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Collaborative R&D for Sustainable Cooling in India

Institutional Reforms to Accelerate Technology Deployment

Himanshu Dixit and Shikha Bhasin

Report | July 2021

Rapid development and deployment of cooling technologies is crucial to provide thermal comfort to all and meet India's larger developmental goals.

Image: Emotivelens

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"Research and technology development happening in silos will not serve the goal of a large-scale sectoral transition geared towards sustainable cooling. What we need is the engagement between policymakers, sector stakeholders, and change agents on a collaborative innovation platform. Only by addressing the institutional and operational processes underpinning research programmes in India can we create conditions of extensive and fruitful research participation and collaboration."

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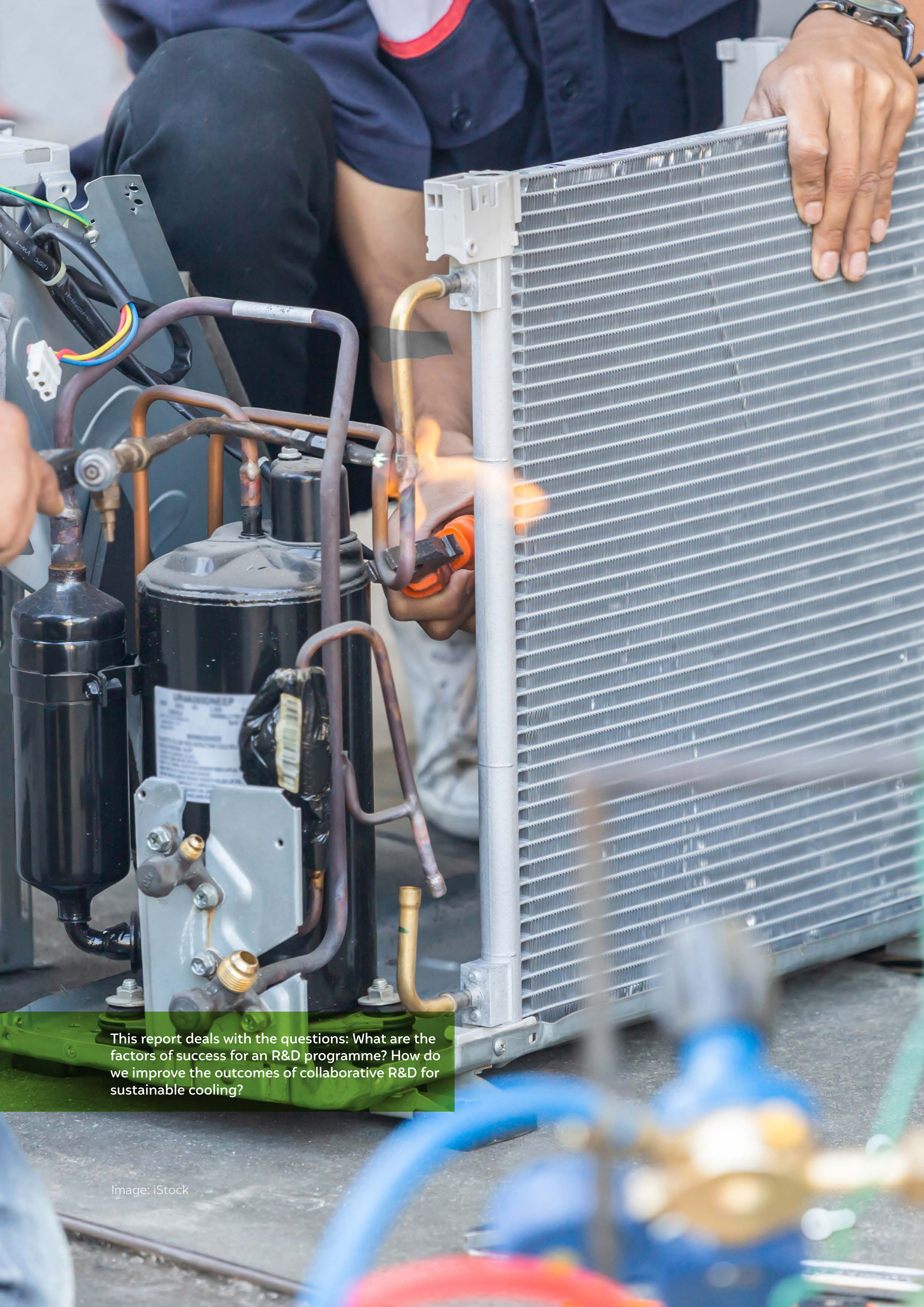
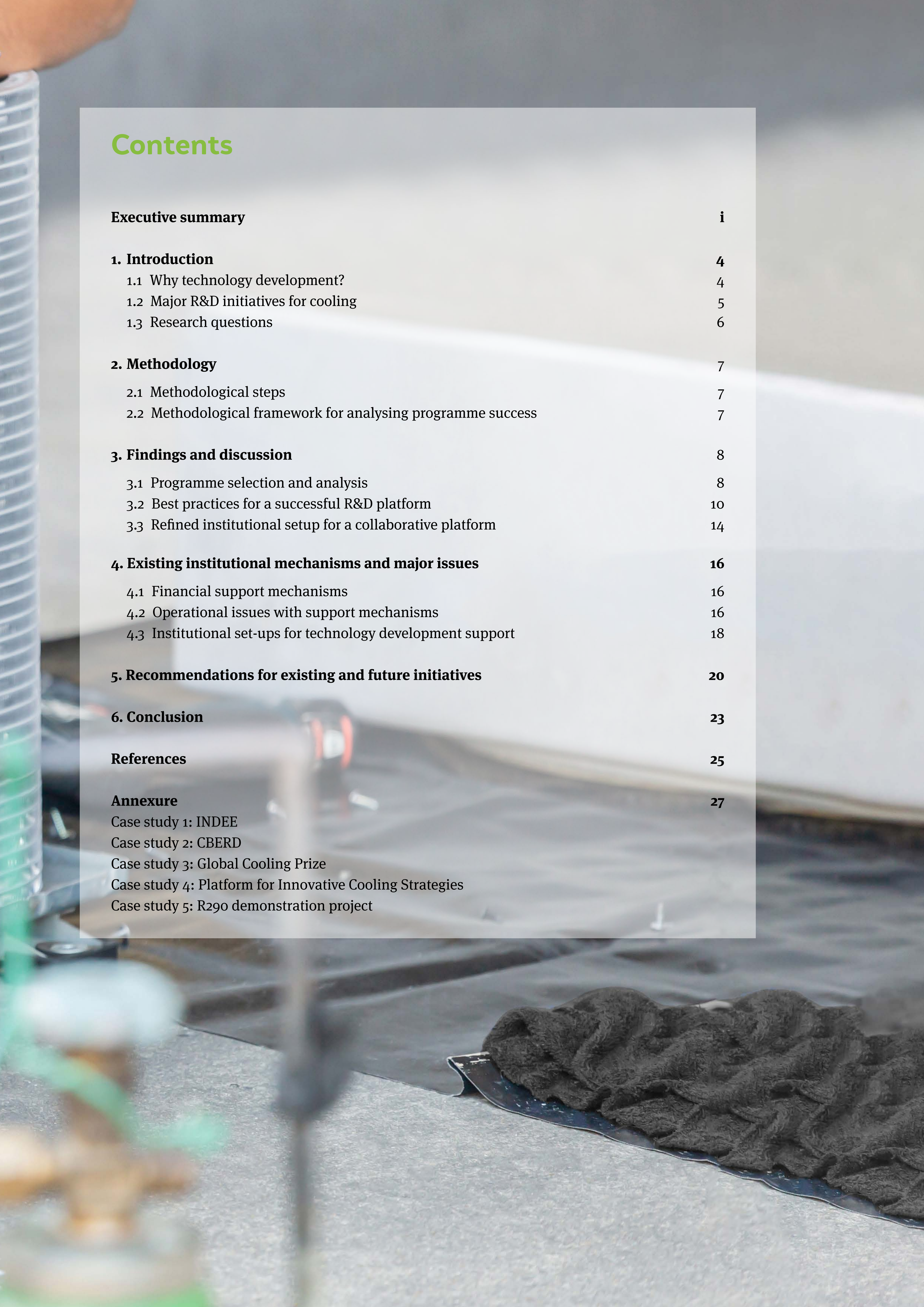
"India has astounding cooling needs across economic sectors and its demography – and each application is central to our development. This study is a nudge to institutionalise and encourage key players to play a catalytic role towards India's development through enhanced access to cooling."



This report deals with the questions: What are the factors of success for an R&D programme? How do we improve the outcomes of collaborative R&D for sustainable cooling?

Image: iStock



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Acronyms

AEEE	Alliance for Energy Efficient Economy
BEEP	Building Energy Efficiency
CBERD	Centre for Building Energy Research and Development
CERI	Clean Energy Research Initiative
DSIR	Department of Science and Industrial Research
DST	Department of Science and Technology
GCP	Global Cooling Prize
GWP	global warming potential
HFCs	hydrofluorocarbons
HVAC	heating, ventilation, and air conditioning
ICAP	India Cooling Action Plan
IIT-M	Indian Institute of Technology—Madras
I-PHEE	Initiative to Promote Habitat Energy Efficiency
LBNL	Lawrence Berkeley National Laboratory
MoEFCC	Ministry of Environment, Forests and Climate Change
MI	Mission Innovation
MNC	multinational corporation
NRDC	National Research Development Corporation
NSTEDB	National Science and Technology Entrepreneurship Development Board
NTNU	Norwegian University of Science and Technology
PACE	Partnership to Advance Clean Energy
R&D	Research and Development
RMI	Rocky Mountain Institute
SINTEF	Stiftelsen for industriell og teknisk forskning
TDB	Technology Development Board
TIFAC	Technology Information, Forecasting and Assessment Council
TPDU	Technology Promotion Development and Utilisation
USD	United States dollar
USDOE	United States Department of Energy

At the programme level, we need to pay attention to preparation, in-process activities and output stages to optimise the impact and outcomes of a collaborative platform for R&D.

Image: iStock

Executive summary

The question before us is simple: Can we cool India with less warming?

Only 8 per cent households currently own ACs in India (ICAP 2019). By 2037, the ownership is expected to increase five-fold to about 40 per cent of households (ICAP 2019). An expected USD 100 billion market for ACs (Indiaspend 2021)— and we haven't even reached the half-way mark yet! Expansion of cold chains, refrigeration for perishables, healthcare and pharma products will become huge markets in themselves. Will it be possible to provide thermal comfort and cooling to population with just in-kind (vapour compression) technologies[1]? Clearly a tall order. On the climate side, can we afford to keep providing more and more energy for cooling? Absolutely not. The only way forward is to make investments in R&D for the development, diffusion and deployment of new and efficient technologies to increase access to sustainable cooling for all people, and across sectors. Here is an opportunity to tap into one of the biggest cooling markets in the world, while mitigating GHG emissions. Hence, to serve the exploding demand for cooling across sectors and for technologies in use, not only levels of in-kind technologies have to be ramped up but also, new and upcoming technological alternatives need to be scaled up.

Increased focus on thermal comfort in India

The Government of India has accorded due importance to cooling in its discussions on development and policymaking as thermal comfort and cooling remain central to human well-being and productivity. Cooling is widely used in residential housing and commercial buildings, for cold storage and refrigeration, in transportation, and in industries in India already, in terms of scale of utilisation as well as types of applications.

Given the low base of cooling access in India, in addition to commitments made within the Kigali Amendment to the Montreal Protocol as well as energy security and utilisation projections, novel technological solutions to cooling are needed. To meet

> **Make investments in R&D for the development, diffusion and deployment of new and efficient technologies to increase access to sustainable cooling for all.**

this growing demand of cooling in future, a dedicated focus on innovation, increasing efforts on cooling R&D, and enhancing industrial competitiveness become highly essential. We need to actively accelerate the identification and deployment of alternatives to current refrigerants (with high global warming potential) in use, enhance energy utilisation and efficiencies, and provide affordable thermal comfort through new applications to the Indian population at large.

National policies such as the *India Cooling Action Plan* incorporate a renewed commitment to accelerate the pace of research and development (R&D) and innovation in the cooling sector so as to develop and deploy novel cooling technologies. Collaboration is the main thrust of India's cooling research efforts. Expertise available across research institutions, universities, companies, government agencies, and private labs must be leveraged to create a thriving ecosystem of collaborative R&D dedicated to cooling.

Creating a collaborative R&D effort for sustainable cooling

To support the accomplishment of this goal, we aim to bridge critical gaps in research on the following questions for India's cooling domain:

1. What are the institutional and operational tenets of success for collaborative R&D programmes in India?
2. What are the institutional mechanisms that currently exist for supporting R&D in cooling sectors?
3. How do we incorporate best practices into ongoing and upcoming collaborative R&D platforms dedicated to cooling?

1 In-kind technologies refer to the technologies that are predominantly used for various applications in a sector. For instance, vapour compression is an in-kind technology as it remains the most popular option for cooling and heating purposes. For more discussion on typology of technologies, see Ghosh et al. (2019).

In order to build evidence to answer the research questions, we undertook extensive desk research to collect information about the Indian government's initiatives to support research and technology development in sustainable cooling. Collaborative innovation programmes and their details such as programme focus, outputs, etc. were also collected during desk research.

Semi-structured interviews with experts and consultative sessions with stakeholders were conducted to complement desk research. These interviews and sessions helped us gain insights into (a) the drivers of success and best practices followed by research programmes *perceived to be successful* and (b) the institutional challenges underpinning collaborative research in India.

By drawing comparisons and experiences from different cases, the institutional and operational practices critical to the success of a collaborative and multi-stakeholder research and technology development programme were identified.

Institutional best practices to promote R&D collaboration

Based on stakeholder interviews and desk research, we developed an analytical framework to compare case studies on key collaborative R&D initiatives in the cooling domain. The following best practices were identified as being critical to their success:

- Setting vision and objectives offers clarity for the long term.
- Integrated model of R&D is central to multidimensional problem solving.
- Building trust is important to develop partnerships.
- Smart public–private financing bestows benefits other than just finance.
- Capacity building is important to build R&D for the future.
- Mutually beneficial and flexible terms help in identifying the right collaborators.
- Regular outreach ensures transparency, feedback, and optimisation.
- Innovation necessitates research, development, and deployment (RD&D) strategy.

Our learnings show that for any institutional mechanism to spur a cooling-centric R&D and innovation platform, in addition to different kinds of support, attention has to be given to key operational aspects of the programme. Many of these best practices can be institutionalised as part of the platform itself to ensure success going forward. The institutional lessons or reforms as presented in the report can be applied to the existing national programmes for a successful collaboration between different actors in the cooling research ecosystem. These can be summarised as follows:

Recommendations for ongoing and upcoming R&D programmes

- Design institutional support such that it dovetails with the programme objectives and purposes.
- Integrate various sectoral research and technology development activities at different stages of maturity to harness complementarities between them.
- Expand the participation and engagement of CSOs and private entities with new and existing programmes.
- Institutionalise an intermediary panel to facilitate better interface, closer cooperation and alignment among different partners in collaborative initiatives.

Source: Authors' analysis

Institutional support for future collaborative programmes

Based on the learnings from our analysis, we propose to support the new R&D initiatives through an elaborate institutional structure, with functions defined to reflect the most important aspects of the programme. This support framework brings together various institutions that have so far been working in silos. It envisages integration of various activities at different stages of research and technology development on one platform. The main aim of institutional integration is to bring together diverse expertise and experiences. The Department of Science and Industrial Research (DSIR) affiliated institutions have a better understanding of industry's functioning while the Department of Science and Technology (DST) knows the

> To facilitate better interface between different partners, close coordination and stakeholder alignment, an intermediary panel should be set up for each programme.

university landscape intimately, for example. It proposes an intermediary panel as an interface structure between different institutions with the major task of liaising with the platform partners and facilitate better coordination. Independent public research organisations that have a strong interface with industry establishment and government bodies can be entrusted to perform the role of an intermediary as it is responsible for both stakeholder and research management. ES1 shows how different institutions can be grouped together to enable a much better thinking, planning, management and collaboration for cooling related R&D and technology development.

ES 1 Institutional groupings and their functions to enable future collaborative cooling R&D

Programme body	Institutions	Main responsibility
Steering committee	DST, DSIR, CSIR, MNRE, MoEFCC, MOP	Set the vision and objectives of the programme.
Consortium committee	DST, DSIR, CSIR, university and research labs, industry partners	Develop and expand the consortium through negotiations and trust- building exercises. Deliberate on technology development strategy and act as a forum for R&D and innovation partners to raise issues.
Intermediaries panel	Select public interest research organisations, industry representatives	Coordinate between different institutions and partners and facilitate external partnering with new and prospective members.
Technical committee	TIFAC, DST, universities and research labs, industry	Decide and assess the research agenda and R&D model for the platform.
Financial committee	DST, DSIR, industry partners, philanthropic funders	Manage and oversee the funding needs of the programme activities.
Operating council	DST, intermediaries, select consortium members, NSTEDB, NRDC	Responsible for the overall operational management of the programme including reviewing, collaboration facilitation, and stakeholder management.
IP management board	DST, patent facilitating centre, industry partners	Conduct all the IP-related negotiations, resolve queries and perform other related activities.
Outreach partners	Public interest research organisations, research labs, industry consortium	Ensure and organize effective benefits delivery, conferences, public events, demonstrations, and press outreach.
Deployment partners	DST, TDB, NSTEDB, NRDC, venture capital funds, investors	Plan and execute the task of taking technologies to market on different scales.

DST: Department of Science and Technology, Government of India

DSIR: Department of Scientific and Industrial Research, Government of India

CSIR: Council of Scientific and Industrial Research, Government of India

MNRE: Ministry of New and Renewable Energy, Government of India

MoP: Ministry of Power, Government of India

MoEFCC: Ministry of Environment, Forest and Climate Change, Government of India

TIFAC: Technology Information Forecasting and Assessment Council, Government of India

NSTEDB: National Science & Technology Entrepreneurship Development Board, Government of India

NRDC: National Research Development Corporation, Government of India

TDB: Technology Development Board, Government of India

Source: Authors' analysis

1. Introduction

The Indian government has accorded due importance to thermal comfort and cooling in its in its development agenda as cooling has been recognised as central to human well-being and productivity (Khosla et al. 2020; Mastrucci et al. 2019). Although cooling is required in various sectors such as residential housing, commercial buildings, cold storage, refrigeration, transportation, and industries, India faces an acute shortage of cooling infrastructure[2] .

Be it cold chains where the existing infrastructure of integrated pack houses, reefer transport, and ripening units is falling short of requirement by more than 90 per cent (NCCD 2015), or residential housing where only about 8 per cent households own air conditioners (ICAP 2019), cooling and thermal comfort needs to be made widely accessible across sectors (not including fans and water coolers, which are accessible). Given India's growth projections, the aggregate cooling demand is expected to steadily increase by five times by 2037–38.[3] To cater to this exploding demand for cooling across sectors and for existing technologies, the production levels of in-kind technologies[4] have to be ramped up and the new and upcoming technological alternatives have to be scaled up (IEA 2020).

1.1 Why technology development?

A large part of space and commercial cooling requirements are currently served by vapour compression technologies that commonly utilise synthetic refrigerants, largely hydrofluorocarbons (HFCs) (Abhyankar et al. 2017). This technology in wide use and demand for which is increasing rapidly poses two main challenges to policymakers. The first challenge is the management of refrigerants with high global warming potential (GWP). The Kigali Amendment to the Montreal Protocol, to which India is a party, requires countries to phase down and ultimately phase out high-GWP gases as per the agreed upon schedules.[5] Finding alternatives to high-GWP refrigerants and use of climate-friendly technologies as cooling demands in India are set to rise exponentially is a challenge.

The second challenge is creating the energy supply needed to match the growing cooling demand. The share of cooling in India's electricity system peak loads will rise from 10.1 per cent in 2016 to 44.1 per cent in 2050 as per the baseline projection (IEA 2018). However, energy-efficient technologies in cooling can drastically reduce the energy requirement to around 19.3 per cent of the total peak load (IEA 2018). Hence there is a need to develop energy-efficient cooling technologies to lower energy demand, especially in India, which has a hot and humid climate in many states.

The India Cooling Action Plan (ICAP), a comprehensive policy document that defines the roadmap to achieve sustainable cooling and thermal comfort for all, has duly acknowledged cooling as an energy-guzzling sector. The ICAP has also coupled Kigali commitments and energy efficiency as pillars on which the future of cooling needs to be imagined and built.

Technology has a crucial role to play in cooling sector to cater to the growing demand as well as to provide alternatives to the current technologies that use climate-unfriendly ingredients. The current technologies in use and manufacturing capacities are also not viable given the accelerated trends of global warming and climate change. Hence, a technology-aided market transformation becomes very imperative. At the policy level, some developments in this regard have offered much needed direction.

The Kigali Amendment to Montreal Protocol has provided the member countries a platform to affirm the need for leapfrogging to low-GWP, energy-efficient cooling technologies as key to decarbonising our future. In India, policies such as ICAP stress on a renewed commitment to accelerate the pace of research and development (R&D) and innovation in the cooling sector to develop and deploy emerging technologies. The ICAP has charted a few areas of focus in refrigerant technology, heating, ventilation, and air conditioning

Technology has a crucial role to play in cooling sector to cater to the growing demand as well as to provide alternatives to the current technologies.

2 See, for example, CEEW (2018), CEEW (2019), ICAP (2019), TERI (2020), among others.
3 For detailed projections, refer to India Cooling Action Plan (2019).
4 For a typology of technologies, refer Ghosh et al. (2019).
5 As per its commitments, India has agreed to phase out 85 per cent HFCs by 2047. For more, see https://ozone.unep.org/treaties/montreal-protocol/amendments/kigali-amendment-2016-amendment-montreal-protocol-agreed

(HVAC) technologies, and design, which are to be achieved in the short, medium, and long term. These goals necessarily require the involvement of all actors of Indian R&D landscape—equipment manufacturers, academia, research labs—to work together as part of a R&D ecosystem. To develop promising and feasible technologies, the diverse expertise in different research institutions, universities, and private labs must be leveraged and brought on to one platform. Since this kind of thriving ecosystem of collaborative R&D dedicated to cooling needs to be galvanised in India, a closer look at the existing landscape is essential.

1.2 Major R&D initiatives for cooling

The Government of India has announced a number of initiatives for research and technology development in the cooling sector. We evaluate them before embarking on a project to build and improve the cooling R&D ecosystem in India.

In September 2016, the Ministry of Environment, Forest and Climate Change (MoEFCC) announced its intent to establish "an ambitious collaborative R&D programme to develop next generation, sustainable refrigerant technologies as alternatives to HFCs" in India (Press Information Bureau 2016). The ICAP, launched by the MoEFCC in 2019, envisions the development of a vibrant ecosystem that encourages collaboration between the government agencies, universities, and industry players (ICAP 2019). Although these initiatives show the serious intent of the government in focusing on R&D in cooling, they have to be pushed at a faster pace given a short window of time.

The Government of India launched the Clean Energy Research Initiative (CERI) in 2009 to give thrust to developing sustainable technologies. The initiative is aimed at "developing national research competence to drive down the cost of clean energy"[6] by supporting translational research, disruptive innovation, and

> **The current technologies in use and manufacturing capacities are also not viable given the accelerated trends of global warming and climate change.**

> **GoI's Clean Energy Research Initiative (CERI) emphasises collaboration between industry, academia, and research institutions.**

institutional capacity development (DST 2009). The objectives of CERI quite clearly articulate the emphasis on collaboration between industry, academia, and research institutions. The CERI aims to achieve its objectives through "creation of knowledge networks".

Another big push to R&D and innovation in the country came in the form of Mission Innovation (MI). Initiated in 2015, MI is a global initiative with 23-member countries, which aims to mobilise both public and private money to accelerate the pace of innovation in clean energy. MI bets on leveraging multilateral and bilateral collaborations to enable knowledge sharing and mutually beneficial technological development. Seven innovation challenges have been identified under MI, one of which is affordable heating and cooling of buildings (Mission Innovation India 2017). The frontier areas, research priorities, gaps, and opportunities in all the seven areas have been deliberated upon and relevant projects under various programmes are now in progress in collaboration with the member countries (Mission Innovation India 2019). The most recognised initiative under the innovation challenge 7 of MI is the Global Cooling Prize. It is an international competition that recognises breakthrough space cooling technologies that deliver cooling with over 5X lower climate impact as compared to the technologies in use today.

In addition to multilateral R&D collaborations, the Government of India has also launched the national programme called Initiative to Promote Habitat Energy Efficiency (I-PHEE) to improve energy performance of buildings and cities (Press Information Bureau 2017). As of today, the programme funds 31 research projects in leading universities and research institutions in the country. Apart from such programmes with specific research mandates, various ministries such as the Ministry of New and Renewable Energy (MNRE) and MoEFCC launch their own schemes and disburse funds to support research projects of general interest depending upon contingent needs and requirements.[7]

6 Although the ambit of CERI is quite large in principle, research projects concerning renewables have the lion's share in the programme, and the HVAC sector remains quite marginalised.

7 For more information on the same, please see https://mnre.gov.in/research-and-development/solar and https://repmismoef.nic.in/Public/Home1.aspx

As part of North–South bilateral technology and R&D collaboration, the Government of India has been engaged in several R&D programmes with the United states, the United Kingdom, Norway, Switzerland, and other countries. The prominent ones include Centre for Building Energy Research and Development (CBERD)[8] with the United States, Residential Building Energy Demand Reduction in India (RESIDE)[9] with the United Kingdom, a project on reducing energy demand, and Building Energy Efficiency (BEEP)[10] project with Switzerland. All these programmes have a dedicated focus on the building sector covering the aspect of cooling.

A review of the mentioned initiatives and partnerships would help identify the gaps in the cooling R&D ecosystem in India. Despite several programmes holding the promise of robust collaboration between many players, in actual practice, the interface between public and private R&D efforts is weak.[11] Broadly speaking, lack of participation from Indian industry players in many of these programmes is quite obvious. Moreover, mere participation of different stakeholders does not make it a good collaboration. A convergence of efforts on all fronts is a prerequisite for success. Barring a few projects and programmes, a robust level of collaboration is missing in the cooling sector.[12] There is a large scope to enhance the public–private interface and make R&D collaborations successful.

> **Mere participation of different stakeholders does not make it a good collaboration. A convergence of efforts is a prerequisite for success.**

1.3 Research questions

Before addressing structural challenges of the cooling sector,[13] institutional shortcomings, if any, need to be fixed. As a first step towards realising the goal of increasing public–private collaboration and improving the outcomes of collaborative R&D, an institutional reset must happen. Hence, in this report, we focus on the institutional mechanisms in place to support and oversee the various R&D efforts taking place.

We pose the following research questions:

- What are the institutional and operational tenets of success for collaborative R&D programmes in India?
- What are the institutional mechanisms that currently exist for supporting R&D in cooling sectors?
- How do we incorporate best practices into ongoing and upcoming collaborative R&D platforms dedicated to cooling?

By answering these questions, we recommend a refined institutional setup involving public agencies, universities, and private players to encourage and facilitate collaborative cooling R&D initiatives. The answer to the first question will help us look into the institutional and operational practices embedded in successful and not so successful programmes, with the assumption that they largely explain the success of collaborative R&D efforts. The second question will give us a sense of the existing institutional framework for supporting different facets of R&D and technology development cycles, and how well it is serving the

8 Please see http://cberd.org/
9 Please see https://www.reside-energy.org/
10 Please see https://www.beepindia.org/
11 This conclusion has been arrived at by looking at the list of accepted proposals and projects that were awarded under CERI and IPHEE over the years. Most of them have been awarded to standalone researchers with no industry participants. Also, Dhar and Saha (2014) have analysed this problem in detail and arrived at a similar conclusion, more generally about collaborative R&D as a whole.
12 Public–private collaboration in other sectors like agriculture, biotechnology, telecommunications, which have experienced transformation due to R&D and technology development, can be contrasted here.
13 The cooling and refrigeration sector in India are largely organised around an import-assembled business model. See https://www.bloombergquint.com/business/indias-plan-to-curb-chinese-imports-may-hurt-air-conditioner-makers.

complex and interconnected needs of R&D. Lastly, the best practices and learnings from successful programmes will have to be 'institutionalised' and operationalised for present and future initiatives. We do this by recommending a set of institutional reforms and by introducing some additions and changes to the existing framework of institutions.

Having laid out the motivation behind the report, the important initiatives of the Government of India to spur cooling R&D and technology development and the key research questions herein, in the subsequent chapters, we focus on providing answers to the research questions posed. Chapter 2 briefly outlines the research methodology, the steps we take to answer each research question, and the rationale for adopting this approach. In Chapter 3, we share the details of collaborative programmes and findings from our analysis. Distilling the learnings and best practices gathered from the cases, we detail the key tenets of success of an R&D collaboration, followed by the sort of recommendations that can be drawn from them. Chapter 4 looks at the various institutions and institutional mechanisms already in place to support the innovation activities in the country, and some of the challenges and issues associated with them. Chapter 5 proposes recommendations for the key institutional and operational reforms for an existing, multi-stakeholder R&D initiative. An institutional structure to carry out different responsibilities and functions to support future R&D initiatives is also provided in Chapter 5. Finally, Chapter 6 concludes the report with key considerations for a way forward.

2. Methodology

In order to answer the research questions, the following methodological steps were adopted.

2.1 Methodological steps

1. Through extensive desk research, we mapped the existing institutions and agencies operating within the ambit of the government that provide R&D and innovation support to different entities, both public and private. This mapping was crucial to gain an understanding of the support mechanisms currently available to both industry players and public universities from the government.

> We evaluated the intellectual and managerial input to the programme as well as its operational dynamics to arrive at a comprehensive success metric for the programme.

2. Using semi-structured interviews with R&D experts, we learned the shortcomings and deficiencies in institutional support and mechanisms, thus answering our second research question. We relied on inputs from 18+ interviews conducted in September and October 2020, with building science researchers, refrigeration industry R&D leaders, and cooling sector policy experts to understand the gaps in and needs of a collaborative R&D ecosystem. One closed-door consultation in November with leading international experts in refrigeration was also conducted to get insights on the experience outside India.

3. Adapting the frameworks established in scientific literature, we evaluated the success of select industry–academia and public–private R&D collaborations. We answered the first question by analysing (a) primary information collected using semi-structured interviews with programme managers and R&D professionals and (b) secondary information in the form of programme documents. This analysis is provided in the form of case studies of these programmes. Using comparative case study[14] method, the learnings from these cases were then further analysed, compared, and integrated to recommend a refined set of institutional and operational practices as drivers of success of the programmes.

4. Considering the existing institutional framework and capacities, the best practices derived in the earlier chapter were given an institutional shape by integrating the existing institutional channels on one platform. This answers the third research question by combining the insights from the first and second questions.

2.2 Methodological framework for analysing programme success

To understand and assess the performance of the programme and its success factors, we need a framework to take stock of the activities across different stages and processes of the industry–academia collaborative programmes. Based on Brown

14 Comparative case study is a research approach through which the analysis and synthesis of the similarities, differences, and patterns across more than two case studies can be done. It helps produce knowledge about causal questions regarding how and why particular programmes fail or succeed.

(2007), Perkmann et al. (2011), and Fernandes et al. (2017), we divide a collaborative programme into three broad stages: (i) preparation, (ii) in-process activities, and (iii) closure and post-programme.

The outcomes of the programme are assessed in order to ascertain its success or failure. Moreover, to arrive at a more comprehensive view of the reasons for success, we must also include (a) what was the intellectual and managerial *input* to the programme and (b) what were the operational dynamics. In each stage, several components were identified that in literature are thought to be causally related to certain desired outcomes, hence positively contributing to the overall success of the programme. Several measurable indicators were also identified for each component to take stock of the important tangibles and intangibles of the programme. We collected these indicators from the programme information and progress documents. Wherever this information is not documented, interviews with key personnel of the programmes were used to fill the critical gaps.

Our mapping methodology serves two purposes. One, it lets us capture both the institutional character of the programme by considering the preparation stage as well as the operational details as highlighted in the activities stage. Two, the choice of framework components and their indicators constitute the factual as well as the analytical aspect of the programme, since a priori these are understood to be the main drivers of success.

Table 1 Framework for assessment of a collaborative programme

Preparation	In-process activities	Closure	Impact
Collaborators' capability	Collaboration intensity	Innovations and solutions	Achievements
Motivation	Knowledge creation	Spin-offs	
Opportunities	Benefits dissemination		
Research areas			

Source: Fernandes, G., Eduardo B. Pinto, Madalena Araújo, Pedro Magalhães, and Ricardo J. Machado. 2017. "A Method for Measuring the Success of Collaborative University–Industry R&D Funded Contracts." Procedia Computer Science 121: 451–460.

3. Findings and discussion

3.1 Programme selection and analysis

The programmes selected for analysis are:

(a) INDEE,

(b) Centre for Building Energy Research and Development (CBERD),

(c) Global Cooling Prize,

(d) Platform for Innovative Cooling Strategies, and

(e) Godrej–GIZ collaboration.

The reasons for choosing these programmes were fairly straightforward. All these programmes were either ongoing or concluded fairly recently. For instance, the oldest programme was the Godrej–GIZ collaboration, which concluded in 2012, while the Global Cooling Prize is still in progress. Another key reason for selecting them was the availability of documentation and information on these programmes. Lastly, with the exception of Platform for Innovative Cooling Strategies, all the programmes were perceived as successful due to concrete outcomes and level of participation and traction.

Despite several similarities, the programmes also differed from each other in important ways. The programme INDEE was a bilateral collaboration to execute a demonstration R&D project, which investigated the conditions of equipment use for Indian climate. CBERD was a bilateral partnership but a consortium-driven programme with a portfolio of research verticals focussed on basic R&D, applied R&D, and demonstration projects. Global Cooling Prize is an innovation competition that follows an induced self-assembly model of organisation as the R&D collaboration for the purpose of competition alone. All the finalists are participating in a collaborative group of two to four. Lastly, Platform for Innovative Cooling Strategies is more a facilitation platform for examining innovation

> One of the common aspects among the successful programmes profiled in this study is the strong vision that drive them.

proposals for piloting and bankability and Godrej–GIZ is a partnership to enhance and upgrade the capacity of a single manufacturing plant.[15]

The selection reflects the diversity of programme focus and different institutional mechanisms through which they have been conceptualised. This would help us in acquiring various kinds of learnings in different contexts. The analysis and key takeaways for each programme has been provided in the Annexure. We discuss the mapping of different facets of programme design and execution for INDEE and CBERD as an illustration in this chapter. More details are available in the Annexure.

Table 2 captures the details across various stages of an industry–university collaborative programme. It gives the reader a sense of the proxy indicators through which areas like competence of researchers (qualification and citations record), the underlying motivation for them to work (policy vision, financial), the number of research projects, the collaboration intensity (idea exchange sessions), and the intellectual output of the programme (papers, patents) can be gauged. An empirical treatment of success indicators is useful to make a convincing case and justify the perceived level of success of programmes. It also provides the opportunity to take these data points and probe how getting these areas right was central to the success of programmes.

For INDEE and CBERD, the framework captured all the important details of these conventional industry–academia research partnerships. The other programmes, namely, the Global Cooling Prize, Godrej–GIZ collaboration, and Platform for Innovative Cooling Strategies are uniquely structured and all their details cannot be mapped with the same framework. However, indicators provide the basis for guiding questions to probe into the perceptions about their success, thus helping us frame the cases (see Annexure). Another point to keep in mind is that the Global Cooling Prize has just concluded and the Platform for Innovative Cooling Strategies is still a work in progress. So, we are yet to see the concrete results beyond healthy participation.

Table 2 Mapping case details of INDEE and CBERD

Component	Indicator	INDEE	CBERD
Collaborators' capability	Researchers with past experience in collaborative research	5	38
	Researchers with high education qualification (PhDs) or equivalent research	5	25+
	Scientific impact of researchers (h index)	Min—20, Max—24	Min—13, Max—33
Motivation	Innovation policy/Replication of similar successful programmes earlier	Bilateral partnership	US–India Partnership to Advance Clean Energy (PACE)
	Monetary incentives for researchers	No	No
	Funding and cost sharing	No cost sharing, Norwegian funding	Equal US and Indian funding, 2.5 times industry funding
Opportunities and challenges	No. of research areas/opportunities identified	1	2
Research activity	No. of project ideas	1	7
Collaboration intensity	No. of lead partner meetings	1	Many
	No. of progress/review meetings	1	1 meeting per project per year
	No. of technical team meetings/Research exchanges	1	44
	No. of result sharing events	4 workshops and training programmes	4 major events and many minor events
Knowledge creation	No. of patent applications	0	4
	No. of published papers and technical reports	7 papers	130 papers

15 It remains the only credible attempt at building capacity to manufacture room air conditioners (RACs) based on natural refrigerant technology at sufficient scale.

Component	Indicator	INDEE	CBERD
Innovations + solutions	Tools and technologies	0	9
	Facilities and test beds	1	14
	No. of new solution concepts	1	1
	Open software solutions and policy documents	0	4 open-source software, 2 best practices documents
	New project ideas	1	Several
Achievements	No. of patents granted	—	4
	Turnover growth due to R&D	—	—

Source: Authors' compilation

3.2 Best practices for a successful R&D platform

Based on the learnings from different case studies, we identify several key areas for renewed emphasis and improvement in order to ensure the success of collaborative programmes.

Setting vision and objectives offers clarity for the long term

One of the common aspects among the successful programmes profiled in this study is the strong vision that drive them. The bilateral agreement between the United States and India, Partnership to Advance Clean Energy (PACE), is the foundation for programmes such as CBERD.[16] The basis for the Global Cooling Prize is its vision to usher in cooling technologies with 5 times less climate impact, apart from convergence with the vision and objectives of Mission Innovation for India.[17] INDEE is based on a strong North–South partnership between Norway and India to cooperate on the

> Mission-driven programmes can play a transformative role as they are anchored around making a precise diagnosis of technological and sectoral systems.

16 CBERD was an outcome of PACE-R, the Indo-US research partnership. The other aspect of the partnership is deployment, also known as PACE-D. For more information on PACE initiative, see https://www.iusstf.org/program/indo-us-pacesetter-fund. Also see annexures to learn about CBERD in detail.

17 See Annexure.

technology front.[18] Thus it is clear that a strong policy announcement holds a critical place in paving the way and guiding the formation of a collaborative innovation platform for cooling. In this context, emphasising ICAP's vision and giving it a shape in the form of research programme objectives is very important.

Mission-driven programmes can play a transformative role as they are anchored around making a precise diagnosis of technological and sectoral systems which an innovation policy is engineered to change (Mazzucato 2018). The new-age mission-oriented projects such as in energy and environment focus intensely on the diffusion of technologies, economic feasibility and affordability, and development of both radical and incremental technologies. It becomes clear that old R&D missions in areas of defence, aerospace, and nuclear energy shared none of these characteristics—wide societal diffusion was not needed, economic feasibility was a non-issue, and only radical breakthroughs were chosen for development. Inherently, then, the new-age mission creates the need to involve a large number of actors across different stakeholder groups to fulfil the mission objectives, thus completing a virtuous cycle by orienting them all through a common vision.

Integrated model of R&D is central to multidimensional problem solving

Successful programmes show evidence of a strong sectoral and thematic focus in order to deliver the right outcomes. Cooling is both a multi-sectoral and polythematic domain, which means that solving one problem will require us to integrate different areas of research. For instance, one research breakthrough or innovation will have to be considerably modulated to be applicable in different segments. Hence, taking a cue from the CBERD programme, which identified several themes for R&D, intense efforts have to be invested in designing the R&D model, with the capability to be divided into different research verticals. The R&D model of CBERD went through many refinements before the research focus of the programme was finalised. Starting with a primary research question to developing an integrated framework to benefit building science in both India and the United States, CBERD's technology outlook entailed creation of open-source software, best practices for policy input, research infrastructure, and patentable technologies. The crucial insight to derive from this programme is how different levels of research and technology development cycles were integrated into a seamless whole.

> **Establishing trust is key to get research and industry partners to sign up for the R&D platform.**

We draw a similar lesson from the Global Cooling Prize (GCP), which set a high benchmark of testing and performance protocols, resulting in rigorous and innovative as opposed to half-baked solutions. Also, GCP is very clear that it is not a technology platforming initiative. GCP expects solutions in the form of working products based on proven prototypes that can be scaled without too many technology development iterations. In this sense, GCP's focus has been on products that are prepared and ready to be deployed as pilots immediately. This clear-cut direction has ensured that there is no ambiguity about what the platform is looking for.

At a more operational level, our analysis indicates that the discussions to decide the programme focus must include all stakeholders and experts. In this respect, the ICAP does offer the initial direction regarding areas of priority. The short-term and medium-term focus should be combined to approach and solve a problem end to end. For instance, a research focus on refrigerant technologies for commercial refrigeration segment would need to include work on technologies that are not so well established (basic and applied research), technologies that are established in conditions not similar to India, established technologies that are not in use due to a variety of reasons (translational research), and those that do not have proven business models to hit the market. A cohesive strategy to address all the pain points and R&D bottlenecks related to refrigerant technologies in the above-mentioned segment need to be addressed to arrive at proper solutions.

Build trust to develop partnerships

The foundation for any successful collaboration begins with the long and hard process of building trust. It plays a very crucial role in all facets of the programme, whether institutional or operational. It is only trust that led the industry consortium members of CBERD to expand their engagement with research institutions beyond the programme timeline. From GCP too, we learn that extensive conversations

18 See Annexure.

were conducted to assuage apprehensions of the participants about the programme. Whether it was getting the Indian ministries on board or having to convince innovators that full protection would be extended to the participants' intellectual property, GCP administrators built a high level of comfort for everyone involved with the programme.

Establishing trust is key to get research and industry partners to sign up for the R&D platform. The objective of forming a large consortium in India can be fulfilled only through trust-building exercises with each partner. The trust between partners will need to be built through extensive consultations between the relevant government agencies, research institutions, industry partners, and diverse interested parties. For the programme to take off, the custodians must get this right. An institutional mechanism must be evolved to carry out the trust-building process as evidence suggests that different partners do not see eye-to-eye on several issues. Two examples of this divergence are: (a) industry's reluctance in approaching the government for public funding on collaborative projects and (b) industry not placing sufficient confidence in academic partners. Hence, involving research institutions and civil society organisations as intermediaries to facilitate initial conversations to bridge the gaps can prove to be critical. For instance, in the CBERD programme, the lead research partners and managers led this exercise particularly with the members of the industrial consortium.

The trust-building exercise would also ensure that different collaborating partners know the intentions and motivations of each other. This becomes especially important in the case of technology development. In case of consortium-driven R&D programmes, participation of competing industrial establishments also necessitates that a modicum of trust exists between them in order to cooperate and collaborate.

Smart public–private financing bestows benefits other than just finance

For any collaborative R&D endeavour to prove its worth, financing from as many sources as possible is essential. Since R&D is conventionally understood to be a risky investment, it is important a right balance is struck between public and private financing. Apart from risk sharing, there are other reasons to have smart co-financing collaborations (that combine a mix of patient and impatient capital) in place as well. As seen in the case of GCP, public–private funding signals trust and confidence, which forms the bedrock of a long-term, fruitful partnership. Despite having the ability to source philanthropic and private sponsors for the prize, the public money was crucial for GCP as it signified the material support and blessing to the initiative by the government. What it achieves is the confirmation that in future the government will offer the best possible support to industry for scaling the solution through policy measures. In other words, in addition to the quantity of finance, the quality of finance is equally important.

> **Both the quantity of finance and the quality of finance is equally important.**

The other aspect of financing is that even if the government funds the programme, public money should be leveraged to get non-governmental sources to make the investment significant. In addition to expanding the quantum of funds, this is also crucial to realise convergence between different R&D endeavours.

One important learning from the CBERD programme was that the industry partners would gauge the relevance and potential impact of research and technology development. Their funding of the programme would be a consequence of their interest in the research work. From that perspective, it is crucial then to mobilise the research partners to broker such co-financing deals by convincing not just industry players but also philanthropic organisations to invest in solutions of the future, as they are the ones having the expertise to explain the research needs and specific ways in which industry players can help.

Lastly, novel buy-in arrangements such as in-kind support to the programme instead of big investment can also make a difference to mid-sized industry players who are not sure of investing. Having such diversity on the platform is important as companies of different sizes bring unique competitive advantages to the fore, which can later be harnessed.

Capacity building to build R&D for the future

Capacity addition is both the precondition for and consequence of an R&D programme. In the case of asymmetric capacity of research partners, mechanisms have to be created to leverage the strengths of more endowed partners to build capacity in areas in which weak links are seen. High degree of engagement in the programme, mobilising the research institutions as coordinators of the programme, and increasing capacity of academia by increasing the intake of post-doctoral students are all possible ways that can be explored in order to increase capacity to manage research programmes and also aid future research.

In the case of CBERD, capacity building was one of the focus research areas as the necessary infrastructure and facilities were found to be missing in India. As a result of the programme, various laboratories in India are now endowed with state-of-the-art testbeds and research apparatuses. In terms of specific recommendations, principal investigators should be allowed to hire postdocs on programme budget. Using inputs from research labs, the government agencies should invest in designing capacity-building projects by providing necessary training, exposure, and through exchange programmes.

Another aspect of capacity building on such a platform is to facilitate the bilateral partnership between industry partners to transfer technologies and add requisite capacities to make gainful use of such technology in manufacturing and productisation. The collaboration between Godrej and GIZ to transform a production line to produce R290-based air conditioners benefitted the Indian AC manufacturer immensely and till now remains the only effort in the RAC segment to develop natural refrigerant-based equipment in India.

Mutually beneficial and flexible terms help in identifying the right collaborators

Trust-building exercises and negotiation go hand in hand for collaborative programmes. Whether it is CBERD or GCP, a platform with many collaborating partners will have to stay open to negotiating the terms. Naturally, a platform can invite many partners only if it offers agreeable terms to the parties involved. For instance, , the process- and rule-heavy approach that accompanies government-driven R&D may not serve the platform very well. It restricts the researcher's choice and disincentivises them to avail public money because of the hassles they go through. Instead, the terms should be arrived at using an outcome-based, flexible approach. The financing terms of the government–academia R&D model ought to be replaced with more congenial terms that can give room to course correct in the middle of the research.

Industry players are suspect when it comes to intellectual property (IP) rights management on the platform. Starting from IP identification to IP protection and licensing should be made an essential process of the programme. For achieving this, a clear institutional mechanism and framework has to be put in place through due deliberations between the concerned parties to give the research collaborators their rightful due.

It is also seen that big companies might be more wary of exposing their IP to the collaborators for fear of misuse and theft. Hence, mechanisms to protect the participants' IP from each other is of utmost importance to inspire confidence. Institutionally, non-disclosure agreements are widely used to ensure it, but operationally it must be achieved through trust and recognition of help and cooperation.

Drawing on the experience of CBERD, in addition to open source and free license innovations, the platform must also facilitate the creation of patented innovations owned by the researchers and other collaborators, as the case may be. For instance, basic software developed under the CBERD programme was available for free, though the source code can be further expanded to develop a proprietary software protected by copyright. This is how both public purpose and private interest can be structured in the programme.

Mechanisms for collaboration is key to keep partnerships buzzing with activity

Both CBERD and INDEE demonstrated a high degree of collaboration between the research and industry partners as evidenced in the joint output of the programmes. In case of public–private partnership, collaboration is achieved through research exchanges, research infrastructure sharing, and diffusion of talent and fellowships. Particularly between industry and academic researchers, collaboration can be formalised by granting access to facilities, test beds, and letting key R&D personnel to work with academia. Since collaboration is part of programme dynamics, based on situational assessment, different modes of collaboration can be conceived.

Collaboration is as much operational part of the programme as it is institutional. Indeed, aspects such as fellowship and research exchanges of researchers are institutionally decided, but at the most quotidian level too, collaboration and engagement between various parties must be integral to the programme. One insight from the case studies that provide a very useful way of thinking about collaboration is the role research coordinators are meant to play. As intermediaries in the programme tasked with documentation and stakeholder management, they can be leveraged to catalyse collaboration and develop a common understanding of needs and necessities. Frequent technical team meetings and review sessions can be conducted to gauge the collaboration dynamics and make timely and appropriate interventions.

Regular outreach ensures transparency, feedback, and optimisation

Though not an intrinsic feature of R&D platforms, outreach nonetheless played a definitive role in making CBERD and INDEE successful. Only through outreach efforts, wider awareness about the research programme can be created. Outreach in this sense creates curiosity and interest among industry and other researchers, which makes out-of-platform collaboration possible. Because of outreach, the INDEE programme has been expanded further as INDEE+ with much larger involvement and participation by commercial establishments.

Letting the relevant group of stakeholders know about the research at regular intervals creates feedback loops for the programme, which can be used to optimise, repurpose, and course correct the research and technology development trajectories. In this sense, outreach both during the programme and end of programme should be done. Similarly, with demonstrations and workshops, the network effect kicks in and generates commercial interest in the research. For these purposes, the capacity of a large consortium must be utilised fully to keep everyone posted of the developments. Again, an able set of research managers on the platform must be devoted to this task. The GCP model of having dedicated outreach partners to provide extensive coverage to the programme can also be explored. This in effect means that an outreach strategy should be an essential part of the programme.

Innovation necessitates research, development, and deployment (RD&D) strategy

Technology development cycles have an inbuilt component of commercialisation in terms of scale and production and interface with the end user. However, given the complex nature of R&D, the deployment aspect is sometimes forgotten or relegated to institutional processes separate from the R&D platform itself. The experience and varied inputs from experts suggest that it is counterproductive to separate the two. The deployment agenda and research agenda must go hand in hand. An innovation platform must couple the two at the programme/project level.

> With demonstrations and workshops, the network effect kicks in and generates commercial interest in the research.

Commercial integration can be achieved in many ways. It can be done by engaging early-stage innovators, start-ups, and small manufacturers and have them absorb the developed technologies. Exploring business aspects of technology at the early stages of research increases the chances of uptake later. Also, the start-up model of deployment makes the marketisation process nimble as large firms will probably wait for the right market scale to adopt the technology.

Right through the process of validation, development, demonstration, and deployment, different kinds of assistance must be provided on the platform. In this regard, both public and private technology-to-market pipelines should be part of the programme design. Moreover, these pipelines should also be accompanied by market creation methods such as confidence-building projects to gauge end consumer sentiments and needs.

3.3 Refined institutional setup for a collaborative platform

Our learnings from successful collaborations clearly indicate that any institutional mechanism to spur a cooling-centric R&D and innovation platform has to cover the programme end to end and provide support and direction to key operational aspects. Some of the aspects are listed as emerging areas of intervention in chapter 3, and the institutional mechanism must be created with an emphasis on success factors. These areas of interventions can be further distilled into five distinct categories, which will be more amenable to recognition and incorporation through the institutional design. Table 4 summarises these categories and specific recommendations with respect to each one of them.

Table 3 Recommendations for key operational and institutional elements of the platform

Element	Recommendations
R&D—Innovation focus	
Idea stage	Integrate different stages of technology development cycle on a single platform in order to ensure continuity and long-term industry engagement.
Patent stage	
Pilot	
Pre-commercial	
Basic research	
Bench scale	
Field testing	
Commercial scale	
Financing and incentives	
Public	
Private	Tie the various stakeholders' interests together by having them invested in the platform to secure their proactive participation.
Philanthropic	Maximise leverage on public money to send positive signals to the industry at large
Multilateral fund	In terms of the use of funds, ensure accountability but at the same time instead of focusing on strict accounting, make provisions for flexibility and deviation from the proposed use of funds, if done judiciously.
Intellectual property rights management	
IP identification	A clear intellectual property management framework needs to be in place to inspire confidence in a commercial establishment. This includes institutional support for intellectual property identification, protection, and filing.
IP filing	In addition to IP protection, open innovation paradigms must also be emulated for the platform where the benefits can be commonly reaped.
Licensing	
Open innovation	
Collaboration and outreach	
Resource sharing	A robust collaborative mechanism between different partners needs to be designed.
Research exchange	A unique way of having industry partners not financing the R&D but still interested in the platform and engage with it is by letting them provide in kind support, facilitate researcher' visits, and review and comment on technology developments.
Demonstration	Institute periodic reviews as an inalienable part of the programme to keep open possibilities of course correction, finance rationalisation and improvement.
Reviews	
Conferences	
Deployment	
Public grants	Integrate market-oriented skill sets and scientific thinking by including young entrepreneurs who can be nimble on their feet in terms of taking early technologies to the market.
Validation	Both public and private support channels must be designed for the purpose of deployment.
Manufacturing	
Incubators	
Venture capital support	

Source: Authors' analysis

4. Existing institutional mechanisms and major issues

4.1 Financial support mechanisms

Having studied the various aspects that contribute to the success of a collaborative R&D programme, we now ask: What are the structures in place now for public sector R&D? Learning about R&D institutional architecture is crucial for implementing the best practices as explained in the chapter 3. Our research indicates that there are several institutions dedicated to the exclusive purpose of driving R&D and technology development in the country. These institutional mechanisms to support and fund R&D and technology development can be broadly classified in three ways[19]:

(i) Support and funding controlled and managed by the Department of Science and Technology (DST)

(ii) Support provided through various programmes and agencies under the Department of Science and Industrial Research (DSIR)

(iii) Financing support provided to specific research projects through line ministries

DST is the leading government agency tasked with supporting cross-cutting R&D activities taking place in a range of different organisations and sectors. Its extensive research portfolio includes funding support to research in universities, public research organisations, and multilateral and bilateral research partnerships. Most of these funds are disbursed on a programme by programme basis in which proposals are accepted and evaluated. The selected projects are then bankrolled on satisfaction of certain conditions.

Ostensibly, many R&D projects are being funded by the government through DST. All the research projects under CERI and I-PHEE have been evaluated and supported by DST. However, most of these projects are not integrated with each other and thus lack potential to prove useful for market deployment, that is, without technology integration, technology diffusion will not take place. The projects are also marked by a complete lack of industry–university collaboration. In fact, by DST's own admission, its interface with the industry is not very strong and needs improvement.

Although there is nothing in the research proposals of DST that stops the involvement of industry in a project or creation of large industry and research consortiums, it seems that no extra efforts are made from an institutional perspective to interlink the stakeholders of sectoral R&D activities. Clearly, provisioning for collaboration in general directives is not enough. Institutional coordination to actively facilitate the formation of partnerships is necessary. However, we have not really seen such institutional creativity on part of the DST to engender collaboration between different entities, the mechanism through which funds are disbursed, and monitoring of fund use for R&D activities.

4.2 Operational issues with support mechanisms

Our interviews with key stakeholders brought to focus some of the operational issues with DST-funded research. Some of the leading experts and researchers who have engaged with industry and public collaborative innovation programmes in the past highlighted what the present institutional design and mechanism of government-funded R&D lacks. Views of select industry R&D leaders have also been gathered to understand what can enable their participation. Based on the analysis of these inputs, we identify a host of issues in the present model of public sector R&D, which involves the government and academia.

- A major part of DST funds for R&D are allocated to standalone researchers in the academia. The process starts with the announcement of a research programme by defining its vision, objectives, and research areas of focus. Thereafter, proposals from researchers, largely in academia, seeking funds for projects under that programme are submitted. These proposals are then evaluated by DST experts and after approval the funds are disbursed for research activities to begin. Two main problems can be identified to arise from this mechanism.

> **Institutional coordination to actively facilitate the formation of partnerships is necessary.**

19 This is our classification based on desk research. Most of the autonomous institutions, research labs, and oversight boards function under the ambit of DST and CSIR.

(a) Apart from the fact that the proposals are not chosen considering the possible use of knowledge and research work for commercial purposes, the R&D effort in the programme gets fragmented due to lack of cohesion and complementarity between different projects. This also leads to the problem of replication and duplication of work.

(b) The orientation of a large proportion of academic research is towards publishing peer-reviewed papers, not technology proofing and development. It can be attributed to inertia in academia, how incentives for researchers are structured, and lack of opportunities. Academia needs industry support to carry out any useful work in this regard, which is not very forthcoming. As a result, the actual academic research output remains far removed from what is needed for technology development with commercial potential.

- Involvement of industry is crucial for the development of marketable technology, requisite investment for deployment, and to craft novel business models. As mentioned earlier, the interface of DST with industry, particularly in a cross-cutting sector such as cooling, is not strong. Scarce involvement of industry in DST-funded projects and programmes is a big barrier to innovation. It must be noted, however, that DST mechanisms as such do not restrict industry participation in university research projects. Industry and academia are free to collaborate with each other. However, a robust institutional push and initiative on part of the DST is missing so that entities interested in commercialisation could join hands with academia. In other words, inputs and participation from industry and market-oriented players are not actively sought when it comes to granting funds and executing an R&D project.
- As DST operates with a large mandate of promoting research and development in the country, the corpus of funds meant for research projects look to serve many purposes. These funds not only have to bankroll research but also sponsor Masters and PhD students. There are certain other limitations as well such as how the funds can be utilised during the course of the project. Deviation from the purpose for which funds are allocated as approved in the proposal cannot be done, which leaves no room for course correction. This lack of flexibility and process-heavy approach, especially in long projects where the initial proposal cannot predict the future needs of the research project, makes it difficult for researchers to manoeuvre the funds optimally.

> **Involvement of industry is crucial for the development of marketable technology, requisite investment for deployment, and to craft novel business models.**

- In terms of academia–industry partnership, even when not facilitated by DST, the two share a complex relationship. Barring a few researchers from select institutions who are enterprising and have demonstrated their skills and value in industry-driven projects, academia in India does not come across as a credible partner in such collaborations. The industry perception of researchers in academia is that of scholars interested in publishing papers and reports and not getting into the long and hard business of building commercial technological solutions. Hence, academia–industry relations suffer from a credibility gap.

It has been repeatedly pointed out that the problem of R&D in India is an institutional problem, not a financial one. In the given setup between DST and academia, DST can offer more funds, but the individual researchers do not have the capacity to absorb extra funds. It looks like the inverse of the problem relating to orientation and nature of academic research, but it actually brings forth the issue of lack of capacity and capability in the academia. Even our interviews with experts suggest that in a few big projects involving industry and academia, research management is a huge problem.

Lack of mid-level research personnel in academia, a role traditionally played by post-doctoral researchers, has been an issue. So, in many cases, this important function is relegated to the doctoral students. A fairly common scenario narrated to us is that doctoral students join the project mid-way and leave before the project is completed. In other words, the research project cycle does not match the PhD student's engagement cycle. This, in turn, affects the continuity of research projects. For fixing the shortage of human resources and liberalising the way funds are used, postdocs hold the key in redressing this problem.

Contrary to DST, the interface of DSIR with the industry is much stronger. Through Technology Promotion, Development and Utilisation (TPDU) programmes, the department has played a pivotal role in engaging industry players in the commercialisation process. This involvement often kicks in after a technology is proven at the laboratory level and ready for further improvement and enhancement, thereby paving the way for the successful technology transfer to industry and introduction to market. Notably, promoting cooperative and co-creation models of R&D are encoded in the primary functions of DSIR, but largely its industry linkages are limited to technology transfers to industry establishments and providing fiscal incentives for in-house R&D.

The problem here is institutional imagination again. The process of industrial technology development is seen as distinct from the choice of research projects and fund allocation for them, not requiring any industry involvement. Hence, on the key issue of public–private collaboration across different stages of research, technology development, and innovation, the institutional mechanisms provided by DSIR leave much to be desired.

The financial support provided through line ministries has not made a huge difference in the renewable energy and environment sector till now. The projects are largely allotted on an ad-hoc basis without developing a full-fledged programme. This is reflected in the quality of projects and their outcomes.

In the next section, we look at some of the prominent institutional set-ups to support and promote technology development and commercialisation.

4.3 Institutional set-ups for technology development support

The tryst with technology and ways to support its development is not new. Through various programmes and establishment of institutions at different times, the government has been able to devise mechanisms to tap into the vast science and technology infrastructure of the country for useful and transformative innovations.

> The process of industrial technology development is seen as distinct from the choice of research projects and fund allocation for them.

Within the Ministry of Science and Technology, under the aegis of DST and DSIR, a clutch of entities has been established to perform functions such as technology landscape assessment, technology development facilitation, IP management services for academia, technology transfer to industry, entrepreneurship development based on S&T, etc. Looking at these institutions and mechanisms is important as a collaborative cooling R&D platform will benefit immensely from the rich experience they bring to the table.

a) National Research Development Corporation

Established in 1953 as an enterprise of DSIR, the mandate of National Research Development Corporation (NRDC) is primarily to promote and facilitate the commercialisation of proven technologies through technology transfer to industries. Pursuant to its mandate, NRDC works both with the national R&D labs and universities and the market players. By providing services such as intellectual property (IP) consulting and setting IP policy and process support to the knowledge creators i.e. the labs and academia, the institution prepares the supply end of technology transfer pipeline. These indigenously developed technologies are henceforth protected under the intellectual property rights. At the other end, NRDC maintains a repository of these technologies and leads negotiations to enter into technology transfer and licensing agreements with the interested parties. It also spreads awareness about adoption of IPR among entrepreneurs and MSMEs. During its many decades of existence, NRDC has forged strong links with the scientific and industrial community in India and abroad, and has also been instrumental in establishing a wide network of research institutions.

b) Technology Development Board

The Technology Development Board (TDB) was established under the administrative control of DST with a mission to strengthen the level of technology development and commercialisation in a given sector. A large part of its work deals with project financing and capital investment for risk sharing in developing technologies that are nascent and not ready for scale-up. TDB provides this support in three modes: loan, equity and grant, each with different terms and conditions. Motivating the enterprises to constantly push for product innovation is also a part of its mandate. TDB also participates in venture capital funds to invest in early stage enterprises working with indigenous technologies. The unique support offered by TDB in the domain of technology development has benefitted many small and medium industries.

c) National Science and Technology Entrepreneurship Board

The National Science and Technology Entrepreneurship Board (NSTEDB) is an institutional mechanism under the guidance and control of DST to help promote knowledge driven and technology intensive enterprises. Its objectives are to bridge gap between technology and business thus fostering high end entrepreneurship, network various agencies and facilitate informational services to engender entrepreneurship. NSTEDB in the past has been involved with some key ministries to start technology business incubators and S&T parks, thus giving it a healthy interface with the early stage start-ups and commercial establishments.

d) Technology Information Forecasting and Assessment Council

The Technology Information Forecasting and Assessment Council (TIFAC) was started in 1988 as a registered society under DST as an autonomous body. The vision behind the institution was to provide direction to India's technology development targets so bring about socio-economic transformation. TIFAC activities encompass a wide range of sectors and fill a critical gap in the S&T system in India. Over the years, TIFAC has gained tremendous experience in areas like technology assessment, technology foresight exercise, technology development, technology linked business opportunities etc. Patent Facilitation Centre was also set up in 1995 as a unit of TIFAC to create awareness about intellectual property in the country.

Table 4 Available institutional mechanisms for the promotion and development of technology

Institution	Department	Function
National Research Development Corporation	DSIR	To promote, develop, nurture, and commercialise innovative, reliable, and competitive technologies from R&D institutes through value addition and partnership
National Science and Technology Entrepreneurship Development Board	DST	To promote knowledge-based and innovation-driven enterprises and facilitate generation of entrepreneurship and self-employment opportunities for science and technology persons
Technology Information, Forecasting and Assessment Council	DST	Assess state-of-the-art technology and set directions for future technological development in India
Technology Development Board	DST	Financial assistance to Indian industrial concerns and other agencies, attempting development, and commercial application of indigenous technology, or adapting imported technology to wider domestic applications
Patent Facilitating Centre	DST	Introducing patent information as a vital input in the process of promotion of R&D programmes

Source: Various government sites

It is imperative that these institutions are part of the collaborative cooling R&D platform as envisaged in the ICAP. Collectively, these institutions have the experience of implementing a wide range of financial support and technology development programmes over the years. Integrating their institutional knowledge on one consortium-driven, target-based platform will help us adhere to the best practices we have outlined in chapter 3.

To understand the reason for aligning institutions and/or institutional mechanisms designed to cater to many different aspects of innovation on a single platform, we must look at the best practices as a whole. Take, for instance, the idea of building trust with the stakeholders of R&D ecosystem. The institutions are not attuned to have the same level and *kind* of engagement with the stakeholders. TDB and NSTEDB has the expertise to deal with early stage start-ups, SMEs and large companies on issues such as commercial development of technology. NRDC on the other hand specialises in ironing out issues related to intellectual property management in academia and consequent licensing and technology transfer to industry, which is a crucial value-add to start the process of commercialisation.

The cooling R&D platform needs both TDB and NRDC to effectively coordinate and complement their specialised functions to ensure deep engagement with stakeholders, productive intellectual property negotiations and successful deployment of working technologies. It needs TIFAC too for its technical expertise which is crucial to prioritise the problems to be solved and develop a R&D model with maximum impact and innovation outcomes. Having all of them in one place will help in advanced preparation and planning, multi-dimensional problem solving and capacity addition. Through their close working, the various issues that fall through the cracks due to separate and siloed functioning of these institutions will also get addressed.

Based on this reasoning, chapter 5 proposes a set of recommendations to improve the functioning of some of the existing programmes as well as a governance structure for a collaborative innovation platform with the purpose to align these institutions, and tackle all issues pertaining to technology development as part of a continuum.

5. Recommendations for existing and future initiatives

Based on the best practices from successful programmes as presented in Chapter 3 and the areas earmarked for changes and the salient recommendations for such areas as indicated in Table 3, this chapter draws attention to a set of reforms that can be implemented on priority for the existing R&D initiatives. These institutional reforms are recommended keeping in mind the cross-cutting nature of cooling R&D and with potential to benefit from more integration and participation of various market and research actors. These reforms and their possible beneficiaries are explained in the points as follows:

> General institutional support mechanism can lead to sub-optimal outcomes, while a more specialised institutional support can help expedite a lot of processes.

(a) **Institutions that can best serve the outcomes and goals of the programme must be a part of the design of the programmatic set-up.** Although this principle is followed in most cases, it is important to signify that general institutional support mechanism can lead to sub-optimal outcomes, while a more specialised institutional support can help expedite a lot of processes. For example, if a certain programme is designed for piloting and technology deployment, it will be more useful in terms of getting financial, knowledge and network support to have agencies such as TDB supporting the programme which is a specialised body under the administrative control of DST, as opposed to DST which is a large institution with many different functions. Both the second phase of INDEE and Platform for Innovative Cooling Strategies can benefit from the right institutional grouping on their respective platforms. Both these programs look to roll out commercial pilots, and can gain from institutions engaged in promoting technology entrepreneurship and technology transfer to industry. This linkage seems to be missing at the moment and hence these programmes should be nudged to get support from TDB, NRDC, NSTEDB etc. Another prospective beneficiary of this feature can be the winners of the Global Cooling Prize, who will now push their technical innovations into the commercial pipeline.

(b) **The analysis of successful programmes indicates the benefits integrating the activities at different stages of research and technology development on one platform.** For instance, the INDEE project is largely focussed on development and demonstration of CO_2 based refrigeration systems in India. Given the potential and use of natural refrigerants in room air conditioners in different parts of the world, the second phase of the project, INDEE+, can easily branch out and include R&D work on RAC systems as well, and thereby, utilise and apply the knowledge and expertise developed during project INDEE. For the Platform for Innovative Cooling Strategies, we recommend to segment the techno-business proposals as per the different technology levels being dealt with. For example, for a relatively mature technology, the nature of support and institution that can provide it is different from a nascent technology. This will provide more clarity for financial support as well as the institutions that can step in for the required mentoring.

(c) **An important component of institutional integration is combining diverse expertise and experience from different institutions.** For example, DSIR-affiliated institutions have a better understanding of industry's functioning while DST administered institutions know the university landscape intimately. Hence, we need to bring them into the fold to leverage their respective interfaces with different research actors and ecosystems. In this context, expanding the participation and engagement of CSOs and other private players with INDEE+ and other programmes is equally important.

(d) **As part of developing an interface structure between different institutions, the programmes are recommended to form an intermediary panel, whose main task is to liaise with the platform partners and facilitate better coordination.** Since this function requires stakeholder management as well as research management, independent public research organisations having a strong interface with industry and government bodies can be entrusted to perform this function. This is expected to improve the coordination and alignment among different stakeholders operating in a programme.

Apart from the recommendations to improve existing programmes, as highlighted above, lessons gleaned from success stories in India are also useful from the point of view of any new collaborative platform being established focussed on cooling technologies' R&D, demonstration and deployment. Table 5 shows how multiple dedicated agencies can be brought together, so that all aspects of programme management, collaboration and commercialisation can be addressed, depending on the focus of the programme.

The proposed institutional structure can afford us multiple benefits in managing and supporting large initiatives conceived to function on longer time frames, with a portfolio of projects, to improve not just knowledge and technology outputs but, given the impending growth and technology transitions envisaged in India, the desirable market outcomes as well. The focus on deployment is particularly crucial as there have been cases when despite successful technology development, not enough was done to create and expand the market for them. Hence, in the interest of real, material change, deployment and commercialisation must be at the core of the institutional foundation of a R&D and technology programme.

There have been cases when despite successful technology development, not enough was done to create and expand the market for its deployment.

> **In the interest of real, material change, deployment and commercialisation must be at the core of the institutional foundation of a cooling R&D and technology programme.**

Table 5 **Proposed institutional structure to support public–private collaborative cooling R&D**

Programme body	Institutions	Main responsibility
Steering committee	DST, DSIR, CSIR, MNRE, MoEFCC, MOP	Set the vision and objectives of the programme.
Consortium committee	DST, DSIR, CSIR, university and research labs, industry partners	Develop and expand the consortium through negotiations and trust- building exercises. Deliberate on technology development strategy and act as a forum for R&D and innovation partners to raise issues.
Intermediaries panel	Select public interest research organisations, industry representatives	Coordinate between different institutions and partners and facilitate external partnering with new and prospective members.
Technical committee	TIFAC, DST, universities and research labs, industry	Decide and assess the research agenda and R&D model for the platform.
Financial committee	DST, DSIR, industry partners, philanthropic funders	Manage and oversee the funding needs of the programme activities.
Operating council	DST, intermediaries, select consortium members, NSTEDB, NRDC	Responsible for the overall operational management of the programme including reviewing, collaboration facilitation, and stakeholder management.
IP management board	DST, patent facilitating centre, industry partners	Conduct all the IP-related negotiations, resolve queries and perform other related activities.
Outreach partners	Public interest research organisations, research labs, industry consortium	Ensure and organize effective benefits delivery, conferences, public events, demonstrations, and press outreach.
Deployment partners	DST, TDB, NSTEDB, NRDC, venture capital funds, investors	Plan and execute the task of taking technologies to market on different scales.

DST: Department of Science and Technology, Government of India
DSIR: Department of Scientific and Industrial Research, Government of India
CSIR: Council of Scientific and Industrial Research, Government of India
MNRE: Ministry of New and Renewable Energy, Government of India
MoP: Ministry of Power, Government of India
MoEFCC: Ministry of Environment, Forest and Climate Change, Government of India
TIFAC: Technology Information Forecasting and Assessment Council, Government of India
NSTEDB: National Science & Technology Entrepreneurship Development Board, Government of India
NRDC: National Research Development Corporation, Government of India
TDB: Technology Development Board, Government of India

Source: Authors' analysis

This institutional structure takes off from the existing institutions and mechanisms that already provide assistance- financial, technical, operational - to many RD&D initiatives across different sectors. This structure allows dedicated focus on the most critical facets of a research and technology development initiative, which we discovered in the earlier part of the report to be contributing to the success of such initiatives. For example, if we are dealing with the issue of coordination between different participants, an intermediary panel whose sole purpose will be to facilitate better coordination and interface between them, can go a long way in addressing this problem for a lot of future programmes.

In a similar way, instituting an intellectual property rights management board will help support negotiations on IP issues and emergent commercial complications on a case by case basis, rather than having a one-size-fits-all policy. This arrangement of assigning a special focus also applies to the aspect of deployment. Preparing a nascent technology into a viable product for the market requires deliberate effort. But at the same time, having ready tech-to-market pipelines on the platform do help emphasise the commercial nature of the endeavours. It signals a purpose for the R&D activities itself that the absence of such pipelines, in the form of investors and venture capital, will make difficult to establish.

The constituent institutions to perform the respective functions can vary from one initiative to the other, depending on the sectoral and research focus. However, what remains of critical importance is that these functions must be performed in a coordinated manner, and be vividly highlighted as such to make the overall governance of R&D activities effective.

6. Conclusion

Technologies that involve the use of high-GWP refrigerants or components that are not energy efficient which lead to global warming and climate change have to be replaced with sustainable technologies. The technology profile of the cooling sector necessitates changes as the current technology in use is environmentally unsustainable, and their applications are limited. Hence, the transition to sustainable technologies and identification of relevant applications across sectors needs R&D, product development, and innovation. More importantly, it has to be underscored that the success of such endeavours would critically depend on how well different actors in cooling collaborate with each other.

Since India's cooling sector requires a thriving R&D ecosystem, we engaged in a research to ascertain how this may be encouraged through the introduction of institutional reforms in existing innovation programmes dedicated to cooling. We started by examining some of the key public–private R&D collaborations that have led to successful outcomes and determined the underlying factors of success. These factors were then analysed in the form of the best practices that collaborative innovative programmes follow across many different areas such as policy vision, financing, intellectual property negotiations, intensity of collaboration and deployment strategies in order to increase chances of success, operational efficiency, etc. These institutional lessons were further contextualised and an initial set of recommendations were prepared for programmes *in general*. In other words, a summary of best practices and ways of operationalising them was offered by way of these recommendations.

Through the implementation of the best institutional practices in research programmes, we believe that the overall R&D and technology outcomes will become better. This will help us arrive at the goal of clean and sustainable technologies faster. These smaller goals are subservient to our larger goal to make the country a net-zero carbon emitter, which is indeed closely linked to reducing the carbon footprint of cooling applications. It is only going to be possible through the realisation of technology transitions in different end-use applications.

In terms of expanding the conversation around this topic, a fair bit of analysis is still required to be done to fix the incentive structure for different research actors to innovate in the country. There are more insights to be gained about how research in academia can be aligned and shaped in response to the industrial realities and priorities, not just in terms of a programme, but as engendering of a collaborative innovation ecosystem. In addition, a deeper investigation of the institutional mechanisms, and set-ups that support technology development in the country have to be undertaken to streamline the processes they follow. There may also

> **Institutional assessment for upgrading their capacity and outreach and building new functions within them must be conducted.**

be a need to assess the institutions for promotion of technology development in terms of upgrading their funding, capacity and outreach, and building new specific functions within them.

Going forward, questions related to cooling supply chains in India and the issues that import dependent supply chains pose to cooling R&D and adoption of new technologies will be examined. It will be a befitting complement to the attempts made by the Government of India to give a fillip to manufacturing in the white goods sector through a Production Linked Incentives (PLI) scheme. Further linkages between public research labs and industrial research will also be highlighted as part of the ongoing work on collaborative R&D.

As a final word, the success of the proposed recommendations will depend on the zeal and commitment with which they are implemented. Articulating the changes as the first step must be followed by a long process of canvassing with concerned authorities to discuss these changes and modulate them as per the specific context and identified opportunities and limitations.

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Annexure

Case study 1: INDEE

Introduction

As a collaborative research project between SINTEF, an independent research organisation based in Norway, Norwegian Institute of Science and Technology (NTNU), and the Indian Institute of Technology—Madras, INDEE was geared towards demonstrating the application of natural refrigerant technologies in developing countries in which high ambient temperatures are prevalent. The project focussed on creating a test bed to analyse the performance of CO_2-based small refrigeration systems in Indian conditions. The core idea was to establish the boundary conditions of the system, make the technology work in the laboratory, and thereby build a demonstration project for larger outreach.

Project preparation

The project was initiated when a call for research cooperation between Norway and India was made based on the interest of Norwegian partners to introduce clean energy solutions in developing countries. Once the draft proposal was accepted, SINTEF, a highly collaborative organisation, agreed to play the role of a coordinating partner. It is in the business of conducting contract-based science and engineering research. Also, NTNU and SINTEF have a long history of collaboration with each other. Therefore, the mature relationship between the two partners on the Norwegian side augured very well for expected outcomes of the project. On the Indian side, the demonstrated expertise of IIT Madras researchers in dealing with the emerging refrigeration technologies and the availability of required facilities provided much-needed vigour in the partnership. The weather in Chennai (where IIT-M is located) too offered ideal test conditions to monitor and develop the system.

Project support and dynamics

Leveraging the technological strengths of Enex, an Italian firm specialising in design and production of CO_2-based high-efficiency refrigeration systems, and Danfoss, a multinational refrigeration solutions company, a fully equipped, a 30 kW refrigeration system suitable for lab conditions was provided to IIT-M researchers. Since the refrigeration professionals and researchers are not familiar with trans-critical CO_2 refrigerant technology, the project developed from the very start a strong emphasis on knowledge production and training. The non-availability of spare parts in India was a major issue, which could have delayed the research work. However, the problem was navigated easily with the support of SINTEF, NTNU, and Danfoss, which ensured timely delivery of components.

Closure and impact

Outreach and knowledge dissemination were a key component of the programme achieved through demonstration, result-sharing events, and courses to teach participants to demonstrate how the unit performs. The researchers' role was not just confined to technical aspects of the project. Through the demonstration seminars, there was a distinct focus on the business aspects of technology development. The partners were very clear that if cost-efficient technology development would be pursued, it was extremely important to engage with the technical personnel in the long term to instil a business perspective in them.

After the formal conclusion of the project, further applications and development piggybacking on the technological strides made during INDEE have been proposed in the form of INDEE+. Keeping the institutional architecture almost identical, INDEE+ is focussed on technology deployment, implementation, and adoption of small and medium-size systems in supermarkets, dairy industry, and hotels. Installation of a CO_2-based refrigeration system in an Akshaya Patra kitchen in Bangalore is confirmed and already underway. INDEE+ is expected to generate a high commercial interest and already the involvement of Indian industry is much higher than it was in the first phase.

Drivers of success and key takeaways

Based on the project design, outcomes, and inputs from the research partners, we distil the key factors that shape the success of a research collaboration like INDEE.

- *Razor sharp focus*: The partners of a collaborative project should never lose sight of the core aim of the project. It begins with a clear evaluation of the project proposal, which in the case of INDEE was done very well. This was complemented by a precise definition of roles and responsibilities of the collaborating partners. Lastly, the execution stayed true to the project as planned on paper.

- *Industry–academia collaboration*: The industry brings to the project a practical approach, which supports and contrasts the more esoteric and computation-driven approach of academia. This principle applies to funding as well. Smart funding combines both industry and public funding for a common cause. A good programme also adopts a complementary approach of industry and academia with smart funding. In the case of INDEE, the financial cost was borne by the Norwegian embassy, but critical in-kind support was provided by the industry players.
- *Partners*: It is extremely important while choosing industry partners to understand their intention. This includes examining questions such as are they in it to support reverse engineering of an existing technology or to develop a completely new technology. In the event of multiple industry partners who happen to be competitors, they are to be given responsibility for handling different cases of the project. In terms of project benefits, it should be clearly specified as to what piece of information will be exclusive to the partner and what will be shared among all. Thus, the project should identify different elements for every partner from the point of view of technology transfer.
- *Training and capacity building*: For post-programme implementation to be successful, an important precondition is the availability of human resources familiar with the technology and expertise. For instance, one of the barriers to the adoption of natural refrigerant cooling technologies in India is the lack of servicing and maintenance professionals who can provide vital support to functioning systems. For such a servicing ecosystem to flourish, we require a large number of trainers and experts who can take up the task of training. This can be done most effectively if training is an integral part of the project conceptualisation with wide dissemination of benefits. Apart from the nodal researchers, several post-graduate and doctoral students were roped in to support the project. As a result, INDEE ended up facilitating quite a few theses and dissertations on CO_2 refrigerants. Also, the INDEE programme envisaged mid-programme training for the researchers at SINTEF laboratory in Norway. As part of technical team meetings, researchers from NTNU came to IIT-M to monitor and understand the progress made in the project. During the course of the project, several workshops were organised by the partners to generate interest in the larger stakeholder ecosystem about the new developments taking place. The success of these measures is reflected in the concrete outcomes achieved as a result, in the form of joint publications, conference presentations, and training workshops.
- *Outreach*: Although outreach is not a core component of research, its criticality in deciding the success of a research platform cannot be undermined. INDEE became INDEE+ only because of effective outreach done at regular intervals. It communicated the project development and thus prepared industry players to take the R&D efforts as potentially transformative and disruptive. Not only does it stoke interest, but also generates possibilities of further research, spin offs, and expansion.

Case study 2: CBERD

Introduction

As part of the US–India Partnership to Advance Clean Energy (PACE) initiative to strengthen energy cooperation between the two countries, the bilateral Centre for Building Energy Research and Development (CBERD) programme was launched in 2012. Designed as a five-year long programme commencing in 2013, it brought together multidisciplinary expertise from 11 leading research and academic institutions in the two countries to conduct collaborative research to promote building energy-efficient innovations. Despite many challenges, the programme succeeded in identifying research areas that were mutually beneficial to both countries and drew up unique R&D and collaboration models to optimise the overall effect of the programme.

Programme preparation

In terms of institutional structure, CBERD was administered by the US Department of Energy (USDOE) and the Government of India's Department of Biotechnology (DBT), and Department of Science and Technology (DST) with the support of the Indo-US Science and Technology Forum (IUSSTF). On top of the strong governance foundation, at the operation level, Lawrence Berkeley National Laboratory (LBNL) and Centre for Environmental Planning and Technology (CEPT)University were chosen as lead partners on the US and Indian sides, respectively. The lead partners then expanded the team and partnered with several research institutions on the basis of their strength and capabilities, thus forming an R&D consortium. The consortium had its responsibilities defined in terms of their assigned research verticals. In addition to the R&D partners, the programme also included over two dozen industry partners including architecture and engineering (A&E) firms, building and software product and service companies, developers, and deployment partners to facilitate co-sponsorship, co-development, and demonstration projects.

The programme team formulated a novel lifecycle performance assurance framework that integrated building IT systems with physical systems. Hence, three broad research areas were identified: (a) simulation and modelling, (b) integrated sensors and controls, and (c) monitoring and benchmarking.

Programme support and dynamics

The collaboration in CBERD was a programme design feature, which has been achieved through its researcher exchange for bilateral transfer of scientific approaches and methods. More than 40 researcher exchange visits occurred during the programme, resulting in international experience, access to new ideas, training on scientific approach and test beds, and technical assistance in capacity building. More than 50 per cent of the programme output is jointly credited. The knowledge sharing between researchers is complemented by the active participation by industry partners who provided the projects both cash and in-kind support. These exchanges have strengthened the relationship between CBERD partners, thus driving expansion of international networks of excellence in building R&D.

Closure and impact

CBERD could stake its claim to many achievements when it concluded after five years of functioning. A highly impressive amount of knowledge was generated as evidenced by more than 125 journal publications, conference proceedings, and technical reports. In addition, quite a few software tools for public use, prototype technologies, and material leading to products and best practices modules and policy guidelines were developed as deployable products.

Specifically, for India, capacity building in the form of training of researchers, ideas exchange, and creation of research infrastructure such as test beds, labs, and facilities has been of great value and importance in terms of giving impetus to future R&D activities.

The programme delivered benefits to both sides in spite of them being at a different stage in their building sector development (US building stock is almost saturated while India's is still going to develop a lot). Apart from the aforementioned ready-to-deploy outputs, co-development of inventions and technologies with real-world benefits based on the R&D work is underway. The institutional trust building has led to a continuity in relationship and the consortium is still humming with activity. For the first time, Building Energy Efficiency Higher and Advanced Network (BHAVAN), a fellowship programme on building energy efficiency, has been instituted to continue the agenda of forming research linkages between the two countries. As a whole the programme has been instrumental in engendering technical advancement in cutting-edge building technologies. New innovate–validate–demonstrate models have been established, which will accelerate market deployment of end use products. In terms of original IP creation, at least four patents have been granted in India and the United States, out of the work done in the programme. Several spin-off projects based on CBERD are still ongoing both in the United States and India. Incubating Market Propelled Entrepreneurial Mindset (IMPEL) programme to connect 'market-oriented skill sets with advanced scientific thinking' is one such prominent deployment platform whose birth is directly attributable to the success of CBERD.

Drivers of success and key takeaways

The programme custodians strongly believe that CBERD was an exemplary programme in the way it was planned, executed, and delivered outcomes. Some of the institutional and operational practices that ensured its stellar performance are the following.

- *Planning and management*: There is unanimous opinion that a lot of work went into deciding the specifics of the programme. It was based on a clear vision, backed by policy commitments where partners were ready to walk the talk. Formulation of research models and verticals and then integrating them as complementary parts of a singular whole was exemplary and considered a highlight of the programme. On the level of execution, the management was near perfect, attributed to capable research managers. Despite strong planning, there was flexibility to course correct the research focus.

- *Powerful platform*: The programme was able to incorporate some of the prominent players in the buildings sector: 100+ researchers, world-class R&D organisations, and 31 cost-sharing industry collaborators. Through many deliberations and smart project choices, even competitive industry players were accommodated in the programme. In terms of choosing the consortium partners, the programme leads were very thoughtful in selecting a healthy mix of start-ups, mid-sized companies, and large companies, which brought their unique strengths to the group. For example, large companies with their resources and market penetration can scale up really quickly, while start-ups and small firms can operate nimbly and develop products quickly.
- *Shared investment*: Though cost effectiveness was an important tenet of the programme, it attracted a significant amount of capital and investment. A total of USD 28 million was pooled between the USDOE, DST, and industry partners. The public investment was leveraged manifold as for every dollar of public money, US and Indian industry combined invested about USD 2.5. This became a great driver of success because the funding was symbolic of industry commitment to back research efforts to completion and deployment., The industry also provided all possible support by sharing resources, intelligence, and researchers.
- *Strong engagement*: The programme set new standards in engagement among the researchers involved across universities, institutions, and industry. With 18 joint workshops and conferences and 44 researcher exchanges, the intensity of collaboration in CBERD contributed substantially to enhancing the learning and capacity of researchers. Subsequently, the programme has given a great fillip to the culture of big R&D collaboration and cultivating a new crop of scientists and researchers.
- *Outreach*: The idea of course correction was probably an unarticulated principle of the programme, which led the CBERD team to present at many stakeholder forums to get constant feedback. These activities were instrumental in providing insights into new facilities, populations, and energy markets, which was highly useful for stakeholders not directly involved with the programme. Such outreach to take ongoing (not finished) work to stakeholders at regular intervals fetched inputs on better integration with demonstration and markets, thus keeping the programme in touch with and relevant for ground realities.

Case study 3: Global Cooling Prize

Introduction

The Global Cooling Prize is an innovation competition which seeks to award cooling solutions that create five times less climate impact than the room air conditioners presently in the market. It involves a large coalition of sponsors, administrators, and outreach partners. The key organisations include Rocky Mountain Institute (RMI), Conservation X Labs, CEPT University, Alliance for Energy Efficient Economy (AEEE), and DST. Launched in November 2018 amidst much fanfare, the prize has generated a considerable amount of interest among multinational air conditioning equipment manufacturers, independent innovators, start-ups, and civil society organisations. The support of Mission Innovation (MI) and extensive media coverage have enhanced the competition's profile and created an impression of a revolutionary and potentially disruptive moment for the room air conditioner industry.

The 5× innovation is the main thrust of GCP, which RMI claims is possible using the technologies available today. With extensive modelling, it has been shown that one of the pathways to achieve 5× impact using conventional technologies is implementing efficiency improvements to vapour compression cycle, advanced dehumidification, solar photovoltaic (PV) integration, and cooling economisation in one equipment. That aside, several other not in-kind technologies can also be innovated to leapfrog to 5× less impact. In this way, GCP has established the technological feasibility of the challenge.

As an effort to spur innovation, GCP has offered an unprecedented platform for practically anybody to productise by employing the available technologies and demonstrate it on a global scale. The innovation though is not in development of new technologies but rather in the way the GCP is structured. A rigorous prize criterion in combination with strict testing protocols have really made GCP different.

Institutional structure of Global Cooling Prize

Supervisory board

- Establish and provide guidance to the operating council
- To be composed of top lawmakers, policymakers, and sponsors

Operating council

- Responsible for design, planning, organisation, and implementation of the prize
- Establish technical review committee and investment committee
- Current members: RMI, Conservation X labs, CEPT University, and AEEE

Innovation advisers

- Global ambassadors to provide their independent guidance to operating council

Technical review committee

- Recommend teUnitchnical criteria, application requirements, and testing protocols to the operating council
- Select finalists and winning technology
- Independent and credible members

Outreach partners

- Support global marketing and outreach efforts under guidance of operating council

Investment committee

- No more than six entities interested in investing or supporting breakthrough cooling technologies
- Current members: Carrier, Danfoss, Trane Technologies, Third Derivative

Drivers of success and key takeaways

- *Substance + Style*: Global Cooling Prize is not just about glamorising next generation cooling innovation. A close look at the details of prize criteria and testing protocols speaks volumes about the rigorous and difficult conditions innovators will have to meet to reach the finals and eventually win the prize. In other words, the technical depth and expertise of the administrators inspires a lot of confidence among the participants. Beyond the innovation, the extremely effective outreach, information dissemination, and buzz creation have taken it to the next level. The prize is not simply about USD 1 million monetary incentive for participants, but it has become prestigious for large multinational corporations (MNCs).
- *Large coalition*: The GCP is truly global in character due to its association with a network of ambassadors and outreach partners including the Government of India, Mission Innovation, United Nations Environment Programme (UNEP), World Economic Forum (WEF), World Wildlife Fund (WWF), and Sir Richard Branson. In addition, GCP targets industry associations and major manufacturers around the world through regional workshops. Despite requisite funding available, the GCP has elected to engage with the Indian government at two levels: (1) there is a public–private partnership (PPP) angle to the prize and (2) the endeavour gets policymakers' sanction, which might pave the way for policy push to create a market for the transformative solution.
- *Favourable terms for participants*: There is no restriction of any sort on the participants. They can be small or large companies, start-ups, or standalone innovators. It is probably due to this freedom and openness that a large number of intent letters are received followed by slightly downsized volume of detailed proposals. Another important aspect of the platform is transparency. Non-disclosure agreements (NDAs) have been signed with all the applicants and between them there is strictly no information sharing. This fanatical protection of participants' intellectual property has made them trust the administering organisations and disclose their inventions without fear.

Case study 4: Platform for Innovative Cooling Strategies

The Platform for Innovative Cooling Strategies was launched at the World Sustainable Development Summit, 2019, to help translate viable technology ideas as pilots to market. It brings together the MoEFCC, National Resource Defence Council (NRDC), India, Shakti Foundation, and Honeywell, India, with The

Energy and Resources Institute (TERI) as its secretariat. The platform is conceptualised as a 'matchmaking' initiative that accepts proposals from myriad sources, engages in due diligence of evaluating their feasibility, potential impact, and relevance for the market, and thereafter sends it to the ministry for consideration. Thus, the platform bridges the discovery gap between technologies that need investment. This mechanism is meant for early stage, potentially lab-tested technologies, that can be further developed into a pilot in order to gauge their performance in real conditions.

As regards institutional structure, the platform is governed by three committees with representation from all the partners. It is made up of a core committee consisting of the founding members, a technical evaluation committee, and a financial feasibility committee. The proposals are first sent to the technical committee for appraisal. The details on how to submit proposals, their format, and parameters on which they are judged are clearly furnished by the committee. Thereafter, it goes to the financial feasibility committee to determine the required amount of funding. This mechanism is focussed around a sector which in the first cycle of proposals is identified as room air conditioners.

Since its launch in February 2019, the development has been really slow and the platform did not take off as expected. After one-and-half years, the platform has not been able to select the first compendium of proposals to be sent to the MoEFCC. There are many reasons for this slow progress, but mainly generating interest within the industry has been difficult and the COVID-19 situation has made the progress even worse. Also, since previously tested mechanisms of this kind do not exist, it takes time to convince people. Besides, the outreach in the programme is extremely low. Till today there is no dedicated website or a social media page for the platform.

We also find that the programme suffered from some institutional challenges. At the preparation level, the objective, scope, and focus of the platform were not strictly defined. This is crucial as people come with a wide range of proposals, most of which are not relevant to the platform. Hence a narrow channel is necessary to push it to the right people. There was also a lack of clarity on the role of stakeholders. With coordination comes intent, but that was missing in this case.

Case study 5: R290 demonstration project

The collaboration between Godrej and Boyce and German development agency, GIZ, came about in 2012 as a result of the International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in cooperation with the Government of India represented by the Ozone Cell, Ministry of Environment and Forests. It was conceived as a demonstration project for the conversion of production facilities for the manufacturing of split and window-type air conditioning equipment from halogenated chemicals to natural climate-friendly cooling agents.

The broader objective of the collaboration was to transfer the technical know-how and add human, entrepreneurial, and institutional capacities for diffusion of hydrocarbon-based application of air conditioning technologies in India.

The project saw Godrej and Boyce installing a production line for room air conditioners working on the R290 (propane) technology. Product certification and training too were an important part of the project. The tangible outcome of the project was that 180,000 R290-based room air conditioning units were produced in India. The other expectation was the proliferation of R290 technology in India to other manufacturers, which unfortunately did not happen. However, as a first of its kind endeavour to bring natural refrigerant-based technologies in India, eight years later, Godrej still remains the only manufacturer with the capability to produce R290 AC units in India.

The reasons for R290 not becoming a popular choice of manufacturers are beyond the remit of project collaboration. The collaboration successfully transferred the technology and developed in-house capacity at Godrej. However, it was the peculiar political economy of the RAC market, regulatory barriers, and business models that rely on Chinese imports that hindered the further progress of R290 in India.

Institutional reforms in financing, outreach and deployment can be the difference between successful and not-so-successful R&D platforms in India.

Image: iStock

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