Proklima

Climate-friendly Refrigeration and Air Conditioning: A Key Mitigation Option for INDCs

Working paper

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CONTENT

SUMMARY

The global energy demand for cooling will significantly increase in the next decades due to growing population, urbanization and food chains, in particular in emerging economies. The Green Cooling Initiative (GCI, 2014) estimates the refrigeration and air conditioning sector (RAC) to account for 13% of the global greenhouse gas (GHG) emissions by 2030, making the RAC sector a rapidly increasing contributor to climate change.[1] Meanwhile, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are debating a new global climate deal, which shall be agreed upon at the UN climate conference in December 2015 (COP21) in Paris, and for which Parties agreed to prepare and submit Intended Nationally Determined Contributions (INDCs).

The objective of this working paper is to inform decision makers involved in INDC preparation on the role that the RAC sector could play in countries' INDC implementation as a key sector to achieve the goals formulated in the INDC. The paper briefly introduces the latest UNFCCC developments, GHG emission trends and reduction potentials of the RAC sector. Country case studies (on Indonesia and Ghana) that are both characterized by rapidly growing RAC markets help showcase the range of technology options, policies, and measures in transitioning towards a sustainable RAC sector development. Subsequently, the main challenges in transforming the RAC sector to a key GHG mitigation sector are summarized. The paper finally concludes by highlighting aspects that should be considered when integrating climate friendly cooling in national efforts to combat global climate change. In brief the paper concludes that:

- Without any fundamental technology changes in the global RAC market, GHG emissions in the RAC sector will rise rapidly in the next three decades due to increased use of hydrofluorocarbons (HFCs) and energy consumption as a response to the growing cooling demand. However, GHG mitigation in the RAC sector can be realized in a well-defined field of action with relatively low costs, straightforward measurement, reporting and verification (MRV) as well as socio-economic benefits. Climate-friendly cooling, therefore, holds a large potential to contribute to a successful INDC implementation and consequently to combat global climate change.

- The UNFCCC including its INDCs process builds the necessary accounting framework for indirect (CO_2) and direct (HFC) emissions in the RAC sector. The Montreal Protocol's institutions have the sector know-how, capacities, and structures to coordinate the HFC phase-down and enable the accelerated use of low global warming potential refrigerants. Therefore a joint and synergetic approach to tackle HFC mitigation shall be chosen.

- The NAMA concept helps package an accelerated HFC phase-down by combining the promotion of low GWP refrigerants with progressive energy efficiency policies. The NAMA concept is already applied as an implementation tool (e.g. in Thailand or Indonesia) for GHG mitigation beyond business-as-usual (BAU) practices in the RAC sector, entailing valuable experiences for INDC design and implementation.

- Countries are well advised to assess the specific environmental, technological and economic potential in the RAC sector to determine its relevance for the design and implementation of its INDC in the upcoming years towards 2020 and beyond.

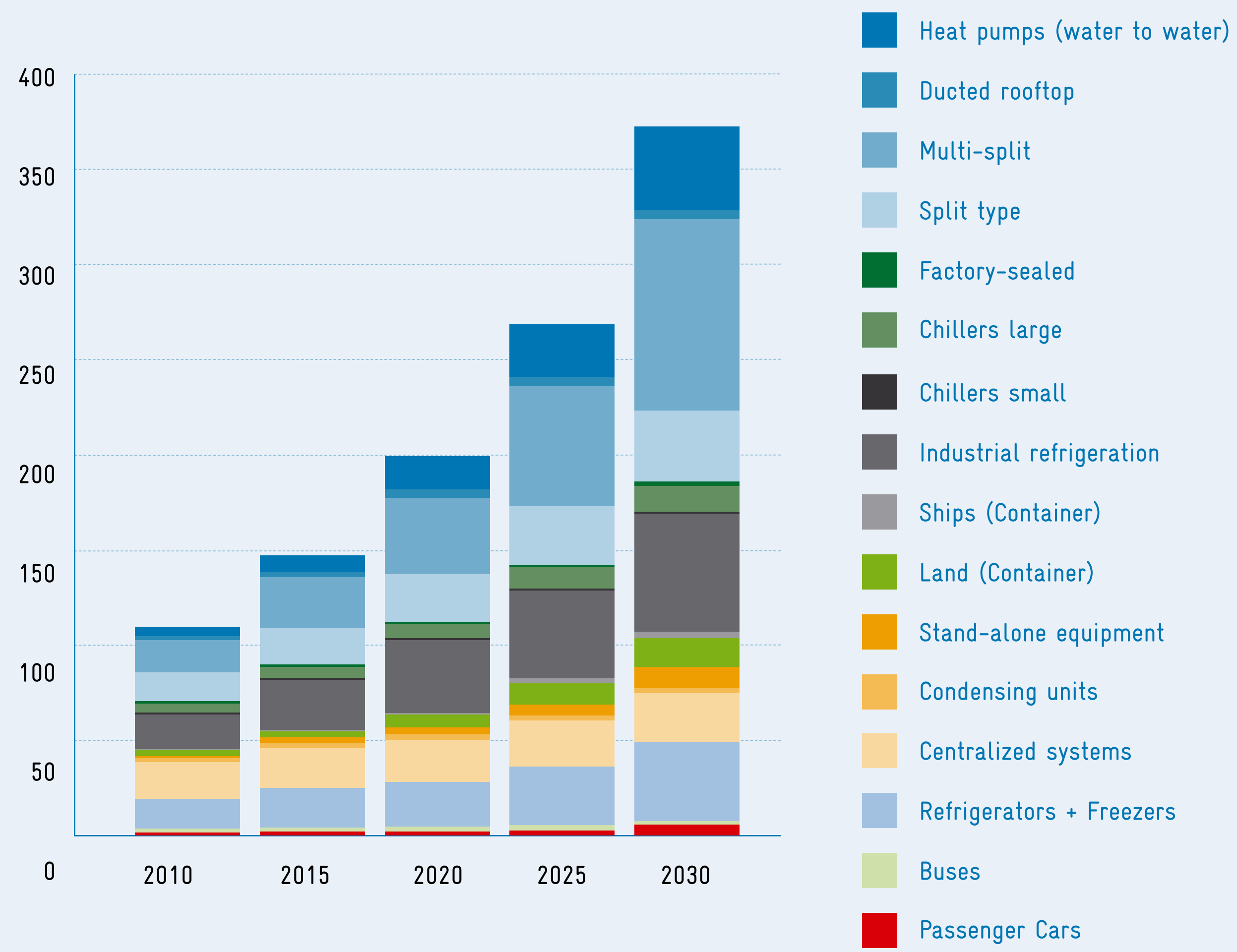
1 See: www.green-cooling-initiative.org

CLIMATE IMPACT OF THE RAC SECTOR

Economic growth, in particular the expanding middle-class and changing lifestyles in developing countries and emerging economies is responsible for the vast market growth of various cooling appliances, which is currently estimated at a market volume of about 150 billion EUR (based on Schwarz et al., 2011).

GHG emissions in the RAC sector result from fossil fuel combustion for electricity generation (indirect emissions) and the release of fluorinated gases (F-GHGs) used as refrigerants for cooling purposes (direct emissions) in the appliances listed in Figure 1.

Figure 1: Global market volume in different applications in refrigeration and air conditioning in billion EUR (based on data from Schwarz et al., 2011)



Refrigeration and air conditioning accounted for approx. 16% of the global electricity consumption in 2012 (GCI/IEA 2014a)[2]. With more than a 200-percent increase projected in the market volume of cooling and refrigeration appliances between 2010 and 2030 (see Figure 1), a rapid growth in the energy consumption from this sector is to be expected. The resulting indirect emissions can be reduced by increasing energy efficiency or by decarbonizing the energy supply for cooling and refrigeration appliances.

According to calculations by the Green Cooling Initiative, direct emissions resulting from refrigerant leakage contribute approx. 29% to the total emissions of the RAC sector. This is due to the high global warming potential (GWP) of F-GHGs used as refrigerants or foam blowing agents. Direct emissions can be reduced by replacing F-GHGs with natural refrigerants (CO_2, ammonia, hydrocarbons, air, and water) as they have no or negligible GWP.

HFC emission trends and reduction potential

There are four main groups of F-GHGs, namely: Hydrochlorofluorocarbons (HCFCs) Hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs) and sulphur hexafluoride (SF_6). While HCFC are already regulated under the MP, PFC and SF_6 are mainly used in industrial processes and products. HFCs are the most prominent F-GHGs used in the RAC sector. They are emitted during manufacturing, operation, servicing, and from the disposal of RAC equipment and refrigerant cylinders and containers. HFCs have exceptionally high global warming potentials (GWP). For example, HFC-134a, one of the most commonly used HFCs, has a GWP of 1,300 considering a 100-year time horizon (IPCC, 2013). This means that HFC-134a is 1,300 times as harmful to the climate with respect to global warming as the equal amount of carbon dioxide (CO_2).

The large increase in the use of HFCs in the RAC sector is primarily because they serve as the main substitutes for ozone depleting substances (ODS), which are globally regulated under the Montreal protocol. Especially in emerging and developing countries with a rapidly growing cooling demand, this leads to a rising consumption of HFCs.

Total HFC emissions are projected to reach between 1.9 Gt CO_2eq (US EPA, 2012)[3] and 3.6 Gt CO_2eq (Velders et al., 2009)[4] by 2030. Projections for 2050 even range from 3.7 Gt CO_2eq (Gschrey and Schwarz, 2009) up to 8.3 Gt CO_2eq per year (Velders et al., 2009) under HFC-related BAU scenarios.[5] For the latter, HFC emissions from the cooling sector would account for 8.9% of total projected GHG emissions in 2050.[6]

Low GWP technology options as an alternative to HFCs exist for almost every RAC appliance (listed in Figure 1). About 55% of HCFC in use can be substituted by natural refrigerants and foam blowing agents which would help to avoid a climate-damaging 'HFC technology lock-in' (Zeiger et al., 2014).

2 Relative share calculated based on global electricity consumption for RAC in 2012 by green cooling initiative in relation to global electricity consumption in 2012 by IEA (2014a).

3 These emission projections are based on an inventory of ODS substitution measures in the USA. This data was adapted to other countries to estimate their respective HFC emissions in terms of tons of CO2 equivalent based on their ODS consumption (which is reported to UNEP in terms of Ozone Depletion Potential (ODP) as required by the Montreal Protocol). Both reported data and estimations are subject to a variety of assumptions, thereby resulting to significant uncertainties.

4 Velders et al. (2009) estimated emissions separately for all major HFCs. Their results have been corrected for more recent values of GWP according to IPCC (2013) and are illustrated in Figure 2 and 3. This modification results in a slight reduction of projected total HFC emission in means of CO_2eq.

5 While Velders et al. (2009) assume that the consumption of HFCs depends on population and GDP, Gschrey and Schwarz (2009) assume specific growth rates for each cooling sector for both developed and developing countries.

6 This value is derived from the comparison of the corrected RAC-related HFC emission data from Velders et al. (2009) with the corresponding IPCC Special Report Emissions Scenarios (SRES) for CO_2, methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2000).

Figure 2: Total global HFC emissions according to different emission scenarios.

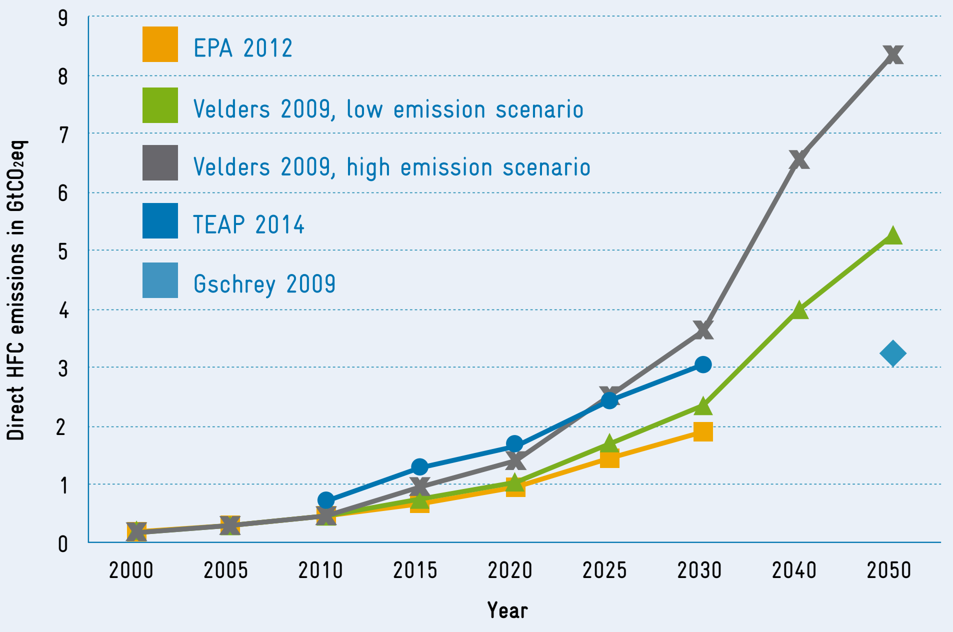
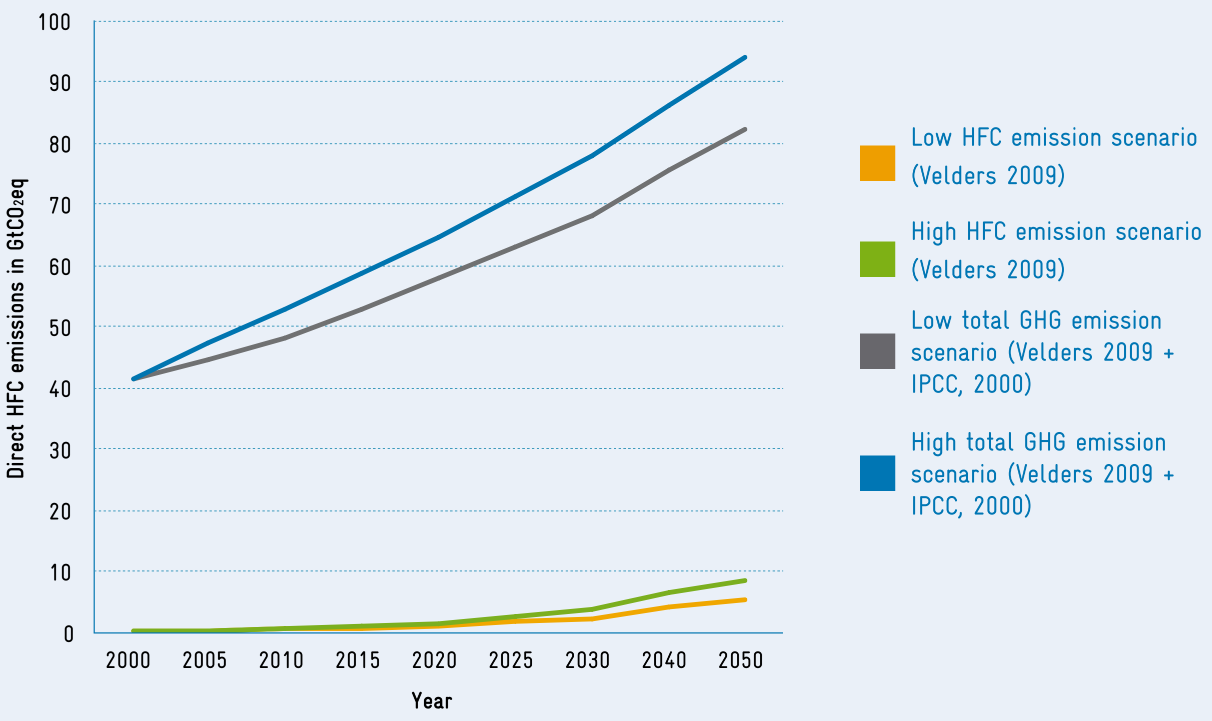


Figure 3: Total global HFC emissions according to high and low emission scenario from Velders et al. (2009) and total global GHG emissions from combined data from Velders et al. (2009) for HFC emission and from the SRES scenarios for CO_2, CH_4, and N_2O emissions.



REGULATORY FRAMEWORK FOR F-GHGS

The success and future potential of the Montreal Protocol

Amongst F-GHGs, HFCs require special attention as they are highly potent GHGs and account for the dominant proportion of F-gas emissions with the largest growth rate among all GHGs. Moreover, they are increasingly used by many countries as substitutes for ozone depleting substances (ODS) such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), the phase-down of which are regulated under the Montreal Protocol (MP). Whereas CFCs have been phased out worldwide in 2010, the phase-down of HCFCs is yet to be completed by 2020 in developed countries and by 2030 in developing countries (with a minor tail for servicing of equipment until 2040). The MP is the first Multilateral Environmental Agreement (MEA) to achieve universal ratification in the United Nations history and has enabled both developed and developing countries to achieve a near total phase-down in the production and use of ODS (UNEP 2014).

So far, HFC is accounted as a GHG under the UNFCCC but its necessary phase-down has not been regulated, neither in the UNFCCC nor in the MP. Attempts are ongoing to adjust the Montreal Protocol in order to regulate HFC production and consumption, which will otherwise neutralize large amounts of CO_2 emission reductions.[7] The North American Amendment Proposal suggests accumulated emission savings of 90 – 111.5 Gt CO_2eq by 2050 (UNEP, 2015). Technological improvements associated with the phase-down of HFCs would imply energy efficiency gains and thereby even greater GHG mitigation (IEA, 2007). A near time decision on this issue at the Meeting of the Parties (MOP) of the Montreal Protocol in November 2015 could state a clear signal to the INDC process and the following COP in Paris a couple of weeks later.

F-GHGs in the UNFCCC

Following the plan to negotiate a comprehensive climate agreement by 2015, which shall enter into force in 2020, Parties to the UNFCCC decided at the COP 19 in Warsaw in 2013 to invite all Parties to prepare so-called 'Intended Nationally Determined Contributions' (INDC). The intention to "develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties" is routed in the work of the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) that was established at COP17 in Durban.[8] With global participation, these INDCs play a vital role in the post-2020 global climate agreement, which shall ultimately aim at limiting global warming to 2°C in order to prevent the irreversibly disparaging effects of climate change. At COP19 in Warsaw in 2013, Parties have been invited to initiate or intensify the preparation of INDCs towards achieving the objective of the Convention and to communicate the INDCs well in advance of the 21st session of the COP21 held in Paris at the end of 2015.[9]

The need to include F-GHGs in INDCs

Parties are currently in the process of preparing their INDCs for submission or are initiating a process to further elaborate their INDCs for implementation, a process that is expected to last beyond COP21 until the actual agreement turns into implementation in 2020. Countries' INDCs, in support to a global climate agreement, could comprise the seven types of GHGs controlled under the UNFCCC and the Kyoto protocol to date: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). More than half of the submissions so far state F-gases in their INDC.[10]

7 Four Amendment proposals to manage HFC under the Montreal Protocol have been submitted by 40 countries (by the USA, Canada, and Mexico, by India, by the EU and by eight Pacific Island States); furthermore a non-paper by the 55 African states, see http://conf.montreal-protocol.org/meeting/oewg/oewg-36/presession/SitePages/Home.aspx

8 See Decision 1/CP.17.

9 See paragraph 2 of FCCC/CP/2013/10/Add.1 at http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf.

10 56 countries have submitted their INDC by 24th of August, 2015, 43 of them include F-GHG (39 industrialized Annex 1 countries and 4 countries categorized as Non-Annex 1 countries under the UNFCCC (China, Mexico, Serbia, and Singapore), see: http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx (State: August 18, 2015)

Indeed, phasing down F-GHGs, in particular HFCs, present a high GHG mitigation potential. Emission trends demonstrate the tremendous increase of F-GHGs emissions within the next decades, both on an absolute scale and in comparison to other GHGs. Although alternatives to F-GHG only make a small proportion of technologies in use, viable alternatives are available and are already in use, partly for a long time. For example, more than 700 million domestic refrigerators with the low GWP hydrocarbon butane are in households worldwide, and 75% of the global market are expected to use hydrocarbon in 2020 (TEAP 2015). Ammonia (NH_3) has long been used for large-capacity refrigeration plants and CO_2 has been gaining popularity in supermarket refrigeration systems. More than 40% of worldwide emissions from the RAC sector could be omitted by replacing HFCs with less harmful refrigerants and by simultaneously advancing energy efficient technologies.[11]

Although the Montreal Protocol does currently not include F-GHGs, it provides the expertise and structural institutions needed for a sustainable transformation in the RAC sector. Most countries are currently engaged in their HCFC phase-out management plan (HPMP), which imply technological modifications in the affected sectors. Extending existing regulations to HFCs would mean driving this present regulative and transformative momentum towards environmentally-friendly cooling and foam blowing technologies. As a consequence, emission savings are comparatively easier to achieve and cost-efficient in the RAC sector.

Furthermore, INDCs provide an appropriate and well-timed framework to integrate F-GHG mitigation into national climate goals as INDCs define activities beyond 2020. By this time, HCFCs will have been banned under the MP in industrialized countries and reduced by 35% in developing countries – allowing for the phase-down of HFCs to be integrated into ongoing and established HCFC phase-out measures in the RAC sector.

Recent submissions of INDCs reflect awareness of the F-GHG problem by stating the relevant gases under GHG gases to be covered. So far, primarily industrialized countries have included F-GHGs in their INDCs, e.g. Canada aims to gradually phase down HFCs in the next 10 to 15 years.

The European Union has equally taken regulatory action to combat climate change with a new F-gas regulation, which applies from 1 January 2015. According to this regulation, F-gas emissions shall be cut by two-thirds compared with 2014 levels by 2030. Expected emission reductions would amount to 5 Gt CO_2eq by 2050.[12] So far, the EU hasn't addressed this regulation in their INDC.

Mexico is the first emerging economy to include F-gases in their INDC. In order to achieve the maximum emission reduction potential in the RAC sector, other developing countries and emerging economies need to target F-GHGs specifically and include them in their INDCs.

11 See www.green-cooling-initiative.org

12 http://ec.europa.eu/clima/policies/f-gas/index_en.htm

COUNTRY PROFILES

Indonesia

Indonesia is among the fastest growing economies in Asia.[13] The constant need for cooling due to high temperature and humidity combined with high rates of economic growth translates into a significantly increasing demand for refrigeration and air conditioning in the country. In 2014, the RAC sector accounted for approx. 9% of the country's total GHG emissions excluding LUCF.[14] Driven by growing prosperity and changing lifestyle, demand for refrigeration and air conditioning in Indonesia is rapidly rising; this is true not just in private households, but increasingly in the commercial and industrial sectors as well. For instance, air conditioners are forecast to be sold at an annual growth rate of 13% during 2013 and 2018 (TechSci Research, 2014).

Although the energy saving potential in industrial and commercial sector is estimated at 15-30% (GoI, RIKEN 2011), energy efficiency has not gained much attention yet due to highly subsidized electricity prices, an underdeveloped RAC service market, and low capacities in the safe and energy-efficient operation of RAC technologies. This large, untapped potential for energy saving and GHG emissions reduction especially applies to inefficient RAC technologies.

Since COP13 in Bali in 2007, Indonesia has significantly advanced its climate mitigation policy framework. The National Action Plan for GHG Emission Reduction (RAN-GRK) aims to reduce 26% of GHG emissions compared to BAU in 2020 and an additional 15% with international assistance. Currently, the RAN-GRK is revised to ensure further alignment with its national development plans and its sustainable development agenda (GoI 2013). Indonesia's INDC is currently being developed and is expected to build upon the existing climate mitigation policies. The national GHG mitigation target shall be achieved by gradually decoupling emissions from economic growth in which Nationally Appropriate Mitigation Actions (NAMAs) shall play a key role for implementation. A number of NAMAs are presently under development, a few of which are in early stages of implementation.[15]

In 2010, Indonesia completed its CFC phase-out under the MP and has developed a 2012-2018 HCFC phase-out management plan targeting the sectors foam, commercial refrigeration and air-conditioners. The most commonly used refrigerant in Indonesia is the HCFC-22 with a GWP of 1760 given a time horizon of 100 years. The HFC R32 with a GWP of 677 is currently being introduced as an alternative to HCFC (e.g. R22) and promoted as a more climate-friendly solution. However, moving from HCFC to HFC can only be seen as a temporary relief as the vast growing numbers of air conditioning and refrigeration units in the market would easily neutralize these emission savings within approximately eight years.

The Green Cooling Initiative[16] estimates GHG emissions originating from refrigeration and air conditioning at 71.6 Mt CO_2eq (2014). They are projected to reach 215 Mt CO_2eq in 2030 (cf. Fig. 2). In the AC sector direct emissions caused by leakage of climate-damaging refrigerants are estimated to be about 24% of the total GHG emissions. The remaining 76% are indirect emissions that result from energy use for cooling equipment. By 2030, GHG emissions of up to 92 Mt CO_2eq per year can be avoided with the introduction of more energy-efficient technologies and the use of natural refrigerants. More specifically:

- 52 Mt CO_2eq through equipment with improved energy efficiencies (reduction from 169 to 118 Mt CO_2eq).
- 40 Mt CO_2eq through direct emission reductions by avoiding refrigerant leakage and introducing appliances with low GWP refrigerants (from 45 to 5 Mt CO_2eq)

13 Bloomberg 2015, http://www.bloomberg.com/news/articles/2015-02-25/the-20-fastest-growing-economies-this-year

14 Total GHG emission data 1990-2012 taken from CAIT, 2015. 2014 data was derived using the average annual growth rate between 2007 and 2012 to extrapolate 2012 total GHG emission data excluding land-use change and forestry (LUCF). Emission data for the RAC sector was taken from the Green Cooling Initiative.

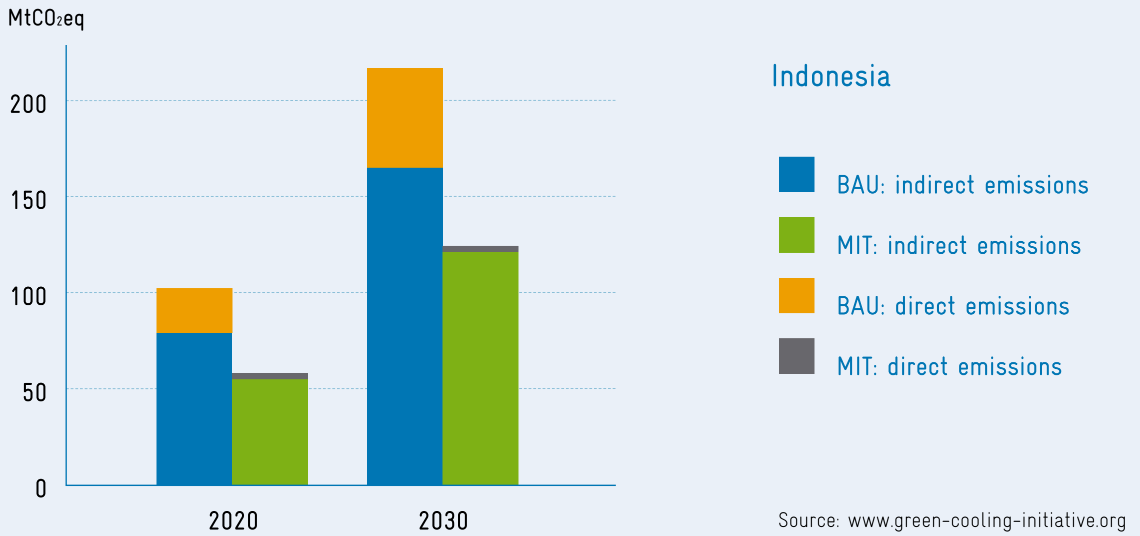
15 For further details on Indonesian NAMAs, see http://ranradgrk.bappenas.go.id/rangrk/images/documents/Kerangka_Kerja_Indonesia_untuk_NAMAs_English.pdf

16 www.green-cooling-initiative.org

These projections are based on the following two assumptions:

- Refrigerants alternative to HFCs are available, which have either no (ammonia) or negligible (hydrocarbons and CO_2) GWP, and have proven to be commercially viable.
- Substitution of F-GHGs usually goes hand in hand with improvements in energy efficiency, which range among the most attractive measures in terms of abatement costs.[17]

Figure 4: Indirect and direct emissions in business-as-usual (BAU) and mitigation (MIT) scenario in 2020 and 2030 (in Mt CO_2eq) for Indonesia.



Source: www.green-cooling-initiative.org

In the case of Indonesia, commercial (hotels, malls, office buildings) and residential cooling systems are often not well adjusted to the required cooling capacity, which results in higher energy consumption. Proper cooling needs assessments and fine-tuned system designs during the construction stage, improvement of refrigeration cycles and reduction of parasitic losses in operation stages can yield large electricity savings. Policies to tap this savings potential can include energy performance standards and labeling. Incentives (e.g. tax reductions, waving import duties or concessional loan programs), subsidized energy audits, and trainings and programs to change behavior can ease the enforcements of standards and labeling.

Moreover, there is a large potential for hydrocarbons (e.g. propane, butane) for different RAC technologies, which in many cases only require little technology adoptions. However, due to its flammability, suppliers and end-users are still hesitant to use propane (R290) as a refrigerant – even though it is already locally produced and widely used for residential and commercial cooking purposes. Convincing pilot measures that demonstrate the technical feasibility combined with awareness programs and training on how to safely operate RAC equipment using natural refrigerants can help overcome this hesitance.

17 See: http://ec.europa.eu/clima/policies/f-gas/alternatives/index_en.htm

The German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB) through its International Climate Initiative (ICI) addresses the mitigation potential in the Indonesian RAC sector by supporting a project on the development of a NAMA for energy-efficient cooling systems and cold supply in Indonesian industry and commerce.[18] This NAMA is divided into four complementary working packages, namely (1) development of the national mitigation strategy (including establishment of an MRV system), introduction and improvement of (2) establishment of incentive schemes (with the aid of specific energy performance and safety standards), (3) pilot projects, to demonstrate energy savings and (4) GHG mitigation capacity building for relevant stakeholders (such as manufacturers, distributors, installers and operators).

Ghana

Electricity access in Ghna has risen from approx. 60% to more than 70% in the past five years; however, electrification is much more developed in urban areas, where the electric supply reaches 90% of the population (GSS 2009, IEA 2014b). Due to its National Electrification Scheme launched in 1989, Ghana is one of the most successful African countries in improving electricity access (IEA 2014b). About two thirds of energy capacity is generated by hydropower stations such that the carbon intensity of electricity is less than half the global average.[19]

Ghana is developing a National Climate Change Policy, which incorporates plans to reduce GHG emissions and aims to "ensure a climate-resilient and climate-compatible economy, which addresses a low-carbon growth path for Ghana while achieving sustainable development".[20] By 2008, Ghana completed its CFC phase-out and is currently implementing an HCFC phase-out plan (2010-2019). Currently, most AC units operate on HCFC-22, which still generates emissions of 1.8 Mt CO_2eq annually.[21]

Ghana's per capita GHG emission from the cooling sector appears small compared to Indonesia, owing to a much lower electricity penetration. However, emissions from the Ghanaian cooling sector play a dominant role in overall GHG emissions in Ghana: In 2014, the RAC sector accounted for approx. 12.5% of the country's total GHG emissions excluding LUCF.[22] Rapid electrification translates into rising demand of RAC equipment. With respect to emissions as well as growth rates, the RAC sector in Ghana is dominated by split room air conditioners. Currently, more than 50,000 AC devices are sold annually with a growth rate of 8% (IEA 2007). Ghana relies on imports of RAC equipment, in which China holds about 50% of the market share. Compared to more developed countries, the energy efficiency of devices sold in Ghana is very low, as manufacturers send their least efficient models to Ghana or Africa in general. There is a large market for used appliances, especially for refrigeration. As a result, the Ghanaian RAC sector shows a high proportion of old appliances – 30% of ACs are between 15 and 40 years old – with low energy efficiency, high servicing frequency and major refrigerant leakages. Although energy efficiency standards already exist, enforcement programs have not yet been established due to a lack of resources.

In 2014, the cooling sector in Ghana caused GHG emissions of ca. 3.66 Mt CO_2eq – a figure that is projected to increase to almost 11 Mt CO_2eq by 2030 under a business-as-usual scenario according to the Green Cooling Initiative (cf. Fig. 2). In the Ghanaian AC sector, direct emissions account for almost 50% of emissions.

18 Further information at: http://www.greenchillers-indonesia.org/index.php/en/

19 http://www.iea.org/statistics/statisticssearch/report/?year=2012&country=Ghana&product=ElectricityandHeat

20 Ghana National Climate Change Policy, Ministry of Environment Science, Technology and Innovation, 2013 http://iess.ug.edu.gh/index.php/publications/reports-miscellaneous?download=57:ghana-national-climate-change-policy

21 Hydrochlorofluorocarbon Phase-out Management Plan (HPMP) for Ghana, 2010, http://www.gh.undp.org/content/ghana/en/home/library/environment_energy/HPMPdoc.html

22 Total GHG emission data 1990-2012 taken from CAIT, 2015. 2014 data was derived using the average annual growth rate between 2007 and 2012 to extrapolate 2012 total GHG emission data excluding land-use change and forestry (LUCF). Emission data for the RAC sector was taken from the Green Cooling Initiative.

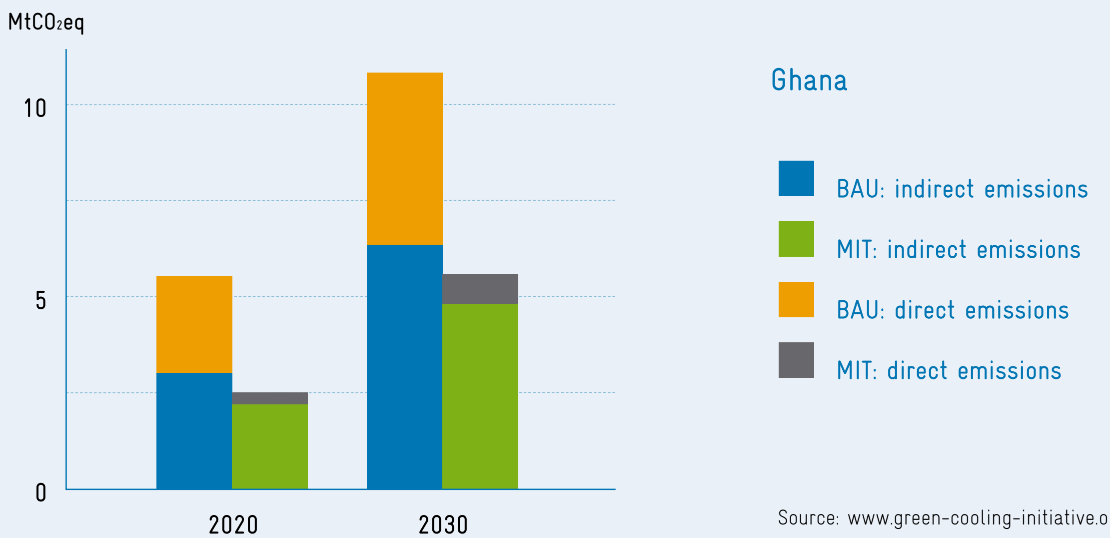
Due to high leakage rates and low carbon intensity of electricity, the emission reduction potential of direct emissions by converting to natural refrigerants is disproportionally high in Ghana compared to other countries.

By 2030, 5.66 Mt CO_2eq can be avoided, which is about half of BAU emissions, under the assumptions stated in the Indonesia case study. The savings are composed of:

- 3.81 Mt CO_2eq from direct emissions, which corresponds to almost 90% of the BAU scenario, saved by converting to natural refrigerants and reducing leakage rates,
- 1.85 Mt CO_2eq from indirect emissions, i.e. 30% compared to BAU, saved by improving energy efficiency of cooling appliances.

The great importance of direct emissions to GHG emissions from the cooling sector in Ghana suggests that a primary path towards emission reductions is to allow for F-gas-free RAC appliances to enter the Ghanaian market by modifying import patterns. Policy transformations regarding import regulations facilitate corresponding processes. With minimum energy efficiency performance standards (MEPS) already at hand, Ghana would especially benefit from measures that improve their enforcement such as testing facilities, capacity building and trainings. Subsequently, the generation of incentives for the end-user to invest in energy efficient new devices requires a sound implementation of standards and consistent labeling schemes.

Figure 5: Indirect (GHG) and direct (F-GHG) emissions in business-as-usual (BAU) and mitigation (MIT) scenario in 2020 and 2030 (in Mt CO_2eq) for Ghana.



Source: www.green-cooling-initiative.org

CHALLENGES

The RAC sector holds an enormous mitigation potential in numerous countries, especially in developing countries (like Ghana) and emerging economies (like Indonesia). However, countries face institutional, regulatory, and technological challenges upon including GHG emission reductions in the RAC sector in their domestic efforts to combat climate change:

- Both regimes, the UNFCCC and the MP are characterized by different institutional settings. Focal points to the UNFCCC and National Ozone Units (NOU) to the Montreal Protocol are often located in different institutions. Designing national mitigation strategies in the RAC sector requires alignment of mandates and closer cooperation among climate policy officers, F-gas regulators and energy efficiency policy makers at national and international level.

- Under the MP, measures are undertaken to control production and consumption of ODS whereas the UNFCCC mechanisms and concepts (such as the Clean Development Mechanism (CDM) or NAMAs) are based on control of emissions, which are addressed through projects (CDM) or policies and regulations (NAMAs). This does not only imply different approaches in transforming the relevant markets but also different methods of accounting and inventory between F-GHGs and non F-GHGs.

- Despite general awareness about high emissions and the corresponding reduction potential in the RAC sector, many countries have not developed F-GHG inventories or reflected F-GHGs in their overall emissions inventories (National Communications, Biennial Update Reports).[23] A RAC inventory provides policy makers with a comprehensive picture of all emissions in the RAC sector in order to identify suitable mitigation options in accordance with a country's development priorities.[24]

- Energy-efficient and low-GWP alternatives to HFC-based technologies in developing countries often face higher up-front investment requirements and limited incentives to convert to natural refrigerants.

- Most climate-friendly refrigerants are flammable or toxic and, hence, require more comprehensive safety considerations and technological modifications as well as additional capacities for installation and servicing. Proven safety requirements are available; however, obstructive standards exist in many instances and countries which do not reflect these requirements that would enable the use of natural refrigerants.

- Subsidized electricity prices, such as those in Indonesia, prevent market development for energy services that would help harvest savings from improved efficiency.

- The F-gas market features strong oligopoly structures. Producers of synthetic refrigerants strongly promote F-gas based air conditioning and refrigeration technologies as they bring in higher profits due to intellectual property rights and patents and control production. Natural refrigerants on the contrary are widely-used gases that can be easily produced by local companies. Transforming a national RAC market towards natural refrigerants, therefore, requires considerable local market penetration and infrastructure development for the manufacture, supply, and servicing for green cooling equipment.

23 CO_2 emissions result from fossil fuel combustion for electricity generation for RAC appliances and are fall under the IPCC category energy, the release of fluorinated gases (F-GHGs) used as refrigerants for cooling purposes in RAC appliances are direct emissions that fall under the IPCC category industrial processes.

24 The RAC&F NAMA technical handbook comprises of guiding steps on how to develop an inventory, the handbook is available online at: http://www.giz.de/expertise/html/4809.html

OPTIONAL POLICIES AND ACTIONS AND THE ROLE OF NAMAS

Along with the RAC sector's emissions to the overall GHG emissions, the emission reduction potential also increases, making it a potentially meaingful building block for INDCs. Tapping this reduction potential requires a set of policies and measures adapted to the respective country situation. The following table summarizes possible policies and actions in different stages of the RAC technology cycle.

	Policies and actions to reduce direct F-GHG emissions in the RAC sector	Policies and actions to reduce indirect GHG emissions in the RAC sector
RAC manufacture, supply and distribution	**Phase-down of F-gas supply through**: • Avoidance of use of F-gas based refrigerants through import regulations • Ban on new applications operating on F-gases • Support manufacturers in converting production lines from F-gases to natural refrigerants • Inform and train distributors and servicing industry on how to properly install and maintain RAC equipment with natural refrigerants	• Introduction of Minimum Energy Performance Standards (MEPS) and labeling • Training/guidelines on cooling needs assessments and fine-tuned system designs at construction stages
RAC operation	• Incentives (e.g. accelerated depreciation, tax rebate, waving import duties or concessional loan programs) for purchase and installation of low GWP cooling equipment • Adoption, issuance and enforcement of safety standards • Capacity building on installation and maintenance of RAC equipment with natural refrigerants (leakage checks, safety measures)	• Promotion of energy audits, trainings, and programs aimed at changing behavior can ease the enforcements of standards and labeling • Training on energy efficiency measures (e.g. improvement of refrigeration cycles and reduction of parasitic losses in operation stages)
RAC disposal (End-of-life)	• Standards on end-of-life treatment of F-gas based refrigerants and cooling equipment • Training on proper disposal of contaminated RAC equipment • Creation of disposal service facilities	

Table 1: Climate friendly policies and measures in the RAC sector

The phase-out of ODS in many countries results in a rapid increase of climate damaging HFC emissions for which technology alternatives are so far not adequately considered in developing countries and emerging economies. Additionally, an even larger untapped mitigation potential exists with regard to energy efficiency as illustrated in the above-mentioned country profiles. Current INDC submissions show that many countries do include HFCs as one of the targeted gases for mitigation, together with CO_2 reduction. The latter partially arises from energy efficiency measures.

Nationally Appropriate Mitigation Actions (NAMAs) are currently used as the main vehicle for non-annex 1 countries to the UNFCCC to mitigate GHGs. Most countries currently use the NAMA concept to frame a set of policies and measures that would enable them to achieve their nationally set GHG mitigation targets in 2020. The NAMA concept allows countries to adjust policies towards GHG mitigation by introducing a technology change, enabled by optional international support and capacity-building – all of which are carried out in a measurable, reportable, and verifiable manner. So far, only a few NAMAs are in early stages of implementation, mainly through NAMA support projects by the NAMA facility[24]. With additional climate funds plenished in the Green Climate Fund (GCF), more NAMAs can potentially reach scales that induce enough leverage in the private sector to enable GHG mitigation in a transformative sense.

INDCs are currently being prepared in many countries for the new climate change mitigation agreement after 2020. NAMAs are expected to be a promising bridging tool that would generate valuable experiences – both, for further INDC elaboration pre-2020 and for INDC implementation post-2020.

With regard to the RAC sector, NAMAs can play a key role in introducing and deploying more energy-efficient RAC technologies with low-GWP refrigerants in the next years. This could pave the way for more ambitious climate-friendly cooling as part of a global climate agreement from 2020 onward. The following table shows NAMAs that are currently being developed in the RAC sector:

24 http://www.nama-facility.org/start.html

Country	RAC target sector	Stage / support
Thailand	Whole sector	**Implementation to start in 2016** (technical and financial assistance by UK GER NAMA facility with 14 Mio EUR)
Indonesia	Commercial and industrial refrigeration / air conditioning	**NAMA concept under development** (BMUB IKI project supports establishment of NAMA, volume: 4,1 Mio EUR)
Mexico	Commercial refrigeration	A complete inventory of all sub-sectors has been developed; NAMA concept for commercial refrigeration under development
Colombia	Domestic refrigeration	Preparation to create GHG inventories (energy use and refrigerants) of all sub-sectors; official partner under BMUB IKI

Table 2: NAMA development in the RAC sector

The development and deployment of more energy-efficient RAC technologies using low-GWP refrigerants do not only result in GHG mitigation, but also contribute to energy security and cost savings on micro- as well as macro-economic levels. Furthermore, natural refrigerants can be produced locally, thereby reducing dependence on suppliers of chemical refrigerants and vulnerability to corresponding market changes.

CONCLUSIONS

The increasing use of energy-inefficient and climate-damaging RAC technologies, especially in developing countries, call for political action – on a national level as well as on the international level through the UNFCCC.

The Montreal Protocol presents itself as the appropriate platform to effectively coordinate the HFC phase-down as it already regulates the production and consumption of ozone depleting F-gases in the RAC sector. Reaching an agreement on the Montreal Protocol amendment to regulate the phase-down of HFCs would send a clear signal to major emitters and their contributions to the post-2020 climate agreement. The current INDC preparation process provides a good opportunity to draw the required attention to the RAC sector and its significant potential for climate protection.

INDCs are expected to 'take the next level' in terms of GHG mitigation ambition, comparability, and accuracy. Within their INDC development processes, Parties to the UNFCCC are currently assessing relevant sectors according to their emission reduction potential, abatement costs, and (socio-economic) co-benefits. Emissions of F-GHGs such as HFCs usually occur as direct emissions from appliances and processes and can be reduced with relatively little effort, at relatively low costs and with a high level of accuracy. Good practices made in the Montreal Protocol in phasing out F-gases can be helpful when designing effective policies and measures to maximize GHG mitigation in the RAC sector.

Harmonizing the different inventories, funding sources and mitigation policy making of F-GHGs and non F-GHGs can be mutually reinforcing. The Multilateral Fund (MLF) of the MP, for instance, finances projects to demonstrate climate-friendly and energy-efficient technology alternatives to HCFCs, often the conversion of production lines. In the next years and as outlined in the country cases, NAMAs could build on these production-based demonstrations and help up-scale upgrading and deployment of efficient and clean technologies with incentives, capacity building and training on safety standards and efficiency standards in order to reach transformative scale. In this context, NAMAs can have a bridging function by generating valuable experiences that can be used to set policies for INDC implementation.

Parties to the UNFCCC are expected to communicate their INDC submission well in advance of the 21st session of the Conference of the Parties (COP21) at the end of 2015. However, the harmonization of accounting frameworks and mitigation policy making of F-GHGs and non F-GHGs requires more time to maximize GHG mitigation with cooling technologies. Each party is therefore well advised to assess the environmental, technological and economical potential of its RAC sector to determine its relevance for the design and implementation of its INDC in the upcoming years towards 2020.

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