Indonesia's National Cooling Action Plan (I-NCAP)

2024

Indonesia's

National Cooling Action Plan

(I-NCAP)

Acknowledgments

This document is the result of a multi-stakeholder collaboration initiated by the Directorate of Energy Conservation (KE), Directorate General of New, Renewable Energy and Energy Conservation (EBTKE), the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), and the United Nations Environment Program's (UNEP), Sustainable Energy for all (SEforAll), and other experts under the framework of the Cool Coalition. The NCAP development process included a stakeholder consultation process involving various entities within the cooling sector, including the Ministry of Environment and Forestry, Ministry of Public Works and Housing, Ministry of Industry, Ministry of Agriculture, Ministry of Marine Affairs and Fisheries, Ministry of Health, Green Building Council Indonesia (GBCI), ASHRAE Indonesia Chapter, CLASP, Indonesia Cold Chain Association (ARPI), and cooling industry players.

The analysis presented in this document is developed following the Cool Coalition National Cooling Action Plan Methodology (Cool Coalition *et al*., 2021).

Foreword

Cooling demand is increasing rapidly as temperatures rise and the uptake of cooling equipment and appliances increases. This is leading to increasing electricity and refrigerant consumption, with significant implications for progress in meeting national energy and emissions-related targets. As outlined in its enhanced National Determined Contribution (NDC), Indonesia is committed to mitigating climate change with a plan to reduce emissions in 2030 by 31.89% and up to 43.20% with international support. In the energy sector, a commitment to has been made to reduce emissions by 12.5% – an equivalent 358 million tonnes of CO_2e. Of this amount, it is estimated 1/3 can be achieved through the use of energy-efficient appliances, including refrigeration and air conditioning (RAC) equipment. It is estimated the RAC sector contributes to 15.4% of total energy sector emissions.

These facts highlight the crucial role of the Directorate of Energy Conservation (DKE) of the Ministry of Energy and Mineral Resources (MEMR) to take initiative and provide leadership in the efforts to expand access to increasingly necessary cooling services in the face of climate change and the increased frequency of heat events, while reducing emissions from the cooling sector. Indonesia needs a roadmap for addressing the cooling challenge. This National Cooling Action Plan can serve as a systematic and comprehensive framework for realising lower energy demand and emissions while increasing the resilience of populations and economic sectors.

This document is the result of a multi-stakeholder collaboration initiated by the Directorate of Energy Conservation (KE), Directorate General of New, Renewable Energy and Energy Conservation (EBTKE), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), United Nations Environment Program's (UNEP) and SEforAll under the framework of the Cool Coalition. The NCAP development process included stakeholder consultations involving various entities within the cooling sector, including but not limited to: the Ministry of Environment and Forestry, Ministry of Industry, Ministry of Agriculture, Ministry of Marine Affairs and Fisheries, Ministry of Health, Green Building Council Indonesia (GBCI), ASHRAE Indonesia Chapter, CLASP, Indonesia Cold Chain Association (ARPI), and cooling industry players, and others. This document will be updated regularly according to data availability and policy developments in the Indonesia cooling sector.

Finally, thank you for the contribution of all parties. Hopefully, this NCAP document will benefit Indonesia by catalysing new and strengthened policy and actions for realizing energy savings, reducing emissions, and supporting a sustainable domestic cooling sector.

Eniya Listiani Dewi
Director General of New and Renewable Energy
and Energy Conservation-MEMR

Foreword

As the world steps into an era marked by the intensifying impacts of climate change, rapid urbanization, and rising purchasing power, the need for sustainable cooling solutions has never been more critical. Access to cool spaces and energy-efficient, environmentally friendly cooling services is not merely a matter of comfort or convenience but has become an increasingly vital necessity to protect people from rising temperatures and extreme heat and ensure public health, food security, and economic productivity. However, the growing demand for cooling leading to a vicious cycle of more cooling & emissions thereby creating climate change and raising temperatures.

Indonesia, with its hot and humid climate and growing population, stands at a pivotal juncture in addressing the growing challenges faced by its people, power systems and climate ambitions. Indonesia's National Cooling Action Plan (I-NCAP) represents a comprehensive roadmap to achieving sustainable cooling that reduces energy demand and greenhouse gas emissions, while providing services essential for both human well-being and economic development through the triple strategy of passive cooling, energy efficiency and phase down of climate warming refrigerants. It sets forth a strategic vision for a cooling sector that is resilient, inclusive, and environmentally sustainable.

Within the framework of the Cool Coalition, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the United Nations Environment Programme (UNEP), with the technical support of Sustainable Energy for All, are proud to have contributed to the development of the I-NCAP.

The I-NCAP followed an inter-ministerial approach led by the Ministry of Energy and Mineral Resources, and benefited from the contributions from a range of national and international stakeholders. It provides a holistic view of current and future cooling energy demand across multiple cooling sectors, including space cooling, cold chains and mobile air conditioning. It presents a comprehensive set of interventions to reduce cooling demand, provide thermal comfort and buffer against the impacts of rising temperatures and increasing frequency of extreme heat events. Its implementation could reduce electricity consumption by 57% and mitigate greenhouse gas emissions by 55% in 2040, as compared to business-as-usual.

We congratulate MEMR on the publication of this landmark policy roadmap, which can help pave the way for a cooler, more sustainable future for Indonesia. We hope that the I-NCAP will serve as a catalyst for robust policy action and the implementation of practical measures to deploy equitable, climate-friendly, energy efficient cooling that supports socioeconomic development. The release of this Plan is a testament to Indonesia's leadership and commitment to sustainable development and climate action.

Sincerely,

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Abbreviations and acronyms

AC	Air-conditioner
ARPI	Indonesian Cold Chain Association
ASEAN	Association of Southeast Asian Nations
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAU	Business as Usual
BOE	Barrel of oil equivalent
BPS	Statistics Indonesia
Bappenas	National Development Planning Agency / Ministry of National Development Planning
CLASP	Collaborative Labeling and Appliance Standards Program
CM1	Counter Measure 1 (unconditional mitigation scenario)
CM2	Counter Measure 2 (conditional mitigation scenario)
DX	Direct expansion
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
GBCI	Green Building Council Indonesia
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	German Corporation for International Cooperation
GWP	Global warming potential
km	Kilometre
$kTCO_2e$	Kilotons of carbon dioxide equivalent
kW	Kilowatt
kWh	Kilowatt hour
MEPS	Minimum energy performance standard
MEMR	Ministry of Energy and Mineral Resources
MoEF	Ministry of Environment and Forestry
$MTCO_2e$	Million tonnes of carbon dioxide equivalent
NCAP	National Cooling Action Plan
NDC	Nationally Determined Contribution
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SNI	Indonesian National Standards
TCO_2e	Tons of carbon dioxide equivalent
TR	Ton of refrigeration
U4E	United For Efficiency
UNEP	United Nations Environment Programme
VRF	Variable refrigerant flow
W/W	Cooling energy (watts) / electrical energy (watts)

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Context and Objectives

The cooling sector consumes a significant share of final energy consumption and contributes a large share of national emissions. Emissions from the refrigeration and air-conditioning sector reached 77 million tons of carbon dioxide equivalent (CO_2e) in 2015, equivalent to 15 per cent of total energy sector emissions. At the same time, the cooling sector is expected to grow rapidly along with the growth of both Indonesia's population and economy.

Under its 2022 Enhanced Nationally Determined Contribution (NDC), Indonesia has committed to mitigating climate change with a plan to reduce emissions in 2030 by 31.89 per cent unconditionally and 43.20 per cent conditionally. It has committed to reduce energy emissions against the BAU scenario by 12.5 per cent, equivalent to 358 million tons of CO_2e. Of this amount, the use of energy-efficient appliances will lead to estimated savings of 25.87 million tons of CO_2e in the household sector and 1.91 million tons of CO_2e in the commercial sector.

Cooling needs must be met through affordable and sustainable solutions to reduce heat stress, productivity losses, food and agricultural waste, and medical product losses. At the same time these needs must be met in an energy-efficient and climate-friendly manner. According to a report from the Efficient Cooling Initiative[1], a 30 per cent improvement in the energy efficiency of room air-conditioners can save enough energy to avoid building up to nearly 1,600 megawatts (MW) of peak power plants by 2030 and up to 2,500 MW by 2050. To provide cooling to different groups, a mix of policies, technologies, finance, and services needs to be applied, including targeted approaches for the most vulnerable. How well the demand for space cooling and refrigeration is met will influence economic growth, comfort and well-being, food supplies and health care.

The Indonesia NCAP has been developed based on the Cool Coalition's National Cooling Action Plan Methodology[2]. The NCAP utilizes data covering three thematic areas: building and space cooling; mobile air-conditioning; and food cold chains (see Box 1). The NCAP has also helped identify gaps in cooling data within different sectors and end uses.

This NCAP is designed to assist the government to:

- Understand and address cooling through a comprehensive approach covering different sectors and end uses;
- Ensure the integration of both met and unmet cooling needs into policy and regulation;
- Drive alignment and integrative action across multiple sectors of cooling;

1 An initiative under the Climate and Clean Air Coalition aimed at enhancing energy efficiency in the cooling sector while countries implement the phase-down of hydrofluorocarbon (HFC) refrigerants under the Montreal Protocol.

2 The National Cooling Action Plan Methodology was developed by the Alliance for an Energy Efficient Economy under the leadership of the Cool Coalition, the United Nations Environment Programme (UNEP), the United Nations Economic and Social Commission for Asia and the Pacific, and the Kigali Cooling Efficiency Program (K-CEP), together with members of the NCAP Working Group (the United Nations Development Programme, UNEP United for Effiicency (U4E), OzonAction, Energy Foundation China, World Bank Group, GIZ, CLASP, Birmingham University and Sustainable Energy for All. It is available for download at: https://coolcoalition.org/national-cooling-action-plan-methodology.

- Integrate existing policies and institutional efforts related to cooling;
- Identify solutions for energy-efficient and climate-friendly cooling and the implementation pathway maximizing the socio-economic benefits.

Box 1. Prioritized cooling sectors for Indonesia's NCAP

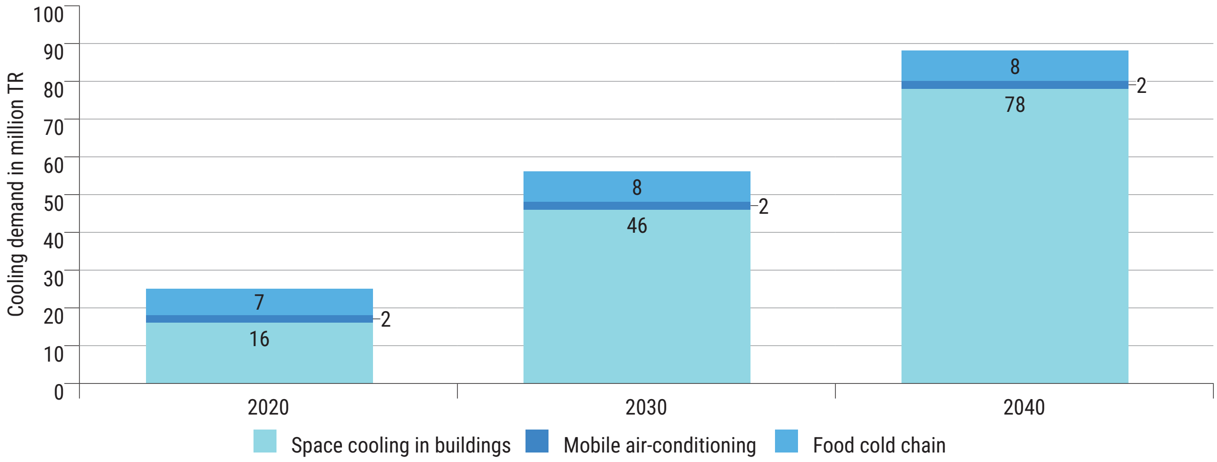
- Space Cooling: Space cooling provides thermal comfort to the building occupants, supporting health and wellbeing while enhancing productivity.
  - » Energy consumption for space cooling is dominated by refrigerant-based direct expansion (DX) air-conditioning systems. Demand for the energy consumption for space cooling can be reduced through the integration of efficient urban planning, passive cooling systems, low energy non-refrigerant based cooling, not-in-kind systems, efficient service practices for refrigerant handling, and the use of intelligent controls.
  - » To quantify direct and indirect emissions in the space cooling sector for Indonesia, the analysis considered data for the following equipment types: self-contained unitary air-conditioners, room air-conditioners (fixed speed split technology), room air-conditioners (inverter technology), chillers (screw, scroll, centrifugal types), variable refrigerant flow (VRF), packaged DX system and fans.
- Mobile Air-Conditioning: Mobile air-conditioning caters to passenger comfort cooling requirements in light-duty vehicles, heavy-duty vehicles, trucks and trains. Mobile air-conditioning uses refrigerant-based vapor compression technology to remove heat and moisture from inside the cabin. For Indonesia, cooling data on light-duty vehicles, heavy-duty vehicles, and freight vehicles (passenger cooling only) were considered to quantify direct and indirect emissions.
- Food Cold Chain: The food cold chain is a series of logistics that delivers perishable products to markets, thus empowering producers by enabling expanded market reach. The cold chain involves controlling environmental parameters such as temperature, humidity, air composition, and packaging to extend the product's life cycle and safeguard its nutrient quality. Due to data limitations, the indirect emissions for the baseline year, the BAU and Intervention scenarios were calculated for the food cold chain sector. To quantify indirect emissions, the analysis considered the areas of ice-cooling (fishing), cold stores for red meat and poultry, refrigeration for dairies, refrigeration for horticulture, transport, domestic refrigerators, and commercial data.

Scenarios and Emission Calculations

Based on the availability of the data inputs, sectoral analysis for building space cooling, mobile air-conditioning and food cold chains was carried out to calculate energy consumption, indirect and direct emissions. The cooling demand assessment considered the "baseline" year for cooling demand as the year 2020, as well as future cooling demand projections for the following two decades (2030 and 2040). The assessment considered met and unmet cooling demand and associated impacts on energy consumption, greenhouse gas emissions and refrigerant demand.

The two future growth projections included a "Business-as-usual (BAU)" scenario that assesses how the current baseline will evolve based on the current level of efforts, and an "Intervention" scenario

Figure 1. Cooling demand for building space cooling, mobile air-conditioning and the food cold chain in 2020, 2030 and 2040 under the BAU scenario



that evaluates how the cooling growth could evolve based on accelerated efforts across policies, technologies, and market enablers.

Indirect emissions were calculated by quantifying the cooling demand and energy consumption of technology and infrastructure. To calculate the indirect emissions for technology or infrastructure, stock information including average capacity of cooling equipment, cooling equipment efficiency, average operational hours, utilization factors, and primary energy factors were considered.

Direct emissions were calculated by quantifying the refrigerant leakage from cooling equipment during their operation and quantifying the refrigerant not recovered from the equipment at the end of their service life. Direct emissions for cooling technology and infrastructure were calculated using stock information, replacement factors, the charge rate of cooling equipment, leakage rates and recovery rates and refrigerant mixes[3].

Analysis, Results and Recommendations

Following data collection and emissions calculations, information from the data model was analysed to draw evidence-based conclusions. This analysis has informed sector-specific priorities, including rapid and high-impact opportunities, as well as longer-term strategic interventions.

The total cooling demand from the three selected sectors of space cooling, mobile air-conditioning, and the food cold chain was estimated to be 25 million tons of refrigeration (TR) in 2020. Under the BAU scenario, demand is expected to grow to 56 million TR in 2030 and to 88 million TR in 2040. Sectoral growth in cooling demand is depicted in Figure 1.

Space cooling was responsible for 64 per cent of analysed cooling demand in 2020. It is projected to nearly triple from 16 million TR in 2020 to 46 million TR in 2030, and to nearly quadruple to 78 million in 2040.

This increase in cooling demand will be coupled with a rise in electricity consumption, increasing from 79 terawatt-hours (TWh) in 2020 to a projected 183 TWh in 2030 and 265 TWh in 2040. This is

3 Exclusions include the direct greenhouse gas emission estimation for the food cold chain sector, for which data or benchmarks related to refrigerant consumption were not available for analysis. For more on the methodology, see Appendix 2.

coupled with an increase in the indirect emissions from cooling from 88 million tons of CO_2e in 2020 to 172 million tons of CO_2e in 2030 and 215 million tons of CO_2e in 2040.

The building space cooling, mobile air-conditioning and food cold chain sectors together contributed direct emissions from refrigerant consumption totalling 8,860 kilotons of CO_2e in 2020. This is expected to increase to 12,540 kilotons of CO_2e in 2030 and to 17,880 kilotons of CO_2e in 2040, representing a two-fold increase, more than 37 per cent of which is attributed to space cooling in buildings.

In the coming decades, Indonesia is projected to release total greenhouse gas emissions of 184 million tons of CO_2e in 2030 and 233 million tons of CO_2e in 2040, due to cooling requirements for space cooling, mobile air-conditioning and food cold chains. However, through the adoption of appropriate policy responses and recommendations, the country can mitigate its greenhouse gas emissions, improve access to cooling, lower energy demand and reduce local environmental impacts.

Under the BAU scenario, the following inferences are drawn based on the combined data analysis of cooling sectors in Indonesia:

- In 2030, total greenhouse gas emissions from the analysed sectors will reach 184 million tons of CO_2e, with 71 per cent of the emissions coming from space cooling in buildings, followed by mobile air-conditioning (17 per cent) and the food cold chain (12 per cent).

- In 2040, total greenhouse gas emissions from the analysed sectors will reach 233 million tons of CO_2e, with 72 per cent of the emissions coming from space cooling in buildings, followed by mobile air-conditioning (18 per cent) and the food cold chain (10 per cent).

Space cooling for buildings has the highest potential for mitigating greenhouse gas emissions among all cooling sectors, with a mitigation potential of 34 million tons of CO_2e by 2030 and 114 million tons of CO_2e by 2040. This is due to the expected penetration of passive cooling measures through building energy codes and energy-efficient room air-conditioner units. The food cold chain sector has a mitigation potential of 3 million tons of CO_2e by 2030 and 7 million tons of CO_2e by 2040, while the mobile air-conditioning sector has a mitigation potential of 3 million tons of CO_2e by 2030 and 7 million tons of CO_2e by 2040.

Under an Intervention scenario, the emission mitigation potential across the three analysed sectors – in terms of indirect and direct emission contributions – was assessed for 2030 and 2040 (see Figure 15) and is presented in Table 1.

Table 1. Mitigation potential for building space cooling, mobile air-conditioning and food cold chains

2030	2040
The total mitigation potential of the three sectors is 39 million tons of CO_2e, or a 21 per cent reduction from BAU.	The total mitigation potential of the three sectors is 128 million tons of CO_2e, or a 55 per cent reduction from BAU.
Of this total, indirect emissions account for 37 million tons, or a 20 per cent reduction.	Of this total, indirect emissions account for 119 million tons, or a 51 per cent reduction.
Direct emissions account for 2 million tons, or a 1 per cent reduction.	Direct emissions account for 9 million tons, or a 4 per cent reduction.

The Structure of Indonesia's National Cooling Action Plan

Indonesia's National Cooling Action Plan is organized into five chapters, as follows:

Chapter 1 contains an overview of the cooling context, including explanations of socio-economic conditions, energy and grid parameters, the policy and regulatory landscape, and Indonesia's international commitments. The chapter ends with a technical and market context covering climate mapping, energy efficiency, the room air-conditioner market situation, and its emissions.

Chapter 2 introduces the importance of the National Cooling Action Plan (NCAP) for the country with regard to energy and capacity saving, contributions to achieving the country's Nationally Determined Contribution (NDC) and the UN Sustainable Development Goals, and support for COVID-19 recovery. The chapter describes the methodology of the development of the NCAP and the organization of the report.

Chapter 3 contains the framework, cooling data assessment methodology, data collection process and approach for each sector.

Chapter 4 discusses the cooling demand assessment results and their analysis in country-level results and sector breakdown.

Chapter 5 contains recommendations and ways forward for sustainable cooling in Indonesia. The chapter includes advice and future steps to update the NCAP to a more comprehensive document.

1 Overview of Indonesia's National Cooling Context

1.1 Background

Indonesia is characterized by climate change-induced warming, population growth, and rapid urbanization coupled with development trends that contribute to rising greenhouse gas emissions. Indonesia is the largest archipelagic country globally, and the fourth most populous country worldwide, with more than 275 million people in 2022. Over the period 2010-2020, the average growth rate of Indonesia's population was 1.25 per cent per year. The population growth rate is projected to be 0.74 per cent during 2015-2045, with more than 72 per cent of Indonesia's population living in urban areas by 2045 (Sustainable Energy for All 2022). Based on the 2045 Indonesian Vision, economic growth is projected to average 5.7 per cent annually during 2016-2045 (Ministry of National Development Planning 2019).

These socio-economic drivers have led to an unprecedented increase in the demand for cooling that will extend well into the future. As a developing country, Indonesia is experiencing significant growth in several sectors of the economy to meet critical needs related to thermal comfort in buildings, agriculture and food supply chains, the storage and transport of vaccines and medical products, mobility, and industrial processes. At the same time, people face increasingly severe heat exposure risks due to rising temperatures and a lack of adequate access to cooling, which is essential to health, well-being and productivity. An estimated 33.6 million rural and poor in Indonesia are at high risk due to a lack of cooling, while lower-middle income and middle-income populations face medium and low risk levels.

The realization of national targets and the Sustainable Development Goals (SDGs), particularly those related to energy and climate, is associated with the developmental demand for cooling. At the same time, refrigerants – which contribute to cooling in buildings, industries, cold chain refrigeration and transport – are regulated under the Montreal Protocol and its Kigali Amendment, to which Indonesia is a Party. Indonesia has stated its commitment to these agreements in Presidential Regulations No. 95/2016 and 129/2022, ratifying the Montreal Protocol and the Kigali Amendment, respectively.

Under its 2022 Enhanced Nationally Determined Contribution (NDC), Indonesia has committed to mitigating climate change with a plan to reduce emissions in 2030 by 31.89 per cent unconditionally and by 43.20 per cent conditionally (Ministry of

Environment and Forestry 2022). It has committed to reduce energy emissions against the BAU scenario by 12.5 per cent, equivalent to 358 million tons of CO_2e. A national study estimated that the country's emissions from refrigeration and air-conditioning totalled 77 million tons of CO_2e in 2015, equivalent to 15 per cent of total energy sector emissions (Dietram, Herlianika and Past 2017). It also suggested that using energy-efficient appliances can save 26 million tons of CO_2e in the household sector and 1.9 million tons of CO_2e in the commercial sector by 2050.

These facts highlight the need to develop a national plan to identify pathways to address the cooling demand more sustainably, and to reduce energy- and refrigerant-related emissions from the cooling sector, while improving access to cooling and supporting the achievement of Indonesia's SDG and NDC commitments. This National Cooling Action Plan (NCAP) aims to provide a comprehensive assessment for the cooling sector in Indonesia as well as recommended policy actions for regulation, technology, market interventions and capacity-building.

1.2 Socio-Economic Context

Population and GDP Growth

Based on the 2020 census, Indonesia had a population of 270.2 million and a population density of 141 people per square kilometre. During the decade from 2010 to 2020, the population grew at an average annual rate of 1.25 per cent. Geographically, Indonesia is unique in being the world's largest archipelagic country, with 17,504 islands scattered across both sides of the equator, around 6,000 of which are inhabited. Indonesia has 38 provinces, and Jakarta is the capital as well as the largest city of Indonesia with more than 10 million people.

Indonesia's population is concentrated on the island of Java, which is inhabited by 151.6 million people or 56.1 per cent of the population, followed by Sumatra (21.7 per cent), Sulawesi (7.4) per cent), Kalimantan (6.2 per cent), Bali-Nusa Tenggara (5.5 per cent) and Maluku-Papua (3.2 per cent) (Statistics Indonesia 2020). Population projections predict a 0.74 per cent growth rate for 2015-2045, with more than 72 per cent of Indonesia's population living in urban areas by 2045 (Statistics Indonesia 2018). The Ministry of Energy and Mineral Resources (MEMR) reports that the household electrification rate in 2021 reached 99.45 per cent (MEMR 2022).

Based on the 2045 Indonesian Vision, economic growth during 2016-2045 is projected to average 5.7 per cent (Ministry of National Development Planning 2019). Following the COVID-19 outbreak, the country's economic growth fell in 2020 but bounced back in 2021 and recorded impressive growth beginning in 2022.

Energy and Power Grid Parameters

According to the *Handbook of Energy & Economic Statistics of Indonesia 2021* (MEMR 2022), in 2021 the primary energy supply totalled 1.49 billion barrels of oil equivalent (BOE), and final energy consumption reached 909 billion BOE. Energy consumption is projected to increase by nearly 2,000 petajoules (PJ) (5.6×10^5 gigawatt-hours, GWh) by 2030 in the absence of increased energy efficiency gains, electrification, avoided demand and fuel switching (International Energy Agency [IEA] 2022).

The peak load of the electric power system (especially in the Jamali region) occurs at night, between 5:00 p.m. and 10:00 p.m., which coincides with the time when people return home from work and turn on the air-conditioner, lights, and other electrical equipment and appliances. Reducing energy demand in the cooling sector is important for lowering peak loads and reducing stress on the electricity grid. Reducing cooling demand also minimizes the need to build new power plants. Reducing cooling demand through a 30 per cent improvement in the energy efficiency of room air-conditioners could save enough energy to avoid building an estimated 1,600 megawatts (MW) of peak power plants by 2030, and up to 2,500 MW by 2050 (Climate and Clean Air Coalition 2022).

1.3 Policy and Regulation Context

Within Indonesia, a variety of cross-ministerial roles and regulations, as well as the country's international commitments, are related to the cooling sector.

Regulation and Institutional Setting

Indonesia's cooling sector is regulated through a cross-ministerial arrangement ranging from macro-level laws down to technical codes and regulations. A summary of each relevant ministry and its role in the Indonesian cooling sector is presented in Table 2, and cooling sector-related regulations are presented in Table 3.

Table 2. List of ministries and roles relevant to the cooling sector

Name of Ministry	Role
Ministry of Energy and Mineral Resources (MEMR)	Regulator of energy conservation and efficiency in Indonesia
Ministry of Environment and Forestry (MoEF)	Regulator for matters related to environmental issues including greenhouse gas emissions
Ministry of Industry (MoI)	Regulator for monitoring and controlling equipment used in industry
Ministry of Trade	Regulator for monitoring and controlling material and equipment in market
Ministry of National Development Planning (Bappanas)	Regulator that creates a national priority scale that will influence budget policy and programme implementation in technical ministries
Ministry of Housing and Public Works (MoHPW)	Regulator on building codes, including green building
Ministry of Marine Affairs and Fisheries (MoMAF)	Regulator for the use of fishing vessels, block ice machines, flake ice machines and cold storage
Ministry of Agriculture	Regulator for the use of cold storage and logistics for agriculture
Ministry of Foreign affairs	Users to develop rural border areas
Ministry of the village, development of Disadvantage Regions	Regulator for fisher development in remote villages trading
National Energy Council (NEC)	Provides consideration, monitoring, and evaluation of national and regional energy planning, particularly in the implementation of the National and Regional Energy Plan

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Table 2 continuation

Statistics Indonesia (BPS)	Establishment and maintenance of basic statistics, coordination of national and regional statistics programme, facilitation of government's programme related to statistical data

Table 3. Summary of regulations related to the cooling sector

Regulation	Summary of regulation
Law No. 30/2007 on Energy	National energy conservation is the responsibility of the national and local governments, businesses and communities
Government Regulation No. 70/2009 on Energy Conservation	Energy users ≥ 6,000 tonnes of oil equivalent (TOE) are required to perform energy management, namely appointing an energy manager; carry out regular energy audits; carry out recommendations on the results of energy audits; and report on the implementation of energy conservation every year. The government and local governments provide facilities and incentives to domestic energy users and energy-saving equipment manufacturers implementing energy conservation.
Government Regulation No. 79/2014 on the National Energy Policy	Energy conservation plays a vital role in achieving national energy policy targets, including energy elasticity of less than 1 in 2025 aligned with the economic growth target; and achieving a reduction in the final energy intensity of 1 per cent per year until 2025.
Presidential Regulation No. 22/2017 on the National Energy Planning	Achieve energy elasticity of less than 1 per cent in 2025 Reduce final energy intensity by 1 per cent annually to 2025 Reduce final energy consumption 17 per cent by 2025 and 39 per cent by 2050
Presidential Regulation Number 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK)	Work plan documents for the implementation of various activities directly or indirectly to reduce greenhouse gas emissions in accordance with national development targets
Regulation of the Minister of Energy and Mineral Resources No. 14/2021	Minimum Energy Performance Standard for equipment, including. air-conditioner (KepMen ESDM No. 103.K/EK.07/DJE/2021) and and refrigerators (KepMen ESDM No. 113.K/EK.07/DJE/2021).
Regulation of the Minister of Environment and Forestry Republic of Indonesia No. P.73/MENLHK/ SETJEN/ KUM.1/12/2017 Concerning Implementation and Reporting Guidelines National Greenhouse Gas Inventory	Guidelines for calculating greenhouse gas emissions for energy management and use, industrial process and product use, forestry and other land use, and waste, based on the Intergovernmental Panel on Climate Change's 2006 Guideline for National Greenhouse Gas Inventories.
Regulation of the Minister of Industry No. 41 / M-IND / PER / 5/2014 concerning the Prohibition of Using Hydrochlorofluorocarbon (HCFC) in the Industrial Sector	Prohibits HCFC-22 and HCFC-141b from being used for filling in the production process of air-conditioning units and refrigeration devices. Industrial companies that violate the provisions will be subject to administrative sanctions in the form of revocation of Industrial Business Permits or Industrial Registration Certificates.
Regulation of the Minister of Environment No. 02/2007 Concerning Technical guidelines and competency requirement for retrofit and recycle implementation in the refrigeration system	Standard operational procedure (SOP) and appropriate facilities work standards for competent technicians to ensure implementation retrofit and recycle in accordance with applicable regulations.

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Table 3 continuation

Regulation of the Minister of Industry of the Republic of Indonesia No.75 / M-IND / PER / 10/2016 concerning conformity assessment agencies in the context of enforcing and monitoring mandatory Indonesian national standards for air conditioners, refrigerators, and washing machines	Regulates the organization or institution that oversees the implementation of the Indonesian National Standard air-conditioners, refrigerators and washing machines.
Regulation of Ministry of Trade Indonesia no. 03 / MDAG / PER / 1/2012	Indonesia is in the process of eliminating the use of ozone-depleting substances. Still, some industries need some of these compounds as main or supporting materials. In total, 23 items of ozone-depleting substances are prohibited from being imported into Indonesia, and 41 items of the import trade system are regulated.
Regulation of The Minister of Health of The Republic of Indonesia no. 1077/ MENKES/ PER/V/ 2011 Guidelines for Air Healing the Home Space	Guidance on air quality monitoring, system design, maintenance, and operation at home to protect public health from disease.
Regulation of The Minister of Health of The Republic of Indonesia no. 24 /2016 about technical requirements for hospital building and infrastructure	Air-conditioning installation in hospital buildings must be designed to prevent disease transmission and should also consider energy-saving and environment-friendly principles.
National Standard SNI 6390:2020 on Energy Conservation in Building's Air Conditioning System	Guidance on energy conservation in air-conditioner system design, maintenance, and operation in commercial and office buildings in general.
National Standard SNI 02-6572-2001 Indonesia Standard Procedures for designing ventilation and air conditioning systems in buildings	Guidelines for optimizing the performance of equipment and components according to the criteria for effective energy use for new installations and replacements for ventilation and air-conditioning system equipment and components.
National Standard SNI 6389:2020 on Energy Conservation in Building's Envelope	Guidelines for designing building envelopes to conserve energy use in buildings.
National Standard SNI 6500:2018 Fixed Installation of Refrigeration System – Safety and Environmental Requirements	Guidelines for fixed installation of refrigeration systems in consideration of safety and environmental requirements.
National Standard SNI ISO 817:2018 refrigerant's designation and safety classification	Guidelines on the designation and safety classification of refrigerants.
National Standard SNI 8476:2018 Methods for assessing and testing the performance of chilled water coolers with vapor compression systems	Guidelines on methods for assessing and testing the performance of chilled water coolers with vapour compression systems.
National Standard SNI 7647:2010 Hydrocarbon Refrigerants	Standards regulating the quality and safety of sampling, test methods, requirements for passing the test, packaging, and marking of hydrocarbon refrigerants.
National Standard SNI ISO 50002:2014 on Energy Audit	Guidelines for conducting energy audits in industry and buildings.
National Standard SNI ISO 50001:2018 on Energy Management System	Guidelines for implementing energy management system in industry and buildings.
National Competency Standard SKKNI 2015-080	Personnel competency standard for energy manager.
Technical Guidelines Infrastructure Air Conditioning System on The Hospital Building. By Ministry of Health 2012	A guideline for hospital development that prioritizes safety, security and comfort aspects for patients and other hospital users.

Table 4. Emission reduction targets by sector in Indonesia's Enhanced NDC

Sector	GHG Emission Level 2010* (million tons CO_2e)	GHG Emission Level 2030 (million tons CO_2e)			GHG Emission Reduction (million tons CO_2e)		Share of Total BAU		Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		BAU	CM1	CM2	CM1	CM2	CM1	CM2		
Energy*	453.2	1,669	1,311	1,223	358	446	12.5%	15.5%	6.7%	4.50%
Waste	88	296	25	253	40	43.5	1.4%	1.5%	6.3%	4.00%
IPPU	36	69.6	63	61	7	9	0.2%	0.3%	3.4%	0.10%
Agriculture	110.5	119.66	110	108	10	12	0.3%	0.4%	0.4%	1.30%
Forestry and Other Land Uses**	647	714	214	-15	500	729	17.4%	25.4%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**1,953**	**1,632**	**915**	**1,240**	**31.89%**	**43.20%**	**3.9%**	**3.20%**

Notes: CM1 = Counter Measure 1 (unconditional mitigation scenario); CM2 = Counter Measure 2 (conditional mitigation scenario)
* Including fugitive
** Including emissions from estate and timber plantations
Source: Government of Indonesia 2016.

International Commitments

Indonesia has issued a series of laws and regulations related to reducing greenhouse gas emissions, including the National Action Plan (RAN) for GHG Emission Reduction, as outlined in Presidential Decree No. 61/2011, and the GHG inventory, designated through Presidential Decree No. 71/2011. At the international level, through its 2022 Enhanced NDC (Ministry of Environment and Forestry 2022), the national government has committed to reducing greenhouse gas emissions by 31.89 per cent in 2030 through its own efforts and resources (unconditional mitigation) and by 43.2 per cent with international assistance (conditional mitigation); this compares to the business-as-usual projection of 2.89 gigatons of CO_2e emissions by 2030. Indonesia's updated NDC is aligned with the country's Long-Term Low Carbon and Climate Resilience Strategy 2050, with a vision to achieve net zero emissions by 2060 or sooner. The projected emission reduction from each sector category is presented below.

In its Enhanced NDC, Indonesia has committed to reducing emissions in the energy sector by 358 million tons of CO_2e under the unconditional counter measure (CM1) scenario. Activities to achieve this include implementing renewable energy, energy efficiency, low carbon-emitting fuels, clean coal technology, new gas power capacity and post-mine reclamation. Outlined energy efficiency programmes include an enhanced energy management mandate that could save 71 million BOE, and the energy efficiency improvement of equipment, which could save a cumulative 15,187 GWh of electricity by 2030. Minimum energy performance standards (MEPS) for air-conditioners are included in the energy efficiency programmes. The use of energy-efficient cooling appliances is projected to reduce emissions by around 29.3 million tons of CO_2e in 2030 (Dietram, Herlianika and Past 2017).

By 2030, the emission reduction potential from the cooling sector contributes around 11 per cent of the total emission reduction in the energy sector and 4 per cent of the total emission reduction in the NDC.

The cooling sector contributes both indirect and direct greenhouse gas emissions. Direct emissions come from the refrigerants used in cooling equipment, which are regulated under the Montreal Protocol and its Kigali Amendment. Indonesia's commitment to the Montreal Protocol is stated in Presidential Regulation No. 95/2016, signed on 21 November 2016.

In preparation for the ratification of the Kigali Amendment, Indonesia defined its supporting actions. It then ratified the Kigali Amendment on November 1, 2022 through Presidential Regulation No. 129/2022. Under the Kigali Amendment, Group 1 developing countries, such as Indonesia, must freeze their consumption of hydrofluorocarbons (HFCs) by 2024 and reduce them (from the baseline) 10 per cent by 2029, 30 per cent by 2035, 50 per cent by 2040, and 80 per cent by 2045.

There is also a pressing need to curb indirect emissions in the cooling sector, which come from the use of electricity generated from fossil fuels. Energy efficiency measures have been implemented through mandatory minimum energy performance standards (MEPS) across end uses. According to the International Energy Agency, growth in electricity demand could slow by 40 per cent over BAU by 2050 with expanded and strengthened MEPS for air-conditioners and home appliances, and the enforcement of energy regulations for buildings, even as the residential building floor area is expected to more than double over that time (IEA 2022).

1.4 Drivers of Cooling Demand

Indonesia's cooling demand is related to the country's tropical climate and growing economy. High temperature and humidity in most areas in Indonesia require cooling for space, perishable foods and pharmaceutical goods.

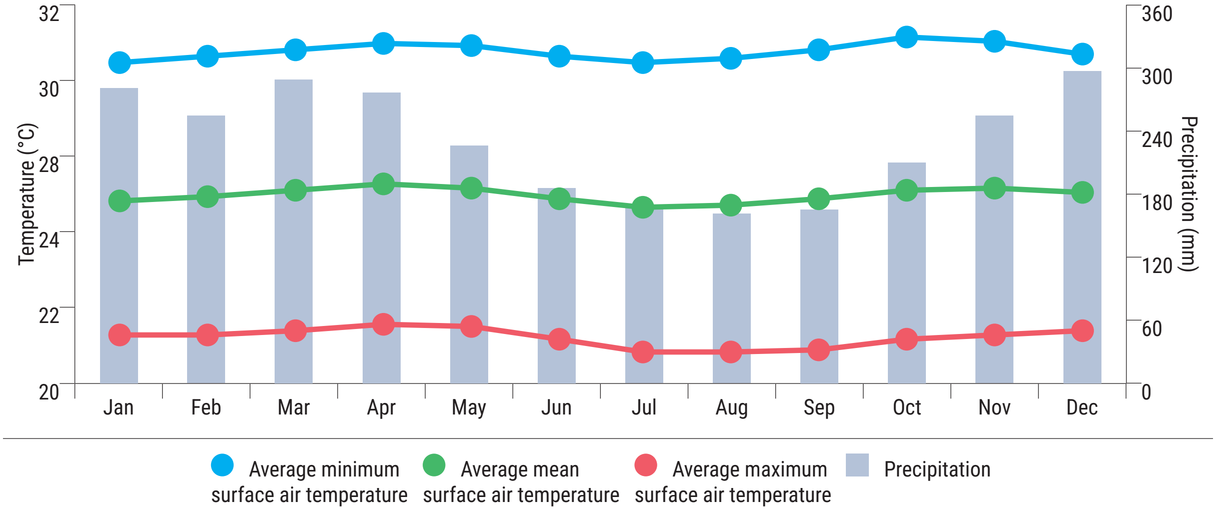
Climate and Temperature Profile

Indonesia's climate is almost entirely tropical, with most of the country situated along the equator. Indonesia is mainly hot and humid, with rainfall occurring primarily in low-lying areas, and mountainous regions experiencing cooler temperatures. The temperature varies little between seasons, and there is relatively little change in the length of daylight hours throughout the year. The rainy season occurs between November and April, leaving May through October typically dry.

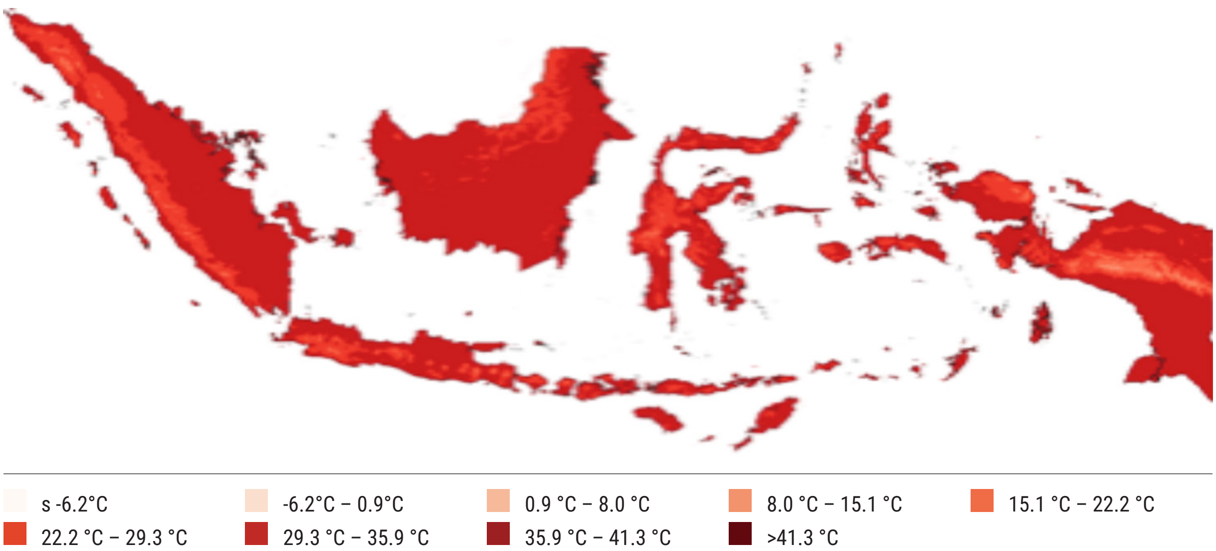
Figure 2 shows the monthly temperature (mean, minimum and maximum) and precipitation in Indonesia from 1991 to 2020. The data illustrate the minimal variation between maximum and minimum temperatures throughout the year, indicating the continuous need for cooling for thermal comfort and to support food and medical cold chains.

Over the past century, the average annual temperature in Indonesia has increased by 0.75 degrees Celsius (see Figure 3), which is attributed to global warming. With expected continued temperature rise into the future, the demand for cooling will increase. Concurrently, as the country's economy grows, cities are expanding along with it. Presently, Indonesia has 15 cities and urban centres that have populations of more than 1 million people. Based on these combined factors, the need for cooling in the country will only increase in the future. Concrete measures are needed in the immediate

Figure 2. (a) Monthly mean, maximum, and minimum temperatures (˚C) and precipitation (millimetre) trends in Indonesia, 1991-2020, (b) Average maximum temperature in Indonesia, 2010-2018

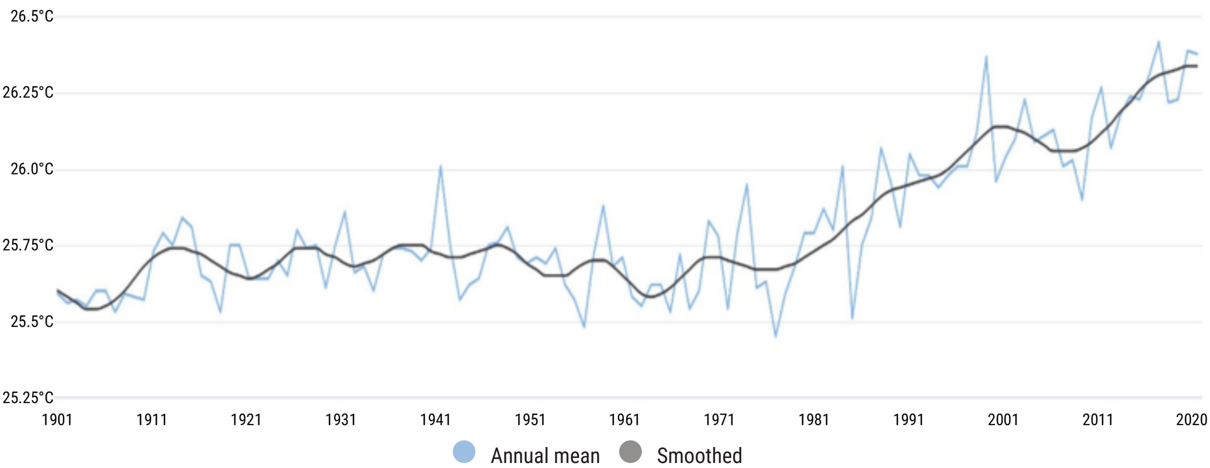


Source: A) Climate Change Knowledge Portal, World Bank



Source: B) SEforALL Analysis

Figure 3. Observed average annual temperatures for Indonesia, 1901-2020



Source: Climate Change Knowledge Portal, World Bank term to ensure access to cooling services and to mitigate energy demand and emission growth.

Increasing Market Demand

In line with economic growth, the refrigeration and air-conditioning market in Indonesia continues to expand. During 2000-2016, sales in this market increased 6.5 per cent annually on average, with commercial refrigeration experiencing the fastest growth of 17.3 per cent per year, followed by domestic refrigeration (7.3 per cent) and unitary air-conditioning (6.7 per cent). In 2016, domestic refrigeration led the market at 61.5 per cent of total sales, followed by unitary air-conditioning (27.5 per cent) and mobile air-conditioning (10.3 per cent) (see Figure 5) (Dietram, Herlianika and Past 2017).

Indonesia is considered to have strong market potential for businesses that are based on the cold chain and serve the industrial sector, which has shown robust growth. The industrial sector includes livestock, fisheries, processed foods, chemicals, and the pharmaceutical and drug industries. These industries play a central role in national development, as can be seen from their contributions to Indonesia’s gross domestic product (GDP). According to Statistics Indonesia (BPS), in 2018 the livestock sector contributed 1.5 per cent of the total GDP, or 231.7 trillion Indonesian rupees. The fisheries sector contributed 2.6 per cent of GDP, and the food and beverage industry contributed 6.2 per cent. The chemical, pharmaceutical, and drug sectors contributed 1.6 per cent of the total GDP.

The demand for cold storage is expected to increase greatly in the coming years, along with the installed capacity. A survey by the Ministry of Marine Affairs and Fisheries reported that in 2022, the cold storage capacity for fisheries totalled 763,372 tons (Kementerian Kelautan dan Perikanan 2022). Based on the trends demonstrated by major cold storage facilities, the need for cold storage can be expected to increase between 10 per cent and 20 per cent annually on average.

2 Introducing a National Cooling Action Plan for Indonesia

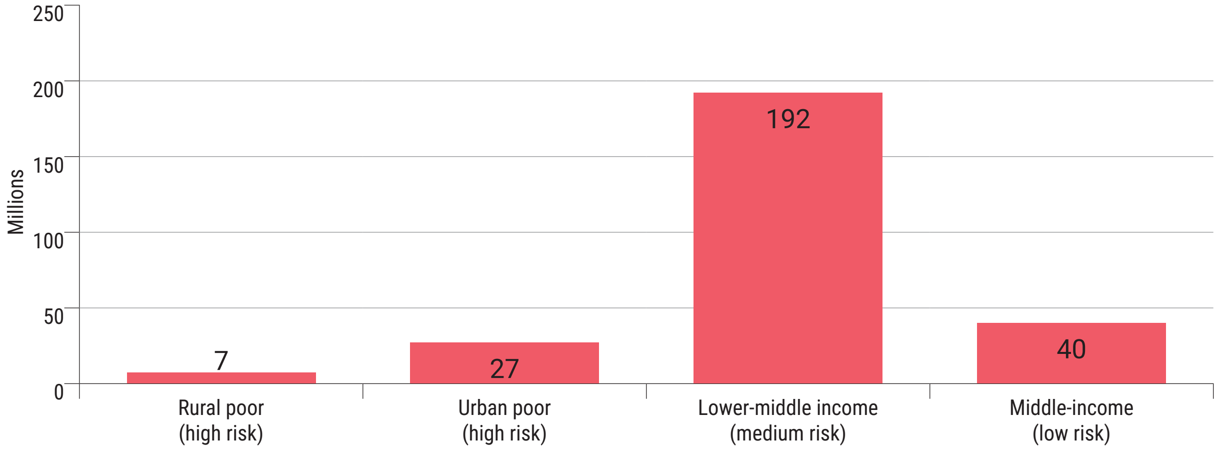
2.1 The Need for a National Cooling Action Plan (NCAP)

Population and Access to Cooling

Indonesia's population reached more than 275 million people in 2022. Income levels, access to electricity and the affordability of cooling solutions are key determinants of a population's ability to meet cooling needs for thermal comfort, food preservation and health care. Sustainable Energy for All (SEforALL) estimates that across Indonesia, 33.6 million rural and poor are at high risk due to a lack of access to cooling, whereas lower-middle income and middle-income populations face medium and low risk levels (see Figure 4) (SEforALL 2022).

Cooling needs must be met through affordable and sustainable solutions to reduce heat stress, productivity losses, food and agricultural waste, and medical product losses in an energy-efficient and climate-friendly manner. To provide cooling to different groups, a mix of policies, technologies, finance and services must be applied, including targeted approaches for the most vulnerable.

Figure 4. Indonesia's population at risk due to the lack of access to cooling



Source: SEforAll 2023.

The NCAP is designed to assist the government to:

- Address cooling demand through a comprehensive approach covering the different sectors and end uses;
- Ensure the integration of both met and unmet cooling needs;
- Drive alignment and integrative action across multiple sectors of cooling;
- Integrate existing policies and institutional efforts related to cooling;
- Identify solutions for energy-efficient and climate-friendly cooling and the implementation pathway maximizing socio-economic benefits.

Energy Use and Saving Potential

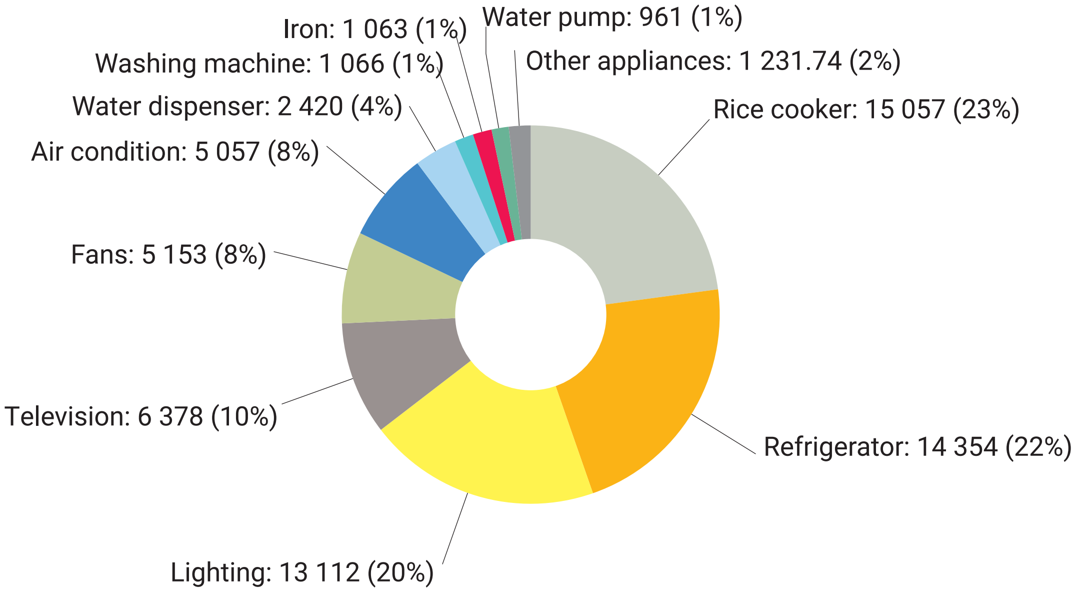
The cooling sector consumes a large share of Indonesia's electricity. In 2015, the sector consumed an estimated 81.8 TWh, or 41 per cent of the nation's electric power generation (Dietram, Herlianika and Past 2017). According to a report from the Efficient Cooling Initiative[4], a 30 per cent improvement in the energy efficiency of room air-conditioners could save enough energy to avoid building nearly 1,600 megawatts (MW) of peak power plants by 2030 and 2,500 MW by 2050 (Climate and Clean Air Coalition 2022). This is confirmed by a recent survey of energy consumption in the household sector of Indonesia (CLASP 2020), which provides estimates for the share of electricity consumption for 42 household electrical appliances (in GWh and per cent), along with hourly electricity consumption trends.

Air-conditioning units, fans and refrigerators together account for an estimated 30 per cent of household electricity consumption (see Figure 5). Air-conditioners were found to be owned mainly by wealthy households, which typically own more and higher-wattage appliances. Only 5 per cent of households surveyed nationwide own air-conditioners. Thus, the share of energy consumption from air-conditioners in households is relatively low. However, the market for air-conditioners is growing. The operation of air-conditioners also coincides with the peak load of the Indonesian power system, which occurs between 5:00 and 10:00 p.m. (CLASP 2020; McNeil *et al.* 2019), as shown in 6 and 7.

By 2030, the electricity peak demand is projected to be distributed mainly among residential air-conditioners (21 gigawatts, GW), the commercial sector (13.3 GW) and the industrial sector (14.8 GW). At the peak in 2030, the share from residential air-conditioners, lighting, and refrigerators (50 per cent) is larger than the share from the commercial and industrial sectors (36 per cent). The contribution of air-conditioners to the peak load grows roughly 10-fold between 2010 and 2030 (McNeil *et al*. 2019). These projections suggest that improvements in the energy efficiency of air-conditioning can offer significant benefits not only for energy saving but also for power system capacity requirements.

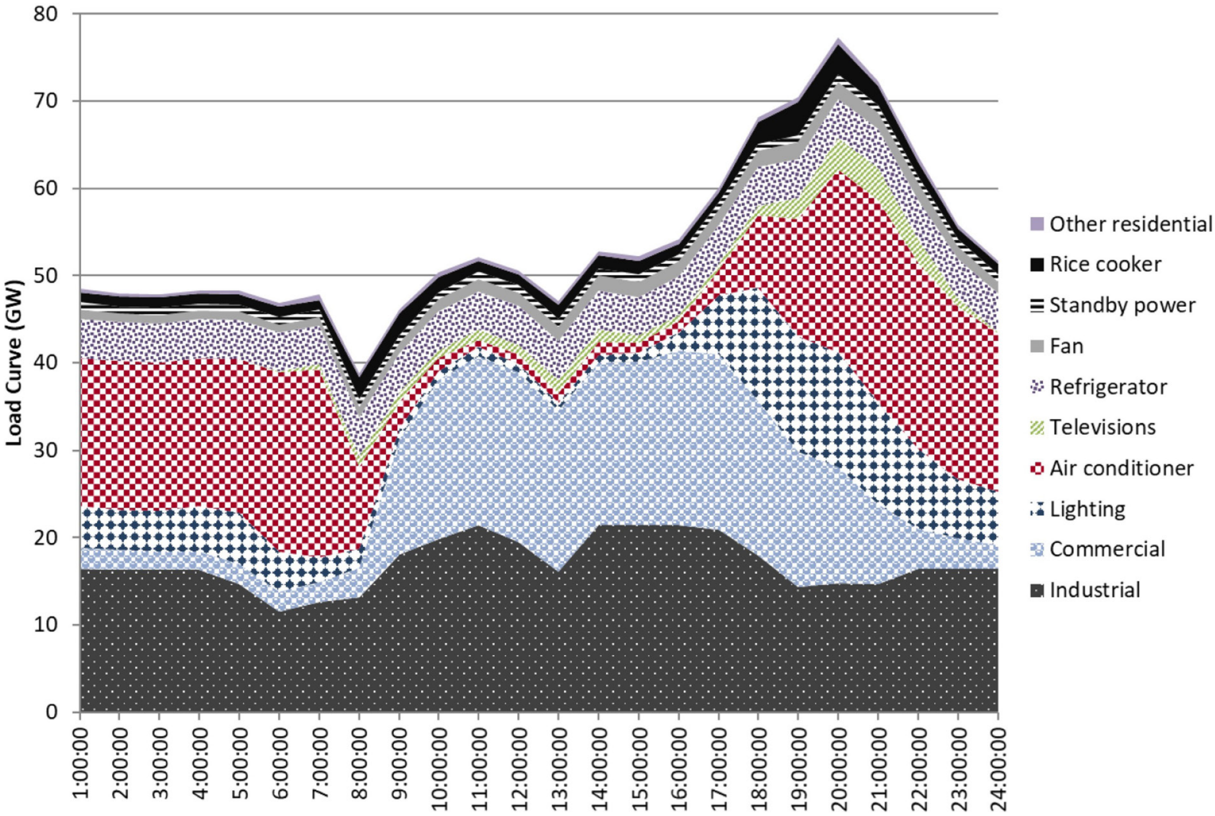
4 Initiative under Climate and Clean Air Coalition aimed for to enhance energy efficiency in the cooling sector while countries implement the phase-down of HFC refrigerants under the Montreal Protocol.

Figure 5. Share of electricity consumption estimates for 42 electrical appliances in Indonesian households (GWh and per cent)



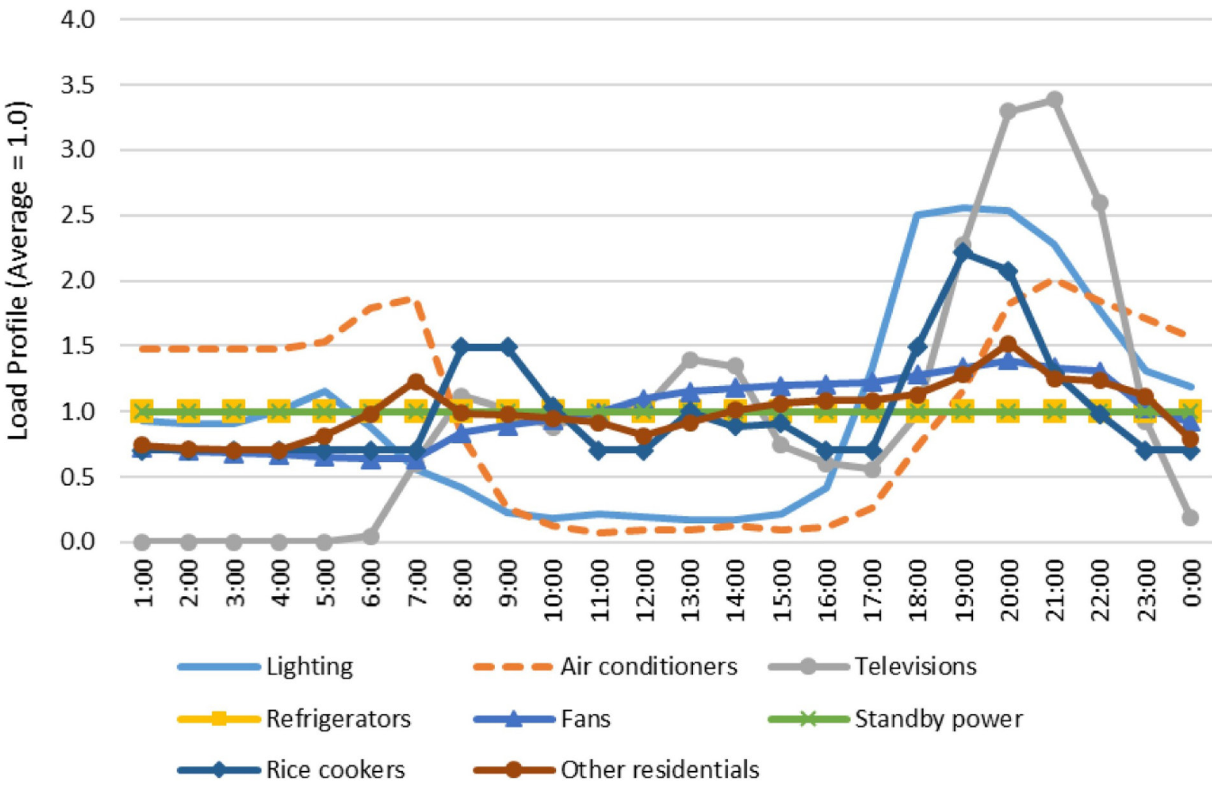
Source: IEA 2022b.

Figure 6. Indonesia average daily load curve in the BAU scenario in 2030 by end use and sector



Source: McNeil *et al.* 2019.

Figure 7. End-use load profile of the Indonesian residential sector



Source: McNeil *et al*. 2019.

Contribution to the Achievement of Indonesia's NDC and SDG Objectives

The cooling sector is essential to realizing the objectives of Indonesia's Nationally Determined Contribution (NDC) submitted under the Paris Agreement, including the country's commitment to reduce emissions in the energy sector by 12.5 per cent. The NCAP is also expected to stimulate further progress towards achievement of energy- and climate-related Sustainable Development Goals.

Cooling and Climate Change

Small annual variations in temperatures, as well as monthly average temperatures of 18°C or above, are characteristic of tropical climates. Annual precipitation is plentiful and displays varied degrees of seasonal periodicity. Sunlight is also strong. The type of settlement growth throughout the tropics is of particular importance because of the high endemism and species diversity. Large-scale land cover changes in tropical regions have been attributed mostly to the dynamics of urbanization and agriculture expansion. The tropics, according to climate researchers, are particularly susceptible to climate change (IPCC 2014a). Recent studies show that there have been more hot weather occurrences worldwide. Heat waves are becoming more intense and frequent in the tropics, and as climate change accelerates, the frequency and severity of extreme heat events is expected to rise significantly.

Cities are affected by climate-related heat, and as cities continue to urbanize, more people will be exposed to high levels of heat through heat waves, the urban heat island effect and urban warming. The urgency of solving these problems is increased by the fact that many tropical nations have poor incomes and thus have limited potential for adaptation.

Cooling is crucial to reducing these negative consequences. For the well-being and productivity of tenants, spaces must be cooled. The preservation of food, perishable commodities, medical supplies, and pharmaceuticals all depend on cooling.

Support for the COVID-19 Recovery Effort

The COVID-19 pandemic triggered the most significant global economic shock since World War II. The number of people living in extreme poverty is projected to increase compared to pre-pandemic projections due to the lingering effects of the pandemic, the Russian Federation's war in Ukraine, and the spike in food prices, all of which are making the external environment for many countries much more difficult (World Bank 2022). Countries' pandemic responses have highlighted the importance of space cooling and refrigeration as essential services to support people's well-being during lockdowns, and to facilitate local delivery and storage of vaccines. Cooling is therefore a critical intervention area to help serve short-term emergency needs and to support long-term economic recovery while contributing to sustainable development and building greater resilience to future shocks (United Nations Environment Programme 2021).

2.2 National Cooling Action Plan Methodology

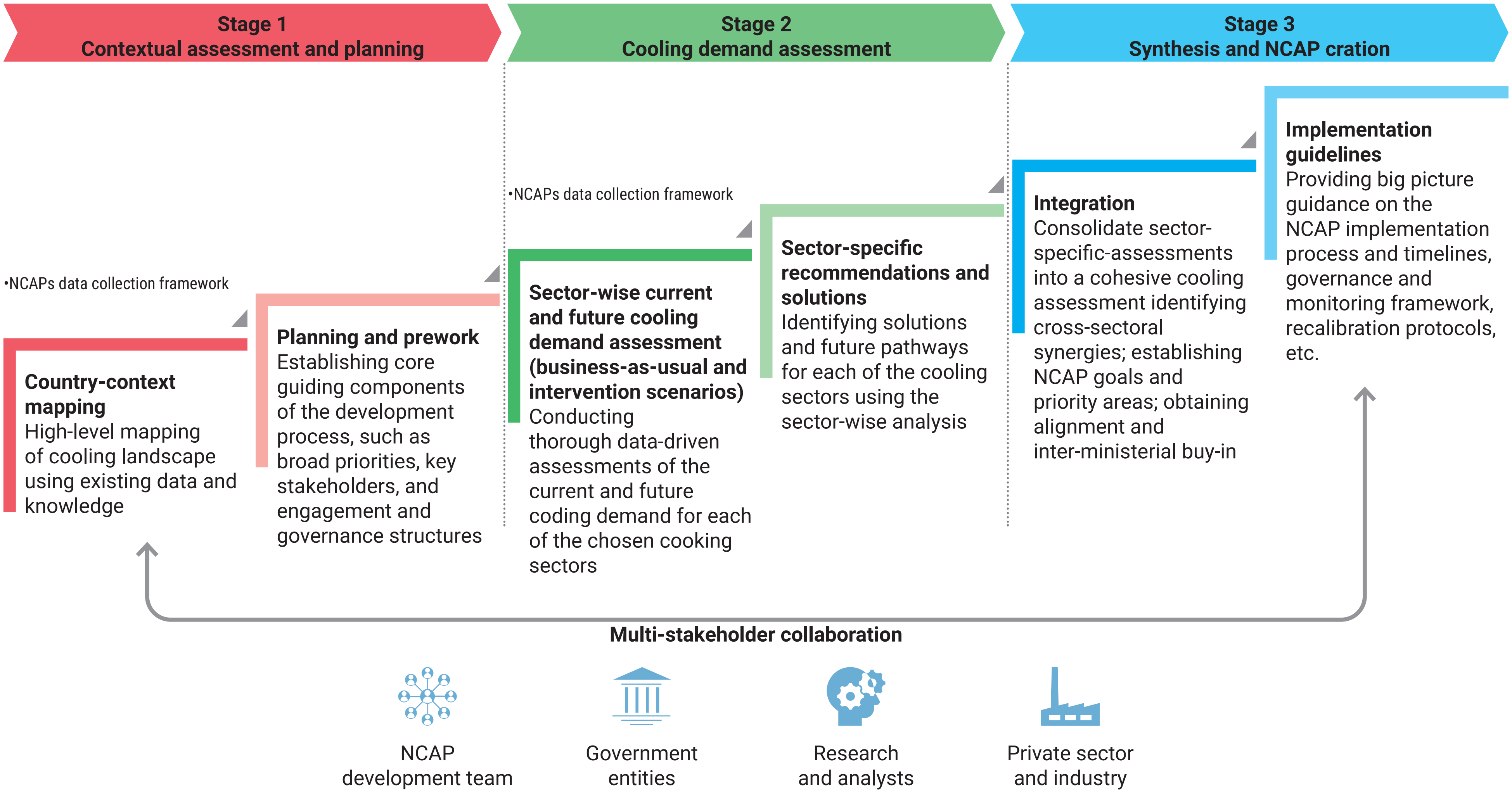
Indonesia's National Cooling Action Plan (I-NCAP) was developed using the Cool Coalition's National Cooling Plan Methodology. This methodology is designed to support a holistic, multi-sector approach to delivering energy-efficient, climate friendly and affordable cooling. The I-NCAP was developed in three sequential stages – Contextual Assessment and Planning, Cooling Demand Assessment, and NCAP Synthesis (Petrichenko and Duran 2020) – which frame the consultative and analytical process, as outlined in Figure 8.

Stage I: Contextual Assessment and Planning – This foundational stage helped to identify the priorities of the NCAP that are specific to the country and provides guidance to the overall planning process. It establishes the broad framework and key stakeholders for the country's NCAP development. Country Context Mapping and Planning and Prework are the two essential steps that define this stage.

Stage II: Cooling Demand Assessment – This constituted a data-driven assessment of the current and future cooling demand (and impacts) that will inform sector-specific priorities, including quick and high-impact interventions, and the longer-term strategic interventions.

Stage III: Synthesis and NCAP Creation – This stage consolidated the sector-specific assessments into a cohesive nationwide cooling overview. Cross-sectoral synergies were identified, and actionable recommendations were informed by the technical analysis and the national consultations.

Figure 8. The National Cooling Action Plan Methodology



Throughout the six steps of the NCAP development process, effective engagement of stakeholders was critical to enable comprehensive information gathering and for developing a holistic set of key recommendations with cross-sectoral benefits.

Governance and Stakeholder Engagement

Indonesia's National Cooling Action Plan (I-NCAP) involved consultations with representatives from various stakeholder categories. While each ministry and its role was summarized in Table 3, associations can be further grouped into their specialization or involvement related to refrigeration and air-conditioning applications for data collection and the consultation process.

The various stakeholders that were consulted fall into four general categories, as shown in Table 5.

The multi-stakeholder engagement process of the I-NCAP development included a kick-off meeting, cross-ministerial governmental engagement, one-on-one stakeholder consultations, a data input consultation workshop and sectoral stakeholder meetings. This process enabled the validation and finalization of data, information and key recommendations.

Table 5. Stakeholders engaged in the NCAP development process

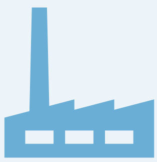
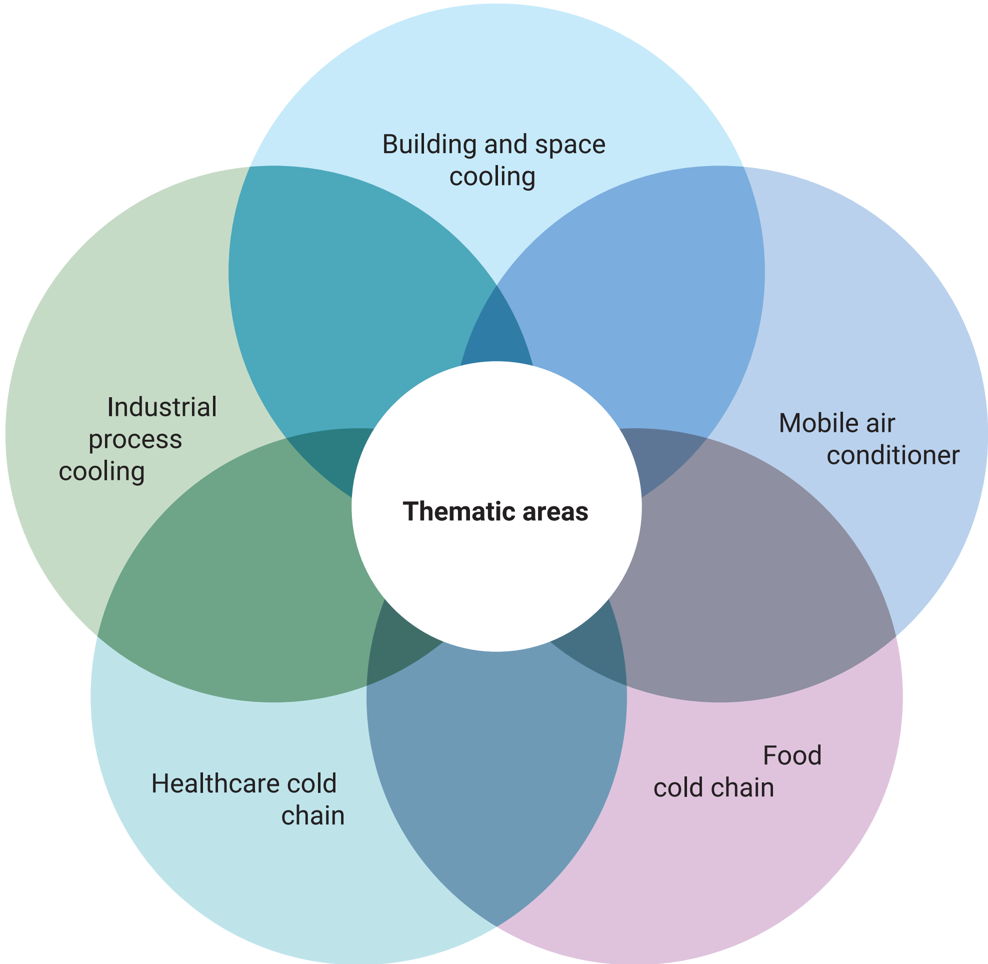
Stakeholder category	Description
 NCAP development team	MEMR, UNEP, ESCAP, SEforALL and national expert consultants
 Government entities	Ministry of Environment and Forestry, Ministry of Public Works and Housing, Ministry of Industry, Ministry of Agriculture, Ministry of Marine Affairs and Fisheries, Ministry of Health
 Researchers and analysts	Green Building Council Indonesia (GBCI), ASHRAE Indonesia Chapter, CLASP, Indonesia Cold Chain Association (ARPI)
 Private sector and industry	Cooling appliances manufacturers and industries

Figure 9. Thematic areas for stakeholders consultation



The objectives of the kick-off meeting were to raise awareness about the importance of developing the NCAP document, to share the framework and methodology, to collect inputs from stakeholders, and to introduce the importance of data collection and preparation of the tailored data collection templates for each group according to their thematic areas (see Figure 9).

A workshop was organized under the leadership of the Energy Conservation Directorate of the MEMR, with support from national and international consultants, to gather inputs from air-conditioning and refrigeration experts and stakeholders in Indonesia (Table 6). The core team discussed the approach for estimating the direct and indirect emissions from the identified cooling sectors. The workshop was instrumental in identifying relevant sources for input data for these sectors. Bilateral meetings with experts were then organized to further elaborate the data discussed in the stakeholder consultation meeting, including with the Ministry of Fisheries and Marine Affairs, the Ministry of Environment and Forestry, the Ministry of Public Works and Housing, the Ministry of Agriculture and the Ministry of Health.

Table 6. List of associations according to specialization or relation to refrigeration and air-conditioning applications

Specialty	List of Association
Building and space cooling	• ASHRAE Indonesia (association on the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields) • GBCI (Green Building Council Indonesia) • IAFBI (building physics expert association) • BOMA (building owner and management association) • PHRI (hotel association) • ASATHI (hotel engineers association) • BEA (Building Engineer Association) • ACE Indonesia (Association of Chief Engineers)
Mobile air-conditioners	• ASHRAE Indonesia • AIKI (Indonesian Motor Vehicle Importer Association) • GAIKINDO (Association of Indonesian Automotive Industries) Automotive Industries)
Food cold chain	• ASHRAE (association on the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields) • ARPI (cold chain association) • Fisherman Association • Farmers Association • Supermarket Association
Healthcare cold chain	• ASHRAE Indonesia • HISFARIN (Industrial Pharmacy Association) • Hospital Association • IDI (Indonesian Medical Association) • Healthcare Importers Association
Industrial process cooling	• ASHRAE Indonesia

The final I-NCAP draft was validated in the [WORKSHOP on X date] led by the Energy Conservation Directorate of MEMR with the participation of experts and selected stakeholders. The final draft is signed by Minister [NAME]

3 Cooling Demand Assessment for Indonesia

3.1 Methodology

Indonesia is one of the first countries in South-East Asia where this comprehensive NCAP methodology has been applied, using a multi-sectoral approach to develop a cooling demand assessment. Data-driven assessments of the country's current and future cooling demand, electricity and refrigerant gas use, and related climate impacts informed sector-specific priorities, including quick and high-impact interventions as well as longer-term strategic interventions. The assessment was conducted by a team of national and international consultants under the aegis of the Ministry of Energy and Mineral Resources.

Data Collection Process

The data collection process began in 2019 and was performed in two stages: 1) mapping of secondary data from various surveys and study reports, including existing policies, strategies, plans and interventions related to the cooling sectors; and 2) stakeholder consultation (SEforALL 2022) and working sessions to complete and validate data inputs and assumptions to enable the development of future scenarios of cooling demand, energy consumption, refrigerant demand and savings potentials. The data collection covered three priority cooling sectors: space cooling in buildings, mobile air-conditioning and the food cold chain.

Many data points for indirect emissions and cooling access were collected for the first time in the country, and, due to the pandemic, many data gaps remained even after primary and secondary surveys (notable data gaps were detected for the food cold chain, the healthcare cold chain and the process cooling sector ((Ministry of National Development Planning 2019; Statistics Indonesia 2020)). In many cases, missing data points had to be estimated using proxy values based on existing industry standards or similar data in other countries.

Prioritized Cooling Sectors and Emission Calculations

Based on the availability of data, Indonesia's NCAP includes the following three priority cooling sectors:

Table 7. Technologies and categories considered for the cooling demand assessment

Cooling sectors	Technologies and equipment
Space cooling	Self-contained unitary air-conditioners, room air-conditioners (fixed-speed split technology), room air-conditioners (inverter type), chiller systems (screw type), chiller systems (scroll type), chiller systems (centrifugal type), variable refrigerant flow (VRF) systems, packaged DX system and fans
Mobile air-conditioning	Light-duty vehicles, heavy-duty vehicles and freight vehicles (passenger cooling only)
Food cold chain	Domestic refrigerators, commercial refrigerators (stand-alone and remote condensing unit types), packhouses, cold stores and distribution hubs for seafood, horticulture, dairy and meat

- **Space cooling in buildings:** This includes refrigerant and non-refrigerant based space cooling for enhancing thermal comfort in the indoor spaces of residential and commercial buildings. In this sector, energy consumption is dominated by refrigerant-based direct expansion (DX) air-conditioning systems. The energy consumption in space cooling can be reduced through the integration of efficient urban planning, passive cooling systems, low-energy not-in-kind systems, efficient service practices and intelligent controls.

- **Mobile air-conditioning:** Mobile air-conditioning caters to the cooling requirements for passenger comfort in light-duty vehicles, heavy-duty vehicles and the passenger cooling cabins of freight vehicles. Mobile air-conditioning uses refrigerant-based vapour compression technology to remove heat and moisture from inside the cabin to the outside.

- **Food cold chain:** The food cold chain is a chain of logistics activity to service the market connectivity of perishable products from their production stage to consumers, including domestic refrigeration. While the cold chain is commonly understood as covering temperature-controlled warehousing and transport, it also involves the control of other environmental parameters (humidity and air composition) and packaging requirements to extend the product's life cycle and to safeguard its nutrient quality.

The technologies and infrastructure categories considered for the assessment are listed in Table 7.

Modelling Approach for Cooling Demand Assessment

The cooling demand assessment considered 2020 as the baseline year and established future cooling demand projections for the subsequent two decades (i.e., 2030 and 2040). The assessment considered the met cooling demand and the associated impacts in terms of energy consumption, greenhouse gas emissions and refrigerant demand. Two projections of future growth were established: 1) a business-as-usual (BAU) scenario that assesses how the current baseline will evolve based on the current level of efforts, and 2) an Intervention scenario that evaluates how the cooling growth will evolve based on accelerated efforts across policies, technologies and market enablers. (For more on the inputs and assumptions used to develop these scenarios, see Appendix 4.)

Indirect emissions for space cooling in buildings were calculated based on quantification of the cooling demand and energy consumption of the individual equipment types listed in Table 7. Indirect emissions for each equipment type were calculated considering information on their annual stock, average capacity, efficiency, average operational hours, utilization factor, and electricity grid emission factor, as well as the market penetration of efficient equipment.

Food cold chain emissions were estimated in two steps. The first step was to use data on production, domestic supply, import and export data for the perishable food categories of fishery, meat, dairy and horticulture, as quantified for Indonesia by the Food and Agriculture Organization of the United Nations (FAO 2022; MEMR 2022a). Future projections for demand in individual food categories were made based on population growth, the increase in the dietary requirements per person, and the rate of reduction in food losses in the country. The total energy consumption and the respective greenhouse gas emissions were then estimated based on the cooling requirements (chilled or frozen) of the food categories using their specific energy consumption (MEMR 2022a) and grid emission factors. In the second step, the emissions of domestic and commercial refrigerators were estimated based on annual stock information, average capacity of cooling equipment, cooling equipment efficiency, market penetration of efficient equipment, average operational hours, utilization factors and the electricity grid emission factor.

Based on the total met and unmet demand for the food cold chain, requirements for packhouses, cold stores and distribution hubs were estimated for seafood, horticulture, dairy and meat food products.

Indirect emissions from mobile air-conditioners were estimated based on the stock of vehicles with air-conditioning, the efficiency of individual vehicle types, the share of fuel consumption for cooling, the average annual distance travelled with air-conditioners in “on” mode, the utilization factor, and the fuel mix and its respective emission factors.

Direct emissions from refrigerants used for cooling were based on a study performed by the Indonesia chapter of ASHRAE related to consumption of HCFCs, HFCs and HFOs (IEA 2022a). The study also discussed the scenario for HFC phase-down using alternative refrigerants that have low and ultra-low global warming potential (GWP), as aligned with Indonesia’s commitment to the Kigali Amendment to the Montreal Protocol. The study also presented the climate-friendly refrigerant transition for space cooling equipment, domestic refrigerators, commercial refrigerators, reefer vehicles and mobile air-conditioning units. Direct emissions results presented here may differ from future studies and assessments under the Montreal Protocol, where a more in-depth data collection effort will be carried out. Those results shall be considered in subsequent I-NCAP updates.

The NCAP Intervention scenario includes the interpolation of the direct emissions for the refrigerant transition as per the implementation schedule of the Kigali Amendment. However, the scenario uses the 2020 refrigerant consumption data as the baseline and includes the direct emission mitigation potential from greater penetration of the current low-GWP alternatives in the market. The Intervention scenario also considers measures such as the reduction in the annual operational leakage rate and the increased recovery of refrigerants at the end of life of equipment.

The Electricity Grid Emission Factors (EGEF) used for the estimation of the indirect emission through electricity consumption (for both BAU and intervention scenarios) are based on the Current Policy Scenario (CPOS) from the Indonesia Long-Term Strategy for Low Carbon and Climate Resilience [1].

3.2 Country-level Results

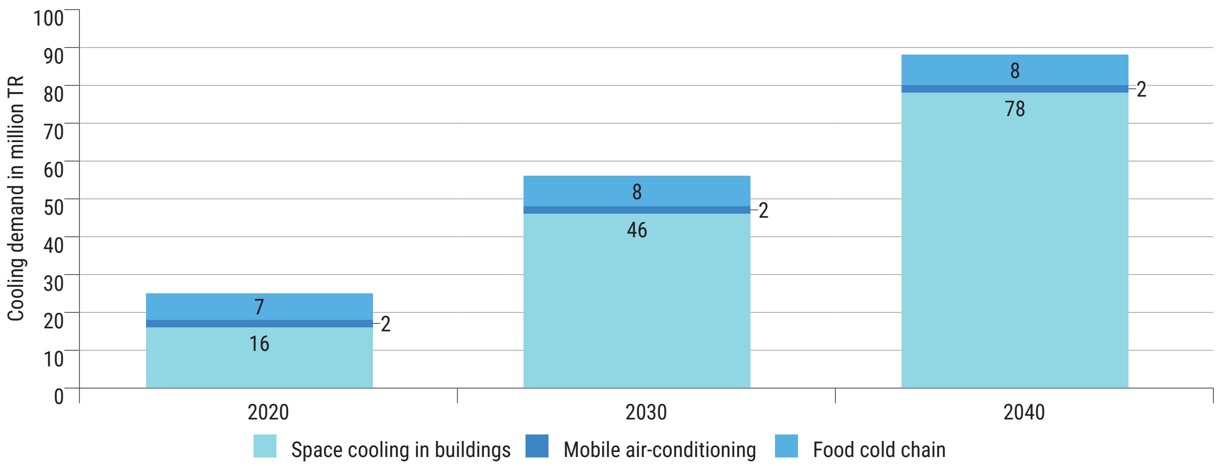
The country-level cooling demand assessment covered the three prioritized cooling sectors – space cooling in buildings, mobile air-conditioning and the food cold chain. The results for cooling demand, electricity consumption, refrigerant demand and greenhouse gas emissions are presented in the following sections. (For more on the assumptions for the BAU and Intervention scenarios, see Appendix 4.)

Cooling Demand Outlook

The total demand for cooling across the three analysed sectors is projected to increase from 25 million tons of refrigeration (TR) in 2020 to 56 million TR in 2030 and 88 million TR in 2040. Cooling demand is expected to grow around 1.3 times by 2030 and 2.6 times by 2040, above 2020 levels. This growth is propelled by Indonesia's economic growth, rate of urbanisation, increase in the building construction rate, and expected increase in the demand for space cooling (both residential and commercial air-conditioning), with higher aspirations for thermal comfort among the local population and increasing hospitality facilities for the tourism sector. Demand for space cooling in buildings alone is expected to increase from 16 million TR in 2020 to 46 million TR in 2030 (1.9 times growth) and to 78 million by 2040 (3.9 times growth). The growth in cooling demand by sector is shown in Figure 10.

The implementation of passive cooling measures through building energy codes is expected to reduce the cumulative cooling demand in buildings by up to 10.7 million TR by 2040 (Government of Indonesia 2016); this assumes that all new buildings comply with the building codes starting in 2025 (Svendsen 2022) and that 2 per cent of the building stock in 2024 is retrofitted with passive cooling solutions every year

Figure 10. Cooling demand for building space cooling, mobile air-conditioning and the food cold chain in 2020, 2030 and 2040 under the BAU scenario



(IEA 2022b). The impacts of passive cooling measures are explained in detail in the following chapter.

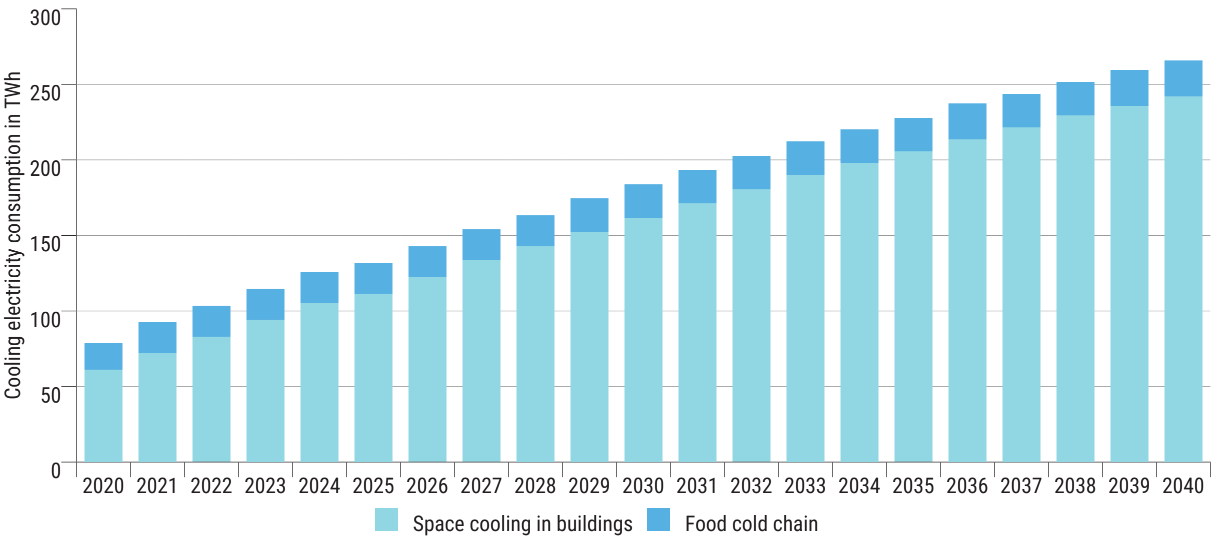
Cooling demand in the mobile air-conditioning sector is projected to increase from 1.8 million TR in 2020 to 1.9 million TR in 2030 and 2.0 million TR in 2040. Light-duty vehicles have the highest growth in cooling demand (from 1.6 million TR in 2020 to 1.8 million TR in 2040), followed by heavy-duty passenger vehicles.

Cooling demand in the food cold chain sector is projected to increase from 6.9 million TR in 2020 to 7.6 million TR in 2030 and 8.4 million TR in 2040. This increase is propelled by a growing population with rising demand for food[5], by growth in commercial refrigerators (from 0.2 million TR in 2020 to 0.8 million TR in 2040), and by the growth in cold storage cooling demand of 0.7 million TR between 2020 and 2040. The expected increase in demand for cold storage is due to consideration of targets to reduce food losses, which contribute to loss of 4-5 per cent of Indonesia's GDP (CLASP 2020)).

Electricity Consumption Outlook

The total electricity consumed by building space cooling and the food cold chain sector[6] combined in 2020 was 79 TWh, equivalent to 30 per cent of Indonesia's total electricity consumption. Under the BAU scenario, the electricity consumption associated with space cooling and food cold chain services is projected to reach 183 TWh in 2030 and 256 TWh in 2040 (see Figure 11).

Figure 11. Estimated electricity consumption for building space cooling and the food cold chain, 2020-2040 under the BAU scenario



5 Indonesia's current per capita food supply is 572 kilograms annually, compared to an average of 904 kilograms annually in the Global North (United States, Europe, Canada). It is assumed that Indonesia will achieve the Global North's average calorific and food supply per capita figures on average (2014-2018) by 2040, as defined by the FAO (2016).

6 Mobile air-conditioning was omitted from the electricity consumption analysis, as the energy sources are fuels including diesel, petrol and natural gas.

Table 8. Total final electricity consumption and savings potential under the BAU and Intervention scenarios

	Electricity consumption in TWh					Savings potential in TWh and percentage savings	
	2020	2030		2040		2030	2040
	Baseline	BAU	Intervention	BAU	Intervention		
Space cooling (including ceiling fans)	62	162	131	241	104	31 (19%)	137 (57%)
Food cold chain	17	21	19	24	16	2 (11%)	7 (31%)
Total	**79**	**183**	**150**	**265**	**120**	**33 (18%)**	**144 (54%)**

Total energy savings from space cooling in buildings and the food cold chain sector are an estimated 33 TWh in 2030 and 144 TWh in 2040. This translates to 18 per cent savings in 2030 and 24 per cent savings in 2040 compared with the BAU scenario. The potential electricity savings by 2040 are estimated to be 137 TWh for space cooling and 7 TWh for the food cold chain sector (see Table 8).

Under the Intervention scenario, the estimated energy savings for space cooling in buildings is due to the expected reduction in cooling demand through the implementation of passive cooling strategies in new and existing buildings, as well as through the enhanced energy efficiency of cooling equipment and its penetration in the market, as shown in Table 16 in Appendix 4.

Electricity consumption in the food cold chain sector is projected to grow due to additional cold storage requirements and to the increased penetration of commercial and domestic refrigerators. Under the Intervention scenario, energy savings are expected to be realized due to improvements in the energy efficiency of the refrigeration equipment, as defined in Table 20 in Appendix 4.

Refrigerant Consumption Outlook

Refrigerant consumption in Indonesia led to total direct greenhouse gas emissions of 12 million tons of CO_2e in 2020 (see Figure 12), including from space cooling in buildings, mobile air-conditioning, the food cold chain and other sectors that are not modelled in detail in the NCAP (such as industrial refrigeration, refrigerated vehicles and aerosols).

The refrigerants considered in the analysis are defined by the refrigerant transition stated in the scenario for HFC consumption and phase-down for Indonesia, released in August 2021 by the Indonesia chapter of ASHRAE to meet the targets of the Kigali Amendment (see section 3.1).

The refrigerant transition aims to eradicate the consumption of HCFC-22 by 2030 and involves the use of alternative refrigerants. This includes refrigerants that have low global warming potential (GWP). of less than 1,000 (such as R-32) and those with ultra-low GWP of less than 10 (such as R-290, R-1234yf and R-600a). These refrigerants are being used to replace the high-GWP HFCs in use, such as HFC-404A, HFC-134A and HFC-410A, in order to implement Indonesia's targets for HFC phase-down in the Article 5, Group 1 category under the Kigali Amendment.

Figure 12. Direct greenhouse gas emissions from the analysed cooling sectors in 2020, 2030 and 2040 under the BAU scenario

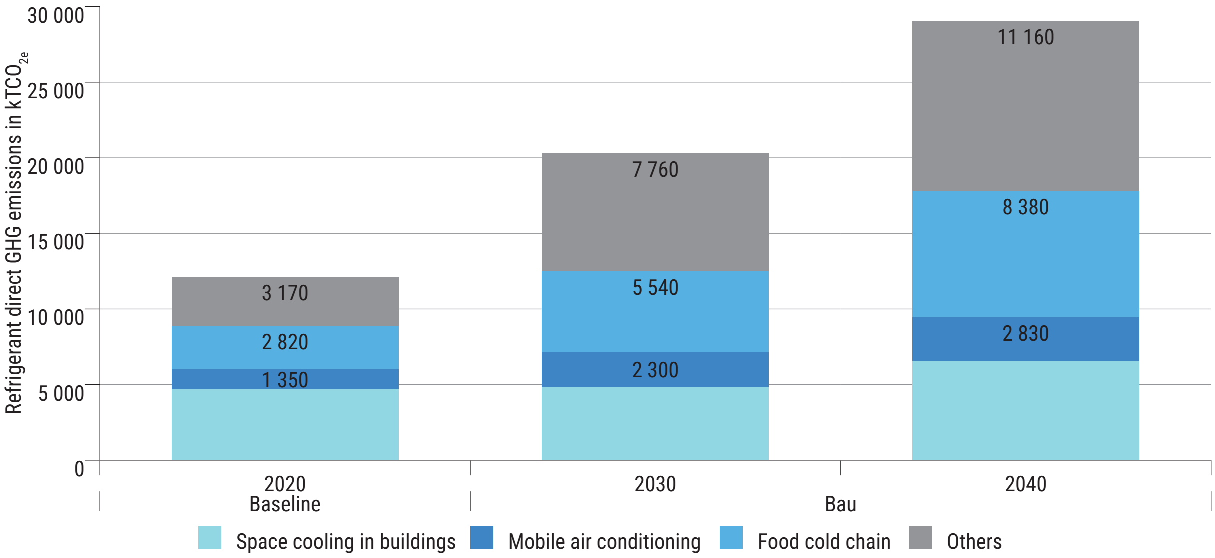


Figure 13. Refrigerant transition scenarios for direct greenhouse gas emissions from the analysed cooling sectors, 2020-2040

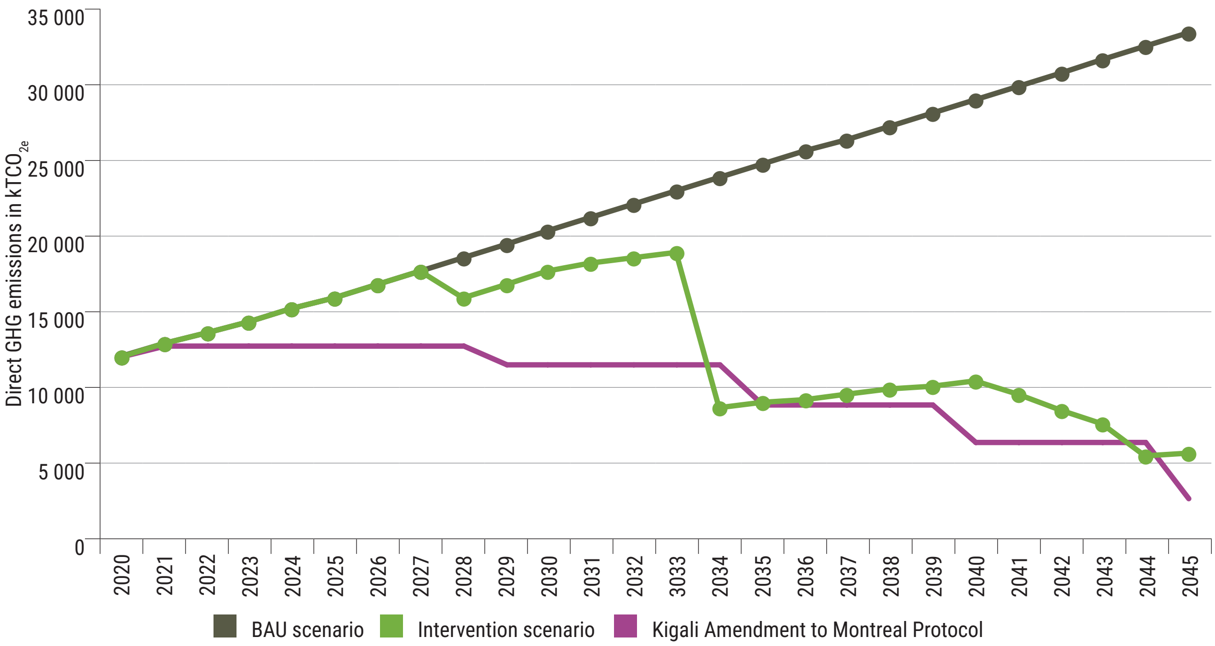


Figure 13 shows the country-level scenarios for direct greenhouse gas emissions, including: 1) the BAU scenario with no action on HFC consumption, 2) the HFC phase-down steps as per the Kigali Amendment (see Appendix A4.4), and 3) the Intervention scenario with refrigerant consumption in 2020 as the baseline and the interpolation of the Kigali Amendment refrigerant transition until 2040. The interpolation in the Intervention scenario considers the average annual reduction in refrigerant consumption between each interval in the HFC phase-down mentioned in the Kigali Amendment refrigerant transition. For example, a reduction in HFC consumption of 15 per cent between 2028 and 2034 in the Kigali Amendment transition is reflected in the Intervention scenario as a 2.1 per cent reduction in HFC consumption annually.

Under the Intervention scenario, mitigation of the direct emissions from refrigeration consumption is an estimated 2,600 kilotons of CO_2e in 2030 and 18,600 kilotons of CO_2e in 2040. A major breakthrough in the refrigerant transition is the use of R-32 refrigerant in the residential air-conditioning market. Higher penetration rates of R-32 are already being seen in unitary, fixed-speed split and inverter type air-conditioners. R-600a is another refrigerant with low GWP that is being used in the domestic refrigerator market in Indonesia. The transition in the mobile air-conditioning sector is set to begin starting in 2034, as per the schedule of the Kigali Amendment.

Greenhouse Gas Emissions and Mitigation Potential

In 2020, the analysed cooling sectors contributed total greenhouse gas emissions of 97 million tons of CO_2e. Space cooling in buildings contributed 59 per cent of the total emissions, followed by mobile air-conditioning (23 per cent) and the food cold chain (18 per cent) (see Figure 14). The total emissions from these cooling sectors are expected to increase two times by 2030 and nearly 2.5 times by 2040, from 2020 levels.

The direct and indirect emissions for all three sectors are included in the analysis, with the exclusion of the refrigerants defined in Appendix A4.4.

Under the BAU scenario, due to the rapid increase in the penetration of room air-conditioners, the emissions from space cooling are expected to increase from 58 million tons of CO_2e in 2020 to 131 million tons in 2030 and 167 million tons in 2040 (Table 11). Room air-conditioner units using inverter technology are expected to grow from 0.4 million units in 2020 to 4.7 million units in 2040, and fixed-speed split technology room air-conditioner units are expected to increase five-fold from 18.7 million units in 2020 to 92.6 million units in 2040 (see section 3.1).

Figure 14. Total greenhouse gas emissions from the analysed cooling sectors, by sector and type, 18% in 2020, 12% in 2030, and 10% in 2040 under the BAU scenario

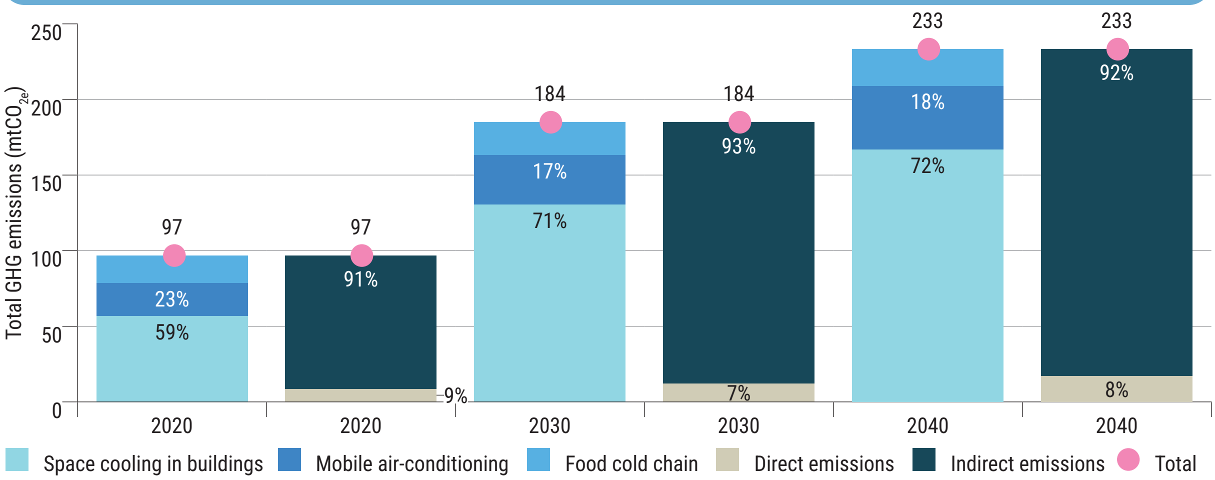


Table 9. Direct and indirect greenhouse emissions and mitigation potential (million tons of CO_2e)

	Baseline Emissions	BAU Emissions		Intervention Scenario Emissions		Mitigation Potential	
	2020	2030	2040	2030	2040	2030	2040
Space Cooling in Buildings							
Indirect Emission	52	126	160	93	49	33	110
Direct Emission	5	5	7	4	2	1	4
Mobile Air-conditioning							
Tailpipe Emission	21	30	39	27	36	2	4
Direct Emission	1	2	3	2	0	0	3
Food Cold Chain							
Indirect Emission	14	16	16	14	11	2	5
Direct Emission	3	6	8	4	6	1	2
Overall Cooling Sector							
Overall Indirect emissions	88	172	215	134	96	37	119
Overall direct emissions	9	13	18	11	8	2	9
Total emissions	97	185	233	145	104	39	128

Total emissions from the food cold chain sector are expected to increase under the BAU scenario from 17 million tons of CO_2e in 2020 to 22 million tons in 2030 and 24 million tons in 2040 (Table 9). The lower emission growth in this sector is attributed to the saturation in domestic refrigerator equipment sales, indicated by a compound annual growth rate of only 0.2 per cent annually between 2020 and 2040.

Indirect emissions from the three sectors in the BAU scenario are expected to reach 172 million tons of CO_2e in 2030 and 215 million tons in 2040. In the Intervention scenario, the indirect emission mitigation potential for all cooling sectors is an estimated 37 million tons of CO_2e in 2030 and 119 million tons of CO_2e in 2040.

In terms of reducing emissions, the space cooling sector has the highest potential among the three cooling sectors, with the potential to mitigate a total of 114 million tons of CO_2e of indirect emissions by 2040. This is due to the expected penetration of passive cooling measures in building energy codes and to the uptake of increasingly energy-efficient refrigeration and air-conditioning units (resulting from the adoption of ambitious MEPS and market enablers that promote super-efficient equipment). The food cold chain sector has a mitigation potential of 7 million tons of CO_2e, whereas the mobile air-conditioning sector has a higher mitigation potential for direct tailpipe emissions of 4 million tons of CO_2e.

The combined greenhouse gas mitigation potential in the cooling sector, including for indirect and direct emissions, is presented in Box 2 for 2030 and 2040.

The mitigation of GHG emissions from the cooling sector can improve up to 39 million tons of CO_2e by 2030 and 148 million tons of CO_2e by 2040 if the electrical power generation mix transforms as per the Transition Scenario (TRNS) of LTS-LCCR. This will lead to 10 per cent and 30 per cent reduction in indirect emissions by 2030 and 2040 respectively, in comparison with the CPOS. In the case

Box 2. Total mitigation potential for building space cooling, mobile air-conditioning and food cold chains in 2030 and 2040

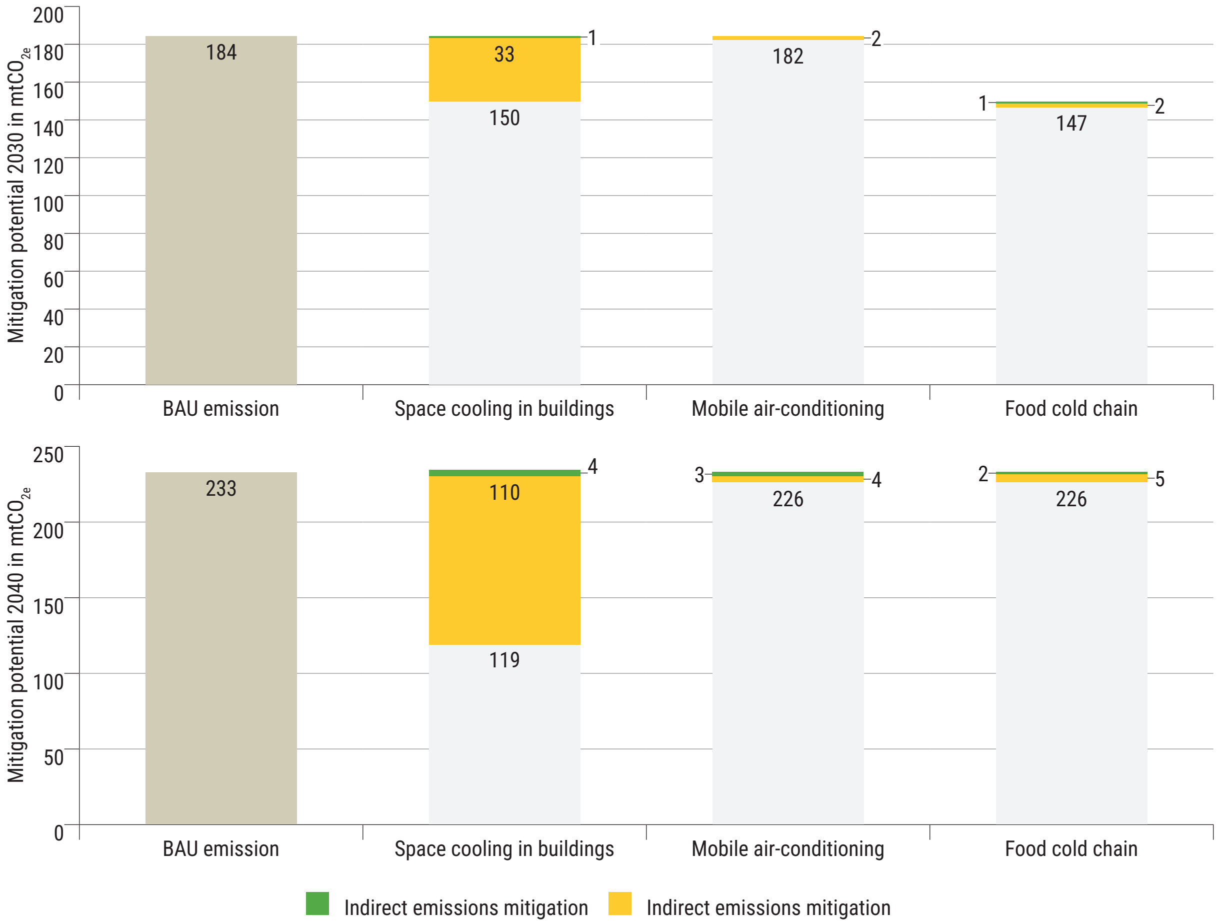
2030

- Combined direct/indirect emission mitigation potential – 39 million tons of CO_2e, or a 21 per cent reduction compared with total emissions in the BAU scenario.
- Contribution of indirect emissions – 37 million tons of CO_2e, or a 20 per cent reduction.
- The contribution of direct emissions – 2 million tons of CO_2e, or a 1 per cent reduction.

2040

- Combined direct/indirect emission mitigation potential – 128 million tons of CO_2e, or a 59 per cent reduction.
- Contribution of indirect emissions – 119 million tons of CO_2e, or a 55 per cent reduction.
- Contribution of direct emissions – 9 million tons of CO_2e, or a 4 per cent reduction.

Figure 15. Mitigation potentials of building space cooling, mobile air-conditioning and the food cold chain for 2030 and 2040 under the Intervention scenario



of adoption of the Low Carbon Scenario compatible with Paris Agreement (LCCP), the mitigation of indirect emissions can improve up to 50 million tons of CO_2e by 2030 and 320 million tons of CO_2e by 2040, leading to reduction of 41 per cent and 182 per cent of indirect emissions, in comparison with the CPOS.

3.3 Current and Future Cooling Demand Assessments by Sector

This section discusses the results of data-driven assessment of current and future cooling demand for each of the prioritized cooling sectors.

Building Space Cooling

In Indonesia, the buildings sector is one of the fastest growing sectors and the largest energy consumer. Within this sector, residential buildings are the most prominent energy users. Residential and commercial building floor space is increasing by 5-6 per cent annually, with the highest increase among residential buildings (MEMR 2022b). In 2020, building construction and operations accounted for 21.6 per cent of Indonesia's total energy consumption, including electricity, gas and liquefied petroleum gas (LPG) (Statistics Indonesia 2020).

The following technologies were considered to estimate the cooling demand, energy consumption and indirect emissions in building space cooling, using the bottom-up modelling methodology discussed in section 3.1:

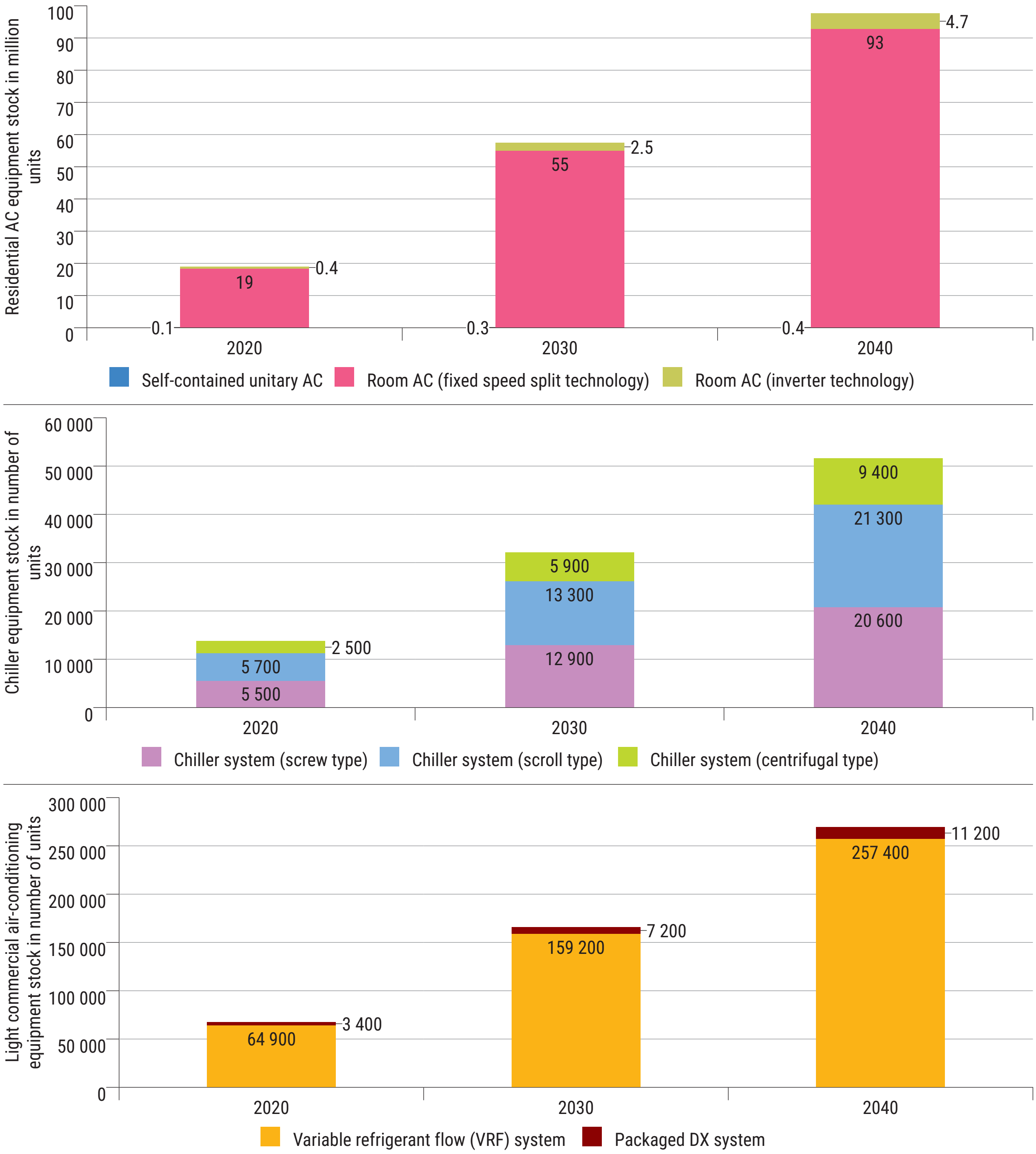
- room air-conditioners: unitary air-conditioners and split air-conditioners with fixed-speed and inverter technologies;
- chillers with scroll, screw and centrifugal compressors;
- light commercial air-conditioners, including variable refrigerant flow (VRF) and packaged direct expansion (DX) systems; and
- ceiling fans (measuring only their energy consumption and indirect emissions).

Direct emissions were estimated for all of the technologies above except ceiling fans using data provided by the Indonesia chapter of ASHRAE. (For more detailed methodological descriptions and formulas, see Appendices 3 and 4.)

The current penetration of room air-conditioners in Indonesia is low (see Figure 16), indicating a predominant reliance on fans for cooling in households. An estimated 155 million fans were present in the country's 68 million households in 2020, and this number is expected to triple to 460 million fans by 2040 (CLASP 2020b).

The total cooling demand from the air-conditioning equipment used for space cooling in buildings in 2020 was 16 million TR, excluding fans (see Figure 17). This is projected to increase to 46 million TR in 2030 and 78 million TR in 2040. Fixed-speed room air-conditioners represented most (82 per cent) of the cooling demand in 2020, followed by VRF (6 per cent), screw chillers (5 per cent) and centrifugal chillers (4 per cent). Fixed-speed room air-conditioners will continue to dominate the market, with annual sales growth of 1 per cent. Their equipment stock is projected to grow from 18.6 million units in 2020 to 55 million units in 2030 and 93 million units in 2040. This shows the potential for high energy savings by transitioning to energy-efficient inverter technology for room air-conditioners.

Figure 16. Building space cooling equipment stocks, by type, in 2020, 2030 and 2040 under the BAU scenario



The total stock of chillers and VRF systems in 2020 was around 78,500 units and is expected to increase to 191,000 units by 2030 and 309,000 units by 2040 (Figure 16).

The total electricity consumption from building space cooling was 61,500 GWh in 2020 (see Figure 18). The sector’s rising energy consumption is driven by the growing market share of fixed-speed room air-conditioners (73 per cent), followed by scroll-type chiller systems (21 per cent). Under the BAU scenario, the total electricity consumption from building space cooling is projected to increase to 162,100 GWh in 2030, and 241,400 GWh in 2040.

Figure 17. Building space cooling demand, by equipment type, in 2020, 2030 and 2040 under the BAU scenario

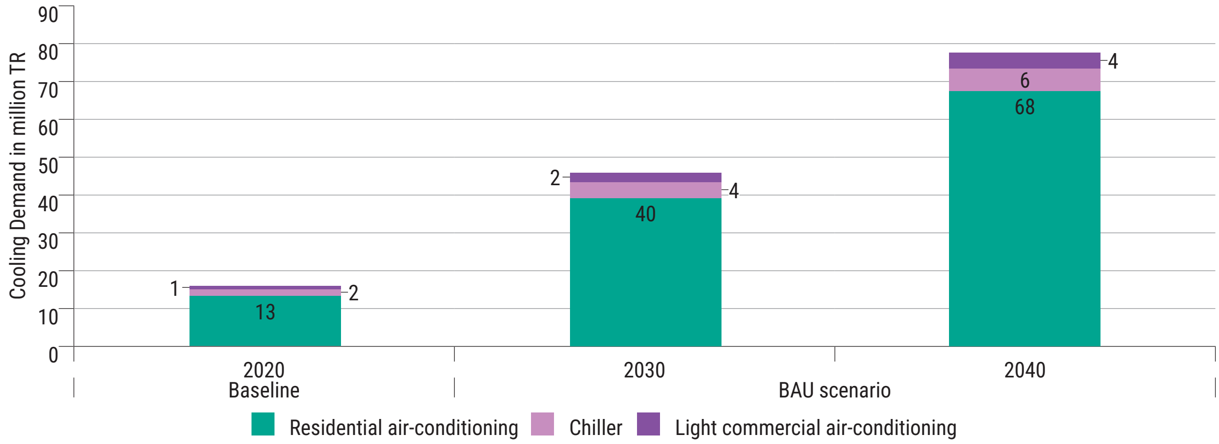
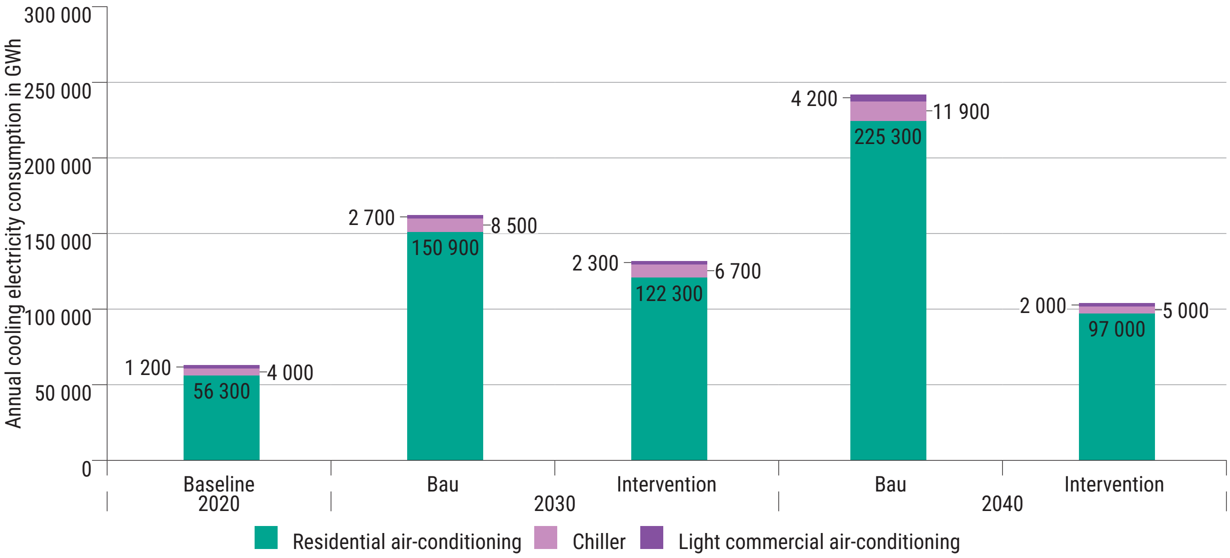


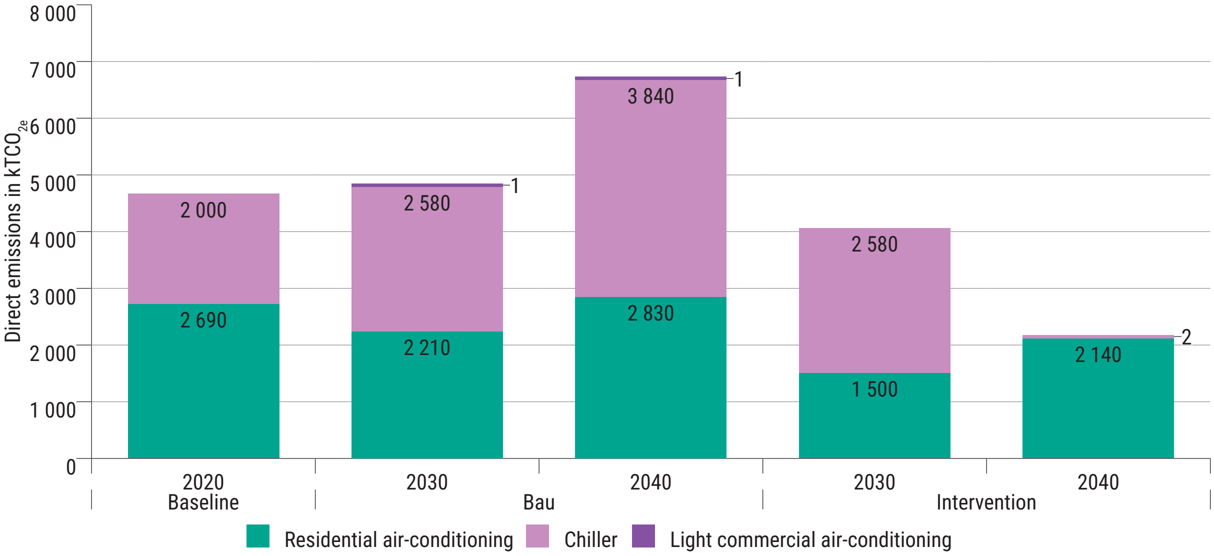
Figure 18. Electricity consumption from building space cooling, by equipment type, in 2020, 2030 and 2040 under the BAU and Intervention scenarios



The Intervention scenario considers the penetration of passive cooling strategies in building design and construction, improvements in the energy efficiency of equipment, and the increased penetration of efficient equipment. Combined, these measures are expected to result in energy savings of 30,800 GWh (19 per cent) in 2030 and 137,400 GWh (57 per cent) in 2040, compared to BAU levels. In the residential air-conditioner category, the rising share of electricity consumption from fixed-speed room air-conditioners is due to limited efficiency improvements for this equipment type, whereas other equipment types are estimated to achieve higher energy efficiency in the future (see Appendix 4.1 for energy efficiency variations for future scenarios).

The direct emissions from space cooling in buildings totalled 4,690 kilotons of CO_2e in 2020 and are projected to increase to 4,791 kilotons in 2030 and 6,671 kilotons in 2040, in the BAU scenario (see Figure 19). The refrigerants currently in use in the space cooling sector include high-GWP refrigerants such as HCFC-22, HFC-134a

Figure 19. Direct greenhouse gas emissions from refrigerants used in building space cooling, by equipment type, in 2020, 2030 and 2040 under the BAU and Intervention scenarios



and HFC-410a. The Intervention scenario incorporates the refrigerant transition targets of the Kigali Amendment, under which the consumption of these refrigerants is expected to decline sharply over the next decade as the use of low- and ultra-low GWP refrigerants increases. Existing efforts include the adoption of residential and light commercial air-conditioners that use R-32, which has one-third the GWP of HFC-410A and HCFC-22 and half the GWP of HFC-134a. The refrigerant transitions proposed for the BAU and Intervention scenarios are provided in Table 31 in Appendix 4.4.

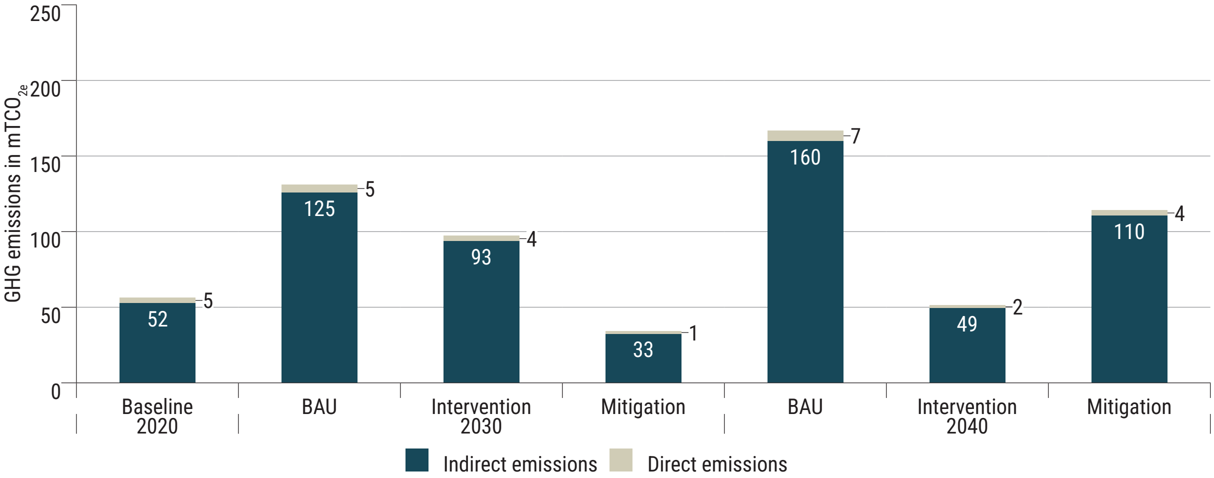
The total greenhouse gas emission mitigation potential for building space cooling (in kilotons of CO_2e), as well as the indirect and direct emission contributions for 2030 and 2040, are shown in Figure 20.

The total greenhouse gas emissions from space cooling in buildings in 2020 were 57 million tons of CO_2e. Under the BAU scenario, these emissions are projected to reach 131 million tons of CO_2e in 2030 and 167 million tons of CO_2e in 2040. This is attributed mainly to indirect emissions from residential air-conditioners, specifically fixed-speed room air-conditioners, which are expected to grow at a higher rate.

The implementation of mitigation measures – such as passive cooling strategies and the penetration of energy-efficient equipment – would reduce the indirect emissions from space cooling in buildings by an estimated 33 million tons of CO_2e by 2030 and 110 million tons of CO_2e by 2040. This translates to a 25 per cent reduction in total emissions in 2030 and a 66 per cent reduction in total emissions in 2040, compared to the BAU scenario.

The climate-friendly refrigerant transition and efficient refrigerant handling will lead to the mitigation of direct emissions of 1 million tons of CO_2e by 2030 and 4 million tons of CO_2e by 2040. This translates to a 1 per cent reduction in total emissions

Figure 20. Greenhouse gas emissions (direct and indirect) from building space cooling in 2020, 2030 and 2040 under the BAU and Intervention scenarios and with mitigation



in 2030 and to a 3 per cent reduction in total emissions in 2040, compared to the BAU scenario.

Implementing the mitigation measures for both direct and indirect emissions would result in a reduction in the total greenhouse gas emissions in 2030 of 34 million tons of CO_2e, or a 26 per cent emission reduction compared to the BAU scenario (see Box 3). Implementing indirect and direct emission mitigation measures would reduce the total greenhouse gas emissions in 2040 by 114 million tons of CO_2e, or a 69 per cent reduction compared to the BAU scenario.

Box 3. Mitigation potential for building space cooling in 2030 and 2040

2030:
- BAU scenario – space cooling sector greenhouse gas emissions reach 131 million tons of CO_2e.
- Intervention scenario, indirect emissions – mitigation potential of 33 million tons of CO_2e, or a 25 per cent reduction.
- Intervention scenario, indirect and direct emissions – mitigation potential of 34 million tons of CO_2e, or a 26 per cent reduction.

2040:
- BAU scenario – greenhouse gas emissions reach 167 kilotons of CO_2e by 2040.
- Intervention scenario, indirect emissions – mitigation potential of 110 million tons of CO_2e, or a 66 per cent reduction.
- Intervention scenario, indirect and direct emissions – mitigation potential of 114 million tons of CO_2e, or a 69 per cent reduction.

Mobile Air-conditioning

The cooling demand assessment for the mobile air-conditioning sector includes passenger cooling for light-duty vehicles, heavy-duty vehicles and freight vehicles. Due to data limitations, railways, aviation and shipping are excluded from the analysis. The methodology for estimating the cooling demand and the direct and indirect emissions for mobile air-conditioning is discussed in section 3.1. (For more on the inputs and assumptions considered for the modelling, see Appendix 4.)

Passenger car (light-duty vehicle) ownership in Indonesia totalled 7.4 million units in 2020 (see Figure 21). Due to increasing purchasing power and the availability of favourable financing mechanisms, ownership is expected to increase to 19.8 million units by 2030 and to quadruple to 30.5 million units by 2040. For passenger heavy-duty vehicles, the stock is projected to increase steadily from 2.1 million units in 2020 to 2.3 million units in 2030 and 2.5 million units in 2040. The freight vehicle stock is expected to grow 1.5 times by 2030 and to double by 2040, compared to 2020.

The total cooling demand in the mobile air-conditioning sector was 1.8 million TR in 2020 and is expected to increase to 1.9 million TR in 2030 and 2 million TR in 2040 (see Figure 22). The steady growth in cooling demand is attributed to the relatively lower growth rates in the equipment stock in comparison with the building space cooling sector.

Light-duty vehicles will contribute greatly to the overall cooling demand from mobile air-conditioning – representing 88 per cent of the total in 2020 and 2040 – followed by heavy-duty vehicles at 8 per cent.

Figure 21. Vehicle stock by type in 2020, 2030 and 2040 under the BAU scenario

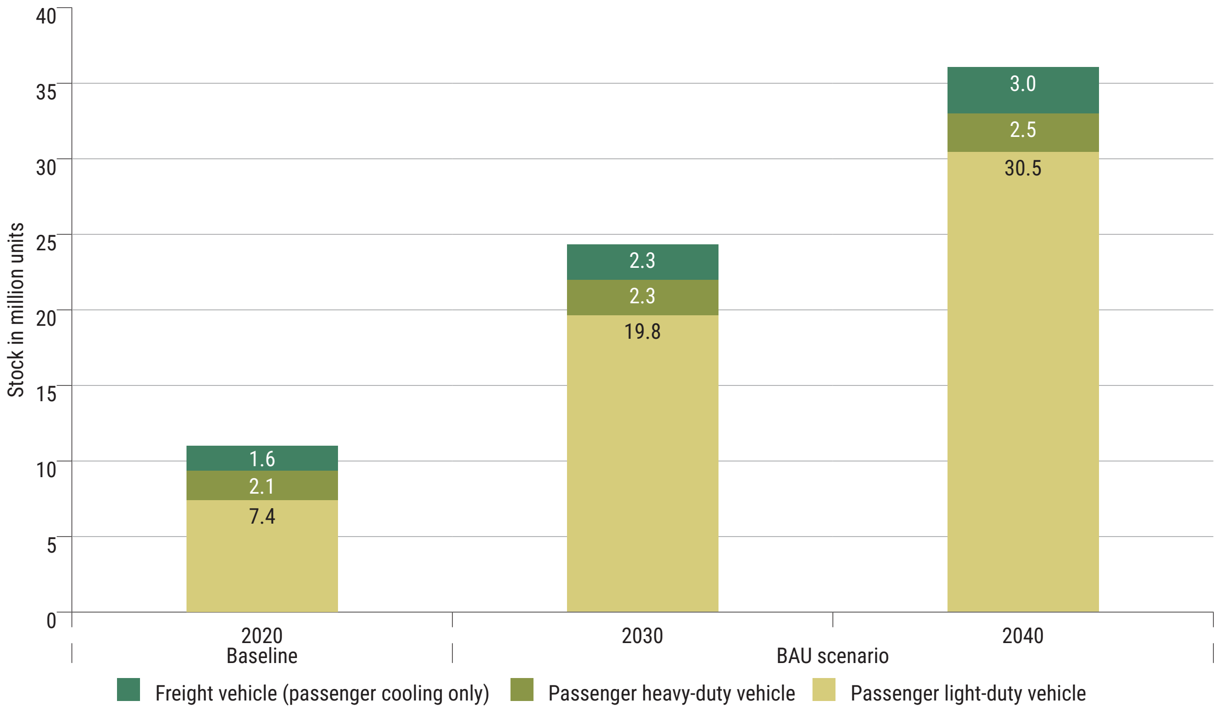
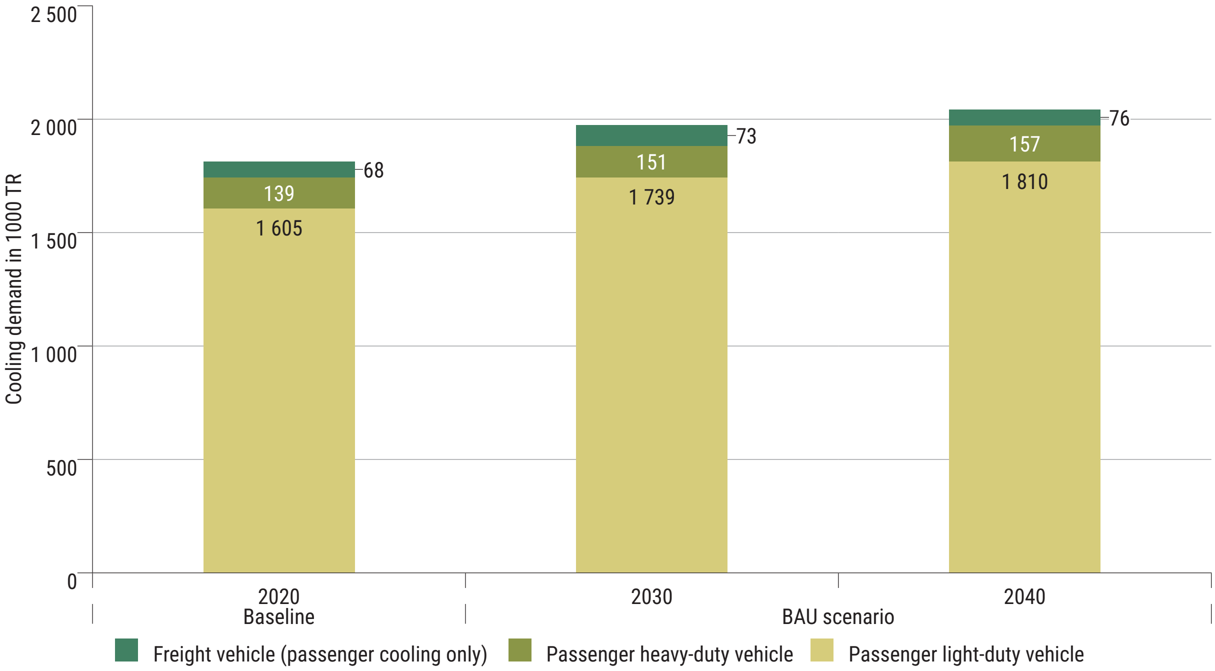


Figure 22. Cooling demand for mobile air-conditioning, by vehicle type, in 2020, 2030 and 2040 under the BAU scenario



The refrigerant HFC-134a, which has a global warming potential of 1,430, dominates the mobile air-conditioning market, with 100 per cent of the equipment currently using this refrigerant. This led to direct emissions from refrigerant consumption in the sector of 1,350 kilotons of CO_2e in 2020 (see Figure 23). Under the BAU scenario, the direct emissions from refrigerant consumption in the sector are projected to increase to 2,300 kilotons of CO_2e in 2030 and 2,830 kilotons of CO_2e in 2040.

The major alternative to HFC-134a in the mobile air-conditioning sector is HFO-1234yf, with a GWP of just 4. But the penetration of HFO-1234yf is expected to be low globally due to the higher patent cost of the refrigerant, which will increase its price to manufacturers by a factor of 2 to 6 and to consumers by a factor of 4 to 15, compared to the production price (Sherry *et al*. 2017; Seidel and Ye 2015).

The intervention scenario considers the implementation schedule of the Kigali Amendment, in which the phase-out of HFC-134a in the mobile air-conditioning sector starts in 2034, leading to a reduction of the direct emissions from the sector to 10 kilotons of CO_2e by 2040 in this scenario.

The greenhouse gas emissions from space cooling in the mobile air-conditioning sector in 2020 totalled 22 million tons of CO_2e (see Figure 24). Under the BAU scenario, these emissions are projected to increase to 33 million tons of CO_2e in 2030 and 41 million tons of CO_2e in 2040. This increase can be attributed mainly to direct tailpipe emissions from light-duty passenger vehicles.

Mitigation measures – such as a transition to climate-friendly refrigerants starting in 2034, as per the Kigali Amendment Implementation Plan, and the provision of efficient refrigerant handling during servicing – have the potential to reduce direct emissions from the sector by 3 million tons of CO_2e by 2040. These mitigation

Figure 23. Direct greenhouse gas emissions from refrigerants used in mobile air-conditioning in 2020, 2030 and 2040 under the BAU and Intervention scenarios

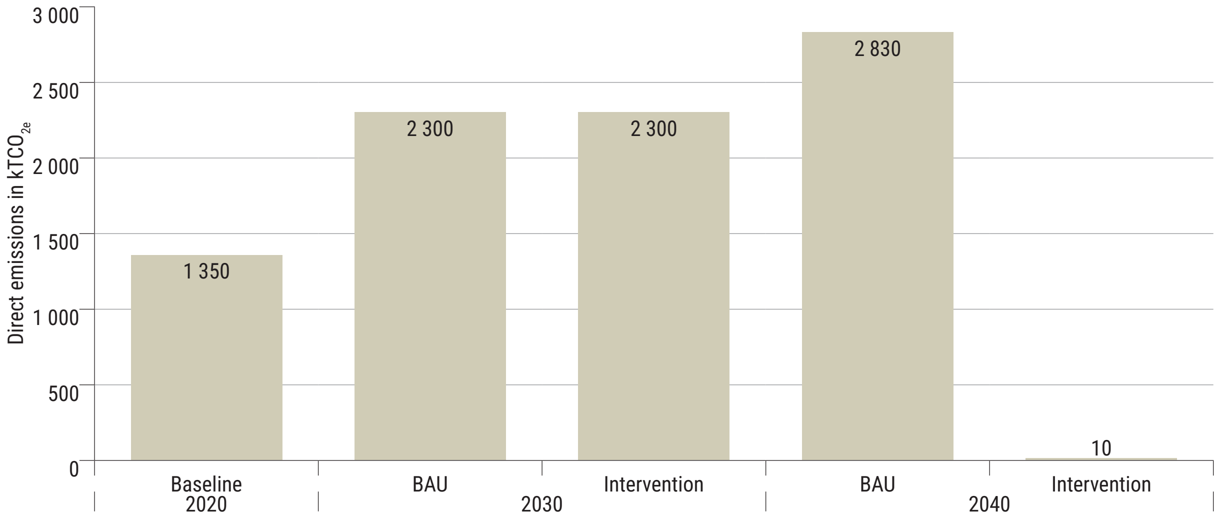
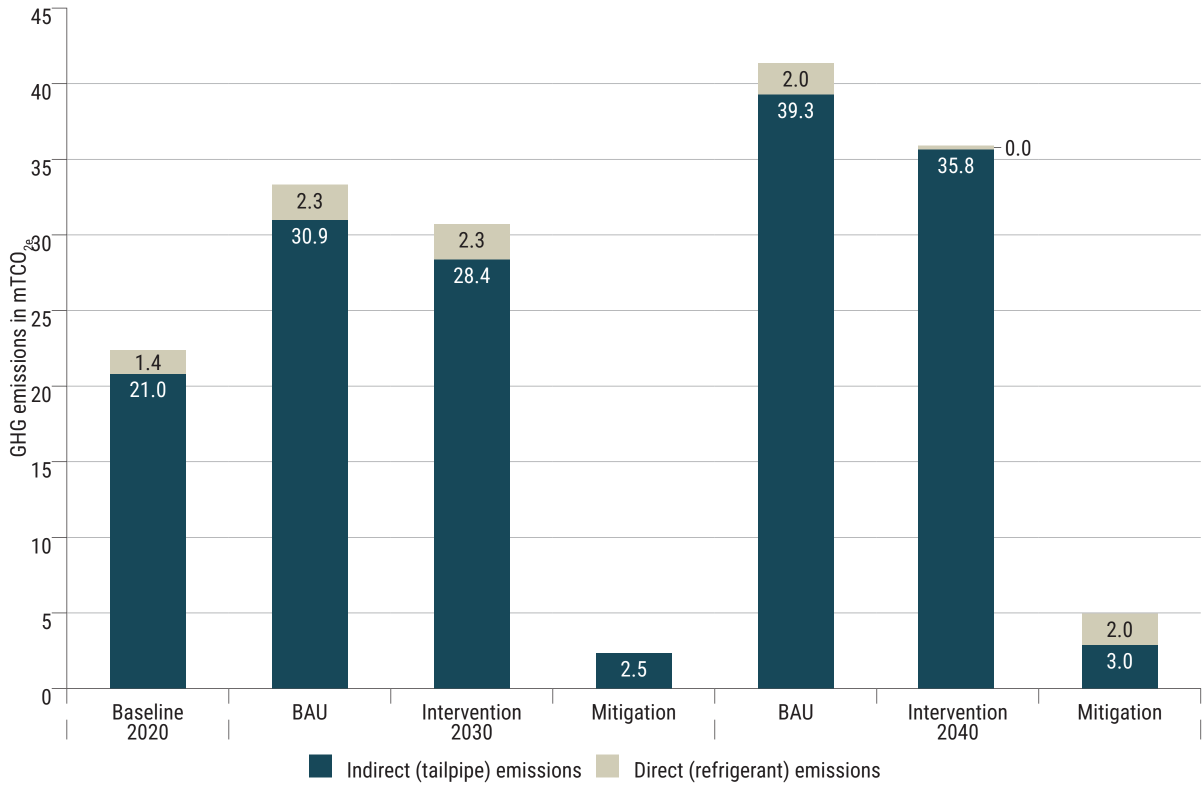


Figure 24. Greenhouse gas emissions (direct and indirect) from mobile air-conditioning in 2020, 2030 and 2040 under the BAU and Intervention scenarios



measures are expected to result in a 5 per cent reduction in the total emissions by 2040, compared to the BAU scenario.

The total greenhouse gas emissions from the mobile air-conditioning sector will decline to 30 million tons of CO_2e in 2030, or a 6 per cent reduction compared to the BAU scenario (see Box 4). In 2040, these emissions are expected to decline further to 36 million tons of CO_2e, or a 12 per cent reduction compared to the BAU scenario.

Box 4. Mitigation potential for mobile air-conditioning in 2030 and 2040

2030:
- *BAU scenario* – greenhouse gas emissions reach 33 million tons of CO_2e.
- *Intervention scenario, direct emissions from refrigerants* – direct greenhouse gas emissions do not decrease.
- *Intervention scenario, direct and indirect emissions from refrigerants and fuel consumption* – direct and indirect greenhouse gas emissions decrease by 2 million tons of CO_2e, or a 6 per cent reduction.

2040:
- *BAU scenario* – greenhouse gas emissions reach 41 million tons of CO_2e.
- *Intervention scenario, direct emissions from refrigerants* – direct greenhouse gas emissions decrease by 3 million tons of CO_2e, or a 25 per cent reduction.
- *Intervention scenario, direct and indirect emissions from refrigerants and fuel consumption* – direct and indirect greenhouse gas emissions decrease by 7 million tons of CO_2e, or a 12 per cent reduction.

Food Cold Chain

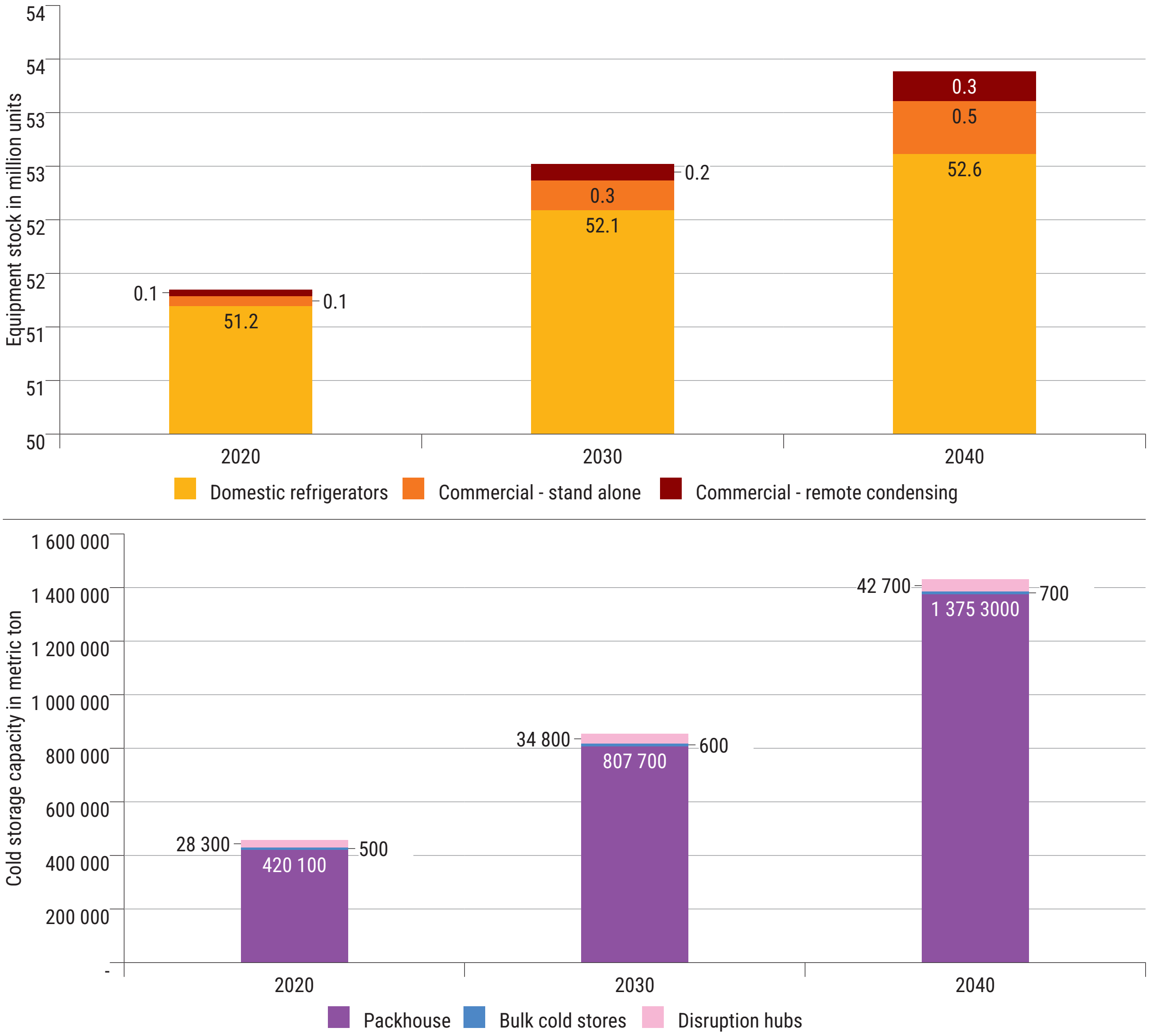
The equipment stock for the cold chain sector is divided into the two main categories of cold storage and refrigerators. The assessment for cold storage resulted in an estimation of Indonesia's cold storage system capacities and their cooling demand, based on the country's requirements for access to cooling and its goal to reduce post-harvest food losses, as detailed in Appendix 3.

The baseline equipment stock in the food cold chain sector is dominated by domestic refrigerators, with 51.2 million units (see Figure 25), but in future scenarios their growth is only between 1 per cent (2021-2025) and 0.3 per cent (2031-2040) annually. Commercial refrigerators, which have a lower stock in 2020 (stand-alone and remote condensing types) are poised to see higher growth in the future.

For food cold storage, the infrastructure stock in 2020 was an estimated 448,900 tons and is expected to increase to 843,100 tons in 2030 and 1,418,100 tons in 2040. Packhouse infrastructure has the highest storage capacity in the cold storage category, with a 420,100 ton capacity, due to the use of packhouses by the largest end-use segments such as fisheries and meat. (For a detailed explanation of the cold chain infrastructure and of the end-use sectors, see Appendix 3.)

Total cooling demand from the food cold chain sector was an estimated 6.9 million TR in 2020 and is expected to increase to 7.6 million TR in 2030 and 8.4 million TR in 2040 (see Figure 26). The domestic refrigerator stock has reached saturation in the market, leading to slower expected growth in the future, but commercial refrigerators are projected to experience a 4 times growth in cooling demand between 2020 and 2040, leading to an overall increase in cooling demand in the sector. Among cold storage facilities, packhouses are expected to lead the surge in cooling demand to 2040 (from 2020 levels). (For details on the estimation of cooling demand for cold storage infrastructure and domestic and commercial refrigerators, see Appendix 4.)

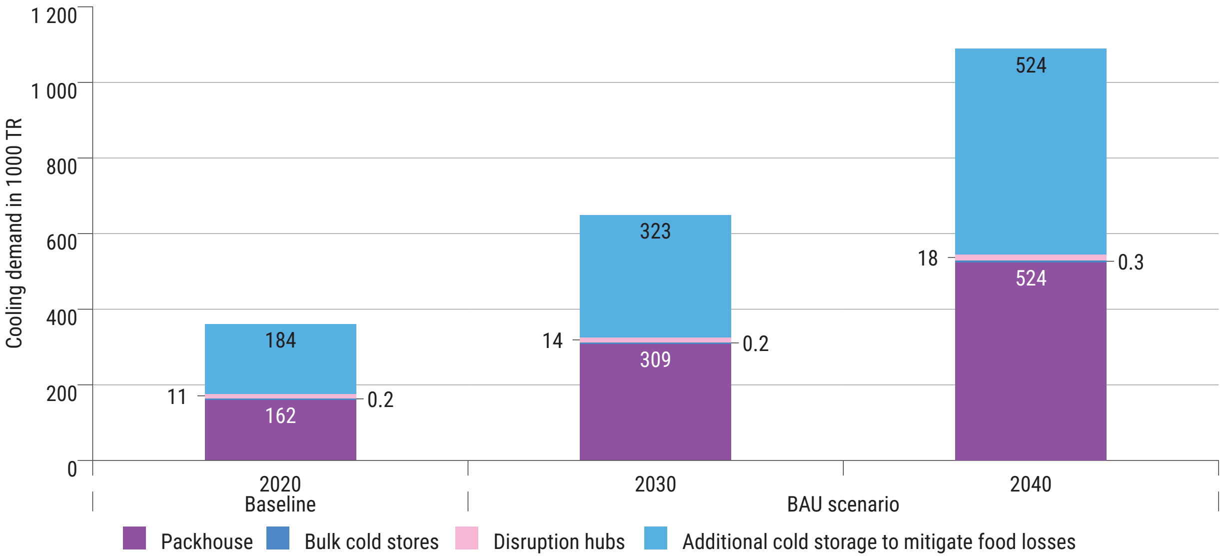
Figure 25. Cooling equipment stocks for the food cold chain, by type, in 2020, 2030 and 2040 under the BAU scenario



The cooling electricity consumption from the food cold chain sector in 2020 reached 17,000 GWh (see Figure 27), with domestic refrigerators representing 77 per cent of the total, followed by the cold storage sector (20 per cent) and commercial refrigerators (around 3 per cent). Electricity consumption in the sector is projected to reach 21,100 GWh in 2030 and 23,500 GWh in 2040, under the BAU scenario. Energy consumption from commercial refrigerators is projected to increase more than 3 times by 2030 and 4.5 times by 2040, from 2020 levels. Similarly, energy consumption in the cold storage sector is projected to grow 1.5 times by 2030 and 2.5 times by 2040, from 2020 levels.

Under the Intervention scenario – which includes the penetration of refrigeration equipment with enhanced energy efficiency in the food cold chain sector – energy consumption in the sector is projected to fall to 18,800 GWh in 2030 and 16,200 GWh in 2040. By 2040, electricity savings of 2,700 GWh from domestic refrigerators and 3,000 GWh from the seafood sector are projected, due to the larger stock replacement in the refrigerators and to the increase in food volumes and exports in the cold storage sector.

Figure 26. Cooling demand for the food cold chain, by equipment type, in 2020, 2030 and 2040 under the BAU scenario



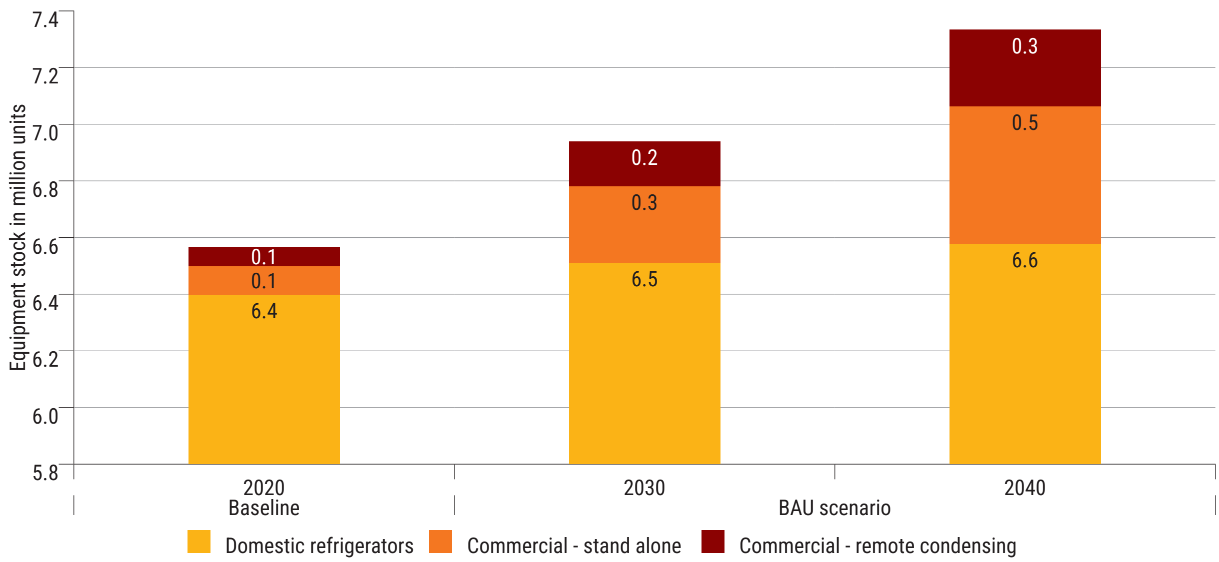


Figure 27. Cooling electrical energy consumption from the food cold chain sector, by equipment type, in 2020, 2030 and 2040 under the BAU and Intervention scenarios

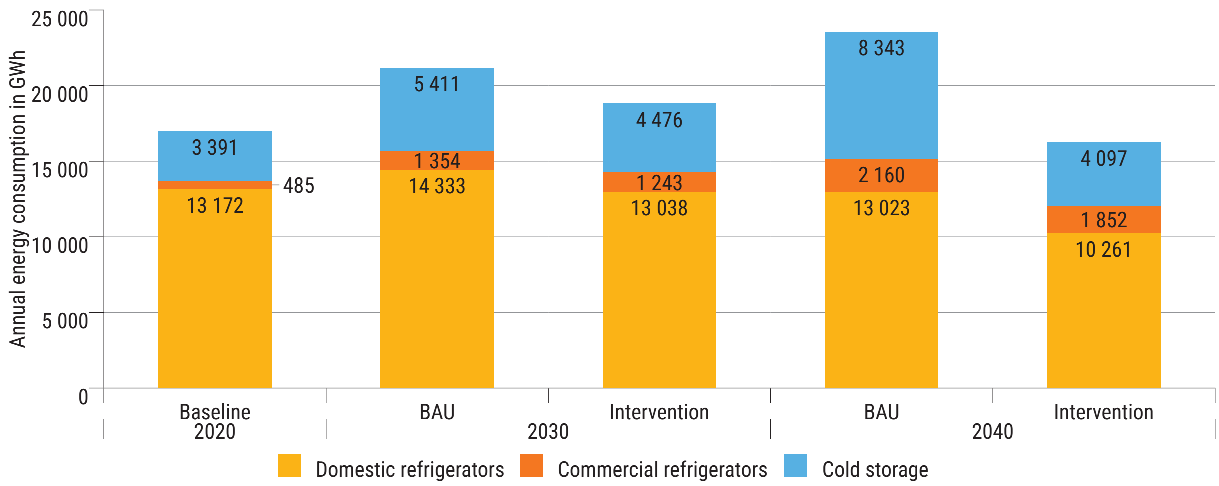
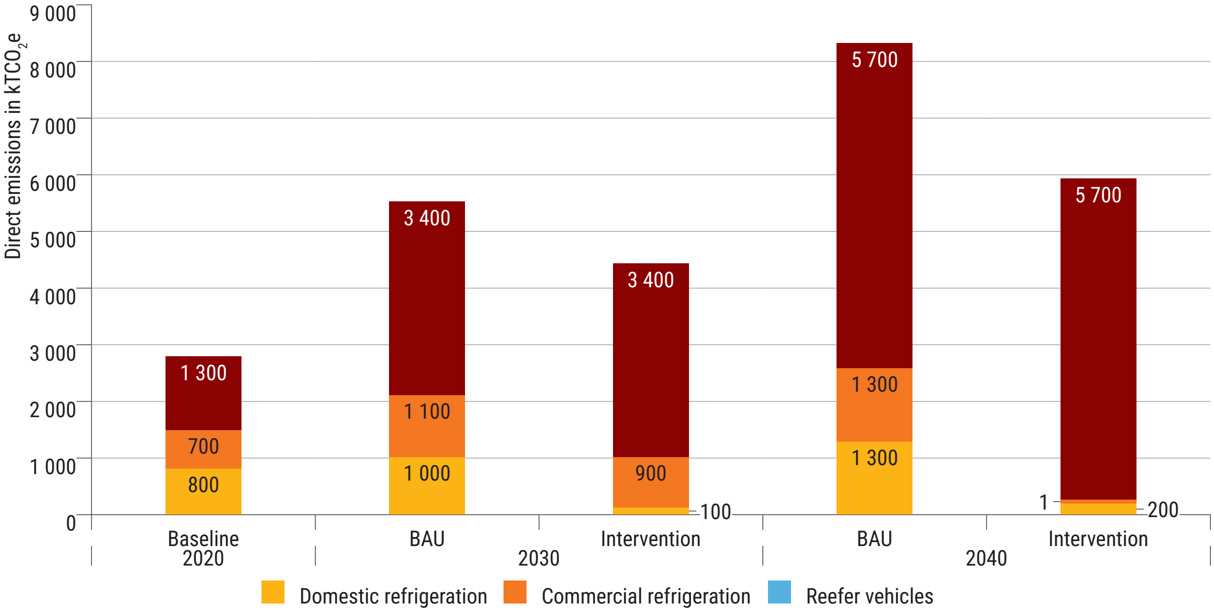


Figure 28. Direct greenhouse gas emissions from refrigerants used in the food cold chain sector, by equipment type, in 2020, 2030 and 2040 under the BAU and Intervention scenarios



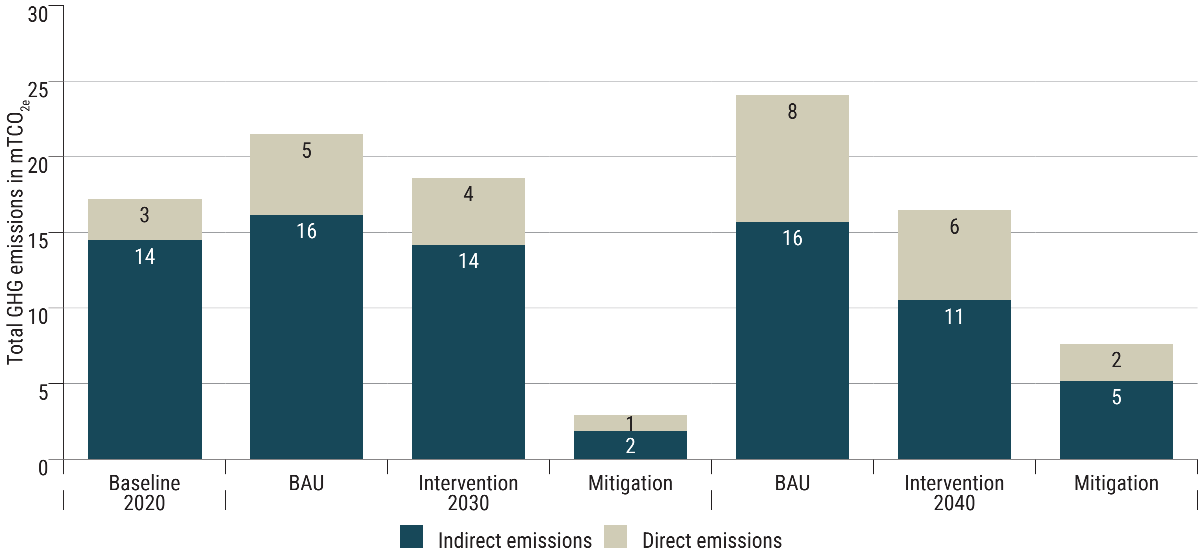
Refrigerants used in the food cold chain sector include HFCs such as HFC-410A, HFC-404A, HFC-134A and HFC-407C, along with HCFC-22 (including refrigerant consumption in reefer vehicles). Direct emissions from the food cold chain sector totalled 2,800 kilotons of CO_2e in 2020 and are projected to increase to 6,500 kilotons in 2030 and 8,300 kilotons in 2040, under the BAU scenario (see Figure 28). The refrigerant transition, as per the Kigali Amendment, is considered in the Intervention scenario for the phase-out of existing high-GWP HFCs and HCFC-22, which are substituted with low-GWP alternatives. (For the schedule of implementation and the list of alternative refrigerants, see Table 21 in Appendix 4.)

Under the Intervention scenario, direct emissions from the food cold chain are projected to fall to 4,400 kilotons of CO_2e in 2030 and 5,901 kilotons of CO_2e in 2040 (see Figure 29). Higher direct emission mitigation is expected in domestic and commercial refrigeration of 1,100 kilotons of CO_2e by 2030 and 2,399 kilotons of CO_2e by 2040, compared to the BAU scenario. The refrigerant transition for reefer vehicles, as per the phase-down schedule starting in 2044, leads to no changes in direct emissions between the BAU and Intervention scenarios.

Greenhouse gas emissions from the food cold chain sector totalled 17 million tons of CO_2e in 2020 and are projected to increase to 22 million tons of CO_2e in 2030 and 24 million tons of CO_2e in 2040, under the BAU scenario.

Mitigation measures – such as a transition to climate-friendly refrigerants and the provision of efficient refrigerant handling during servicing – have a direct emission mitigation potential of 1 million tons of CO_2e by 2030 and 2 million tons of CO_2e by 2040. These mitigation measures are expected to result in a reduction in the total emissions of 5 per cent by 2030 and 10 per cent by 2040, compared to the BAU scenario.

Figure 29. Total greenhouse gas emissions from the food cold chain sector in 2020, 2030 and 2040 under the BAU and Intervention scenarios and with mitigation



The total direct and indirect greenhouse emissions from refrigerants and electricity consumption in the food cold chain sector are projected to decrease to 18 million tons of CO_2e in 2030, or a 14 per cent reduction compared to the BAU scenario (see Box 5). In 2040, the total emissions are expected to decline further to 17 million tons of CO_2e, or a 32 per cent reduction compared to the BAU scenario.

Box 5. Mitigation potential for the food cold chain in 2030 and 2040

2030:

- *BAU scenario* – greenhouse gas emissions reach 21 million tons of CO2e.
- *Intervention scenario, direct emissions from refrigerants* – mitigation potential of 1 million tons of CO2e, or a 5 per cent reduction.
- *Intervention scenario, direct and indirect emissions from refrigerants and electricity consumption* – emissions decrease by 3 million tons of CO2e, or a 13 per cent reduction.

2040:

- *BAU scenario* – greenhouse gas emissions reach 24 million tons of CO2e.
- *Intervention scenario, direct emissions from refrigerants* – mitigation potential of 2 million tons of CO2e, or a 10 per cent reduction
- *Intervention scenario, direct and indirect emissions from refrigerants and electricity consumption* – emissions decrease by 7 million tons of CO2e, or a 32 per cent reduction.

4 Recommendations and the Way Forward

In the coming decades, Indonesia is projected to emit 233 million tons of CO_2e greenhouse gas emissions by 2040 due to cooling requirements from space cooling for buildings, mobile air-conditioning, and the food cold chain sector. Without interventions, the current development trend will hinder the achievement of national energy and climate objectives. As demonstrated in this report, the adoption of appropriate policy responses and recommendations has the potential to mitigate greenhouse gas emissions, while also improving access to cooling services, lowering energy demand and the strain on energy systems, and supporting economic development.

The opportunity exists to reduce emissions from the cooling sector by a total of 129 million tons of CO_2e by 2040. The building space cooling sector has the highest potential among all cooling sectors, with the ability to lower electricity consumption 57 per cent below 2020 levels by 2040, saving 137 TWh of electricity and reducing indirect emissions by 110 million tons of CO_2e. The transition to climate-friendly refrigerants would reduce emissions by a further 4 million tons of CO_2e. In the food cold chain, more energy-efficient equipment and the refrigerant transition could reduce direct and indirect emissions within this sector by a third, while parallel measures in the mobile air-conditioning sector could achieve a 18 per cent reduction. The refrigerant transition across all three sectors could save 9 million tons of CO_2e.

4.1 Recommendations for Strategic Action

To realize these mitigation potentials, recommendations have been categorized into five topic areas:

- Policy and international cooperation
- Market enablers and regulatory enforcement
- Technological interventions

- Financial sources and mechanisms
- Capacity-building and awareness-raising

Policy and International Cooperation

International Cooperation

P1 Implement committed interventions and targets established under the Paris Agreement and the United Nations Sustainable Development Goals.

P2 Implement the refrigerant transition schedule targets set in the Kigali Amendment to the Montreal Protocol .

P3 Participate in international initiatives to accelerate actions for sustainable cooling, such as the Cool Coalition, the Clean Cooling Collaborative, the Sustainable Cooling Initiative of the World Bank, and the Sustainable Cooling Innovation Program of the International Finance Corporation.

P4 Actively participate in and contribute to the World Green Building Council's global project Advancing Net Zero, which is working towards total decarbonisation of the building sector by 2050.

P5 Engage actively in developing and implementing the *Roadmaps Toward Sustainable and Energy-Efficient Buildings and Space Cooling in the Association of Southeast Asian Nations (ASEAN)*.

National Policy

P6 Institutionalize a data collection campaign across cooling sectors (especially in the food cold chain, the healthcare cold chain and process cooling) to refine estimates of direct and indirect emissions.

- *Potential benefit*: This will allow evidence-based policy development and support in the deployment of an effective measurement and verification system.

P7 Establish a high-level coordination committee/commission – involving key ministries and industry stakeholders involved in the cooling sectors – to periodically review the progress of NCAP implementation and provide strategic direction based on the country's priorities and commitments.

- *Potential benefit:* This action will facilitate inter-institutional and inter-sectoral coordination.

P8 Strengthen minimum energy performance standards (MEPS) and mandatory energy labels to be aligned with major market trends and global best practices for cooling equipment, such as room air-conditioners, chiller-based air-conditioning systems, variable refrigerant flow systems, domestic and commercial refrigerators, ice-lined refrigerators, vaccine refrigerators, fans and process cooling chillers. Ensure that MEPS and labels are updated at least once every five years.

- *Potential benefit* This will ensure alignment with the technological trends of available products, reduce inefficient use of electricity and peak load demand, and help protect the market from imports of sub-optimal equipment.

P9 Improve and implement comprehensive building energy codes and ensure compliance and enforcement. Introduce model building codes with key performance indicators (KPIs) for various building typologies to facilitate benchmark-setting and the development of technical guidelines and regulations.

- *Potential benefit* This action will reduce building-related cooling demand and energy consumption. The codes should emphasize the performance requirements of passive cooling systems and mechanical cooling

P10 Introduce passive cooling strategies in the building code and guidelines, with a timetable for expanded compliance.

- *Potential benefit* If 20 per cent of the new building stock adopts passive cooling strategies through building code compliance, this will reduce the annual cooling demand by 1.2 million TR, leading to annual energy savings of 3,773 GWh by 2040.

P11 Encourage increased certifications such as Greenship, EDGE and Net Zero Healthy for new and existing buildings, interior spaces, homes and neighbourhoods. Raise public awareness of the benefits of low-carbon and healthy buildings.

- *Potential benefit* Market demand will grow for energy-efficient and green buildings and urban spaces.

P12 Establish government programmes at the national and city levels to design, retrofit and operate public facilities to reduce reliance on and use of mechanical air-conditioning. The initiative could introduce net zero design and green building certification requirements, support energy retrofits, and encourage efficient operations for the nation's public buildings .

- *Potential benefit* Public facilities would set an example for climate-friendly buildings and build the market for energy-efficient and climate-friendly technologies and design approaches.

P13 Develop and implement policies for boosting demand-side improvements by supporting and enforcing large-scale cooling consumers to incorporate energy efficiency, refrigerant management and transition, and renewable energy for cooling purposes.

- *Potential benefit* Targeting large consumers will enable relatively fast changes at the sectoral level, which can then be mandated to increasingly smaller cooling consumers.

Market Enablers and Regulatory Enforcement

M1 Support bulk procurement of cooling equipment such as air-conditioners, refrigerators and fans.

- *Potential benefit:* This can introduce economies of scale to reduce costs and lead to accelerated adoption of super-efficient refrigeration and air-conditioning equipment.

M2 Engage utilities to implement demand-response programmes, such as charging higher prices for electricity during peak periods, offering subsidies/incentives for the purchase of more efficient systems, encouraging large-scale use of thermal storage (ice or chilled water), and providing information or awareness campaigns.

- *Potential benefit:* This can shift consumer behaviour and choices to minimize the cooling sector's impact on energy systems.

M3 Promote the adoption of innovative "not-in-kind" cooling technologies, such as district cooling systems, direct renewable energy-driven cold storage and vaccine refrigerators, geothermal cooling, absorption/adsorption cooling, phase change material-based cooling, etc.

- *Potential benefit:* This can lead to large-scale efficiencies and reduced greenhouse gas emissions.

M4 Promote the use of renewable resources for cooling and encourage the deployment of innovative technologies such as LNG-regasification based waste cooling use, waste-heat/solar-heat based absorption cooling systems, seawater cooling, etc.

- *Potential benefit:* This can lead to reduced greenhouse gas emissions.

M5 Promote the adoption of regulations to reduce cooling demand and energy consumption for mobile air-conditioning, such as requiring imported and manufactured vehicles to have insulated bodies, high-performance glazing, improved fan blowers and energy-efficient compressors.

- *Potential benefit:* This can lead to reduced greenhouse gas emissions.

M6 Promote cooling system automation and management systems such as SCADA and/or building management systems (BMS).

- *Potential benefit:* Facility operators are able to optimize and manage cooling system operations and preventive maintenance.

M7 Encourage the faster adoption of electric and clean fuel-operated vehicles.

- *Potential benefit:* This can reduce fuel-related emissions from the mobile air-conditioning sector.

Technological Interventions

T1 Explore the potential applications of innovative "not-in-kind" cooling technologies, such as district cooling systems, direct renewable energy-driven cold storage and vaccine refrigerators, geothermal cooling, absorption/adsorption cooling, phase change material-based cooling, etc.

- *Potential benefit:* This can lead to the identification of opportunities to introduce cooling technologies that offer energy saving and emission advantages over currently used technologies.

T2 Provide government support for district cooling pilot projects to test technology, assess policy frameworks and develop business models.

- *Potential benefit:* Pilots could lead to a district cooling roadmap to integrate these systems into national policy frameworks, such as urban planning and building regulation, or voluntary approaches through environmental guidelines.

T3 Undertake a more detailed cold chain needs assessment, addressing gaps identified during the NCAP development process.

- *Potential benefit:* An expanded assessment could provide the underlying direction for creating a holistic and sustainable cold chain and cooling infrastructure, streamline cold chain programmes across departments, and identify the best technologies and their appropriate use according to the country's needs.

T4 Support research and development in the areas of technology and business model innovations.

- *Potential benefit:* Technologies and approaches are improved to best meet the needs of the Indonesian market.

T5 Develop government-backed platforms that engage industry, academia, vocational schools, research institutions and the private sector to advance sustainable practice within the cooling sector through research, sharing of best practices, and skill development (for example, of technicians and facility managers).

- *Potential benefit:* This can raise industry awareness of government cooling-related objectives and targets and enable the industry to adopt, operate, and maintain existing and new technologies and approaches for delivering energy-efficient and climate-friendly cooling services.

Financial Sources and Mechanisms

F1 Organize financial mechanisms to speed up the adoption of sustainable cooling. The country can explore accessing funds from climate change mitigation funds, multilateral development banks, and national and private financial institutions to support sustainable cooling initiatives. These funds can be purposed for better planning and blending of financing sources with appropriate mechanisms, creating a more suitable financial ecosystem, including risk- and cost-sharing arrangements.

F2 Select a set of financial mechanisms to implement, and provide flexibility for users to get access to cooling that is energy efficient and clean at an affordable cost. Mechanisms include equity, concessional loans, guarantee, risk-sharing facilities, technical assistance grants, and fiscal incentives for technologies or substances that have low ozone-depleting and global warming potentials.

F3 Promote the use of innovative business models such as servitization[7] for greater adoption of sustainable cooling in the country.

F4 Foster collaboration to mobilize financial resources from climate-related mechanisms, including the carbon trading mechanism under Article 6 of the Paris Agreement, the World Bank, the Green Climate Fund, the Global Environment Facility, the Asian Development Bank, donor countries, development partners and others.

Capacity-building and Awareness-raising

C1 Organize long-term public awareness campaigns for broader adoption of energy-efficient cooling equipment and improved user choices and cooling consumption behaviour.

C2 Strengthen educational and technical programmes to improve installation and servicing practices of cooling equipment. Focus areas should include right-sizing of equipment, improving the energy performance of cooling equipment, reducing refrigerant leakages and improving refrigerant recovery at the equipment end-of-life.

C3 Roll out capacity-building programmes for cooling system operators and facility managers to improve efficiency by monitoring energy use and quantifying refrigerant leakages in their facilities.

C4 Develop a dedicated communications and outreach strategy geared towards informing industry about compliance with policy updates, such as minimum energy performance standards, appropriate product labelling, etc. The initiative should prepare stakeholders for changes and build consumer awareness regarding requirements and their underlying benefits.

C5 Engage with the tourism sector to foster educational programmes for travellers, emphasizing the importance of energy efficiency and environmental conservation.

7 Servitization is where customers pay for a service – such as air conditioning – rather than buying the equipment themselves.

4.2 Summary of Interventions

Table 10 provides a summary of interventions by sector, including projected timelines for intervention, the government lead agency and supporting stakeholders.

Table 10. Interventions by sector

Intervention	Timeline	Lead Agency	Supporting Stakeholders
OVERARCHING			
Establish a cross-ministerial mechanism to facilitate the implementation of Indonesia's National Cooling Action Plan	Short term	MEMR	MEF, MPWH, MMAF
Ratify Kigali Amendment to the Montreal Protocol	Short term	MEF	MEMR, MoI, MoT
Submit second NDC	Short term	MEF	MEMR
BUILDING SPACE COOLING			
Policy and regulation			
Develop minimum energy performance standards (MEPS) for household cooling equipment: air conditioners, refrigerators, heat pumps	Medium term	MEMR	MoI, MoT
Establish government programmes at the national and city levels to design and build low-income community housing to reduce reliance on and use of mechanical air conditioning (e.g. Indonesia Green Affordable Housing Program, IGAHP).	Medium term	MPWH	MEMR, MHA, GBCI
Develop and implement Green Building Performance Standard for new and existing buildings	Short term	MPWH	MEMR, MHA, GBCI
Implement climate-responsive building design and energy-efficient retrofitting of existing buildings for public/government buildings	Short term	MPWH	MEMR, MHA, GBCI
Establish mandatory public procurement (e-proc) guidelines for highest-star-rate d energy-efficient air conditioners, fans, chillers, etc. with low-GWP options, where ever feasible	Medium term	LKPP	MPWH, MEMR, MHA
Develop and implement Energy Management System Standard for buildings	Short term	MEMR	MPWH, BSN, GBCI
Organize policies and programmes to implement the accelerated transition to low-GWP refrigerants for buildings' cooling systems	Short term	MEF	MEMR, MWPH, MoL
Develop Personnel's Competency Standard of Building Energy Audit and Management System	Short term	MEMR	MWPH, MoL, MEF
Include energy efficiency consideration of hospital and health facilities	Long term	MH	MEMR, MWPH
Establish mandatory reporting of energy management monitoring and evaluation for buildings using >10,000 MWh per year	Medium term	MEMR	MWPH, MoI, MHA
Market enablers and regulatory enforcement			
Institute bulk procurement of high-efficient cooling equipment	Medium term	MoT	MEMR, MoI

Intervention	Timeline	Lead Agency	Supporting Stakeholders
Engage utilities in the implementation of successful demand-response programmes	Medium term	MEMR	MWPH, MSE
Technological interventions			
Promote the adoption of innovative not-in-kind cooling technologies in buildings	Medium term	BRIN	MEMR, MWPH, University
Financial sources and mechanisms			
Support green building financing	Medium term	MoF	MWPH, MEMR, MEF
Capacity-building and awareness-raising			
Organize public awareness campaigns for broader adoption of energy-efficient cooling equipment and improved user behaviour by the end users	Short term	MEMR	MCI
Roll out capacity-building programmes for technicians to improve the installation and servicing practices of cooling equipment	Short term	MEF	MWPH, MEF, GBCI, HAKE
Support the capacity-building of cooling system operators and facility managers	Medium term	MEMR	MWPH, MEF, GBCI, HAKE
Promote the use of renewable resources for cooling	Medium term	MEMR	MWPH, MEF, GBCI, HAKE
Promote cooling system automation and management systems	Medium term	MEMR	MWPH, MEF, GBCI, HAKE
MOBILE AIR CONDITIONING			
Policy and regulation			
Establish policy on new electric vehicles and conversions	Medium term	MoTrans	BRIN, MEMR, MEF
Establish policies to improve energy efficiency and the adaptation of low-GWP refrigerants, especially in hybrid and electric vehicles	Medium term	MoTrans	BRIN, MEMR, MEF
Market enablers and regulatory enforcement			
Promote the adoption of regulations to reduce cooling demand and energy consumption for mobile air conditioning, such as requiring imported and manufactured vehicles to have insulated bodies, high-performance glazing, improved fan blowers and energy-efficient compressors	Medium term	MoTrans	MEMR, MoT, MoI, Gaikindo
Technological interventions			
Explore the potential applications of innovative "not-in-kind" cooling technologies, such as direct current compressors for electric vehicles	Medium term	BRIN	MoTrans, MEMR, Universities
Financial sources and mechanisms			
Provide subsidies and/or rebates for energy-efficient vehicles (e.g. electric and hybrid electric)	Short term	MoF	MoTrans, MEMR, MoT, MoI, Gaikindo

Intervention	Timeline	Lead Agency	Supporting Stakeholders
Capacity-building and awareness-raising			
Strengthen educational and technical programmes to improve installation and servicing practices of cooling equipment. Focus areas should include right-sizing of equipment, improving the energy performance of cooling equipment, reducing refrigerant leakages and improving refrigerant recovery at the equipment end-of-life	Short term	MEMR	MoTrans, MEF, MoL, MoT, MoI, Gaikindo
FOOD COLD CHAIN			
Policy and regulation			
Develop technical guidelines for energy-efficient cooling equipment in the fishery cold chain	Short term	MMAF	MEMR, MoL
Develop personnel competency standards in fishery cold chain design, installation, operation and maintenance	Medium term	MMAF	MEMR, MoL, MEF
Promote energy-efficient cooling equipment in the agriculture cold chain	Medium term	MA	MEMR
Develop personnel competency standards in agriculture cold chain design, installation, operation and maintenance	Medium term	MMAF, MM	MEMR, MoL, MEF
Market enablers and regulatory enforcement			
Institute bulk procurement of high-efficiency cooling equipment	Short term	LKPP	MEMR
Engage utilities in the implementation of successful demand-response programmes	Medium term	MEMR	MSE
Promote the adoption of innovative not-in-kind cooling technologies	Medium term	BRIN	MEMR, Universities
Promote the use of renewable resources for the cold chain	Medium term	MEMR	MMAF, Universities
Promote cooling system automation and management systems for the cold chain	Medium term	MEMR	MMAF
Institutionalize data collection on energy use in the cooling systems of the cold chain	Short term	MMAF	MEMR, BPS
Technological interventions			
Support research and development in the areas of technology and business model innovations. ensuring a focus on innovations that support enhanced affordability of energy-efficient and clean cooling for low-income populations in coastal areas	Medium term	BRIN	MMAF, MEMR
Financial sources and mechanisms			
Organize financial mechanisms	Medium term	MoF	MEMR, MMAF
Promote the use of innovative business models	Medium term	MMAF	MEMR
Capacity-building and awareness-raising			
Organize public awareness campaigns for broader adoption of energy-efficient cooling equipment and improved user behaviour by the end users	Short term	MEMR	MMAF, MA

Intervention	Timeline	Lead Agency	Supporting Stakeholders
Roll out capacity-building programmes for technicians to improve the installation and servicing practices of cooling equipment	Short term	MEF	MEF, MMAF, MA
Support capacity-building of cooling system operators and facility managers	Short term	MEMR	MEF, MMAF, MA

4.3 The Way Forward

The development of Indonesia's National Cooling Action Plan, covering the 20-year period to 2040, aims to support the identification of synergies and the implementation of cross-cutting integrated policies and actions needed to realize environmental advantages, while addressing the nation's developmental objectives.

The Implementation Framework for Indonesia's National Cooling Action Plan

The Indonesia NCAP has been designed as an interministerial project, requiring coordinated action among ministries, given the cross-cutting nature of cooling. Since several ministries are involved in the agenda for cooling, strong cooperation among the various ministries, regional governments, and concerned departments and agencies is essential to its successful execution. In addition, the best possible social and economic outcomes of the I-NCAP will depend on integration with ongoing projects and programmes.

The Directorate of Energy Conservation of the Ministry of Energy and Mineral Resources can be the leading agency in coordinating the implementation of the I-NCAP. Commitments have been obtained at the directorate level during the finalization workshop from the Ministry of Environment and Forestry, the Ministry of Public Works and Housing, the Ministry of Marine Affairs and Fisheries, and the Ministry of Industry. The leading agency should engage other relevant stakeholders in the implementation as well as updating the I-NCAP.

Monitoring, Review and Evaluation

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

Particularly with the project of creating Nusantara, the future new Indonesian capital on the island of Borneo, the NCAP must act as a real support tool providing huge opportunities to reduce energy consumption and greenhouse gas emissions, while ensuring that everyone has access to the cooling they need. The recommendations in this NCAP, if properly implemented, will best integrate this new city into its fragile ecosystem, protecting both people and the planet.

Time Frame and Steps for Expanding and Updating Indonesia’s National Cooling Action Plan

The I-NCAP is a living document that needs to be updated regularly. The implementation of recommendations with suggested time frames is provided in Table 10 above, which are divided into short, medium and long terms. The Directorate of Energy Conservation of the Ministry of Energy and Mineral Resources, as the leading agency, can expand and update the I-NCAP every three years based on the monitoring, review and evaluation results.

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Appendix 1. **List of Data Sources**

Data	Source
Indonesia Residential Energy Use survey	CLASP and Ipsos 2020 CLASP and PricewaterhouseCoopers 2020
Air-conditioning equipment market	Oppelt, Herlianika and Papst 2017
Population and growth	Statistics Indonesia 2020
Power grid factors	Government of Indonesia 2021
Access to cooling	SEforALL 2022
Cold storage	Kementerian Kelautan dan Perikanan 2022

Appendix 2. **Detailed Methodology and Formulas for Emissions Calculations**

Space Cooling

Indirect emissions were estimated by calculating annual energy consumption using the following equation:

Annual energy consumption =
Annual stock × Average refrigeration capacity × Annual run time × Utilization factor
× Energy efficiency of refrigerant equipment [1]

The direct emissions from annual refrigerant consumption were estimated using the emissions data for the available refrigerants from the Kigali Amendment Implementation schedule provided by the ASHRAE Indonesia chapter, as outlined in Appendix A3.4

Mobile Air Conditioning

The bottom-up approach using sales data was applied to estimate mobile air conditioning stock. Technologies considered in this sector were as follows:

- Light-duty vehicle
- Heavy-duty vehicle
- Truck air conditioner

Due to data limitations, for this first attempt at NCAP development, aviation and shipping were excluded. Annual total fuel consumption for mobile air conditioning was estimated using the following equation

Annual total fuel consumption for mobile air conditioning use [million litres] =
Annual total stock of vehicle × Measure of energy efficiency with air conditioning on [km/litres]
× Share of fuel consumed used for cooling [per cent]
× Annual distance travelled with air conditioning on [km] per vehicle/10^6 [2]

The annual direct tailpipe greenhouse gas emissions [in million tons of CO_2e] were calculated by conducting a summation of the emission factor multiplied by the fuel consumption of individual fuels.

The direct emissions from annual refrigerant consumption were estimated using the emission data for the available refrigerants from the Kigali Amendment Implementation schedule provided by the ASHRAE Indonesia chapter, as outlined in Appendix A3.4

Food Cold Chain

In general, demand assessment for the food cold chain sector was conducted by considering the supply chain of food products, as depicted in Figure 25.

- Assessment in this sector was then conducted for each type of product:
- Ice cooling for fish production, storage and distribution
- Cold storage for red meat and poultry
- Dairy – milk chilling and processing
- Cold storage for horticulture
- Refrigerated vehicular transport of food cold chain
- Domestic refrigeration
- Commercial refrigeration
    - Standalone systems
    - Remote condensing unit (RCU) systems

For refrigerant systems, a conventional demand assessment approach in the estimation of direct and indirect emissions was adopted by involving data as presented in Table 10.

For cold storage systems, the approach used for estimating demand-side energy consumption and its indirect emissions was based on the following data:

- Capacity of food cold stores (source: ARPI)
- Benchmarks of energy consumption per unit quantity of food stored or per unit volume of cold storage unit (source: FAO; other research reports)

The capacity of storage in food cold chain infrastructure was calculated using the following equation:

Storage capacity for packhouse =
(Total production [kg]) / (365 days ÷ Food storage cycle [days])
Storage capacity for bulk cold store =
(Total Import [kg] + 41 per cent of domestic supply (kg)) / (365 days ÷ Food storage cycle [days])
Storage capacity for bulk cold store=
(Total domestic supply (kg)) / (365 days ÷ Food storage cycle [days]) [3]

Energy consumption for the food cold chain sector was calculated using the following equation:

Demand side energy consumption=
(Food storage quantity [kg])/(Average density of food type [kg/m^3])
× Energy consumption benchmark for cold store [kWh/(m^3 per year)] [4]

Fish Cooling

In the fish cooling sub-sector, two cooling demands were identified: 1) ice cooling for fish production, storage and distribution, and 2) storage warehouses.

Energy consumption for ice requirements for fish was estimated using the following equation:

Energy Consumption = Quantity of fish captured [MT]×kWh/(MT of ice) [5]

In this report, the ice requirement while fishing is assumed to be 2 kilograms of ice mixed with 1 kilogram of seawater per 6 kilograms of fish, or equivalent to 0.33 kilograms of ice required per kilogram of fish (Shawyer and Medina Pizzali 2003).

For a storage warehouse, energy consumption was estimated using the following equation:

Energy Consumption = Quantity of fish stored [MT]×kWh/(MT of ice) [6]

Meat storage

In meat storage, the cooling requirement is to bring the temperature of the meat to 2°C from the ambient temperature. Energy consumption for that purpose was estimated using the following equation:

Energy consumption =
Quantity of meat stored [MT]×kW/(MT per day for chilling of meat) × Annual hours of operation [7]

The amount of refrigeration required per *kilogram* of meat is *based* on the data provided in the FAO Manual on meat cold store operation and management (Cano-Muñoz 1991).

Dairy

Energy demand in the dairy sub-sector was estimated using the following equation:

Energy Consumption =
Volume of milk chilled × Density of milk × Specific energy consumption (kWh/MT)/1000 [8]

Data on milk, butter and cream production and supply were drawn from FAO statistics, 2018.

Horticulture

Energy consumption for the cooling requirement for horticulture products was estimated using the following equation:

Energy Consumption=
Horticulture produce storage quantity [kg] × energy consumption benchmark [kWh/(m3 per year)])
/(Average density of food type [kWh/(m3 per year)]) [9]

Appendix 3. **Assumptions Used in Cooling Demand Assessment**

The following assumptions and inputs were mapped and used to model the cooling demand assessment for the three sectors of space cooling for buildings, mobile air conditioning and the food cold chain. The data inputs were collated based on a secondary literature survey, mapping of equipment efficiencies in Indonesia, international benchmarks and validation by national expert consultations.

A3.1 Space Cooling for Buildings

Table 11. Equipment efficiency parameters for building and space cooling

	Units	Baseline	BAU	Intervention	BAU	Intervention
		2020	2030	2030	2040	2040
Self-contained unitary air conditioner	Cooling energy (watts) / electrical energy (watts), or W/W	2.7 W/W for 95% of the stock and 3.2 W/W for 5% of the stock	2.7 W/W for 81% of the stock and 3.6 W/W for 19% of the stock	2.7 W/W for 64% of the stock and 4.0 W/W for 36% of the stock	2.7 W/W for 65% of the stock and 4.0 W/W for 35% of the stock	2.7 W/W for 30% of the stock and 4.8 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 3.2 W/W to 4.0 W/W between 2020 and 2040, ~ 1.3% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 3.2 W/W to 4.8 W/W between 2020 and 2040, ~ 2.6% annual growth rate					
Room air conditioner (fixed-speed technology)		2.9 W/W for 95% of the stock and 3.2 W/W for 5% of the stock	2.9 W/W for 81% of the stock and 4 W/W for 19% of the stock	2.9 W/W for 64% of the stock and 4.5 W/W for 36% of the stock	2.9 W/W for 65% of the stock and 4.8 W/W for 35% of the stock	2.9 W/W for 30% of the stock and 5.9 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 3.2 W/W to 4.8 W/W between 2020 and 2040, ~ 2.6% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 3.2 W/W to 5.9 W/W between 2020 and 2040, ~ 4.4% annual growth rate.					
Room air conditioner (inverter technology		2.9 W/W for 95% of the stock and 3.7 W/W for 5% of the stock	2.9 W/W for 81% of the stock and 4.2 W/W for 19% of the stock	2.9 W/W for 64% of the stock and 4.7 W/W for 36% of the stock	2.9 W/W for 65% of the stock and 4.8 W/W for 35% of the stock	2.9 W/W for 30% of the stock and 5.9 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 3.7 W/W to 4.8 W/W between 2020 and 2040, ~ 1.6% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 3.7 W/W to 5.9 W/W between 2020 and 2040, ~ 3.1% annual growth rate.					

		Baseline	BAU	Intervention	BAU	Intervention
		2020	2030	2030	2040	2040
Chiller (screw type)	W/W	4.4 W/W for 95% of the stock and 6.7 W/W for 5% of the stock	4.4 W/W for 81% of the stock and 7.6 W/W for 19% of the stock	4.4 W/W for 64% of the stock and 8.5 W/W for 36% of the stock	4.4 W/W for 65% of the stock and 8.6 W/W for 35% of the stock	4.4 W/W for 30% of the stock and 10.5 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 6.7 W/W to 8.6 W/W between 2020 and 2040, ~ 1.5% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 6.7 W/W to 10.5 W/W between 2020 and 2040, ~ 3.0% annual growth rate.					
Chiller (scroll type)	W/W	2.8 W/W for 95% of the stock and 4.0 W/W for 5% of the stock	2.8 W/W for 81% of the stock and 4.54 W/W for 19% of the stock	2.8 W/W for 36% of the stock and 5.1 W/W for 64% of the stock	2.8 W/W for 65% of the stock and 5.1 W/W for 35% of the stock	2.8 W/W for 30% of the stock and 6.3 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 4.0 W/W to 5.1 W/W between 2020 and 2040, ~ 1.5% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 4.0 W/W to 6.3 W/W between 2020 and 2040, ~ 3.0% annual growth rate					
Chiller (centrifugal type)		6.1 W/W for 95% of the stock and 6.7 W/W for 5% of the stock	6.1 W/W for 81% of the stock and 7.9 W/W for 19% of the stock	6.1 W/W for 64% of the stock and 9.1 W/W for 36% of the stock	6.1 W/W for 65% of the stock and 9.3 W/W for 35% of the stock	6.1 W/W for 30% of the stock and 11.8 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 6.7 W/W to 9.3 W/W between 2020 and 2040, ~ 2.0% annual growth rate. Intervention: 6 Energy efficient equipment efficiency increases from 6.7 W/W to 11.8 W/W between 2020 and 2040, ~ 4.0% annual growth rate.					
Variable refrigerant flow (VRF) system	W/W	4.3 W/W for 95% of the stock and 4.8 W/W for 5% of the stock	4.3 W/W for 81% of the stock and 19 W/W for 35% of the stock	4.3 W/W for 64% of the stock and 5.7 W/W for 36% of the stock	4.3 W/W for 65% of the stock and 5.7 W/W for 35% of the stock	4.3 W/W for 30% of the stock and 6.6 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy efficient equipment efficiency increases from 4.8 W/W to 5.7 W/W between 2020 and 2040, ~ 1.0% annual growth rate. Intervention: Energy efficient equipment efficiency increases from 4.8 W/W to 6.6 W/W between 2020 and 2040, ~ 2.0% annual growth rate.					
Packaged direct expansion system		2.7 W/W for 95% of the stock and 3.2 W/W for 5% of the stock	2.7 W/W for 81% of the stock and 3.7 W/W for 19% of the stock	2.7 W/W for 64% of the stock and 4.1 W/W for 36% of the stock	2.7 W/W for 65% of the stock and 4.1 W/W for 35% of the stock	2.7 W/W for 30% of the stock and 5.1 W/W for 70% of the stock
Growth rate of efficiency	BAU: Energy-efficient equipment efficiency increases from 3.2 W/W to 4.1 W/W between 2020 and 2040, ~1.5% annual growth rate Intervention: Energy-efficient equipment efficiency increases from 3.2 W/W to 5.1 W/W between 2020 and 2040, ~3.0% annual growth rate					

		Baseline	BAU	Intervention	BAU	Intervention
		2020	2030	2030	2040	2040
Fans	Watts (W)	54.5 W for 87% of the stock and 30 W for 5% of the stock	54.5 W for 77% of the stock and 30 W for 23% of the stock	54.5 W for 56% of the stock and 30 W for 44% of the stock	54.5 W for 65% of the stock and 30 W for 35% of the stock	54.5 W for 28% of the stock and 30 W for 78% of the stock
Growth rate of efficiency	No growth rate in efficiency considered; Best available technology for fans with 30 W electrical power is considered the efficient case for all years in BAU and Intervention scenarios					

Table 12. Grid emission factors

	Baseline	BAU	Intervention	BAU	Intervention
	2020	2030	2030	2040	2040
Self-contained unitary air conditioner	0.85				
Room air conditioner (fixed-speed technology)	0.85				
Room air conditioner (inverter technology)	0.85				
Chiller (Screw type)	0.85				
Chiller (Scroll type)	0.85				
Chiller (Centrifugal type)	0.85				
Variable refrigerant flow (VRF) system	0.85				
Packaged direct expansion system	0.85				

Table 13. Assumptions for other parameters for building space cooling

		Baseline	BAU	Intervention	BAU	Intervention
	Units	2020	2030		2040	
Unit Capacity						
Self-contained unitary air conditioner	Ton of refrigeration (TR)	0.7				
Room air conditioner (fixed-speed split technology)		0.7				
Room air conditioner (inverter technology)		0.7				
Chiller (screw type)		142				
Chiller (scroll type)		28.4				
Chiller (centrifugal type)		256				
Variable refrigerant flow (VRF) system		15				
Packaged direct expansion system		2.7				
Fan	Watt (W)	54.5				
Annual Runtime						
Self-contained unitary air conditioner	No. of hours per year	3 650				
Room air conditioner (fixed-speed split technology)		3 650				
Room air conditioner (inverter technology)		3 650				
Chiller (screw type)		2 400				
Chiller (scroll type)		8 760				
Chiller (centrifugal type)		4 745				
Variable refrigerant flow (VRF) system		2 400				
Packaged direct expansion system		2 400				
Fan		1 944				

	Units	Baseline 2020	BAU 2030	Intervention 2030	BAU 2040	Intervention 2040
Utilization Factor						
Self-contained unitary air conditioner	%	75%				
Room air conditioner (fixed-speed split technology)	%	95%				
Room air conditioner (inverter technology)	%	50%				
Chiller (screw type)	%	80%				
Chiller (scroll type)	%	93%				
Chiller (centrifugal type)	%	73%				
Variable refrigerant flow (VRF) system	%	60%				
Packaged direct expansion system	%	90%				
Fan	%	100%				

A3.2 Mobile Air Conditioning

Table 14. Equipment efficiency parameters for mobile air-conditioning

	Units	Baseline 2020	BAU 2030	Intervention 2030	BAU 2040	Intervention 2040
Equipment Efficiency						
Passenger Light Duty Vehicle	km/ Liters	12.1 km/litre for 95% of the stock and 13.8 km/ litre for 5% of the stock	12.1 km/litre for 83.2% of the stock and 13.8 km/litre for 16.8% of the stock	12.1 km/litre for 69% of the stock and 13.8 km/ litre for 31% of the stock	12.1 km/litre for 70% of the stock and 13.8 km/ litre for 30% of the stock	12.1 km/litre for 40% of the stock and 13.8 km/ litre for 60% of the stock
Passenger Heavy Duty Vehicle		3.2 km/litre for 100% of the stock and 3.6 km/litre for 0% of the stock	3.2 km/litre for 96% of the stock and 3.6 km/litre for 4% of the stock	3.2 km/litre for 93% of the stock and 3.6 km/litre for 7% of the stock	3.2 km/litre for 97% of the stock and 3.6 km/litre for 8% of the stock	3.2 km/litre for 85% of the stock and 3.6 km/litre for 15% of the stock
Freight vehicle (passenger cooling only)		2.7 km/litre for 100% of the stock and 3.1 km/litre for 0% of the stock	2.7 km/litre for 96% of the stock and 3.1 km/litre for 4% of the stock	2.7 km/litre for 93% of the stock and 3.1 km/litre for 7% of the stock	2.7 km/litre for 92% of the stock and 3.1 km/litre for 8% of the stock	2.7 km/litre for 85% of the stock and 3.1 km/litre for 15% of the stock

Table 15. Assumptions for different parameters used in mobile air-conditioning

	Units	Baseline	BAU		Intervention	
		2020	2030	2040	2030	2040
Share of Fuel Consumption Used for Cooling						
Passenger light-duty vehicle	litre/km			0.012		
Passenger heavy-duty vehicle				0.048		
Freight vehicle (passenger cooling only)				0.056		
Annual Distance Travelled with Air Conditioning on per Vehicle						
Passenger light-duty vehicle	in km			16,000		
Passenger heavy-duty vehicle				50,000		
Freight vehicle (passenger cooling only)				50,000		
Proportion of Fuel Use						
Passenger light-duty vehicle	Diesel	5%			5%	
	Petrol/Gasoline	95%			95%	
	Gas (CNG/LPG)	0.01%			0%	
Passenger heavy-duty vehicle	Diesel	99.99%			85%	
	Petrol/Gasoline	0.00%			15%	
	Gas (CNG/LPG)	0.01%			0%	
Freight vehicle (passenger cooling only)	Diesel	100%	100%	5%	100%	5%
	Petrol/Gasoline	0%	0%	95%	0%	95%
	Gas (CNG/LPG)	0%	0%	0%	0%	0%

Note: CNG = clean natural gas; LPG = liquefied petroleum gas

A3.3 Food Cold Chain (Domestic and Commercial Refrigeration)

Table 16. Equipment efficiency parameters for food cold chain

	Units	Baseline	BAU	Intervention	BAU	Intervention
		2020	2030	2030	2040	2040
Domestic refrigerators	kWh/year	300	300 kWh/year for 83% of the stock and 150 kWh/year for 17% of the stock	300 kWh/year for 67% of the stock and 150 kWh/year for 33% of the stock	300 kWh/year for 65% of the stock and 150 kWh/year for 35% of the stock	300 kWh/year for 30% of the stock and 150 kWh/year for 70% of the stock
Growth rate in energy efficiency	BAU : 300 kWh/year to 150 kWh/year between 2020 & 2040, ~ 1.84% annual growth rate. Intervention: : 300 kWh/year to 150 kWh/year between 2020 & 2040, ~ 3.68% annual growth rate.					

	Units	Baseline	BAU	Intervention	BAU	Intervention
		2020	2030	2030	2040	2040
Commercial refrigerators standalone	W/W	2.5	2.45 W/W for 83% of the stock and 3.50 W/W for 17% of the stock	2.5 W/W for 71% of the stock and 3.50 W/W for 29% of the stock	2.5 W/W for 65% of the stock and 3.50 W/W for 35% of the stock	2.5 W/W for 70% of the stock and 3.50 W/W for 30% of the stock
Growth rate in energy efficiency	BAU : 2.5 W/W to 3.5 W/W between 2020 and 2040, ~ 2 % annual growth rate. Intervention: : 2.45 W/W to 3.5W/W between 2020 and 2040, ~ 4 % annual growth rate					
Commercial refrigerators - remote condensing units		1.9	1.9 W/W for 83% of the stock and 3.5 W/W for 17% of the stock	1.9 W/W for 67% of the stock and 3.5 W/W for 33% of the stock	1.9 W/W for 65% of the stock and 3.5 W/W for 35% of the stock	1.9 W/W for 30% of the stock and 3.5 W/W for 70% of the stock
Growth rate in energy efficiency	BAU : 1.9 W/W to 3.5 W/W between 2020 and 2040, ~ 2% annual growth rate. Intervention: : 1.9 W/W to 3.5W/W between 2020 and 2040, ~ 4% annual growth rate					

Table 17. Grid emission factor for food cold chain

	Baseline	BAU	Intervention	BAU	Intervention
	2020	2030	2030	2040	2040
Domestic refrigerators			0.85		
Commercial refrigerators - standalone			0.85		
Commercial refrigerators - remote condensing units			0.85		

Table 18. Assumptions for different parameters used in different sectors of food cold chain

	Value	Unit	Reference
Sea Food			
Production			
The amount of ice required while fishing is assumed to be 2 kg ice mixed with 1 kg of seawater per 6 kg of fish, or equivalent to 0.33 kg of ice required per kg of fish	0.33 60	kg ice / kg fish kWh/ton	
Total seafood production	1000	ton	
Domestic Supply			
Share of seafood (comprising fish, shellfish, etc.) from production, preserved (with ice flakes) and sent directly to local market	59%		
Share of seafood (comprising fish, shellfish, etc.) from production, frozen	41%		
The freezing operation (-18°C) is assumed to use 120 kWh/ton of fish, and further chilling needs takes 20 kWh/ton of storage	140	kWh/ton	
The use of flake ice, crushed ice, ice block, etc. takes an average range on 55-74 kWh/ton; 60 units is taken for calculation here.	60	kWh/ton	

	Value	Unit	Reference
The ice-to-fish ratio for holding fish for the local market is 1:3	0.33	kg ice / kg fish	
40% of this further needs 20 kWh/ton for storage	0.4 20	[ ] kWh/ton	
Ratio of ice to aquatic product for all aquatic products preserved through ice	60	kWh/ton	
Further 40% of the products are cold stored at 20 kWh/ton	0.4 20	[ ] kWh/ton	
All domestic supply for freshwater fish is preserved through ice (flakes, block etc.) 1:3 ice-to-fish ratio at 60 kWh/ton of ice	60 0.33	kWh/ton kg ice / kg fish	
Further 30% cold stored at 20 kWh/ton	0.3 20	[ ] kWh/ton	
Imports			
All imports are assumed to be chilled at 20 kWh/ton	20	kWh/ton	
Exports			
All exports are assumed to be frozen at 120 kWh/ton of fish plus 20 kWh/ton of cold storage	140	kWh/ton	
Meat			
The average density for red meat, offal is assumed	900	Kg/m^3	FAO/INFOODS 2012
The average density for chicken/poultry is assumed	1000	Kg/m^3	Kassama and Ngadi, 2016
The average density for eggs is assumed	600	Kg/m^3	
The mean storage equipment centre for warm conditions for chilled temperature operation	60	kWh/m^3 .year	Evans *et al.* 2015
The mean storage equipment centre for warm conditions for frozen and chilled operation	80	KWh/m^3 .year	
Domestic Supply			
Red meat required frozen and chilled operation	0.3	per cent	
Red meat required chilled temperature operation	0.7	per cent	
Poultry meat for frozen and chilled operation	0.1	per cent	
Poultry kept at chilled temperature	0.9	per cent	
Eggs kept at mild chill (5-10°C) temperature	0.5	per cent	
Energy density	40	kWh/m^3 .year	
Offal kept at chilled temperature	0.5 60	[ ] kWh/m^3 .year	
Import			
Meat is kept at chilled temperature	60	kWh/m^3 .year	
Egg is kept at mild chill temperature	40	kWh/m^3 .year	
Offal kept at chilled temperature	60	kWh/m^3 .year	
Export			
Meat kept at frozen and chilled temperature	80	kWh/m^3 .year	
Eggs kept at mild chill temperature	40	kWh/m^3 .year	
Poultry kept at frozen and chilled temperature	80	KWh/m^3 .year	
1 GWh	1000000	GWh	

	Value	Unit	Reference
Dairy			
The average energy consumption in a conventional dairy farm is assumed to be 4.1 MJ per kg	1.14	kWh/kg	Shine *et al*. 2020
The average energy consumption for cooling in the dairy industry is around 30% of the energy consumption	0.34	kWh/kg	Dairy Australia 2023
Horticulture			
The average density for fruits is 800-900 kg/m^3/year	800	Kg/m^3 /year	Venkatesh *et al*. 2015
The average density of vegetables is 200-700 kg/m^3/year	400	Kg/m^3 /year	Sharan and Rawale 2003
Fruit cold storage need is 15% for domestic supply	0.15		PT Capricorn Indonesia Consult 2019
Vegetable cold storage need is 10% for domestic supply	0.1		Kusano 2019
100% of vegetables and fruits imported/ exported are stored	40	kWh/m^3 .year	Kusano 2019: 101-147
Chilled operation of only cold storage (bulk/hub)	40	kWh/m^3.year	

Fish Cooling

In the fish cooling sub-sector, two cooling demands are identified: 1) ice cooling for fish production, storage and distribution, and 2) storage warehouses.

The energy consumption for ice requirements for fish was estimated using the quantity of fish captured and the ice requirement per kilogram of fish.

The amount of ice required while fishing was assumed to be 2 kilograms of ice mixed with 1 kilogram of seawater per 6 kilograms of fish, or equivalent to 0.33 kilograms of ice required per kilogram of fish (SEforALL 2020). For a storage warehouse, energy consumption was estimated in the same manner using data on the quantity of fish stored.

Meat Storage

In meat storage, cooling is used to bring the temperature of meat to 2°C from the ambient temperature. Energy consumption for that purpose can be estimated from the quantity of meat stored, the required energy for cooling per volume and the annual operating hours. The amount of refrigeration required per kilogram of meat is based on data provided in the FAO manual on meat cold store operation and management (Fritsch 2019).

Dairy

Energy demand in the dairy sub-sector was estimated using product, density and specific energy consumption information (Lestari et al. 2020). Data on milk, butter and cream production and supply were drawn from FAO statistics (Fritsch 2019).

Horticulture

Energy consumption for the cooling requirement for horticulture products was estimated using each product's quantity, energy consumption benchmarks, and average density of the food type.

Food Storage Capacity

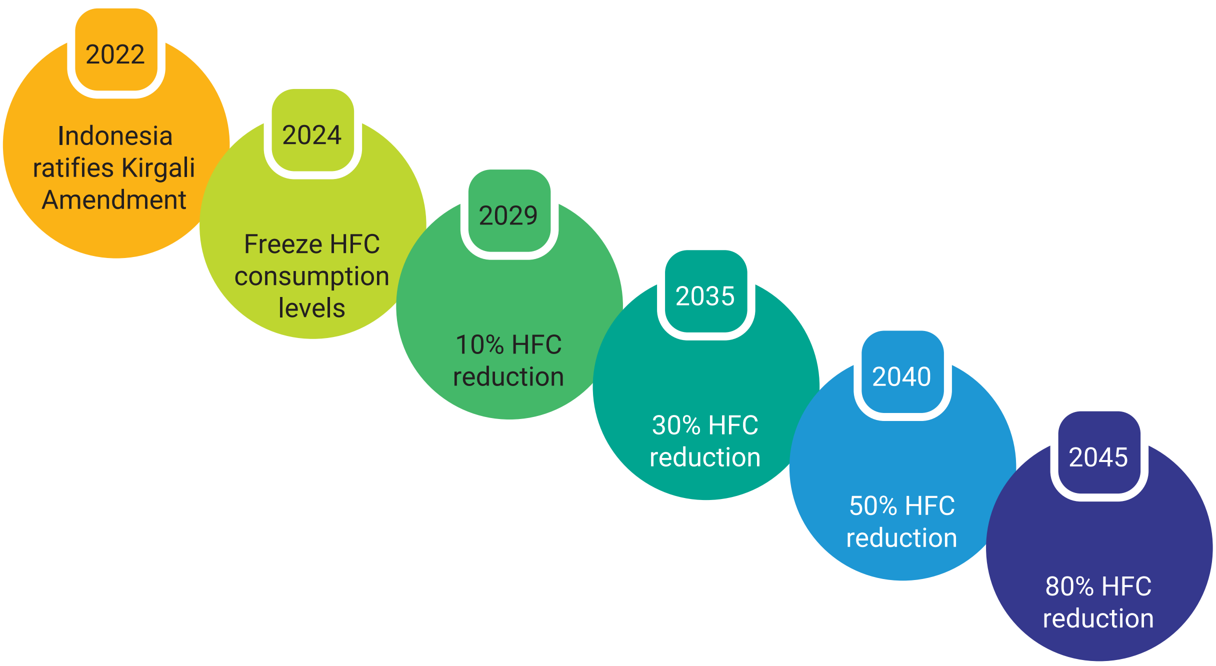
The food storage capacity for the cold chain sector was estimated by considering the expected increase in food consumption per capita and the population growth rate. Packhouses are expected to grow exponentially from 420,080 tons of food storage capacity in 2020 to 1.375 million tons by 2040. This increase is due to the expectation that local food production and domestic supply will use packhouses for pre-cooling, packaging and storage before transport, and that packhouses have a low cycle of storage of the food produces in comparison with bulk cold stores or distribution hubs

A3.4 Direct Emissions from Refrigerants

Refrigerant Transition for Mitigation of Direct Emissions as per the Kigali Amendment

As a Group 1 developing country under the Kigali Amendment to the Montreal Protocol, Indonesia has targets to freeze HFC consumption levels by 2024, and to achieve reductions from the baseline of 80 per cent by 2045, with numerous interim targets (see Figure 30).

Figure 30. Indonesia's Kigali Amendment commitments and timelines



Refrigerants Considered in the Transition

The following tables indicate the implementation schedule for the phase out of different refrigerants applied in the end-use sectors.

Table 19. Phase-down schedule and alternatives for HFC-134A

Phase down HFC-134A (GWP = 1,430)			
Sector	Year	Replacement	GWP
Domestic refrigeration	2028	R-600a	3
Commercial refrigeration	2028	HC	3
Industrial refrigeration	2034	R-455A	146
Light commercial air conditioning	2028	R-32	675
Chiller	2034	R-1234ze	1
Mobile air conditioning	2034	R-1234yf	4
Aerosol	2028	R-152	124

Table 20. Phase-down schedule and alternatives for HFC-404A

Phase down HFC-404A (GWP = 3,922)			
Sector	Year	Replacement	GWP
Commercial refrigeration	2034	HC	3
Industrial refrigeration	2034	R-448A	1273
Transport refrigeration	2044	R-455A	146
Chiller	2039	R-1234ze	1

Table 21. Phase-down schedule and alternatives for HFC-404A

Phase down HFC-410A (GWP = 2,088)			
Sector	Year	Replacement	GWP
Residential air conditioner	2028	R-32	675
Light commercial air conditioner	2028	R-32	675
Commercial air conditioner	2034	R-452B	698
Variable refrigerant flow (vrf) air conditioner	2039	R-454B	466
Chiller	2039	R-454B	466
Commercial refrigeration	2034	HC	3