National Cooling Action Plan for Grenada

A sector mitigation strategy in contribution to Grenada's Nationally Determined Contribution (NDC)

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Foreword

The National Cooling Action Plan (NCAP) for Grenada has been developed to assist the country in meeting its new obligations under the Kigali Amendment to the Montreal Protocol on substances that deplete the ozone layer. Grenada, being one of the early ratifiers to the Kigali Amendment for the phase down of hydrofluorocarbons (HFCs), is committed to early and ambitious actions, targeting the major sectors of the refrigeration and air-conditioning (RAC) industry.

The overarching objective of this NCAP is to reduce the direct and indirect greenhouse gas (GHG) emissions associated with the RAC sector and create a stronger and more sustainable energy and building infrastructure.

The NCAP in its undertakings establishes a strong linkage with Grenada's Nationally Determined Contributions (NDCs) for synergistic and mutual achievements of the country's Montreal Protocol and Paris Agreement commitments, as well as, contributing to meeting the country's 2030 sustainable development goals.

The Grenada NCAP has been developed utilizing information acquired from a comprehensive GHG inventory of the RAC sector and the inclusive contributions of all RAC stakeholders. This plan would constitute the core implementation activities that Grenada would undertake to promote it's green and sustainable cooling initiatives.

This successful implementation of the NCAP is expected to contribute to the global efforts and targets of the Kigali Amendment, to reduce global atmospheric temperature by 0.4°C by the end of this century. In doing so, it is critical that all the major players, inclusive of government, private sector and industry, work collaboratively towards achieving the ultimate objectives of the NCAP. Due to the participatory approach, relevant stakeholders were involved in the development of the NCAP at an early stage and feedback was collected and incorporated in the course of two workshops. We would like to thank all private stakeholders from the refrigeration & air-conditioning sector as well as public entities for their valuable input and feedback and look forward to the joint implementation.

The National Ozone Unit (NOU) in the Energy Division of the Ministry of Infrastructure Development, Public Utilities, Energy, Transport & Implementation is grateful to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and its implementing agency GIZ Proklima together with staff and consultants under the Cool Contributions fighting Climate Change (C4) project in making this activity a resounding success.

Leslie Smith

National Ozone Unit
Ministry of Infrastructure Development, Public Utilities, Energy, Transport and Implementation of Grenada

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List of Abbreviations

AC	Air Conditioner
BAU	Business-as-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
C4	Cool Contributions fighting Climate Change
CARICOM	Caribbean Community
CREEBC	CARICOM Regional Energy Efficiency building code
CFC	Chlorofluorocarbons
CUBiC	Caribbean Uniform Building Code
CROSQ	CARICOM Regional Organisation for Standards and Quality
EE	Energy Efficiency
EER	Energy Efficiency Ratio
F-Gases	Fluorinated greenhouse gases
GCI	Green Cooling Initiative
GDP	Gross Domestic Product
GEF	Grid Emission Factor
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GRENLEC	Grenada Electricity Services
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HEAT	Habitat, Energy Application and Technology GmbH
HFC	Hydrofluorocarbon
HPMP	Hydrofluorocarbons Phase Out Management Plan
HVAC	Heating, Ventilation and Air Conditioning
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LAC	Latin America and the Caribbean
MAC	Mobile Air Conditioning
MEPS	Minimum Energy Performance Standard
MIT	Mitigation scenario
MRV	Measuring, Reporting and Verification
NDC	Nationally Determined Contributions
NOU	National Ozone Unit
nZEB	net-zero energy buildings
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
OECS	Organization of Eastern Caribbean States
OTEC	Ocean Thermal Energy Conversion
PPU	Physical Planning Unit
RAC	Refrigeration and Air Conditioning
REEBC	Regional Energy Efficiency Building Code

SPODS	A Sustainable and Climate-friendly Phase out of Ozone Depleting Substances
SWAC	Sea Water Air Conditioning
TAMCC	T.A. Marryshow Community College
UAC	Unitary Air Conditioning
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

Overview – Policy actions

Policy action area	Responsible government entity	Relevant national policy	Implementation pathway			Current standard	Best practice
			Early action (Now – 2030)	Mid-term action (2031 – 2040)	Long-term action (2041 – 2050)		
Building performance standards							
Building codes are sets of standards for buildings or building systems determining minimum requirements of energy performance	Energy Division/ NOU/ Ministry of Infrastructure Development/ Physical Planning Unit (PPU)	CARICOM Regional Energy Efficiency building code (CREEBC) OECS Building Code, based on the Caribbean Uniform Building Code (CUBiC)	Update and strengthening building code New Buildings MEPS introduction and improvements Residential sector: 46 kWh/m^2/yr (2022) 32 kWh/m^2/yr (2025) 19 kWh/m^2/yr (2028) 17 kWh/m^2/yr (2031) Commercial sector: 92 kWh/m^2/yr (2022) 60 kWh/m^2/yr (2025) 30 kWh/m^2/yr (2028) 25 kWh/m^2/yr (2031) Existing buildings Renovation rate Residential & commercial: 3% (2026)	New buildings: Implementation of high energy performance standards striving for 17 and 25 kWh/m2/year, residential and commercial sector respectively. Existing buildings: Set standards for deep renovation of buildings Review and approve building plans for EE elements.	Improve the energy performance of renovated buildings striving for Zero-Carbon-Renovation[1]. Increase penetration of rooftop Photovoltaics (PV) on all buildings	New Buildings Residential sector: 62 kWh/m^2/yr (2017) Commercial sector: 131 kWh/m^2/yr (2017) Existing buildings Renovation rate Residential & commercial: 0.3% (2017)	New Buildings Residential sector: 17 kWh/m^2/yr (2050) Commercial sector: 25 kWh/m^2/yr (2050) Existing buildings Renovation rate Residential & commercial: 3% (2050)
Increase energy efficiency of RAC appliances[2]							
Appliance energy efficiency	CARICOM Regional Organization		MEPS, Unitary AC (UAC): EER 3.5 (2022), EER 4.2 (2026),	MEPS, UAC: EER 5.2 (2033) EER 5.7 (2040)	MEPS, UAC: EER 6.2	2017 Avg. EER: 3.2 (sales)	2050

[1] A deep renovation with large-energy consumption reductions, where the energy needed to supply the resisting need is carbon neutral (e.g. through on site renewable energy supply) (GBPN, 2013)
[2] All values are given in EER (W/W)

Policy action area	Responsible government entity	Relevant national policy	Implementation pathway			Current standard	Best practice
			Early action (Now – 2030)	Mid-term action (2031 – 2040)	Long-term action (2041 – 2050)		
standards MEPS and labels	for Standards and Quality (CROSQ), NOU, Energy Division, Grenada Bureau of Standards		EER 4.7 (2030) Similar schemes can be developed for other AC incl. chillers, refrigerators, stand-alone units Development and implementation of mandatory energy efficiency labelling for household and light commercial RAC appliances, in line with CROSQ (which already established the standard), using a consistent design. Recommended focus: refrigerators, UACs, optional: stand-alone units additionally. National adoption by Bureau of Standards was completed for refrigerators, workplan by Technical Committee still ongoing for unitary AC appliances.				Avg. EER: 6.6 (sales/MIT scenario)
Endorsement label	CARICOM Regional Organization for Standards and Quality (CROSQ), NOU, Energy Division, Grenada Bureau of Standards		• Continued voluntary endorsement label (Natural Refrigerant Sticker) for refrigerators and expanding to room AC with natural refrigerants, taking international standards and best practice into account. • Supporting the roll-out of EE labels for AC and domestic refrigeration appliances in line with regional initiatives • Incentives for AC high efficiency (with low GWP refrigerants) such as rebate schemes or tax exemptions/ reductions	• Extend range of products to chillers, Mobile AC (MAC), commercial refrigeration and transport refrigeration; allow Green Building Code only with endorsement label installed; allow Green Public Procurement only for appliances with endorsement label		N/A	N/A
Shift to natural refrigerants and new technology							
Refrigerant standards and regulations	NOU/ MoIPET&I[3], Grenada Bureau of Standards /	Ratification of Kigali Amendment	Support the phase out for HFC refrigerants in domestic refrigeration and 30% increase in the use of natural refrigerant in UAC	Restriction on HFC refrigerants for domestic refrigerators, chillers, commercial refrigeration for all refrigerants above GWP 150	Extend ban to all refrigerants with GWP over 10 (Best practice: use of hydrocarbon refrigerants for AC, domestic and commercial	<u>2017</u> HFC share >90% (sales), except domestic (ca. 75%) and	<u>2050</u> HFC share 0% (sales/MIT scenario) for UAC, chillers, domestic and

[3] MoIPET&I: Ministry of Infrastructure Development, Public Utilities, Energy, Transport & Implementation

Policy action area	Responsible government entity	Relevant national policy	Implementation pathway: Early action (Now – 2030)	Implementation pathway: Mid-term action (2031 – 2040)	Implementation pathway: Long-term action (2041 – 2050)	Current standard	Best practice
	Ministry of Finance, Customs Division		Units (international best practice: EU F-Gas Regulation[4])	(International best practice: EU F-Gas Regulation[5])	refrigeration, additionally CO_2 and NH_3 for commercial refrigeration)	industrial refrigeration	industrial refrigeration, low remaining Shares for commercial refrigeration[6]
			Further progressing the standards development with the purpose of allowing the safe use of low GWP refrigerants, including flammable A3 refrigerants with higher charge size: National adoption of horizontal and product safety standards (IEC 60335, EN 378, ISO 5149)				
RAC inventory	NOU / Energy Division		Update current inventory prior to 2022 NDC process. Capturing current ODS banks as part of EU SPODS focus area ensuring robust inventory report	Recurrent update of inventory data in line with globally acceptable timelines. Access to additional funds using inventory report as leverage to show mitigation potential. In addition to, information fed into the national communications to the UNFCCC		N/A	N/A
Sea Water Air Conditioning (SWAC) and Ocean Thermal Energy Conversion (OTEC)	NOU / GIZ		Review of existing feasibility studies to determine applicability of SWAC/OTEC in suitable locations			N/A	N/A
Cross-cutting							
Communication							
Awareness raising and information campaigns are programs transmitting	NOU/ GIZ/ Energy Division		Implement information policies to complement regulatory policies or financial support policies to inform the targeted audience about the existence and eligibility of such policies. Two main information policies that should continuously be implemented: • Capacity building and training policies aim to educate designers, builders, building code officials and other key stakeholder about requirements in building policies			N/A	N/A

[4] Regulation (EU) No 517/2014: ban of split domestic refrigerators and freezers that contain HFCs with GWP ≥ 150 by 2015, ban of split ACs that contain HFCs with GWP ≥ 750 by 2025

[5] Regulation (EU) No 517/2014: ban of stationary refrigeration equipment, that contains HFCs with GWP ≥ 2500 by 2020, ban of commercial refrigerators and freezers that contain HFCs with GWP ≥ 150 by 2022, ban of multipack/centralised commercial refrigeration systems with a rated capacity ≥ 40 kW that contain f-gases with GWP ≥ 150b< 2022 (in the primary refrigerant circuit of cascade systems f-gases with a GWP < 1500 may be used)

[6] Remaining shares (ca. 50%) assumed for condensing units (within subsector commercial refrigeration), continuous HFC use assumed for rooftop ducted and multi-split AC

Policy action area	Responsible government entity	Relevant national policy	Implementation pathway			Current standard	Best practice
			Early action (Now – 2030)	Mid-term action (2031 – 2040)	Long-term action (2041 – 2050)		
general messages to the whole population.			• Advice and information campaigns build awareness about buildings policies and their respective long-term financial benefits and should thus be central to the implementation phase of regulatory and support policies. • Awareness measures for informed end-users and adequate purchase decisions: explaining the importance of life-cycle costs, adequate equipment sizing, regular maintenance, resulting in proper operation modes and energy performance. Trainings and other regional meetings will be used to communicate about the project and create visibility for its objectives and achievements. The main focus will be on discussing ongoing activities, lobby and advocacy as well as on policy dialogue. The dialogues will also present and discuss experiences and learnings made during the process. The project will produce a variety of information and communication material for distribution among the target groups. This can include for instance short videos, fact sheets, or roll-ups. Some of these materials will be distributed during the events, but also online through social media channels. The project will communicate the action through social media channels or websites available.				
Technology Roadshow	NOU/ GIZ		This traveling exhibition will showcase partners and industries that have developed or adopted climate- and ozone-friendly RAC technology. In addition, results, best practices and lessons-learned from the action can be presented and discussed during stakeholder dialogues.			N/A	N/A
Capacity development							
Increasing national technical capacity: for conformity to Regional Energy Efficiency Building Code (REEBC) focusing on assessment of RAC compliance	NOU/Energy Division		Capacity development for stakeholders of the RAC sector to support implementation of the EE building code: 1. Simulation tools for EE in buildings, using e.g. eQuest, RETScreen & LEAP (Long-range Energy Alternatives Planning System) 2. Certified Energy Managers certification 3. Bankable Calculations, Analyses and Financial Modelling for Sustainable Energy Projects using Quick and Detailed Calc. excel based tool 5. Detailed training for engineers, architects, and technician on design and installation of the sustainable cooling system in buildings and specific RAC subsectors	Assessment of building plans for stipulated energy efficiency building codes including RAC requirement targets.		N/A	N/A

Policy action area	Responsible government entity	Relevant national policy	Implementation pathway			Current standard	Best practice
			Early action (Now – 2030)	Mid-term action (2031 – 2040)	Long-term action (2041 – 2050)		
			Support the development of cool training curriculum in local tertiary institutions to be offered to local and regional participants				
Increasing capacity of RAC technicians nationally: for proper handling of refrigerants including natural refrigerants	NOU / T.A. Marryshow Community College (TAMCC) / Vocational training schools	HPMP, Cool Training under C4 by GIZ Proklima	Ongoing strengthening of capacities of RAC trainers and technicians in best practices and safe handling of refrigerants with special attention to natural refrigerants. Currently, RAC technician curricula already include a module on natural refrigerants; tools and equipment for working with flammable refrigerants have been provided under HPMP.	Continuous development of RAC technician training curriculum to match market situation and demand		N/A	N/A
Collaboration with parallel projects	NOU CC/ Focal points/ Environment Division/ Energy Division		Identify regional National Ozone Units interested in duplication of C4 inventory methodology within their respective countries. Use of inventory reports to leverage funding for follow-up activities and attracting additional funding sources.			N/A	N/A
			Working along and sharing lessons learnt with other regional initiatives in energy and cooling efficiency such as KCEP/CCOOL-U4E program. Integration of RAC specific issues into the NDC-Partnership Implementation plan and the upcoming revision of the NDC and the Third and fourth National Communication to the UNFCCC.				
Support policies							
Sustainable public procurement: organized purchase by public bodies requirements	NOU/ Ministry of Finance, Department of Economic and Technical Cooperation/ Ministry of Infrastructure development	Public Procurement	• Amend current Procurement Act to include Green Procurement. • Strengthen enforcement and compliance together with the Green Building Code and to include RAC requirements	<u>New buildings:</u> Implementation of high energy efficient performance appliances and AC units <u>Existing buildings:</u> Set standards for deep replacement of buildings AC systems		Procurement Act*	Amend Act to include a "Green Procurement " component/ regulations
Financial support policies: aimed at encouraging actors to	NOU/ Ministry of Finance, Department of Economic and Technical Cooperation/	Value Added Tax (VAT) Act*	• Scoping of suitable financial incentives to encourage investment in more ambitious energy performance than required	• With successful enforcement of tight building codes subsidies should be reduced and access to conventional finance encouraged	• Continued implementation of energy incentive schemes and prices to provide a disincentive to	N/A	N/A

Policy action area	**Responsible government entity**	**Relevant national policy**	**Implementation pathway**			**Current standard**	**Best practice**
			Early action (Now – 2030)	Mid-term action (2031 – 2040)	Long-term action (2041 – 2050)		
comply/exceed suggested best practice	Ministry of Infrastructure development. Grenada Development Bank		• Assess strategies to assist in providing finance to meet building energy code requirements • Develop financial instruments to incentivize renovation of existing buildings. Continuously update these instruments after evaluating ex-post experience to make sure desired deep renovation rates are reached (3%/year by 2030) Implement economic instruments in the form of subsidies such as tax incentives or grants or access to preferential loans as incentive to encourage early adopters to invest in energy efficiency in buildings. Blended Loan/Grant schemes at concessionary rates.	• Scale-up private investment in energy-efficient buildings to realize the full economically efficient energy saving potential • Continuously update financial instruments supporting the renovation of buildings after evaluating ex-post experience to make sure desired deep renovation rates are reached.	consume energy in buildings • To complement stringent building codes easy access to finance should be guaranteed to enable the last adopters to invest in energy efficiency in buildings Strive for an increase of the rate of deep renovation of existing buildings (3%/year) through appropriate financial incentives.		
Certification of RAC technicians	NOU/ MoIPET&I, Grenada Bureau of Standards		• Establishment of a mandatory certification scheme for technicians handling with RAC appliances and refrigerants • Establishment of a registration database of certified RAC technicians	• Continuous implementation of RAC certification scheme and registration of technicians		N/A	N/A
Establish a take-back scheme for RAC appliances and refrigerants contained therein	NOU/ Ministry of Health/ Ministry of Finance, Customs Division		• Implementation of extended producer responsibility • Establishment of a take-back scheme and recycling of refrigerants. • Establishment of a nationwide collection system and the management of ODS and HFC banks.	• Continuous implementation of take-back schemes tailored to the market situation and demand		N/A	N/A

1 Introduction

Scope and definitions

The present paper shall serve as input to Grenada's NDC process, by providing quantitative and qualitative analyses on mitigation actions related to space cooling in buildings.

Initially, the document provides relevant background information of Grenada's building as well as refrigeration and air conditioning (RAC) sector.

In the following, Grenada's building and RAC sectors are analyzed in depth, emphasizing the key variables and underlying assumptions for efficient mitigation of GHG emissions related to space cooling in buildings. Different GHG emissions pathways are developed for both the building and RAC sector, to then show the mitigation potential in each of these two subsectors. The technical emissions reduction potential is then quantified, and corresponding policy measures are delineated, which are based on international and regional best practice examples. Based on a gap analysis of best practice examples and the status quo, barriers are identified, and appropriate interventions and concrete steps proposed. With regard to the RAC sector, the main focus of this report is on the unitary AC (UAC) subsector, and in particular on single-split AC appliances[7], as they are most frequently used for space cooling in buildings. Nonetheless, other key appliances within the RAC sector, namely chillers as well as domestic and light commercial refrigeration, are considered to some extent in this paper. This link from single-split AC to other RAC appliances is relevant in regard to the policy framework, market mechanisms and capacity building/awareness, and for eventually making the best use of potential synergies within existing and planned initiatives within these fields of action.

The relevance of space cooling in the building sector

Buildings represent the largest energy-consuming sector in the global economy, with over one-third of all final energy and half of global electricity consumed in the sector. As a result, buildings are also responsible for more than one-quarter of global energy related CO_2 emissions in 2017, when emissions from power generation is taken into account (IEA, 2017). Space cooling in buildings accounts for nearly 20% of total electricity used in buildings around the world today and is projected to grow strongly, driven by an increasing demand in developing and emerging economies. In hot climates cooling often accounts for more than 50% of the energy consumption of a building (Katili, Boukhanouf and Wilson, 2015). Applying best available technologies has substantial energy savings potential by reducing energy needs for cooling in buildings (IEA, 2013b).

In 2015, worldwide emissions attributed to the refrigeration and air conditioning (RAC) sector accounted for approximately 3,830 Mt CO_2eq, which account for approximately 11% of the global greenhouse gas (GHG) emissions, with approximately 50% of the emissions attributed to space cooling in buildings (GCI 2013)[8]. Continued low levels of energy efficiency of buildings and appliances as well as high leakage rates of refrigerant gases with high global warming potential in combination with activity drivers such as population increase and wealth growth are responsible for these high and steadily increasing emission levels.

[7] Please note that the terms single-split AC and room AC are used interchangeably in this paper. If not otherwise stated, split AC refers explicitly to single-split AC which is non-ducted.

[8] These figures were estimated by means of top down estimates based on an assessment of global RAC based emissions and estimated country emissions reflecting country specific factors (climate, GDP, persons, etc.).

To meet the central goal of the Paris Agreement, i.e. holding global mean warming to well below 2°C (2DS) and pursue efforts to limit warming to 1.5°C (B2DS), unprecedented emission reductions and corresponding policy action is required.

IEA suggests that for a 2DS, buildings-related emissions would need to be 85% lower in 2060 compared to a baseline scenario that considers existing commitments, such as the Nationally Determined Contributions (NDCs), by countries under the Paris Agreement. Under the B2DS, buildings-related emissions are 56 Gt CO_2 (cumulative) lower than in the 2DS to 2060, including 32 Gt CO_2 of additional reductions in direct emissions from fossil fuel use in buildings (IEA, 2017).

It should be noted that the IEA climate mitigation scenarios rely on negative emissions during the second half of this century, and that without these assumptions emission mitigation will have to take place much earlier both under the 2DS and B2DS scenario (van Vuuren *et al.*, 2018).

To achieve the required buildings-related emissions reductions, average building envelope performance needs to improve by 30% by 2025 and annual deep energy renovations[9] across the global buildings stock needs to increase from currently 1% to 2% of existing stock per year to more than 3% per year in 2025. In addition, global electricity consumption in buildings for appliances and equipment needs to be halved from the current 3% increase per year over the last decade to a 1.5% annual increase by 2025, and coupled with a decarbonization of the electricity sector by 2050 (IEA, 2017). In this context, there is a need for early and rapid investment to prevent locking in carbon intensive technologies (Climate Bonds Initiative, 2016). While spending on energy efficiency in heating, ventilation and air conditioning (HVAC) appliances increased by 17% in 2017 compared to the previous year, spending on building envelopes, the largest component of expenditures in buildings, dropped globally by 3% in the same period (IEA, 2018b).

A transition to low-carbon cooling is only possible when adopting an integrated approach where improved building envelopes, to reduce the need for cooling in a first place, are realized in parallel with the market transformation to low GWP refrigerants and energy-efficient RAC appliances. Additionally, the electricity supply for cooling appliances has to be sourced increasingly from renewable energy sources, with buildings offering an important space for direct integration of electricity generation from renewable energy (sector coupling) which should be combined with improved building envelopes (IEA, 2013a).

However, current policies and investments in building energy efficiency are not on track to achieve emission levels compatible with 2DS or even B2DS. Nearly two-thirds of countries still do not have any **building performance standards** in place and a similar share of energy-consuming equipment in buildings globally is not covered by **mandatory energy efficiency policies** (IEA, 2017). In addition, in many countries that introduced energy performance standards for buildings or appliances, these standards are often not ambitious enough, outdated or not adequately enforced.

The demand for space cooling is expected to triple between 2010 and 2050 by applying current construction methods and cooling technologies which will lock-in unnecessary emissions for a long time. Thus, the priority for countries with hot climates, such as Grenada or other Caribbean Community

[9] Cost analysis shows that deeper retrofits are more economically viable with a longer-term perspective (to 2050) compared to shallower performance retrofits. This analysis included possible energy reductions on the order of 80% to 85%. The initiative Renovate Europe for instance is calling for a 60% to 90% reduction in existing building energy consumption, with an average improvement of 80% (IEA, 2013b).

(CARICOM)[10] countries, should be the introduction and enforcement of ambitious building and RAC appliance standards, which together carry a considerable GHG mitigation potential turning these sectors into a key element for country's implementation of NDCs (IEA, 2013b). Figure 1 presents a regional map with all CARICOM member states.

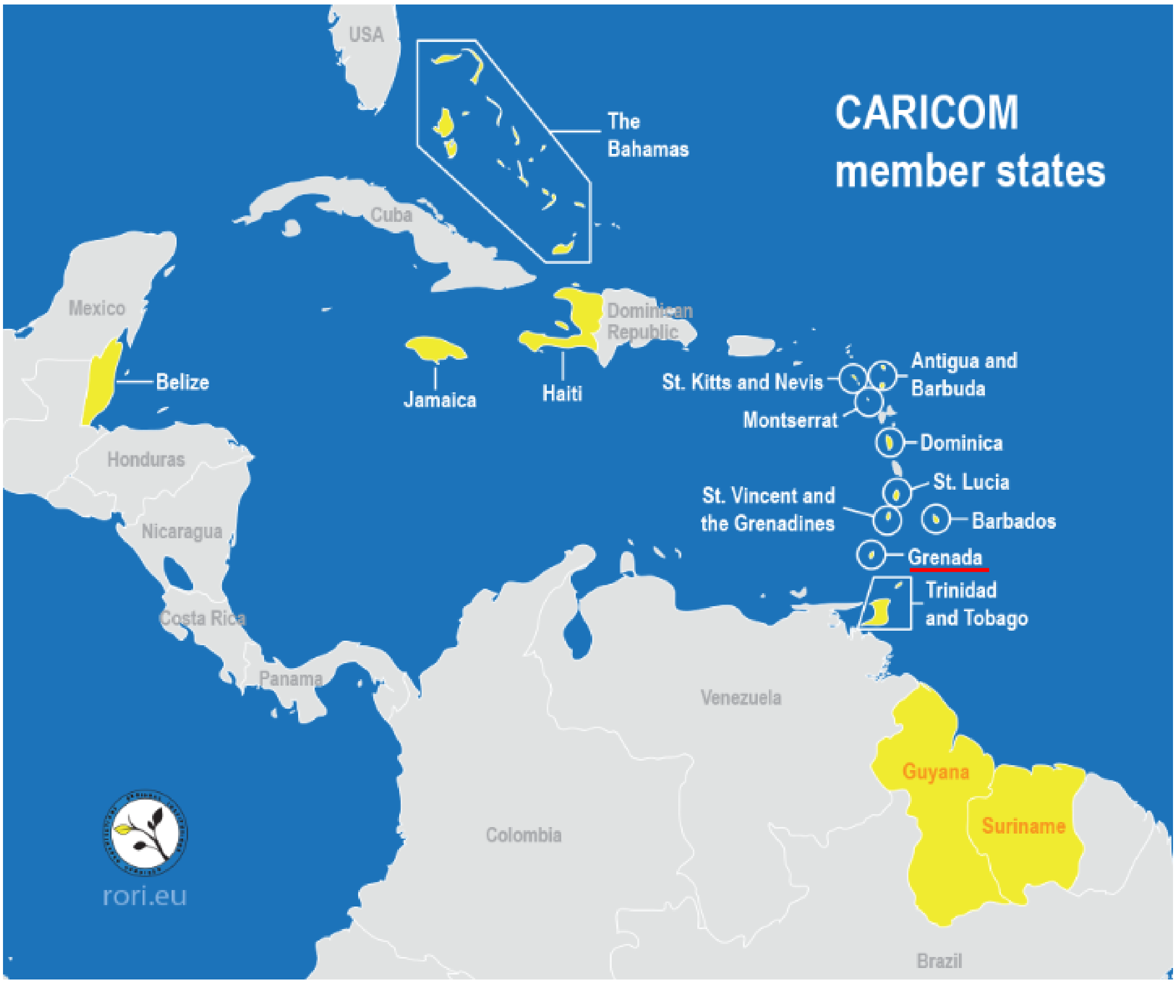

Figure 1. Regional map with all CARICOM member countries marked in yellow (CARICOM, 2019).

Regional trends in CARICOM countries

The total energy consumption for space cooling in selected CARICOM countries is estimated to amount to 3.4 TWh in 2016, which is projected to grow by about 180% until 2030 and up to 250% until 2050 (GCI, 2013). Out of the overall RAC emissions in the selected CARICOM countries, approximately 40% stem from the building sector. This share is expected to increase to 50% or more in average by 2050 (GCI, 2013). Table 1 provides a summary of GHG emissions associated with space cooling for a set of CARICOM countries. Grenada is one of the relatively sparsely populated countries within the set of CARICOM nations. Therefore, its share of emissions in the CARICOM region is low. However, Grenada has one of the highest per capita GHG emission levels for space cooling, which can be explained by the

[10] The Caribbean Community (CARICOM) is an organisation of fifteen Caribbean nations and dependencies: Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, St Kitts and Nevis, St Vincent and the Grenadines, Suriname, Trinidad and Tobago. CARICOM's main objective is to promote economic integration and cooperation among its members, to ensure that the benefits of integration are equitably shared, and to coordinate foreign policy.

country's comparatively high GDP per capita growth rates in the region (World Bank, 2018). The GHG emissions for space cooling are assumed to still undergo a sharp increase, from currently 0.66 to 1.07 t CO_2eq per capita in 2030 and up to 1.56 t CO_2eq per capita in 2050. Likewise, Grenada's unitary air-conditioning (UAC) share of total RAC emissions is expected to grow above regional (CARICOM) average.

Table 1. Current and projected annual GHG emissions under the business as usual scenario from space cooling* (UAC; chillers not included).

Category	**Emissions (kt CO_2eq)**			**Emissions per capita (t CO_2eq)**		
Country \ Year	2016	2030	2050	2016	2030	2050
CARICOM *(selection as below)*	2,644	4,612	6,354	0.42	0.63	0.87
Bahamas	236	380	514	0.60	0.86	1.08
Grenada	**69**	**119**	**171**	**0.66**	**1.07**	**1.56**
Haiti	1,060	2,270	3,530	0.10	0.18	0.25
Jamaica	568	872	1,050	0.20	0.30	0.39
Trinidad & Tobago	711	964	1,060	0.53	0.70	0.82

**Only emissions from UAC were considered for this analysis, fuel mix for power generation and thus all grid emission factors were assumed to remain constant; based on GIZ Proklima / HEAT, 2019 for Grenada, others from Green Cooling Database (GCI, 2013); population figures taken from online source*[11]

2 GHG impact and mitigation potential of space cooling in Grenada

In Grenada, the residential and commercial sectors accounted for about 53% of final energy consumption in 2013 (Espinasa *et al.*, 2015), most of which is attributed to the building sector. An energy audit in the CARICOM region for a number of building types including hotels, public offices and schools as well as residential buildings has shown that air conditioning accounts for 48.1% of buildings' energy consumption (GIZ, 2016). The share of building energy used for cooling was also assessed for selected public buildings in Grenada as part of the National Energy Audit Initiative (NEAI) in 2012 (Roden *et al.*, 2012) and gave even higher results ranging from 60% (St. George's University) to 71% (Ministry of Education complex). From this, it can be concluded that cooling represents the most important energy use for all types of air-conditioned buildings in Grenada.

The building sector in Grenada

According to estimates by the national RAC GHG inventory (GIZ, 2020), space cooling of buildings in Grenada[12] caused GHG emissions of 0.067 Mt CO_2eq in 2014 (direct and indirect emissions), corresponding to 16% of total national GHG emissions in 2014. Indirect, energy-related emissions alone were estimated at 0.055 Mt CO_2eq in 2014 and represent a share of 19% of national GHG emissions

[11] https://www.populationof.net/grenada/

[12] Based on UAC only, contribution by air-conditioning chillers is marginal (< 10%)

caused by energy use and domestic transport in 2014 (Government of Grenada, 2017)[13]. As shown in Figure 2, indirect energy-related emissions (excluding direct, refrigerant-related emissions) from the building sector are projected to increase under a *low ambition scenario* by 105% until 2030 and to peak by 2042. By 2050, emissions from the building sector will be 121% higher compared to 2015 levels. This emissions trajectory corresponds to 0.15 Mt CO_2eq/year in 2030 and 0.16 Mt CO_2eq/year in 2050. Of all energy-related emissions from space cooling in 2050 (2030), 72% (51%) originate from new buildings, 16% (43%) from old buildings and up to 11% (6%) from renovated buildings[14]. Electricity demand for space cooling increases significantly, by 186% between 2015 and 2050, accounting for 336 GWh in 2050. Of this demand, new buildings account for 70%, and old and renovated buildings for 18% and 12%, respectively. Projections are based on a set of assumptions[15] on the current energy performance of buildings, introduction of minimum energy performance standards (MEPS) for buildings, renovation and demolition rates, the increased use of air conditioning, as well as the power generation mix. As an effect of growing GDP and higher living standards, the share of floor space being cooled is assumed to reach 95% by 2050. Compared to the current levels of 10% and 90% in the residential and commercial sector, respectively, this increased use of air conditioning is one of the main reasons for the rise in emissions. The national electricity grid is assumed to experience an increased share of installed renewable energy capacity following historic trends between 2012 and 2018 (Grenlec, 2018a). This results in a decreasing grid emission factor, which contributes together with the introduction of MEPS as well as the renovation and demolition of existing buildings to a decline in emissions after they have peaked around 2040. A decreasing grid emissions factor is essential for decarbonizing the building sector, but implies challenges to the power supply, as a growing demand for electricity has to be met with a larger installed renewable energy capacity for power generation.

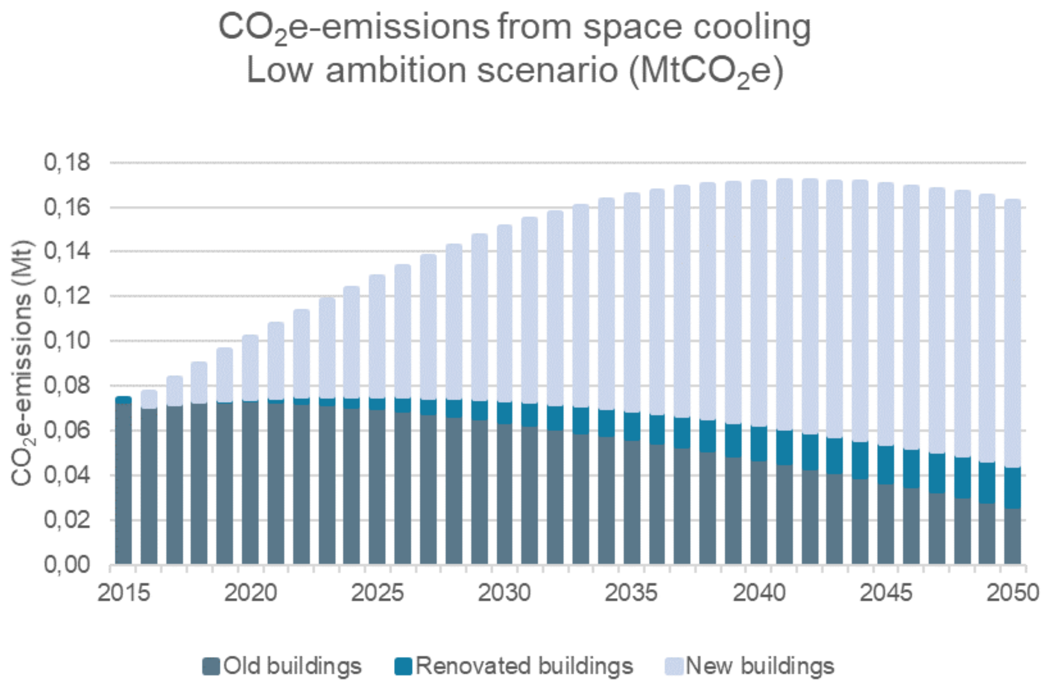

Figure 2. Projected aggregated CO_2-emissions from residential and commercial buildings in the low ambition scenario.

[13] National data as per Second National Communication: 406.6 kt CO_2eq total GHG emissions in 2014, thereof 285.5 kt CO_2eq GHG emissions by energy use including domestic transport.

[14] Old buildings refer to all existing buildings before the base year (2015), while new and renovated buildings refer to buildings that have been built or renovated after the base year. Renovated buildings refer to the energy efficiency refurbishment of old buildings through the replacement of materials and appliances.

[15] See Annex I for a comprehensive list of assumptions and Annex II for further scenario results.

Under the *low ambition scenario,* the analysis assumes that MEPS are introduced in 2030 to gradually enhance ambition towards 2050, when all new buildings should be net-zero energy buildings (nZEB) (see Box 1 for further explanations). As for the old building stock, it is assumed that 1% of the old stock is demolished annually, while renovation rates are used that are typical for the Latin American and the Caribbean region, reaching 1.5% of original stock annually in 2025 (GBPN, 2012). Like new buildings, renovated buildings are assumed to reach nZEB standards by 2050. Lastly, it is assumed that all space cooling is powered by electricity, originating either from the national grid or from onsite rooftop solar PV, depending on the building type. It is important to mention that this scenario does not represent a projection based on current policies but exemplifies a hypothetical scenario that orients itself along global trends.

Box 1: Net-zero Energy Buildings in Hot and Humid Climates

A nZEB in our projections is defined by good practice examples in tropical climates (Ürge-Vorsatz and al., 2012). Accounting to this source, residential nZEB buildings typically consume 17 kWh/m^2/year while the corresponding demand for commercial nZEB is 25 kWh/m^2/year (Ürge-Vorsatz and al., 2012) for cooling*. The electricity demand for space cooling is reduced by minimizing heat transfer by installing shading systems, insulating walls and glazed as well as insulated windows. Secondly, efficient ACs can reduce the energy demand for cooling, combined with active ventilation and heat exchanger systems (to reduce heat losses through ventilation and to ensure a comfortable room climate), as there may be less natural ventilation from the insulation of walls (IEA, 2018a).

Once energy efficiency measures are applied and the energy demand has been minimized, the remaining electricity demand can be met by onsite rooftop solar PV, to further reduce emissions. By doing so, the building is independent in terms of power production and can therefore be defined as a building with net-zero energy consumption. As the power supply origins from renewable sources, the resulting emission factor will be zero.

* The nZEB definition is based on hot climates in the LAC region. In certain areas, there may be physical and technical limitations to achieve the maximum technical potential upon which the nZEB definition is based. A more detailed analysis considering national conditions on such limitations should be conducted for a more accurate nZEB definition.

As can be observed in Figure 3, the combined assumptions lead to an increased aggregate energy use for space cooling, despite the gradually replacement of low performing old buildings. As a result, energy demand for space cooling increases towards 2045 to remain stable between 2045 and 2050, while emissions slowly decrease. However, the annual renovation rate of 1.5% is not enough to completely replace the old building stock by 2050. The latter is relevant for Grenada’s NDC, which includes the retrofitting of all buildings, without specifying a timeframe, as one of the main energy efficiency measures (Government of Grenada, 2015).

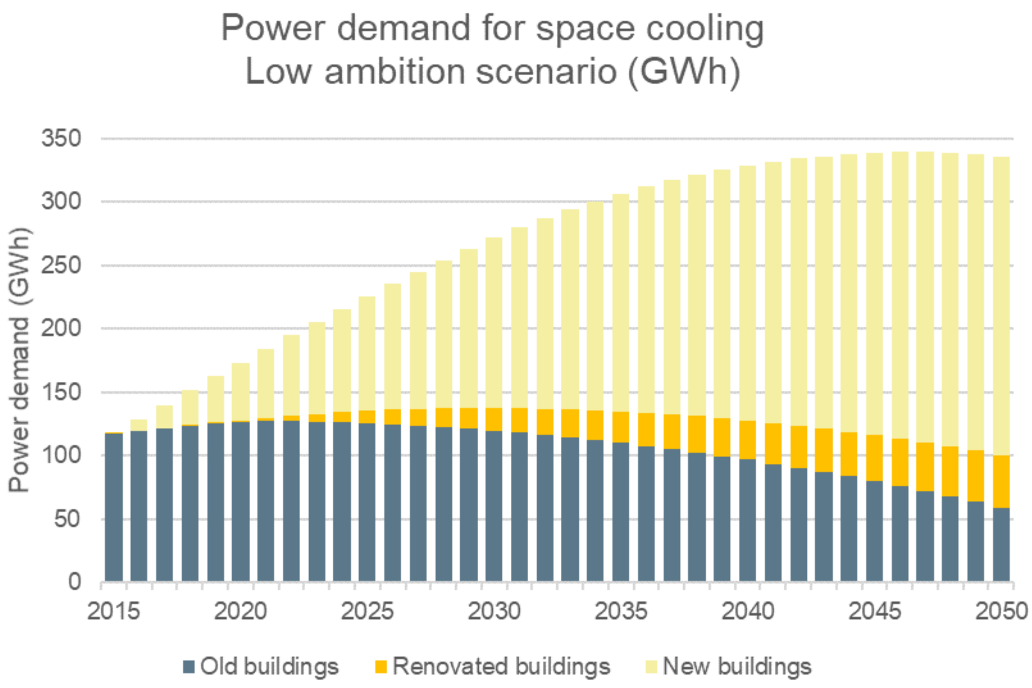

Figure 3. Projected power demand for space cooling of commercial and residential buildings in the Low ambition scenario.

The RAC sector in Grenada

According to estimations based on collected data from primary and secondary data sources, Grenada's RAC sector was responsible for GHG emissions about 0.13 Mt CO_2eq in 2017 including emissions from refrigerant and energy use (GIZ, 2020). The total national greenhouse gas emissions in Grenada amounted to 0.41 Mt CO_2eq in 2014 (Government of Grenada, 2017) , leaving a share of approximately 29% to the RAC sector[16].

With the predicted growth of RAC appliances[17], the GHG emissions from the RAC sector are expected to increase from currently about 0.13 Mt CO_2eq (2017) to 0.19 Mt CO_2eq in 2030 and up to 0.23 Mt CO_2eq in 2050 (Figure 4), if unabated. The growth of appliances has been extrapolated based on past growth patterns, population and household growth, GDP growth, urbanization and ownership saturation factors.

[16] Referring to total RAC emissions (direct and indirect) of 119 kt CO_2eq in 2014

[17] Modelled along economic and populational growth projections under consideration of local RAC stakeholder expertise

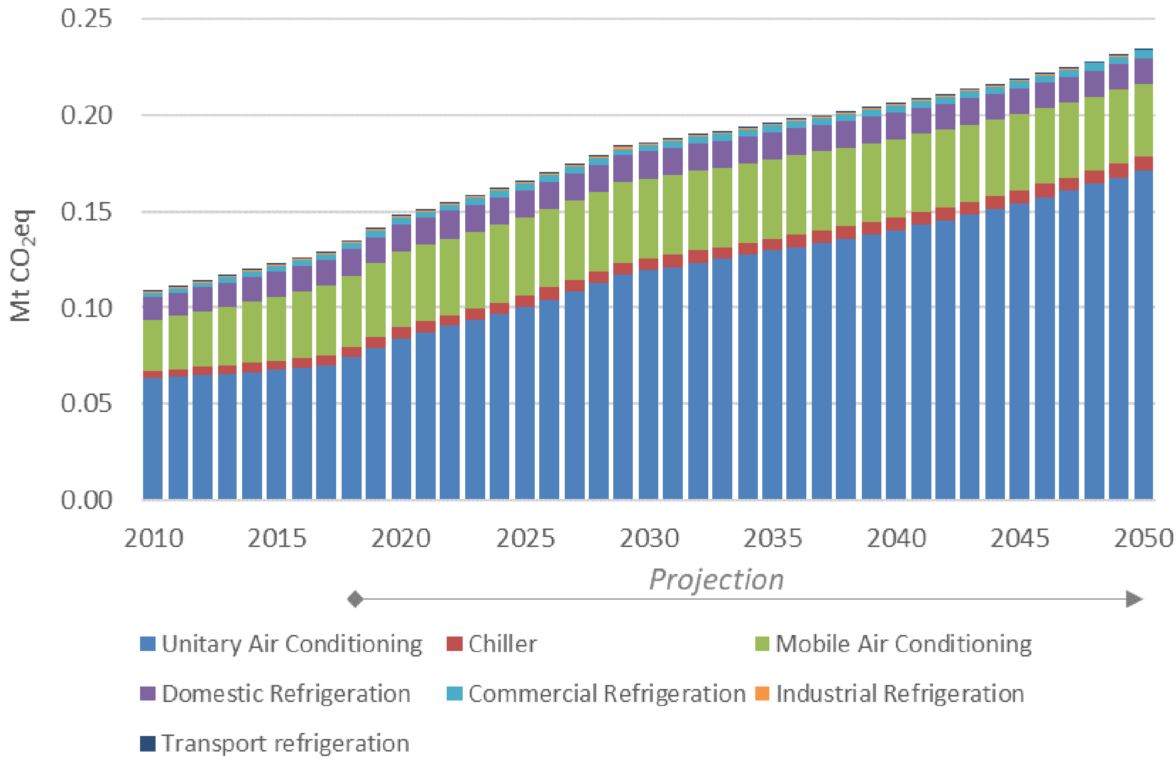

Figure 4. Emissions from Grenada's RAC sector (in Mt CO_2eq) (Based on GIZ, 2020[18]).

The electricity consumption in Grenada's RAC sector amounted to 113 GWh in 2013, which makes 64% of the total national electricity consumption (176 GWh), according to the Inter-American Development Bank (2015). With an estimated electricity consumption of 87.3 GWh in 2013, UAC alone contributed approximately 50% to Grenada's total electricity consumption, thereby representing a key subsector for decoupling GHG emissions from a growing cooling demand.

Relevant policy intervention areas for energy efficiency in buildings and for appliances

To decouple the growing demand for space cooling in buildings from energy consumption and GHG emissions, the following four complementary and interdependent options are analyzed:

First, **upgrading building envelope**[19] through ambitious and mandatory building standards. The building envelope is critical to reduce the energy required to cool a building (i.e. the cooling load) and thus affects the size and type of cooling appliances needed.

Second, **increasing energy efficiency of RAC appliances** through more ambitious energy performance standards and their enforcement. This is of high relevance as RAC appliances consume electricity, resulting in large amounts of CO_2 emissions (indirect emissions).

[18] The distribution of refrigerant types in the UAC subsector was adjusted from 2020 onward as per recent information by NOU.
[19] Upgrading the building envelope encompasses inter alia to achieve high-levels of insulation in walls, roofs and floors, the adoption of high-performance windows and highly reflected surfaces as well as properly sealed structures and minimisation of thermal bridges (IEA, 2013b).

In order to reduce emissions from the use of RAC appliances further, full decarbonization of the energy supply is essential. However, this consideration is out of the scope of the building and appliance sector.

Third, **replacing high-GWP refrigerants with natural refrigerants** as most of the appliances use fluorinated gases – HCFCs or HFCs – as refrigerants to transfer the heat. As these gases leak – for example during servicing or when an appliance is scrapped – they cause substantial emissions as well (direct emissions).

Fourth, **best practice in the handling of refrigerants**, comprising the strengthening of capacities and certification of RAC technicians as well as the establishment of organized waste streams for refrigerants. As appliances using fluorinated gases are locked in for at least 10 more years, the mid-term effect by improved refrigerant handling will be significant (direct emissions).

3 GHG mitigation options for Grenada's NDC

In September 2015, Grenada's government submitted its Intended Nationally Determined Contributions (INDCs) to the UNFCCC, committing to undertake GHG emissions reductions of 30% of the 2010 level by 2025 and an indicative reduction of 40% of 2010 emissions compared to the BAU scenario by 2030[20]. Grenada ratified the Paris Agreement in April 2016, confirming its INDC as its first Nationally Determined Contributions (NDC)[21]. The NDC specified the following sector contributions, naming forested areas as the focus (Government of Grenada, 2015):

- Electricity: 30% reduction by 2025, therein 10% from renewables and 20% from energy efficiency measures; the latter considering:
    - retrofitting of all buildings (20% reduction),
    - establishment of policies for energy efficiency building codes for all building sectors (30% reduction) and
    - implementation of energy efficiency in hotels (20% reduction)
- Transport: 20% reduction by 2025
- Waste: reduce methane emissions from waste by 90%, by controlled (or capped) landfill
- Forestry: increase protected area to 17% of Grenada's terrestrial area (currently 11% of its forested area is protected)

Grenada has included fluorinated gases, as the only new greenhouse gas added to the NDC update from 2020.

According to NREL (2015), several policies and programs have been implemented to help meet ambitious energy efficiency goals and to become 100% renewable by 2030, including demand-side energy efficiency programs and the Government Energy Efficiency Program, which targets a 10% reduction in government electricity use.

Grenada's past and current adaptation actions have been formulated in the National Climate Change Policy and Action Plan (NCCPAP 2007-2011), which is currently being reviewed. Moreover, Grenada's Cabinet has already approved the National Climate Change Adaptation Plan (NAP) 2017-2021, which sets out a number of measures to mitigate against the impact of climate change in key sectors.

[20] The Intended National Determined Contributions were communicated to the UNFCCC on 30 September 2015. The mitigation contribution has been formulated based on the assumption that the related costs will be covered through access to multilateral and bilateral support including through the Green Climate Fund, multilateral agencies and bilateral arrangements with development partners conditioned on the extent of financial resources, including technology development & transfer, and capacity building, that will be made available to Grenada.
http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Grenada/1/Grenada%20INDC.pdf

[21] UNFCCC registry: https://unfccc.int/process/the-paris-agreement/status-of-ratification

For the refinement and further setting of NDC sector targets, sectoral lead agencies should present mitigation options based on existing and planned sector policies and programs.

The consideration of mitigation options related to energy efficiency in buildings coincides with the relevance of GHG emissions related to this sector on one hand and the overall GHG emissions reduction target on the other hand. This is also in line with global trends, where some progress towards realizing the untapped potential in the global buildings sector has been seen since the Paris Agreement in 2015, as for instance nearly 90 countries have registered building actions in their NDCs (IEA, 2017).

In addition, the government of Grenada expressed its willingness to reduce GHG emissions from the RAC sector with agreeing to the Kigali Amendment to the Montreal Protocol during the 28th MOP in Kigali in October 2016. Under the Kigali Amendment, Grenada's government commits to freezing HFC consumption from 2024 and then gradually phasing down the use of HFCs after 2028. In May 2018, Grenada became the 37th country among the 197 Parties to the Montreal Protocol to ratify the Kigali Amendment[22]. HFCs were not yet covered in the scope of gases in Grenada's NDC in 2015, but f-gases have been added to the revised NDC of 2020.

Technical GHG emissions reduction potential per policy intervention area

(1) Upgrading of building envelopes

Since energy efficiency of building envelopes is the most important factor that affects the energy consumed by cooling equipment, optimizing building envelope design should be a key part of any energy use reduction and consequently climate change mitigation strategy (IEA, 2013a). The level of energy efficiency of a building is commonly expressed in energy consumption per square meter of floor area per year (kWh/m^2/year) and measured against energy consumption benchmarks which vary according to building type and climatic condition (UNIDO/REEEP, 2008).

As a result of globally growing coverage of building energy codes, the average energy intensity of the global buildings stock decreased by nearly 33% from 225 kWh/m^2/year in 1990 to roughly 150 kWh/m^2/year in 2014, despite growing ownership of energy-consuming equipment and paralleled by the doubling of total floor area since 1990 (IEA, 2017). The IPCC and the Global Alliance for Buildings and Construction set out targets in the range of 15-30 kWh/m^2/year for hot and humid climates deploying available and often cost effective technologies (Lucon *et al.*, 2014; GABC, 2016).

An *enhanced ambition scenario,* shaped around current international best practice examples and technology, will result in 62% lower emissions from the building sector by avoiding around 0.10 Mt CO_2eq of energy-related emissions in Grenada's building sector in 2050 compared to the *low ambition scenario*, which corresponds to a 16% decrease compared to 2015 levels. As observed in **Error! Reference source not found.**, 81% of total energy-related emissions for space cooling in 2050 origins from new buildings while renovated buildings are responsible for 19%.

Emissions will peak in 2027, after which emissions from new buildings remain almost constant while emissions from renovated buildings still increase. After the peak, total energy-related emissions decrease at a high pace until the old building stock is fully renovated, which stresses the importance of renovating old buildings for untapping the emissions reductions potential. As a result of an ambitious renovation rate, the old building stock is completely renovated by 2047, in line with the target mentioned in the country's NDC. A renovation policy package should ideally be a mix of the following key themes: regulatory measures with binding but dynamic short to long-term national as well as building type specific targets in terms of CO_2 or energy savings; mandatory code requirements and ambitious labelling schemes; financial instruments such as incentive schemes and taxation mechanisms; economic

[22] https://www.ecacool.com/en/news/kigali_grenada_propane_ac/ (accessed on 02 October 2019)

instruments such as utility-funded programs; capacity building and awareness raising campaigns as well as the compilation of a database on building typology and characteristics and the identification of consumer behaviour and energy saving opportunities (GBPN, 2015). All these policy instruments should relate to the specific political, economic and social situation in Grenada.

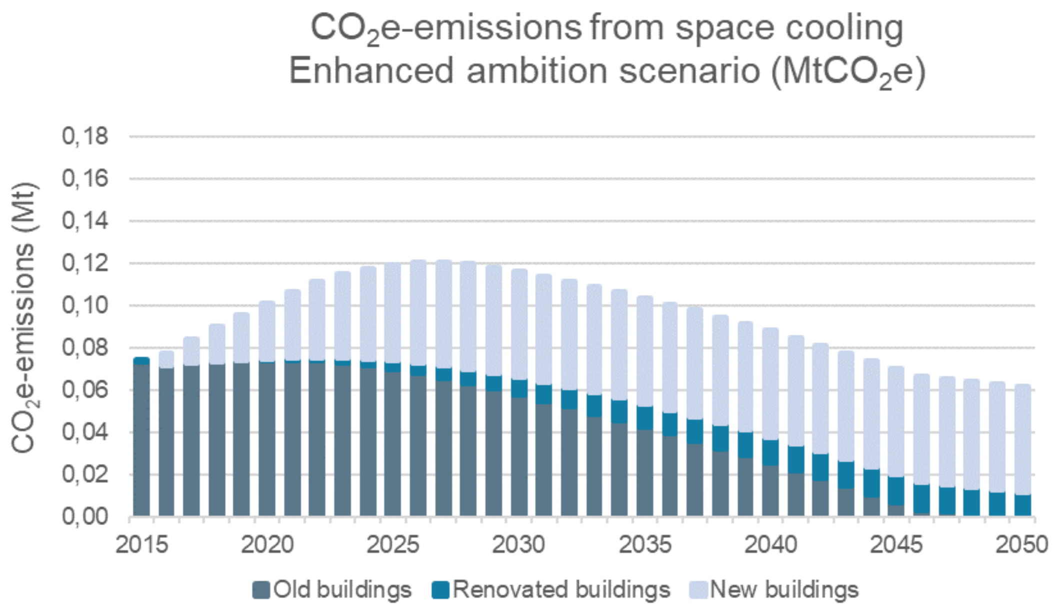

Figure 5. Projected aggregated CO_2-emissions from residential and commercial buildings in the Enhanced ambition scenario.

As Figure 6 shows, the power demand for space cooling increases by 65% between 2015 and 2050, accounting for 194 GWh, which is a 42% reduction compared to the *low ambition scenario*. This increase in aggregated power demand is to a large extent an effect of growing demand for air conditioning, combined with an increasing floor space per capita. The significant share of emissions and energy demand from new buildings is partly due to the poor energy performance of buildings constructed in the early 2020s, before ambitious policies have been put in place. This drives a lock-in effect, causing higher emission throughout the whole time period, due to the long lifetime of buildings.

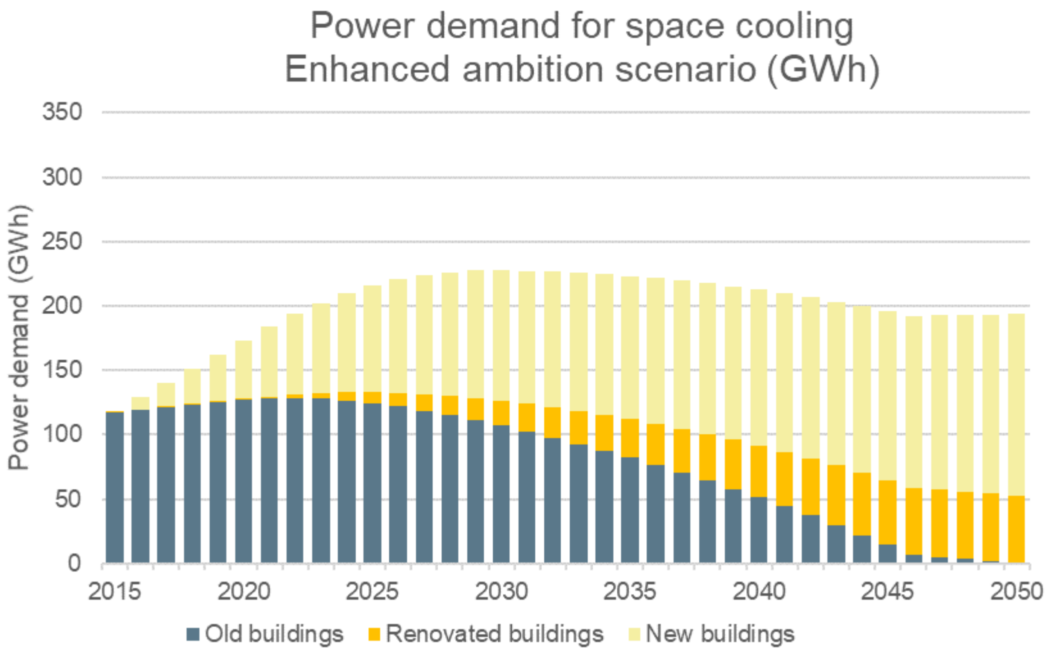

Figure 6. Power demand for space cooling of commercial and residential buildings in the Enhanced ambition scenario.

An early introduction of mandatory MEPS put into force in 2022, which are regularly updated and strengthened, aims at increasing the share of nZEB in new buildings to 100% in 2030. With regards to the renovation of old buildings, it is assumed that by 2030, 3% of the existing stock is renovated annually. This level of ambition is based on current recommended renovation rates in the Netherlands (Filippidou, Nieboer and Visscher, 2017; Filippidou *et al.*, 2018) and assumes a successful implementation of a renovation policy package, as described above. There are, however, uncertainties with regards to the balance between demolition and renovation of the old building stock – depending on the state of old buildings, it may be more efficient to demolish and build new buildings instead of performing a renovation. The energy performance of renovated buildings is gradually improved and reach best-practice standards already in 2030. In addition to energy efficiency improvements for new and renovated buildings, ambition is enhanced through the gradual equipment of all buildings with rooftop solar PV. The latter is in line with Grenada's target to achieve 100% renewable electricity by 2030.

The reduction of emissions from new buildings, both from the residential and commercial sector, are achieved through ambitious stepwise improved mandatory MEPS for new buildings (Figure 7 and Figure 8), combined with the gradual installment of rooftop PV on all buildings. Based on recommendations from the report on 'Development of MEPS for Public and Commercial Buildings in CARICOM Countries', MEPS are improved every 3 years assuming full compliance, reaching nZEB standards by 2030 (GIZ, 2016). For the residential sector, this means an introduction of MEPS of 45 kWh/m^2/year in 2022 which is updated again in 2025, 2028 and 2030.

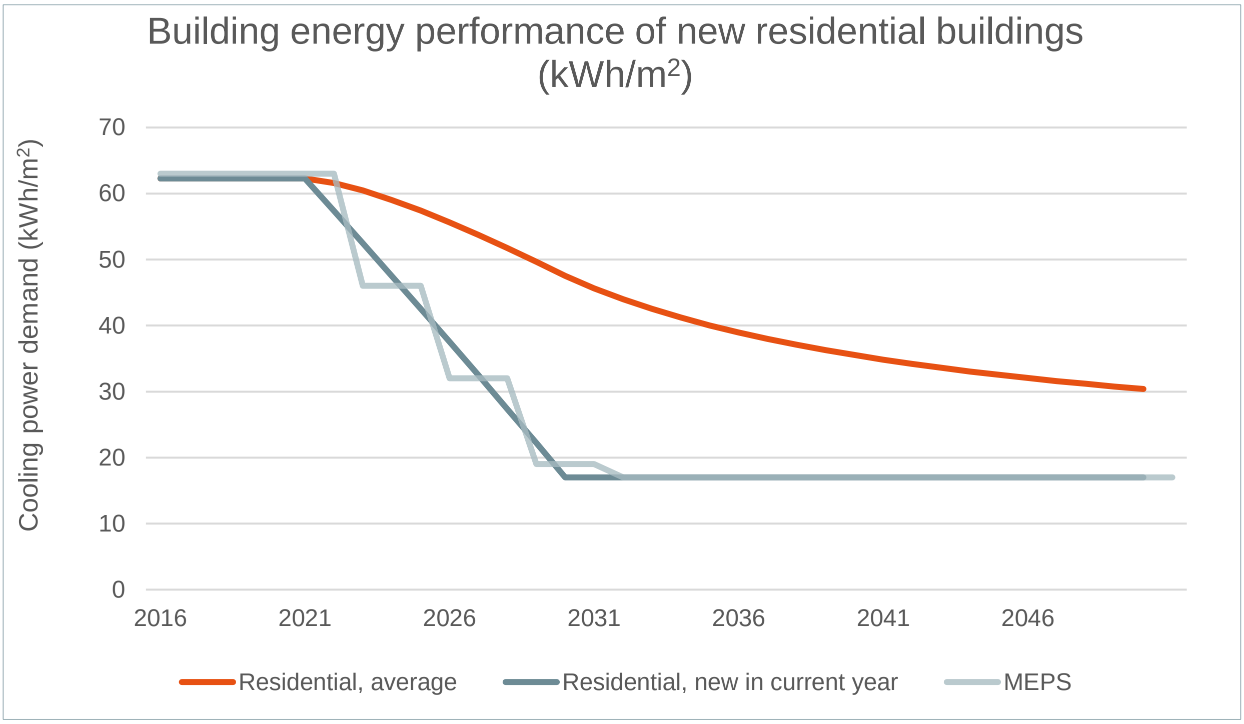

Figure 7. Energy performance per square meter for new residential buildings in the Enhanced ambition scenario.

A similar pathway is suggested for the commercial sector which faces a greater challenge as the energy demand for commercial buildings generally is higher; starting from 92 kWh/m^2/year in 2022, reaching 25 kWh/m^2/year in 2030.

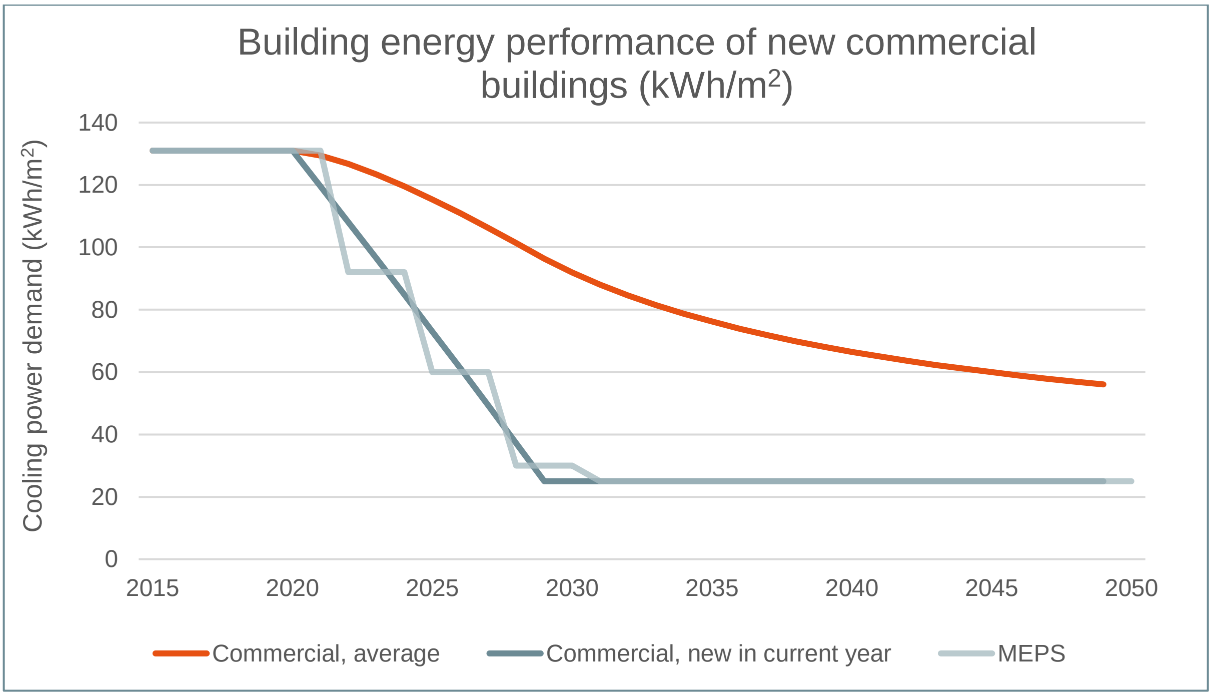

Figure 8. Energy performance per square meter for new commercial buildings in the Enhanced ambition scenario.

Figure 7 and Figure 8 demonstrate the required increase in stringent MEPS for new buildings. It is important to highlight that, if including the old building stock, the average energy performance will be significantly higher. To untap the abovementioned emissions reductions potential, MEPS need to be mandatory and performance based. Ensuring compliances is a precondition to achieve the suggested

pathway. This will lower the lock-in effect from new houses with low energy performance, which would contribute to higher emissions throughout their lifetime unless renovated at a later stage. By using performance-based MEPS, the aspired and technically feasible average energy performance can be ensured.
Based on this analysis, the main steps to untap the abovementioned emissions reductions potential in the building sector are:

- Ensure an early and ambitious introduction of mandatory and performance MEPS to minimize the lock-in effect from new buildings with high energy intensity. By applying best available technology and methods, significant emissions and energy demand reductions can be achieved. The earlier MEPS are introduced, the more emissions from highly energy intensive new buildings can be avoided. In addition, compliance of mandatory standards needs to be ensured.
- Prioritize the renovation of old buildings: As the old building stock is highly energy intensive compared to new good practice buildings, the prioritization of the renovation of old buildings is a prerequisite to achieve the desired level of emissions reductions. For this purpose, an annual renovation rate of 3% of the original stock should be applied. This corresponds to current best practice in other countries and ensures that the entire existing building stock will be renovated by 2050.
- Ensure that buildings are renovated with best available technology to maximize energy efficiency. In addition to the stepwise improved MEPS for new buildings, a similar strategy should be considered for renovated buildings, aiming to reach near-nZEB levels for renovated buildings by applying best available technology by 2030.
- Decarbonize the power supply: Despite the application of best available technology in terms of ventilation, AC, shading and insulation, a certain energy demand will remain to ensure comfortable inside air quality. In the *enhanced ambition scenario*, a growing power demand for space cooling remains as a result of an increasing floor space per capita once the old stock is completely renovated. To target emissions from that remaining power demand, options to decarbonize the power generation mix must be considered. Equipping all new and renovated buildings with rooftop PV will contribute to reduce emissions from space cooling and decrease the pressure on the national power grid.

Achieving net-zero emissions[23] from space cooling is challenging because of the mentioned remaining power demand. Further emissions reductions could theoretically be realized through a more ambitious introduction of rooftop PV on all new buildings as well as all renovated buildings. A limiting factor to such enhancement, which requires further analysis, is the availability of rooftop space[24]. Presently, renewable energy generation in Grenada accounts for a tiny fraction of supply with about 1% from off-grid, i.e. rooftop PV generation. There is still some uncertainty over future regulatory frameworks. While the 2016 Electricity Supply Act was amended in 2017, regulations still need to be updated and implemented to facilitate private investment in renewable plants and to address self-generation and distributed renewable energy (IMF, 2019). Additional improvements in energy efficiency will be difficult to achieve as MEPS will have to be implemented faster than current good practice examples. While this might seem highly unlikely under current circumstances, the diffusion of technology in other sectors (especially renewable energy in the power sector) suggest that this can be achievable through a concentrated effort.

Further barriers linked the realization of the suggested renovation and construction of nZEB are related to financial, technical and social aspects (Karlsson *et al.*, 2013): Upfront costs for an nZEB are usually

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[23] See Annex III for more details on a net zero emissions scenario.
[24] Grenada's renewable resources more than exceed current electric sector capacity. Solar PV in particular has high potential with the country's global horizontal irradiation exceeding 5 kWh/square meters per day and solar PV efficiency continuously improving (NREL, 2015).

higher than those of a standard building and profitability depends on multiple factors such as cost of energy and access to capital. To implement the improvements suggested in this study technical skills and expertise is needed that are at the moment probably inaccessible in Grenada considering the low market penetration of nZEB in Latin America and the Caribbean. Also, as nZEB business models are relatively new, information campaigns are needed to inform prospective buyers that the energy efficiency measures are worth the additional cost. For this purpose, a well-developed Energy Service Company (ESCO) market would be an important instrument. ESCOs provide a broad range of energy solutions including designs and implementation of energy savings projects. To overcome some of the above-mentioned barriers Grenada can justify the need for international assistance to successfully increase the market penetration of nZEB.

(2) Increase energy efficiency of RAC appliances and (3) Shift to low-GWP (natural) refrigerants

The transition towards low-GWP, natural refrigerants will yield lower direct emissions, and simultaneously, allows enhancing energy efficiency of key appliances which results in avoided indirect emissions. Realizing this integrated approach can avoid about 0.022 Mt CO_2eq of emissions in Grenada's RAC subsector annually by 2030 and up to 0.087 Mt CO_2eq in 2050 (adjusted GHG modelling based on GIZ, 2020[25]). The largest share of GHG emissions and related mitigation potential is attributed to the unitary air-conditioning (UAC) subsector, especially split-type air conditioners (> 95% in the UAC market). Figure 9 illustrates the GHG mitigation potential in the UAC subsector distinguished by direct and indirect emission saving potential[26], amounting to annually saved emissions of 3.1 kt CO_2eq (direct) and 16 kt CO_2eq (indirect) in 2030, increasing to 12 (direct) and 59 (indirect) kt CO_2eq annually in 2050. UAC is projected to contribute approximately 75% to the electricity consumption in the overall RAC sector[27] and stands out for an estimated saving potential of 25 GWh annually in 2030, and up to 95 GWh annually in 2050. It is recommended to prioritize mitigation efforts within this subsector and scale up the market share of air conditioners within the highest efficiency label class (according to ambitious mandatory MEPS and label categories) and of AC appliances using low GWP refrigerants to at least 40% in 2025 and 90% in 2030, which would correspond to the estimated emission reductions. Based on an analysis of single-split ACs carried out under the Cool Contributions fighting Climate Change (C4) project both in Grenada and internationally, an ambitious MEPS level for Grenada in year 2022 could be at an Energy Efficiency Ratio (EER) in the range of 3.4 with stepwise increase up to 4.7 in 2030[28].

[25] The distribution of refrigerant types in UAC subsector was adjusted from 2020 onward according to recent information by the National Ozone Unit (NOU).
[26] For UAC, the mitigation scenario is shown below, with the emission reduction potential subdivided in direct and indirect emissions above; the regular BAU scenario is shown for the remaining subsectors, which have relatively low mitigation potential compared to UAC.
[27] Excluding mobile AC and transport refrigeration, as such cooling equipment is currently not driven by electrical power.
[28] in W/W; the analysis carried out as part of the survey suggests a lift of the MEPS will result in lower lifetime costs for end users.

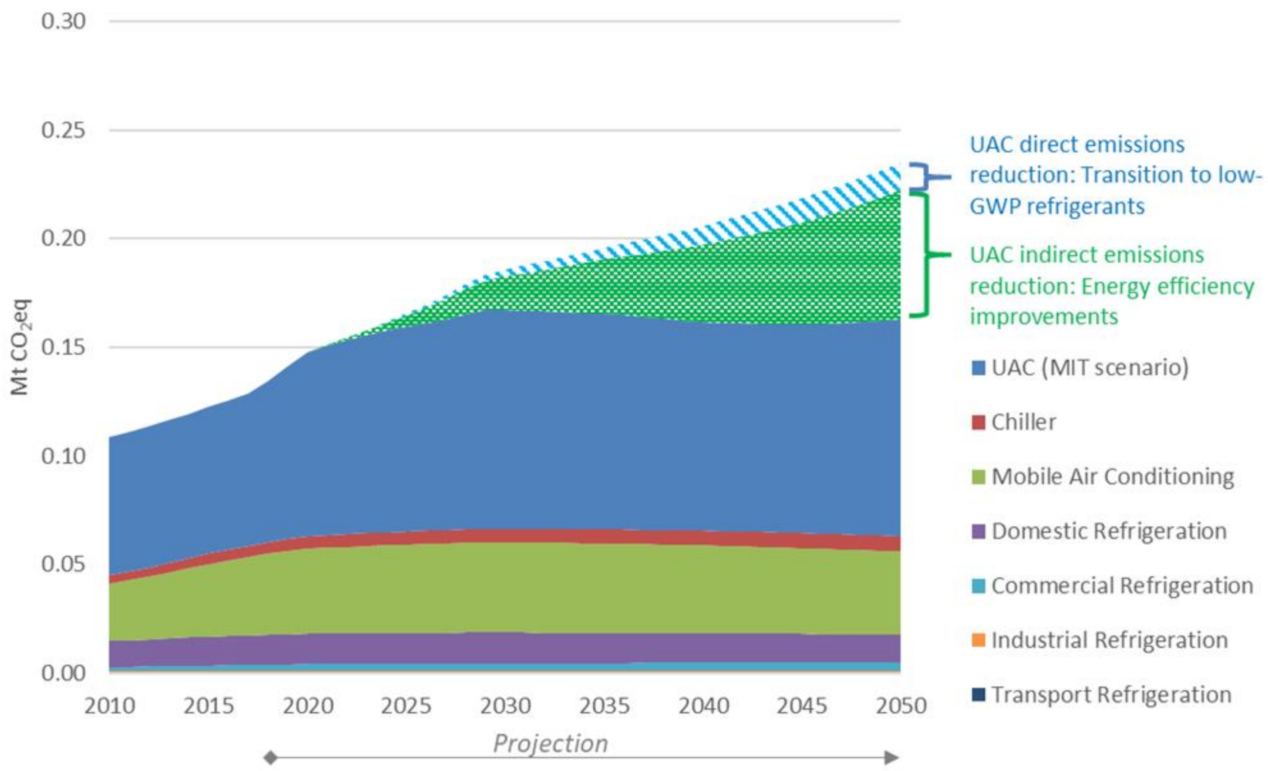

Figure 9. Projected UAC mitigation potential of direct and indirect GHG emissions along with BAU emissions of other RAC subsectors, in Mt CO_2eq (based on GIZ, 2020[29]).

(4) Best practice in the handling of refrigerants

Implementation of best practice in the handling of refrigerants from installation through the entire equipment lifetime and beyond can offset further direct emissions that are caused by leakage. As appliances using fluorinated gases are locked in for at least 10 more years in Grenada's installed base of RAC equipment, the mid-term effect by improved refrigerant handling will be significant (direct emissions).

Description of policy actions

Considering the large share that buildings account for in total national energy consumption, with space cooling representing the most important energy use and thus the largest share within the RAC sector in the country's overall GHG emissions, a successful implementation of specific building and RAC sector policies would present an important opportunity for meeting Grenada's mitigation targets. To maximize climate benefits, it is recommended to follow an integrated approach that combines building and RAC-specific sectoral energy efficiency policies and the transition to low GWP refrigerants.

The recommendations presented in this paper focus on **building codes** and **appliance standards and labels** as evidence has shown that these regulatory policies have been among the most cost-effective policy instruments to untap the mitigation potential related to space cooling in buildings (Lucon *et al.*, 2014).

[29] The distribution of refrigerant types in the UAC subsector was adjusted from 2020 onward as per recent information by NOU.

(1) Upgrading of building performance standards

The way buildings are designed, built and operated has a huge impact on the need for cooling, and the need for energy to provide those services. Once a building is erected, the amount of active cooling needed to provide a given level of thermal comfort is effectively locked in. This makes it all the more important that the thermal performance of a building, including opportunities for passive cooling, is taken fully into consideration when it is being designed, built or renovated (OECD/IEA, 2018). In order to reach 2DS targets building energy intensities need to decrease by at least 80% by 2050 and building envelope improvements to reduce cooling loads will be critical to achieving those ambitions (GABC and UNEP, 2016). Regulatory policy instruments such as building energy codes are effective tools to determine minimum energy efficiency standards for the residential and commercial building sector (CESC, 2016). The fact that Grenada is located in a geographic area prone to the exposure of hurricanes makes compliance with sound building standards for both renovated and new buildings all the more important (International Monetary Fund, 2016).

In Grenada there are two main building code regimes, one established by the Organization of Eastern Caribbean States (OECS) and another one promoted by the Energy Unit of the CARICOM Secretariat:

With assistance from the United Nations Centre for Human Settlements (UNCHS) the **OECS** developed standard building codes and guidelines for its member countries. The original OECS code and guidelines were prepared in 1992 and are based on the Caribbean Uniform Building Code (CUBiC) as well as other regional codes (CEP International, 2003). The code remains essentially uniform across the entire OECS, with only minor amendments made by member countries through additional appendices to provide more specific information on certain topics. The code should become part of each country's regulatory mechanism for ensuring adequate building standards. The 6th Edition of the OECS Building Code, which uses the St Lucia Building Code of 2002 as a base code, covers specifically Grenada together with three[30] other countries (OECS, 2015a).

The **CARICOM Regional Energy Efficiency Building Code (CREEBC)** was developed based on the 2018 International Energy Conservation Code and is a joint effort by the CARICOM Regional Organization for Standards and Quality (CROSQ), the International Code Council and ASHRAE (CARICOM Today, 2018). The CREEBC is meant to meet the specific needs of nations in the Caribbean and other countries with tropical climates. The code primarily intends to improve building efficiency by addressing the building envelope and energy consuming equipment covering both commercial and residential construction. Building energy efficiency is promoted under this code by establishing requirements for the building envelope, cooling systems, ventilation, pumping, lightning, and water heating systems in buildings. In addition, it aims at improving maintenance practices and standardizing the roles and qualification requirements of code officials as well as building professionals (Grenlec, 2018b).

Both codes do not set standards based upon buildings' actual energy use, but instead address individual technologies or design features.

The scenarios presented in this study recommend an early and ambitious introduction of mandatory and performance-based MEPS, i.e. adopting building codes that require buildings to meet certain measurable or predictable performance requirements, such as energy intensity, without a specific prescribed method by which to attain those requirements.

Table 2 presents the recommended step wise improved MEPS suggested under the *enhanced ambition scenario*.

[30] St Vincent & the Grenadines, St Lucia and Montserrat.

Table 2. MEPS distribution for residential and commercial sector under the enhanced ambition scenario.

MEPS distribution (kWh/m²/year)					
Scenario	**Sector**	**2022**	**2025**	**2028**	**2031**
Enhanced ambition	Residential	46	32	19	17
	Commercial	92	60	30	25

Table 3 gives an overview of the recommended renovation rates and their results under the *low* and *enhanced ambition scenario*.

Table 3. Renovation rates and characteristics under the enhanced ambition scenario as well as under the low ambition scenario for reference.

Renovation rates[31]					**Renovation characteristics**	
Scenario	**2022**	**2025**	**2028**	**2030**	**Old stock replaced** (year)	**Deep renovation reached** (year)
Enhanced ambition	1.5%	2.4%	2.9%	3.0%	2046	2030
Low ambition	1.2%	1.5%	1.5%	1.5%	Beyond 2050	2041 - 2045

The introduction of ambitious MEPS as well as the replacement of the old building stock through deep renovation measures are faced with several barriers. Table 4 gives an overview of barriers and related potential interventions to improving energy efficiency in buildings.

Table 4. Barriers and proposed interventions related to energy efficiency in buildings.

BARRIERS/ CHALLENGES	PROPOSED INTERVENTIONS	ACTION TAKEN/ NEXT STEPS
Knowledge and information barriers.	Reduce uncertainties about performance of buildings, potential energy savings and market development of more energy efficient buildings.	• Inform actors about cost-effective options for energy efficiency improvement in buildings through MEPS for buildings. • Implement demonstration project using, e.g. public buildings to highlight the adequacy, feasibility and cost-effectiveness of energy efficiency measures and onsite rooftop solar PV in buildings.
The financing cost associated with the implementation of energy efficient solutions required to meet the MEPS may prove to be a difficult hurdle for low income population.	Provide financial relief through adequate support policies and (international) financial instruments.	Implement policies in conjunction with MEPS for buildings to reduce costs and improve access to energy efficiency measures in the building sector, such as removal of duties and taxes.
Institutional barriers including lack of institutional capacity in key agencies and resource constraints as well as a corresponding lack of effective enforcement and inspection of standards and procedures.	Create an enabling institutional environment to ensure effective policy implementation.	Put in place a proper institutional framework by, for example, creating a government agency (building inspectorate) tasked to control, enforce, monitor and evaluate the implementation of MEPS for buildings.

[31] The renovation rate is given as the share of the original old stock that is renovated in the current year.

Lack of skilled engineers, architects and building professionals.	Increase access to knowledge about energy efficiency standards for buildings.	Provide targeted trainings and introduce building codes and guidelines as part of the curriculum of technical and vocational colleges.
Lack of economy-specific data on building stocks and construction to ensure compliance with MEPS.	Establish statistical data through regular mandatory energy audits & reporting of buildings and their cooling systems.	Establish a monitory system tracking the data per m^2 of new or renovated buildings.
Overall performance requirements, e.g. for energy efficiency, are difficult to claim as the current building codes are prescriptive codes, which mandates specific construction practices but provides no target energy use levels for a building as a whole.	Adjust the building codes to an extent that buildings are required to meet measurable performance requirements, e.g. for energy efficiency.	Discuss potential to convert building codes into a performance-based code in the scope of the next regular revision of the code.
Large amount of informal housing not covered by building codes in place.	Identify opportunities to ensure minimum energy performance standards for informal housing.	Increase coverage of existing building codes to also address informal housing or define other appropriate mechanisms to improve such housing.

Source: (Jones, no date; OECS, 2015b; Energy Dynamics Ltd, 2016)

It is worth mentioning that no single policy is sufficient to achieve the potential energy savings in buildings and evidence shows that only a combination (package) of policies can have results that are bigger than the sum of the individual policies (Lucon *et al.*, 2014). Thus, building codes should be complemented by a set of other information measures and economic instruments such as sustainable public procurement, building labels and certificates as well as financial incentives, like grants, subsidies or preferential loans, to meeting certain efficiency standards when constructing or renovating buildings. The specific policies, regulations, programs and incentives needed are highly dependent on the product, market structure, institutional capacity, and the background conditions in each country.

(2) Increase energy efficiency of UAC appliances

The introduction of mandatory energy performance standards and label standards, along with their stepwise increase to more ambitious levels over time, will eliminate the share of low energy efficiency appliances in the market and thereby increase the average energy efficiency. Currently, no mandatory appliance standards exist in Grenada's RAC sector. In 2019, however, CARICOM has approved a regional label standard for refrigerators, and a similar energy efficiency labelling standard is being developed for air-conditioners. Similarly, CARICOM is also developing MEPS for member states to adopt and implement. Moreover, the Grenada Climate Change Policy (2017-2021) provides exemptions on VAT for renewable energy and energy efficient technologies. Supportive measures such as product databases and awareness campaigns for informed purchase decisions (promoting the evaluation of life-cycle costs, adequate equipment sizing, energy-efficient operation modes, regular maintenance) will build the backbone of energy efficiency enhancement and facilitate further mitigation in the AC sector through improved energy performance.

With currently USD 0.43 per kWh[32], electricity prices are relatively high in Grenada both at regional[33] and at global level. Updated MEPS for room air conditioners (and eventually also chillers) can be ambitious, still leaving end users with lower life cycle costs. Table 5 below suggests the recommended MEPS for split ACs.

[32] Electricity tariffs given in the Energy Report Cards within "CARICOM Member states energy profiles" (CARICOM, 2019)
[33] Caribbean regional average electricity rate of USD 0.33/kWh in 2015, according to NREL, 2015.

Table 5. BAU and MIT scenarios for MEPS and average efficiency recommendation for single- split AC sales [EER in W/W] (GIZ, 2020).

Scenario	Indicator	2017	2020	2022	2026	2030	2040	2050
BAU	Avg. EE	**3.20**	**3.26**	**3.28**	**3.32**	**3.36**	**3.46**	**3.56**
MIT	**Avg. EE**	**3.20**	**3.26**	**3.71**	**4.52**	**5.00**	**6.00**	**6.60**
All split ACs	MEPS	-	-	3.4	4.2	4.7	5.7	6.2

Based on currently encountered barriers, Table 6 presents a set of actions to trigger the adoption of energy efficient RAC appliances in Grenada.

Table 6. Barriers and proposed interventions related to increasing energy efficiency of RAC appliances.

BARRIERS/ CHALLENGES	PROPOSED INTERVENTIONS	NEXT STEPS
MEPS and labels not yet implemented, approach towards setting the levels of MEPS and labels not clear or not fully transparent.	Establish mandatory MEPS and labelling requirements (according to ISO 817 or ASHRAE 34, see also Annex IV), using clear and well documented methodologies for setting the level of MEPS and labels.	Set MEPS at ambitious levels based on life cycle cost analysis and regional benchmarking, searching for synergies by CARICOM efforts for establishing MEPS and labels.
No standardized approach for a regular revision of policies applied by key stakeholders (e.g. Energy Division).	Implement a standardized approach of evaluation and reviewing energy performance standards every 2-3 years to continuously improve or ratchet up MEPS and verify the consistency and effectiveness of labelling categories.	Develop a roadmap or action plan for major RAC end-users with clear milestones on tangible energy efficiency and GHG targets and transparent pathways to reach them.
Lack of stringent market surveillance methods, processes and capacities with lacking enforcement; No central product database (only lists with Customs Department - TBC).	Establish a central RAC product database covering refrigerants and energy efficiency, with a clear definition of roles and responsibilities among the relevant actors.	Establish sanctions for deviations from mandatory standards; Name responsible institutions to verify labels and define sanctions for infringements, verification of awarded labels via field testing of appliances.
Adaptation of policy actions for chillers, as initial policies are expected to focus on split AC and domestic refrigeration. AC chillers are responsible for 6.8% of emissions for space cooling (2017 estimate)	It is recommended to extend mandatory efficiency standards (targets) to other UAC equipment and to (AC) chillers in line with the split AC targets.	Extending proposed MEPS and labels to other UAC and to (AC) chillers.
Lack of end-user awareness of life-cycle costs, but focus on initial investment. Meanwhile equipment is often not sized to the actual demand and regular maintenance neglected, leading to inefficient operation modes.	Inform end-users about the importance of life-cycle costs, equipment sizing tailored to the actual cooling needs, regular maintenance and energy-efficient operation modes; make energy use transparent (awareness campaigns after introduction of EE labels), continued use of voluntary endorsement label (Natural Refrigerant Sticker) for refrigerators and expanding to room AC with natural refrigerants , taking international standards and best practice into account.	Provide incentives to accelerate market uptake / Import tax depending on energy efficiency / Public procurement / New for old scheme for replacement of equipment / Grant to balance higher investment costs / User campaigns explaining life-cycle costs and promoting energy-efficient operation modes

Source: own elaboration

(3) Shift to low-GWP (natural) refrigerants

Driven by significant increase of UAC installations, the continuing use of high GWP refrigerants for air conditioners such as HCFC-22 (GWP of 1760) in existing installations, as well as HFC-410A (GWP of 1924) or HFC-32 (GWP of 677) as a substitute to HCFC in recent installations results in an increase of direct emissions over time. Along the HFC phase-down schedule set out in the Kigali Amendment of the Montreal Protocol, Grenada's government can consider the early adoption of additional policy measures to accelerate the deployment of technology alternatives with low GWP air conditioning applications to ensure a non-disruptive and cost-effective transition avoiding double or triple conversions of installed systems. Supportive in this regard is the national adoption of horizontal and product safety standards (IEC 60335, EN 378, ISO 5149). Currently, a code of good practice for flammable refrigerants is in place. Table 7 proposes in its mitigation scenario the exemplary accelerated introduction of low GWP refrigerants for single-split air conditioning applications (adapted based on GIZ, 2020[34]). It is noteworthy that Grenada is already making progress in the adoption of low-GWP technology within the recent single-split AC installations. Accordingly, notable gains of R290 are already assumed within the refrigerant distribution in the BAU scenario. Solid framework conditions consisting of comprehensive training of RAC technicians along with the installation of the first 30 single-split ACs that use R290 refrigerant, both within the GIZ Proklima C4 project, and Grenada demonstrating its intentions of rapid adoption of relevant normative schemes made the ground for this recent achievement. This way, Grenada established connections with a known R290 split AC manufacturer and continues looking out for further import opportunities. Grenada is currently one of the leading countries in adopting R290 single-split ACs, especially among importing countries without domestic fabrication. As presented in the development of refrigerant distribution in the mitigation scenario, additional support will enable Grenada to strongly accelerate this technology transition and diminish the importance of R32 after 2025, thereby enhancing Grenada's role model position with great replication potential for the CARICOM region and beyond.

Table 7. Refrigerant distribution for the BAU and the mitigation scenario, single-split ACs sales.

Scenario	Refrigerant	2020	2025	2030	2040	2050
BAU scenario	R410A	75%	20%	0%	0%	0%
	R32	15%	55%	55%	35%	5%
	R290	10%	25%	45%	65%	95%
Mitigation scenario	R410A	75%	10%	0%	0%	0%
	R32	15%	50%	10%	0%	0%
	R290	10%	40%	90%	100%	100%

Under the Kigali amendment, the GHG equivalent of HFC consumption will be put under a quota system. The baseline will be determined from the HFC consumption (CO_2eq) from 2020-2022 and 65% of the HCFC baseline. The first control will take place with a freeze of the consumption effective from January 1, 2024 to December 31, 2028. The first reduction step will take place from January 1, 2029 with an initial reduction step of 10%. Further reduction steps are occurring in 5-year intervals. Figure 10 shows

[34] The distribution of refrigerant types in the single-split AC subsector was adjusted from 2020 onward as per recent information by NOU.

the BAU scenario and the Kigali reduction steps based on the estimated baseline refrigerant consumption.

To reflect the effects for appliances used for space cooling, i.e. UAC and Chillers (which together constitute about 22% of Grenada's installed RAC appliances), it has been assumed that for the BAU scenario, UAC and Chillers will consume a proportional amount of CO_2eq weighted HFCs as it is reflected in the baseline. The effective future allocation of HFC for space cooling appliances depends on the quota allocation given to the various appliance groups such as appliances for space cooling. Most of the UAC are currently imported as pre-charged equipment. The HFC amounts of pre-charged equipment will not be accounted as consumption under the Kigali Amendment, only the refrigerants used for servicing these units later on[35].

This effect will backload the demand for refrigerants for space cooling appliances. It is recommended that Grenada adopts a forward looking strategy to approach the expected scarcity of HFCs under the coming Kigali quota system: (1) early transition to appliances using low GWP refrigerants where low GWP alternatives are readily available such as in domestic refrigeration and single-split AC; and (2) limit leakages through improved servicing where possible.

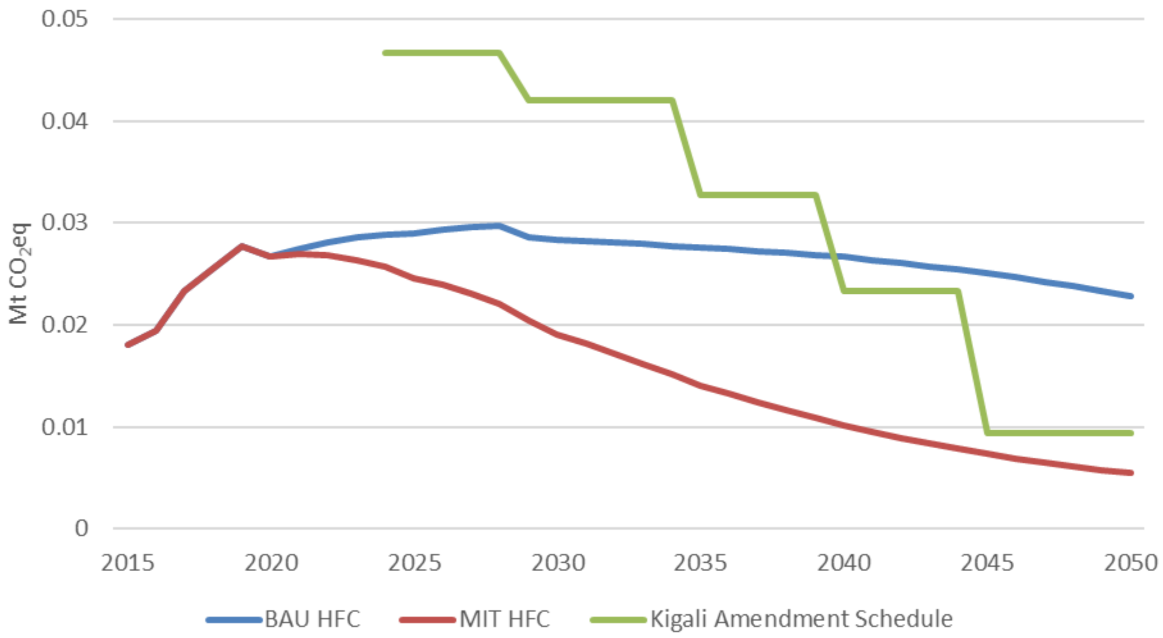

Figure 10. HFC consumption under BAU and MIT scenario and the Kigali Amendment reduction steps, Kigali phase-down based on BAU scenario (GIZ, 2020).

Table 8 presents current barriers of transitioning to low-GWP RAC appliances in Grenada and outlines a set of actions to remove these barriers.

Table 8. Barriers and proposed interventions related to transitioning to low-GWP RAC appliances.

BARRIERS/ CHALLENGES	PROPOSED INTERVENTIONS	NEXT STEPS
Continued use of high-GWP refrigerants in RAC appliances	Create incentives (e.g. tax reductions) for import of RAC appliances using low-GWP refrigerants	Introduce bans for high/medium GWP refrigerant; orientation by EU F-gas directive: 2025: GWP < 750 2030: GWP < 10

35 Good Practice under UNFCCC reporting takes refrigerant amount imported in pre-charged equipment into account (Gytarsky *et al.*, 2006).

High commitment required to obtain market access to low-GWP alternatives (both appliances and refrigerants)	Bulk procurement together with other CARICOM member states	Agreements between countries
Limited recognition of RAC technician skills by international technology providers in handling low-GWP (especially hydrocarbon) refrigerants	Comprehensive capacity building, improvement of structure/training and certification of technicians[36], with low-GWP refrigerants as a mandatory part of RAC technician curriculum, cooperation local with service companies; agreement on international certification standards of RAC technicians (e.g. EN 13313 on competences of RAC technicians)	Implement compulsory certification, verification of measures
Few existing low-GWP refrigerant technologies[37] and related experiences in Grenada in the non-appliance sector	Promote the exchange of knowledge and experience in the CARICOM region and beyond	Build regional knowledge and service hubs in the CARICOM region
Lack of stringent market surveillance methods, processes and capacities with lacking enforcement; No central product database (only lists with Customs Department - TBC).	Establish a central RAC product database covering refrigerants and energy efficiency, with a clear definition of roles and responsibilities among the relevant actors.	Establish sanctions for deviations from adhering to refrigerant restrictions (bans); Name responsible institutions to define sanctions for infringements.
Lack of national standards for refrigeration and low-GWP refrigerants in particular	Adopt horizontal international refrigeration safety standards (e.g. EN 378, IEC 60335) into national standards and implement a system for safety testing and validation based on IEC 60335 for imports	

Source: own elaboration

(4) Best practice in the handling of refrigerants

In addition to the aforementioned mitigation options, refrigerant-related activities can include provisions for proper refrigerant handling and containment such as strengthening of capacities and certification of RAC technicians, as well as recovery, recycling and destruction of refrigerants. Training of RAC technicians is available in Grenada for the handling of HCFC and HFCs, including routine training in natural refrigerants. The curricula of the HVAC technical institutions have been upgraded to include a module on natural refrigerants. To cover additional safety measures for natural refrigerants, several trainers attended GIZ Proklima's Cool training. Building on this, the relevance of natural refrigerants in the training of RAC technicians, as well as other important aspects for proper handling of refrigerants facilitating the safe and efficient operation of RAC equipment with minimized refrigerant leakage, should be further consolidated in the national curricula. As an initial step in this regard, the responsible RAC trainers for this training should be further trained (train-the-trainer principle). Currently, the certification of RAC technicians is not enforced. Therefore, a mandatory scheme on national level should be established, regulating that any technician who works with refrigerants must be certified. This process is to be accompanied by an authorized certification body. For a systematic implementation, it is recommended to set up a national registration database where all certified technicians are listed. The informal sector may be further

[36] Current estimate: 50% of technicians are trained in the use and handling of natural refrigerants

[37] Domestic Refrigeration is gaining increasing share of HC-600a driven by the global market. Most commercial stand-alone refrigeration equipment now imported is charged with R290.

integrated by providing incentives which promote the installation and maintenance through certified technicians. Regarding refrigerant waste streams, the current infrastructure is not fully organized. It is recommended to set up take-back schemes and create incentives for ordered return of RAC appliances and therein contained refrigerant after their decommissioning. In this process, extended producer responsibility can be aspired, and existing refrigerant collection points can be strengthened. For adequate planning of the infrastructure, ODS and HFC banks should be inventoried. The planning process of ODS banks management is described in detail in (Heubes, Gloel and Papst, 2017) . Regarding the recycling and destruction of refrigerant, Grenada can aim for a regional solution (e.g. as a joint effort of CARICOM countries).

Table 9. Barriers and proposed interventions related to best practices in refrigerant handling.

BARRIERS/ CHALLENGES	PROPOSED INTERVENTIONS	NEXT STEPS
Limited capacity of RAC technicians in best practice in handling of refrigerants and in specific requirements for using natural refrigerants	Strengthen natural refrigerants in the technician training curriculum	Continue train-the-trainer strengthening of capacities across all HVAC technical institutes and vocational schools
Certification of RAC technicians working with refrigerants is currently not enforced	Establish a nationwide mandatory scheme for the certification of technicians; set up a national registry of certified RAC technicians	Integrate the informal sector, e.g. by linking incentive schemes with the installation through certified technicians
Limited organizational level of waste streams for refrigerants	Set-up take-back schemes and create incentives for refrigerant collection by RAC technicians and forwarding to collection centers	Strengthen existing refrigerant collection points; Call on producers for extended producer responsibility

4 NDC readiness actions to facilitate enhanced energy efficiency in buildings as well as energy-efficient and low-GWP refrigerant based UAC

Action	Lead Department (supporting institutions)	Timeline	Support projects
Prepare comprehensive RAC sector emissions inventory	National Ozone Unit (NOU), Energy Division	January 2018 – October 2019	GER - BMUB IKI C4 Project (implemented on behalf of GIZ)
Demonstrate and monitor energy consumption of 30 R290 split ACs (high EER, low GWP refrigerant R290) in various building types.	National Ozone Unit (NOU), Energy Division, Ministry of Finance and Energy	June 2018- December 2019	GER - BMUB IKI C4 Project (implemented on behalf of GIZ)
Discuss and agree on space cooling policy measures in contribution to NDC	Ministry of Finance, Department of Economic and Technical Cooperation	Until Q1/2020	
Updating of Policy gap analysis (Policy brief) and updating of UAC GHG modelling	National Ozone Unit (NOU), Energy Division	Until Q2/2020	GER - BMUB IKI C4 Project (implemented on behalf of GIZ). Kigali Amendment Enabling Activities Project (MLF/UNIDO) SPODS Project - UNIDO
Integrate RAC sector approach in NDC	NOU/ Ministry of Climate Resilience	Q3/2019	GER - BMUB IKI C4 Project (implemented on behalf of GIZ)
Design MEPS roadmap	NOU, Energy Division, Grenada Bureau of Standards	Q4/2021	GER - BMUB IKI C4 Project (implemented on behalf of GIZ) HPMP - UNEP
Training of RAC technicians on safe use of low GWP refrigerants equipment	NOU	August 2018	GER - BMUB IKI C4 Project (implemented on behalf of GIZ) HPMP Stage II
Study on barriers, enablers of and recommendations to adopt green ACs in public procurements	National Ozone Unit (NOU), Ministry of Finance	Until Q1/2020	GER - BMUB IKI C4 Project (implemented on behalf of GIZ) HPMP Stage II

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6 Annex I

ASSUMPTIONS BUILDINGS POLICIES TOOL GRENADA - CONSTANT PARAMETERS[38]

Parameter	Assumption	Unit	Explanation	Source
Constant across all scenarios				
Floor space				
Residential, base year (2015)	18.9	m^2/cap	According to inventory report, the typical residential household in the CARICOM region is 85 m^2. According to the UN, the typical family size is between 4-5 people. The average residential floor space per capita is derived from dividing 85 by 4.5	(UN, 2017; GIZ, 2020)
Residential, projection year (2050)	35.0	m^2/cap	High uncertainty. Is likely to increase with increased GDP/cap. However, it also depends on the context in terms of culture, family size etc. Assumed to increase towards EU standards.	(Euroconstruct, 2018); Expert judgement.
Commercial, base year (2015)	8.1	m^2/cap	High uncertainty. If we assume that 70% of the floorspace is residential (average share in Europe), then commercial floorspace in the base year will be (Residential floor space*(3/7)). Values have been compared to data from Buildings sector tool in CAT and are similar to those of Mexico.	(EU, 2013; Climate Analytics and NewClimate Institute, 2019a)
Commercial, projection year (2050)	19.9	m^2/cap	Calculating commercial floor space per capita from raw data found in the CAT building sector tool, the value for EU in 2010 is 15.3 m^2/capita, and the corresponding for the US is 24.4 m^2/capita. Assuming Grenada will reach somewhere in-between those by 2050.	(Climate Analytics and NewClimate Institute, 2019b)

Drivers of cooling demand considered

[38] Data types: (i). Input data collected directly from primary or secondary data (yellow), or (ii). Derived data; own calculations based on several input data sources (green).

Population growth	see source	million people		(UN, 2019)
Floor space per person (% increase base year-end year)	84 (res); 250 (com)	%	Assumed to increase for both residential and commercial. Very high increase in commercial as assumed to reach EU standards by 2050, but also high uncertainty on start year data. Possibly likely that floor space per capita in residential will increase more than assumed 13%.	
Increased use of AC	95% (res) 95% (com)	%	Assumed that 95% of commercial and residential new floor space is equipped with cooling by 2050.	Expert judgement.

Buildings energy performance

Residential, existing/old stock	62.3	kWh/(m^2 *year)	GBPN data, typical energy use in building that only needs cooling in LAC region is 77 kWh/(m^2*year) for urban buildings and 54 kWh/(m^2*year) for rural buildings. About 36% of the population (WBG) lives in urban areas. Hence, the average energy demand for cooling in a building in Grenada is: 0.36*77 + 0.64*54 (Result is similar to assumption in GEA)	(GBPN, 2012b; World Bank Group, 2018)
Residential, best practice	17.0	kWh/(m^2 *year)	Table 10.13 for tropical countries in LAC region.	(Ürge-Vorsatz, 2012)
Residential, no policy	62.3	kWh/(m^2 *year)	No policy buildings are assumed to have the same energy demand as old buildings due to increased demand for cooling.	Expert judgement
Commercial, existing/old stock	131.0	kWh/(m^2 *year)	Table 10.13 for tropical countries in LAC region.	(Ürge-Vorsatz and al., 2012)
Commercial, best practice	25.0	kWh/(m^2 *year)	Table 10.13 for tropical countries in LAC region.	(Ürge-Vorsatz and al., 2012)
Commercial, no policy	131.0	kWh/(m^2 *year)	No policy buildings are assumed to have the same energy demand as old buildings due to increased demand for cooling.	Expert judgement.

Energy performance, renovated buildings

Residential, retrofit, start year	50.0	kWh/(m^2 *year)	Table 10.13 for tropical countries in LAC region.	(Ürge-Vorsatz and al., 2012)
Residential, retrofit, deep	20.4	kWh/(m^2 *year)	Assuming almost best practice level can be reached.	Expert judgement.
Commercial, retrofit, start year	65.0	kWh/(m^2 *year)	Table 10.13 for tropical countries in LAC region.	(Ürge-Vorsatz and al., 2012)
Commercial, retrofit, deep	30.0	kWh/(m^2 *year)	Assuming almost best practice level can be reached.	Expert judgement.

Share of floor space cooled

Residential, old stock	10	%	The old buildings are assumed to gradually be equipped with AC, reaching 95% in 2050 (linear growth).	Exper interview
Residential, new stock	95	%		Expert judgement
Residential, retrofit	95	%		Expert judgement
Commercial, old stock	90.0	%	High uncertainty. No data available – thus assumptions based. Assumed to be higher than residential. Highly dependent on what the commercial/services sector looks like in the country.	Expert interview
Commercial, new stock	95.0	%		Expert judgement
Commercial, retrofit	95.0	%		Expert judgement

Parameter	Scenario			Unit	Explanation	Source
Varying across scenarios						
	Low Ambition (LA)	**Enhanced ambition** (EA)	**net-zero by 2050** (nZ)			
Grid emission factor (GEF)						
Existing (old) buildings	National grid – increasing RE	National grid – increasing RE	National grid – increasing RE	gCO_2/ kWh	These buildings are assumed to be connected to the national grid with an increasing share of renewables. The growth rate of the share of renewable installed capacity is based on the growth rate from 2012 – 2018.	(Grenlec, 2017; GIZ, 2020)
No policy buildings	National grid – increasing RE	Increasing PV	Increasing PV	gCO_2/ kWh	EA - PVs are installed on No policy, renovated and best practice buildings but at different rates; For no policy buildings, 30% of the buildings are equipped with PV by 2050 while the corresponding share for renovated buildings is 50% and 100% (from start) for best practice. In the nZ scenario, it is assumed that renovated buildings are increasingly (linear growth) equipped with PV. By 2050 all renovated buildings are fed by power from PV for cooling. Same for no policy buildings	
Renovated buildings	National grid – increasing RE	Increasing PV	Increasing PV	gCO_2/ kWh	Same as No policy buildings	
Best practice buildings	0.0	0.0	0.0	gCO_2/ kWh	These buildings are assumed to be equipped with rooftop PV which generates the power required for space cooling of the building. These buildings are nZEB.	
Demolition rate						
Residential	1.0	1.0	1.0	%	Standard rate LAC region	(GBPN, 2012b)
Commercial	1.0	1.0	1.0	%	Standard rate LAC region	(GBPN, 2012b)
Renovation rate						

Residential	1.5	3.0	3.5	%	LA – Typical rate in Latin American region EA – Current high ambition recommendations in EU; Grenada national target to renovate old building stock completely. nZ - Renovation curve is "shifted to the left" meaning it has the same improvement rate as in EA, but is shifter to happen earlier in time	(Government of Grenada, 2015; Filippidou, Nieboer and Visscher, 2017; Filippidou *et al.*, 2018)
Commercial	1.5	3.0	3.5	%	LA – Typical rate in Latin American region EA – Current high ambition recommendations in EU; Grenada national target to renovate old building stock completely. nZ - Renovation curve is "shifted to the left" meaning it has the same improvement rate as in EA but is shifter to happen earlier in time.	(Government of Grenada, 2015; Filippidou, Nieboer and Visscher, 2017; Filippidou *et al.*, 2018)
Residential, deep renovation level is reached	2045	2027	2024	year	Results (controlled by user)	
Commercial, deep renovation level is reached	2041	2025	2024	year	Results (controlled by user)	
Total old stock is renovated (residential)	-	2046	2041	year	Results	
Total old stock is renovated (commercial)	-	2045	2042	year	Results	

Energy performance of new buildings

Residential					
Introduction of MEPS	2030	2022	2020	year	Best practice buildings are introduced and grows linearly to reach 100% share of new building type by full compliance year.
Full compliance and ambition rate of MEPS	2050	2030	2025	year	By this year, all new buildings are according to best practice definition.
Commercial					
Introduction of MEPS	2030	2022	2020	year	Best practice buildings are introduced and grows linearly to reach 100% share of new building type by full compliance year.
Full compliance and ambition rate of MEPS	2050	2030	2025	year	By this year, all new buildings are according to best practice definition.

7 Annex II

Space cooling of buildings: results from *low- and enhanced ambition* projections.

1. *Building stock*
    a. *Commercial sector*

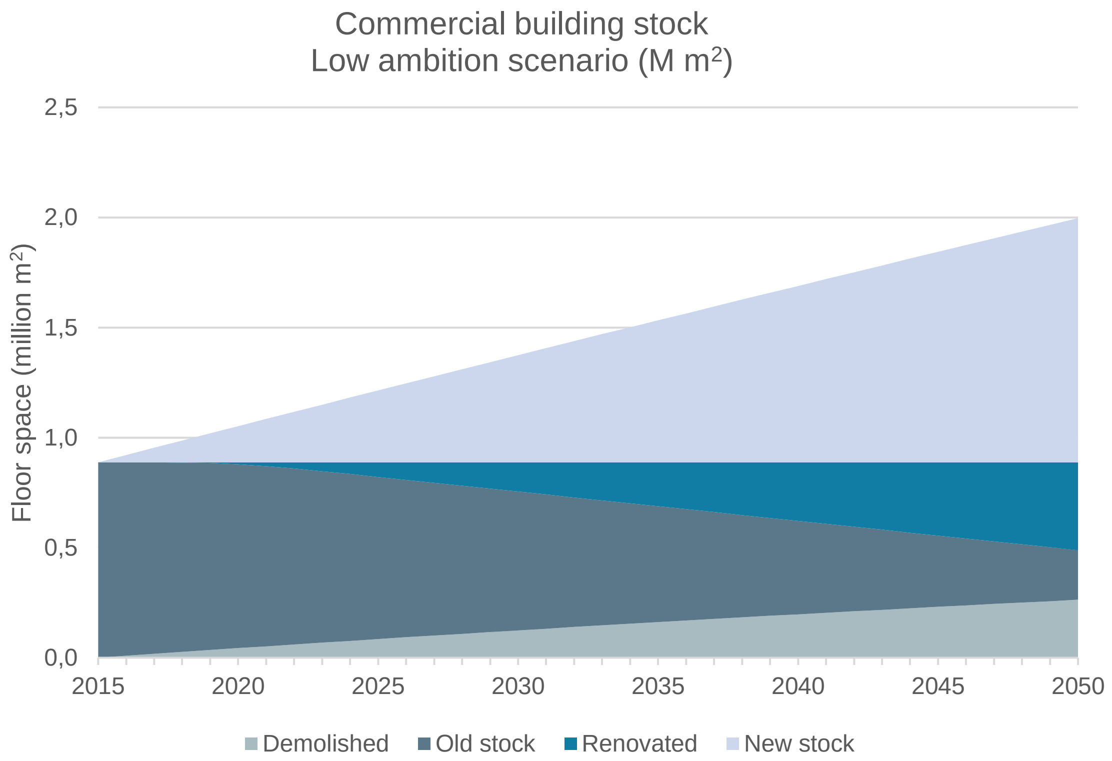

Figure 11. Commercial building stock, low ambition scenario.

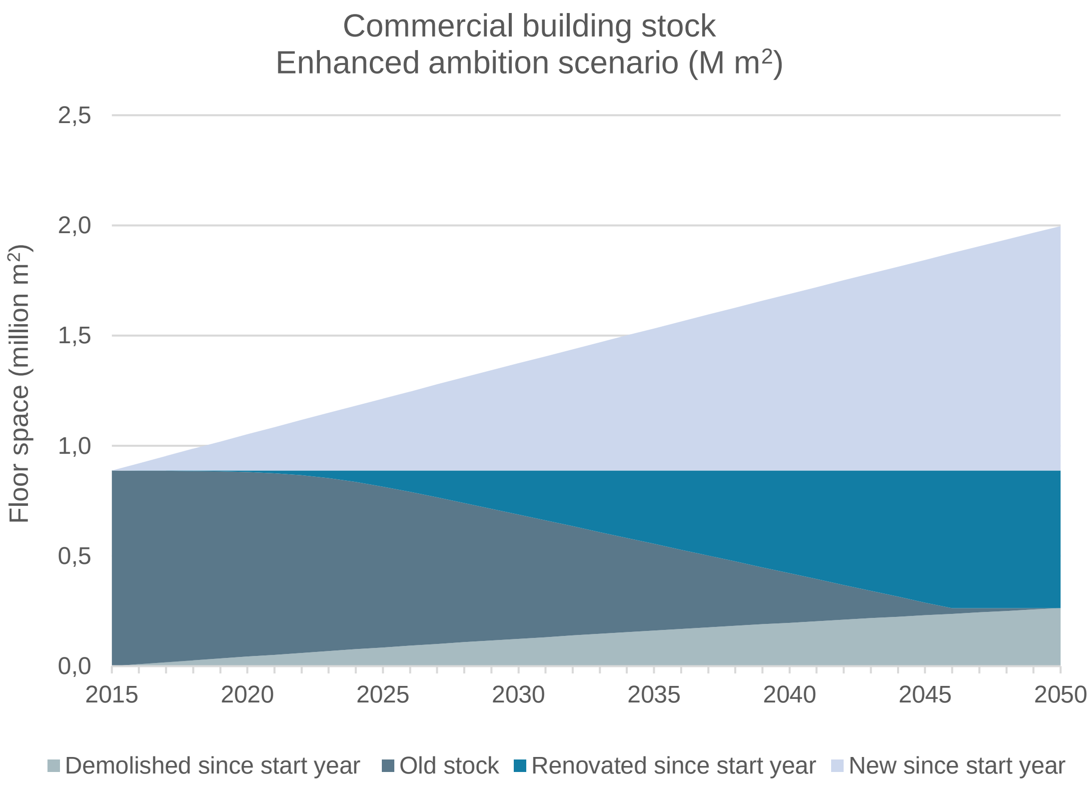

Figure 12. Commercial building stock in the enhanced ambition scenario.

b. *Residential sector*

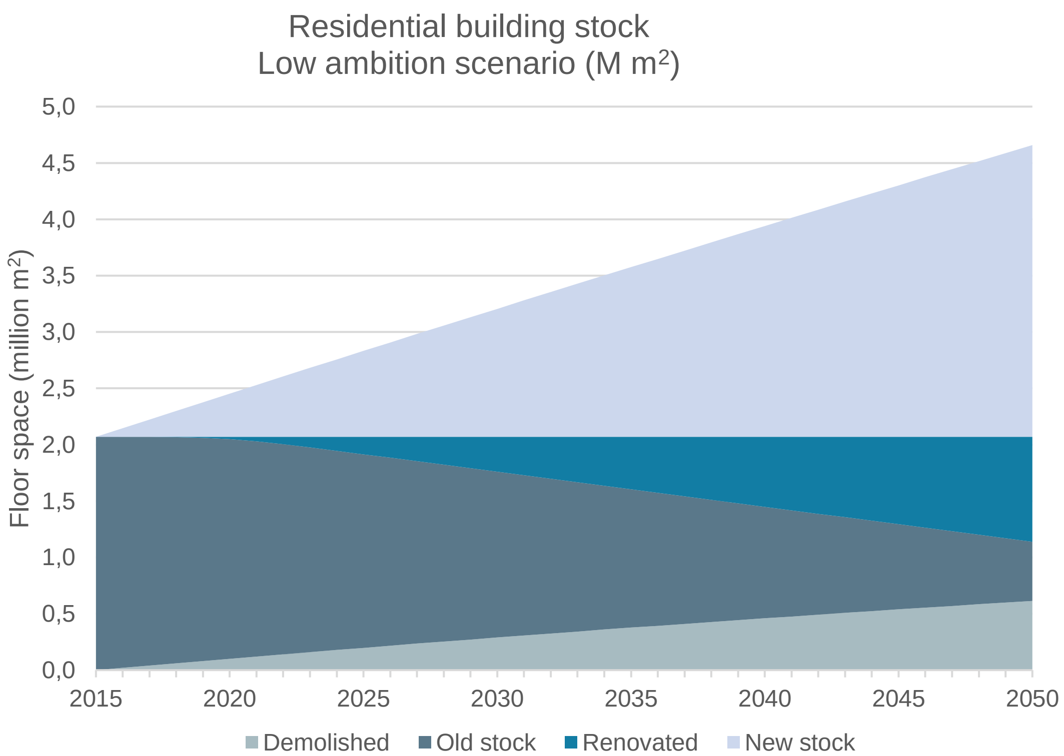

Figure 13. Residential building stock in the low ambition scenario.

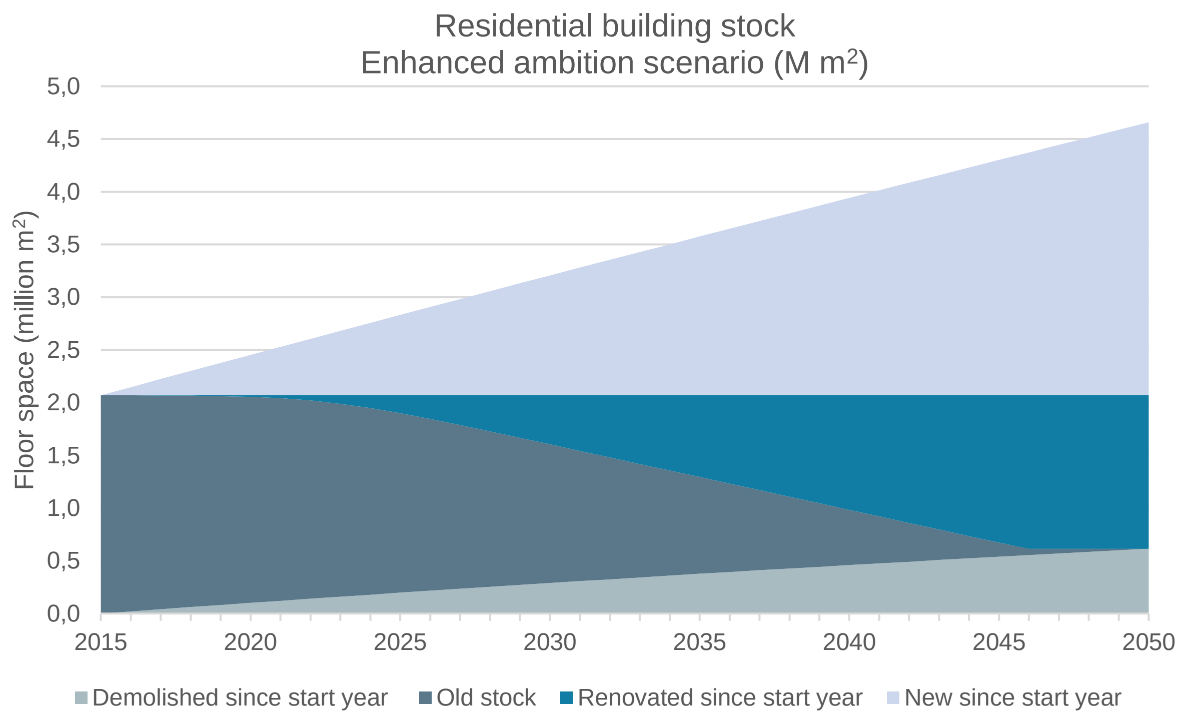

Figure 14. Residential building stock in the enhanced ambition scenario.

2. *Energy demand*
   a. *Commercial sector*

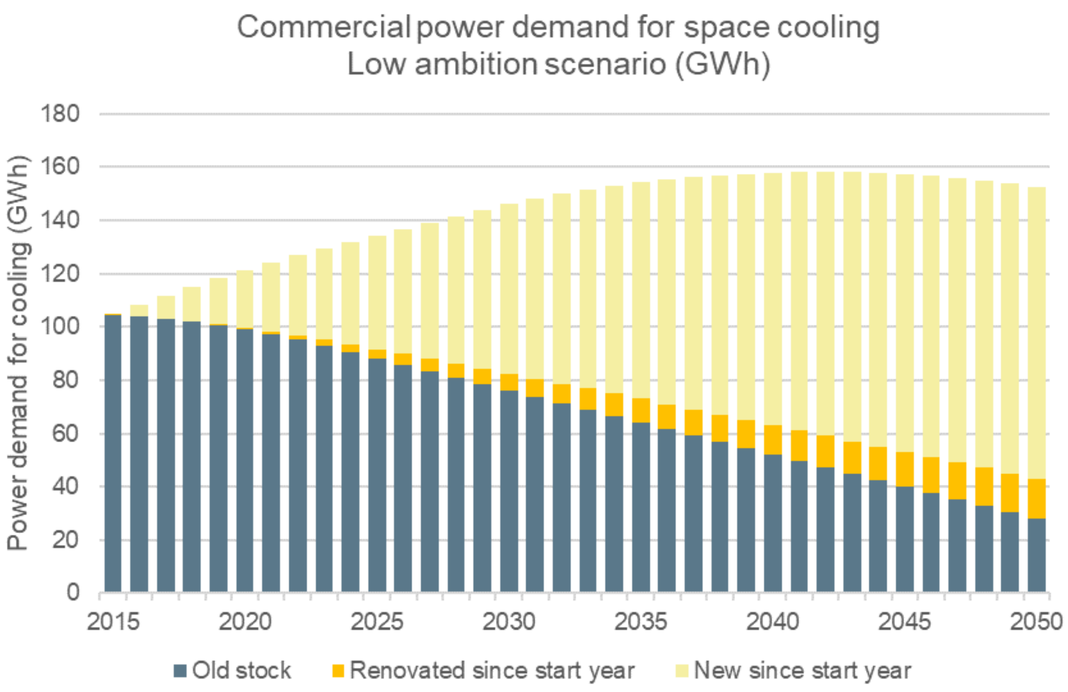

Figure 15. Power demand for space cooling of the commercial sector in the low ambition scenario.

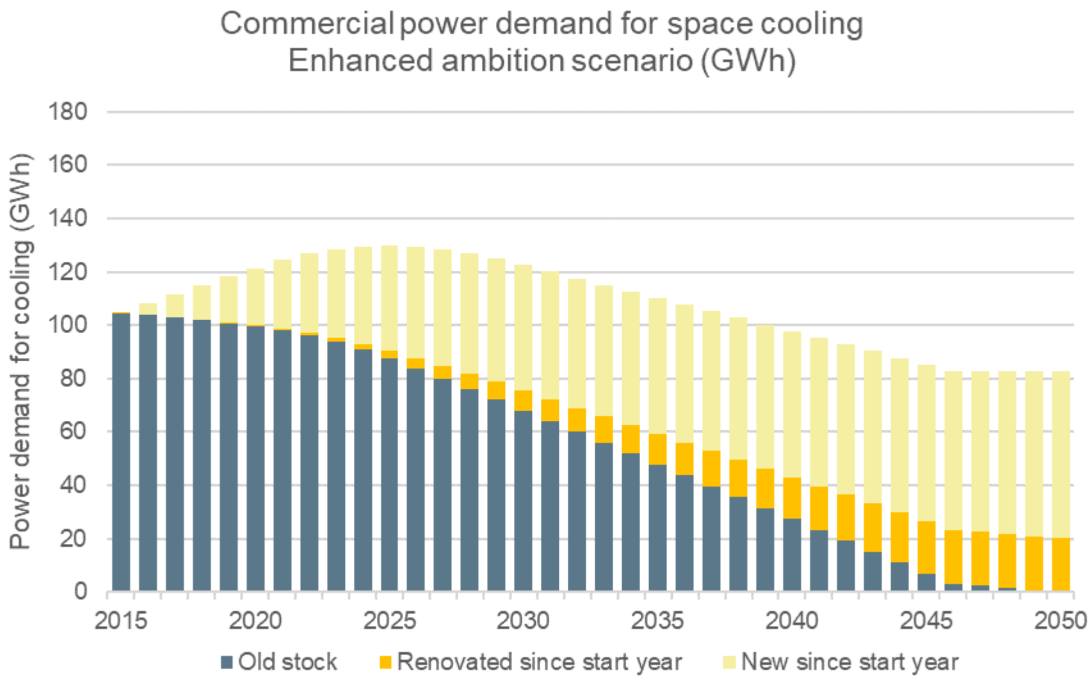

Figure 16. Power demand for space cooling of the commercial sector in the enhanced ambition scenario.

b. Residential sector

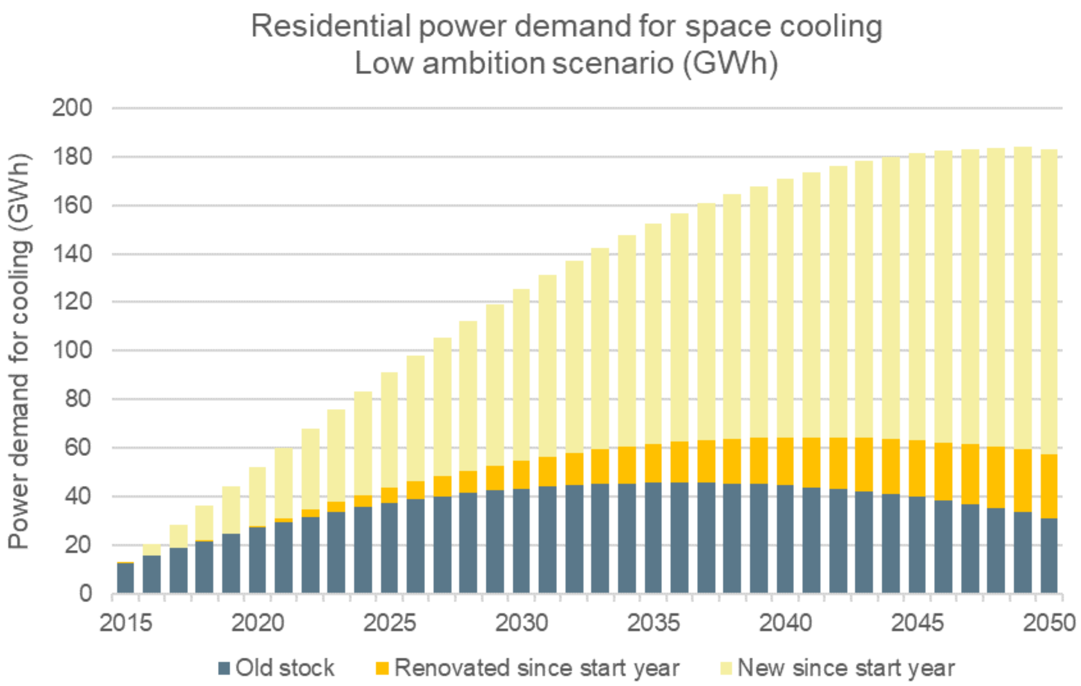

Figure 17. Power demand for space cooling of the residential sector in the low ambition scenario.

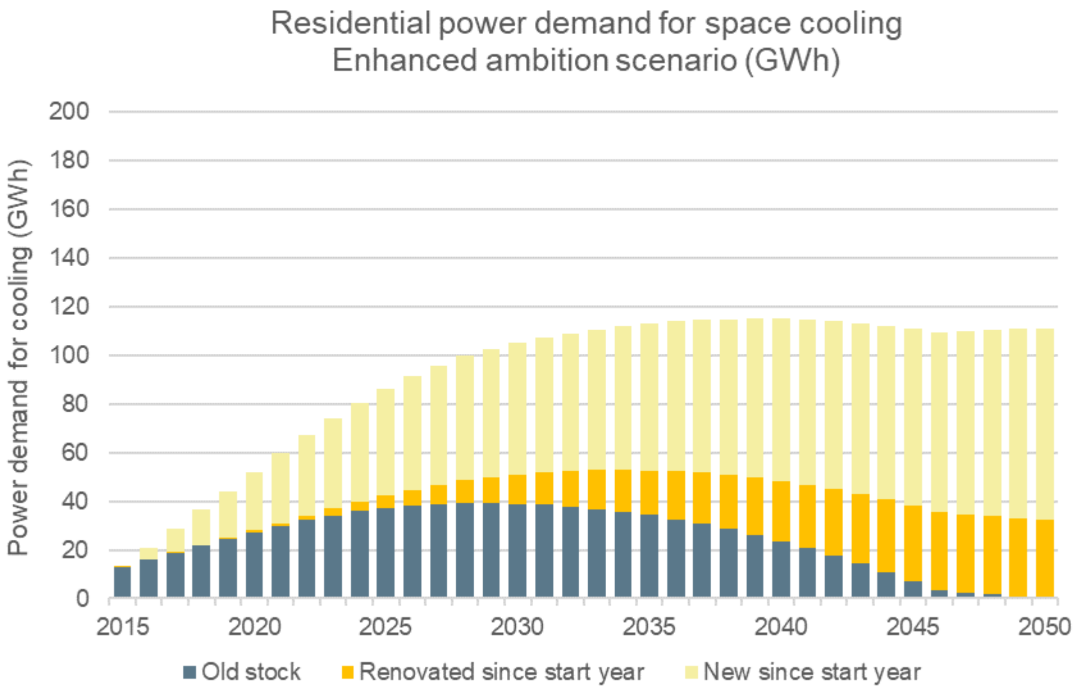

Figure 18. Power demand for space cooling of the residential sector in the enhanced ambition scenario.

3. Emissions
    a. Commercial sector

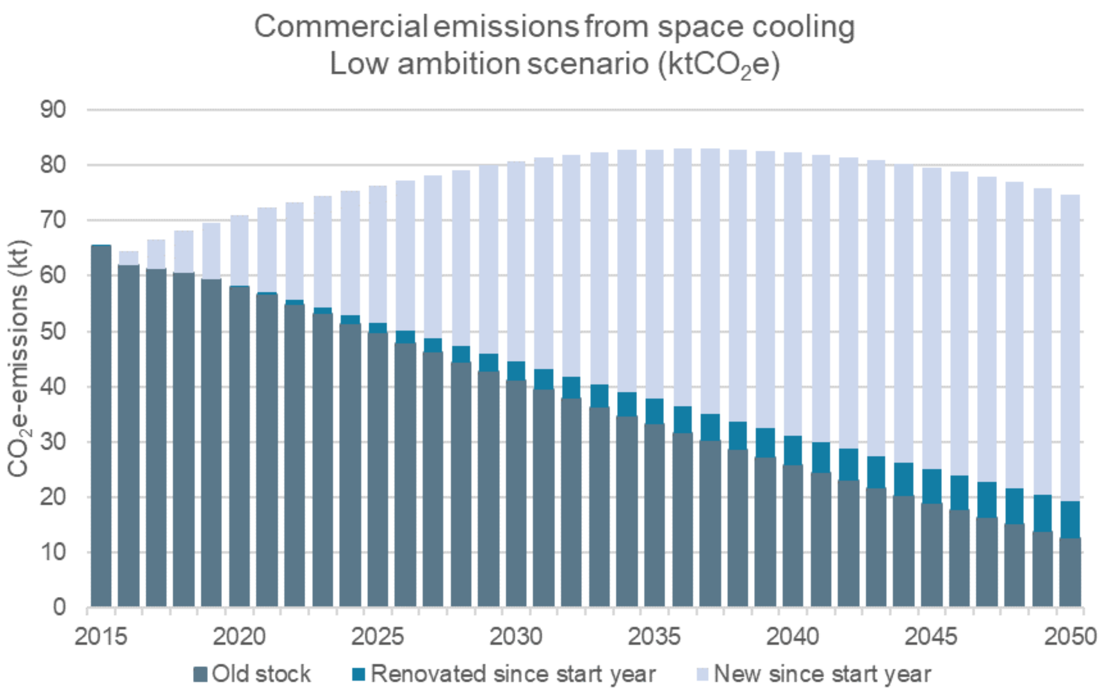

Figure 19. CO_2 emissions (direct and indirect) from space cooling of the commercial sector in the low ambition scenario.

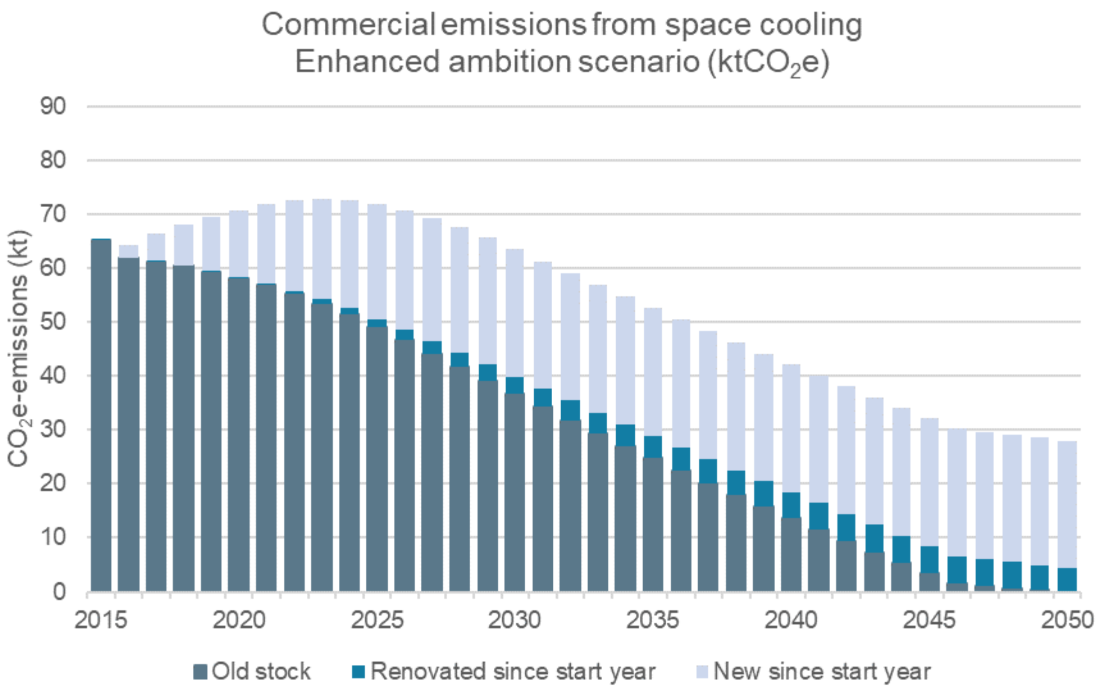

Figure 20. CO_2 emissions (direct and indirect) from space cooling of the commercial sector in the enhanced ambition scenario.

b. Residential sector

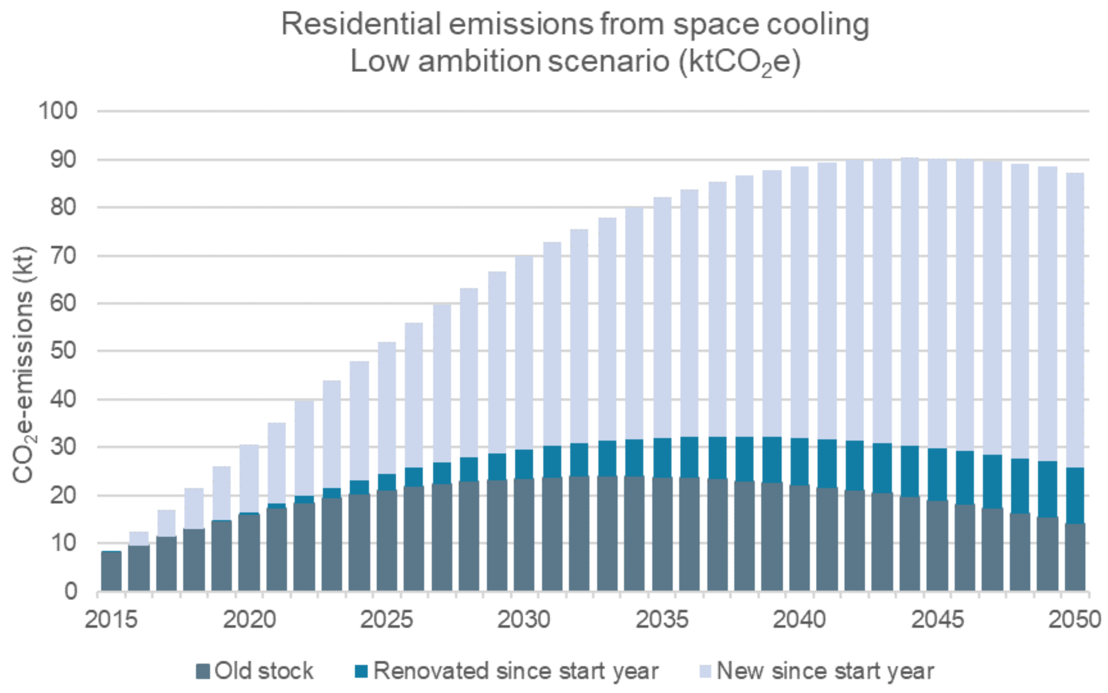

Figure 21. CO_2 emissions (direct and indirect) from space cooling of the residential sector in the low ambition scenario.

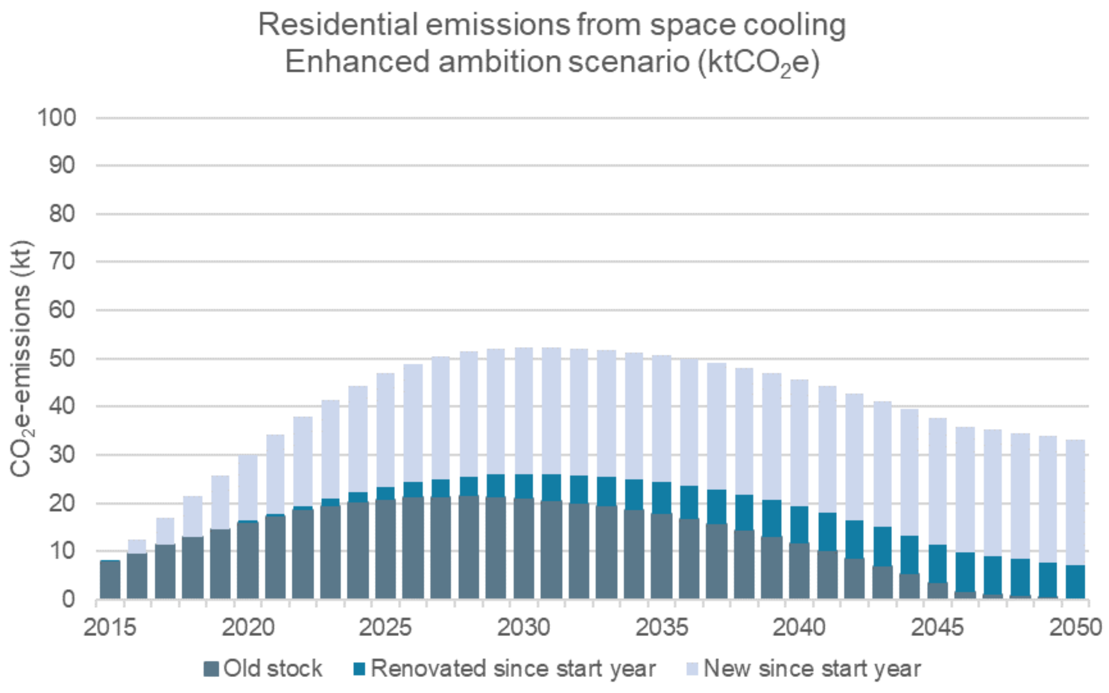

Figure 22. CO_2 emissions (direct and indirect) from space cooling of the residential sector in the enhanced ambition scenario.

8 Annex III

Space cooling of buildings, results from *net-zero by 2050* projections.

1. *Building stock composition*

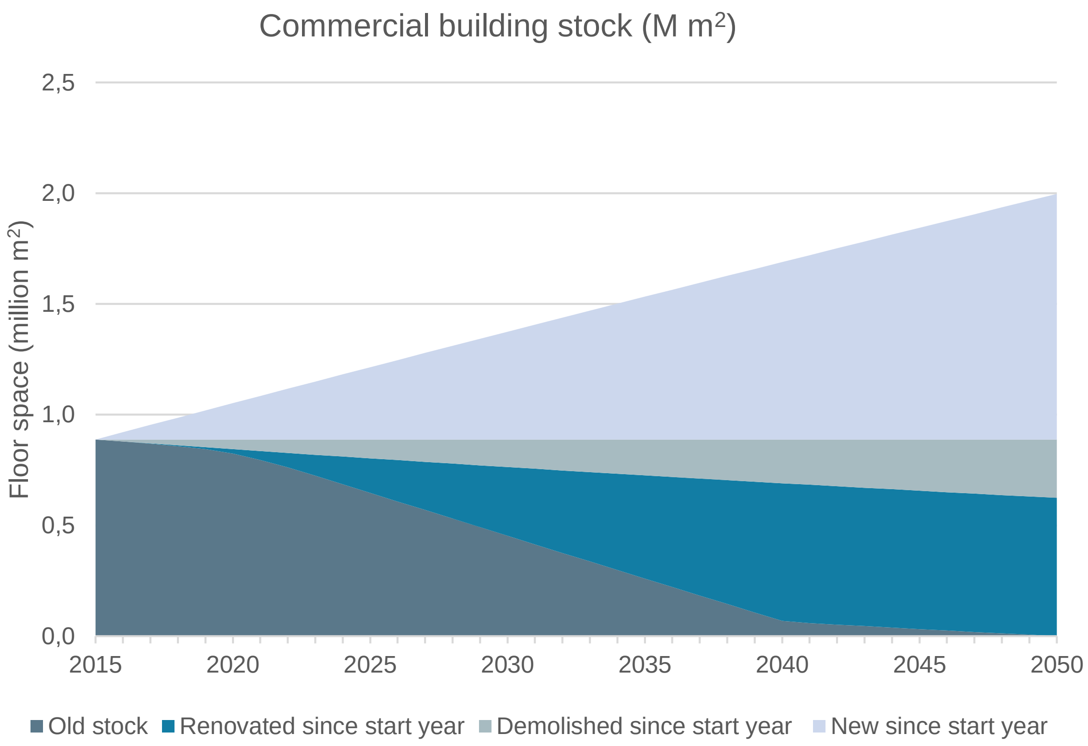

Figure 23. Commercial building stock in the net-zero by 2050 scenario.

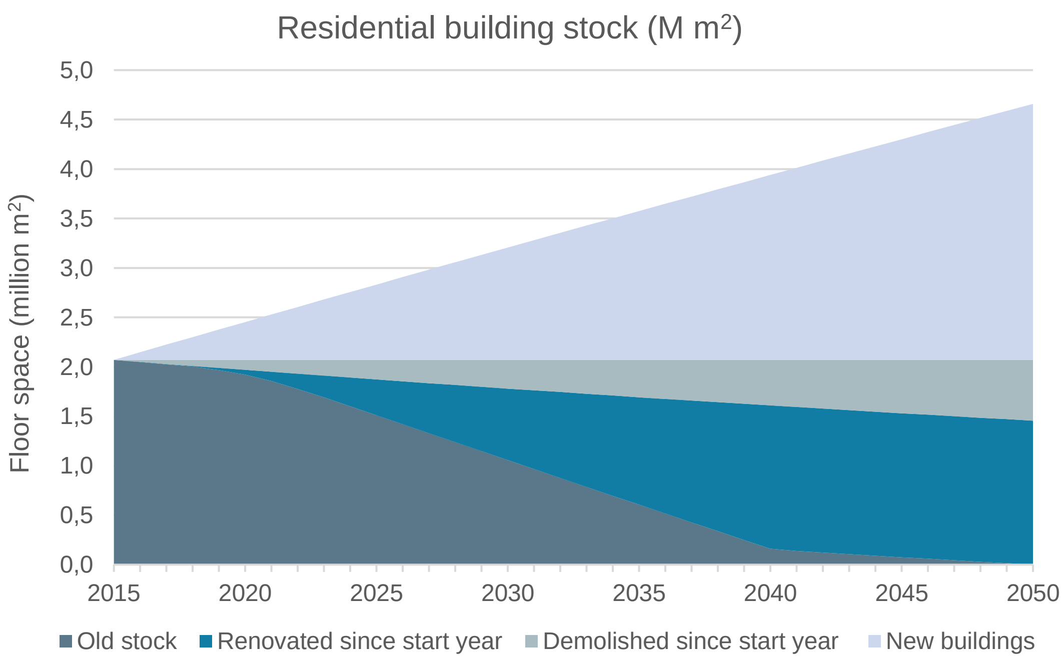

Figure 24. Residential building stock in the net-zero by 2050 scenario.

Energy demand for space cooling

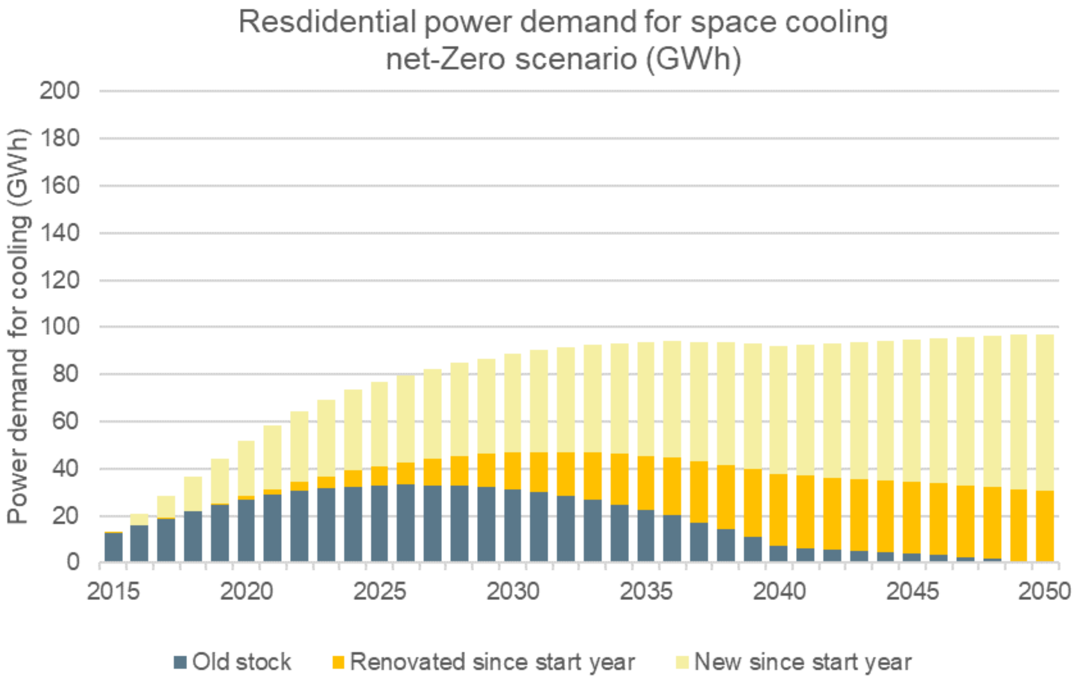

Figure 25. Power demand for space cooling of the residential sector in the net-zero by 2050 scenario.

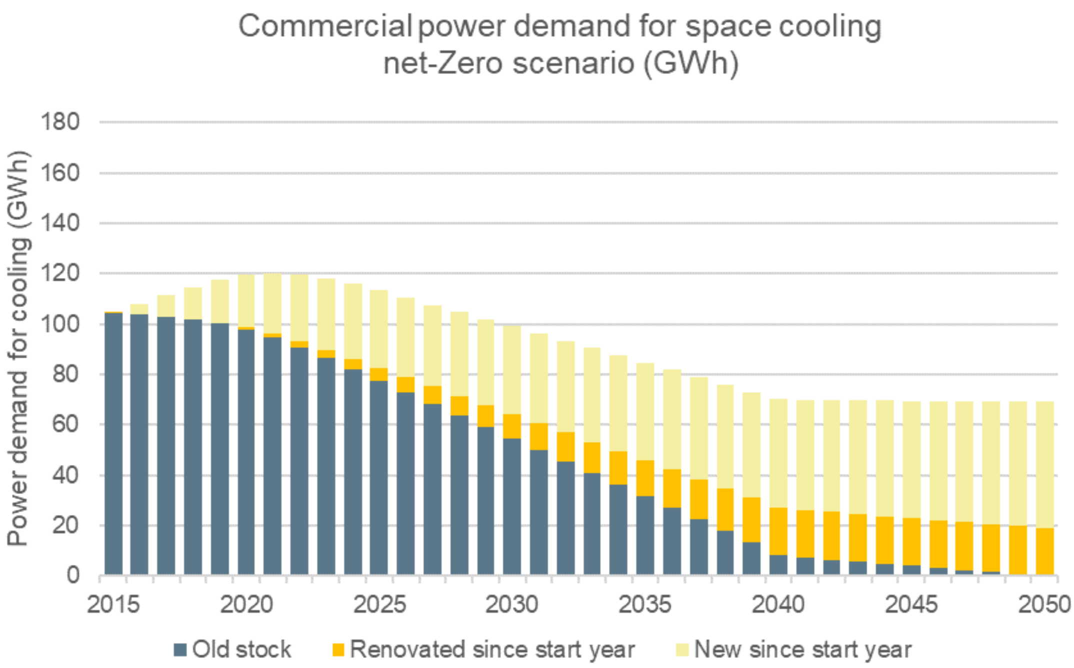

Figure 26. Power demand for space cooling of the commercial sector in the net-zero by 2050 scenario.

2. Emissions form space cooling (direct and indirect)

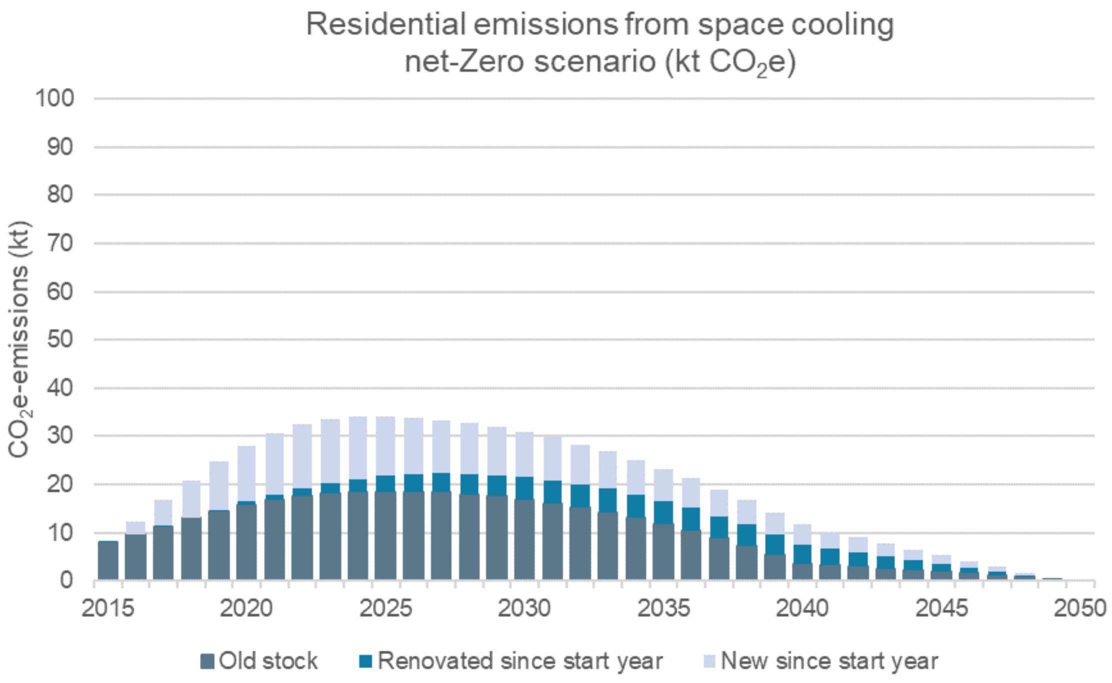

Figure 27. CO_2 emissions (direct and indirect) from space cooling of the residential sector in the net-zero by 2050 scenario.

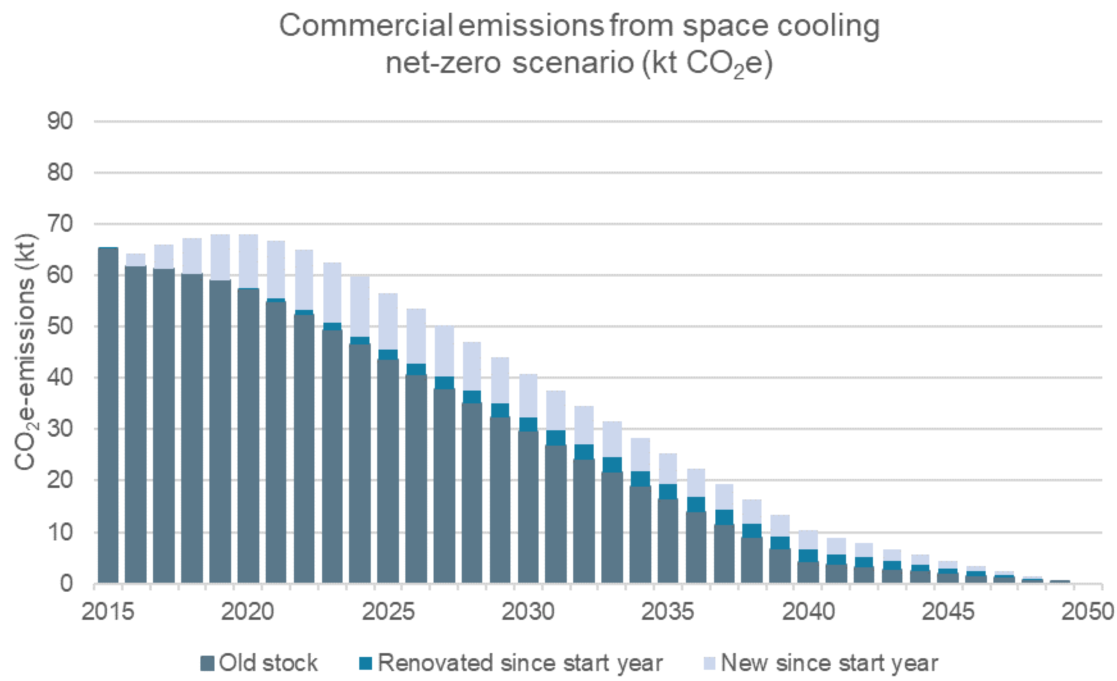

Figure 28. CO_2 emissions (direct and indirect) from space cooling of the commercial sector in the net-zero by 2050 scenario.

9 Annex IV

Product labels shall be affixed on the product in a location that is readily visible for the consumer.

Product information to be included in the energy efficiency label of UAC appliances; recommendations by UNEP (2019):

- Model name / serial number;
- Type of unit [single-split, self-contained, or portable];
- Country where the product was manufactured;
- Rated cooling (and heating, if applicable) capacity in kW;
- Rated maximum power consumption in kW;
- Rated performance grade;
- Rated energy efficiency in [CSPF[39], APF, EER, or COP], and yearly electricity consumption in kWh;
    - *Note: all representations of energy performance shall indicate that the performance rating is an indicative value and not representative of actual annual energy consumption in all situations. [CSPF, APF, EER or COP] shall be declared to three significant digits and include the reference*
- Outdoor temperature bin hours distribution that is used.
- Refrigerant designation in accordance with ISO 817 or ASHRAE 34, including ODP and GWP.

According to UNEP (2019), the requirements on the Declaration of Conformity shall reflect the product information categories above and shall de demonstrated in the Conformity Assessment Report (CAR) which:

- demonstrates that the product model fulfils the requirements of this Regulation;
- provides any other information required to be present in the technical documentation file; and
- specifies the reference setting and conditions in which the product complies with this regulation.

The CAR shall be submitted to the responsible agency[40] for review prior to making the product available for sale. If the CAR for the designated model is approved, which is confirmed by written correspondence from the responsible agency and listing of the product on any applicable product registration system, the model may be sold in the market. If a CAR is rejected, a written explanation will be provided to the submitter. All aspects identified in the written explanation shall be addressed in a revised CAR. Until the CAR is approved, the product is ineligible for sale in the market. The CAR is valid for the designated model for 24 months. An updated CAR or a notice of withdrawal shall be submitted to the responsible agency at least 90 days prior to the change in specifications of or cancelation of production of the currently certified product.

[39] CSPF: Cooling Seasonal Performance Factor, pursuing a similar concept to Seasonal Energy Efficiency Ratio (SEER) by weighted consideration of part load conditions depending on the climate conditions; this procedure is recommended for inverter technologies.

[40] Responsibilities may be split across various agencies