REPORT FOR WORKSHOP ON
"DEVELOPMENT OF APPROPRIATE SAFETY STANDARDS FOR THE USE OF HYDROCARBON REFRIGERANTS IN THE RAC SECTOR"

26-27 APRIL 2016, DELHI

Centre for Science and Environment
New Delhi 110 062, India

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EXECUTIVE SUMMARY

As part of the current negotiations on phase down of Hydrofluorocarbons (HFC) under the Montreal Protocol, countries are being urged to move from high GWP HFCs to low GWP alternatives. Hydrocarbons have come up as a major contender for replacing HFCs as they are non-proprietary low-GWP refrigerants without any uncertainty with respect to emerging environmental regulations. These gases also have higher energy efficiency than traditional f-gases. This means a switch to hydrocarbons will not only reduce direct emissions from HFCs, but will also have indirect emissions reductions from the high energy efficiency offered by these refrigerants. These energy savings, combined with international and national efforts to improve energy efficiency will be crucial for achieving the goals set under the Paris agreement.

According to the Technological and Economic Assessment Panel (TEAP) created under the Montreal Protocol, hydrocarbons can be used as an alternative in all Refrigeration and Air-conditioning (RAC) sectors, with the possible exception of mobile air conditioning. The only major barrier to the large scale use of hydrocarbons has been the safety concerns over the high flammability of these refrigerants especially in room air conditioning. These concerns stem from studies that were performed decades ago, with little consideration for the technological improvements made to ensure safety in hydrocarbon based RAC systems. This perception of diminished safety has led to restrictive safety standards under the two major international standards regimes, i.e. International Electrochemical Commission (IEC) and the International Standards Organisation (ISO).

New studies have shown that the maximum charge size limits set under these standards are restrictive. This has been because the test conditions used to come up with the current standards were overly restrictive and not representative of practical use. More realistic studies of the safety concerns related to gas leakages in hydrocarbon based RAC systems reveal that the charge size of these systems can be increased (with the use of available safety features) by up to 3 times the current limits. This will allow for the use of hydrocarbon based RAC systems with higher cooling capacity in much less restrictive circumstances (room size limits). It is estimated that such a change in the hydrocarbon standards can allow for a smooth transition to hydrocarbons in almost all household ACs which are the dominant part of stationary air conditioning (SAC) applications. The SAC sector accounts for more than 30 percent of the global HFC emissions and a switch to hydrocarbons in this sector will make a significant impact on mitigation of HFC emissions.

WORKSHOP OUTLINE

The Development of appropriate safety standards for the use hydrocarbon refrigerants in the RAC sector" workshop brought together experts from all over the world working in the field of Refrigeration and Air-conditioning (RAC). These experts came together to articulate the specific issues that need to be addressed in order to develop Indian standards (through the Bureau of Indian Standards, BIS) for use of hydrocarbons in RAC sector. The workshop included presentations on the current state of international negotiations and the benefits from the use of hydrocarbon based refrigerants, barriers to switching from f-gas to hydrocarbon based RAC systems in India and the international state of standards and changes needed for wide scale implementation of hydrocarbon refrigerants in India.

The presentations were followed by breakout sessions, where changes needed in international standards were discussed. The group decided to focus on the Stationary air conditioners only considering the fact that current market situation where most of the refrigeration system have already adopted HC and market growth in air conditioners up to 11kW, the scope was defined as air conditioners up to 11 kW. The group unanimously agred unanimously agreed that HC standards around the world were restrictive and needed change for India to phase out HFCs. Some of the key findings and recommendations from the workshop were:

- To modify ISO 5149 and IEC 60355-2-40 to make them more suitable to Indian conditions
- To compile latest information on safety of hydrocarbons including tests done on hydrocarbon based RAC equipments and develop a dossier to support the need for an appropriate standard for India. If required, additional tests could be conducted in labs to substantiate the global experience on safety of hydrocarbons in RAC sector.
- To prepare draft standards for charge size in hydrocarbons taking into account EER improvements and average heat load for Indian conditions (between 75-150 W/m^2).
- To engage with a wider group of stakeholders for consensus

OVERVIEW

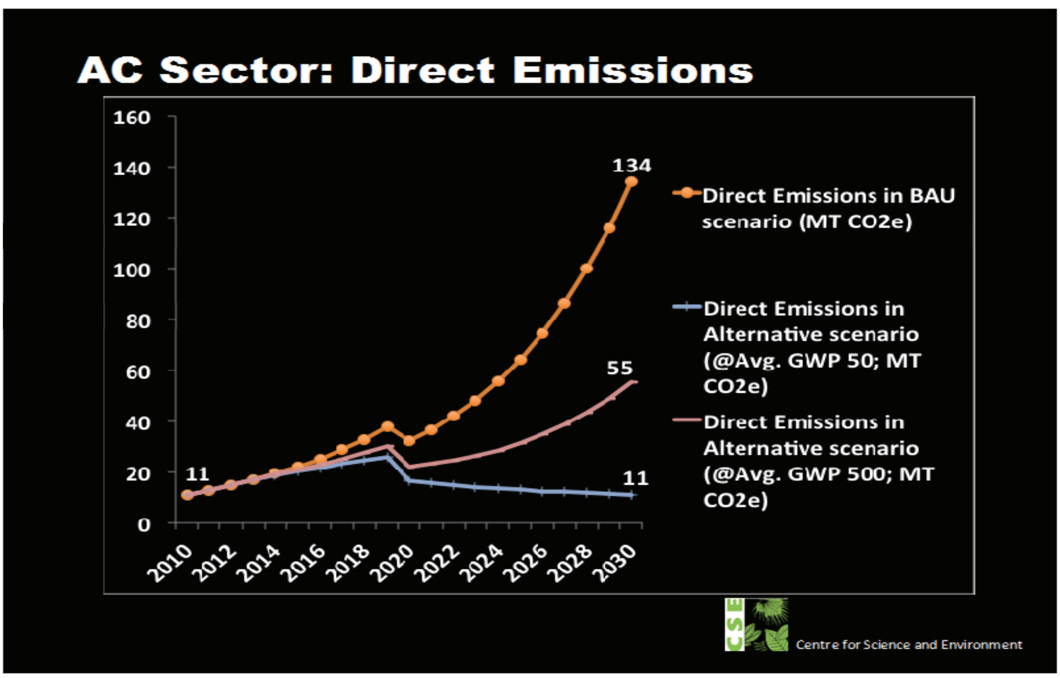
Context and background

With the world moving towards ratification of the Paris climate change agreement, mitigation of non CO_2 gases are crucial for a future with less than 2 degrees Celsius of warming. Most of these gases like HFCs, methane are short lived climate pollutants, which have high GWP and low atmospheric lifetimes. Mitigating these gases would therefore provide greater climate benefits in short term.

Among the alternatives available for the replacement of HFCs, perhaps the most appropriate for developing countries like India are hydrocarbons. This is not only because of their low GWP, but of their ease of availability and better energy efficiency in high ambient temperature conditions. The table below shows that almost all sectors with the possible exception of mobile air conditioning have hydrocarbon based alternatives available:

Sector	CFCs	HCFCs	HFCs Pure & Blends	HCs	CO2 Ammonia	Unsaturated HFCs Pure	Blends with Unsaturated HFCs
Domestic Refrigeration	CFC-12		HFC-134a	HC-600a		HFC-1234yf	R-450A, "XP-10"
Commercial Refrigeration (SA, CU, CS)	CFC-12 R-502	HCFC-22	HFC-134a R-404A R-407A R-407F	HC-600a HC-290	CO2 Ammonia	HFC-1234yf HFC-1234ze(E)	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Transport Refrigeration		HCFC-22	HFC-134a R-410A R-407C	HC-290 HC-1270	CO2	HFC-1234yf	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Industrial refrigeration		HCFC-22	HCFC-22 HCFC-123	HC-1270 HC-290	Ammonia CO2	HFC-1234yf	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Water heating heat pumps		HCFC-22	HCFO-1233zd(E)	HC-290 HC-600a	CO2 Ammonia	HFC-1234yf HFC-1234ze(E)	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Air Conditioners		HCFC-22	HFC-134a HFC-32 R-410A R-407C	HC-290	CO2	HFC-1234yf	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Chillers	CFC-12 CFC-11	HCFC-22 HCFC-123 HCFO-1233zd(E)	HFC-134a R-404A R-410A R-407C	HC-290 HC-1270	Ammonia CO2	HFC-1234yf HFC-1234ze(E)	R-444B,R-448A,R-449A,R-450A, "L-40" , "L-41" , "DR-5" , "XP-10"
Mobile Air Conditioner	CFC-12		HFC-134a R-410A R-407C		CO2	HFC-1234yf	R-450A, "XP-10"

Historical use
Current use on a commercial-scale
Potentially feasible or limited use such as for demonstration, trials, niche applications, etc



The decrease in direct HFC emissions may be accompanied by a corresponding reduction in indirect emissions through energy efficiency improvements, especially in the case of hydrocarbons. These energy efficiency reductions, coupled with the current policies for the promotion of energy efficiency can lead to significant energy/emissions savings. According to studies, about 100 million tons of CO_2 eq can be saved by 2030 just from the AC sector with a doubling of energy efficiency. The choice of alternative refrigerant must therefore take into account the energy efficiency improvements.

The switch to natural refrigerants like hydrocarbons will also serve as a long term solution to the chemical treadmill that has been created by the Montreal Protocol. The current chemical families considered as the alternative to HFCs are Hydrofluorolefins (HFO). These chemicals, due to their chemical instability, breakdown in the atmosphere quickly thus having low GWP. They however may have harmful by-products like TFA (triflouro acetic acid), which is phytotoxic and may be harmful to aquatic life at certain concentrations. TFA is already ubiquitous in the atmosphere as a by-product of HFC breakdown. Studies estimate that the large scale adoption of HFO 1234yf (a refrigerant used mainly in the mobile air conditioning sector) may lead to more than 5 times as much TFA than HFC134a.

In addition to the health and environmental concerns HFOs also have concerns related to its broad patent protection. The patent protection has been found in a study commissioned by CSE to be broad based and almost impenetrable. This means that companies that find new manufacturing processes won't be able to sell or do research on the refrigerant until the patent protection expires. Also, the price of HFOs are so high that it is likely that traditional HFCs will be used for servicing, and with the phase down they will become a black market.

Taking these concerns into the account, it is essential to leapfrog HFCs to natural refrigerants like hydrocarbons. There are however a number of barriers to such a transition. The main barriers are a lack of buy-in from major manufacturers of RAC systems largely because of exaggerated safety concerns related to the refrigerant. These concerns however can be quelled with the help of increased awareness and more accommodating safety standards.

Objectives and scope

As current standards are the major barriers for a successful transition to hydrocarbon based refrigerants, the workshop aims to come up with an outline of requirements needed to make changes to standards and making them more accommodating. Global standards applicable to RAC are mainly from the International Standardisation Organisation (ISO) and the International Electrotechnical Commission (IEC) in addition to some of the regional (EN) and country specific standards (ASHRAE).It is a common practice that international and regional standards are adopted at the national levels. During this procedure, standards can be modified to suit the best local demands and conditions.

India faces a number of barriers related to standards for HCs. India does not have a standard for room ACs. So, Indian HC Air Conditioner manufacturers have followed "restrictive" international standard (like EN378) for its Split ACs using HC-290. Although IEC 60335-2-40 is under revision and India is a member of ISO, a process needs to start in India for developing its own standard in line of ISO. It is important for India to develop its own version of a standard as it will help the local industry stay independent and take the decision to move in the direction in the best interest of the industry and environment.

The process

The two day meeting was a close group meeting of experts in standards from all over the world. A total of 22 participants attended the meeting. After the initial presentations the plenary was divided into two working groups. In order to facilitate free and frank discussions, inputs were recorded live on a board. On day 1, participants were divided in the working groups and asked to come out with an agenda for the working group and issues and challenges with existing international standards. On day 2, the same working groups were asked to come out with recommendations and propose the way forward to resolve the challenges.

BREAK OUT GROUPS

Group One

Group one discussed in detail about various options available to address the flammability safety standards so as to have an increased charge size. The four options identified by the group as a way to address flammability standards were

- Modify ISO 5149 with national differences
- Adopt Product standard IEC 60355-2-40
- Adopt New National standard on charge size for ACs using A3 refrigerants
- Propose changes to IEC 60355 with national differences

The group decided to limit the scope of the discussion to room air conditioners up to 14KW as ISO 5149 standard is obstructive to room air conditioners under 4 tonnes but has safety concerns resolved for commercial air conditioners. Also as ISO 5149 standard is being considered for adoption by BIS, the group decided that it would be better to make amendments to it than to start work on any a new standard

Group Two

Group two decided to go through both the relevant international standards, i.e. IEC 60335-2-40 and ISO 5149 (I-IV) to see how these standards can be customized for Indian conditions. This would complement the work done by group one on the changes needed to maximum charge size limits to make the current standards more accommodating. According to the group, the clauses where separate Indian standards existed or needed changing because of the Indian electrical power or weather or socio-economic conditions should be reviewed

The major recommendations of the group were to request BIS to fast track the adoption of ISO 5149 with recommended amendments and look at the adoption of IEC 60335-2-40 at a later stage.

Additionally, the group also focused on how stakeholder buy-in could be materialized for the adoption of the above amendments and they came up with the following plan of action:

- Ensure that all BIS committee (MED 03) members are made part of the discussions and increase buy-in within the RAC manufacturers, including organisations like Refrigeration and Airconditioning Manufacturers' Association RAMA
- Since, BIS does not have in-house expertise / opinion on the standards, a multi-stakeholder consultation committee will be crucial for progress on the standards
- QCI (Quality Council of India) can facilitate the process of standard development and the subsequent conformity assessment system needed through multi-stakeholder involvement and consultation process.

ISSUES AND CONCERNS FOR THE DEVELOPMENT OF ACCOMMODATING STANDARDS

Widespread use of hydrocarbon refrigerants around the world

In recent years there has been an increase in the adoption of hydrocarbon based technologies in the RAC sector. For instance, commercial refrigeration in UK has seen a large increase in the adoption of hydrocarbon based technologies with the number of stores increasing from 14 to 1800 in the last 10 years. There is also widespread use of hydrocarbon refrigeration and air conditioning technologies in China, with 400,000 stand alone cabinets, 322,000 ice cream freezers and 2,500 bottle coolers & vending machines being powered by hydrocarbon based refrigeration technologies.

These systems have shown improvements in energy efficiency of up to 33 percent over their fluorine based counterparts. The energy efficiency improvements make the lifetime costs of natural refrigerant based RAC systems almost equal to traditional systems.

Large scale implementation of hydrocarbons however requires better coordination with industry, support framework for training, maintenance, components, standards and more aggressive marketing.

Restrictive nature of current international standards

Charge limits are important in international standards as charge in a system is proportional to the cooling (or heating) capacity and charge limits dictate how large a product range can use which type of refrigerant.

The current international standards ISO, IEC and the corresponding regional and national standards use the same formula for the charge size for A/C, which in most cases is even more restrictive than for refrigeration. The current charge size is very restrictive and for safe use of HC-290, and as per the current standards a practical limit of 8 g/m^3 (0.23 g/cft) may not be exceeded in a closed space or room. So, in a typical room of 14'x12'x9' (high), with a volume of 43 m^3 (1512 cu. ft.), the safety limit would be about 350 g of HC-290 making it restrictive to use over 1.5 tonnes of air conditioners.

Global organisations	**ISO**	**IEC**	
Examples	ISO 5149	IEC 60335-2-40	By definition voluntary
Regional organisations	CEN	CENELEC	
	EN 378, EN 12284	EN 60335-2-40	Some partly mandatory (Presumption right)
National organisations	ANSI, BIS, BSI, DIN, DS, etc…		
Examples	ASHRAE 15, IS 10594	UL 60335-2-40, DS EN 60335-2-40	Some voluntary, Some mandatory

Barriers to switching to hydrocarbon refrigerants in the RAC sector

The perceived safety concerns with the use of hydrocarbons are a major barrier to its large scale use. The use of HCs is however safe when adequate precautions are taken. In order to look at the barriers faced during implementation of hydrocarbon based refrigeration, Godrej's experience with these systems was studied.

The non-availability of Indian standards for the use of HC RAC was a concern in the initial stages. Godrej adopted EN 378, which is a European standard and has restrictive charge size limits. This led to challenges of smaller volume-high efficiency condensers and compressors, equipment that has to be matched to specific hydrocarbon among others. This in turn led to an increase in the production cost.

Godrej adopted EN 378 for development and testing of their hydrocarbon refrigerant based RAC systems. In addition to the tests prescribed under the standard, Godrej also conducted independent safety testing with the help of international experts to ensure the safety of the product and the manufacturing facilities.

There were also changes required in the purity levels of the hydrocarbons to use them as refrigerants, change in handling processes needed for flammable substances and servicing challenges, where proper equipment and training was needed.

Godrej had reported an initial shortage of appropriate equipment due to shortage of demand, i.e. condensers (with low internal volumes) – multi channel heat exchangers and small diameter tube condensers.

Godrej also faced a number of challenges during the product after sales process. This included training for trainers and technicians and making the requisite equipment available to the service personnel.

Additionally, Godrej faced the following barriers during procurement of the refrigerants:

- Specific regulation on storage and transport of small quantities needed.
- Appropriate communication to Chief Controller of Explosives(CCOE), Department of Excise and customs, Fire Department(FD), Directorate General of Supplies and Disposals(DGS&D), etc required for ease of permissions and approvals

SAFETY CONCERNS WITH CHARGE SIZE LIMITS

Current charge size limit formula in the standards is $m_{max} = 2.5 \times LFL^{1.25} \times h \times \sqrt{A}$
Where m_{max} = allowable charge size in a room
h = installation height of appliance (0.6 for floor mounted, 1.0 for window mounted, 1.8 for wall mounted and 2.0 for ceiling mounted)
LFL = Lower Flammability limit
A= Room Area

The Basis for formula is that

- The Entire charge leaks in 4 minutes
- The Leak is from “diffuser” device
- And the Installation height corresponds to AC type (& must be >0.6 m)

Existing formula – validity of 4 minute leak time and installation height

According to the lab tests conducted by Daniel Colbourne, they could never get a floor concentration anywhere near to that of a diffuser test which would leak in under 4 minutes. At the time of the development of formula, tightness was largely absent. The current formula also underestimates mass for h>0.6 m and overestimates mass for h<0.6 m making the results from the formula incorrect.

The Current requirements for AC charge size limit within standard are:

- Based on very limited knowledge 15 – 20 years ago
- Almost no experience and negligible research
- Choice of unit heights inappropriate
- Assumption of "diffuser" to mimic release incorrect
- Use of 4 minute leak time which is close to impossible.

Risk analysis approach

A rational approach would try to identify elements that contribute to flammability risk to design and construction characteristics of Air conditioning, refrigeration and heat pump equipment. Such characteristics may include leak protection measures like

- Location of parts
- Tightness
- Airflow
- Mass of refrigerant
- Room size
- Leak rate
- Height of refrigerant containing parts
- Equipment housing geometry.

The formula was written without taking tightness into consideration, so in principle a leaky machine made in a garage with rudimentary tools or a tight product on a production line have the same standard being applied expecting the same leakage. Some additional measures to improve tightness can be made mandatory like strength pressure test and leak tightness test with additional optional tests like mechanical impact, vibration, resonance, cycling, drop, corrosion, long-term run can be done for increasing charge size in specific cases.

The formula in the standard assumes the leak rate for R32 and R 290 as the same when R32 has almost 3 times the leak rate of R290. Because of which it is a massive benefit for R32 and a disadvantage for R 600a.

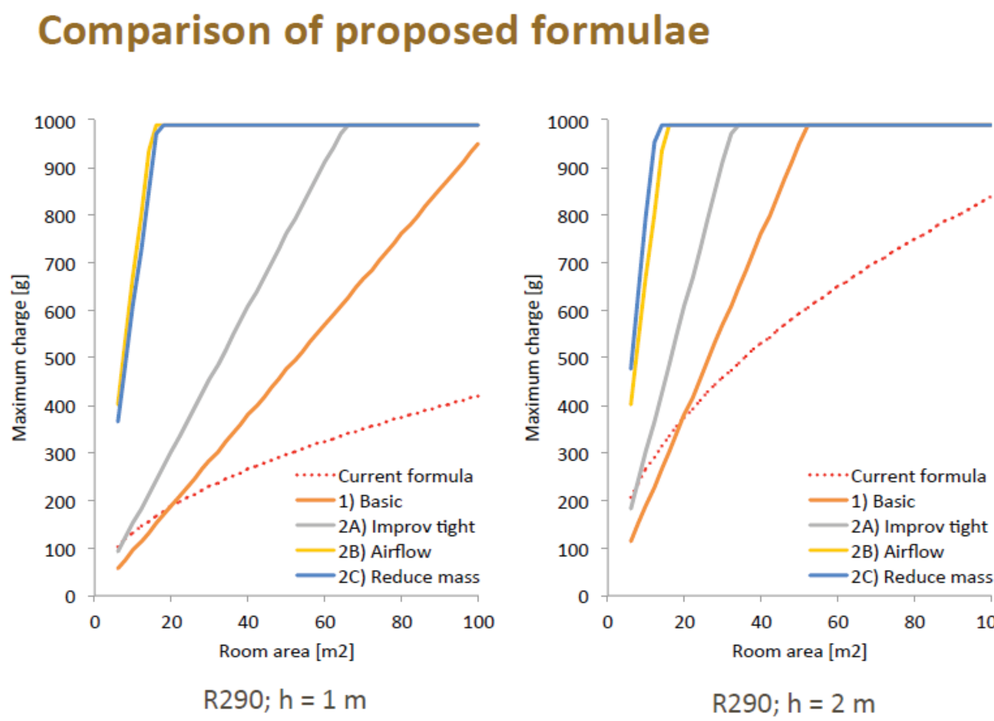
	R600a	R290	R1270	R1234yf	R32
p_sat (bar)	9	23	27	18	42
mf_crit (g/min)	29	59	73	81	168

The chances that the leak to occur very rapidly even if there is a massive rupture with a required air mixture, with no people to detect, with no airflow or infiltration, and with an active source of ignition, all at the same time is infinitesimally low.

Considerations for new requirements

By referring to two Japanese studies by JARECO and JSRAE[1] on determination of leak hole size, Daniel Colbourne proposed possible new formulae with improved tightness, airflow and reduced released mass. The formula would help increase the charge size of the formula are as below.

1) Basic	m_{max} = 0.25 x h x LFL x A_{room}
2A) Improved tightness	m_{max} = 0.40 x h x LFL x A_{room}
2B) With airflow	m_{max} = 0.80 x LFL x V_{room}
2C) Reduced released mass	m_{max} = { any of 1), 2A) or 2C) } + retained mass
Proof by test	According to test when C_{max} < 90% LFL



1. Overview of risk assessment and safety guidelines for VRF systems using A2L by Ryuzaburo Yajima

THE WAY FORWARD

At the workshop participants worked in two breakout groups to identify the way forward to address the concerns in safety standards. The way forward decided by the groups was to identify and make changes to ISO 5149 to reflect new science and development of safety system in hydrocarbon based room air conditioners. BIS would be requested to consider this draft standard for discussion and adoption. The group decided that the work done by Daniel Colbourne could be used for draft recommendations as it has solid scientific analysis. However, if required, an independent analysis and lab tests should be performed in India to support Daniel's proposed formulae taking into account EER improvements and average heat load for Indian conditions

Once the group has done work on ISO 5149, it can also work on modifying IEC 60355-2-40 to suit Indian condition.

The groups also felt that there is a need for:

- Increasing consensus within India on hydrocarbons by disseminating information on current research on charge size limits and available safety features
- Raising industry/consumer awareness about the restrictive nature of the current standards and exaggeration of safety concerns
- Increasing stakeholder buy-in through constant engagement with BIS committee members
- Proposing changes to the ISO and IEC standards to make them more accommodating to hydrocarbons and amenable to Indian conditions
- Developing India specific installation guide.

ANNEX -1: AGENDA

DEVELOPMENT OF APPROPRIATE SAFETY STANDARDS FOR HYDROCARBON REFRIGERANTS IN RAC SECTOR

PROGRAMME AGENDA

DAY 1: APRIL 26, 2016

SILVER OAK HALL–I, INDIA HABITAT CENTER, LODHI ROAD, NEW DELHI

INTRODUCTORY SESSION – 9:00 TO 11:00

- Background and objective of the meeting — **Chandra Bhushan, CSE**
- Naturals as replacement to fluorinated refrigerants — Global experiences **– Avipsa Mahapatra, EIA**
- Growth of natural refrigerants and current state of standards in China — Zhou Yi, Hitachi Shanghai
- Barriers to use of natural refrigerants in RAC sector — **Burzin. J. Wadia, Godrej**
- Closing remarks by **Shri Manoj Kumar Singh,** Joint Secretary, Ministry of Environment, Forest and Climate Change

TEA BREAK 11:00 – 11:15

STATUS OF SAFETY STANDARDS FOR NATURAL REFRIGERANTS – 11:15 TO 13:30

- Current state of international standards — Asbjørn Vonsild
- Overview and current state of Indian standards — Sukumar Devotta
- Developments at BIS including engagements with IEC and ISO — Khushboo Kumari, BIS
- Latest research on charge limits and proposing new limits for Hydrocarbons — Daniel Colbourne

LUNCH 13:30 - 14:30

PLANNING SESSION 14:30 – 15:15

- This session will discuss the agenda, modalities and the expected outputs for the breakout sessions.

TEA BREAK 15:15 – 15:30

BREAKOUT SESSION I – 15:30 – 18:00

- Working groups to discuss specific issue/issues and come out with recommendations.

DAY 2: APRIL 27, 2016

MAGNOLIA HALL, INDIA HABITAT CENTER, LODHI ROAD, NEW DELHI

REPORTING FROM BREAKOUT SESSION – 10:00 – 10:30

- The groups will report back to the meeting with progress made on the previous day

TEA BREAK 10:30 – 11:00

BREAKOUT SESSION 2 – 11:00 – 13:00

- This session will take the feedback from the plenary and continue discussions in breakout sessions on the issues assigned

LUNCH 13:00 - 14:00

CONCLUDING SESSION – 14:00 – 16:00

- This session will discuss the outputs from the breakout groups, finalize and aggregate the actions suggested and make final recommendations on way forward.

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ANNEX –II PARTICIPANTS LIST

S.No	Name	Company
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2	Burzin .J.Wadia	Godrej & Boyce Mfg. Co. Ltd.
3	Abhijeet Achrekar	Godrej & Boyce Mfg. Co. Ltd.
4	Dr. Sukumar Devotta	Consultant
5	Manjunath V	Underwriters Laboratories (UL)
6	Rajesh Maheshwari	National Accreditation Board for Certification Bodies (NABCB)
7	Shobha Hegde	National Accreditation Board for Certification Bodies (NABCB)
8	L.M. Joshi	Haier
9	Manoj Kumar	GOI
10	Daniel Colbourne	GIZ
11	Asbjorn Vonsild	Consultant
12	Avipsa Mahapatra	EIA
13	Darshi Dhaliwal	Toro Cooling Systems Pvt. Ltd
14	Manish V Tamhane	ATE - HMX
15	Vivek Gilani	C Balance
16	Ravi Kapoor	Consultant
17	Zhou Yi	Hitachi Shanghai
18	Wang Youyin	Hitachi Shanghai
19	Deepak Verma	Danfoss
20	Chandra Bhushan	Centre for Science and Environment
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