total Annual Electricity Generation (2018) - 15,255.0 GWh (100%)
Energy Consumption in Domestic refrigeration - 1,595.0 GWh (10%)
Energy Consumption in Cold Chain Sectors - 375.7 GWh (3%)
Energy Consumption in all the other uses - 13,284.3 GWh (87%)

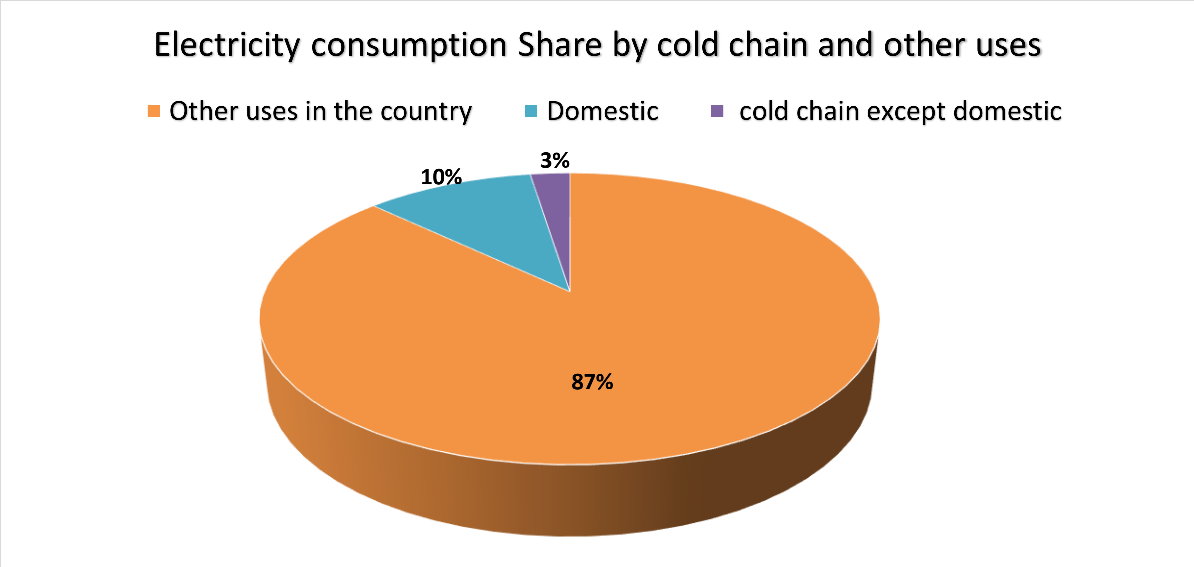


Figure 3. 6. **Share of the total power generated with Co chain sectors in 2018 (Based on 2019, Central Bank Annual Report and industry information)**

3.6. Future Growth trend of Cold chain sectors

Data available in the reports published by Department of Census and statistics, Live-stock Development Board, Annual Reports published by the enterprises, Sri Lanka Export Development Board, Scholarly articles of research institutes and data collected from questionnaire-based field survey were used for the analysis of current and future trends of the cold chain sectors. The combined annual growth rates (CAGR) of each sector have been utilized to project the evolution of the cold chain sector and CAGR is presented in Annex 2 Table F-1

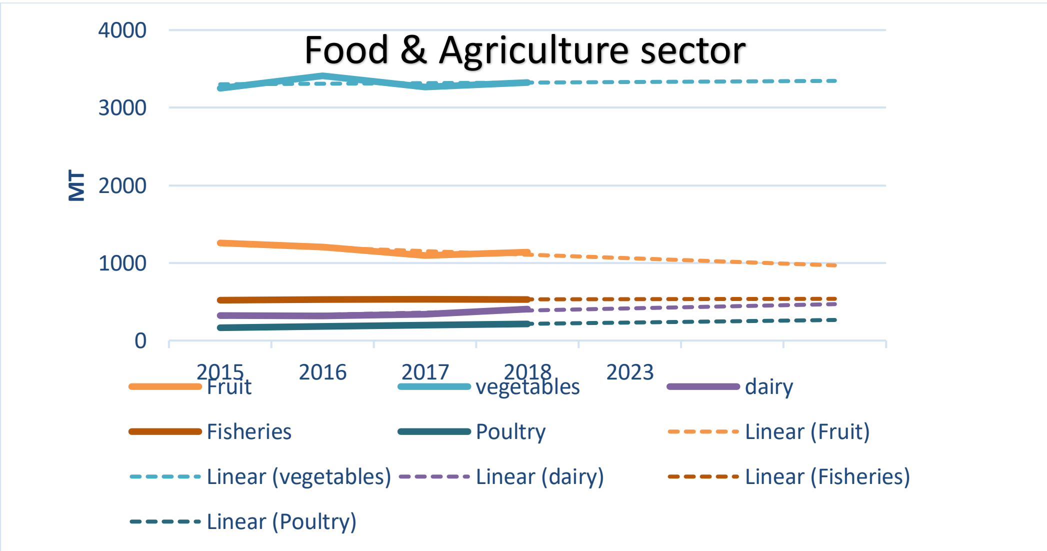


Figure 3. 7. **Annual Growth Trend of Food & Agriculture sector (Source: Annex 2, Table F-1)**

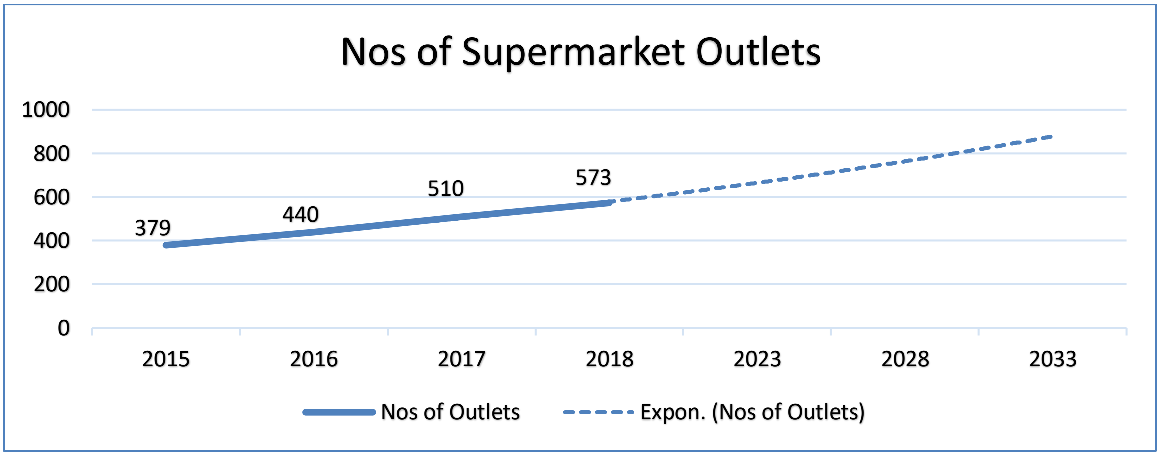


Figure 3. 8. **Growth Trend of Commercial refrigeration sector (Source: Annex 2, Table F-2)**

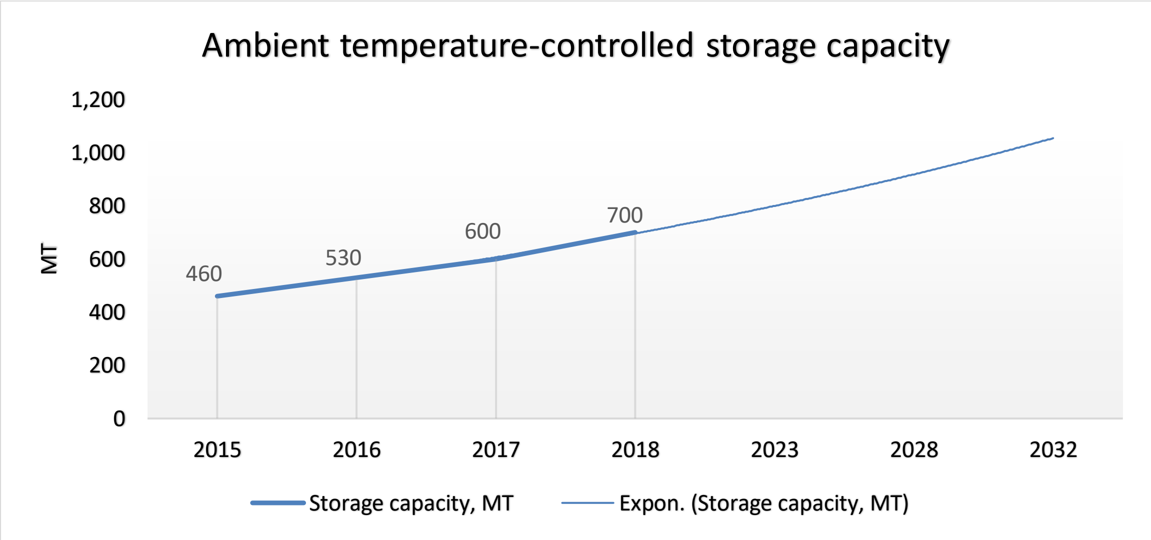


Figure 3. 9. **Growth Trend of storage capacity of Health Service sector (Source: Annex 2, Table F-3)**

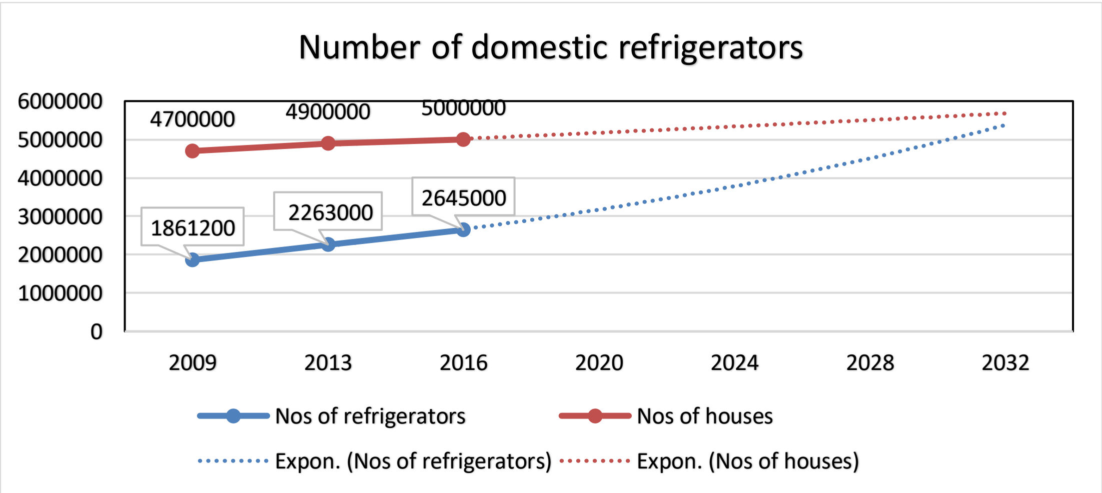


Figure 3. 10. **Growth. Trend of Domestic refrigerators**

Summary of forecast for the growth of cold-chain sectors, growth of refrigeration capacity and growth of annual energy demand (Business as Usual scenario) is shown in Annex 2, Table E-1.

The intervention scenario in energy consumption is considered based on the potential improvement in energy efficiency of refrigeration equipment and alternative low Global Warming Cooling Technologies, *etc*.

According to the available data and industry information, about 70% of refrigeration systems in Food & Agriculture sector(fruits, vegetables, dairy, fisheries, and poultry/meat) are using refrigerants such as Ammonia, R -134a, R-404A and R-507A which are of zero Ozone Depleting Potential (0 ODP) . Ammonia refrigeration systems dominate in dairy, fisheries, and poultry/meat sector and will be continued for a longtime, as ammonia is a good energy efficient refrigerant. In the meantime, freezing and cold storages systems operating on HCFC-22 in this sector are being replaced mainly with Ammonia, R-404A and R-507 systems, because promising new generation low GWP technologies are yet to be introduced in Sri Lanka.

However, the Commercial refrigeration (supermarket and retail) sector in Sri Lanka has undergone tremendous changes over recent years and the use of hydrocarbons and carbon dioxide technologies in supermarket refrigeration systems will significantly increase during the next 5 years and beyond.

Growth of hydrocarbon technology in the domestic refrigeration sector is incredibly significant and R-600a is leading in domestic refrigerators and a few deep freezers are operating on R-290.

3.7. Assumption for Business as Usual (BAU) and intervention scenario

A Business as Usual (BAU) and Intervention scenarios were developed assuming the future development of equipment/appliances in line with overall technical performance, the use of alternative low-GWP refrigerants , energy efficient technologies, and expected energy-saving potential. For example, using a variable speed compressor, high performance heat insulation will increase the energy efficiency rate. With a transition to ozone-friendly, climate-friendly, and energy-efficient appliances, direct and indirect GHG emissions can be reduced while reducing demand for power supply.

To forecast the intervention scenario for a energy efficiency ratio against a BAU scenario, the energy experts were consulted and referred to similar RAC assessments in other regional countries.

Table 3.6 lists the refrigerant and assumed energy performance improvements for new appliances in the Intervention Scenario. While all sub-sectors' efficiencies increase significantly, it is of note that domestic refrigerator's nearly triple, and there is a general movement towards the use of natural refrigerants.

The improved efficiencies result in an overall reduction of CO_2 from indirect emissions (i.e., a reduction in electricity demand)

Table 3. 6. Energy efficiency ratios; BAU and Mitigation (intervention) scenarios

Subsector	Refrigerants				Energy Efficiency ratios		
Category	**Current (2018)**	**2023/24**	**2028/29, 2032/33**	**Current**	**2023/24 (INT)**	**2028/29 (INT)**	**2032/33 (INT)**
Food & Agriculture (Industrial)	HCFC -22, HFC -134a, R 404A, R-717	HCFC-22, R-717, R 744 HFO1234 ze,	R-717, R -744 HFO1234 ze,	2.1	2.2	2.4	3.3
Commercial	HFC -134a, R-404A, HCFC-22	R-290, R 600a, R -744, HFO	R-290, R 600a, R -744, HFO	2.1	2.4	2.6	3.5
Health Services	R-410 A, HFC - 134a	R-410A, R-290, R-744 HFO-1234yf	R-290, R-744 HFO-1234yf	2.6	2.9	3.2	3.8
Domestic	HFC -134a, R- 600a	HFC -134a, R-600a	R-600a	1.3	1.5	2.1	3.1

Metrix of Energy consumption in Business as Usual (BAU) and intervention scenario are shown for all sectors in Annex 2 Table E-1 and E-2 and it is presented in Figure 3.11.

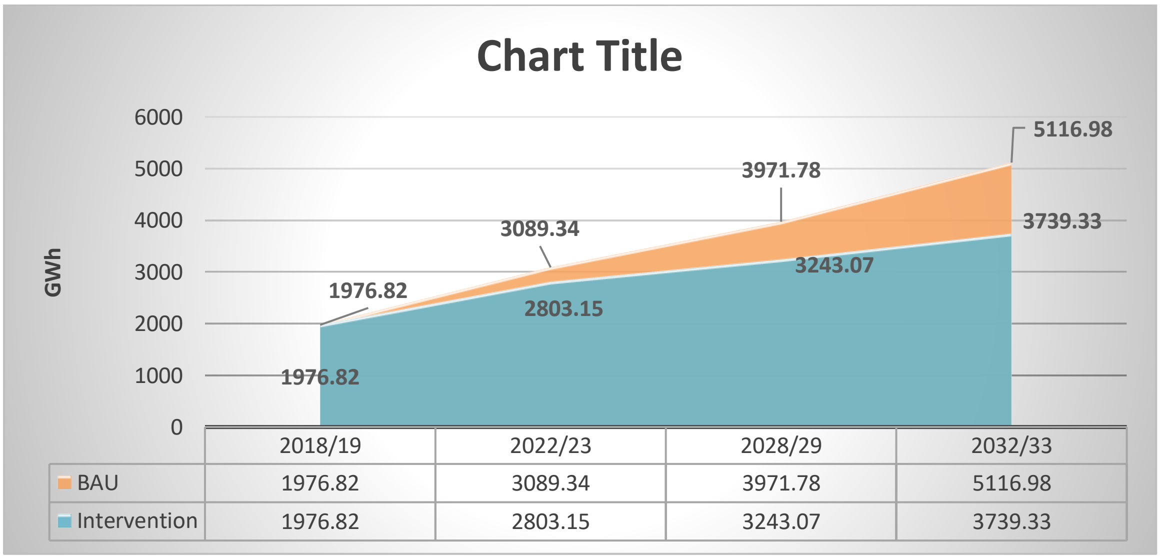


***Figure 3. 11*. BAU and Intervention projected energy consumption of Cold chain sector**

3.8. Emission from Cold chain sectors

Indirect Emission

Household energy use in Sri Lanka represented as 4,200 GWh of electricity in 2018. Approximately 38% of this consumption is from domestic refrigerators, making the fridge one of the top power consuming appliances. Approximately 65% of the whole electricity generated in Sri Lanka is based on coal, and petroleum. Since CO_2 emissions per kWh of electricity is equal approximately to 0.8 kg CO_2/kWh GWP, approximately 0.83 million tons of CO_2 have been emitted just from refrigerators in households. At present 95% of refrigerators are using HFC-134a.

To estimate the direct (refrigerant related) emissions, it was necessary to account for refrigerant use and losses throughout the appliance's useful life:

- Refrigerants used to fill newly manufactured products,
- Refrigerants used to refill systems in operation to account for annual losses (average annual stocks),
- Refrigerants that remain in appliances at decommissioning

From research data extracted from Eurostat (http://epp.eurostat.ec.europa.eu) on refrigerants environmental impact it was assumed that there would be a leakage of 15% during the manufacturing process. This is the maximum leakage permitted by the US Environmental Protection Agency. During the usage phase, 1 to 2 grams of refrigerant leakage per year is often seen in domestic refrigerators. It is also assumed that one recharge is required over the lifetime of a domestic refrigerator up to the original 120 grams of refrigerant. Based on the assumption described in Annex 4 Table G, the refrigerant leakage to the atmosphere is converted to CO_2 emissions in the lifetime of a refrigerator (15years) and shown on the figure below.

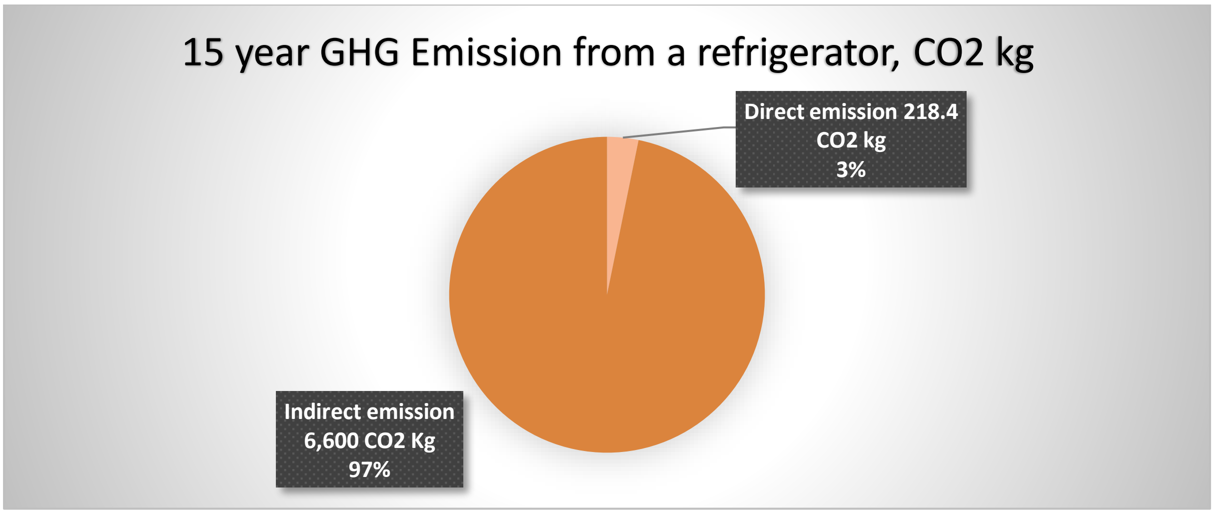


Figure 3. 12. **GHG emission from a refrigerator in 15 years lifetime.**

It is clear from the above figure that the major emissions contributor by a large factor is the power usage of the compressor. The next major emissions contributor is the refurbishing and recharge of refrigerant in old refrigerators for further use. In considering commercial and industrial refrigeration, GHG emission from generating power to drive refrigeration systems is much greater than direct emission from refrigerant.

Table 3. 7. Estimated annual electricity consumption and emission of Cold chain refrigeration sector in 2018

	Consumption (GWh/year)	Emission of CO_2 (MT)	Percentage (%)
Food & Agriculture sector	240.74	125,800	12.42
Commercial refrigeration	117.43	60,973	6.50
Health service	17.52	9,110	0.08
Domestic refrigeration	1,595.0	828,169	81.00
Total	**1,976.82**	**1,024,052**	

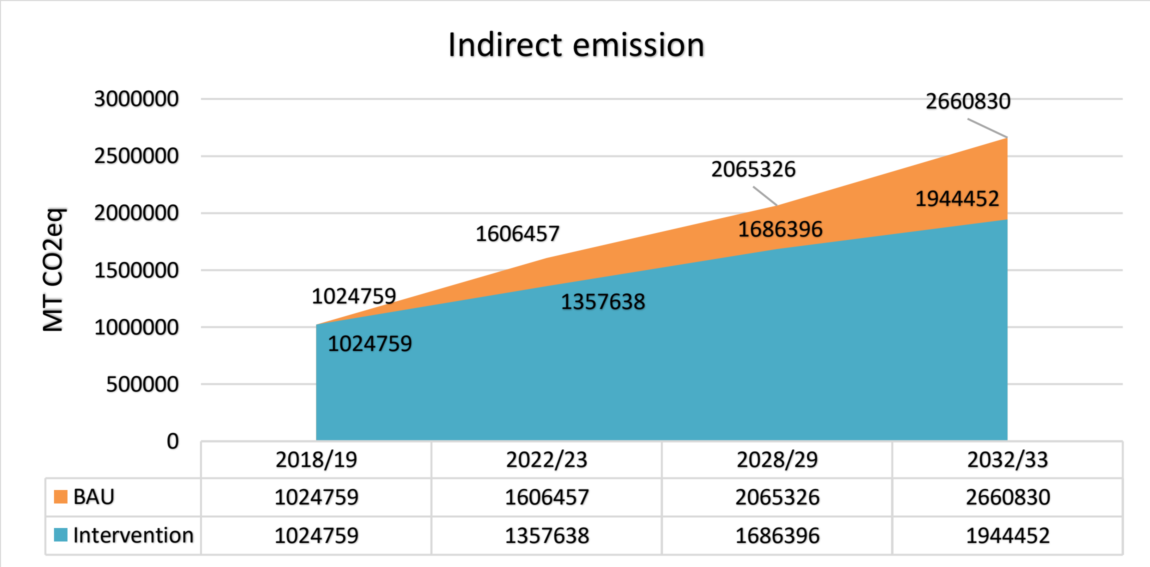
The most significant contribution to emissions in the cold chain sector is domestic refrigeration which is 0.82 million MT CO_2-eq. The next significant subsector is Food & Agriculture with about 0.12 $MTCO_2$-eq in 2018.

Direct Emission

Direct GHG emissions in the RAC sector result from the manufacturing process, from leakage and service over the operational life of the equipment and from disposal at the end of the useful life of the equipment. These gases have 100-year global warming potentials (GWPs), which are typically greater than 1,000 times that of CO_2, so their potential impact on climate change can be significant. . By the same token, any reductions of these gases can have a large potential of climate benefit.

The data on potential emission levels and sources of emissions are greatly missing; to track the details associated with GHG emission of equipment. However, modelling parameters mentioned in Table G in Annex 4 were taken from http://www.green-cooling-initiative.org and modified according to stakeholder/industry consultation.

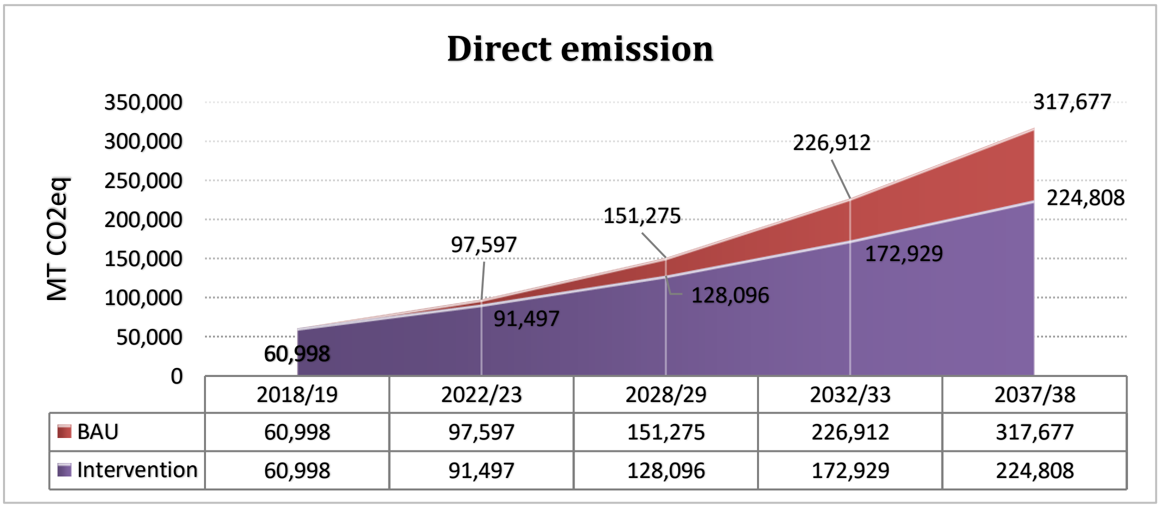
The domestic refrigeration sub-sector has already seen considerable transformation towards clean and efficient cooling. Today, globally, R-600a refrigerators have overtaken R-134a versions in new refrigerator units on the market and inverter compressors are increasingly being used on new units. Promoting renewable and alternative energy technologies for the four cold chain sectors, it is estimated that approximately 26% (0.71million $MTCO_2$-eq) will be reduced as direct GHG emissions from BAU levels by 2032.



	2018/19	2022/23	2028/29	2032/33
BAU	1024759	1606457	2065326	2660830
Intervention	1024759	1357638	1686396	1944452

Figure 3. 13. **Indirect emission BAU and Intervention scenario in cold chain sectors**

With a stable stock of domestic refrigerators (operating with HC- 600a), lower direct emissions from refrigerants and with improved energy efficiencies, GHG emissions from refrigerators are expected to decrease in the BAU scenario by 25-30% compared to 2018. Promoting low GWP technologies for the other three cold chain sectors as well, a 34% (90,000 $MTCO_2$-eq) overall reduction in GHG emissions from BAU levels by 2037 is expected.



	2018/19	2022/23	2028/29	2032/33	2037/38
BAU	60,998	97,597	151,275	226,912	317,677
Intervention	60,998	91,497	128,096	172,929	224,808

Figure 3. 14. **Direct emission BAU and Intervention scenario in cold chain sectors**

3.9. Improvement of energy efficiency in cold chain refrigeration system

Emissions could be reduced by improving the existing systems performance, and also by reducing the use of High GWP refrigerant (HCFC, HFC). These actions can be implemented in several ways as presented below.

Domestic refrigeration:

- Use of propane and isobutene-based refrigeration systems,
- Change HFC-134a compressor for isobutene compressors, charge with isobutene. (lower consumption compared with the HFC-134a original system)
- Encourage the exchange of refrigerators with more than 10 years of work through the valuation of the old equipment and with the option of paying in installments for the new unit.

Commercial refrigeration

- Ensure that the equipment is correctly selected and installed properly.
- Ensure adequate air flow in the exchangers.
- Reduce the heat load by decreasing the intake of hot and humid air (properly close doors)
- Use of intelligent technologies such as variable speed motors and electronic controls.
- Good maintenance practice.

Industrial refrigeration

- Replacement of compressors, pumps, electrical controls with more than 25 years of operation or poor performance.
- Improvement of the maintenance system for equipment, systems, and facilities
- Eliminate HCFC -22, R -404A, R-507A systems, with the use of ammonia.

3.10. Key Challenges for the cold chain industry in Sri Lanka

1. Most farming communities lack pre-cooling, cold storage, and ripening facilities in vegetables and fruit growing/collecting areas. Almost 40% of harvest is perishes due to inadequate cold chain facilities. Further, well-developed third-party logistics for cold chain facilities and transport are also inadequate for effective cold chain operation.
2. Inefficient handling of perishables leads to the quality of temperature-sensitive product deteriorating, if not handled well. Therefore, greater awareness of this aspect is required. In addition, appropriate capacity development needs to be done on handling of perishables.
3. The availability of Skilled Manpower in the cold chain industry is currently affected by limited availability of trained personnel in cold chain management. This is due to the lack of vocational or other training institutes that are focusing on cold chain logistics in Sri Lanka.
4. Difficult to access affordable financing options for smallholding farmers.
5. Higher initial capital investments in cold storages, transport infrastructure and higher payback period.

6. Lack of technology in development of indigenous refrigeration. Temperature control systems are overshadowed by increased accessibility to modern equipment and technology that are imported from foreign countries.
7. Farmers are very conservative and often have limited financial awareness regarding infrastructure investments.

3.11. Recommendations

Short Term

1. Formulation of National Policies for food security by promoting cold chain technology.
2. Enhance awareness of farmers to manage produce both pre-harvest and post-harvest, to minimize spoilage.
3. Introduction of appropriate policy measures to improve energy efficiency of equipment.

Medium Term

1. Encourage developing cold chain infrastructure with use of low-GWP refrigerant based energy efficient cooling systems.
2. More intervention by the government to build a cost effective, unbroken chain of temperature-controlled storages, and transport from the point of harvest to the marketplace in order to avoid produce spoilage and to connect farmers with higher value market options overseas or in distant urban centres.
3. Offering of more incentives from the government for cold chain investments that help to improve farm incomes. It will also be a major move in supporting achievement of Sustainable Development Goals (SDG 1 – No poverty and SDG 2 – Zero hunger).
4. Providing specialized training facilities for cold chain professionals and technicians to promote proper utilization and operation of technology, as well as energy efficiency.
5. Active interventions by both the government and private sector for developing cold-chain infrastructure to achieve better cooling energy performance.
6. Designing the programme for retrofitting of existing cold storages to reduce refrigerant demand and energy consumption.

Long Term

1. Standardization of design, construction, and associated specifications for cold-chain infrastructure components
2. Further strengthening of an inter-ministerial collaboration to facilitate infrastructure development and improve overall efficiency of the cold-chain system.
3. Promotion of research and development of low-cost technologies to address the specific problems of local supply chain.

4. Retrofitting or replacing of the old and inefficient cold chain systems with low-GWP, energy efficient and right-sized cold chain equipment
5. Implement standards and labelling programmes for commercial and industrial refrigeration equipment.

3.10. References

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Chapter 4

Transport and Air Conditioning in Sri Lanka

4. Transport Refrigeration and Mobile Air Conditioning

4.1. Mobile Air Conditioning and Transport Refrigeration

Mobile air conditioning and transport refrigeration has emerged significantly in Sri Lanka in the last few years, due to factors such as the growth of the economy, development of tourism, growth of the cold chain industry, addition of luxury buses for highways and a growing number of reefer trucks. Emissions from various sources such as industry, increased vehicle fleets on the road and traffic congestion have increased air pollution. These facts, along with rising ambient temperatures, have eventually led individuals to use AC in vehicles.

In Sri Lanka, motor cars account for a significant portion of the total automobile air conditioning systems in comparison to air-conditioned buses and dual-purpose vehicles. Mobile AC consumes more energy than any auxiliary components. Therefore, cooling related energy consumption is an important factor to predict the future energy demands pertaining to the transport sector.

Similar to the rise in the demand for air conditioning for dual-purpose vehicles and buses steadily, the demand for transport refrigeration equipment also seems to be growing rapidly, due to huge demand for food processing and transport. The main refrigerants used for mobile air conditioners and transport refrigeration include HFC-134a, HCFC-22, R-404A and R-507A. (For detailed information please refer Annex 3)

4.2. Projected Vehicle Population

In this exercise, the population and the GDP projections were used as the main driving force for estimating future demand for vehicles, which are fitted with MAC such as motor cars, buses, and dual-purpose vehicles. Annual growth rate of population (Department of Census and Statistics, 2018) and the GDP (Central Bank Sri Lanka, 2018) were considered to be 1.1% and 5.8% (Average growth rate during the period (2010-2017) respectively throughout the period. According to the data gathered from website of the Ministry of Transport, it was recorded that motor cars, buses, and dual-purpose vehicles account for nearly 60%, 8% and 32% respectively, of the total number of considered motor vehicles with MAC in the country during the period 2017-2018 (http://www.transport.gov.lk). Total average numbers of motor cars, buses, and dual-purpose vehicles during the period 2017-2018 were considered as the baseline for (future) projections. Figures 4.1, 4.2, 4.3 show the projection for estimated motor cars (passenger), buses, dual purpose vehicles respectively up to years 2037–38, considering the aforesaid annual growth rate of population and GDP.

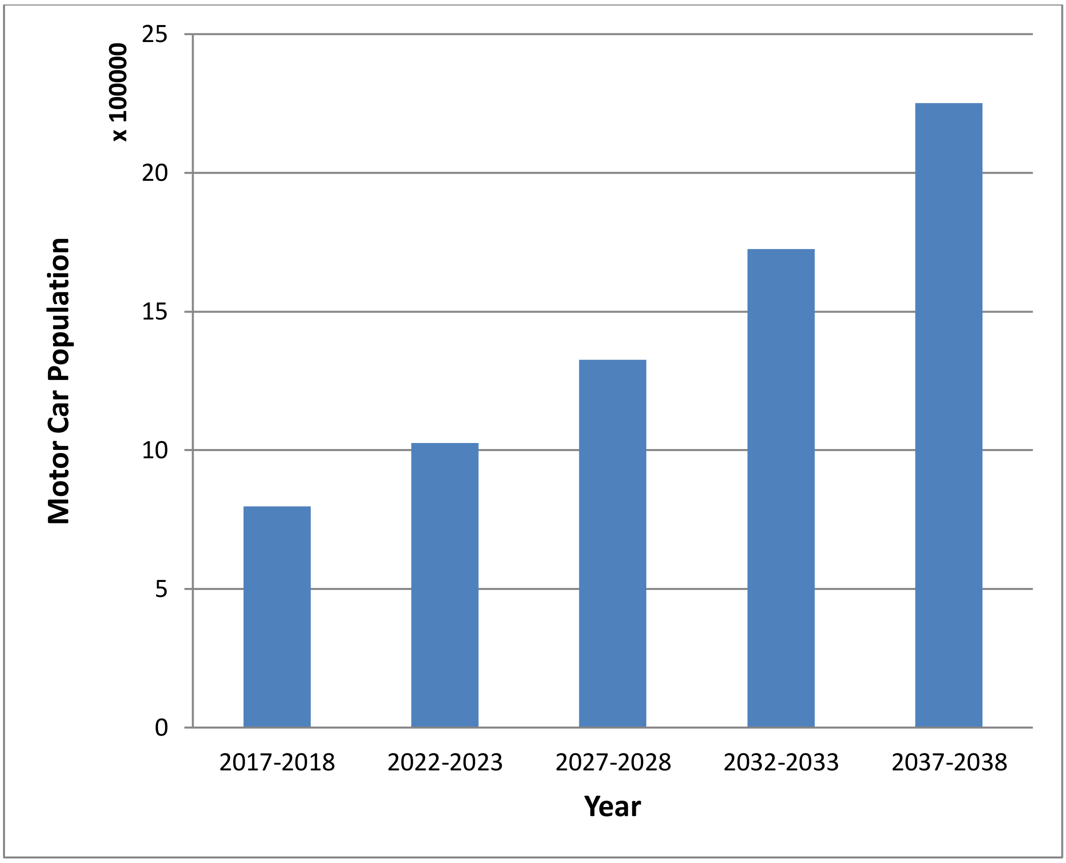

Figure 4. 1. **Projected Motor Car Population**

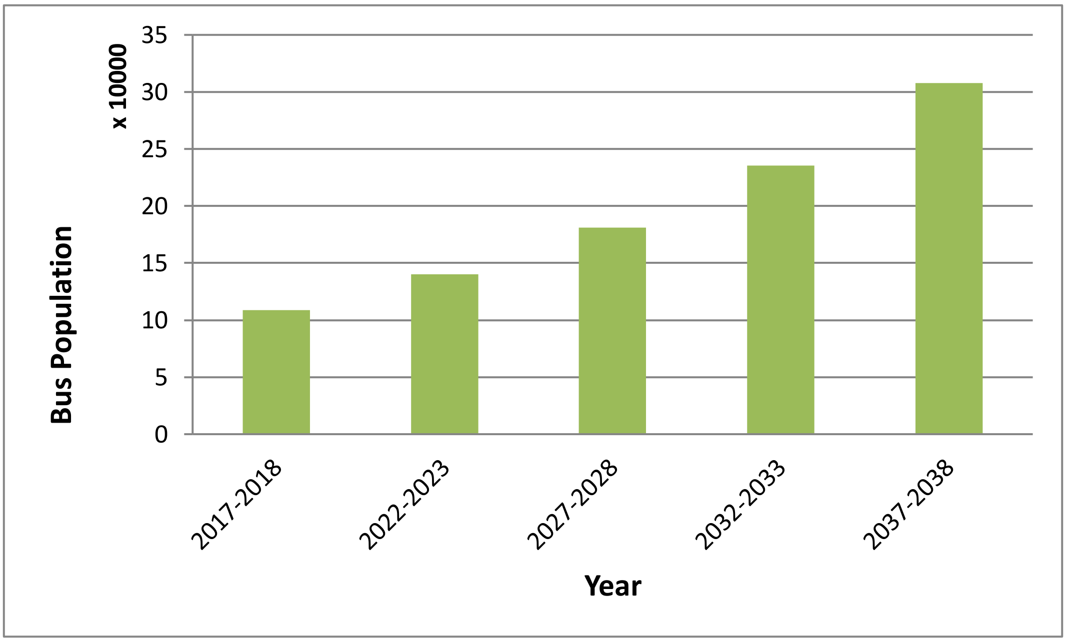

Figure 4.2. **Projected Bus Population**

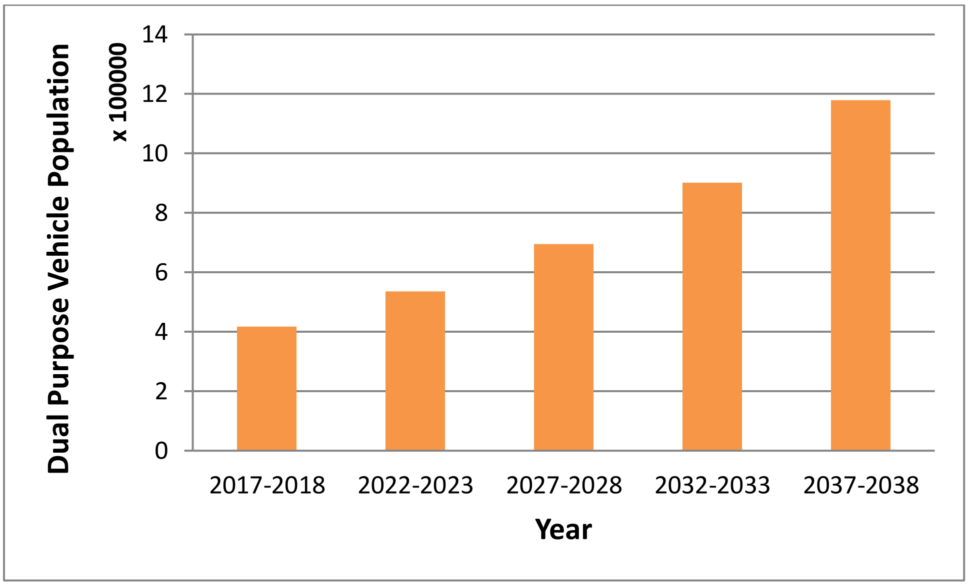

Figure 4.3. **Projected Dual-purpose Vehicle Population**

According to the above figures, it is projected that Sri Lanka's motor car, bus and dual-purpose vehicles population will reach nearly 2.2, 0.3 and 1.2 million respectively by the year 2037-38.

4.3. Refrigerant demand for transport sector - Current and projected

Refrigerant containing vehicles include motor cars, dual purpose vehicles, buses, etc. A motor car requires 400g to 700g of refrigerant to effectively provide comfort to passengers, while buses and dual-purpose vehicles contain approximately 4 kg and 1 kg respectively. It is estimated that the leakage rate of the MAC sector in developing countries is close to 20% on average annually (IPCC, 2010). Total average numbers of motor cars, buses, and dual-purpose vehicles during the period 2017-2018 were considered the baseline for (future) projections.

4.3.1. Motor Cars

Demand for refrigerant in the motor car segment for BAU scenario has been estimated based on a 20% leakage rate (IPCC, 2000), (0.11kg) throughout the projected duration, and for the intervention scenario it is estimated based on a 10% leakage rate after 2025. It is expected that this reduction would be achieved through implementing good practices, organizing more awareness/training programmes for technicians and introducing improved technological methods.

Estimation of holding capacity of refrigerant for motor cars would be around 13-14x 10^2 MT by 2038 as per the Figure 4.4.

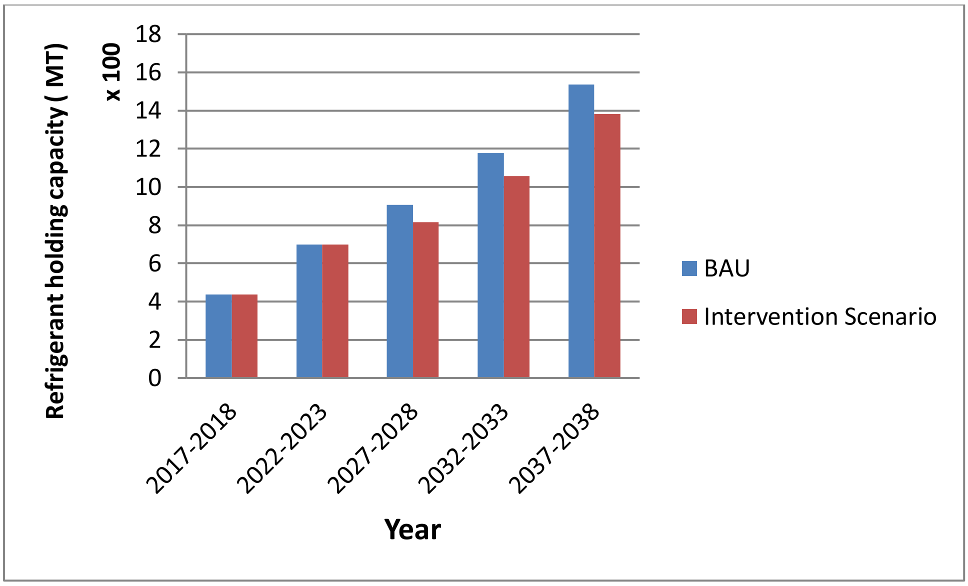

Figure 4.4. **Projected Refrigerant Holding Capacity in Motor Cars**

4.3.2. Buses

The same method has been adopted to the bus sector, assuming only 10% of the bus population is fitted with AC, to estimate refrigerant demand considering the leakage of 0.8kg/year. Estimation of holding capacity of refrigerant buses would be around 130-140 MT by 2038 as per the Figure 4.5.

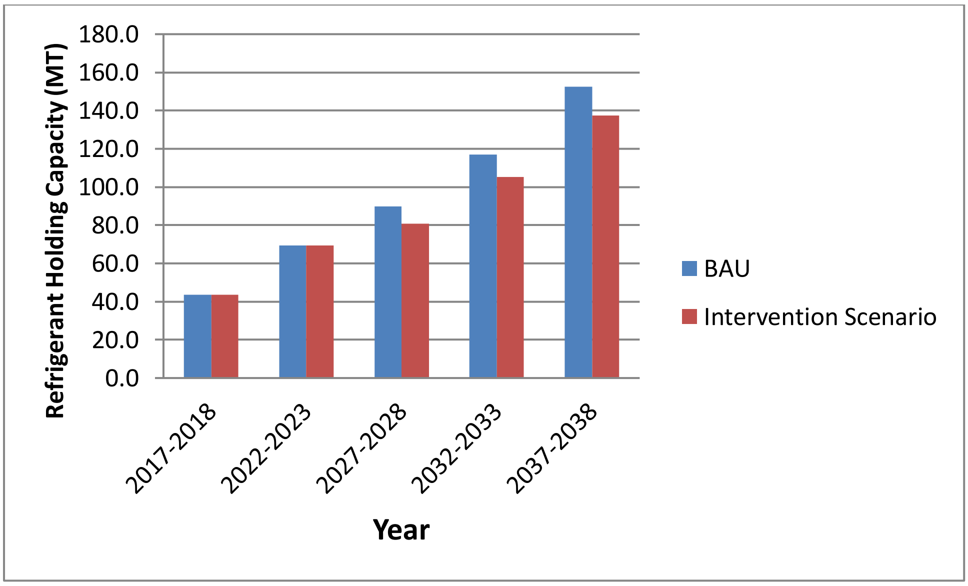

Figure 4.5. **Projected Refrigerant Holding Capacity in Buses**

4.3.3. Dual Purpose Vehicles

The same assumptions as for motor cars were used for the dual-purpose vehicles sector, assuming only 80% of the dual-purpose vehicles population is fitted with AC, to estimate refrigerant demand for dual purpose vehicles, considering the leakage rate of 0.2kg/year. Estimation of holding capacity of refrigerant for dual purpose vehicles would be around 1000-1100 MT by 2038 as per the Figure 4.6.

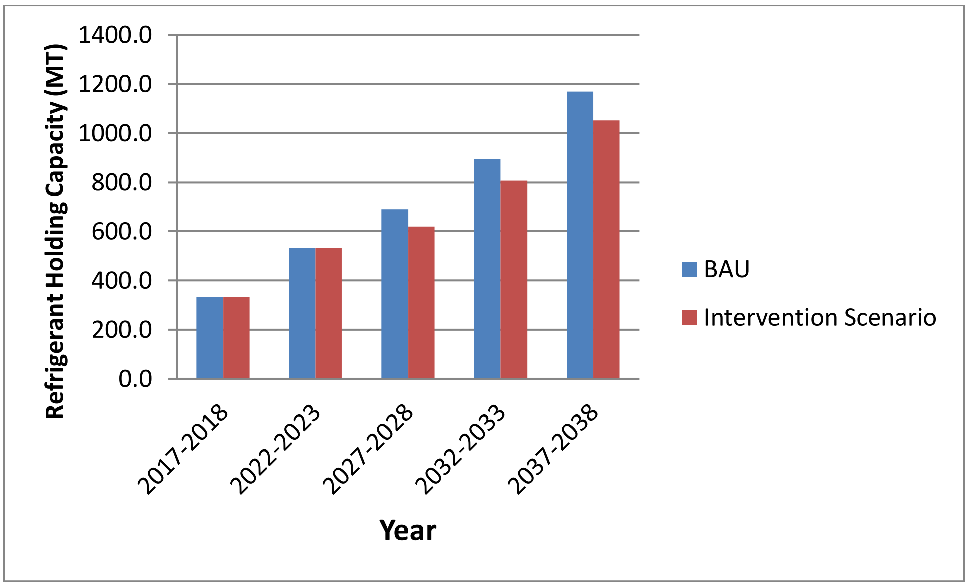

Figure 4.6. **Projected Refrigerant Holding Capacity in Dual Purpose Vehicles**

4.4. Conclusion

Projections implicate that, the refrigerant demand for the transport sector in Sri Lanka is rapidly growing. When the growth of the motor car population is considered, urban areas contribute almost twice that of the rural.(Central bank Annual Report, 2019, Table 13.5/A). Recognizing this, the country has to identify future scenarios integrated with socio-economic factors in order to successfully face future challenges of the refrigerant and energy needs. Identification of current and future trends of growing demand leads to a better understanding of country-specific needs and is an initial step towards adopting key actions facilitating sustainable energy measures. It is vital to ensure that, Sri Lanka identifies, prioritizes, and shifts to new technologies / alternatives that soundly fit with the social, environmental, and economic background of Sri Lanka.

Through collaborative measures of global phase-down of HFCs, the world has the opportunity to mitigate 100 billion CO_2 equivalent metric tons by 2050 (Environmental Investigation Agency, 2018). Fortunately, HFC free technologies are available to minimize adverse climatic consequences. Rapid transition to HFC free technologies is challenging but critical to protect the climate. Being a party to the Montreal Protocol, Sri Lanka has to successfully implement its obligations and plan to enforce Kigali amendments to achieve a swift global phase-down of HFCs. Finding the Ideal refrigerant to replace HFC will be a challenge, where use of natural refrigerants will have practical difficulties. Enhancing collaboration between policy makers, civil society and the private sector is vital in this rapid transformation. Co-benefits of improved clean, efficient cooling initiatives in the transport sector include improved thermal comfort and productivity and reduced food waste pertaining to cold chain refrigerated vehicles, consequently lowering Methane emissions from agriculture productions. These initiatives ensure contribution towards 2030 Sustainable Development Goals (SDGs) of the United Nations, including reduced hunger and poverty, food security, sustainable agriculture, affordable, reliable, sustainable, modern energy for all, sustainable cities, combating climate change and its impacts and global partnerships for sustainable development.

4.4.1. Alternatives for HFC in transport sector

1. Natural Refrigerants

CO_2 is currently used in the new manufacturing of cars and expected to be widely used in other automotive air conditioning including buses, trains, and trucks.

2. Hydrofluoric-olefins (HFOs)

The currently used refrigerant, 1,1,1,2 Tetrafluoroethene (HFC-134a), for mobile air conditioning may be controlled in new manufacturing. The HFO-1234yf is an HFO, introduced as a replacement for R 134a, which has minimal global warming potential. The substance would be one of the promising options for next generation of refrigerants for automotive air conditioning. The beneficial characteristics of the substance include:

- Mildly flammable and non-toxic
- Similar cooling capacity as HFC-134a
- More Energy efficient than competitive counterparts and contributes to a lower carbon footprint.
- Low Global Warming Potential (99.7% lower than HFC-134a)
- Compatible with all climatic conditions.

4.5. Recommendations

The most commonly used refrigerant in transport sector in Sri Lanka is HFC-134a. It is essential to phase down HFCs, according to the Kigali amendment. The only reliable available alternative at present is HFO-1234yf. However, it may not be feasible due to its high cost. Following recommendations are partly based on the said facts.

Short Term

1. Review existing energy policies related to the transport sector and adopt strategies concerning climate energy co-benefits. This requires multi-disciplinary policy approaches linking all relevant sectors including transport, energy, food, health, agriculture *etc*.

2. Prioritize country specific energy sources, energy efficient transportation methods, and existing cooling demands for the transport sector *etc*.

   Challenges in the areas of energy efficiency, costs and safety, policy and regulatory frameworks and service sector training needs and country specific climatic factors as well as special challenges to be faced need to be identified and addressed.

3. Encourage use of new technologies, such as HFO 1234yf and CO_2 in the field of mobile air conditioning.

4. Expand training opportunities in the automotive air-conditioning sector for capacity building which would be immensely beneficial during the transition process of introducing new refrigerants.

5. Provide incentives or rebates for energy efficient technologies, which comply with the fuel/energy efficiency standards.

Medium and Long Term

1. Conduct further feasibility studies on available alternative technologies in the transport refrigeration subsector in the context of applying the most suitable alternative technology.

4.6. References

1. Department of Motor Traffic, Ministry of Transport and Civil Aviation, Sri Lanka. (http://www.transport.gov.lk)
2. CEB Long term generation plan, 2018-2037, https://www.ceb.lk
3. Department of Census and Statistics, 2018. Annual report http://www.statistics.gov.lk/
4. Central Bank Sri Lanka, 2018 and 2019. Annual Report https://www.cbsl.gov.lk/en/
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6. IPCC, 2000, IPCC good practices guidelines and uncertainty management in national greenhouse gas inventories.

Chapter 5

Refrigeration and Air Conditioning Equipment Manufacturing and Service Sector

5. Refrigeration and Air Conditioning Equipment Manufacturing and Service Sector

5.1. Introduction

In Sri Lanka manufacturing of refrigeration and Air Conditioning equipment is extremely limited and it is confined to the manufacture of domestic refrigerators, bottle coolers and more recently; manufacturing deep freezers. Commercial and industrial RAC equipment and accessories are imported. However, Sri Lanka has a long history of manufacturing refrigerators since the 1950s. A Sri Lankan company commenced manufacturing domestic refrigerators in limited quantities. These refrigerators were designed to operate with CFC -12 refrigerant and had a heavy demand since no refrigerators were imported to the country. In 1980s two more companies initiated manufacturing refrigerators in order to meet the growing demand. In the meantime, commercial and industrial refrigeration and air-conditioning had been introduced parallel to the growth of the economy and multi-sector development. As a result, the services sector enterprises are spread now throughout the country.

Given the penetration of air-conditioners, refrigerators and vehicles are growing fast in the country, the number of servicing sector enterprises are still growing. It is estimated, that around 3,000 RAC servicing workshops are providing services at present, excluding inhouse service workshops in industrial and commercial institutions.

5.2. Implementing Montreal Protocol Obligations

Sri Lanka, as a party to the Montreal Protocol on substances that deplete the ozone layer, is obliged to phase out the use of ODSs in all applications including the manufacturing and service sector. In this context, Sri Lanka received financial and technical assistance from the Multilateral Fund of the Montreal Protocol (MLF) to implement several projects in order to phase out ODS use in refrigerator, foam manufacturing and RAC service sectors. Vocational education programmes on RAC were improved to train technicians on new technologies. For example: conversion of RAC equipment from ODS to non-ODS technologies (National Ozone Unit, 1994-2017).

Through these activities, Sri Lanka was able to phase out CFCs in all sectors in advance of Montreal Protocol time targets.

5.3. HCFC Phase-out Management Plan

The Hydrochloroflourocarbon Phase out Management Plan (HPMP) was launched to comply with HCFC phase out schedule set up by the Montreal protocol. Accordingly, Sri Lanka has taken steps to regularize import of HCFCs under the Gazette notification issued in 2013 and introduced several regulations. Sri Lanka consumes only 03 out of 40 chemicals (HCFC-22, HCFCF-123 and HCFC-141b)

HCFC-141b in blended form has been used as blowing agent for manufacturing insulated foams until 2015. Thereafter, the foam manufacturing sector has changed over to HFC and hydrocarbon (HC) based technologies.

In addition, RAC service sector consumed 3-4 MT of HCFC-141b annually for cleaning refrigeration systems. As a result of extensive education and awareness created among technicians, they are now using dry CO_2 instead of HCFC-141b. Import of the HCFC-22 refrigerant is under control and new policies are in place for controlling imports of brand-new HCFC-22 RAC equipment as well.

As a result of these conversion and adoption to alternative technologies, Sri Lanka was able to stop imports of HCFC-141b before the official time targets of Montreal Protocol.

5.4. Refrigerator/Deep freezer manufacturing sector

Refrigerators/Deep freezers and bottle coolers are mainly imported by several companies *however a few companies in Sri Lanka also produce this equipment using natural refrigerant* HC-600a and cyclopentane as blowing agent.

Foreign companies established in export processing zones, manufacture refrigerators/deep freezers, commercial refrigerators, and bottle coolers for export purposes.

Table 5.1 and Figure 5.1 show refrigerators/deeps freezers which are manufactured for the local market by Regnis Lanka PLC and Damro industries. (Survey data, 2019). The detail of the survey is described in Chapter 1 under “Survey and data collection”.

Table 5. 1. Production of refrigerators 2015-2018

Company	2015	2016	2017	2018
Regnis Lanka PLC	118,100	139,490	133,178	159,992
Damro Industries	82,300	90,300	97,400	99,830
TOTAL	200,400	229,790	230,578	259,822

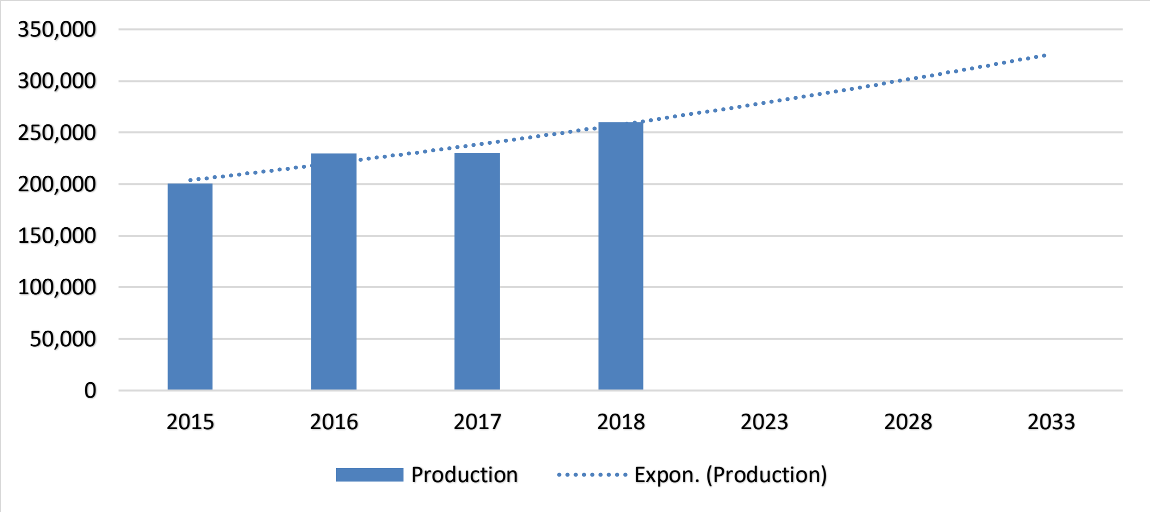

Figure 5. 1. **Production of refrigerators 2015-2018**

These two companies have established island-wide franchised sales and service networks in order to provide maintenance facilities for their customers. In addition, some other companies that imported refrigerators in bulk have also established island-wide sales and service networks to provide maintenance facilities for their customers. The majority of refrigerators currently used in Sri Lanka still work with HFC based HFC-134a refrigerant. However, the refrigerator manufacturing companies in Sri Lanka have recently converted their production lines to use natural refrigerant HC-600a, and it will take some time for total penetration to the market.

5.5. Domestic refrigeration equipment Import sector

Sri Lanka manufactures small quantities of domestic refrigerators, deep freezers, water coolers, heat pumps and bottle coolers *etc.*, and market demand is met mainly by imports. The quantity of equipment imported depends on market demand.

This equipment has been used in the domestic sector, small and medium scale business premises and office buildings. Campaigns to promote Hydrocarbon (HC) based refrigeration equipment has already been implemented by the equipment importers using incentive schemes in trading old HFC/HCFC based equipment for new HC equipment.

Import data and bar charts on smaller capacity refrigeration equipment including domestic refrigerators, deep freezers, water coolers, heat pumps and bottle coolers *etc.*, are shown in Table 5.2 during 2015-2018 and Figure 5.2 (External Trade Statistics (HS codes), Sri Lanka, Department of Customs, 2015-2018).

Table 5.2. Imports of domestic and smaller capacity refrigeration equipment during 2015-2018

Year	2015	2016	2017	2018
Nos of Units	171629	189669	184795	156285

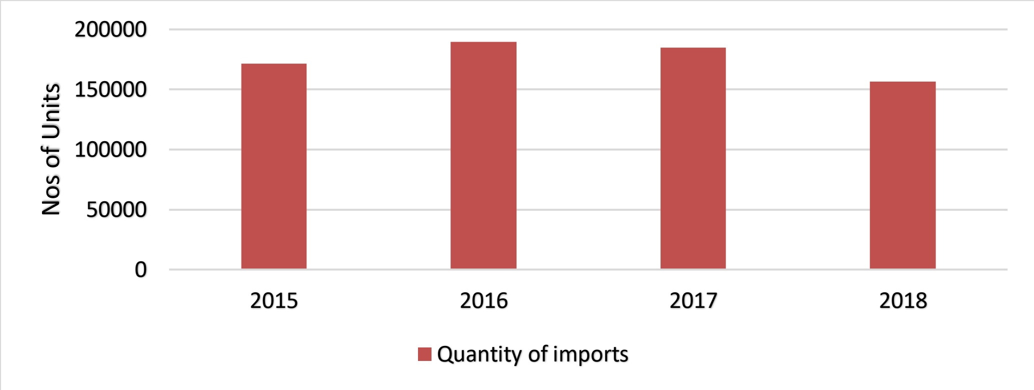

Figure 5. 2. **Import data of Small Capacity Refrigeration units (External Trade Statistics (HS codes), Sri Lanka, Department of Customs, 2015-2018).**

5.6. Domestic air conditioning

Split type air conditioners are popular and ideal for domestic and medium capacity office building air conditioning applications. There are a few indoor models, such as floor, wall and ceiling mounted indoor units to suit customer requirements. There is less demand for window type air conditioners.

Low and medium capacity (9000 Btu/h. to 36000 Btu/h) split type air conditioners designed to operate with R-410A refrigerant are manufactured for export by a company located in the Katunayaka free trade zone. Some companies import R-410A, HFC-32 and HCFC-22 based split type air conditioners for domestic requirements.

Table 5.3 and figure 5.3 show imports on split type air conditioners imported by major private sector companies during 2015-2018. Additional information is given in Annex 4. Considering the environmental issues, imports of used RAC equipment is banned irrespective of the refrigerants contained in the equipment (Annual Reports, National Ozone Unit, 1994-2017).

Table 5.3. Imports of split type air conditioners (2015-2018), Survey data

	HCFC-22 split type air conditioners	R-410A split type air conditioners	HFC-32 split type air conditioners
2015	22,173	10,859	0
2016	47,650	80,007	0
2017	36,527	100,300	940
2018	11,560	142,628	1,640
Total (2015-2018)	117,910	333,794	2,580

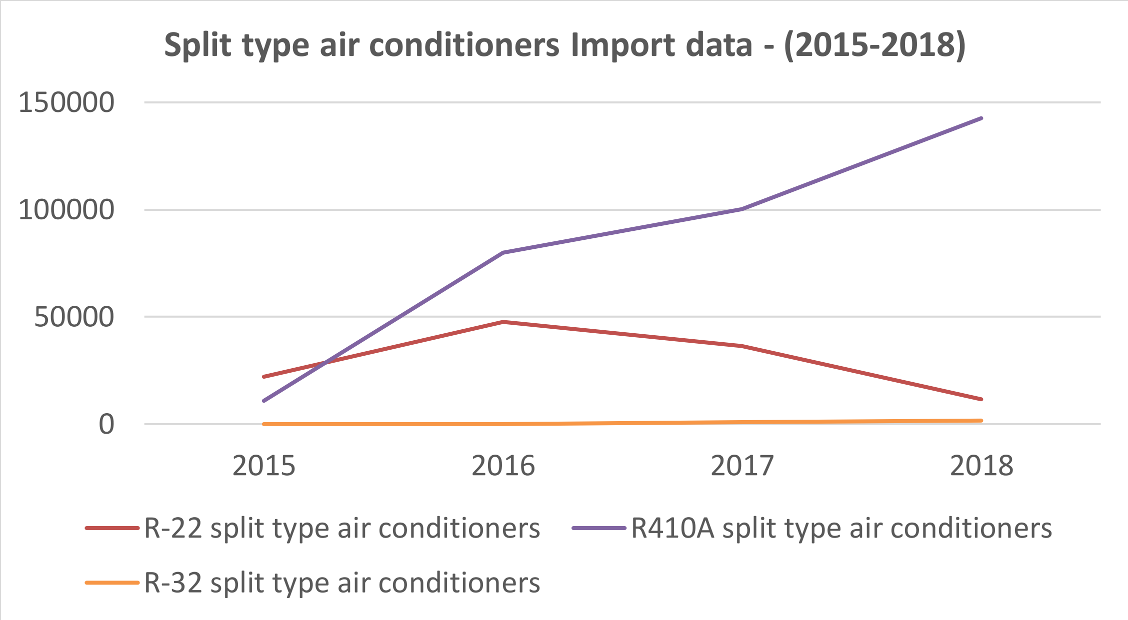

Figure 5. 3. **Imports of split type air conditioners (2015-2018)**

Consumption of HCFC-22 refrigerant is controlled and a reduction by 10%, 35% and 67.5% from base line is effective from January 2015, January 2020 and 2025 respectively according to the Montreal Protocol. This will affect the service sector by limiting the supply of HCFC-22 refrigerant for servicing of existing equipment. Therefore, the National Ozone Unit of the Ministry of Environment has taken a policy decision to ban import of brand-new refrigeration and air conditioning equipment containing HCFC-22 refrigerant from January 2018. Due to the control of importation of HCFC-22 refrigerant, import of split type ACs with HCFC-22 refrigerant has been drastically reduced, while there is a significant increase in import of ACs with R-410A during the last few years (Figure 5.3). Split type ACs, designed and utilising HFC-32, have also entered the market from 2018. The pilot project that was launched by NOU in 2017 under the financial assistance of the Multilateral Fund to promote the installing of ACs working with lower global warming potential refrigerants promoted import of HFC-32 ACs.

5.7. Commercial and Industrial RAC sector

Sri Lanka does not manufacture large-capacity commercial and industrial type RAC equipment. However, companies import popular brands of RAC equipment and then install them island-wide in tourism, dairy, building, fishery sectors *etc.* These companies are bound to provide services and maintenance after sales and commissioning for a few years to their customers. Before 2007, most of equipment imported contained HCFC-22 and some of them are still in operation (Annex 5).

There is a trend in importing RAC equipment designed for HFC-134a, R-410A, and R-407C *etc*. The commercial and industrial sector end users consume refrigerants, such as HCFC-22, HFC-134a, R-410A, for servicing RAC equipment. The RAC technicians in these companies recover

HCFC-22 refrigerant and follow good practices while repairing RAC equipment. The Ministry has established 09 HCFC-22 refrigerant reclamation centres covering the whole country and they report annual HCFC-22 refrigerant reclaimed data to NOU. This data reveals that some service sector workshops reclaimed the recovered refrigerant through reclaiming centres. This is a solution to the shortage of HCFC-22 to a certain extent (Annual Reports, National Ozone Unit, 1994-2017).

5.8. RAC Service Sector

The RAC service sector provides maintenance and repair services for RAC equipment installed at various locations, and approximately 5000 technicians are engaged in this sector. In addition, there may be an unaccounted number of technicians working independently who are skilled but uncertified or certified.

Most of the refrigerant emissions to the atmosphere lead to global warming and ozone layer depletion. Therefore, new technologies, such as refrigerant recovery, recycling and reclaiming, have been introduced to the RAC service sector by the NOU in order to protect the global environment. Even though these refrigerant conservation practices are popular among technicians in the service sector, they are not fully practiced due to inadequate technological capacity. NOU has launched technician training programmes at the grass root level to promote these technologies. Further, a pilot project was launched by the Ministry of Environment for establishing refrigerant reclamation centres in 2015. New regulations were also introduced under the National Environment Protection Act in prohibiting the release of refrigerants to the atmosphere. Under this programme nine (09) HCFC-22 refrigerant reclamation centres were established covering all provinces. Recovery pump cluster centres were also established with these reclaiming centres. The service sector was able to recover and reclaim a certain amount of HCFC-22 refrigerant from these centres. Since there is no manufacturing of commercial and industrial refrigeration equipment, all imports of refrigerants are used in the service sector. As such, it was estimated that the annual consumption of all types of refrigerant in RAC service sector workshops is around 360- 400mt, including 200mt of HCFC-22. Data in respect of HCFC-22 Refrigerant reclaimed by the service sector in the past few years are given in Table 5.4 and Figure 5.5.

Table 5.4. HCFC-22 Refrigerant reclaim data (Kg)

Year	2013	2014	2015	2016	2017	2018
HCFC -22 (kg)	610	720	880	1180	1340	1960

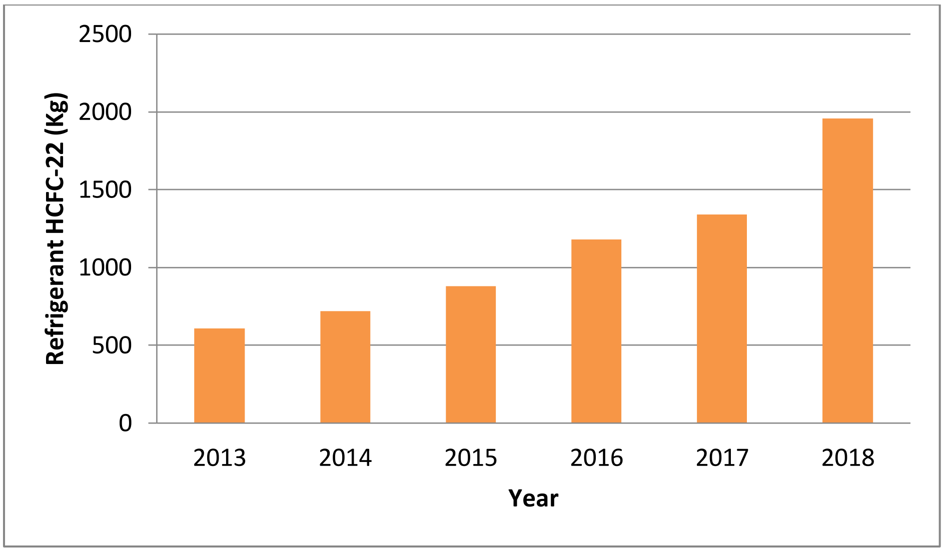

Figure 5. 4. **HCFC-22 refrigerant reclaim data**

The NOU has conducted meetings and discussions with all commercial banks to provide soft loan facilities to the RAC sector in 2018. Awareness programmes on RAC sector green technologies were also conducted for bank officers, in order to make them aware of new technologies. All commercial banks have conditionally agreed to provide soft loans for the RAC sector. RAC service sector companies are expected to purchase recovery equipment and accessories utilizing this soft loan scheme.

5.8.1. Maintenance of RAC Systems

Preventive maintenance programmes of RAC systems are necessary to maintain equipment in a healthy condition and to reduce refrigerant emissions and energy consumption that ultimately increases the life span of systems. As such, it is important to employ trained service technicians and update their skills on new technologies, which will serve as a valuable long term investment for companies.

5.8.2. Good practices in RAC service sector

RAC equipment in faulty condition can be brought back into operational condition through proper repairing and servicing. During this process, technicians follow practices such as refrigerant recovery, recycling and reusing, leak testing, brazing, pressure testing, vacuuming, flushing refrigeration circuits, gas charging *etc*.

Multilateral Fund (MLF) of the Montreal Protocol provided financial assistance to implement the Montreal Protocol obligations in the RAC service sector since its inception. Some of these funds were utilized for revising the RAC vocational education sector curriculum in order to promote “green technology” among technicians during in-house training programmes. Apart from that, the MLF supported capacity building (Train the Trainers - TOT) programmes for the RAC instructors in order to enhance their subject knowledge. The main objective of organizing TOT programmes was to engage them for training of technicians at a national level.

The NOU has taken a policy decision to make refrigerant recovery a mandatory requirement in the service sector from the year 2018. The Central Environmental Authority (CEA) acts as the implementing agency for environment law under the National Environmental Act. The NOU and CEA have jointly organized a series of seminars for Environmental Officers (EO) to make them aware on refrigerant recovery, recycling, reclaim and reuse technologies. As result of the seminar series, EOs are now well aware of the process of refrigerant recovery technologies and accessories needed to implement these policy decisions.

The CEA is the mandated agency in issuing the Environment Protection Licenses (EPL) to all service sector workshops operating in the country. The CEA does not issue EPL to any workshop without verifying the availability of a proper recovery system and accessories. The officers monitor these workshops to see if they have obtained the EPL. The implementation of these regulations of CEA are expected to commence within 03 years, from 2019.

5.8.3. RAC Service sector workshops

The NOU conducted a survey during the year 2019 to recognize RAC service sector workshops that are in operating in all 9 provinces in the country. Field officers and *Grama Niladhari* attached to all divisional secretariats participated in this survey. A common questionnaire was circulated among service sector workshops to obtain data about the workshops. Results of the survey are given in the Table 5.5 and Figure 5.6. (Country assessment report, 2020). It is estimated that more than 3000 RAC service sector workshops are in service around the country.

Table 5.5. Number of service sector workshops

Province	Northern	Southern	Eastern	North-Central	Western	Sabaragamuwa	Uva	Central	North-Western
No. of workshops	22	460	65	145	1640	111	80	340	180

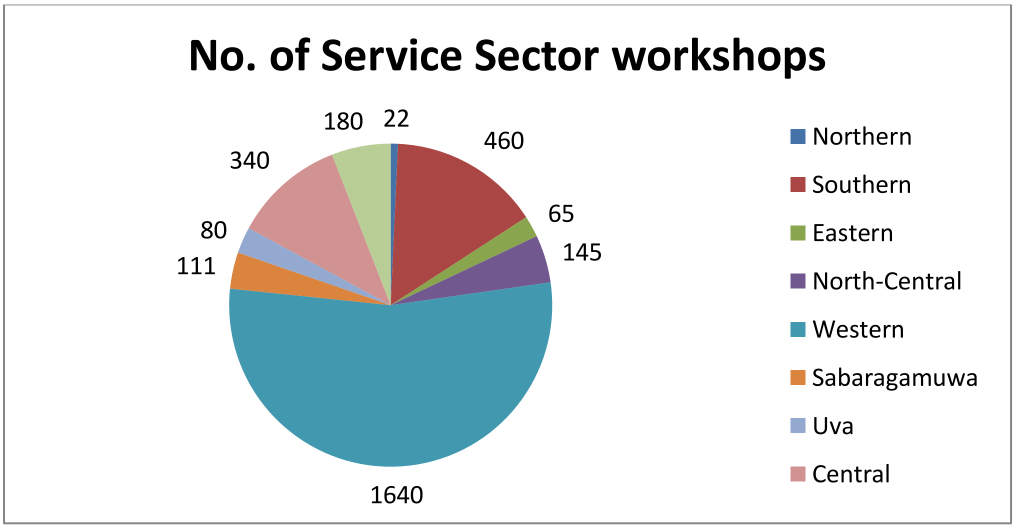

Figure 5. 5. **Number of service sector workshops**

5.8.4. Categorized RAC repair and service sector workshops

The RAC service sector can be divided into two groups: organized (formal) and unorganized (informal). Organized service sector companies have all the infrastructure facilities necessary to complete RAC related services. They are registered with respective government agencies to run workshops and employ engineers, supervisors, and technicians. These agencies are engaged in repairing and maintenance of RAC systems such as larger RAC plants, MAC systems, domestic refrigerators, air conditioners and other types of RAC equipment. Mostly, the companies in the sector are also dealers and agents for popular branded RAC systems. They advertise their workshops and services in the Rainbow Pages and display advertising boards in main business locations.

It is estimated that around 10% of 3000 workshops belong to the organized sector, which includes: industrial, commercial, marine refrigeration and air conditioning sectors. Such companies attend to, repair, and maintain larger plants such as RAC systems, and chiller plants. Workshops can be identified as MAC, Refrigerators and ACs, while their numbers differ from province to province as per the Table 5.6.

Table 5.6. RAC Workshop distribution by province

Provinces	MAC (%)	Refrigerators (%)	ACs (%)
Western, Southern, North-Western	30	10	60
Northern, Central, North- central, Eastern	40	10	50
Uva, Sabaragamuwa	40	20	40

Source: Country assessment report, 2020

5.8.4.1. RAC sector refrigerant usage

The HFC-134a, HCFC-22 and R-410A are the main refrigerants imported to Sri Lanka. In addition, R-404A, R-407C, R-507 R- 717, HC-600a, HC-290 and HFC-32 refrigerants are also imported to Sri Lanka. Approximately, 90% of refrigerant imports are used for RAC equipment servicing purposes and the balance 10% for manufacturing purposes. It is estimated that around 40% of HCFC-22 and R-410A refrigerant imports are consumed in servicing of split type air conditioners. The remaining 60% of HCFC-22 and R-410A refrigerants are used for maintenance of other RAC systems such as package type air conditioners, chillers, *etc*. The MAC sector consumes the largest amount of refrigerant HFC-134a, which is nearly 100%. The R-404A, R-407C and R-507 are also used in servicing and repairing of refrigeration systems. In addition, HC-600a and HC-290 are consumed in refrigerator and deep-freezer manufacturing and service sectors.

5.8.4.2 Refrigerant Emission from RAC Service Sector

Many refrigerants that are commonly used in refrigeration and air conditioning systems are ozone-depleting/ Global Warming substances. Managing refrigerant emissions is an important strategy for protecting environment as well as human health (refrigerant are harmful at high concentration). Poor servicing practices can lead to refrigerant emission and affect to the performance of RAC equipment and systems. The emission is mainly happened due to leak, at refilling or discarding equipment. Wider adoption of below mentioned good servicing practices by RAC service technicians shall lead to reduction in the consumption of refrigerants during servicing of air conditioning equipment.

Repairs to Leaking Equipment: An important concern in the service sector is attending to rectify refrigerant leak out of the RAC system immediately. Due to lack of timely leak testing, practices like refrigerant top-up‟," the actual consumption of refrigerant during operation of equipment and servicing is much higher. Therefore, equipment leakages and operation must be supervised by trained service technicians for the system to perform optimally.

Requirements Evacuation: RAC technician must recover refrigerant in air-conditioning and refrigeration equipment when opening for the equipment for maintenance, service, repair, or disposal. To ensure that they are recovering the correct level of refrigerant, technicians must use the recovery equipment according to the directions of its manufacturer.

Avoid use refrigerant for flushing: Refrigerant gases are also used for flushing the system, leading to further usage of the gases during servicing.

5.8.4.3. Impact of Poor Servicing on Energy Efficiency

Poor servicing practices can also lead to decrease in the energy efficiency of in-use air conditioning equipment. Even if an appliance with high potential efficiency is installed, it will not be able to realize its potential while in-use if it is not installed, maintained, and serviced properly, thus leading to increased electricity consumption.

5.9. RAC technical and vocational education

5.9.1. Training and certification

Training has to encompass various aspects, such as installation, operation, safety, maintenance, repair, and servicing in order to provide technically sound service. Training involves both theoretical and practical aspects of good management practices. The vocational education system provides training for all technicians engaged in RAC sector.

5.9.2. Vocational and technical educational system in Sri Lanka.

Vocational and Technical Education is provided free of charge by the Government for technical students. A number of Vocational and Technical Education institutions have been set up. These Technical Education institutions are managed by a body initiated for regulating standards.

5.9.3. Technical and vocational education regulatory agency

The Tertiary Vocational Education Commission (TVEC) is the apex body of the technical and Vocational Education training (TVET) sector in the country. The prime responsibilities of TVEC include policy formulation, planning, quality assurance, coordination and development of tertiary and vocational education. It registers public and private sector TVET institutes and accredits courses mainly on the National Vocational Qualification (NVQ) framework. These programmes provide certificates, Diplomas and Degree qualifications at NVQ levels at the University of Vocational Technology (UNIVOTEC). All Tertiary Vocational Education institutes are required to obtain registration and accreditation of their programme.

5.9.4. Technical and vocational education training institutes

According to the Tertiary Vocational Education Commission (TVEC), there are registered and accredited Technical and Vocational Education Training Institutes conducting RAC training courses, as shown in Table 5.7.

Table 5.7. No. of training centers, conducting RAC courses

Agency	Vocational Training Authority of Sri Lanka (VTA)	Technical Education and Training Dept (TE &TD)	National Apprenticeship and Industrial Training Authority (NAITA)	Ceylon German Technical Training Institute (CGTTI)	National Youth Services Council (NYSC)	Department of Social Services (DSS)	Private Sector Institutes	Sri Lanka institute of advanced technological education (SLIATE)
No. of Training Centers	30	22	03	01	05	02	08	03

NVQ Level 3 and 4 are the lowest level courses and the duration is one and half years (One-year institutional training and six month industrial training). The course levels are accredited by TVEC. After the training period, trainees are called for an assessment by TVEC. After completion of the assessment, trainees are offered the NVQ Level certificate by TVEC. The training assessment is done by trained assessors under the purview of TVEC. Around 700 - 800 RAC service sector technicians successfully complete the course annually. The RAC vocational course curriculum also includes all the good practices in the refrigeration service sector such as refrigerant recovery. The series of workshops have been conducted by NOU on “good practices in refrigeration” for technicians since 2002. Further studies in the RAC vocational sector are also available in few centres and vocational degree level certificates could be obtained from UNIVOTEC. Apart from the said programmes, RAC courses at higher national diploma level are conducted by the private sector higher education institutes.

5.9.5. Recognition of Prior Learnings (RPL) system

There is a wide variation in failure rates depending on knowledge and skill levels of technicians, who are primarily from the informal sector without proper access to technology and training. The segment of room air conditioners and commercial refrigerators are the biggest responsible for the consumption in servicing sector in Sri Lanka. Therefore, NOU in collaboration with the UNEP commenced the Recognition of Prior Learnings (RPL) system in 2020.

The RPL is a process for technicians to assess their competencies acquired through informal, non-institutional learning methods, to determine the extent to which the technician has achieved the required competencies (as set out in the relevant National Skills Standard) leading to a qualification of the NVQ framework. One of the concerns of the above assessment is the lack of proper theoretical understanding of the subject, which leads to environmentally unsound practices.

5.10. Recommendations

Short Term

1. Promote RAC appliances working with green refrigerants for:
    - Domestic refrigeration appliances such as refrigerators, bottle, and water coolers. *Etc*., (HC-600a, R-717)
    - Low capacity (domestic) and medium capacity air conditioners working on HFC-32, HC-290 (subject to develop national safety standards)
2. In order to improve energy efficiency and provide environment friendly solutions in RAC systems:
    - Strengthen preventive maintenance programmes for RAC systems.
    - Promote refrigerant conservation technologies.
    - Expand good servicing practices in refrigeration.
    - Provide financial assistance to service sector for purchasing new environmental and user-friendly tools and accessories.
    - Implement certification of uncertified technicians in the service sector.
    - Monitor and improve environment protection license system for the RAC service sector.
3. Formulate new policies and regulations to ensure professional maintenance staff in commercial and industrial applications where the refrigerant quantity charge is greater than 100Kg.
4. Provide continuous education capacity building programmes on RAC sector for the trainers and accesses.

5. Adopt training modules on new and improved technologies and continue updating curriculum of vocational training courses on the RAC sector
6. Continue updating environment aspects into the curriculum of vocational training courses related to RAC.
7. Extend the existing certification system (RPL) for uncertified RAC technicians.

Medium and Long Term

1. Launch programmes for promoting energy efficient and environment friendly RAC equipment for:
    - Food processing sector (NH_3, CO_2)
    - Dairy sector (farm tanks refrigeration system with HC-290, NH_3)
    - Fishery sector (NH_3)

2. In order to improve energy efficiency and provide environment friendly solutions in RAC systems:
    - Replace existing systems by new systems working with zero ozone depleting and low global warming potential.
    - Enhance infra-structure facilities and set up a research and development unit in vocational education sector.

3. Enhance training facilities on NH_3 and CO_2 RAC systems

5.11. References

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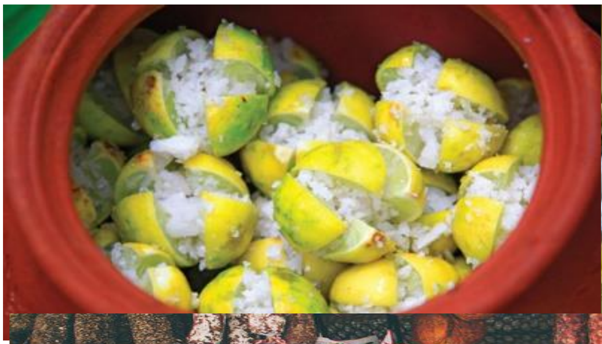
Chapter 6



Indigenous Knowledge and Research

6. Indigenous Knowledge and Research

6.1. Introduction

The ancestors of Sri Lanka have developed their own cultural practices and lifestyle that were in harmony with nature. Sri Lanka has a long history of indigenous knowledge that evolved over the centuries. Traditional methods have been practiced by the community for a variety of purposes including agriculture, energy generation, food preservation, building houses and transport. It is widely accepted that there is much to be learned from indigenous knowledge of local people. Indigenous knowledge comprises ecosystem management strategies led by the community to address potential negative impacts to the environment. Indigenous concepts respect the principals of sustainability leading to environmental and socio-economic benefits, consequently sustaining life on earth. It makes sound decisions regarding the use of locally available resources and eco-system conservation methods (Dharmasena 2010).

6.2. Traditional methods of food conservation

Indigenous practices of agriculture were highly based on traditional knowledge and were continuously adapted to changing environmental conditions and cultural aspects hence soundly fitting with particular geographical conditions (Abeywardana et al. 2019). There is historical evidence to prove that Sri Lanka was a country of self-sufficiency and prosperity hence there was no concern about food security (Perera, 2008). Ancient farmers in Sri Lanka used traditional practices of food production and preservation. Traditional practices have been tested over a long period. The ancient food conservation/ storage methods in Sri Lanka involve culturally accepted practices and use of locally available resources as preservatives. The indigenous knowledge pertaining to food preservation still remains and is practiced by the local community, particularly in rural areas. These practices seem to be environmentally friendly, energy free and have minimal/no harm to nature. Our ancestors have practiced various methods of conservation for wild meat, fish, different kinds of seeds and flour enabling storage for a long period. Common methods include dehydration, smoking and sun drying (Abeywardhana and Perera, 2009). It is realized that use of indigenous knowledge assures sustainable aspects of agriculture as respected by the modern world. This involves problem solving strategies to achieve profitable output in the food production process. The ancient paddy seed storage for long periods is a classic example of preservation techniques practiced by traditional farmers. Harvested seeds are kept for long periods for future use. Figure 6.1 indicates the traditional food preservation methods used in Sri Lanka. All these methods address the efficient utilization of resources with minimum or no artificial energy consumption, ensuring sustainable principles of food production.

The indigenous techniques inherited from our ancestors would tremendously contribute to identify solutions for efficient food storage instead of relying on massive energy consuming cooling processes that are currently being used.

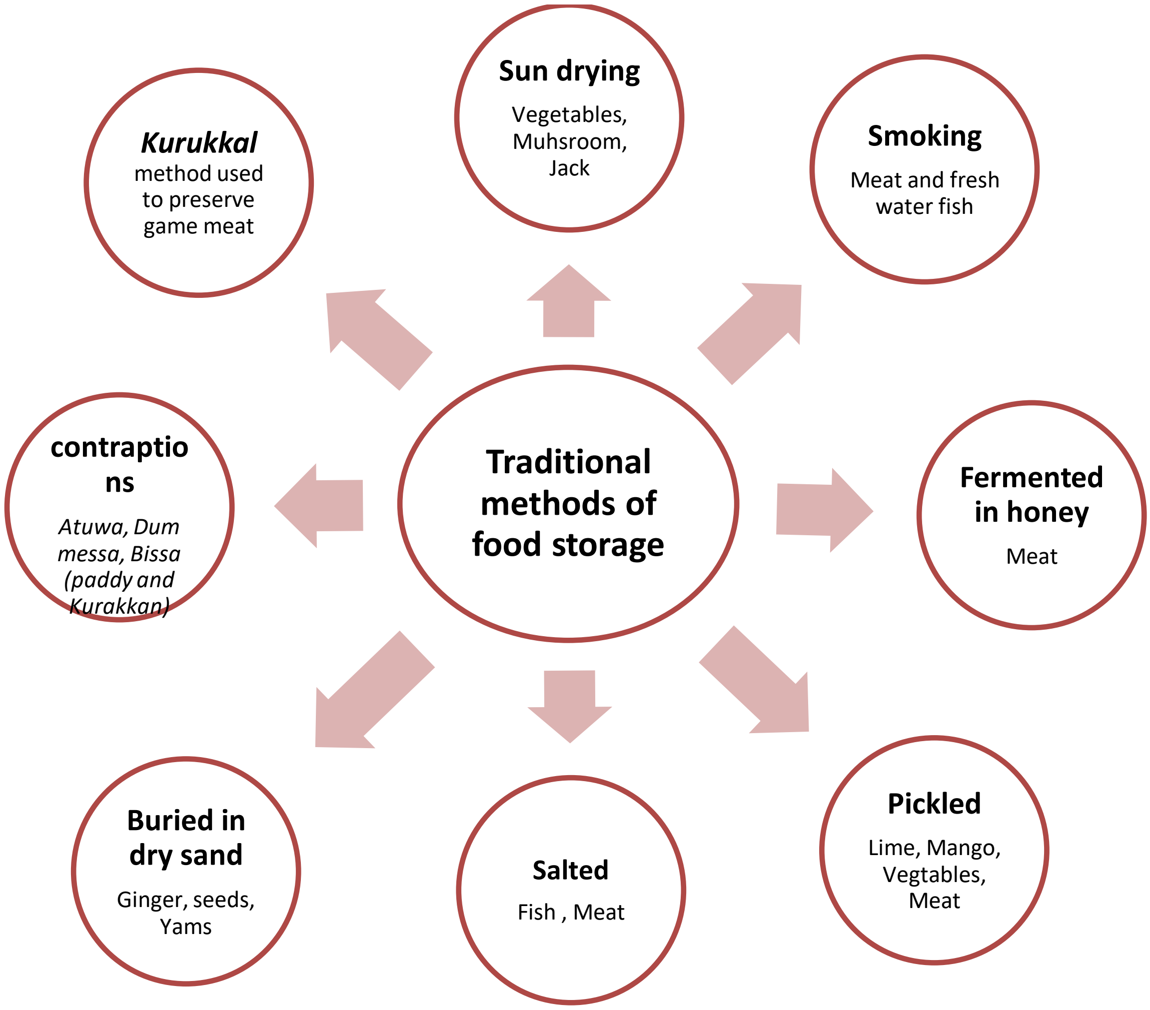


Figure 6. 1.**Traditional food conservation methods in Sri Lanka**

6.3 Indigenous knowledge for Biodiversity Conservation

Article 8(j) of the Convention of Biodiversity emphasized the importance of indigenous knowledge embodying traditional lifestyles relevant to the conservation and sustainable use of biological diversity. This knowledge has been accumulated through long term cultural practices and transmitted through generations. In particular, practices based on indigenous knowledge has contributed to biodiversity conservation, and sometime biodiversity enhancements. The principles of indigenous knowledge imply community-based resource management systems benefiting humans and the environment. In terms of food production, crop selection, seed storage methods, harvesting practices, pest control techniques based on indigenous knowledge aid in conservation of genetic, species and ecosystem diversity. There is ample evidence implying that indigenous food conservation and seed storage methods used in Sri Lanka contributed to crop diversity and diversified landscape planning leading to enhanced productivity. Similarly, use of energy for food processing and food preservation methods were also effectively diverse and sustainable in comparison to contemporary methods.

6.4. Construction/ Designing buildings

Indigenous knowledge is not confined to agriculture, environment, or biodiversity. It is immensely beneficial in construction/ designing buildings. Architectural practices are now moving towards green technology. Green architecture is characterized by energy efficiency, working with the climate, sustainable use of resources, and minimum waste generation based on green building principles. Sri Lanka has had long architectural traditions in harmony with nature dating back from the period of ancient kings. This architectural tradition has been steadily influenced by Buddhist culture, Mediterranean characteristics from Arab traders and then Dutch and British influences. Indigenous construction materials involved wattle and daub, brick, coconut, and thatch. The ancient methods of site selection, application of suitable materials, use of natural light and ventilation and climatic responsibility is based on principals of sustainability. Natural lighting and ventilation is the most important aspects of traditional or vernacular architecture that needs to be learned from history in designing energy efficient buildings using modern architecture.

Natural ventilation provides great benefits, in contrast to mechanical ventilation strategies (Asfour, 2015). Addressing natural ventilation is the primary requirement in designing green buildings, particularly in hot and humid countries like Sri Lanka. Some of the buildings in Sri Lanka are classical examples that demonstrate the principals of green architecture including the national library building Colombo, Parliament building in Sri Jayawardenapura Kotte, Audience hall in the Kandyan Art Association, Kandy and Kandalama Hotel, Kandalama. These buildings demonstrate the application of traditional forms of roofs, natural construction materials, natural ventilation methods/ minimum artificial ventilation requirements, clay roof tiles, natural shading effects etc.

6.5. Research perspectives

Urban areas consume more energy and emit significant amounts of heat to the surrounding leading to higher ambient temperature levels in comparison to the rural environment. Recognizing this issue modern architecture is moving towards principles of green building concepts with socio-economic and environmental benefits. Most conventional building consumes massive amounts of energy resulting in negative environmental consequences. The commercial and the industrial sector, which comprises of large-scale buildings, account for 60% of the electricity consumption in Sri Lanka, mainly for air conditioning, ventilation, and lighting.

(Presidential task force on energy demand side management, Sri Lanka). On average air conditioning (AC) systems generally consume 40% - 50% of the total electricity consumption in residential buildings (Prasath et al., 2016). Improving energy efficiency of building is an important of the country's sustainable energy development strategy.

During the past few years, professionals in Sri Lanka related to construction, have considerably focused on sustainable issues pertaining to designing building. University of Peradeniya and University of Moratuwa are key leading academic institutes in Sri Lanka to undertake research particularly focused on architecture in harmony with nature and improvement of energy performance. Some of the research undertaken include use of appropriate construction materials, use of energy, and response of built structures to the geo-climatic conditions and renewable energy options. Despite indigenous concepts provide sound solutions for minimizing negative environmental consequences, their application in present context is less considered. Further research addressing this issue would immensely contribute to fill the knowledge gap. More research is needed to analyze the traditional or vernacular architecture that existed in the past, and future use of these techniques in addressing sustainable issues. The table 6.1 includes some important research in Sri Lanka related energy conservation / improving performance of air conditioning systems.

Table 6. 1. Research conducted on refrigeration and air-conditioning and renewable energy options

	Title of the research	**Research output**	**Reference source**	
01	Identify the differences of AC load requirement with respect to the floor number in high rise buildings	It was revealed that in high-rise buildings surrounding temperature generally increases by 1.0 - 1.7°C for a 10-story building and the cooling load requirement of 10th floor in a high-rise building increases by 9-10% with respect to the ground floor.	Madhusanka et al. 2018	
02	Applicability of PCMs (Phase Change Materials) for peak load shifting of air conditioning and mechanical ventilation systems of office building in tropical climates.	The study recommends to incorporate the PCMs on the building envelops of sunlit walls to reduce the peak cooling load of the building with the aim of reducing the energy consumption by the air conditioning and mechanical ventilation system.	Wijewardane et al. 2017	

03	Applicability of rotary thermal wheels to hot and humid climates.	Findings reveal that the use of rotary thermal wheels in hot humid climate can be highly recommended.	Herath et al. 2019	
04	Analysis of the heat column formation in a 10 storey building	Results indicated that significant loss of performance of the AC system can be expected due to influence of the hat column. Study recommends identifying the load pattern of residential building prior to design the system.	Prasath et al. 2016	
05	Strategies to overcome barriers for cleaner generation technologies in small developing power systems: Sri Lanka case study	The case study reveals that lack of financing instruments, high initial cost and lack of assurance of resource supply seems to be main barriers of renewable technologies.	Wijayathunga et al. 2006	

6.6. Towards sustainability with renewable energy options

The growing rate of electricity demand is 6% per year. The Ministry of Power and Renewable Energy in Sri Lanka has adopted strategies to increase Renewable Energy capacity from existing 32% in 2016 to achieve the status of carbon neutrality by 2050 (Ministry of power and energy 2017). Renewable sources are great for our energy portfolio as a sustainable option of energy generation in contrast to conventional sources. Sri Lanka has a long history of power generation through renewable resources from early 20th century for tea plantations with small hydropower plants (Sayanthan and Kannan 2017). The energy policy has to identify and address these indigenous sources of power generation to meet the ever-increasing energy demand. Solar power generation has been identified as a promising option to meet energy demand in Sri Lanka. Sri Lanka is blessed with several renewable energy resources including solar, wind and biomass. Some of the resources are already in use for the purpose of energy generation while the remaining sources need to be assessed to evaluate their potential. Therefore, further research is encouraged to explore their technical and socio-economic feasibility for use in the future.

The Government of Sri Lanka inked an agreement with the Government of Canada to construct a floating solar power generation plant in the Maduru Oya Reservoir in the Mahaweli Economic Zone. It is expected that construction to generate the total capacity of 100 MW will be completed by the end of September 2020. The project is expected to be further expanded in the rest of the country to meet 50% of the total electricity requirement through renewable energy sources by the year 2030.

Highway solarization has become an ideal option of power generation as it generates electricity without CO_2 or other GHG emissions. Since highway construction has become one of the key development processes in Sri Lanka, identifying highway solarization opportunities would significantly benefit the country.

Electric vehicles (EVs) serve a range of benefits including zero emission and energy efficiency. Since combustion of fossil fuels has become a global issue in terms of atmospheric warming electrical vehicles are globally beneficial, especially concerning environmental benefits. EVs do not cause health impacts or ecological damage when they are charged with electricity from renewable energy sources, such as solar power, and when battery disposal is correctly handled. This option is highly recommended.

6.7. Recommendations

Short term

1 Identification and analysis of methods and practices adopted by ancient Sri Lankans for food conservation and assess their potential use for sustainable food storage in future.

2 Take steps for conservation of indigenous knowledge and methods that are healthy options for food preservation.

3 Identification of policy gaps related to identification and promotion of indigenous knowledge and developing strategies to incorporate traditional practices into energy related processes in order to reduce GHG emission.

Medium and Long term

1 Promote further research to explore the range of socio-economic and environmental benefits of indigenous knowledge and their current applications which are still isolated or confined to particular areas of the country.
2 Given the geographical location of Sri Lanka, the effect of the Sun, wind and other climatic factors need to be considered in designing building with the objective of climate-sensitive design in the Sri Lankan context.
3 Encourage research to assess the opportunities of incorporating indigenous techniques which are environment friendly, to modern constructions.

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Chapter 7

7. Conclusion, Recommendation and Timeline

Cooling is a predominant requirement and therefore an integrated and long-term vision across several sectors is a prerequisite for addressing the cooling requirement in a sustainable manner. It is evident from the preceding chapters that the cooling demand in the country is increasing very rapidly. In the refrigeration sector, especially the domestic refrigerator, the cooling demand has been increasing at a higher rate. Currently around 52% households have domestic refrigeration facilities and by around 2030-32, it will reach even higher levels in the country. The use of cooling appliances in the commercial building sector, comprising hospital, hotels, restaurants, retail, office buildings, educational institutions, transit buildings, airports, and warehouses are also on the increase. Different types of air-conditioners (including splitsystems), chillers (screw, reciprocal, and centrifugal etc.) are used in commercial sector buildings. In the commercial refrigeration and in cold chain sector, the growth is expected to be around 10-12%, and the demand of cooling shall increase two-fold during the period from 2018 to 2030.

Projections implicate that, the refrigerant demand for the transport sector in Sri Lanka is rapidly growing. When the growth of motor car population is considered, urban areas contribute almost twice that of the rural.(Central bank Annual Report, 2019, Table 13.5/A). Recognizing this, the country has to identify future scenarios integrated with socio-economic factors in order to successfully face future challenges of the refrigerant and energy needs. Identification of current and future trends of growing demand leads to a better understanding of country-specific needs as an initial step towards adopting key actions facilitating sustainable energy measures. It is vital to ensure that, Sri Lanka identifies, prioritizes, and shifts to new technologies / alternatives that soundly fit with the social, environmental, and economic background of the country.

Through collaborative measures of global phase-down of HFCs, the world has the opportunity to mitigate 100 billion CO_2 equivalent metric tons by 2050 (Environmental Investigation Agency, 2018). Fortunately, HFC free technologies are available to minimize adverse climatic consequences. Rapid transition to HFC free technologies is challenging but critical to protect the climate. Being a party to the Montreal Protocol, Sri Lanka has to successfully implement its obligations and plan to enforce Kigali amendments to achieve a swift global phase-down of HFCs. Finding the Ideal refrigerant to replace HFC will be a challenge, where use of natural refrigerants will have practical difficulties. Enhancing collaboration between policy makers, civil society and private sector is vital in this rapid transformation. Co-benefits of improved clean, efficient cooling initiatives in the transport sector include improved thermal comfort and productivity and reduced food waste pertaining to cold chain refrigerated vehicles, consequently lowering Methane emissions from agriculture productions. These initiatives ensure contribution towards 2030 Sustainable Development Goals (SDGs) of the United Nations, including reduced hunger and poverty, food security sustainable agriculture, affordable, reliable, sustainable, modern energy for all, sustainable cities, action to combat climate change and its impacts and global partnerships for sustainable development.

It may further be conceptualized that sustainable cooling can only be achieved through reduction in cooling load, passive cooling interventions for buildings, moving towards more energy efficient RAC equipment, sustainable energy sources, operational efficiency enhancements and use of new and alternative technologies including not-in-kind technologies. The move to sustainable cooling shall also be reinforced through appropriate rules and regulations, standards and skilled RAC service technicians.

The NCP is the overarching and integrated approach on regulatory, technical, environmental, and operational matters. It is an important step for Sri Lanka to contribute towards the targets of the Paris Agreement and the Kigali Amendment of the Montreal Protocol. Considering the above factors and taking into account the current standing of the country in respect of geography, environment as well as the economic level and the international obligations the following recommendations are provided as suggestions to be considered in the future.

	Recommendation	Short Term (1-3 y)	Medium Term (3-5 y)	Long Term (>5 y)
Space Cooling	Encourage Passive Cooling as much as possible instead of air conditioners subjected to the building requirement	X	X	X
	Enhance awareness of building designers to apply building codes to manage energy efficiently and to follow the green procurement guidelines for procuring HVAC equipment and systems	X	X	
	Introduce appropriate policy measures and guidelines to improve energy efficiency in Space cooling through implementing MEPS and labelling of AC equipment	X	X	
	Make further intervention by the government to apply Green Building Guidelines in all commercial buildings for cost effective temperature-controlled indoor environment	X	X	
	Provide specialized training facilities for professionals and civil engineering personnel to promote new building technology, well as energy efficiency equipment selection	X	X	X
	Further strengthen inter-ministerial collaboration to improve overall efficiency of the Commercial building industry			X
	Promote standardization of design, construction, and associated specifications for building construction	X	X	
	Implement standards and labelling programme for commercial and industrial refrigeration equipment		X	X
	Enhance standardized training programs and certification systems in building industry		X	X
	Promote Research and development activities including indigenous methods for air conditioning throughout the country at appropriate institutes to achieve national needs and objectives	X	X	X

Cold Chain	Formulate of National Policies for the food security by promoting cold chain technology and developing cold chain infrastructure with use of low-GWP refrigerant based energy efficient cooling systems	X	X	
	Enhance awareness of farmers to manage produce both pre-harvest and post-harvest to minimize the spoilage	X	X	X
	Introduce of appropriate policy measures to improve energy efficiency of equipment	X	X	X
	Make more intervention by the government to build cost effective temperature-controlled storages and transport to help improve farm incomes	X	X	
	Provide specialized training facilities for cold chain professionals and technicians to promote proper utilization and energy efficient operation of technology,	X	X	X
	Further strengthen inter-ministerial collaboration to facilitate infrastructure development and to improve overall efficiency of the cold-chain system			X
	Standardize design, construction, and associated specifications for cold-chain infrastructure components		X	X
	Implement standards and labelling programme for commercial and industrial refrigeration equipment		X	X

Transport Refrigeration	Review existing energy policies related to the transport sector considering its multidisciplinary nature and adopt strategies related to climate energy co-benefits.	X		
	Prioritize country specific energy sources, energy efficient transportation methods focusing on cost, safety, service sector training needs and country specific climate factors and existing cooling demands for the transport sector.	X		
	Encourage use of new technologies, such as HFO 1234yf and CO_2 in the field of mobile air conditioning to replace existing HFC-134a.		X	X
	Expand training opportunities in the automotive air-conditioning sector for capacity building which would be immensely beneficial during the transition process of introducing new refrigerants.	X	X	
	Provide incentives or rebates for energy efficient technologies, which comply with the fuel/energy efficiency standards.	X	X	
	Conduct further feasibility study on available alternative technologies in the transport refrigeration subsector in the context of applying the most suitable and affordable alternative technology. .		X	X

RAC Service sector	Promote appliances design for natural refrigerants for domestic and industrial RAC applications.	X	X	X
	Strengthen preventive maintenance programmes for RAC systems implemented by suppliers.	X	X	X
	Promote refrigerants (single/blended) conservation technologies and expand training on good servicing practices among RAC service sector.	X	X	X
	Provide financial assistance to service sector for purchasing new environmental and user-friendly tools and accessories.		X	X
	Implement the existing (RPL) certification system for uncertified RAC technicians.	X	X	
	Monitor and improve environment protection licensing system for the RAC service sector.	X	X	
	Introduce regulations requiring employing trained and skilled maintenance staff in commercial and industrial institutions, where the refrigerant holding capacity greater than 100Kg in order to obtain EPL.	X	X	
	Continue capacity building programmes on RAC vocational trainers on new technologies	X	X	X
	Adopt training modules on new technologies and continue updating curriculum of RAC vocational education sector.	X	X	X
	Replace existing systems by new systems design for zero ozone depleting and low global warming potential refrigerants and enhance infra-structure facilities for small scale research and development units in RAC vocational education institutes.		X	X
Indigenous knowledge and research	Formulate renewable energy policies for maximum utilization of renewable energy sources.		X	
	Conduct further survey and research on applicability and effectiveness of indigenous methods of food preservation preparation.		X	X
	Develop pilot Projects to revisit and assess traditional methods of construction used by ancient Sri Lankans for introducing in modern construction practices.		X	
	Encourage indigenous communities in implementation of energy alternatives.		X	
	Incorporate indigenous knowledge into climate change policies for contributing to development of energy efficient, cost effective and sustainable adaptation strategies.		X	X

Annexures

Annex 1– Space Cooling

Table A: Cooling Capacities, Energy Consumption and GHG emissions in Residential Space Cooling

Description	Nos of Houses with AC	Estimated Stock	CC per house TR	Total CC, TR	Energy Consumption kW	Nos hours working	Nos of Units, kWh/d	Total kWh/year	GWh
Single House	233,750	233,750	1	233750	257125	6	1542750	509107500	509
Multi-storied	81,200	162,400	3	243,600	267960	6	1607760	530560800	531
Apartment	11,700	35,100	4	40950	45045	6	270270	89189100	89
Total	325,950	431,250		518300				1,128,857,400	1129

Note.

1. Conversion 1GWh – 800 MT CO_2eq)
2. Since 65% total power generation by thermal power, GHG emission was calculated as 65% of total energy demand.

Table B : Cooling Capacities, Energy Consumption and GHG emission in Commercial Building Space Cooling

Description	Estimated Stock	Average estimated Cooling Capacity per unit, TR	Total Cooling Capacity, TR	Energy Consumption per TR, kWh	Nos working hrs	Nos of units. kWh/d per TR	Nos of units kWh/d	Total kWh/y	GWh
Chillers	2400								
Scroll (20%)	620	50	31,000	0.9	12	10.8	334800	107136000	107
Screw (75%)	1650	350	577,500	0.8	12	9.6	5544000	1774080000	1774
Centrifugal (5%)	130	1,000	130,000	0.6	12	7.2	936000	299520000	300
Residential Acs	515,000	1.50	772,500	1	8	8	6180000	1977600000	1978
VRF /Package	9,400	12	112800	0.9	8	7.2	812160	259891200	260
Total	529200	1413.5	1,623,800	4.2	52	42.8	13806960	4418227200	4418

Table C: Energy Consumption of Fans and Air Coolers

Description	Estimated Numbers	Penetration as %	Estimated Total Quantity	Average Energy Consumption per fan kWh/year	Total Energy consumption GWH	GHG Emission MT CO_2eq
Fans						
Household	5,500,000	61	3,355,000	200	671	
Commercial	2,500,000	100	2,500,000	200	500	
Industrial	400,000	100	400,000	200	80	
Sub Total	8,400,000				0	
Air Coolers			20,000	600	12	
Total					**1263**	**1,010,400**

Table D : Modelling parameters for GHG emission analysis for equipment

Equipment Type	Lifetime (Years)	Main Refrigerant	Average Charge (kg)	Leakage Rate(%)	Service Emission Factor	Disposal Emission Factor
Split residential AC	08	R-410 A, R- 22, R -32	1.2	10	0.5	0.95
Ducted Packaged AC	11	R-407C, R- 410A	15	20	0.1	0.75
VRF	12	R-407C, R- 410A	16	20	0.1	0.8
Scroll Chillers	16	R-407C, R- 410A, R-22	40	10	0.2	0.8
Screw Chillers	18	R-134a, R-22	320	20	0.22	0.9
Centrifugal Chillers	18	R-134a, R-123	600	10	0.2	0.85

Source: http://www.green-cooling-initiative.org and modified according to stakeholder/industry consultation

Table E : Cooling Capacity Demand BUA Scenario (TR)

	2018	2022/23	2028/29	2033/34
Residential cooling	745,050	1,251,684	2,102,829	3,532,752
Commercial Building cooling	1,623,800	2,727,984	4,583,013	7,699,462

Table F: Projection of Energy Consumption, BAU and Intervention Scenario (GWh)

	2018	2022/23	2028/29	2033/34
BAU	5547	7637	11226	17064
Intervention	5547	7164	9162	13341

Table G: Projection of GHG Emission, BAU and Intervention Scenario (million MT CO_2 eq)

	2018	2022/23	2028/29	2033/34
BAU	2,89	3.97	5.83	8.87
Intervention	2.89	3.72	4.76	6.93

Annex 2- Cold Chain

Table A. Estimated refrigeration capacity and power consumption by Food and Agriculture sector

	Description	Refrigeration capacity kW	Energy consumption, kWh	Energy consumption kWh/day	Annual Energy Consumption GWh	GHG Emission MT, CO2eq
Fruit & vegetables	Cold storage	1500	1350	32,400		
	Sub total	**1,500**	**1,350**	**32,400**	**11.82**	
Dairy	Milk chilling	16,900	11,000	55,000		
	Ice-cream hardening	17,258	18,100	90,500		
	Other dairy product (assumption)	17,250	18,110	108,660		
	Cold storage	6,652	4,324	51,888		
	Sub total	**58,060**	**51,534**	**306,048**	**111.70**	
Fisheries	Chilling	1,832	1,190	5,950		
	Freezing	23,598	24,777	123,889		
	Cold storage	4,540	2,950	35,400		
	Sub total	**29,970**	**28,917**	**165,239**	**60.31**	
Poultry/ Meat	Chilling	2,122	1,380	6,900		
	Freezing	20,503	21,528	107,640		
	Cold storage	5,260	3,420	41,400		
	Sub total	**27,885**	**26,328**	**155,940**	**56.91**	
	Total of the sector	**117,415**	**108,129**	**659,627**	**240.74**	**125,184**

Source: HCFC Survey 2019 and industry information

Table B-1. Supermarket grouping

Category of Supermarket	No of outlets	No of chill rooms (+2/ +5^{0}C)	No of Frozen rooms (-18/ -22^{0}C)	Nos of Island Freezers	Nos of wall cabinets and Serve-overs
A	25	2 or more	2 or more	12 or more	8 or more
B	175	1	2	6-9	5-7
C	284	1	2	4-6	5-6
D	66	1	1	4-5	4-5
E	23		1 small	3	4

Source: Survey data 2019

Table B-2. Estimated refrigeration capacity and daily Energy consumption in commercial refrigeration (supermarket and retail outlets)

Group of Supermarket	No of outlets	No of cold room	No of Island freezers and wall cabinet, serve-overs	Ref. capacity kW	Energy Consumption kWh	Energy consumption kWh/d	Annual Energy consumption GWh	GHG Emission MT, CO2eq
A	25	100	500	15,600	1,248	24,960		
B	175	700	2,450	70,150	5,612	112,240		
C	284	568	3,124	50,590	6,447	128,940		
D	66	66	594	13,790	1,103	22,060		
E	23	0	161	3,450	276	5,520		
Groceries	100	0	300	19,500	1,400	28,000		
Total	**673**	**1,434**	**7,129**	**173080**	**16,086**	**321,720**	**117.43**	**61,064**

Source: Survey data 2019

Table C: Estimated refrigeration capacity and daily Energy requirement in Health Service sector

	Description	Refrigeration capacity kW	Energy consumption, kWh	Energy Consumption kWh/day	Annual Energy Consumption GWh	GHG Emission MT, CO2eq
Pharmaceutical / medicine stores	Ambient temperature -controlled storage	2,400	3,168	48,000	**17.52**	**9,110**

Table D: Estimated refrigeration capacity and daily Energy requirement in domestic refrigerators in 2018

Year	Nos of refrigerators (approx.)	Average Refrigeration Capacity of refrigerator, Watt	Average Energy consumption per refrigerator, kWh/year *	Annual Energy Consumption, GWh	GHG Emission MT, CO2eq
2018	2,900,000	180 (0.18kW)	550	**1,595.0**	**829,400**

* *The average energy usage of modern refrigerators is 400-600 kWh per year. This translates to 33 kWh-50 kWh per month, or an average wattage of 46 to 69 Watts (this equates to an average hourly power consumption of 46 to 69 Wh).(US-EPA, Energy data for Refrigerators, 2018)*

Average energy consumption was considered as 550 kWh per year.

Table E -1. Summary of forecast for the growth annual energy requirement (Business as Usual scenario)

Sector	average annual growth rate %		2018/2019	2023/2024	2028/2029	2033/2034
Food & Agriculture						
Fruit and vegetable	1	E.R, GWh	11.82	12.41	13.03	13.68
Dairy	7	E.R, GWh	111.70	156.38	218.93	306.52
Fisheries	3	E.R, GWh	60.31	69.95	79.75	91.71
Poultry/meat	6	E.R, GWh	56.91	75.69	100.66	133.87
Sub Total (F&A)		E.R, GWh	**240.74**	**313.83**	**412.37**	**545.78**
Commercial	8	E.R, GWh	**117.43**	**172.62**	**253.75**	**373.01**
Health Services	5	E.R, GWh	**17.52**	**22.25**	**28.25**	**35.88**
Domestic	5	E.R, GWh	**1595.0**	**2580.64**	**3,277.41**	**4162.31**
Total			**1976.82**	**3089.34**	**3971.78**	**5116.98**

Table E-2. Summary of forecast for the growth of annual energy demand (Intervention scenario)

Sector		2018/2019	2023/2024	2028/2029	2033/2034
Food & Agriculture					
Fruit and vegetables	E.R, GWh	11.82	11.78	11.98	12.31
Dairy	E.R, GWh	111.70	148.56	193.03	269.73
Fisheries	E.R, GWh	60.31	66.45	73.37	82.53
Poultry/meat	E.R, GWh	56.91	71.90	92.60	120.48
Total	E.R, GWh	**240.74**	**298.69**	**370.98**	**485.05**
Commercial	E.R, GWh	**117.43**	**160.87**	**225.27**	**310.61**
Health services	E.R, GWh	**17.52**	**21.02**	**25.22**	**30.27**
Domestic	E.R, GWh	**1595.0**	**2322.57**	**2621.60**	**2913.40**
Total		**1976.82**	**2803.15**	**3243.07**	**3739.33**

Table F-1. Annual production trend of Food and Agriculture sector

Sector	Unit	Annual Production				CAGR %
		2015	2016	2017	2018	
Fruit	MT ('000)	1,257	1,207	1,096	1,141	1
Vegetable	MT ('000)	3,250	3,411	3,268	3,322	1
Dairy	Liters ('000)	311,341	306,142	329,011	391,530	7
	MT ('000)	322.2	316.8	340.5	405.2	
Fisheries	MT ('000)	520	531	532	527	3
Poultry/meat	MT ('000)	165	183	201	214	6

Source: Department of census and statistic 2018/2019 and survey data 2019

Table F-2. Annual growth trend of commercial refrigeration (supermarket and retail)

Sector	Unit	Number of outlets				CAGR %
		2015	2016	2017	2018	
Commercial	Nos of outlets	379	440	510	573	10

Source: survey data 2019

Table F-3. Annual growth trend of Health service refrigeration

Sector	Unit	Ambient temperature-controlled storages				CAGR %
		2015	2016	2017	2018	
Health service	MT (approximately)	460	530	600	700	8

Source: survey data 2019

GHG emission from a refrigerator in 15 years lifetime

Amount of refrigerant in a domestic refrigerator: 120 grams
Amount of refrigerant leakage per year: 2 grams
Maximum refrigerant leakage during manufacturing: 18 grams
CO2 emissions per kWh of electricity: 0.8 kg CO2/kWh
GWP relation between refrigerant and CO2: 1 gram R134a = 1300 grams CO2
Usage period of the refrigerator 15 years

Emission source	Original Scale	Converted to CO_2 Kg
Refrigerant charge at manufacturing (Kg)	0.12	156.0
Refrigerant leakage at manufacturing (kg)	0.018	23.4
Refrigerant leakage over 15 years	0.03	39.0
kWh used for 15 years	550 kWh/y	6,600
Total CO2 emission per refrigerator in lifetime		6818.4

Table G: Direct Emission from Cold Chain Sector (Domestic, Food & Agriculture, Commercial and Health)

Applications	Estimated Equipment Stock	Average charge (kg)	Refrigerant Stock (kg)	Leakage rate (%)	Leakage Amount Kg	GWP refrigerant	GHG Emission Kg CO_2eq
Domestic refrigerators	2,900,000	0.12	348000	0.3	1044	1450	1,513,800
Milk Chillers	450	10	4,500	10	450	1450	652,500
Ice cream hardening	25	250	6,250	12	750	2100	1,575,000
Freezing	350	120	42,000	15	6300	2100	13,230,000
Cold Storages (Condensing units)	680	150	102,000	17	17340	2100	36,414,000
Commercial	3500	5	17,500	30	5250	1450	7,612,500
Total	**2,905,005**		**520,250**		**31134**		**60,997,800**

Annex 3: Transport sector

Introduction

The geographical position of Sri Lanka benefits the country in terms of global transport, linking the most important sea lanes in the world. As an international hub, Sri Lanka enjoys an excellent relationship in global trading with its counterparts of the Asian continent and the world. The island has been experiencing a significant economic growth and awaits a rapid growth in the near future due to improvement of infra-structure and transport network development. Increase of growth and prosperity in other major economic segments, including agricultural, industrial and tourism, has substantially impacted on the transport system in Sri Lanka. On the other hand, an enhanced transport network leads to numerous benefits to the economic sector. Sri Lanka is on the path towards sustainable energy use including the transport sector, prioritizing renewables and indigenous opportunities of energy efficiency.

Overview

Until the nineteen eighties, the majority of the people relied on public transport systems, especially trains for long journeys and transport of commodities. With the rapid growth of the economy, transport has become a crucial component leading to an enhanced road network in terms of quantity and quality. It is an emerging fact that the use of personally owned vehicles has increased in comparison to public road transport and trains over the last few decades.

Internal Transport within the country relies on railway system and road network. In 2018, the total vehicle population on road was 7,727,411 and it has been experiencing a continuous increase. The figure below shows the overview of the inland transport system in Sri Lanka.

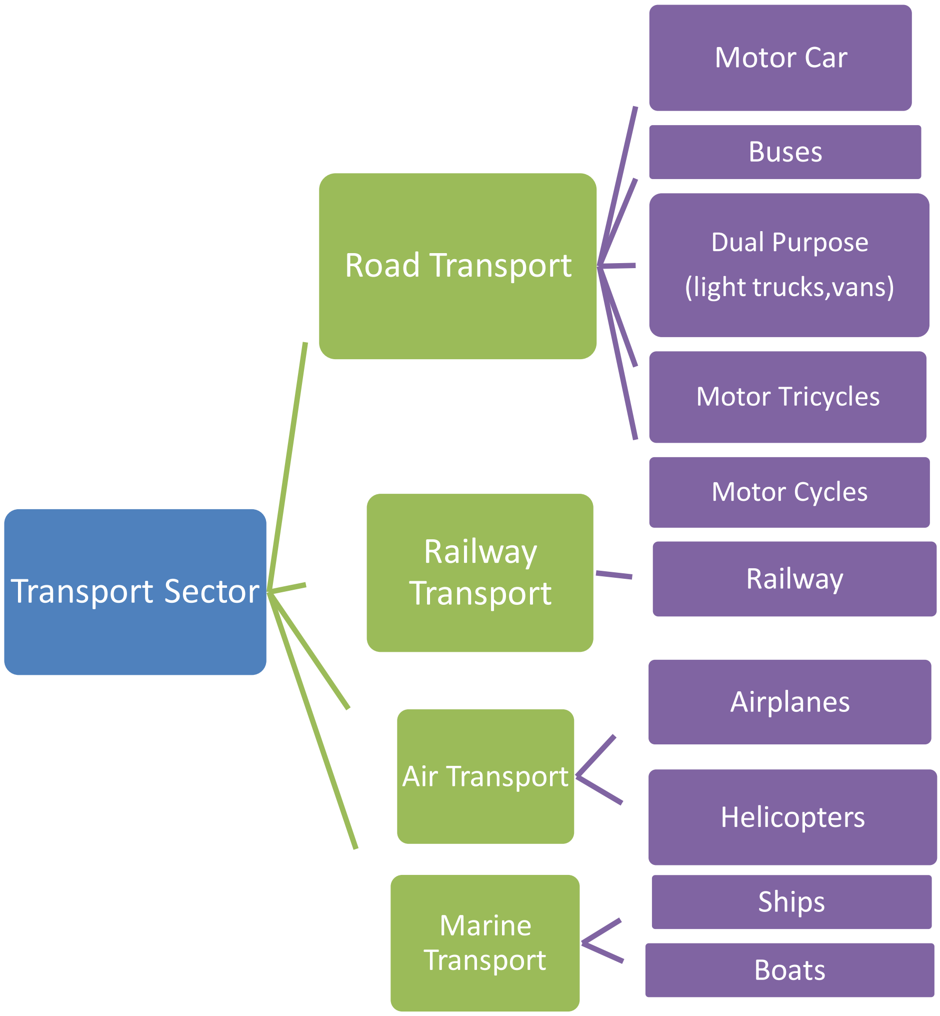

***Figure 4. 7.* Overview of Transport Sector in Sri Lanka**

The vehicle population in Sri Lanka (http://www.transport.gov.lk) over the last few years has increased considerably. Motor cars, buses, dual purpose vehicles account for nearly 60%, 8% and 32% respectively of the total number considered motor vehicles types with Mobile Air Conditioning (MAC), in the country during the period 2017-2018 (Fig.4.8). The Fig. 4.9 illustrates a distinct growing trend of all types of vehicles. The increase in the number of vehicles is primarily influenced by economic growth, increase of individual income and population growth. Rapid growth of highway road systems has strongly impacted on private vehicle usage, leading to a significant increase, and it is expected to continue further in future if remedial measures are not taken and implemented.

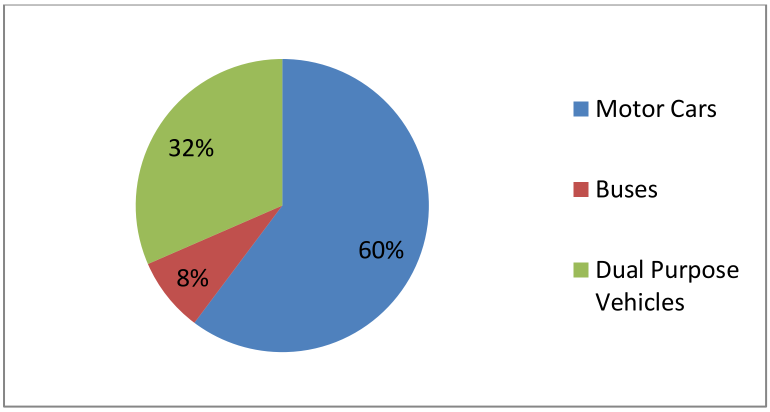

Figure 4.8. **Vehicle Population in Sri Lanka during 2017 -2018 (http://www.transport.gov.lk)**

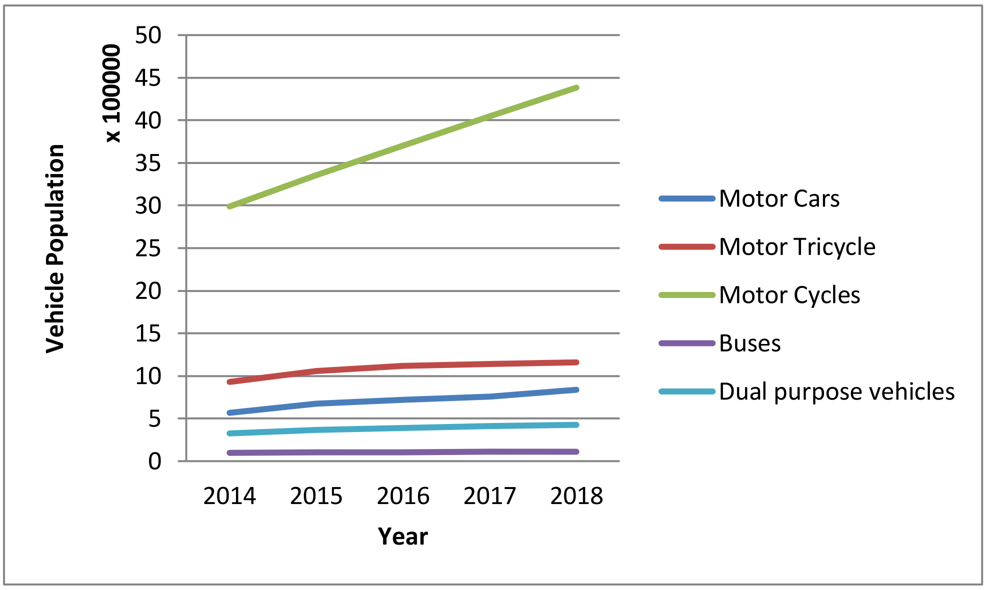

Figure 4.9. Trends in Vehicle Population in Sri Lanka 2014-2018 (http://www.transport.gov.lk)

Energy Demand in the Transport Sector

The transport sector is an important pillar of the economy. A sustainable transport system yields socio-economic benefits linking the urban and rural communities. It is a fact that, transport significantly contributes to global warming through direct and indirect greenhouse gas emissions, via combustion of fossil fuel.

In 2015, the transport sector has accounted for 29% of the total energy demand (CEB Long term generation plan, 2018-2037), which is expected to increase with population and economic growth, posing both environmental and economic challenges in future. This emphasizes the need for strategic balance to meet future energy demands in the transport sector to continuously support economic prosperity while minimizing the negative impact to the environment, particularly focusing on climate change mitigation strategies. In this context, the country needs to identify the current energy consumption pertaining to the transport sector and future trends driven by socio-economic factors. This will provide an overview of energy requirements for each segment of the transport network. Under the Paris agreement, Sri Lanka has submitted Nationally Determined Contributions (NDC) and has planned to reduce emissions by substantial amounts in the transport sector by 2030 from the business as usual scenario. The amount to be reduced in the energy sector is 20% from the business as usual scenario.

Annex 4: Import of domestic air conditioners by major importers

Year	Importer	R-410A	HFC-32	HCFC-22
	Craft Lanka			
2015		459	0	2713
2016		1492	0	2466
2017		2370	0	45
2018		2450	0	0
	Soft logic			
2015		1600	0	4160
2016		1900	0	1640
2017		2200	0	260
2018		2600	0	0
	Damro			
2015		1200	0	3160
2016		1300	0	1840
2017		1200	120	360
2018		1900	600	0
	Singer Sri Lanka			
2015		1400	0	4260
2016		1400	0	1940
2017		2100	0	560
2018		2600	0	0
	Abans			
2015		2100	0	3440
2016		2600	0	2940
2017		2600	0	440
2018		2900	0	0
	Others			
2015		4100	0	4440
2016		3600	0	3340
2017		4600	340	460
2018		5900	640	0

Annex 5: Data gathered from the participants of stakeholder workshop held in June 2019

No	Institute	System type	Type of refrigerants	Refrigerant capacity (RT)	RT% with respect to refrigerant in total capacity HCFC-22, R-410A, HFC-134a
01	Bank of Ceylon HQ	Water cool chillers, Air cool package chillers, Precession control Acs Split type	HCFC-22 HFC-134a R-410A	925 4000 100	18 80 2
02	Cinnamon Lakeside Hotel	Water cool chillers, Air cool package chillers	HCFC-22 HFC-134a R-410A	1250 80 100	6 87 7
03	Serendib Hotel	Water cool chillers	HFC-134a	306	100
04	Air Port Aviation Services Ltd	Water cool chillers, Air cool package chillers, Precession control ACs Split type	HCFC-22 HFC-134a R-410A R-404A	1000 2000 1000 900	20 40 20 20
05	Ceylon Cold Stores	Water cool chillers, Refrigeration systems	HCFC-22 HFC-134a R-410A R-404A NH3	60 430 25 550 450	5 28 2 36 30
06	Ceylon Fishery Corporation	Air cool package chillers, Refrigeration systems	HCFC-22 HFC-134a R-410A	650 500 350	43 33 24