POLICY BRIEF

Advancing sustainable cooling in Cambodia to reduce energy consumption and greenhouse gas emissions

ENERGY

ESCAP
Economic and Social Commission for Asia and the Pacific

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Summary

Economic development, population growth, urbanization, and industrialization, coupled with rising temperatures driven by climate change, are leading to skyrocketing cooling demand. Cooling is not a luxury, but a necessity for human health and wellbeing, particularly in developing countries with hot and humid climates. Thermal comfort is important for productivity and learning, and cooling solutions are required along cold chains for food and medical supplies, in transport, and in industrial processes. Yet, the demand for cooling is straining power systems in some areas, while greenhouse gas emissions are rising rapidly from power consumed and the use of refrigerants with high global warming potential.

Cooling links to numerous national and international sustainable development objectives and targets, including the Sustainable Development Goals and the NDCs under the Paris Agreement. In some countries cooling is responsible for approximately half of electricity demand. Cooling's influence on power systems, the energy transition, climate efforts and resilience is large. Yet, cooling does not receive adequate attention within national policy frameworks of either energy or environment.

To help address this shortcoming, a National Cooling Action Plan Methodology was developed to support the assessment of national cooling sectors and to help establish comprehensive frameworks for meeting cooling needs in an energy-efficient and climate-friendly manner. The methodology was developed by UN Environment, ESCAP, and the Alliance for an Energy Efficient Economy (AEEE), in collaboration with members of the Cool Coalition, and was piloted in Cambodia.

Cambodia offers an excellent case study for broader lessons learned, as the nation has booming cooling demand due to numerous socioeconomic development factors, alongside rising temperatures. It also has a nascent cooling technologies market and minimal regulations guiding its development. To help put Cambodia on a pathway toward a more sustainable cooling sector, a National Cooling Action Plan was developed, led by the Ministry of Environment of Cambodia, and supported by ESCAP and UNEP.

The cooling sector assessment in Cambodia revealed a picture of growing cooling demand across sectors, alongside growing energy consumption and energy- and refrigerant-related emissions. An intervention scenario, based on a set of key policy recommendations, revealed the energy and emissions savings potentials at national and sectoral levels. Key policy recommendations to expand access to cooling services and transition towards the use of energy-efficient and climate-friendly technologies include:

- Adoption of urban planning and building design standards that include passive cooling strategies;
- Adoption of minimum energy performance standards for cooling equipment;
- Promotion of innovative "not-in-kind" (NIK) cooling technologies;
- Development of market monitoring mechanisms to support regulations compliance;
- Strengthening of cold chains;
- Creation of market enablers and financial delivery mechanisms;
- Unlocking various financial sources.
- Strengthening of international cooperation and partnerships

The development of a National Cooling Action Plan engages government and non-government actors across sectors and helps link and strengthen the existing policy base related to the cooling, and it also sends an important signal to development partners and investors that the nation is ready to move forward on implementing sustainable cooling initiatives. In the case of Cambodia, additional resources were mobilized to support the implementation of passive cooling strategies, feeding into the next round of the NDC updates.

Abbreviations

AC	air conditioner
ADB	Asian Development Bank
AEEE	Alliance for an Energy Efficient Economy
BAU	business-as-usual
CCAC	Climate and Clean Air Coalition
CO_2	Carbon dioxide
EPA	General Directorate of Environmental Protection
GDP	Gross Domestic Product
GHG	Greenhouse gas
GWh	gigawatt-hours
GWP	Global warming potential
HFC	hydrofluorocarbon
IEA	International Energy Agency
K-CEP	Kigali Cooling Efficiency Programme
MEPS	minimum energy performance standards
mm	millimeter
MoE	Ministry of Environment
MVE	monitoring, verification and enforcement
NCAP	National Cooling Action Plan
NCSD	National Council for Sustainable Development
NIK	not-in-kind
PCS	passive cooling strategies
PRS	product registration system
SDGs	Sustainable Development Goals
UHIE	urban heat island effect
UN DESA	United Nations Department of Economic and Social Affairs
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNEP	United Nations Environment Programme

References to dollars ($) are to United States dollars unless otherwise stated.

I. Introduction

Cooling is the unseen climate challenge. For many Asia-Pacific developing nations, the cooling sector – including space cooling, refrigeration, cold chains, mobile air conditioning, and industrial cooling – is a top driver of electricity demand and greenhouse gas emissions. At the same time, rising temperatures and heat stress are negatively impacting populations, economies, and power systems, and further increasing the need for cooling, creating a self-reinforcing cycle.

The ability to manage heat, build resilience, and ensure access to cooling services is a fundamental requirement of modern economies and healthy societies in regions that experience heat and humidity. Cities that incorporate green and blue spaces into urban landscapes lower the risk of heat stress for their populations by reducing the urban heat island effect that pushes temperatures higher in densely developed areas. Space cooling in buildings located in warm climates is crucial for physical comfort, health, and wellbeing, and comfortable interior environments are proven to boost productivity levels and student performance. Refrigeration helps keep food fresh longer and supports healthcare systems by keeping medicines and vaccines viable. Industrial cooling underpins numerous economic sectors, while cold chains enable the expansion of agricultural and fishery markets, minimize food wastage and facilitate vaccine distribution.

While access to cooling services has improved the quality of life for many people, large shares of populations, particularly in developing nations, remain without access. The penetration rates of household air conditioners are still in the single digits in many of the region's fastest growing economies. Rising temperatures and heat stress from climate change will increasingly impact populations, while growing household spending power will propel cooling demand upward. Unmanaged cooling growth would play a significant part in keeping fossil-derived electricity in the energy system. At the same time, refrigerants used in conventional technologies are up to 4,000 times more damaging In terms of their global warming potential than CO_2. In major growth markets, which are powered primarily by fossil fuels, the annual rise in electricity demand from cooling is outpacing annual renewable energy generation capacity additions, increasing stress on power systems and posing a serious challenge to reducing the sector's emissions.

Only recently has the cooling sector begun to receive the comprehensive policy attention needed to maximize its potential social and economic benefits, while minimizing its environmental impacts. Yet, the need for sustainable cooling solutions has never been more urgent, and requires a collaborative effort from policymakers, industry leaders, and civil society. Cambodia, a developing nation that is facing rising temperatures and the exponential growth of cooling demand, provides an example of how nations can take the first steps toward meeting the sustainable cooling challenge.

A. CAMBODIA'S COOLING CONTEXT

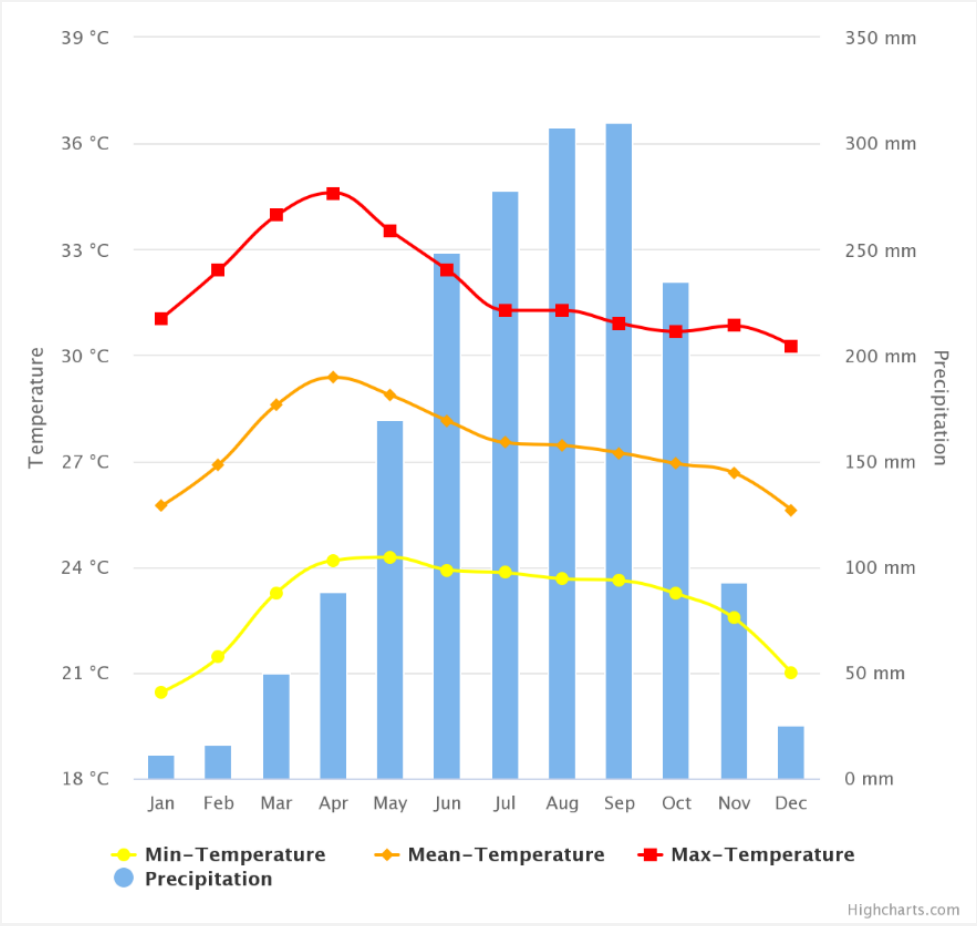
In Cambodia, high temperatures and humidity levels (Figure 1) make cooling not a luxury, but an increasing necessity. Climate change is driving a progressive rise in the average annual temperature (Figure 2), and is expected to increase the frequency and intensity of heatwaves, making the cooling challenge an

increasingly urgent issue. In recent years, the country has experienced a growing number of heatwave incidents, with temperatures reaching up to 42 degrees Celsius.

Urban areas are particularly vulnerable, where dense development and heat-absorbing surfaces contribute to the urban heat island effect that increases temperatures in cities. With climate shifts, an increasing number of people are at risk of experiencing heat-related medical conditions, particularly children, the elderly, the chronically ill, and those belonging to heat-exposed occupational groups. Heat stress is Cambodia is already estimated to cause an annual GDP loss of at least US$1.12 billion.

CAMBODIA EXPERIENCES A HOT AND HUMID CLIMATE

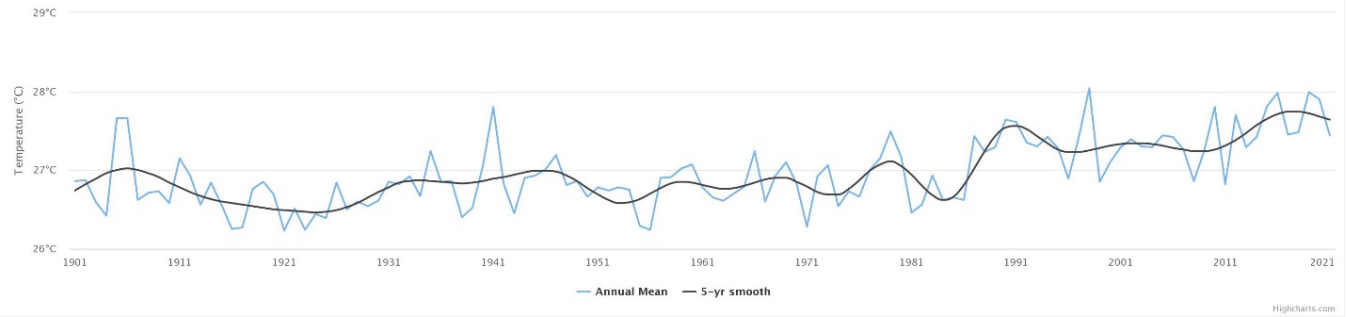
FIGURE 1: MONTHLY CLIMATOLOGY OF MIN-TEMPERATURE, MEAN-TEMPERATURE, MAX-TEMPERATURE & PRECIPITATION 1991-2020



Source: World Bank, 2021. Cambodia, Climate Change Knowledge Portal.
Available at: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-historical

TEMPERATURES ARE RISING IN CAMBODIA AS A RESULT OF CLIMATE CHANGE.

FIGURE 2: OBSERVED AVERAGE ANNUAL MEAN TEMPERATURE OF CAMBODIA, 1901-2021



Source: World Bank, 2021. Cambodia, Climate Change Knowledge Portal.
Available at: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-historical

In addition to climate factors, population growth, urbanization, and rising income levels are increasing the demand for cooling in Cambodia. In 2010, the nation had 14.3 million inhabitants. In 2021, that figure had risen to 16.5 million, and is expected to grow to more than 18 million by 2030. In 2010, one out five people lived in urban areas where the risk of exposure to heat stress is greater. That figure was one out of four in 2020, and the urbanization trend is expected to continue. Cambodia is also experiencing rising incomes. According to the World Bank, the annual gross domestic product (GDP) growth of Cambodia was between 6 and 7 per cent from 2010 to 2019. Following a decline in 2020 due to the global pandemic, economic growth of 4.8 per cent was predicted for 2022 and is projected to accelerate to 5.2 per cent in 2023. A growing economy means more people, institutions, and businesses will have the spending power to purchase and operate cooling equipment. New building construction is on the rise to meet growing demand for residential and commercial spaces. However, building energy codes and passive design guidelines have yet to be introduced to the sector.

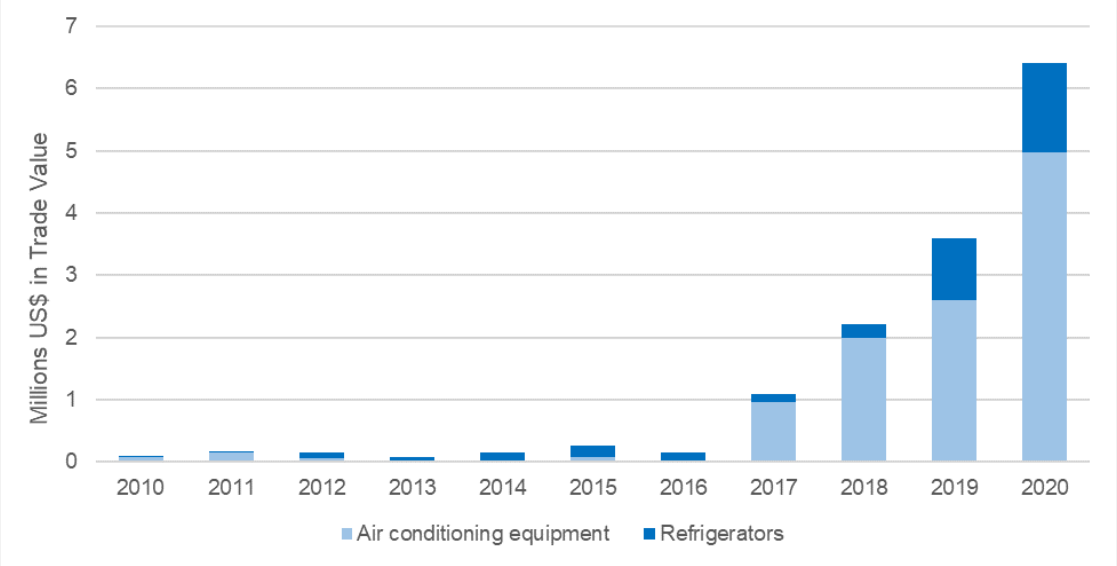
All of these factors have led to a surge in the installation of cooling appliances and their use. While the penetration rate of space cooling is in the single digits in Cambodia, the current rate of uptake of air conditioning, along with refrigeration, as illustrated by imports (Figure 3), is exponential.

Already the cooling sector is significantly influencing the nation's energy system and greenhouse gas emissions. The demand for cooling is a key factor behind a nearly nine-fold increase in power generation between 2010 and 2020. In 2020, UNEP-ESCAP analysis estimated that cooling and refrigeration accounted for 45 per cent of total electricity consumption. However, due to rapid demand growth, the Ministry of Mines and Energy has suggested that share is now closer to 60 per cent.

Considering that cooling currently accounts for such a large share of Cambodia's electricity demand, it is a central influencer on power system development and the nation's sustainable energy transition. To meet power demand in recent years, Cambodia's supply has been expanded through the introduction of hydropower and coal, the most carbon-intensive of fossil fuels. Cooling is placing stress on the power system and increasing peak demand; at the same time, it is responsible for a growing share of greenhouse gas emissions. This is not only from the consumption of electricity, of which half is generated from fossil fuels, but also from the use of refrigerants, including hydrofluorocarbons, or HFCs, which work well to cool, but are hundreds to thousands of times more potent as greenhouse gases than carbon dioxide.

THE EXPONENTIAL UPTAKE OF COOLING EQUIPMENT IS DRIVING ELECTRICITY DEMAND.

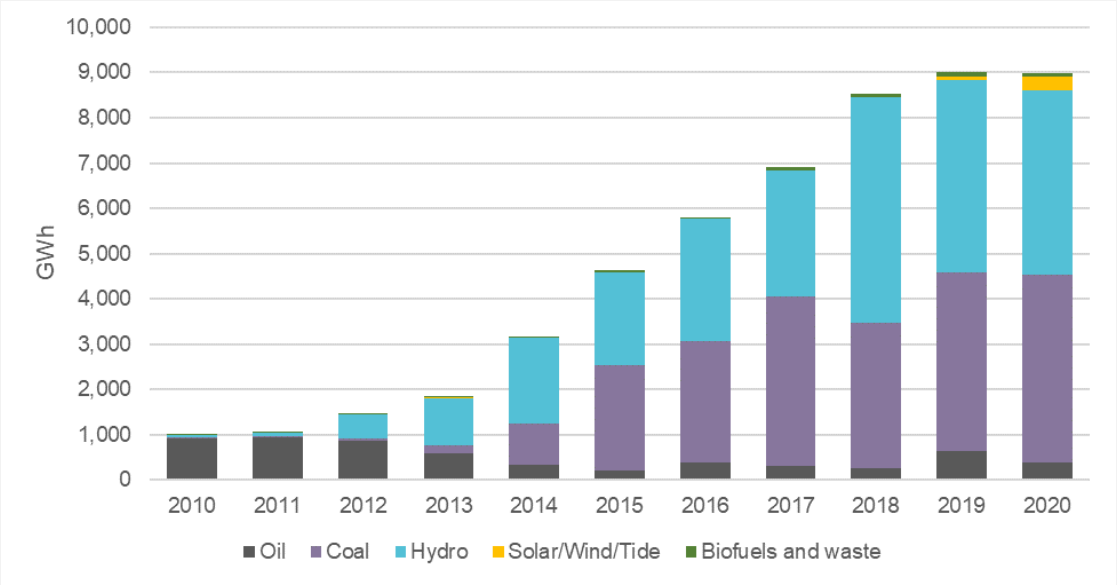
FIGURE 3: CAMBODIA AIR CONDITIONER AND REFRIGERATOR IMPORTS, 2010-2020



Data source: UN Comtrade

CAMBODIA IS HIGHLY RELIANT ON COAL TO MEET RISING POWER GENERATION NEEDS

FIGURE 4: ELECTRICITY PRODUCTION BY SOURCE, 2010-2020



Data source: IEA

The fastest growth in the cooling sector has been for space cooling for buildings, in particular, those serving the tourism sector such as hotels and restaurants. In terms of the building sector, the residential sector will be responsible for the vast majority of future added floor space. And while only a single-digit share of households have air conditioners, recent trends suggest that uptake in the residential sector will be rapid. Mobile air conditioning in the transport sector is also growing significantly.

Regarding refrigeration and food cold chains, the penetration rates of residential and

commercial refrigeration is low, but rising. For the agricultural and fishery sectors, which play an important role in the economy of the country, refrigeration is integral to cold chains that enable products from farms and waterbodies to reach customers without losing integrity or nutritional value. Cold chains consist of several components that usually include pre-cooling, cold storage and refrigerated transport. The lack of adequate and reliable cold chain access is one of the main contributing factors to food loss in Cambodia. Additionally, cold chains are applicable not only to food sectors, but are also vital for the medical sector to transport and store temperature-sensitive health products such as vaccines, blood products and medicines.

As Cambodia continues to develop, and climate change drives temperatures higher, the demand for cooling will continue to intensify, along with the impacts on energy systems and the environment from the use of space cooling, refrigeration, and process cooling equipment. Recent analysis of Cambodia's cooling sector predicts that the total stock of room air conditioners will grow two-fold by 2040, while chiller systems are expected to increase by 41 per cent. Variable flow refrigerant systems are projected to triple. Over the same period, the stock of domestic refrigerators and freezers will increase by 1.7 million units, while cold storage systems will increase by nearly seven times current levels (Ministry of Environment, National Council for Sustainable Development, 2022).

B. CHARTING A SUSTAINABLE COURSE FOR COOLING IN CAMBODIA

The scale of the sustainable cooling challenge is immense. It is also a cross-sectoral issue that requires a holistic and comprehensive approach. High-level political support and decisive actions are needed to develop targeted and synergized policy across sectors. The introduction of regulatory and financial market levers that drive the utilization of passive cooling strategies and the uptake of best-in-class energy efficient and climate-friendly active cooling technologies is needed.

In 2019, the UN Secretary General called for greater ambition on cooling through the development of National Cooling Action Plans (NCAPs). NCAPs have been identified by the development community as a tool to support nations to analyze current and future cooling needs across sectors, and to develop a strategic framework of actions, timelines and roles to meet those needs in a sustainable manner. In 2021, Cambodia became the first nation in South-East Asia to embark on the development of a comprehensive NCAP. To do so, the Department of Climate Change of the General Directorate of Policy and Strategy of the Ministry of Environment, the National Council for Sustainable 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 (ESCAP), in the context of the Cool Coalition[1] to pilot a newly-developed National Cooling Action Plan Methodology. Following a series of in-depth consultations, information gathering efforts, analysis, and validation, Cambodia's National Cooling Action Plan was launched at an ESCAP side event at COP27 in 2022, and then nationally in March 2023. The launch marked the completion of a significant policymaking effort and the achievement of the first cooling-related milestone set in the nation's updated 2020 Nationally Determined Contribution to the Paris Agreement (NDC) – the implementation of an NCAP to lower direct and indirect emissions from the cooling sector.

[1] The Cool Coalition, a global multi-stakeholder network that connects a wide range of key actors from government, cities, international organizations, businesses, finance, academia, and civil society groups to help solve the cooling challenge.

II. The National Cooling Action Plan (NCAP) and its advantages

A. OBJECTIVES OF AN NCAP

To help address the rapidly emerging cooling challenge through national policies, and to encourage cooperation amongst government, industry, and private sector stakeholders, the UNEP-led Cool Coalition and ESCAP, in collaboration with Alliance for an Energy Efficient Economy (AEEE), developed the National Cooling Action Plan Methodology. The methodology was built on the expertise of the members of the Cool Coalition's NCAP Working Group, facilitated by the Clean Cooling Collaborative, and was informed by the lessons learned from early adopters of cooling action plans, including China and India.

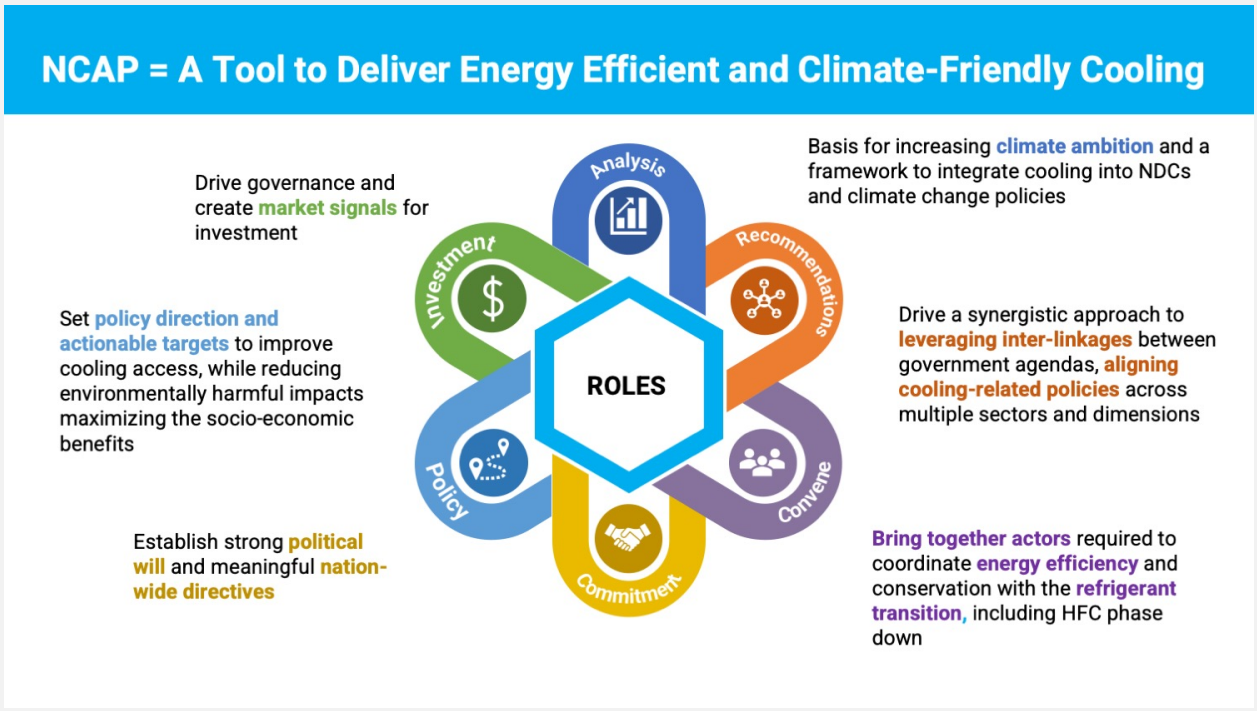
The Cool Coalition NCAP methodology helps nations address three internationally-agreed goals simultaneously – the Paris Climate Agreement, the UN Sustainable Development Goals, and the Montreal Protocol's Kigali Amendment – while pursuing national priorities and socioeconomic benefits. It is a tool that takes the approach of thinking holistically and planning strategically, while providing a modular format that is customizable to any country's context.

The NCAP development process convenes stakeholders to analyze the cooling sector's development trends and needs, and follows with a set of key recommendations to guide policy development and initiatives. The resulting NCAP document serves as a framework that offers clear policy direction for addressing access to cooling and ensuring the availability of services that underpin the comfort, health and well-being of populations, as well as important economic sectors. At the same time, it looks to minimize the environmentally harmful impacts through energy efficiency and the transition to low-global warming potential (GWP) refrigerants across end-uses.

B. THE MULTIPLE ROLES OF AN NCAP

An NCAP serves a number of roles, as illustrated in Figure 4. No single sector or ministry can offer the solution to the cooling challenge. Thus, an NCAP serves as an important instrument to align various stakeholders, help establish political will, and leverage inter-linkages between national and international agendas. The adoption of an NCAP also generates market signals, indicating that the nation is ready to move forward on the cooling challenge in a comprehensive manner, and is better prepared to receive technical and financial support.

FIGURE 5: ROLES OF A NATIONAL COOLING ACTION PLAN



Source: Author adapted from UNEP

C. THE NCAP DEVELOPMENT APPROACH

The NCAP methodology aims to outline a structure and method that is adaptable to most contexts and within the reach of most countries today. It reduces time and effort by providing an overarching process and guiding framework that addresses typical areas of inquiry, information sources, analytical approaches, and the development of a set of peer-reviewed key recommendations. An NCAP is also intended to be a living document that, once new information or technologies become available, can be periodically updated.

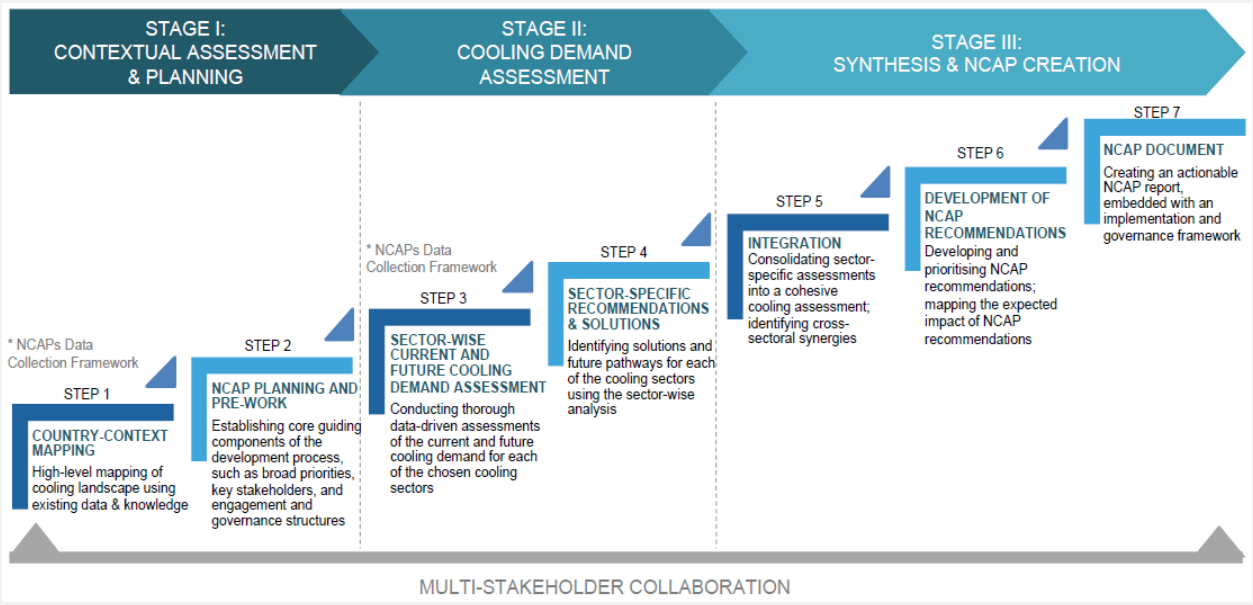
The methodology follows an integrated approach to developing strategies to achieve three primary objectives: first, to decrease cooling demand by implementing passive cooling strategies; second, to meet cooling demand utilizing the most energy efficient and climate-friendly technologies; and third, to optimize cooling operations and behaviors.

Three sequential stages make up the development process:

1) Contextual assessment and planning, 2) Cooling demand assessment, and 3) Synthesis and NCAP creation (Figure 6). The process is augmented by data assessment frameworks supporting the identification of key data inputs, data analysis to estimate current and future cooling demand and impacts, and the identification of potential development pathways. Multi-stakeholder collaboration is a constant throughout the NCAP development process, and includes government entities, researchers and analysts, the private sector, and industry.

THE NCAP DEVELOPMENT PROCESS HAS BEEN STANDARDIZED

FIGURE 6: THE THREE-STAGE NATIONAL COOLING ACTION PLAN METHODOLOGY



Source: UNEP, Cool Coalition, ESCAP, AEEE, 2021

III. Cambodia's NCAP

A. SUMMARY OF SCOPE AND KEY FINDINGS

Cambodia was the first nation to develop an NCAP utilizing the Cool Coalition National Cooling Action Plan Methodology. Cambodia's NCAP offers an overview of the cooling sector with focused analysis in five main areas: 1) building space cooling, 2) food cold chains, 3) healthcare cold chains, 4) mobile air conditioning, and 5) process cooling. The document provides sectoral data and modeled estimations for cooling demand under "business as usual" and "intervention" scenarios and projects energy demand and greenhouse gas emissions under each. The table below summarizes the technologies which were analyzed during the preparation of the NCAP.

TABLE 1: 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

Source: Cambodia's National Cooling Action Plan, 2022

The NCAP reveals a pressing need for action. According to the cooling assessment prepared as part of the NCAP, in 2020 the cooling sector in Cambodia (excluding mobile air conditioning) consumed a total of 4,738 gigawatt-hours (GWh) of electricity and emitted 6.3 million tons of carbon dioxide (CO_2) equivalent. Building space cooling contributed 37 per cent of total emissions, followed by mobile air conditioning (30 per cent) and process cooling (27 per cent). NCAP modeling estimates that, by 2040, in the absence of significant action towards introducing energy efficient and climate-friendly cooling technologies and approaches, electricity consumption will nearly double (Table 2) and emissions nearly triple (Table 3).

To mitigate energy consumption and emissions, interventions are proposed in four main areas for the short- to long-term: 1) policy and regulatory instruments, 2) technological interventions, 3) market-supporting instruments and 4) capacity-building and awareness-raising. The NCAP analysis – which considered contextual factors, current policies, and available technologies – suggests that the implementation of recommended policy measures under an intervention scenario could lead to a 14 per cent savings of total electricity consumption by 2030, and 23 per cent by 2040.

TABLE 2: ELECTRICITY DEMAND (GWH) BY COOLING SECTOR IN 2020, 2030 AND 2040, BAU AND INTERVENTION SCENARIOS

	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: Cambodia's National Cooling Action Plan, 2022
Note: Mobile cooling is excluded from this analysis

TABLE 3: GREENHOUSE GAS EMISSIONS (METRIC TCO_2-EQUIVALENT) BY COOLING SECTOR IN 2020, 2030 AND 2040, BAU AND INTERVENTION SCENARIOS

	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: Ibid.

B. KEY BARRIERS TO BE OVERCOME

The assessment of cooling sector in Cambodia identified key barriers and challenges for efficient development and implementation of modern technologies, including the following:

I. Unplanned urban growth

Cambodia is experiencing an economic transformation, urbanization and industrialization. The share of Cambodia's population living in urban areas rose from 20 per cent in 2010 to 25 per cent in 2021 (World Bank, 2022) and is expected to grow. However, the pace of this process is difficult to access because it depends on various factors of the country's economic development. Increasing urbanization leads to higher energy consumption, increased GHG emissions, population density and escalation of the urban heat-island effect. Robust and comprehensive city planning that incorporates a range of passive cooling strategies is essential to ensure sustainable development and human wellbeing.

II. Lack of building energy codes and regulations

Building efficiency codes and regulations are important tools to improve the energy performance of buildings and equipment by mandating minimum levels of energy performance. Knowledge and practice of energy-efficient building design and technologies among developers and building sector professions is limited. In Cambodia, buildings are responsible for approximately half of all energy consumed. The current lack of building energy codes hinders efforts to introduce advanced building performance standards and guidelines, including for passive cooling strategies. The nation's NDC and Energy Efficiency Policy call for the introduction of building energy codes, which have been drafted and are currently under consideration by relevant ministries. Introducing building energy codes and regulations would support the nation to avoid locking into inefficient building assets, while also enabling the development of systems to monitor building performance and set energy reduction targets for various building typologies.

III. Lack of MEPS and labelling

The development and implementation of minimum energy performance standards and labels for cooling equipment as is crucial to lower energy demand and emissions from the cooling sector. While some initiatives have been undertaken to implement MEPS and energy labeling for refrigerators and air conditioners, these have yet to be mandated. Relevant institutions to draft standards, test and certify products are required, along with a prioritization of targeted appliances. It is important to make sure that the proposed standards are comparable and easily measurable to ensure detailed assessment and update.

IV. Lack of development strategies

In its Nationally Determined Contribution (NDC) Cambodia sets a target for a 40 per cent reduction of energy related GHG emissions by 2040 in order to reduce the climate impact, meanwhile the path to this target is not developed yet. Cooling sector plays a key role in energy consumption and GHG emissions. Clear vision and comprehensive cooling strategies are required to achieve ambitious climate targets and ensure sustainable development of cooling sector.

V. Poor data availability and quality

Data availability and quality are a common challenge for developing countries, particularly for energy end uses. However, data is a crucial element for the assessment of current situations and future outlooks. In order to identify opportunities and to develop sustainable strategies for the cooling sector, a reliable system of cooling sector data collection from across sectors is needed.

VI. Lack of cooperation between stakeholders

Cooling is a multisectoral and multidimensional issue that requires the involvement and collaboration between different stakeholders, including various government ministries, industry, the private sector and the general population. Current dialogue between stakeholders in the cooling sector is poor. To enable the achievement of cooling sector as well as broader development goals, coordination and cooperation between government agencies and between government and non-government actors should be strengthened.

VII. Lack of financial resources

Adequate funding is a crucial element of development and implementation of cooling strategies. Finance mechanisms include multilateral climate funds, development banks and other facilities and programmes. With limited domestic resources, it will be necessary to unlock various funding sources to drive the transition to more efficient and climate-friendly cooling. To create an investment-friendly environment, the Government must broaden supportive policies and regulations to shape the cooling market in line with stated objectives, create predictability, and incentivize sustainable cooling investments.

C. KEY RECOMMENDATIONS

NCAP policy recommendations are provided to guide the development of an enabling environment for sustainable cooling, including increased access and the transition to energy-efficient and climate-friendly technologies. They are also designed to address sectoral and market challenges. Cambodia's NCAP contains detailed recommendations coupled with suggested timelines and implementing stakeholders. Recommendations provided by the NCAP include the following:

VIII. Adoption of urban planning and building design standards that include passive cooling strategies.

How cities are planned, the manner in which structures are spaced and orientated, the thermal properties of materials used to construct buildings and streets, the presence of greenery and water features, as well as waste heat from vehicles, air conditioning units and other equipment are all factors that influence temperatures in urban areas. Temperatures in city centres are often significantly higher than surrounding areas, leading to a greater risk of heat stress for people who live and work in them. Urban planning and building design approaches that provide shade, lower surface temperatures, and integrate natural ventilation and air flow, are examples of passive cooling strategies that create multiple benefits, including reduced cooling demand and energy consumption, while improving the thermal comfort, productivity, and wellbeing of people. The integration of passive cooling strategies into planning and design standards can support low-carbon buildings and low-carbon living. Recommend actions include the development of an energy building code, expanded use of green building rating systems, and guidelines on design and the use of materials.

IX. Adoption of stringent minimum energy performance standards for cooling equipment.

Performance standardization, including minimum energy performance standards (MEPS) and energy labels, is among the fastest approaches to improve energy efficiency. The introduction and enforcement of MEPS should be done to align with the achievement of national energy and emissions targets, to shape markets, and encourage innovation. Labeling of products makes it easier for consumers to identify and

purchase energy-efficient appliances and equipment, reduce energy consumption and lower energy bills. In Cambodia, MEPS and labels for cooling equipment, including domestic and commercial refrigerators, cooling systems and equipment, are needed to manage electricity consumption and peak load for the electricity grid, while also lowering associated greenhouse gas emissions from the use of refrigerants and fossil-fuel based power.

X. Promotion of innovative "not-in-kind" (NIK) cooling technologies.

NIK cooling technologies include district cooling systems, direct renewable energy-driven cold storage and vaccine refrigerators, geothermal cooling, absorption/adsorption cooling, phase change material-based cooling, and so on. The use of these technologies helps to reduce environmental effects through the efficient delivery of cooling services. To promote the use of these technologies, programmes targeting public buildings and public-led major real estate developments could be developed. Also, it is important to create utility-level technological solutions, such as monitoring of household cooling consumption to promote demand-side management and optimized tariff setting.

XI. Development of market monitoring mechanisms to support regulations compliance.

To ensure trust from consumers and businesses in the performance of energy efficient cooling products and fair markets, the NCAP analysis pointed to the need for monitoring, verification and enforcement (MVE) of standards. This includes programme administrators that oversee products sold in the market, verify compliance with MEPS and labels, enforce the application of energy codes, and report results. A product registration system (PRS) or database is a recommended resource to support MVE activities.

XII. Strengthening of cold chains.

To increase the market strength and availability of quality, temperature-sensitive products, and to improve living standards in Cambodia, it is important to ensure robust, continuous, and accessible cold chains for food, medicine, and vaccines. The NCAP pointed to the need for a detailed cold chain needs assessment to identify the gaps and potential areas for optimization. At the same time, responsible government entities should work together with academia and the private sector to adopt and implement best available technologies and approaches.

XIII. Creation of market enablers and financial delivery mechanisms.

Market transformation is a crucial step to support the use of climate-friendly cooling technologies. Several fiscal and financial business models can be implemented to overcome market barriers, increase local investor confidence, and mobilize private sector investments and participation. Sample measures include public bulk procurement of high-efficiency cooling products to lower consumer prices, tax incentives for the purchase of energy-efficient technologies, cooling-as a service, on-bill financing, and revolving funds.

XIV. Unlocking various financial sources.

Funding is one of the key barriers to the implementation of key recommendation of Cambodia's NCAP. Public funds are limited, and, thus, unlocking external financial resources is necessary. Cambodia can explore climate change mitigation funds, financing from multilateral development banks, bilateral carbon trading mechanisms, and private funds to support sustainable cooling initiatives and raise investor confidence.

XV. Strengthening of international cooperation and partnerships

The NCAP recommends that Cambodia continue the implementation of commitments and interventions under the Paris Agreement, the Kigali Amendment to the Montreal Protocol, and the Sustainable Development Goals.

In addition, Cambodia can accelerate sustainable cooling progress through participation in international cooling-related initiatives to gain sectoral knowledge, strengthen capacities, and implement best practices.

D. LINK BETWEEN CAMBODIA'S NCAP AND THE NATION'S INTERNATIONAL COMMITMENTS

Sustainable cooling, which maximizes access and energy efficiency while minimizing environmental impacts, is linked to three important areas of Cambodia's international sustainability commitments.

Firstly, under the Paris Agreement on Climate Change and Cambodia's Nationally Determined Contribution (NDC), key areas of action to support achievement of Cambodia's 2030 total emissions reduction target of 42 per cent and energy emissions reduction target of 40 per cent, compared to business as usual, include: the application of passive cooling strategies, energy efficient mechanical cooling, and the transition to low-GWP refrigerants. Notably, in Asia and the Pacific, Cambodia is one of the few nations to explicitly identify sustainable passive and active cooling and the hydrofluorocarbon (HFC) refrigerant phasedown as mitigation measures in its NDC.

Linked to the climate ambitions of the Paris Agreement is the Kigali Amendment to the Montreal Protocol, which entered into force in 2019 and is a binding international agreement on the phasedown of HFC refrigerants and HFC-based equipment widely used for air conditioning and refrigeration. While the Montreal Protocol led to the successful phasedown of ozone-depleting substances, climate-damaging HFCs were introduced as replacements. The phase down of HFCs and the transition to low-GWP options is critical as global demand for air conditioning and refrigeration is rapidly rising, driven by developing countries. The implementation of the agreement by its parties is expected to prevent up to 80 billion tonnes CO_2-equivalent of global emissions by 2050, and has the potential to avoid up to 0.1℃ of warming by 2050 and up to 0.4℃ by 2100 (CCAC, 2020). Cambodia ratified the agreement in 2021, committing to an HFC freeze and phasedown by 80-85 per cent by the late 2040s, while also opening the door to financial and technical assistance in that effort. Sustainable cooling also supports the achievement of several Sustainable Development Goals (SDGs), including: Goal 2 – Zero Hunger, through refrigeration that keeps foods fresh longer; Goal 3 – Good Health and Well-Being by supporting access to refrigerated medicines and vaccines, Goal 7 – Affordable and Clean Energy, by increasing energy efficiency, Goal 8 – Decent Work and Economic Growth, by helping create safe and productive work environments; Goal 10 – Reducing Inequality, by supporting social equality through improved access to services; Goal 11 – Sustainable Cities and Communities, by enabling sustainable urbanization; and Goal 13 – Climate Action, with its contribution to emissions reductions. Thus, efforts to increase access and the sustainability of cooling facilitates SDG progress, including against objectives set out in the Cambodia Sustainable Development Goals (CSDGs) Framework (2016-2030).

E. CAMBODIA'S NCAP IN THE CONTEXT OF NATIONAL POLICIES

Cambodia's government has advanced the country's sustainable development progress through the introduction of a wide range of policies, plans, and strategies, including many that interlink with the development of Cambodia's cooling sector. Cambodia's NCAP, as a comprehensive, cross-sectoral framework, can contribute to, build upon, and benefit from the implementation of various related policies. The NCAP details actions needed in various areas to achieve energy savings and emissions reductions, which contribute to a broad range of existing policy objectives. At the same time, it offers a direction for the policy development into the future. Following is a summary of key policy documents and their interlinkages with the NCAP.

TABLE 4: COOLING-RELATED POLICES

POLICY	MEASURE(S) THAT INTERLINK WITH THE NCAP	RELATED NCAP RECOMMENDATIONS
National Energy Efficiency Policy 2022-2030	Targets to reduce energy consumption in relation to a BAU trajectory by 2030 include at least: • 34 per cent in the residential sector, from 17,981 GWh to 11,826 GWh • 25 per cent in commercial buildings (including public buildings), from 8,552 GWh to 6,431 GWh; For the residential sector, the policy looks to the development of standards and labelling programmes for appliances and equipment, including the introduction of MEPS. For buildings, it calls for the development of a building energy code, its implementation, along with green building guidelines and necessary certifications.	Outlines key recommendations on lowering energy consumption through a) passive cooling strategies for urban planning and building design to reduce cooling demand, and b) energy-efficient mechanical space cooling and refrigeration, through the introduction of MEPS and labelling. Also identifies market transformation options such as public procurement, time-of-use tariffs, cooling-as-a-service, and various financing schemes.
Long-Term Strategy for Carbon Neutrality (LTS4CN)	For the energy sector, the LTS4CN notes energy efficiency and conservation measures as one of three priorities to reduce emissions, particularly in buildings and industry. Identifies the need to restrict high GWP refrigerants, research life cycle emissions for refrigerant use in refrigeration/air-conditioning equipment, and management of gases.	Outlines steps to lower energy demand and emissions through passive strategies, not-in-kind technologies, MEPS and labelling, compliance, and market enablers. Offers analysis and scenarios on electricity and refrigerant consumption, by refrigerant types, in the building space cooling and process cooling sectors.

Rectangular Strategy for Growth, Employment, Equity and Efficiency, 2018-2023.	Targets four priority areas: human resource development, economic diversifications, promotion of private sector development and employment, inclusive and sustainable development. Under the fourth priority area, the strategy aims at increasing the usage of environment- and climate-friendly technologies to reduce climate impact.	The NCAP includes recommendations on the use of energy-efficient technologies and offers analysis on how technological interventions could support emissions reduction.
Cambodian Sustainable Development Goals Framework 2016-2030	National actions on Goal 13 to combat climate change and its impact include the following key targets, among others: • Integration of climate change measures into national policies and strategies; • Awareness rising and capacity building on climate change mitigation, adaptation and impact reduction.	The NCAP contains sectoral analysis, and a set of measures for climate change mitigation, awareness raising, and capacity development.
National Strategic Plan on Green Growth 2013-2030	Provides overarching framework for green growth, including the efficient use of natural resources, environmental sustainability, green technology, green investment and green job creation. Energy saving, energy efficiency and green buildings and construction are key areas of action.	The NCAP outlines specific interventions in the areas of passive cooling strategies, building space cooling technologies and skills development for cooling sector green jobs. Identifies directions for obtaining green investment.
Cambodia Climate Change Strategic Plan 2014-2023	The goals among others included: Shifting towards a green development path by promoting low-carbon development and technologies;Promoting public awareness and participation in climate change response actions.	The NCAP includes recommendations on the use of passive cooling strategies, energy-efficient cooling technologies and awareness raising actions.
Energy Efficiency and Conservation Master Plan of Cambodia	The legislative aspect focuses on five aspects: 1) energy management system development, 2) Standards and labeling, 3) ESCOs, 4) Building energy efficiency code/guidelines; 5) Penalties for non-compliance	The NCAP offers benchmarking of energy demand for the cooling sector, and includes recommendations on MEPS and labelling, building energy code and green certifications guidelines, and public awareness campaigns.

Construction Law	Provides guiding principles for the regulatory framework of the construction sector. It also highlights building efficiency and green building concepts.	NCAP provides an overview and projections of cooling demand in the building sector, as well as recommendations for energy and emissions reduction through passive cooling strategies and energy efficient active cooling.

Source: Author's review

A number of additional policies are under development, including the NDC Roadmap for Low-Carbon, Climate-Resilient Buildings and Construction in Cambodia, Vision to 2050; building energy codes; the draft Sub-decree on Energy Efficiency Standards and Labelling for Electrical Appliances and Equipment, and an updated law on land management and urban planning.

IV. Way forward

Implementation of the NCAP is a process that requires the involvement of multisectoral stakeholders over the short to long term. The NCAP puts forward a comprehensive set of key recommendations and their associated timelines, lead government agency, and supporting stakeholders.

To kick start the implementation process for one of the key recommendations, from 2022 ESCAP, UNEP and the Ministry of Environment began collaborating on a pilot demonstration of passive cooling strategies (PCS) to lower energy demand and emissions, as well as reduce the urban heat island effect (UHIE). Cambodia's NCAP determined that space cooling for buildings holds the greatest energy and emissions savings potential, accounting for nearly three-quarters of cooling sector electricity savings leading up to 2030 under an intervention scenario. These savings are expected to result from the integration of passive cooling strategies and energy efficient mechanical cooling technologies.

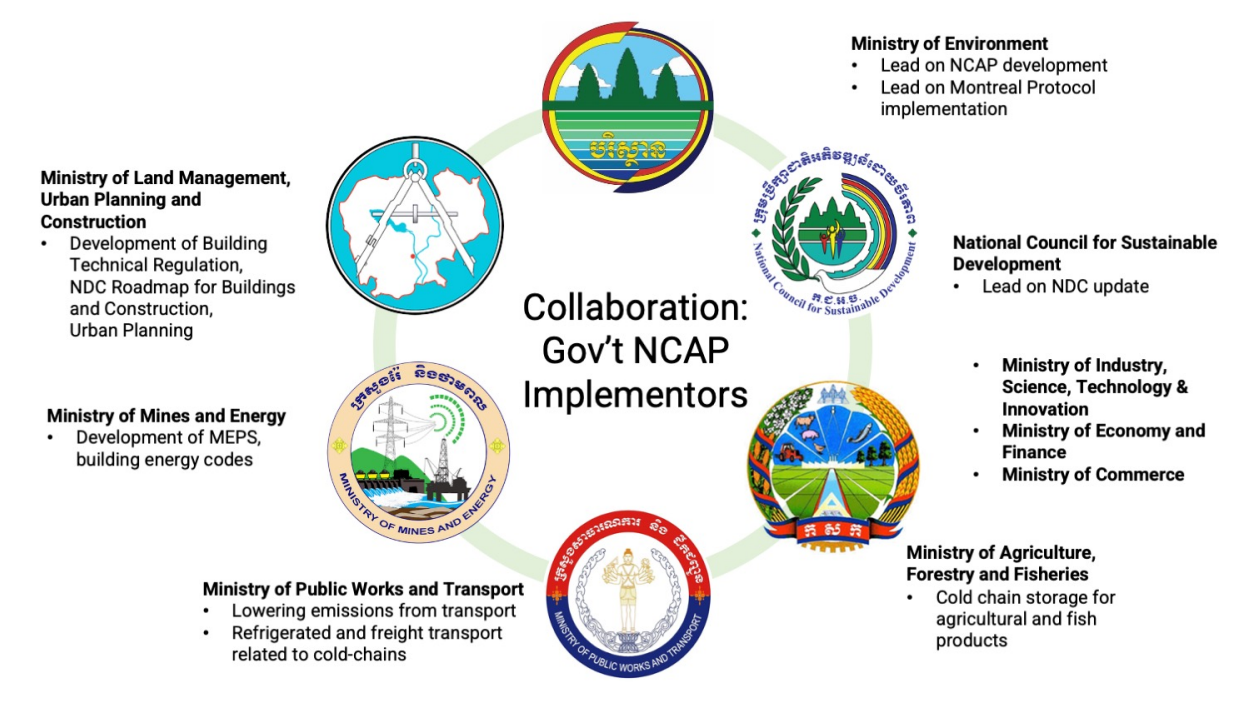
PCS are neither present in the national building guidelines nor technical building regulations under development in Cambodia. Nor are they adequately considered by architects, engineers and construction sector practitioners in the design and construction of new buildings.

Demonstrating the benefits of PCS in the real world will expand the evidence base for the development of building energy performance standards and codes. The results of the project could also be used to support the development of regulations that can enable Cambodia to achieve its emissions reduction targets under the nation's NDC.

Importantly, the full implementation of the NCAP key recommendations requires a coordinated effort from various governmental agencies (Figure 7). Cooperation between agencies can facilitate the development and implementation of comprehensive policies and strategies that are aligned with sectoral development objectives. Effective collaboration can leverage resources and expertise to advance research and development in cooling strategies and technologies, promote knowledge-sharing and capacity-building, and foster innovation.

SUSTAINABLE COOLING REQUIRES CROSS-MINISTERIAL COLLABORATION

FIGURE 7: MINISTRIES INVOLVED IN THE IMPLEMENTATION OF CAMBODIA'S NATIONAL COOLING ACTION PLAN



Source: Author

V. Implications for other economies

A defined process and methodology for assessing the status and future outlook of cooling across sectors was followed in Cambodia, revealing context-specific areas for action, as well as lessons that can be applied more broadly. Following is a set of areas for action that, even in the absence of a formal NCAP, can be taken by economies to help set the stage for comprehensive action toward a more sustainable cooling sector.

I. Data collection

Data is the basis of accurate assessments and evidence-based decision-making, and is needed for both active and passive aspects of the cooling sector. For active cooling, comprehensive, comparable data is needed, such as market size, appliance and equipment energy performance, refrigerant use, and growth outlooks for various technologies across sectors. Such data is critical for introducing and revising minimum energy performance standards. Key sectors for data gathering include building space cooling, cold chains, mobile air conditioning, and process cooling.

For the passive aspect, data on building material performance and share of buildings that meet construction and performance codes is needed to enable the introduction of improved design guidelines and codes to reduce cooling demand. In addition, data regarding urban temperatures and heat island hot spots supports improved urban planning and the prioritization of interventions.

Data requirements are cross sectoral, and experience in Cambodia and other countries has pointed to the need for establishing a national framework for collecting and sharing data on cooling with a view to enabling comprehensive assessments and action plans. Mechanisms for verifying data accuracy and comparability should be integrated into these frameworks.

II. Development of performance standards across cooling sectors

The development of energy performance standards is essential for promoting energy-efficient cooling technologies. Government should work with relevant stakeholders to develop and enforce standards and practices for various cooling sectors, for example building codes, MEPS and labelling. These standards could include energy efficiency requirements, as well as guidelines for the use of more energy efficient materials and low-global warming potential refrigerants. Additionally, promoting practices for right-sizing of equipment, operations and maintenance can help ensure the most effective use of technologies to reduce energy consumption and greenhouse gas emissions.

III. Raised awareness on the importance of cooling

Raised awareness is critical for driving the adoption of energy-efficient cooling systems, energy-conscious operations and practices. Awareness campaign can highlight the importance of energy efficiency and cooling,

encourages the public to take action to reduce their energy and carbon footprints, and help generate demand for energy efficient products and buildings.

IV. Coordinated effort between various governmental and non-governmental institutions

Effective implementation of cooling solutions requires coordinated understanding and action between various governmental and non-government institutional stakeholders in industry, the real estate and construction sector, agriculture and fisheries. One of the possible options is the establishment of a coordinating body that brings together relevant agencies and stakeholders to facilitate information sharing, priority identification, and collaboration on the development of cooling related policy, regulation and actions. The coordinating body could be responsible for facilitating a comprehensive strategy to reduce greenhouse gas emissions.

V. Strengthening of regional and international cooperation

Regional and international cooperation can advance national progress For example, economies can engage in regional and international efforts to share knowledge and best practices, and initiatives to harmonize performance standards, i.e. MEPS for air conditioning equipment, to enable energy efficient cooling markets to expand and mature.

Conclusion

Urbanization, population growth, increased incomes and climate change are driving growing demand for cooling services, with impacts to energy systems and the environment. Energy-efficient and climate-friendly cooling technologies and strategies are necessary to provide more sustainable and affordable solutions to:

- increase physical comfort, health, and well-being in homes, vehicles, as well as commercial and educational spaces to support productivity and learning;
- develop sustainable cold chains to keep food fresh and medicines viable; and
- enable economic development by supporting the expansion of agriculture and fisheries markets.

To ensure that the people, businesses and services that require cooling have access, cooling must be affordable. On one hand, this means lowering cooling demand through passive cooling solutions. This includes strategies such as energy-efficient building envelopes that incorporate heat load-reducing designs and nature-based solutions for keeping building interiors cool, while reducing the urban heat-island effect. On the other hand, this means pushing markets toward best-in-class technology efficiency levels and ensuring the proper installation and operation of equipment.

An NCAP can be the first step in identifying the actions needed to provide access to sustainable and affordable cooling, and to realizing energy demand and greenhouse gas emissions reductions in accordance with national and international targets. For Cambodia, the NCAP links with objectives under the nation's energy and climate policies, as well as international commitments under the Paris Climate Agreement, the UN Sustainable Development Goals, and the Kigali Amendment to the Montreal Protocol. Estimates show that implementation of recommended NCAP measures in Cambodia could lead to a 14 per cent electricity savings by 2030 and 23 per cent by 2040. The interventions could also help save up to an estimated 12 and 17 per cent of emissions, respectively, thus pushing Cambodia closer to achievement of its target.

The National Cooling Action Plan Methodology was created to provide a tool for countries to develop their own strategy for the cooling sector, and Cambodia has been the first to develop and approve an NCAP using it. However, the tool is designed to be adaptable to each country's context, and is modular in nature. NCAPs are also meant to exist as living documents, to be updated as the sector develops and more data and information becomes available.

Importantly, developing and adopting a National Cooling Plan also plays a critical role in creating a policy environment conducive to investment. For most countries, the implementation of an NCAP's key recommendations will require significant financial resources, as well as technical support. By positioning itself to address cooling in a comprehensive manner, Cambodia has demonstrated its commitment to action, and has attracted initial investment in support of the implementation of the NCAP's recommendation on passive cooling strategy integration into building regulations and NDC commitments. This demonstrates how an NCAP can be effectively leveraged to strengthen policy frameworks and unlock much-needed investments.

To move forward on sustainable cooling, governments have options to engage at the international level and gain support through such organizations as the Cool Coalition, and initiatives like the Global Cooling Pledge. Members of the Cool Coalition, including ESCAP, can be contacted for further information.

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