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Developing an Ecosystem to Phase Out HFCs in India

Establishing a Research and Development Platform

Shikha Bhasin, Lekha Sridhar, and Vaibhav Chaturvedi

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CEEW Report

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A report on 'Developing an Ecosystem to Phase Out HFCs in India: Establishing a Research and Development Platform'.

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Contents

Acronyms and Abbreviations

AC	Air-conditioners
ACMA	Automotive Component Manufacturers Association of India
BEE	Bureau of Energy Efficiency
CAC	Commercial Air-conditioning
CEEW	Council on Energy, Environment and Water
CFC	Chlorofluorocarbons
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council of Scientific and Industrial Research
DST	Department of Science and Technology
EU	European Union
GWP	Global Warming Potential
HFC	Hydroflourocarbons
HFO	Hydrofluoroolefin
IICT	Indian Institute of Chemical Technology
IIT	Indian Institute of Technology
INR	Indian Rupee
IPR	Intellectual Property Rights
MAC	Mobile Air-conditioning
MoEFCC	Ministry of Environment, Forests & Climate Change
MLF	Multilateral Fund
NIS	National Innovation System
NREL	National Renewable Energy Laboratory
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
OECD	Organisation for Economic Co-operation and Development
RAC	Residential Air-conditioning
RAMA	Refrigeration and Air-Conditioning Manufacturers Association
REGMA	Refrigerant Gas Manufacturers Association
RASSS	Refrigeration and Air-Conditioning Service Sector Society
R&D	Research and Development
RDP	Research and Development Platform
SEED	Science for Equity, Empowerment and Development
SIAM	Society of Indian Automobile Manufacturers
UAY	Uchchatar Avishkar Yojna
UN	United Nations
USD	United States Dollar

Executive Summary

In September 2016, the Ministry of Environment, Forest and Climate Change (MoEFCC) announced its intention to establish "an ambitious collaborative R&D programme to develop next generation, sustainable refrigerant technologies as alternatives to HFCs" in India[1]. As per its official press release, "the collaboration of research institutes as well as industry will create [a] larger ecosystem for developing sustainable solutions, and eventually [for] deploying low global warming potential HFCs on a national scale."[2]

Within the ambit of the Montreal Protocol[3], India successfully negotiated the international space to enable it to address technological and systemic gaps to build the required ecosystem for phasing out HFCs in India. Hence, the Government of India's national initiative of a collaborative research and development (R&D) programme must seek to deliver to this end. The ongoing development of a National Cooling Action Plan reiterates and supports the government's intention to create an ecosystem that allows industries, and the country, to move along a pathway that is climate friendly and resource efficient, without impeding economic growth or constraining economic interests.

Building on the Council on Energy, Environment and Water's (CEEW) previous work on HFCs that identified the need for R&D[4], as well as the Government of India's recent announcement, this report highlights the relevance of, and presents an institutional design for, a dedicated multi-stakeholder R&D platform to address India's domestic concerns and to meet its international commitments for the phasing out of HFCs. The methodology followed included desk research on the use of HFCs in India, innovation systems literature, and collaborative research frameworks, in-depth meetings with industry stakeholders, and consultations with key experts from the Government of India and academia.

Systemic Transition to low-GWP Refrigerants

Industry stakeholders confirmed the need for (1) policy certainty for the transition to low-global warming potential (GWP) refrigerants; and (2) indicators to reassure industry players that the government is, in fact, keen to facilitate R&D in India, such that it is not only the first-movers (particularly international companies and export suppliers) that gain advantage. In addition, they emphasised the need for ecosystem factors such as safety standards, technology referencing and certification, as well as financial commitments to enable sector-wide transformations along the supply chain.

Based on the systemic needs outlined by industry experts, and the targets laid down by the Government of India for a transition to low-GWP refrigerants, we envisage a Research and Development Platform dedicated to facilitating the phase-out of HFCs in India by supporting R&D and the adoption of low-GWP alternatives.

The Platform would be set up as an autonomous body similar to the Bureau of Energy Efficiency (BEE). It would not only facilitate basic research, but would also focus on the larger "innovation ecosystem" to ensure

1 Press Information Bureau (2016) "Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives," available at http://pib.nic.in/newsite/mbErel.aspx?relid=149825; accessed 17 June 2017.

2 Press Information Bureau (2016) "Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives," available at http://pib.nic.in/newsite/mbErel.aspx?relid=149825; accessed 17 June 2017.

3 The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) came into force on 1 January 1989.

4 Chaturvedi, Vaibhav, Bhaskar Deol, Steve Seidel, Anjali Jaiswal, Ankita Sah, Mohit Sharma, Nehmat Kaur, and Stephen O. Andersen (2016) Cooling India with Less Warming: Examining Patents for Alternatives to Hydrofluorocarbons. Issue Paper 12. . New Delhi: CEEW, NRDC, C2ES, IGSD, pp. 1–12. Available at http://ceew.in/pdf/CEEW%20-%20Issue%20Paper-Cooling%20India%20with%20less%20warming06Oct16.pdf

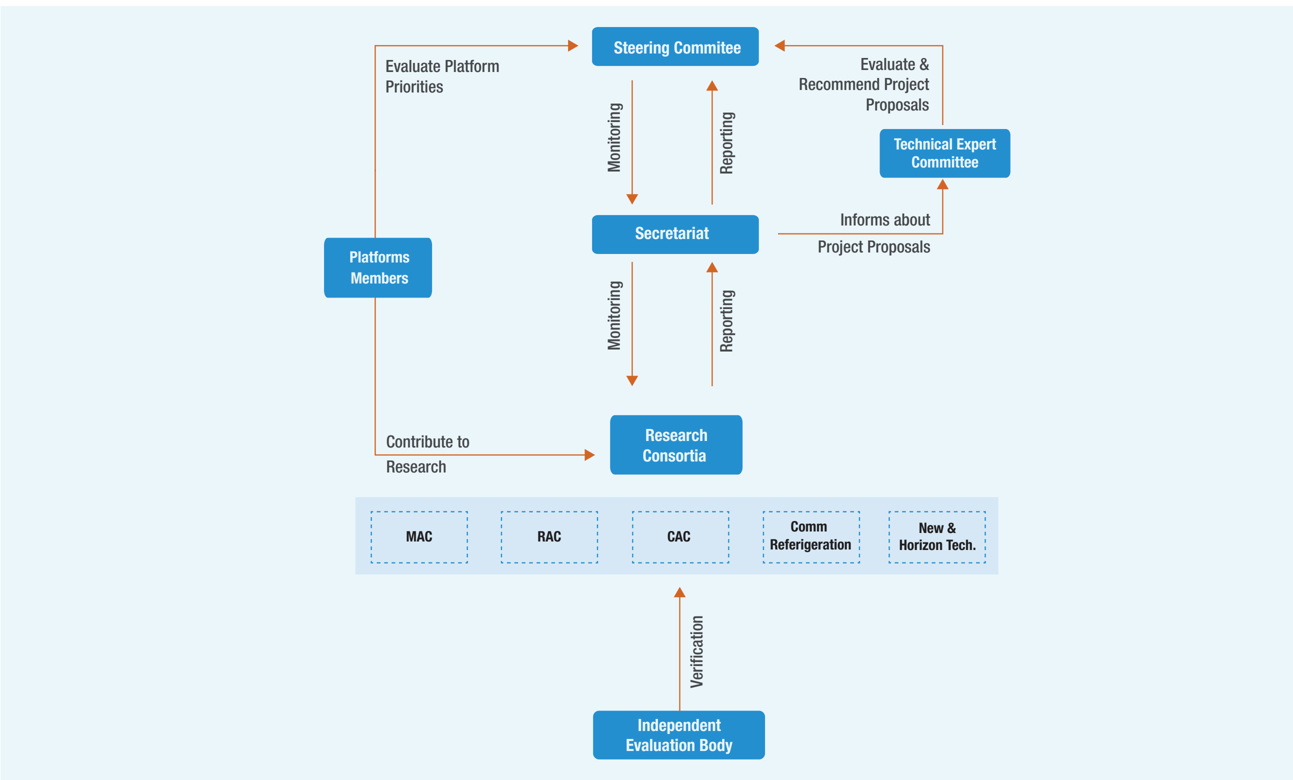
the success of technical transformations, such as recommending standards, applications, consumer-incentive programmes, and similar supporting aspects for HFC replacements. This will be achieved through active engagement with all relevant stakeholders who would be the Members of the Research and Development Platform (RDP). The Platform would be a one-stop authority for assessing the alternatives to HFCs in India and for determining the requirements for replacing HFCs, with the following activities being undertaken collaboratively:

- Facilitate basic research
- Facilitate and encourage applied research
- Facilitate technology testing facilities
- Recommend standards for usage, performance, and safety
- Recommend policies for market integration and low-GWP refrigerant usage
- Suggest consumer-based programmes
- Function as a knowledge and information clearing house
- Encourage stakeholder interactions
- Support linkages between industry, R&D institutions, and policy makers
- Recommend skill development and training programmes, and
- Any other related programme or aspect deemed necessary for the adoption of low-GWP refrigerants in place of HFCs.

Establishing a R&D Platform for recommending and coordinating various policy-push and market-integration interventions is especially well timed, with approximately ten years to go before India needs to freeze on its HFCs and initiate the transition to alternative technologies.

How would it function?

Figure 1: Institutional and Functional Structure



Source: CEEW Analysis (2017)

The **Steering Committee** would be the high-level strategic lead of the R&D Platform. It would be chaired by a representative of MoEFCC. It would consist of representatives from the Indian Institute of Chemical Technology (IICT), Council of Scientific and Industrial Research (CSIR), Hyderabad; the Department of Science and Technology, Ministry of Science and Technology; the Ministry of Chemicals and Fertilizers; the Ministry of Commerce and Industry; industry; and civil society organisations. This government-led committee would facilitate and encourage the work of the Platform, ensuring transparency in project selection and information-sharing. It is also important that this committee allows the Secretariat to function independently.

A **Technical Expert Group** will advise the Steering Committee on the selection of research projects and on the disbursal of funds. The group will be a panel of seven to ten key experts from industry and civil society, and will also include the Chair of the Steering Committee. The role of the group would be to review research proposals submitted to the Platform and to advise the Steering Committee on the selection of proposed projects.

The **R&D Platform Secretariat** will act as the executing agency for the platform, and will require dedicated staff that has knowledge of HFC alternatives, is aware of the state of development of relevant industrial sectors in India, and possesses project management and effective stakeholder-engagement skills. This could initially be a team of three people—consisting of a CEO, a technical staff member, and a support staff member—to operationalise the Platform and to pursue its mandate.

The **Platform Members** would include knowledge partners (universities, research laboratories, and other institutions), facility providers, funding partners, industry associations and companies, training and certification centres, and any other interested stakeholders. These stakeholders would be actively invited to join the platform and to hold regular meetings with the Steering Committee, once every quarter at least, to suggest and identify priority areas for the Platform. Based on these factors, all Members would be invited to create consortia and propose projects for R&D within the ambit of the Platform's agenda.

The **projects** should have at least three collaborative partners, and the consortium lead should be a legal Indian entity, with at least 50 per cent Indian ownership, to safeguard the interests of Indian industry and to realise national benefits. The project collaborators must aim to co-finance and share existing infrastructure and facilities as much as possible. Other criteria for project selection could include potential to meet India's Kigali and climate change targets, the potential impact of the project on policy development and on India's economic growth, and the value return of the project for the Platform and for its members at large, and any other criteria that the Steering Committee may think applicable. When evaluating the research proposals, the Platform should promote research related to low-GWP refrigerants that are non-patented and easily accessible.

To ensure that the findings that are reported from various research verticals are scientifically sound and true, an **independent evaluation and verification** will be undertaken, and the results will be reported to the Steering Committee. This body could be set up as a roster of experts in various sectors and technologies that are considered priorities for of the Platform. These evaluations would be undertaken every six to eight months for each project.

1. Introduction

In the 1980s, recognising the threat posed by chlorofluorocarbons (CFCs) to the ozone layer, hydrofluorocarbons (HFCs) were introduced as viable alternatives. Since then, the uses of HFCs as substitutes for ozone-depleting substances (ODS) have grown tremendously. This is, in part, due to the widespread use of such chemicals as aerosols, foam-blowing agents, and solvents in the air-conditioning and refrigeration sectors, particularly in emerging and less-developed countries where living standards have been improving over time.

Scientific evidence and studies have established that HFCs, while safe for the ozone layer, constitute a major threat to efforts aimed at mitigating global warming.[5] In light of this, countries have been negotiating the details of how and when to phase out the use of HFCs for the past several years. October 2016 marks a watershed in global HFC and climate change politics that have been negotiated within the ambit of the Montreal Protocol.[6] The Kigali Agreement established the necessary conditions to transition from HFCs to low GWP alternatives for various country groups, based on their levels of development and technical capacities. According to a report on the Kigali process and its outcome, "Environmental groups had hoped the deal could reduce global warming by half a degree Celsius by the end of this century. This agreement gets about 90% of the way there."[7]

As per the Kigali Agreement, early industrial developers such as the United States, Japan, and European nations will start phasing out synthetic HFCs in 2019; China and other developing countries that are already on an industrial path of producing and using alternative refrigerants agreed to ensure that their HFC emissions peak in 2024; and India led a third track of countries, including Pakistan, Iran, and Iraq, where the production and consumption of HFCs has just started from a low base and where their uses are growing, in choosing 2028 as their peak year in order to gain time for growth and for their industries to be able to transition successfully.

Already several alternatives to HFCs are known to exist and are in use in various parts of the world, and several more are being developed, tested for applicability, and being further refined. Countries, including those in North America and the European Union, and companies, such as Coca-Cola and Unilever, have started switching to climate-friendly and natural refrigerants that are also more energy efficient. In India, almost none of these are in commercial use with the intention of replacing HFCs. The majority of companies in India rely on HFCs and will have to invest in R&D, buy patented refrigerant technologies, or replace their current equipment with equipment based on HFC alternatives already in use and with proven efficacy in other geographies and ambient conditions. Some companies in India are also betting on various synthetic and natural refrigerants. However, the application processes, standards, and usage patterns of refrigerants are yet to be defined for the Indian market, as are the costs, maintenance requirements, and the technical feasibility standards for their large-scale adaptation and adoption.

Various stakeholder consultations held by the Government of India in the lead-up to the Kigali meeting identified and underlined gaps in technology know-how, adaptability, and capacity. As a result, in September 2016, the Ministry of Environment, Forest and Climate Change (MoEFCC) announced its intention of establishing "an ambitious collaborative R&D programme to develop next generation, sustainable refrigerant

5 For example, see Velders, G. J. M., D. W. Fahey, J. S. Daniel, M. McFarland, and S. O. Andersen (2009) "The large contribution of projected HFC emissions to future climate forcing," Proceedings of the National Academy of Sciences 106(27): 10949–10954.

6 Established to phase out Ozone Depleting Substances (ODS).

7 Durwood Zaelke, President of the Institute for Governance and Sustainable Development, quoted in the Guardian. See Johnston, Chris, Oliver Milman, and John Vidal (2016) "Climate Change: Global Deal Reached to Limit Use of Hydrofluorocarbons," Guardian, 15 October. Available at https://www.theguardian.com/environment/2016/oct/15/climate-change-environmentalists-hail-deal-to-limit-use-of-hydrofluorocarbons; accessed 17 June 2017.

technologies as alternatives to HFCs" in India.[8] According to the official press release, "**the collaboration of research institutes as well as industry will create [a] larger ecosystem for developing sustainable solutions, and eventually [for] deploying low global warming potential HFCs on a national scale.**"[9]

Having successfully negotiated the international space for India to address and overcome technological and systemic gaps so that it can then build the required ecosystem for phasing out HFCs, the Government of India's national initiative of a collaborative R&D programme must seek to deliver to this end. This report highlights the relevance of, and presents an institutional design for, a dedicated multi-stakeholder R&D Platform to address India's domestic concerns and to meet its international commitments in phasing out HFCs.

Section 2 examines what an 'innovation ecosystem' entails and highlights the need for government support and ambition to successfully transition to low-GWP refrigerants in India. Section 2 also outlines the need for, and the functions of, and Section (3) the framework for, a collaborative R&D platform that may be able to support India's transition to such alternatives. Section 4 identifies some relevant research areas that the Platform could explore. Section 5 presents an indicative budget and identifies streams of potential financing for such a platform. The findings and recommendations presented in this report are based on desk research on the literature on innovation systems and collaborative research frameworks, as well as in-depth stakeholder consultations with key experts from the Government of India, industry, and academia.

8 Press Information Bureau (2016) "Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives," available at http://pib.nic.in/newsite/mbErel.aspx?relid=149825; accessed 17 June 2017.

9 Press Information Bureau (2016) "Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives," available at http://pib.nic.in/newsite/mbErel.aspx?relid=149825; accessed 17 June 2017.

2. A Research and Development Platform for HFC Alternatives

2.1 Relevance of Research and Development Platforms

Why R&D?

Investment in R&D is grounded in economic theories of productivity and growth. It is widely acknowledged that the capital, tangible and intangible, and knowledge acquired as a result of scientific R&D and innovation leads to long-term economic growth and improved competitiveness.[10] It is no surprise, then, that global spending on R&D has been increasing, and is forecast to exceed USD 2 trillion in 2017.[11] [12]

The median gross domestic spending[13] in OECD countries for R&D as a percentage of GDP is 2.4 per cent, and industry spending dominates research investments.[14] Several studies have observed and concluded that public investments in R&D also have a direct and positive effect on private investments.[15] India still ranks low in innovation (ranked 66 out of 128 countries),[16] and its earmarked R&D budget is small relative to its GDP (less than 1 per cent)[17]. However, given the size of its economy, India is still the sixth largest monetary contributor towards R&D globally (2016), and according to experts, the recent government commitment to R&D spending could result in India overtaking South Korea (ranked fifth) and Germany (ranked fourth) in total R&D investments by 2018.[18]

While the private sector remains the dominant protagonist in the domain of technology deployment globally, policymakers play a critical role in indicating or determining the priority sectors for investment and innovation, and also in building capacity for adoption and adaptation of new technologies. It is observed that dedicated funding streams for R&D in particular sectors have led to high returns in terms of factor productivity and increased private investments. For example, the United States' National Renewable Energy Laboratory's work ranges from technical and scientific research to market transitions, all of which is aimed at transforming the energy systems of the country. The National Renewable Energy Laboratory (NREL) is run by the US Government's Department of Energy (DOE), and functions in collaboration with various partners that include local governments, industry, and educational institutions. **Every USD 1 invested by the government in NREL has resulted in USD 5 in private investment**. Moreover, modelling assessments, qualitative case studies, and other forms of rigorous academic work have shown complementarities between

10 See, for example, Porter (1991), Porter and van der Linde (1995), Coccia (2010), Guellec and van Pottelsberghe de la Potterie (2001 and 2003).
11 This value is based on the Purchasing Power Parity (PPP) for the 115 countries that have R&D investments of more than USD 100 million each.
12 Industrial Research Institute and R&D Magazine (2017) "2017 Global R&D Funding Forecast," available at http://digital. rdmag.com/researchanddevelopment/2017_global_r_d_funding_forecast?pg=3#pg3; accessed 30 July 2017.
13 Gross domestic spending on R&D is defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country. It includes R&D funded from abroad, but excludes domestic funds for R&D performed outside the domestic economy. This indicator is measured in million USD and as a percentage of GDP. See OECD (2016). "Gross Domestic Spending on R&D," available at https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm; accessed 15 June 2017.
14 This varies across OECD nations. For example, only 11 per cent of R&D in the USA is undertaken by the government, but in China the corresponding figure is more than 60 per cent.
15 See, for example, Guellec and van Pottelsberghe (2003).
16 Global Innovation Index (2017) "Analysis," available at https://www.globalinnovationindex.org/analysis-indicator; accessed 10 July 2017.
17 Press Information Bureau (2017) "Low Expenditure on Research and Development," available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=160228; accessed 17 June 2017
18 Industrial Research Institute and R&D Magazine (2017) "2017 Global R&D Funding Forecast," available at

public and private R&D spending. Coccia (2010) concludes that **"the largest portion of public resources should drive firm labs to invest more in scientific research whereas only a small portion should be allocated to the financing of basic research".**[19]

Sustainability-Oriented Innovation Systems

Increase in innovations and breakthroughs in scientific R&D are dependent on well-developed national innovation systems (NIS).[20] It is well established that NIS are weak in less-developed economies[21] Thus, to realise the success of any new technology within a sector, a concerted effort is needed across the entire innovation system for any transformation to take place.

BOX 1: Innovation Systems

As shown in Figure 2, a typical innovation system includes the following sub-components, alluding to the fact that it is not just technical innovation, but rather all sorts of market and innovation ecosystem factors that influence commercial experience and success. The progress of technology development and deployment is not necessarily linear and requires simultaneous encouragement across various sub-elements as highlighted above. In addition to the capacities of firms to adapt technologies to local contexts, there is a need to create networks of local suppliers, users, and research institutions to enable dynamic growth, to facilitate improvements in learning, and to sustain a technological sector (Bell and Figueiredo, 2012; Lundvall, 2010). Thus, technological acumen, innovation systems, and firms' capabilities in developing economies are dependent on much more than just access to intellectual property rights and technology availability (Bell and Pavitt, 1996).

The need for policy support is even more significant for new climate-friendly technologies. As we push for mitigating greenhouse gases by using environment-friendly alternative technologies, a strong policy imperative is a prerequisite for the development and diffusion of these technologies at an optimal pace for the protection of global goods.[22] This is mainly for two reasons: first, the externalisation of environmental *costs* makes low-GWP technology products uncompetitive compared to the conventional technologies that are already in commercial use; and second, the cost of transitioning from incumbent technologies and substances to low-GWP alternatives acts as a deterrent. This is especially so for technologies that require systems-change.

Second, the *social benefits* or the global goods advantages of low-GWP technology innovations cannot be fully realised by individual firms (United Nations Economic and Social Council, 2010). The investment for developing and using low-GWP technologies and the accruing benefit of climate change mitigation are not proportionate. Thus, the investments needed to optimise low-GWP development to curtail climate change need to be proactively encouraged. Policy directives to encourage such transitions may work in the form of carrots (incentivise early adoption, encourage R&D, provide fiscal support, etc.) and/or sticks (impose mandatory deadlines, charge fines/taxes for non-compliance, etc.).

As Altenburg and Pegels (2012) affirm, the timely transition to low-carbon technological pathways being adopted and adapted requires that concerted policy transitions and frameworks be developed throughout entire innovation systems. The adoption and propagation of climate-friendly technologies requires such an approach, that is, of *sustainability-oriented innovation systems*, where various dimensions of market failures, differing trade-offs, and embedded institutional characteristics are coordinated through policies. This works

19 Coccia, Mario (2010) "Public and private R&D investments as complementary inputs for productivity growth," International Journal of Technology, Policy and Management, 10(1/2): 73–91.

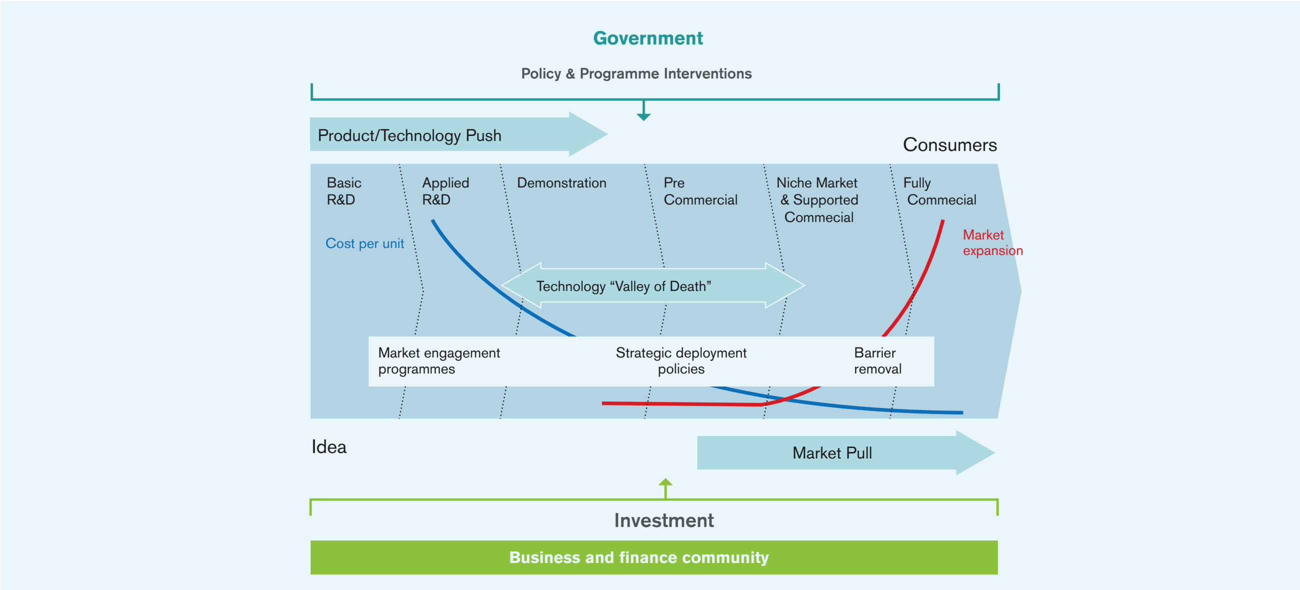
20 Lundvall, Bengt-Åke (ed.) (2010) National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning. London: Anthem Press; and Bell, Martin, and Keith Pavitt (1995) "The Development of Technological Capabilities," in Irfan ul Haque and Martin Bell (ed.), Trade, Technology and International Competitiveness, Washington, D.C.: The World Bank.

21 Gallagher, Kelly Sims, John P. Holdren and Ambuj D. Sagar (2006) "Energy–Technology Innovation," Annual Review of Environment and Resources 31: 193–237.

22 Bhasin, Shikha (2014) "Enhancing International Technology Cooperation for Climate Change Mitigation: Lessons from an Electromobility Case Study," Discussion Paper 26/2014. German Development Institute. Available at https://www.die-gdi.de/uploads/media/DP_26.2014.pdf

at multiple levels of governance, and requires coordination between local, national, and international frameworks as well (Altenburg and Pegels, 2012).

Figure 2: Innovation Systems



Source: Grubb (2004)

Reaffirming this rationale, the Government of India's initiative to set up a collaborative R&D platform that encourages and benefits an "innovation ecosystem" for the phasing out of HFCs is on point. Examples of R&D programmes and platforms that systematically intervene at various stages of an innovation cycle are given in Annex 1. These are amongst the most successful cases of collaborative and high-potential innovation platforms that have had a direct and positive impact on investments, industry, and innovations.

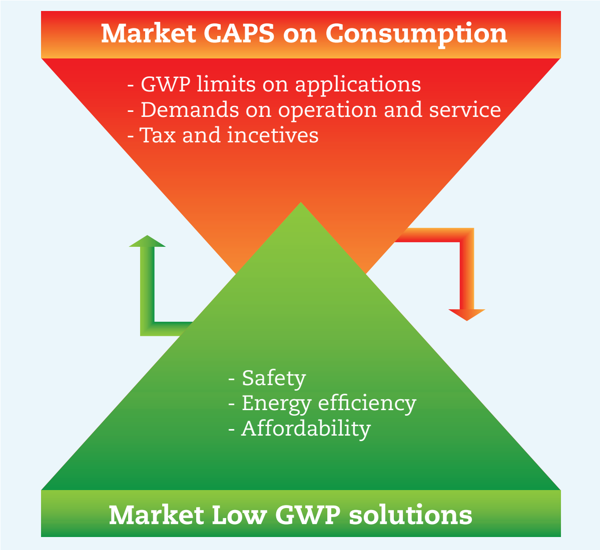
2.2 Relevance of an HFC alternative Research and Development Platform (RDP)

India has just over a decade before it needs to begin phasing out HFCs. Adopting an innovative system-wide approach to finding and integrating alternative refrigerants would boost Indian industry, benefit the global environment, and increase India's leadership in international environmental regimes . The initiative of the government to encourage the "innovation ecosystem" for the phasing out of HFCs is well directed, and as highlighted by the government and also as revealed during our stakeholder consultations, it resonates with the needs of relevant domestic stakeholders.[23]

To assess and understand the needs of the industry, several semi-structured interviews and two roundtable discussions were conducted with industry leaders and associations related to the residential air conditioning, commercial refrigeration, mobile air conditioning, and the foam sectors, as well as government officials.[24] All industry stakeholders confirmed the need for (1) policy certainty for the transition to low-GWP refrigerants; and (2) indicators that the government is, in fact, keen to facilitate R&D in India, such that it is not only the first-movers (particularly international companies and export suppliers) that gain advantage. In addition, the stakeholders emphasised the need for safety standards, technology referencing and certification, as well as financial commitments to enable sector-wide transformations along the supply chain. A global leading supplier of air-conditioning and refrigeration solutions has outlined the following elements as part of a core strategy from the government to enable a successful transition to low-GWP refrigerants:[25]

23 See Annexures 2 and 3 for the interview list and the questionnaire.
24 See Annexures 2 and 3 for the interview list and the questionnaire.
25 This is based on the company's successful transition in Europe, based on EU regulations.

Figure 3: Measures for Refrigeration Phase Down



Source: Danfoss (2017)

"Regulation, both national and international, has been one of the most important drivers for spurring investment in new technology. The figure below charts an overview of phase-downs or phase-outs that have already been imposed on the industry and [presents] some possible projections for the future. Guidance measures can be voluntary or imposed by regulation (the red triangle), but they all mean to place limits within the market. Besides guidance measures on market development, there is an underlying concern of the availability of sustainable solutions (the green triangle). When new regulations are made, they are intended to encompass these parameters and [to] predict reasonable successful outlooks, but there are always a number of challenges that needs to be solved by industry leaders and legislators along the path of change."[26]

Based on the need for a systemic transition to HFC alternatives, we suggest a Research and Development Platform (RDP) that would facilitate collaborative R&D, as well as coordinate policy push and market-integration regulatory recommendations. This is an opportune time to initiate such an exercise, given that India has approximately ten years to go before it needs to freeze on its HFCs and initiate the transition to alternative technologies.

As highlighted above, to transform a sector successfully and to support its transition effectively, a policy impetus is required at various levels of technology development and deployment, besides basic R&D. This Platform would be set up in recognition of the fact that **innovation and technical transitions are not just about technical know-how. Their adoption and adaptation depend on systemic integration as well as market shifts.** Since the transition of HFCs in India is still in the very nascent stages, a government-backed body that supports this shift would send a positive signal about the potential benefits that could accrue to companies.

The primary objective of the Platform would be to facilitate the phase-out of HFCs in India by supporting R&D and the adoption of alternatives. Its mission would be to facilitate technical R&D for India and build the larger "innovation ecosystem" that is required by recommending standards, application testing, consumer-incentive programmes, and similar supporting aspects for low-GWP HFC alternatives. This would be achieved through active engagement with all relevant stakeholders as members of the RDP. The Platform would be a one-stop authority for all matters related to HFC alternatives and the requirements for replacing HFCs in India, with the following activities being undertaken collaboratively:

- Facilitating basic research
- Facilitating and encouraging applied research
- Facilitating technology testing facilities
- Recommending standards for usage, performance, and safety
- Recommending policies for market integration and low-GWP refrigerant usage
- Suggesting consumer-based programmes
- Functioning as a knowledge and information clearing house
- Encouraging stakeholder interactions
- Supporting linkages between industry, R&D institutions, and policy makers

26 Danfoss (2017), "Regulation", available at http://refrigerants.danfoss.com/hfc/#/; accessed on 10 July 2017.

- Recommending skill development and training programmes, and
- Any other related programme or aspect deemed necessary for the adoption of low-GWP refrigerants in place of HFCs.

While India has set its freeze date internationally and signalled a transition period for HFCs, domestically the conversations have just begun and have not progressed much. Information on this front is scarce, especially amongst smaller companies. **Setting up a collaborative platform to support industry through this transition would send a positive signal to all relevant stakeholders, informing them of this intent, as well as to the market at large, in line with India's domestically proclaimed ambitions of Make-in-India growth programmes and sustainable development plans.**

This Platform would allow for the **pooling of resources** by the government and various industry partners. If it is established as an independent unit under the aegis of the Government of India, external and international financing would be easier to accumulate and use. In addition, being a large economy with several Southern bilateral and multilateral partnerships, as well as having diverse geographical and climatic conditions, India would have much to gain from the lessons learnt about various refrigerants and their applicability in different ambient conditions, which would give it an edge amongst various less-developed country partners. **The lessons learnt from this sector-level transformation could be a key area of expertise that India could then export, as well as deploy best-case experiences internationally**. If a concerted effort is not made to develop these best cases, India's domestic suppliers will also stand to lose in the domestic market. India is amongst the largest anticipated growth markets for air conditioners and refrigeration, and it is only a matter of time before foreign companies develop and deploy their own alternatives to HFCs and gain increasing market share.

Given that the benefits of adopting alternatives to HFCs are known, **it is important for India to act sooner rather than later**. For example, R-290 provides a unique opportunity to realise energy-efficiency gains. Currently, Godrej is the only manufacturer of R-290-based air conditioners (ACs); these are amongst the most energy-efficient ACs available in the market, with an ISEER rating of 5.8 (3.9 EER). According to Chaturvedi et al. (2016), "If India adopts R-290, and assuming an average efficiency improvement of 15% over the BAU refrigerant due to R-290, cumulative GHG emissions from India's residential space cooling could be reduced by 37% between 2010 and 2050."[27] Moreover, as Purohit et al., (2016) point out, "There are significant cost savings during 2020–50, valued at 53 Bn Euros, primarily in the residential air-conditioning sector due to [the] lower cost of [the] alternative refrigerant (R-290) as well as higher energy efficiency if residential and commercial applications transition to high efficiency alternatives by 2020."[28]

From an environmental and climate change perspective, as well as from a planned sustainable development perspective, this is a unique opportunity for India to take the lead and achieve its targets.

27 Chaturvedi, Vaibhav, Bhaskar Deol, Steve Siedel, Anjali Jaiswal, Ankita Sah, Mohit Sharma, Nehmant Kaur, and Stephen O. Andersen (2016) Cooling India with Less Warming: Examining Patents for Alternatives to Hydrofluorocarbons. New Delhi: CEEW, NRDC, C2ES, IGSD, Issue paper 12. Available at http://ceew.in/pdf/CEEW%20-%20Issue%20Paper-Cooling%20India%20with%20less%20warming06Oct16.pdf

28 Purohit, Pallav, Lena Höglund-Isaksson, Imrich Bertok, Vaibhav Chaturvedi, and Mohit Sharma (2016) Scenario Analysis for HFC Emissions in India: Mitigation Potential and Costs. New Delhi: CEEW–IIASA.

3. Proposed Institutional and Functional Design: Research and Development Platform (RDP)

In this section, we put forward a collaborative stakeholder design for promoting a sustainable transition from HFCs in India, such that the targets set out at Kigali are met, an even playing field is extended to Indian companies, and a holistic transformation of the sector is encouraged.

Based on the financial capacity and level of ambition of the Government of India to facilitate and lead the transition to HFC alternatives in India, we envisage the setting up of a Research and Development Platform (RDP) as an autonomous body similar to the Bureau of Energy Efficiency (BEE). It would facilitate technical R&D of HFC alternatives suitable to India, based on priorities outlined by members of the RDP and the Steering Committee. It would also focus on creating the larger "innovation ecosystem" by recommending standards, applications, consumer-incentive programmes, and similar supporting aspects for these HFC replacements—all crucial aspects that would determine the success of technical transformations, particularly those aimed at mitigating climate change.

As highlighted above, the primary objective of the RDP will be to facilitate the phase-out of HFCs in India by supporting R&D and the adoption of alternatives.

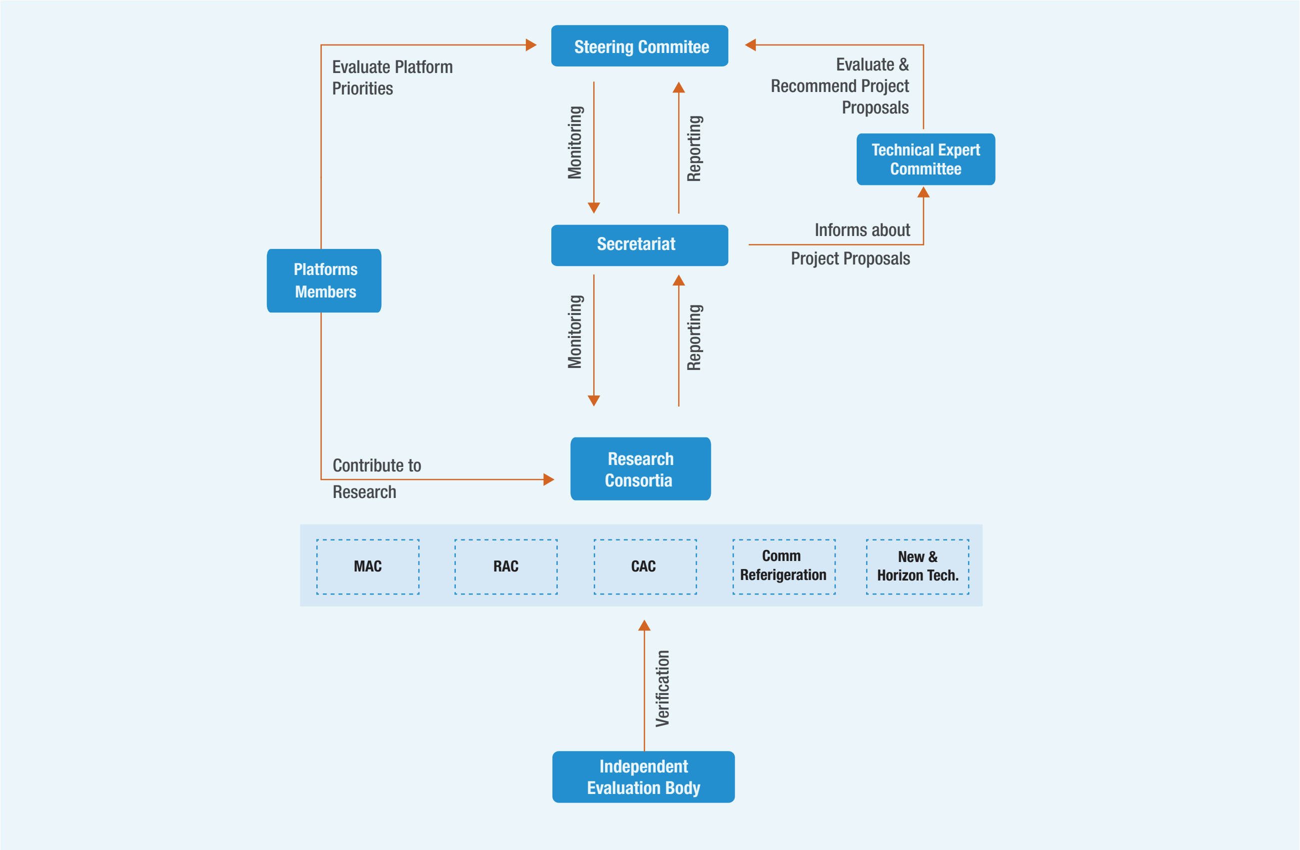
I. Steering Committee

The Steering Committee would be the high-level strategic lead of the RDP. The ambition for the phase-down of HFCs in India is primarily impelled or prompted by climate change concerns and by India's international commitments under the Kigali Agreement. We propose that MoEFCC should be the nodal ministry involved with the working of the RDP. MoEFCC's previous work, led through the Ozone Cell, as well as its intention to initiate a collaborative R&D programme, makes it well placed to identify, understand, and respond to the various challenges that stakeholders will face in transitioning to low-GWP refrigerants. Thus, we propose that the Steering Committee be should be chaired by a representative of MoEFCC, and that it should consist of representatives from the Indian Institute of Chemical Technology (IICT), Council of Scientific and Industrial Research (CSIR), Hyderabad; the Department of Science and Technology, Ministry of Science and Technology; the Ministry of Chemicals and Fertilizers; the Ministry of Commerce and Industry; industry; and civil society organisations.

Role:

1. Lead and be overall responsible for RDP
2. Decide the strategic direction of RDP
3. Sign off on R&D projects
4. Disburse funds

Figure 4: Institutional and Functional Structure



Source: CEEW Analysis (2017)

This government-led Steering Committee will facilitate and encourage the work of the Platform, ensuring transparency in project selection and information-sharing. It is also important that the Steering Committee allows the Secretariat to function independently. Each position can have a fixed tenure of two to three years. A Technical Expert Group—consisting of industry, government, and non-government experts—would advise the Steering Committee on the selection of research projects and the disbursal of funds.

II. Technical Expert Group

A **Technical Expert Group** would advise the Steering Committee on the selection of research projects and the disbursal of funds. The group would be a panel of seven to ten key experts from industry and civil society, as well as the Chair of the Steering Committee. Its role would be to review research proposals submitted to the Platform and advise the Steering Committee on the selection of proposed projects. The members of the group could have a rolling tenure of three years, which may be extended as deemed necessary by the Steering Committee.

The members of this group would meet when proposals for each funding cycle (at least once a year) have been submitted to the Secretariat. It would also hold quarterly meetings with the Secretariat and the Steering Committee to keep them abreast of their expert views on sector-level developments both in India and abroad.

The members of the Technical Expert Group would evaluate proposals and recommend these, based on a majority vote, to the Steering Committee for selection. The criteria for project selection could include co-financing (ideally, at least 50 per cent of the project finance should come from the consortium members), potential to meet India's Kigali and climate change targets, the potential impact of the project on policy development and on India's economic growth, the value return of the project for the Platform and for its members at large, and any other criteria that the members, by majority, may think applicable. When evaluating the research proposals, insofar as possible, the Platform should promote research related to low-GWP refrigerants that are non-patented and easily accessible. While the Steering Committee would not be obligated to accept the suggestions of the Technical Expert Group regarding projects, it must consider the group's recommendations and record in writing the reasons for disagreement, if any, with the group's suggestions and why these were not accepted, if that is the case.

III. R&D Platform Secretariat

The R&D Platform Secretariat will act as the executing agency for the Platform. It will have a dedicated staff possessing knowledge of HFC alternatives as well as the state of development of relevant industrial sectors in India. It will also have project-management and effective stakeholder-engagement skills. This could initially be a three-member team, consisting of a CEO, a technical staff member, and a support staff member. Their functions are listed below.

Role:

1. Engage actively with stakeholders to encourage their participation in, and engagement with, the Platform
2. Manage the website and oversee communications
3. Support the Platform by raising funds, increasing the stakeholder base, and managing all back-end functions
4. Present updates to the Steering Committee on developments in key sectors globally
5. Undertake knowledge management
6. Undertake background research, conduct fact checking, and provide assessments of submitted research proposals
7. Liaise with the Technical Expert Group in advising the Steering Committee
8. Monitor and review various research studies being undertaken through the Platform
9. Update the Steering Committee on a monthly basis on all Platform-related work

IV. Platform Members

The Platform Members would include:

1. Knowledge partners (universities, research laboratories, other institutions)
2. Facility providers
3. Funding partners
4. Industry associations and companies
5. Training and certification centres
6. Other interested stakeholders

These stakeholders would be actively invited to join the Platform and to hold regular meetings with the Steering Committee, once every quarter at least, to suggest and identify priority areas for the Platform to pursue. Based on these priorities, all Members would be invited to create consortia and to propose projects for R&D within the ambit of the Platform. The idea behind a broad stakeholder base is to encourage networking and collaborative work in order to come up collectively with different sets of expertise and solutions. In addition, a wide-ranging stakeholder base would be useful because Members would facilitate the identification of all technical, policy-related, and economic gaps that need to be addressed in order to phase out HFCs in India. From the private sector, initially only Indian companies and associations and foreign companies with Indian manufacturing facilities would be invited to join. There would be a minimum annual fee for membership to encourage a sense of ownership amongst all stakeholders. Subject to approval by the Steering Committee, all industry stakeholders will be required to pay a membership fee to join the Platform as Members- large industrial houses and OEMs (original equipment manufacturers) may be charged INR 20,000 annually and small and medium enterprises may be charged INR 5,000 annually. We recommend that all not-for-profit organisations and institutions (such as universities, think tanks, research laboratories, civil society organisations, and others) be allowed to become members without a fee.

A list of potential stakeholders that should be invited to join the Platform is given in Annex 5.

V. Research Consortia

The research consortia will be developed sectorally and will facilitate the actual projects that will be undertaken as part of the RDP. Thus, we expect that the Platform would have at least the following research verticals:

1. Room/Residential Air Conditioners (RAC)
2. Mobil Air Conditioners (MAC)
3. Commercial Air Conditioners
4. Commercial Refrigeration
5. New and Horizon Technologies

The Steering Committee could either issue an open call (for projects) or highlight particular areas for research and invite tenders. The projects should have at least three collaborative partners, and the consortia lead should be a legal Indian entity (with at least 50 per cent Indian ownership). In addition, the project outcomes should be relevant to other Platform members to ensure that public money is not being used to create a preferential bias for the benefit of only a few. The project collaborators should aim to co-finance, and must share the existing infrastructure and facilities as much as possible. As highlighted above, the criteria for project selection could include co-financing (ideally, at least 50 per cent of the project finance should come from the consortium members), the potential to meet India's Kigali and climate change targets, the potential impact of the project on policy development and on India's economic growth, the value return of the project for the Platform and for its members at large, and any other criteria that the steering commitee, by majority, may think applicable. When evaluating the research proposals, insofar as possible, the Platform should promote research related to low-GWP refrigerants that are non-patented and easily accessible.

VI. Independent Evaluation Body

To ensure the accuracy and applicability of the findings reported by various research verticals, independent evaluation and verification will be undertaken, and the results of this exercise will be reported to the steering committee. This could be set up as a roster of experts in various sectors and technologies that are considered priorities by the RDP. The evaluation and verification for each project would be undertaken every six to eight months.

Ensuring Functionality

In order to ensure that the above-mentioned institutional framework delivers on its mission of supporting a sector-wide transition through its research verticals and stakeholder partnerships, we looked at previous studies conducted by CEEW on collaborative networks and alliances, and have outlined the following measures to mitigate risks that a collaborative multi-stakeholder body may inherently entail:

1. Establishing clear responsibilities and coordination within multi-partner research verticals and projects
2. As this Platform could be the nodal agency at the heart of the HFC-free transition that India needs, encouraging and amassing a wide stakeholder base is important.
3. Encouraging different projects within the same sectoral research vertical to limit bias towards particular refrigerants
4. Controlling the withdrawal or exit of project partners through legal contracts
5. Minimising disruption in meeting financing needs through instruments such as contingency funds

To minimise concerns and conflicts related to intellectual property rights, clear contracts must be drawn up at the beginning of the project. As a general policy, the R&D Platform should prescribe that all and any knowledge generated through the Platform should be open access and should be available for all to use. Public money cannot be used for private innovations. However, the logic of protecting knowledge is based on the belief that protection at times allows for further innovations to be expedited, and some project proposals from companies may be able to successfully argue that having a patent will encourage further investments in innovation and will eventually spread and benefit Indian industry, or society, at large. Therefore, depending on (1) the amount of funding proposed for each project by a consortium; and (2) subject to the consortium being able to prove to the Steering Committee that patenting will help spur further innovation for the larger benefit of India, the Steering committee may enter into a contract that allows for licensing in such unique cases for a limited period of time. A similar policy that balances the need for R&D for public good while encouraging innovation has been adopted by CGIAR, a collaborative research organisation dedicated to agricultural research. Its policy lays down only four caveats for limiting the sharing of technology or knowledge generated through its research studies and programmes, centred around the need to encourage further innovation or to ensure financial payback to the research centre itself. A CEEW study notes, “Under the CGIAR Intellectual Assets Policy, centres are able to: restrict access in order to improve research results or to assist with uptake and adoption; limit access to obtain third party products and services; register or allow third parties to register patent or plant variety rights protection on centre [CGIAR] intellectual assets; and charge fees for providing access to intellectual assets (see CGIAR 2012).”[29]

29 Ghosh, Arunabha, Anupama Vijayakumar and Sudatta Ray (2015) Climate Technology Partnerships: Form, Function And Impact, Fixing Climate Governance Series Paper No. 2,Centre for International Governance Innovation, pp i-24.

4. Suggested Research Tracks for the Platform

The table below lists some important options for replacing HFCs. In terms of applicability, there is no one alternative solution that fits all uses of HFCs Hence, the following research verticals under which various R&D projects can take place are indicated:

1. Room/Residential air conditioners (RAC)
2. Mobile air conditioners (MAC)
3. Commercial air conditioners
4. Commercial refrigeration
5. New and horizon technologies

Different refrigerants, both natural and synthetic, are being used as HFC alternatives. Some refrigerants that are relevant for India are listed below.

Sector	Baseline Refrigerant in Use	Low-GWP Alternative	GWP	Patent Status/Information
Commercial Air Conditioners	HFC-134a	R-32 + HFO blend	92–1577	R-32 Generic
		R-134a + HFO blend	>547	R-134a's patent expired in 2015
		R-1234yf	<1	Patent will expire by 2025
		R-1234ze	6	Mexichem Amanco Holding S.A. de C.V (filing date 16/04/2010) (application suspended)
	HCFC-22	R-32 + HFO blend	675	R-32 Generic
		R-290	3	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011)
		R-1270	2	Mexichem Amanco Holding S.A. de C.V (filing date 16/04/2010)
Commercial Refrigeration	HFC-22	N20 (R-32 + HFO blend)	675	Honeywell
		Water		Generic
		R-290	3	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011)
		R-717 (ammonia)	1	Generic
		R-600a	3	-
		R-744 (carbon dioxide)	1	Mexichem Amanco Holding S.A. de C.V (application suspended) Dürr Somac GmbH (filling date 16/04/2010)
		R-32 + HFO blend	675	R-32 Generic
	HFC-134a	(XP 10/ R513A) R-134a + R-1234yf blend	631	Dupont/Chemours

Sector	Baseline Refrigerant in Use	Low-GWP Alternative	GWP	Patent Status/Information
Residential Air Conditioners	R-410A	R-290	3	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011)(Application suspended)
		R-32	675	Open access (Daikin)
		DR-5 (R32 + R1234yf)	490	DuPont/Chemours
		R-744 (carbon dioxide)	1	
		R-32 + HFO blend	675	R-32 Open access
	HCFC-22	R-32 + HFO blend	675	R-32 Generic
		R-290	3	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011) (application suspended)
		R-32	675	Open access (Daikin)
Mobile Air Conditioners	R-134a	R-32	675	Open access (Daikin)
		R-744 (carbon dioxide)	1	Mexichem Amanco Holding S.A. de C.V (application suspended) Dürr Somac GmbH (filing date 16/04/2010)
		R-1234yf	4	Honeywell
		R-152a	124	Dupont de Nemours (filing date 03/09/2010)
		R-32 + HFO blend	675	R-32 Open access (Daikin)
Household Refrigeration	R-600a		<20	Generic
	R-134a	R-1234yf	<20	Dürr Somac GmbH (filing date 30/07/2015)
		R-290 and R-600 blend	<20	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011) (application suspended)
Foam Sector	HCFC-141b	R-290	3	Mexichem Amanco Holding S.A. de C.V (filing date 24/06/2011) (application suspended)
		R-152A	124	Dupont de Nemours (filing date 03/09/2010)
		R-1234ze	6	Mexichem Amanco Holding S.A. de C.V (application suspended)
		Metaforma		
		Isopentane	20	
		Water		
		Cyclopentane (C5h10)		
		R-1234ze	6	Mexichem Amanco Holding S.A. de C.V. (filing date 16/04/2010) (application suspended)

Source: Author, based on CEEW (2016), Linde (2017a, 2017b, 2017c), and Intellectual Property of India (2017)

In Annex 6, we have listed a few subjects on which the Platform could focus initially. These suggestions are based on factors such as cost, risk, applicability, availability, patent registration, and familiarity with the Indian market.

5. Financial Outlay

For the Platform to become operational, a succinct business, financial, and operational plan would be required, in addition to a concept note (given in this study), and an indicative budget and financial resources (listed below).

Budget

The exact budgetary needs and spending of the Platform would depend on the number and type of research projects that are facilitated, as well as the physical infrastructure and secondment programmes that the government can already make use of for the Platform. Based on our desk research, as well as feedback from industry stakeholders, we have estimated a short-term budget for the initial three years of the Platform's operation.[30]

Estimated Budget for the Research and Development Platform (RDP) (Years 1–3) (in INR)			
	Year 1	**Year 2**	**Year 3**
Operational Costs[1]	75,00,000	75,00,000	75,00,000
Research Verticals[2]	25,00,00,000	25,00,00,000	25,00,00,000
Total	25,75,00,000	25,75,00,000	25,75,00,000

1. Operational costs include expenses for:
   - 3 dedicated staff members who will form the Platform's Secretariat
   - Office space and functional expenses
   - Website development and maintenance
   - Stakeholder meetings
   - Other outreach materials and meetings
2. The costs of the Research Verticals will be approximately INR 5 crore for each research project, including infrastructure, personnel, and materials costs. This figure has been estimated on the basis of the funding cycles of ongoing research projects such as the Norwegian pilot programme on transcritical carbon dioxide, the initial investments made by GIZ and Godrej in developing, setting up, and rolling out their R-290 AC units, and on feedback from other industry stakeholders.[31]

Financial Resources

A number of sources of financing will be available to the Platform in addition to the core funding provided by MoEFCC. Some of these sources have been discussed below.

Platform membership fees:

All industry stakeholders will be required to pay a membership fee to join the Platform as members. Large industrial houses and OEMs may be charged INR 20,000 annually, and small and medium enterprises

30 The medium- and long-term budgets would depend on the scope, mandate, and tenure of the R&D Platform as decided by the government.

31 Godrej is the only Indian manufacturer selling ACs with R-290 as the primary coolant. Its involvement with this new refrigerant began when it responded to an open call by the German development agency, GIZ, and the Government of India inviting companies to explore the production of climate-friendly refrigerants for air conditioners. GIZ provided INR 9 to 10 crore and Godrej invested INR 3 to 4 crore to develop 180,000 machines. According to experts at Godrej, the hardware costs for setting up an R-290-based AC manufacturing facility would be less than INR 20 lakh. A majority of this expense would go towards incorporating safety precautions, while the rest of the AC manufacturing infrastructure would not require additional investments for R-290.

may be charged INR 5,000 annually. We recommend that all not-for-profit organisations and institutions (universities, think tanks, research laboratories, civil society organisations, and others) be allowed to become members without a fee.

Industry co-financing:

For every research project proposal, the budget must include at least 50 percent financing from industry. In addition, companies that are not part of the research consortia undertaking the project, but would want to support the project financially, would be encouraged to do so. Moreover, in-kind support through the use of existent infrastructure and space that is available to research laboratories, industries, certification centres, etc. would be encouraged for all research verticals and projects.

Multilateral and other Funds:

The Montreal Protocol has a dedicated Fund to support countries in their transition to cleaner refrigerants, as do various multilateral and philanthropic bodies. The Kigali Cooling Efficiency Programme (K-CEP) and the Climate and Clean Air Initiative are only two examples of programmes that have specific financing windows for switching to low-GWP refrigerants. The Platform would also be able to apply for grants to the Government of India's Uchchatar Avishkar Yojna[32] (UAY) and other research programmes.

32 All Central Government Schemes/Pradhan Mantri Yojana (2017) "Uchchatar Avishkar Yojana UAY Guidelines," available at http://www.pradhanmantriyojana.co.in/uchchatar-avishkar/; accessed 17 July 2017.

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Annexure 1

Examples of Collaborative Technology-focused Platforms

1.1 NREL's Solar Programme

The National Renewable Energy Laboratory (NREL) is the primary national laboratory for renewable energy and energy efficiency research of the United States Department of Energy (DOE). Its work ranges from technical and scientific research to market transitions aimed at transforming the energy systems of the United States. NREL functions in collaboration with various partners that include local governments, industry, and educational institutions. Every USD 1 invested by the DOE in NREL has led to USD 5 in private investment. At the end of 2015, NREL had over 900 partnership agreements; over 50 per cent of these were with businesses, both small and large. Its website states: "NREL enables industry, government, research, and nonprofit partners to conceive innovative ideas, develop concepts into prototypes, and accelerate market-ready technologies. Together, we can address the nation's energy challenges while strengthening U.S. economic competitiveness and supporting America's homes, businesses, and infrastructure."

The total budget spend of NREL in 2015 was USD 357 million, and the evaluated economic impact totalled USD 872.3 million. Every USD 1 invested by the DOE in NREL has led to USD 5 in private investments, evidence of the new opportunities it is facilitating and the market transformation that it is leading.

Various streams of work function within the NREL as different departments, including but not limited to strategic energy analysis, energy systems integration, solar photovoltaic, wind technology, bio-energy, hydrogen and fuel cells, buildings, and transportation.

NREL was established in 1977 as the Solar Energy Research Institute. Over time, it came to encompass several other streams of renewable energy as well as energy efficiency. In 1990, it was elevated to the status of a national laboratory and renamed the National Renewable Energy Centre.

To understand the nodal role played by NREL in leading sector-level transformation, it is important to examine some key tenets of the solar energy programme being led by it. These themes indicate how NREL encapsulates all the technical and "ecosystem" factors necessary for a sector-wide technical transformation. It highlights its role as a nodal research agency beyond pure technical R&D; with established mandates for the testing and referencing of technologies; pertinent emphasis on systems integration of solar as a technology; safety indicators; "soft" research on costs and reliability; assistance for decision-makers; grid integration; and regulations. These have been tabulated based on the information available on NREL's programmatic webpage for "Solar Research".

Technology Area	Specific Research Theme
PV Research:	1. Silicon materials and devices 2. Polycrystalline thin-film materials and devices 3. III-V multijunction materials and devices 4. New materials, devices, and processes 5. Measurements and Characterization 6. Performance and Reliability 7. Engineering
Concentrated Solar Power	1. Supporting the development of new designs, materials, and manufacturing processes for solar components and systems with an emphasis on improved performance, reliability, and service life 2. Developing power tower and parabolic trough technology for solar electricity generation 3. Analyzing the cost, performance, and value of solar systems
Solar Grid and Systems Integration	NREL research addresses the technical challenges associated with integrating PV technologies into a stable grid. Integration with the electric grid 1. Modeling, including the System Advisor Model (SAM) 2. PV engineering 3. PV performance reliability and safety 4. Solar resource sensing, measurement, and forecasting 5. Technology systems analysis
Solar Market Research and Analysis	NREL is working to enable faster, easier, and less expensive installations by addressing soft costs and market barriers through data collection, analysis, and assistance to decision-makers who affect solar markets. 1. Solar Market and Cost Analysis • Solar market trends • PV system prices • Soft-cost tracking and analysis • Finance 2. Policy and Regulatory Research • Net metering • Community solar • Value of solar • Solar policy
Assistance to Decision-Makers	1. Technical Assistance for Decision-Makers 2. Distributed Generation Interconnection Collaborative 3. PV Operations and Maintenance Best Practices 4. Midscale Commercial Solar Market 5. Finance
NREL also has resources related to solar maps and renewable resource data.	

Source: Based on information accessed from https://www.nrel.gov/solar/

Criteria for investments and partnerships:

NREL develops and implements technology partnerships based on the standards established on the following principles:

"1. Balancing Public and Private Interest: Form partnerships that serve the public interest and advance U.S. Department of Energy goals. Demonstrate appropriate stewardship of publicly funded assets, yielding national benefits. Provide value to the commercial partner.

2. Focusing on Outcomes: Develop mutually beneficial collaborations and align actions with business outcomes.

3. Reflecting Core Values: Conduct technology partnership processes through professional practices, action, and a respect for duty. Align with the fundamental values of honesty, integrity, fairness, stewardship, and quality.

4. Creating Transparency: Keep partners informed of goals, processes, decisions, and the status of actions as agreements are developed.

5. Ensuring Confidentiality: Maintain deep respect for proprietary business information and data.
6. Seeking Continuous Improvement: Measure, monitor, and seek feedback about processes and outcomes. Use this information to improve processes and practices."

Source: www.nrel.gov and https://www.nrel.gov/solar/

1.2 BEE

The Government of India set up the Bureau of Energy Efficiency (BEE) in 2002 under the provisions of the Energy Conservation Act, 2001. **The mission of the BBE is to assist in developing policies and strategies with a thrust on self-regulation and in promoting market principles with the primary objective of reducing the energy intensity of the Indian economy.**

Role of BEE

BEE coordinates with designated consumers, designated agencies, and other organisations, and recognises, identifies and utilises the existing resources and infrastructure, in performing both the regulatory and promotional functions assigned to it under the Energy Conservation Act, 2001.

The major functions of BEE are to:

1. Create awareness of, and disseminate information on, energy efficiency and conservation
2. Arrange and organise training of personnel and specialists in techniques for the efficient use of energy and its conservation
3. Strengthen consultancy services in the field of energy conservation
4. Promote research and development
5. Develop testing and certification procedures and promote testing facilities
6. Formulate and facilitate implementation of pilot and demonstration projects
7. Promote use of energy-efficient processes, equipment, devices, and systems
8. Encourage preferential treatment for the use of energy-efficient equipment or appliances
9. Promote innovative financing of energy efficiency projects
10. Provide financial assistance to institutions for promoting efficient use of energy and its conservation
11. Prepare educational curricula on efficient use of energy and its conservation
12. Implement international cooperation programmes relating to efficient use of energy and its conservation

Since its establishment, BEE has grown and developed as an independent regulatory authority that has successfully transformed the lighting sector, as well as earmarked various appliances under its Standards and Labelling programme designed to raise efficiency levels of various consumer applications in India.

Source: https://www.beeindia.gov.in/content/about-bee and https://www.beeindia.gov.in/content/star-labelled-appliances

1.3 SEED

"[The] Science for Equity, Empowerment and Development (SEED) Division has been set up under the Department of Science and Technology, established with the broad objectives of providing opportunities to motivated scientists and field-level workers to take up action-oriented and location-specific projects aiming towards socio-economic upliftment of poor and disadvantaged sections of society through appropriate technological interventions, especially in rural areas."[33] SEED works with various national laboratories and institutions, as well as NGOs, to promote grass root-level interventions that focus on beneficiaries, contribute to the development of women, backward classes, and other disadvantaged members of society,[34] and address location- and occupation-specific challenges.[35]

According to its website, **"SEED has achieved significant breakthroughs in developing and demonstrating replicable technology packages and field models in several sectors with [the] involvement of its partners, S&T based field groups and S&T institutions."[36] These include the development of a solar photovoltaic-based electronic milk tester and a modified filature for silk spinning.**

Amongst other developments and breakthroughs, a recent project is the development of a Hip Protective Device under the Technological Interventions for [the] Elderly programme of SEED aimed at preventing hip fractures due to falling. The device has been conceptualised and developed at the Indian Institute of Technology (IIT), Delhi, and is now being sold commercially. It "works by dampening the shock of a fall, through its microcellular structure by spreading the impact energy to the sides, thereby protecting the protruding edge of the 'greater trochanter' bone, which on a sudden fall impact leads to the fracture of the neck of the femur."[37] *This is a prime example of technology being developed and facilitated by and through public interest and finance for commercial utilisation and social benefit.*

While a description of an institutional framework for SEED is not publicly available, its website highlights a strong monitoring and evaluation framework to ensure that its research findings are valid and true.

"The progress of approved projects is monitored through presentations at Group Monitoring Workshops in the presence of experts and other principal investigators. This is very effective for the success of the projects as mid-course corrections are suggested and projects can be recommended for support . . . Impact assessment is judged based on the basis of people's acceptability of the proposed intervention, techno-economic viability, ecological sustainability, and replicability potential taking into account social dimensions. Acceptance of such interventions for wider replication [is] in the form of appropriate technology packages/ models in rural sectors by line function departments."[38]

These structured checks and balances for ensuring relevance, and for reviewing progress and findings, have also been suggested for the R&D Platform to ensure its validity and success.

Source: http://www.scienceandsociety-dst.org/Aboutus.htm, http://www.scienceandsociety-dst.org/Monitoring.htm, and http://www.scienceandsociety-dst.org/highlights.htm

33 Science for Equity, Empowerment and Development (2017b) "Science & Technology Policy, 2003," available at http://www.scienceandsociety-dst.org/; accessed 16 June 2017

34 Science for Equity, Empowerment and Development (2017c) "Objective and Mandate," available at http://www.scienceandsociety-dst.org/objective.htm; accessed 17 June 2017.

35 Science for Equity, Empowerment and Development (2017c) "Objective and Mandate," available at http://www.scienceandsociety-dst.org/objective.htm; accessed 17 June 2017.

36 Science for Equity, Empowerment and Development (2017a) "Highlights and Achievement," available at http://www.scienceandsociety-dst.org/highlights.htm ; accessed 17 June 2017

37 Ozla Healthcare (2017) "Trogaurd Hip Protector", available at http://www.ozlahealthcare.com/products.php?cid=Mjg=; accessed 10 September 2017.

38 Department of Science and Technology (2017), "Monitoring and Evaluation", available at http://www.scienceandsociety-dst.org/Monitoring.htm; accessed on 10 September 2017.

Annexure 2

Questionnaire for Stakeholders on the RDP

General information

1. Stakeholder details (company or individual)
2. Stakeholder interests
3. Stakeholder needs
4. Stakeholder goals
5. Product/output details

Views on HFC phase-down

6. Supply of information on the recent HFC agreement: What do you know? What do you think?
7. Relevance
8. Apprehensions, if any
9. Plan of action, if any
10. How does it affect your supply chain? (if relevant)
11. Information on the R&D Platform: What do you know? What do you think?
    a. Any thoughts on the nodal agency appointed to carry this platform forward (Vigyan Prasar)?
12. What is the status/general tone of conversation in the industry/your network on this issue?

R&D Platform

13. How is a collaborative R&D Platform (RDP) of interest to you/your stakeholder group?
14. What outcome do you expect from an RDP?
15. What value do you hope to get from the RDP?
16. What are the primary functions you hope the RDP would undertake or perform?
    a. How much financing would be required to carry out these functions?
    b. What sort of infrastructure would be required?
    c. What is the kind of participation/other stakeholders that the RDP should have?
17. What sort of support can you offer/contribution can you make to the RDP?
18. What are your necessary and optional conditions for participating in the RDP?
19. Who all should be members of the RDP?
    a. What is the kind of interaction that you expect to have through the RDP?
    b. Should only Indian companies be allowed as participants?
    c. Are there companies whose involvement may be unfavourable to/have an adverse effect on your own participation?
20. How should the technology outcomes be shared?
    a. What are the patent-related requirements?
21. What are the trust-enabling factors that one should consider when setting up such an RDP?
22. How should the RDP be institutionalised and governed?

Technology alternatives

23. Which of the following technology alternatives do you think are most relevant to your company/ stakeholder group?
    a. Hydrocarbons
    b. R32
    c. R32-HFO blends
    d. HFOs
    e. CO2
    f. Ammonia
    g. Non-refrigerant chemicals in blends
24. What sort of application testing would be ideal for each of these?
25. Do you have a priority or preference for developing/applying these alternatives through the RDP?
26. Which of these functions would you want the RDP to focus on?
    a. High ambient temperature region testing
    b. Other technical changes like reducing charge size, using different materials for components
    c. Energy efficiency improvements
    d. Changes/additions/updates to standards (including storage and transportation of chemicals)

Company/stakeholder group details, as relevant

27. Financial turnover
28. R&D spending
29. Innovation/technology development capacity
30. Supply chain details, if relevant
31. Client details, if relevant

Annexure 3

Stakeholder Consultation List

MAC:

1. Maruti Suzuki
2. Tata Motors
3. Subros

RAC:

4. Daikin
5. Blue Star
6. Honeywell
7. Godrej

Building and Cold Storage:

8. BAANI Real Estate
9. Framework Architecture
10. Modern Bazaar
11. Polka Bakery

Associations:

12. Society of Indian Automobile Manufacturers (SIAM)
13. Refrigeration and Air-Conditioning Manufacturers Association of India (RAMA)
14. Automotive Component Manufacturers Association of India (ACMA)
15. Refrigerant Gas Manufacturers Association (REGMA)

Expert Meetings/Review of Work:

16. Dr Sukumar Devotta, Former Director, National Environmental Engineering Research Institute, India
17. Dr Radhey S. Agarwal, Professor, Mechanical Engineering Department, Indian Institute of Technology Delhi (IIT Delhi) and Senior Advisor and Coordinator of Sector Phase-out Plan Unit (SPPU), Ozone Cell, Ministry of Environment, Forest and Climate Change, Government of India
18. CGIAR
19. Stockholm Environment Institute
20. InnoZ Berlin
21. Institute for Governance and Sustainable Development (IGSD)
22. Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)
23. Dr Matt Kennedy, Head of Strategy and Business, International Energy Research Centre (IERC)

Government of India Meetings and Consultations:

24. Dr Amit Love, Scientist 'D' / Joint Director, Ozone Cell, Ministry of Environment, Forest and Climate Change, Government of India
25. Shri Manoj Kumar Singh, Former Joint Secretary, Ministry of Environment, Forest and Climate Change, Government of India
26. Launch of India's HCFC Phase-out Management Plan (HPMP) Stage-II and Stakeholder Consultation Meeting, MoEFCC
27. Meeting to discuss issues related to research in the field of alternatives to HFCs, convened by MoEFCC

Annexure 4

PIB Press Release of MoEFCC's Intent regarding the R&D Platform

Press In formation Bureau
Government Of India

Ministry of Environment and Forests
(15 September, 2016 09:46 IST)

Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives

The Ministry of Environment, Forest and Climate Change (MoEFCC) today announced an ambitious collaborative R&D programme to develop next generation, sustainable refrigerant technologies as alternatives to HFCs. This R&D initiative brings together Government, research institutes, industry and civil society to develop long term technology solutions to mitigate impact of currently used refrigerant gases on the ozone layer and climate. With this initiative, India reaffirms its commitment to working with all other nations to safeguard the Earth's natural ecosystem.

Some of the key players of the initiative include the Council of Scientific & Industrial Research and its allied institutions; Department of Science and Technology; Centre for Atmospheric & Oceanic Sciences; as well as key industry players in the sector. Members of this initiative have already had multiple rounds of consultation to reach a consensus on the contours and decide on
the roadmap for this initiative.

India has a small carbon footprint at citizen level and its sustainable lifestyle results in low contribution of the country to overall emissions of greenhouse gases and ozone depleting substances, as compared with other developed countries. However, there is an urgent need for developing new technologies indigenously as alternatives available today are patented apart from being expensive. A research based programme to look for cost effective alternatives to the currently used regfrigerant gases is, therefore essential.

The initiative is a significant step forward in line with India's national focus on research, innovation and technology development and Mission Innovation. The research initiative of the Ministry will be led by the CSIR's Indian Institute of Chemical Technology, Hyderabad. The MoEF&CC, along with the Department of Science and Technology (DST), Council of Scientific & Industrial Research (CSIR) has also decided to create a corpus fund for this research programme, with Industry also committing to contribute to the effort.

The collaboration of research institutes as well as industry will create larger ecosystem for developing sustainable solutions, and eventually deploying low global warming potential GWP HFCs on a national scale. By establishing an effective collaboration between all important stakeholders, the initiative is focused on prioritising areas of research in new refrigerant technologies and natural refrigerants. This shall help the country leapfrog from the current technology high GWP HydroFluoroCarbons or HFCs to technologies with lower climate impact.

The Ministry reiterated that the proposed initiative is an important step in the direction of enabling the country achieve national development goals, while continuing to maintain a sustainable environmental footprint.

Annexure 5.

List of Potential Members of the Platform

This is not an exhaustive list of those who should be invited to join the Platform, but may be used as a starting point to guide the Steering Committee in this regard.

Private Sector Associations:

1. All India Air Conditioning and Refrigeration Association (AIACRA)
2. Automotive Component Manufacturers Association of India (ACMA)
3. Indian Polyurethane Association (IPUA)
4. Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)
5. Refrigeration and Air-conditioning Manufacturers' Association (RAMA)
6. Society of Indian Automobile Manufacturers (SIAM)
7. Confederation of Indian Industry (CII)
8. Consumer Electronic and Appliance Manufacturers Association (CEAMA)
9. Refrigerant Gas Manufacturers Association (REGMA)
10. Refrigeration and Air-Conditioning Servicing Sector Society (RASSS)

Companies:

11. Ashok Leyland
12. Asian Aerosol Pvt. Ltd.
13. Birla Aircon
14. Blue Star India
15. BMW
16. Carrier Corporation
17. Carrier Transicold
18. Carrier - United Technologies Corporation
19. Daikin Airconditioning India Pvt. Ltd.
20. Daimler AG
21. Danfoss Industries Pvt. Ltd.
22. Emergent Ventures
23. Delphi Automotive Systems Pvt. Ltd.
24. Dupont India Pvt. LtdEmerson
25. Euro Air [give full name of company; there is also an airlines with the same name]
26. Ford Motor Company
27. General Motors (GM)
28. Godrej & Boyce Mfg. Co. Ltd.
29. Godrej Appliances
30. Gujarat Fluorochemicals Limited
31. Hindustan Motors

32. Honda
33. Honeywell India
34. Hitachi
35. Industrial Foam Pvt. Ltd.
36. Intertek India Pvt. Ltd.
37. Johnson Controls Ltd.
38. Lloyd Electric and Engineering Ltd.
39. Mahindra
40. Maruti Suzuki
41. Ingersoll Rand Engineering & Technology Centers – India
42. Mexichem
43. Mongia & Co., Chandigarh
44. Navin Fluorine International (NFIL)
45. Panasonic
46. Samsung
47. Sevcon India Pvt. Ltd.
48. SRF Limited
49. Subros Ltd.
50. Swegon India
51. Tata Motors
52. Tirupati Foam Limited
53. Toyota
54. Trane India
55. Toro
56. Volkswagen
57. Voltas Limited
58. Whirlpool Corporation

Laboratories and Think Tanks:

59. Centre for Science and Environment (CSE)
60. Council of Scientific and Industrial Research (CSIR)
61. Council on Energy, Environment and Water (CEEW)
62. Indian Institute of Technology (IIT)
63. Ingersoll Rand Engineering and Technology Centers – India
64. Institute for Governance and Sustainable Development (IGSD)
65. Natural Resources Defense Council (NRDC)
66. mean Shakti Sustainable Energy Foundation
67. The Energy and Resources Institute (TERI)
68. Underwriters Laboratories
69. United Nations Environment Programme (UNEP) India
70. WWF India
71. GIZ India

Annexure 6

Suggestions for Research Themes

Based on factors such as costs, risks, applicability, availability, patents, and familiarity with the Indian market, some initial areas on which the Platform could focus are:

1. RAC: Developing standards for R-290 as an energy-efficient alternative for new ACs
2. RAC: Developing R32 and HFO blend as a retrofitted alternative for existing ACs
3. MAC: Evaluating and developing R152A
4. MAC: Evaluating and application testing of HFO 1234yf
5. Commercial refrigeration: Evaluating and application testing of transcritical carbon dioxide
6. Researching new and horizon technologies relevant for India

Some of these research themes and their proposed use and relevance in India are discussed below.

RAC: R-290 as an energy-efficient alternative for new ACs

With improving living standards, the increase in the market size of room air conditioners is anticipated to be large. According to a published study by CEEW, "the stock of stationary ACs will increase from 2.6 million units in 2005 to 38 million units in 2020, and further to 445 million units in 2050 (Chaturvedi et al., 2016) ... Accordingly, an exponential increase is expected in stationary air-conditioning for the residential and commercial sector in the period 2010 to 2050."[39] The current level of AC penetration and usage is already straining India's electricity grid. Reportedly, 40 to 60 per cent of Delhi's peak load demand stems from the use of ACs.[40]

Given this increase in the number of units, the air-conditioning sector (residential and commercial) is expected to contribute over 63 per cent HFC emissions by 2050.[41] As evaluated by CEEW researchers, baseline HFC emissions will increase from 10 Mt CO2eq (including HCFC emissions) in 2010 to 503 Mt CO2eq (HFC emissions only) in 2050 in a business-as-usual scenario (not accounting for the phase-down schedule mandated by the Kigali amendment).[42] The study indicates that this growth is mainly a function of increased HFC emissions from refrigeration and air conditioning applications.

Currently, there is no one refrigerant that is being bet on across the industry to replace HFCs. The predominant alternatives are R-290, R32, and R410A.[43] Given the large anticipated increase in market growth for this segment and the potential for emissions reduction, we suggest the use of R-290 as an energy-efficient alternate for new ACs.

Various studies have established that replacing low-efficiency and high-GWP room ACs with high-efficiency and low-GWP ACs is amongst the most feasible solutions to drive down GHG emissions without incurring a very high cost. Shah et al. (2015) find that "shifting the 2030 world stock of room air conditioners from

39 Chaturvedi, Vaibhav, and Mohit Sharma (2015) Modelling long-term HFC emissions from India's residential air-conditioning sector. Climate Policy 16 (7), 877-893.

40 Lawrence Berkeley National Laboratory (2015) Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning. Washington, D.C.: United States Department of Energy, Office of Energy Efficiency and Renewable Energy.

41 Purohit, Pallav, Lena Höglund-Isaksson, Imrich Bertok, Vaibhav Chaturvedi, and Mohit Sharma (2016) Scenario analysis for HFC emissions in India: Mitigation potential and costs, New Delhi: CEEW-IIASA.

42 Purohit, Pallav, Lena Höglund-Isaksson, Imrich Bertok, Vaibhav Chaturvedi, and Mohit Sharma (2016) Scenario analysis for HFC emissions in India: Mitigation potential and costs, New Delhi: CEEW-IIASA

43 For a brief comparison of these, see Chapter 4, Purohit, Pallav, Lena Höglund-Isaksson, Imrich Bertok, Vaibhav Chaturvedi, and Mohit Sharma (2016) Scenario analysis for HFC emissions in India: Mitigation potential and costs, New Delhi: CEEW-IIASA.

the low efficiency technology using high-GWP refrigerants to higher efficiency technology and low-GWP refrigerants in parallel would save between 340–790 gigawatts (GW) of peak load globally, which is roughly equivalent to avoiding 680–1550 peak power plants of 500MW each. This would save over 0.32 GT/year annually in India[, which is] equivalent to roughly twice India's 100GW solar mission target."[44]

A commonplace low-GWP and high-efficiency refrigerant is R-290. R-290 is high-purity propane. Its environmental characteristics include having no ozone-depletion potential (ODP) and a GWP of 3. It also has excellent thermodynamic measures of efficiency. It has a high cooling capacity, and performs well in high ambient conditions, characteristic of India's climate.

It is available in a range of packable sizes to suit several applications, including but not limited to residential air conditioning, commercial refrigeration, industrial refrigeration, and industrial/commercial air conditioning. It is already in use as a natural refrigerant in the AC sector in various countries.

A 2015 study by CEEW has evaluated that phasing out HFCs with R-290 could potentially reduce greenhouse gas emissions from room ACs in India's residential sector by 38 per cent by 2050.[45]

R-290 has also entered the Indian RAC market and is amongst the best rated efficient and low-GWP AC units. However, its uptake in the market is low; only one company offers it as a product. There is also widespread apprehension about using R-290 given its high flammability and the resulting concerns about safety.

In order to support the switch from high-GWP, inefficient or expensive alternatives to HFCs, the Government of India would do well to suggest R-290 as an adequate alternative. This recommendation is premised on R-290's environmental qualities of having a low GWP, while also being effective in high ambient conditions, in addition to being cost-effective, patent-free, highly energy efficient, easily available, and not requiring major manufacturing overhauls to existing capacities. We elaborate below.

Efficiency gains from R-290:

R-290 based room AC units can provide significant energy savings. A study analysing HFC transition alternatives in China estimated that HC-290 air conditioners would save over five times as much energy as a HFC-410A air conditioner. In Vietnam, as part of a UNIDO (United Nations Industrial Development Organization) project, R-290 units were installed in four pilot test projects for keeping small cold room temperatures at -20°C at ambient temperatures of 35°C using cooling units containing just 1.6 kg of R-290 each, which is similar to a room-size AC.[46] This programme has noted average energy efficiency gains of 20–25 per cent in the four pilot projects, one of which has even achieved energy savings of up to 42 per cent compared to the previous R22-based system.[47] For India, such energy savings are likely to be much higher given that AC usage is already straining the peak demand energy load.

The Godrej R-290 room AC has been awarded the highest (five-star) rating by India's BEE without the use of inverter technology, which is likely to increase its efficiency such that it would qualify for two more stars. In addition, the 2015 CEEW study quoted above found emissions reductions of 38 per cent when using R-290 and also indicated that *15 per cent of this reduction would be the result of energy efficiency.*[48]

44 Lawrence Berkeley National Laboratory (2015) Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning. Washington, D.C.: United States Department of Energy, Office of Energy Efficiency and Renewable Energy.

45 Council on Energy, Environment and Water (2015) "Energy efficiency gains with lower global warming impact: A profile of air conditioners using R-290," available at http://ceew.in/pdf/ceew-nrdc-a-profile-of-air-conditioners-using-R-290-30nov14.pdf; accessed 23 August 2017.

46 Cold Link Africa Online (2017) "Efficiency Gains for Vietnam's R-290 Cold Stores," available at http://www.coldlinkafrica.co.za/index.php/homepage/news-archive/616-efficiency-gains-for-vietnam-s- R-290-cold-stores; accessed 17 June 2017.

47 Cold Link Africa Online (2017) "Efficiency Gains for Vietnam's R-290 Cold Stores," available at http://www.coldlinkafrica.co.za/index.php/homepage/news-archive/616-efficiency-gains-for-vietnam-s- R-290-cold-stores; accessed 17 June 2017.

48 Council on Energy, Environment and Water (2015) "Energy efficiency gains with lower global warming impact: A profile of air conditioners using R-290," available at http://ceew.in/pdf/ceew-nrdc-a-profile-of-air-conditioners-using-R-290-30nov14.pdf; accessed 23 August 2017.

Limitations and the Way Forward:

There is a strong pushback from the room AC industry on the use of R-290. The primary concern is its flammability. The secondary reason is the preference for R32 rather than R-290 as an alternative.

While there has been no reported incident (of flammability) in all the units that have been sold so far, Indian standards for safety and applicability need to be formalised. Godrej follows the "European Standard" for safety precautions and keeps to 360 grams of R-290 to be used in a 1.5 tonne AC that is for sale. The pace of development of Indian standards on this front has been slow; to induce more players to enter this market, a legitimate body for promoting standardisation needs to set safety and usability standards for R-290. In addition, for R-290 to gain in market size, larger application sizes need to be tested and other safety and feasibility testing needs also need to be undertaken.

Thus, questions about the parameters of safety, testing for standards on flammability and efficiency, and applicability in various sizes of room ACs require attention from the industry and from the government if R-290 is to become a large-scale viable refrigerant that will replace HFCs in India.

However, it must be noted that R32, which is used in Daikin ACs, for instance, offers an advantage in the Indian market thanks to its retrofit-friendly applications that R-290 does not. According to the manufacturer Linde Gas, "R-290 is suitable for new R-290 systems. It is a flammable refrigerant and therefore not suitable for retrofitting existing fluorocarbon refrigerant systems."[49]

Given the technical impracticality of retrofitting ACs for switching to R-290, the Platform could explore the use of R32 as an alternative that requires R&D for retrofit ACs in India.

R152a: Secondary loop mobile air-conditioning

Mobile air-conditioning currently uses R134a as a refrigerant, which is a high-GWP HFC. Apart from R1234yf and R744, which are the refrigerants of choice for most car manufacturers, some manufacturers are also considering the use of a 'secondary loop refrigeration system' with R152a, which has a GWP of 140. Since R152a is slightly flammable and toxic, it cannot be used in a conventional refrigeration system where the evaporator is located inside the passenger compartment of a car; in case of a leak, the refrigerant could affect passengers. However, in a secondary loop system, the refrigerant is located inside a chiller which cools a secondary fluid (generally, water is used) which then circulates around the passenger compartment.

The many advantages of this system are that it requires smaller refrigerant charges, there are no patent-related costs associated with the R152a, it performs very well in hot ambient climates, and it continues to cool even during short stops. However, it also has certain disadvantages. It is not a drop-in replacement, it adds to the weight of the vehicle, and it also requires slightly more electrical power than conventional systems. Nevertheless, there are many opportunities for achieving efficiency improvements through further R&D.

Currently, Tata Motors is the only Indian automobile manufacturer testing R152a with an SUV (sports utility vehicle) from its fleet, through a demonstration project funded by the Climate and Clean Air Coalition.[50]

49 Linde Gas (2017) "Industrial Gases," available at http://www.linde-gas.com/en/products_and_supply/refrigerants/natural_refrigerants/r290_propane/index.html; accessed on 11 June 2017.

50 EPA (2010) Transitioning to Low-GWP Alternatives in MVACs. Washington, D.C.: Environmental Protection Agency.

Transcritical Carbon Dioxide: An HFC-Alternative for Commercial Refrigeration

Commercial refrigeration in India—that is, cold stores, supermarkets, and pack houses—currently account for a much smaller share of HFC consumption than the automobile and residential air-conditioning sectors. However, this is set to change with the adoption of government policies aimed at increasing the network of pack houses in rural areas as well as the exponential growth of the food and beverage industry. By 2030, CEEW research studies estimate that commercial refrigeration will be responsible for 17 per cent of all HFC emissions in a business-as-usual scenario.

Commercial refrigeration requirements range from -18°C (for deep freezes) to 12°C (for fruit/bakery displays). At present, most cold stores in rural India use ammonia for their cooling needs; ammonia is a natural refrigerant with negligent GWP. Supermarkets and the food and beverage industry use R134a and R404A, which are both high-GWP refrigerants.

The Montreal Protocol's Technology and Economic Assessment Panel (TEAP), in its 2016 update of available technologies, found that HFC blends like R-448A, R-449-A, R-449B, R-450A, and R-513A are becoming the refrigerants of choice in Europe and the United States.

Amongst natural refrigerants, the use of ammonia continues to be limited to rural or sparsely populated areas because of safety risks associated with its use. However, carbon dioxide (known as R744) in cascaded systems (that is, those with a secondary refrigerant like R134a) and in transcritical systems have shown great promise. Indeed, more than 8,700 supermarkets in Europe have already moved to R744-based cooling systems.[51] While there have been some doubts about the performance of R744 in hot ambient climates, preliminary testing conducted by the Indian Institute of Technology (IIT) Madras in collaboration with SINTEF, Norway, and Danfoss, India has shown great promise. A demonstration project is also under construction and is expected to be functional by July 2017.[52]

After this initial round of testing, there are likely to be many opportunities for further R&D, including testing with equipment produced by Indian refrigeration manufacturers and demonstration projects in collaboration with food and beverage companies for their specific needs.

51 European Commission (2017) "Availability of alternatives to HFCs in commercial refrigeration in the EU," available at https://ec.europa.eu/clima/sites/clima/files/20161201_briefing_supermarket_en.pdf; accessed 20 June 2017.

52 Maiya, M.P. (2017) at the EU-India Green Cooling Conference, New Delhi, 27 April 2017.

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