Kingdom of Cambodia

Nation-Religion-King

Cambodia's National Cooling Action Plan

August 2022

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Acknowledgements

This National Cooling Action Plan (NCAP) was developed as a collaboration between the Department of Climate Change of the General Directorate of Policy and Strategy of the Ministry of Environment/ the National Council for Sustainable Development and the General Directorate of Environmental Protection (EPA) of the Ministry of Environment in collaboration with the United Nations Environment Programme (UNEP) and the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) in the context of the Cool Coalition, with technical support provided by the Alliance for an Energy Efficient Economy and Sustainable Energy for All. Financial support was provided by the Danish International Development Agency (DANIDA) and Energy Foundation China.

The NCAP is designed to realize Cambodia's long-term development vision in building a sustainable, green, clean, and low-carbon society based on climate-friendly and energy-efficient technology in the cooling sector. It is the first national strategic plan to establish an overarching national framework for inter-sectoral collaboration and multi-stakeholder participation for sustainable, climate-friendly, and energy-efficient development of the cooling sector that contributes to achieving the Sustainable Development Goals, the Paris climate agreement, and the Kigali Amendment to the Montreal Protocol.

The development of this NCAP has gone through numerous consultations and discussions with relevant ministries and stakeholders and includes invaluable contributions from both national and international consultants. I would, therefore, like to take this opportunity to express my sincere thanks to H.E. Mr. Chea Sina, Under Secretary of State and the EPA team for their leadership and commitment during the NCAP development process. I also appreciate Dr. Hak Mao, Director of the Department of Climate Change of the General Directorate of Policy and Strategy for his active engagement and insightful advice. My sincere thanks go to the United Nations Environment Programme (UNEP), the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) for providing both technical and financial support to make this action plan possible. I also appreciate the contributions and participation extended by key relevant stakeholders involved in the process.

Pak Sokharavuth
Director General
General Directorate of Environmental Protection
Ministry of Environment

Foreword

On behalf of the Ministry of Environment and the National Council for Sustainable Development, I would like to express my profound gratitude to **Samdech Akka Moha Sena Padei Techo Hun Sen**, Prime Minister of the Kingdom of Cambodia who has always provided strong support in transitioning Cambodia towards a green, low-carbon, and resilient society.

Cambodia has achieved remarkable progress in all key sectors. The economy has performed incredibly well over the last two decades with an average growth of 7% per annum, together with significant improvements in education, incomes, poverty reduction, and living standards. Notably, the country has advanced in the fight against COVID-19 pandemic. With economic and population growth, the demand for energy consumption in all key sectors has continued to increase. Undoubtedly, the demand for energy consumption in the cooling sector has increased due to increasing economic activities and social development.

In response to increasing demand for energy consumption and to reduce GHG emissions, there is an urgent need for the development of National Cooling Action Plan (NCAP). The plan is designed to realize Cambodia's long-term development vision in building a sustainable, green, clean, and low-carbon society based on climate-friendly and energy efficient technology in cooling sector. It serves as an overarching national framework for inter-sectoral collaboration and multi-stakeholder participation for the development of cooling sector, which will contribute to achieving Sustainable Development Goals, Paris Climate Agreement, and the Kigali Amendment. The successful implementation of the NCAP is expected to contribute to the total savings potential from all the cooling sectors in 2040 of 2,075 GWh which represents a 23% savings from the consumption projected under the BAU scenario. The electricity savings from building space cooling are expected to be 1,223 GWh (59% of the total savings), food cold chain is projected to be 632 GWh (32% of the total savings), while process cooling is expected to be 221 GWh (11% of the total savings).

I wish to take this opportunity to thank H.E. Mr. Chea Sina, Under Secretary of State, H.E. Mr. Pak Sokharavuth, Director General of the General Directorate of Environmental Protection, and their team members for leadership, guidance, and facilitation during the process of the development of the NCAP. I also wish to appreciate Dr. Hak Mao, Director of the Department of Climate Change of the General Directorate of Policy and Strategy for his active engagement and insightful advice.

My sincere thanks also go to our collaborative partners for their contribution to the development of this important document, including the United Nations Environment Programme (UNEP), the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) with technical support by the Alliance for an Energy Efficient Economy (AEEE) and Sustainable for All (SE4ALL) and financial assistance from Danish International Development Agency (DANIDA) and Energy Foundation China (EFC).

I also appreciate the contributions and participation extended by key relevant stakeholders involved in the process.

Say Samal
Minister of Environment
Chair of the National Council for Sustainable Development

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Acronyms and Abbreviations

°C	Degrees Celsius
BAU	Business as Usual
BREEAM	Building Research Establishment Environmental Assessment Method
CCCSP	Cambodia Climate Change Strategic Plan
CFCs	Chlorofluorocarbons
CO_2	Carbon dioxide
CSDGs	Cambodian Sustainable Development Goals
EPA	General Directorate of Environmental Protection
ERIA	Economic Research Institute for ASEAN and East Asia
F-gases	Fluorinated gases
GDE	General Department of Energy
GDP	Gross domestic product
GHG	Greenhouse gas
GSSD	General Secretariat of the National Council for Sustainable Development
GWh	Gigawatt-hour
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
MEPS	Minimum energy performance standards
MLUMPC	Ministry of Land Management, Urban Planning and Construction
MVE	Monitoring, verification and enforcement
NCAP	National Cooling Action Plan
NCSD	National Council for Sustainable Development
NDC	Nationally Determined Contribution
tCO_2	Ton of carbon dioxide
U4E	United for Efficiency

Executive Summary

The cooling sector in Cambodia is expected to expand rapidly due to economic and population growth. The country's population has increased from 14.3 million inhabitants in 2010 to 16.7 million in 2020, and the Gross Domestic Product (GDP) has increased nearly 2.5 times over the same period. Cooling is used in diverse sectors of the economy to provide essential services related to thermal comfort in buildings, cold storage along agricultural and food supply chains, the storage and transfer of vaccines and other medical products, transport, and industrial processes.

Delivering cooling services often relies on mechanical systems that consume large amounts of electricity, increase peak loads on the electricity grid and use refrigerant gases that are harmful for the environment. Cooling systems that use electricity generated from fossil fuels contribute to Greenhouse Gas (GHG) emissions, and emissions intensities are higher when the systems are inefficient. Due to the increased use of ozone-depleting substances, the cooling sector has contributed greatly to ozone depletion and is also directly emitting GHGs, as the Global Warming Potential (GWP) of these substances is often very high.

In Cambodia, the cooling sector consumed a total of 4,738 gigawatt-hours (GWh) of electricity in 2020, and this is expected to nearly double to 8,944 GWh1[1] by 2040 in the absence of significant action towards sustainable cooling. National refrigerant consumption for all cooling sectors totalled 1,226 Metric tons (Mt) in 2020 and is based on products with high GWP as well as some ozone-depleting substances, such as hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs). The annual GDP loss due to heat stress in Cambodia is in the range of an estimated US$1.12 billion to $1.26 billion, and the loss of crops and produce from broken links or a lack of infrastructure in the food cold chain is significant. The cooling sector contributed 6.27 million tons of carbon dioxide (CO_2) equivalent emissions in 2020.

Space cooling in buildings was responsible for 37 per cent of total cooling sector emissions, followed by mobile air conditioning at 30 per cent and process cooling at 27 per cent. Total cooling emissions are expected to increase 1.8 times by 2030 and 2.7 times by 2040 from 2020 levels.

Addressing Cambodia's rising cooling demand requires a comprehensive approach where cooling loads are reduced to the extent possible. This can occur first through efficient building design and construction, passive cooling practices and improved urban planning. The next step is to serve cooling loads efficiently through energy-efficient and climate-friendly cooling equipment and solutions across cooling subsectors. Finally, there is a need to optimize cooling operations and behaviours, for example through good operations and maintenance practices, user adaptations, etc., to ensure that cooling is delivered only where and when it is needed.

In response to this challenge, the Department of Climate Change of the General Directorate of Policy and Strategy of the Ministry of Environment/ the National Council for Sustainable

[1] As per the NCAP's business-as-usual (BAU) scenario.

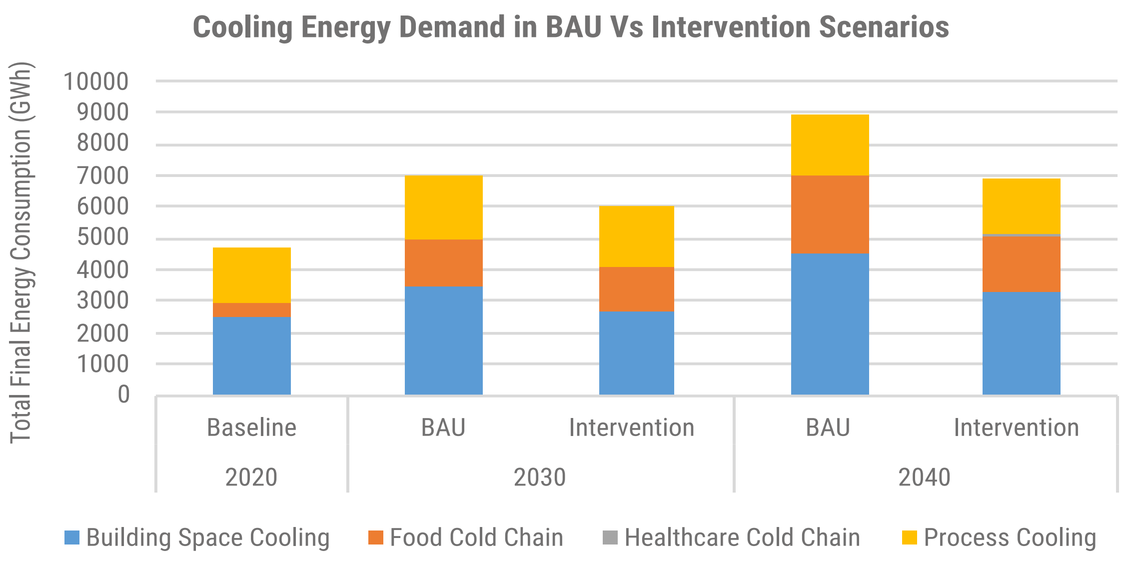
Development (NCSD) and the General Directorate of Environmental Protection (EPA) of the Ministry of Environment (MoE) partnered with the United Nations Environment Programme (UNEP) and the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) in the context of the Cool Coalition to develop this National Cooling Action Plan (NCAP) for Cambodia. The development of this NCAP is also in alignment with Cambodia's 2020 Updated Nationally Determined Contribution (updated NDC), where the country committed to the development and implementation of an NCAP.

The aim of the NCAP is to pave the way for a transition towards climate-friendly cooling by reducing cooling demand, improving the energy efficiency of appliances and promoting low-GWP refrigerants to help reduce GHG emissions. The NCAP also would enable policymakers to send market signals and to create favorable conditions for a streamlined transformation that provides investment security to producers and end users, while maximizing preparation for anticipated future requirements.

The NCAP focuses on five main areas: 1) Building Space Cooling, 2) Food Cold Chain, 3) Health-care Cold Chain, 4) Mobile Air Conditioning, and 5) Process Cooling. The interventions under the NCAP are divided into three main periods: the short term (5 years), medium term (10 years), and long term (20 years). *(Please see the comprehensive set of interventions outlined in Table 10 in Section 9.)*

The NCAP analysis indicates that the total savings potential from all cooling sectors in 2040 under an intervention scenario is an estimated 2,075 GWh, which represents a 23 per cent savings from the consumption projected under the business-as-usual (BAU) scenario. The electricity savings potential from building space cooling is expected to be 1,223 GWh (59 per cent of the total savings), from food cold chain to be 632 GWh (30 per cent) and from process cooling to be 221 GWh (11 per cent).2[2] Figure 1 shows the energy demand projections by sector calculated under the NCAP analysis.

Figure 1. Electricity demand for cooling in 2020 and under the two scenarios, 2030 and 2040



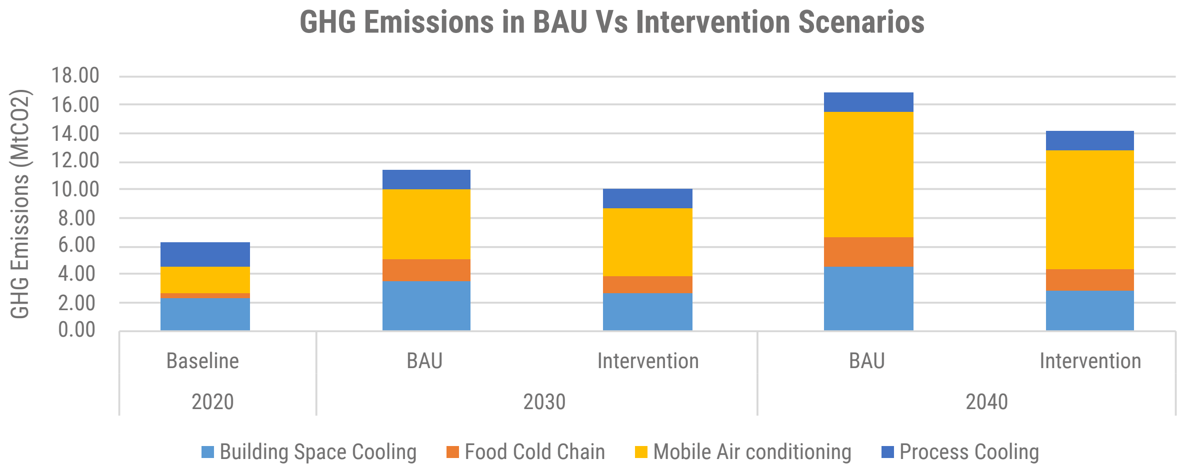
Source: Authors, NCAP Assessment

[2] The MAC was not considered in the electricity potential savings analysis

The refrigerant transition plan of Cambodia's National Ozone Unit aims to eradicate the use of HCFC-22 and other HCFCs by 2030. With the country's ratification of the Kigali Amendment to the Montreal Protocol, more emphasis will be placed on introducing alternative refrigerants with low and ultra-low GWP. Under the projected trend in the BAU scenario, low and ultra-low refrigerants will dominate the market in 2040 with a 51 per cent share.

Under the Intervention scenario, as proposed in the NCAP, a combined reduction of 54 per cent in HFC consumption could be achieved by 2040 in the cooling sector, accelerating the Kigali Amendment schedule[3]. The NCAP proposed combined actions – including passive cooling measures and the use of low-GWP refrigerants coupled with efficiency improvements – are expected to have a 17 per cent emissions reductions potential by 2040 compared to the 2020 baseline. The buildings sector followed by food cold chain are the cooling sectors that can contribute most in achieving the emissions reductions goals, as shown in Figure 2.[4]

Figure 2. **Greenhouse gas emissions from cooling in 2020 and under the two scenarios, 2030 and 2040**



Source: Authors, NCAP Assessment

The NCAP proposes a multi-pronged approach towards meeting a country's cooling demand. This includes the following measures:

- Reduce cooling demand, and where possible the need for mechanical cooling, through better urban planning and building design, and the use of nature-based solutions such as green public spaces and green roofs and walls;
- Shift towards renewables-based cooling, district cooling approaches, solar-powered cold chains, etc.;
- Improve conventional cooling by increasing the efficiency of air conditioning and refrigeration equipment and demand response measures; and
- Protect vulnerable people from the effects of extreme heat and the consequences of unreliable medical and agricultural cold chains.

[3] The Kigali Amendment requires a 50 per cent phase-down of HFC consumption by 2040 compared to the baseline year for Article 5 countries in Group 1, such as Cambodia.

[4] Healthcare cold-chain was not included in the graph as the consumption estimated with the available data was very low in comparison.

TIn addition, countries should continue to pursue pathways to phase down HFCs where necessary.

The proposed NCAP interventions reflect the measures outlined in Cambodia's updated NDC for better addressing cooling demand, including enhancing minimum energy performance standards (MEPS), implementing passive cooling measures in cities and in public and commercial buildings, transitioning away from fluorinated gases (F-gases) in all cooling sectors, and supporting sustainable cooling for the food and beverage industries, among others. These interventions would contribute to reducing GHG emissions, improving living conditions, improving storage for vaccines and food supply, and saving energy costs, among other benefits.

1. Introduction and Background

We are living in an increasingly warming world. The seven-year period from 2014 to 2020 was the hottest in 140 years of records, reflecting an ongoing and dramatic warming trend (National Aeronautics and Space Administration 2021) and signaling the rising impact of greenhouse gas (GHG) emissions on Earth's climate. As populations continue to grow – predominantly in the tropics – and as countries urbanize rapidly, the impact of global warming is driving a rising demand for cooling services.

The cooling sector plays a crucial role in economic activity and in people's daily lives, from the need to cool down commercial and residential buildings and industrial processes, to transport, health care, the food chain and others. Cooling is important to keep children healthy, vaccines stable, food nutritious, energy supply stable, economies productive and the environment clean. The urban heat-island effect – commonly observed in densely populated cities – exacerbates the heat waves from climate change in the urban environment. The urban heat-island effect puts populations that lack access to cooling in buildings under the risk of heat exposure, with negative impacts on their health and productivity. Research shows that the world's cities are heating up at twice the global average rate due to the urban heat-island effect (Cool Coalition et al. 2021; World Bank 2021).

Southeast Asia is experiencing significant urbanization. In 2000, 35 per cent of the region's population lived in urban areas; by 2020, the urban share had risen to 50 per cent. In Cambodia, the average penetration rate for cooling equipment was an estimated 2 per cent in 2017, and energy consumption for comfort cooling in the country's hot-humid climate is likely to increase as the economy grows steadily. More than one-third of the total final energy consumption in Cambodia occurs in buildings, and space cooling accounts for the largest share of electricity use in building operations.

Cambodia's economy has been growing at an average annual rate of 7.7 per cent, driving the increase in energy use. Electricity consumption is forecast to more than triple between 2015 and 2030. Meanwhile, Cambodia's updated Nationally Determined Contribution (NDC) sets a target for a 40 per cent reduction in energy-related GHG emissions by 2030 compared to a business-as-usual (BAU) scenario (Ministry of Land Management, Urban Planning and Construction-MLMUPC 2021). Buildings are a priority sector, with the target to achieve 25 per cent energy savings through energy efficiency measures.

Globally, the use of ozone-depleting substances in refrigeration and air-conditioning applications made it possible to meet rising demand for cooling for many decades; however, this led to severe ozone depletion. Consumption and production of these substances is now largely under control as result of numerous measures introduced under the 1985 Vienna Convention for the Protection of the Ozone Layer (which entered into effect in 1988) and the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (which entered in effect in 1989), with universal ratification in 2009 (United Nations Environment Programme-UNEP 2020a).

Ozone-depleting substances, particularly chlorofluorocarbons (CFCs), have been fully replaced with non-ozone-depleting substances, particularly hydrofluorocarbons (HFCs). This resulted in a 14 per cent decline in the total atmospheric chlorine concentration by 2016 (compared to the 1993 level) and in ozone layer recovery of around 3 per cent per decade since 2000 (at above 40-kilometres altitude in the northern mid-latitude and upper stratosphere) (UNEP 2020a; World Meteorological Organization-WMO 2018). However, replacing CFCs and HCFCs with HFCs has led to an increase of the latter in the atmosphere. According to the WMO (2018), HFC emissions rose 23 per cent between 2012 and 2016, accounting for around 1.5 per cent of total emissions of long-lived GHG (measured in carbon dioxide (CO_2) equivalents).

Although HFCs are not ozone-depleting substances, they are potential GHG. Although HFCs and other fluorinated gases (F-gases) currently contribute only a small share of total global greenhouse gas emissions, their global warming potentials (GWPs) are much higher than for CO_2 (Intergovernmental Panel on Climate Change 2014). For example, HFC-23 has the highest 100-year GWP, of 12,690, compared to the CO_2 molecule (WMO 2018). In 2016, the Kigali Amendment to the Montreal Protocol laid out the latest control measures to phase down HFCs, which are used primarily as refrigerants. Improving the energy efficiency of cooling equipment could potentially avoid an estimated 260 billion tons of CO2-equivalent emissions and save around $3 trillion in energy generation and transmission costs (UNEP and International Energy Agency 2020).

The Royal Government of Cambodia ratified the Kigali Amendment in April 2021. As a party to the Montreal Protocol, Cambodia is required to freeze and phase down HFCs 80-85 per cent by the late 2040s (United Nations Development Programme-UNDP n.d.). Developed countries were expected to freeze HFC consumption by 2019, followed by developing countries in 2024 and 2028 (UNDP n.d.).

In her updated NDC, Cambodia commits to developing and implementing a National Cooling Action Plan (NCAP), which aims to freeze and phase down HFCs (GSSD / MoE, 2020). The interventions outlined in the updated NDC for F-gas reductions include enhancing minimum energy performance standards (MEPS), implementing passive cooling measures in cities and in public and commercial buildings, transitioning away from F-gases for air conditioners and refrigerants in residential and commercial buildings, and supporting sustainable cooling for the food and beverage industries, among others. These interventions would contribute to reducing GHGs, improving living conditions, improving storage for vaccines and food supply, and saving energy costs, among other benefits.

There is a need to collaborate on science, policy, finance and technology to meet growing demands for cooling in a comprehensive manner. These efforts should be aimed at raising climate ambition in the context of the UN Sustainable Development Goals while complementing the goals of the Kigali Amendment and the Paris Agreement. To achieve the intended goals, a multi-pronged approach is required, with key features such as:

- Reduce cooling demand, and where possible the need for mechanical cooling, through better urban planning and building design and the use of nature-based solutions such as green public spaces and green roofs and walls;
- Shift towards renewables-based cooling, district cooling approaches, solar-powered cold chains, etc.;
- Improve conventional cooling by increasing the efficiency of air conditioning and refrigeration equipment and demand response measures; and
- Protect vulnerable people from the effects of extreme heat and the consequences of unreliable medical and agricultural cold chains.

The purpose of the NCAP of Cambodia is to provide a clear pathway and actions to be taken for the phase-down of HFCs, in order to ensure sustainable cooling and maintain socio-economic development, human health, and well-being while protecting the environment through efficient and climate-friendly cooling technology. The NCAP focuses on five main areas: 1) Building Space Cooling, 2) Food Cold Chain, 3) Health-care Cold Chain, 4) Mobile Air Conditioning, and 5) Process Cooling. The interventions under the NCAP are divided into three main periods: the short term (5 years), medium term (10 years) and long term (20 years).

Given the significant and growing energy consumption in the country, controlling these cooling sectors is necessary. Effective and impactful measures in the cooling sectors would reduce cooling demand and sustain Cambodia's economic development, helping to build a sustainable, green, clean and low-carbon Cambodian society.

This NCAP is divided into 10 main sections, as follows:

Section 1 (Introduction and Background) provides a brief background on global trends in CFC and HFC consumption in refrigeration and air conditioning, on the potential contribution of HFCs to global warming, and on Cambodia's NDC and NCAP.

Section 2 (National Cooling Action Plan Framework) provides the overall framework of the NCAP and definitions of the cooling sector.

Section 3 (Regulatory Framework, Relevant Policies and Projects) provides brief summaries of some of the key legal instruments relevant to Cambodia's cooling sector.

Section 4 (Implementation Framework and Governance) elaborates the data collection process and analysis for the NCAP, which involves literature review and consultations with key stakeholders.

Section 5 (Overview of Cooling in Cambodia) provides data on the drivers of cooling and climatic conditions in Cambodia, as well as on access to cooling and the population at risk.

Section 6 (Cooling Demand Assessment) presents the results from assessment in the areas of cooling demand, electricity consumption, refrigerant consumption, and GHG emissions.

Section 7 (Cooling Demand Assessment of Individual Cooling Sectors) presents the results from Cambodia's five main cooling sectors: Building Space Cooling, Food Cold Chain, Health-care Cold Chain, Mobile Air Conditioning, and Process Cooling.

Section 8 (NCAP Recommended Strategic Actions) proposes key interventions – ranging from the regulatory and policy framework to technological change and market instruments – in the short, medium and long terms.

Section 9 (NCAP Recommended Strategic Actions: Summary of Interventions) provides a tabular summary of the proposed interventions.

Section 10 (Monitoring and Evaluation) provides an overarching framework for implementation, monitoring and evaluation of the NCAP.

Aims: Cambodia's National Cooling Action Plan (NCAP) aims to support existing efforts and commitments of the Royal Government of Cambodia towards the Vienna Convention, the Montreal Protocol, the Paris Agreement and the Sustainable Development Goals. The NCAP is developed following the needs of Cambodia to enhance energy efficiency and promote energy security for the purpose of economic development and achieving the country's targets for reducing GHG emissions.

Vision: To realize Cambodia's long-term development vision in building a sustainable, green, clean, and low-carbon society based on climate-friendly and energy-efficient technology in the cooling sector.

Mission: To establish an overarching national framework for inter-sectoral collaboration and multi-stakeholder participation for sustainable, climate-friendly, and energy-efficient development of the cooling sector in Cambodia that contributes to achieving the Sustainable Development Goals, the Paris Agreement, and the Kigali Amendment.

Goals:

- Propose policy, regulatory and actual interventions for climate-friendly and energy-efficient practices;
- Enhance climate-friendly and energy-efficient technologies and practices;
- Explore and develop market mechanisms for accessible and affordable cooling technologies;
- Build stakeholder capacities and promote public awareness and stakeholder engagement on energy efficiency in the cooling sector;
- Contribute to a combined reduction in direct and indirect GHG of 12 per cent in 2030 and 17 per cent in 2040 as compared to the Business-As-Usual (BAU); and
- Reduce total electricity consumption in the cooling sector of 14 per cent by 2030 and of 20 per cent by 2040 as compared to the NCAP BAU projection.

Strategic Objectives

To achieve the above aims, vision, mission, and goals, the NCAP proposes five strategic objectives:

Strategic Objective 1: Develop/amend policies and regulations to address the national cooling demand more sustainably and enhance the adoption of climate-friendly and energy-efficient technologies and practices.

Strategic Objective 2: Strengthen national institutional capacities for policy implementation and regulation enforcement, monitoring and evaluation.

Strategic Objective 3: Develop incentives and promote market mechanisms to accelerate the transition to climate-friendly, energy-efficient cooling solutions.

Strategic Objective 4: Strengthen collaboration among government institutions, development partners, civil society, the private sector and other key stakeholders.

Strategic Objective 5: Promote public awareness on sustainable cooling in all sectors.

2. National Cooling Action Plan Framework

2.1 NCAP Development Process

The NCAP development process started in September 2020 and was completed in August 2022. As shown in Table 1, the NCAP development involved three main stages: Stage 1 – Contextual Assessment and Planning (September to October 2020), Stage 2 – Cooling Demand Assessment (October 2020 to June 2021) and Stage 3 – Synthesis and NCAP Creation (June 2021 to April 2022).

- Stage 1 involved country mapping and NCAP planning (which required collecting high-level data to set the context and guide data collection for the sectors) and determining the scope and extent of the NCAP, with a focus on country-specific priority areas and on understanding the socio-economic implications. This foundational stage helped inform the priorities of the NCAP specific to the country and guide the overall planning process, in addition to establishing key stakeholders for development of the NCAP.

- Stage 2 focused on sectoral data collection, analysis and interventions. Sectoral data cover space cooling in buildings, cold chain and refrigeration (for food and health care), mobile air conditioning and industrial process cooling. Data analysis and interventions involved combining results, defining the met/unmet national demand, projecting the demand growth, developing a scenario of ambitious policies for comparison purposes, and identifying suitable and impactful policy interventions.

- Stage 3 involved integrating the findings and recommendations into the NCAP draft, which was reviewed by experts and an inter-ministerial working group. Stage 3 started with developing and prioritizing recommendations, mapping the expected impacts, validating with the working group, consulting with experts, preparing the draft, review of the draft by the Steering Committees and working group, revising the draft and submitting it for final approval.

Table 1. Stages of the NCAP development process

Stage I. Contextual Assessment and Planning	Country Mapping and NCAP Planning	September –October 2020	Established the NCAP coordinating entity and national technical committee. Collected high-level data to develop the cooling landscape and understand socio-economic implications. Determined the scope of the NCAP and country-specific priority areas.
Stage 2. Cooling Demand Assessment	Sector Data Collection	October 2020 – March 2021	Carried out capacity-building on the NCAP data frameworks and development of the data collection templates. Completed data collection through research, stakeholder outreach and interviews led by the NCAP coordinating entity.
	Sector data analysis and interventions	March – May 2021	Combined data results and defined the met/unmet national demand. Built cooling demand and greenhouse gas emissions projection scenarios for BAU and an Intervention case. Identified suitable and impactful policy interventions.
Stage 3. Synthesis and NCAP Creation	NCAP integration and final recommendations	May – July 2021	Integrated and prioritized NCAP recommendations. Mapped the expected impact of NCAP recommendations. Validated through consultations with experts.
	NCAP draft and review	May – November 2021	Completed contextual and methodological chapters. Completed policy recommendations chapter. Revised based on reviews by Technical Committee and partners. Submission for approval.

The stakeholders and institutional structure for the NCAP development process are outlined in Table 2.

Table 2. Stakeholders for the NCAP development process

Stakeholder Category	Description
Government Lead Entities	• Department of Climate Change of the General Directorate of Policy and Strategy, Ministry of Environment/ the National Council for Sustainable Development • General Directorate of Environmental Protection (EPA) of the Ministry of Environment
NCAP Technical Assistance Team	• United Nations Environment Programme • United Nations Economic and Social Commission for Asia and the Pacific • Alliance for an Energy Efficient Economy • Sustainable Energy for All
Government Entities	• General Directorate of Policy and Strategy (then General Secretariat of the National Council for Sustainable Development) • Department of Renewable Energy and Other Energies, Ministry of Mines and Energy • National Ozone Unit, Ministry of Environment • Ministry of Foreign Affairs and International Cooperation • Ministry of Public Works and Transport • Ministry of Land Management, Urban Planning and Construction • Ministry of Labour and Vocational Training • Department of Technical Affairs and Public Relation, Ministry of Commerce • Department of Hazardous Management, Ministry of Environment • Department of Inspection and Law, Ministry of Environment • Department of Water Quality Management, Ministry of Environment • Department of Solid Waste Management, Ministry of Environment • Ministry of Industry, Science, Technology, and Innovation
Researchers and Analysts	• Laboratory, Ministry of Environment • Royal University of Phnom Penh
Private Sector, International Partners and Industry	• United Nations Development Programme • Industry associations related to equipment manufacturing and refrigerant companies

2.2 Cooling Sector Definitions

- Building Space Cooling: Building space cooling provides thermal comfort to building occupants, improving their health and well-being, while enhancing their productivity. Energy consumption for building space cooling is dominated by refrigerant-based direct-expansion air-conditioning systems. This energy demand can be reduced through the integration of efficient urban planning, passive cooling systems, low-energy non-refrigerant-based cooling, not-in-kind (NIK) technologies, efficient service practices for refrigerant handling and the use of intelligent controls. For the building space cooling sector in Cambodia, the analysis considered data on room air conditioners (both fixed-speed and inverter technologies), chillers (centrifugal type), variable refrigerant flow systems and fans.

- Food Cold Chain: Cold chain is a chain of logistics to deliver perishable products to distant markets, thus empowering producers by expanding their market reach. The cold chain involves control of environmental parameters such as temperature, humidity and air composition, preconditioning, packaging, pre-cooling and dispatch through refrigerated vehicles to terminal markets/distributions hubs to extend the product's life cycle and safeguard its nutrient quality. This use sector includes cooling requirements for ice cooling for fisheries, bulk storage, and pack houses, dairies, and refrigerated trucks, as well as domestic and commercial refrigerators. For the food cold chain sector in Cambodia, the analysis considered data on ice cooling (fishing), cold storage (bulk/hub), ripening chambers, transport, domestic refrigerators and domestic freezers.

- Mobile Air Conditioning: Mobile air conditioning caters to passengers' comfort cooling requirements in light-duty vehicles, heavy-duty vehicles, trucks, buses and trains. It uses refrigerant-based vapour compression technology to remove heat and moisture from inside the cabin to outside. For the mobile air-conditioning sector in Cambodia, the analysis considered data on light- and heavy- duty vehicles and truck passenger cooling.

- Health-care Cold Chain: Health-care cold chain consists of a chain of storage and transport to ensure that vaccines and other health-care products (including blood products and medicines) are kept at the manufacturer's recommended temperature until they reach the targeted beneficiary. It involves controlled environmental storage and packaging to extend the vaccine's life cycle and safeguard its quality as per the World Health Organization and national government recommended protocols. For the health-care cold chain sector in Cambodia, the analysis considered only data related to vaccine refrigerators and ice-lined refrigerators.

- Process Cooling: Process cooling includes any cooling solution deployed for 1) making a product through physical, chemical, biological processes or a combination of these processes, or 2) controlling temperature and humidity for the desired functioning of electronic or mechanical or electromechanical systems. Examples of applications for process cooling include data centres and pharmaceutical, textile, plastic, chemical and detergent industries. For process cooling in Cambodia, the analysis considered predominantly data obtained for screw chillers and scroll chillers in 2020.

3. Regulatory Framework, Relevant Policies and Projects

A wide range of laws, policies, plans, and strategies on Cambodia's cooling sectors either exist or are being drafted. The followings are brief summaries of some of the key legal instruments.

- Rectangular Strategy for Growth, Employment, Equity and Efficiency 2019-2023 – This guiding policy for inclusive and sustainable national development stresses the need to intensify efforts to reduce the impacts of climate change by strengthening adaptation capacity and resiliency to climate change, and to contribute to global GHG emissions reductions (RGC 2018a).

- National Strategic Development Plan 2019-2023 – The Plan emphasizes the need to decarbonize the economy to combat climate change, and to sustainably manage natural resources, in order to achieve sustainability and stability of Cambodia's economic growth and development. Environmental issues, including climate change, are cross-cutting and require close collaboration among government agencies (at the national and sub-national levels), the private sector and all stakeholders (RGC 2019a).

- Cambodian Sustainable Development Goals (CSDGs) Framework 2016-2030 – The CSDGs Framework provides an overarching framework and guidance for national policy formulation and implementation monitoring. It places high emphasis on leaving no one behind, ensuring that all Cambodians share equally the fruits of future development and prosperity in which national economic growth is maintained, while abundant natural capital is protected for current and future generations, and efforts to combat climate change are continuously made. The CSDGs are integrated into policymaking, planning, budgeting, and implementation and monitoring (RGC 2018b).

- Cambodia's Updated Nationally Determined Contribution (updated NDC) – The updated NDC represents the Royal Government of Cambodia's commitment to combating climate change. It embraces Cambodia's ambitious targets to reduce greenhouse gas emissions around 42 per cent from business as usual by 2030, in which energy becomes the second largest sector, playing a key role in achieving the target. Cooling has among the highest consumption in the energy sector. Key measures for reducing energy consumption and greenhouse gas emissions are: energy efficiency improvements, sustainable energy practices, transitioning F-gases in room cooling and refrigeration, passive cooling in commercial and residential buildings and in public spaces and transport, and enhanced minimum energy performance standards (Table 3). Development of the NCAP would not only increase energy efficiency, but also help to reduce greenhouse gas emissions from the energy sector and to reach the updated NDC targets.

Table 3. **NDC actions related to cooling**

- Urban planning tools for climate change mitigation and urban planning solutions in three secondary cities.
- Application of electrical equipment labelling and MEPS (lighting, cooling and equipment) – Reduce 1.2 TWh (29.7%) of electricity use by 2030.
- Improvement of process performance of energy efficiency by establishing energy management in buildings.
- Public awareness campaigns and energy efficiency information centres – Reduce energy consumption 2% by 2030.
- Building codes and enforcement/certification for new buildings and those undergoing major renovation – Reduce electricity consumption 10% by 2030.
- Climate-friendly cooling of public sector buildings – Reduce 0.04 million tons of CO_2 equivalent per year, transform Battambang city into a green city; integrate 5 Sangkats of Battambang municipality into a green city by 2025.
- Implementation of National Cooling Action Plan – Enhanced MEPS and F-gas transition for room air conditioners and residential refrigerators, targeting new and existing equipment stock in the country.
- Inclusion of performance requirements of passive cooling systems in the Building Energy Code of Cambodia – 20% of newly constructed buildings to comply with the Building Energy Code.
- Implementation of passive cooling measures in cities (addressing the urban heat-island effect) and public buildings and commercial buildings – Analyse the cities of Phnom Penh and Siem Reap for mitigating the urban heat-island effect and retrofit 2% of the existing public and commercial buildings with passive cooling measures.
- Integration of climate change response measures into the construction design for buildings and rural housing (use of modern integration of technology).
- Develop resilient infrastructure of school buildings in response to climate change.
- Implement climate change and disaster-resilient construction and infrastructure standards, including for public sector and community-focused buildings covering public health, education, and water, sanitation and hygiene, etc.
- Promote land-use planning tools for urban houses and building construction adaptive to climate change benefits for low-income and unhoused people.
- Develop building code that includes mainstreaming climate change into building designs.

- Cambodia Climate Change Strategic Plan (CCCSP) 2014-2023 – The CCCSP was developed to address increasing threats from climate change to the economic development and well-being of the Cambodian people. The CCCSP's vision is to navigate Cambodia's development towards a green, low-carbon, climate-resilient, equitable, sustainable and knowledge-based society. One of the strategic objectives is to promote low-carbon planning and technologies to support sustainable development. The development of the NCAP will provide support to this strategic objective through the deployment of low-carbon technology in the cooling sector. The ultimate goal of the NCAP is to provide recommendations to adopt more energy-efficient technologies, specifically low-carbon technologies, which will reduce greenhouse gas emissions (National Climate Change Committee 2013).

- National Strategic Plan on Green Growth (NSP) 2013-2030 – The NSP was formulated to boost Cambodia's shift towards a green economy, taking into account the efficient use of environmental resources and green job creation. Among the strategic directions outlined in the NSP, green investment and green job creation have a direct link to the development of the NCAP. In this strategic direction, green building and construction are encouraged to adopt renewable energy, energy savings and energy efficiency, water savings, and green and clean development. Green building and energy efficiency are particularly related to the need to introduce energy-efficient cooling equipment. The development of the NCAP will uphold the strategic vision envisaged in the NSP (National Council on Green Growth 2013).

- Draft National Energy Efficiency Policy 2018-2035 – The policy was developed to respond to the rise in energy demand as the country develops. A main goal of the policy is to increase the transfer and adoption of energy-efficient technology to reduce energy intensity. The policy aims to reduce energy use in industries and buildings by 25 per cent. A high urbanization rate and improvements in income and living standards have stimulated the consumption of cooling equipment including air conditioning and refrigerators, which led to increasing energy demand. The Draft National Energy Efficiency Policy and the NCAP will complement each other in addressing greenhouse gas emissions from the energy sector and the increased use of electrical appliances in buildings (RGC 2017).

- Draft Sub-decree on Energy Efficiency Standards and Labelling for Electrical Appliances and Equipment – Drafted by the Ministry of Mines and Energy, the goal of the sub-decree is to manage energy consumption and improve energy efficiency by implementing minimum energy performance standards and energy efficiency labelling on regulated electrical appliances and equipment. The sub-decree will prevent the import of electrical appliances and equipment that do not comply with MEPS. Once the sub-decree is put into practice, it would allow only highly efficient electrical appliances and equipment to be installed in buildings, which would reduce energy consumption in the buildings sector. In the long run, introducing this sub-decree in the buildings sector will offer economic benefits through energy savings, contribute to lower greenhouse gas emissions and help achieve Cambodia's climate change mitigation targets (RGC 2020).

- Energy Efficiency and Conservation Master Plan of Cambodia – The Plan was developed in 2020 by the General Department of Energy of the Ministry of Mines and Energy with support from the Economic Research Institute for ASEAN and East Asia (ERIA). The master plan focuses on five programmes and policies: 1) energy service companies, 2) growth in energy managers, 3) a standard and labelling system, 4) education and campaigns, and (5) preparation of energy efficiency indicators. The cooling sector would be part of the standard and labelling system. Consumers in Cambodia mainly pay attention to capacity and prices when buying electrical appliances such as air conditioners and refrigerators; most consumers are not aware of the energy efficiency level. Therefore, the implementation of energy labelling and standards on electrical equipment is particularly important for energy saving, as well as lowering greenhouse gas emissions. The master plan also proposed a detail road map for setting up MEPS and an energy labelling system (Ministry of Mines and Energy and ERIA 2020).

- Construction Law – The law, which officially entered into force in 2019, sets the guiding principles for the regulatory framework of the construction sector. The law also identifies the construction materials, equipment or products that are required to bear the Cambodia Standards mark or to have accreditation or compliance certification with building technical regulations. In addition, the law highlights building efficiency and green building concepts that ensure green development, natural resource and environmental protection; construction quality, security and safety; and the protection of property and well-being of construction. Incorporation of minimum energy efficiency standards in the regulation is necessary to avoid "locking in" an inefficient built environment. In Cambodia, building projects of less than 3,000 square metres in total floor area require a construction permit from the provincial and municipal administration, while larger developments are approved by the Ministry of Land Management, Urban Planning and Construction (MLUMPC) (RGC 2019b).

- Draft NDC Roadmap for Low-Carbon, Climate-Resilient Buildings and Construction in Cambodia, Vision to 2050 – The roadmap is formulated "to support MLMUPC and the RGC in further raising the climate ambition in this sector, in line with the country's updated NDC target to increase economy-wide mitigation targets and implementation by 2025". It aims to provide a holistic approach to transform the sector by covering eight activity areas identified by the Global Alliance for Buildings and Construction through its Regional Roadmap for Building and Construction in Asia. These areas are: "urban planning, new buildings, existing buildings (retrofits), building operations, systems and appliances, materials, resilience and clean energy" (MLUMPC 2021).

4. Implementation Framework and Governance

The NCAP will be implemented by the existing Inter-sectoral Working Group for the Implementation of Conventions, Protocols, and International Agreements related to Environmental Protection, established by the Declaration of the Ministry of Environment, No. 245 Prokor, Bor. Stor. dated 14 December 2020. The Working Group is chaired by a representative of the Ministry of Environment with membership from representatives of 13 ministries, 2 national councils, 1 public university and 1 institute, as detailed in Table 4.

The Secretariat of the Working Group is based under the General Directorate of Environmental Protection of the Ministry of Environment. The Secretariat is responsible for convening meetings of the Working Group, preparing reports of the meetings, reporting progress, and providing information related to the implementation of projects under conventions, protocols and agreements related to environmental protection. The institutional framework for NCAP implementation is summarized in Table 4.

The roles and responsibilities of the Working Group include:

- implementing conventions, protocols and agreements related to environmental protection in Cambodia, in which the NCAP is included;
- serving as a secretariat and giving policy advice to decision makers for decision-making and promoting the implementation related to effective environmental protection;
- conducting research and formulating policy, regulation and legal instruments related to environmental protection;
- proposing national policies and action plans related to environmental protection for policymakers to consider and approve;
- providing comments on the draft of legal instruments, and on an action plan related to project implementation under conventions, protocols and agreements on environmental protection;
- sharing ideas, conducting research, and evaluating challenges and weaknesses of the implementation of projects related to environmental protection, and reporting of decision makers of relevant ministries; and
- reporting progress on the implementation of projects under conventions, protocols and agreements related to environmental protection, for decision makers to consider and approve.

Table 4. Institutional framework for NCAP implementation

Lead Entity	Ministry of Environment
NCAP Implementation Secretariat	Chair: General Directorate of Environmental Protection of the Ministry of Environment
Implementing Inter-sectoral Working Group	Members: 1) General Directorate of Policy and Strategy (then General Secretariat of the National Council for Sustainable Development), 2) Ministry of Labor and Vocational Training, 3) Ministry of Foreign Affairs and International Cooperation, 4) Ministry of Public Works and Transport, 5) Ministry of Commerce, 6) Ministry of Water Resources, and Meteorology, 7) Ministry of Education, Youth, and Sport, 8) Council for the Development of Cambodia, 9) Ministry of Economy and Finance, 10) Ministry of Interior, 11) Ministry of Health, 12) Ministry of Agriculture, Forestry, and Fisheries, 13) Ministry of Information, 14) Ministry of Mines and Energy, 15) Ministry of Industry, Science, Technology, and Innovation, 16) Royal University of Phnom Penh, and 17) Institute of Technology of Cambodia
Other Key Stakeholders	• International implementing agencies and development banks • Utilities and electricity companies • Provincial, city and local body authorities • Civil society organizations and academia including laboratories • Industry associations including manufacturing and refrigerant producers • Service technicians and vocational training institutes

5. Overview of Cooling in Cambodia

5.1 Drivers and Climatic Conditions

SOCIO-ECONOMIC DRIVERS

The population of Cambodia was around 16.7 million people in 2020 and is expected to increase to more than 18.8 million by 2030, according to the United Nations Department of Economic and Social Affairs (2019). Although 75 per cent of the population currently lives in rural areas, the country is experiencing rapid urbanization. The demand for cooling services is expected to increase not only to serve the needs of the growing population, but also to meet the infrastructure demands of growing cities.

Cambodia's economy grew at an average annual rate of 7.7 per cent between 1998 and 2019, making it one of the world's fastest growing economies (World Bank n.d.). Increased prosperity has enabled more businesses and houses to access cooling services. Energy consumption is projected to increase 5.2 per cent annually on average between 2009 and 2035, and rising demand for cooling is an important factor behind this growth.

The main sectors driving the country's cooling demand are tourism (such as hotels and restaurants, due mainly to the use of air conditioners and also refrigeration) and the transport sector (mobile air conditioning). In addition, the following five categories have been stimulating economic growth in Cambodia and are likely to contribute to rising cooling demand:

- new industries and manufacturing (including natural resource processing and the assembly of machinery, mechanic/electronic/electric equipment and means of transport);
- small and medium enterprises in sectors related to drugs and medical equipment production, construction materials, packaging equipment for export, furniture manufacturing and industrial equipment;
- agro-industrial production for export and domestic markets;
- various supporting industries for the agriculture, tourism and textile sectors; and
- information and communication technology, energy, heavy industries, cultural/historical/traditional handicrafts and green technology.

Cambodia remains highly vulnerable to the impacts of climate change due to its strong dependence on climate-sensitive sectors such as agriculture, water resources, forestry, fisheries, and tourism, which are critical to its economic growth and support the livelihoods of a large majority of its population. Cambodia's population relies heavily on agriculture and fisheries, which provide 25 per cent of GDP and employ 49 per cent of the labour force[5]. Climate change adaptation efforts will likely drive the demand for refrigeration equipment to strengthen the cold chain and ensure the preservation of foods and medicines while reducing waste, as well as the need to provide thermal comfort to the population.

CLIMATIC CONDITIONS

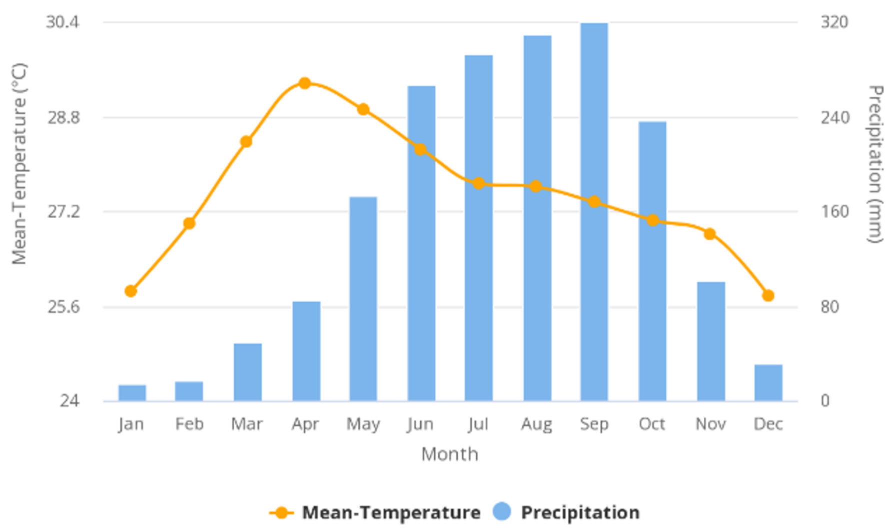
Cambodia's climate can be broadly classified into two types: tropical savanna and tropical monsoon. In the capital city of Phnom Penh, the number of annual cooling degree days on average is 6,269.6, with the highest cooling degree days observed in April, at close to 615. In Siem Reap, the number of annual cooling degree days on average is 3,447.1, with the highest value observed in April, at around 333.3. The country has experienced a surge in heatwave incidents in recent years, with temperatures reaching up to 42 degrees Celsius (˚C).

Rising temperatures will translate into an increasing demand for cooling, reflected either in the deployment of more cooling appliances or in their higher annual runtime (or both). This in turn will impact peak cooling demand, cooling energy consumption, refrigerant demand and cooling-related greenhouse gas emissions. As temperatures rise, it will become increasingly important to provide clean, affordable and reliable cooling to all.

Figure 3 shows the monthly mean temperature and precipitation in Cambodia from 1991 to 2020, and Figure 4 shows the average maximum temperature. These data illustrate the wide variation in the maximum temperature, indicating the need for cooling for thermal comfort, food and agriculture, and medical cold chains throughout the year.

Over the past century, the average annual temperature in the country has increased more than 1˚C (Figure 5), which could be attributable to global warming and to urban heat-island effects due to rapid urbanization. With temperatures expected to rise further in the future, the demand for cooling will expand significantly.

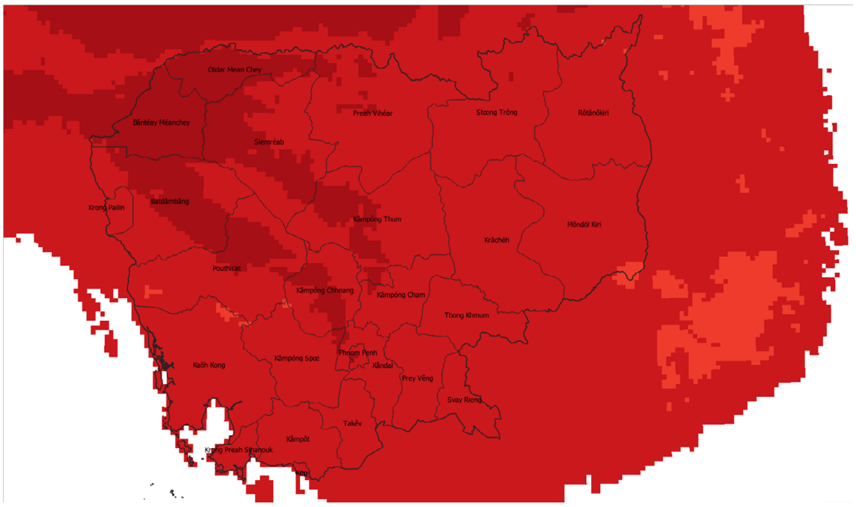
Figure 3. Monthly mean temperature and precipitation in Cambodia, 1991-2020



Source: Climate Change Knowledge Portal 2022

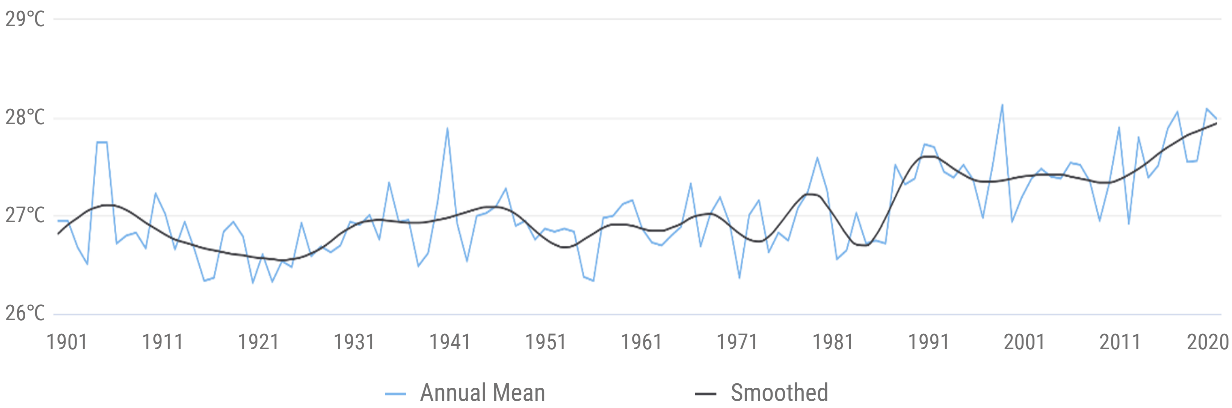
[5] https://climateknowledgeportal.worldbank.org/country/cambodia

Figure 4. Average maximum temperature in Cambodia



Source: Climate Change Knowledge Portal 2022

Figure 5. Observed average annual temperature in Cambodia, 1901-2020



Source: Climate Change Knowledge Portal 2021

5.2 Access to Cooling and Population at Risk

The number of people in Cambodia that can meet their cooling needs for thermal comfort, food security and health care depends mainly on income level, on the electrification rate and on the affordability of the cooling solutions available. Sustainable Energy for All tracks the number of people within different groups that are not able to meet their cooling needs, described as follows:

- Rural poor – The rural poor are populations that do not have access to electricity and that live below the poverty line. Where there is electricity access, these people may not be able to afford a cooling appliance (fan or refrigerator). They typically engage in subsistence farming and lack access to a cold chain enabling them to add value to their yield. Due to the lack of reliable electricity or medical cold chain infrastructure, they also may not be able to access vaccines and other health care.

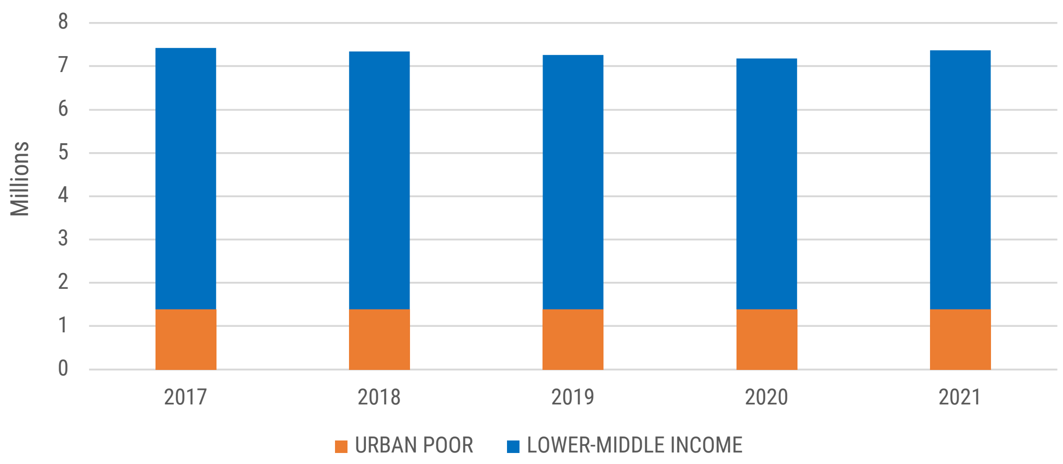
- **Urban poor** – These are people living under the poverty line in urban centres/cities. They may have access to electricity, but it is unreliable and in some cases not affordable to them. They have low-quality housing and cannot afford cooling appliances. They may be able to access vaccines due to living closer to the central vaccine distribution systems.

- **Lower-middle income** – This population has access to electricity and can afford it. Income levels are above the poverty line but less than $10.01 per day. These people can afford a fan and refrigerator and maybe an air conditioner. Due to their lower purchasing power, however, they are likely to purchase energy-inefficient cooling systems that tend to have a cheaper upfront cost but higher operating costs, adding stress to limited household budgets.

- **Middle income** – This is the population living on between $10.01 and $20.01 per day with access to electricity. They tend to be mostly concentrated in urban areas. They own appliances for their cooling needs and may be able to afford more energy-efficient cooling solutions.

The trends of cooling needs for the urban poor and the low-middle income group are depicted in Figure 6 (data for the rural poor and for the middle-income group are not available). Since 2017, the trends have fluctuated annually in different groups owing to different global and national conditions. Overall, the number of urban poor declined during 2017-2021, but in 2021 the number again approached 2017 levels. A similar trend is observed in the lower-middle income group.

Figure 6. Populations with different cooling needs in Cambodia, 2017-2021



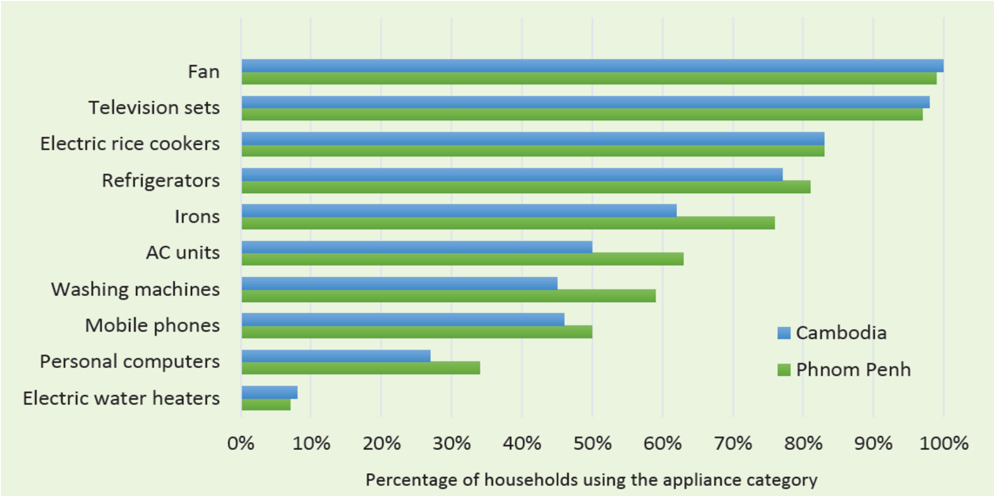
Source: Sustainable Energy for All 2021

The cooling needs of the above-mentioned groups highlight the need for solutions that are affordable and sustainable, so that issues such as heat stress, productivity loss risks, food/agricultural waste and health care are addressed in an energy-efficient and climate-friendly manner.

THERMAL COMFORT

Currently the ownership of cooling appliances for thermal comfort is focused on solutions such as fans and air conditioners. Although not all population groups are able to afford an air conditioner, as income levels rise the market penetration of this equipment is expected to increase. As of 2020, around 1 million air conditioners and 1.2 million refrigerators were estimated to be in use in Cambodia (Figure 7), with the majority of the units in urban households, where only 25.1 per cent of the population lives. For those who cannot afford air conditioning, there is a need to ensure that at least fans are available. Both of these active cooling solutions need to be energy efficient so that they are affordable and reduce the added electricity supply capacity.

Figure 7. **Appliance ownership in Cambodia, by type, 2018**



Source: Building Energy Structure and Lifestyle Database of Asia 2018

Addressing the need for thermal comfort in commercial and work spaces is an important factor to ensure that no productivity loss occurs due to heat stress compounded by climate change. The annual GDP loss due to heat stress in Cambodia is an estimated $1.12 billion to $1.26 billion, and the associated loss of working hours is expected to rise sharply by 2030 (Figure 8).

Figure 8. **Productivity loss due to heat stress in Cambodia, 1995 and 2030**

Source: International Labour Organization 2019

As an emerging economy, Cambodia will continue to experience rapid urbanization and industrialization. As such, it will be important that the cooling solutions that are provided for comfortable workspaces and buildings are not energy intensive and have no environmental externalities. These cooling solutions should include not only active energy-efficient solutions, but also passive solutions such as energy-efficient building envelopes, heat load-reducing designs and nature-based solutions for reducing urban heat-island effects in cities – all of which can reduce the active cooling load.

FOOD AND AGRICULTURE

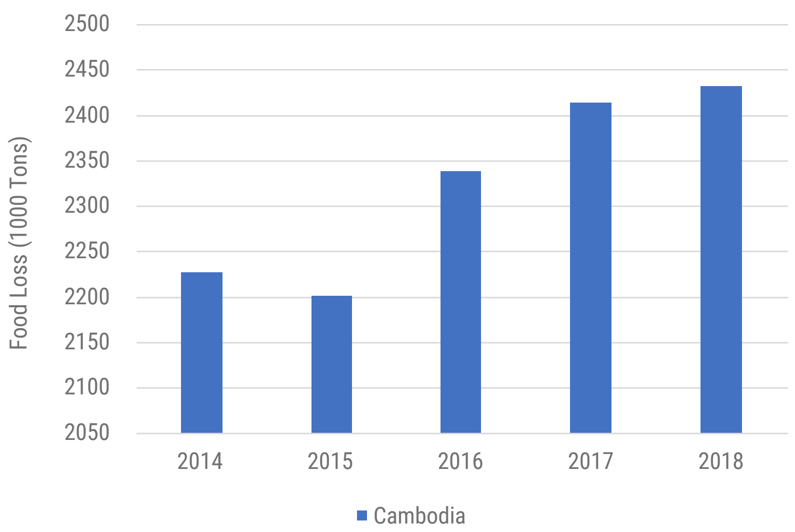
Like other emerging economies, Cambodia is transitioning from an agrarian economy to an industrial one. Still, agriculture remains a major part of the economy for exports and domestic consumption. Refrigeration is integral to the agriculture and food value chain to ensure that produce from the farm reaches the plate without losing integrity and nutritional value. As of 2018, around 77 per cent of Cambodian households had a refrigerator. This share is likely to increase as refrigerators become an essential household appliance to preserve food. It will be important to ensure that refrigeration systems are energy efficient for the rising middle class and affordable to enable the most vulnerable populations to improve their living standards.

Cold chains are critical to ensure food security and the preservation of yields so that farmers can get the best market value. Through the cold chain, farmers can extend the reach of their produce to distant markets and consumption centres, which are better-paying markets and can bring increased income. Crop production accounts for an estimated 48 per cent of the income of small farmers in Cambodia (Food and Agriculture Organization of the United Nations [FAO] n.d.a), and there is a need to provide affordable and accessible cooling solutions that help to preserve crops and increase the value-added yield to improve farmer income. This is even more critical in locations where electricity is underserved and/or unreliable.

Such an approach would need to be part of a comprehensive planning of agriculture and food cold chain systems along the entire supply chain (including production, processing, storage and distribution) to reduce food losses. Food loss and wastage are significant greenhouse gas emitters, and additional resources (energy, water etc.) must be used to make up for the lost production to meet demand.

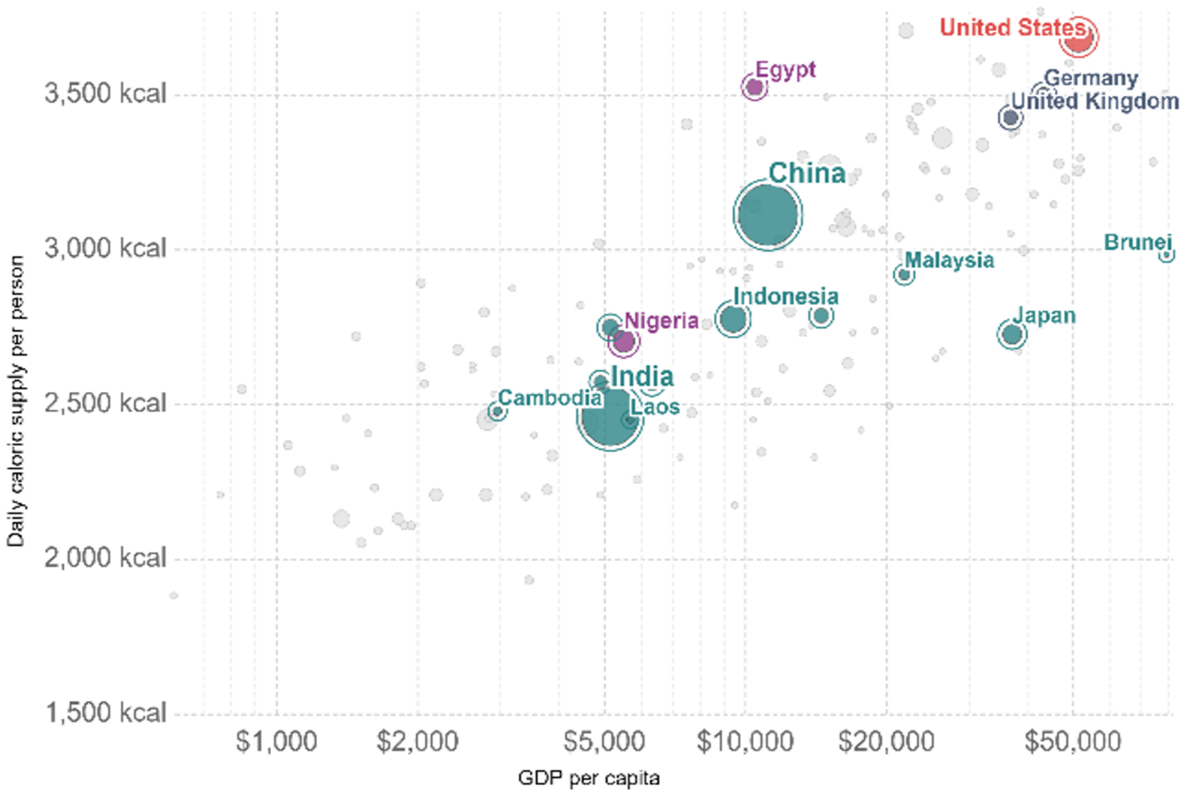
The lack of adequate and reliable cold chain access is one of the main contributing factors to rising food loss (Figure 9). To achieve the average per capita calorific supply of more advanced economies (Figure 10), Cambodia would need to address its cold chain requirements to meet requisite domestic supply and imports. The development of an energy-efficient and climate-friendly cold chain is important to ensure that the country's food exports are competitive and meet the needs of an evolving global market.

Figure 9. Food loss in Cambodia, 2014-2018



Source: FAO n.d.b

Figure 10. Per capita calorific supply vs GDP in Cambodia and selected countries, 2013



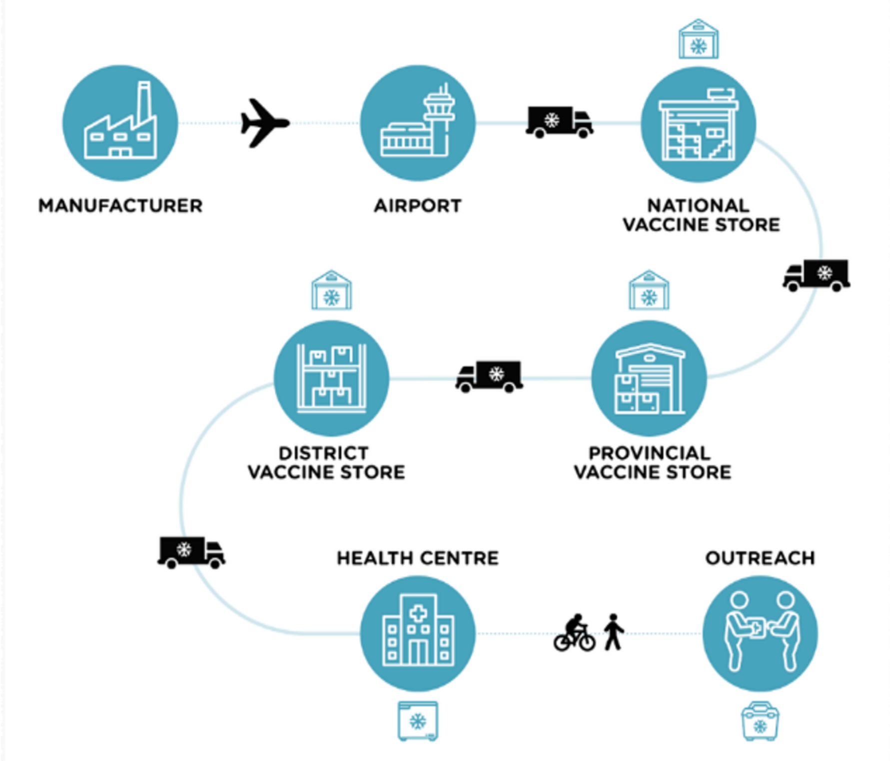
Source: FAO 2017

HEALTH CARE AND VACCINATION

Cold chains consist of several components that usually include at least pre-cooling, cold storage and refrigerated transport. For the medical sector, the cold chain is typically used for the transport and storage of temperature-sensitive health products that include but are not limited to vaccines, blood products and a range of medicines that support common health services. The COVID-19 pandemic has highlighted the need for strong vaccine cold chains that are able to handle different temperature control requirements depending on the vaccine technology (for example, the Pfizer mRNA vaccine requires temperatures as low as -80˚C).

The success of immunization efforts (Figure 11) depends on maintaining the cold chain, as vaccines may lose their integrity if exposed to temperatures outside the recommended ranges for long periods of time. Energy access is critical for maintaining cold chains and preserving vaccines; however, procurement processes often do not consider the energy cost of the vaccine cold chain.

Figure 11. General structure of vaccine cold chain in routine immunization programmes



Source: TEAP 2021 Progress Report

The lack of application-specific energy efficiency standards and policies also leads to inefficient systems being added to the cold chain. Energy efficiency needs to be an important criterion in procurement guidelines for countries to ensure that the energy requirement from the cold chain is kept to a minimum.

The COVID-19 pandemic greatly impacted Cambodia's economy, which relies heavily on tourism, the garment industry, construction and foreign investment. The United Nations estimated that in 2020, economic growth in the country would fall from 7.7 per cent to -4.1 per cent; poverty would nearly double to 17.6 per cent; and unemployment would rise to 4.8 per cent, due largely to the closure of schools. Forecasts indicate an aggregate decline in the Human Development Index of 4.21 per cent, which is equivalent to erasing the previous four years of progress in human development (UNICEF 2020).

As of 2014, Cambodia had 113 health posts, 992 health centres, 61 district hospitals, 17 provincial hospitals, and 9 regional hospitals, with increases projected for the coming years (WHO 2014). The pandemic has revealed that Cambodia needs to upgrade its cold chain equipment to accommodate the expected volume of COVID-19 vaccines. Other challenges include a lack of equipment for temperature monitoring (either unavailable, not computerized or inadequate) and an inability to maintain the cold chain in times of power outage, especially if a natural disaster strikes.

Therefore, it is important that development of the medical cold chain considers the evolving requirements of health care and vaccination and also considers addressing last-mile issues with sustainable solutions.

6. Cooling Demand Assessment

Data collection and analysis for this NCAP took place over a period of nine months, from September 2020 to April 2021. It was conducted by a consultant from the Cambodia National Ozone Unit in collaboration with local governments and analysed by an international expert team. Questionnaires were used to interview owners, suppliers, company representatives, service sectors, ice factories and manufacturing, public buildings, business centres, supermarkets, hospitals, clinics, schools, hotels, guest houses, restaurants, casinos and other primary users of refrigeration and cooling appliances.

The research team made follow-up calls and visits when necessary for further data collection and validation. In most places, it took a long time for respondents to fill out and return the survey form. There was also a need to verify the validity and accuracy of estimates of the number of households with and without air conditioning and the number of air-conditioning and other cooling appliances per household.

In addition to the primary data collection, secondary data and literature were collected and analysed, including existing policies, strategies, plans, and interventions related to cooling sectors including construction, energy, transport, health, agriculture, urban planning, industry and others.

Cooling demand assessment is a data-intensive analytical step vital for NCAP development. Data-driven assessment of the current and future cooling demand (and impacts) will inform sector-specific priorities, including quick and high-impact interventions as well as longer-term strategic interventions. The five cooling sectors analysed were: 1) Building Space Cooling, 2) Mobile Air Conditioning, 3) Food Cold Chain, 4) Health-care Cold Chain and 5) Process Cooling. The technologies considered for the analysis are listed in Table 5.

Table 5. Equipment and infrastructure considered for cooling demand assessment, by sector

Cooling sector	Equipment considered for the assessment
Building Space Cooling	Room air conditioners (fixed speed), room air conditioners (inverter type), chiller systems (centrifugal type), variable refrigerant flow systems, fans
Mobile Air Conditioning	Light-duty vehicles, heavy-duty vehicles, freight vehicles (passenger cooling only)
Food Cold Chain	Ice cooling equipment for fishing, refrigeration systems in cold storages, refrigeration systems in ripening chambers, mobile reefer vehicles, domestic refrigerators and freezers
Health-care Cold Chain	Refrigerators for vaccines, ice-lined refrigerators
Process Cooling	Scroll chillers, screw chillers

The cooling demand assessment considered 2020 to be the baseline year for cooling demand and established future cooling demand projections for the subsequent 20 years, i.e., until the year 2040. The assessment considered the met and unmet[6] cooling demand and the associated impacts in terms of energy consumption, greenhouse gas emissions, and refrigerant demand, as applicable.

Two projections of future growth were established: a business-as-usual (BAU) scenario that assesses how the current baseline will evolve based on the current level of efforts, and an intervention scenario that evaluates how the cooling growth will evolve based on accelerated efforts across policies, technologies and market enablers.

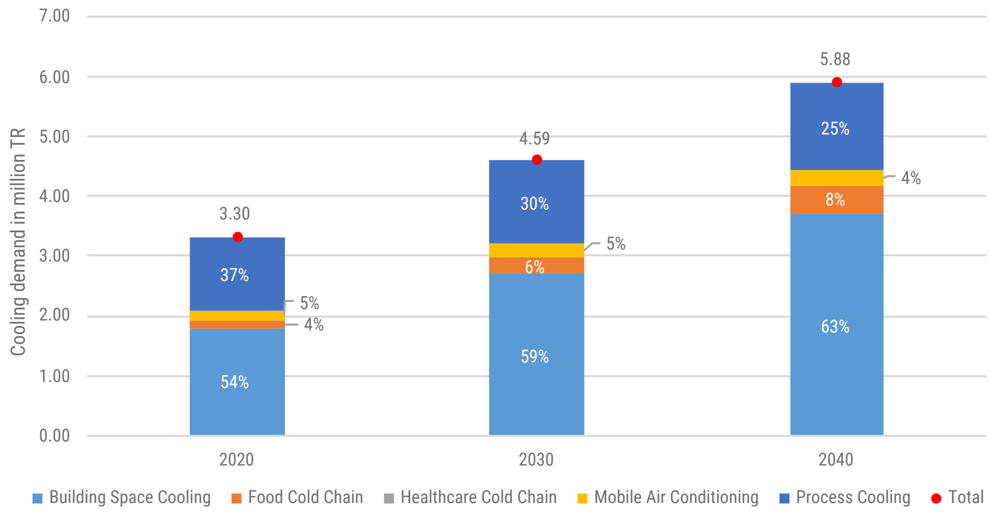
Indirect emissions were calculated based on quantifying the cooling demand and energy consumption of technology/infrastructure. Indirect emissions for technology or infrastructure were calculated using stock information, the average capacity of cooling equipment, cooling equipment efficiency, average operational hours, utilization factor and primary energy factor. Direct emissions were calculated based on quantifying the refrigerant leakage from cooling equipment during its operation and quantifying the refrigerant not recovered from the equipment at the end of its service life. Direct emissions for cooling technology/infrastructure were calculated using stock information, replacement factor, refrigerant charge rate of cooling equipment, leakage rate, recovery rate and refrigerant mix.

Synthesizing the outputs from the sector-specific data assessment further helped derive meaningful recommendations and future pathways to address cooling growth in the respective sectors.

6.1 Total Cooling Demand

The total cooling demand from all five cooling sectors is projected to grow 1.4 times by 2030 (an increase of 4.6 million tons of refrigeration) and 1.8 times by 2040 (an increase of 5.9 million tons of refrigeration), compared to the increase of 3.3 million tons of refrigeration in 2020. This growth is attributed mainly to an increase in the cooling demand of building space cooling, from 1.8 million tons of refrigeration in 2020 to 3.71 million tons of refrigeration by 2040 (a 2.1 times increase). The projected growth in cooling demand by sector in the BAU scentario is presented in Figure 12.

Figure 12. Cooling demand by sector in 2020 and in the BAU scenario, 2030 and 2040



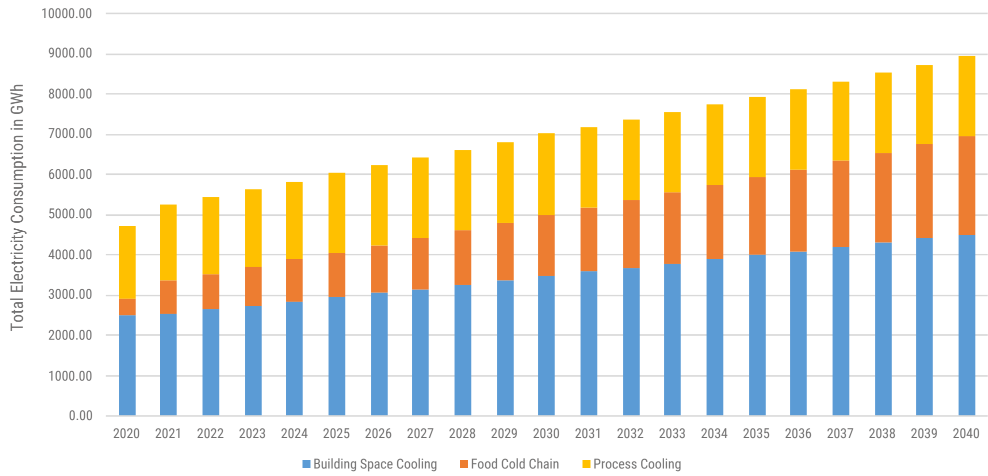
Source: Authors

[6] Met cooling demand represents the cooling delivered through mechanical means and therefore the energy and refrigerant consumption associated with cooling. Unmet cooling demand refers to the demand growth to bridge the lack of access to cooling.

6.2 Total Electricity Consumption

The total electricity consumed by the cooling sectors (excluding mobile air conditioning[7]) in 2020 was 4,738 gigawatt-hours (GWh). By 2040, this is expected to grow to 8,944 GWh under the BAU scenario (Figure 13). In 2020, building space cooling dominated cooling electricity consumption (with a 53 per cent share), followed by process cooling (38 per cent). The contribution of the health-care cold chain sector to cooling electricity consumption is expected to remain extremely low, rising from only 3 GWh in 2020 to 6.4 GWh[8] in 2040 (Table 6).

Figure 13. **Electricity consumption by sector in the BAU scenario, 2020-2040[9]**



Source: Authors

Table 6. **Total final electricity consumption by sector in 2020 and in the two scenarios, with savings potential, 2030 and 2040**

	2020	2030		2040		Savings potential (GWh)	
	Baseline	BAU	Intervention	BAU	Intervention	2030	2040
Building Space Cooling	2 491	3 473	2 732	4 509	3 286	21%	27%
Food Cold Chain	426	1 533	1 367	2 450	1 817	11%	26%
Health-care Cold Chain	3.0	5.69	5.69	6.40	6.40	-	-[10]
Process Cooling	1 818	2 014	1 907	1 979	1 758	5%	11%
Total	4 738	7 026	6 011	8 944	6 868	14%	23%

Source: Authors, NCAP Assessment

[7] This analysis includes only the electricity contribution of the energy consumption due to cooling, hence it does not consider the energy contributions of mobile air conditioning and reefer vehicles (in the food cold chain).

[8] Only vaccine refrigerators and ice-lined refrigerators were considered for the cooling demand assessment for the health-care cold chain sector. Limited information was available regarding the electricity consumption of walk-in cold rooms, walk-in freezers and cooling requirements for ice/gel packs for vial storage.

[9] Health-care cold chain is not shown as the estimated consumption was too small to compare in the graph.

[10] The assessment considered vaccines refrigerators and ice lined refrigerators for which more efficient alternatives couldn't be identified at the time, savings potential was defined to zero.

The growth in electricity consumption in the building space cooling sector is lower than in other sectors. This is mainly because the BAU scenario asssumes moderate equipment efficiency levels for cooling equipment and moderate penetration of energy-efficient equipment.

Electricity consumption in the food cold chain sector is projected to grow steadily (from 9 per cent of total cooling electricity consumption in 2020 to 27 per cent in 2040), due to additional requirements of cold storages in the country and increased penetration of domestic refrigerators and freezers in households.

The total electricity savings potential from the four analysed cooling sectors in 2030 is estimated at 1,014 GWh, or 14 per cent savings in the Intervention scenario compared to the BAU scenario (Table 6). The projected electricity savings from building space cooling is estimated at 741 GWh (73 per cent of the total savings), from food cold chain is 167 GWh (16 per cent) and from process cooling is 106 GWh (10 per cent).

The total electricity savings potential from the four cooling sectors in 2040 is an estimated 2,075 GWh, translating to 23 per cent savings in the Intervention scenario compared to the BAU scenario. The projected electricity savings from building space cooling is 1,223 GWh (59 per cent of the total savings), from food cold chain is 632 GWh (30 per cent) and from process cooling is 221 GWh (11 per cent). Electricity consumption due to mobile air conditioners was not calculated in the analysis.

6.3 Total Refrigerant Consumption

The total refrigerant consumption in the five cooling sectors (including mobile air conditioning) was an estimated 1,202 Metric tons[11] in 2020. The growth in refrigerant consumption to 2020 is attributed to the sudden spike in sales of inverter room air conditioners[12].The refrigerant transition planned by the National Ozone Unit aims to eradicate the consumption of HCFC-22 by 2030, with an emphasis on introducing alternative refrigerants with low and ultra-low GWPs. In the BAU scenario, these refrigerants represent 51 per cent of the market share in 2040 (Figure 14). The Intervention scenario shows a combined reduction in HFC consumption of 54 per cent by 2040 in the cooling sectors[13].

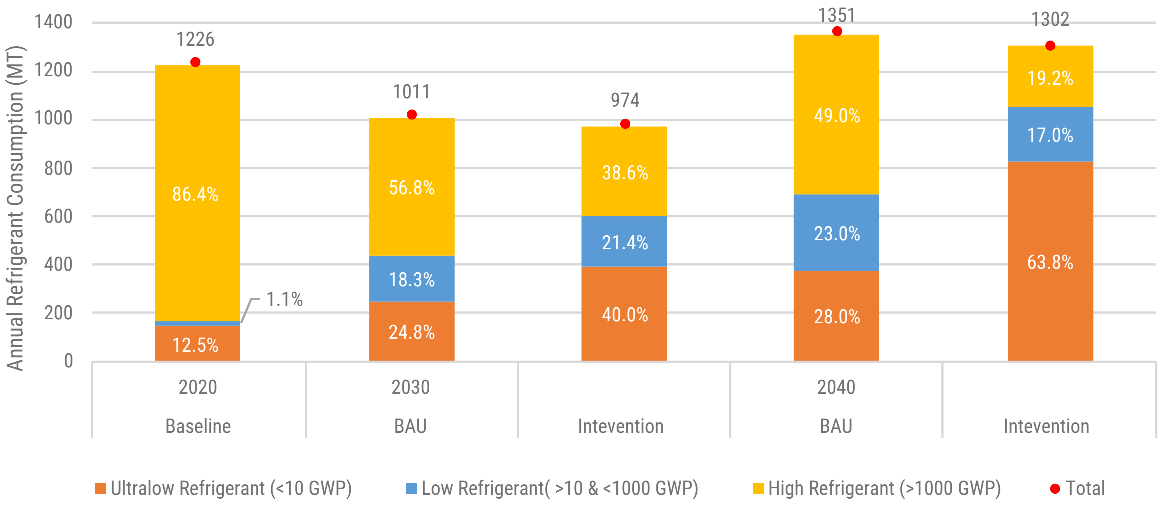
An aggressive intervention pathway – with an emphasis on reducing operational leakage and improving the recovery of refrigerants at the end of the life cycle of air-conditioning equipment – leads to a reduction in the annual consumption of refrigerants. In this Intervention scenario, annual refrigerant consumption is projected to decrease 4 per cent in both 2030 and 2040 compared to the BAU scenario. Meanwhile, the share of low and ultra-low GWP refrigerants is projected to increase to 61.4 per cent in 2030 and 80.8 per cent in 2040.

11 This includes the refrigerant charge in the imported cooling equipment in 2020 and the refrigerant requirements for addressing operational leakages.

12 For the modelling, the average growth rate in sales of inverter air conditioners from the past 10 years was considered.

13 The Kigali Amendment requires a 50 per cent phase-down of HFC consumption by 2040 compared to the baseline year for Article 5 countries in Group 1, such as Cambodia

Figure 14. Annual refrigerant consumption by type in 2020 and in the two scenarios, 2030 and 2040

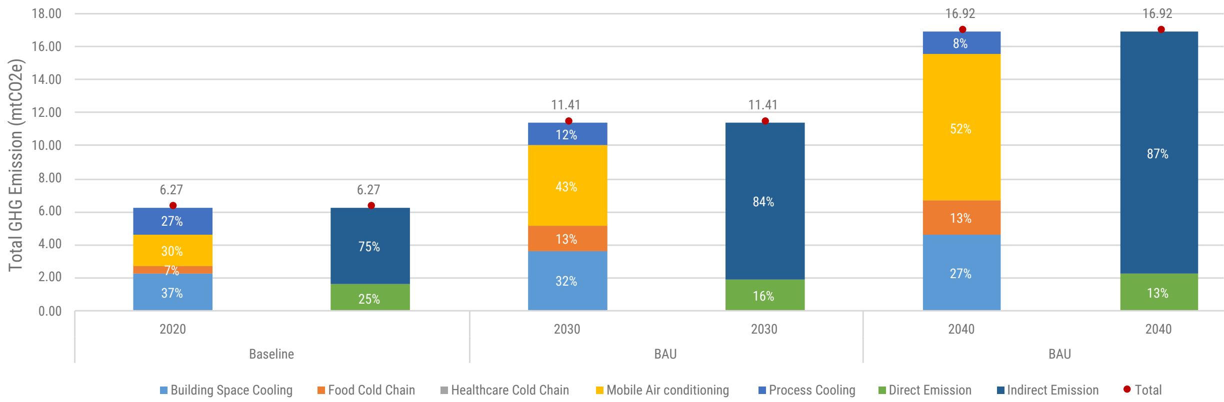


Source: Authors, NCAP Assessment

6.4 Total Greenhouse Gas Emissions

The five cooling sectors accounted for a combined 6.327 million tons of CO2-equivalent emissions in 2020 (Figure 15). Building space cooling contributed 37 per cent of the total, followed by mobile air conditioning (30 per cent) and process cooling (27 per cent). The total emissions from cooling are expected to increase 1.8 times by 2030 and 2.7 times by 2040, from 2020 levels. The share of indirect emissions is 75 per cent in the baseline year (2020), 84 per cent in 2030 and 87 per cent in 2040.

Figure 15. Total greenhouse gas emissions from the cooling sectors, by sector and type, in 2020 and in the BAU SCENARIO, 2030 and 2040



Source: Authors, NCAP Assessment

The share of emissions from the mobile air conditioning sector is expected to increase from 30 per cent in 2020 to 52 per cent in 2040 in the BAU scenario, due to the higher projected growth rates in vehicle sales compared to other sectors (for passenger cars/ light-duty vehicles annual growth rates are 16 per cent in 2021-2030 and 11 per cent in 2031-2040; for passenger buses/ heavy-duty vehicles annual growth rates are 10 per cent in 2021-2030 and 7 per cent in 2031-2040; and for freight vehicles annual growth rates are 14 per cent in 2021-2030 and 10 per cent in 2031-2040).

The total emissions in the BAU scenario by 2040 are an estimated 16.92 million tons of CO_2-equivalent (Table 7 and Figure 16). The projected total mitigation potential through the intervention measures is around 2.94 million tons of CO_2-equivalent emissions. The indirect emissions mitigation potential is 1.81 million tons of CO_2-equivalent, and the direct emissions mitigation potential is 1.13 million tons of CO_2-equivalent.

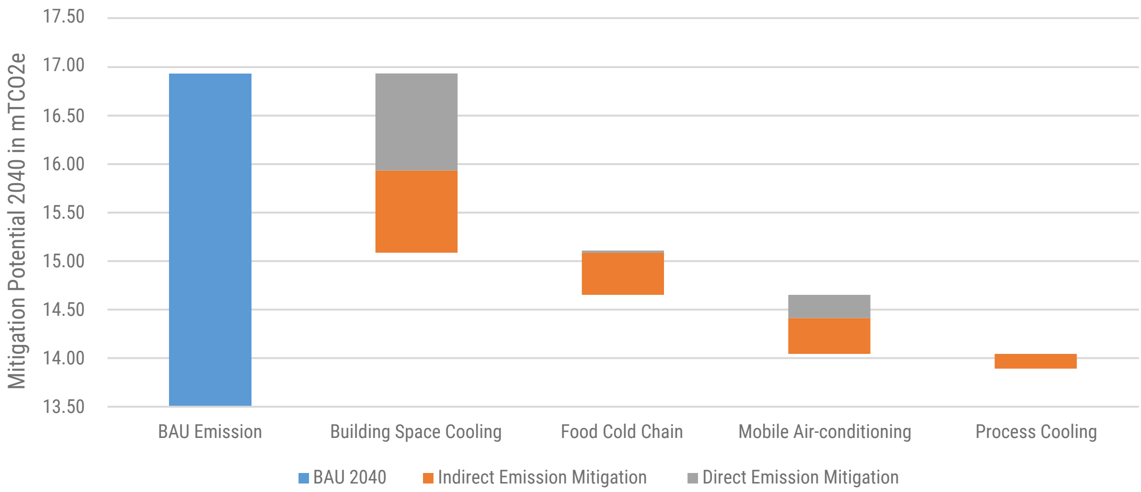
Table 7. **Greenhouse gas emissions by sector in 2020 and in the two scenarios (metric tCO2-equivalent), 2030 and 2040**

	2020	2030		2040		Savings potential	
	Baseline	BAU	Intervention	BAU	Intervention	2030	2040
Building Space Cooling	2.29	3.63	2.62	4.57	2.82	28%	38%
Food Cold Chain*	0.44	1.48	1.36	2.12	1.67	8%	21%
Mobile Air Conditioning	1.87	4.89	4.73	8.87	8.26	3%	7%
Process Cooling	1.66	1.41	1.34	1.37	1.21	5%	11%
Total	6.27	11.41	10.05	16.92	13.98	12%	17%

* The greenhouse gas emissions scenario for food cold chain does not consider emissions related to food loss.

Source: Authors, NCAP Assessment

Figure 16. **Mitigation potential of greenhouse gas emissions by sector and type for the year 2040**



Source: Authors, NCAP Assessment

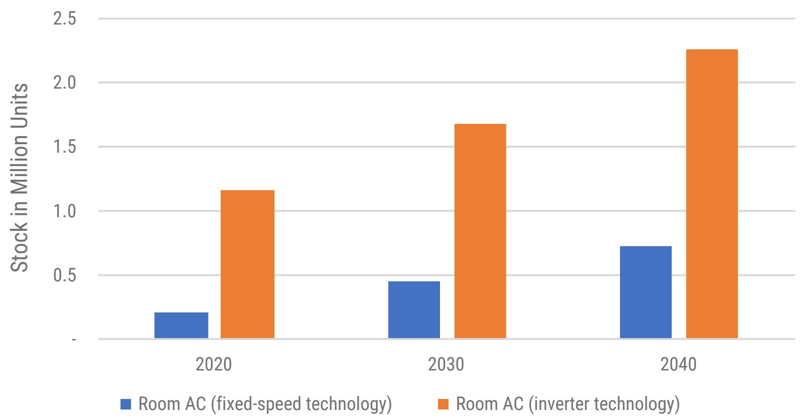
The building space cooling sector has the highest mitigation potential among all cooling sectors, at a total of 1.74 million tons of CO_2-equivalent emissions. The food cold chain, mobile air conditioning and process cooling sectors present higher mitigation potential for indirect emissions, at 0.44 million, 0.61 million, and 0.15 million tons of CO_2-equivalent respectively.

7. Cooling Demand Assessment of Individual Cooling Sectors

7.1 Building Space Cooling

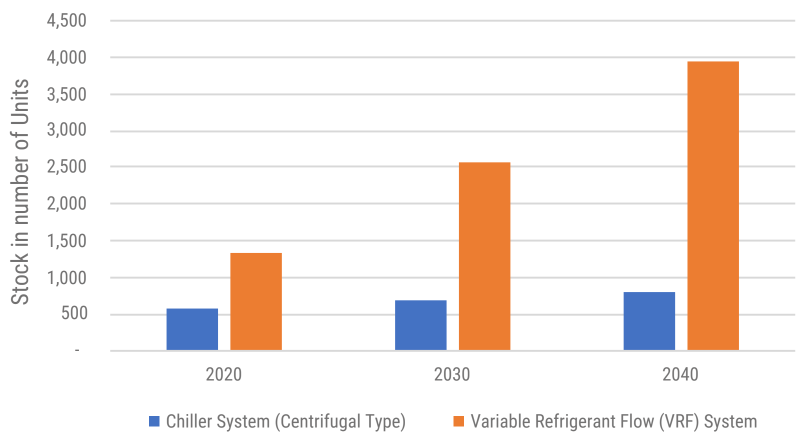
The building space cooling sector has been the dominant sector driving cooling demand growth in Cambodia. Figures 17-19 illustrate a more than doubling in the absolute cooling demand by 2040 in the BAU scenario for different equipment types. However, in the Intervention scenario, using the appropriate efficiency measures, there is potential to achieve 27 per cent electricity savings and a 38 per cent reduction in greenhouse gas emissions in 2040, compared to the 2020 baseline (see Tables 6 and 7 above).

Figure 17. Room air conditioner equipment stock in 2020 and in the BAU scenario, 2030 and 2040



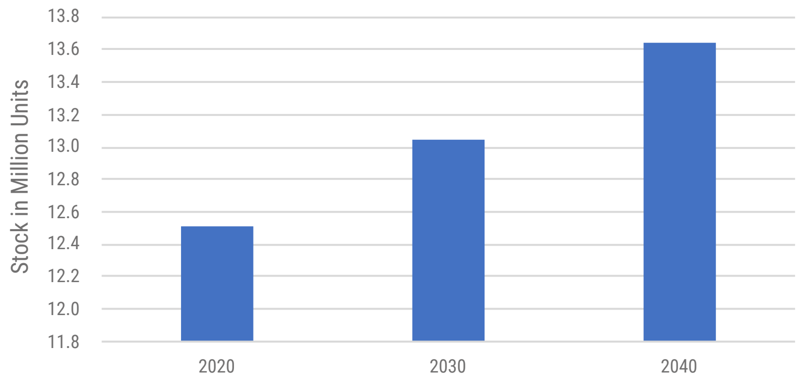
Source: Authors, NCAP Assessment

Figure 18. Centralized air conditioner equipment stock in 2020 and in the BAU scenario, 2030 and 2040



Source: Authors, NCAP Assessment

Figure 19. Fans stock in 2020 and in the BAU scenario, 2030 and 2040



Source: Authors

The inputs and assumptions considered for the data assessment of the building space cooling sector are provided in Annex 1.

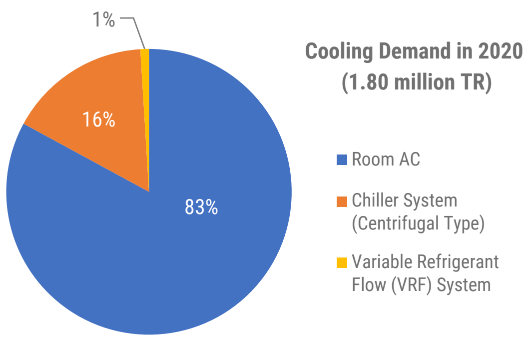
The current penetration of room air conditioners in the country is low, indicating household reliance on predominantly fans for attaining thermal comfort. The total stock of room air conditioners is expected to grow two-fold by 2040. The total stock of room air conditioners in 2020 was 1.4 million units, of which around 85 per cent were inverter-type units. The inverter air-conditioner stock is projected to surge to 1.68 million units by 2030 and 2.26 million units by 2040, with average annual sales growth of 1.19 per cent.

The total stock of chillers and variable refrigerant flow systems in 2020 was 1,902 units, of which 70 per cent were inverter-type variable refrigerant flow systems. This can be attributed to fewer large-sized air-conditioned commercial buildings in the country requiring chilled water systems, and to wider adoption of variable refrigerant flow systems in small and mid-sized commercial buildings. Variable refrigerant flow systems exhibit high growth, with a doubling of the stock in 2030 (2,568 units) and a tripling of the stock (3,949 units) in 2040. The chiller stock is expected to grow 41 per cent by 2040 (798 units) compared to the 2020 baseline.

The penetration of fans in households is high, with a stock of 12.5 million units in 2020, and is expected to reach 13.6 million by 2040, with overall growth of 9 per cent.

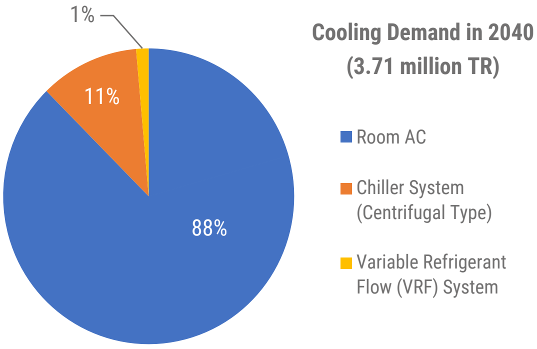
The total demand for building space cooling in 2020 was 1.8 million tons of refrigeration (Figure 20). Room air conditioners contributed 83 per cent of the total demand from the sector, followed by chiller systems and variable refrigerant flow systems. This is attributed to the sudden growth in sales of inverter room air conditioners in the past five years, driven by market transformation and the improved affordability of inverter units.

Figure 20. Demand for building space cooling, by equipment type, 2020



Source: Authors, NCAP Assessment

Figure 21. Demand for building space cooling, by equipment type, in the BAU scenario, 2040



Source: Authors, NCAP Assessment

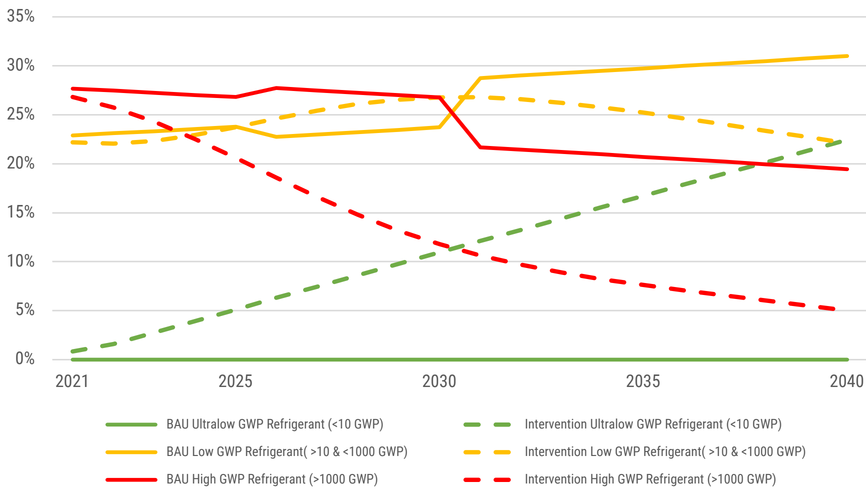
The total cooling demand in the sector is projected to grow to 3.71 million tons of refrigeration in 2040 (Figure 21), up two-fold compared to 2020. The increase in the share of room air conditioners (from 83 per cent in 2020 to 88 per cent in 2040) is attributed to the expected increase in the penetration of room air conditioners in households.

Total refrigerant consumption in the building space cooling sector was 834.5 Metric tons in 2020. This high level of consumption is attributed to the quantity of refrigerant stored in new equipment, followed by refrigerant used to compensate for operational leakages.

Direct emissions estimated in the BAU scenario correspond to the refrigerant transition planned by the National Ozone Unit of Cambodia, which is in line with the country's commitments to the Kigali Amendment to the Montreal Protocol. The refrigerant transition considered in the Intervention scenario aims to achieve an accelerated transition to low and ultra-low GWP refrigerants (45 per cent each by 2040), thereby reducing the direct greenhouse gas emissions from the cooling sector.

The consumption of high-GWP refrigerants (including HCFC-22, HFC-134a and HFC-410a) in the building space cooling sector is expected to decline sharply over the next 10 years, whereas the use of low and ultra-low GWP refrigerants is expected to increase. The National Ozone Unit has set a goal to eradicate HCFC-22 consumption by 2030, supplemented by growth in the use of low-GWP refrigerants. This refrigerant transition is considered in developing the BAU scenario (Figure 22).

Figure 22. Refrigerant consumption in the building space cooling sector, by refrigerant type, in the two scenarios, 2021-2040

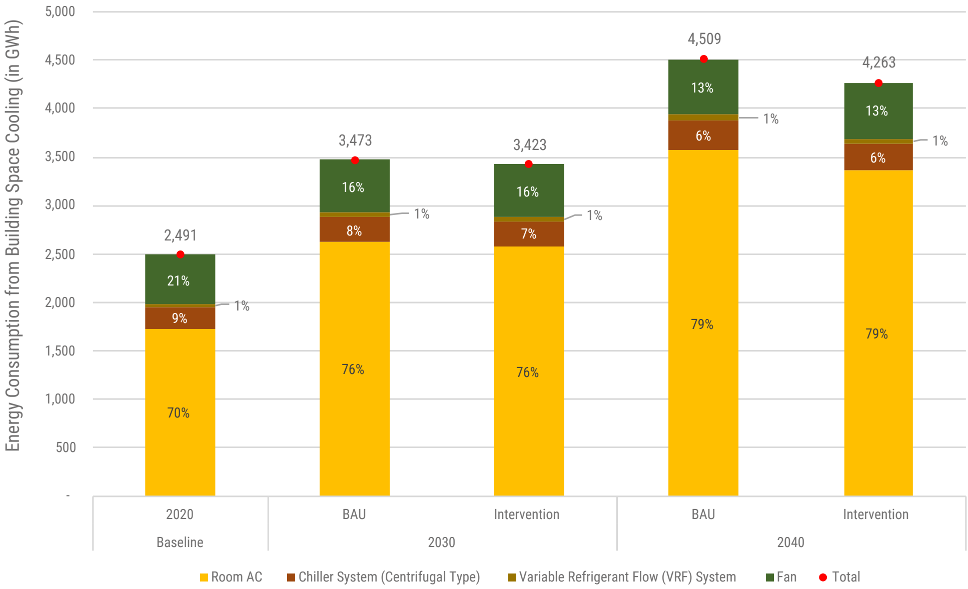


Source: Authors, NCAP Assessment

To promote the use of ultra-low GWP refrigerants and further reduce direct greenhouse gas emissions, an additional compelling refrigerant transition is considered in the Intervention scenario. This scenario considers measures such as reducing the annual operational leakage rate and increasing the recovery of refrigerants at the end-of-life of air-conditioning equipment, as indicated in Figure 22 by the decline in refrigerant consumption in the Intervention scenario until 2040.

The total electricity consumption from building space cooling was 2,491 GWh in 2020 (Figure 23). Much of this was due to the growing market for room air conditioners (70 per cent), followed by fans (21 per cent). In the BAU scenario, the total electricity consumption is projected to increase 28 per cent in 2030 and 81 per cent in 2040 (compared to 2020), with average annual growth of 1.5 per cent. The Intervention scenario – which considers the penetration of passive cooling solutions, improvements in equipment energy efficiency and increased penetration of efficient equipment – is expected to bring energy savings of 26 per cent in 2030 and 28 per cent in 2040, compared to the BAU levels. The increasing share of electricity consumption by fixed-speed room air conditioners reflects the only-limited energy efficiency improvements available for this equipment type, while other equipment types achieve higher efficiency.

Figure 23. **Energy consumption from building space cooling, by equipment type, in 2020 and in the two scenarios, 2030 and 2040**



Source: Authors, NCAP Assessment

7.2 Food Cold Chain

The food cold chain sector in the country is growing at a rapid pace, and high growth is expected in the coming decades. In the Intervention scenario, energy efficiency and demand reduction measures in the sector will lead to energy savings of 26 per cent and greenhouse gas emission reductions of 21 per cent by 2040 compared to BAU (see Tables 6 and 7 above).

The food cold chain analysis does not include the contribution from commercial refrigeration systems (such as display cabinets, visi-coolers, deep freezers, remote condensing units and centralized cooling systems) due to the unavailability of input data. Commercial refrigeration systems can have a significant contribution to direct and indirect emissions from the cold chain.

The food cold chain in Cambodia is represented in this assessment by requirements of ice cooling for fishing, refrigeration systems in cold storages and ripening chambers, reefer vehicles, and domestic refrigerators and freezers. The inputs and assumptions considered for the data assessment of the food cold chain are provided in Annex 1.

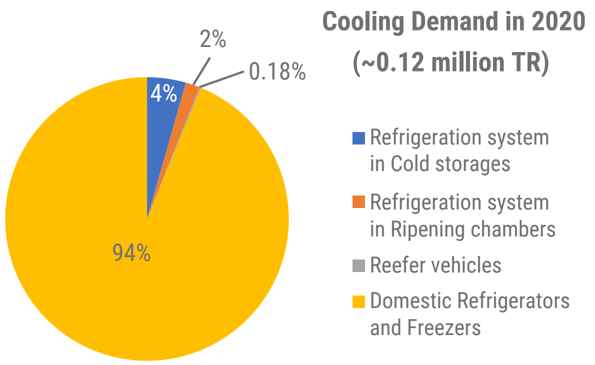
The stock of domestic refrigerators and freezers is expected to increase by 0.8 million units by 2030 and another 0.92 million units by 2040, compared to the 2020 stock of 0.67 million units (Table 8). The stock for cold storages will increase 3.3 times by 2030 (from 1,261 units in 2020 to 4,149 units in 2030) and 6.9 times by 2040 (to 8,640 units), compared to the baseline year. Overall cooling demand for the food cold chain sector is expected to increase 4 times by 2040 compared to the baseline year, with 88 per cent of the share attributed to domestic refrigerators and freezers (Figures 24 and 25).

Table 8. **Equipment stocks in the food cold chain, by type, in 2020 and in the BAU scenario, 2030 and 2040**

Stock data (in thousands)	Baseline	BAU Scenario	
	2020	2030	2040
Equipment/System for ice cooling (fishing)	11.09	12.59	14.82
Refrigeration system in cold storages	1.26	4.15	8.64
Refrigeration system in ripening chambers	0.84	2.50	5.05
Reefer vehicles	0.35	0.89	1.66
Domestic refrigerators and freezers	669.37	1 471.72	2 387.14

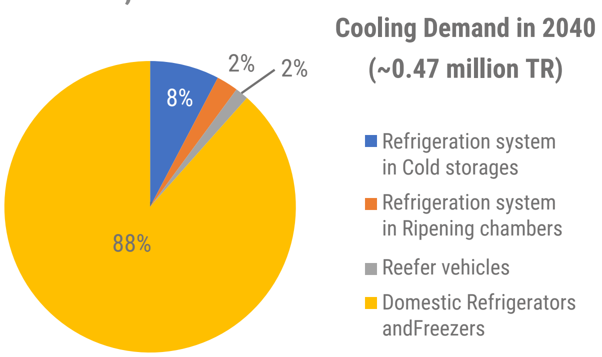
Source: Authors, NCAP Assessment

Figure 24. **Cooling demand for food cold chain, by equipment/infrastructure type, 2020**



Source: Authors, NCAP Assessment

Figure 25. **Cooling demand for food cold chain, by equipment/infrastructure type, in the BAU scenario, 2040**



Source: Authors, NCAP Assessment

Overall energy consumption in the food cold chain sector is expected to increase 3.6 times in 2030 and 5.7 times in 2040 compared to the baseline year. In the BAU scenario, the biggest contribution to energy consumption in the year 2040 will come from domestic refrigerators and freezers (2,109 GWh, or 87 per cent) followed by cold storages (147 GWh, or 6 per cent).

The Intervention scenario shows the potential to reduce refrigerant demand 9 per cent and to reduce energy consumption 26 per cent in 2040. The reduction in energy consumption is associated with the implementation of policy and market enablers to support energy-efficient compressors, enhanced insulation and optimized operations.

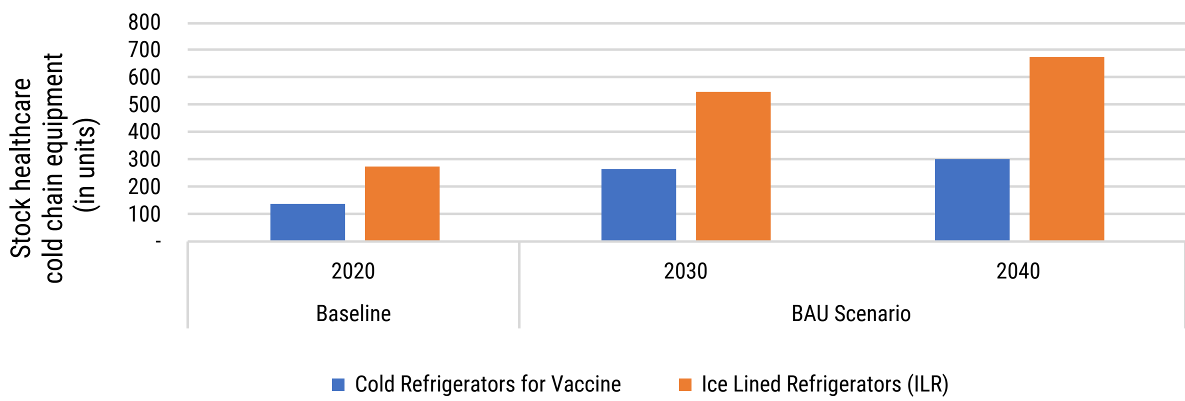
During the analysis, limited information was available for the commercial refrigeration sector, consisting of deep freezers, visi-coolers, remote condensing units, water coolers, and super and hyper markets. It is recommended to include these equipment types in subsequent stages of the NCAP development process.

7.3 Health-care Cold Chain

Cooling demand assessment of the health-care cold chain in Cambodia considered refrigerators for vaccine storage and ice-lined refrigerators used in hospitals and primary health centres.

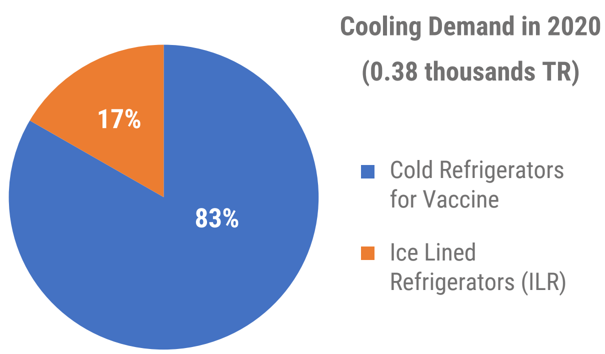
Stocks of vaccine refrigerators and ice-lined refrigerators are expected to increase at annual average rates of 5.8 per cent and 7.4 per cent respectively between 2020 and 2040 (Figure 26). Cooling demand in the sector is expected to more than double to 0.8 million tons of refrigeration by 2040, with vaccine refrigerators contributing 81 per cent of the total (Figures 27 and 28).

Figure 26. Equipment stocks in the health-care cold chain, by type, in 2020 and in the BAU scenario, 2030 and 2040



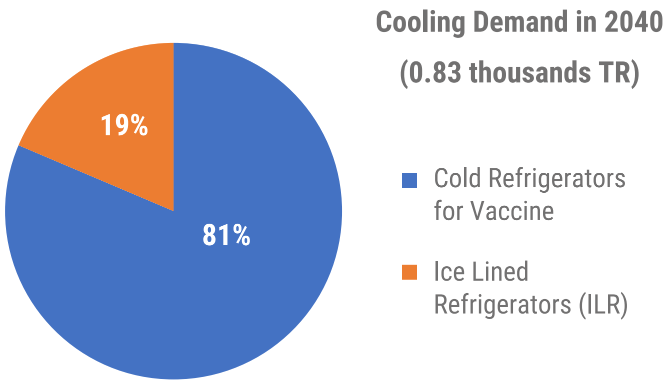
Source: Authors, NCAP Assessment

Figure 27. Cooling demand for the health-care cold chain, by equipment type, 2020



Source: Authors, NCAP Assessment

Figure 28. Cooling demand for the health-care cold chain, by equipment type, in the BAU scenario, 2040



Source: Authors, NCAP Assessment

Similarly, energy consumption in the health-care cold chain sector will more than double to 6.4 GWh in 2040 (from 2.98 GWh in the baseline year 2020). The Intervention scenario, which considers the transition from high-GWP refrigerants such as 134a and 404a to low-GWP refrigerants such as 600a, results in a marginal reduction of direct greenhouse gas emissions of 181.5 tons of CO_2-equivalent in 2040.

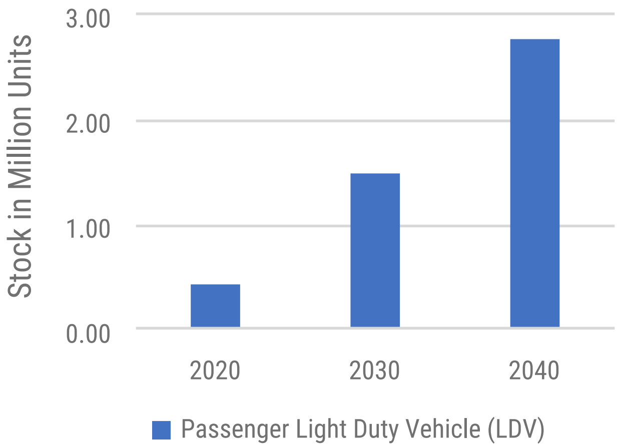
Due to the non-availability of data related to improvements in the energy efficiency of vaccine refrigerators and ice-lined refrigerators in Cambodia, reductions in energy consumption and in indirect emissions were not calculated for the health-care cold chain. Information was also limited on walk-in cold rooms, walk-in freezers and ice/gel packs for vial storage in the country. The Cambodia NCAP recommends the institutionalization of cooling-related data collection for the health-care sector to better understand the sector's emission mitigation potential.

7.4 Mobile Air Conditioning

Cambodia imports all of the vehicles available in the country, and more than 95 per cent of these vehicles are fitted with air conditioners. These air conditioners are now operated year-round due to higher temperatures and increased air pollution. The cooling demand assessment for the mobile air conditioning sector included passenger cooling for light-duty vehicles, heavy-duty vehicles and freight vehicles.

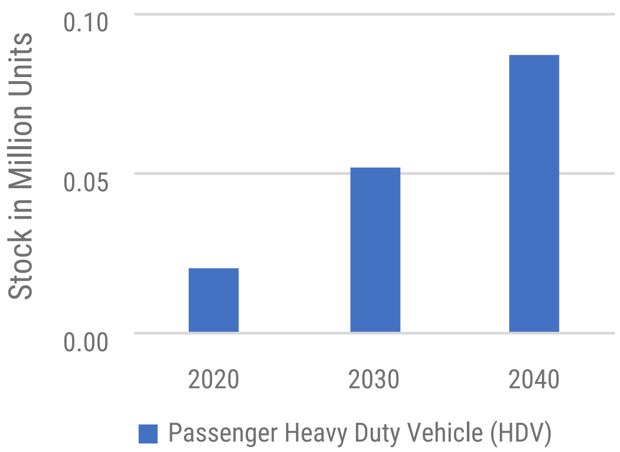
In the urban centres of Cambodia, due to increased income levels, ownership of light-duty passenger cars is expected to increase 6.7 times by 2040 compared to the baseline year (2020) (Figure 29). The stock of heavy-duty vehicles and freight vehicles is projected to increase 4.3 times and 4.7 times, respectively, by 2040 compared to the baseline year (Figures 30-31). This will increase the total cooling demand in the mobile air conditioning sector to 0.24 million tons of refrigeration by 2040, a 1.5 times increase compared to the baseline year (Figures 32-33).

Figure 29. **Light-duty vehicle stock in 2020 and in the BAU scenario, 2030 and 2040**



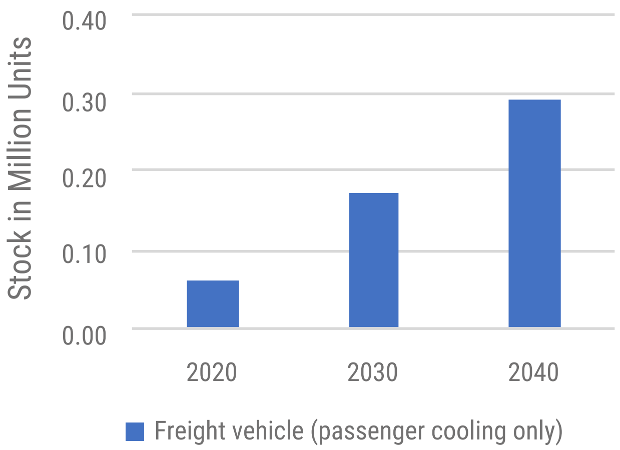
Source: Authors, NCAP Assessment

Figure 30. **Heavy-duty vehicle stock in 2020 and in the BAU scenario, 2030 and 2040**



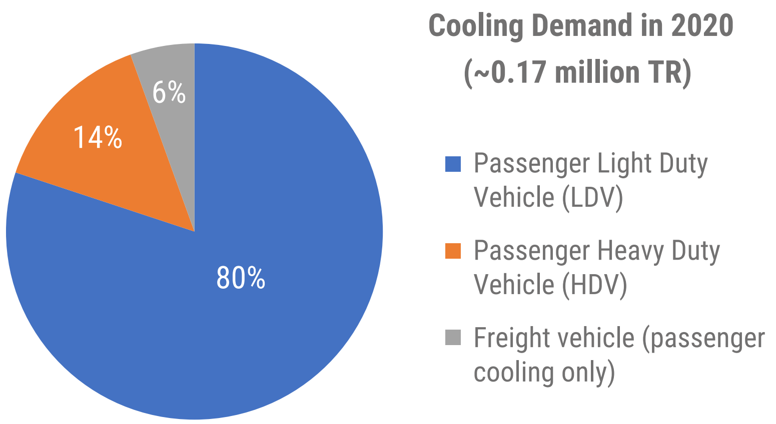
Source: Authors, NCAP Assessment

Figure 31. **Freight vehicle stock in 2020 and in the BAU scenario, 2030 and 2040**



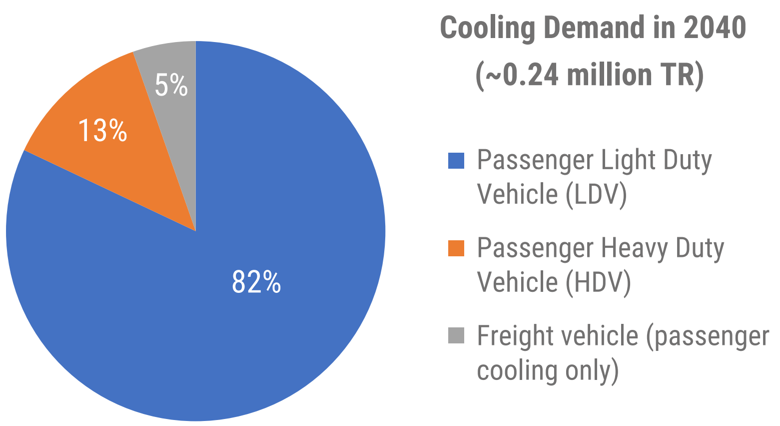
Source: Authors, NCAP Assessment

Figure 32. Cooling demand for mobile air conditioning, by vehicle type, 2020



Source: Authors, NCAP Assessment

Figure 33. Cooling demand for mobile air conditioning, by vehicle type, in the BAU scenario, 2040



Source:Authors, NCAP Assessment

Light-duty vehicles constitute 360 Metric tons of refrigerant demand, or 92 per cent of the total refrigerant consumption in the mobile air conditioning sector in 2040 (a 10-fold increase compared to the baseline year) and increased cooling demand of 0.2 million tons of refrigeration by 2040 (to comprise 82 per cent of the sector). The Intervention scenario, which considers passive measures for reducing cooling demand and improving the fuel efficiency of vehicles, results in fuel efficiency savings of 13.7 per cent in cooling.

The penetration of climate-friendly HFO-1234yf is expected to be low in Cambodia due to the higher patent cost of the refrigerant, which will increase the price for manufacturers by a factor of 2 to 6 and the price for consumers by a factor of 4 to 15, compared to the production price (Sherry et al. 2017; Seidel and Ye 2015). The country needs to develop a strategic action plan for faster adoption of electric and clean fuel-operated vehicles to reduce fuel-related emissions from mobile air conditioning.

7.5 Process Cooling

The process cooling requirements in Cambodia in 2020 were served mainly by 10,973 screw chillers and 338 scroll chillers (Table 9). Cooling demand in the sector is projected to increase to around 1.5 million tons of refrigeration, up from around 1.2 million tons in 2020, with screw chillers continuing to dominate (Figures 34 and 35).

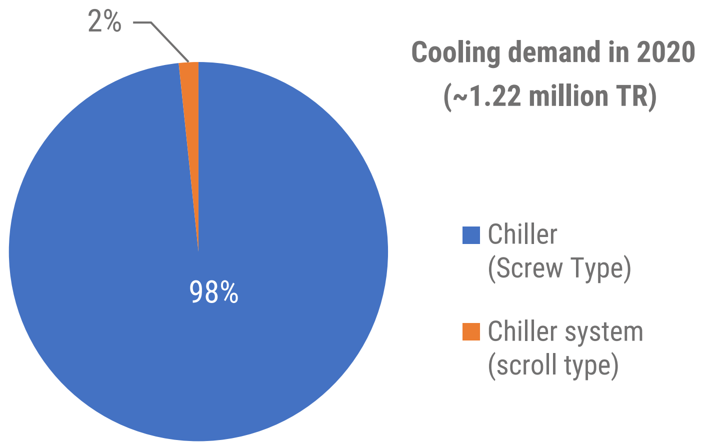
Improving the efficiency of chiller systems would lead to potential energy savings of 11 per cent, or 221 GWh of energy savings, in 2040. The refrigerant transition planned by the National Ozone Unit envisages eradicating the use of HCFC-22 in process cooling by 2030. This target is planned to be achieved in three steps: 1) reduce the share of HCFC-22 use by 44 per cent (from a 64 per cent market share in 2020 to 36 per cent in 2021), 2) reduce the share by a further 36 per cent starting in 2026 (from a 36 per cent market share in 2025 to 12.6 per cent in 2026) and 3) eradicate HCFC-22 by 2030.

Table 9. Equipment stocks for process cooling, by type, in 2020 and in the BAU scenario, 2030 and 2040

Stock data (in thousands)	Baseline	BAU Scenario	
	2020	2030	2040
Chiller systems (screw type)	10.97	12.35	12.92
Chiller systems (scroll type)	0.34	0.46	0.53

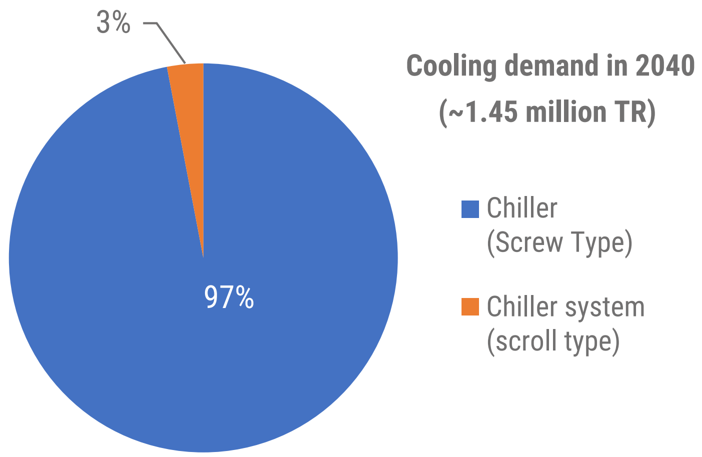
Source: Authors, NCAP Assessment

Figure 34. Cooling demand for process cooling, by equipment type, 2020



Source: Authors, NCAP Assessment

Figure 35. Cooling demand for process cooling, by equipment type, in the BAU scenario, 2040



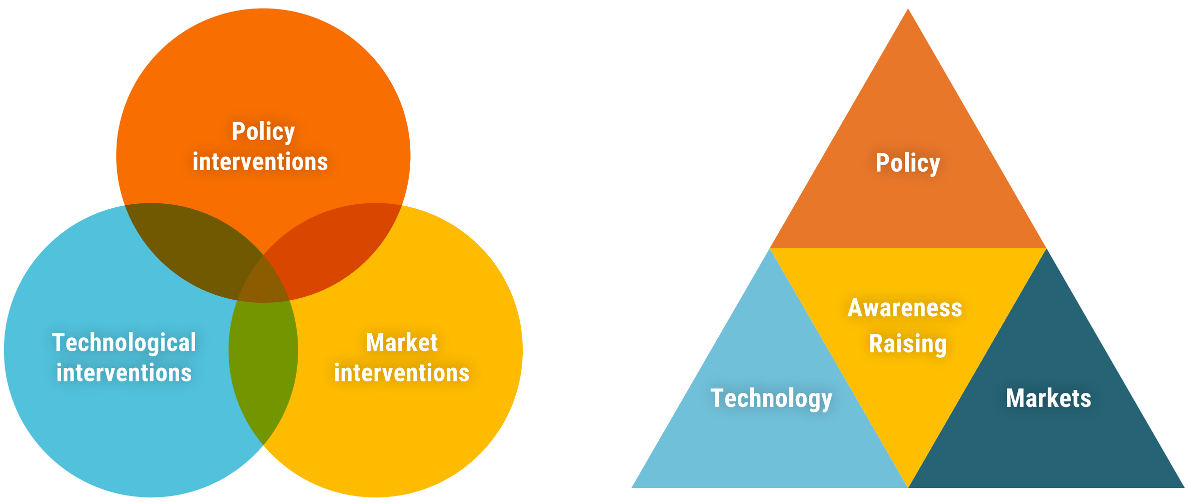
Source: Authors, NCAP Assessment

8. NCAP Recommended Strategic Actions

This section presents a set of solutions that lay out a pathway to drive Cambodia towards energy-efficient and climate-friendly cooling while enabling access to cooling for all. The interventions have been developed based on the contextual and analytical sections of the present NCAP, along with reviewing potential alignment and synergy with existing efforts, available technological solutions for more sustainable cooling and engagement with public and private sector stakeholders through the consultative process.

The interventions are classified in four areas (Figure 36): 1) Policy and Regulatory Interventions, 2) Technological Interventions, 3) Market-Supporting Instruments and 4) Capacity-Building and Awareness-Raising. Even if these are independent of one another, there are overlapping areas.

Figure 36. **Illustration of proposed intervention areas for reducing greenhouse gas emissions in the cooling sector in Cambodia**



- Policy and Regulatory Interventions: Policy and regulatory enablers aim to scale up sustainable cooling. These include the establishment of minimum energy performance standards (MEPS) and labelling, building energy codes, and reinforcement of vehicle emission standards, among others.

- Technological Interventions: Leapfrogging to efficient technologies including inverter technologies in air conditioners can be critical to address the growing cooling energy demand. Apart from deployment of high-efficiency technologies, some of the important technical factors important to energy efficiency include enhancing the efficiency of cooling systems (by ensuring the proper installation and maintenance of heating, ventilation, and air conditioning (HVAC) equipment, improving building design, and better materials, among others), exploring not-in-kind (NIK) and low-energy technologies, low-GWP refrigerant alternatives, and cooling solutions for off-grid or weak-grid locations, supported by academia or private sector research and development and expertise. A number of proposed technology improvement schemes can be implemented, including: 1) low-GWP refrigerant alternatives in room air conditioning, large air-conditioning systems, transport air conditioning and refrigeration systems; 2) health-care cold chain vaccine temperature monitoring through sensors and the Internet of Things; and 3) for mobile air conditioning, accelerated adoption of insulated vehicle bodies and high-performance glazing.

- Market-Supporting Instruments: These include financing and debt subsidy instruments to promote sustainable cooling, innovative business models to deliver and scale up sustainable cooling, and public procurement.

- Capacity-Building and Awareness Raising: This includes strengthening institutional and professional capacities (including training of technicians) and enhancing consumer and stakeholder awareness. Capacity-building and awareness raising are cross cutting and are to be applied in conjunction with other interventions to ensure their efficacy and to unlock the expected benefits.

From the demand assessment and various rounds of consultations, it has been acknowledged that ample opportunities are available to reduce the cooling demand through passive cooling solutions, optimizing the cooling load by promoting energy efficiency in equipment, operational efficiency enhancements in different sectors, reducing the demand for or transitioning towards low-GWP refrigerants through the adoption of new alternatives, and better servicing through immediate and long-term actions.

Key to implementing the plan and to setting out interventions is multi-stakeholder coordination, including relevant departments, industry, and academia, through the Technical Committee established for the development of the NCAP or through the establishment of a new commission or implementing working group.

The NCAP interventions are presented in Table 10 in Section 9, which summarizes thematic and sectoral interventions as well as the responsible authorities for implementing and prioritizing the actions. In the following sub-sections, a thematic discussion of key recommendations is presented to provide more detail to support the transition to implementation.

8.1 Urban Cooling and Building Policies and the Integration of Passive Cooling Solutions

Cambodia should set policies to enable a transition towards a climate-friendly, energy-efficient and resilient buildings and construction sector. The provision of parks and urban forests, lakes, streams and canals is essential to maintain the coolness of cities with hot climates and to reduce the urban heat-island effect. The form and compactness of buildings, as well as mutual shading, can impact energy demand and renewable energy potential.

In addition to nature-based solutions and urban form and planning, which represent strong measures to reduce heat, the development of cool surfaces (roofs and walls) has a major impact. When sunlight hits a dark-coloured roof, 38 per cent of its energy heats the atmosphere, 52 per cent heats the city air, and only 5 per cent is reflected back. In comparison, when sunlight hits a light-coloured reflective roof, 10 per cent heats the atmosphere, 8 per cent heats the city air, and 80 per cent is reflected.

According to the NDC Buildings and Construction Roadmap draft for Cambodia (MLMUPC 2021), consultations with key experts and stakeholders agreed that urban planning should prioritize an integrated approach that supports low-carbon buildings and low-carbon living, reducing the urban heat-island effect through urban design standards and the promotion of off-grid solar street lighting. The integration of requirements of cooling sufficiency and urban heat-island mitigation in urban planning control rules enables getting multiple benefits such as reduction in cooling demand and energy consumption of the built environment, improved outdoor thermal comfort, etc.

The Ministry of Mines and Energy and the Ministry of Land Management, Urban Planning and Construction, in cooperation with other ministries and relevant authorities, should develop and implement comprehensive building energy codes for new buildings and for existing buildings undergoing major renovation. This will reduce building-related cooling demand and energy consumption. The codes should emphasize the performance requirements of passive cooling systems and mechanical cooling. Implementation of passive cooling solutions through building codes for 20 per cent of the new building stock within the first year (i.e., 2021) with a compound annual growth rate of 5 per cent would reduce the total cooling demand in the year 2040 by 530,000 tons of refrigeration.

Cambodia Green Building Council is a promoter of green practices and a sustainability reference organization within the growing construction market sector. The Council aims to make green buildings and communities for all Cambodians and to drive the country to become the green building leader in Southeast Asia. It aims to involve policymakers, professionals and society at large in the quest for transforming the building industry into one that respects the environment by embracing green issues (Cambodia Green Building Council n.d.).

The Council is developing the Guidelines and Certification for Green Buildings in Cambodia, a key enabling component for the development of the energy building code. In addition to design considerations, materials, and other technical aspects, the guidelines highlight implementing measures such as a green building rating system that could be used as a marketing tool to increase competition among building and architectural companies.

An example of an effective green building rating that can be highlighted is BREEAM (Building Research Establishment Environmental Assessment Method). This global rating system is used to measure the environmental performance of new and existing buildings and infrastructure projects. The BREEAM system includes criteria such as energy, land use, materials, transport, and health and well-being, which are designed to promote more sustainable environments that enhance the well-being of the people who live and work in them and help protect natural resources.

An energy code that integrates a comprehensive approach to cooling will help to create new green jobs in the buildings and construction sector, as well as improve the living standards for Cambodian residents. The guidelines and certification scheme should be promoted through industry-specific training and an awareness-raising workshop, particularly for architects and construction companies in Cambodia.

8.2 Not-in-kind Technologies

The government should promote the adoption of innovative "not-in-kind" (NIK) cooling technologies to reduce greenhouse gas emissions. These include technologies such as district cooling systems, direct renewable energy-driven cold storage and vaccine refrigerators, geothermal cooling, absorption/adsorption cooling, phase change material-based cooling, etc. Programmes targeting public buildings and public-led major real estate developments can be developed to pilot for industry the cost effectiveness and policy support for such solutions. Utility-level technological solutions such as better monitoring of household cooling consumption to promote demand-side measures helps in rationalizing the tariffs.

District cooling systems are the most energy-efficient means to provide air-conditioning service in dense areas of cities and should be promoted at an accelerated pace. Several countries in the Global South have progressed in adopting district cooling systems including China, India, Malaysia, the Philippines, and Singapore, among others. The efficiency and refrigerant consumption of on-site cooling equipment varies greatly depending on the product, building and cooling system design, operation and maintenance, and even the building's ownership structure. In general, in dense urban areas, energy and refrigerant use for air conditioning is far lower if clusters of buildings and even whole townships are connected to a district cooling system.

District cooling systems provide a wide range of benefits in comparison to conventional on-site cooling systems – including energy efficiency, reduced refrigerant consumption, optimal operations, etc. According to reports, district systems consume 35 per cent and 20 per cent less electricity as compared with conventional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers, respectively (Electrical and Mechanical Services Department n.d.). With improved operations and renewables, this can increase to beyond 50 per cent.

The demand aggregation by combining many diverse load profiles provides economies of scale that allow district cooling systems to cost effectively use high-efficiency and sustainable technologies (such as tri-generation) that are less economically and technically feasible at the individual building level. District cooling also offers a huge benefit to building owners of not having to procure, install, operate, and maintain air-conditioning plants, which consume large portions of annual budgets (EESL 2021). Finally, the centralized approach of district cooling allows the safe and controlled use of environmentally friendly refrigerants that are not appropriate or available at the individual building level.

The implementation of district cooling should be promoted, as it opens up the possibility of using more-efficient technologies and system configurations. District cooling systems can be promoted through government support for pilot projects to lead the market and test the technology, policy and business model. A district cooling roadmap can be developed to help integrate these systems into national policy frameworks, such as urban planning and building regulation, or voluntary approaches through environmental guidelines.

Work with international partners can be undertaken to develop investment proposal requests to unlock funding through incentive schemes or financial mechanisms to help kick start district cooling systems in Cambodia. Complementary training and capacity-building can help to equip different stakeholders with the knowledge and skills to deliver this technology.

8.3 Equipment MEPS and Labelling Programme

Along with more sustainable building and construction solutions, it is equally important to promote energy efficiency in the cooling equipment used to cool buildings, preserve food and health products in the cold chain, provide refrigeration services for industry and satisfy mobile cooling requirements.

Performance standardization of active cooling equipment including air conditioners, chillers, cold chains and mobile air conditioning is key to reduce electricity consumption and the peak load in the electricity network as well as to reduce the overall demand for refrigerant gases. Better serving these cooling loads can greatly reduce the capacity of active cooling equipment needed.

Minimum energy performance standards (MEPS) and energy labels, if well designed and implemented, are among the fastest and most effective approaches to improve efficiency. MEPS and energy labels should be updated and enforced to ensure that the national market adopts energy-efficient technology in line with global trends on equipment and to avoid the dumping of inefficient products that cannot be sold elsewhere.

Setting up MEPS and labels for cooling equipment, such as domestic and commercial refrigerators and air-conditioner systems, offers an opportunity to reduce electricity consumption, reduce peak load in the electricity grid and reduce the associated indirect greenhouse gas emissions coming from fossil fuel power plants. On top of this, if the regulation is jointly set to limit the use of high-GWP refrigerants, then direct emissions can be abated significantly. Technologies are widely available to improve energy efficiency and to use lower-GWP refrigerants. These efforts also contribute greatly to achieving the commitments that Cambodia has established both in its NDC under the Paris Agreement and in the ratified Kigali Amendment to the Montreal Protocol.

China, the biggest manufacturer of cooling equipment globally, has set MEPS and labels for air conditioners and domestic refrigerators. These are expected to take effect in 2022 and should have significant impacts on the cost and availability of energy-efficient air conditioners. This should make more efficient equipment available in the region, given the size of the domestic and export markets.

The national entity and competent agencies that will pursue the establishment of MEPS and energy labels, and/or HEPS (High Energy Efficiency Performance Standards) can consult and benchmark against the United for Efficiency (U4E) Model Regulation Guidelines (U4E n.d.), available for domestic and commercial refrigeration and room air conditioners. The NCAP Intervention scenario (see section 6) considers in its assumptions that the average energy efficiency and GWP level of equipment in Cambodia is above the minimum ambition scenario of those Guidelines. Therefore, adopting the minimum levels as a baseline and carrying out complementary efforts at the higher tiers of these guidelines – through voluntary programmes and incentive mechanisms for the adoption of super-high-efficient equipment – will lead the country to unlock the potential savings.

The country can use higher ambition levels as the basis to procure superior products to qualify for optional incentive programmes, and/or as a voluntary approach for an interested market segment that wishes to go beyond baseline MEPS requirements (e.g., a Sustainable Public Procurement Programme or hotels that wish to demonstrate their leadership on sustainable cooling).

MEPS and labels should be updated at least once every five years to ensure alignment with the technological trends of available products and to adequately protect the market from inefficient equipment.

8.4 Market Surveillance to Support Regulations Compliance and Updating

An effective monitoring and verification mechanism is critical to achieve the intended objectives and to provide evidence and market knowledge through data to support the upgrade process of the efficiency levels.

Monitoring, verification and enforcement (MVE) ensures a fair market as programme administrators oversee products sold in the market, help verify compliance with MEPS and labels (e.g., through product testing), enforce these requirements and report the results. Therefore, consumers and businesses trust and benefit from cooling products that meet their energy claims.

Data collection and the existence of a functioning legal and administrative framework are critical to a successful MVE system. When establishing an MVE scheme, authorities need to establish a strong and clear national framework to define the responsible legal authority, enforcement powers and penalties. In addition, the legal frameworks must clearly delineate responsibilities among the different government agencies that implement MVE nationally.

A product registration system (PRS) or database is a key resource to support the MVE activities in relation to product efficiency standards and labelling programmes. A PRS is a comprehensive and integrated data repository that helps the government gather information on products being imported and/or being offered for sale, as well as certification of whether the equipment meets the established regulations and is approved for import/sale. The system serves as an updated repository of information related to national room air conditioning equipment plants and facilitates the identification of technology trends and the monitoring of efficiency and progress in the refrigerant transition. Moreover, such systems can facilitate national and international energy and greenhouse gas reporting requirements.

8.5 Strengthening the Cold Chain

Ensuring a strong, unbroken and accessible cold chain for foods, medicines and vaccines will improve the quality of life of the Cambodian population. Farmers and fishers with affordable access to such services can improve their participation in the market, and food and medicine loss can be greatly reduced, contributing to less waste as well as a reduction in associated greenhouse gas emissions.

The Cambodia NCAP contains a general cold chain assessment (see sections 7.2 and 7.3) that provides the direction and baseline to present strategic recommendations for some of the most impactful and readily available solutions.

The relevant government entities should undertake a more detailed cold chain needs assessment to provide the underlying direction for creating holistic and sustainable cold chain and cooling infrastructure and to rationalize cold chain programmes across ministries. The Cooling for All needs assessment, developed by Heriot-Watt University and Sustainable Energy for All, can be leveraged to assess cooling needs across buildings, cities, agriculture and health and to identify the policy, technology and finance measures to address those needs.

Understanding and quantifying the current cooling demand, existing cold chain capacity and future needs, as well as their associated energy demands and impacts on natural resources and the environment, is essential to identify the gaps and potential areas for optimization. Authorities should build approaches and mechanisms to support innovations in technologies and business models via public and private finance.

Responsible government entities must work together with academia and the private sector to develop the necessary skills and capacity in the cold chain subsectors to adopt, operate and maintain new technologies that the industry is ready to offer. This will strengthen the market and facilitate the adoption and adequate use of efficient technologies and access to the associated economic, social and environmental benefits. In parallel, it is critical to develop and implement finance and business models, such as servitization, that create and share value and overcome perceived issues around affordability and viability.

Such partnerships should also drive large-scale system demonstrators to show the impact and how the interventions can work together to create sustainable and resilient solutions for scaling. Large-scale system demonstrators are important to provide a ground for accelerated deployment of interventions by eliminating the performance risk and demonstrating impact through live market testing, including the indirect and potential positive and negative consequences.

8.6 Market Enablers and Financial Delivery Mechanisms

Realizing the transition to more energy-efficient, climate-friendly and affordable cooling solutions requires mobilizing the market to reduce the barriers to adoption of more sustainable solutions. Public (domestic and non-domestic) and private funding sources are required to help finance this transition.

For the market transformation towards climate-friendly cooling, several fiscal and financial business models can be leveraged to overcome market barriers, increase local investor confidence, and mobilize private sector investments and participation. Cambodia can carry multiple policy interventions to drive market adoption of better technologies. These include:

- public procurement of super energy-efficient appliances, for example, fans and air conditioners;
- replacing old, inefficient refrigerators and air conditioners at the commercial and domestic scales;
- retrofitting inefficient process cooling systems;
- using time-of-use tariffs to promote optimal peak load management; such tariffs would allow the economical production and storage of cooling resources during off-peak hours, and dispatch during on-peak hours;
- applying disincentives for the purchase of inefficient cooling equipment that either does not meet modern MEPS or that contains ozone-depleting substances or has high GWP; by doing so, the market would eventually migrate towards energy-efficient equipment; and
- providing incentives for businesses to preferentially invest in the most energy-efficient cooling technologies by allowing a reduction of the overall businesses tax liability.

Such measures can be achieved by implementing financial delivery mechanisms to enable the flow of funding to be matched with efficient and climate-friendly cooling targets established. Cambodia can carefully select a set of these mechanisms to implement in the country and provide flexibility for users to get access to cooling that is energy efficient and clean at an affordable cost. Some of these mechanisms include[14] :

- cooling-as-a-service (CaaS) business model
- on-bill financing schemes
- shared and guaranteed savings energy performance contract models
- trade-in or replacement programmes and public procurement

[14] For more on financial delivery mechanisms and other market enabling mechanisms, see The Carbon Trust et al. (2018), The Carbon Trust (2019) and Climate Finance Advisors and Natural Resources Defense Council (2019).

- revolving fund
- bulk procurement programmes.

Each of these models has different advantages, uses a different path to overcome specific barriers, and requires the full support of the various public and private sector stakeholders. These models may be combined with financial and non-financial risk mitigation mechanisms and tailored to local conditions (more on these and other models can be found in the Manual of Financial Mechanisms (U4E and BASE 2019)). Their success depends on a thorough understanding of the market, strong engagement of the key stakeholders, the successful creation of an environment of trust, and a well-designed model offering a sustainable solution by creating value for all involved players.

8.7 Sources of Finance

Several funding sources can be used to drive the transition to more efficient and climate-friendly cooling – both public (domestic and non-domestic) and private (U4E 2017a). Cambodia can explore accessing funds from climate change mitigation funds, multilateral development banks, and national and private financial institutions to support sustainable cooling initiatives and help initiate programmes, raise investor confidence and attract private investors (U4E 2017b). These funds can be purposed for better planning and blending of financing sources with appropriate mechanisms, creating a more suitable financial ecosystem, including risk- and cost-sharing arrangements. Other financial mechanisms include equity, concessional loans, guarantee and risk-sharing facilities, technical assistance grants, and fiscal incentives and penalties. Public finance can be used to maximize the leverage of private sector capital.

As a low-middle income country, Cambodia continues to face challenges related to the availability of public investment for implementation of the NCAP. Financial mobilization from external sources including multilateral funds, bilateral funds and private sector participation will be required to support implementation of the interventions proposed in the NCAP.

Having operated since 1991, the Multilateral Fund was established with an aim to "assist developing country parties to the Montreal Protocol whose annual level of consumption of ozone-depleting substances is less than 0.3 kilograms per capita to comply with the control measures of the Protocol". The Fund has supported more than 8,600 projects worth over $3.9 billion in a range of areas from industrial conversion to technical assistance, training and capacity-building (UNEP OzonAction n.d.). The Multilateral Fund is clearly a key funding source for implementation of the NCAP.

As a second source, potential bilateral collaboration between the Royal Government of Cambodia and developed countries can be sought for the implementation of actions under the NCAP. Financial resources can also be mobilized from climate-related mechanisms including the carbon trading mechanism under Article 6 of the Paris Agreement, the World Bank, the Green Climate Fund, the Global Environment Facility, the Asian Development Bank, donor countries, development partners and others.

Many barriers inhibit investments in energy efficiency, including high upfront costs, lack of access to finance, high perceived risk, lack of trust in new technologies, competing investment priorities, lack of knowledge and awareness, and split incentives. Many of these barriers can be overcome, at least in part, with well-designed financing mechanisms, incentives, and business models, together with complementary measures such as policies, regulations, awareness-raising activities and behaviour change initiatives (U4E and BASE 2019).

8.8 International Cooperation and Partnerships

Cambodia can continue to implement committed interventions under international commitments and cooperation such as the Paris Agreement, the Kigali Amendment to the Montreal Protocol and the United Nations Sustainable Development Goals. Cambodia can also participate in international initiatives to accelerate actions for sustainable cooling, such as joining the Cool Coalition, the Sustainable Cooling Initiative of the World Bank, the Sustainable Cooling Innovation Program of the International Finance Corporation, and others.

More detail recommendations with sectoral mappings and thematic segregation are presented in Table 10 in Section 9. Proposed actions are categorized as short term (5 years), medium term (10 years) and long term (20 years). The institutions in charge of implementing proposed actions are also clarified in the table. Each action can be implemented based on the availability of resources: human, finance and technology. The interventions are prioritized based on the approach elucidated in Table 10.

The implementation of the NCAP should be regularly monitored and evaluated by the Inter-Ministerial Working Group once it is endorsed, to ensure effective implementation and course correction. A Monitoring and Evaluation System can also be established to serve this purpose, as described in detail in section 10. After five years of NCAP implementation, provided that the human resources are available, the NCAP should be reviewed for progress and challenges, and possible revision.

9. NCAP Recommended Strategic Actions: Summary of Interventions

Table 10. Proposed actions for the short term (5 years), medium term (10 years) and long term (20 years)

Building Space Cooling					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Policy and Regulatory Interventions	SC.1: Establish building codes and enforcement/ certification for new buildings and those under major renovation. SC.2: Reduce the reliance on and use of mechanical air conditioning in public sector buildings. SC.3: Establish a product gateway system to help enforce the compliance on regulated products. SC.4: Adopt MEPS and energy labels for air conditioners. SC.5: Comply with low-climate impact performance standards for all new city assets (or during regular maintenance and retrofit cycles).	• Lower electricity and energy consumption. • Lower operational cost for users. • Improve health and well-being. • Thermal comfort for everyone. • Increased productivity. • Reduction in greenhouse gas emissions. • Increased technology transfer.	Medium term	Ministry of Land Management, Urban Planning and Construction	Ministry of Economy and Finance; Ministry of Mines and Energy

Technological Interventions	SC.6: Include a performance requirement for passive cooling systems in building energy codes.		Short term	Ministry of Mines and Energy	Ministry of Environment; Ministry of Land Management, Urban Planning and Construction
	SC.7: Promote and encourage the use of energy-efficient room air conditioners based on the highest tiers defined in the energy labels.		Short term	Ministry of Mines and Energy	Ministry of Environment
	SC.8: Increase the use of energy-efficient centrifugal chiller systems.		Medium term	Ministry of Mines and Energy	Ministry of Environment
	SC.9: Promote the use of energy-efficient variable refrigerant flow systems.		Medium term	Ministry of Mines and Energy	Ministry of Environment
	SC.10: Promote the use of energy-efficient components, retro-commissioning, retrofitting, automation, and better operation and maintenance.		Medium term	Ministry of Mines and Energy	Ministry of Environment
	SC.11: Promote energy efficiency in fans.		Short term	Ministry of Mines and Energy	Ministry of Environment
	SC.12: Pilot ultra-low GWP refrigerant alternatives in room air-conditioning and large air-conditioning systems.		Medium term	Ministry of Environment	Ministry of Industry, Science, Technology and Innovation Private Sector
	SC.13: Promote water-cooled chillers.		Short term	Ministry of Mines and Energy	Ministry of Environment
	SC.14: Promote district cooling in targeted cities through pilot projects and supportive policy.		Long term	Ministry of Land Management, Urban Planning and Construction	Ministry of Mines and Energy

Market-Supporting Instruments	SC.15: Promote business models / market mechanisms to make energy-efficient space cooling systems affordable. SC.16: Establish mandatory energy consumption disclosure for all public buildings and large commercial buildings. SC.17: Establish a robust framework and process for collaboration so the benefits of multi-stakeholder engagement can be effectively leveraged.		Short term	Ministry of Mines and Energy	Ministry of Environment
Mobile Air Conditioning					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Policy and Regulatory Interventions	MAC.1: Reduce cooling and refrigerant demand in mobile air-conditioning systems by shifting passengers towards public transport. MAC.2: Promote electric vehicles with efficient mobile air-conditioning systems and promote biofuel adoption.	• Energy-efficient mobile air conditioning. • Increased technology transfer. • Lower electricity and energy consumption. • Reduced greenhouse gas emissions.	Medium term	Ministry of Public Works and Transport	Ministry of Environment
Technological Interventions	MAC.3: Promote and encourage the use of efficient and clean technologies in mobile air conditioning with adequate and regular maintenance. MAC.4: Accelerate the adoption of insulated vehicle bodies and high-performance glazing. MAC.5: Adopt low-GWP refrigerants in the mobile air-conditioning segments.		Short term	Ministry of Mines and Energy	Ministry of Environment

Food Cold Chain					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Policy and Regulatory Interventions	FCC.1: Adopt MEPS and energy labels for domestic and commercial refrigeration equipment. FCC.2: Reduce energy consumption and greenhouse gas emissions in cold storages through legislation promoting energy-efficient technology and improved building design (e.g., optimized sizing, insulation with optimum thermal performance, shading and air curtains in loading area, etc.). FCC.3: Quantify and benchmark energy use and greenhouse gas emissions in the existing food cold chain, identify data gaps, develop forecasts and identify opportunities for reductions.	• Reduced food waste. • Lower energy and electricity consumption. • Reduced greenhouse gas emissions; and • Promotion of the use of high-quality technology.	Long term	Ministry of Environment	Ministry of Mines and Energy; Ministry of Land Management, Urban Planning and Construction
Technological Interventions	FCC.4: Assess and apply the highest-potential energy efficiency measures (equipment and operation) for ice cooling systems (fishing). FCC.5: Coordinate a national market assessment focused on commercial refrigeration equipment.		Short term	Ministry of Agriculture, Forestry and Fisheries	Ministry of Environment; Ministry of Public Works and Transport
	FCC.6: Standardize the design specifications for all food cold chain components.		Short term	Ministry of Mines and Energy	Ministry of Environment; Ministry of Agriculture, Forestry and Fisheries

Market-Supporting Instruments	FCC.7: Adopt low-GWP refrigerants for cold chain vapour compression equipment.		Medium term	Ministry of Environment	Ministry of Agriculture, Forestry and Fisheries
	FCC.8: Introduce market transition financial mechanisms that promote high-quality and affordable refrigerators.		Short term	Ministry of Environment	Ministry of Mines and Energy; Ministry of Commerce
	FCC.9: Promote the use of refrigerated or insulated vehicles or containers where appropriate in the market to reduce food waste.		Medium term	Ministry of Public Works and Transport	Ministry of Environment; Ministry of Agriculture, Forestry and Fisheries
Health-care Cold Chain					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Policy and Regulatory Interventions	HCC.1: Promote building infrastructure for hybrid cold chains with the dual purpose of food storage and medical use.	• Improved energy efficiency and productive use. • Improved resilience and adaptability.	Medium term	Ministry of Environment	Ministry of Health; Ministry of Agriculture, Forestry and Fisheries
Technological Interventions	HCC.2: Establish vaccine temperature monitoring through sensors and the Internet of Things. HCC.3: Improve energy efficiency and use low GWP refrigerants in storage refrigerators through acquiring new technologies.	• Lower energy and electricity consumption. • Reduced greenhouse gas emissions. • Improved storage in the health-care system.	Medium term	Ministry of Environment	Ministry of Health

Process Cooling					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Policy and Regulatory Interventions	PC.1: Establish a ban to prevent the discharge of refrigerant gases to the atmosphere when servicing industrial vapour compression equipment.	• Lower energy and electricity consumption. • Reduced greenhouse gas emissions. • Safe working environment.	Medium term	Ministry of Environment	Ministry of Industry, Science, Technology and Innovation
	PC.2: Reinforce the establishment of a mechanism for collection and further destruction of refrigerants.		Medium term	Ministry of Environment	Ministry of Industry, Science, Technology and Innovation; Ministry of Economy and Finance
Technological Interventions	PC.3: Encourage and promote the use of energy-efficient chiller systems (both scroll and screw type) and promote continuous system monitoring, maintenance and calibration. PC.4: Develop a processing and recycling scheme to handle room air-conditioning equipment at the end of its useful life.		Long term	Ministry of Mines and Energy	Ministry of Environment

Cross-sectoral					
	Intervention	Impact and Benefits	Timeline	Lead Agency	Supporting Stakeholder(s)
Capacity-Building and Awareness-Raising	CS.1: Raise public awareness and promote training, education, and participation around energy efficiency and potential greenhouse gas emissions from the cooling sector.		Short term	Ministry of Environment	Ministry of Information

<table>
<tr><td rowspan="3"></td><td>CS.2: Strengthen awareness programmes on energy demand and potential greenhouse gas emissions in the cooling sector (including mass media campaigns, high-level events, publications, posters, television and radio spots, documentaries, workshops), targeted where possible to specific groups/ sectors, in collaboration with national non-governmental organizations and universities.</td><td rowspan="3">• Increased understanding of energy-efficient technology.
• Reduced greenhouse gas emissions.
• Lower energy and electricity consumption.
• Increased coordination among relevant stakeholders in the cooling sector.
• Increased technicians in the cooling sector.
• Increased technology transfer.</td><td>Medium term</td><td>Ministry of Environment</td><td>Ministry of Mines and Energy; Ministry of Information</td></tr>
<tr><td>CS.3: Undertake national awareness campaigns on relevant laws and policies related to energy efficiency in the cooling sector.</td><td>Short term</td><td>Ministry of Mines and Energy</td><td>Ministry of Environment</td></tr>
<tr><td>CS.4: Develop an awareness programme and tools to facilitate access by the public to competent room air-conditioning servicing technicians to install, service and handle their equipment.
CS.5: Develop an awareness programme to change the behaviour of consumers to properly repair leaks instead of topping up refrigerant.
CS.6: Strengthen the capacity of local experts in the cooling sector as well as research, information and management, technology transfer and acquisition, through education and training.</td><td>Medium term</td><td>Ministry of Mines and Energy</td><td>Ministry of Environment</td></tr>
</table>

	CS.7: Build capacity for the servicing sector on proper equipment installation, servicing and waste handling (refrigerants and equipment).		Short term	Ministry of Mines and Energy	Ministry of Environment
	CS.8: Build capacities of customs agents, designated enforcement officers and personal in charge of monitoring product imports to ensure that efficiency and climate regulations are enforced during and beyond the customs checkpoint.		Medium term	Ministry of Economy and Finance	Ministry of Mines and Energy; Ministry of Commerce
	CS.9: Train procurement officers in the public sector to ensure that purchasing decision-making includes energy-efficient and climate-friendly considerations.		Medium term	Ministry of Mines and Energy	Ministry of Environment
	CS.10: Train vendors and technology suppliers to properly interpret energy labels and to consider the lifetime cost of the units when estimating the investment costs.		Medium term	Ministry of Mines and Energy	Ministry of Economy and Finance
	CS.11: Coordinate with national academic institutions to update vocational and university programmes for cooling professionals to be consistent with best practices, regulations and national targets on sustainable cooling.		Short term	Ministry of Environment	Ministry of Mines and Energy

	CS.12: Train relevant government and other stakeholders in the food/agriculture and health-care sectors on best practices for sustainable cooling solutions.		Short term	Ministry of Agriculture, Forestry and Fisheries	Ministry of Mines and Energy; Ministry of Environment
	CS.13: Develop a capacity-building programme for room air-conditioning servicing technicians to follow good service practices, to ensure that equipment is operated at the optimum energy performance, that leakage of refrigerant is minimized and that safety is followed.		Medium term	Ministry of Mines and Energy	Ministry of Environment
Policy and Regulatory interventions	CS.14: Strengthen regional and international cooperation to address issues related to the cooling sector through regional discussion at the ASEAN level. CS.15: Strengthen collaboration and harmonize initiatives with activities under other relevant conventions and organizations.		Short term	Ministry of Environment	Ministry of Mines and Energy
	CS.16: Develop policies or regulations on promoting or acquiring energy-efficient and low-GWP technology in the cooling sector.		Medium term	Ministry of Mines and Energy	Ministry of Environment

	CS.17: Develop/update policies or regulations to ensure the safe adoption of climate-friendly technologies that use low-GWP refrigerants that are flammable, toxic or have higher working pressure. CS.18: Develop a mechanism to track and evaluate access to sustainable cooling.		Medium term	Ministry of Environment	Ministry of Mines and Energy
	CS.19: Promote women's participation in the decision-making process related to updating policies or amending regulations, and provide opportunities in the servicing sector.		Medium term	Ministry of Mines and Energy	Ministry of Environment; Ministry of Women's Affairs
	CS.20: Establish a competency assessment programme to ensure that only competent room air-conditioning and mobile air-conditioning servicing technicians are allowed to install, service and handle equipment.		Medium term	Ministry of Mines and Energy	Ministry of Environment
Market-Supporting Instruments	CS.21: Develop and utilize public procurement guidelines that set requirements for energy efficiency in public buildings and super-efficient cooling appliances.		Medium term	Ministry of Mines and Energy	Ministry of Environment; Ministry of Land Management, Urban Planning and Construction

	CS.22: Garner international finance through various channels such as the Multilateral Fund, Green Climate Fund, Global Environment Facility, etc., to implement innovative cooling solutions related to policies, technologies and business models.		Short term	Ministry of Environment	Management, Urban Planning and Construction Ministry of Mines and Energy
	CS.23: Develop innovative business models and financial delivery mechanisms to promote energy-efficient low-GWP cooling technologies in different sectors.		Medium term	Ministry of Mines and Energy	Ministry of Industry, Science, Technology & Innovation Ministry of Environment

10. Monitoring and Evaluation

Monitoring and evaluation are critical components of the NCAP. They are useful in monitoring progress, results and challenges during plan implementation. Monitoring and evaluation also allow for an adaptive management capability and ensure the flexible nature that characterizes effective and efficient implementation of the NCAP. Periodic assessments and reviews serve to inform about performance and whether strategies or actions need to be modified depending on the findings. Monitoring should be a continuous process so that it can detect unexpected changes requiring urgent attention. Reporting can be done annually and in response to the obligations agreed upon.

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