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Conference Paper

Green Cooling Summit

Online event on 25th – 27th May 2021

by:

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On behalf of the German Environment Agency

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Zusammenfassung

Die Online-Konferenz « Green Cooling Summit » vom 25. bis 27. Mai 2021 brachte verschiedene Akteursgruppen aus der Kälte- und Klimatechnikbranche zusammen und vermittelte ein umfassendes Bild zum Thema nachhaltige Kühlung. Veranstalter waren das Umweltbundesamt, die Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) und das Bundesministerium für Umwelt Naturschutz und nukleare Sicherheit. Der « Summit » bot einen Überblick zur Frage, wie der HFKW Phase-down gemäß des Beschlusses von Kigali zum Montrealer Protokoll am besten mit der Nutzung von natürlichen Kältemitteln und verbesserter Energieeffizienz umgesetzt sowie politisch und technisch beschleunigt werden kann.

Seitens der Vortragenden und Teilnehmenden wurde ein breites Kompetenzspektrum abgebildet. Sie repräsentierten politische Entscheidungsträger, Wissenschaftler, technische Berater und Hersteller nachhaltiger Kühl- und Klimatechniken. Die Konferenz erstreckte sich über drei Tage, wobei jeder Tag einem anderen Schwerpunktthema gewidmet war.

Der erste Tag konzentrierte sich auf die politischen Ansätze zur Umsetzung des HFKW Phase-down mit natürlichen Kältemitteln. Nachhaltige Kühl- und Klimatechniken sowie die sichere Nutzung natürlicher Kältemittel standen am zweiten Tag im Fokus. Am letzten Tag wurden neueste Forschungsergebnisse zu verschiedenen Themen, welche für Kühlung und Klimatisierung relevant sind, vorgestellt und diskutiert.

Während der Konferenz konnten die Teilnehmenden auf die begleitende Veranstaltungsplattform zugreifen, die u.a. mit einer virtuellen Messe, einer Kontaktvermittlungsoption und einer Auswahl an Videos zu klimafreundlichen Kühltechniken aufwartete.

Was ist “Green Cooling” (nachhaltige Kühlung)?

Die Kombination aus natürlichen Kältemitteln, energieeffizienter Technik und, im Idealfall, elektrischer Energie aus erneuerbaren Quellen.

Die Einblicke und gute-Praxis-Beispiele, welche auf der Konferenz präsentiert wurden, boten eine gute Grundlage die derzeitige Praxis im Kälte-/Klimabereich einer kritischen Überprüfung zu unterziehen und ermöglichten den Teilnehmerinnen und Teilnehmern, sich ein Bild von nachhaltigen Kühlungskonzepten, Standards und politischen Ansätzen zu machen. Insgesamt zeigten die Vorträge und Diskussionen, dass natürliche Kältemittel eine ökonomisch tragfähige und ökologisch nachhaltige Option darstellen, teilfluorierte Kohlenwasserstoffe (HFKW) und teilhalogenierte Fluorchlorkohlenwasserstoffe (HFCKW) zu ersetzen und damit das HFKW Phase-down gemäß des Beschlusses von Kigali zum Montrealer Protokoll einzuhalten. Es wurde jedoch auch deutlich, dass die bloße Einhaltung des Beschlusses nicht ausreichend ist, um einen ausreichend wirksamen Beitrag zum Klimaschutz zu leisten. Folgerichtig haben manche Staaten und Unternehmen bereits angekündigt, über die Ziele des Beschlusses von Kigali hinauszugehen, zum Beispiel der Inselstaat Grenada, der anstrebt, die erste HFKW-freie Insel der Welt zu werden. Der belgische Lebensmitteleinzelhändler Colruyt plant eine vollständige Umstellung seiner Märkte auf natürliche Kältemittel bereits bis zum Jahr 2030.

Der überwiegende Teil der Vortragenden und Podiumsdiskussionsteilnehmenden stimmten darin überein, dass der Ersatz halogenierter Kältemittel durch natürliche jetzt erfolgen muss und keinen Aufschub duldet. Regierungshandeln wurde oft als einer der wichtigsten Faktoren für die breite Anwendung natürlicher Kältemittel genannt. Dies beinhaltet

- Eine zeitnahe Umsetzung des Beschlusses von Kigali und beschleunigter HFKW Phase-down,

- Anreize für die Nutzung von Techniken mit natürlichen Kältemitteln wie etwa verminderter Importsteuer und Förderprogramme (wie z.B. in Ghana),
- Einschränkung und Verbot der HFKW-Nutzung (wie in der EU F-Gas-Verordnung EU umgesetzt), um einen verlässlichen Rahmen für Hersteller und Endverbraucher zu gewährleisten und
- Weiterbildung von Kältetechnikern und Kapazitätsaufbau im Kälte-/Klimasektor.

Nach Einschätzung einiger Sachverständiger liegt das Marktpotential von Anlagen und Geräten mit natürlichen Kältemitteln im gesamten Kälte-/Klimasektor zwischen 75 und 85 %. Andere gehen sogar davon aus, dass ein vollständiger Ersatz von HFKW nicht nur möglich, sondern folgerichtig ist.

Anlagen und Geräte mit natürlichen Kältemitteln sind deutlich energieeffizienter (20-50 %) im Vergleich zu HFKW-Techniken. Im Fall von R290-Monosplit-Klimageräten ist ein Energieeffizienzvorteil von 10 bis 16 % in Abhängigkeit der Außentemperaturen im Vergleich zu R22-Geräten zu verzeichnen. Interessanterweise weisen auch gewerbliche HFKW-Anlagen, die auf R290 (Propan) umgerüstet wurden, eine verbesserte Energieeffizienz auf. Solche Umrüstungen erfordern sorgfältige Begutachtung und Sicherheitsmaßnahmen, um die potentielle Brandgefahr auszuschließen.

Der sichere Einsatz brennbarer Kältemittel wurde nicht als Hindernis, sondern eher als Herausforderung angesehen, der mit einem angemessenem Anlagenkonzept und technischen Maßnahmen wie etwa Gassensoren, Außenaufstellung und mehreren Kältekreisläufen in Flüssigkeitskühlern um die Füllmenge zu reduzieren, begegnet wird. Die Brennbarkeit ist in internationalen Normen sehr restriktiv adressiert, Änderungen sind jedoch bereits auf den Weg gebracht, z.B. in der Gerätenorm IEC 60335-2-40. Die überarbeitete Norm erleichtert den Einsatz von R290-Splitgeräten, auch bei solchen mit größerer Nennkälteleistung (bis zu 15 kW). Der informelle Sektor in Entwicklungsländern wird als Sicherheitsproblem wahrgenommen, da unzureichend ausgebildete Techniker ohne Zertifizierung oft in unangemessener Art und Weise mit brennbaren Kältemitteln umgehen.

In mehreren Wortmeldungen und Diskussionen wurde angemerkt, dass die Überbetonung der Sicherheitsaspekte und die Aufschiebung des Übergangs zu natürlichen Kältemitteln nicht auf wissenschaftlichen Erkenntnissen basiert bzw. auf einen Mangel an halogenfreien Kühltechniken zurückzuführen ist. Dies ist vielmehr dem Eigeninteresse der Kältemittelindustrie geschuldet, welche die Vermarktung ihres Produktportfolios über entsprechende Einflussnahme auf die Normung vorantreibt, unter anderem auch durch die Errichtung von Hindernissen für natürliche Kältemittel. Darüber hinaus werden diese Profitinteressen seitens einiger Vertragsstaaten des Montrealer Protokolls unterstützt. Die Gewinnspannen natürlicher Kältemittel, welche teilweise Nebenprodukte der Öl- und Gasgewinnung sind oder im Falle von CO_2 (R744) aus Emissionen gewonnen werden, sind vergleichsweise niedrig. Folglich werden diese von Herstellern von synthetischen Kältemitteln nicht in Betracht gezogen.

Neueste Erkenntnisse zum Verbleib des ungesättigten HFKW-1234ze, welcher als Kältemittel und Treibmittel in der Polyurethanschaumherstellung verwendet wird, zeigten, dass dieser in der Atmosphäre zunächst zu Trifluoracetaldehyd (CF_3COH) und anschließend zu HFKW-23 mit einer Ausbeute von 9 bis 12 % abgebaut wird. Das bedeutet, dass die Klimawirkung von HFKW-1234ze mit einem GWP (Global Warming Potential) von 1.400 insgesamt deutlich größer ist als bisher angenommen. Dieser Befund wird dadurch gestützt, dass er in der Lage ist, den kürzlich beobachteten Anstieg der HFKW-23-Konzentration in der Atmosphäre zu erklären.

HFKW-1234ze wird als Alternative für R134a (GWP=1.430) eingesetzt. Dieser Sachverhalt zeigt, dass falsche Entscheidungen bei der Auswahl der Anlagentechnik getroffen werden, wenn bei der Einschätzung der Umweltwirkung von Kältemitteln deren atmosphärische Zerfallsprodukte nicht berücksichtigt werden.

Der urbane Hitzeinseleffekt, der den thermischen Komfort und die Gesundheit von Stadtbewohnern erheblich beeinträchtigt, kann durch Begrünung (Baumpflanzung, Errichtung grüner Fassaden und Dächer), blaue Infrastruktur (Teiche, Seen, Brunnen), Minderung von anthropogenen Wärmequellen, Verschattung und weitere Maßnahmen reduziert werden. Während die einen Sachverständigen angeben, dass Hitzeinseln die thermische Behaglichkeit in Innenräumen beeinflussen, gehen andere davon aus, dass dies zumindest im gemäßigten Breiten eher vernachlässigbar ist. Der Einfluss von Maßnahmenpaketen gegen den Hitzeinseleffekt ist relativ klein (1 bis 2 K) wenn lediglich Außenlufttemperaturen betrachtet werden. Im Gegensatz dazu können erhebliche Effekte von -10 K und mehr insbesondere durch Verschattungs-maßnahmen wie Baumpflanzungen und Sonnensegel beobachtet werden, wenn der Indikator Physiologisch äquivalente Temperatur (PET) herangezogen wird.

Online-Zugang zu allen Konferenzmaterialien und Highlight-Videos

650 Registrierungen aus 100 Ländern, 330 Fragen aus dem Publikum, 32 Vortragende, 3 Tage, 1 Ziel: nachhaltige Kühlung gemeinsam voranbringen! Sämtliche Konferenzmaterialien sind auch online erhältlich:

Highlights

Tag 1: Vorträge und Aufnahmen

Tag 2: Vorträge und Aufnahmen

Tag 3: Vorträge und Aufnahmen

Die folgende Zusammenfassung der Konferenz wurden mit der Absicht erstellt, den Inhalt so objektiv wie möglich abzubilden. Trotzdem kann diese lediglich das Verständnis der Autoren wiedergeben, welches von der intendierten Botschaft der Vortragenden abweichen kann.

Aus Gründen der Zweckmäßigkeit sind Links zu den Präsentationen in den entsprechenden Abschnitten angegeben.

Summary

The online event Green Cooling Summit from May 25 to May 27, 2021 brought together different stakeholder groups and provided a holistic update around the topic of sustainable (green) cooling. The summit was jointly hosted by the German Environment Agency (UBA), the Proklima programme within Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU). It gave an overview on how the phase-down of hydrofluorocarbons (HFCs), according to the Kigali Amendment of the Montreal Protocol, can best be implemented and accelerated politically and technically through the use of natural refrigerants and improved energy efficiency.

Presenters and participants covered a wide range of expertise. They consisted of political decision-makers, researchers, technical advisors as well as suppliers of Green Cooling solutions. The conference was held over a period of 3 days. Each conference day focused on specific topics.

The first day concentrated on policies regarding the implementation of the HFC phase-down with natural refrigerants. On day two, Green Cooling technologies and the safe use of natural refrigerants were in focus. Finally, on the last day, latest research results on different cooling-relevant topics were presented and discussed.

During the conference, an accompanying event platform consisting of several features such as a virtual showroom, a matchmaking option, and a movie theatre that played a selection of films on climate-friendly cooling was open to participants.

What is Green Cooling?

The combination of natural refrigerants, highly energy efficient equipment, and, ideally, electricity from renewable energy sources.

The insights and functional good practices presented at this conference provided a solid basis for a critical rethinking of current cooling practices and encouraged the audience to realise Green Cooling concepts, standards, and policies. Taken together, presentations and discussions showed that natural refrigerants are an economically viable and the most sustainable option to replace HFCs and HCFCs and by that to comply with the HFC phase-down according to the Kigali Amendment to the Montreal Protocol. However, it also became clear that even full compliance is not enough in order to prevent a fatal climate change pathway. Hence, some organisations and countries already pledged to go beyond Kigali Amendment goals, namely the Belgian retailer Colruyt. The company plans to switch all its markets to natural refrigerants by 2030. Also, Grenada aims to become the first HFC-free island in the world.

Most presenters and panellists agreed that action to replace halogenated refrigerants with natural ones is needed now and further postponement is not an option. Government action was often mentioned as one of the most important drivers to promote the spread of natural refrigerants. Such actions are:

- Early implementation of the Kigali Amendment and accelerated HFC phase-down
- Incentives for natural refrigerant technologies such as lower import taxes and support programmes (e.g., in Ghana)
- Restriction and prohibition of HFC use (as implemented in the EU Fluorinated Greenhouse Gas [F-gas] Regulation) providing certainty for manufacturers and end-users

► Training technicians and capacity building in the refrigeration and air conditioning sector

Market potential of natural refrigerant technologies in the entire air conditioning and cooling sector are believed to lie between 75% and 85% according to some experts. Others argue that even a complete replacement of HFCs by natural refrigerants is not only possible, but rational.

Natural refrigerant technologies are extremely energy efficient compared to HFC technologies, with efficiency gains ranging from 20% to 50%. For R290 single-split air conditioning (AC) units, a 10%-16% increase was observed compared to R22 units, depending on the ambient conditions. Interestingly, commercial HFC refrigeration installations also show better energy performance when retrofitted with R290. This of course requires careful evaluation and safety measures to prevent ignition.

The safe use of flammable refrigerants was not considered as an obstacle, but rather as a challenge, which can be taken up with appropriate design and technical measures such as multiple circuits in chillers to lower the charge, gas sensors, and outdoor installation. Flammability is addressed in a restrictive way in international norms, but changes are under way, e.g., in IEC 60335-2-40. The code will alleviate the use of R290 split air conditioners and allow for greater cooling capacities (up to 15 kW). The informal sector in developing countries is a safety issue because untrained technicians without certification might handle appliances with flammable refrigerants inappropriately.

In several statements and discussions, it was mentioned that the overemphasis of safety issues and postponement of the switch to natural refrigerants is not based on scientific evidence and lack of halogen-free refrigerant technologies, respectively. It is rather the vested interest of the chemical industry that successfully rolls out their product portfolio by setting standards accordingly and raising barriers for natural refrigerants at the same time. Furthermore, some parties to the Montreal Protocol see themselves responsible in safeguarding the profits of the respective industry. Margins of natural refrigerants, which are in some cases by-products of the oil and gas industry (such as propane) and generated from waste streams (CO_2) are comparably low. Therefore, those are not considered by manufacturers of synthetic refrigerants.

Latest findings on the fate of unsaturated HFC-1234ze used as refrigerant and foam blowing agent showed that it dissociates to trifluoracetaldehyde (CF3COH) and subsequently to HFC-23 in the atmosphere with a 9%-12% yield. This means that the overall climate impact of HFC-1234ze is much greater than previously thought and equals a global warming potential (GWP) of 1,400. Moreover, the atmospheric model is able to explain the recent increase of HFC-23 concentrations in the atmosphere. Given that HFC-1234ze is considered an alternative mainly for R134a (GWP=1,430), this example shows that wrong decisions are taken by disregarding the atmospheric dissociation products when assessing their environmental impact.

The urban heat island (UHI) effect, which significantly affects thermal comfort and health of people living in cities, can be reduced by urban greening (planting of trees, establishment of green facades and roofs), water related design (ponds, lakes, fountains), anthropogenic heat release reduction, shading, and other measures. Whereas some experts state that UHI effects indoor thermal comfort and energy consumption, others believe that the latter is rather negligible, at least in moderate climates. The effect of combined UHI reduction measures is relatively small (-1.2 K) when just considering the air temperatures. In contrast, substantial

effects of -10 K and more are generated regarding the comfort indicator Perceived Equivalent Temperature (PET), especially through shading measures such as trees or artificial shading.

Online access to all conference materials and highlights video

650 registrations from 100 countries, 330 questions from the audience, 32 speakers, 3 days, 1 goal: Advancing Green Cooling together! All conference materials are also available online:

Highlights

Day 1: Presentations and recordings

Day 2: Presentations and recordings

Day 3: Presentations and recordings

Disclaimer: The following content summaries are created with the intention to reproduce the content as objectively as possible. Nevertheless, this content can only reflect the understanding of the authors, which may deviate from the intention of the speakers.

For convenience reasons, links to the presentation slides are provided in the respective paragraphs.

1 Day One - May 25, 2021: Policy Day

1.1 Opening Session, Day One

The conference was opened by hosts Daniel de Graaf from the German Environment Agency (UBA) and Julika Schmitz, who led through the whole event as a moderator and facilitator.

Daniel de Graaf gave an overview of the program of the first day and an introduction into the Kigali Amendment, which requires a phase-down of worldwide consumption of hydrofluorocarbons (HFCs). He explained the key intention of the conference which is to foster the implementation of Green Cooling solutions, i.e., cooling technologies with natural refrigerants. That should be achieved by showcasing examples of a successful implementation which could serve as an inspiration and role model.

Hereafter, recordings of welcoming speeches by Svenja Schulze (Federal German Minister for the Environment), Dirk Messner (President of the UBA) and Tanja Gönner (Chair of the management bord of Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ]) were shown.

Svenja Schulze demanded in her video message that it had to be ensured that the increasing cooling demand can be met without drastically effecting the climate. The global implementation of the Kigali Amendment alone would already reduce global warming by 0.5 °C by the year 2100. She highlighted three necessary steps in the field of cooling:

1. Reduction of HFC emissions

2. Replacement of HFCs with natural refrigerants

3. Increase of energy efficiency of cooling systems and cooling demand reduction measures

Thereafter Dirk Messner pointed out in his message to the audience that compared to CO_2, it is much easier to avoid HFCs by simply replacing them by natural refrigerants and by that leapfrogging costly interim solutions, e.g., HFO refrigerants. Action could be made instantly and on national level by several measures, such as inclusion of HFCs into the National Determined Contributions (NDCs).

Tanja Gönner highlighted in her welcoming speech the variety of successful international activities of the GIZ for Green Cooling and the implementation of natural refrigerants. The GIZ activities range from policy advice via Green Cooling technology transfer to trainings for technicians.

Afterwards, Heike Litzinger from the German Federal Ministry for Economic Cooperation and Development picked up the importance of Green Cooling in partner developing countries for health and insuring the food chains. For that she sees capacity building as an important aspect of the cooperation.

The following keynote presentation with the title “The final phase-down: Why natural refrigerants are the ultimate solution” was presented by Prof. Armin Hafner (Norwegian University of Science and Technology). In his presentation, Armin Hafner talked through the history of refrigerant and presented examples of due to his opinion real Green Cooling solutions, like the breakthrough of CO_2 (R744) in supermarket refrigeration (he gave examples from Portugal and Jordan), mobile air conditioning (AC) systems and heat pump chillers (he mentioned an example from India, where the chiller provided AC and hot water). Furthermore, also propane (R290) for split AC and ammonia (R717) for chillers are due to his opinion real Green Cooling examples. Finally, he emphasised the importance of training and knowledge

transfer as well as mandatory information and smart loans to accelerate the phase-in of **Green Cooling**.

1.2 Session 1: Good practice examples of country-specific policies for HFC phase-down

1.2.1 Example EU, presented by Arno Kaschl

Session 1 started with a presentation of Arno Kaschl (Policy Analyst, European Commission (DG CLIMA)) on reducing HFCs in the EU with the fluorinated greenhouse gas (F-gas) Regulation. He reported that the EU already started to regulate F-gas use in 2006 —well before the Kigali Amendment. The second F-gas Regulation has been in place since 2014 and introduced the phase-down quota system and other direct measures to reduce consumption. He stressed that direct measures in form of prohibitions (e.g., the prohibition to service equipment with a refrigerant with a global warming potential [GWP] > 2,500 or the requirement of GWP > 150 refrigerants for new domestic and commercial plug-in refrigerators and large multi-packs, plug-in-ACs, and small split ACs) only make sense when safe, efficient, and economical alternatives are available. In the light of the increase of EU climate target (savings of 55% by 2030 and carbon neutrality by 2050) **the option of a steeper HFC phase-down or additional restrictions (e.g., HFCs in switchgear) are actually discussed and aimed to be put in a revised regulation which may be in place in 2022**.

1.2.2 Example Ghana, presented by Emmanuel Osae-Quansah

The second presenter of Session 1 was Emmanuel Osae-Quansah (Focal Point, National Ozone Unit Ghana). Emmanuel Osae-Quansah took the audience through the Ghanaian cooling policy. The actual Ghanaian NDCs include the abatement of F-gases in stationary ACs by a low GWP limit. Moreover, the government plans to foster the transition to R290 split ACs by a rebate program for split ACs in combination with consumer lending. Already since 1995, imports of ozone depleting substance (ODS) equipment have been restricted and have been prohibited since 2005. Cooling accounted for 23% of Ghana's total greenhouse gas (GHG) emissions in 2016. **Over 50% of the cooling related emissions is caused by small, single-split units that are mainly operated with the refrigerants R22 and R410A.** Beyond the activities financed by the Multilateral Fund (MLF) of the Montreal Protocol, about 400 installations of R290 split units have been realised in a project framework. Currently, a certification scheme for technicians is developed in cooperation with GIZ. Furthermore, an eco-fridges program to promote more efficient domestic refrigeration has been established.

1.2.3 Questions and Answers Session, presented by Arno Kaschl and Emmanuel Osae-Quansah

In the Questions and Answers Session (Q&A), Arno Kaschl specified that additional EU incentives on natural refrigerants are currently not considered due to reasons of technology neutrality and existing technical issues. But he also pointed out that a further tightening of the EU F-gas Regulation would automatically also promote natural refrigerants as those that have no, or just an ultra-low GWP. Emmanuel Osae-Quansah highlighted the training of technicians as a key measure to ensure good maintenance, which is necessary for an efficient operation. He believes that being a front-runner in Green Cooling will be advantageous for Ghana. In response to a question about the front-runner role of the EU, Arno Kaschl stated that the EU had already been the front-runner for the global F-gas phase-down activities and technology development. He claimed that the EU is still the frontrunner in the field of refrigeration, but he also admitted

that there is some potential in AC and other sectors. On the question if a new method of determination of GWP is required, which also considers the byproducts and decomposition products that are harmful for the environment, Arno Kaschl explained that refrigerants with byproducts like R23 are already not allowed to be imported into the EU. Regarding the question of decomposition products, he said that there is a discussion underway. Due to their consulting scientists, decomposition is currently not a recognised issue. Furthermore, he emphasised the relevance of consideration of upfront emissions. Emmanuel Osae-Quansah explained in response to another question **as to why Ghana has focused on supporting R290 split ACs, that that was due to the demonstrated availability, safety, and efficiency of this technology**. He said that just the advantages need to be better transported to the customers to overcome existing prejudices. He is convinced that a further push can be expected by the planned reduction of import tax for R290 split ACs.

1.2.4 Example Colombia, presented by Nidia Pabón

The second part of Session One started with a presentation by Nidia Pabón (National Ozone Office - Ministry of Environment and Sustainable Development) about the Policy approach to manage the HFC phase-down in Colombia. Right at the beginning, Pabón clarified that there is not yet a specific public policy for the HFC phase-down, but Colombia is working on a design for a national plan based on the existing regulatory and policy framework. On the one hand, there is the National Development Plan (Pact for Colombia, Pact for Equity), which is the roadmap of public policy and investments determining Colombia's actions in the period from 2018 to 2022. Thus, this plan needs to be considered when designing the plan for the HFC phase-down. The National Development Plan is composed of three principals, which are legality, entrepreneurship, and equity. It includes a Pact for Sustainability that demands "To produce while conserving" and to "Conserve while producing" to reduce GHG emissions. The plan therefore commits sectors to sustainability and mitigation of climate change.

The National Policy for Hazardous Waste (HW) Management, created in 2005, is the second national policy that plays a role in the national HFC phase-down. It lays out an updated plan for 2021 through 2030 that contains the life cycle of HW and controlled substances. Its main motivation is to apply the application of the waste hierarchy, which also includes an environmentally sound management of HFCs. It is expected that in the framework of the implementation of this policy, activities such as collection, recovery, recycling, and reclaim of HFCs will be conducted and contribute to their phasing-down in Colombia.

The National Policy for the Management of Waste of Electrical and Electronic Equipment (WEEE), which was created in 2017, contains an action plan for 2017 through 2032 and includes refrigeration and AC equipment. Its main objectives are to prevent and minimise the generation of WEEE and to promote a comprehensive management of it.

The National Climate Change Policy, issued in 2017, is also setting framework for the HFC phase-down, which aims at incorporating climate change management into public and private decisions to advance a path of development that is resilient against climate change, low in carbon emissions, and will eventually make the country carbon-neutral.

Based on the National Climate Change Policy, Colombia submitted its NDC in 2020, which is considered one of the most ambitious in the Latin America and Caribbean region. It includes the target to achieve carbon neutrality by 2050. The updated NDC incorporates three components: GHG mitigation, adaption to climate change, and implementation tools as an instrumental component of policies and actions for a low carbon, adapted and climate-resilient development.

Other national policies and strategies to be considered are the National Policy for Sustainable Production and Consumption, the National Program for the Rational and Efficient Use of Energy and Unconventional Energy Sources, and the National Circular Economy Strategy.

Colombia recognises that a sustainable policy and regulatory framework is a key aspect to manage the HFC phase-down. In order to be successful, **Colombia has a strong ambition to transform the RAC sector to energy efficient equipment with climate-friendly, low GWP refrigerants**. The country therefore uses the described regulatory framework for the implementation of the Montreal Protocol and the lessons learnt.

1.2.5 Example Grenada, presented by Leslie Smith

Leslie Smith (Head of National Ozone Unit, Grenada) stated that Grenada ratified the Kigali Amendment in May 2018 and is being supported in its ambitions to achieve all the targets and actions with regards to the implementation of the Kigali Amendment from several other bilateral agencies (EU, GIZ, United Nations Environment Program, United Nations Industrial Development Organization (UNIDO), United Nations Development Programme) and by the MLF for the implementation of the Montreal Protocol. Following an inclusive approach, multiple national stakeholder consultations were conducted.

To achieve Green Cooling with the use of natural refrigerants, Grenada is convinced that it does not only need adequate equipment, but also adequate policies and regulations that aim at increasing the thermal efficiency of buildings, improving urban planning, and facilitating funding and financial mechanisms for market transformation. Another focus of Grenada's policy and legislative approach is set on supporting behavioural changes in the use of air condition and refrigeration equipment. Therefore, a policy gap analysis was conducted to identify and close the existing gaps. Then, an implementation and enforcement plan was invented, that underlines strategies to establish the correct policies and to achieve Green Cooling with the use of natural refrigerants. A monitoring and evaluation plan should enable benchmarking the achievements and possible improvements.

Consequently, several activities have been undertaken to support the goal, such as the establishment of standards (for labelling), capacity development, and training. For example, a refrigerant driving license or the establishment of a regional training centre for natural hydrocarbon refrigerants where 80% of the local AC technicians have be trained to the use of hydrocarbon (HC) refrigerants, improving public awareness and education. Education was improved by establishing Green Cooling communication strategy with customised information for different stakeholder groups. Another activity established fiscal and economic incentives, such as the exemption from 15% Value Added Tax (VAT) for imported R290 split units to be price competitive with conventional systems. Also, a RAC sector-wide GHG inventory was made, and the National Cooling Action Plan was created.

Smith ended his presentation with the conclusion that the process of achieving Green Cooling is considered as a work in progress with several ongoing activities such as the review, an update of building energy efficiency codes, and the amendment of the Montreal Protocol Act. Finally, **he highlighted that Grenada is the only country in Latin America and the Caribbean where R290 ACs are commercially available. Currently, the demand of those systems surpasses the supply by far**.

1.2.6 Q&A, presented by Nidia Pabón and Leslie Smith

Nidia Pabón explained that the Columbian NDCs contain the following three sectors where relevant mitigation measures apply: 1) District cooling 2) Domestic refrigeration sector 3) ODS

and HFC banks for end-of-life management. Currently, the possibilities of measures regarding the specific support of natural refrigerants are checked. Leslie Smith stated that the national cooling plan for Grenada will be adopted in 2021. For 2025 a revision is planned. Regarding the Grenadian communication strategy, he pointed out that the initial development took 6 months, but there was the necessity of customisation for the stakeholder groups, which is available now. Furthermore, **he highlighted that Grenada intends to phase-down HFCs much earlier than foreseen in the Kigali Amendment and there have been discussions to become the first HFC-free island in the world**. He suggested that within the Montreal Protocol community, and the HVAC industry, **opportunities and incentives must be provided to encourage manufacturing companies to change their technology portfolio** similar to what GIZ has achieved in India. An increasing demand on R290 systems also in other countries would encourage manufactures to change their portfolio.

1.3 Panel Discussion: How to route the way for a successful HFC phase-down pathway with natural refrigerants

The panellists of the discussion were Clare Perry (Climate Campaigner at the Environmental Investigation Agency (EIA)), Ole Nielsen (Chief at UNIDO Montreal Protocol Division), Jiang Feng (China Household Electrical Appliances Association (CHEAA)), pre-recorded statements, Bernhard Siegele (Head of GIZ Proklima), and Arno Kaschl (EU Commission):

The discussion started with a set of opening statements beginning with Clare Perry who pointed out that the key to the success of an HFC phase-down would be twofold: Start with ratification of the Kigali Amendment by all parties and then intact replenishment of the MLF to support developing countries in their HCFC phase-out and maximise the benefits of such a phase-out. This requires national policies but ultimately also investments in the Montreal Protocol politically and financial insurance it is fit for this purpose. This was followed by remarks from Arno Kaschl that there are many good replacement solutions for F-gases available in many sectors already that are climate-friendly, affordable, and energy efficient. Arno Kaschl's pitch was to go for those solutions right away and not wait. **Ole Nielsen stated that he was a believer in regulatory certainty, which is the key driver for industry. His pitch was: "Let's have maximum regulatory certainty for a successful HFC phase-out."** Bernhard Siegele finally added that countries around the world need to get it right this time. Previous efforts were not bold enough. He agrees with Ole Nielsen that with regulatory certainty, industry will provide the technological solutions. But what also is needed is knowledge sharing and information awareness in order to avoid misinformation and wrong decision-making.

The first question was about why we are moving so slowly in the direction of natural refrigerants. Ole Nielsen commented that natural refrigerants are in the lead already but there are some sectors where they are still facing cost issues. Clare Perry agreed with this but complements that **since the start of the Montreal Protocol the fluorochemical industry has been successful at reinventing itself, which landed us into this chemical treadmill of CFCs, HCFCs, and so on**. **Another issue of natural refrigerant systems is higher upfront costs. That has been a real factor in why natural refrigerants are not across the board now. This is because funding guidelines for refrigerant projects used to not take the whole life cycle of the refrigerant into consideration, leading to wrong investment decisions**. Arno Kaschl adds that in the past, flammability was not a big issue, but it is with natural refrigerants (such as ammonia). **Flammability poses real risks to informal sectors with little formal training in developing countries.** This needs to be addressed through safety and health capacity building of local technicians.

A pre-recorded video by Jiang Feng played as follows: On the question of what role natural refrigerants play in the HFC phase-down in China and on a global scale, Jiang Feng stressed the double challenge of HCFC phase-out and HFC phase-down. The Chinese industry prospectively chose the natural refrigerant propane (R290) as alternative to HCFC-22 to both reduce ozone depletion and climate warming. This also helps avoid double conversion of HCFC to HFC and to non-HFC, thus preventing a waste of resources and useless technology investment in the second conversion phase. CHEEA engaged in exchanges with international agencies for relevant standard revision and technical exchanges. To the second question on how to better promote R290 single-split units, she answered that firstly the current safety standards for R290 are too strict, leading to high cost and low competitiveness and secondly the flammability of R290 is overemphasised and the risk can be controlled. Thirdly, the solution lies in better safety training for the transport, installation, and maintenance.

Bernhard Siegele added that further measures to promote green refrigerants need to focus on larger markets than Grenada or Colombia in order for it to really take off. This takes time. MLF players like the Green Climate Fund (GCF) or the Green Economy Financing Facility need to step up more and tackle large markets. Ole Nielsen contributed that although a good idea, one would need to further harmonize the intervention of both funds to to ensure a synergetic approach.

The next question asked to the panel was on how active are R290 producers in Europe. Arno Kaschl replied that for single-split units, which already are available in China, the traditional big players are reluctant to enter. It would be up to the Chinese players then to bring this large scale to Europe. Arno Kaschl and Clare Perry agree that the last revision of the F-gas Regulation, which had a prohibition on single-split units with HFCs but with a GWP of 750 scheduled for 2025, gave a signal that the GWP does not necessarily need to go down to propane levels. That sent a wrong signal leading to a large influx of single-split units with HFC-32 even though the ban has not taken place yet. **Claire Perry added that if the climate was a priority, there really should not be a GWP threshold of 150 but it should always be as low as possible (i.e., GWP=1).**

An interesting point made by Julika Schmitz was that the profit margin for natural refrigerants is small and hence they are not an interesting business case for incumbent refrigerant manufacturers. She asked the panel what bolder incentives and disincentives can be introduced as a next step. According to Clare Perry, it comes back to reviving investment into the Montreal Protocol so that there is more effective coordination with institutions like UNFCCC. **Bernhard Siegele stresses that restrictions of natural refrigerant uses are not science-based but defined by the industry.**

Hence the next question asked to the panel was about an outright general ban on refrigerants with GWPs >15. From an EU commissions perspective, it is administratively impossible to impose an outright ban for all industries. A targeted industry by industry approach is the only viable option. **From the IEA perspective, 2050 targets are not a good idea. Short-term targets are needed instead.** Ole Nielsen stated that an outright general ban is difficult because there will be industries that cannot possibly follow. Lastly, **Bernhard Siegele argued that only a ban would help with climate change and is therefore needed.**

2 Day Two - May 26, 2021: Industry Day

2.1 Opening Session, Day Two

Day two was opened with an interview of Daniel Colbourne (CEO, Re-phridge/HEAT), followed by the keynote speech from Monika Witt (Managing Director of TH. WITT and eurammon board member).

2.1.1 Interview of Daniel Colbourne

In the interview Daniel Colbourne explained the ongoing activities regarding AC standards, which are anticipated to be finalised by end of summer, and the parallel activities on safety standards. **He said that he recognised the discussion about safety of refrigerants has become more fact based and less emotional in the recent years, but it is also influenced by the interests of different stakeholder groups**.

2.1.2 Keynote speech "The Future Is Natural" by Monika Witt

In her keynote speech entitled "The Future Is Natural", Monika Witt talked about the most relevant natural refrigerants, along with a story about the history of the company TH.WITT. She started with her—as she said—preferred refrigerant ammonia (R717) that has the main advantage in being cost-efficient. The refrigerant CO_2 (R744) is more challenging due to the necessity of high pressures. But now, a variety of systems is available and gaining relevance, e.g., refrigeration systems for supermarkets. The flammable refrigerant propane (R290) is already common in petrochemical industries, but not so widespread in other industries. Current technologies like sensors to detect leakages, better standards, and training should allow for a breakthrough for this efficient refrigerant. Finally, Butane (R600a) is state of the art in household refrigerators, although there also have been concerns when it was introduced because of its flammability. She stated that effects of natural refrigerants are well known and mostly part of the human metabolism. For example, ammonia is toxic but could be smelled far before it becomes a health issue. **The decomposition products of the fourth generation of refrigerants are environmentally harmful, e.g., by contaminating water with persistent trifluoroacetic acid (TFA). Monika Witt identified certification documentation of the electrical equipment and insurance considerations as the major issue of flammable refrigerants.** She hopes that soon companies such as Godrej and Midea will sell their propane AC products with CE mark to the European markets. Her second wish is the adaptation of the standards to allow for larger flammable refrigerant charges. Finally, she wishes that more installers get familiar with natural refrigerants.

2.2 Session 2: Latest technology trends in AC

2.2.1 International norms and standards by Daniel Colbourne

Session 2 started with a presentation by Daniel Colbourne on international norms and standards. His introducing statement was about well balanced (minimise risk vs. unhindered use) safety standards being critical to a successful deployment of natural refrigerants. He stated that HCs especially are still severely hindered. **He said he observed a strong push of some industry stakeholders against changing the restrictive standards for HC refrigerants.** New research results, e.g., on the size of leakages and technologies like detection systems, help to improve existing standards, as well as support a greater participation of natural refrigerant stakeholders in working groups of the standards.

He introduced the audience to the current status of the four main safety standards, which are:

- IEC 60335-2-89:2019 on commercial refrigeration equipment, which was published in 2019 where the max refrigerant charge size of R290 was increased from 150 g to 500 g, compared to the previous version of the standard.
- IEC 60335-2-40 on ACs and heat pumps, which has been in progress since 2015, and will hopefully go out for the final vote in summer 2021. The current version permits up to 1 kg of R290 in ACs and allows for enough refrigerant per square meter, as it is needed to provide cooling.
- The European standard EN 378 on other equipment (except commercial refrigeration and air-conditioners) is also still in progress but in a much earlier stage.
- The further development of ISO 5149, which has the same content scope as EN 378, is still uncertain and may be finalized in 2023.

Finally, Daniel Colbourne encouraged the audience to become stakeholders in standard development and contribute to the positive developments regarding natural refrigerants.

2.2.2 Insights into the handling of different relevant natural refrigerants by Marius Appenzeller

The second speaker of the of Session 2 was Marius Appenzeller (Strategic Market Manager Westfalen Group). Westfalen Group is one of the biggest distributors of refrigerant in central Europe. Marius Appenzeller gave insights into the handling of different relevant natural refrigerants. He started with ammonia, which requires specially equipped locations for storage and an operating permit. Currently, he sees a lack of specialised installers as a barrier. The storage of other flammable natural refrigerants such as isobutane or propane is only regulated in case of high quantities. Storage cylinders must be smaller than for non-flammable gases. For CO_2, Marius Appenzeller emphasised the importance of high quality the gas to prevent corrosion or high pressure drops. Over 50% of the CO_2 distributed by Westfalen Group is procured from waste gases. He is convinced that due to the EU climate goals an extensive change regarding refrigerant use is necessary, where natural refrigerants will play an important role. **Marius Appenzeller identified the necessity of trainings and building up know-how in the industry, as well as clear and pragmatic rules, for the safe use of flammable refrigerants as major challenges.**

2.2.3 Experiences in training for the introduction of natural refrigerants to the market by Vilim Mergl

The third speaker was Vilim Mergl, Managing Director of Cool Tool Technology, an engineering company in the field of software development. His presentation was about the experience in training for the introduction of natural refrigerants to the market. Vilim Mergl gave an overview of the activities and experience of Cool Tool Technology, which goes back to 1995 and covers design and calculation software for refrigeration equipment, monitoring systems, consulting, and trainings on natural refrigerants. Afterward, he presented an overview table of an assessment of the three most relevant natural refrigerants/refrigerant classes, respectively: R744, R717, and hydrocarbons (R290, R1270, R600a, etc.), whereas the hydrocarbons score best in his opinion in terms of efficiency, compatibility, and range of application. On the next slide Vilim Mergl presented a six-step training program on natural refrigerants which covered the subjects of risks, technological requirements, benefits, work safety, and practical experiences. He showed an example of a small deep freezer where the original refrigerant R404A was exchanged by R290. After the necessary readjustment of the control instruments, the measured Energy

Efficiency Ratio (EER) could be improved from 1.4 to 2.0. He continued by giving an overview of HC charge limitations for systems according to EU standards, which are mainly dependent on usage. For public areas, as an example, limits range from 1.5 kg to 5 kg, while for controlled areas such as offices range from 2.5 kg to 10 kg. Regarding cold rooms, a refrigerant charge of 2.5 kg allows a cooling capacity of up to 10 kW and for deep freezing rooms up to 6 kW. Water chillers are available with a capacity of 5 kw to 500 kW. Those require refrigerant charges between 1.5 and 8.5 kg per refrigeration circuit. For lower temperature glycol chillers sized from 10 kW to 800 kW, 4 kg to 18 kg propane is required. For compact chillers with a charge size of 2.5 kg propane, a cooling capacity of 80 kW can be reached. **Finally, Vilim Mergl stated that systems with natural refrigerants can cover 75%-85% of the market.**

2.2.4 Natural refrigerants in light commercial refrigeration by Alex Panas

The last presentation of Session 2 was about natural refrigerants in light commercial refrigeration and was held by Alex Panas, Group Commercial Director of Sanden Intercool. He started his presentation by giving a market overview of the segment of light or plug-in commercial refrigeration. According to his estimation, annually 25-30 million units are sold. He estimated that GHGs of the sector occur 15% to 25% from direct emissions and 70% to 80% from indirect emissions, while 3% to 7% come from secondary sources like disposal. He believes that hydrocarbons are the ideal solution, because of their thermodynamic properties, their high energy efficiency, which can lead to an energy reduction of up to 50 %, their cost effectiveness, and their operational efficiency. They are a future-proof solution. The flammability issue has already been addressed by existing safety standards and procedures. The main remaining concerns are the service networks, which can hinder widespread adoption. Service partners and technicians need to be trained to get familiar with the new technology. Finally, Alex Panas explained that adoption differs by region with the highest shares in Europe and America and the lowest in Asia and the Middle East. Sanden is actively promoting the worldwide implementation of hydrocarbon systems.

2.2.5 Q&A on Session 2 with Daniel Colbourne, Marius Appenzeller, Vilim Mergel, Alex Panas and Monika Witt

In the following Q&A Session, Monika Witt explained that ammonia is not suitable to be used for compression refrigerators as it produces too much flash gas. An alternative would be absorption chillers. Vilim Mergl added that there is no need as HC are already a perfect solution for refrigerators. On the next question Daniel Colbourne clarified that the GHG emissions for the production process of natural refrigerants are extremely low. They are much lower than those of synthetic refrigerants and depend rather on the particular production process than on the type of refrigerant. In response to another question, he said that he thinks the revision of IEC 60335-2-40 policy can open up markets of ACs and heat pumps massively. **Due to current standards, R290 wall split units are limited to a capacity of 3 kW to 5 kW (depending on climate) and a limit of about 5 m pipe-length. With the new standard, capacities could reach 15 kW to 20 kW.** Questioned on the market share of sold HC equipment of Sanden, Alex Panas stated that it is about 90%, which is expected to increase, especially due to the new regulation that allow HC for larger capacity compressors. Afterwards, Vilim Mergl explained that despite for cascade systems for deep freezers, in his opinion HCs have a major advantage compared to CO_2 or ammonia. **With a switch from HFCs to HCs, no change of compressor is necessary, just a specific handling to prevent ignition is needed.** On further question, Marius Appenzeller said that he thinks HC technologies will increase in Asian markets. A contributor from the audience stated that in the EU there are currently illegal refrigerant imports of about 30 Mt CO_2 equivalent. Marius Appenzeller does not think that illegal imports of natural

refrigerant is or will be an issue, but maybe more the quality of those. That was underlined by Monika Witt with the example of the problems from early CO_2 systems. Finally, questioned on the topic of A2L refrigerants **Daniel Coulbourne said that he expects the market share of A2L refrigerants with a GWP less than 150 will increase in the future**. That was confirmed by Marius Appenzeller.

2.3 Session 3, Day Two: Last technology trends in AC

2.3.1 R290 in Split ACs of Godrej & Boyce by Narendra Shedge

Narendra Shedge (Senior Manager at Godrej & Boyce Mfg. Ltd., India) started his presentation with an overview of Godrej, one of the largest private companies in India with a huge product portfolio and a high commitment to the environment. He stated that Godrej & Boyce was the first Indian company to introduce HC refrigerators in 2000. HC ACs were introduced in 2012 as result of R290 AC project together with GIZ and Ozone Cell (Indian Ministry of Environment, Forest, and Climate Change). To fulfil the charge limitations of EN 378, the company implemented micro channel heat exchangers. The production line was equipped with a variety of approved safety measures and was set up for a production of 180,000 units per year. In 2020 the product was significantly improved, and the production was increased to 400,000 units per year. In parallel, a number of technicians were trained and certified to install R290 units. **A comparison between R22 and R290 indicated 7%-10% drop in cooling capacity, but a 10%-16% increase of Coefficient of Performance (COP), dependent on the ambient conditions. R290 also evidenced efficient operation at high ambient temperatures (e.g., at 52 °C a COP 2.04 instead of 1.86 for R22).** Up to now, Godrej has experienced no single complaint regarding the issue of flammability. Further optimisations and energy improvements are planned for upcoming years.

2.3.2 R290 products of Midea by Jonathan Li

Jonathan Li (Head of Overseas Product Planning Department of Midea) began his presentation with an overview of global CO_2 emissions of room ACs and fans, which contributed 3.8% (1.3 billion tons) in 2018. Energy consumption of cooling is expected to triple by 2050. In 2015, 1.3 billion tons of equivalent CO_2 emissions were caused by HFCs. The speaker presented an overview of policy standards and regulations regarding the Kigali Amendment followed by the historical product development of R290 products from the first multilateral funded product line in 2010 up to the planned market entry of R290 split units in the EU in 2021. He explained that Midea's R290 product portfolio covers dehumidifiers, portable AC, and (with EC/A++[1]/Blue Angel[2]) certified mini-split units with a cooling capacity of up to 12 kW. Jonathan Li pointed out that, in his opinion, manufacturing and sales of products requires policies to create demand for the new products. Furthermore, **he also mentions the relevance of trainings and related certification of technician competencies as a prerequisite to smooth market introduction.** Finally, he showed demonstration projects where R290 AC has been installed and operated successfully (e.g., the first R290 inverter split unit project in a college in Jiaxing in 2016 and further projects in Seychelles and Ghana.). 90% of Midea's R290 products (portable units) have been delivered to A2 (i.e., developed) countries. With about 10% R290 products already reached

[1] According to the European Regulation No 626/2011 on energy labelling of air conditioners
[2] The ‚Blue Angel' is the German ecolabel. Single split air conditioners may be certified according to the award criteria of DE-UZ 204 Stationary Air Conditioners (https://www.blauer-engel.de/en/products/electric-devices/stationary-air-conditioners).

a significant share of their exports in 2020. Although the shares of their R290 products are increasing, currently R32 and R410A products are still dominating.

2.3.3 Hydrocarbon chillers of Secon by Joachim Schadt

Joachim Schadt (CEO, Secon GmbH) started his presentation with an introduction of Secon GmbH, a manufacturer of R290 chillers. He stated that chillers with natural refrigerant can serve all application types. While R290 is suitable for a broad range of applications, R1270 is only suitable for low and medium temperature refrigeration. R600a is best suitable for high temperature refrigeration and heat pumps. He showed realised systems with air cooled outdoor units ranging from low (-34 °C) to medium (- 8 °C) as well as high temperatures including a chiller of a shopping mall AC system (outlet temperature: 8 °C) and process cooling (outlet temperature: 12 °C). Due to safety reasons, the compressors of the latter example are situated in separate outdoor compartments, which are equipped with gas sensors and fans. Further examples were provided with two compact, water-cooled indoor AC chillers which had to consider even higher restrictions regarding refrigerant charges. Joachim Schadt then summarised the benefits of hydrocarbon refrigerants. Among those, hydrocarbon refrigerants have a wide application range and low operation cost. **The safe use of R290 systems is not an obstacle, but merely a challenge**. He identified a strongly increasing market at least in the German-speaking markets for Secon. **In his final statement, he pointed out that there is no reason to continue using synthetic refrigerants**.

2.3.4 Natural refrigerant in industrial refrigeration systems by Alexander Cohr Pachai

Firstly, Alexander Cohr Pachai (Senior product specialist at Johnson Controls Denmark ApS) explained the huge range of capacities (100 kW to 100 MW) and temperature levels of -100 °C to 180 °C that are covered in industrial refrigeration. Afterwards he gave an overview of the state of the technology of natural refrigerants. CO_2 and NH_3 are already widely used, while HCs are gaining increasing acceptance. Also, water as a refrigerant is emerging. Air is suitable for low temperatures (< -80 °C). He thinks that required global CO_2 reduction creates markets, especially for heat pumps. He gave the example of a newly planned 50 MW CO_2-based heat pump plant in Denmark, which uses sea water cooling and is intended to balance the electricity output of a nearby windfarm. He highlighted the importance of district heating in Denmark, which is already high but still further increasing. He stated that heat pumps, which are serving both demand sides (heating and cooling) are an efficient option. Finally, he gave an overview of the required fields for pushes for change to natural refrigerants which are: Policies, economics, technology, and society.

2.3.5 Q&A on Session 3 with Narendra Shedge, Jonathan Li, Joachim Schadt, and Alexander Cohr Pachai

Narendra Shedge explained on the first question that Godrej has sold 1.3 million R290 split AC systems mainly in the Indian market. Actually, the company is working together with GIZ to obtain the CE label. **He expects that Godrej will be able to sell R290 models on the EU markets by end of 2022.** The units will contain efficient hermetic rotary compressors. Regarding another question on the R290 product availability in the Middle East and North African markets, Alexander Cohr Pachai answered that Johnson Controls is already providing R290 chillers for outdoor installation to countries in Middle East and Asia. Narendra Shedge said that the company would firstly have to study the market conditions and national regulations before starting to enter them. **Asked for the differences in production costs between R290 and R410A split systems, Jonathan Li answered that the marginal cost for new R290**

production lines could be reduced if the expected market volumes would get higher. Furthermore, regarding R290 trained and certified installers in the EU, he explained that the company is working with local contractors, but he does not have an overview. GIZ is providing specific R290 installer and servicing trainings in different regions globally. Alexander Cohr Pachai confirmed that the lack of trained and experienced technicians is a problem, but he also sees opportunities of growth as it is a future-proof market. **In his opinion, the existing excessive safety discussions on natural refrigerants are due to the vested interests of the chemical industry and its lobby.** With that he was supported by Joachim Schadt, that added the only thing missing is a ban of TFA emitting refrigerants. Jonathan Li pointed out that for a further uptake of natural refrigerants, the value chain has to be further developed. The value chain development should start with the creation of need from local importers, which also need creation support from political initiatives or regulations. That statement was also supported by Narendra Shedge**. A comment from the audience contradicts in a way that the first step must come from the manufacturers as the end users do not understand the relevance of refrigerants.** Alexander Cohr Pachai agreed with that, and he also thinks that regulatory measures like bans would be helpful. Joachim Schadt brought in the idea of the creation of an independent refrigerant label. He also clarified that the German BAFA incentive program, which subsidises natural refrigerant systems up to 50 %, has been the major driver for the indicated uptake of their business. Furthermore, also a tax system on refrigerants can be effective, Alexander Cohr Pachai added. Joachim Schadt contributed that such a tax system should not only be based on GWP but also on further environmentally relevant issues. Narendra Shedge explained on the last question that there were many factors, such as the commitment to environmentally sound products of Godrej, the support of the National Ozone Cell of the Indian government, and a set of adequate standards which supported the uptake of the R290 product portfolio in India. He said that AC demand is increasing not least because of global warming, which increases the need of energy efficient AC.

2.4 Closing remarks by Daniel Colbourne

Daniel Colbourne hopes that the revision of the EU safety standards, and the widespread introduction of HC refrigerant systems (especially R290 split units), will take place in 2022 as has been promised but postponed already for many years. For the global climate, it is important to harvest the low hanging fruits of a widespread introduction R290 split units. All stakeholders including politicians and technicians should sit down and try to find bridges and ways to overcome remaining barriers.

3 Day Three - May 27, 2021: Research Day

3.1 Opening Session, Day Three

3.1.1 Interview of Collin Bootsveld

The third day was opened with an interview of Collin Bootsveld (Refrigeration Engineer at Colruyt). **He pointed out that by 2030 all Colruyt Supermarkets will be refrigerated with natural refrigerants.** In his opinion, the industry is ready for Green Cooling solutions. Now it is up to the policymakers to do the next step to move Green Cooling ahead. He explained that the company's switch to natural refrigerants had other impacts, e.g., on the demand of gas heaters, which was reduced significantly from the use of waste heat by heat pumps. Everyone should prepare for disruptive changes. **Collin Bootsveld is convinced that the switch to natural refrigerants is also economically the right decision.**

3.1.2 Keynote speech "Latest Findings on the Fate of HFO-R1234ze in the Atmosphere" by Christopher Hansen

Christopher Hansen (lecturer and fellow of the discovery early research career award from the Australian research council at UNSW Sydney) opened his presentation on the photodissociation of CF3CHO providing a new source of CHF3 (HFC-23) in the atmosphere with an overview of atmospheric models. Afterwards, he introduced some specifics of HFO-1234ze, which, according to him, unlike HFO-1234yf is not flammable and does not decompose to TFA. In the atmosphere it decomposes to triflouroacetaldehyde (CF3CHO), which itself is quickly removed by photolysis by mostly producing CHF3 and CHO. CF3CHO is also a decomposition product of other HFOs. A smaller portion of CF3CHO (up to about 2 %) is photolyzed to CHF3 and CO. That is critical as CHF3 (HFC-23) has a 100-year GWP of more than 12,000. In the following, Christopher Hansen dived deeper into the carbonyl photochemistry. On the example of the well-studied acetaldehyde CH3CHO-the non-fluorinated analogue of CF3CHO-he explained the relation of photolyze products and energy levels of the four different possible reaction channels. Within those four, the channel with to products CH4 and CO is the most exothermic one. Although the long research history of CH3CHO photolysis, the yields of the different channels are not fully clear. From calculation it could be evidenced that the chemistry of CF3CHO shows high similarity to the much better examined one of CH3CHO. Regarding the reaction channel with the product CHF3, the activation energy and the energy level of the products is less than the one of the comparable CH4 channel. In the following, he explained the measurement method (velocity mapped ion imaging) which he and his team have applied for their examinations. From the results they could confirm the high analogy of CF3CHO to the CH3CHO chemistry and that there is an unequivocally reaction channel to HFC-23. Regarding the relative quantum yields, they have observed that the quantum yield of CF3CHO is 2.5-times greater than the ones of CH3CHO. When scaling these results to the atmospheric pressure it must be considered that collisional quenching lowers the quantum yield which results in a yield of 1 % per photon. As the removal of CF3CHO by atmospheric OH radicals is 30 times slower than the removal of CH3CHO, CF3CHO absorbs on average 11 photons instead of just two before it is reacting with OH. **From that simple atmospheric model, it could be concluded that 11 ± 5.5% of the CF3CHO becomes HFC-23, which would mean an effective 100 year GWP of HFO-1234ze of 1,400 ± 700[3].** To verify these results, they are currently executing an experimental and modelling program to

[3] Numbers result from GWP=12,690 for HFC-23. According to the 4th IPCC Assessment Report, a GWP of 14,800 applies for HFC-23. The lower molecular weight of HFC-23 compared to CF3CHO is not taken into account. Since GWPs are expressed on a mass basis, this has an impact on the calculation.

determine the fate atmospheric of CF3CHO more explicitly. Preliminary results show agreement with the previous findings, so they have already engaged with atmospheric modellers to incorporate their data into their models. The final results are expected by end of July 2021. A preprint of the study, which is currently peer-reviewed is available at the DOI:10.21203/rs.3.rs-199769/v1.

After his presentation Christopher Hansen pointed out that with switching to natural refrigerants the risks of HFO refrigerants could be prevented. Asked on the outlook of other unsaturated HFCs he explained that most of those are also studied in a preliminary phase. Asked on whether R1233zd experiences the same fate as HFO-1234ze, he answered that this substance is surely also studied but it may have different decomposition products and a different fate in the atmosphere. Currently, indirect decomposition products are not included in the definition of the GWPs of refrigerants. Therefore, a change of the definition would be necessary to consider the preliminary results from the studies of Christopher Hansen and his team.

3.2 Session 4: Evaporative cooling and urban heat island prevention

3.2.1 Natural mitigation strategies for urban heat islands in South America by Massimo Palme

At the beginning of his presentation, Massimo Palme (Associate Professor Universidad Católica de Norte, Antofagasta, Chile) introduced the phenomenon of urban heat islands (UHI). UHI in cities causes temperatures that are higher than in the surroundings. He explained that four different types of UHI can be distinguished, whereas the canopy layer is the most common one which refers to temperature differences at street level. As key factors for UHI he specified: impervious materials, urban morphology, and anthropogenic heat generation. He explained that the profile of the UHI is not uniform and depends on the climate and other influencing factors. The UHI effect is always present at night but can also occur during daytime. He said that the UHI is not well examined in South America, although there are a lot of large cities with more than 1 million inhabitants. **He explained that UHI has impacts on the energy consumption of buildings, the thermal comfort (indoor/outdoor) as well as on the public health in case of heat waves. As best proofed mitigation strategies he mentioned: Urban greening, water-related urban design, cool materials, reduction of anthropogenic heat release, design with shadows, and breezes** as shown at an example of the effects of the sea breeze in Lima. He also showcased geothermal solutions or environmentally friendly artificial cooling. Massimo Palme pointed out that another impact mitigation option is to improve the distribution of the adaptive capacity. With the example of Santiago de Chile, he showed heat sensitivity maps of the population in relation to the local UHI effects. **That lead him to his final statement that the poorest people are always more affected by the impacts of UHI.**

3.2.2 Sustainable AC in Europe and beyond "Sustainable AC in Europe and beyond - Concepts to Avoid UHI and for a Comfortable Indoor Climate" by Markus Offermann, Sibylle Braungardt, and Michael Bruse

Markus Offermann (Associate Director at Guidehouse) introduced into the project with the title "Sustainable Air-conditioning in Europe and beyond - Concepts to avoid UHI and for a comfortable indoor climate" which is financed by the UBA. The project aimed to identify and quantify the increasing overheating stress in urban areas and in buildings to develop and proof climate neutral solutions and to suggest suitable actions. It targets cities in different climate zones and covers existing as well as new neighbourhoods. The project consisted of four work packages: 1) basic state of the knowledge, 2) development and simulation-based proof of

optimised concepts, 3) actor analysis and workshops and 4) proposals for adapting the legal framework. Within the project neighbourhoods in five cities (Tunis, Madrid, Hamburg, Cologne and Frankfurt) were examined in detail using a new approach with coupled microclimate and building simulations.

In the second part of the presentation, Sibylle Braungardt (Senior Researcher at Öko-Institut) gave an overview of key findings about the general knowledge on UHI. Hooking-up what Massimo Palme already covered in his presentation Sibylle Braungardt mentioned the main influencing factors specified in the literature: Building geometries, construction materials, surfaces, and anthropogenic thermal release. She also highlighted that UHI causes increasing negative health impacts. Furthermore, she said that they found literature that claimed that a reduction of UHI also reduce the cooling demand in cities. From the literature the following UHI reduction measures were reported: Trees, green roofs, and facades, improved ventilation, increased albedo, water surfaces, avoidance of soil sealing, and smart shading structures. In colder climates as in Germany, municipalities, like Freiburg, are increasingly engaging in UHI reduction. Municipalities need to integrate the issue into urban planning, based on well-founded information on the causes and the effects of specific counter measures.

As next speaker, Michael Bruse (Full Professor Geoinformatics at the University of Mainz and CDO of ENVI-met GmbH) presented a deep dive into the results of microclimate simulations with the example of an existing neighbourhood in Tunis, Tunisia. The neighbourhood consisted of a dense mixture of different building types and almost no green. Ambient temperatures in Tunis typically reach over 40 °C in summer. As improvement measures for the neighbourhood the researcher team added several trees and artificial shading elements into their model. Furthermore, also a whitening of the roofs has been considered to increase the albedo. With the whole year microclimate simulations, individual weather files for every building were produced as input data for the further building simulation. Adding on that also detailed simulations with a higher resolution were performed to evaluate the ambient comfort. Michael Bruse showed the results of the detailed microclimate simulations in form of colour-contour maps of air temperature and the Perceived Equivalent Temperature (PET) at 2 m above street level. For the status quo, the temperatures within the neighbourhood in Tunis at a summer day at 4 p.m. range from 36.8 to nearly 40 °C at some spots. **With the implementation of the previously specified measures the air temperatures could be reduced just by up to 1.2 K.** A view on the PET shows that the differences get much bigger. Currently the PET in the examined neighbourhood reaches up to 60 °C mainly due to direct and indirect solar radiation. **With the optimisation measures a reduction of PET by 10 K and more could be reached, especially by shading.**

Finally, Markus Offermann presented the results of the dynamic thermal building simulations. Due to those, the considered measures on urban level lead just to a slight reduction of the overall cooling demand of the buildings. Because of the brighter roofs and shading of the trees, also a slight increase of the heating demand could be observed. Regarding the overall energy demand of the selected neighbourhood, he showed a graph with four variants of the neighbourhood with different building supply concepts. By the consideration of more efficient cooling (e.g., by split units using natural refrigerants) in the second variant the overall electricity demand could be reduced significantly. A further significant reduction would be possible by simply changing the setpoint temperatures from 24 °C to 26 °C. **With an advanced building variant Markus Offermann provided evidence that a zero net energy supply** (equally greater than remaining grid electricity demand equals photovoltaics (PV) surplus) **by the implementation of a rooftop PV system (30 % roof coverage) is possible.** Finally, he summarised the findings of their simulations: **The identified most effective measures to improve the urban microclimate are safeguarding the tree population and the planting of new trees, shading of open**

spaces and the use of light-coloured materials for roofs. Additionally, for new developments the preservation of urban air circulation and an appropriate ratio between buildings and open spaces (depending on climate) is important. **On the building level, the following measures to ensure a high comfort and compatibility with the climate targets are relevant: Effective external sun protection, (night) cooling ventilation, adequate insulation and glazing as well as sustainable cooling without fluorinated refrigerants powered by renewable energy. For new buildings also the building design and the thermal mass play a relevant role.**

3.2.3 Q&A on Session 4 with Massimo Palme, Markus Offermann, Sibylle Braungardt, and Michael Bruse

On specific request Massimo Palme explained that regarding UHI mitigation actions are also similarly UHI adaptation actions. In response to the next question, Markus Offermann explained that the relevance of the rejected heat of ACs on microclimate is small compared to the key driving factors like wind and solar radiation. **Michael Bruse added that the influence of all anthropogenic heat sources (including cars and heaters etc.) on larger scale is in the range of 10% and so within the accuracy-range of the models. But it surely can get locally relevant, e.g., if a huge amount of heat is rejected into a narrow street canyon.** Massimo Palme said that for South America the results of the UBA study may not simply be transferred as a lot of cities are located in tropical climates and have another structure e.g., existence of neighbourhoods with extremely poor population. But many proposed strategies can be used as starting points for further examinations. As role model for urban design Massimo Palme highlighted the cities Curitiba and Medellín, which have for example implemented public transportation systems to reduce the number of motor vehicles. Especially Medellín has a lot of publicly accessible parks with a lot of green. On the international level, he named Singapore as role model for UHI prevention measures. Answering the next question, Michael Bruse explained that during daytime shading is the most relevant factor on the PET, whereas it is not important if the shading is a nature-based or an artificial shading. But in comparison to artificial shading, water-based solutions have the potential to remove heat by conversion into latent heat (evaporation) also during the night. Finally, Sibylle Braungardt explained that for the realisation of UHI mitigation measures, municipality stakeholders must be brought together; however, discussions within the project also showed that also scientific support is needed to select the right measures. Micheal Bruse agreed and added that integrative concepts are necessary to be successful. Markus Offermann contributed that the best way of implementation also depends on the local political responsibility structures. Massimo Plame agreed and raised again the example of Medellín, Colombia, where the municipality is mainly independent from the national government. In his opinion, regionalisation of the political power is an import driver to the realisation of UHI counter measures.

3.3 Session 5: Climate-friendly production, transport, and food storage

3.3.1 *Natural refrigerant trends in the cold chain* by Ilana Koegelenberg

Ilana Koegelenberg (Market Development Manager, Shecco) started her presentation with an overview of the trends driving the industry. Due to increased urbanization and online shopping, she sees a trend away from large supermarkets to smaller stores and an increased amount of distribution centres. According to Koegelenberg, policy remains both the biggest driver and barrier for the uptake of natural refrigerants. For example, the revision of the EU F-gas Regulation. **Regarding supermarkets, the number of transcritical CO_2 installations is increasing rapidly on a global scale (with about 34% increase per year up to about 50,000**

systems in 2021). The majority of such installations can be found in Europe, but numbers are also increasing in warmer climates. Furthermore, integrated systems (systems that also use the warm side to produce hot water) are becoming more popular. The growing demand is lowering equipment costs. Also, servitization models are further removing barriers. Besides the demand of CO_2 equipment also the demand of R290 equipment is increasing. Although the International Electrotechnical Committee (IEC) has recently accepted the raise of HC charge limit to 500 g, it is still a barrier due to several national regulations. Within the different global regions there are diverse distributions of applications: While in Europe and the US, supermarkets have a share of about 90% of all installed CO_2 cooling system installations, Japan has 80%—the highest share in small stores. That is due to national restrictions. In Canada, installations are much more distributed among sectors, with 15% each for industrial cooling and data centres, 30% ice rinks and 40% supermarkets. The second part of her presentation, Koegelenberg covered cold storages and light industrial applications. A market driver in these sectors is increasing demand of frozen food globally. Within the industrial segment ammonia systems are most common. Although, due to safety concerns in some countries, there is a trend towards lower charges e.g., by CO_2-ammonia cascade systems. In industrial refrigeration she identified a trend to lager CO_2 compressors and an increased R&D focus. Globally, there are about 4,000 low charge ammonia installations, most of them in Europe. Ilana Koegelenberg is convinced that regulatory and incentive pressure will drive the growth of natural refrigerant systems. CO_2 is expected to take market shares of ammonia. The number of products and players is increasing, creating healthy competition, which will lead to decreasing product prices. She ended her presentation with the statement: “The future is natural.”

3.3.2 Modular Cooling Systems by Collin Bootsveld

Collin Bootsveld started his presentation with an explanation of his understanding of modular cooling systems. For him modular systems are systems which are reproduceable, can be copied, replaced, and cut into pieces to be handled separately. He showed pictures of a compact chiller system (with ventilated enclosure according to EN 378) with the natural refrigerant propane which Colruyt has installed in 2015. They requested the systems to be: 1) reusable if a supermarket is re-modelled and 2) redundant to ensure constant operation and supply of heating and cooling at the same time. The solution, a simple plug-in system allowed for easy repair and replacement in case of a failure. Besides modular cooling machines, Colruyt also acquired modular connections and pumps. That allowed them to prefabricate and test the cooling and heating systems in a separate container. With that they were able to reduce the change-over times dramatically. Furthermore, they also copied the system also for other applications like data centre cooling or an air handling unit for a basil farm. That these systems can be implemented all over the world was evidenced by a showcase of a Brazilian company (Eletrofrio). Currently, they have over 100 of their shops converted to propane cooling. To serve higher heating demands of large shops they needed an additional system with larger heating capacity. A suitable system they found at a producer in Northern France. Together with a local distributor they arranged trainings and the import of that specific 35 kW propane heat pump, which is now commonly available on the Belgian market. Finally, Collin Bootsveld presented Colruyt’s water loop propane cabinets, which are equipped with two 150 g propane cooling units. He sees the double compressor water loop system as an advantage, because of backup reasons and therefore also as an ideal solution for all small shops. The solution is also suitable for shops in warm climates as simply adding another water loop would allow to release the heat via a dry cooler at the rooftop. **He closed with the statement that there are already so many intelligent solutions on the markets, and no new inventions are necessary. It is just about finding those and making those available.**

3.3.3 Q&A on Session 5 with Ilana Koegelenberg and Collin Bootsveld

Asked on the trends of cooling appliances in the healthcare sector Ilana Koegelenberg said that in that important sector there are currently not so many success stories about natural refrigerants. But there is much potential in Europe regarding CO_2 AC and CO_2 heat pumps. There is also further potential at refrigeration, e.g., for vaccines. She highlighted an example of South Africa, where one of the main hospital brands have implemented indirect evaporative cooling for precooling of the AC system. She stated that innovative solutions are available now and almost everywhere. Collin Bootsveld explained that one strong argument for the switch to future-poof solutions when appealing to management is the limited engineering capacity for servicing. Also important arguments around making the switch were internal decision structures, which allowed for direct decisions made by the inhouse technicians without complex approval requirements. Finally, experience to identify what needs to be considered when implementing flammable substances have been helpful for their conversion. On the next question Ilana Koegelenberg described that her main arguments to convince others to switch to natural refrigerants depend on who she is talking to. In developed countries it is, besides putting the known positive facts on the table, mostly more an emotional argumentation. But in developing countries the implementation of Green Cooling has to compete with a lot of other often fundamental problems. Asked about the main causes of breakdowns of chillers, Collin Bootsveld explained that many breakdowns occur during the first year due to the failure of a single component. He brought up examples that ranged from broken pipes to compressor failures. That is one key argument for their modular redundancy approach. Questioned on the most relevant protection measure against impacts of propane leakages he named gas detectors inside boxed systems, which activate a fan and an alarm. Only when concentrations get critical, the systems would stop automatically. **Due to his experiences, leakages have always been small, often below detection limit.**

3.3.4 Closing remarks of Session 5 by Collin Bootsveld

In his wrap-up of the third day, Collin Bootsveld highlighted that for the switch to Green Cooling we need both good technical approaches and good human approaches. Also, he repeated that development does not always goes linearly. Regarding the presentation of Christopher Hansen, he concluded that it is not enough to look on a refrigerant molecule but also to the more stable further decomposition products, like TFA or R23, which are environmentally harmful. He stated: **"Don't use refrigerants that contain Chlorine or Fluorine. Choices always must be made on incomplete information, but regarding the information on natural refrigerants which is available so far, they currently seem to be the best choice."**

3.4 Concluding remarks by Sophie Geoghegan (Climate Campaigner at EIA), Volkmar Hasse (Cooling expert and former head of GIZ Proklima), Alexander Cohr Pachai, Collin Bootsveld, and Julika Schmitz

Sophie Geoghegan started the final Session by emphasising that she is happy that the relevance of the need for greening cooling is increasing with larger discourse on climate change. She also stated that it is impossible to reach net zero emissions without reducing cooling emissions. She alluded to the net zero cooling product list of available Green Cooling products, which has recently been published by the EIA with support from shecco. Alexander Cohr Pachai spoke from experience around the uptake of natural refrigerants at industrial cooling. Within the natural refrigerants field, he could not confirm the previously mentioned shift from ammonia to CO_2. Collin Bootsveld referred on a statement of Daniel Colbourne on day two, where he asked "Why wait until next year? Let's do it now!". Volkmar Hasse stated that we could learn from the past.

As example he highlighted the CFC phase-out discussions and that together with the German government, they tried to convince the rest of the word that R290 and R600a are the best go-to alternatives. The initiative was opposed by the US government that claimed that its chemical industry needed at least 10 more years to shift away from R22. 10 years later, R22 was indeed subject to phase-out programs within the Montreal Protocol framework in the HCFC phase-out management plans and HPMPs with support of the US government. Despite the support of natural refrigerants in the amendment of the Montreal Protocol, the chemical industry requested 10 more years for the shift to natural refrigerants. Those are over now, and we recognise a widespread introduction of HFC R32. Volkmar Hasse emphasised that phase-downs and phase-outs of the Montreal Protocol and later the Kigali Amendment were needed to force the industry in the right direction. Regarding climate, he sees that we already passed the tipping point and need to catch up now. To move forward, standards must be updated**. Updating is still blocked by some high influence players of the industry** like Daikin. He urged a joining of forces to enable sufficiently revised standards as soon as possible. Sophie Geoghegan added that a quick phase-down of F-gases would have an immediate effect to at least reduce the probability to exceed the terrifying climate tipping points. She said that the Montreal Protocol is one of the most successful treaties in the past, but that there are still huge challenges ahead of the world e.g., with the revision of EU F-gas Regulation next year. In her opinion, the existing version of the EU F-gas Regulation was too weak. Hooking-up on their previously mentioned net zero cooling product list she shared the observation that currently AC and transport refrigeration are far behind industrial and commercial refrigeration regarding the switch to natural refrigerants. She also sees a major issue with heat pumps, which are surely required for the energy transition but should urgently be shifted to natural refrigerants to prevent long-term, lock-in effects. She stated that the list of available sustainable cooling products is also on the EIAs cool technology website. Collin Bootsveld also spoke on the problem with transport refrigeration that which already has a solution called Liquid Ice Technology. The solution features liquid ice that was prepared by an ammonia chiller and then transferred to the trucks. Furthermore, **Collin Bootsveld criticised the discussion on percentages of CO_2 reduction by certain times and emphasised again that we need to act now.**

For the implementation of new cooling systems it is important to identify the right intervention point, which lies between “too early and vague” and “too late”. Alexander Cohr Pachai said that his learning from the past is that things take time, but now we have no more space for being patient. He brought up that globally there a more than 8 Million people dying because of air pollution, which itself is mainly caused by wrong profit thinking. To prevent this, he pointed out that we need courageous politicians to intervene now. Furthermore, he emphasised the high danger from lock-in effects caused by the further use of F-gases. Industrial cooling systems, for example, have typical lifespan of 35 years. He concluded that we needed action in the past, and also now. Volkmar Hasse agreed and added that all required technical solutions are already there. We would now need a joined effort to get our administrators and politicians on bord as the future is now. Sophie Geoghegan highlighted the relevance of fast completion of the revision of the standards. The ground for stopping wrong choices is prepared. Collin Bootsveld encouraged the experts to join the standards committees as the natural refrigerant stakeholders’ fraction is too small compared to the stakeholder groups with interests in prolonging HFC use. **Furthermore, he encouraged not to wait for the revision of standards, as solutions are already possible within the framework of the existing standards.** Finally, Julika Schmitz closed the Green Cooling Summit with thanking all participants and organisers and gave the promise that this summit will not be the last one.

4 Moving Forward: Pending Decisions and Required Actions in The Cooling Sector

The overall message of the Green Cooling Summit is clear: The cooling and air conditioning sector holds enormous potential to reduce global warming and meet climate targets. The use of natural refrigerants, especially in room air conditioning, is a "low-hanging fruit" (quote Daniel Colbourne, Day 2) that needs to be harvested as soon as possible. There are several landmark decisions coming up in the near future that will have a significant impact on the further global development of sustainable cooling systems using natural refrigerants:

- Raising the charge limits of the IEC 60335-2-40 would remove one of the major barriers to the widespread EU market introduction of R290 split units and heat pumps. The final vote for the revision of IEC 60335-2-40 is planned for summer 2021.
- A further significant milestone can be achieved through the revision of the EU F-Gas regulation planned for 2022. Legislators have been called upon from several sides to act by announcing bans on HFCs in the AC sector as well. To be able to prepare accordingly, comprehensive, far-reaching perspective specifications are also welcomed by the industry.

There was a broad consensus among the participating experts that the initiation of a worldwide change towards more sustainable cooling must come from politics through the creation of clear regulations. Only planning security can break the vicious circle of lack of demand leading to high costs due to a lack of economies of scale. Countries like Ghana, Colombia, and Grenada are pioneers in this regard and show how sustainable cooling regulations are possible.

To support policy makers, every stakeholder of sustainable cooling can contribute to oppose the successful profit-driven climate-damaging lobbying of some market leading companies:

- Manufacturers and assemblers can develop new product lines of climate-friendly cooling and AC systems with natural refrigerants even without legal obligations. At the conference a variety of manufacturers and assemblers like TH. WITT, Medea, Godrej & Boyce, Sanden Intercool, Secon GmbH, and Johnson Controls evidenced that this courage paid off.
- Trade and distribution can promote these products more intensively, e.g., like Westfalen Group demonstrated, one of the biggest distributors of refrigerant in central Europe
- Training centers should teach the advantages and safe handling of systems with natural refrigerants. The GIZ has successfully implemented such training programs in a variety of countries.
- Engineers and installers could train themselves accordingly and make recommendations to their customers. At the conference a good practice example for that was presented by Cool Tool Technology.
- Organizations like shecco, Eurammon, and EIA act as hubs to collect and provide information
- Research is responsible for creating the basis for targeted measures to protect the climate and improve our quality of life. On the final day of the Green Cooling Summit, several researchers from UNSW Sydney, Universidad Católica de Norte, Antofagasta, Chile, Guidehouse, ENVI-met GmbH, and Öko-Institut presented their latest results.

- Finally, end-users can also take climate protection into account as an important factor in their purchase decision. At the conference, the Belgian retailer Colruyt elaborated on the advantages of their switch to natural refrigerant cooling systems.

The urgently needed transition of the cooling sector towards sustainable cooling with natural refrigerants can only be achieved through swift, courageous action by stakeholders in all areas.

A Appendix: Conference Agenda

Tuesday, May 25		**Wednesday, May 26**		**Thursday, May 27**	
1:30 P.M. – 2:00 P.M.	Coffee Chat (Microsoft Team Chat)	8:30 AM – 9:00 AM	Coffee Chat (Microsoft Team Chat)	1:00 P.M. – 1:30 P.M.	Coffee Chat (Microsoft Team Chat)
2:00 P.M. – 2:10 P.M.	Opening Dr. D. de Graaf, J. Schmitz (Live Stream)	9:00 AM – 9:10 AM	Opening Day 2 J. Schmitz, D. Colbourne (Live Stream)	1:30 P.M. – 1:40 P.M.	Opening Day 3 Ir. C. Bootsveld, J. Schmitz (Live Stream)
2:10 P.M. – 2:20 P.M.	Official Welcome to the Green Cooling Summit (pre-recorded) S. Schulze, D. Messner, T. Gönner (Live Stream)	9:10 AM – 9:30 AM	Keynote M. Witt (Live Stream)	1:40 P.M. – 2:10 P.M.	Keynote: Latest Findings on the fate of HFO-1234ze in the atmosphere Dr. C. Hansen (Live Stream)
2:20 P.M. – 2:30 P.M.	Cooling from a development view Dr. H. Litzinger, J. Schmitz (Live Stream)	9:30 AM – 11:00 AM	Session 2: Latest technology trends in AC (incl. Q&A) M. Appenzeller, V. Mergl, A. Panas, D. Colbourne (Live Stream)	2:10 P.M. – 3:15 P.M.	Session 4: Evaporative cooling and urban heat island prevention (incl. Q&A) Dr. M. Palme, M. Offermann, Dr. S. Braungardt, Prof. Dr. M. Bruse (Live Stream)
2:30 P.M. – 2:45 P.M.	Keynote: The final phase-down – Why natural refrigerants are the ultimate solution Prof. A. Hafner (Live Stream)	11:00 AM – 11:15 AM	Break	3:15 P.M. – 3:30 P.M.	Break
2:45 P.M. – 3:00 P.M.	Break	11:15 AM – 12:45 P.M.	Session 3: How to use natural refrigerants safely (incl. Q&A) N. Shedge, J. Li, J. Schadt and A. Cohr Pachai	3:30 P.M. – 4:30 P.M.	Session 5: Food sector (production and storage, incl. Q&A) I. Koegelenberg, Ir. C. Bootsveld (Live Stream)

Tuesday, May 25		**Wednesday, May 26**		**Thursday, May 27**	
3:00 P.M. – 3:45 P.M.	Session 1a: Country-specific policies to manage the HFC phase-down (EU & Ghana, incl. Q&A) E. Osae-Quansah, A. Kaschl (Live Stream)	12:45 P.M. – 1:00 P.M.	Closing Day 2 J. Schmitz, D. Colbourne (Live Stream)	4:30 P.M. – 4:40 P.M.	Closing Day 3 Ir. C. Bootsveld, J. Schmitz (Live Stream)
3:45 P.M. – 4:30 P.M.	Session 1b: Country-specific policies to manage the HFC phase-down (Grenada & Colombia, incl. Q&A) N. Pabón, L. Smith (live Stream)			4:40 P.M. – 5:00 P.M.	Concluding Remarks (Live Stream)
4:30 P.M. – 5:00 P.M.	Break				
5:00 P.M. – 5:50 P.M.	Panel discussion: How do we pave the way for a successful HFC phase-down with natural refrigerants O. Nielsen, B. Siegele, A. Kaschl, C. Perry, J. Feng (Live Stream)				
5:50 P.M. – 6:00 P.M.	Closing Dr. D. de Graaf, J. Schmitz (Live Stream)				