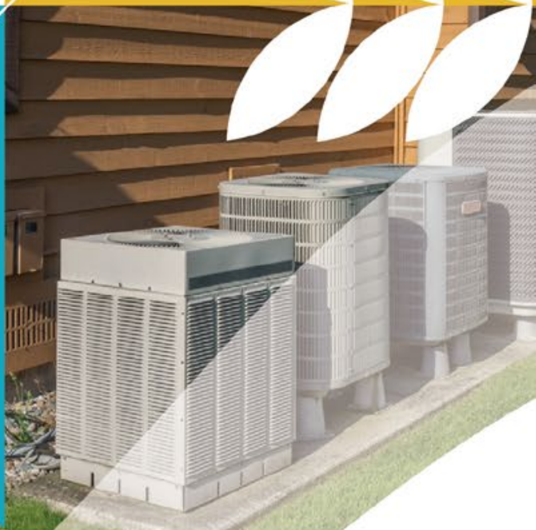
Sustainable Cooling in the ASIA-Pacific Region: Tackling Climate Change and Enhancing Quality of life

Policy brief



UNITED NATIONS
ESCAP
Economic and Social Commission for Asia and the Pacific

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Summary

- photo credits:01: Mishaal Zahed/Unsplash; 02: Polina Tankilevitch/Pexels; 03: Sergei Akulich/ Pexels; Page 15: Tomas Luka/Shutterstock; 04: Maudib/iStock; 05: Athena/Pexels; Back cover: Leo Patrizi/iStock.
- Cooling is a fundamental requirement to improve the well-being of the world's population and ensure sustainable economic development.
- Cooling interconnects three predominant international commitments - Nationally Determined Contributions (NDCs) under the Paris Agreement, Kigali Amendment to Montreal Protocol and the United Nations Sustainable Development Goals (SDGs).
- Cooling is cross-cutting in its nature. It is needed for a wide range of applications like space cooling of buildings, food cold chain, mobile-air conditioning, healthcare cold chain and process cooling.
- Every country should analyze and address its socio-economic and environmental issues related to access to cooling (especially for vulnerable groups of the population), refrigerant-related emissions and energy-use-related emissions.
- The pathway for mainstreaming "sustainable cooling" can be achieved through robust policy responses and the implementation of related actions. Sustainable cooling requires the development and implementation of national policies, targets and regulations, international collaborations, utilization of market enablers and appropriate financial mechanisms and capacity building for technicians and other relevant stakeholders.

Abbreviations

AC	Air Conditioner
AEEE	Alliance for Energy-Efficient Economy
AI	Artificial Intelligence
ASEAN	Association of Southeast Asian Nations
BEC	Building Energy Code
BSC	Building Space Cooling
CO_2	Carbon Dioxide
DHL	Dalsey, Hillblom and Lynn
DX	Direct Expansion
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
GHG	Green House Gas
$GtCO_2e$	Gigatonnes of Equivalent Carbon Dioxide
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HVAC	Heating Ventilation and Air-Conditioning
IEA	International Energy Agency
IFC	International Finance Corporation
IPLV	Integrated Part Load Value
K-CEP	Kigali Cooling Efficiency Program
km	Kilometre
kW	kilowatt
MAC	Mobile Air-Conditioning
MEPS	Minimum Energy Performance Standards
$MtCO_2e$	Million Tonnes of Carbon Dioxide Equivalents.
PCS	Passive Cooling Solutions
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy For All
SEER	Seasonal Energy Efficiency Ratio
TR	Ton of Refrigeration
TWh	Terawatt-hour
UHIE	Urban Heat Island Effect
UN	United Nations
UNEP	United Nations Environment Programme
WHO	World Health Organisation

01

Introduction

Cooling is not a luxury but a necessity to enhance the well-being and safeguard the health of the world's population. Cooling requirements can be distinguished as needs for air-conditioning and refrigeration. Cooling has significant impacts on climate change through indirect emissions caused by electricity use and direct emissions due to refrigerant leakage from the cooling equipment during its manufacturing, operation, and the end of service life. Beyond climate impacts, cooling also leads to several positive socio-economic impacts.

"Sustainable Cooling"[1] is linked to three important international commitments

- The Paris Agreement on Climate Change and related Nationally Determined Contributions (NDCs)
- The Kigali Amendment to Montreal Protocol
- The Sustainable Development Goals (SDGs)

Policymakers need to implement viable decarbonization solutions to strengthen their country's NDCs in order to to address the commitments under the Paris Agreement. This can be attained by limiting the global temperature increase to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius compared to pre-industrial levels[i].

Reducing the production and consumption of hydrofluorocarbons (HFCs) under the Kigali Amendment to Montreal Protocol can reduce global warming up to 0.4°C by the end of the century[ii].

The COVID-19 impact of reducing emissions from cooling should not be misinterpreted as a sign of greening of an economy but rather be considered as an opportunity to build back better. Emissions naturally reduce during times of lower economic activity and in the event of a slower recovery. However, a weaker economy is also an impediment to the process of sustainable change in the cooling sector. As the nations in the Asia-Pacific region emerge from the pandemic and plan for "Build Back Better", the investment in building energy efficiency and clean energy are considered as one of the key recommendations for the policymakers[iii].

"Sustainable cooling" also contributes to multiple SDGs, e.g. access to the cold chain can increase farmers' and fishermen's income (SDG1). Food cold chains are instrumental in ending hunger and malnutrition. Healthcare cold chains deliver universal access to vaccines and medicines to ensure the health and well-being of the population (SDG3). Sustainable cooling further links with SDG 7: Affordable and clean energy, SDG 11: sustainable cities and communities, and SDG 13: climate action.

The related climate impacts and contribution to the SDGs underscore the urgency to place collaborative and synergetic efforts to implement sustainable cooling solutions. A combination of measures to improve the operational efficiency of cooling equipment with the transition to low Global Warming Potential (GWP) refrigerants can help avoid cumulative Green House Gas (GHG) emissions of up to 210-460 gigatonnes of carbon dioxide (CO_2) equivalent[vi] over the next four decades.

Inadequate government policies, poor energy performance standards, higher product costs, outdated building and product regulations and a lack of training for service and installation personnel are some of the key issues to be addressed to mitigate the impacts of cooling.

This policy brief discusses the issues and practical interventions that United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) member States and countries in other parts of the world can consider to accelerate the transition to sustainable cooling.

1 Sustainable cooling is understood as the approach to cooling that considers economic, social and environmental aspects of achieving SDG7 and complying with Kigali Amendment, as well as providing access to cooling to satisfy the needs for cooling of those, who needs it, in an efficient and climate friendly manner

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Cooling Sectors

Cooling could be responsible for as much as thirty per cent share in the region's peak electricity demand by 2040 without implementing stronger measures to encourage the adoption of more efficient cooling systems.[https://www.iea.org/reports/the-future-of-cooling-in-southeast-asia] Cooling is a necessity for comfortable living by protecting the population from extreme heat and enhancing access to nutritious food and safe medicines. The cooling application sectors can be classified as:

Building Space Cooling

Building Space Cooling (BSC) deals with providing thermal comfort to the building's inhabitants. BSC improves health and well-being of building occupants while enhancing their productivity[vi].Energy consumption for BSC is dominated by refrigerant-based direct expansion (DX) air-conditioning systems. Energy demand for BSC can be reduced through the integration of efficient urban planning, passive cooling strategies, low energy non-refrigerant based cooling, not-in-kind systems, efficient service practices for refrigerant handling and use of intelligent controls.

Food Cold Chain

A 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 controlling environmental parameters like temperature, humidity and air composition and packaging to extend the product's life cycle and safeguard its nutrient quality. This application sector includes cooling requirements for ice-cooling for fisheries, bulk storages, pack houses, dairies, refrigerated trucks, domestic and commercial refrigerators.

Healthcare Cold Chain

Healthcare cold chain consists of entire chain of storage and transport technologies to ensure the vaccines and other healthcare products (including blood products and medicines) are maintained at the temperatures recommended by manufacturer until they reach the targeted beneficiaries. It involves controlled environmental storage and packaging to extend the vaccine's and medical products life cycle and safeguard its quality as per the World Health Organisation (WHO), or national government recommended protocols.

Mobile Air-Conditioning

Mobile Air-Conditioning (MAC) caters to passenger's comfort cooling requirements in light-duty vehicles, heavy-duty vehicles, trucks and trains. MAC uses refrigerant-based vapour compression technology to remove heat and moisture from inside the cabin.

Process Cooling

Process cooling includes any cooling solution deployed for

a) manufacturing a product through physical, chemical, biological or a combination of these processes;

b) controlling temperature and humidity for the desired functioning of electronic, mechanical or electromechanical systems.

Some examples of process cooling are data centers, pharmaceutical, textile, plastic, chemical and detergent industries.

03

Issues Related to Cooling

Access to Cooling

- Access to Cooling refers to providing affordable and sustainable cooling solutions to address the population's needs, such as access to nutritious food and safe medicines as well as protection from harmful heat exposure.
- About 1.09 billion people globally (mainly rural and urban poor) are at high risk due to a lack of access to cooling. Out of this number, 484 million of urban poor reside in Asia, who may have some access to electricity and often live in a poor quality of housing. Another 2.34 billion are considered lower-middle-income people, which means that they are likely to have the ability to purchase the most affordable air conditioner or refrigerator on the market. However, price sensitivity and limited purchasing options mean they favour devices that are likely to be inefficient, which will result in increased GHG emissions.[vii]
- Across the globe, there are 54 high-impact countries, with at least 3.43 billion people still facing cooling access challenges, with global risks amplified by an additional 50 million people at high risk in 2021. The number of urban poor at high risk has been growing since 2015 due to urbanization trends. The COVID-19 pandemic exacerbates this challenging situation further.

Thermal Comfort

The quality of housing for urban poor is often very low, and their income may not be sufficient to purchase or run space cooling appliances. The lack of access to thermal comfort systems, aggravated by soaring temperatures due to global warming, and the Urban Heat Island Effect (UHIE)[viii],is common to many cities in Asia and the Pacific, leading to heat stress-induced into the indoor environment. This can cause mortality, morbidity, and loss of productivity.

Nutrition and food security

Most of the rural poor are likely to engage in subsistence farming but lack access to an intact cold chain that would enable them to sell their products further afield at a higher price. Meanwhile, the urban poor may own or have access to a refrigerator, but intermittent electricity supply often causes interruption or insufficiency of refrigeration leading to spoilages of food, and increasing the risk of poor nutrition or food poisoning.

In 2018, 821.6 million people worldwide were undernourished[ix]. This correlates with the food losses across the world due to lack of adequate cold chains (about 9 per cent of lost production of perishable foods in developed countries and 23 per cent in developing countries)

Project Drawdown[xi] estimates that reduced food loss and waste brought about by consumer behaviour change and improved cold chains and agricultural practices would avoid 93.7 gigatonnes of carbon dioxide equivalent (GtCO2e) of emissions between 2020 and 2050. The potential impact of improved cold chains alone could account for 19-21 GtCO2e of these avoided emissions.

Healthcare services

Cooling is required in the healthcare sector for safe health centers, transportation and storage of vaccines and medical products. Temperature control and vaccine cold chains are certainly key contributing factors in delivering vaccines across the globe. A recent Dalsey, Hillblom and Lynn (DHL) logistics study concluded that even with conventional cold storage requirements, the proportion of the world's population with good access to a vaccine would only be about 70 per cent. On this basis, approximately 2.7 billion people would lack dependable access to vaccines-because of insufficient logistics capabilities related to cold chains, which is particularly alarming in the situation of the need for urgent vaccination of people around the world due to the COVID-19 pandemic.

Dramatic expansion in cold chain equipment will be necessary to guarantee equitable distribution of COVID-19 vaccines. Support for sustainable cold chains represents an opportunity to address immediate equity considerations and deliver a lasting impact in support of the economic and social recovery from the pandemic.

Cooling Refrigerant-Related Emissions

Direct emissions from refrigerant gases contribute to climate change as they are released into the atmosphere. The higher the GWP (reference value is GWP of CO_2 = 1) of the refrigerant, the stronger its negative impact on climate is, which can occur at any stage of the cooling equipment's lifetime, e.g. during its manufacturing, operation and/or disposal.

According to global estimates[xiii], air-conditioning accounts for 65 per cent of the total HFC-related emissions linked to cooling, while refrigeration contributes the remaining 35 per cent. Air-to-air air-conditioners (ACs) are responsible for 45 per cent of the emissions from air-conditioning, while another 36 per cent is attributed to mobile air conditioning, with chillers and heating only heat pumps contributing 15 and 4 per cent, respectively.

Case study 1:Sistem monitoring logistik secara elektronik(smile)

The United Nations Development Programme (UNDP) has introduced Sistem Monitoring Imunisasi Logistik secara Elektronik (SMILE), an innovative technological solution that aims to strengthen the immunization supply chain system in Indonesia. The system aims to ensures that safe and effective vaccines are available to all children, at all times. SMILE enables real-time visibility of vaccine cold chain logistics by digitizing stock supplies and storage temperature across vaccine cold chain points.

SMILE has been included in the Ministry of Health system since 2020. The Ministry aims to implement the system across all cold chain points, covering 10,000 facilities, as part of its five- year immunization programme.

SMILE consists of a mobile app for cold chain handlers, a web interface for data storage and a temperature logger that monitors storage temperature of vaccines to ensure that quality vaccines are dvelivered as required in a timely manner. Following its implementation in 2018, SMILE has focused on expanding reach to 600 Public Health Centers by 2021.

SMILE have reduced vaccine stock wastage by 90%, with stock-out levels reduced by 74% and over-stocking reduced by 47%, in the 2,723 integrated health centers across Indonesia. (UNDP Indonesia[xii])

The most significant portion of refrigeration-related emissions (73 per cent) comes from commercial refrigeration, followed by 20 per cent from industries related to food processing and other processing industries, with 5 per cent contributed by the refrigerated transport, and 2per cent - by domestic refrigerators.

Across all the sectors, 40 per cent of the refrigerant-related emissions occur during filling the refrigerants into the new equipment, while 60 per cent taking place during operation of the equipment throughout its lifetime, as the amount of refrigerant in the equipment decreasing, leading to lower performance. Faster phasedown of HFCs, as stipulated by the Kigali Amendment to Montreal Protocol, can be achieved through their replacement in the cooling equipment with low-GWP alternatives. Table 1 provides information on commonly used HFCs in various cooling sectors and some of the more climate-friendly options. Several low-GWP refrigerant alternatives are commercially available or under development, including HFO-1234yf, R-290, R600a, CO_2, HFC-152a and Ammonia, used in secondary loop designs that can achieve higher overall energy efficiency (Blumberg et al. 2019)

Table 1: Current refrigerants in use and alternative low-GWP refrigerants in cooling application sectors

S. No	Cooling application sectors	Commonly used HFC refrigerants (GWP)	Low-GWP alternatives (GWP)
1	Building Space Cooling		
1.1	Room air-conditioners	HFC-410A (2100) HFC-22 (1780)	HFC-32 (677) HC-290 (3)
1.2	Centralized air-conditioning (Chillers)	HFC-134A (1360)	HFO-1234ze (<1) HFO-1233zd (1) R-514A (0)
2	Food cold chain		
2.1	Domestic refrigerators	HFC-134A (1360)	HC-600A (1)
2.2	Cold storage refrigeration systems	R-404A (4200)	R-744 (1) R-513a (573)
2.3	Refrigerated transport vehicles	HFC-134A (1360)	HFO-1234yf (1) R-744 (1)
3	Mobile air-conditioning	HFC-134A (1360)	HFO-1234yf (1)
4	Healthcare cold chain		
4.1	Ice lined refrigerators	HFC-134A (1360) R-404A (4200)	HC-290 (3)
4.2	Vaccine cold stores	R-404A (4200)	R-744 (1) R-513a(573)
5	Process cooling	R-22 (1780)	R-717 (0) R-514A (0)

In the mobile air-conditioning sector alone, transitioning to refrigerants with a GWP under 150 will result in global GHG emission reductions of 150–200 million tonnes of carbon dioxide equivalent (MtCO2e) per year (Blumberg et al. 2019).

Some of the challenges with the abatement of HFC-related emissions include:

- Physical properties of the refrigerants, like flammability and toxicity in the indoor environment, etc., cause concerns with transitioning to some of the refrigerants. For instance, refrigerants like R-290a and R-600a are highly flammable in nature, leading to their limited use only with safer components like strong insulation and only in stationary air conditioning systems.
- The servicing professionals require training on the safe handling of inflammable refrigerants and proper installation for optimal efficiency and performance. Recovery of refrigerants during service and at the end-of-life of equipment can only be achieved if the service professionals are trained well.
- Reduction of the service refrigerant consumption of Hydrochlorofluorocarbons (HCFC) and high GWP HFCs requires a more extended period, as replacing refrigeration and air-conditioning equipment in use currently is a challenging task for both users and the governments.

case study 2: Refrigerant recovery and reuse - cambodia

Recoolit is a startup in Cambodia devoted to fighting climate change by recovering refrigerant from end-of-life consumer cooling devices. Recoolit partners with the second hand shops (Suppliers) which procure the older refrigerators, and acquires the refrigerant gas by sending their trained technicians to the supplier's site. The company pays the supplier for each refrigerator provided for recovery. The acquired gas is then purified by removing moisture and contaminants from the gas and repressurized before reuse in new equipment.

case study 3: Refrigerant transition - bangladesh

Walton Hi-Tech Industries, in partnership with National Ozone Unit of Bangladesh and UNDP is working on the MLF assistance for the conversion of three domestic refrigerator

manufacturing lines and a compressor manufacturing facility all from HFC-134a with GWP of 1360 to Hydrocarbon refrigerant R-600a (isobutane) with a GWP of 3. This program aims at emissions reduction of about 282,000 tonnes of CO2 equivalent GHG

Cooling Energy-Related Emissions

The operational energy consumption by cooling systems with vapour compression technologies is highly energy-intensive, resulting in substantial GHG emissions. The global cooling equipment stock for air conditioning, refrigeration, and mobile cooling was estimated to consume 3,900 Terawatt-hour (TWh) per annum (Around 17 per cent of total demand for electricity) in 2018.iv South-East Asia will witness an exponential increase in the sales of air-conditioning due to increasing temperature and due to higher disposable income. The overall number of air-conditioner units in 2040 could rise from 40 million units in 2017 to 300 million units in 2040, half of which will be in Indonesia[v].

By 2050, the global electricity generation capacity will more than double from 2018 levels, with significant contributions coming from the USA, followed by China and India. Energy demand for residential air-conditioning is projected to exceed demand for heating by 2070 and increase 40-fold by 2100 relative to 2000 levels[xv].

MAC for cars, vans, buses and trucks emits around 420 MtCO2e of GHG per year (approximately 70 per cent from fossil fuel combustion and 30 per cent from refrigerants) and is expected to rise to 1.3 GtCO2e in 2050 without further policy action[iv]. Compared with other sectors, the food cold chain is a growing sector with 405,340 million m3 of cold storage available across the world (per capita space of 52 m3 in the developed countries and with only 19 m3 in the developing countries[xvi]). In addition to this, a refrigerator is the second-highest energy-consuming appliance in most households after a domestic air-conditioner. Also, the energy demand by commercial refrigeration systems constitutes around 60 per cent of the energy consumed in supermarkets[xvii].

Highly efficient cooling offers the opportunity to more than double the effects of mitigation through HFC phasedown and improve the quality of living. Efficiency can be achieved through the implementation of passive cooling measures, utilization of highly efficient appliances, and improvement of efficiency in design, commissioning and operational practices, as well as in maintenance and management of cooling processes.

Stock of air conditioning units in Southeast Asia in the Stated Policies Scenario,2010-2040

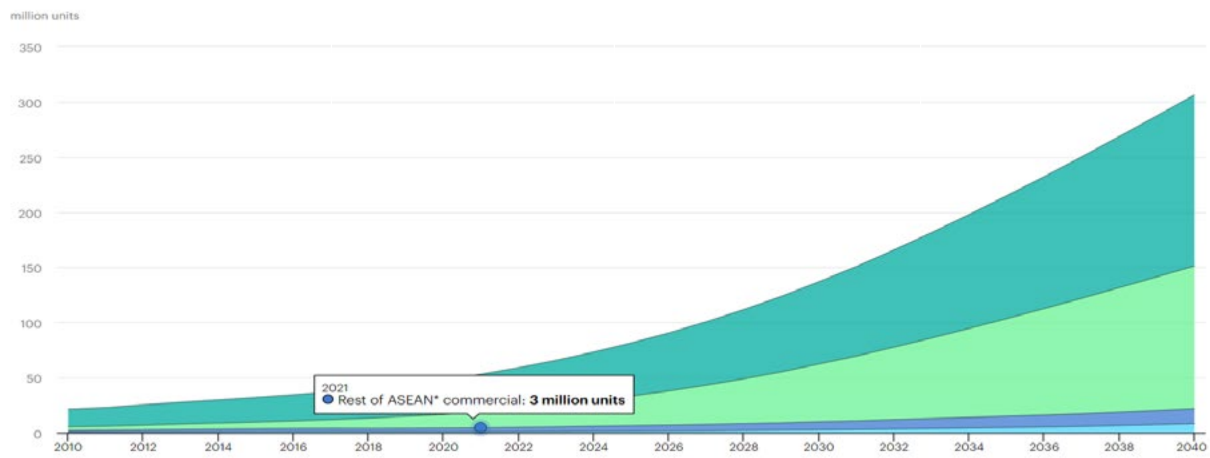


Table 2: Potential equipment energy efficiency transitions for the cooling sectors

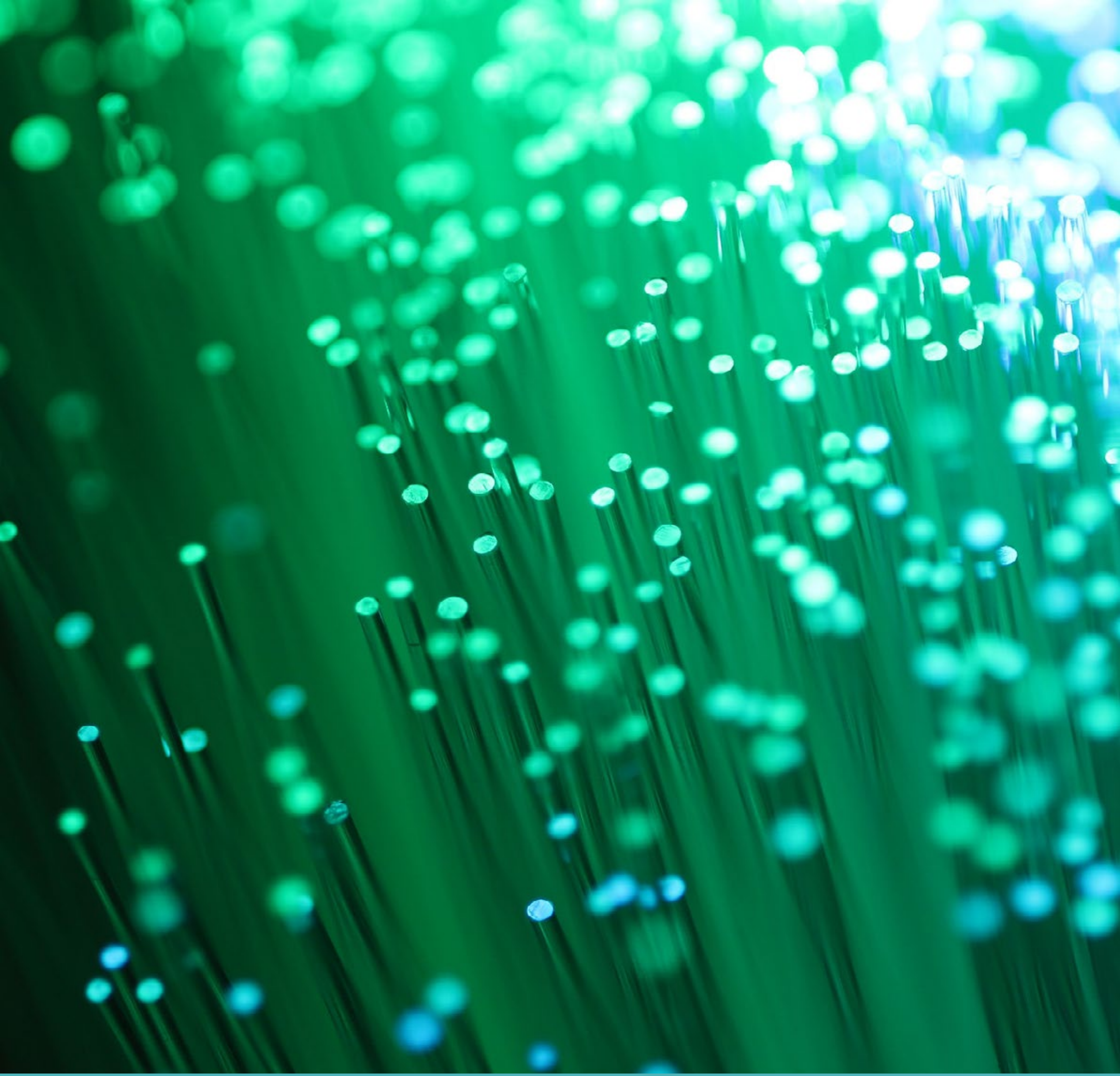
Sector & Appliances	Current equipment efficiency	Highest available equipment energy efficiency	Source
Building Space Cooling			
Room Air Conditioners	Seasonal Energy Efficiency Ratio (SEER) - 3 (kW/kW)	SEER – 12 (kW/kW)	India BEE Star Labelling for Window ACs, Split ACs
Chiller systems[xviii]	Plant Integrated Part Load Value (IPLV) kW/TR - 1	Plant IPLV kW/TR – 0.65	Demand Analysis for Cooling, Indo-German Energy Forum
Variable Refrigerant Flow systems[ix]	kW/TR – 0.81	kW/TR – 0.73	
Food Cold Chain & Refrigeration			
Domestic Refrigeration	400-600 kWh/year	200 kWh/year	India BEE Star Labelling for Refrigerators
Commercial refrigeration	kW/TR – 0.9	kW/TR – 0.65	India Cooling Action Plan
Mobile Air Conditioning			
Passenger Cars	0.012 litre/km of fuel for cooling	0.007 litre/km of fuel for cooling	International Energy Agency (Cooling on the Move, 2019)
Passenger Heavy-Duty Vehicles (Buses)	0.05 litre/km of fuel for cooling	0.023 litre/km of fuel for cooling	
Process Cooling[ix]	Plant IPLV kW/TR - 1	Plant IPLV kW/TR – 0.65	Demand Analysis for Cooling, Indo-German Energy Forum

Design concepts like end-use oriented cooling load estimations, peak and regular load separation through sequencing, balanced and efficient hydronics and efficient airside with free cooling can lead to significant energy savings during operations. The cooling loads can be reduced drastically through penetration of passive cooling measures like insulation and shading of structures, leakage reduction from building envelope, free air cooling and utilization of available natural ventilation. Up to 29 per cent of energy savings[xix] can be achieved through engaging finely tuned control systems with the cooling system. Further savings and insights on cooling operations and management can be achieved through the utilization of solutions with enhanced data analytics, supported with artificial intelligence (AI).

Clean energy sources like solar, geothermal, waste heat and others integrated with thermal energy storage offset the requirement of energy supply or improve the efficiency of the cooling equipment. Solar photovoltaic operated cold storages and refrigerators can be installed in remote locations to address access to cooling needs for agriculture (fisheries, horticulture storage) and healthcare (vaccine and medical products) requirements. The use of solar or waste heat-based absorption/adsorption cooling and geothermal cooling of direct-expansion condensers can significantly offset energy requirements for cooling.

Some of the challenges related to the reduction of energy-related cooling emissions include:

- Limited availability of best efficiency cooling appliances across the global markets.
- Slower adoption of highest efficiency appliances due to their higher cost implications.
- Expected growth in renewable power not yet achieved across the globe due to economic reasons and due to the impacts of COVID-19.
- Inefficient design, commissioning, and operation of HVAC equipment.
- Need for penetration of improved operational energy efficiency through automation. and preventive/predictive maintenance and management systems.
- Lack of cooling energy benchmarks for application sectors like food and healthcare cold chain and mobile air conditioning.
- Need for promotion of locally developed energy-efficient not-in-kind technologies.
- A shift in user behavioural change is needed, especially in the emerging economies, to curb energy poverty created by the over-usage of cooling systems.



case study 4: asean shine project

Association of Southeast Asian Nations (ASEAN) SHINE project for harmonization of testing standards for energy-efficient air-conditioning systems achieved a full-scale market transformation favouring more efficient air-conditioners (ACs) and led to a reduction in electricity consumption by 5373 GWh per year. The implementation of project results will reduce GHG emissions by 2.7 million tonnes per year. For ASEAN consumers, buying more highly efficient ACs would save them about $ 800 million in electricity bills (over five years, monetary savings are on average $ 256 per household[xx]).

Way forward: Transition to Sustainable Cooling

There are significant opportunities to address environmental impacts related to cooling as a considerable number of buildings, air-conditioners, as well as mobile and cold chain cooling systems, which will be required to meet future cooling needs, are not yet constructed or manufactured. The potential to make those future cooling solutions more sustainable can help to avoid a lock-in effect and, in combination with the replacement of existing inefficient cooling systems, can significantly reduce cooling-related contribution to climate change and other adverse environmental impacts. This section discusses some of the proven policy responses and recommendations for sustainable cooling.

Policies and International Cooperation

Adoption of **international commitments** by national governments through the ratification of the Paris Agreement, Kigali Amendment to Montreal Protocol and UN's Sustainable Development Goals.

Collaboration through **international initiatives** gives the opportunity to national governments to work jointly with various international experts and institutions on accelerating actions for sustainable cooling. Such initiatives include, but are not limited to, Cool Coalition[xxi], Kigali Cooling Efficiency Program (K-CEP)[xxii], - the Sustainable Cooling Initiative by World Bank[xxiii], Sustainable Cooling Innovation Program by International Finance Corporation (IFC)[xxiv].

The development of **National Cooling Action Plans (NCAPs)** can synergize cooling policies in different cooling sectors and accelerate the transition to sustainable cooling.

Minimum Energy Performance Standards (MEPS) for cooling equipment like refrigerators, air-conditioners, chillers, fans, and mobile air-conditioning complimented by **Labelling Programmes** can accelerate the adoption of energy-efficient and low GWP cooling and phasing out of inefficient and polluting technologies from the market.

Building Energy Codes (BECs) address an integrated approach for energy efficiency in buildings through demand-side efficiency along with cooling supply-side efficiency to minimize GHG emissions related to comfort cooling. BECs encourage the adoption of passive cooling systems, low energy and not-in-kind technologies like evaporative cooling, vapour absorption cooling, vapour adsorption cooling, deep lake and seawater cooling.

The inclusion of **UHIE mitigation measures** into urban planning can help cities to cope with increasing temperatures within the urban environment and reduce heat stress for their population

SELECTED INNOVATIVE APPROACHES TO SUSTAINABLE COOLING

Urban Planning with due importance given to open areas, vegetation, water bodies, material selection, cool roofs, and traffic management will reduce the urban heat island effect (UHIE) and, consequently, cooling demand.

District Cooling (DC) System typically require about 15 per cent less capacity than conventional distributed cooling systems for the same cooling loads due to load diversity and flexibility in capacity design and installation. DC system also reduces significant refrigerant demand.

MAC energy consumption can be reduced through improvements in electrical components (blowers) and mechanical components (compressors). MAC cooling demand load can be reduced through changes in-vehicle components such as improved insulation, window coatings and reflective paints.

Cooling-as-a-service is a novel business model (pay-per-service model) for sustainable cooling systems, which eliminates upfront investment in clean cooling technologies for customers who instead pay per unit of cooling they consume and strengthen incentives for efficient consumption.

Digital monitoring of vaccines temperature along the entire cold chain can strengthen immunization programmes and reduce vaccine wastage.

National and sub-national governments should include measures for improving access to cooling for thermal comfort, food supply and healthcare in their strategies to support rural poor as well as vulnerable and low-income groups of population in urban areas (e.g. in urban slums and informal settlements).

NATIONAL COOLING ACTION PLANS DEVELOPMENT

Following ESCAP's mandate to support its member States in achieving the Sustainable Development Goals (SDGs), and the United Nations Environment Programme's (UNEP) role as the leading global environmental authority that promotes the coherent implementation of the environmental dimension of sustainable development within the UN system, UNEP and ESCAP have been collaborating within the framework of Cool Coalition to accelerate policy development on sustainable cooling for all in the Asia Pacific Region. The main aim of this collaboration is to equip national governments to conduct holistic assessments of their countries' cooling needs and develop National Cooling Action Plans (NCAPs), as well as to feature sustainable cooling in countries' Nationally Determined Contributions (NDCs). As part of this work, ESCAP and UNEP partnered with the Alliance for Energy-Efficient Economy (AEEE) to develop a methodology and guidance for national governments on NCAP development.

The NCAP Methodology is comprehensive in its scope and covers various cooling sectors, such as space cooling in buildings, mobile AC, cold chain & refrigeration (both for food and healthcare).

NCAP Methodology outlines a process that can be tailored to a specific country's context and can enable identification and prioritization of actions on sustainable cooling. The proposed process for the NCAP development has two parts:

- NCAP development methodology. An overarching Methodology lays out the sequence of steps and activities involved in the NCAP development, including guidelines, good practices, and available resources where applicable. The Methodology consists of three sequential stages––Contextual Assessment and Planning, Cooling Demand Assessment, and Synthesis and NCAP Creation––with each stage divided into several steps with related activities.
- Data assessment framework. Data collection and analysis is a core element of the NCAP Methodology. To adequately support this process, the Methodology includes a toolkit of Data Assessment Frameworks for several cooling sectors. The Frameworks provide directional guidance, presenting the key data inputs that can be used to estimate the current and future cooling demand and related direct and indirect GHG emissions, as well as different pathways for data analysis of both met and unmet cooling demand to account for the population, who currently does not have access to cooling, but might be getting it in future.

For addressing the cooling needs, the Methodology advocates for an integrated approach that includes:

- First, reduce the cooling loads to the extent possible. Such as through thermally efficient building design and construction and passive cooling practices in case of the building sector
- Then, serve the cooling loads efficiently. Such as with appropriate and efficient cooling equipment and solutions that deliver the required amount of cooling with less energy and lower overall emissions
- Optimize the cooling operations and behaviours. Such as through good operation and maintenance practices, user adaptations etc. to ensure that cooling is delivered only to where and when it is needed

The full text of the methodology can be found here[2].

2 https://www.unescap.org/kp/2021/national-cooling-action-plan-methodologyv

Market Enablers

Bulk Procurement of cooling equipment like air-conditioners, refrigerators can bring economies of scale to reduce costs and can lead to accelerated adoption of super-efficient refrigeration and air-conditioning equipment.

Utility Engagement can lead to the implementation of successful demand response programmes, like imposing higher tariffs for electricity during peak periods, offering subsidies/incentives for the purchase of more efficient systems, and encouraging large-scale utilization of thermal storage (ice or chilled water), and information or awareness campaigns.

Financial Mechanisms

Policies response and market enablers should be complemented by financial mechanisms to speed up the adoption of sustainable cooling. National governments can explore accessing funds from climate change mitigation funds, multilateral development banks, philanthropies, federal and private financial institutions to support sustainable cooling initiatives. Other financial mechanisms include equity, concessional loans, guarantee and risk-sharing facilities, technical assistance grants and fiscal incentives and penalties.

K- CEP has established Window 3: Finance programme of 10 million USD of grant support initiatives leading to faster implementation of efficient, clean cooling and to mobilize additional sources of public and private investment. The selected proposals cover air conditioning, refrigeration, district cooling, cold chains and systems approaches across a range of sectors – from commercial and industrial applications to public and residential buildings. These proposals employ different financing approaches such as on-bill payment, credit lines and procurement schemes, and financial mobilization from private equity and debt, multilateral and national development banks, and commercial banks.

Capacity Building

Building capacity and training of technicians will improve the installation and servicing practices of cooling equipment. This will result in enhancement of the energy performance of cooling equipment, reduction of refrigerant leakage and improvement of refrigerant recovery at the end of the service life of the equipment. Extensive capacity building efforts is needed to make all the stakeholders understand the integrated approach to sustainability in the cooling sectors.

CASE STUDY: DEVELOPMENT OF THE NATIONAL COOLING ACTION PLAN IN CAMBODIA

Cambodia is the first country, where the comprehensive NCAP methodology developed by ESCAP, UNEP and AEEE has been piloted. Ministry of Environment in Cambodia has taken the leadership position to engage and coordinate with all the relevant government ministries (e.g. the Ministry of Land Management, Urban Planning, and Construction, the Ministry of Mines and Energy, and the Ministry of Public Works and Transport) and stakeholders for necessary data collection and verification of the data. The National Council for Sustainable Development, which oversees the implementation of the country's NDCs, worked on preparion of the text of the the NCAP based on the data analysis prepared by the ESCAP-UNEP-AEEE international expert team.The overall process of the NCAP development took eleven months.

The Cambodian NCAP addresses the following cooling sectors: space cooling in buildings, food and healthcare coldchains, mobile air-conditioning, and industrial process cooling. It uses 2020 as the baseline year and develops a 20-year future outlook projecting growth under two scenarios –– that is, Business-as-usual (BAU) and Intervention scenarios.The process of data collection in Cambodia started from mapping of existing data, initiatives , policies and stakeholders related to cooling. At the next stage a more in-depth data collection took place for each of the cooling sectors in accordance with the template provided by the NCAP Methodology and adapted to Cambodia's needs and priorities. Ministry of Environment in collaboration with the Cambodia National Ozone Unit collected a substantial part of the required data.

Main highlights of data analysis and recommendations from the NCAP development in Cambodia can be summarized as following:

- The effective implementation of the NCAP in Cambodia is estimated to save 6.71 million Tonnes of cumulative GHG emissions by 2040.
- Building space cooling, mobile air-conditioning and food cold chain were identified as priority sectors for developing recommendations under the NCAP.
- Implementation of labelling and MEPS programmes for air-conditioning and refrigeration equipment will reduce the operational energy use for cooling.
- Development and implementation of comprehensive building energy codes (BECs) for new buildings and existing buildings undergoing a major renovation will reduce building-related cooling demand, energy consumption and related GHG emissions. Implementation of Passive Cooling Solutions (PCS) through building code considering 20% of the new building stock will comply in the first year (i.e. 2021) with a CAGR of 5% is estimated to reduce the total cooling demand by 530,000 TR by 2040.
- Integration of the requirements of cooling sufficiency and UHIE into urban planning control rules will result in multiple benefits, like reduction in cooling demand & energy consumption of built environment and improvement in outdoor thermal comfort etc.
- Organization of public awareness campaigns on sustainable cooling could facilitate broader adoption of energy-efficient cooling equipment and encourage behaviour change toward more sustainable cooling choices by end-users.
- Roll-out of capacity building programmes for technicians are essential to improve installation and servicing practices of cooling equipment.
- Promotion of innovative not-in-kind cooling technologies, like district cooling systems, renewable energy operated cold storage, geothermal cooling, absorption/adsorption cooling etc., should be considered among the measures to reduce cooling-related GHG emissions.
- Promotion of innovative business models, like servitization and bulk procurement, could further facilitate adoption of sustainable cooling in the country.

A similar initiative of the NCAP development is undergoing in Indonesia with the support of ESCAP, UNEP, AEEE and Sustainable Energy for All (SE4ALL). The NCAP development work in Indonesia has been spearheaded by the Ministry of Energy and Mineral Resources.

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Conclusion

Sustainable cooling solutions are vital for addressing global climate change and for achieving the Sustainable Development Goals in all countries. These solutions can also help to meet the cooling needs of vulnerable groups of the population related to protection from heat, access to nutritious food, as well as safe vaccines and other healthcare options.

Vapour compression-based cooling technologies have significant contributions to both direct and indirect carbon emissions. To increase the adoption of sustainable cooling solutions, countries should develop enabling policy mechanisms and utilize financial solutions to support their effective implementation.

National Cooling Action Plans based on rigorous data collection and analysis can consolidate and outline various policy priorities and sustainable cooling solutions across different cooling sectors within one strategic policy document, which will guide implementation of sustainable cooling agenda tailored to the unique context of each country. Use of energy-efficient technologies and climate-friendly refrigerants, integration of renewable energy sources and good service practices can significantly accelerate the transition of countries toward more sustainable cooling and support the progress on important goals set by SDGs, Paris Agreement and Kigali Amendement to Montreal Protocol.

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