CEEW
THE COUNCIL

SHEETAL
Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All

Technology Gaps in India's Air-Conditioning Supply Chain

Enhancing Jobs, Growth, and Sustainability

Himanshu Dixit and Shikha Bhasin

Report | May 2022

With 8 times increase projected in cooling demand over the next 2 decades, the room air-conditioning sector has a great manufacturing opportunity.

Image: iStock

CEEW
THE COUNCIL

SHEETAL
Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All

Technology Gaps in India's Air-Conditioning Supply Chain

Enhancing Jobs, Growth, and Sustainability

Himanshu Dixit and Shikha Bhasin

Report
May 2022
ceew.in

Suggested citation: Dixit, Himanshu, and Shikha Bhasin. 2022. *Technology Gaps in India's Air-conditioning Supply Chain: Enhancing Jobs, Growth, and Sustainability.* New Delhi: Council on Energy, Environment and Water.

Disclaimer: The views expressed in this report are those of the authors and do not necessarily reflect the views and policies of Council on Energy, Environment and Water or the Children's Investment Fund Foundation. The Foundation also does not guarantee the accuracy of any data included in this publication nor do they accept any responsibility for the consequences of its use.

Jamshyd N. Godrej, who is the Chairman and Managing Director of Godrej & Boyce Manufacturing Co. Ltd., is also a member of the Board of Trustees at CEEW. It is clarified that Mr Godrej was not involved in any capacity in the preparation of this report.

Cover images: Alamy (Front); iStock (Back).

Peer reviewers: The authors are grateful for reviews and feedback from the following experts who took the time to offer their insights and recommendations to improve this research: Mahesh Karlekar, Chief Executive Officer, Hytech ACR Private Limited; Balakrisha Mahajan, Founder- Director, TicketDesign; Jitendra Bhambure, Advisor, CEEW; and Deepak Yadav, Programme Associate, CEEW.

Acknowledgments: We would sincerely like to acknowledge the support and inputs provided by various individuals at different stages of the preparation of this report. Our special gratitude is reserved for the Children's Investment Fund Foundation which gave us the financial support to embark on this study.

For their time and expertise, we would like to extend our deepest thanks to Sushil Choudhury, BlowTech Air Devices; Vikram Murthy, ISHRAE; Nikhil Joshi, Alpha ICT; Debashish Roy, Bluestar; Shankar Deshpande, Ishwar Trading; Paras Sirohia, Cruise AC; Ashutosh Jha, Danfoss; Prakash Tamboskar, Mehta Tubes; S.P. Amrutkar, Samcon Industrial Controls; Vikash Sekhani, SAFE A&T; Jai Sarnobat, Prijai; Shankar Sapaliga, ICA; and Ajit Panicker, RATA. The final report owes a lot to the learnings based on the specific experiences and inputs of these individuals. It wouldn't have been possible without their contributions.

Props are due to the Outreach team for helping publish and disseminate this study.

Publication team: Kartikeya Jain (CEEW); Alina Sen (CEEW); Amit Dixit; Aspire Design; and FRIENDS Digital Colour Solutions.

Organisations: The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. It prides itself on the independence of its high- quality research, develops partnerships with public and private institutions, and engages with wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*. The Council has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

SHEETAL is a consortium of CSOs led by TERI and partners AEEE, CEEW and supported by Children Investment Fund Foundation to facilitate the implementation of the India Cooling Action Plan (ICAP) recommendations.

Council on Energy, Environment and Water
ISID Complex, 4, Vasant Kunj Institutional Area,
Vasant Kunj II, Vasant Kunj, New Delhi - 110070, India

About CEEW

The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public.

The Council's illustrious Board comprises Mr Jamshyd Godrej (Chairperson), Mr Tarun Das, Dr Anil Kakodkar, Mr S. Ramadorai, Mr Montek Singh Ahluwalia, Dr Naushad Forbes, Ambassador Nengcha Lhouvum Mukhopadhaya, and Dr Janmejaya Sinha. The 140-plus executive team is led by **Dr Arunabha Ghosh**. CEEW is certified as a Great Place To Work®.

In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*, including being ranked as **South Asia's top think tank (15th globally) in our category for the eighth year in a row**. CEEW has also been ranked as South Asia's top energy and resource policy think tank for the third year running. It has consistently featured among the world's best managed and independent think tanks, and twice among the world's 20 best climate think tanks.

In ten years of operations, The Council has engaged in 278 research projects, published 212 peer-reviewed books, policy reports and papers, created 100+ new databases or improved access to data, advised governments around the world nearly 700 times, promoted bilateral and multilateral initiatives on 80+ occasions, and organised 350+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the **CEEW Centre for Energy Finance.** In August 2020, **Powering Livelihoods** — a CEEW and Villgro initiative for rural start-ups — was launched by Minister Mr Piyush Goyal, Dr Rajiv Kumar (NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: The 584-page *National Water Resources Framework Study* for India's 12th Five Year Plan; the first independent evaluation of the *National Solar Mission*; India's first report on global governance, submitted to the National Security Adviser; irrigation reform for Bihar; the birth of the Clean Energy Access Network; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, *Swachh Bharat*; pathbreaking work for the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); critical minerals for *Make in India*; modelling uncertainties across 200+ scenarios for India's low-carbon pathways; India's largest multidimensional energy access survey (ACCESS); climate geoengineering governance; circular economy of water and waste; and the flagship event, Energy Horizons. It recently published **Jobs, Growth and Sustainability: A New Social Contract for India's Recovery**.

The Council's current initiatives include: A go-to-market programme for decentralised renewable energy-powered livelihood appliances; examining country-wide residential energy consumption patterns; raising consumer engagement on power issues; piloting business models for solar rooftop adoption; developing a renewable energy project performance dashboard; green hydrogen for industry decarbonisation; state-level modelling for energy and climate policy; reallocating water for faster economic growth; **creating a democratic demand for clean air**; raising consumer awareness on sustainable cooling; and supporting India's electric vehicle and battery ambitions. It also analyses the energy transition in emerging economies, including Indonesia, South Africa, Sri Lanka and Vietnam.

The Council has a footprint in 22 Indian states, working extensively with state governments and grassroots NGOs. It is supporting power sector reforms in Uttar Pradesh and Tamil Nadu, scaling up solar-powered irrigation in Chhattisgarh, supporting climate action plans in Gujarat and Madhya Pradesh, evaluating community-based natural farming in Andhra Pradesh, examining crop residue burning in Punjab, promoting and deploying solar rooftops in Delhi, Bihar and Meghalaya.

The authors

Himanshu Dixit
himanshu.dixit@ceew.in

Himanshu is a Research Analyst in the Technology, Finance and Trade team at CEEW. His primary responsibility is to support The Council's ongoing work in the cooling programme on the implementation roadmap of the India Cooling Action Plan and phasing down hydrofluorocarbons. He was trained as a chemist at the Indian Institute of Technology, Bombay and recently at the National Law School of India University, Bengaluru as a public policy professional.

"The GOI has put a lot of policy attention on manufacturing through large initiatives such as Make in India and AatmaNirbhar Bharat. If these are to become successful, we must examine deeply the factors that affect competitiveness. Air-conditioning as a targeted sector has the potential to contribute to jobs and growth in the economy, as well as establish domestic supply chains. However, technology remains a pain point for various reasons and must be addressed in addition to capital availability."

Shikha Bhasin
shikha.bhasin@ceew.in

Shikha is a researcher on climate change mitigation policies with a keen interest in innovation systems of low-carbon technologies. She is currently leading The Council's research on cooling and phasing down hydrofluorocarbons (HFCs). She has previously worked on regulatory frameworks required to meet India's Kigali Amendment commitments, and the institutionalisation of an R&D platform for supporting the phase-out of HFCs in India. A co-author of the *India Cooling Action Plan* (ICAP), she continues to represent CEEW as a member of ICAP working groups to implement its R&D and servicing sector goals.

"As the cooling market grows, can jobs and industrial growth be realised to benefit India's development? If so, MSMEs will be indispensable in transforming the supply chains. This report is a first undertaking to understand their needs and requirements, so as to achieve this ambitious end."

The infrastructure gap in key components of India's cold chain (such as pack-houses, reefer transport and cold chambers) is as high as 90%.

Image: iStock

Contents

Acronyms

B2B	Business to Business
BLDC	brushless direct current
CBU	completely built units
EMS	electronics manufacturing services
GOI	Government of India
GVC	global value chain
HDI	high density interconnect
HFC	Hydrofluorocarbons
HVAC	heating, ventilation and air-conditioning
IC	integrated circuits
ICAP	India Cooling Action Plan
MOSFET	metal–oxide–semiconductor field-effect transistor
OBM	original brand manufacturer
ODM	original design manufacturer
OEM	original equipment manufacturers
PCB	printed circuit board
PLI	production linked incentives
RAC	room air-conditioning
SME	small and medium enterprises
SMT	surface mount technology
THT	through hole technology
UNIDO	United Nations Industrial Development Organisation
VFD	variable frequency drives

Be it global warming mitigation, protection from extreme heat events, or economic efficiency, every metric points to India's need to enhance cooling and thermal comfort.

Image: iStock

Executive summary

The conversation about manufacturing, particularly in countries where it is low, is salient today as fundamental changes are afoot in the world. The energy transition is not going to be about energy alone; it will bring along with it big economic transformations. Industrial development remains a critical marker of the progress of a nation. As a fait accompli, the COVID-19 pandemic-induced economic disruption has brought into focus India's manufacturing industries and the need to build back the economy better. India, therefore, needs a new social contract that is able to deliver on the trifecta of jobs, growth, and sustainability (CEEW 2020).

The HVAC industry in India is one sunrise sector that has the potential to contribute to India's manufacturing story

The HVAC industry in India is one such sunrise sector that has the potential to contribute to India's manufacturing story. In an economic sense, it is one of those boats that rise with the rising tide. Economic prosperity creates better and bigger growth opportunities for the HVAC sector, which further fuel economic growth. With its climate footprint, it is indeed a crucial sector. It is also certain that the HVAC value chains will get reconfigured. Unsurprisingly, the India Cooling Action Plan (ICAP) has predicted eight times growth in cooling by 2037 based on the present penetration of around 5-6 per cent households, i.e. households with an air-conditioner. Further, the average growth will be 12 per cent up to 2027 and 10 per cent thereafter for the next 10 years (ICAP 2019).

India needs to meet the Kigali Amendment[1] commitments with the freeze starting in 2028 (Press Information Bureau 2016) and voluntary commitments to be achieved by 2030. The multiple transitions necessitated by these commitments will warrant investment in adoption of new technologies by large manufacturers in system design and by MSMEs who supply the subsystems and components for the sector. Given its potential for growth, it will in the process

a. **create many skilled and semi-skilled jobs**
b. **have transformational impact on productivity and the economy as a whole**
c. **offer opportunities to decarbonise India by reducing emissions embedded in its manufacturing supply chain and secondary emissions by reducing electricity usage**
d. **imbibe and absorb technology across the supply chain**
e. **create an ecosystem to become self-reliant**

1 The Kigali Amendment to the Montreal Protocol is an international agreement to phase-down and eventually phase-out hydrofluorocarbons (HFCs), chemical substances used as refrigerants in cooling applications. HFCs have high global warming potential (GWP) and cause many hundreds of times of heating as compared to carbon dioxide, thus earning the dubious distinction of being called super pollutants. Upholding the principle of differentiated needs and development circumstances of member countries, the Kigali Amendment provides for two groups within developing countries, thus allowing for different baseline and freeze years.

Thus, embedded in the larger discourses about the Indian economy, levels of industrialisation, and the need to become self-sufficient (a*atmanirbhar*), this report seeks **to explore the challenges faced by the heating, ventilation and air-conditioning sector in India**. By analysing the sectoral supply chain and **issues pertaining to research and development in firms, the report looks at the areas of technology adoption in small and big manufacturers to achieve global competitiveness**. In this sense, the report provides the argument and basis to set the agenda for working on technology bottlenecks in India to improve and develop the domestic value chain in the cooling sector.

The report explores and answers the following **research questions**:

1. Across the HVAC—particularly RAC (refrigeration and air conditioning) —value chain, where and what are the most pressing R&D and technology challenges impeding the competitiveness of firms?
2. What are the challenges and barriers to address the R&D needs of the HVAC sector?
3. What can be done to address the technology challenges of the RAC sector?

The peculiar challenges of the HVAC sector, non-availability of quantitative R&D data of firms and certain theoretical issues with measures of technological upgrading are some unavoidable aspects of this research. It, thus, leads us to choose a qualitative research method to collect insights from key persons of the HVAC sector.

The interviewees were shortlisted keeping in mind the following points:

- There are sub sectors in the HVAC & R (refrigeration) industry ranging from room AC to chillers and from retail refrigeration products to Cold Rooms and the technology requirement for each sub sector is different.
- There are quite a few HVAC and HVAC component segments.
- Each segment has its own value chain nuances.
- R&D and technology issues differ at different points in the value chain.
- Experience of successful and not so successful firms will vary. Struggling firms might provide a unique perspective as to the reasons for it.

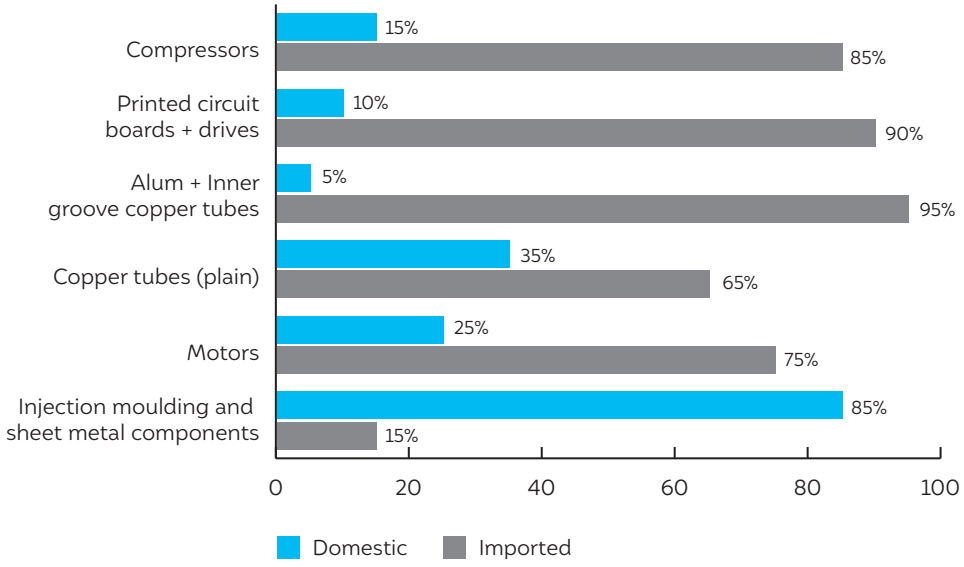
A. Component manufacturing and technology challenges

The manufacturing in HVAC sector is often described as following an import-assembly model. Some of the major components are sourced from countries that manufacture them at very competitive prices. These components are then assembled here by different manufacturers. Completely built units (CBUs) of ACs are also imported, although it has stopped due to India imposing a ban on this practice[2]. At a granular level, significant variations are seen in the share of domestically manufactured and imported AC components. The noteworthy point here is that the import share is higher in case of technology-intensive components like compressors and drives, while components which are relatively easy to manufacture are sourced from domestic market. Some of these nuances have been captured in Figure ES1.

The import share in RAC sector is higher in case of technology-intensive components like compressors and drives

2 In October 2020, the Directorate General of Foreign Trade (DGFT) moved to ban the import of CBUs of air-conditioners to give a boost to domestic manufacturing. About 28-30 per cent of total ACs sold in India were imported CBUs.

Figure ES1 Share of imports and domestically manufactured AC components



Source: Market research commissioned by CEEW

An interesting paradox of the Indian HVAC sector is that, despite the size and growth potential of the Indian market, not having scale is often cited as a major barrier to countering the dominance of imports. This is explained, in large part, by the fragmented manufacturing base in India. There are too many small and medium enterprises (SMEs), and even the large firms are not large enough when compared with their Chinese counterparts[3]. These structural constraints of the sector cause a number of technology handicaps.

An important facet of this technology challenge is that it is not the cutting-edge, state-of-the-art technologies, which are difficult to access and not available in India. Compressors and drives are examples of that. However, in a big measure, the challenges in many segments are of a type that can be characterised as 'small-tech' needs which helps manufacturers improve the overall quality and performance of their products. These include quality enhancement tools, new machinery, testing labs, etc. Access to these technologies and research infrastructure enhances the marketability of products and creates scope for further product innovation. This is particularly relevant for SMEs. Another part of the technology challenge is the lack of ability in firms to deploy new technologies to add new competencies to make their processes optimal.

In addition to these general challenges, we also identify specific technology challenges with the manufacturing of major air-conditioning components.

3 China is a globally dominant force when it comes to air-conditioning manufacturing. However, there might be several others that occupy the second and third spots.

Table ES1 Technology issues identified for different components

Component	% of imports	Technological and other issues
Compressors	More than 85%	• High investment needed • Process know-how layered, complicated, IP dependent • SMEs not involved even in subsystems or components that go in compressors
PCBs (assembly) & controllers	80+ %, manufacturing base for sub-components doesn't exist in India	• Complex supply chain • Circuit design skills absent • Miniaturisation a growing challenge • Quality systems need improvement (EMS vendors) • Scale needed in procurement of chips
Motors (BLDC + non-BLDC)	80% imported	• Raw material and magnets • China is too competitive • Other technological bottlenecks not clear
Heat exchangers (finned tubes)	Assembled in-house	• Process knowledge mature in India • Coating facility for copper and aluminium not here • MSME design capabilities lacking
Fans and blowers	20% imported	• Design capabilities in India-manufactured fans and blowers • Help needed in advance tooling development • Performance testing facilities needed
Grooved copper tubes	100% imported	• Manufacturing competitive due to high price of raw copper • Process know-how difficult to obtain • Quality concerns due to recycled copper • Duty structure of India vs FTA with few countries who have matured manufacturing base

Source: Authors' analysis

B. Way forward to address technology challenges

Quite a lot of technology challenges identified above require: a) better coordination and knowledge transfers across the supply chain; b) collaboration between industry and academia; c) access to critical infrastructure for R&D and quality improvement such as testing and accreditation labs. In addition, SMEs need to be given special focus to ensure the robustness of supply chains.

With the technology issues identified in the sector, it's clear that we need to take measures at different levels to improve the competitiveness and attractiveness of Indian air-conditioning enterprises and develop local options in the supply chain. These key issues and possible interventions have been mapped as follows:

Enhancement of vendor development programmes: Lack of process knowledge and product requirements is often cited as a handicap by small component manufacturers. Through better coordination between OEMs and SMEs, technical know-how and product knowledge can be effectively transferred and imparted to SMEs. This can help SMEs standardise, improve and adopt updated management processes.

Capital support for technology adoption: Component manufacturers are always trying to balance expected quality requirements with their bottomline. Their weak cashflow cycle makes these matters even worse. To improve technology diffusion and upgradation, debt-linked support in the form of soft loans can help SMEs acquire new machinery and facilities to bring their manufacturing units up to the mark. Technological upgradation will help in improving processes and demand for quality consistency.

Access to affordable public certification labs: For small players in the supply chain, cost of certification and compliance with standards is quite high. It is also an extremely important part of technology infrastructure to make the sector export-ready. Certification gives authenticity to the claims of the vendor as well as act as the first stamp of approval to manufacturers and tells buyers about various compliances the manufacturers adhere to. Low-cost certification facilities can mitigate these barriers and gaps, and enhance attractiveness of sellers. This can be achieved by building adequate capacity of labs and issuing licenses to provide affordable access to relevant players.

Industrial upgrading programmes: It is observed that inefficient management practices are followed in the MSME space for a variety of reasons. One of the major reasons is the availability of right people and expertise at desired wages. The knowledge required to rectify these issues can be imparted through a concerted effort of industry bodies and the government. This can be coordinated by international agencies like UNIDO to improve the factory floor practices followed by SMEs such as Six Sigma, The Toyota Way, etc. While most of the entrepreneurs have knowledge and vigour as a start-up in the initial days, they need help in devising growth strategies and management skills at different levels of business turnover. Targeted short courses diffused to the lowest level are needed. Cost of poor quality should be made an important management criterion.

R&D collaboration platform and opportunities: Technology diffusion with respect to standardisation of manufacturing processes and benchmarking is a persistent pain-point. An industry-academia-government platform can make this knowledge and research infrastructure accessible to a large number of players. Centres of excellence with SME focus can also have a wide-reaching impact. This needs to be an ongoing process. A forum of retired technical experts at different levels can be formed and integrated in such initiatives.

Both technology and fiscal support are required to scale-up manufacturing in the HVAC sector.

Image: Alamy

1. Introduction

Industrial development is one of the most important markers of the progress of a nation. Through competitive economic performance which generates income and facilitates international trade, industrial development becomes a major driver of poverty alleviation and shared prosperity in a country (ILO 2014). Although industrialisation contributes to the universal objective of growth and development, its impact differs based on the country's level of development. In developed economies, industrial activity is about achieving and maintaining higher productivity, adopting cutting-edge technologies, optimising the production processes, and reducing the effects of industry on the environment (UNIDO 2020). On the other hand, developing economies, being at a lower level of industrialisation, build their manufacturing industries fuelled by technology partnerships with industrially developed economies, innovation (at times, frugal innovation) and indigenously developed technologies (IMF 2019). Such an expansion of the manufacturing sector is crucial to create low-wage jobs, and thus help lift people's standard of living by reducing poverty. Over time, though, this also requires introduction and promotion of new technologies to produce essential goods and services for the market and not lose the competitive edge (Weforum 2018).

The production systems around the world will have to evolve to meet the climate challenge

The conversation about manufacturing, particularly in countries where it is low, is salient today as fundamental changes are afoot in the world. The energy transition is not going to be about energy alone; it will bring along with it big economic transformations. Be it the changes in the source of power supply from coal-based electricity to renewables-generated electricity, or the changes in manufacturing processes having high emissions intensity to zero-carbon or carbon-neutral processes, the production systems around the world will have to evolve to meet the climate challenge (United Nations 2021). At every level of industrial production and different points in the supply chain, various decarbonisation strategies are and will be implemented (Deloitte 2016). This process is already underway and will gain velocity in the coming decade.

The role of technology in decarbonising and greening our economies will be fundamental. Particularly in manufacturing, the path to rebuild and be competitive in the new economy will be paved through new-age technologies. There is also a consensus emerging that such technologies already exist. They perform well at laboratory and prototype stages (Scientific American 2021). However, the challenge before us is to escort such promising technology prototypes through the commercial valley of death[4] (PWC 2018). While not insurmountable, it isn't an easy task either.

4 The valley of death refers to the difficulty new technologies face in the period of their maturation. It is the time when significant financial resources are needed to boost the development, demonstration, performance and commercialisation of a proven technology.

Moreover, India aims to become net-zero by 2070 (PIB 2021). Subsidiary targets for reducing carbon emissions and carbon intensity of the economy have been set for 2030 (DST 2021). These goals mandate that we embrace the era of economic and technological churn. Significant financial bets on new technologies are required (UNFCCC 2020). In this context, however, the developing countries face the dual challenge of technology development and solutions for technology diffusion and adoption. The technology development is indeed a global endeavour and countries already at the forefront of innovation are more likely to be successful in it. Technology and knowledge diffusion across the manufacturing ecosystem such that there is widespread adoption of latest technologies and know-how of processes is a different problem (OECD 2009). This happens to be a major concern in developing countries such as India.

As a fait accompli, the Covid-19 pandemic-induced economic disruption has brought into focus India's manufacturing industries and the need to build back the economy better. India needs a new social contract that is able to deliver on the trifecta of jobs, growth, and sustainability (CEEW 2020). One is also tempted to add resilience as a defining feature of the economy we need to desperately reboot.

Thus, embedded in the larger discourses about the Indian economy, levels of industrialisation, and the need to become self-sufficient (a*atmanirbhar*), this report seeks **to explore the challenges faced by the heating, ventilation and air-conditioning sector in India**. By analysing the sectoral supply chain and **issues pertaining to research and development in firms, the report looks at the areas of technology adoption in small and big manufacturers to achieve global competitiveness**. In this sense, the report provides the argument and basis to set the agenda for working on technology bottlenecks in India to improve and develop the domestic value chain in the cooling sector.

1.1 Manufacturing in India and global value chains

The Indian manufacturing sector is one of the three pillars of the economy, the other two being the agrarian and services sectors. At 17 per cent of India's total gross domestic product (Reserve Bank of India 2021), it is a highly significant driver of jobs and incomes. Over the years, India has built competitive strengths in several sectors of the manufacturing economy. Even in high technology and knowledge-intensive industries like telecommunications (Mani 2012) and pharmaceuticals[5] (Mani 2009), India has left an impressive footprint. For a developing country like India, these achievements are a source of pride.

Speaking of manufacturing, the days of all production activities taking place in one country or on one factory floor have passed. In the world of complex products, manufacturing and production have become highly distributed processes. What has made manufacturing so distributed? It is the idea that no one country or firm can be competitive in every aspect of production. By leveraging the competitive advantages of different firms located across the globe, and availability of human resource both as labour and skilled manpower for innovation and adoption of new technologies as well to scale-up the business, we can achieve better products at lesser prices. This has led to the emergence of global value chains (GVCs).

Developing countries face the dual challenge of technology development and solutions for technology diffusion and adoption

What constitutes GVCs are inter-firm networks that focus on "sequences of tangible and intangible activities of value generation" in the making of a product (Gereffi and Stark 2016). Thereby, a firm's participation in GVCs is a function of what abilities it brings to the table. One of the manifestations of this is that it has given rise to the phenomenon of large companies operating at scale, specialising in one or several areas of the manufacturing

5 India is the largest manufacturer of generic drugs in the world, fulfilling 50 per cent of global vaccine demand and 25 percent of all medicines in the United Kingdom.

process, and thus dominating the market. Moreover, such companies have developed tremendous capabilities to adapt to the ever-changing economic landscape and markets (WTO 2021). At the same time, they are always able to offer products at highly competitive prices. All this sounds like good news.

The accompanying disruption due to climate change might lead to the narrowing of the gap between the abilities of different countries

The globally distributed and interconnected nature of economic production has also posed several challenges. One obvious problem is of trade imbalance: more buying than selling. Apart from the issue of economic dependence, sooner or later we confront the question: how does one pay for all the imports? For example, semiconductors are extremely critical components for many industries. Despite its best efforts, India has not been able to develop a semiconductor manufacturing sector in the country (The New Indian Express 2021). This has made us quite dependent on imports, on top of the import bill which comes with it (Business Standard 2021). Even if the money can be found and is not a concern, import dependence makes the economy more prone to supply-side shocks (World Trade Report 2021). In other words, India's key industries can be disrupted because of a precarious trade relationship or become interlinked with the economic fortunes of a distant place. This scenario ought to be mitigated.

Even in the context of mass commodities fabricated with known manufacturing technologies, some of our industries are not competitive enough to survive the market pressure (Financial Express 2020). This has led to the migration of many opportunities for creating and adding value domestically to other hubs of manufacturing outside India. Simply put, India underperforms in comparison to its ambition, requirements and latent capabilities. It seriously needs to develop competencies and competitive advantages in manufacturing to become a significant player in GVCs.

The worldwide movement for recalibrating the economies presents an invaluable opportunity. As climate change forces us to push the reset button, the accompanying disruption might lead to the narrowing of the gap between the abilities of different countries. Granted the edge will be with firms that have hitherto performed well. However, new competitive advantages will take shape (Fortune 2021). The sectors where we don't have a big presence right now might offer opportunities for intervention. This will come with its own set of challenges. But in this decade of economic transformation, we cannot miss the bus to building a thriving manufacturing ecosystem.

The HVAC industry in India is one such sunrise sector that has the potential to contribute to India's manufacturing story. In an economic sense, it is one of those boats that rise with the rising tide. Economic prosperity creates better and bigger growth opportunities for the for the HVAC sector, which further fuel economic growth. With its climate footprint, it is indeed a crucial sector. It is also certain that the HVAC value chains will get reconfigured. Given its potential for growth, it will in the process a) achieve many skilled and semi-skilled jobs; b) have transformational impact on productivity and the economy as a whole; and c) offer opportunities to decarbonise India by reducing emissions embedded in its supply chain and emissions that result from end-use applications.

With this background, the report explores and answers the following **research questions**:

1. Across the HVAC, particularly RAC, value chain, where and what are the most pressing R&D and technology challenges impeding the competitiveness of firms?

2. What are the challenges and barriers to address the R&D needs of the HVAC sector?

3. What can be done to address the technology challenges of the HVAC sector?

As climate technologies are mainstreamed, new supply chains of components and raw materials will be created.

Image: iStock

2. Research methods

Before getting into the approaches used to collect and analyse data, we have to take stock of the nature of the problems, and how they can be tackled and addressed. This includes specific constraints due to less sectoral knowledge, lack of data sources and other similar issues.

There also exists a large body of literature that examines the relationship of research, development, technology adoption, and technology diffusion with the firm's capabilities, competitiveness, and upgradation. To understand more about the linkages and nuances that govern these fairly complicated assimilation processes, we take a look at how technology issues have been studied for various value chains, and examined from both quantitative and qualitative perspectives. Through this, we hope to absorb methodological lessons and acquire a rich taxonomy of technology upgrading and diffusion in the context of value chains.

2.1 Industrial upgrading and technology development in global value chains

If there is a clear case for industrial upgrading, it is Indian manufacturing SMEs

Industrial or economic upgrading is a multidimensional concept that refers to the process of improvement by firms in order to become competitive and more profitable (Gereffi 1999). It can be of four types: function, process, inter-chain and product (Humphrey and Smitz 2000). The process upgrading and product upgrading are most relevant for our discussion. When firms change the method or organisation of production (Bhide 2009), it is called process upgrading. For example, the clustering of manufacturing firms to remain competitive. Product upgrading takes place when a supplier firm assumes the design functions in addition to manufacturing functions (Nathan 2017).

Industrial upgrading in the context of India needs particular attention. Indian manufacturing depends a great deal on SMEs[6]. About 90 per cent of the SMEs are involved in manufacturing, which contribute around 45 per cent of India's industrial output (IBEF 2011). Their ubiquity and importance in the Indian economy can't be denied. However, a large number of Indian SMEs continue to be uncompetitive due to lack of technology upgradation, poor human resources and ungainly marketing skills (Mukherjee 2018). If there is a clear case for industrial upgrading, it is Indian manufacturing SMEs.

6 The small and medium enterprises constitute a large sector in India. These enterprises are defined as per the composite criteria of investment in plant and machinery and annual turnover. For small enterprises, an investment of INR 1-10 crore with turnover of INR 5-50 crore is the criteria, while for medium enterprises, investment< INR 50 crore with annual turnover <INR 250 crore suffices.

Most manufacturing SMEs in India serve their immediate local demand, and participate in GVCs as suppliers of intermediate goods for larger firms active in the domestic and export market (CII 2018). With better infrastructure, adherence to standards, and technology innovation (CII 2018), many of these manufacturing SMEs can directly engage with global firms, thereby upgrading and improving their positions in GVCs (Nathan 2017). Examples from the automotive industry demonstrate how small auto-component suppliers went under a learning sequence as a response to survive and excel in GVCs (Tewari 2019). Likewise, there are other cases in mid-tech sectors where chasing low costs without upgrading resulted in 'the low-quality trap' (Tewari 2019), thus killing their prospects of becoming competitive.

R&D-driven technology development is also a critical factor in determining a firm's competitiveness[7]. Most studies attest the innovation outcomes and productivity gains to firms engaged in R&D. To add to it, value chains offer enabling conditions for inter-firm technology transfer (Baldwin 2016), which can reduce the gestation period of technology development.

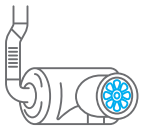
Further, in the context of value chains, the ability to work together with partners enables firms to integrate and link operations for increased effectiveness as well as embark on both radical and incremental innovation (Soosay 2008). Several studies also point out how increased coordination and collaboration can enhance the supplier's innovation, not just the manufacturer's, to achieve cost reduction (Kim 2000).

The phenomenon of technology diffusion in developing countries is perhaps more important (OECD 2015). It is the dissemination of frontier as well as input technologies among value chain participants, which is key to innovation across all the participants. Indeed, this hugely depends on the nature of the GVCs in question, as Gereffi, Humphrey and Sturgeon (2005) inform us. Another difference comes from the size of firms. Quite a few studies suggest that larger firms are more likely to absorb a new technology or innovation than smaller firms (Rose 1990; Attewell 1992; Andrews 2015). Reasons for this include a small circle of trust, limited capability to source and adopt technology and the inability to subsequently spread this knowledge among their peers (Jones-Evans 1998). So, small firms in developing countries are the real cause for concern as far as technology adoption is concerned.

Technology upgradation is certainly required in the HVAC sector across the manufacturing of all components, so that a larger share of global value can be captured domestically. However, the information on the latest technology trends in the sector, technology issues and thus their possible remedies doesn't exist. There is also the question of size of firms, and specific issues pertaining to technology adoption faced by small firms. Hence, we take stock of the challenges posed by the HVAC sector, and decide on appropriate methods to gather data thereafter. The next section lists out some broad features of the sector and outline the challenges in studying it systematically. Based on that, a suitable set of methods will be chosen to build the required evidence.

7 This is pertinent for large national and multinational firms that absorb the latest developments to push their knowledge frontier and technology capabilities. These activities often result in the creation of new intellectual property.

2.2 Challenges posed by the air-conditioning sector and other issues



The HVAC sector is highly competitive and cost plays a significant role in shaping which technologies are used and not used.

The HVAC sector presents a challenging set of conditions for research. The HVAC market in India is highly fragmented with the preponderance of SMEs in certain segments while the RAC sector being driven by large OEMs at varying levels of technology competency, with dependence on domestic and international suppliers of components.

First, apart from the structure of firms, the nature of the HVAC sector itself makes it difficult to collect information. The sector depends on very elaborate value chains where the production is distributed across the world. Granular knowledge of the sector is akin to understanding the supply chains of many different items, and the respective sub-components and materials needed to manufacture them. This is an overwhelming task.

Second, a large number of components are manufactured with many different technologies of different degrees of complexity, and several technologies are used in the production of a small component of an HVAC product. This makes the task of creating a taxonomy for manufacturing technologies employed in the HVAC sector daunting.

Third, apart from technologies, the sector is highly competitive and cost plays a significant role in shaping which technologies are used and not used. Hence, information about technologies alone will not tell us much about the sector; it will have to be contextualised in the complex business scenario in which the Indian firms operate. It also rules out a direct comparison of technologies and know-how employed by other international firms with Indian HVAC firms as the business conditions are different. Great care will have to be taken to sufficiently understand their business, trajectory of their learning over the years, and what technological challenges they face currently.

The research, thus, requires a deep-diving with key persons in the HVAC sector, preferably with years of experience dealing with different technologies and changing market dynamics. Only then can the economic context be understood with prevalent technology diffusion and challenges thereof.

Issues with empirical measures of technological upgrading

Another important aspect to be underscored is the inherent issues with empirically measuring the technology and R&D-based upgrading in firms. Measures of patents and R&D expenditure are less informative in developing countries as R&D in these countries is used for catching up and adoption to meet local conditions in applied format rather than pushing the frontier of knowledge (Verhoogen 2021). As far as measures of technology use are concerned, direct information is very difficult to obtain (Verhoogen 2021). Also, the rate of technology adoption is not informative enough to make definitive conclusions about technology challenges. In addition, specific manufacturing technologies can be captured only with narrow surveys. On top of all this, an overarching challenge and issue is the availability of data to carry out this analysis.

These challenges point us in the direction of in-depth qualitative research design as a potential way to overcome various challenges and issues. This is discussed in detail in the next section.

2.3 Qualitative B2B/industrial market research

The peculiar challenges of the HVAC sector, non-availability of quantitative R&D data of firms and certain theoretical issues with measures of technological upgrading are some unavoidable aspects of this research. It, thus, leads us to choose a qualitative research method to collect insights from key persons of the HVAC sector. This particular method is termed as qualitative B2B market research[8].

Business to business (B2B), and particularly its industrial segments, requires a significantly different approach to market research because of the importance of both performing and interpreting research in the business context. Sophisticated research techniques, while valuable, are less important than understanding technical product applications or complex business models. In B2B market research, you not only need to get the data right, you also need to be a strategist and approach each research project as a business-case analysis.

Another challenge here is that while conducting interviews you might have to get your respondents to divulge sensitive, semi-confidential information about their organisation's activities. This includes information about their clients, their requirements and preferences, how a business relationship was forged, etc. As a consequence of dealing with complex interconnecting pieces of information, you must be familiar with the business environment and basic product knowledge to be able to ask probing questions and hold a conversation about technology aspects of the business.

Interviewing strategy

The interviews, in the first instance, were conducted to gather a lot of real-world information to form an initial understanding of the topic itself. This information was then used to provide a description or status of R&D in the sector and what the pain-points are from the perspective of technology.

The interviewees were shortlisted keeping in mind the following points:

There are sub sectors in the HVAC & R (refrigeration) industry ranging from room AC to chillers and from retail refrigeration products to Cold Rooms and the technology requirement for each sub sector is different.

- There are quite a few HVAC and HVAC components segments.
- Each segment has its own value chain nuances.
- R&D and technology issues differ at different points in the value chain.
- Experience of successful and not so successful firms will vary. Struggling firms might provide a unique perspective as to the reasons for it.

The information collected in the interviews was triangulated with other sources of information such as company websites, annual disclosures, market intelligence, etc. The table below provides the number and type of interviewees contacted for this study. The information collected through interviews was also supplemented with three focus-group discussions with industry stakeholders.

In B2B context, understanding technical product applications and complex business models is of primary importance

8 For more, check https://www.hello-adience.com/blog/insights/how-to-conduct-b2b-qualitative-research/

Table 1 Respondents' type and numbers

Value chain function	Type of firm	Number interviewed
Original equipment manufacturer	Large Indian subsidiary of an MNC	2
Original equipment manufacturer	Large Indian companies	4
Component manufacturers	Small and medium enterprises	12
Trading firms	Small and medium enterprises	3
Industry associations	Sector-specific focus	3

2.4 Analysis of trade and industry data

Trade data can also prove to be an extremely useful resource to understand and map the existing supply chains. Using relevant Harmonised System (HS) trade codes, we try to assess the import dependence in the sector as well. Also, the industry data from Chinese industry watch ChinaIOL.com is gathered and analysed to understand the trends in air-conditioner and components manufacturing. As China is the leading manufacturer of many HVAC components, it is useful to look at how these parts are being manufactured and used as per type, capacity, and refrigerant compatibility. Apart from this, studies have been commissioned to gather sensitive supply chain data from various firms. These data points have been compared and vetted by industry experts to arrive at the status quo of supply chains and manufacturing in the sector.

The next section aims to look at the growing economic opportunity in the HVAC sector, the predominant business models adopted by the firms, and how these choices have shaped their supply chains.

The high percentage of import of components and finished units in HVAC sector points to the need to localise the supply chains.

Image: Alamy

3. HVAC supply chain mapping

To identify the technology issues, it is important that we first build an understanding of the supply chain of crucial AC components. More often than not, the ability to deploy technology depends to a large extent on favourable market forces and business opportunities. Hence, we start by looking at the growth potential of the HVAC sector to get a sense of important segments. Thereafter, we map the HVAC components supply chain, its key actors, and their functions.

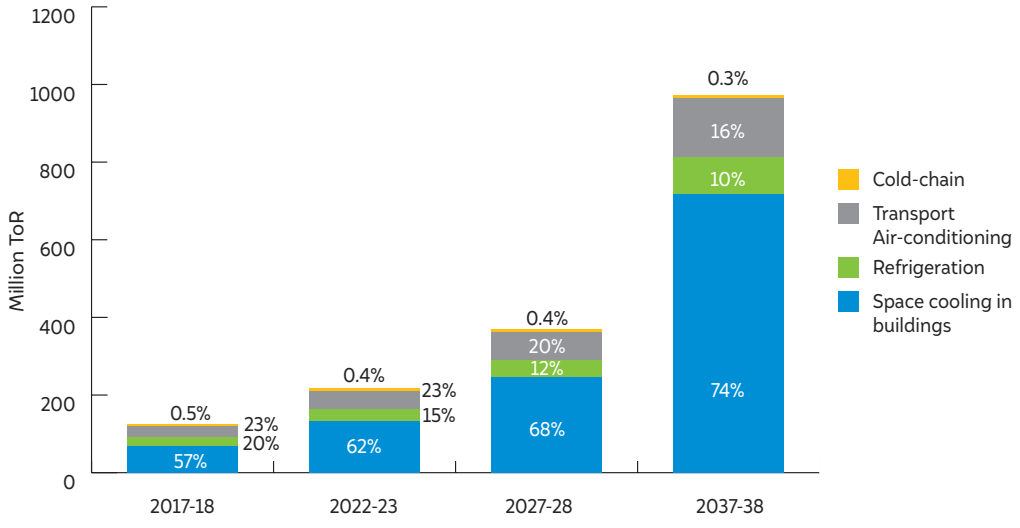
By 2037-38, the demand for space cooling in buildings will register the most significant growth, i.e. 11 times the demand in the reference year (2017-18)

3.1 India's HVAC sector: What the future holds

The most comprehensive attempt to develop a policy framework for the HVAC sector has been the India Cooling Action Plan (ICAP). It was published in 2019 with the aim to reduce the consumption of refrigerants and energy intensity of the sector. It largely focuses on cooling, which is also the largest component of the HVAC sector in India. There are several reasons for the need to have a concerted plan for the HVAC sector. These pertain to a) potentially high demand for cooling in coming years; b) its impact on climate and environment; and c) the large energy consumption for heating and cooling applications.

Specifically, when it comes to cooling demand, one notes a tremendous scope for the growth of the sector. For instance, consider the following data point: in terms of aggregate tonnage of refrigeration (ToR), by 2037-38, the total demand will be roughly eight times of what it is presently (Ozone Cell 2019). A more granular picture of the growth potential of the sector emerges from figure 1. It makes clear the point that across different HVAC segments, the demand will increase many folds. Within this aggregate increase, however, the demand

Figure 1 Sector-wise projection of cooling demand over 20 years



Source: Ozone Cell (2019)

for space cooling in buildings will register the most significant growth, i.e., 11 times the demand in the reference year (2017-18). These projections are based on a robust analysis of key variables, which include economic development, rising incomes, expansion of the aspirational class, rate of urbanisation, etc. The trend growth of these variables eventually tells us about cooling growth.

The unprecedented growth in the HVAC sector is a huge economic opportunity, which India must seize to become self-sufficient in the sector

In the space cooling of buildings, one notes that four technologies or product categories are dominant. These are also the major product offerings of the HVAC sector. They are a) room air conditioners; b) chiller systems; c) variable refrigerant flow (VRF) systems; and d) packaged DX. Importantly, among these products, the share of room air conditioners in aggregate tonnage is the highest.

What about the growth in these product categories? The existing trends of the last few years and inputs from industry experts suggest that the sale of room air conditioners is set to grow at 9-10 per cent CAGR in a low-growth scenario. However, it can be as high as 15 per cent CAGR in a high-growth scenario (Ozone Cell 2019). Chiller systems, on the other hand, will grow at 5-10 per cent CAGR depending on compressor type classification (Ozone Cell 2019). The HVAC industry experts also expect the low-efficiency chillers to be replaced by high-efficiency ones in the near future. When it comes to VRF (variable refrigerant flow) systems which have high-technology components requirement of controllers for the functioning, about 15 per cent CAGR is expected in the next decade or so owing to its energy efficiency as compared to conventional systems resulting in increasing popularity in certain segments. The Packaged DX market will not grow as much and only see a modest 5 per cent growth (Ozone Cell 2019). Table 2 shows how the market size of these product types varies as per the aggregate tonnage of refrigeration in the next two decades.

Table 2 Tonnage of refrigeration-based HVAC equipment stock

Product types	Stock in 2022-23 (130 million ToR)	Stock in 2027-28 (245 million ToR)	Stock in 2037-38 (720 million ToR)
Room AC	85%	87%	88%
Chiller system	7%	6%	5%
VRF system	4%	4%	5%
Packaged DX	4%	3%	2%

Source: Ozone Cell (2019)

All projections indicate that because of a number of factors, the demand for HVAC products is set to explode. The sector might see an unprecedented growth. This is a big economic opportunity, and one that India must seize in order to achieve self-reliance in the HVAC industry. The dependence on HVAC imports must be decreased. However, this poses questions like what is the status of HVAC manufacturing in India, which areas of the supply chain depend on imports, what are the technology issues therein, and why these issues continue to persist, etc. We explore all these issues later in the report.

In the next section, how manufacturing is structured in the supply chains is analysed. This will help in drawing a cognitive map of the sector, its various players and their responsibilities.

3.2 HVAC supply chain: Actors and their functions

The HVAC industry follows a mix of different models which greatly overlap depending on product portfolio, manufacturing capacity and existing supply chains

Manufacturing in the HVAC sector is highly distributed, i.e. parts and components of air-conditioning products are made in lots of different firms specialising and competitive in specific kinds of manufacturing. The supply chain is structured around what is called a 'lead firm'. A lead firm is usually a large company responsible for functions like developing and designing of products, sourcing the right components, assembling, marketing of products to end-consumers, etc. A little upstream in the supply chain, there are the component manufacturers. These manufacturers depend largely on lead firms for their business. Further upstream, there are material suppliers and producers which provide basic raw material for component manufacturing.

Depending on the work and functions outsourced, the business models of firms can be understood. Broadly, the HVAC industry follows a mix of different models which greatly overlap depending on product portfolio, manufacturing capacity and various other considerations. Business models are useful to understand the value-addition process at different stages of the supply chain.

a. **Original equipment manufacturers (OEMs)**: In supply chains, the lead firms facilitate the design and manufacturing of products in whole or in part. The process of research, product development and design, specification of components, etc. is controlled at this level. The cases where, apart from manufacturing, product design and product development functions are also internalised within a firm, original design manufacturer (ODM) replaces the term OEM. There are original brand manufacturers (OBM) as well that sell products made by another company under its own name. In this context, the OEMs are sometimes also referred to as value-added resellers, i.e., companies that add features or services to a product, or sell it as part of an *integrated* product.

   Specifically, in the air-conditioning industry, it is difficult to draw a line between the OEMs, ODMs and OBMs. This is because these functions are not clearly demarcated, and a lot of the time, the lead firms use all or some of them to meet their requirements. For instance, contract manufacturing is an established practice in the Indian HVAC industry. In this form of outsourcing, the lead firm approaches a manufacturer with its designs to carry out the manufacturing process, and later sells the products under its brand. As such, it is a combination of ODM and OBM business models. The same company might also import completely built units (CBUs) and sell them in the domestic market as its own, which is more aligned with the OBM approach.

b. **Electronic manufacturing services (EMS) vendors:** Over the years, electronic components have become a significant part of many consumer products. Even in HVAC, which works primarily on application of mechanical concepts and parts, electronics have come to play a significant role in product enhancement and improvement. EMS vendors or companies essentially function as contract manufacturers to aid OEMs. They provide product design, circuit board fabrication and layout, software design, testing, repair and many such services to the OEMs. These are categorised separately as only a small fraction of EMS vendors are integrated as part of the HVAC supply chains and follow their own complex manufacturing and supply chain ecosystems. However, they need attention as they form a significant cost component for OEMs, and will be central to a lot of future product development.

c. **Component manufacturers and suppliers:** These are essentially companies specialising in components or subsystems used in the final assembly of the HVAC product. Most manufacturers have capabilities in manufacturing at low cost while for designs and specifications they rely on the lead firms. For specific requirements, the lead firms have to transfer the required know-how to these companies. These include manufacturers of fan and blowers, DC motors, injection-moulding components, refrigerants, etc. In the Indian context, this aspect is particularly important to note. The Indian HVAC component manufacturing comprises a lot of small and medium-sized players which need to be supported during the manufacturing phase. Why this is so will be explored in detail later in the report.

The Indian HVAC component manufacturing comprises a lot of small and medium-sized players which need to be supported during the manufacturing phase

d. **Sub-component manufacturers and suppliers:** The component manufacturers depend on sub-component makers for sourcing on important parts of subsystems or sub-assemblies. EMS vendors, for instance, need hundreds of small sub-components such as capacitors, resistors, MOSFET, diodes, etc. to assemble and mount on a printed circuit board (PCB), and for the manufacturing of compressors, outdoor fans and indoor blower control boards as well. Wires, tubes and sheets used for making many other components are also manufactured in these firms. Most of these small components are standardised and no design or manufacturing input is required from the client firm downstream. These firms, like EMS vendors, are also integrated in different sectoral supply chains because of their utility in other sectors and industries.

e. **Material suppliers:** This is the most upstream point in the supply chain at which materials used by sub-component and component manufacturers, OEMs, etc. are supplied. These include copper, aluminium, steel ingots, plastics, chemicals for refrigerant production, etc. The quality and purity of material becomes important for various manufactures and, as we shall see later, plays a role in determining their competitiveness.

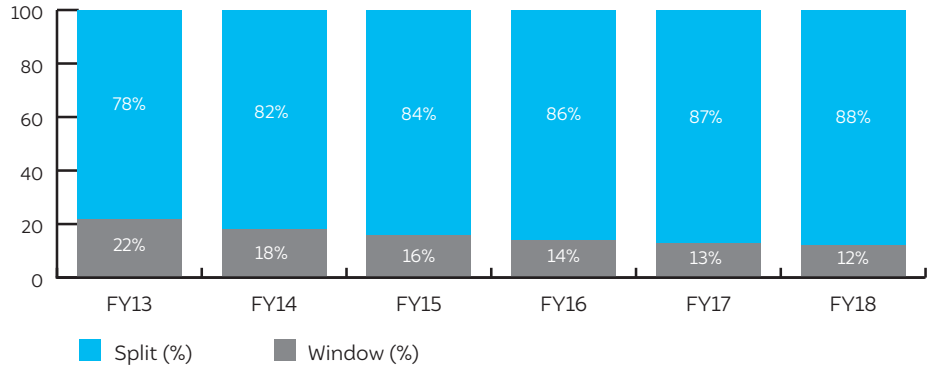
4. Manufacturing of key room air-conditioning components

Image: iStock

In order to understand the cost and technology constraints in the air-conditioning sector, we will have to begin by focussing on key components, their importance to manufacturers, and the status of their manufacturing in India. As there are too many components, the discussion will be limited to high-value components and sub-assemblies only.

For reference, we take the most popular size and model in the Indian market, i.e., a split 1.5-ton AC, which comprises about 70 per cent of the market, and the rest 18 percent is captured by 1.0- and 2.0-ton varieties, as shown in figure 2. It continues to displace window AC as the preferred choice of consumers.

Figure 2 Split ACs share in Indian market



Source: Motilal Oswal Financial Services (2019)

Compressors, PCBs, fans and blowers, heat exchangers and copper tubes/valves and aluminium contribute close to 75% of the manufacturing cost of air-conditioners

To understand which AC parts are most important in terms of cost and manufacturing, the following table offers a 'bill of materials' as percentage of total manufacturing cost of the air-conditioning unit.

Table 3 Bill of materials of a non-inverter 1.5-ton split AC unit

S. no.	Component	% of total cost
1	Valves	2-3
2	Fan motor	8-10
3	Compressor	30
4	Sheet metal	5
5	Fan blade	2-3
6	Blower	2-3
7	Aluminium + copper tubes	20
8	Printed circuit board/controllers	20
9	Others	5-8
	Total	**100.0**

Source: CEEW analysis

The approximate bill of materials in table 3 tells us that

(i) Compressors comprise a lion's share of 30 percent of the AC manufacturing cost

(ii) Printed circuit boards or controllers share about 20 percent of the cost

(iii) Fan motors account for 8-10 percent of the cost

(v) Aluminium and copper are expensive raw materials and share about 20 percent of the total cost

It is clear from the cost comparison of different components that compressors, PCBs, fans and blowers, heat exchangers and copper tubes/valves and aluminium are broadly of interest. These components contribute close to 70-80 per cent of the manufacturing cost of air conditioners. What we need to examine now is their manufacturing and procurement by different firms in the sector.

4.1 Compressors

Compressors are one of the most important components in any HVAC device. These include devices of all sizes ranging from small 1-2-ton room air-conditioners to large 50+ ton commercial cooling systems. Depending on the application, therefore, the compressor type changes as well. Listed below are the compressors used for specific applications.

a. **Scroll compressors:** Designed for advanced cooling and refrigeration, scroll compressors or pumps are largely used for commercial applications or in central cooling systems.

b. **Reciprocating compressors:** Mainly used to displace gas at high pressures, reciprocating compressors find use and application in refrigeration, but can also be used for cooling in inclement climates.

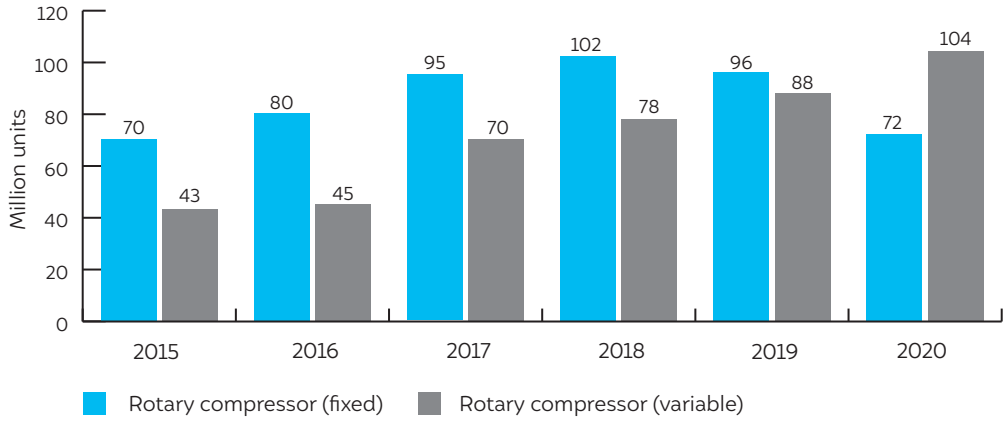
c. **Rotary compressors:** Placed between scroll and reciprocating compressors in terms of capacity, rotary compressors are largely used for room air-conditioning systems.

A discussion on manufacturing trends of rotary compressors is most salient. Firstly, it is important to note that two kinds of rotary compressors are used in air-conditioning: fixed speed and variable speed, and both have a significant market share. Secondly, from a global supply chain standpoint, it must be said at the outset that no discussion about compressor manufacturing is complete without China. With more than 200 million units (JARN 2019) delivered, China boasts upwards of 80 per cent of global RAC compressor production. Thailand grabs the second spot with production capacity of about 15 million compressors (Nicholson 2019). With these data points, it's easy to conclude that China remains the most dominant and competitive in compressor manufacturing, and, therefore, Chinese compressors figure at the top in export markets as well.

Next, we look at the split between fixed- and variable-speed compressors. Figure 3 show how the two types are faring year on year. The data from the Chinese industry reveals that the variable speed compressors, owing to their technological superiority and performance are produced more and more, thus gaining new market share. With increasing emphasis on energy efficiency and performance, the suggested trend of variable-speed compressors cornering higher share of use in the RAC industry will hold.

When it comes to India, compressor manufacturing doesn't happen at the scale that is needed. In some ways, India is a new kid on the block. However, increasing cooling demand and rising incomes are pushing up the demand for room air conditioners. These macro trends suggest that a whopping 300 million air-conditioning units will be sold in India by 2037-38 (Indiaspend 2021). Such projections have attracted global players in the air-conditioning supply chain to set up manufacturing facilities in India to cater to the massive domestic demand, as well as regional markets like the Middle East. With 5-6 per cent penetration of room air conditioning among households, which is fairly low, there is good ground for the confidence that it will grow at a more than healthy rate.

Figure 3 China's total production of fixed-speed and variable-speed rotary compressors



Source: ChinaIOL.com

In 2018, Highly India was responsible for production of two-thirds of India's compressor manufacturing capacity, with plans of expanding it from 2 million units to 4 million units by 2021 (Nicholson 2019; Highly India 2018). The other compressor plant is operated by Tecumseh India and Emerson, which manufactures about one million units of R-22 compatible compressors. Tecumseh compressors are largely supplied to Indian OEMs for refrigeration applications, while Highly India is able to export a portion of its output to the Middle East market as well owing to its product specification and quality. Tecumseh and Highly are Indian subsidiaries of fairly large American and Chinese firms, respectively. Their India operations represent only a fraction of their total manufacturing capacity.

In terms of type of rotary compressors, India has manufacturing capacity only for fixed-speed units. For variable-speed compressors, which includes the extra component of drives, it largely depends on imports of units manufactured in China. This poses considerable supply chain dependence as variable-speed compressors are used in about 40 per cent of total split RACs sold, with shares increasing every year.

4.2 Drives and controllers

It would not be an exaggeration to say that the share of electronic components in any consumer product has increased tremendously. Not only has it improved user experience, it has enabled us to make the products efficient in many ways. In the HVAC sector, with increase in complex control features, a lot of enhancements have been made to the microcontrollers and drives for variable-speed compressors, as well as the printed circuit boards (PCBs) over the years.

The temperature control devices maintain the proper temperature inside the room as per our comfort requirements. The setting of the temperature is done by the user manually or automatically using the remote-control device of the air-conditioning system. One of the most commonly used devices for controlling the room temperature is the room thermostat.

In terms of global manufacturing, Taiwan and China command a dominating presence accounting for more than 90 per cent of semiconductor production. Taiwan Semiconductor Manufacturing Company (TSMC) is the world's largest and most valuable semiconductor foundry. It has more than 70 per cent of the global market share of semiconductor production and designing.

India doesn't have a semiconductor manufacturing base. Most of the wafers and other subcomponents are imported from China, Taiwan, Japan and the US. In terms of design capabilities though, India has developed a fair bit of competency. Particularly in the non-RAC segment of the HVAC sector, the controller design is becoming a core technology and is not outsourced. Additionally, using surface mount technology, the assembly of circuit boards is increasingly done domestically. The control boards for larger air-conditioning equipment are also manufactured within India. Estimates for the percentage of PCBs manufactured in-house by OEMS or procured from local producers vary significantly. Some accounts suggest it is as high as 50 per cent, while others put it in the range of 10-20 per cent.

4.3 Heat exchangers

In the non-RAC segment of the HVAC sector, the controller design is becoming a core technology and is not outsourced

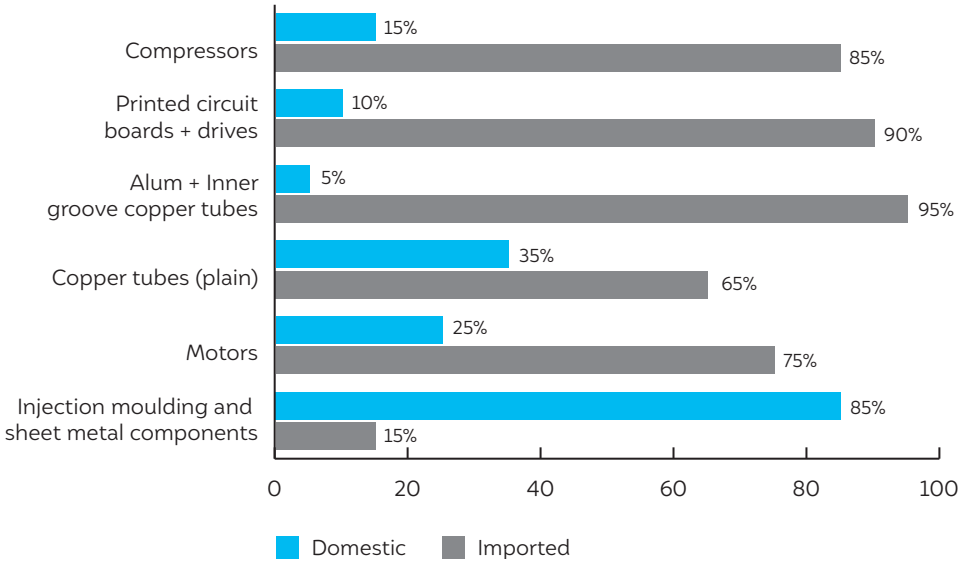
Heat exchangers are essential elements in the air-conditioning system. They are used to transfer heat from the refrigerant to the ambient environment, thus providing the cooling needed. Fin- and tube-type heat exchanger coils are made of copper and aluminium, where copper is used for tubes and fins are made up of aluminium.

Economies of scale are key to make heat exchangers at a competitive price. Since final cost plays the decisive role, lowering it at all stages of the production process is very important. This includes procuring the raw material such as high-grade copper and aluminium at cheap prices, maintaining precision in manufacturing, optimising the production time and reducing the labour costs. All these factors depend to a large extent on the competitiveness of the economy as a whole, where land, labour, and cost of capital all play their part, and help deliver the final output at a desirable cost.

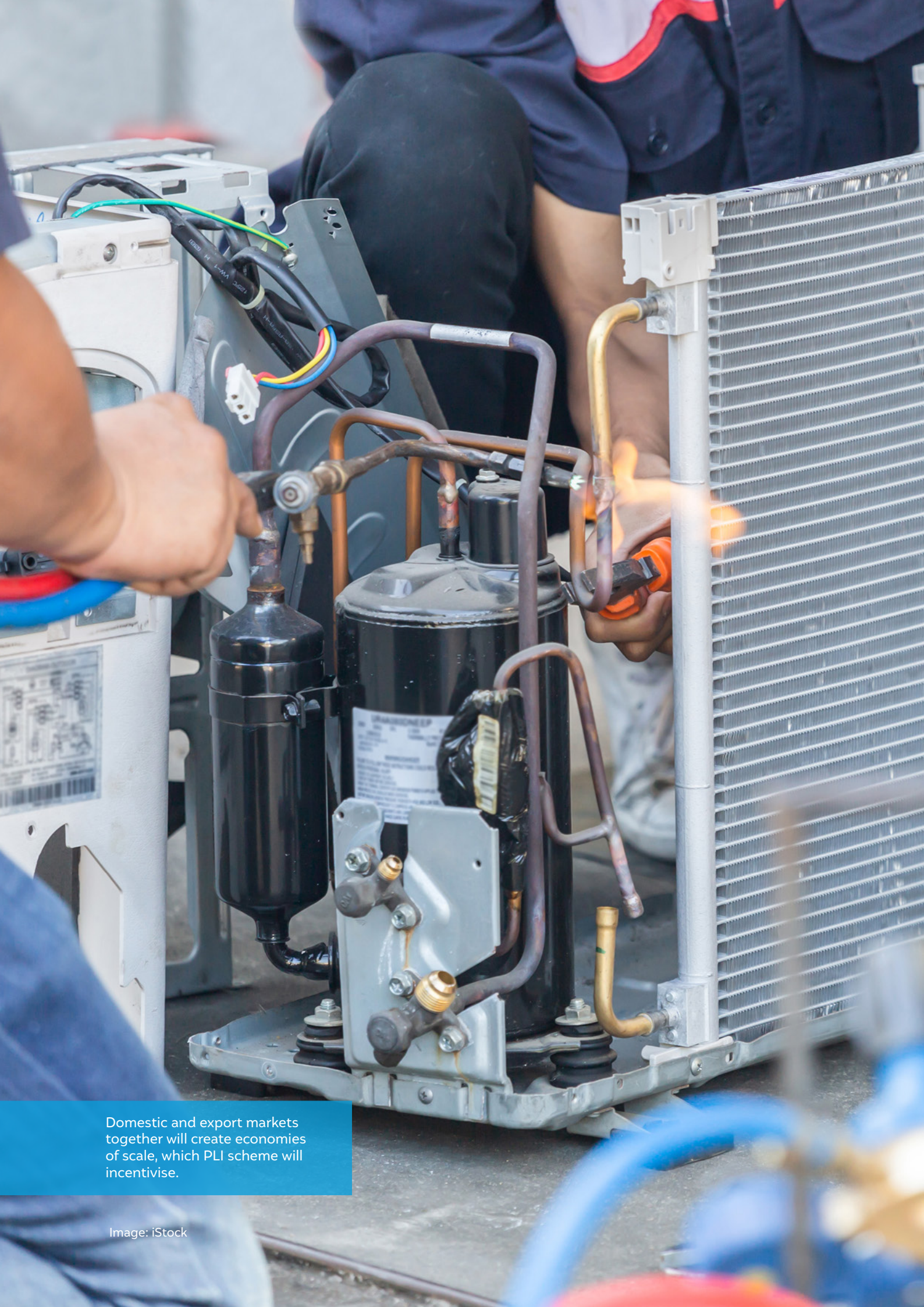
In the case of heat exchangers, the prevailing situation is that most heat exchanger units are manufactured or assembled in India. However, the critical raw material needed for heat exchangers, namely, copper tubes and aluminium, are imported from abroad. The reasons for this are largely the highly competitive prices offered by exporting countries due to their strengths in delivering bulk orders, availability of cheap raw materials, superior know-how to deliver quality products, and overall favourable macroeconomic conditions and policy support for manufacturing. The estimates for a break-up of import data from different countries has not been sourced, but the bottom line remains clear: high-grade copper and aluminium needs to be made available at competitive prices to increase the domestic value addition in this component segment.

Figure 4 shows an approximate share of imported items and domestically procured components. Broadly speaking, the data confirms one thing: the high technology items are imported to a larger extent, while low technology or less crucial items are sourced from the local manufacturers. It also establishes cost as the primary driver of decision-making for the buyers. In the next section, the role of technology and quality in creating this difference is explored.

Figure 4 Share of imports and domestically manufactured AC components



Source: Market research commissioned by CEEW



Domestic and export markets together will create economies of scale, which PLI scheme will incentivise.

Image: iStock

5. Technology issues in the HVAC sector

One of the objectives of this report is to understand how technology issues trouble the HVAC sector and affect its competitiveness. In the earlier section, it was explained how success in the HVAC sector in India depends on inter-firm coordination and collaboration in the supply chain. Firms downstream in the value chain retain certain core skills and competencies like product development, product design, assemblies, and manufacturing of critical components. These lead firms or headquarter firms, as they're referred to, need component suppliers and manufacturers to obtain the parts they don't themselves manufacture.

The lead firms try to distribute their supply-chain risks by engaging with domestic suppliers

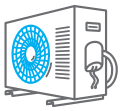
There are broadly three ways these products can be sourced. One way is to get local manufacturers to make them for you. The second way is to obtain them from traders and stockists that import parts from big HVAC manufacturing hubs like China, Thailand and others. The third way is to manufacture them on your own and not rely on supply chain players.

As trade numbers tell us, Indian OEMs import a lot of components as well as completely designed units (CDUs). The large volume of imports indicates that the basic problem Indian HVAC component manufacturers face is lack of competitiveness vis-a-vis their counterparts in China and Thailand. Indian manufacturers are neither cost-competitive, nor do they operate at a scale large enough to deliver the volumes demanded.

In fact, it is reported that for a lot of small components, SMEs are made vendors to a lead firm only to balance and distribute supply-chain risks. Trade-dependency is a precarious business. The lead time to get the product delivered is quite long. The other systemic inefficiencies such as clearing of freight at customs, port charges in India, clearance rate at ports, etc. also add to uncertainties of OEMs and other importers. Hence, most lead firms try to distribute their risks by engaging with domestic suppliers. Business relationships are also crucial to get into such arrangements.

In the case of international firms, these opportunities are more difficult to come by. This is due to the stringent product and quality standards expected by global firms. So, cost considerations and quality considerations both affect decision-making. The same is reflected in the trade data and the bottom-line of small companies, i.e., the AC component segment doesn't create a substantial portion of the total value created in the sector. According to some market estimates, the domestic value-addition in the AC and AC component sector is only

about 25 – 30 per cent (The Times of India 2021) to about 50 per cent of total value (Dolat Capital 2020). This is a big range and due to the complexity of the value chain it is difficult to ascertain the exact number.



The domestic value-addition in the AC and AC component sector is only about 30% of total value

Where does one place technology in all this? One of the interesting paradoxes of the Indian HVAC sector is that, despite the size and growth potential of the Indian market, not having scale is often cited as a major barrier to counter the dominance of China. This is explained, in large part, by the fragmented manufacturing base of the sector. There are too many SMEs, and even the large firms are not large enough when compared with their Chinese counterparts. These structural features of the sector mutate as constraints and cause a number of technology handicaps as a result.

An important facet of this technology challenge is that it is not about the cutting-edge, state-of-the-art technologies, which are difficult to acquire and not available in India. For specific component segments, keeping up with the knowledge development is hard, and there is certainly a gap on that front. Compressors and drives are examples of that. However, in a big measure, the challenges in many segments are of a type that can be characterised as 'small-tech' needs which helps manufacturers improve the overall quality and performance of their products. These include quality enhancement tools, new machinery, testing labs, etc. Access to these technologies and research infrastructure enhances the marketability of products and creates scope for further product innovation. This is particularly relevant for SMEs. Another part of the technology challenge is the lack of ability in firms to deploy new technologies to add new competencies, which can make their processes optimal.

5.1 Technology trends and challenges in HVAC components

As explained briefly in the previous section, the interplay of economic constraints, structure of the sector itself and availability of cheaper imports contributes to technology issues faced by the sector. Even if the technology is available, its adoption gets limited to very few firms. Whereas, a large number of small firms don't find it economically feasible to have them. These decisions differ as per the requirements of different components. In this section, we look at technology trends and challenges specific to key AC components.

1. Compressors

Two types of rotary compressors are used for air conditioning: fixed-speed and variable-speed. The fixed-speed compressors operate on a simple cycle. They are switched on when a room is warm, and switched off when the room cools down. They are so named because the motor in the compressor runs at a fixed speed. It requires simple controls but the efficiency is low as well.

The variable-speed compressors, on the other hand, can operate on more than one speed. This leads to a complex operating cycle, where a compressor is not required to be switched off and on. As the space attains the desired temperature, the compressor power is reduced and it operates at a low speed to maintain the set temperature. Inverter technology lets a variable-speed compressor operate at a continuum of speeds.

The challenge with variable-speed compressors based on inverter technology is that they demand sophisticated electronic control systems, also known as drives, which add to their manufacturing costs and make them expensive. This technology is very crucial if India is to achieve its energy efficiency targets through minimum energy performance standards (MEPS) for the air-conditioning sector. With the next upgradation in the

standards and labelling (S&L) programme, the three-star and five-star ratings can be achieved only through inverter technology.

- **Lack of intellectual property:** Compressor manufacturing technology is highly knowledge-intensive. Efforts are constantly made to push the frontier of knowledge about compressors. A lot of these efforts are protected under intellectual property rights. Some analysis shows that very few companies have filed patent applications in compressor technology in the last 30 years. These are essentially Japanese and Korean companies like Daikin, Samsung, Hitachi, Toshiba and LG. In recent years, Chinese company Midea has also been at the forefront of patenting new developments in compressor technology through its subsidiary company GMCC which is the largest producer of rotary compressors in the world.

  Within the family of patents critical for compressor manufacturing, the lubricants and oils used in the compressor are key. Specific types of oils like polyolester and polyvinyl ether are the basis for advanced formulations for both HFC and non-HFC based compressors. This is important to meet the miscibility criteria for refrigerants with the lubricants. In terms of new challenges, the existing formulations are found to be incompatible with R-32 refrigerants. Hence, more miscible oils have been developed and patented.

- **High capital cost:** Apart from being a knowledge-intensive and IP-protected business, compressor manufacturing requires very high investment in plant, machinery and equipment. It also calls for significant spending on research and development. Even if the money can be found, the firm will require economies of scale to manufacture units at a competitive price. For instance, Highly India had to invest USD 72 million in 2013 for a manufacturing plant of 1 million units/year capacity. Since Highly is well-integrated in the global supply chain, it already had the scale to justify the investment. Therefore, every new player entering this market will have to face tremendous challenges, both in terms of not having scale and not having the requisite knowledge and technology.

- **Research and knowledge development:** With emphasis on low-GWP refrigerants and regulations for MEPS as mentioned before, the knowledge and technology landscape of compressors is constantly evolving. For instance, the compressor design and cycle, oils and lubricants, and the refrigerants which can be used, need to be in conformity with each other. The high energy efficiency in compressors also demands investment in technology to keep manufacturing costs low. Moreover, the frontier companies have the advantage of possessing the background IP needed to develop the new compressor knowledge which is regulation-ready.

With emphasis on low-GWP refrigerants and regulations for MEPS, the knowledge and technology landscape of compressors is constantly evolving

2. Printed circuit boards

As air-conditioning units get more sophisticated, the electronic controls required for it are also getting quite complex. PCBs route the electrical signals through the electronic item. As such, they are an indispensable item for the HVAC industry.

PCB manufacturing and PCB assembly services is a complex process. Only after years of experience and training can one successfully run this business. The process ranges from designing a PCB prototype to large-scale production of PCBs through PCB Assembly Services (PCBA). Any flaws in the process can lead to defects, and so reliability is a key concern for clients. Due to the nature of the work, a lot of it is outsourced to EMS vendors. Various technologies and R&D are crucial at different stages of the manufacturing

process. Some aspects of this process, the key technologies used and challenges thereof are discussed below.

- **Design:** It starts with EMS companies providing a product concept or design which satisfies the client's product specification and needs. Clients can also share their own design with the EMS company and get a head start in the manufacturing process. However, by entrusting the design to the EMS company, clients get the benefit of having experts work on the design. PCB layout is the most critical part of the design process. Many software tools have been developed to aid PCB layout, and continue to be updated according to industry trends. The availability of these softwares is not a challenge. However, getting the right talent to perform this key function, and getting better overtime to achieve competitive performance is certainly a problem.

- **Manufacturing:** The main competence of EMS providers is to provide their clients PCB assembly services, while the product design skill is an add-on that might differentiate one EMS vendor from the other. In this respect, EMS vendors employ one of two types of PCB technology: (i) surface mount technology (SMT), and (ii) through hole technology (THT).

  When manufacturing is done using THT, it involves drilling holes into the PCB to insert components with tails or leads. As a result, strong mechanical bonds are created. THT also exhibits fewer solder issues as compared to SMT. All this bodes well for reliability of the PCBs. Other positives of this type of manufacturing are that it makes the prototyping easier, coupled with better heat tolerance. However, THT as a process can be more expensive due to additional drilling and printing on both sides of the PCB.

  On the other hand, manufacturing using SMT involves mounting components directly onto the PCBs' top surface. Due to the smaller and less expensive size of SMT components, faster production of PCBs can be achieved. However, a more advanced level of design, production, skill, and technology is required for SMT in comparison to THT.

- **Testing:** To ensure reliability and to ensure that the electronic product has met the customer's requirements, quality testing after manufacturing of each batch of PCBs is an established practice. It can be performed at the PCB level and the product level.

  In PCB-level testing, electrical testing is done to see if the ICs or integrated circuits are operating well. Meanwhile, product-level testing is where a product is tested as it will actually be used by end-users. Testing infrastructure for small EMS vendors is a gap area which came up in conversations with several stakeholders.

- **High-density interconnect (HDI) technique:** HDI technique can be very useful to achieve high performance in miniaturised devices, especially when it comes to routing traces. It can be done as HDI facilitates the placement of fewer layers on a board and boosts very high signal transmission speeds.

  However, HDI technology encounters problems with producing traces. For instance, it may end up routing more traces on a smaller region, thus introducing further problems such as noise. Therefore, more R&D is required to solve these challenges for the HDI technology to thrive.

- **Energy-efficient electronics:** Environmental concerns must be framed in terms of the entire lifecycle of the electronics, not just as part of the production process.

To build a value-added manufacturing process instead of setting up assembly lines, EMS vendors will have to invest more in R&D

In this context, minimising energy consumption is not only an effective way of reducing costs, it also makes companies create and consumers adopt low-energy consuming devices.

The trend towards energy-efficient electronics has led to high demand for and uptake of technologies like voltage supervisor ICs[9].

Miniaturisation of PCBs is going to pose a serious challenge to EMS vendors, particularly the small ones

- **Other technology challenges:** The ubiquitousness of PCBs has ensured that EMS is a fast-moving industry. On the technology front, new techniques are being developed continuously for productivity gains as well as developing new capabilities. Advanced manufacturing processes lend the early adopters competitive advantages. In this context, miniaturisation of PCBs is going to pose a serious challenge to EMS vendors, particularly the small ones. They will have to automate most of their processes as it will become impossible to work with the PCBs manually. The uptake of HDI technology in this regard will also be a challenge.

Another issue raised commonly by PCB assemblers in India is that of quality-control systems. They need to be enhanced, and manual contact needs to be minimised at the quality-control stage. This requires a higher degree of automation of the assembling process in addition to investment in testing infrastructure, which is not easy for companies struggling with scale.

Unmounted PCBs are sourced largely from China and account for 50 per cent of the cost of the final assembly. To build a value-added manufacturing process instead of setting up assembly lines, EMS vendors will have to invest more in R&D. A chip manufacturing ecosystem is going to be crucial in this regard. Getting high-quality water and electricity supply is also essential for this.

3. Variable-frequency drives

At the core of inverter technology which is key to making ACs more energy-efficient is a variable-frequency drive (VFD). It works with a compressor to modulate its speed and not let it exceed its operating limits. It is the most important function because, with changes in speed of the compressor, the amount of lubricants and refrigerants flowing through the compressor also changes. VFD regulates the application constraints to ensure that an optimal level of refrigerant flows through a compressor at different speeds. Therefore, VFD and compressor integration has to be very carefully done.

- The first challenge is with respect to manufacturing of VFDs in India. Of late, a few multinationals have come to manufacture VFDs in India. A few assemblers providing assembly support to multinationals have also set up businesses in India. However, there isn't a manufacturing ecosystem for high-technology semiconductor products in India. The scale of manufacturing remains very small. Within the RAC industry, almost all VFDs are imported from abroad. Specific algorithms have to be developed too for their proper functioning.

- At the level of compressor-VFD integration, the OEMs face certain challenges. First, strong mechanical engineering attributes have to be complemented by strong electronics engineering skills as well as programming. Second, for compressor manufacturers, oil management in a compressor is the main problem. Changing compressor speed makes oil management more complex. Lastly, support of both compressor manufacturer and drive manufacturer is required by OEMs for system integration.

9 It's a voltage supervisor that monitors the power supply in the system. As such, it helps reset the PCBs if voltage drops below a certain threshold.

- When it comes to technology trends, the third-generation semiconductor materials will create an important shift. Silicon carbide (SiC) is emerging as an alternative to displace the incumbent materials. It has the potential to reduce the product size and enhance low-loss driving[10]. However, these trends and developments are still in a nascent stage, and will take time to become mainstream. Since there is no manufacturing ecosystem in India for high-technology semiconductor products, a fast-changing industry will be difficult to break into.

4. Fans, blowers and motors

Fans and blowers are an important component of residential air-conditioning units. These are mounted on electric motors to discharge heat from the system through the external unit, and throw cool air in the room through the internal unit. India has a fairly expansive set of manufacturers in MSMEs and large companies. OEMs, therefore, end up procuring a large percentage of their fans and blowers from local vendors. However, in the case of motors, options for standard DC motors are available, but not for energy-efficient brushless DC (BLDC) motors.

The technology concerns of fan and blower manufacturers are closely linked with the scale at which they operate. The small manufacturers are reluctant to fully automate their manufacturing plants, due to payback uncertainties on upfront capital investment. Test facilities for benchmarking and upgrading of products is crucial to stay competitive in the market. Improvements in tooling development to maintain quality of products and accuracy is also cited as an area requiring support. These are a few gaps identified in the sector, particularly for small enterprises.

5. Refrigerant controls

Refrigerant controls are a selection of components that are an extremely important sub-system in air-conditioning units. They comprise small parts such as thermostatic valves, electronic expansion valves, pressure switches, etc. which help facilitate the flow of refrigerant through the system. These are critical for the performance of the system. Therefore, manufacturers are keen on ensuring their quality through proper vendor auditing and compliance-check. As a result, a lot of these components end up getting imported.

For Indian valve manufacturers, the topmost problem is lack of competitiveness vis-a-vis manufacturers abroad, mainly China. This is due to the superior know-how and scale of these firms. Other issues include lack of standardisation and certification which hampers backward and forward integration, as it becomes difficult to determine authenticity. Manufacturers also commonly face compatibility issues with system design. So, lack of inhouse design capabilities to expand product portfolio appears to be a problem too[11].

Lack of standardisation and certification hampers backward and forward integration, as it becomes difficult to determine authenticity

5.2 Technology barriers specific to SMEs

As discussed before, the Indian HVAC sector consists of a lot of SMEs as well. Although the technology challenges apply equally to them, SMEs face uphill tasks of their own when it comes to new technology adoption to enhance competitiveness.

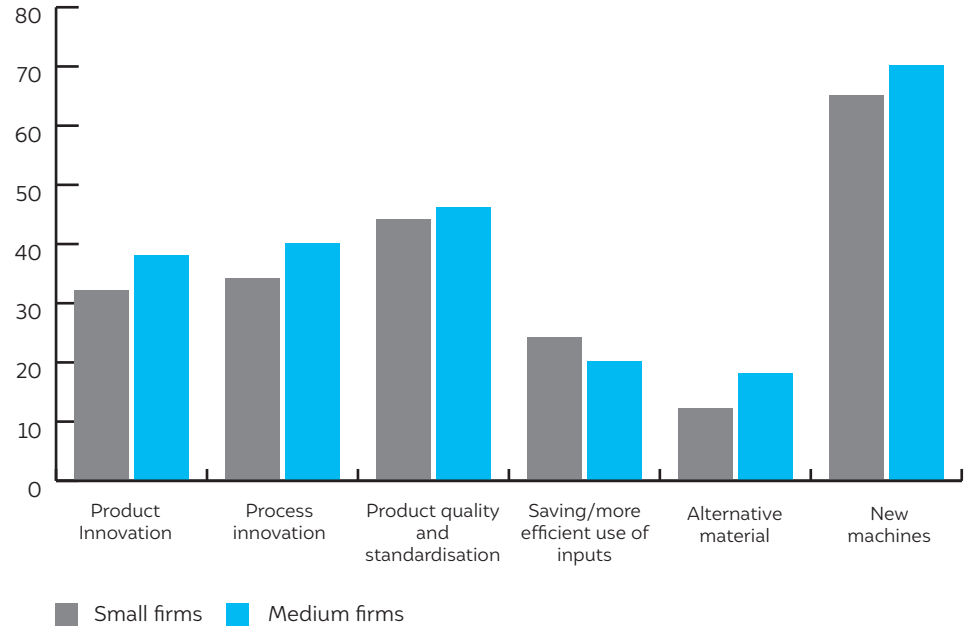
First, let's understand how SMEs can innovate. The need to invest in small, incremental technology was emphasised earlier. Here, the different types of innovations reported by SMEs include product innovation, process innovation, product quality and standardisation, savings or more efficient use of inputs, use of alternative material in production, and

10 https://www.invt.com/news/vfd-opportunity-challenge-125
11 https://www.techsciresearch.com/blog/top-5-challenges-valve-industry-will-face-in-2018/82.html

installation of new machines (Indian National Innovation Survey 2014). Figure 5 shows the share of innovative firms engaged in different types of innovation activities.

The figure indicates that the technology gaps that need to be bridged in SMEs, which are very important to the supply chain, are of an incremental nature. These are largely related to achieving better quality and standardisation of products as well as staying updated with new machinery and manufacturing processes. Rather than differentiating themselves in the market, these measures help them keep the course and remain competitive as the manufacturing technology landscape evolves. Balancing quality and cost as per market standards is also an important part of these efforts.

Figure 5 Percentage of innovative SMEs pursuing different innovations



Source: Indian National Innovation Survey, 2014

Despite the fact that innovation and technology needs in SMEs are fairly modest given the scale of their operations, several barriers to making even these incremental improvements are reported by SMEs. Some of these are as follows:

1. **Human resources attrition:** Scarcity of skilled and talented workforce working in SMEs is a major issue. Even after training people, the ability of SMEs to hold on to them is minimal as SMEs can't afford to offer high salaries. This seriously affects the quality control and maintenance systems of SMEs, which depend on skilled technicians and test engineers. In dynamic industries like electronics manufacturing, it becomes a serious drawback as much knowledge and technology intensive work is required to be done. These skills can be accumulated only over a period of time, and SMEs suffer due to constant exits of skilled people.

2. **Payback risk and payments:** Whether it is internal R&D-driven innovation or acquisition of new machinery, it comes at a cost. Finance, thus, is a key barrier to enhancing processes and technology in SMEs. In India, the large-scale payment delays effectively render SMEs dysfunctional by choking their cash flow, thereby disrupting their operations. Lack of access to cheap and subsidised credit is also cited as a persisting bottleneck in the pursuit of making SMEs competitive.

3. **Lack of R&D infrastructure:** Not having enough finance also leads to the problem of lack of in-house infrastructure. Even otherwise, SMEs don't have the financial heft to invest in testing laboratories and R&D. In the HVAC sector, there is no mechanism to provide access to shared laboratories and R&D facilities.

4. **Demand uncertainties:** In addition to already bad financials that SMEs deal with, uncertain markets are a persistent risk for SMEs. Apart from that, since innovation carries a cost whose payback is not guaranteed, the investment becomes much too risky if demand is not assured or there are too many competitors vying for a small share of the market. Dominance of large overseas players and their monopoly in certain segments are also key factors which render Indian SMEs uncompetitive.

Industrial design provides the foundation for manufacturing competitiveness as it reflects in the way you approach tooling, machining, production processes and quality processes

5.3 Other technical challenges

So far, challenges regarding specific components and SMEs operating in the sector have been discussed. In addition, there are quite a few other technical challenges which aren't unique to the air-conditioning sector. Some of these are foundational in nature, affecting the manufacturing sector as a whole and holding back its growth. However, some of these challenges are felt more sharply in AC manufacturing than in other sectors. A few salient ones are as follows:

- **Industrial design capabilities:** A basic feature of a good product is its effective design. This issue is not just about the attractiveness of products. In the B2B market, the ability to design parts and subsystems in line with product requirements as well as innovate with changing end-product design is highly valued. Industrial design provides the foundation for manufacturing competitiveness as it reflects in the way you approach tooling, machining, production processes and quality processes. Therefore, instead of a separate skill, it must become a complementary skill and get integrated in the manufacturing processes and product development activities of an organisation.

  SMEs acutely suffer from this issue. Their design thinking isn't mature. This is partly because SMEs rely a lot on reverse engineering and copying. It helps them cut the costs of design and development of a product being made from scratch, but hampers their overall learning process. This learning process is crucial to develop a culture of innovation, and compete in difficult market conditions.

- **Quality systems and compliance:** Another important concern about Indian industry is quality. Quality is a complex attribute. It is as much a function of culture as it is of accessibility to and knowledge of right quality adherence tools and infrastructure. In the first notion of quality as culture, it differs from one firm to the other. Variations will exist from one sector to the other as well. High value, export-worthy and competitive products come out of robust quality systems. However, the low value, domestically consumed products often suffer from quality issues.

  When it's about having quality systems and infrastructure to design quality assurance tools, SMEs again come into focus. When cost is an important criterion, and more emphasis is given to cutting costs, quality takes a backseat. Since the AC-parts sector is highly competitive, SMEs are found wanting in terms of quality assurance infrastructure due to the burden of extra costs. Lack of domestic standards informed by local manufacturing practices is also a concern.

- **Upgradation of plant and machinery:** Automation has become a norm in manufacturing industries. Quite rapidly and frequently, the old and existing machinery is getting redundant and being replaced by automated machines. This is important to build up the scale. Also, automation vastly improves the quality of products as well as brings

consistency in production processes and outputs. Fixing quality and consistency issues helps us deal with the export challenge of the sector.

Most of these automated machines are designed to perform specific functions. A lot of them are imported from countries like Italy, China, Taiwan and others. Naturally, since machines have utility for a limited task, quite a few systems will have to be integrated to fully automate the plant. Cost is a big burden as local options are not available, and SMEs, in particular, find it difficult to keep on upgrading their plant and machinery.

In addition to these overarching challenges, a brief summary is provided in table 4 of the key technology issues with basic components and parts used in ACs.

Table 4 Technology issues identified for different components

Component	% of imports	Technological and other issues
Compressors	More than 85%	• High investment needed • Process know-how layered, complicated, IP dependent • SMEs not involved even in subsystems or components that go in compressors
PCBs & drives	90%, manufacturing started recently	• Complex supply chain • Circuit design skills absent • Miniaturisation a growing challenge • Quality systems need improvement (EMS vendors) • Scale needed in procurement of chips
Motors (BLDC + non-BLDC)	80% imported	• Raw material and magnets • China is too competitive • Other technological bottlenecks not clear
Heat exchangers (finned tubes)	Assembled in-house	• Expensive raw material aluminium and copper • Coating facility for copper and aluminium not available • MSME design capabilities lacking
Fans and blowers	20% imported	• Design capabilities in India-manufactured fans and blowers • Help in advance tooling development • Performance testing facilities needed
Grooved copper tubes	100% imported	• Manufacturing competitive due to high price of raw copper • Process know-how difficult to obtain and operationalise • Quality concerns due to recycled copper • Duty structure of India vs FTA with few countries that have matured manufacturing base

Source: Authors' analysis

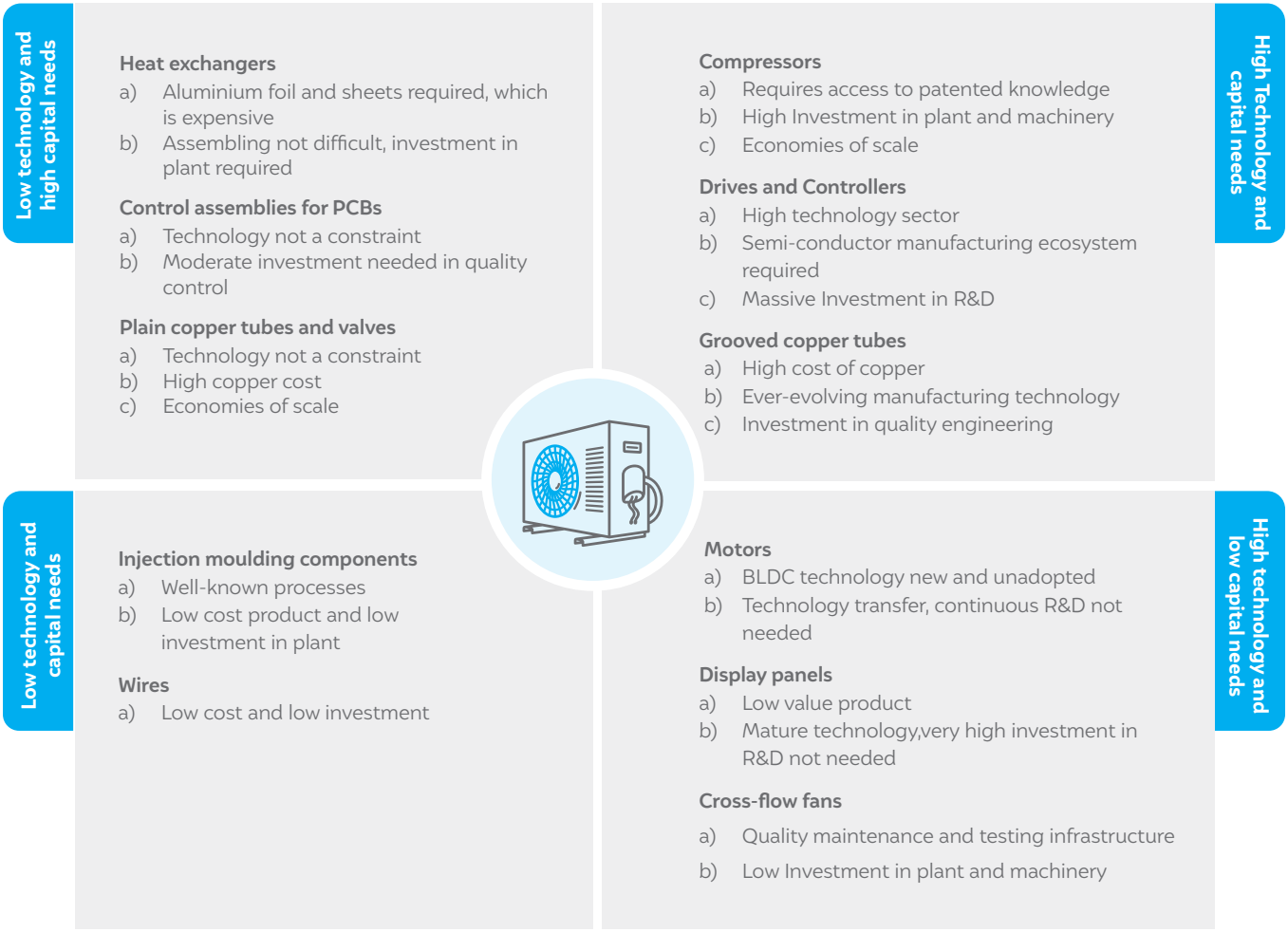
Based on the technology challenges and trends of different components, it might also be useful to understand component manufacturing as a combination of technology and capital needs relative to each other. Therefore, a capital-technology matrix has been prepared to understand which components depend extensively on capital investment and technology.

Technology and capital-intensive components include compressors, drives and controllers and grooved copper tubes. The reasons to categorise them as such are (i) high cost of setting up a large enough manufacturing facility to stay competitive, (ii) the corresponding investment in R&D to internalise the required technical know-how and standards as well as be in step with new and upcoming technologies, (iii) Requirement of technology transfer and intellectual property sharing arrangements with leading firms in the sector, which is a knowledge intensive and expensive process.

In technology intensive but non-capital-intensive category, components like motors, display panels and cross-flow fans are included. For manufacturing these components, technology is the first barrier. Upgradation to new manufacturing processes and technologies to improve cost and quality is a requirement. For certain components, technology needs are fairly low, but capital required to set up competitive manufacturing plant is substantial. These components are aluminium finstock (foil and sheets) for heat exchangers, copper tubes and control assemblies for PCBs. Finally, there are low-value components that don't pose technology or capital challenges such as sheet metal, injection moulding, wires etc. Figure 7 captures these requirements for major components in an air-conditioner.

The technology-capital matrix can help us prioritise the target segments for providing manufacturing and technology support. This is important to ascertain because certain components are not suitable for such an intervention due to large knowledge gaps between firms in India and abroad. Also, capital requirements are important as SMEs have limited capacity and willingness to take risk and invest.

Figure 7: Technology-capital nexus in AC components



Source: Authors' analysis

The next section takes a look at policy measures announced and implemented for the air-conditioning manufacturing sector in the country. The alignments between them are discussed and how interventions to address the technology challenges can supplement them.

Image: iStock

6. Policy alignments and way forward

In recent years, a lot of emphasis has been given to manufacturing in India. It shows that the policy leadership of the country understands the criticality of increasing India's manufacturing output and its potential impact on jobs, growth, and sustainability. On the one hand, the phenomenon of jobless growth needs to be mitigated, and on the other, at this historical juncture the world is eyeing India as a potential manufacturing hub. Herein lies the opportunity to ambitiously pursue the goal of manufacturing while solving India's jobs and sustainability mandates. In this regard, several policies exist that seek to provide an enabling atmosphere to make it successful.

The flagship initiative of the Government of India known as *Make in India* is perhaps the most visible effort to give a boost to manufacturing in the country. As part of its ambitious plan, the government seeks to achieve a) 12-14 per cent growth in manufacturing every year; b) creation of 100 million manufacturing jobs; and c) share of manufacturing in GDP at 25 per cent (GOI 2014). To make India an attractive destination for manufacturing companies all over the world, the government is systematically working on improving its ease of doing business ranking as well as competitiveness ranking. About 25 target sectors have been identified under the initiative.

If Make in India is about attracting global giants and foreign direct investment in India, the production-linked incentive (PLI) scheme is about giving Indian companies monetary incentives to set up manufacturing facilities in India. The scheme is focussed on developing manufacturing supply chains within India to a) decrease dependence on imports for finished goods and key components for assembly, and b) capture a larger part of the value chain to increase domestic value-addition (GOI 2021). PLI for white goods is one such scheme which has been rolled out with the objective of developing a manufacturing ecosystem for air-conditioning parts and components in the country. Till date, about INR 5,000 crore worth of investment has been committed to avail the PLI incentives. It is worthwhile to mention that this investment in plant and machinery is expected to achieve INR 81,000 crore of incremental production. In the process, it will also generate about 44,000 direct jobs in the sector (GOI 2021).

The focus on manufacturing is not just an imperative for jobs and growth. Our sustainability goals, too, will be fulfilled with this approach. Under the Kigali Amendment to the Montreal Protocol, India is committed to phase-out 85 per cent of HFCs in use by 2047. As the phase-down process will start, the end-use sectors will have to replace HFCs with alternative refrigerants. With local manufacturing emerging in the sector through the PLI scheme, the alternatives will be easier to implement. Energy efficiency will also get a fillip as new manufacturing capacity will offer more control to OEMs to adhere to the increasing standards of energy efficiency for air conditioners.

As policies bring into focus fiscal support for manufacturing, technology gaps shouldn't be playing spoilsport in realising India's manufacturing potential. Therefore, in addition to providing economic incentives, policy must not lose sight of ensuring the technology readiness of different enterprises. It also seems that the PLI scheme will not benefit SMEs, which face a lot of such technology challenges and shortcomings. Therefore, it becomes germane that ways are found with an eye to fulfilling their technology needs, and fill these important gaps in the air-conditioning supply chain. This will help us further strengthen and localise the supply chains.

In the previous section, various technology trends and issues with different HVAC components have been identified. These give us a sense of the level of technology readiness in the sector. These must also become the basis to design interventions at the policy level to improve the competitiveness and attractiveness of Indian HVAC firms, particularly SMEs, to develop local options in the supply chain, and make India's export capability better. These measures and their potential impact in mitigating the challenges are summarised below.

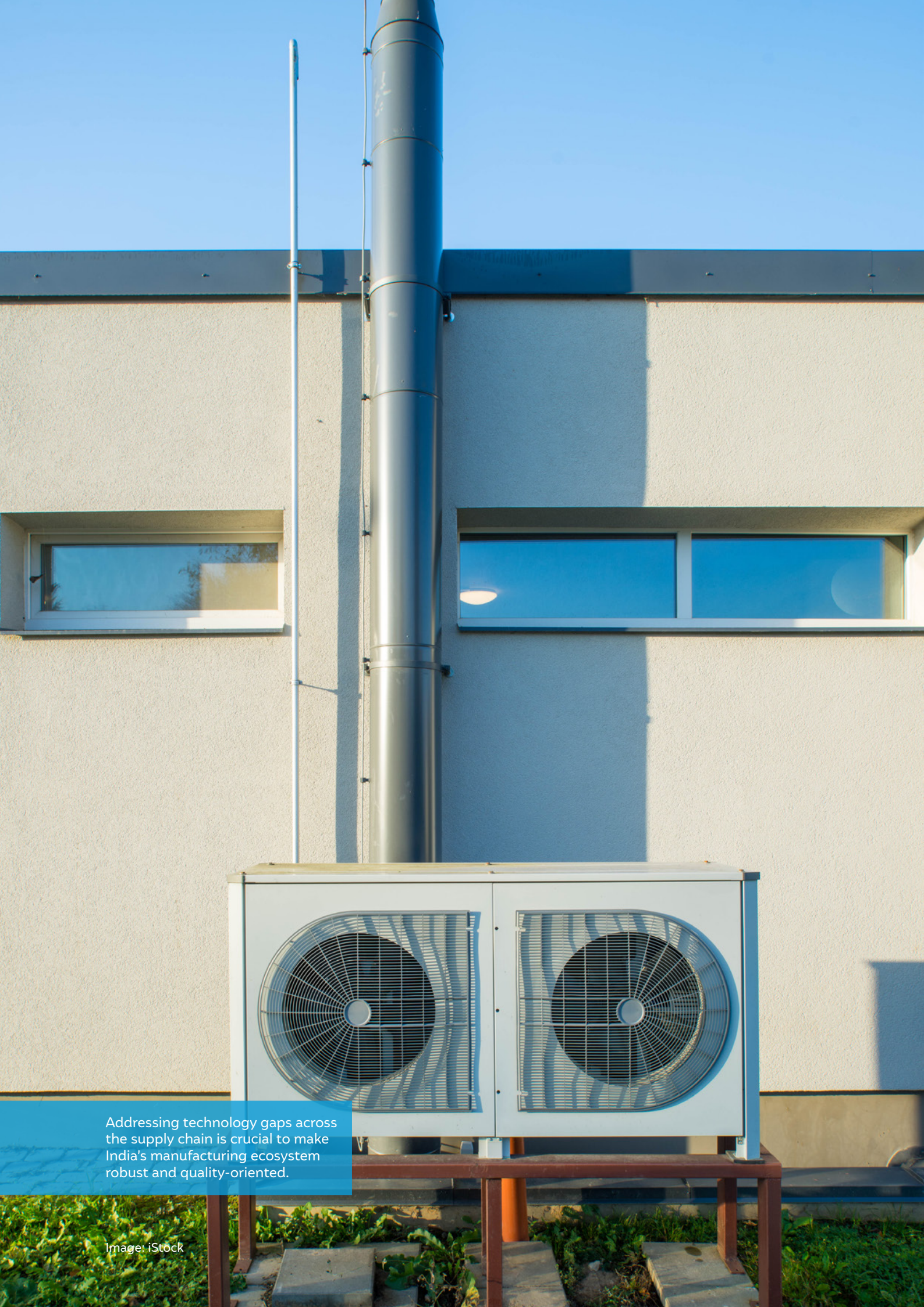
- **Enhancement of vendor development programmes:** Lack of process knowledge and product requirements is often cited as a handicap by small component manufacturers. Through better coordination between OEMs and SMEs, technical know-how and product knowledge can be effectively transferred and imparted to SMEs. This can help SMEs standardise, improve and adopt updated management processes.
- **Capital support for technology adoption:** Component manufacturers are always trying to balance expected quality requirements with their bottom line. Their weak cashflow cycle makes these matters even worse. To improve technology diffusion and upgradation, debt-linked support in the form of soft loans can help SMEs acquire new machinery and facilities to bring their manufacturing units up to the mark. Technological upgradation will help in improving processes and demand for quality consistency.
- **Access to affordable public certification labs:** For small players in the supply chain, cost of certification and compliance with standards is quite high. It is also an extremely important part of technology infrastructure to make the sector export-ready.

As policies bring into focus fiscal support for manufacturing, technology gaps shouldn't be playing spoilsport in realising India's manufacturing potential

Certification gives authenticity to the claims of the vendor as well as act as the first stamp of approval to manufacturers and tells buyers about various compliances the manufacturers adhere to. Low-cost certification facilities can mitigate these barriers and gaps, and enhance attractiveness of sellers. This can be achieved by building adequate capacity of labs and issuing licenses to provide affordable access to relevant players.

- **Industrial upgrading programmes:** It is observed that inefficient management practices are followed in the MSME space for a variety of reasons. One of the major reasons is the availability of right people and expertise at desired wages. The knowledge required to rectify these issues can be imparted through a concerted effort of industry bodies and the government. This can be coordinated by international agencies like UNIDO to improve the factory floor practices followed by SMEs such as Six Sigma, The Toyota Way, etc. While most of the entrepreneurs have knowledge and vigour as a start-up in the initial days, they need help in devising growth strategies and management skills at different levels of business turnover. Targeted short courses diffused to the lowest level are needed. Cost of poor quality should be made an important management criterion.

As policies bring into focus fiscal support for manufacturing, technology gaps shouldn't be play spoilsport in realising India's manufacturing potential



Addressing technology gaps across the supply chain is crucial to make India's manufacturing ecosystem robust and quality-oriented.

Image: iStock

7. Conclusion

- **R&D collaboration platform and opportunities:** Technology diffusion with respect to standardisation of manufacturing processes and benchmarking is a persistent pain-point. An industry-academia-government platform can make this knowledge and research infrastructure accessible to a large number of players. Centres of excellence with SME focus can also have a wide-reaching impact. This needs to be an ongoing process. A forum of retired technical experts at different levels can be formed and integrated in such initiatives.

Coordination between supply chain players, access to technology infrastructure, opportunities for collaborative R&D are some of the ways in which MSMEs can be improved

Cooling for India is a development imperative. With the growing need to provide access to thermal comfort to large swathes of population, as well as ramp up cold-chain infrastructure, there are tremendous business opportunities presenting themselves in the sector. However, the bane of the problem remains the low levels of manufacturing of cooling units in India. This report takes cognisance of this problem and analyses in detail the constitutive elements of it.

The most daunting part to solve is the room air-conditioning sector as the domestic value addition is extremely low. Being the largest and most valuable cooling segment, manufacturing across and deeper into the supply chain can deliver variegated growth and trade benefits. The potential to scale-up component manufacturing remains large to cater to national as well as export markets.

These opportunities have been identified by both the industry leaders and the policymakers. To revitalise the manufacturing ecosystem, a production linked incentives scheme for the air-conditioning sector has been designed. The scheme is expected to give rise to more investment in production capacity by air-conditioning component manufacturers. As per latest developments, the scheme is showing great offtake and selection of companies with corresponding allocation of incentives has been achieved.

Apart from getting more investment, it is equally important to focus on technology challenges posed by a dynamic and evolving sector. There is increasing emphasis on energy-efficient air-conditioning units, phasing-down of high-GWP refrigerants and adoption of natural and low-GWP refrigerants, and transforming consumer durables through Internet of Things (IoT) paradigm. These challenges can be met only through robust supply chains and increased technology diffusion in India.

The transformation of the air-conditioning manufacturing ecosystem will necessarily involve important supply chain partners like MSMEs. With financial heft and the human resources at their disposal, large players can adopt new technologies with less difficulty. However, the small players struggle with technology adoption as well as staying updated with incremental changes and trends in manufacturing processes, tooling and automation. In addition, the critical R&D infrastructure like performance testing labs, certification and standardisation labs also add-up to the cost of operation for MSMEs. These technological bottlenecks render MSMEs uncompetitive in the global value chains.

It is therefore important that a comprehensive approach is taken to solve the manufacturing woes in the sector. The large players will require economic support and incentives to survive in the global markets. Small players will require both economic and knowledge support. This report offers a blueprint of what those supportive measures can look like, at the level of industry-driven and policy-driven initiatives. Coordination between supply chain players, access to technology infrastructure, opportunities for collaborative R&D are some of the ways in which MSMEs can be improved. However, going forward, the possibility of a targeted incentive programme for MSMEs should also be given due consideration. In addition to providing them capital support, incentivising MSMEs for economic upgrading and to ramp up production can be a long-term solution for the problem of inadequate supply chains. Hence, as a follow-up to this piece of work, analysis of existing PLI scheme and examination of feasibility and outlines of a similar scheme for HVAC MSMEs are proposed to be undertaken.

References

Baldwin, Richard. 2016. *The Great Convergence*. Harvard University Press.

Bhide, Amar. 2009. "The Venturesome Economy: How Innovation Sustains Prosperity in a More Connected World". *Journal of Applied Corporate Finance* 21(1): 8-23. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1394685.

Business Standard. 2021. "Will India be Able to Attract Global Chipmakers?". https://www.business-standard.com/podcast/current-affairs/will-india-be-able-to-attract-global-chipmakers-with-10-bn-incentive 121121700069_1.html.

Confederation of Indian Industry. 2018. "Global Value Chains Expanding Boundaries of Indian SMEs". https://ciisme.in/pdf/MSME-report-theme-paper.pdf.

Council on Energy, Environment and Water. 2020. *Jobs, Growth and Sustainability: A New Social Contract in India's Recovery*. https://www.ceew.in/publications/jobs-growth-and-sustainability.

Deloitte Consulting. 2016. "Using Renewable Energy to Drive Supply Chain Innovation". https://www2.deloitte.com/us/en/pages/manufacturing/articles/renewable-energy-supply-chain-innovation.html.

Department of Science and Technology. 2021. "India Needs to Increase its Capacity of Non-Fossil Fuel Energy to Achieve Carbon Neutrality by 2070". https://dst.gov.in/india-needs-increase-its-capacity-non-fossil-fuel-energy-decrease-carbon-intensity-achieve-carbon.

Dolat Capital Enterprises. 2020. "A Play on AC Under Penetration and Outsourcing Story". https://www.bloombergquint.com/research-reports/dolat-capital-amber-enterprises-a-play-on-ac-under-penetration-and-outsourcing-story.

Financial Express. 2020. "Why is India Not Competitive in Manufacturing Cost? Analysis by Mahindra and Mahindra MD". https://www.financialexpress.com/industry/why-is-india-not-competitive-in-manufacturing-cost-analysis-by-mahindra-mahindra-md/2005467/.

Fortune. 2021. "Why Climate Action is About Becoming More Competitive?". https://fortune.com/2021/09/13/why-climate-action-is-about-becoming-more-competitive-ceo-daily/.

Gereffi, Gary. 1999. "International Trade and Industrial Upgrading in the Apparel Commodity Chain". *Journal of International Economics* 48(1): 37-70. https://www.sciencedirect.com/science/article/abs/pii/S0022199698000750.

Gereffi, Gary, John Humphrey. 2005. "The Governance of Global Value Chains". *Review of International Political Economy* 12: 78-104. https://www.fao.org/fileadmin/user_upload/fisheries/docs/GVC_Governance.pdf.

Gereffi, Gary, Karina Fernandez-Stark. 2016. *Global Value Chain Analysis: A Primer*. Duke Centre on Globalisation, Governance and Competitiveness. https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/12488/2016-07-28_GVC%20Primer%202016_2nd%20edition.pdf.

Government of India. 2014. "Make in India". Accessed from https://www.makeinindia.com/

Government of India. 2021. "9 PLI Schemes Approved by Cabinet So Far". Press Information Bureau. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1710134.

Humphrey, John, Hubert Schmitz. 2000. "Governance and Upgrading: Linking Industrial Cluster and Global Value Chain Research". IDS Working paper 120. https://www.ids.ac.uk/download.php?file=files/Wp120.pdf.

Inani, Rohit. 2021. "Despite the Make in India Push, the Share of Manufacturing Sector in the GDP has Stayed Stagnant". April 13, 2021. https://scroll.in/article/992066/despite-the-make-in-india-push-the-share-of-manufacturing-sector-in-the-gdp-has-stayed-stagnant.

IndiaSpend. 2021. "Indians Will Buy 300 million ACs in 20 years". https://www.indiaspend.com/pollution/indians-will-buy-300-mn-acs-in-20-years-and-theyre-choosing-brands-features-over-energy-efficiency-746363.

Indian Brand Equity Foundation. 2011. "SMEs Role in India's Manufacturing Sector". https://www.ibef.org/download/SMEs-Role-in-Indian-Manufacturing.pdf.

International Labour Organisation. 2020. *Transforming Economics: Making Industrial Policy Work for Growth, Jobs and Development*. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_242878.pdf.

International Monetary Fund. 2019. "All the Way to the Top: Industrial Policy, Innovation and Sustainable Growth." November 13, 2019. https://blogs.imf.org/2019/11/13/all-the-way-to-the-top-industrial-policy-innovation-and-sustained-growth/.

Japan Air-conditioning, Heating and Refrigeration News Limited. 2019. "Compressor World Market Situations". https://ejarn.com/detail.php?id=57181&l_id=.

Jones-Evans, Dylan. 1998. "Role of the University in the Technology Transfer Process: A European View". *Science and Public Policy* 25(6): 373-80. https://academic.oup.com/spp/article-abstract/25/6/373/1728265?redirectedFrom=PDF.

Kim, Bowon. 2000. "Coordinating an Innovation in Supply Chain Management". *European Journal of Operational Research* 123(3): 568-84. https://www.sciencedirect.com/science/article/abs/pii/S0377221799001137.

Ministry of Commerce and Industry. 2021. "42 Companies Selected Under the PLI-WG Scheme". Department for Promotion of Industry and Internal Trade. https://dpiit.gov.in/sites/default/files/Press_Release-PLIWG-Selection-03112021.pdf.

Mani, Sunil. 2009. "Why is the Indian Pharmaceutical Industry More Innovative Than Its Telecommunications Equipment Industry?". In *Sectoral Systems of Innovation and Production in Developing Countries,* edited by Franco Melarba and Sunil Mani. Edward Elgar Publishing. https://www.elgaronline.com/view/edcoll/9781848446564/9781848446564.00008.xml.

Mani, Sunil. 2012. "The Mobile Communications Services Industry in India: Has it led to India Becoming a Manufacturing Hub for Telecommunication Equipment?". *Pacific Affairs*. 85(3): 511-530. https://www.ingentaconnect.com/content/paaf/paaf/2012/00000085/00000003/art00003.

Mukherjee, Sonia. 2018. "Challenges to Indian Micro Small Scale and Medium Enterprises in the Era of Globalization". *Journal of Global Entrepreneurship Research* 8 (article no. 28). https://link.springer.com/article/10.1186/s40497-018-0115-5.

Nathan, Dev. 2017. "GVCs and Development Policy: Vertically Specialized Industrialization". In *Development with Global Value Chains: Upgrading and Innovation in Asia*. Cambridge University Press.

Nicholson, Scott. 2019. "Mapping the Supply Chain for Room Air Conditioning Compressors". National Renewable Energy Lab. https://www.osti.gov/biblio/1524770-mapping-supply-chain-room-air-conditioning-compressors.

Organisation for Economic Co-operation and Development. 2009. "Innovation and Growth: Chasing a Moving Frontier". https://www.oecd-ilibrary.org/science-and-technology/innovation-and-growth/technology-diffusion-in-the-developing-world_9789264073975-10-en.

Ozone Cell, Ministry of Environment, Forests and Climate Change. 2019. "India Cooling Action Plan", available at http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

PricewaterhouseCoopers. 2018. "Bridging the Technological Valley of Death". https://www.pwc.no/en/bridging-the-technological-valley-of-death.html.

Press Information Bureau. 2016. "India Welcomes Landmark HFC Agreement at Kigali", available at https://pib.gov.in/newsite/PrintRelease.aspx?relid=151685

Press Information Bureau. 2021. "National Statement by Prime Minister Shri Narendra Modi at COP26 Summit in Glasgow", available at https://pib.gov.in/PressReleasePage.aspx?PRID=1768712

Reserve Bank of India. 2021. "Handbook of Statistics on Indian Economy", available at https://www.rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy

Scientific American. 2021. “The Technology to Reach Net-Zero Carbon Emissions is Not Ready for Prime Time”. https://www.scientificamerican.com/article/the-technology-to-reach-net-zero-carbon-emissions-isnt-ready-for-prime-time-but/.

Soosay, Claudine. 2009. “Supply Chain Collaboration: Capabilities of Continuous Innovation”. *Supply Chain Management* 13(2): 160-69. https://www.emerald.com/insight/content/doi/10.1108/13598540810860994/full/html.

Tewari, Meenu. 2019. “Learning Sequences in Lower Tiers of India’s Automotive Value Chain”. In *Development with Global Value Chains: Upgrading and Innovation in Asia*. Cambridge University Press.

The New Indian Express. 2021. “Chip Production: A Long Way to Go”. https://www.newindianexpress.com/business/2021/dec/26/chip-production-a-long-way-to-go-2399744.html.

The Times of India. 2021. “With PLI the AC industry Poised to Create Jobs, Shape a Self-Reliant India”. https://timesofindia.indiatimes.com/blogs/voices/with-pli-the-ac-industry-poised-to-create-jobs-shape-a-self-reliant-india/.

United Nations. 2021. *Theme Report on Energy Transition: Towards the Achievement of SDG7 and Net-Zero Emissions*. https://www.un.org/sites/un2.un.org/files/2021-twg_2-062321.pdf.

United Nations Climate Change Conference. 2020. “Net-Zero Financing Roadmaps”. https://assets.bbhub.io/company/sites/63/2021/10/NZFRs-Key-Messages.pdf.

United Nations Industrial Development Organisation. 2020. *Industrial Development Report*. https://www.unido.org/sites/default/files/files/2019-11/UNIDO_IDR2020-MainReport_overview.pdf.

Verhoogen, Eric. 2021. “Firm Level Upgrading in Developing Countries”. NBER working paper 29461. https://ideas.repec.org/p/nbr/nberwo/29461.html.

World Economic Forum. 2018. “Will New Technology in Developing Countries be a Help or a Hindrance?”. October 9, 2018. https://www.weforum.org/agenda/2018/10/will-new-technologies-help-or-harm-developing-countries/.

World Trade Organisation. 2021. *Global Value Chain Development Report: Beyond Production*. https://www.wto.org/english/res_e/booksp_e/00_gvc_dev_report_2021_e.pdf.

World Trade Organisation. 2021. *World Trade Report 2021: Economic Resilience and Trade*. https://www.wto.org/english/res_e/booksp_e/wtr21_e/00_wtr21_e.pdf.

Critical R&D infrastructure such as performance testing labs, as well as certification and standardisation facilities can make a huge difference.

Image: Alamy

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

ISID Complex, 4, Vasant Kunj Institutional Area,
Vasant Kunj II, Vasant Kunj, New Delhi - 110070, India

info@ceew.in | ceew.in | @CEEWIndia | ceewIndia