ISB
INDUSTRIAL SERVICES BUREAU

FINAL REPORT

The National Survey on Chillers in Sri Lanka

Submitted to

Sri Lanka Sustainable Energy Authority

Submitted by

Industrial Services Bureau (ISB)

INDUSTRIAL SERVICES BUREAU
141, Kandy Road, Kurunegala, Sri Lanka Tel: 037 2223721 – 3 Fax: 037 2223562
E-mail: info@isb.lk Website: www.isb.lk

SLSI SYSTEM CERTIFIED ISO 9001

TABLE OF CONTENTS

LIST OF TABLES

`

LIST OF FIGURES

EXECUTIVE SUMMARY

Central air conditioning systems, particularly chillers, play a critical role in Sri Lanka's commercial sectors, encompassing industries like food and beverages, shopping malls, and large government and commercial buildings. Despite their importance, there has been no comprehensive survey of chillers in Sri Lanka until now. Recent energy audits by the Sri Lanka Sustainable Energy Authority (SLSEA) have underscored that many chillers across the country are outdated and inefficient. This highlighted the need for a detailed survey to inventory chiller capacities, ages, and efficiencies, facilitating calculations of their total energy use and potential savings through upgrades to modern units.

The National Survey on Chillers in Sri Lanka, conducted jointly by the SLSEA and the Industrial Services Bureau (ISB), aims to guide building owners and technical personnel in optimizing chiller capacities and selections. The study seeks to enhance energy efficiency in Sri Lanka's commercial and industrial sectors, providing a foundation for implementing energy-saving measures that lead to significant cost reductions and environmental benefits. The data also supports policymakers in developing strategies to promote energy-efficient technologies.

Key Achievements

- Comprehensive Database: Creation of a comprehensive database detailing chiller capacities, ages, efficiencies, and geographical distribution across Sri Lanka.
- Energy Consumption Analysis: Analysis of energy consumption patterns and operational efficiencies of existing chiller systems.
- Recommendations: Recommendations for replacing outdated chillers with modern, energy-efficient models.
- Savings Estimation: Estimation of potential energy and cost savings from implementing these recommendations.

A multi-phase approach was employed for thorough data collection and analysis. Initial data gathering included national-level information from importers, manufacturers, service providers, and industries through phone interviews, emails, secondary data sources, and site visits. Approximately 933 chillers were covered, documenting their geographical distribution, capacities, ages, efficiencies, and other specifics.

The chiller inventory data categorized by age range, total capacity, and number of chillers is summarized as follows:

Table 1 : Summary of Chiller Inventory Data – Chiller Capacity & Nos. of Chillers

Age Range (Years)	Total Capacity		Nos. of Chillers	
	TR	%	Nos	%
0 < x < 5	36,060	21	117	16
5 < x <10	73,300	42	333	46
10 < x <15	38,070	22	165	23
15 < x < 20	13,830	8	52	7
20< x < 25	12,080	7	52	7
Total	173,340	100	719	100

The survey also categorized chiller inventory by sector, providing insights into energy consumption and efficiency improvements specific to each sector.

Table 2 : Summary of Chiller Inventory Data – Chiller Capacity & Sector Wise

Total Capacity												
Age Range (Years)	Commercial		Government		Hospital		Hotel		Industrial		Total	
	TR	%	TR	%	TR	%	TR	%	TR	%	TR	%
0 < x < 5	12,712	32	6,826	22	1,124	8	7,362	21	8,006	15	36,060	21
5 < x <10	11,328	29	9,029	30	5,919	41	18,554	53	28,483	52	73,300	42
10 < x <15	6,729	17	4,556	15	4,734	33	6,742	19	15,311	28	38,070	22
15 < x < 20	2,820	7	7,100	23	1,139	8	1,306	4	1,468	3	13,830	8
20< x < 25	5,814	15	2,989	10	1,473	10	720	2	1,052	2	12,080	7
Total	**39,403**		**30,500**		**14,389**		**34,684**		**54,320**		**173,340**	

Walkthrough audits were conducted on a sample of 100 chillers, and detailed audits were conducted on a sample of 10 chillers across various sectors and capacities (100 to 1600 TR). These audits provided valuable insights into operational efficiencies and areas for improvement, enhancing understanding of chiller performance in Sri Lanka.

The analysis of Sri Lanka's chiller inventory, walkthrough audits, and detailed audits reveals significant opportunities to enhance energy efficiency and reduce greenhouse gas (GHG) emissions. The findings emphasize the potential for impactful interventions across various sectors, contributing to both cost savings and environmental benefits.

The total energy-saving potential is estimated at 69,747,793 kWh (approximately 70 GWh), accompanied by a substantial reduction in GHG emissions totaling 48,404,968 kilograms of CO_2 equivalent.

The industrial sector emerges as the largest contributor to energy savings, accounting for 27% of the total potential. This is followed by the hotel sector, which represents 23% of the savings potential. The government sector contributes 18%, while the commercial and hospital sectors account for 16% each.

In terms of GHG emission reductions, the industrial sector again leads with 12,893,315 kilograms of CO_2 equivalent saved, followed by the hotel sector with 11,041,253 kilograms. The government, commercial, and hospital sectors contribute 8,875,310 kilograms, 7,912,444 kilograms, and 7,680,185 kilograms of CO_2 equivalent reductions, respectively.

These findings highlight the critical importance of addressing inefficiencies in chiller operations across all sectors. Prioritizing energy-efficient technologies and practices can unlock substantial benefits, aligning with national sustainability goals while demonstrating leadership in environmental stewardship. By leveraging these insights, Sri Lanka can pave the way for a more energy-efficient and sustainable future.

According to the LCoE calculation summary, Jetwing Sea, Negombo (218,256 kWh) and Royal Palm Beach Hotel (195,150 kWh) and Deantal Teaching Hospital have the highest energy savings and lowest LCoEs of $ 0.0520, $ 0.0650 and $ 0.0632 respectively. Central Provincial Council (22,598 kWh) has the highest LCoE of ($0.5697/kWhWater-cooled systems offer better cost-effectiveness, than air-cooled systems, with LCoE between $0.0520/kWh and $0.1459/kWh. Investments range from LKR 25 million to 72 million.

In Sri Lanka, the financial analysis including the study if levelized cost of electricity of chiller replacement highlights significant opportunities for energy savings and cost reductions across sectors. By focusing on chillers based on age and refrigerant type, strategic replacements can maximize both energy efficiency and financial returns.

Phase 01 focuses on replacing chillers aged 20 to 25 years, offering potential annual savings of LKR 602.25 million with a quick payback period of 2.3 years. Hospitals, with their critical energy demands, could save approximately LKR 493.84 million annually by upgrading chillers, requiring an investment of LKR 1.65 billion with a payback period of 3.3 years. Additionally, phasing out R22 refrigerant chillers aligns with environmental goals, ensuring compliance with global standards while enhancing energy efficiency.

Phase 02 targets chillers aged 15 to 20 years, projecting annual savings of LKR 511.09 million and a payback period of 3.1 years, alongside government sector replacements yielding LKR 570.69 million in savings annually with a 6.1-year payback. Transitioning from R134a to lower-GWP refrigerants further supports sustainability efforts, reflecting Sri Lanka's commitment to efficient and eco-friendly infrastructure improvements.

These targeted chiller replacements align with global energy efficiency goals and local sustainability efforts, offering substantial energy and financial benefits. Prioritizing these initiatives can support Sri Lanka's path towards enhanced operational efficiency and reduced environmental impact.

`

ABBREVIATIONS

AC	Air Conditioning
AHU	Air Handling Unit
BMS	Building Management System
CEB	Ceylon Electricity Board
°C	Degrees Celsius
CHW	Chilled Water
CHWFR	Chilled Water Flow Rate
CHWR	Chilled Water Return
CHWS	Chilled Water Supply
CW	Condensate Water
CWFR	Condensate Water Flow Rate
CWR	Condensate Water Return
CWS	Condensate Water Supply
EEM	Energy Efficiency Measure (Recommendation for energy reduction)
FCU	Fan Coil Unit
hr	Hours
I	Ampere
ISB	Industrial Services Bureau
kg	kilograms
kVA	Apparent power
kVA_r	Reactive power
kW	Active power
kWh	kilowatt hours
l	liters
SLSEA	Sri Lanka Sustainable Energy Authority
TR	Tonnes of Refrigeration
V	Voltage
VFD	Variable Frequency Drive

`

CHAPTER I
INTRODUCTION

1.1 Background

Central air conditioning systems, particularly chillers, were critical components in Sri Lanka's commercial sectors, including industries such as food and beverages, shopping malls, and large government and commercial buildings. Despite their extensive use, no comprehensive survey had been conducted on chillers until recently. Findings from energy audits conducted by sector experts and the Sri Lanka Sustainable Energy Authority (SLSEA) indicated that most chillers in Sri Lanka were outdated and operated at lower efficiencies. This lack of detailed information on their geographical distribution, capacity, and other specifics necessitated a comprehensive survey to create a detailed inventory of the chiller population in the country, documenting their capacities, ages, and efficiencies. With this information, it became possible to calculate the total energy use of the chiller population and estimate the potential savings from replacing inefficient chillers with modern, efficient units.

The National Survey on Chillers in Sri Lanka, jointly implemented by the Sri Lanka Sustainable Energy Authority (SLSEA) and the Industrial Services Bureau (ISB), focused on providing guidance to building owners and technical personnel engaged in building construction and management, helping them optimize chiller capacities and selection.

This study was crucial as it addressed the critical need for improving energy efficiency in Sri Lanka's commercial and industrial sectors. By identifying and documenting the current status of chillers, the study laid the groundwork for implementing energy-saving measures that could lead to substantial cost reductions and environmental benefits. The data collected also aided policymakers in developing strategies to promote the adoption of energy-efficient technologies and practices.

The survey achieved the following outcomes:

- A comprehensive database of chillers in Sri Lanka, detailing their capacities, ages, efficiencies, and geographical distribution.
- An analysis of the energy consumption patterns and operational efficiencies of existing chiller systems.
- Recommendations for replacing outdated and inefficient chillers with modern, energy-efficient models.
- An estimation of potential energy and cost savings achievable through the implementation of recommended measures.

`

The survey employed a multi-phase approach to ensure thorough data collection and analysis. Initial data collection involved gathering national-level data on chillers from various sources, including importers, manufacturers, service providers, industries, etc. This phase utilized phone interviews, email communications, secondary data sources, and site visits to compile information on vapor compression and absorption type chillers. Approximately 900 chillers currently in operation across Sri Lanka were covered under this phase.

The survey documented detailed information regarding the geographical distribution, capacities, ages, efficiencies, and other specifics of these chillers, addressing the prior lack of data on chiller geographical distribution and capacities within the country.

1.2 Summary of Chiller Inventory Data- Age Range

The following table summarizes the chiller inventory data, showing the distribution of chillers by age range, total capacity in Tonne of Refrigeration (TR), and the number of chillers:

Table 3 : Summary of Chiller Inventory Data – Chiller Capacity & Nos. of Chiller with Age Range

Age Range (Years)	Total Capacity		Nos. of Chillers	
	TR	%	Nos	%
0 < x < 5	36,060	21	117	16
5 < x <10	73,300	42	333	46
10 < x <15	38,070	22	165	23
15 < x < 20	13,830	8	52	7
20< x < 25	12,080	7	52	7
Total	**173,340**	**100**	**719**	**100**

From the entire chiller database, only 719 chillers with identifiable manufacturing dates are included in this summary, while 120 chillers have unidentified manufacturing dates. The identified chillers have been categorized by age, providing insights into their distribution and efficiency over time. The analysis shows that the majority of chillers fall within the 5 to 10-year age range, representing 42% of the total capacity and 46% of the total number of chillers.

1.3 Summary of Chiller Inventory Data - Sector

The table below summarizes the chiller inventory data by sector, showing the distribution of chillers by age range, total capacity in Tonne of Refrigeration (TR), and the percentage of total capacity for each sector:

Table 4 : Summary of Chiller Inventory Data – Chiller Capacity with Sector Wise

Total Capacity												
Age Range (Years)	Commercial		Government		Hospital		Hotel		Industrial		Total	
	TR	%	TR	%	TR	%	TR	%	TR	%	TR	%
0 < x < 5	12,712	32	6,826	22	1,124	8	7,362	21	8,006	15	36,030	21
5 < x <10	11,328	29	9,029	30	5,919	41	18,554	53	28,483	52	73,313	42
10 < x <15	6,729	17	4,556	15	4,734	33	6,742	19	15,311	28	38,072	22
15 < x < 20	2,820	7	7,100	23	1,139	8	1,306	4	1,468	3	13,833	8
20< x < 25	5,814	15	2,989	10	1,473	10	720	2	1,052	2	12,048	7
Total	**39,403**		**30,500**		**14,389**		**34,684**		**54,320**		**173,296**	

From the data, the total capacity of chillers across various sectors in Sri Lanka is 173,296 TR, spread across different age ranges. Key observations from the data are as follows:

Commercial Sector: The total capacity is 39,403 TR, with the largest portion (32%) being in the 0 < x < 5 years age range. The next significant age range is 5 < x < 10 years, which accounts for 29% of the total capacity.

Government Sector: The total capacity is 30,500 TR, with the majority (30%) being in the 5 < x < 10 years age range. The 0 < x < 5 years and 15 < x < 20 years ranges also have significant capacities, accounting for 22% and 23% respectively.

Hospital Sector: The total capacity is 14,389 TR, with the highest portion (41%) being in the 5 < x < 10 years age range. The 10 < x < 15 years range is also notable, accounting for 33% of the total capacity.

Hotel Sector: The total capacity is 34,684 TR, with the largest portion (53%) being in the 5 < x < 10 years age range. The 0 < x < 5 years range also represents a significant share at 21%.

Industrial Sector: The total capacity is 54,320 TR, with the largest portion (52%) being in the 5 < x < 10 years age range. The 10 < x < 15 years range accounts for 28% of the total capacity.

Overall, 42% of the total chiller capacity falls within the 5 < x < 10 years age range, indicating that a significant portion of the chiller population in Sri Lanka is relatively modern but may still benefit from efficiency improvements.

The table below summarizes the number of chillers by age range and sector, along with the percentage of total chillers in each category:

Table 5 : Summary of Chiller Inventory Data – No. of Chillers with Age Range

`

Nos. of Chillers												
Age Range (Years)	**Commercial**		**Government**		**Hospital**		**Hotel**		**Industrial**		**Total**	
	Nos	**%**	**Nos**	**%**	**Nos**	**%**	**Nos**	**%**	**Nos**	**%**	**Nos**	**%**
0 < x < 5	30	21	22	19	6	7	20	16	39	16	117	16
5 < x <10	54	37	46	40	37	44	68	54	128	52	333	46
10 < x <15	33	23	22	19	21	25	29	23	60	24	165	23
15 < x < 20	13	9	12	10	11	13	7	6	9	4	52	7
20< x < 25	15	10	14	12	10	12	2	2	11	4	52	7
Total	**145**	**100**	**116**	**100**	**85**	**100**	**126**	**100**	**247**	**100**	**719**	**100**

From the data, a total of 719 chillers have been identified across various sectors in Sri Lanka. Key observations from the data are as follows:

Commercial Sector: The total number of chillers is 145, with the largest portion (37%) being in the 5 < x < 10 years age range. The next significant age range is 10 < x < 15 years, which accounts for 23% of the total number of chillers.

Government Sector: The total number of chillers is 116, with the majority (40%) being in the 5 < x < 10 years age range. The 0 < x < 5 years and 10 < x < 15 years ranges also have significant numbers, accounting for 19% each.

Hospital Sector: The total number of chillers is 85, with the highest portion (44%) being in the 5 < x < 10 years age range. The 10 < x < 15 years range is also notable, accounting for 25% of the total number of chillers.

Hotel Sector: The total number of chillers is 126, with the largest portion (54%) being in the 5 < x < 10 years age range. The 0 < x < 5 years range also represents a significant share at 16%.

Industrial Sector: The total number of chillers is 247, with the largest portion (52%) being in the 5 < x < 10 years age range. The 10 < x < 15 years range accounts for 24% of the total number of chillers.

Overall, 46% of the total number of chillers falls within the 5 < x < 10 years age range, indicating that a significant portion of the chiller population in Sri Lanka is relatively modern but may still benefit from efficiency improvements.

1.4 Summary of Chiller Inventory Data- Refrigerant

The table below summarizes the number of chillers by age range and refrigerant type, along with the percentage of total chillers using each refrigerant in each age category:

Table 6 : Summary of Chiller Inventory Data – Refrigerant with Age Range

Age Range (Years)	Refrigerant										
	R22		R134a		R407C		R514A		R410C		Total
	Nos	%	Nos	%	Nos	%	Nos	%	Nos	%	Nos
0 < x < 5	4	4	97	85	3	3	10	9	0	0	114
5 < x <10	17	5	299	91	3	1	4	1	5	2	328
10 < x <15	18	11	144	88	2	1	0	0	0	0	164
15 < x < 20	11	19	45	79	1	2	0	0	0	0	57
20< x < 25	27	48	25	45	4	7	0	0	0	0	56
Total	**77**		**610**		**13**		**14**		**5**		**719**

From the data, a total of 719 chillers have been identified across various age ranges in Sri Lanka, categorized by the type of refrigerant used. Key observations from the data are as follows:

R22: The highest portion (48%) of these chillers is in the 20 < x < 25 years age range. Significant portions are also in the 15 < x < 20 years (19%) and 10 < x < 15 years (11%) age ranges.

R134a: The majority of these chillers (91%) are in the 5 < x < 10 years age range. The next significant age ranges are 0 < x < 5 years (85%) and 10 < x < 15 years (88%).

R407C: The highest portion (7%) of these chillers is in the 20 < x < 25 years age range.
R514A: The highest portion (9%) of these chillers is in the 0 < x < 5 years age range.
R410C: The majority of these chillers (2%) are in the 5 < x < 10 years age range.

Overall, the data indicates that R134a is the most commonly used refrigerant, especially in chillers aged between 5 and 10 years. R22 is more commonly found in older chillers, particularly those older than 20 years. The presence of other refrigerants such as R407C, R514A, and R410C is relatively minimal.

The table below summarizes the number of chillers by sector and refrigerant type, along with the percentage of total chillers using each refrigerant in each sector:

`

Table 7 : Summary of Chiller Inventory Data – Refrigerant with Sector Wise

Sector	Refrigerant										
	R22		R134a		R407C		R514A		R410C		Total
	Nos	%	Nos	%	Nos	%	Nos	%	Nos	%	Nos
Commercial	21	14%	112	73%	9	6%	4	3%	8	5%	154
Government	15	11%	117	85%	4	3%	2	1%	0	0%	138
Hospital	22	19%	88	75%	8	7%	0	0%	0	0%	118
Hotel	18	11%	108	67%	19	12%	8	5%	8	5%	161
Industrial	48	15%	247	75%	23	7%	0	0%	10	3%	328
Total	124		672		63		14		26		899

From the data, a total of 899 chillers have been identified across various sectors in Sri Lanka, categorized by the type of refrigerant used. Key observations from the data are as follows:
Overall, the data indicates that R134a is the most commonly used refrigerant across all sectors, particularly in the industrial sector. R22 is the next most common refrigerant, especially in the hospital sector. Other refrigerants, such as R407C, R514A, and R410C, are used to a lesser extent across the various sectors.

1.5 Walkthrough Audits

The walkthrough audits were conducted on a selected sample of chillers used for air conditioning, utilizing the developed chiller inventory. The total sample size comprised 100 units, representing various sectors or categories of chillers available. The sample selection emphasized different chiller capacities ranging from 100 to 1600 TR. This selection process was based on the database prepared during the initial data collection phase and was carried out in consultation with the Sri Lanka Sustainable Energy Authority (SLSEA).

The walkthrough audits were performed using a questionnaire developed from the experience gained through the initial data collection. This ensured that the audits were thorough and reflective of the real-world conditions of the chillers in use.

The selected sample represented the following sectors or categories in approximate proportions, as outlined in Table 8:

`

Table 8 : Nos. of Walkthrough Audits with Sector Wise

Sector/Category	Nos. of Walkthrough Audits
Hotels	25
Commercial	20
Government	15
Hospitals	20
Industrial	20

The walkthrough audits encompassed a total of 222 chillers, categorized into 135 on-duty chillers (61%) and 87 standby chillers (39%). These audits provided valuable insights into operational efficiencies and identified potential areas for improvement across different sectors. This thorough examination contributed to a more comprehensive understanding of chiller performance in Sri Lanka, highlighting key aspects that can enhance energy efficiency and operational effectiveness in the future.

The walkthrough audits of chiller systems across various sectors in Sri Lanka revealed significant insights into energy consumption, maintenance practices, and operational efficiencies. The audits focused on hotels, commercial establishments, government facilities, and hospitals, highlighting both sector-specific challenges and common issues. The following summary provides an overview of the key observations made during these audits, emphasizing the importance of targeted improvements to enhance energy efficiency and performance in each sector.

Hotel Sector: The energy consumption of chiller systems in hotels varies significantly, accounting for 25% to 89% of total electrical energy usage. In addition to chillers, hotels use package and split units for cooling based on their specific needs. Most chillers are equipped with modern energy-efficient technologies and are well-maintained by dedicated technical teams who ensure good housekeeping practices. AC load fluctuates with occupancy levels, and hotels employ VFDs and automatic control systems with separate energy monitoring devices. Some hotels have not upgraded their AHU units and air distribution systems despite installing new chillers. Maintenance issues include cooling towers with fungus and dirt and minor insulation damages. Coastal hotels face corrosion in cooling towers due to the sea breeze.

Commercial Sector: In the commercial sector, the energy consumption of chiller systems ranges from 5% to 73% of total electrical energy usage. Commercial establishments also use package and split units for cooling purposes. Maintenance is handled by either in-house teams or outsourced service providers to support building operations.

Government Sector: Government facilities show a wide range in energy consumption for chiller systems, from 28% to 77% of total electrical energy usage. Some government facilities have chillers that are over 30 years old, operating at lower efficiencies and higher energy consumption. In certain power plants, cooling towers are absent, and water is directly pumped from nearby reservoirs. Several facilities lack technically skilled personnel for chiller maintenance, leading to frequent repairs and replacements. There are mismatches in the capacities of chiller units, condenser water pumps, and cooling tower units in some government facilities.

Hospital Sector: Hospitals' energy consumption for chiller systems ranges from 19% to 81% of total electrical energy usage. Private hospitals generally have dedicated maintenance teams and adhere to good housekeeping practices, while public sector hospitals often lack skilled maintenance personnel. Around 21% of hospitals use air-cooled chillers, all of which are installed in public sector hospitals. Capacity mismatches between chillers and distribution systems are observed, with issues such as algae growth in cooling towers and improper insulation in some hospitals.

Industrial Sector: The energy consumption of chiller systems in the industrial sector varies from 15% to 68% of the total electrical energy usage. At some locations, new chillers have been installed, but the air distribution systems were not updated accordingly. Some facilities operate on shifts with unequal employee counts for day and night shifts; however, the chillers and AHUs run at constant speed. In textile and apparel industries, filters on the return air sides are frequently blocked. Additionally, some locations experience noise issues due to worn-out fan motors, belts, and improper air distribution systems. Overall, the industrial sector benefits from skilled technical staff who maintain the chiller systems efficiently.

CHAPTER II

DATA ANALYSIS AND FINDINGS OF DETAILED ENERGY AUDITS

2.1 Introduction

In Sri Lanka, the efficient operation of chillers is crucial for managing energy consumption across various sectors, including hospitals, hotels, commercial complexes, industries, and government buildings. Chillers play a vital role in maintaining comfortable environments, but their efficiency varies based on factors such as age, operational hours, and maintenance practices. The National Survey on Chillers in Sri Lanka conducted detailed energy audits on a diverse set of chillers to assess their performance and identify opportunities for energy savings.

This chapter synthesizes the findings of these audits, focusing on the analysis of energy consumption, efficiency metrics like the Coefficient of Performance (COP), and the potential environmental impacts of adopting energy-saving measures. The audits involved detailed data logging over seven days to capture information on air conditioning demand, current energy use, and efficiencies under various load conditions.

The study highlights disparities in chiller efficiency across different sectors and identifies sector-specific trends, providing valuable insights into optimizing chiller performance to achieve energy conservation goals in Sri Lanka. By reviewing operational data and efficiency metrics, the report emphasizes the importance of upgrading ageing chiller infrastructure and implementing targeted interventions for enhanced energy efficiency.
Furthermore, the audits included in-depth case studies on energy efficiency improvements and financial analyses for 10 establishments with high energy-saving potential. These case studies aimed to identify opportunities for energy, emissions, and cost savings through energy-efficient retrofits and system optimizations.

The next phase of the study will expand to cover the entire population of chillers in Sri Lanka, conducting a comprehensive statistical analysis to provide a broader overview of the energy-saving potential across the island. This analysis aims to inform policymakers, facility managers, and stakeholders about significant opportunities for reducing energy consumption and greenhouse gas emissions through strategic chiller management practices, fostering a more sustainable approach to energy use in Sri Lanka’s built environment.

2.2 Analysis of Energy Consumption and Efficiency

Table 9 : Summary Data of Detailed Energy Audits Chillers

No	Name	Sector	Capacity (TR)	Type	Year of Manufacture	Age	Rated CoP (kW/kW)
1	Independence Arcade	Commercial	140	Water Cooled	2013	10	4.75
2	Liberty Plaza	Commercial	300	Water Cooled	2005	18	5.55
3	Road Development Authority (RDA)	Government	300	Water Cooled	2011	12	5.45
4	Central Provincial Council	Government	400	Air Cooled	2010	13	5.50
5	General Hospital - Peradeniya	Hospital	150	Water Cooled	1998	25	4.79
6	Dental Teaching Hospital	Hospital	125	Water Cooled	2013	10	5.50
7	Royal Palm Beach Hotel	Hotel	220	Water Cooled	2011	12	5.28
8	Jetwing Sea, Negombo	Hotel	180	Water Cooled	2008	15	5.14
9	Isabella, Katunayake	Industrial	100	Water Cooled	2015	8	5.50
10	MAS - Mahiyanganaya	Industrial	420	Water Cooled	2015	8	5.05

Above Detailed Energy Audits (DEA) revealed notable disparities in chiller efficiency across various sectors. The observations are categorized based on age, sector-specific trends, operational patterns, and capacity utilization as described below.

2.3 Key Observations and Findings

1. **Age and Efficiency**: Older chillers tend to show significantly lower efficiency compared to newer models. For instance, the chiller at General Hospital - Peradeniya, which is 25 years old, has an operating CoP of 1.08, the lowest among the surveyed chillers. This underscores the importance of upgrading ageing infrastructure to improve efficiency. In contrast, newer chillers like those at Independence Arcade and Dental Teaching Hospital, both 10 years old, demonstrate better efficiency with higher operating CoP values of 3.61 and 4.00, respectively.

`

Table 10 : Summary Data of Detailed Energy Audits Chillers – Rated & Operating COP

No	Name	Year of Manufacture	Age	Rated CoP (kW/kW)	Operating CoP (kW/kW)
1	Independence Arcade	2013	10	4.75	3.61
2	Liberty Plaza	2005	18	5.55	5.08
3	Road Development Authority (RDA)	2011	12	5.45	2.75
4	Central Provincial Council	2010	13	5.50	3.10
5	General Hospital - Peradeniya	1998	25	4.79	1.08
6	Dental Teaching Hospital	2013	10	5.50	4.00
7	Royal Palm Beach Hotel	2011	12	5.28	4.64
8	Jetwing Sea, Negombo	2008	15	5.14	3.78
9	Isabella, Katunayake	2015	8	5.50	4.45
10	MAS -Mahiyanganaya	2015	8	5.05	4.83

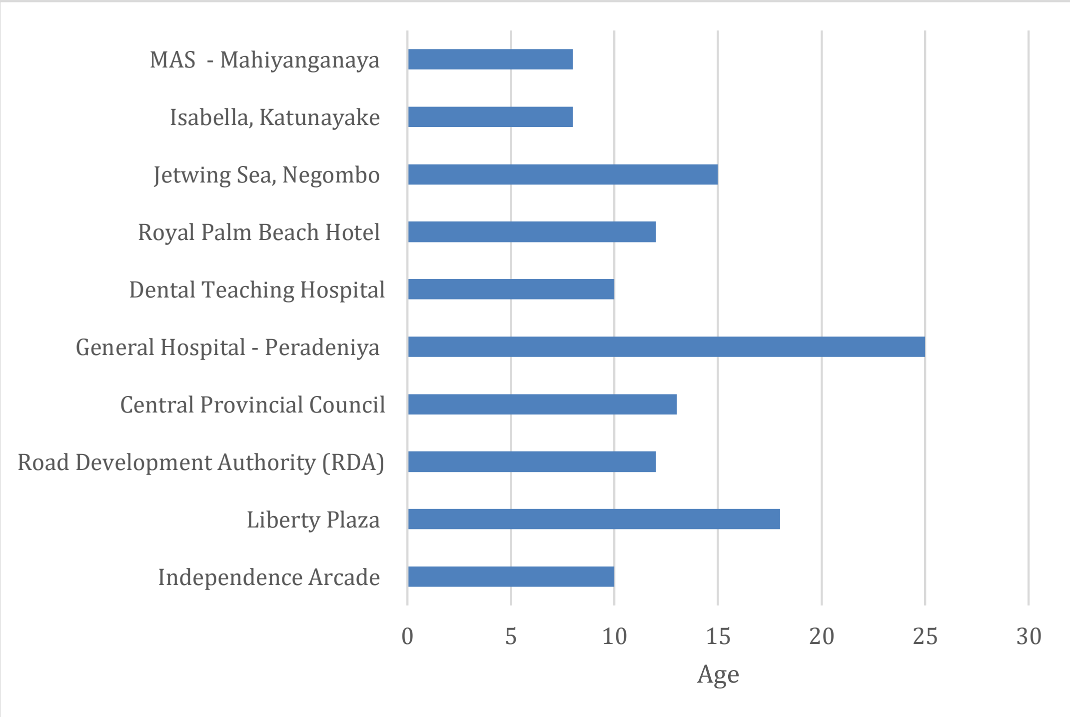


Figure 1 : Age of Detailed Energy Audits Chillers

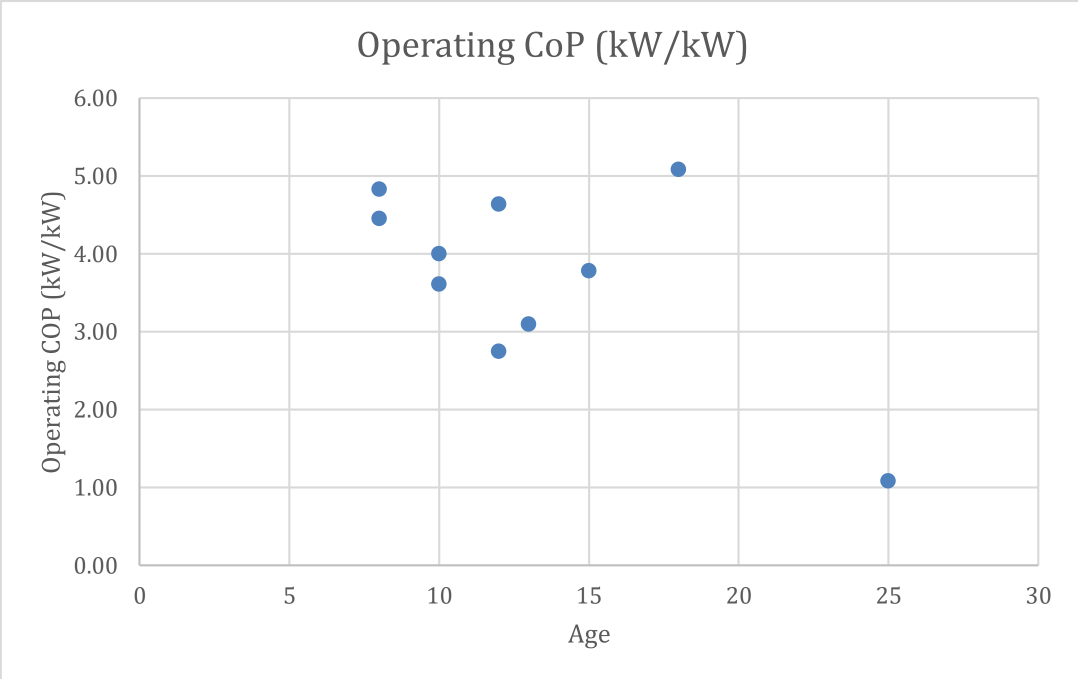


Figure 2 : Operating CoP vs Age of Detailed Energy Audits Chillers

2. Sector-Specific Trends: Different sectors exhibit distinct patterns in chiller efficiency and usage. Government facilities and hospitals generally have older chillers with lower efficiency, highlighting a need for targeted interventions in these sectors. For example, the chillers in government buildings such as the Road Development Authority and the Central Provincial Council show moderate efficiency with operating COPs of 2.75 and 3.10, respectively. In contrast, the commercial and industrial sectors tend to have newer and more efficient chillers.

3. Operational Patterns: Chillers operating for extended hours, such as those in hospitals and hotels, present substantial opportunities for energy savings through efficiency improvements. Hospitals like General Hospital - Peradeniya and Dental Teaching Hospital operate their chillers for 15.5 and 24 hours per day, respectively, resulting in high energy consumption. Similarly, hotels like Royal Palm Beach Hotel and Jetwing Sea, Negombo, also operate their chillers 24 hours per day, indicating significant potential for energy savings with more efficient units.

4. Capacity Utilization: The capacity of chillers also plays a crucial role in their efficiency and energy consumption. Higher capacity chillers, such as the 420 TR chiller at MAS - Mahiyanganaya, tend to have better efficiency with an operating CoP of 4.83. However, capacity utilization must be optimized to ensure energy savings. Underutilized chillers can lead to inefficiencies and higher energy consumption per unit of cooling provided. For instance, the chiller at Central Provincial Council, with a capacity of 400 TR but operating only 2.25 hours per day, indicates potential overcapacity and underutilization.

2.4 Detailed Analysis:

1. **Operating Hours per Day:** The operating hours per day for chillers vary significantly across different sectors, which impacts their efficiency and energy consumption.

Table 11 : Summary Data of Detailed Energy Audits Chillers – Operating Days

No	Name	Operating Hours Per Day	Operating Days per Month
1	Independence Arcade	14.5	30
2	Liberty Plaza	7.3	30
3	Road Development Authority (RDA)	6.5	20
4	Central Provincial Council	2.25	20
5	General Hospital - Peradeniya	15.5	30
6	Dental Teaching Hospital	24	30
7	Royal Palm Beach Hotel	24	30
8	Jetwing Sea, Negombo	24	30
9	Isabella, Katunayake	24	24
10	MAS -Mahiyanganaya	15	20

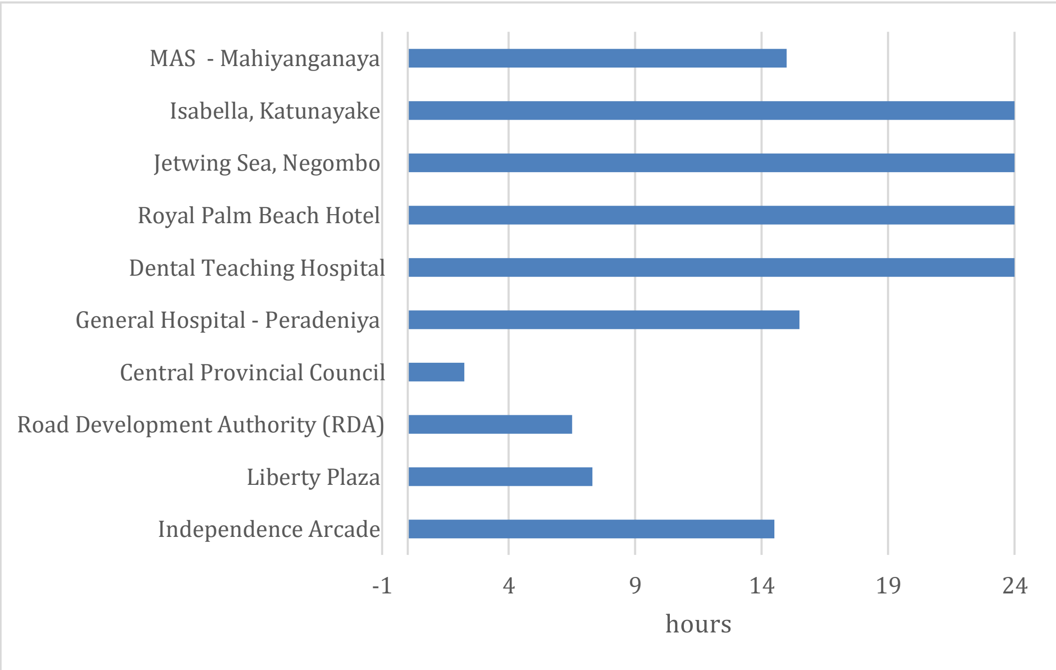


Figure 3 : Operating Hours per day of Detailed Energy Audits Chillers

- High Operating Hours: Chillers in hospitals and hotels operate for extended periods, often 24 hours a day, to maintain controlled environments. For example, the Dental Teaching Hospital and Royal Palm Beach Hotel both have chillers operating 24 hours per day, which can lead to higher energy consumption and wear and tear.

- Moderate Operating Hours: In the commercial and industrial sectors, operating hours vary but are generally lower than in hospitals and hotels. Independence Arcade and Liberty Plaza operate their chillers for 14.5 and 7.3 hours per day, respectively.

- Low Operating Hours: Government facilities, such as the Central Provincial Council, operate their chillers for fewer hours, with the Central Provincial Council's chiller running for only 2.25 hours per day.

2. **Rated CoP (kW/kW) & Operating CoP (kW/kW):** The CoP values indicate the efficiency of the chillers, with higher CoP values representing more efficient performance.

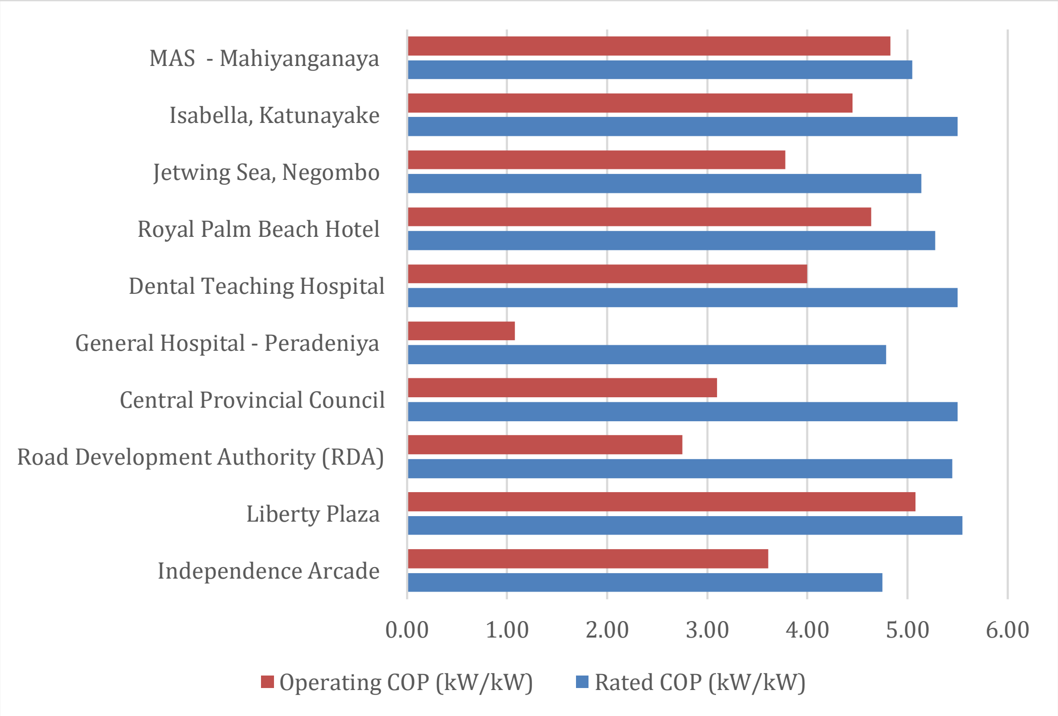


Figure 4 : Operating vs Rated CoP of Detailed Energy Audits Chillers

- High CoP Values: Chillers at Liberty Plaza and the Dental Teaching Hospital exhibit higher rated and operating CoP values, indicating more efficient performance. Liberty Plaza has a rated CoP of 5.55 and an operating CoP of 5.08, while the Dental Teaching Hospital has a rated CoP of 5.50 and an operating CoP of 4.00.

- Low CoP Values: Older chillers, such as the one at General Hospital - Peradeniya, show significantly lower efficiency with a rated CoP of 4.79 and an operating CoP of 1.08. This low CoP value highlights the inefficiency of ageing infrastructure and the need for upgrades.

- Moderate CoP Values: Most chillers in the government and industrial sectors have moderate CoP values, indicating a mix of ageing equipment and varying maintenance practices. For example, the Central Provincial Council has a rated CoP of 5.50 and an operating CoP of 3.10.

3. **Energy Consumption of Present Chiller (kWe/kW) & Energy Saving of a New Chiller (kWe/kW):** The energy consumption of the present chillers and the potential savings from replacing them with new, more efficient units are significant.

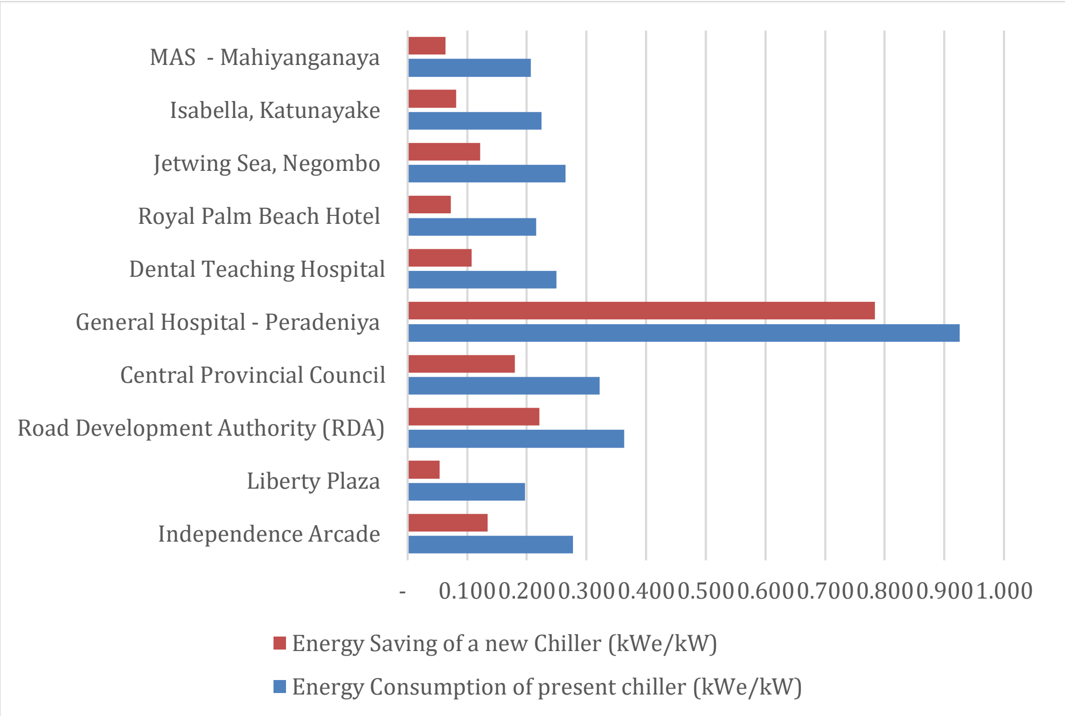


Figure 5 : Energy Consumption vs saving of Detailed Energy Audits Chillers

- High Energy Consumption: The chiller at General Hospital - Peradeniya consumes the most energy, with an energy consumption of 0.926 kWe/kW. Replacing this chiller with a new unit could save 0.783 kWe/kW, resulting in substantial energy savings.

- Moderate Energy Consumption: Chillers in the commercial and industrial sectors have moderate energy consumption. For example, the chiller at Independence Arcade consumes 0.277 kWe/kW, with potential savings of 0.134 kWe/kW from a new chiller.

- Low Energy Consumption: Some government facilities, such as the Central Provincial Council, have lower energy consumption due to fewer operating hours and better maintenance. The chiller here consumes 0.323 kWe/kW, with potential savings of 0.180 kWe/kW.

4. **Levelized Cost of Energy (LCoE) and Energy Savings of New Chillers ($/kWh):** The Levelized Cost of Energy (LCoE) is a key metric to evaluate the cost-effectiveness of replacing existing chillers with new, energy-efficient units. By analyzing the LCoE and annual energy savings of various chillers, decision-makers can prioritize investments that deliver the highest returns and environmental benefits.

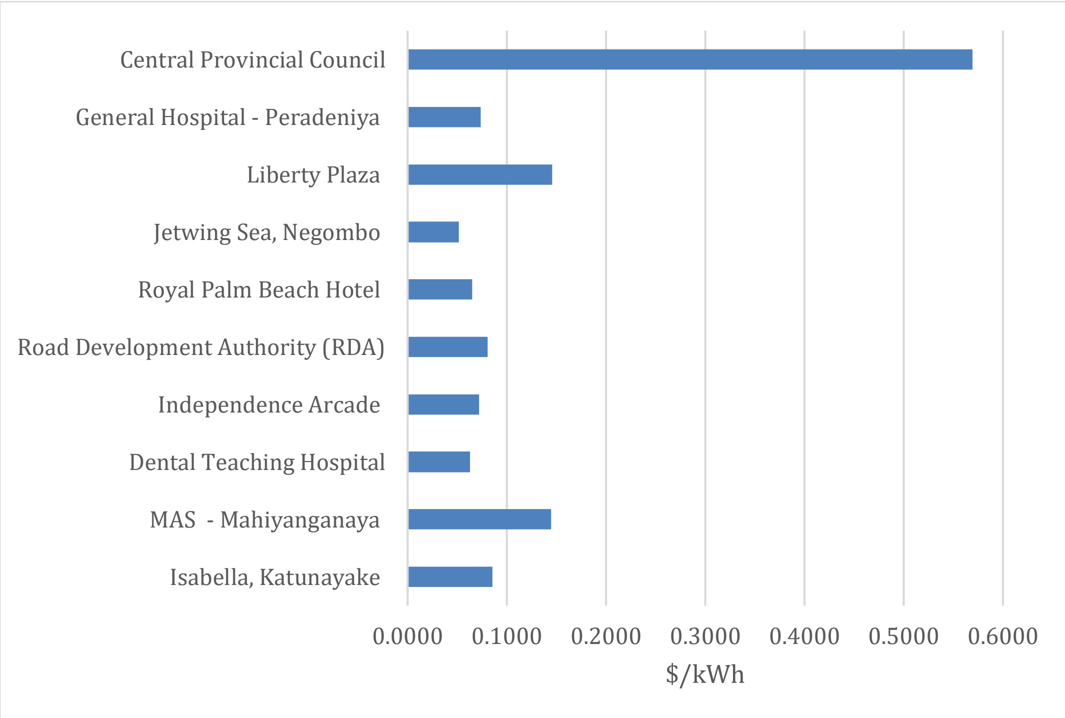


Figure 6 : Levelized Cost of Energy (LCoE) of Detailed Energy Audits Chillers

- Lowest LCoE and Highest Energy Savings: Jetwing Sea, Negombo, exhibits the lowest LCoE at $0.0520/kWh, making it the most cost-effective investment among the evaluated chillers. It also achieves significant annual energy savings of 218,256 kWh, demonstrating excellent energy efficiency.

- Moderate LCoE with High Savings Potential: Dental Teaching Hospital and Royal Palm Beach Hotel show favorable LCoEs of $0.0632/kWh and $0.0650/kWh, respectively, with substantial energy savings exceeding 179,000 kWh annually.

- High LCoE and Limited Savings: Central Provincial Council's air-cooled chiller has the highest LCoE at $0.5697/kWh, reflecting higher costs due to its lower energy savings potential of 22,598 kWh annually.

2.5 Recommendations:

1. Chiller Plant Efficiency Improvement:

Replace Aging Chillers: Prioritize the replacement of older chillers, especially those with low CoP values and high energy consumption, with newer, energy-efficient models. This strategic upgrade will not only enhance cooling efficiency but also reduce operational costs over the long term.

Optimize Chiller Operation: Implement operational strategies such as optimizing compressor sequencing and adjusting chiller load to match building demand. This includes scenarios where one compressor operates efficiently during lower demand periods, thereby conserving energy without compromising cooling requirements.

Replacing older, inefficient chillers with new, energy-efficient models not only reduces energy consumption but also has a significant positive impact on the environment by reducing greenhouse gas (GHG) emissions.

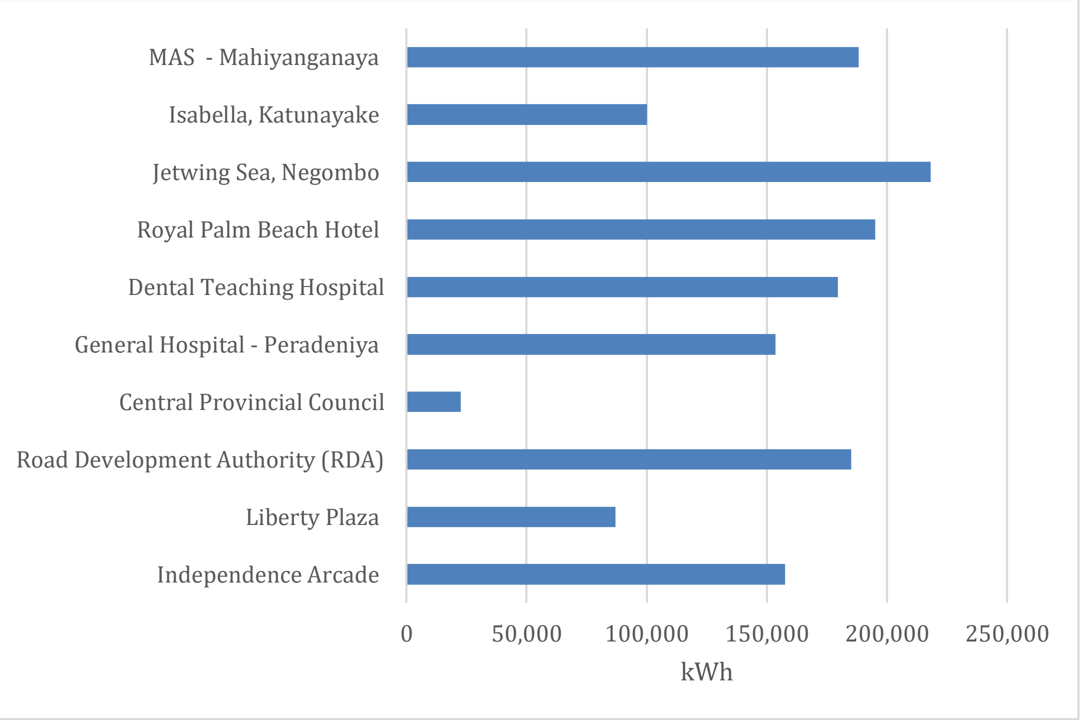


Figure 7 : Annual Estimated Energy Saving Potential of Detailed Energy Audits Chillers

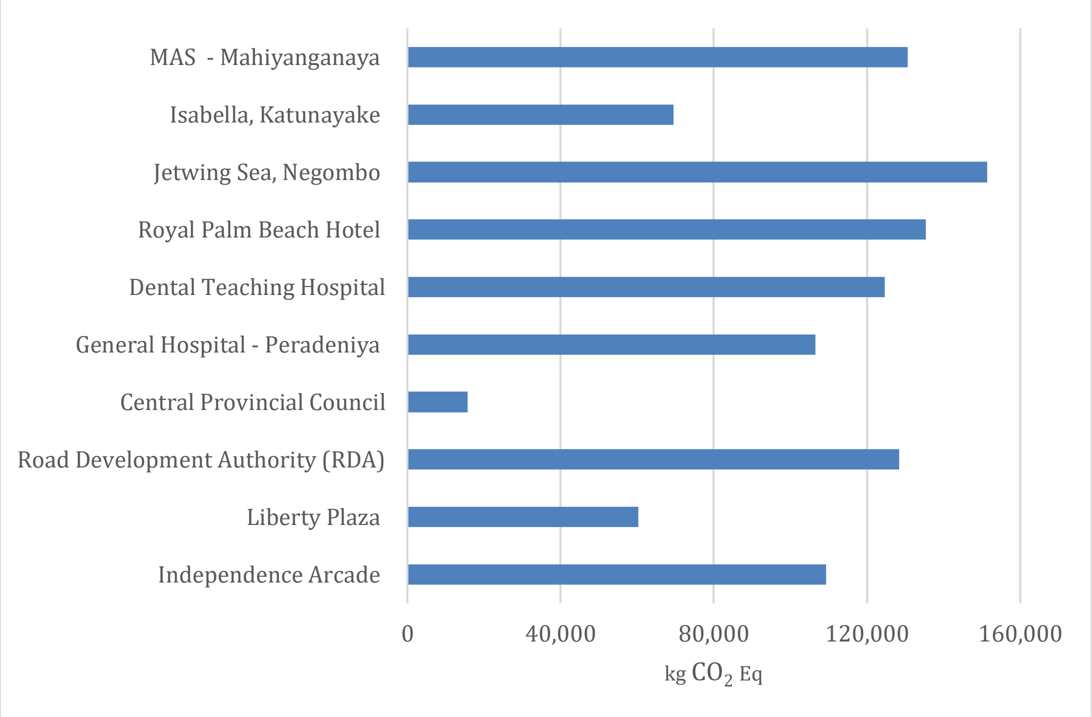


Figure 8 : GHG Emission Saving of Detailed Energy Audits Chillers

- High GHG Emission Savings: The highest GHG emission savings are observed in the chiller replacement at the Jetwing Sea - Negombo, with potential savings of 151,470 kg CO_2 equivalent annually. This is followed by the Dental Teaching Hospital and Royal Palm Beach Hotel with savings of 124,707 and 135,434kg CO_2 equivalent, respectively.

- Moderate GHG Emission Savings: Chillers in the commercial and industrial sectors show moderate GHG emission savings. Independence Arcade and Liberty Plaza can save 109,315 and 60,352 kg CO_2 equivalent, respectively, by upgrading their chillers.

- Low GHG Emission Savings: Government facilities, such as the Central Provincial Council, show lower GHG emission savings due to fewer operating hours and relatively better-maintained equipment. The potential GHG emission savings here are 15,683 kg CO_2 equivalent annually.

2. Enhancement of Existing Chiller Efficiency:

Maintenance and Cleaning: Regularly inspect and clean evaporator and condenser tubes to mitigate scaling and fouling, which can significantly impact chiller performance and efficiency.

Delta T Optimization: Ensure chilled water supply and return temperature difference (delta T) are within optimal ranges to maximize chiller efficiency. Properly matching chilled water flow rates with chiller operating capacity is crucial for achieving rated CoP values.

3. Improvement of Cooling Towers:

Complete Overhaul: Conduct a comprehensive overhaul of cooling towers to improve operational efficiency. This includes optimizing water distribution, addressing algae and debris buildup in tower fills, and ensuring both towers are operational to distribute cooling load effectively.

4. Rehabilitation of Fan Coil Unit (FCU) Valves:

Repair or Replace Faulty Valves: Address malfunctioning motorized valves connected to FCUs to ensure proper modulation and control of chilled water flow rates. This optimization will maximize the efficiency of variable speed drives (VSDs) linked to chilled water pumps, reducing unnecessary energy consumption.

5. Energy Efficient Housekeeping:

Regular Maintenance: Implement proactive maintenance practices such as regular cleaning of FCU filters, inspection of chilled water distribution pipes for leaks, and cleaning of motor surfaces to prevent overheating. Proper maintenance of cooling tower components, including spray nozzles and basin, will minimize drift losses and improve overall system efficiency.

Monitor Water Quality: Regularly monitor and maintain condenser water quality to prevent scaling and fouling, which can degrade chiller performance and increase energy consumption.

6. Employee Awareness and Training:

Educational Programs: Conduct training sessions for facility management staff on energy-efficient practices and the importance of chiller system optimization. Foster a culture of energy conservation and sustainability within the organization to encourage proactive energy-saving behaviours.

7. Continuous Monitoring and Performance Evaluation:

Data-driven Approach: Implement a robust monitoring system to track chiller performance metrics such as COP, energy consumption, and environmental conditions. Use real-time data analytics to identify trends, detect inefficiencies, and make informed decisions for ongoing system optimization.

8. Financial Incentives and Support:

Government Support: Advocate for governmental incentives or subsidies for organizations investing in energy-efficient chiller systems. Explore financing options and grants aimed at promoting sustainable infrastructure upgrades to facilitate cost-effective implementation of recommended improvements.

9. Collaboration and Knowledge Sharing:

Industry Collaboration: Foster collaboration with industry experts, manufacturers, and energy efficiency consultants to stay updated on technological advancements and best practices in chiller system optimization. Participate in forums, workshops, and conferences to share experiences and learn from peers in the field.

By implementing these recommendations, stakeholders can effectively enhance the energy efficiency of chiller systems in Sri Lanka, which leads to reduced energy consumption, reduced operational costs, and contributed to national sustainability goals. These proactive measures not only optimize chiller performance but also promote environmental stewardship and resilience in the face of evolving energy challenges.

The analysis of energy consumption and efficiency across different sectors highlights significant opportunities for energy savings and environmental benefits. Replacing older, inefficient chillers with newer, energy-efficient models can lead to substantial energy and GHG emission savings, particularly in hospitals, hotels, and commercial sectors. Targeted interventions and upgrades in these sectors can significantly contribute to energy conservation and sustainability goals in Sri Lanka.

CHAPTER III

DATA ANALYSIS AND FINDINGS: TOTAL CHILLER POPULATION IN SRI LANKA

3.1 Introduction

This section provides a comprehensive analysis of the distribution of chillers across various sectors and age ranges in Sri Lanka. The data on the number of chillers and their total capacity is categorized based on their age range and sector of operation. This analysis aims to provide insights into the trends and patterns in chiller distribution, which is crucial for understanding the current landscape of chiller usage in Sri Lanka and for planning future strategies in energy management and equipment maintenance.

3.2 Overview of Chiller Distribution

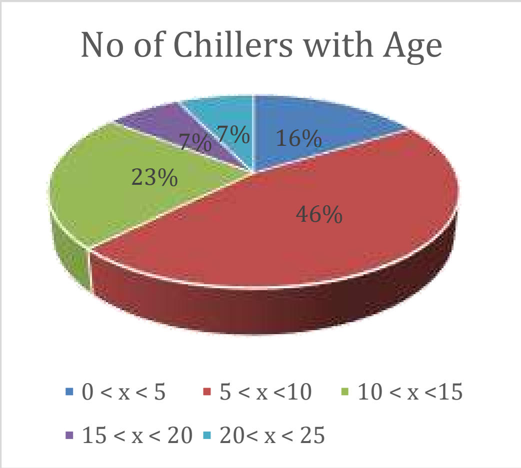
The distribution of chillers in Sri Lanka is categorized by age range and sector. This section presents the data and analyzes the patterns observed in chiller capacity and number distribution.

Age Range Distribution

The total capacity and number of chillers in different age ranges are summarized in the table below:

Table 12 : The Total Chiller Capacity and Number of Chillers in Different Age Ranges

Age Range (Years)	Total Capacity		Nos. of Chillers	
	TR	**%**	**Nos**	**%**
0 < x < 5	36,060	21	117	16
5 < x <10	73,300	42	333	46
10 < x <15	38,070	22	165	23
15 < x < 20	13,830	8	52	7
20< x < 25	12,080	7	52	7
	173,340	**100**	**719**	**100**



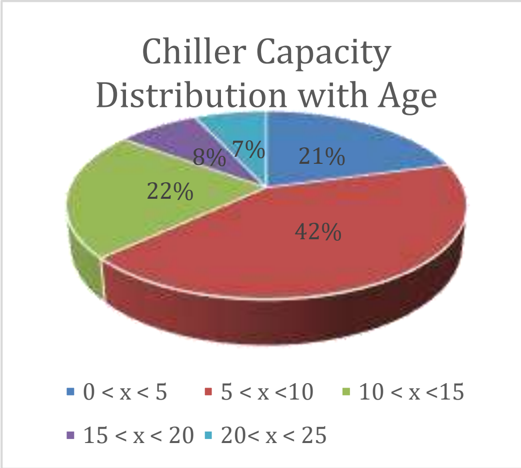


Figure 9 : Nos. of Chillers & Chiller Capacity with Age

Newer Chillers (0 < x < 5 years)
Capacity: 36,060 TR (21%)
Number: 117 units (16%)
Insight: The proportion of newer chillers is relatively low, suggesting that recent investments in chiller technology have been modest.

Mid-Age Chillers (5 < x < 10 years)
Capacity: 73,300 TR (42%)
Number: 333 units (46%)
Insight: This age range holds the majority of chillers, both in terms of capacity and number, indicating a peak period of chiller installations in the past 5 to 10 years.

Moderate-Age Chillers (10 < x < 15 years)
Capacity: 38,070 TR (22%)
Number: 165 units (23%)
Insight: These chillers represent a significant portion of the total, showing steady usage beyond a decade but before reaching the end of their operational life.

Older Chillers (15 < x < 20 years)
Capacity: 13,830 TR (8%)
Number: 52 units (7%)
Insight: The number and capacity of chillers in this age range drop significantly, likely due to the retirement or replacement of older, less efficient units.

Oldest Chillers (20 < x < 25 years)
Capacity: 12,080 TR (7%)
Number: 52 units (7%)

Insight: Similar to the 15-20 year range, this group represents the oldest chillers still in operation, typically maintained for specific needs or due to budget constraints delaying replacement.

Investment Planning: The high proportion of mid-age chillers indicates a potential wave of replacements or upgrades needed in the next 5 to 10 years, requiring significant investment planning.

Energy Efficiency: Older chillers (15+ years) are likely less energy-efficient, suggesting a need for prioritizing replacements to improve overall energy efficiency and reduce operational costs.

Maintenance Strategy: Chillers in the 10-15 year range will require increased maintenance to ensure continued performance, highlighting the importance of a robust maintenance strategy.

Sustainability Goals: Replacing older chillers with newer, more energy-efficient models aligns with sustainability goals and can help reduce the carbon footprint of cooling operations.

By understanding the age distribution of chillers, stakeholders can better plan for future investments, maintenance, and upgrades, ensuring reliable and efficient cooling services across various sectors in Sri Lanka.

Sector-Wise Chiller Distribution

The chiller distribution across various sectors provides insights into where the bulk of the cooling demand is concentrated. The sectors analyzed include commercial, government, hospitals, hotels, and industrial.

Table 13 : The Total Chiller Capacity and Number of Chillers in Different Age Range – Sector Wise

Commercial				
Age Range (Years)	**Total Capacity**		**Nos. of Chillers**	
	TR	**%**	**Nos**	**%**
0 < x < 5	12,712	32%	30	21%
5 < x <10	11,328	29%	54	37%
10 < x <15	6,729	17%	33	23%
15 < x < 20	2,820	7%	13	9%
20< x < 25	5,814	15%	15	10%
Total	**39,403**	**100%**	**145**	**100%**
Government				
Age Range (Years)	**Total Capacity**		**Nos. of Chillers**	
	TR	**%**	**Nos**	**%**
0 < x < 5	6,826	22%	22	19%
5 < x <10	9,029	30%	46	40%
10 < x <15	4,556	15%	22	19%
15 < x < 20	7,100	23%	12	10%
20< x < 25	2,989	10%	14	12%
Total	**30,500**	**100%**	**116**	**100%**
Hospital				
Age Range (Years)	**Total Capacity**		**Nos. of Chillers**	
	TR	**%**	**Nos**	**%**
0 < x < 5	1,124	8%	6	7%
5 < x <10	5,919	41%	37	44%
10 < x <15	4,734	33%	21	25%
15 < x < 20	1,139	8%	11	13%
20< x < 25	1,473	10%	10	12%
Total	**14,389**	**100%**	**85**	**100%**
Hotel				
Age Range (Years)	**Total Capacity**		**Nos. of Chillers**	
	TR	**%**	**Nos**	**%**
0 < x < 5	7,362	21%	20	16%
5 < x <10	18,554	53%	68	54%
10 < x <15	6,742	19%	29	23%
15 < x < 20	1,306	4%	7	6%
20< x < 25	720	2%	2	2%
Total	**34,684**	**100%**	**126**	**100%**
Industrial				
Age Range (Years)	**Total Capacity**		**Nos. of Chillers**	
	TR	**%**	**Nos**	**%**
0 < x < 5	8,006	15%	39	16%
5 < x <10	28,483	52%	128	52%
10 < x <15	15,311	28%	60	24%
15 < x < 20	1,468	3%	9	4%
20< x < 25	1,052	2%	11	4%
Total	**54,320**	**100%**	**247**	**100%**

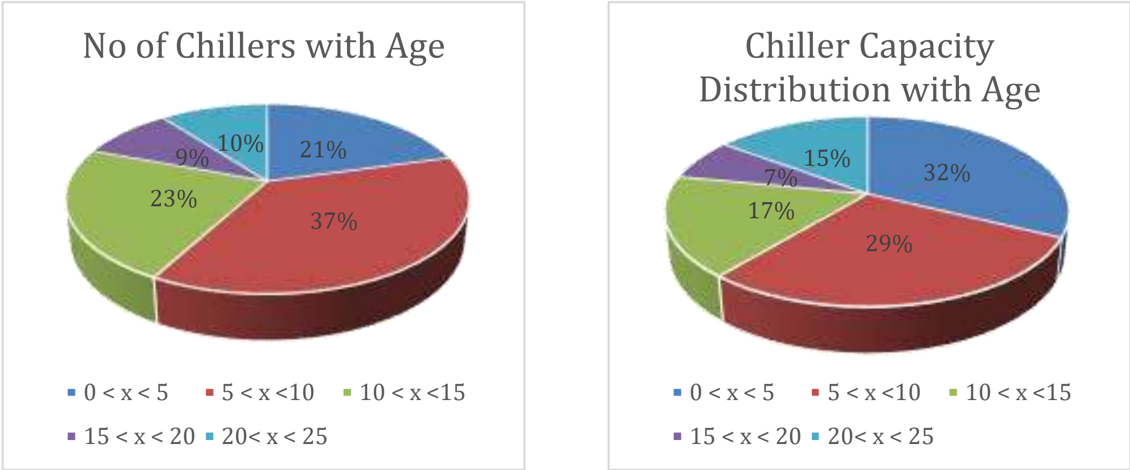


Figure 10 : Nos. of Chillers & Chiller Capacity with Age - Commercial

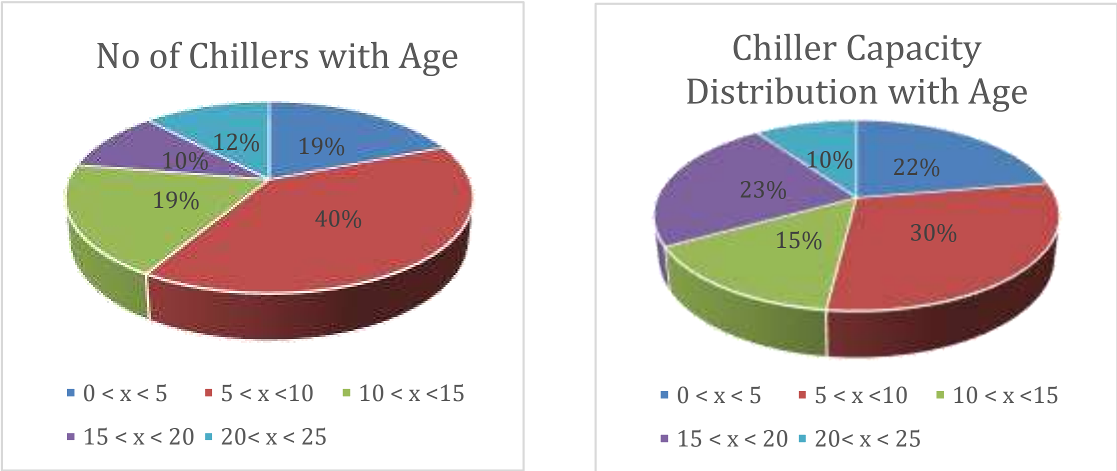


Figure 11 : Nos. of Chillers & Chiller Capacity with Age - Government

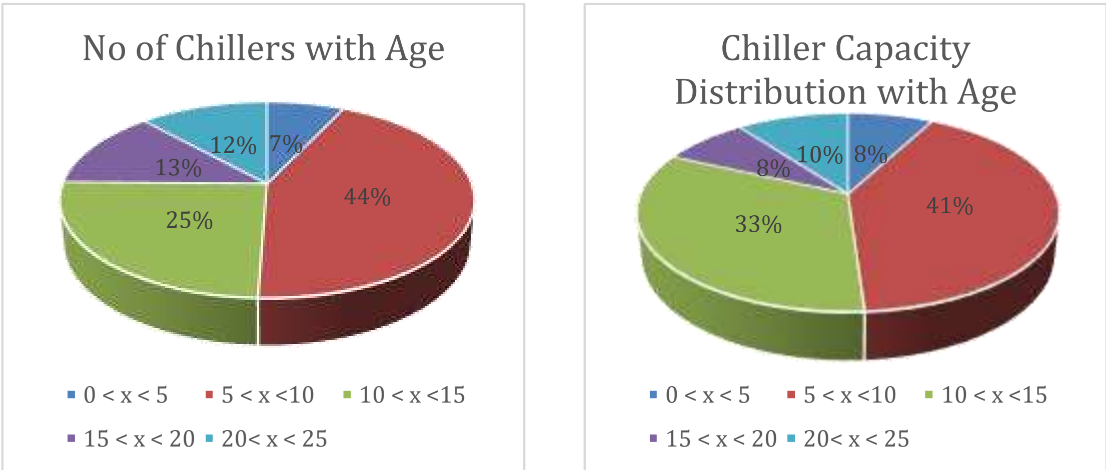


Figure 11: Nos. of Chillers & Chiller Capacity with Age - Hospital

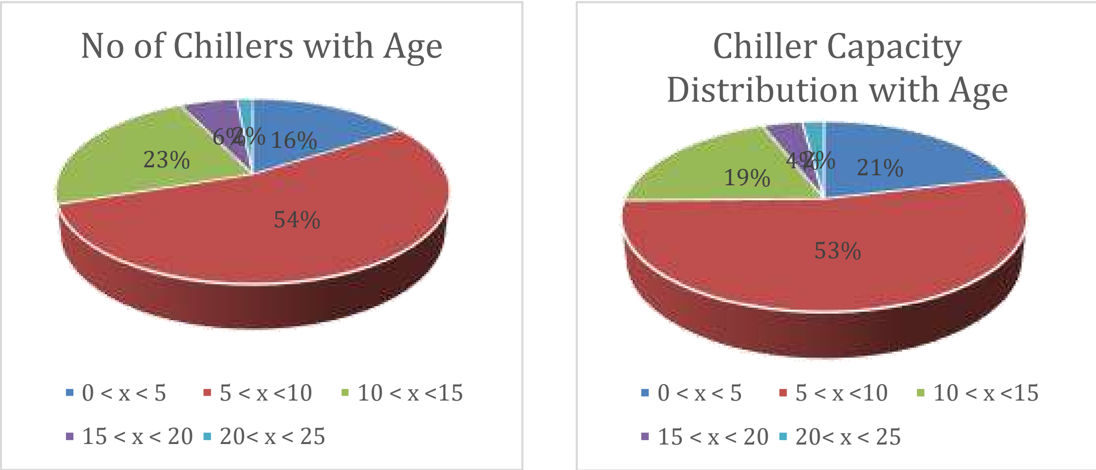


Figure 12 : Nos. of Chillers & Chiller Capacity with Age - Hotel

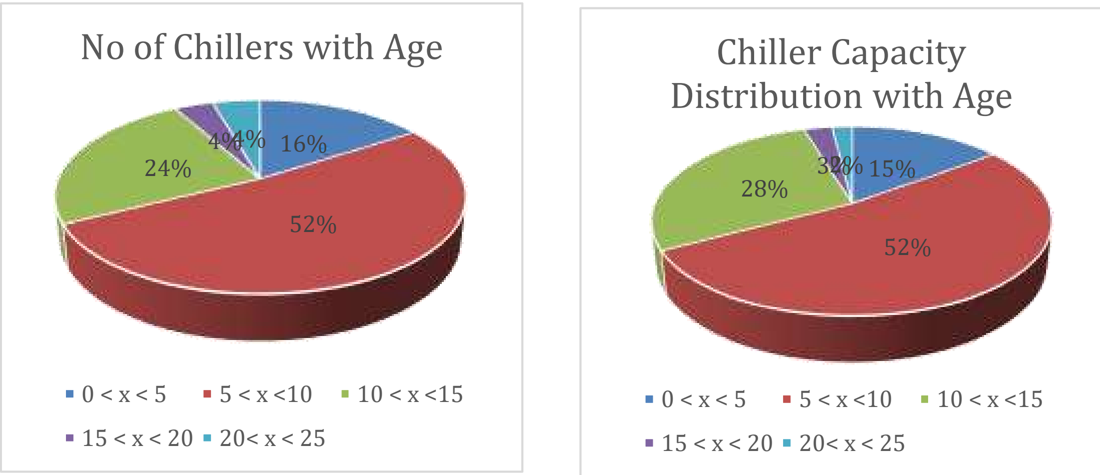


Figure 13 : Nos. of Chillers & Chiller Capacity with Age - Industrial

Age Range Distribution

0 < x < 5 Years: This age range represents the newest chillers, making up 21% of the total capacity and 16% of the total number of chillers. This indicates recent investments in new chiller installations.

5 < x < 10 Years: This category holds the largest share, with 42% of the total capacity and 46% of the total number of chillers, indicating a peak period of chiller installations or replacements around this timeframe.

10 < x < 15 Years: Chillers in this age range account for 22% of the total capacity and 23% of the total number, suggesting they are still relatively efficient but nearing the end of their optimal operational lifespan.

15 < x < 20 Years and 20 < x < 25 Years: Together, these older chillers represent 15% of the total capacity and 14% of the total number. These chillers are likely less efficient and may require more maintenance or replacement soon.

Sector-wise Distribution

Commercial Sector: Dominated by chillers that are less than 15 years old, with a significant portion installed between 0 and 10 years ago, indicating a trend towards modernization and energy efficiency in commercial buildings.

Government Sector: This sector shows a more balanced distribution across all age ranges, with a notable presence of chillers over 15 years old, suggesting a need for upgrades to improve energy efficiency.

Hospital Sector: A large proportion of chillers in this sector are between 5 and 15 years old, emphasizing the critical need for reliable cooling in healthcare facilities. Older chillers may need replacement to ensure uninterrupted service.

Hotel Sector: Over half of the chillers are 5 to 10 years old, highlighting the importance of maintaining guest comfort. Investments in newer chillers can enhance energy efficiency and reduce operational costs.

Industrial Sector: This sector has the largest total capacity, with more than half of the chillers being 5 to 10 years old, indicating recent investments to support industrial cooling needs. The presence of older chillers suggests areas for improvement in energy efficiency.

This chapter has analyzed the distribution of chillers in Sri Lanka by age range and sector. The data highlights trends in chiller installation and usage across different sectors, providing valuable insights for stakeholders to plan for future upgrades and maintenance. Understanding these patterns is crucial for optimizing energy consumption, reducing operational costs, and ensuring reliable cooling services across various sectors in Sri Lanka.

3.3 Annual Operating Time

The table below provides a summary of the annual operating time for chillers in different sectors, expressed in chiller loading hours. This data is crucial for understanding the operational efficiency, energy consumption, and maintenance needs of chillers across various sectors in Sri Lanka. The insights are derived from the results of 100 walkthrough audits, which have been extrapolated to a national context. The walkthrough audits encompassed a total of 222 chillers, and analyzing the annual operating time helps in identifying the operational patterns and demands in different sectors, thereby facilitating more effective energy management and planning.

Table 14 : The Annual Operating Time – Sector Wise

Sector	Annual Operating Time (Chiller loading Hours)	Operating %	Not Operating %
Commercial	2,996	35%	65%
Government	3,655	42%	58%
Hospital	7,070	82%	18%
Hotel	7,706	89%	11%
Industrial	5,046	58%	42%
Average	**5,294**	**61%**	**39%**

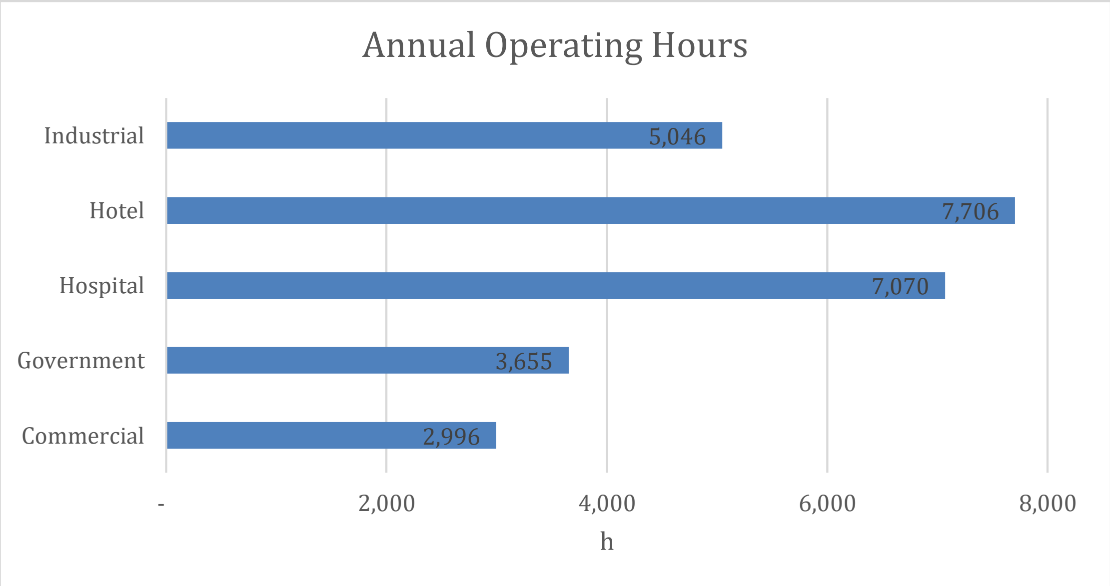
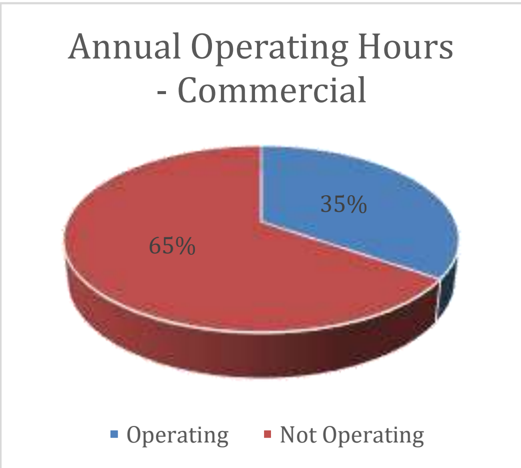
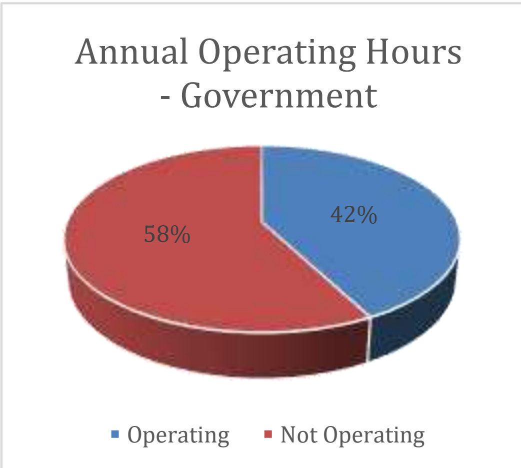
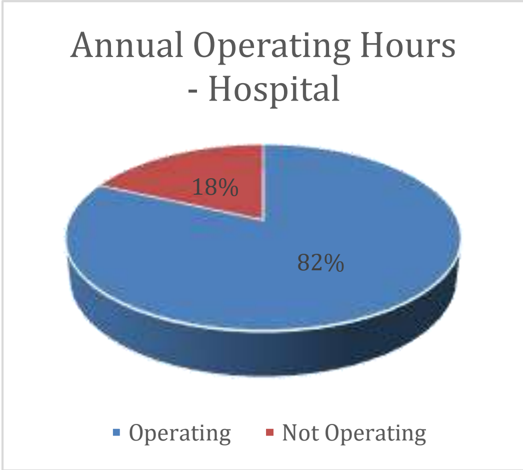


Figure 14 : Annual Operating Hours – Sector Wise







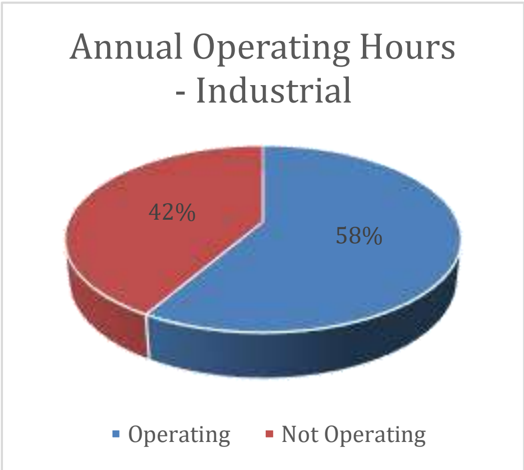


Figure 15 : Annual Operating Pattern – Sector WiseCommercial Sector

Annual Operating Time: 2,996 hours
Operating %: 35%
Not Operating %: 65%

Insight: This sector shows a moderate operating time, which suggests that there is significant downtime. This could be due to lower cooling demands or efficiency measures. However, it also indicates room for optimizing operational hours and energy use.

Government Sector
Annual Operating Time: 3,655 hours
Operating %: 42%
Not Operating %: 58%

Insight: The government sector has a higher operating percentage than the commercial sector. This reflects the continuous service requirements of government facilities. Nevertheless, there is still potential to improve energy efficiency.

Hospital Sector
Annual Operating Time: 7,070 hours
Operating %: 82%
Not Operating %: 18%

Insight: Hospitals have the highest operating time, which is expected due to the critical nature of their operations. The high percentage of operating hours underscores the need for reliable and efficient cooling systems in healthcare settings.

Hotel Sector
Annual Operating Time: 7,706 hours
Operating %: 89%
Not Operating %: 11%

Insight: Hotels also exhibit a high operating time, reflecting the importance of maintaining guest comfort in the hospitality industry. This sector could benefit significantly from energy-efficient technologies and practices to manage such high usage effectively.

Industrial Sector
Annual Operating Time: 5,046 hours
Operating %: 58%
Not Operating %: 42%

Insight: The industrial sector shows a balanced operating time, indicating steady cooling demand. There is potential to further enhance energy efficiency through better management and maintenance practices.

Total Distribution
Average Annual Operating Time: 5,294 hours

Insight: On average, chillers in Sri Lanka operate about 61% of the time. This indicates a significant reliance on cooling systems across various sectors. However, the remaining 39% of non-operational time suggests that there is room for optimizing the efficiency and operational schedules of these chillers.

Energy Management: Understanding operating time is crucial for energy management. Sectors with high operating percentages, such as hospitals and hotels, may benefit from targeted energy efficiency measures to reduce costs.

Maintenance Scheduling: Higher operating times require more frequent maintenance to ensure reliability and efficiency. Sectors with lower operating percentages can optimize maintenance schedules during downtime.

Operational Efficiency: Sectors with lower operating percentages, like the commercial sector, might explore opportunities to further optimize operations and reduce unnecessary energy consumption during off-peak hours.
By analyzing annual operating times, stakeholders can develop strategies to optimize energy use, plan maintenance, and improve operational efficiency across different sectors in Sri Lanka.

3.4 Energy Saving Potential

Chillers are critical components across various sectors, significantly influencing overall energy consumption through their efficiency. This chapter provides a detailed analysis of chiller performance based on age, emphasizing energy consumption and potential savings achievable by upgrading to newer, more efficient models. The insights derived from an extensive energy audit conducted in Sri Lanka, offering valuable data on current conditions and future opportunities for enhancing energy efficiency.

Background of Analysis
Understanding chiller energy consumption patterns is crucial for devising effective energy efficiency strategies. Detailed data from ten (10) facilities in Sri Lanka form the basis of this analysis, revealing how chiller performance deteriorates over time. Collected through a rigorous energy audit, this data set encompasses key sectors such as Commercial, Government, Hospital, Hotel, and Industrial. By examining this representative sample, the study identifies significant potential energy savings correlated with chiller age.

The following table summarizes the key data points for each facility:

`

Table 15 : Summarizes Key Data for Each Facility

No	Name	Capacity (TR)	Age Range	Rated CoP (kW/kW)	Operating CoP (kW/kW)	Energy Consumption of present chiller (kWe/kW)	Energy Consumption of present chiller (kWe/kW) - Age Range	Energy Consumption of a new Chiller (kWe/kW)	Energy Saving of a new Chiller (kWe/kW)	Energy Saving (kWe/kW) with Age Range
1	Isabella, Katunayake	100	5 < x <10	5.5	4.45	0.225	0.2159	0.143	0.082	0.073022
2	MAS - Mahiyanganaya	420	5 < x <10	5.05	4.83	0.207		0.143	0.064	
3	Dental Teaching Hospital	125	10 < x <15	5.5	4	0.250	0.2765	0.143	0.107	0.133683
4	Independence Arcade	140	10 < x <15	4.75	3.61	0.277		0.143	0.134	
5	Road Development Authority (RDA)	300	10 < x <15	5.45	2.75	0.364		0.143	0.221	
6	Royal Palm Beach Hotel	220	10 < x <15	5.28	4.64	0.216		0.143	0.073	
7	Jetwing Sea, Negombo	180	15 < x < 20	5.14	3.78	0.265	0.2307	0.143	0.122	0.087843
8	Liberty Plaza	300	15 < x < 20	5.55	5.08	0.197		0.143	0.054	
9	General Hospital - Peradeniya	150	20< x < 25	4.79	1.08	0.926	0.9259	0.143	0.783	0.783069

The following key parameters were examined:

- Capacity (TR): This denotes the cooling capacity of each chiller, which is a critical factor in determining its energy consumption and performance.
- Age Range: Chillers are grouped into specific age ranges to facilitate comparative analysis and identify trends in performance degradation over time.
- Rated CoP (Coefficient of Performance): This is the expected energy efficiency of the chiller when it was new, serving as a baseline for performance comparison.

- Operating COP: The actual observed energy efficiency during the audit, which often decreases as the chiller ages.

- Energy Consumption of Present Chiller (kWe/kW): This measures the current energy consumption rate, providing insight into the chiller's operational efficiency.

- Energy Consumption of Present Chiller (kWe/kW) - Age Range: This is the average energy consumption within each age group, highlighting how efficiency varies with age.

- Energy Consumption of a New Chiller (kWe/kW): This represents the expected energy consumption of a new, state-of-the-art chiller, offering a benchmark for potential savings.

- Energy Saving after Installation of a New Chiller (kWe/kW): This calculates the potential energy savings achievable by replacing old chillers with new ones.

- Energy Saving (kWe/kW) with Age Range: This denotes the average potential savings categorized by age group, helping to prioritize upgrades for the most inefficient chillers.

- By understanding these parameters, stakeholders can better plan for chiller replacements and upgrades, ensuring more efficient energy use and significant cost and emission savings in the long term.

Key Observations

Efficiency Decline with Age: The data shows a clear trend of declining energy efficiency (CoP) as chillers age. For instance, the General Hospital - Peradeniya chiller, over 20 years old, has a significantly lower operating CoP compared to its rated CoP, resulting in high energy consumption.

Potential Energy Savings: Replacing old chillers with new, efficient models can lead to substantial energy savings. For example, replacing the chiller at the General Hospital - Peradeniya could save approximately 0.783 kWe/kW.

Age Range Analysis: By categorizing chillers into different age ranges, the analysis highlights the potential energy savings across the entire sector. The average energy consumption for each age group can guide targeted interventions for energy efficiency improvements.

Extrapolation and Formula Development

Using the data and trends observed, we can develop a common formula to identify the energy-saving potential for chillers in Sri Lanka. This formula will consider the age of the chiller, its current operating CoP, and the energy consumption difference between older and newer models.

By applying this formula to the entire population of chillers in Sri Lanka, policymakers and facility managers can estimate the overall energy-saving potential and prioritize investments in upgrading chiller systems. This approach not only helps in reducing energy consumption but also contributes to the country's sustainability goals.

Extrapolation Summary for Energy Saving Potential by Age Range

Table 16 : Extrapolation Summary for Energy Saving Potential by Age Range

Age	Age Range	Energy Saving with Age Range (kWe/kW)
2.5	0	0.00000
7.5	5 < x <10	0.07302
12.5	10 < x <15	0.13368
17.5	15 < x < 20	0.08784
22.5	20< x < 25	0.78307

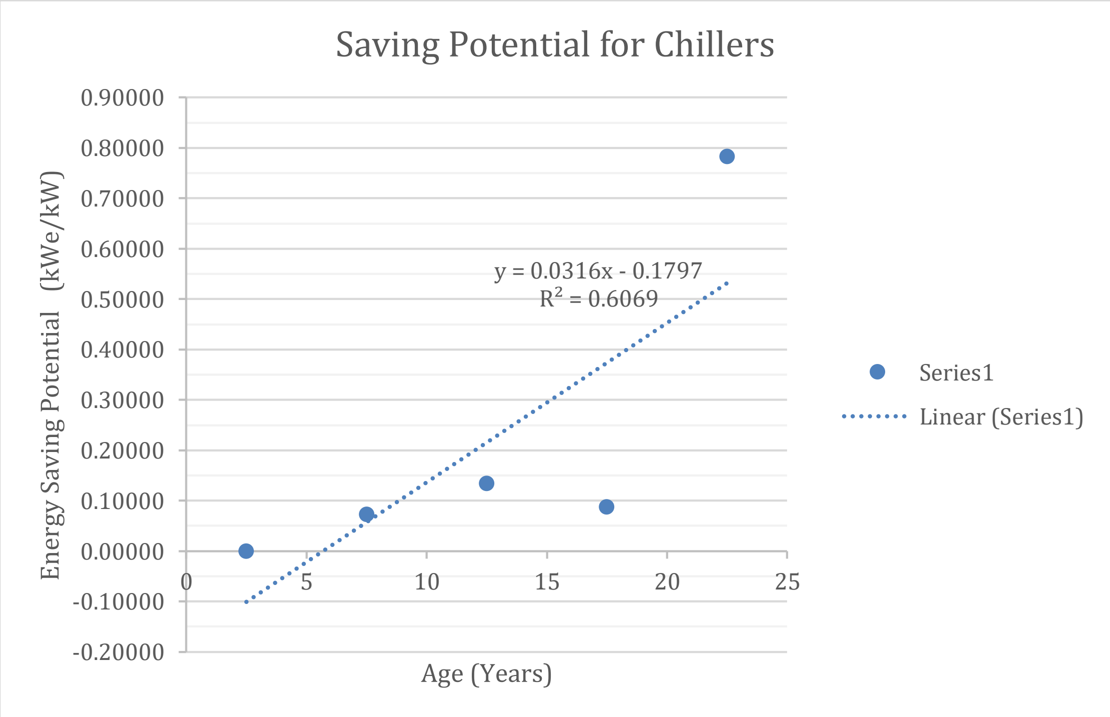


Figure 16 : Saving Potential for Chillers

Saving Potential for total Chillers (kWe/kW): This section calculates the total extrapolated energy saving potential for all chillers combined, using the provided linear regression formula:

y=0.0316x−0.1797.

Table 17 : Saving Potential for Total Chillers with Age

Age	Age Range	Saving Potential for total Chillers (kWe/kW) (y = 0.0316x - 0.1797)
2.5	0	0.00000
7.5	5 < x <10	0.05730
12.5	10 < x <15	0.21530
17.5	15 < x < 20	0.37330
22.5	20< x < 25	0.53130

This detailed analysis provides insights into how energy savings vary across different age ranges of chillers, emphasizing the importance of age-based efficiency assessments in optimizing energy consumption and operational costs across various sectors.

3.5 Overall Saving Potential of Chillers in Sri Lanka

Saving Potential of Chillers in Sri Lanka Based on Age

The table provides a comprehensive analysis of the energy saving potential and environmental impact of chillers in Sri Lanka, segmented by their age ranges. The overall figures indicate a Total Saving Potential of chillers in Sri Lanka of 69,747,793 kWh (70 GWh) and a GHG Emission Saving of 48,404,968 kg CO_2 Eq. The below table describes the parameters based on age range.

Table 18 : Saving Potential & GHG Emission Saving of Chillers in Sri Lanka Based on Age

Age Range (Years)	Saving Potential for Chillers (kWe/kW)	Total Chiller Capacity		Total Chillers Capacity – Running		Running Hours per Years	Total Saving Potential- Running		GHG Emission Saving (kg CO_2 Eq)
		TR	%	TR	%		kWh	%	
0 < x < 5	0.000	36,030	21%	21,978	21%	5,847	-	0%	-
5 < x <10	0.057	73,313	42%	44,721	42%	5,394	13,822,175	20%	9,592,590
10 < x <15	0.215	38,072	22%	23,224	22%	5,240	26,200,576	38%	18,183,200
15 < x < 20	0.373	13,833	8%	8,438	8%	4,332	13,645,600	20%	9,470,047

20< x < 25	0.531	12,048	7%	7,349	7%	4,118	16,079,441	23%	11,159,132
Total		**173,296**		**105,711**			**69,747,793**		**48,404,968**

Energy Saving Potential

The energy-saving potential of chillers in Sri Lanka is assessed based on their age, with significant variations observed across different age ranges. As chillers age increases, their efficiency typically decreases, resulting in higher energy consumption. Therefore, the potential for energy savings increases with the age of the chillers.

0 < x < 5 Years: Chillers in this age range have minimal energy-saving potential because they are relatively new and maintain high efficiency. No significant energy savings are expected from this group.

5 < x < 10 Years: Chillers in this age range show some potential for energy savings. With a total saving potential of 13,822,175 kWh (20%), upgrades or maintenance can yield energy savings, although the impact per chiller remains moderate.

10 < x < 15 Years: Chillers in this age range exhibit a significant potential for energy savings. With a total saving potential of 26,200,576 kWh (38%), as efficiency declines more noticeably, there is a substantial opportunity to reduce energy consumption through upgrades, retrofits, or replacements.

15 < x < 20 Years: This age range shows a high potential for energy savings. With a total saving potential of 13,645,600 kWh (20%), despite representing a smaller percentage of the total capacity, older chillers in this category can benefit greatly from efficiency improvements, leading to considerable energy savings.

20 < x < 25 Years: The oldest chillers have the highest energy saving potential. With a total saving potential of 16,079,441 kWh (23%), their efficiency has degraded significantly, making them prime candidates for replacement. Upgrading these chillers can result in substantial energy savings, underscoring the importance of targeting this age group for efficiency improvements.

GHG Emission Saving with Environmental Effects

Reducing energy consumption in chillers not only saves costs but also significantly impacts environmental sustainability by reducing greenhouse gas (GHG) emissions. The potential GHG emission savings associated with energy savings from upgrading chillers are critical for mitigating climate change and improving air quality.

0 < x < 5 Years: There is no significant GHG emission saving in this age range due to the minimal energy savings potential. The environmental impact is negligible as these chillers are already efficient.

5 < x < 10 Years: Upgrading chillers in this age range can lead to considerable GHG emission savings of 9,592,590 kg CO_2 equivalent. With moderate efficiency improvements, a significant reduction in CO_2 emissions can be achieved, contributing to a lower carbon footprint.

10 < x < 15 Years: This age range offers substantial GHG emission savings of 18,183,200 kg CO_2 equivalent. By targeting these older chillers for upgrades or replacements, a significant reduction in CO_2 emissions can be realized, promoting a cleaner environment.

15 < x < 20 Years: Chillers in this age group show notable potential for GHG emission savings of 9,470,047 kg CO_2 equivalent. Despite their smaller total capacity, the high energy saving potential results in considerable environmental benefits through reduced CO_2 emissions.

20 < x < 25 Years: The oldest chillers provide the greatest opportunity for GHG emission savings of 11,159,132 kg CO_2 equivalent. Their significant efficiency losses mean that upgrades or replacements can lead to substantial reductions in CO_2 emissions. This not only helps in mitigating climate change but also improves air quality and contributes to a healthier environment.

Targeting older chillers for upgrades or replacements in Sri Lanka presents dual benefits: significant energy savings and substantial reductions in GHG emissions. Chillers aged 10 to 25 years are particularly crucial for achieving these benefits due to their lower efficiency and higher potential for improvement. By focusing on these age ranges, Sri Lanka can enhance its energy efficiency, reduce operational costs, and make a positive impact on the environment through decreased carbon emissions. This approach aligns with global sustainability goals and supports the country's efforts in combating climate change.

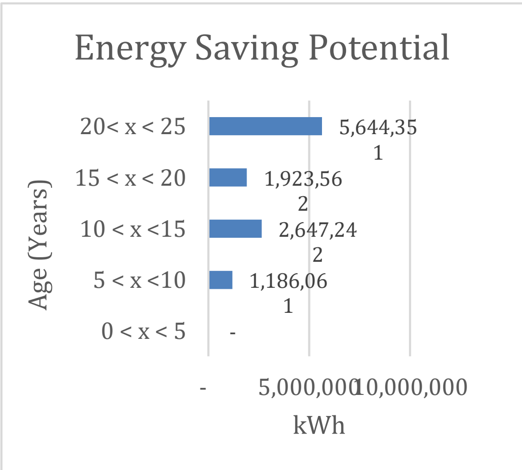
Overall Saving Potential of Chillers in Sri Lanka Based on Age and Sector

The above table 19 provides a detailed analysis of the energy saving potential and environmental impact of chillers in Sri Lanka, segmented by their age ranges and sectors. The overall figures indicate a Total Saving Potential of chillers in Sri Lanka of 69,747,793 kWh (70 GWh) and a GHG Emission Saving of 48,404,968 kg CO_2 Eq. Below is a comprehensive analysis of the energy saving potential and GHG emission savings for each sector, along with the environmental effects.

The energy saving potential of chillers in various sectors in Sri Lanka is assessed based on their age, with significant variations observed across different age ranges. As chillers age, their efficiency typically decreases, resulting in higher energy consumption. Therefore, the potential for energy savings increases with the age of the chillers. The analysis is based on the different sectors considered such as Commercial, Hospital, Hotel, Government and Industrial.

Reducing energy consumption in chillers not only saves costs but also significantly impacts environmental sustainability by reducing greenhouse gas (GHG) emissions. The potential GHG emission savings associated with energy savings from upgrading chillers are critical for mitigating climate change and improving air quality.

Commercial Sector



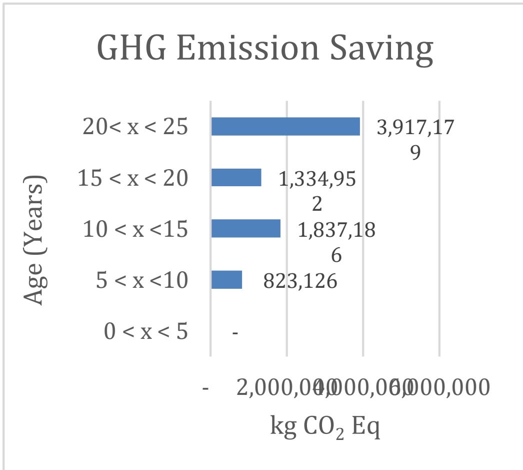


Figure 17 : Energy Saving Potential & GHG Emission saving – Commercial Sector

0 < x < 5 Years: Chillers in this age range are new and efficient, resulting in minimal energy saving potential.

5 < x < 10 Years: This age range shows a moderate energy saving potential, indicating some room for efficiency improvements through regular maintenance. The total saving potential is 1,186,061 kWh (10%).

10 < x < 15 Years: As chillers enter this age range, a notable decline in efficiency becomes apparent, leading to significant energy saving potential. Retrofitting or upgrades are recommended to maintain performance. The saving potential is 2,647,242 kWh (23%).

15 < x < 20 Years: Energy saving potential remains high, highlighting the necessity for systematic upgrades and regular maintenance to optimize performance. The potential savings amount to 1,923,562 kWh (17%).

20 < x < 25 Years: The oldest chillers exhibit the highest energy saving potential due to substantial inefficiency. Replacement or major upgrades are essential to achieve significant energy savings. The saving potential is 5,644,351 kWh (50%).

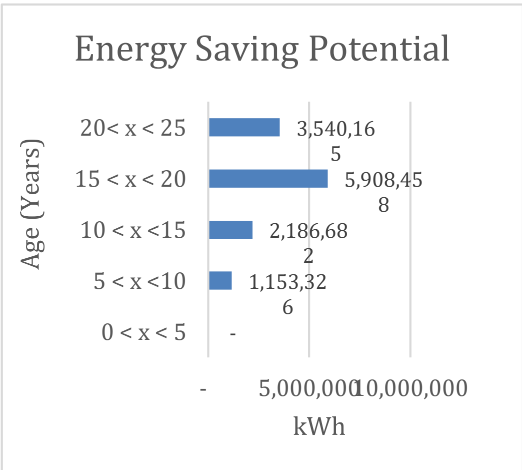
0 < x < 5 Years: No significant GHG emission savings as these chillers are new and efficient.
5 < x < 10 Years: GHG emission savings of 823,126 kg CO_2 equivalent, reflecting moderate efficiency improvements.

10 < x < 15 Years: GHG emission savings of 1,837,186 kg CO_2 equivalent, indicating notable efficiency decline and the importance of upgrades.

15 < x < 20 Years: GHG emission savings of 1,334,952 kg CO_2 equivalent, emphasizing the need for systematic upgrades.

20 < x < 25 Years: GHG emission savings of 3,917,179 kg CO_2 equivalent, showing substantial inefficiency and the urgency of replacements.

Government Sector



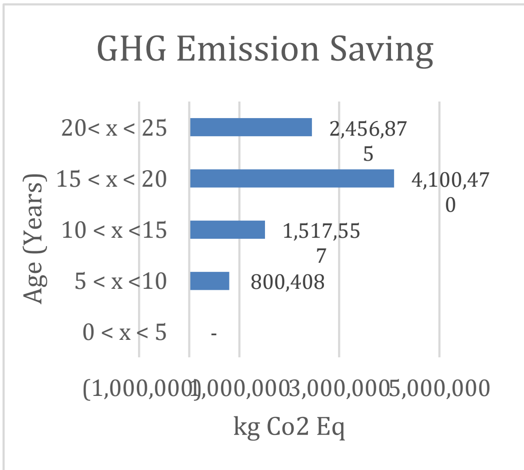


Figure 18 : Energy Saving Potential & GHG Emission saving – Government Sector

0 < x < 5 Years: These new and efficient chillers exhibit minimal energy saving potential.
5 < x < 10 Years: Moderate energy saving potential suggests the need for regular maintenance to sustain efficiency. The total saving potential is 1,153,326 kWh (9%).

10 < x < 15 Years: Significant energy savings can be achieved through retrofitting or system upgrades as efficiency declines with age. The potential savings are 2,186,682 kWh (17%).

15 < x < 20 Years: High energy saving potential indicates substantial efficiency losses, underscoring the importance of regular maintenance and potential upgrades. The potential savings amount to 5,908,458 kWh (46%).

20 < x < 25 Years: Substantial energy saving potential emphasizes the need for replacement or significant upgrades to older and less efficient chillers. The saving potential is 3,540,165 kWh (28%).

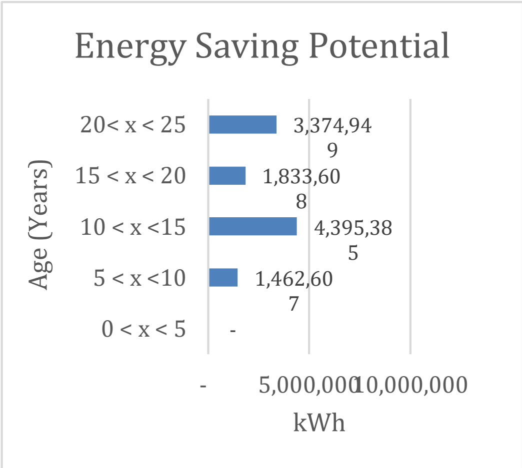
0 < x < 5 Years: No significant GHG emission savings as these chillers are new and efficient.
5 < x < 10 Years: GHG emission savings of 800,408 kg CO_2 equivalent, indicating the need for maintenance.

10 < x < 15 Years: GHG emission savings of 1,517,557 kg CO_2 equivalent, suggesting efficiency decline and the need for retrofitting.

15 < x < 20 Years: GHG emission savings of 4,100,470 kg CO_2 equivalent, emphasizing substantial efficiency losses.

20 < x < 25 Years: GHG emission savings of 2,456,875 kg CO_2 equivalent, highlighting the need for replacements.

Hospital Sector



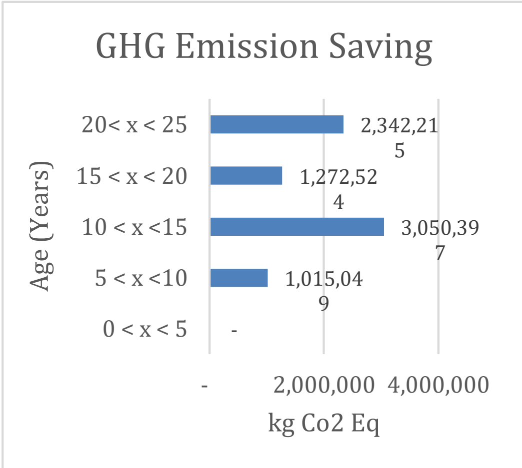


Figure 19 : Energy Saving Potential & GHG Emission saving – Hospital Sector

0 < x < 5 Years: Minimal energy saving potential due to the efficiency of new chillers.

5 < x < 10 Years: Moderate energy saving potential suggests early intervention to maintain efficiency. The total saving potential is 1,462,607 kWh (13%).

10 < x < 15 Years: Significant energy savings indicate a notable decline in efficiency, necessitating retrofitting or upgrades. The potential savings are 4,395,385 kWh (40%).

15 < x < 20 Years: High energy saving potential highlights the importance of continuous maintenance and potential system improvements. The potential savings amount to 1,833,608 kWh (17%).

20 < x < 25 Years: Substantial energy saving potential due to significant inefficiency in older chillers, indicating a strong need for replacements. The saving potential is 3,374,949 kWh (30%).

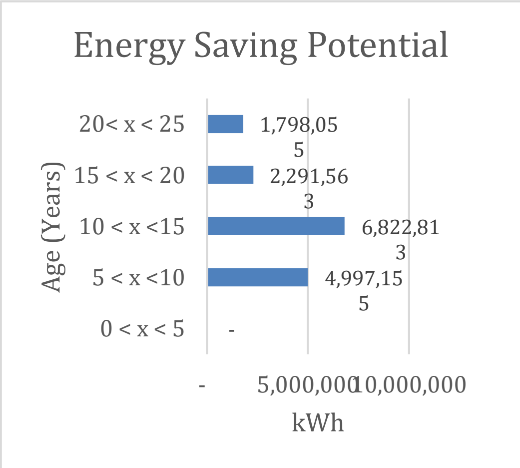
0 < x < 5 Years: No significant GHG emission savings as these chillers are new and efficient.
5 < x < 10 Years: GHG emission savings of 1,015,049 kg CO_2 equivalent, reflecting moderate efficiency improvements.

10 < x < 15 Years: GHG emission savings of 3,050,397 kg CO_2 equivalent, indicating significant efficiency decline.

15 < x < 20 Years: GHG emission savings of 1,272,524 kg CO_2 equivalent, emphasizing the need for continuous maintenance.

20 < x < 25 Years: GHG emission savings of 2,342,215 kg CO_2 equivalent, showing substantial inefficiency and the urgency of replacements.

Hotel Sector



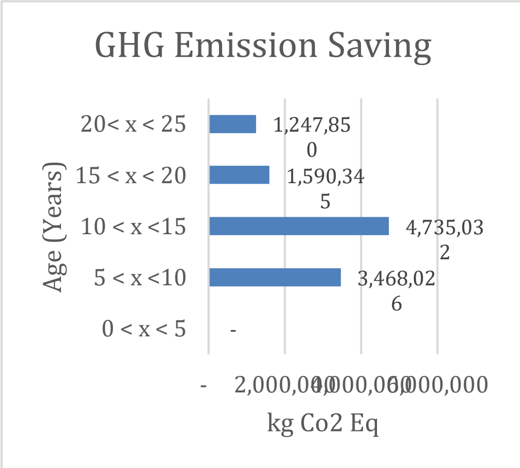


Figure 20 : Energy Saving Potential & GHG Emission saving – Hotel Sector

0 < x < 5 Years: Minimal energy saving potential as these chillers are new and highly efficient.

5 < x < 10 Years: Considerable energy savings can be achieved through maintenance to prevent efficiency losses. The total saving potential is 4,997,155 kWh (31%).

10 < x < 15 Years: Significant energy saving potential indicates that chillers are experiencing efficiency declines, necessitating upgrades. The potential savings are 6,822,813 kWh (43%).

15 < x < 20 Years: High energy saving potential emphasizes the need for regular maintenance and upgrades to optimize performance. The potential savings amount to 2,291,563 kWh (14%).

20 < x < 25 Years: Notable inefficiency in the oldest chillers results in substantial energy saving potential, making replacements essential. The saving potential is 1,798,055 kWh (11%).

0 < x < 5 Years: No significant GHG emission savings as these chillers are new and efficient.

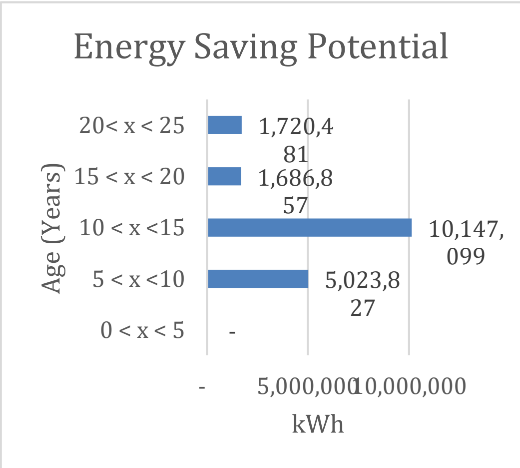
5 < x < 10 Years: GHG emission savings of 3,468,026 kg CO_2 equivalent, reflecting significant efficiency improvements.

10 < x < 15 Years: GHG emission savings of 4,735,032 kg CO_2 equivalent, indicating notable efficiency decline.

15 < x < 20 Years: GHG emission savings of 1,590,345 kg CO_2 equivalent, emphasizing the need for regular maintenance.

20 < x < 25 Years: GHG emission savings of 1,247,850 kg CO_2 equivalent, showing substantial inefficiency and the urgency of replacements.

Industrial Sector



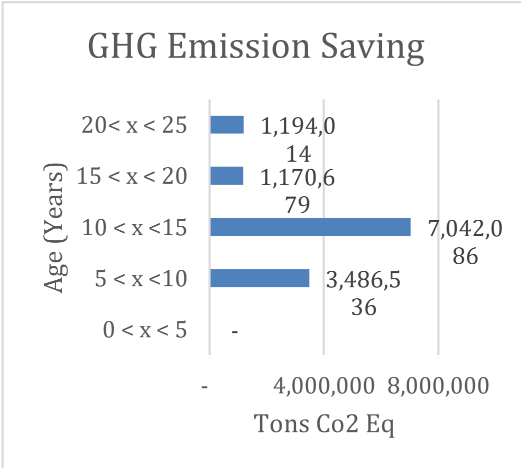


Figure 21 : Energy Saving Potential & GHG Emission saving – Industrial Sector

0 < x < 5 Years: Minimal energy saving potential due to the efficiency of new chillers.

5 < x < 10 Years: Moderate energy saving potential indicates the importance of early maintenance to maintain efficiency. The total saving potential is 5,023,827 kWh (27%).

10 < x < 15 Years: Significant energy savings highlight the need for retrofitting or upgrading older chillers. The potential savings are 10,147,099 kWh (55%).

15 < x < 20 Years: High energy saving potential underscores the necessity for regular maintenance and potential upgrades. The potential savings amount to 1,686,857 kWh (9%).

20 < x < 25 Years: Substantial energy saving potential due to notable inefficiency in older chillers, indicating a strong need for replacements. The saving potential is 1,720,481 kWh (9%).

0 < x < 5 Years: No significant GHG emission savings as these chillers are new and efficient.
5 < x < 10 Years: GHG emission savings of 3,486,536 kg CO_2 equivalent, indicating the need for early maintenance to maintain efficiency.

10 < x < 15 Years: GHG emission savings of 7,047,857 kg CO_2 equivalent, highlighting the need for retrofitting or upgrading older chillers.

15 < x < 20 Years: GHG emission savings of 1,170,800 kg CO_2 equivalent, underscoring the necessity for regular maintenance.

20 < x < 25 Years: GHG emission savings of 1,195,342 kg CO_2 equivalent, indicating a strong need for replacements due to substantial inefficiency.

This comprehensive analysis underscores the importance of regular maintenance, retrofitting, and timely replacements to optimize energy efficiency and reduce GHG emissions across various sectors in Sri Lanka.

Sector-wise Distribution of Total Saving Potential and GHG Emission Savings

The sector-wise analysis of energy saving potential and GHG emission savings in Sri Lanka reveals distinct opportunities and impacts for each sector. By examining these figures, we can better understand the priorities and benefits of improving chiller efficiency in different contexts.

Table 19 : Saving Potential & GHG Emission Saving of Chillers in Sri Lanka Based on Sector

Sector	Total Saving Potential-Running (kWh)		GHG Emission Saving (kg CO_2 Eq)	
Commercial	11,401,217	16%	7,912,444	16%
Government	12,788,631	18%	8,875,310	18%
Hospital	11,066,549	16%	7,680,185	16%
Hotel	15,909,586	23%	11,041,253	23%
Industrial	18,578,263	27%	12,893,315	27%
Total	**69,744,246**		**48,402,506**	

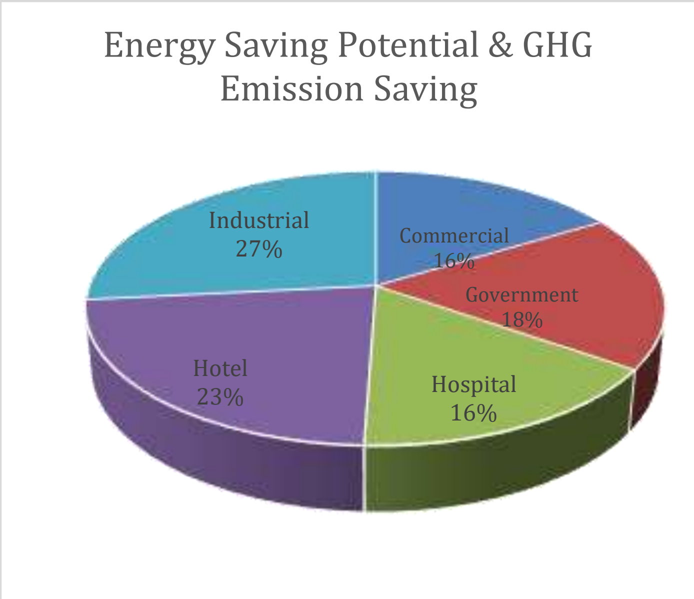
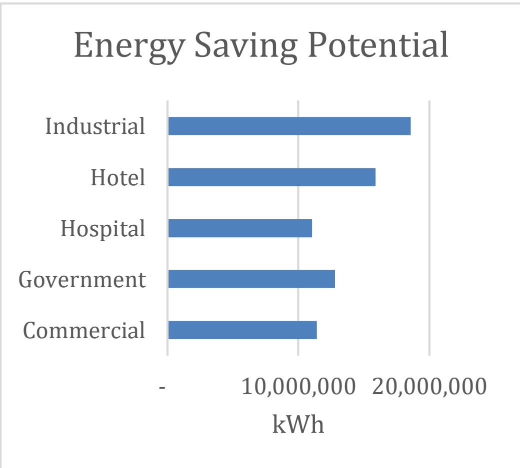


Figure 22 : Energy Saving Potential & GHG Emission saving –Sector Wise



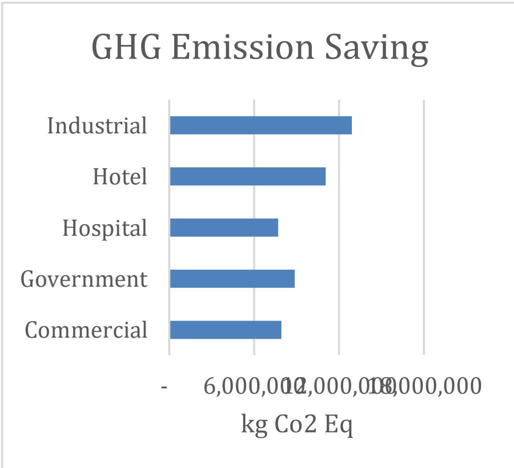


Figure 23 : Energy Saving Potential & GHG Emission saving –Sector Wise with Values

Commercial Sector

Total Saving Potential - Running (kWh): 11,401,217 kWh (16%)
GHG Emission Saving (kg CO_2 Eq): 7,912,444 kg CO_2 Eq (16%)

The commercial sector, which includes office buildings, retail spaces, and other business establishments, shows a notable energy saving potential. However, compared to other sectors, it ranks lower in terms of percentage contribution to the total savings. The sector's contribution is significant but not as high as others, suggesting a moderate impact from chiller efficiency improvements.

Government Sector

Total Saving Potential - Running (kWh): 12,788,631 kWh (18%)
GHG Emission Saving (kg CO_2 Eq): 8,875,310 kg CO_2 Eq (18%)

Government facilities, including administrative buildings and public services, have a slightly higher energy saving potential compared to the commercial sector. The savings reflect the substantial energy usage in government operations, highlighting the importance of upgrading chiller systems to achieve energy efficiency and environmental sustainability in public infrastructure.

Hospital Sector

Total Saving Potential - Running (kWh): 11,066,549 kWh (16%)
GHG Emission Saving (kg CO_2 Eq): 7,680,185 kg CO_2 Eq (16%)

Hospitals, requiring continuous and reliable cooling for patient care and medical equipment, demonstrate a significant energy saving potential. The environmental impact is considerable, emphasizing the need for hospitals to adopt energy-efficient chiller technologies. While the total savings are slightly lower than the commercial and government sectors, the critical nature of hospital operations makes these savings particularly valuable.

Hotel Sector

Total Saving Potential - Running (kWh): 15,909,586 kWh (23%)
GHG Emission Saving (kg CO_2 Eq): 11,041,253 kg CO_2 Eq (23%)

The hotel sector stands out with a substantial energy saving potential, representing 23% of the total savings. Hotels, with their high demand for cooling and comfort, can achieve significant cost savings and environmental benefits by upgrading their chiller systems. The sector's high percentage contribution underscores the potential impact of energy efficiency measures in hospitality.

Industrial Sector

Total Saving Potential - Running (kWh): 18,578,263 kWh (27%)
GHG Emission Saving (kg CO_2 Eq): 12,893,315 kg CO_2 Eq (27%)

The industrial sector leads in energy saving potential, accounting for 27% of the total. Manufacturing plants and industrial facilities, which have extensive cooling requirements, stand to benefit the most from chiller efficiency improvements. The sector's significant energy and GHG emission savings highlight the critical role of energy-efficient technologies in reducing operational costs and environmental impact in industrial operations.

Overall Comparative Impact

Total Saving Potential - Running (kWh): 69,744,246 kWh (70 GWh)
GHG Emission Saving (kg CO_2 Eq): 48,402,506 kg CO_2 Eq
The cumulative analysis underscores the varied yet significant impact of energy efficiency improvements across different sectors in Sri Lanka. While the industrial and hotel sectors show the highest potential for energy and GHG emission savings, all sectors demonstrate considerable benefits from upgrading chiller systems. Implementing these energy efficiency measures across sectors will lead to substantial reductions in energy consumption, operational costs, and environmental footprint, contributing to a more sustainable future for Sri Lanka.

3.6 Refrigerant Data Analysis for Chillers in Sri Lanka

This chapter analyzes the distribution of refrigerants used in chillers across various sectors and age ranges in Sri Lanka. The data provides insights into the types of refrigerants currently in use, their environmental impacts, and potential strategies for transitioning to less harmful alternatives in line with global HFC phase-down agreements.

Refrigeration and air conditioning systems play a critical role in various sectors, including commercial, industrial, government, healthcare, and hospitality. In Sri Lanka, the use of chillers is widespread, and the choice of refrigerants in these systems significantly impacts both environmental sustainability and regulatory compliance. The refrigerants used in these chillers vary widely from older, high-global-warming-potential (GWP) and ozone-depleting substances (ODS) to newer, more environmentally friendly options.

As part of global efforts to combat climate change and protect the ozone layer, Sri Lanka is actively participating in the **HFC phase-down as mandated by the Kigali Amendment to the Montreal Protocol**. This international treaty aims to reduce the production and consumption of hydrofluorocarbons (HFCs), which are potent greenhouse gases. The transition towards low-GWP refrigerants is essential for meeting these international commitments and ensuring a sustainable future.

In this context, understanding the current landscape of refrigerant use in Sri Lanka is crucial. By analyzing data on refrigerant distribution across different sectors and chiller age ranges, we can identify areas that require immediate attention and formulate effective strategies for a smooth transition to greener alternatives. This chapter provides a comprehensive analysis of the refrigerant data, shedding light on the prevalent practices and highlighting the need for change.

Overall Refrigerant Distribution Chillers in Sri Lanka

The distribution of chiller refrigerant usage in Sri Lanka can be summarized as follows:

Table 20 : Overall Refrigerant Distribution of Chillers in Sri Lanka

Chiller Refrigerant Usage				
R22	**R134a**	**R407C**	**R514A**	**R410C**
14%	**75%**	**7%**	**2%**	**3%**

R22: This refrigerant accounts for 14% of the total usage. Despite its historical popularity, R22 is being phased out globally due to its ozone-depleting properties and the push for more environmentally friendly alternatives. Like Sri Lanka, R22 is being phased out worldwide under the Montreal Protocol due to its high ozone depletion potential. Countries are progressively transitioning to alternatives.

R134a: Dominating the market, R134a constitutes 75% of the total refrigerant usage. It is a widely used refrigerant known for its efficiency and lower environmental impact compared to R22, though it is still subject to regulatory scrutiny due to its global warming potential (GWP).Widely used across the globe, R134a is facing phase down regulations in many regions due to its high GWP. The European Union and other countries are moving towards lower-GWP options.

R407C: Representing 7% of the market, R407C is a blend of refrigerants designed to serve as a replacement for R22. It has lower ozone depletion potential and is used in various air conditioning and refrigeration applications. These refrigerants are common global replacements for R22, offering improved environmental profiles. However, they are also being evaluated for their GWP and may face future restrictions.

R514A: This refrigerant makes up 2% of the total usage. It is a newer, environmentally friendly option with low GWP, often used in applications requiring high efficiency and safety.There is a significant global push towards refrigerants like R514A, which offer lower GWP and higher efficiency. The Kigali Amendment to the Montreal Protocol aims to reduce the use of high-GWP refrigerants, driving innovation and adoption of such alternatives.

R410A: Accounting for 3% of the market, R410C is another alternative to R22, commonly used in residential and commercial air conditioning systems due to its efficiency and reduced environmental impact. These refrigerants are common global replacements for R22, offering improved environmental profiles. However, they are also being evaluated for their GWP and may face future restrictions.

Overall, R134a is the most prevalent refrigerant in Sri Lanka, significantly outpacing other types. This distribution reflects a trend towards more environmentally conscious choices while still relying heavily on established refrigerants. The shift towards newer, more sustainable refrigerants like R514A indicates a growing awareness and adaptation to global environmental standards.

Age Range Distribution

The refrigerant data is categorized by the age range of chillers, revealing trends in refrigerant use over time.

Table 21 : Refrigerant Distribution of Chillers in Sri Lanka – Age Range

Age Range (Years)	Refrigerant					Total
	R22	R134a	R407C	R514A	R410C	
0 < x < 5	4%	85%	3%	9%	0%	100%
5 < x <10	5%	91%	1%	1%	2%	100%
10 < x <15	11%	88%	1%	0%	0%	100%
15 < x < 20	19%	79%	2%	0%	0%	100%
20< x < 25	48%	45%	7%	0%	0%	100%

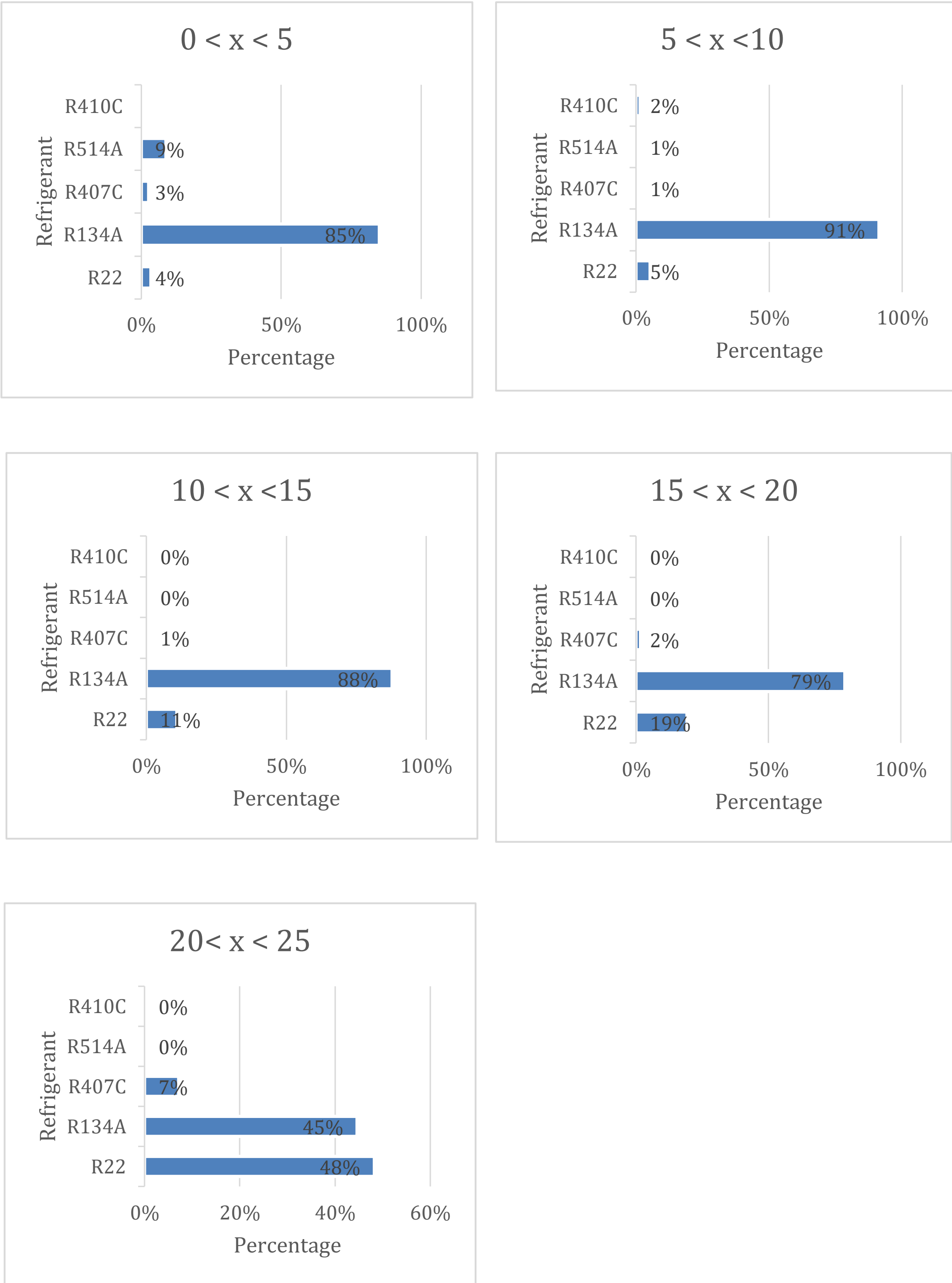


Figure 24 : Refrigerant Distribution of Chillers in Sri Lanka – Age Range

Analysis by Age Range

Newer Chillers (0 < x < 5 years): These chillers primarily use R134a, which, although it has no ozone depletion potential, has a high global warming potential (GWP). The presence of R22 in new chillers is minimal but still concerning due to its high ODP and GWP. R514A, a newer low-GWP alternative, is also being used, indicating a shift towards more sustainable refrigerants.

Mid-Age Chillers (5 < x < 15 years): The reliance on R134a continues, but R22 usage increases slightly, indicating that older units are still in operation and will need replacing soon to comply with environmental standards.

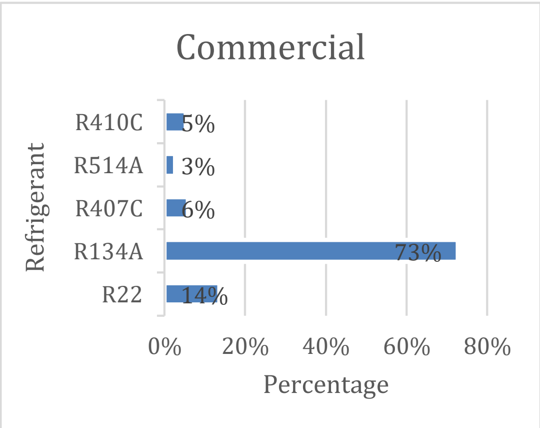
Older Chillers (15 < x < 25 years): These chillers have a higher proportion of R22, especially in the 20-25 years range, highlighting the urgent need for replacement to mitigate environmental impact. The decreasing use of R134a in the oldest units reflects the historical transition from R22 to R134a.

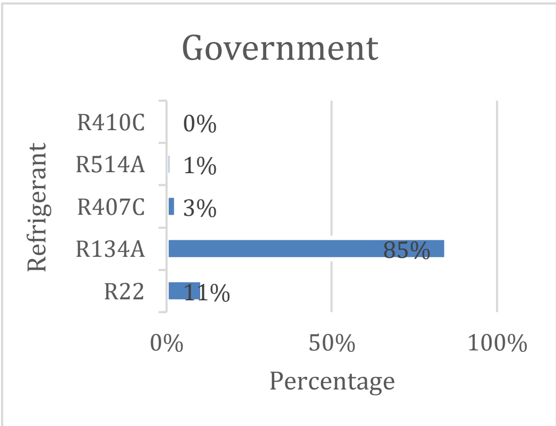
Sector-wise Distribution

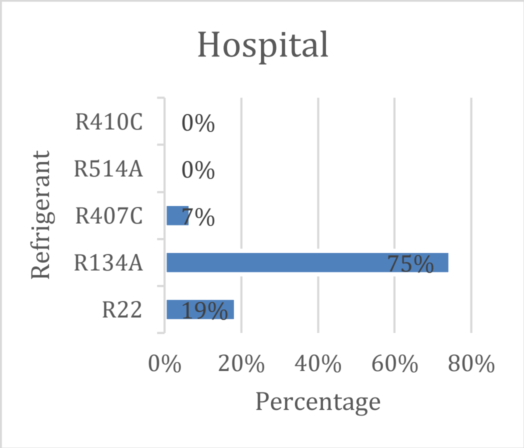
The refrigerant data is also categorized by the sector, showing the prevalence of different refrigerants across various industries.

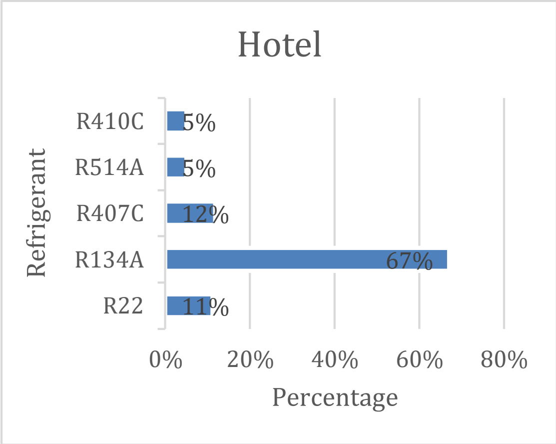
Table 22 : Overall Refrigerant Distribution of Chillers in Sri Lanka – Sector Wise

Sector	Refrigerant				
	R22	**R134a**	**R407C**	**R514A**	**R410C**
Commercial	14%	73%	6%	3%	5%
Government	11%	85%	3%	1%	0%
Hospital	19%	75%	7%	0%	0%
Hotel	11%	68%	12%	4%	5%
Industrial	15%	75%	7%	0%	3%









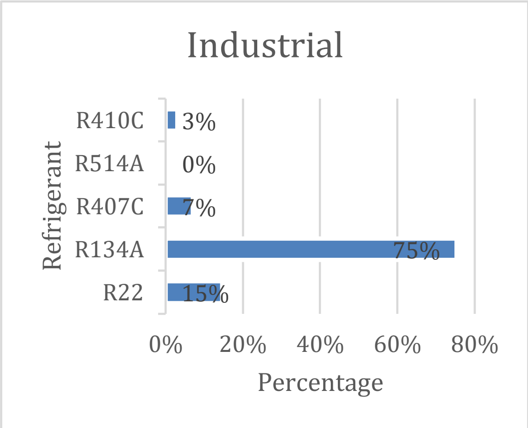


Figure 25 : Refrigerant Distribution of Chillers in Sri Lanka – Sector Wise

Analysis by Sector

Commercial Sector:

Refrigerant Use: Predominantly uses R134a (73%), followed by R22 (14%), R407C (6%), R514A (3%), and R410C (5%). Dominated by R134a, indicating a significant reliance on this refrigerant. However, the presence of R22 suggests some older systems are still in use.

Environmental Impact: The high use of R134a, with its significant GWP, implies considerable contributions to global warming. The presence of R22, although lower, indicates ongoing ozone depletion concerns.

Government Sector:

Refrigerant Use: Dominated by R134a (85%), with minor contributions from R22 (11%), R407C (3%), and R514A (1%).Similar to the commercial sector with a high reliance on R134a but a slightly lower percentage of R22.

Environmental Impact: The extensive use of R134a highlights the sector's significant GWP footprint. R22's presence indicates potential ozone depletion.

Hospital Sector:
Refrigerant Use: Primarily uses R134a (75%) and R22 (19%), with smaller amounts of R407C (7%). Higher usage of R22, is likely due to the critical nature of hospital operations requiring reliable but older systems.

Environmental Impact: The reliance on R134a contributes substantially to global warming, while R22 poses risks to the ozone layer.

Hotel Sector:
Refrigerant Use: Predominantly uses R134a (68%), followed by R407C (12%), R22 (11%), R514A (4%), and R410C (5%).More diversified refrigerant usage with noticeable adoption of R407C and R514A, indicating a mix of older and newer systems.

Environmental Impact: High use of R134a and R407C indicates significant GWP impact, while R22's use suggests ongoing ozone depletion issues.

Industrial Sector:
Refrigerant Use: Majorly uses R134a (75%), followed by R22 (15%) and R407C (7%). Similar to the hospital sector with substantial R22 usage, suggesting the need for targeted replacement strategies.

Environmental Impact: The sector's heavy reliance on R134a contributes to global warming, with R22 posing ozone depletion risks.

Environmental Impact of Refrigerants

Harmful Refrigerants:
R22: High ODP and GWP, making it a significant environmental hazard. Its phase-out is crucial under the Montreal Protocol.

R134a: No ODP but high GWP, contributing significantly to global warming. Its use is being phased down under the Kigali Amendment.

Other Refrigerants:
R407C: No ODP and moderate GWP. It's a blend often used as a drop-in replacement for R22 but still has environmental concerns.

R514A: A newer, low-GWP alternative with minimal environmental impact, aligning well with global sustainability goals.

R410C: Designed for better efficiency and lower GWP compared to R134a and R22 but still not the ideal solution.

HFC Phase-Down Plan in Sri Lanka

Sri Lanka, as part of the Kigali Amendment to the Montreal Protocol, is committed to reducing the use of high-GWP HFCs like R134a and R407C. The country has set targets to reduce the use and import of these refrigerants and promote alternatives with lower environmental impact.

The phase-down plan involves:

- Gradual reduction in the use and import of high-GWP HFCs.
- Promotion of natural refrigerants and low-GWP alternatives.
- Encouraging the adoption of energy-efficient and environmentally friendly technologies.

Replacement of Chillers with Environmentally Friendly Refrigerants

The data indicates a significant presence of old chillers using R22 and R134a, particularly in the 20-25 years age range. Replacing these chillers with modern units that use low-GWP refrigerants can significantly reduce the environmental footprint.

Local and Global Context

Globally, there is a strong push towards sustainable refrigeration and air conditioning solutions. Countries are adopting regulations to limit the use of harmful refrigerants and promote greener alternatives. This aligns with the goals of the Paris Agreement and other international environmental treaties.

In the local context, Sri Lanka has the opportunity to lead by example in the region by adopting sustainable refrigerant practices. The transition to low-GWP refrigerants can also provide economic benefits through energy savings and reduced operational costs.

Strategic Recommendations

To facilitate the transition to environmentally friendly refrigerants in Sri Lanka, the following strategies are recommended:

- Financial Incentives: Provide subsidies and incentives for replacing old chillers with new, energy-efficient models that use low-GWP refrigerants.
- Capacity Building: Invest in training programs for technicians and industry professionals on the handling and maintenance of new refrigerants.
- Awareness Campaigns: Conduct awareness campaigns to educate stakeholders about the benefits of low-GWP refrigerants and the environmental impact of current practices.

- Regulatory Support: Strengthen regulations to phase out high-GWP refrigerants and promote the use of sustainable alternatives.
- Partnerships: Collaborate with international organizations and industry leaders to access advanced technologies and best practices in refrigerant management.

The analysis of refrigerant data for chillers in Sri Lanka highlights the need for a strategic approach to transitioning towards environmentally friendly refrigerants. By addressing the environmental impacts and aligning with global and local initiatives, Sri Lanka can enhance its resilience and contribute to global sustainability goals. The replacement of old chillers with modern, low-GWP alternatives will not only benefit the environment but also provide economic and health advantages for the country's population.

CHAPTER IV

FINANCIAL ANALYSIS FOR ENERGY SAVING POTENTIAL

The cost of chillers with installation, expressed in LKR per Ton of Refrigeration (TR), varies depending on the capacity of the chiller. These modern, energy-efficient chillers typically have a Coefficient of Performance (COP) around 7, with an exchange rate of 1 USD = 310 LKR.

4.1 Cost of Chillers

Here is a detailed breakdown:

Table 23 : Cost of Chillers

No	Chiller Cooling Capacity (TR)	Cost of Chiller with Installation (USD)	Cost of Chiller with Installation (USD/TR)	Cost of Chiller with Installation (LKR)	Cost of Chiller with Installation (LKR/TR)
1	100	80,000	800	24,800,000	248,000
2	150	99,200	661	30,752,000	205,013
3	200	112,000	560	34,720,000	173,600
4	300	128,000	427	39,680,000	132,267
5	400	235,200	588	72,912,000	182,280
	Average		**607**	**40,572,800**	**188,232**

From the data, as the capacity of the chiller increases, the cost per TR generally decreases. This reflects economies of scale, where larger installations benefit from reduced per-unit costs. The average cost of chiller installation stands at approximately 188,232 LKR per TR.

4.2 CEB Tariff Structure

The current tariff rates were issued in March 2024. These rates are subject to periodic review and adjustment by the Ceylon Electricity Board (CEB) to reflect changes in energy production costs, demand fluctuations, and policy directives.

The CEB tariff structure is designed to cater to different types of consumers, with distinct rates for various sectors. The tariff structure is crucial for calculating the operating costs of chillers and understanding potential savings from energy-efficient upgrades.

CEB Tariff

Table 24 : CEB Tariff - Commercial, Government, Hospital Sector

Fixed Charge			5000.00	LKR/Month	Average Unit Cost	
Unit Charge (2024 March Tariff)	Time Period					
	0530 hr	to 1830 hr	45.00	LKR/kWh	44.63	LKR/kWh
	1830 hr	to 2230 hr	55.00	LKR/kWh	44.63	LKR/kWh
	2230 hr	to 0530 hr	38.00	LKR/kWh	44.63	LKR/kWh
Demand Charge			1500.00	LKR/kVA		LKR/kVA

Table 25 : CEB Tariff - Industrial, Hotel Sector

Fixed Charge			5000.00	LKR/Month	Average Unit Cost	LKR/Month
Unit Charge (2024 March Tariff)	Time Period					
	0530 hr	to 1830 hr	30.50	LKR/kWh	30.13	LKR/kWh
	1830 hr	to 2230 hr	37.00	LKR/kWh	30.13	LKR/kWh
	2230 hr	to 0530 hr	25.50	LKR/kWh	30.13	LKR/kWh
Demand Charge			1500.00	LKR/kVA		LKR/kVA

For the industrial and hotel sectors, the tariff rates are lower compared to the commercial, government, and hospital sectors. This reflects an effort to support industrial activity and the tourism industry by reducing energy costs.

The cost of installing chillers and the associated CEB tariffs are critical components of the financial analysis for upgrading chiller systems in Sri Lanka. Understanding these costs helps in evaluating the financial viability of investments in energy-efficient chillers. The lower tariff rates for industrial and hotel sectors provide a significant incentive for these sectors to invest in energy-saving technologies, while the higher rates for commercial, government, and hospital sectors underline the importance of managing energy use efficiently to control operating costs.

4.3 Financial Analysis of Chiller Replacement in Sri Lanka

The financial analysis of replacing chillers in various sectors of Sri Lanka involves evaluating the total energy saving potential, annual potential savings in LKR, and the estimated total investment required. The analysis also highlights the payback period, indicating the viability and potential benefits of chiller replacement.

Sector Wise Financial Analysis

Table 26 : Sector Wise Financial Analysis for Chiller Replacement in Sri Lanka

Sector	Total Saving Potential- Running (kWh)	GHG Emission Saving (Kg CO_2 Eq)	Percentage %	Average Unit Cost (LKR)	Annual Saving Potential (LKR Million)	Total Chiller Capacity - Running	Estimated Total Investment (USD Million)	Estimated Total Investment (LKR Million)	Pay back (Years)
Commercial	11,401,217	7,912,444	16%	44.63	508,8	24,036	14,6	4,524.3	8.9
Government	12,788,631	8,875,310	18%	44.63	570,7	18,605	11,3	3,502,1	6.1
Hospital	11,066,549	7,680,185	16%	44.63	493,8	8,777	5,3	1,652,2	3.3
Hotel	15,909,586	11,041,253	23%	30.13	479,3	21,157	12,8	3,982,5	8.3
Industrial	18,578,263	12,893,315	27%	30.13	559,7	33,135	20,1	6,237,1	11.1

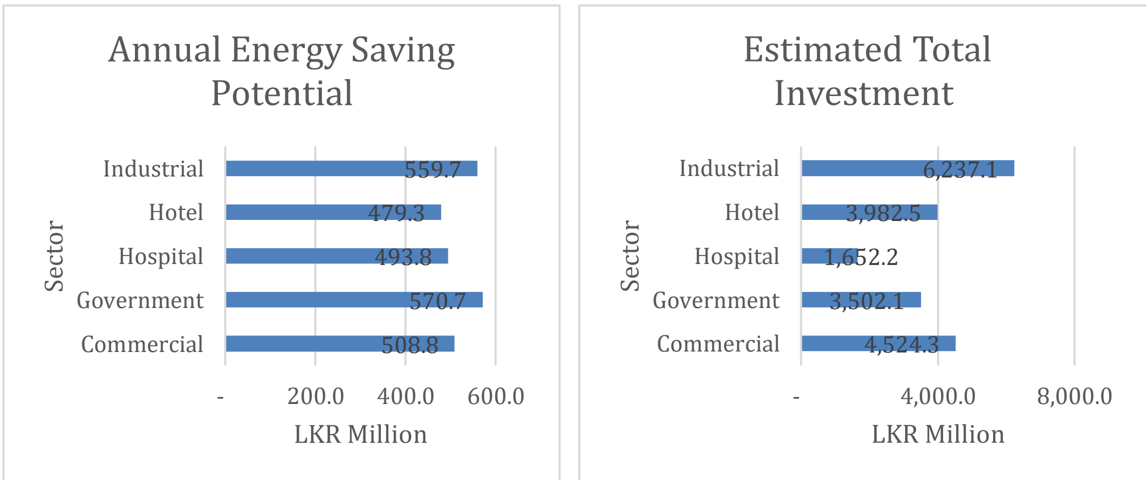


Figure 26 : Energy Saving Potential & Estimated Total Investment – Sector Wise

Commercial Sector

The commercial sector shows a significant energy saving potential of 11,401,217 kWh, translating to an annual saving of approximately 508.78 million LKR. The estimated investment for replacing the chillers is about 4.52 billion LKR, resulting in a payback period of 8.9 years. This indicates that while the initial investment is substantial, the long-term savings make the investment worthwhile.

Government Sector

The government sector can save 12,788,631 kWh annually, with potential savings of around 570.69 million LKR. The investment required for new chillers is approximately 3.5 billion LKR. The payback period is shorter, at 6.1 years, making this sector highly favorable for chiller replacement due to quicker returns on investment.

Hospital Sector

Hospitals have an annual energy saving potential of 11,066,549 kWh, with financial savings of approximately 493.84 million LKR. The investment needed is about 1.65 billion LKR, resulting in a very attractive payback period of 3.3 years. This short payback period highlights the hospital sector as a prime candidate for immediate chiller replacement.

Hotel Sector

Hotels can save 15,909,586 kWh annually, leading to savings of approximately 479.28 million LKR. The investment required is around 3.98 billion LKR, with a payback period of 8.3 years. Despite the higher energy saving potential, the payback period is relatively longer due to the lower tariff rates in this sector.

Industrial Sector

The industrial sector has the highest energy saving potential of 18,578,263 kWh, translating to annual savings of 559.67 million LKR. However, the estimated investment is also the highest at approximately 6.24 billion LKR, leading to a longer payback period of 11.1 years. This indicates that while the savings are substantial, the higher investment cost results in a longer period to recoup the expenses.

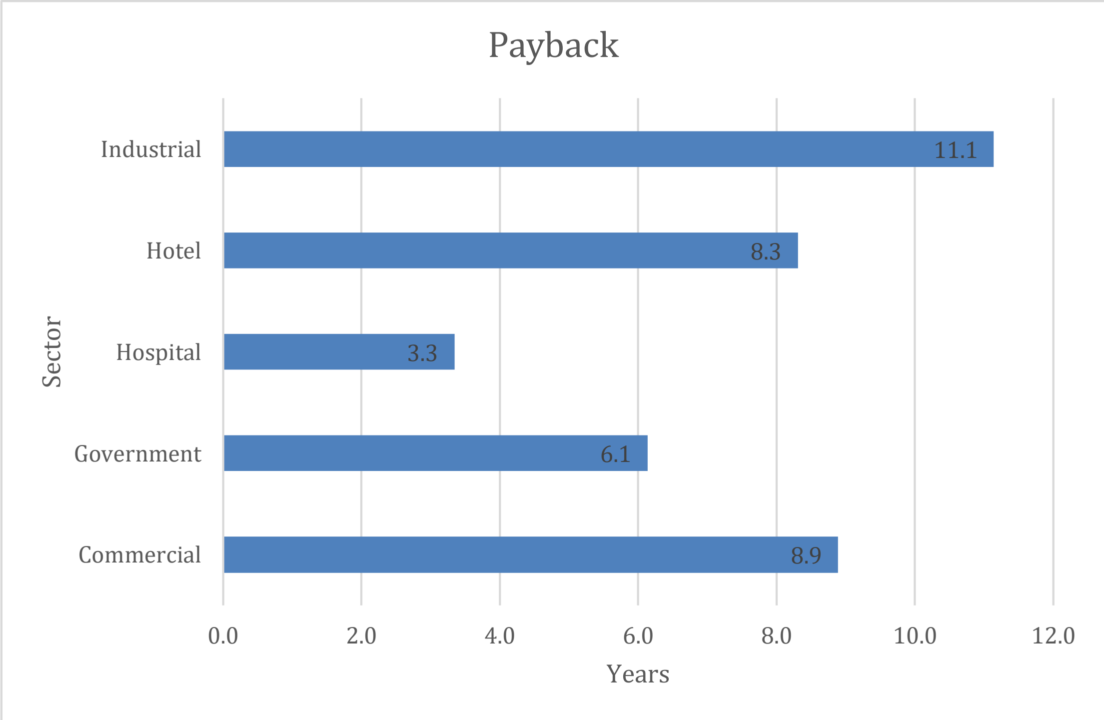


Figure 27 : Pay Back for Investment

4.4 Highlights of Chiller Replacement Potential

The analysis demonstrates the substantial potential for energy savings and financial benefits from replacing chillers across different sectors in Sri Lanka. The payback period varies significantly across sectors, with hospitals showing the shortest period (3.3 years) and the industrial sector the longest (11.1 years).

Investing in energy-efficient chillers presents a viable opportunity to reduce operational costs, enhance energy efficiency, and contribute to environmental sustainability. The decision to replace chillers should consider both the potential savings and the payback period, aligning with the sector's financial strategies and energy goals.

Among the sectors analyzed, hospitals, government, and hotels exhibit the shortest payback periods, making them primary candidates for chiller replacements to achieve substantial energy and cost savings while promoting sustainable practices.

Hospital Sector:
Payback Period (Years): 3.3
Annual Potential LKR Saving: 493,844,754

Government Sector:
Payback Period (Years): 6.1
Annual Potential LKR Saving: 570,692,641

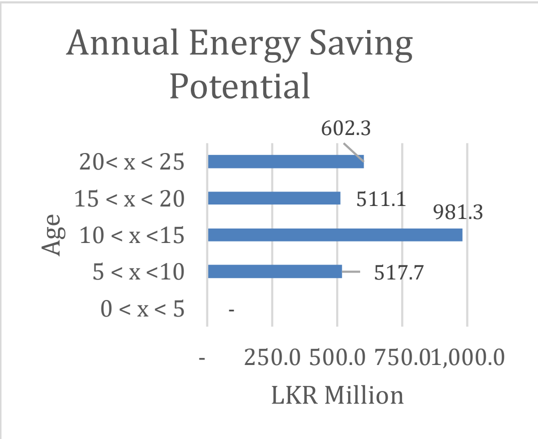
Hotel Sector:
Payback Period (Years): 8.3
Annual Potential LKR Saving: 479,276,273

4.5 Financial Analysis of Chiller Replacement in Sri Lanka - Age wise

This section provides a detailed financial analysis of chiller replacements across different age categories in Sri Lanka. The analysis evaluates the total energy saving potential, annual potential savings in LKR, and the estimated total investment required for chiller replacements. By highlighting the payback period, the analysis underscores the feasibility and benefits of replacing chillers based on their age. This age-wise breakdown aims to assist decision-makers in identifying the most cost-effective and energy-efficient opportunities for chiller replacements, ultimately supporting sustainable practices and reducing operational costs across various sectors.

Table 27 : Total Saving Potential & Pay back for Chiller Replacement in Sri Lanka – Age Range

Age	Total Saving Potential-Running (kWh)	GHG Emission Saving (Kg CO_2 Eq)	%	Average Unit Cost (LKR)	AnnualSaving Potential (LKR Million)	Total Chiller Capacity - Running	Estimated Total Investment (USD Million)	Estimated Total Investment (LKR Million)	Pay back (Years)
0 < x < 5	-	-	0%	37.45	-	21,978	13,3	4,137,0	-
5 < x <10	13,822,175	9,592,590	20%	37.45	517,7	44,721	27,2	8,417,9	16.3
10 < x <15	26,200,576	18,183,200	38%	37.45	981,3	23,224	14,1	4,371,5	4.5
15 < x < 20	13,645,600	9,470,047	20%	37.45	511,1	8,438	5,1	1,588,3	3.1
20< x < 25	16,079,441	11,159,132	23%	37.45	602,3	7,349	4,5	1,383,4	2.3



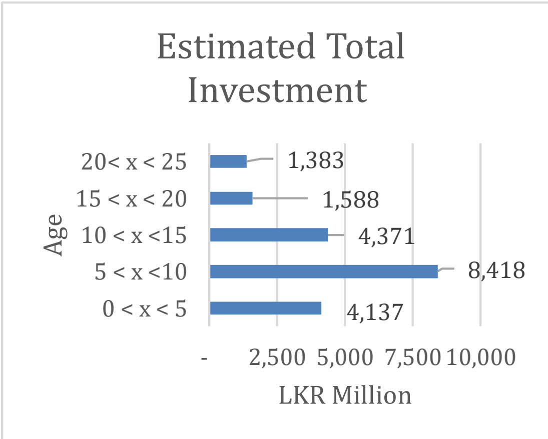


Figure 28 : Energy Saving Potential & Estimated Total Investment – Age Wise

0 < x < 5 Years

For chillers aged between 0 and 5 years, chiller replacement is not considered feasible due to their relatively new condition and the lack of significant wear and tear. Consequently, data on total saving potential in running kWh and annual potential LKR savings are not applicable for this age category. The total chiller capacity for chillers in this age range is 21,978 units. The estimated total investment for these chillers is 4,137.02 million LKR (13.35 million USD). Given the newness of these systems, a payback period is not calculated, as replacement is not recommended at this stage. Future financial analyses will provide more accurate insights as these systems age and their performance can be evaluated over time.

5 < x < 10 Years

Chillers in the 5 to 10 years age bracket have a total saving potential of 13,822,175 kWh annually. This translates to an annual potential saving of approximately 517.71 million LKR. The total estimated investment required for these chillers is about 8,417.91 million LKR (27.15 million USD). The payback period for these chillers is 16.3 years, which suggests a longer timeframe to recoup the investment. Despite the higher initial costs, the significant energy savings potential makes these chillers a strategic investment for long-term operational efficiency and cost reduction.

10 < x < 15 Years

For chillers aged between 10 and 15 years, the total saving potential is 26,200,576 kWh per year. This results in annual potential savings of approximately 981.34 million LKR. The estimated total investment for replacing these chillers is 4,371.48 million LKR (14.10 million USD). The payback period is relatively short at 4.5 years, highlighting the high efficiency and quick return on investment. This age bracket shows a strong case for chiller replacement due to the substantial energy savings and favorable financial outcomes.

15 < x < 20 Years

Chillers in the 15 to 20 years age range have a total saving potential of 13,645,600 kWh annually. The annual potential savings are approximately 511.09 million LKR. The total estimated investment for these chillers is 1,588.33 million LKR (5.12 million USD). The payback period for this category is 3.1 years, indicating a very attractive investment opportunity with quick financial returns. The significant energy savings and short payback period make this age bracket a prime candidate for chiller replacement.

20 < x < 25 Years

For chillers aged between 20 and 25 years, the total saving potential is 16,079,441 kWh per year. This translates to annual potential savings of about 602.25 million LKR. The estimated total investment required is 1,383.37 million LKR (4.46 million USD). The payback period is the shortest among all categories at 2.3 years, making it an excellent investment opportunity the high energy savings and very short payback period strongly support the replacement of chillers in this age bracket.

4.6 Further Highlights of Chiller Replacement Potential

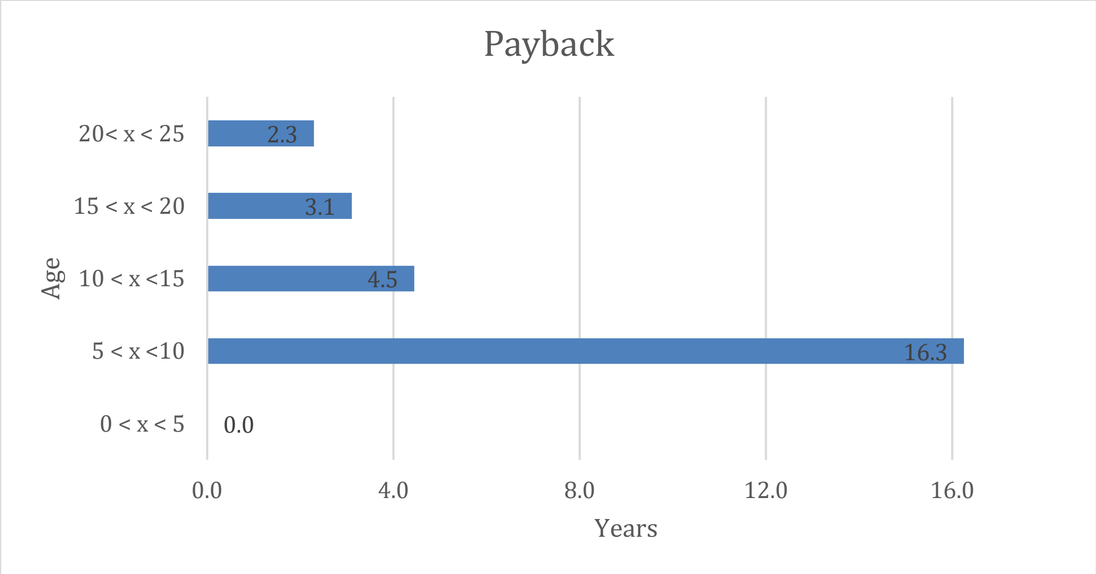


Figure 29 : Pay Back with Age Range

The analysis demonstrates the substantial potential for energy savings and financial benefits from replacing chillers across different age categories in Sri Lanka. The payback period varies significantly, with the shortest period observed in the 20 to 25 years category (2.3 years) and the longest in the 5 to 10 years category (16.3 years).

Investing in energy-efficient chillers presents a viable opportunity to reduce operational costs, enhance energy efficiency, and contribute to environmental sustainability. The decision to replace chillers should consider both the potential savings and the payback period, aligning with financial strategies and energy goals.

Prioritizing chiller replacements in the 15 to 20 years and 20 to 25 years age brackets can lead to significant energy and cost savings while promoting sustainable practices. These categories offer the quickest return on investment, ensuring that the benefits of energy efficiency are realized swiftly.

4.7 Prioritization of Chiller Replacement for Maximum Energy Savings

In the context of Sri Lanka, the financial analysis of chiller replacement across various sectors reveals significant potential for energy savings and operational cost reductions. The analysis evaluates total energy saving potential, annual savings in LKR, and the estimated investment required. This comprehensive assessment also highlights the payback period, indicating the viability and benefits of replacing outdated chillers. By examining chillers based on their age, specific sectors, and the type of refrigerant used, we can identify key areas where chiller replacement will yield the most substantial returns in terms of both energy efficiency and financial savings.

Phase 01

Replace Chillers Aged 20 to 25 Years

For chillers aged between 20 and 25 years, the potential for energy savings is particularly high. These older systems have a total saving potential of 16,079,441 kWh per year, translating to annual savings of approximately LKR 602.25 million. The estimated total investment required for replacing these chillers is LKR 1,383.37 million (4.46 million USD). With the shortest payback period of just 2.3 years among all categories, replacing chillers in this age bracket is an excellent investment opportunity. The high energy savings and very short payback period strongly support the replacement of chillers in this category.

On a global scale, the emphasis on replacing older chillers aligns with international efforts to enhance energy efficiency and reduce greenhouse gas emissions. Ageing infrastructure often consumes more energy and has higher operational costs. By prioritizing the replacement of chillers that are 20 to 25 years old, authorities can achieve significant reductions in energy consumption and carbon footprint, contributing to global sustainability goals.

Replace Hospital Sector Chillers

Hospitals represent another high-priority area for chiller replacement due to their substantial energy usage and the critical nature of their operations. Hospitals have an annual energy saving potential of 11,066,549 kWh, which can result in financial savings of approximately LKR 493.84 million. The investment required for new chillers in the hospital sector is about LKR 1.65 billion with a very attractive payback period of 3.3 years. This short payback period makes the hospital sector a prime candidate for immediate chiller replacement, ensuring both energy efficiency and financial prudence.

Globally, hospitals are significant consumers of energy, and improving their energy efficiency is a priority for many countries. Upgrading to modern, energy-efficient chillers not only reduces operational costs but also ensures reliable and uninterrupted services, which are crucial in healthcare settings. The replacement of chillers in hospitals aligns with international trends of prioritizing energy efficiency in critical infrastructure.

Replace R22 Refrigerant Chillers

Chillers using R22 refrigerant account for 14% of the total refrigerant usage in Sri Lanka. Despite its historical popularity, R22 is being phased out globally due to its ozone-depleting properties under the Montreal Protocol. The push for more environmentally friendly alternatives is strong, and replacing R22 refrigerant chillers are both an environmental and economic priority.

Similar to Sri Lanka, many countries are transitioning away from R22 to alternatives with lower ozone depletion potential and global warming potential (GWP). This global trend is driven by regulatory pressures and the need to meet international environmental standards. Replacing R22 chillers with modern, energy-efficient systems not only helps in compliance with environmental regulations but also offers significant energy savings and operational benefits.

Prioritizing the replacement of chillers in these key areas-older chillers aged 20 to 25 years, hospital sector chillers, and chillers using R22 refrigerant-can lead to substantial energy savings and financial benefits. These replacements align with both local and global efforts to enhance energy efficiency, reduce greenhouse gas emissions, and comply with environmental regulations. By focusing on these high-potential areas, relevant authorities, governments, donors, and other stakeholders can make strategic investments that promote sustainable development and operational efficiency.

Phase 02

Chillers Aged 15 to 20 Years

Chillers in the 15 to 20 years age range present a significant opportunity for energy savings and quick financial returns. These chillers have a total saving potential of 13,645,600 kWh annually, which translates to approximately LKR 511.09 million - in annual potential savings. The estimated investment required for replacing these chillers is LKR 1,588.33 million (USD 5.12 million). The payback period for this age category is 3.1 years, making it an attractive investment opportunity. The combination of substantial energy savings and a short payback period underscores the potential benefits of replacing chillers in this bracket.

Globally, replacing chillers that are 15 to 20 years old aligns with efforts to modernize infrastructure and improve energy efficiency. Many countries are investing in upgrading their HVAC systems to reduce energy consumption and operational costs. This global trend highlights the importance of timely replacements to ensure optimal performance and sustainability.

Government Sector Chillers

The government sector also demonstrates considerable potential for energy savings through chiller replacement. With an annual energy saving potential of 12,788,631 kWh, this sector can save around LKR 570.69 million annually. The investment required for new chillers is approximately 3.5 billion LKR. The payback period for this sector is relatively short, at 6.1 years, making it a highly favourable area for chiller replacement. The quicker returns on investment and significant energy savings make the government sector an ideal candidate for immediate action.

On a global scale, governments are leading by example in adopting energy-efficient technologies to reduce their carbon footprint and operational costs. Upgrading government infrastructure, including HVAC systems, is a priority in many countries to meet sustainability goals and improve public sector efficiency. This trend underscores the importance of similar initiatives in Sri Lanka's government sector.

R134a Refrigerant Chillers

R134a is the most dominant refrigerant in the market, accounting for 75% of the total refrigerant usage in Sri Lanka. It is known for its efficiency and relatively lower environmental impact compared to R22. However, R134a is still under regulatory scrutiny due to its global warming potential (GWP). Replacing chillers that use R134a with systems utilizing lower-GWP alternatives can enhance energy efficiency and comply with evolving environmental regulations.

Globally, the use of R134a is being phased down in many regions due to its high GWP. The European Union and other countries are moving towards refrigerants with lower GWP to mitigate climate change impacts. This shift towards more sustainable refrigerants is part of a broader international effort to reduce the environmental impact of cooling systems. By transitioning away from R134a, Sri Lanka can align with global best practices and regulatory trends.

Prioritizing the replacement of chillers in the 15 to 20 years age bracket, within the government sector, and those using R134a refrigerant can yield significant energy and cost savings. These areas offer quick payback periods and align with both local and global efforts to enhance energy efficiency and reduce environmental impact. Relevant authorities, governments, donors, and other stakeholders can leverage these insights to make informed decisions that support sustainable development and operational efficiency in Sri Lanka.

CHAPTER V

CONCLUSION

The National Survey on Chillers in Sri Lanka has uncovered critical insights into the energy consumption, efficiency, and operational dynamics of chillers spanning various sectors, including hospitals, hotels, commercial complexes, industries, and government buildings. Through rigorous energy audits, significant disparities in chiller efficiency have been elucidated, driven by factors such as age, operational hours, and maintenance practices.

Key Findings

1. **Age and Efficiency:** The study underscores that older chillers exhibit significantly lower efficiency compared to newer models. For instance, the 25-year-old chiller at General Hospital - Peradeniya operates with a CoP of 1.08, highlighting the urgent need for infrastructure upgrades to enhance cooling efficiency and reduce energy consumption.

2. **Sector-Specific Trends:** Variations in chiller efficiency across sectors were observed. Government and hospital facilities often house older and less efficient chillers, necessitating targeted modernization efforts. In contrast, the commercial and industrial sectors tend to feature newer, more energy-efficient chiller systems.

3. **Operational Patterns:** Chillers in sectors like hospitals and hotels operate continuously, sometimes up to 24 hours a day, presenting substantial opportunities for energy savings through efficiency improvements and optimized operational strategies.

4. **Capacity Utilization:** Higher-capacity chillers, such as the 420 TR chiller at MAS - MAS-Mahiyanganaya, demonstrate superior efficiency. However, effective utilization of chiller capacity is critical to achieving maximum energy savings, as underutilization can lead to inefficiencies in energy consumption.

Recommendations

Building on these findings, the following comprehensive recommendations are proposed to enhance chiller efficiency and sustainability across Sri Lanka:

1. **Chiller Replacement and Upgrades:** Prioritize the replacement of ageing chillers with newer, energy-efficient models to improve overall system efficiency, reduce operational costs, and minimize environmental impact.

2. **Optimized Operational Strategies:** Implement advanced operational strategies such as optimizing compressor sequencing, adjusting chiller load to match building demand, and utilizing energy storage solutions to optimize energy consumption while maintaining comfort levels.

3. **Regular Maintenance Protocols:** Establish routine maintenance protocols encompassing regular inspections, cleaning of evaporator and condenser coils, and calibration of controls to ensure optimal chiller performance and longevity.

4. **Enhanced Cooling Tower Management:** Improve cooling tower efficiency through upgrades in water distribution systems, implementation of water treatment solutions to mitigate scaling and corrosion, and regular cleaning to prevent algae and debris buildup.

5. **Fan Coil Unit (FCU) and Valve Optimization:** Upgrade FCU systems with energy-efficient motors and valves, ensure proper insulation of chilled water pipes to minimize energy loss, and implement variable speed drives for enhanced control and efficiency.

6. **Adoption of Energy-Efficient Practices:** Promote energy-saving behaviours among facility occupants, conduct regular training sessions for operational staff on energy-efficient practices, and implement real-time monitoring systems to track energy consumption and identify areas for improvement.

7. **Financial Incentives and Support:** Advocate for governmental incentives, rebates, and financing options to support organizations investing in energy-efficient chiller systems, encouraging broader adoption across all sectors.

8. **Collaboration and Knowledge Sharing:** Foster collaboration among industry stakeholders, manufacturers, and energy consultants to exchange best practices, explore innovative technologies, and stay informed about emerging trends in chiller efficiency and sustainability.

Economic and Environmental Benefits

Investing in energy-efficient chiller systems not only enhances operational efficiency and reduces energy consumption but also aligns with global sustainability goals. The transition to modern chiller technologies offers dual benefits of cost savings through decreased energy use and maintenance, while also contributing to mitigating climate change by lowering greenhouse gas emissions.

`

Policy and Stakeholder Considerations

The findings of this study provide actionable insights for policymakers, businesses, and stakeholders involved in Sri Lanka's infrastructure development and sustainability initiatives. By prioritizing chiller replacements based on age and efficiency assessments, stakeholders can unlock substantial economic savings and environmental benefits, fostering a more resilient and sustainable built environment.

Future Directions

Looking ahead, continuous monitoring and evaluation of chiller performance, coupled with ongoing technological advancements in energy efficiency, will be crucial. Collaboration among government agencies, private sectors, and international partners can facilitate knowledge exchange and support in adopting best practices for sustainable chiller management across Sri Lanka.

Final Thoughts

In conclusion, the strategic deployment of energy-efficient chiller systems represents a pivotal opportunity for Sri Lanka to enhance energy security, reduce operational costs, and achieve its climate mitigation targets. By leveraging the insights and recommendations outlined in this study, stakeholders can pave the way for a greener and more sustainable future while reaping substantial economic benefits in the process

ANNEXURES

Annexure 1: The Finalized Questionnaire

Annexure 2

The list of facilities where walkthrough audits were conducted

Questionnaire for the Survey on Chillers in Sri Lanka (Walkthrough Audits)

09th February, 2023

SURVEY ON CHILLERS IN SRI LANKA

Brief introduction to questionnaire

.

- Sri Lanka Sustainable Energy Authority (SLSEA) of Ministry of Power and Energy has the mandate of promoting Energy Efficiency improvement and Renewable Energy Development. SLSEA conducts many programmes to improve energy efficiency in end use sectors. Among these, central air conditioning systems are identified as a key area for improving energy efficiency.

- It is estimated that in general, electrical energy requirement for central air conditioning systems in commercial establishments is in the range of 40 – 80% of the total use of the total electricity demand. In addition, chillers are used in several process industries. Survey on chillers which has not been done so far. As per the sector experts and SLSEA audit findings, most chillers operating in the commercial sector are very old and have lower efficiencies which are not in an acceptable range. According to the experts in air conditioning sector, it is estimated that there are around 2,000 chiller units operating in Sri Lanka. But geographical distribution, capacity and other details of these units are unknown. Therefore, a survey is to be conducted to get a broad picture of the chiller population within the country and to document their capacities, age, efficiency etc. With this information, it is possible to calculate the total energy use of the chiller population and to predict the potential saving which could be achieved by replacing inefficient chillers with modern efficient units.

- **Important note 1:** We assure you the utmost confidentially of data which will be used for the survey purpose only. The data from individual factories/ commercial establishments will not be divulged to anyone and will be used in analysis only after aggregation with other factories/ commercial establishments.

Basic information

Name of the Industry/Company		
Address		
Contact Person	Name:	
	Position	
	Email:	
	Telephone:	
	District:	

Chiller information

Sector/Category	☐ Hotels ☐ Commercial ☐ Government ☐ Hospitals ☐ Industrial
Chillers	
Type	☐ Vapour Compressoin Chillers ☐ Vapour Absorption Chillers
	☐ Water Cool ☐ Air cool
Brand	
Model	
Capacity/Size (RT)	
Power (kW)	
Date of Manufacture	
Installation Date	
Refrigerants Type	
Compressor Type	☐ Reciprocating ☐ Scroll ☐ Screw ☐ Centrifugal

VFD availability	☐ Yes	☐ No
Availably of Service Provider	☐ Yes	☐ No
Water Treatment	☐ Yes	☐ No
Availability of previous audits	☐ Yes	☐ No
Service Provider Details		
Availably of Maintance Records	☐ Yes	☐ No
Availably of Name Plate Details	☐ Yes	☐ No
Name Plate Details		
Operating Time		
Operating Days per Week		
Operation Data & Other Comments (Set point temperature, Insulation, etc.)		

Cooling towers	
Brand	
Model	
No of Cooling Towers	
Power (kW)	1. 2. 3.
Capacity	1. 2. 3.
Installation Date	
Availably of Name Plate Details	☐ Yes ☐ No
Name Plate Details	
Operating Time	
Operating Days per Week	
Other Comments	

Pumps	
Brand	
Model	
Power (kW) & Head – Chilled water pump	1. 2. 3. 4.
Power (kW) & Head – Condenser water pump	1. 2. 3. 4.
Installation Date	
Operating Time	
Operating Days per Week	
Other Comments	

AHUs	
Brand	
Model	
No of AHUs	
Power (kW)	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.
Capacity	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.
Installation Date	
Availably of Name Plate Details	☐ Yes ☐ No
Name Plate Details	
Operating Time	
Operating Days per Week	
Other Comments	

FCUs	
Brand	
Model	
No of FCUs	
Power (kW)	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.
Capacity	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.
Installation Date	
Availably of Name Plate Details	☐ Yes ☐ No
Name Plate Details	
Operating Time	
Operating Days per Week	
Other Comments	

Field Observation & Special Remarks

WA Team Details

Names	
Interview date and time	

THANK YOU!

Chillers List for Walkthrough Audits

The Survey on Chillers

Submitted To:

Sri Lanka Sustainable Energy Authority

2023

No	Sector / Category	Name of the industry/ company	Capacity / Size (RT)	Installation Date
1	Commercial	Sriyani Dress Point - Kurunegala	110	2016
2	Commercial	Nadias - Kurunegala	110	2016
3	Commercial	LB Finance - Colombo 3	250	2011
4	Commercial	No Limit - Kegalle	125	2011
5	Commercial	House of fashion	250	2013
6	Commercial	House of fashion	250	2013
7	Commercial	K Zone - Jaela	250	2013
8	Commercial	Nolimit - Panadura	180	2013
9	Commercial	Nolimit - Wellawatte	180	2013
10	Commercial	SAITAM Malabe	150	2013
11	Commercial	Star Dust Club (Sri Lanka), Colombo 03	200	2013
12	Commercial	World Trade Centre	1000	2013
13	Commercial	World Trade Centre	1000	2013
14	Commercial	MGM Club, 772 ,Galle Road, Colombo 4	250	2015
15	Commercial	Sriyani Dress Point - Kegalle	130	2016
16	Commercial	Colombo City Center	450	2017
17	Commercial	Colombo City Center	450	2017
18	Commercial	Colombo City Center	450	2017
19	Commercial	Colombo City Center	600	2017
20	Commercial	Colombo City Center	600	2017
21	Hotels	Hilton Hotel	200	2007
22	Hotels	Amaya Hills Hotel	250	2012
23	Hotels	Kingsbury hotel (Ceylon Continental)	250	2012
24	Hotels	Bally's Club	250	2013
25	Hotels	Bellagio Club Colombo	250	2014
26	Hotels	Premier Fortune-Pasikuda	250	2014
27	Hotels	Aitken Spence Resort	250	2015
28	Hotels	Galadari Hotel	250	2015
29	Hotels	Negambo Beach Hotel	250	2015
30	Hotels	Anantara Peace Haven Tangalle Resort, Tangalle	250	2015
31	Hotels	Anantara Peace Haven Tangalle Resort, Tangalle	250	2015
32	Hotels	Ananthara - Kaluthara	200	2016
33	Hotels	Ananthara - Kaluthara	200	2016
34	Hotels	Shangrila -Colombo	150	2017
35	Hotels	Weerawila Resort	250	2017
36	Hotels	Weerawila Resort	250	2017
37	Hotels	Kaluwella Hotel	110	2017
38	Hotels	Kaluwella Hotel	110	2017

39	Hotels	Negombo Hotel- Greentech Systems	110	2017
40	Hotels	Negombo Hotel- Greentech Systems	110	2017
41	Hotels	Shangri-la, Hambanthota – Additional Chiller Project	600	2017
42	Hotels	Cinnamon Grand Colombo	600	2013
43	Hotels	Cinnamon Grand Colombo	600	2013
44	Hotels	Cinnamon Lakeside, Colombo	450	2013
45	Hotels	Cinnamon Lakeside, Colombo	450	2013
46	Government	CEB - Kelanitissa	600	2001
47	Government	Sri Lanka Catering (Private) Ltd	250	2003
48	Government	CEB - Sapugaskanda	250	2004
49	Government	Sri Lanka Parliement	900	2005
50	Government	Sri Lanka Parliement	900	2005
51	Government	Sri Lanka Insurance Corporation	250	2008
52	Government	Sri Lanka Insurance Corporation	250	2008
53	Government	Army Hospital, Narahenpita	250	2010
54	Government	Independence Arcade Square	250	2014
55	Government	Army Headquarters - Auditorium	600	2015
56	Government	BOC Merchants Tower	200	2015
57	Government	BOC Merchants Tower	250	2015
58	Government	Milagiriya-Office Complex	150	2016
59	Government	Milagiriya-Office Complex	200	2016
60	Government	Police Hospital	200	2017
61	Hospitals	Children's hospital, Kandy	150	2005
62	Hospitals	Children's hospital, Kandy	150	2005
63	Hospitals	National Blood Transfusion service	225	2006
64	Hospitals	Hemas Hospitals (Pvt) Ltd- Wattla	250	2008
65	Hospitals	Hemas Hospitals (Pvt) Ltd- Wattla	250	2008
66	Hospitals	National Hospital - Nurotrauma	155	2009
67	Hospitals	National Hospital - Nurotrauma	155	2009
68	Hospitals	Lanka Hospital	420	2011
69	Hospitals	Navy Hospital	250	2012
70	Hospitals	Army Hospital, Narahenpita	120	2013
71	Hospitals	Hemas Hospitals thalawathugoda	120	2013
72	Hospitals	Hemas Hospitals thalawathugoda	120	2013
73	Hospitals	Jayawardenapura Hospital	225	2013
74	Hospitals	Dental Institute	225	2015
75	Hospitals	Dental Institute	225	2015
76	Hospitals	Epilepsy Unit, The National Hospital of Sri Lanka	250	2015
77	Hospitals	Epilepsy Unit, The National Hospital of Sri Lanka	250	2015
78	Hospitals	Apeksha Hospital	200	2016
79	Hospitals	Apeksha Hospital	200	2016
80	Hospitals	Hambanthota Hospital	150	2016

81	Industrial	Lanka Milk Foods (CWE) Ltd	200	2007
82	Industrial	Ready wear Garment	250	2015
83	Industrial	Ceylon Beverage Can (Pvt) Ltd, Horana	200	2016
84	Industrial	Hettigoda Pvt Ltd	200	2016
85	Industrial	Mas Methliya	250	2016
86	Industrial	MAS Shadeline - Mahiyanganaya	250	2016
87	Industrial	Trischel Fabric (Pvt) Ltd	225	2012
88	Industrial	Brandix , Katunayake	250	2011
89	Industrial	Brandix Apparel Solution	250	2017
90	Industrial	Kelum life pvt ltd.	150	2020
91	Industrial	YKK lanka	150	2016
92	Industrial	MAS Synergy	400	2011
93	Industrial	TOS Lanka Pvt Ltd	150	2002
94	Industrial	Crescat	120	2021
95	Industrial	Camso Loadstar	120	2017
96	Industrial	CBL Foods- ASDA Engineering	160	2017
97	Industrial	Hemas Logistics	225	2017
98	Industrial	MELWA	250	2020
99	Industrial	Jay Jay Mills, Trinco	460	2021
100	Industrial	Cargills Dairies (Pvt) Ltd.	360	2017