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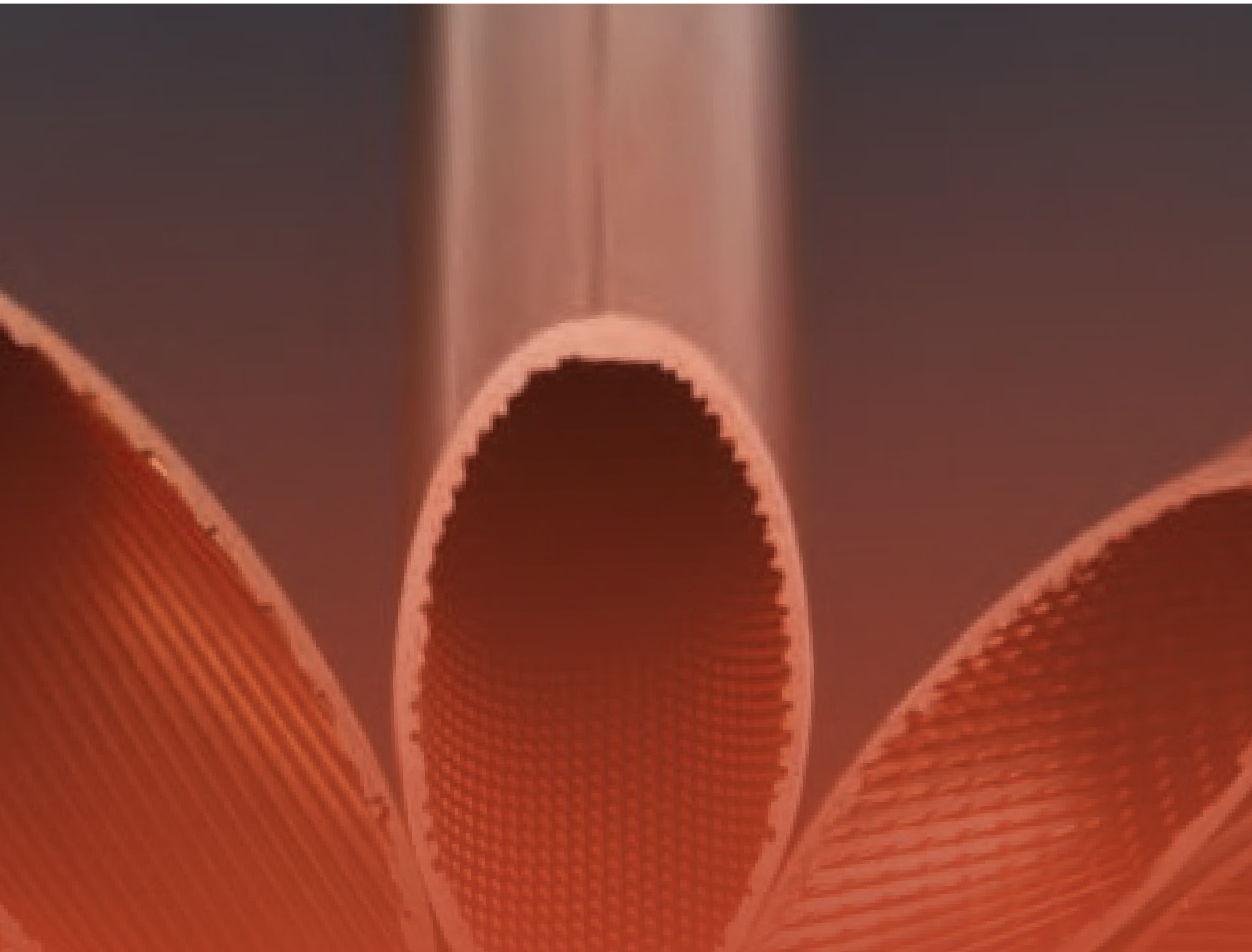
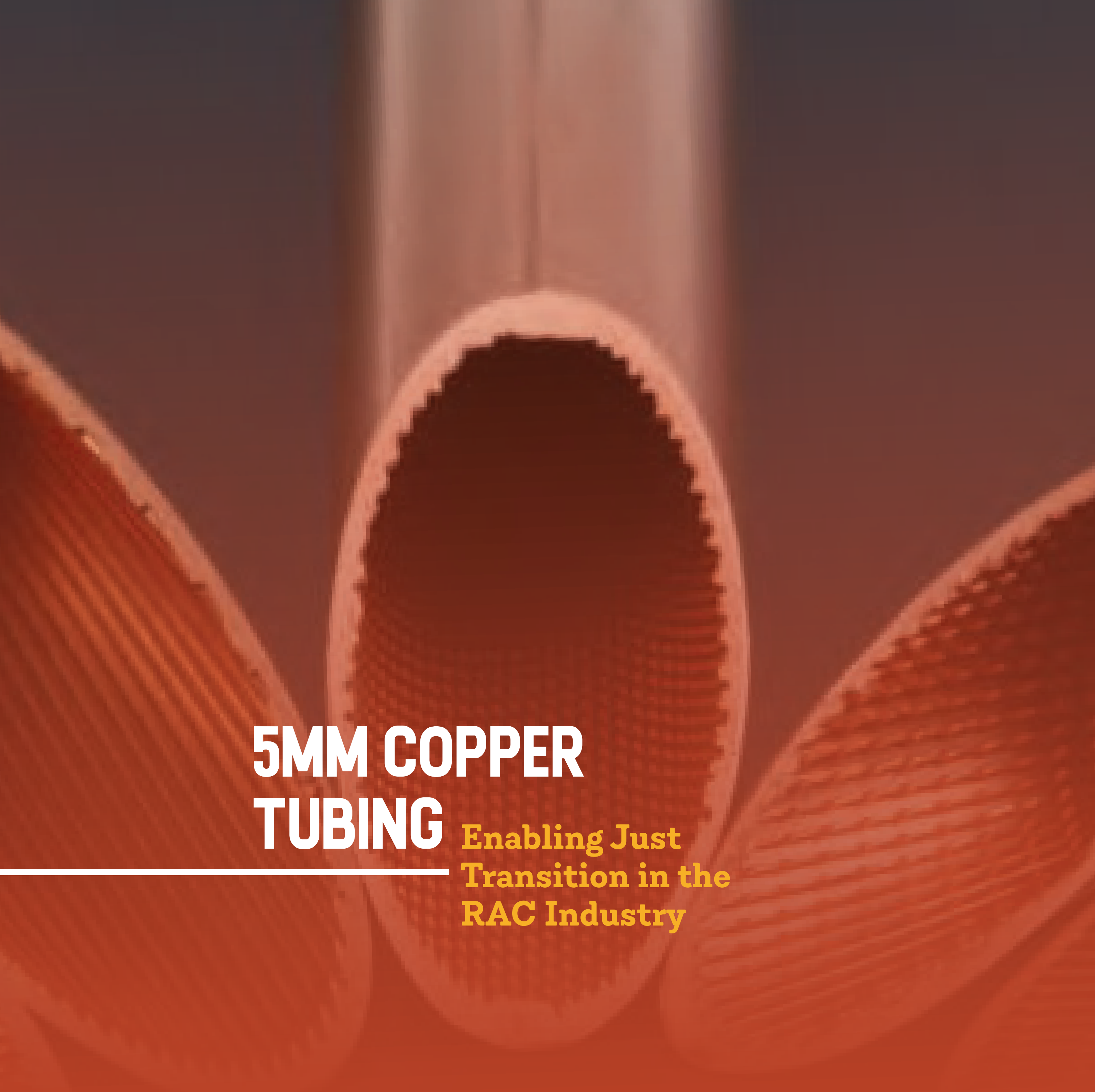


5MM COPPER TUBING

Enabling Just Transition in the RAC Industry

BY ALLIANCE FOR AN ENERGY EFFICIENT ECONOMY

MAY 2022



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Project: 5mm Copper Tubing: Enabling Just Transition in the RAC Industry

The study was conceptualised based on the fact that inner grooved copper tubes (IGTs) consume less refrigerant and energy, and there is great potential to meet India's climate commitments if the IGTs are adopted on a large scale in the Indian room air conditioner (RAC) sector. Further, as 100% of IGTs in India are imported, there are anticipated socioeconomic co-benefits that can be leveraged through domestic manufacturing of IGTs in India, contributing to the Make in India initiative.

In Partnership with International Copper Association, India

The International Copper Association (ICA) is the leading advocate for the copper industry. It is a non-profit organisation bringing together the copper industry and its partners to make a positive contribution to the UN Sustainable Development Goals and support markets for copper. ICA is engaged in the promotion of the beneficial usage of copper for safety, health, the environment, and energy savings. ICA India's activities focus on helping end-users to better understand and appreciate the positive attributes of copper. ICA India actively promotes copper through seminars, workshops, and training programmes throughout India, in collaboration with other organisations, institutions, and trade bodies.

Prepared by: Alliance for an Energy Efficient Economy

Alliance for an Energy Efficient Economy (AEEE) supports policy implementation and enables the energy efficiency market with a not-for-profit motive. AEEE promotes energy efficiency as a resource and collaborates with industry and government to transform the market for energy-efficient products and services, thereby contributing toward meeting India's goals on energy security, clean energy, and climate change. AEEE collaborates with diverse stakeholders such as policymakers, government officials, business and industry, consumers, researchers, and civil society organisations. We believe that our work speaks for itself and we hold Respect, Integrity, and Synergy as central to our efforts.

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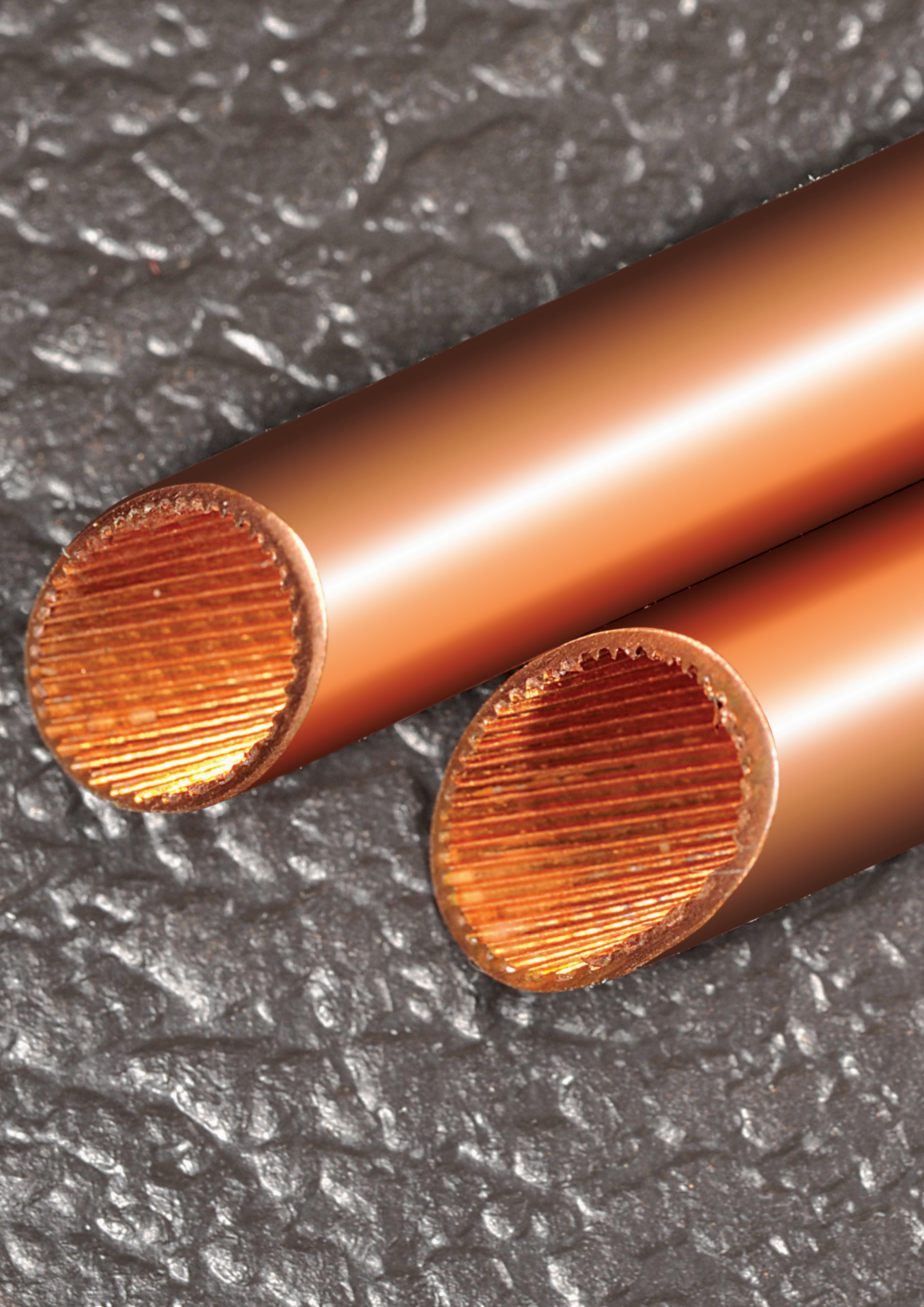

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ABBREVIATIONS

AC	Air Conditioner
AEEE	Alliance for an Energy Efficient Economy
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
BAU	Business-As-Usual
BEE	Bureau of Energy Efficiency
BLDC	Brushless Direct Current Motor
CAC	Commercial Air Conditioning
CAPEX	Capital Expenditure
CIFF	Children's Investment Fund Foundation
CO2	Carbon Dioxide
COP	Coefficient of Performance
COP26	26th United Nations Climate Change Conference of the Parties
COVID-19	Coronavirus Disease 2019
Cr	Crore
CSIR	Council of Scientific & Industrial Research
DPIIT	Department for Promotion of Industry and Internal Trade
DST	Department of Science & Technology
DWV	Drain-Waste-Vent
EER	Energy Efficiency Ratio
FDI	Foreign Direct Investment
FTA	Free Trade Agreement
FY	Financial Year
G	Mass flux in kg/m2s
GB/T	Guobiao (National Standards in Chinese)
GHG	Greenhouse Gas
GST	Goods and Services Tax
GWP	Global Warming Potential
g	Gramme
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	Hydrochlorofluorocarbons Phase out Management Plan
HVAC	Heating, Ventilation, and Air Conditioning
HVAC&R	Heating, Ventilating, Air Conditioning, and Refrigeration
ICA	International Copper Association
ICAP	India Cooling Action Plan
ID	Inner Diameter
IGT	Inner Grooved Copper Tube
IICT	Indian Institute of Chemical Technology
IISC	Indian Institute of Science
IIT	Indian Institute of Technology
INR	Indian Rupee
ISHRAE	Indian Society of Heating, Refrigerating and Air Conditioning Engineers
K	Kelvin
kW	Kilowatt
kPa	Kilopascal
kt	Kilotonne

kg	Kilogramme
LWC	Level Winding Coil
M/o MSME	Ministry of Micro, Small, and Medium Enterprises
m2	Square metre
MEPS	Minimum Energy Performance Standard
MGPS	Medical Gas Pipeline System
mm	Millimetre
MoEF&CC	Ministry of Environment, Forest and Climate Change
MSMEs	Micro-, Small, and Medium-Sized Enterprises
MTOE	Million Tonnes of Oil Equivalent
NFM	Non-Ferrous Metal
NIT	National Institute of Technology
NSQF	National Skills Qualification Framework
OD	Outer Diameter
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substance
OEM	Original Equipment Manufacturer
PC	Pancake Coil
PCB	Printed Circuit Board
PLI	Performance Linked Incentive
PPP	Public-Private Partnership
R&D	Research and Development
RAC	Room Air Conditioner
RAMA	Refrigeration and Air-Conditioning Manufacturers Association
S	Second
S&L	Standards and Labelling
SAV	Surface-Area-to-Volume
SDGs	Sustainable Development Goals
SMES	Small and Medium-Sized Enterprises
TR	Tonne of Refrigeration
VAT	Value-Added Tax
W	Watt
ZED	Zero Defect Zero Effect

KEY DEFINITIONS

1. Heat transfer coefficient[1]

The heat transfer coefficient in thermodynamics is the proportionality constant between the heat flux and the temperature difference (ΔTLM); the heat transfer coefficient is influenced by the thickness and thermal conductivity of the mediums through which heat is transferred. The larger the coefficient, the more easily heat is transferred from its source to the product being heated.

In a heat exchanger, the relationship between the overall heat transfer coefficient (U) and the heat transfer rate (Q) is given by the following equation:

Q=UA ΔTLM

Where:

Q = heat transfer rate, W=J/s [btu/hr], **U** = heat transfer coefficient, W/(m2°C) [Btu/(hr-ft2°F)]
A = heat transfer surface area, m2 [ft2], **ΔTLM** = logarithmic mean temperature difference, °C [°F]

2. Energy efficiency ratio[2]

The energy efficiency ratio (EER) is the ratio of the cooling capacity to the power input (in watts). It can also be defined as the amount of heat removed per hour to the power consumed per unit. The higher the EER rating, the more efficient the air conditioner.

$$\textbf{EER} = \frac{\text{(Cooling capacity or heat removed by the RAC in kW)}}{\text{(Power input or power consumed by the RAC in kW)}}$$

Mass flux[3]

Mass flux is defined as the amount of mass transported per unit time across a unit area that is perpendicular to the direction of mass transport. In room air conditioners (RACs), mass flux can be calculated for the refrigerant that is being transferred within the tubes of the heat exchangers.

G= Density (kg/m3) × Velocity (m/s) = kg/m2s

3. Surface-area-to-volume ratio[4]

The surface area of an object or a body is the total area of all its exposed surfaces, which is simply the outside area of an object. On the other hand, volume refers to the amount of space occupied by the object; it can also be the amount of space inside of the object. The relation between the surface-area-to-volume (SAV) ratio and heat conduction rate can be explained from a flux and surface perspective, focusing on the surface of a body as the place where heat conduction takes place; the larger the SAV ratio, the greater the surface area per unit volume through which the material can conduct heat, and, thus, the higher the heat conduction rate.

1 Overall Heat Transfer Coefficient. TLV: A Steam Specialist Company. Retrieved 21 March 2022, from https://www.tlv.com/global/TI/steam-theory/overall-heat-transfer-coefficient.html
2 Energy efficiency ratio. Airedale Cooling. Retrieved 21 March 2022, from https://www.airedalecooling.com/news/energy-efficiency-ratio-eer
3 Suraishkumar, G. (2014). Mass Flux. Biosystems & Biorobotics, 21-67. doi: 10.1007/978-3-642-54468-2_2
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EXECUTIVE SUMMARY

India is among the countries with the most cooling degree days in the world, with over 3,000 per year. A cooling degree day is a measure of the dema nd for energy needed to cool a building. The imperative of ensuring a thermally comfortable environment is driven by the notion that cooling is a developmental necessity, and is going to increase given the economic growth trajectory of India. Thermal comfort contributes significantly towards the health, productivity, and wellbeing of people in hot climatic zones. Thus, it is crucial to ensure the thermal comfort of billions of people around the world, including over 1.4 billion in India.

India is among the countries with the most cooling degree days in the world, with more than

3,000 per year

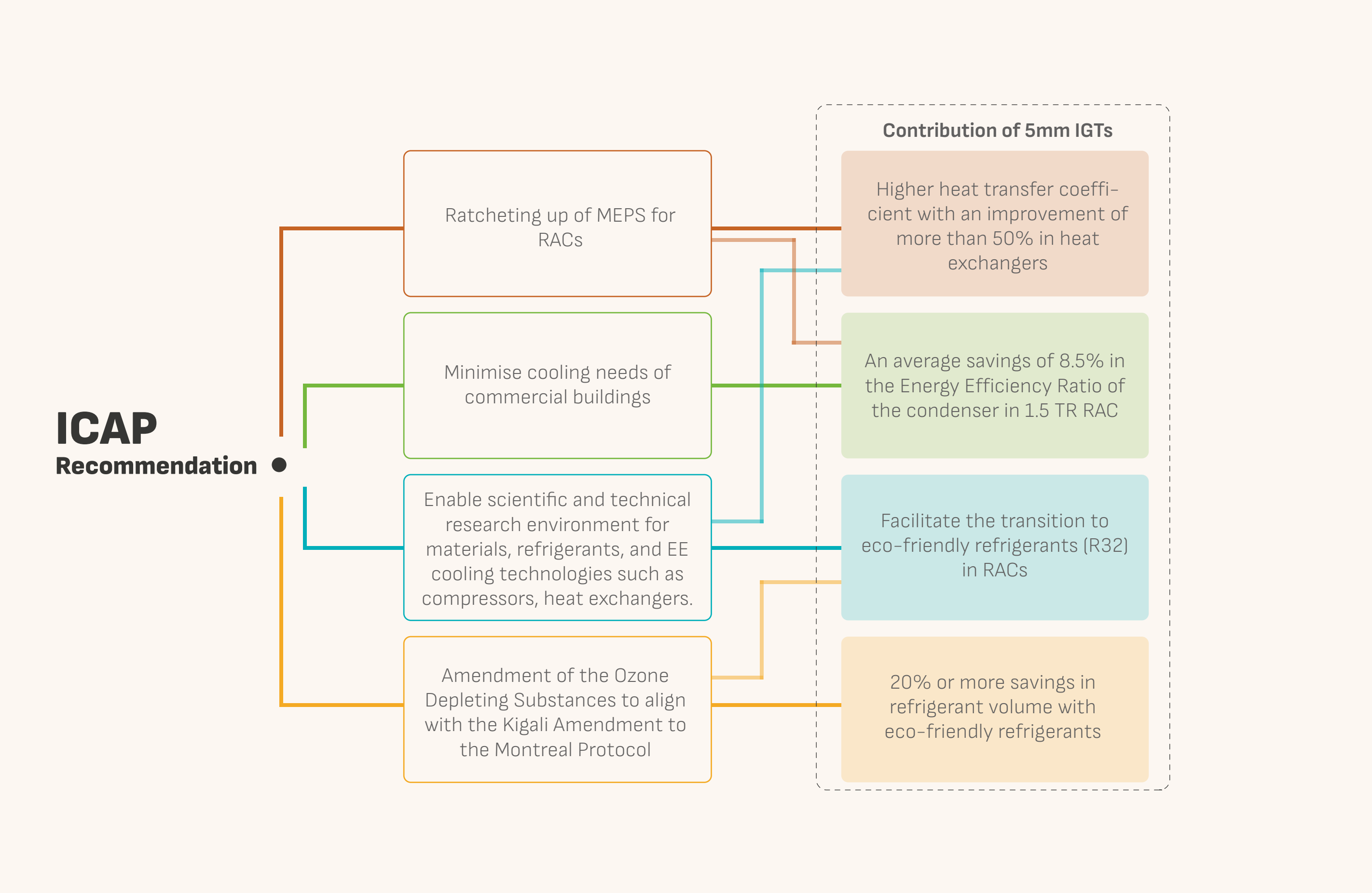
With the launch of the India Cooling Action Plan (ICAP) in 2019 under the aegis of the Ministry of Environment, Forest and Climate Change (MoEF&CC), the country escalated its climate goals and also positioned itself as a nation that is committed to achieving its global and national targets on climate action. The ICAP projects that the share of RACs in households will increase to ~580 million by 2037-38 from its baseline value of ~40 million in 2017-18. Similar trends are envisaged for RAC-based refrigerants and energy use, which are expected to increase by 8x and 6.5x, respectively, in the non-intervention or reference scenarios (ICAP, 2019). Hence, the significance of upgrading/improving air cooling technologies such as RACs has been emphasised in ICAP as an intervention to optimise cooling-based electricity consumption.

Copper has been proven to have exceptional thermal and electric conductivity properties, and enhancing the geometry and reducing the diameter of the copper tubing in the heat exchangers of RACs has resulted in substantial energy reduction, as well as reduction in refrigerant recharge quantity. Thus, the use of IGTs in RAC heat exchangers aligns well with the COP26 Product Efficiency Call to Action, Sustainable Development Goal (SDG) 12, India's Kigali Ratification, ICAP, and India's commitment to becoming net-zero by 2070.

Another crucial aspect of the enhanced demand for refrigerants and energy is the associated increase in greenhouse gas (GHG) emissions. Reducing these emissions is a major part of India's mitigation strategy, which includes the phasing out of ozone-depleting hydrochlorofluorocarbons (HCFCs) in compliance with the Montreal Protocol framework. While HCFCs have been replaced under the aegis of India's commitments under HCFCs Phase-out Management Plans, a parallel shift to non-hydrofluorocarbons (HFCs) and other low-global warming potential (GWP) and natural refrigerants has also been pursued. India's ratification of the Kigali Amendment in August 2021 and its declaration at the 26th United Nations Climate Change Conference of Parties (COP26) in 2021 to become net-zero by 2070 also indicates its renewed commitment to enhanced climate action. These commitments necessitate a more rapid shift towards super energy-efficient sustainable space cooling products, which will entail technological improvements in RAC components to make them compatible with a new class of greener refrigerants.

Enabling component-level efficiency gains in RACs, as shown in the Figure 1 below, can foster implementation of the ICAP goals and contribute to the achievement of international commitments. One innovation that can lead to such efficiency gains is the substitution of large diameter copper tubes with small diameter 5 millimetre (mm) inner grooved copper tubes (IGTs) in RAC heat exchangers. This has been embraced by the RAC industry globally to meet climate commitments and reduce the space cooling energy and refrigerant demand.

Figure 1: IGT contributions to India's climate committments and ICAP goals



On average, 5mm IGTs lead to an energy savings of 8.5% and refrigerant savings of more than 20% and require less material than 7mm diameter copper tubes while providing the same cooling performance. Thus, the use of IGTs contributes to making RACs more affordable and energy-efficient.

5mm IGTs can be an integral component in the transition towards super energy-efficient RACs and contribute to achieving the national target of saving 150 million tonnes of oil equivalent (MTOE) by 2030 and India's climate commitments.

On one hand, domestic RAC manufacturers have made some progress in transitioning to 5mm IGTs by incorporating them into different RAC components. However, on the other hand, 90% of the copper tubes used in the RAC sector are imported.

The transition from 7mm to 5mm IGTs has been noteworthy in the case of condenser coils with 5mm IGT based condensers, accounting for ***37%*** of the overall RAC market share. However, there are several challenges in adoption of 5mm IGTs on the evaporator side, which requires more research and development efforts.

Although IGTs provide substantial environmental benefits, they are currently being imported under the Free Trade Agreement (FTA) with Association of Southeast Asian Nations (ASEAN) countries, with Malaysia, Thailand, and Vietnam accounting for a 90% share in the total imports of copper tubes in India and no any import duties or taxes being levied. At the same time, the same agreement levies a 5% duty on copper-based raw material (copper cathode) imports, leading to an overall price escalation of 5-6% when copper tubes are manufactured domestically.

Imported copper tubes are cheaper than domestically manufactured copper tubes. Consequently, in the last five years, twenty large manufacturers accounting for ***70%*** of the industry's total capacity have shut down operations because they were unable to withstand competition from cheap imports.

As a result, the domestic industry has witnessed a serious loss of market share to international players, and the increased imports also signify a loss of foreign exchange towards the import payments. As depicted in Figure 2 below, if the domestic manufacturing of IGTs becomes a reality, the copper tube manufacturing industry can be valued at around Indian Rupee (INR) 2.3 billion and lead to incremental creation of 6000 new jobs by 2030.

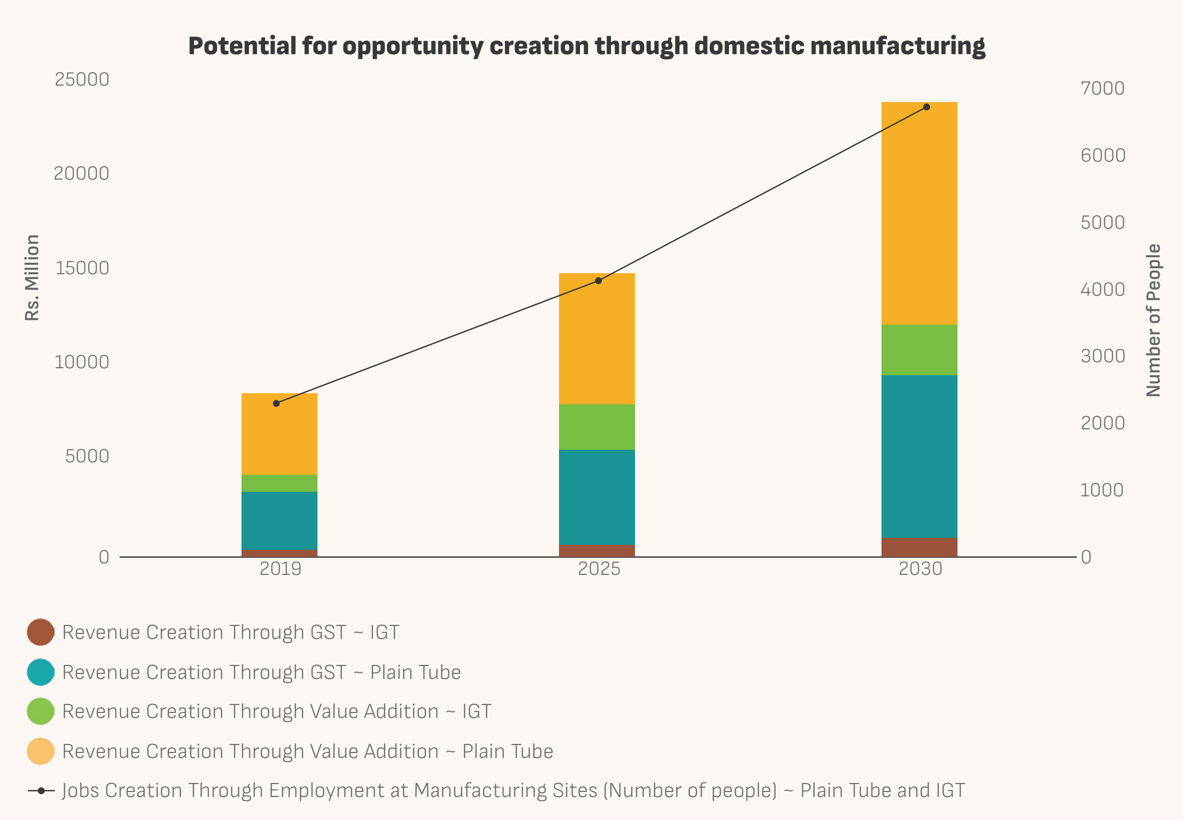


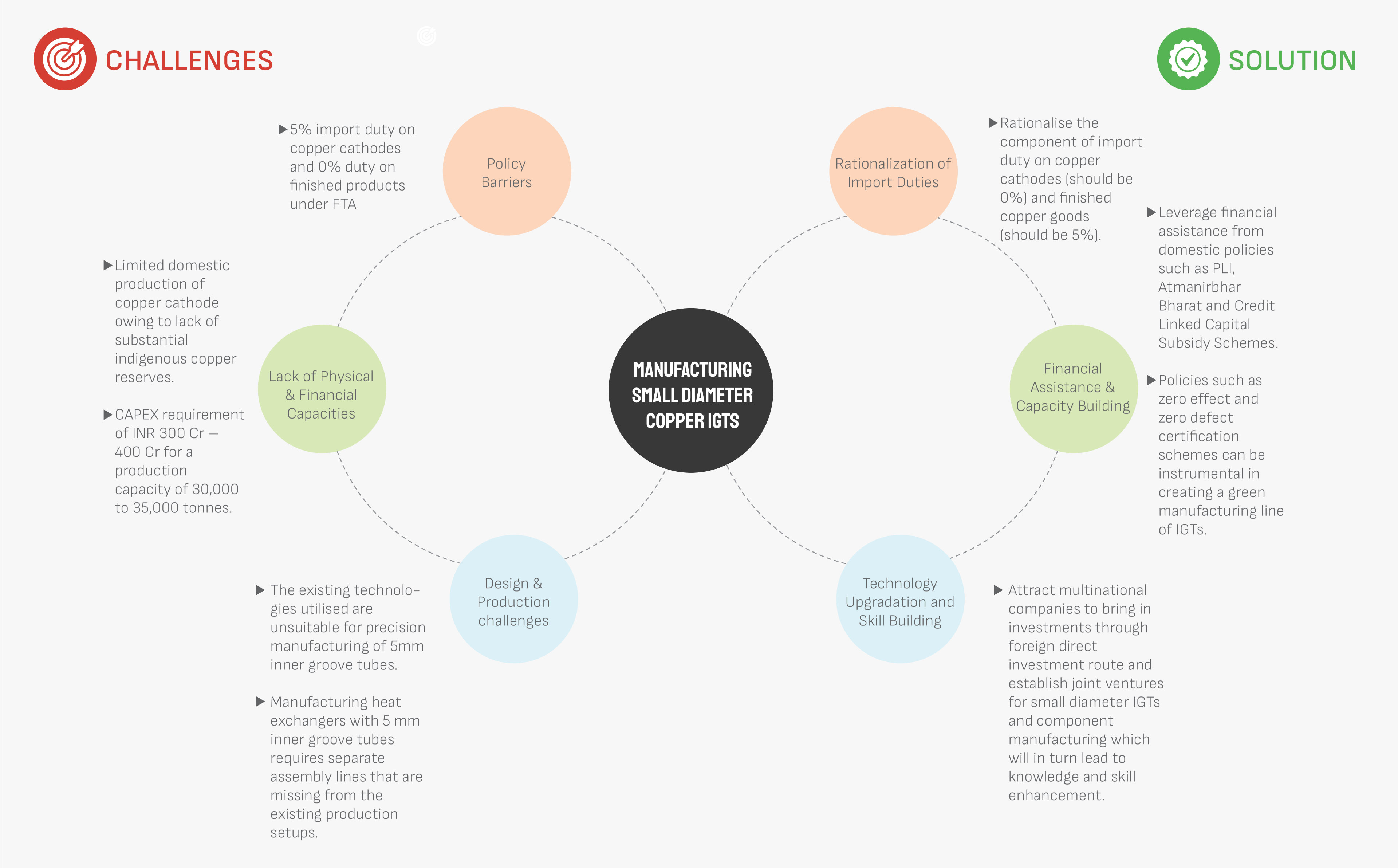
Figure 2: Socioeconomic benefits of domestic IGT manufacturing[5]

The lack of domestic manufacturing capacity and incomplete transition can be attributed to several factors, including the need for modern precision technologies, lack of qualified personnel and skilled labour to operate high tech machinery, high initial installation costs, lack of a research and development (R&D) ecosystem for the technology, and the inverted duty structure under the FTA. Lack of domestic manufacturing capacity and supply chain issues with trade disruptions during the 2019 coronavirus disease (COVID-19) pandemic have further slowed down the pace of IGT integration into appliances, leading to India's delayed adaptation response. A summary of industry-wide challenges and potential solutions mapped in the report is illustrated in Figure 3 below:

A complete transition and domestic manufacturing are the need of the hour, as this can help ensure timely and much-desired climate resilience, enhance the copper tube manufacturing industry, and significantly contribute to India's Panchamrit Vision and its ambition of becoming Atmanirbhar (self-reliant).

5 Author's own analysis

Figure 3: Challenges and proposed solutions[6]



6 The challenges mapped and illustrated in the figure pertain to the period of this study, i.e August 2021 - February 2022.

A complete transition and domestic manufacturing are the need of the hour, as this can help ensure timely and much-desired climate resilience, enhance the copper tube manufacturing sector, and significantly contribute to India's Panchamrit Vision and its ambition of becoming Atmanirbhar (self-reliant).

In light of the projected increase in RAC penetration, as well as the self-reliance goals put forward in the countries' Make in India and Atmanirbhar Bharat Mission, this study looks at the merits of 5mm copper IGTs over 7mm copper IGTs and their aluminium counterparts. The copper tubing market in India and barriers faced by the industry have been evaluated to identify potential policy solutions to cater to the existing scenario, as illustrated in Table 1 below:

Table 1: Recommendations for promoting 5mm IGT adoption and domestic manufacturing in India

S.No	Challenges	Recommendations
A. Facilitating heat exchanger manufacturing in India		
1.	**Research and Development** Facilitating the use of 5mm copper tubes requires re-designing heat exchangers, running simulations on refrigerant flow and temperature changes, and optimising the overall heat transfer performance.	**Recommendation 1:** Set up a national R&D facility such as the Centre for Sustainable Cooling to promote energy efficiency and greener refrigerants in cooling technologies by bolstering national and international collaboration.
2.	**Investment** Manufacturing heat exchangers with 5mm IGTs requires a separate assembly line, entailing investment in a new set of tools and machinery and significant rework for OEMs to switch from an existing 7mm setup to a new 5mm setup.	**Recommendation 2:** Create special incentives under the PLI scheme and multilateral funds on refrigerant and/or clean energy technologies be catalysed towards facilitating the growth of new manufacturing setups.
3.	**Skill development** IGT manufacturing requires a higher degree of sophistication and precision, which is difficult to achieve with the currently available domestic technologies and skill level of domestic plain copper tube manufacturers	**Recommendation 3:** Drive skill-building of the sector through training and national certification schemes.
B. Enabling IGT manufacturing in India		
4.	**Import duties** The existing duty-free imports of finished products such as copper tubes and pipes from Vietnam, Malaysia, and Thailand under the FTA with ASEAN discourages investment in domestic manufacturing of small diameter copper tubes.	**Recommendation 4:** Rationalise the component of import duty on copper cathodes and finished copper goods in the downstream copper industry to create a level playing field for domestic manufacturers.

S.No	Challenges	Recommendations
5.	**FTAs** Complete dependence on imports poses business risks, as witnessed during the COVID-19 pandemic when major supply chain disruptions occurred.	**Recommendation 4:** Rationalise the component of import duty on copper cathodes and finished copper goods in the downstream copper industry to create a level playing field for domestic manufacturers.
6.	**Initial cost** Setting up an IGT manufacturing facility requires a high CAPEX, posing a huge investment challenge for large, small, and medium-sized industry players.	**Recommendation 5:** Form a cluster on value-added copper products. Recommendation 6: Attract multinational companies to bring in investments through the FDI route and establish joint ventures for small diameter IGT and component manufacturing.
7.	**Skill development** IGT manufacturing requires a higher degree of sophistication and precision, which is difficult to achieve with the currently available domestic technologies and skill level of domestic plain copper tube manufacturers.	**Recommendation 7:** Drive skill-building of the sector through training and national certification schemes.

After carefully envisaging the potential solutions, the study has also mapped the various public and private institutions that can play a role in rolling out these recommendations. A recommended rollout plan has been detailed for the concerned departments in Chapter 5. The rollout of the recommendations could be a significant policy action to position India as a leading manufacturer and export destination for progressive and climate-friendly technological innovations.

In light of the current scenario described above, this report is an attempt to create knowledge and awareness about the use of IGTs in RACs. Further information on the existing scenario of IGTs and background of the project is provided in Chapter 1. The report subsequently dwells into the merits of using small diameter IGTs in RACs in terms of resource (energy, refrigerant, and material) efficiency via 5mm copper tubing in Chapter 2. Further details on the market assessment of the use of copper tubing in domestically manufactured RACs have been elaborated in Chapter 3. A landscape of policies promoting the transition internationally and indigenously is presented in Chapter 4. This is followed by a set of recommendations to accelerate the transition to small diameter IGTs in domestic appliances such as RACs, including measures that can potentially lead to the development of a domestic manufacturing ecosystem for the industry, in Chapter 5.

The India Cooling Action Plan (ICAP) 2019 recognises cooling as a developmental necessity, and is going to increase given the economic growth trajectory of India. The imperative to promote sustainable cooling in India is based on the projected cooling growth trajectories across various sectors, including buildings, cold-chain, refrigeration, and transport from 2017-18 to 2037-38.

01 INTRODUCTION

1.1 BACKGROUND

India is among the countries with the most cooling degree days in the world, with more than

3,000 per year

India is among the countries with the most cooling degree days in the world, with more than 3,000 per year. A cooling degree day is a measure to quantify the demand for energy needed to cool a building. The India Cooling Action Plan (ICAP) 2019 recognises cooling as a developmental necessity, and is going to increase given the economic growth trajectory of India. The imperative to promote sustainable cooling in India is based on the projected cooling growth trajectories across various sectors, including buildings, cold-chain, refrigeration, and transport from 2017-18 to 2037-38. Among these, a notable trend is that of space cooling demand in the buildings sector, which is envisaged to increase by 11 times by the end of the next decade[7].

The role of refrigerant-based cooling solutions has been widely documented in ICAP, which highlights the significance of upgrades required in room air cooling technologies such as room air conditioners (RACs), the stock of which is projected to increase to about ~580 million by 2037-38 from its baseline values of ~40 million in 2017-18. Similar trends are projected in the demand for RAC refrigerants and energy use, which are expected to increase by 8x and 6.5x, respectively, in the non-intervention or reference scenarios[8]. One important aspect of the enhanced demand for refrigerants and energy is the associated increase in greenhouse gas (GHG) emissions. Addressing these emissions has been a part of India's mitigation strategy, which includes the phasing out of ozone-depleting hydrochlorofluorocarbons (HCFCs) in compliance with the Montreal Protocol framework. While HCFCs were first replaced with hydrofluorocarbons (HFCs), the HCFC Phase-out Management Plan (HPMP)-II mandates that the country gradually phase down HFCs and shift to non-HFCs and other low-global warming potential (GWP) and natural refrigerants.

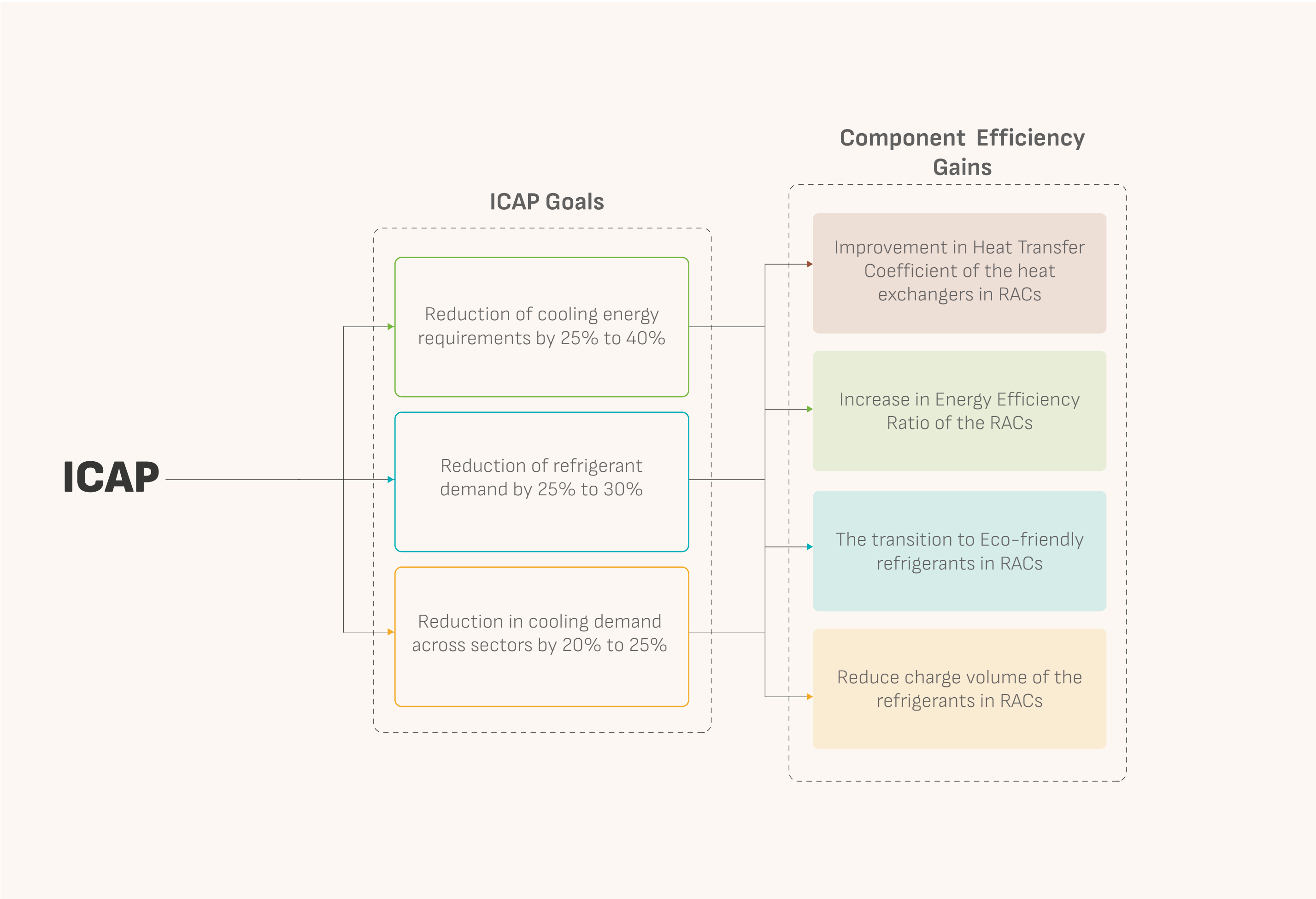
7 Ministry of Environment, Forest & Climate Change (2019). India Cooling Action Plan. New Delhi: Ministry of Environment, Forest & Climate Change.

8 Ministry of Environment, Forest & Climate Change (2019). India Cooling Action Plan. New Delhi: Ministry of Environment, Forest & Climate Change.

India's ratification of the Kigali Amendment in August 2021 and its declaration at the 26th United Nations Climate Change Conference of Parties (COP26) in 2021 to become net-zero by 2070 signal the need for enhanced climate action and transitioning to super energy-efficient sustainable space cooling products. This transition requires technological improvements in end-product components to make them compatible with the new class of refrigerants. There is an emerging and ever-growing need for the country to innovate, adapt, and accelerate the deployment of improved RAC equipment that is compatible with the class of high-pressure, low-GWP refrigerants. This can lead to enhanced RAC efficiency and reduced energy consumption and associated emissions. An emerging body of literature has also emphasised that there is an urgent need to transition to super energy-efficient RACs and promote the use of low-ozone depleting potential (ODP) & -GWP refrigerants.

AEEE's report "Transitioning to Super Energy-Efficient Room Air Conditioners: Fostering ICAP Implementation" also suggests that component level efficiency gains are crucial to achieving a reduction in space cooling energy demand from RACs, supporting ICAP implementation and India's Net Zero commitments. The ICAP goals can be met by enhancing component level efficiency gains within the RACs, as shown in Figure 4 below:

Figure 4: Component efficiency gains' contribution to achieving ICAP goals



One such component that can facilitate the implementation of ICAP recommendations is the substitution of large diameter copper tubes with small diameter 5 millimetre (mm) inner grooved copper tubes (IGTs) in RAC heat exchangers. This is a technological response that has been embraced by the RAC industry globally to meet climate commitments. Cumulatively, the climate policies adopted or ratified by the country necessitate actions to upgrade the energy efficiency standards of cooling appliances such as RACs. This can be achieved by promoting component and material substitutions that support greater heat exchange coefficients, are compatible with modern refrigerants, and are cost-effective, in order to ensure their equitable access and widespread penetration. The set of domestic climate-centric policies and institutional landscapes that can potentially enable the promotion of small diameter IGTs in RACs have been mapped in Table 2 below:

Table 2: Potential implications of climate-centred policies on small diameter copper IGT promotion

S.No.	Institution	Policy, aim, & objectives	Opportunities for component-level efficiency gains in RACs
1	Ministry of Environment, Forest and Climate Change (MoEF&CC)	**ICAP[9] Objective:** To address cooling requirements across sectors and ways and means to provide access to sustainable cooling by: Reducing cooling demand across sectors by 20-25 % by 2037-38. Reducing refrigerant demand by 25-30% by 2037-38. Reducing cooling energy requirements by 25-40% by 2037-38.	The substitution of 7mm copper tubes with 5mm small diameter IGTs enhances the efficiency coefficient of RACs, and they can also withstand the higher operating pressure of low-GWP refrigerants such as R290. A complete transition to small diameter IGTs in RAC components, however, requires additional research and development (R&D) efforts. The acceleration of the transition towards small diameter IGTs can help India comply with the goals on reduction in cooling and refrigerant use set under ICAP.
2	MoEF&CC	**HPMP-II[10] Objective:** HPMP Stage-II was launched in 2017 by the MoEF&CC. Stage II targets phasing out HCFCs in 6 major (RAC) brands by 2022 and training 17,000 RAC technicians. It also aims to convert 10 manufacturing lines in 6 AC manufacturing enterprises from HCFC-22 to HFC-32 (a non-ODS and low-GWP) refrigerant and increase energy efficiency in the building sector.	Transitioning to 5mm IGTs can directly ensure compliance with the HPMP-II by accelerating the transition to non-ODP and low-GWP refrigerants such as R32, thus incentivising improvement in cooling appliance energy efficiency through the adoption of modern refrigerants. Further, the transition to 5mm IGTs can help in the reduction of refrigerant discharge by 20% or more in modern refrigerants compared to 7mm IGTs in an RAC.

9 Ministry of Environment, Forest & Climate Change (2019). India Cooling Action Plan. New Delhi: Ministry of Environment, Forest & Climate Change.

10 EIA Briefing to the 22nd Conference of the Parties (CoP22) to the United Nations Framework Convention on Climate Change (UNFCCC), (2016). Available at: https://eia-international.org/wp-content/uploads/EIA-Kigali-Amendment-to-the-Montreal-Protocol-FINAL.pdf

S.No.	Institution	Policy, aim, & objectives	Opportunities for component-level efficiency gains in RACs
3	Bureau of Energy Efficiency (BEE)	**Standards and Labelling (S&L) Programme** **Objective:** The BEE's S&L programme sets Minimum Energy Performance Standards (MEPS) for various appliances, including RACs, which are to be adhered to by the respective appliance manufacturers in order for them to be able to sell or import the products under the S&L mandatory appliance category.	Compliance with the revised MEPS can stimulate innovation in the adoption of thermodynamically efficient material for components such as small diameter copper IGTs. This can enhance RACs' energy and seasonal efficiency by promoting the use of: ◆ Advanced compressor technologies optimised at a low frequency ◆ Large heat exchangers with thermodynamically effective materials and designs ◆ Low-GWP refrigerants[11].

Although there are opportunities for component-level efficiency gains with respect to RACs through the adoption of 5mm IGTs in the RACs, copper is only available in limited quantities. In addition, the lack of availability of smaller diameter IGTs and technical know-how continues to be a barrier to the rapid adoption of 5mm coils. The Indian AC industry is still dependent on imports for IGTs, which are essential for coils. There are no domestic IGT manufacturers in India, and the Free Trade Agreements (FTAs) with the Association of Southeast Asian Nations (ASEAN) region, which is the primary source of tube imports, are making investment in local manufacturing unviable.

Copper tubes, particularly the small diameter 5mm IGTs in India imported from China, Vietnam, Malaysia, and Thailand, account for 90% of all imports into India, and Indian manufacturers are left with only a 10% market share, translating to a loss of foreign exchange towards the import payments. This also cumulatively represents the economic and social losses the country has suffered in terms of lost opportunities to earn foreign revenue, potential monetary output, and employment in the industry. Thus, this study is an attempt to identify the opportunities in terms of revenue and job creation through domestic manufacturing, assess the environmental impact of the transition to 5mm IGTs, and outline the potential that exists for India.

The report aims to provide insights on the potential benefits of the adoption of 5mm IGTs in heat exchangers in RACs and identify enabling mechanisms for domestic manufacturing of 5mm IGTs in India.

11 Shah, N., Park, W. Y., & Ding, C. (2021). Trends in best-in-class energy-efficient technologies for room air conditioners. Energy Reports, 7, 3162-3170.

1.2 GOALS AND OBJECTIVE

The study was conceptualised based on the fact that IGTs consume less refrigerant and energy; there is a huge potential to meet India's climate commitments if the IGTs are adopted on a large scale in the Indian RAC sector. Further, as 90% of IGTs in India are imported, there are anticipated socioeconomic co-benefits that can be leveraged through domestic IGT manufacturing in India and contribute to the Make in India initiative. Thus, the study had two broad goals:

1. To promote rapid adoption of 5mm copper tubes in the Indian RAC sector
2. To advocate for the creation of enabling mechanisms for mainstreaming domestic production of IGTs in India.

The objective of this report is to provide insights on the value chain benefits of the adoption of small diameter copper tubing in RACs. In addition, since IGTs are currently imported, the report also identifies the barriers and provides recommendations on how to enhance domestic manufacturing and support the adoption of 5mm IGTs in heat exchangers in RACs.

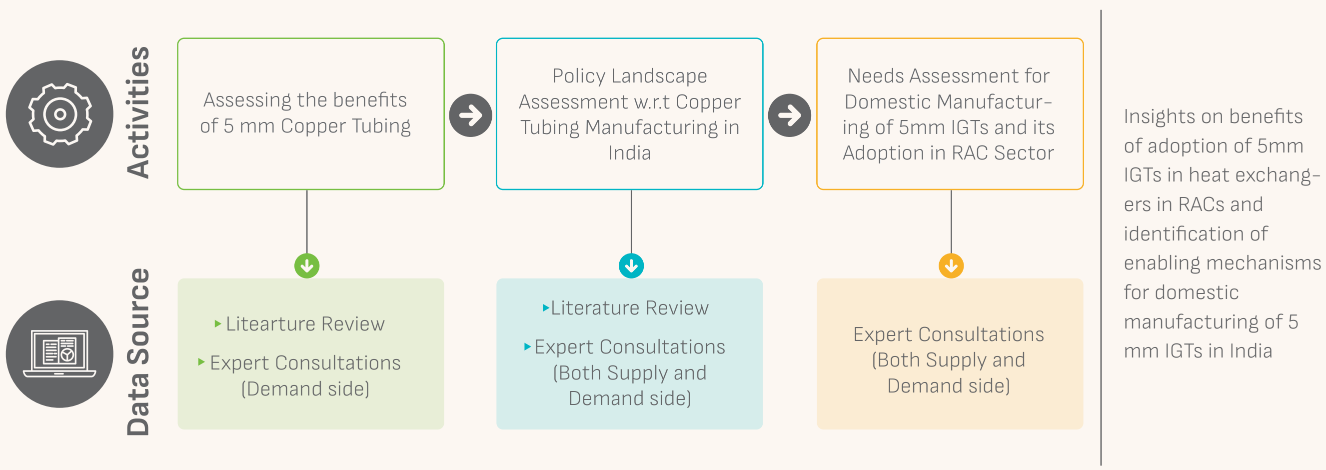
1.2.1 Overall approach

In order to provide information and insights about the value chain benefits (both socioeconomic and environmental) of adoption of 5mm IGTs in heat exchangers in RACs and identify enabling mechanisms for domestic IGT manufacturing, the following activities were undertaken in the study:

- Comparative assessment of performance (energy and refrigerant) of business-as-usual (BAU) ACs & ACs with 5mm copper tubing & identification of value chain benefits for the latter case
- Review of international and national policies and agreements (environmental & socioeconomic) in the context of copper tube import & manufacturing
- Needs assessment for domestic IGT manufacturing in India.

A mixed-mode research method was adopted wherein a literature review and expert consultations were conducted for different steps, as shown in Figure 5 below:

Figure 5: Overall study approach



A literature review was conducted to get a better understanding of the environmental benefits of IGTs, as well as assess the policy measures adopted internationally to upscale domestic IGT manufacturing. The needs assessment for enhancing domestic 5mm IGT manufacturing and IGT adoption in the Indian RAC sector was done through expert consultations.

Key literature sources:

- *Shah, N., Park, W. Y., & Ding, C. (2021). Trends in best-in-class energy-efficient technologies for room air conditioners. Energy Reports, 7, 3162-3170.*
- *Ministry of Environment, Forest & Climate Change (2019). India Cooling Action Plan. New Delhi: Ministry of Environment, Forest & Climate Change.*
- *Shah, N. K., Park, W. Y., & Gerke, B. "Assessment of Commercially Available Energy-Efficient Room Air Conditioners Including Models with Low Global Warming Potential (GWP) Refrigerants," no. October (2017): 1–67.*
- *Cheng, S., Wang, S. F., & Liu, Z. "Cycle Performance of Alternative Refrigerants for Domestic Air-Conditioning System Based on a Small Finned Tube Heat Exchanger." Applied Thermal Engineering 64, no. 1–2 (March 2014): 83–92. https://doi.org/10.1016/j.applthermaleng.2013.12.022.*
- *in der Heiden, P., & Taube, M. "Analysis of Market-Distortions in the Chinese Non-Ferrous Metals Industry," 2017.*
- *Shabtay, Y., Black, J., & Kraft, F. F.. "New Copper-Based Heat Exchangers for Alternative Refrigerants," 2014, 1–10. https://doi.org/https://doi.org/10.1016/j.applthermaleng.2013.12.022.*
- *Singh, M., Gurumurthy, G., and Shreya, S.. "Mapping the Refrigerant Trends in India : An Assessment of Room AC Sector," 2019, 20. https://www.teriin.org/sites/default/files/2019-11/Mapping the Refrigerant Trends in India An Assessment of Room AC sector.pdf.*
- *Weed, R., and Hipchen, J.. "Benefits of Reduced Diameter Copper Tubes in Evaporators and Condensers." In ASHRAE Transactions, 117:166–73, 2011.*
- *MSME Annual Report: 2020-21 https://msme.gov.in/sites/default/files/MSME-ANNUAL-REPORT-ENGLISH%202020-21.pdf*
- *Singhal, A., Sharma, S., & Garg, T. (2021). Transitioning to Super Energy-Efficient Room Air Conditioners Fostering ICAP Implementation. Alliance for an Energy-Efficient Economy.*
- *Avalon Market Research, "Copper Tubes, and Flat Products Market in India," June 2017.*

Stakeholder consultations:

In collaboration with the ICA team, the AEEE team engaged with both supply- and demand-side stakeholders to get a well-rounded overview of the sector's present status with respect to the adoption of 5mm IGTs in the RAC sector in India and assess the domestic manufacturing landscape of 5mm IGTs. During the study, overall, 10 expert consultations were held, which provided insight on existing challenges and potential opportunities for the adoption and manufacturing of 5mm IGTs in India. The stakeholder consultations were held with the following organisations:

- **Copper tube manufacturers:** Indigo and Mehta Tubes
- **Heat exchanger manufacturers:** Danvita, Micro coils, Spirotech, Amber Group, and E-Durables
- **RAC manufacturers:** Daikin and Godrej.

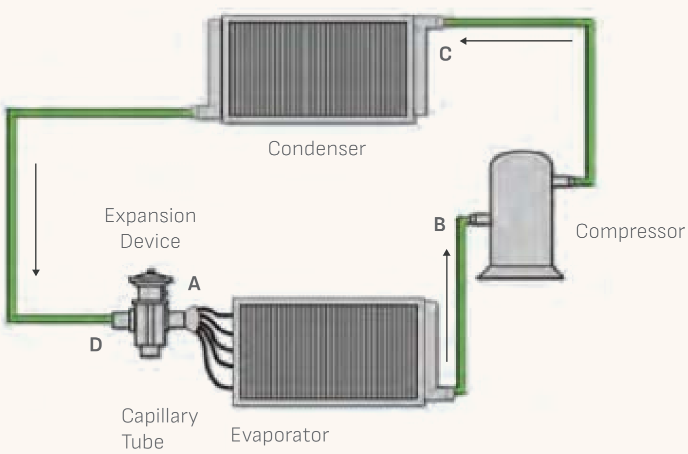
02 SMALL COPPER TUBING AS AN ENABLER FOR SUSTAINABLE COOLING

The substitution of small diameter IGTs for aluminium and large diameter copper tubes in RAC components such as compressors and evaporators leads to significant gains in terms of higher efficiency and resource savings through reduced refrigerant discharge, enhanced RAC performance, and reduced cooling-based demand for energy. Further details on the contributions of small diameter copper IGTs in RACs to sustainable cooling are given in the subsequent sections of this chapter.

2.1 RAC TECHNOLOGY

An RAC consists of five major components: evaporator, condenser, expansion device, compressor, & capillary tube, as shown in Figure 6. Each of these components is connected via tubes and carries refrigerants. Condensers and evaporators in RACs can be categorised as heat exchangers. In the heat exchangers, there are fins and capillary tubes. The fins are usually made of aluminium, whereas the capillary tubes are available in both aluminium and copper.

Figure 6: RAC components[12]



Typically, copper has been the preferred choice for RAC manufacturers; however, in the 1970s, the introduction of aluminium coils made RACs cheaper and more affordable. Nonetheless, in RAC operation, many of the coils come in contact with air, which causes oxidation, and as copper is anti-corrosive, it can better handle the oxidation, thereby increasing RAC lifespan. In addition, copper's higher ductility means that copper pipes are stronger and can easily withstand minor damage. Further, soldering in copper coils is easier compared to in aluminium coils, and aluminium coils are more susceptible to punctures & leaks. The various distinct advantages of copper over aluminium are briefly described in Table 3:

Table 3: Comparison of copper coil vs. aluminium coil

Characteristic	Copper coil	Aluminium coil
Heat transfer	The thermal conductivity of copper is higher, thus resulting in higher overall heat transfer.	Aluminium has only 60% of the thermal conductivity of copper and hence has lower overall heat transfer.
Corrosion	Copper does not react with water, while it reacts with atmospheric oxygen slowly over time. Therefore, it is less corrosive than other metals.	Aluminium has a really high affinity towards oxygen and forms a layer of oxide around its surface, reducing the heat transfer.
Ductility	Copper has good strength and rigidity; hence, it is more durable and stable than aluminium.	Aluminium is not as sturdy as copper and needs heavy protection during its operation.
Repairing	Due to copper's higher strength, it is easy to perform welding and bending processes to repair the copper tubes.	The welding process is a delicate and sensitive process in aluminium, is quite difficult to execute, and requires total replacement.

12 Fundamental series Trane belgium publication, "Air Conditioning Clinic," 2012, https://www.tranebelgium.com/files/book-doc/20/en/20.aqerykdx.pdf.

Table 4: Environmental test conducted on aluminium condenser and copper condenser

Type of RAC	Rated Capacity	Actual Capacity (Post Salt Spray of 1000 Hours)	Rated Power Consumption	Rated Power Consumption (Post Salt Spray of 1000 Hours)	Rated EER	Actual EER (Post Salt Spray of 1000 Hours)
Copper Condenser	5500 W	4852 W	1485 W	1581 W	3.70	3.10
Aluminium Condenser	5275 W	4193 W	1465 W	1587 W	3.60	2.64

Source: 2017. Comparative Analysis of Corrosion of Finned Copper Tube Heat Exchanger and Aluminum Microchannel Heat Exchanger. International Copper Association India.

Table 4 indicates a reduction of 0.96 in the EER of the aluminium-based condenser from its rated EER when an environmental test was conducted on the split air conditioners by salt spray method for a period of 1000 hrs. During the test, it was also observed that there was a drastic reduction in the EER of the aluminium-based condenser compared to the copper-based condenser.

The latest enhancement in the aluminium coil, i.e. introduction of the aluminium micro-channel, still inherits the issues related to durability and higher operating cost; therefore, the RAC industry is shifting back to copper tubes because of the significant performance benefit they offer due to the latest enhancements in smaller diameter copper tubes[13].

2.2 ENERGY PERFORMANCE COMPARISON

Over time, copper tubing has again gained prominence over aluminium coils .

For over 20 years, inner grooves have been adapted in copper tubes used in the RAC industry, and they have proven their effectiveness in increasing RAC performance; combining this with smaller copper tubes, the AC industry can achieve higher efficiency gains. The key parameters that have been considered in the energy performance comparison are the following:

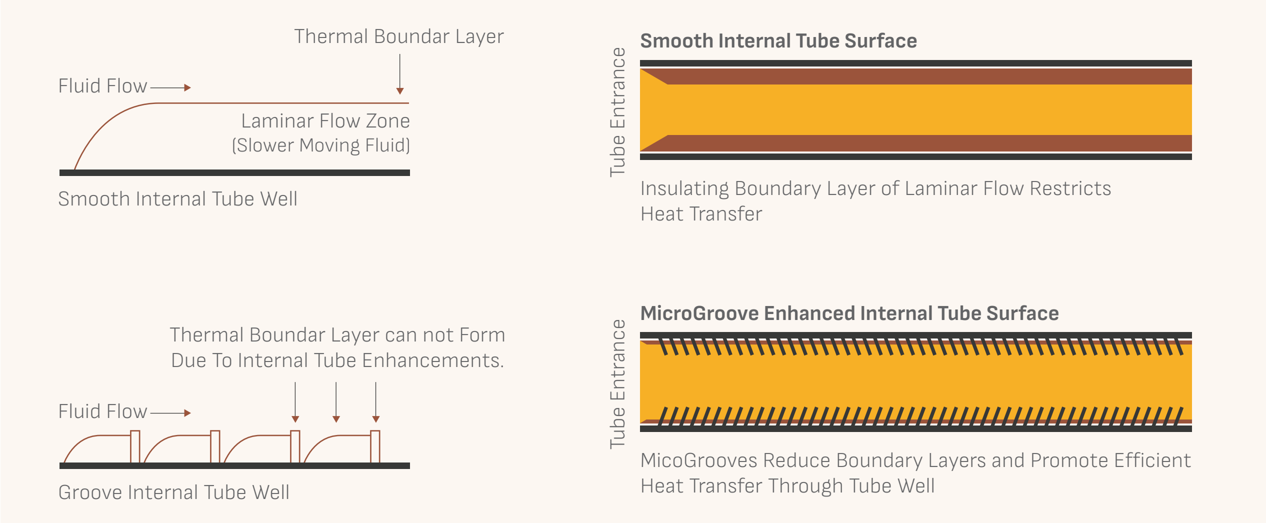
- Heat transfer coefficient
- Surface-area-to-volume (SAV) ratio
- Energy efficiency ratio.

2.2.1 Heat transfer coefficient

The refrigerant inside the copper tube is in the liquid state, and the fluid closer to the surface of the tube moves slower than the fluid in the centre due to friction forming a boundary layer, hindering the heat exchange. The IGTs have micro grooves on the inner surface of the copper tube, as shown in Figure 7, which enhances the geometry of the tube and reduces the friction between the refrigerant and tube surface, reducing the boundary layer hindrance and increasing the overall performance of the copper tube.

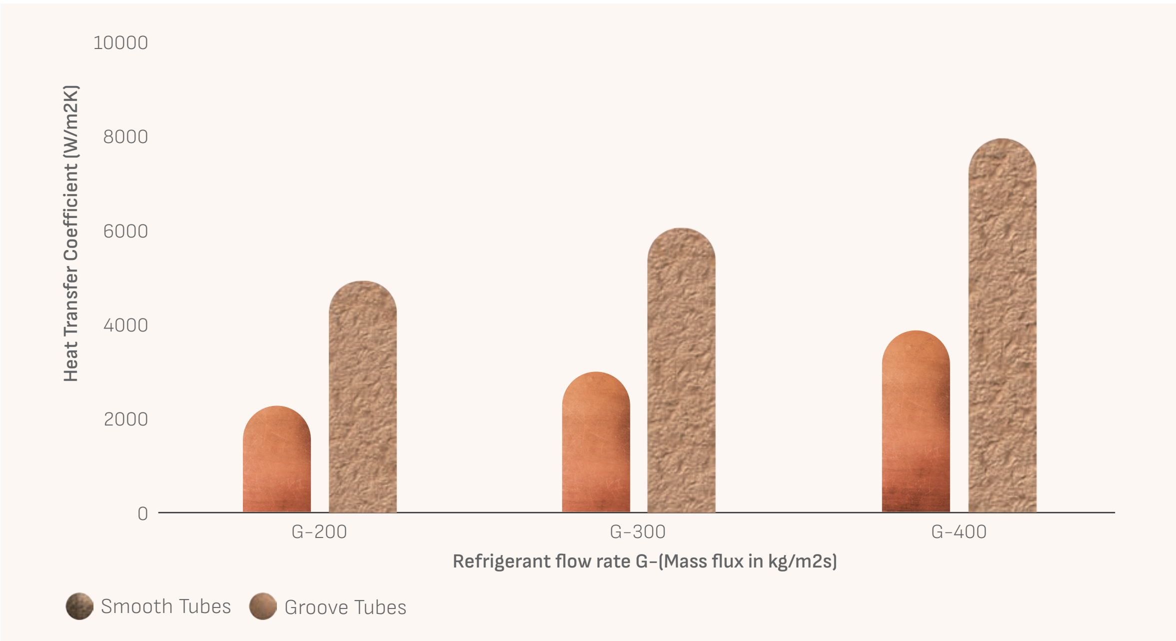
13 Hipchen, J. C., et al., "Simulation-Based Comparison of Optimized AC Coils Using Small Diameter Copper and Aluminum Micro-Channel Tubes," International Refrigeration and Air Conditioning Conference, 2012, 10.

Figure 7: Decrease in boundary layers in IGTs[14]



As shown in Figure 8 below, it has been experimentally proven that there is a significant increase in the performance of the 5mm IGTs compared to 7mm IGTs, keeping other external parameters constant and using R410A refrigerant. The y-axis in Figure 8 is "G," representing the refrigerant's mass flux (kilogrammes per square metre*second (kg/m2s)), while the x-axis represents the heat transfer coefficient (watt per m2*Kelvin (W/m2K)).

Figure 8: Heat transfer coefficient for smooth and grooved copper tubes[15]



14 Weed, R., & Hipchen, J., "Benefits of Reduced Diameter Copper Tubes in Evaporators and Condensers," in ASHRAE Transactions, vol. 117, 2011, 166–73.when modified for smaller diameter copper tubes of 5mm (0.20 inches

15 Weed, R., & Hipchen, J., "Benefits of Reduced Diameter Copper Tubes in Evaporators and Condensers," in ASHRAE Transactions, vol. 117, 2011, 166–73.when modified for smaller diameter copper tubes of 5mm (0.20 inches

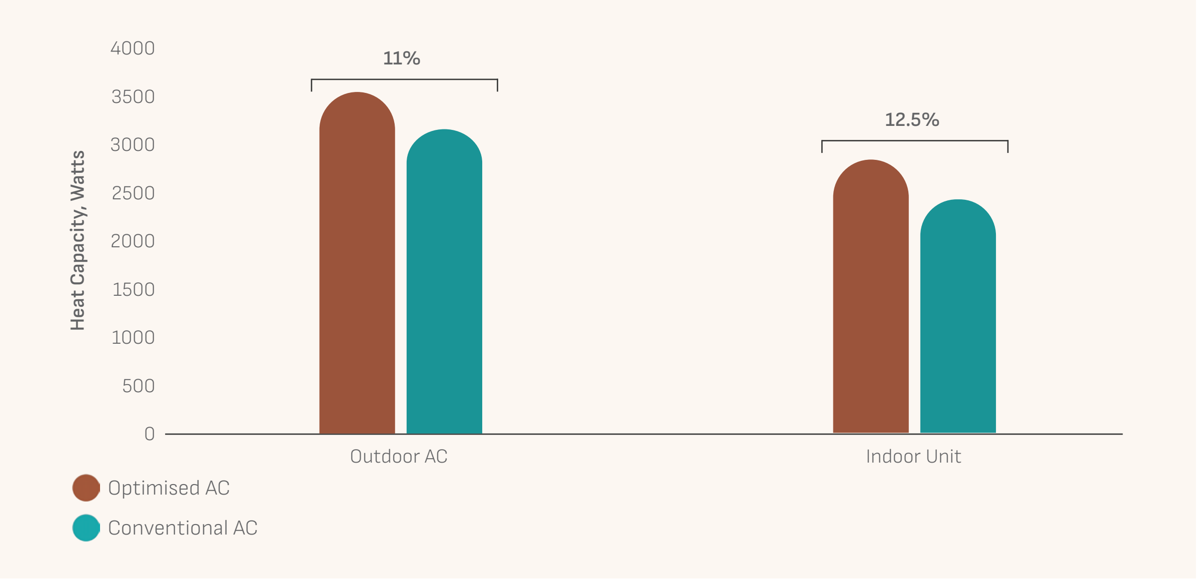
It can be seen in Figure 8 above that, with G (mass flux) = 200 kg/m2s, the heat transfer coefficient for the smooth tube is 2500 W/m2K, whereas for IGTs, it is 5100 W/m2K, suggesting that a performance improvement of over 50% can be achieved in an IGT compared to a smooth copper tube of the same size when tested at multiple flow rates. Further research shows that the decrease in the diameter of the tube leads to a higher refrigerant flow rate due to an increase in the velocity of the refrigerant within the tubes and therefore a higher heat transfer coefficient. Thus, the overall efficiency of the system is higher with IGTs. The total heat transfer from the smaller IGTs represents a significant improvement due to the combined benefit of improved surface and reduced size.

In order to harness the advantages of smaller diameter tubes in the RAC, it is necessary to adjust the design of the fin configuration and coil circuits in the heat exchanger, which requires a computationally intensive programme for designing an optimised heat exchanger. The latest technological enhancement has led to the development of new advanced software that can design these optimised heat exchangers.

The optimised heat exchangers, consisting of 5mm IGTs, are referred to here as optimised RACs, applying to both indoor and outdoor RACs. When tested against conventional RAC units (with 7mm smooth tubes) when using R290 refrigerant, optimised RACs showed significant improvement in performance.

Figure 9 below depicts the comparison of heat extraction capacity (the measure by which an AC system can remove the heat from the room), which improves performance by around 11% in indoor and outdoor units of the optimised RAC (with 5mm copper tubing) compared to the conventional RAC (with 7mm copper tubing) using the same refrigerant (R290).

Figure 9: Comparison of heat capacity: optimised RAC vs. conventional RAC[16]

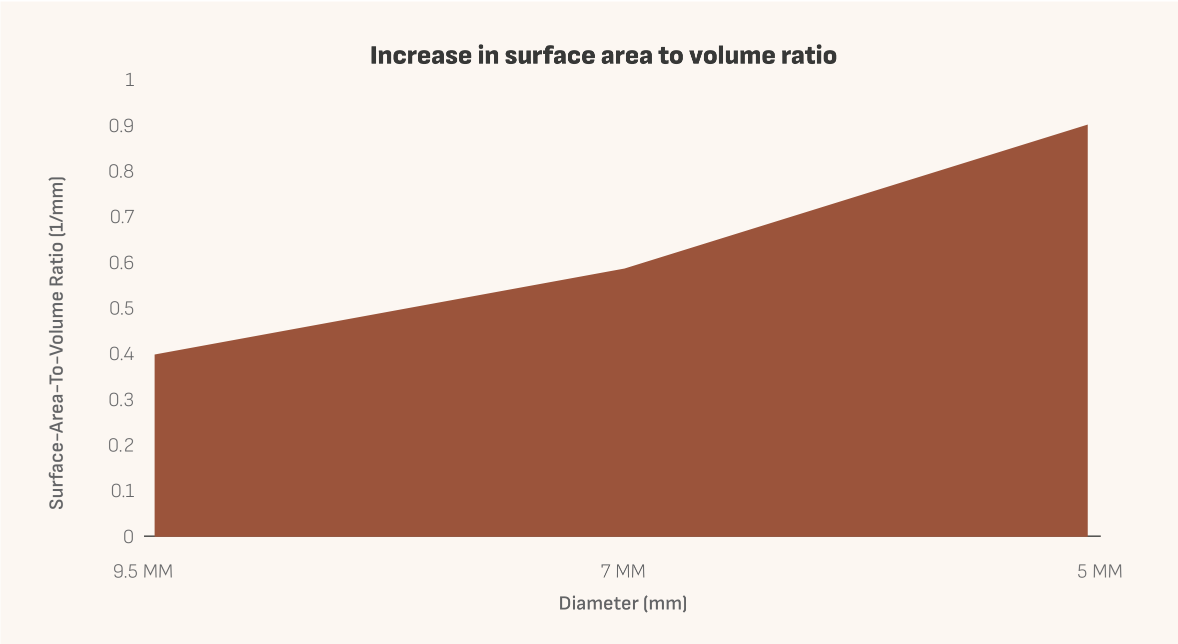


2.2.2 Surface-area-to-volume ratio

To run the RAC, several smaller tubes (5mm) are required to pump a similar amount of refrigerant compared to a larger tube. Therefore, there is an increase in the SAV ratio, as shown in Figure 10.

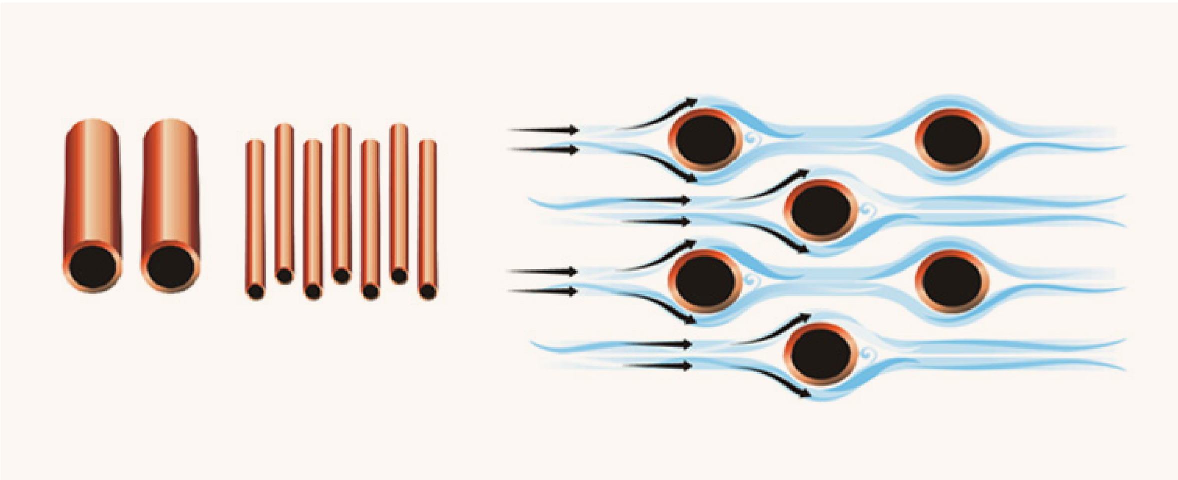
16 Shabtay, Y., Black, J., & Kraft, F.F., "New Copper-Based Heat Exchangers for Alternative Refrigerants," 2014, 1–10, https://doi.org/https://doi.org/10.1016/j.applthermaleng.2013.12.022.

Figure 10: Diameter vs. SAV ratio[17]



In addition, a configuration with multiple parallel copper tubes helps increase the heat transfer rate through increased surface area in contact with air, as shown in Figure 11. However, there is a negligible impact on the cost of the raw material (as copper used by weight is limited), and there is only an incremental cost reduction in the heat exchanger assembly.

Figure 11: Airflow around the tube[18]



2.2.3 Overall improvement in energy efficiency

The improvement in the heat transfer coefficient and increase in SAV ratio have resulted in improvement of the overall efficiency of the RACs when tested with different refrigerants.

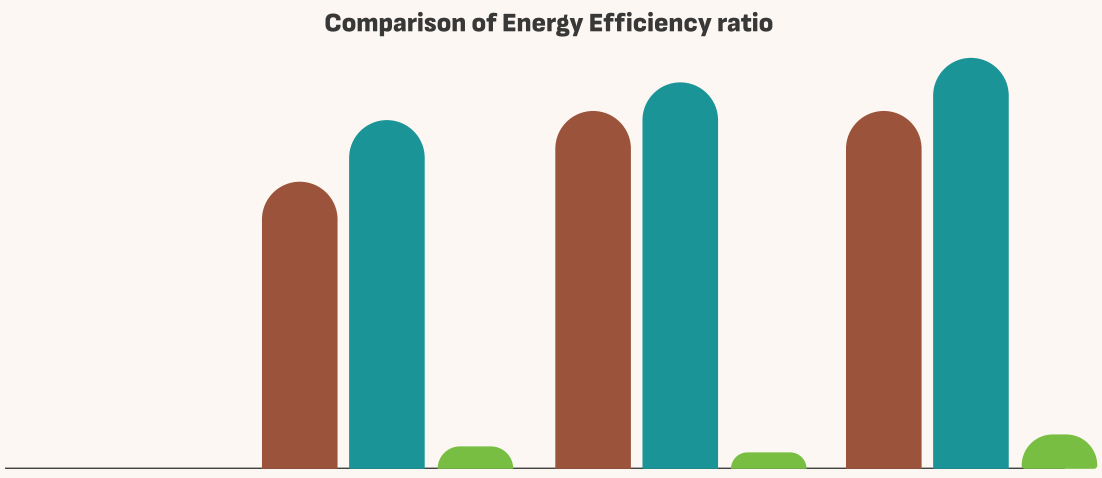
17 Weed, R., & Hipchen, J., "Benefits of Reduced Diameter Copper Tubes in Evaporators and Condensers," in ASHRAE Transactions, vol. 117, 2011, 166–73.when modified for smaller diameter copper tubes of 5mm (0.20 inches

18 "Small Tube Copper Is Economical and Eco-Friendly | The MicroGroove Advantage," accessed December 17, 2021, https://microgroove.net/.

EER = $\frac{\text{(Cooling capacity or heat removed by the RAC in kW)}}{\text{(Power input or power consumed by the RAC in kW)}}$

The greater the EER value, the more efficient an RAC will be; Figure 12 shows the percentage improvement in EER of a typical RAC with 5mm IGTs when tested with different refrigerants that are being widely used in industry, as explained in the subsequent chapters.

Figure 12: Comparison of 5 mm vs. 7mm copper tube in condenser (1.5 TR RAC)[19]



	R22	R32	R290
7 mm Copper Tube	2.95	3.1	3.1
5 mm Copper Tube	3.22	3.28	3.57
Percentage Saving	9%	6%	10.60%

2.3 ENABLING THE REFRIGERANT TRANSITION

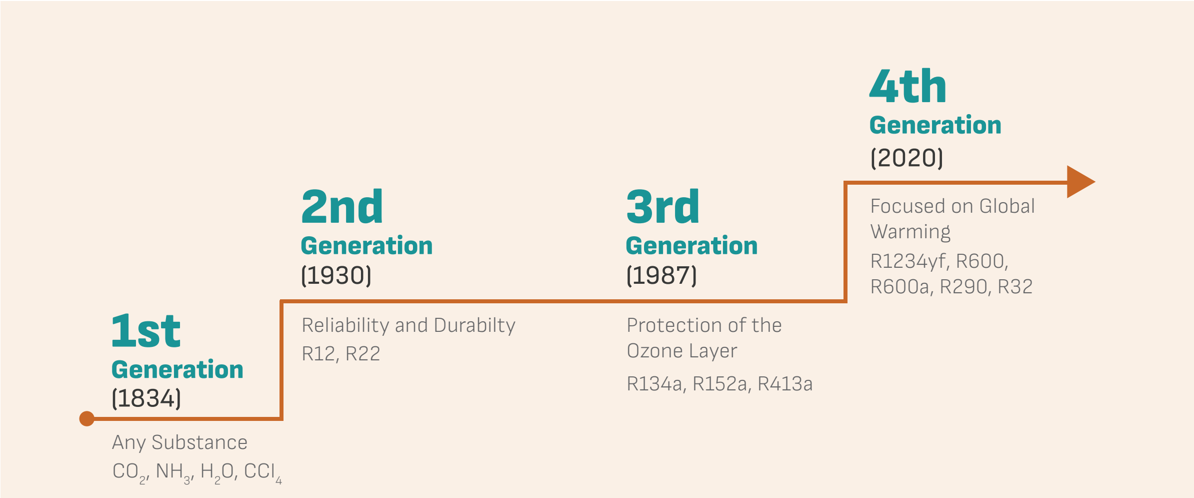
Over the past two decades, India has successfully implemented an ozone depleting substance (ODS) phase-out plan and has enabled the industry to smoothly & systematically transition to ozone-friendly refrigerants. Now, the focus is on low-GWP refrigerants, for which India has accelerated its HCFC phase-out management plan to 2030.

- HPMP I (2012-2015) comprised technology conversion, policies and regulations, technical assistance, training, awareness, coordination, and monitoring in selected HCFC consumption sectors.
- HPMP II (2017-2023) – India is now willing to move towards the adoption of comparatively low-GWP refrigerants like R32 and R290.

A smaller tube can withstand higher pressure, hence making it ideal for alternative and modern eco-friendly refrigerants, which operate at a higher pressure than R22, the most commonly used refrigerant in RACs. This can facilitate the adoption of eco-friendly refrigerants such as R32, creating a much-needed boost for HPMP II. Figure 13 shows the different generations of refrigerants that have been developed over time.

19 "Small Tube Copper Is Economical and Eco-Friendly | The MicroGroove Advantage," accessed December 17, 2021, https://microgroove.net/.

Figure 13: Generations of refrigerants[20]



A brief introduction to some of the widely used refrigerants is given below:

R22: Commonly known as Freon, it has been one of the most widely used AC refrigerants over the years due to its excellent thermodynamic properties. However, due to its significant contribution to ozone depletion and global warming, it has been replaced in most countries.

R410a: It is a mixture of difluoromethane (R32) and pentafluoro-ethane (R125) and is being used as a replacement for R22 refrigerant in ACs. It does not contribute to ozone depletion and is therefore preferred over R22, but due to its high GWP, it is currently being replaced in HPMP II.

R32: R32 is also known as difluoromethane. It belongs to the HFC refrigerant family. This refrigerant is being promoted to replace R410a and R22 because of its lower GWP.

R290: Commonly known as propane, it belongs to the hydrocarbon family. Although it is highly flammable, it has great potential as a refrigerant, with better thermodynamic properties and lower GWP than other refrigerants. It is the future refrigerant for RACs with lower capacity and limitations in charge quantity (up to 1.5 tonnes of refrigeration (TR) split RACs).

As shown in Table 5, R22 has the highest ODP. R410a has the highest GWP, meaning that its use needs to be reduced to ensure a cleaner future. In contrast, R32 and R290 have lower GWP, making them better alternatives and the best existing options for refrigerants of the future.

20 Singh, M., Gurumurthy, G., & Shreya, S., "Mapping the Refrigerant Trends in India : An Assessment of Room AC Sector," 2019, 20, https://www.teriin.org/sites/default/files/2019-11/Mapping the Refrigerant Trends in India An Assessment of Room AC sector.pdf.

Table 5: GWP and ODP of different refrigerants[21]

Refrigerant	Category	GWP	ODP
R22	HCFC	1760	0.055
R410a	HFC	1924	0
R32	HFC	677	0
R290	HC	3	0

2.3.1 Promoting green refrigerants

The newer eco-friendly refrigerants provide a better coefficient of performance (COP) but operate at a higher pressure, thus creating a challenge for their application in standard RACs, since the working pressure is directly proportional to the wall thickness of the tube and inversely proportional to the tube's diameter. The smaller diameter tubes can withstand this higher pressure, meaning that the usage of the eco-friendly refrigerants in smaller IGTs is feasible.

Nevertheless, in the application of smaller IGTs, there is a larger pressure drop. The application of these tubes therefore requires a greater number of circuits than the standard tubes (7mm) to decrease this pressure drop so that an IGT can outperform a standard tube, as shown in Table 6.

Table 6: Pressure drops in 5mm copper tube vs. 7mm copper tube[22]

Parameter	5mm copper tube	7mm copper tube
Number of tubes per row	28	30
Number of rows	2	2
Coil length	750 mm	750 mm
Fin pitch	1.60 mm	1.60 mm
Number of circuits	8	4
Capacity	6.13 kW	6.11 kW
Fluid pressure drop	24.72 kPa	37.42 kPa
Manifold pressure	0 kPa	0 kPa
Total pressure drop - fluid side	24.72 kPa	37.42

The decrease in the pressure drop has enabled widespread incorporation of 5mm IGTs into RAC condensers. The market is now moving towards 5mm IGT integration on the evaporator side.

21 Cheng, S., Wang, S., & Liu, Z., "Cycle Performance of Alternative Refrigerants for Domestic Air-Conditioning System Based on a Small Finned Tube Heat Exchanger," Applied Thermal Engineering 64, no. 1–2 (March 2014): 83–92, https://doi.org/10.1016/j.applthermaleng.2013.12.022.
22 Data obtained from Spirotech, heat exchanger manufacturer, India

2.3.2 Decrease in refrigerant recharge

Modern eco-friendly refrigerants have a high volumetric cooling capacity, which means they can have the same heat capacity at a reduced charge volume of the refrigerant. In addition, with the application of 5mm IGTs, one can further augment savings in refrigerant quantity without affecting the performance. Table 7 presents typical percentage savings of the most common refrigerants for 5mm IGTs vs. 7mm IGTs.

Table 7: Refrigerant savings in 5mm tube vs. 7mm tube for1.5 TR condenser[23]

Refrigerant	7mm copper tube	5mm copper tube	Savings
R22	960 g	870 g	9.3%
R410A	915 g	836 g	8.6%
R32	875 g	700 g	20.0%
R290	480 g	375 g	21.8%

2.4 MATERIAL SAVINGS

Heat exchangers made with 5mm diameter copper tubes require less material than those made with 7mm diameter copper tubes, as shown in Table 8.

Table 8: Material savings in 5mm copper tube vs. 7mm copper tube for 1.5 TR condenser[24]

Material	7mm copper tube	5mm copper tube	Savings
Copper tube weight	1.328 kg	1.050 kg	21%
Aluminium fin weight	2.136 kg	1.168 kg	45%

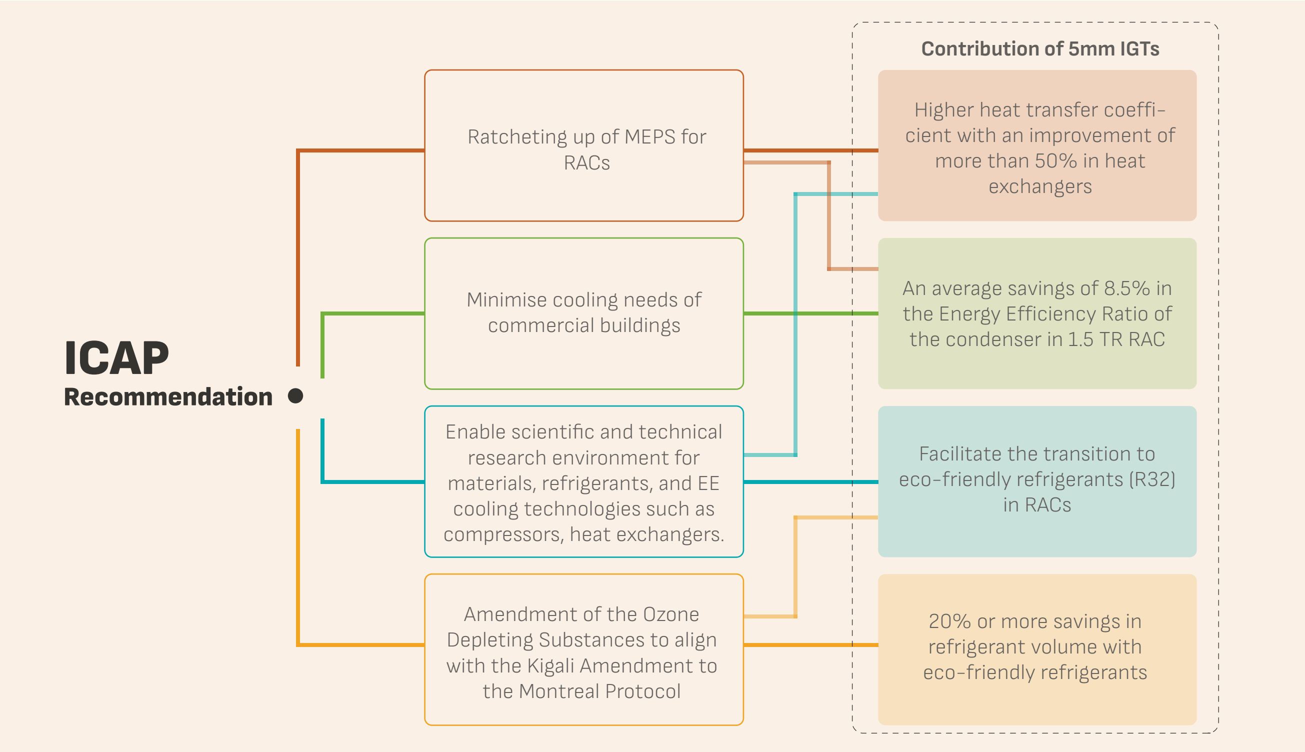
As seen in Table 8, there is an overall savings of around 21% of copper for the capillary tubes and around 45% for the aluminium fins required for the manufacturing of heat exchangers with small diameter IGTs. Thus, the use of IGTs facilitates the development of more affordable and energy-efficient RACs without compromising on system performance.

2.5 SIGNIFICANCE OF SMALL DIAMETER IGTS FOR INDIAN RAC INDUSTRY

ICAP provides an integrated view of cooling across all sectors; the adoption of 5mm IGTs can facilitate implementation of the ICAP recommendations and achievement of the 2037-38 targets. Figure 14 shows the contribution of 5mm IGTs towards ICAP recommendations.

23 "Small Tube Copper Is Economical and Eco-Friendly | The MicroGroove Advantage," accessed December 17, 2021, https://microgroove.net/.
24 "Small Tube Copper Is Economical and Eco-Friendly | The MicroGroove Advantage," accessed December 17, 2021, https://microgroove.net/.

Figure 14: Contribution of 5mm IGTs towards ICAP recommendations[25]

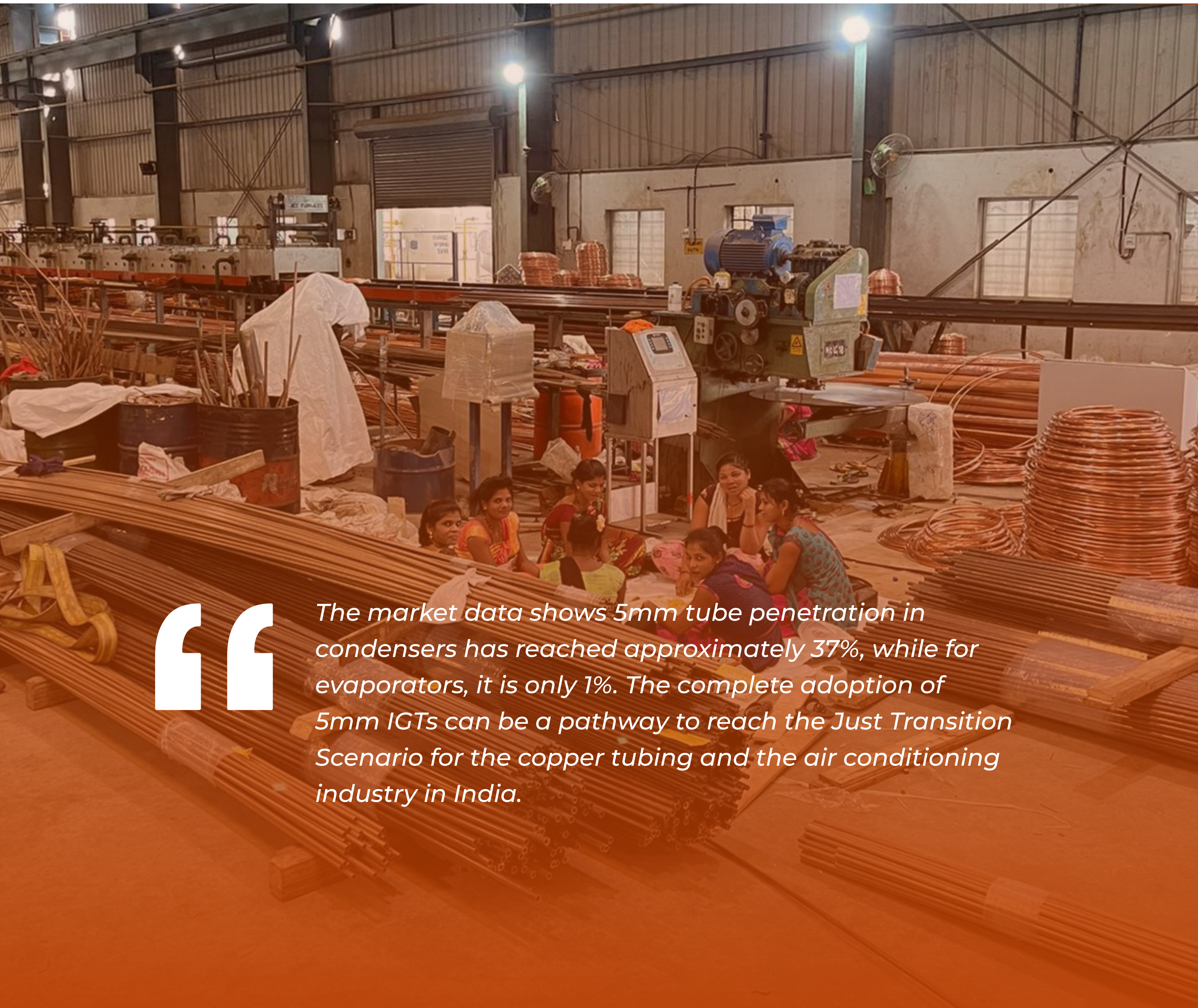


As shown in Fig 10, the contribution of 5mm IGTs toward ICAP implementation can enable improvements in the heat exchange process, leading to improved EERs and reduction in energy consumption. In addition, since 5mm IGTs can withstand higher pressure, these enable the transition to modern climate-friendly refrigerants, and being smaller in diameter reduces the refrigerant recharge requirements.

25 Small Tube Copper Is Economical and Eco-Friendly | The MicroGroove Advantage," accessed December 17, 2021, https://microgroove.net/.

India is presently in a transitional phase, and there is substantial scope to promote faster penetration of the technology within the domestic RAC industry through enabling mechanisms. The lack of domestic manufacturing capacity and supply chain issues with trade disruptions during the 2019 coronavirus disease (COVID-19) pandemic has resulted in slow integration of small diameter IGTs in RACs. This has led to a delayed mitigation response that could otherwise build timely and much-desired resilience in the sector and contribute comprehensively to achieving the country's commitments on climate actions.

Although copper has multiple benefits and could be instrumental in achieving India's climate commitments, it is only available only in limited quantities, with its reserves mainly concentrated in the states of Rajasthan, Madhya Pradesh, Bihar, and Jharkhand. India's refined copper product industry has largely thrived on the imports of copper ore (concentrate), which undergoes smelting & refining domestically, after which finished copper cathodes and other value-added products are exported to countries like China, Singapore, Taiwan, Malaysia, etc. Between 2012-13 and 2016-17, copper cathode exports registered a compound annual growth rate of 6.56 percent. However, copper tubes, particularly the small diameter 5mm IGTs in India, are majorly imported from ASEAN countries and Japan at zero duty charges under bilateral trade agreements—this is further discussed in the following chapter.



"The market data shows 5mm tube penetration in condensers has reached approximately 37%, while for evaporators, it is only 1%. The complete adoption of 5mm IGTs can be a pathway to reach the Just Transition Scenario for the copper tubing and the air conditioning industry in India.

03 SITUATIONAL ASSESSMENT OF COPPER TUBING MARKET AND INDUSTRY BARRIERS IN INDIA

Copper tubing is one of the largest industries when it comes to the application of copper as a metal. In this chapter, we examine the use of copper tubes in the RAC industry, the copper tubing market and manufacturing process, IGT demand in the RAC industry, the status of the 5mm IGT transition in RACs, and both demand-and supply-side barriers to complete adoption of 5mm IGTs.

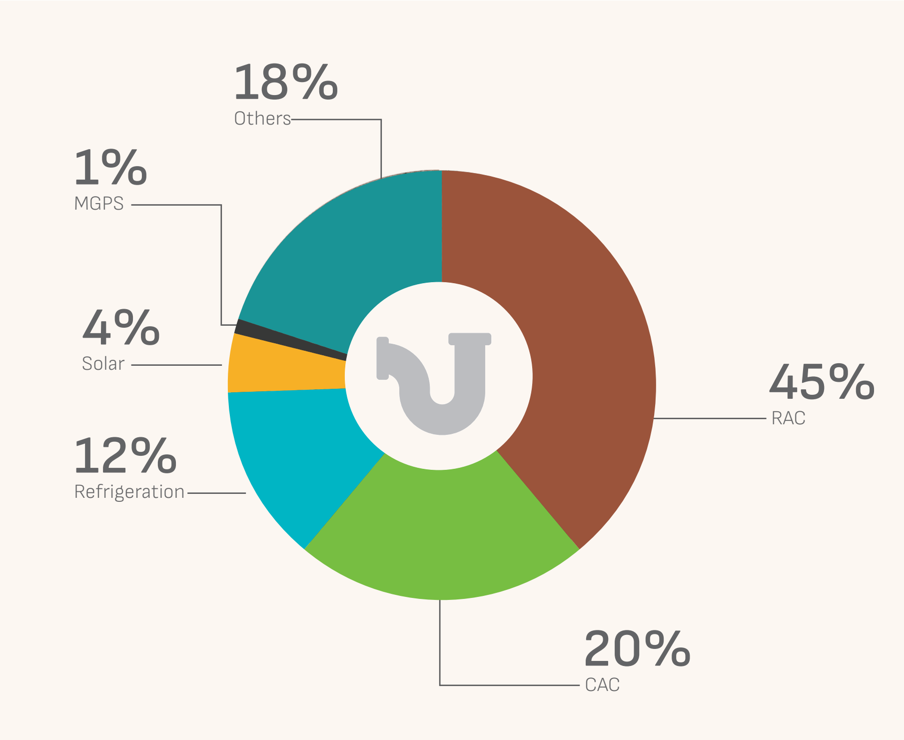
3.1 COPPER TUBE MARKET

To understand India's copper tube market, we need to go downstream and map the demand for copper tubes in Indian industries. This section maps different downstream segments that are end users/consumers of copper tubes, along with the breakdown of total copper tube demand in different downstream segments and for different tube types.

3.1.1 Copper tube demand in downstream industries

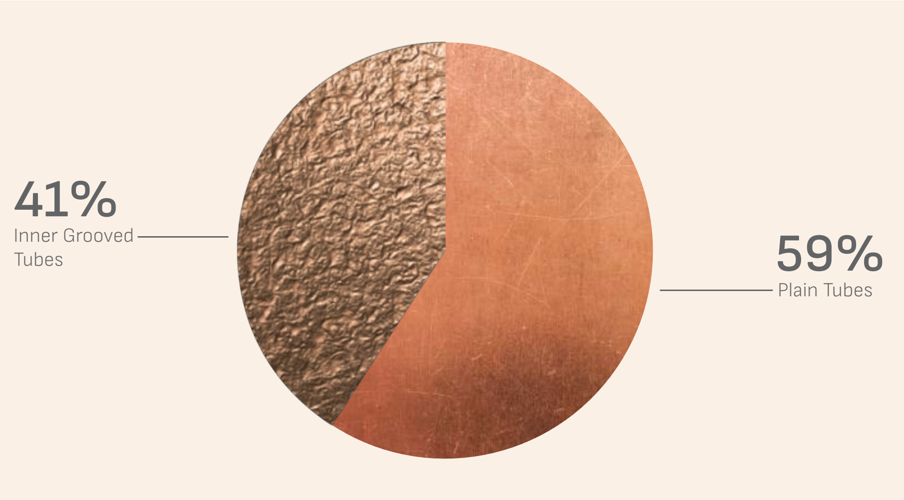
The annual demand for copper tubes in India is about 85000 tonnes. The RAC sector accounts for the highest share of demand (45%), followed by the commercial air conditioning (CAC) sector. The breakdown of total copper tube demand in different downstream segments is presented in Figure 15 below.

Figure 15: Copper tube demand by sector in FY 17[26]



The demand for IGTs is 41%, with the remainder of total demand being for plain tubes, as presented in Figure 16 below. Out of the total IGT demand, RACs account for approximately 90 percent.

Figure 16: Breakdown of copper tube demand by tube type in FY 17[27]



As RACs make up the highest share of total copper tube demand, the following section elaborates on copper tube use in the overall RAC value chain.

26 Avalon Market Research, "Copper Tubes and Flat Products Market in India," June 2017

27 Avalon Market Research, Copper Tubes and Flat Products Market in India," June 2017

3.2 COPPER CATHODE TO RAC VALUE CHAIN

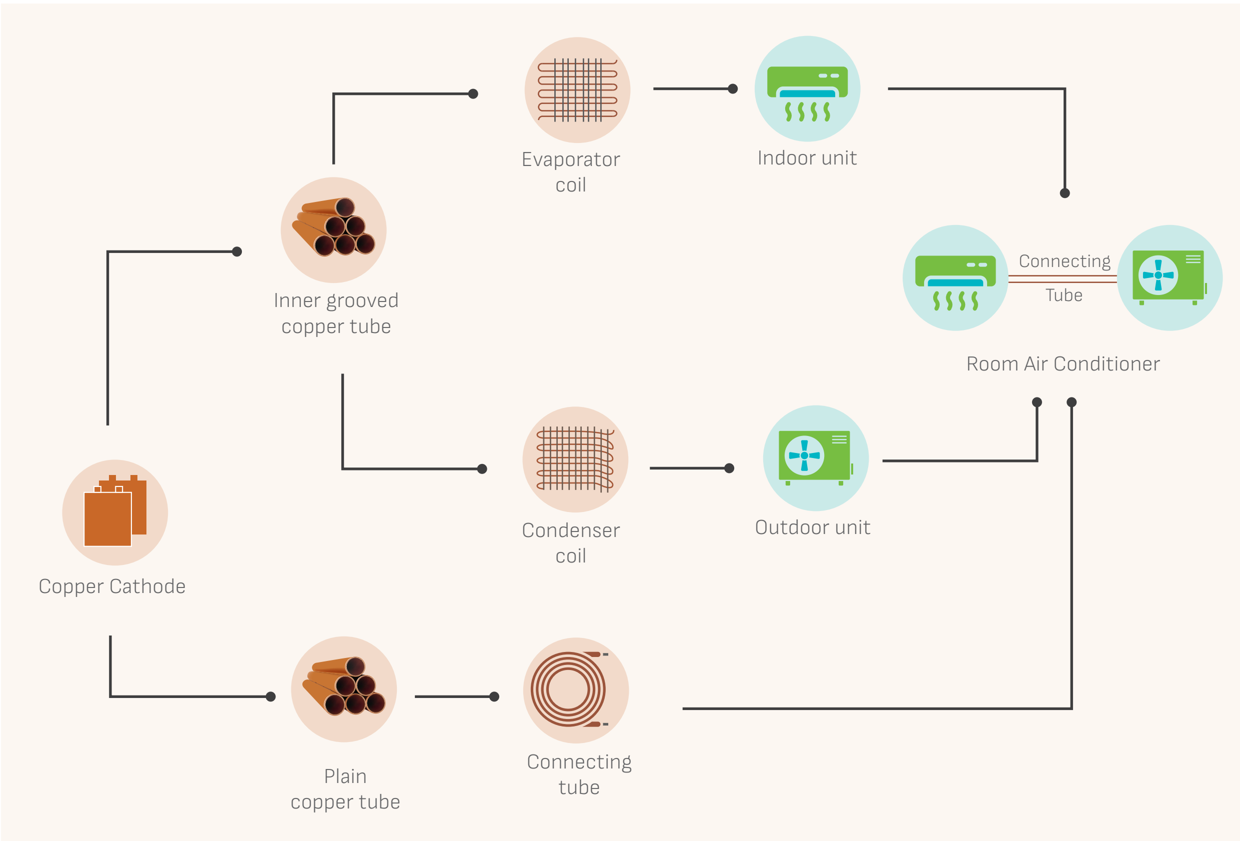
Copper cathodes (containing 99.9% copper) are the raw material used to produce smooth tubes and IGTs.

However, currently, India does not have sufficient domestic capacity to produce copper cathode; demand is largely met through imports. Earlier, India was a net exporter of copper cathodes, but the temporary shutdown of the Sterlite copper unit in the Tuticorin plant in 2018 due to pollution concerns forced the country to become a net importer. The annual refining capacity of the Tuticorin plant was 400 kilotonnes (kt), and it accounted for almost 40% of India's production capacity. Due to the closure of this plant, India's total production of refined copper fell by almost 45%, from 830 kt in FY 2017-18 to 454 kt in FY 2018-19.

3.2.1 Copper tube application in RACs

This section describes the usage of copper tubes in RACs. There are two types of copper tubes used in RACs: plain tubes and IGTs. IGTs are used in the evaporator and condenser coils. The evaporator, together with the fan and air filter, forms part of the indoor unit of a split AC, whereas the condenser, together with the compressor and fan, forms part of the outdoor unit. Plain copper tubes are used to connect the indoor and outdoor units in an RAC.

Figure 17: Copper cathode to RAC value chain[28]



28 Ruby copper Vietnam, https://www.rubycopper.vn/uploads/1/0/3/6/103617890/ruby_copper_product_catalog.pdf,

3.2.2 Copper tube manufacturing

There are three main types of copper tubes used in different applications in India: hard drawn plain tubes, soft drawn plain tubes, and IGTs. The following section highlights the similarities and differences in the manufacturing process for these tube types.

Copper tube manufacturing process

Based on information sourced from Ruby Copper, this section describes the manufacturing process for plain tubes and IGTs. The raw material used for manufacturing plain tubes and IGTs is the copper cathode (minimum 99.95% copper content).

01

First, the copper cathode is melted and then casted, with both operations being carried out in a single furnace. During casting, when the mother tube reaches the desired length, it is fed into a surface milling machine, which removes 4% of the mother tube's material. This discarded material is fed back into the melting process.

02

Next, the mother tube is rolled for wrapping into a coil. Then, there is the combined drawing operation, where it is straight drawn or pulled.

03

After combined drawing, the tube passes through a mold rack in the spinner block machine to reach the desired diameter and thickness.

04

In the case of IGTs, an additional process of in-line annealing, followed by inner grooving, is done after the tube passes through the spinner block machine.

05

Next, the tube goes to the level winding coil (LWC) or pancake coil (PC) machine or straightening machine. Straight tubes that are larger in diameter than the spinner block machine's capacity is sent to the straightening machine for the straight drawing operation.

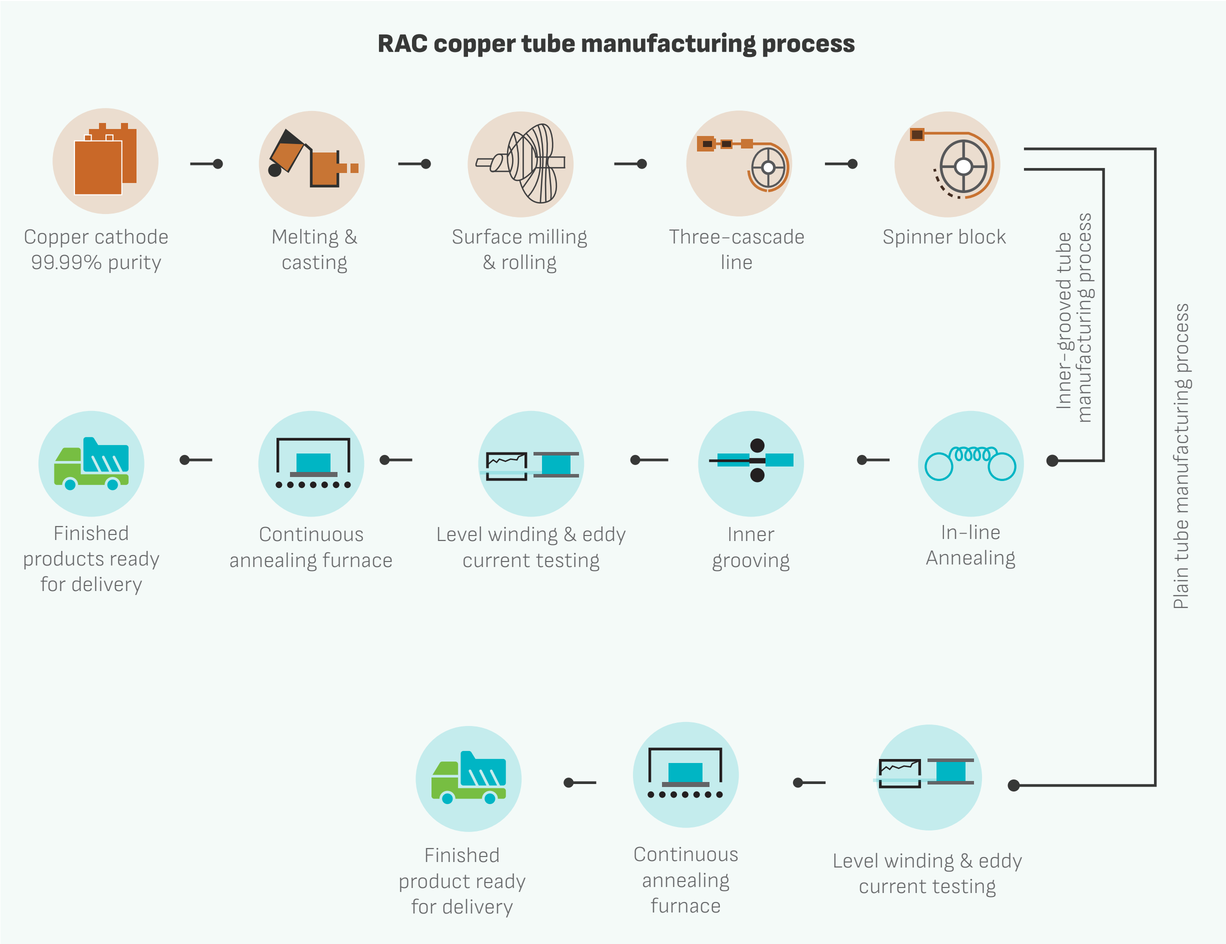
06

LWC and PC tubes are passed through the annealing process to reduce their hardness and are thus called "soft tubes." Straight tubes do not need to be annealed and are hence called "hard tubes."

07

Finally, the tubes are passed through the eddy current machine to identify any defects. Tubes that carry medical gases and refrigerants are cleaned to remove lubricants, traces, and other contaminants. Sample inspection is done to verify that the tubes adhere to the ASTM B88 and other appropriate standards.

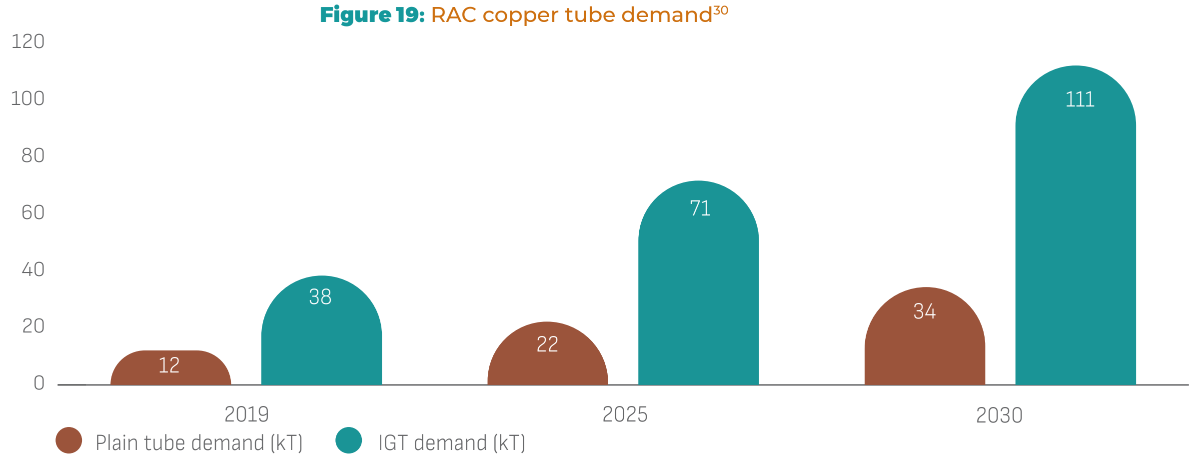
Figure 18: Copper tube manufacturing process[29]



3.2.3 RAC copper tube market

The copper tube market in India has been estimated based on ICAP projections for RACs and past market research studies. As can be seen in Figure 19 below, the projected demand for plain tubes and IGTs in RACs is around 145 kt by 2030, including 111 kt of IGTs.

Figure 19: RAC copper tube demand[30]



29 Ruby copper Vietnam, https://www.rubycopper.vn/uploads/1/0/3/6/103617890/ruby_copper_product_catalog.pdf,

30 Avalon Market Research, "Copper Tubes and Flat Products Market in India," June 2017.

The above graph shows that IGTs have a share of about 77% of the total copper tube demand in the RAC sector.

3.2.4 Domestic manufacturing and import of copper tubes

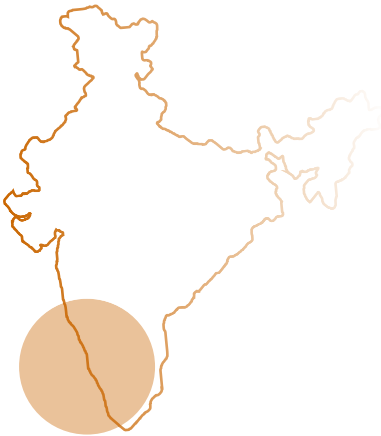
As mentioned above, even though there is a huge demand for copper tubes and pipes in the RAC segment (almost 45% of total tube demand), domestic manufacturing has been declining over the years. The current demand is largely met through imports for both plain tubes and IGTs. Details on the low domestic capacity and reasons for import dependency for both tube types are given below.

3.2.4.1 Plain tubes

India has an installed capacity of about 82,000 tonnes for copper tubes and pipes, of which only 18% has been utilised over the past 4-5 years, with almost 80% of the demand being met through imports. One of the reasons for low capacity utilisation is the existing duty structure on copper cathodes and tubes. The duty on imported copper cathodes stands at 5%, whereas there is no duty on copper tubes (finished product). This has caused an inverted duty structure problem, drastically decreasing domestic manufacturing of copper cathodes and promoting the import of the finished product, i.e. copper tubes. India's FTA with ASEAN countries is the reason for zero duty on copper tubes—Malaysia, Thailand, and Vietnam account for 90% of the total copper tube imports to India. Further, the quality of copper tubes manufactured domestically is not on par with that of the imported tubes, due to the lack of significant demand for the domestic varieties.

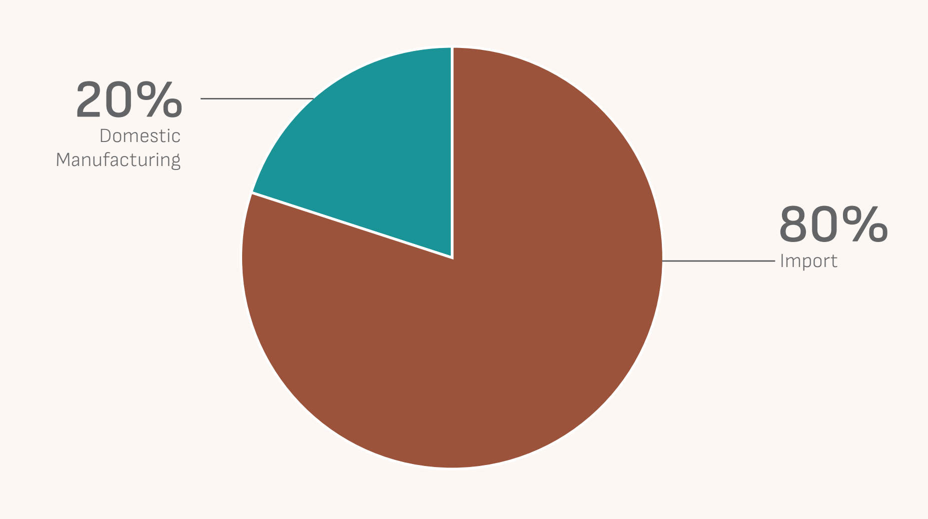
Another reason for low capacity utilisation is cheap imports from ASEAN countries. In the last five years, twenty large domestic manufacturers accounting for 70% of the industry's total tube capacity have closed operations, as they were unable to compete with cheap imports. Further, the imported tubes are manufactured using automatic machines, which produce highly precise tubes, making them preferred over domestically manufactured tubes by some original equipment manufacturers (OEMs) and heat exchanger manufacturers.

The share of domestic manufacturing and imports in RAC plain tube demand is depicted in Figure 20.



India has an installed capacity of about 82,000 tonnes for copper tubes and pipes, of which only **18% has been utilised over the past 4-5 years, with almost 80% of the demand being met through imports.**

Figure 20: RAC plain tube demand in 2019[31]

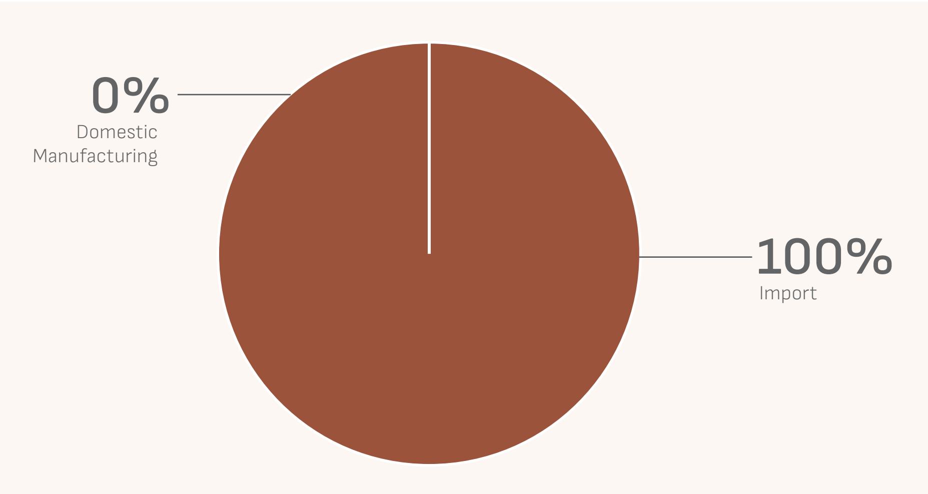


3.4.4.2 Inner grooved tubes

Regarding IGTs, India does not have any installed manufacturing capacity. Stakeholder consultations revealed that while manufacturers are interested in installing IGT capacity, the inverted duty makes it unviable for domestic manufacturers to invest in the precision technology needed to manufacture IGTs. Instead, domestic manufacturers are acting as traders for imported IGTs. Further, domestic manufacturers find it unviable to invest in large-capacity machinery for low margins.

The share of domestic manufacturing and imports in RAC IGT demand is represented in Figure 21.

Figure 21: RAC IGT demand in 2019[32]



**IGTs are imported either as tubes or as part of finished products.*

31 Avalon Market Research, "Copper Tubes and Flat Products Market in India," June 2017.

32 Avalon Market Research, "Copper Tubes and Flat Products Market in India," June 2017.

3.3 STATUS OF 5MM TRANSITION AND DOMESTIC MANUFACTURING OF UPSTREAM PRODUCTS

IGTs are used in heat exchangers in indoor and outdoor RAC units. In the case of condensers, the market has transitioned significantly from 7mm to 5mm tubes. Based on stakeholder consultations, around 37% of the condensers currently use 5mm IGTs (see Figure 22). Hence, the transition to 5mm IGTs in condensers has already begun. Further, the total demand for condenser heat exchangers and outdoor unit assembly is now being met through domestic manufacturing. Most of the OEMs have installed in-house fabrication lines for manufacturing and assembly of 5mm IGT outdoor units.

However, in the case of evaporators, the transition to 5mm tubes is still in the experimental stage, as there are several technical issues related to managing the higher pressure drop caused by the reduced tube diameter and the optimisation of evaporator circuitry and fin redesign to deliver the required capacity. Stakeholder consultations revealed that only 1% of evaporators currently use 5mm IGTs (see Figure 22).

Figure 22: Transition to 5mm tubes in RACs[33]

3.4 CHALLENGES FACED BY THE INDUSTRY IN THE 5MM IGT TRANSITION

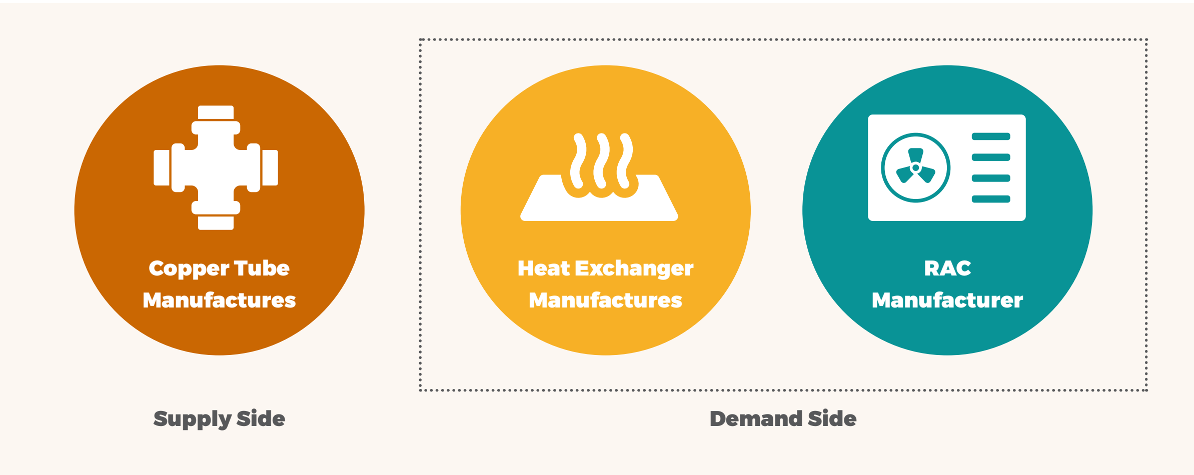
7mm IGTs are currently being used in heat exchangers, both evaporators and condensers, and some RAC manufacturers have already started adopting 5mm IGTs. The market data shows 5mm tube penetration in condensers has reached approximately 37%, while for evaporators, it is only 1% thus far. Although there are numerous proven benefits of 5mm IGTs, such as less required refrigerant charging, material savings, high refrigerant pressure holding capacity, suitability for alternative refrigerants, and higher efficiencies, the transition to 5mm IGTs is still in its early stages. Only plain

33 Stakeholder interaction with copper tube manufacturers, RAC manufacturers, & heat exchanger manufacturers.

tubes are currently manufactured in India, and there is no domestic capacity for IGTs. Therefore, India is entirely dependent on imports from ASEAN countries and China.

Stakeholder consultations with experts from the copper tubing, RAC, and heat exchanger industries were organised to identify the key barriers and challenges related to – i) adoption of 5mm diameter IGTs in RACs, and ii) domestic IGT manufacturing. We have mapped these stakeholders across the supply and demand side in the RAC value chain. IGT manufacturers represent the supply side, while heat exchanger and RAC manufacturers are covered on the demand side of the value chain. A schematic of the supply- and demand-side stakeholders is given in Figure 23.

Figure 23: Supply- and demand-side stakeholders in the RAC value chain[34]



The team interacted with different companies from each category of stakeholders to understand the major issues and challenges in the 5mm IGT transition and domestic manufacturing. We conducted meetings with the following companies and gathered insights on key barriers and challenges, which are presented in the next section:

- **RAC manufacturers:** Diakin, Amber Group, and Godrej
- **Heat exchanger manufacturers:** Danvita, Spirotech, Micro Coils, and ePack Durables
- **Copper tube manufacturers:** Indigo Tubes.

3.5 BARRIERS TO 5MM IGT TRANSITION

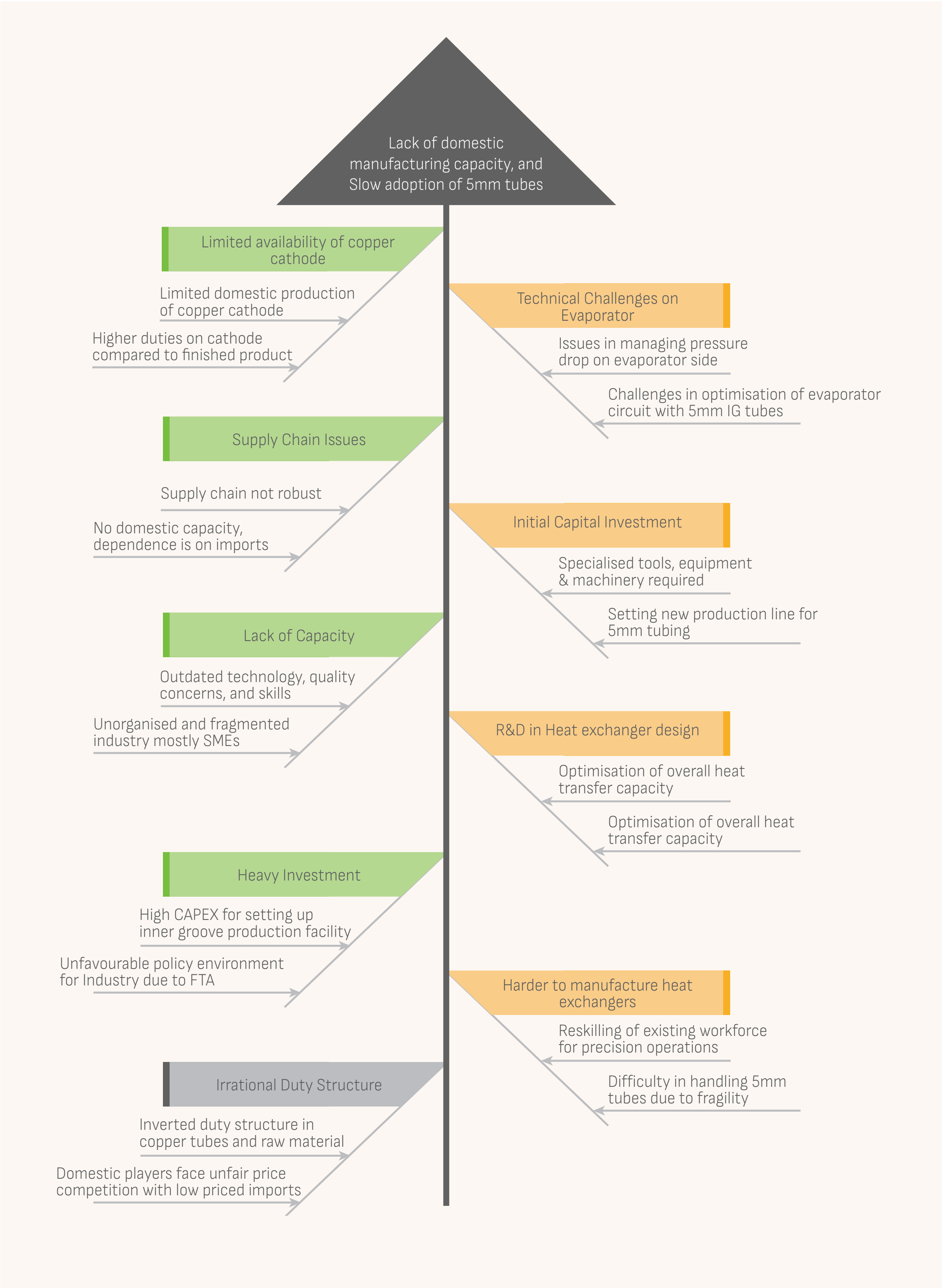
A fishbone diagram is a visualisation tool used in root cause analysis to categorise the potential causes of a problem. Each potential cause contributing to the problem is broken down until the root causes of the problem are identified. We have used this tool to identify the potential causes on the supply and demand sides of 5mm IGTs, according to the boundaries defined in Figure 23.

The analysis has helped in defining and prioritising the potential causes for the lack of domestic IGT manufacturing and the slow transition to 5mm IGTs. In this diagram, the head of the fish represents the problem statement, and the causes that contribute to the problem are mentioned in the branches coming out from the spine. The contributing factors to each cause are specified in the respective branch.

34 Stakeholder interaction with copper tube manufacturers, RAC manufacturers & heat exchanger manufacturers.

The supply-side barriers are mentioned on the left side of the fishbone, while demand-side barriers are mentioned in the Right side and marked in the order of priority. This analysis is based on insights drawn from multiple interactions with the stakeholders. The graphical illustration of the analysis is presented below in Figure 24.

Figure 24: Fishbone diagram of barriers[35]



35 Stakeholder interaction with copper tube manufacturers, RAC manufacturers, & heat exchanger manufacturers.

The supply-side barriers refer to the major issues in IGT manufacturing, while the demand-side barriers explore issues related to the slow transition to 5mm tubes in heat exchangers and final RAC products.

3.5.1 Supply-side barriers

A detailed explanation of the causes for the lack of domestic IGT manufacturing in India is given below.

Irrational duty structure

The existing duty structure does not encourage domestic manufacturing of copper tubing. India imports copper cathode, the raw material required for tube manufacturing. The copper cathode attracts a basic customs duty of 5%, while the finished copper tubes and pipes are imported at 0% duty from countries like Vietnam, Malaysia, and Thailand under the FTA with ASEAN. This has resulted in an inverted duty structure and caused a steep decline in the domestic production of tubes. Many domestic manufacturing units have closed down, while others are under extreme financial pressure. The Government of India has initiated Countervailing Duty Investigation concerning imports of copper tubes and pipes from Malaysia, Thailand, and Vietnam. The domestic players that were manufacturing plain tubes earlier have now started importing them, and they do not wish to set up an IGT facility until the FTA and inverted duty structure issue is resolved.

Heavy investment

As mentioned above, there is no capacity for manufacturing IGTs in the country, and the entire demand is met through imports. As per the discussions with stakeholders, a high capital expenditure (CAPEX) is required to set up an IGT manufacturing line in India—on the order of INR 300-400 Cr for a total production capacity of 30,000-35,000 tonnes of IGTs. Large companies, as well as small and medium-sized enterprises (SMEs), will be involved in IGT manufacturing with varying production capacities, along with the other tube products as part of their product mix. The high CAPEX is a challenge for the industry. Further, because of the unfavourable policy environment due to the FTA, companies are hesitant to make any investments until there is an enabling environment for domestic manufacturing.

There is an urgent need for foreign technology collaboration that facilitates the transfer of technology and financing to develop domestic capacity for high-quality 5mm IGT manufacturing. Along with technology, it is also important to impart technical skills at various levels to enhance the efficiency and productivity of the industries.

Lack of capacity

The Indian copper tube industry is only manufacturing plain tubes at the moment. 5mm IGT manufacturing is a highly sophisticated process and requires precision machinery. The Indian industry still uses outdated technology, which is a key barrier to IGT manufacturing, as close tolerance machining is required. Moreover, as emphasised by the

RAC manufacturers, there are quality concerns and higher rejection rates in domestically manufactured plain tubes than in imported tubes, which indicates a lack of capacity to even produce high-quality plain copper tubing. Currently, the industry is severely lacking in terms of modern technology and is therefore unable to compete with foreign manufacturers.

There is an urgent need for foreign technology collaboration that facilitates the transfer of technology and financing to develop domestic capacity for high-quality 5mm IGT manufacturing. Along with technology, it is also important to impart technical skills at various levels to enhance the efficiency and productivity of the industries.

Supply chain issues

The supply chain for 7mm IGT imports is quite robust, but this is not the case for 5mm tubes. During the consultation, it was mentioned that 7mm IGT supplies are stable due to the large quantity of imports. In contrast, there are low order quantities for 5mm IGTs, which leads to a higher conversion cost for them. Further, there is only a limited number of manufacturers supplying good quality 5mm IGTs in the ASEAN region. Hence, there is less confidence among heat exchanger and RAC manufacturers regarding the supply of 5mm IGTs.

Limited availability of copper cathodes in India

Copper cathode is the basic raw material for the manufacturing of IGTs and connecting tubes used in AC and refrigeration systems. India has limited domestic production of copper cathodes, and the demand is met largely through imports in large quantities. The inverted duty structure mentioned above does not allow domestic manufacturers to compete with imported value-added copper tubes from FTA countries.

The downstream copper industries, mainly SMEs, were very badly hit by the inverted duty structure. The industry needs immediate government support to slash the customs duty on the raw material, i.e. copper cathodes, and thus provide a level playing field for the domestic copper tube industry.

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3.5.2 Demand-side barriers

A detailed explanation of the potential causes for the slow transition to 5mm IGTs is given below.

Harder to manufacture heat exchangers

The wall thickness of the 5mm IGT is very low (~0.20 mm), which makes it fragile and difficult to handle during heat exchanger manufacturing and also at the time of final product assembly. This was the main challenge

in early adoption, when there were issues with pipes getting bent or broken due to the low stability of the material. However, this issue can be overcome with new equipment for bending and lacing tubes and expanding work.

R&D in heat exchanger design

To use smaller diameter IGTs, the heat exchangers need to be redesigned. This requires redesigning the fin and tube circuit, optimising the number of passes between headers, performing computer simulations on refrigerant flow and temperature changes, and optimising the overall heat transfer performance.

Initial capital investment

To manufacture heat exchangers with 5mm inner groove tubes, a separate assembly line needs to be created, which will require investment in a new set of tools and machinery. The new set of tools that will be required includes a fin press, fin-dies, tube expander, and tube bending machine. The approximate investment would be on the order of INR 1.0-1.5 Cr to upgrade the 7mm assembly line to 5mm, whereas to set up a new 5mm heat exchanger assembly line, the total investment would be on the order of 3.5-4 Cr for a production capacity of 1.5 lakh heat exchangers per annum. On the OEM end, switching from an existing 7mm setup to a new 5mm setup will require significant rework on pressure testing, EERs, and new certifications, which have an additional associated cost.

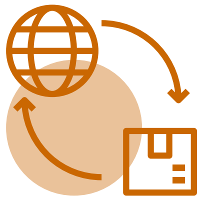
Technical challenges in the adoption of 5mm IGTs in evaporators

5mm IGTs are already being used in condensers; however, on the evaporator side, there has not been much success so far; there is only 1% penetration of 5mm tubes in evaporators, compared to 37% in condensers. Based on our stakeholder consultations, a lot of research is already underway to optimise the evaporator design with 5mm tubing, but there are still some issues. There are two primary challenges: First, with the smaller tube diameter, the refrigerant velocity increases, leading to higher pressure drops. To effectively manage the pressure drop while also maintaining the heat exchanger's cooling capacity, the evaporator circuitry and fin side need to be redesigned. Computation and analysis is needed to optimise the evaporator side, as it is already a low-pressure zone. Second, the software used by designers is not sophisticated enough to optimise the evaporator circuits.

Although there are certain challenges to domestically manufacturing copper tubing in India, undertaking domestic manufacturing of 5mm IGTs can have various socioeconomic benefits, as described in the following section.

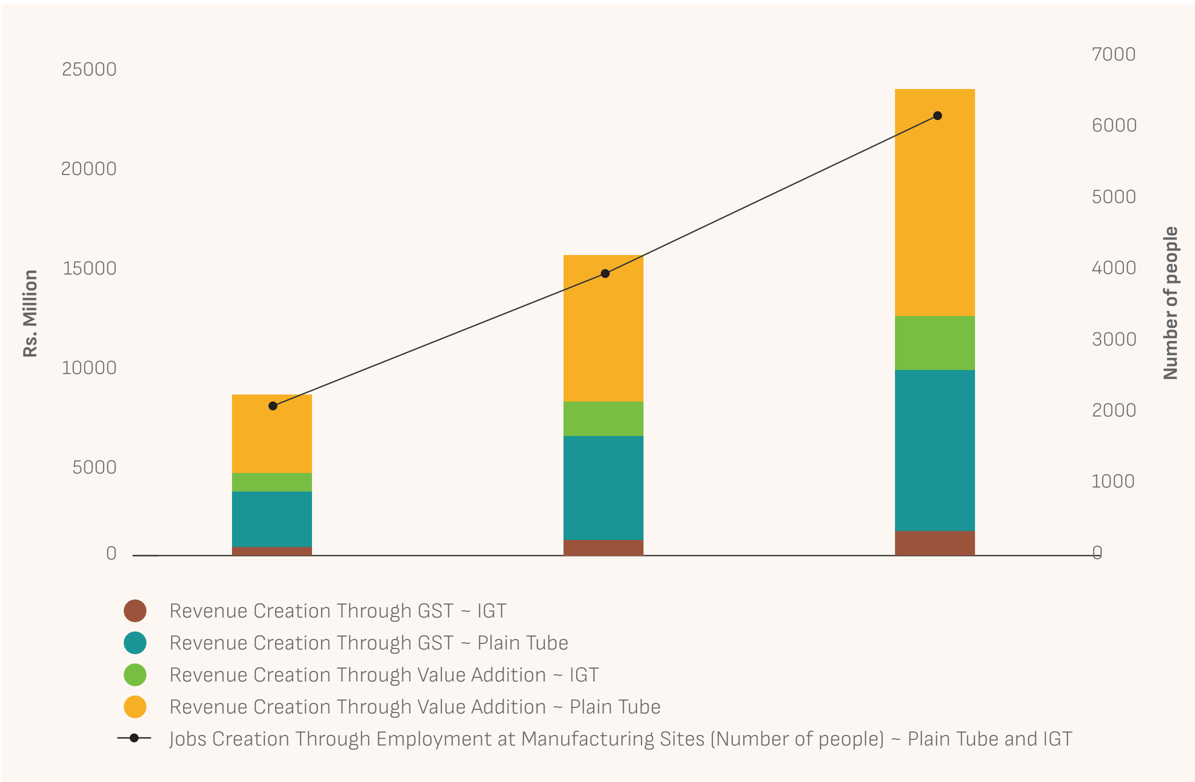
3.6 SOCIOECONOMIC BENEFITS OF DOMESTIC IGT MANUFACTURING

The copper tube manufacturing industry has been severely impacted since India signed the FTA with ASEAN countries in 2010. Since this agreement came into effect, there has been a gradual decrease in the duty of finished copper tube products. On the other hand, to help the domestic refined copper industry grow, the import duty on refined copper, i.e. copper cathode, is currently 5 percent. Nevertheless, as a result of the inverted duty structure, domestic copper tube manufacturing has become an unviable business. As discussed above, major copper tube manufacturers have closed their operations, as they were not able to compete with the low prices of imported tubes. As a result, copper tube imports have been increasing over the years. In the case of soft drawn plain tubes, India is unable to meet its demand through domestic manufacturing. Based on stakeholder consultations, around 80% of plain soft tubes used in India are imported. In the case of IGTs, there is 100% imports, as the manufacturing capacity has not been created due to the high required investment and low profit margins. The RAC sector needs soft-drawn plain tubes and IGTs, and domestically there is a huge demand for them. However, due to dependency on imports, domestic manufacturers are losing out on this significant opportunity, and ASEAN countries and Chinese players are benefiting. Figure 25 below shows an analysis of the estimated potential for opportunity creation through domestic manufacturing, based on RAC demand alone.



Based on stakeholder consultations, it was inferred that around 80% of the plain soft tubes in India are imported. In the case of IGTs, there is 100% imports, as the manufacturing capacity has not been created due to the high required investment and low profit margins.

Figure 25: Potential for opportunity creation through domestic manufacturing[36]



36 AEEE analysis with data sourced from ICAP, Avalon Market Research, and interactions with copper tube, RAC, & heat exchanger manufacturers.

The opportunity in value addition is estimated based on RAC sales data from ICAP, copper tube quantity in RACs from Avalon Market Research, and the copper tube conversion cost from stakeholder consultations. Looking at tax revenue, since there is no duty on copper tube imports, the government only gets the goods and services tax (GST) that is paid on the imported tubes. However, if India starts up domestic manufacturing, the government will receive the excise duty paid by manufacturers, in addition to GST. The additional tax revenue due to domestic manufacturing would therefore be the 12.5% excise duty applicable on copper tubes. Hence, the opportunity in the tax revenue generation is estimated only considering excise duty revenue. Regarding job creation, the estimation is based on ICAP's RAC sales data, Avalon's copper tube quantity data, and employment-related data obtained through stakeholder consultations.

Although copper tubing has numerous value chain benefits, there is a considerable lack of policy push to enable domestic copper tube manufacturing in India. In this context, examples from enabling policies adopted globally should be examined, in order to create a pro-manufacturing ecosystem and promote design innovations for component-level efficiency gains in India; key international examples are presented in the following chapter.

> *Opportunities can be leveraged from a varied set of policies designed to support IGT manufacturing within the ecosystem of micro-, small, and medium-sized enterprises (MSMEs) in India. The revival of the sector can be achieved by promoting the manufacturing of high-quality small diameter IGTs through policy support across the levers of financial assistance, capacity building, and technology upgradation & competitiveness.*

04 INTERNATIONAL AND DOMESTIC POLICY LANDSCAPE PROMOTING MANUFACTURING

Copper is a historical metal, as it has been a key element of industry-wide applications globally for the longest period of time. The copper industry can play an integral role in India's clean energy transition, as it has major application in renewables, electric mobility, and energy-efficient equipment, including cooling appliances such as RACs.

India has an FTA with ASEAN countries that allows cross border trade of goods by eliminating trade barriers such as duties and taxes, leading to free access to the respective markets. This FTA has put India's finished copper product industry at a disadvantage, as the procurement of raw copper and copper cathode invites a ***5%*** duty, which translates into a ***5-6%*** price escalation on the finished domestic products compared to end products sourced from ASEAN countries.

Globally, countries such as China and ASEAN countries have depended on copper-based scrap imports, but have simultaneously emerged as the dominant producers, consumers, and trading countries for non-ferrous metal (NFM) components. Manufacturing growth in the metal-based value chain within the ASEAN region is driven by an FDI-based approach. These manufacturing activities have made significant contributions towards economic prosperity in the respective countries and are further establishing positive synergies to enable climate-friendly technological innovation. 40% of the RACs sold globally are manufactured in China,[37] and it has achieved a much greater improvement in energy efficiency for RAC MEPS between 2010 and 2021 than countries in the South Asian region[38]. Thus, the following section throws light on the policy initiatives governing the NFM industry in China and learnings that can be drawn for India to catalyse domestic manufacturing, which is essential to reduce the cost of copper tubing and contribute to climate commitments.

37 Shah, N. K., Park, W. Y., & Gerke, B., "Assessment of Commercially Available Energy-Efficient Room Air Conditioners Including Models with Low Global Warming Potential (GWP) Refrigerants," no. October (2017): 1–67.

38 Singhal, A., Sharma, S., & Garg, T. (2021). Transitioning to Super Energy-Efficient Room Air Conditioners Fostering ICAP Implementation. Alliance for an Energy Efficient Economy.

4.1 POLICY INSTRUMENTS GOVERNING CHINESE NFM INDUSTRY

The NFM sector, including copper, is a key element of the Chinese government's Strategic Emerging Industry Initiative (launched in 2009) and Made in China 2025 Plan (launched in 2015). A major chunk of NFM enterprises is state-owned, meaning they take part in the nationwide Supply-Side Structural Reforms Initiative focused on enabling these enterprises to emerge as national champions in their respective sectors. Figure 26 highlights the dominant set of policy instruments governing the NFM industry in China.

Figure 26: Policy instruments governing Chinese NFM industry

The major features of these instruments and other demand-side policies are summarised in Table 9:

Table 9: Key policies and features governing the Chinese NFM industry[39]

Demand-side policies	
• China has formulated a "Made in China 2025" long-term strategic plan to upgrade its manufacturing system and quality of domestic products over a ten-year horizon, including the promotion of high efficiency and green products. • China has adopted a green and high-efficiency cooling action plan to increase overall cooling energy efficiency levels by over 25 percent. • It has committed to raising the market share of green and high-efficiency cooling products by over 40% by 2030. • It has prioritised the strengthening of energy efficiency standards by 2022, with improvement targets of 30% for residential AC, and has revised the residential AC MEPS. • Promoting the use of low-GWP refrigerants has led to the accelerated adoption of small diameter tubes.	
Supply-side policies	
Policy instruments	**Major features**
Debt equity swaps	• Cut financing costs by replacing high-interest bank loans with relatively low-cost (dividend) equity capital.

Subsidies/financial grants	• Grants offered for non-operating income to enhance enterprises' financial performance.
	• The grants support the bigger players' efforts towards:
	  • Technology upgradation.
	  • Improved environmental performance
	  • Internationally oriented development.

Other financial grants	These grants are offered as deferred income subsidies that enable enterprises to obtain major assets by spearheading their investments in capital reserves/infrastructure such as R&D centres, production plants, and technology development centres. The other set of grants promotes raw material import, import-substitution, and export promotion by: Including partial refund of value-added tax (VAT) paid on raw material imports. Subsidising upgradation of export product portfolios to strengthen the positioning of enterprises in high tech market segments.

39 Taube, M., & in der Heiden, P., "Analysis of Market-Distortions in the Chinese Non-Ferrous Metals Industry," 2017.

Support for plant relocation	The industry layout in geographic terms is influenced by this instrument. These industrial parks cater to the special needs of the selected industries and foster cluster formation. The support further drives relocation of enterprises across different stages of the value chain to establish robust forward and backward supply linkages. The industrial park administrations offer a range of supporting services in terms of advanced logistics and transport facilities and ready and cheap access to energy, water, raw materials, and other vital inputs. Common public service platforms are created that help companies find suitable professionals and labour, secure financing from local banks, improve R&D capabilities, etc.
Fiscal support for technology innovation and upgrading	Strong incentives at all administration levels are earmarked for boosting innovation capacities. The National Medium- and Long-Term Science and Technology Development Plan (2006-2020) serves as a major set of guidelines and promotes technology imports with domestic assimilation, absorption, and re-innovation to strengthen domestic R&D capabilities. Direct financial support covering research expenses and employee travel expenses is provided by the Government of China.

4.2 DOMESTIC MANUFACTURING POLICY LANDSCAPE TO PROMOTE COPPER TUBE INDUSTRY IN INDIA

Copper tube manufacturing is part of the downstream segment of the copper industry in India. This segment of the industry is characterised by the presence of a large number of micro- and small enterprises that are unorganised and fragmented. The small enterprises in the copper industry, however, have long held a significant share of the export market for semi-fragmented products. However, this trend has reversed in recent years due to the elimination of duties on the imports of semi-fragmented goods, as well as demand for small diameter IGTs emerging from efficiency and design optimisation requirements within the end-use sectors such as the RAC sector.

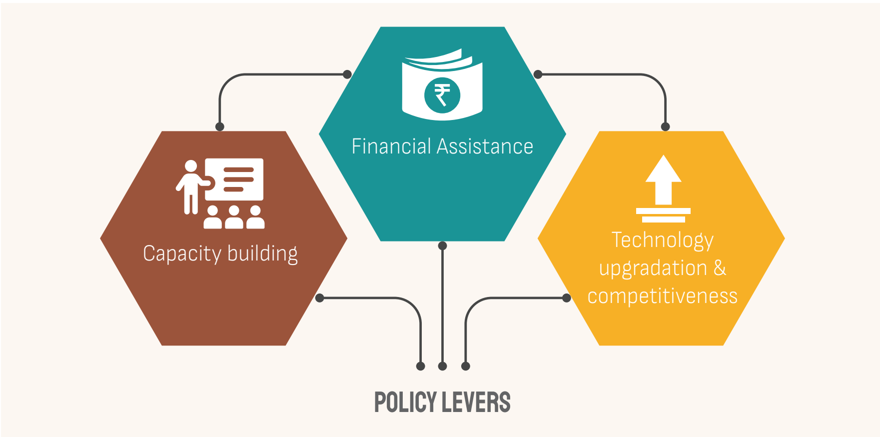
To cater to the changing dynamics of demand from the industry, market players in the tube manufacturing segment of the value chain face several challenges, including:

- Low capacity utilisation
- Outdated technology
- Lack of proper infrastructure
- High financing costs
- Lack of qualified personnel
- High CAPEX[40]

40 KPMG report on Non-ferrous metals industry: Building the future, September 2017. Available at: https://assets.kpmg/content/dam/kpmg/in/pdf/2017/09/non-ferrous-metals.pdf

Enhancing the policy and institutional framework governing the industry is one important way to instill reforms and eliminate the structural & economic barriers to improve growth prospects and industrial performance. This section of the report maps the existing policies in India that can potentially strengthen the industry and enable it to compete globally. Opportunities can be leveraged from a varied set of policies designed to support IGT manufacturing within the ecosystem of micro-, small, and medium-sized enterprises (MSMEs) in India. The revival of the sector can be achieved by promoting the manufacturing of high-quality small diameter IGTs through policy support across the levers of financial assistance, capacity building, and technology upgradation & competitiveness.

Figure 27: Policy levers for promoting copper tube manufacturing in India



The broader set of existing policies in the MSME landscape can act as a safety net and trigger the manufacturing of competitively priced IGTs in the country. The policies can support the formation of manufacturing associations, enhancing skills for promotion & infrastructure development that can ultimately lead to the creation of good-quality processed copper outputs at competitive prices, building domestic use and export potential.

Table 10: Potential policies to enhance the copper tubing industry ecosystem in India[41]

Policy lever	Policy	Features	Significance for copper tubing industry
Financial Assistance	Atmanirbhar Bharat	Rs. 3 lakh crore collateral-free automatic loans for MSMEs to: ◆ Buy raw materials ◆ Meet operational liabilities ◆ Restart businesses.	The policy support can build cost competitiveness and hence create enhanced avenues for refined copper exports. The increased production will make IGTs available to be utilised in the manufacture of energy-efficient RACs.
	Production Linked Incentive Scheme	To kickstart domestic component manufacturing by attracting large-scale investments in the white goods manufacturing value chain. This will boost domestic manufacturing and the competitiveness of local goods and cut down on import bills through: ◆ Tax rebates ◆ Import and export duty concessions ◆ More favourable land acquisition terms. In its first phase, the scheme extended an incentive of 4-6% on incremental sales (over the base year) of goods manufactured in India. Under the Second Round, incentives of 3-5% are to be extended on incremental sales (over the base year, i.e. 2019-20) of goods manufactured in India and covered under the target segment, to eligible companies, for a period of four (4) years.	The incentives under the scheme can lead to the organisation of the downstream industry, enhance its capacity to fetch better trade deals, and further propel vertical integration of the domestic copper industry. The domestically manufactured IGTs can then be utilised in domestic RACs.

41 MSME Annual Report: 2020-21 https://msme.gov.in/sites/default/files/MSME-ANNUAL-REPORT-ENGLISH%202020-21.pdf

	Credit Linked Capital Subsidy Scheme	◆ Upfront 15% capital subsidy (on institutional finance of up to Rs. 1 crore availed of by the enterprise) ◆ Induction of established and improved technologies. ◆ Upfront subsidy of 15% on institutional credit up to Rs. 1.0 crore (i.e. a subsidy cap of Rs. 15.00 lakh) for identified sectors/ subsectors/technologies. ◆ The subsidy has been proposed to also be applicable to investment in acquisition/ replacement of plants & machinery/equipment & technology upgradation of any kind.	The policy can reduce the cost of credit for investments in machinery/equipment and enhance the IGT manufacturing supply chain in India.
Capacity Building	ZED Certification Scheme	The scheme aims to enable MSMEs to manufacture quality products by inculcating zero defect zero effect (ZED) practices to ensure continuous improvement, thereby supporting the Make in India initiative. ◆ Financial assistance to be provided to the MSMEs for ZED certification. ◆ Constant upgradation, achieving higher productivity with the least damage to the environment. ◆ Increasing public awareness on ZED products through the ZED Rating and Grievance Redressal Portal.	The scheme could be instrumental in creating a green manufacturing line of IGTs compatible with the SDGs (12) on promoting responsible production. The certification can further lead to enhancing skills and productivity and create a manufacturing ecosystem that can serve both the domestic and export markets.
Technology Upgradation through R&D	Startup India	Government of India's flagship initiative to build startups and nurture innovation. The policy focuses on eliminating barriers and promoting faster growth through: ◆ Simplification and handholding ◆ Funding support and incentives ◆ Industry-academia partnerships and incubation.	The policy support can create an ecosystem of innovation and entrepreneurship within the copper tubing industry and OEMs by establishing a robust R&D framework.

Synthesising the learnings from international experience and potential instruments to promote the industry domestically, the next chapter outlines specific recommendations and also provides recommended rollout strategies.

"Establishing a Centre for Sustainable Cooling to promote domestic manufacturing ecosystems for super energy-efficient and climate-friendly space cooling technologies can be a way forward for India to position itself as a global catalyst of climate action and will further strengthen the ethos and relevance of domestic actions to fulfil the international commitments made in COP26.

05 POLICY AND REGULATORY RECOMMENDATIONS

One of ICAP's recommendations is to constitute a steering committee for R&D with representation from the Ministry of Science & Technology, Ministry of Human Resource Development, Bureau of Energy Efficiency, experts from academic and research institutions, and industry. A Centre for Sustainable Cooling shall be established under the aegis of MoEF&CC.

A series of policy measures that have reformed the industry in China and potential policy measures that can be leveraged to overcome the barriers in India were listed in Chapter 4. This chapter synthesises key information on India's environmental goals and targets, maps them with the existing policy and institutional landscape, and provides recommendations to enable the following:

- Accelerated transition to 5mm small diameter IGTs in domestic RACs.
- Promotion of domestic capacity building for small diameter IGT manufacturing.

Based on the analyses on market status and barriers faced by the industry regarding the manufacturing and use of small diameter IGTs in RACs, the following section puts forward a set of recommendations as foundational steps to accelerate the transition within RAC components and kickstart domestic manufacturing of IGTs.

5.1 ACCELERATE THE TRANSITION TO 5MM SMALL DIAMETER IGTS IN DOMESTIC RACS

Table 11 highlights the existing challenges for the industry in accelerating the transition of IGTs in domestically manufactured RACs. It also illustrates the potential opportunities that can be leveraged with the right policy and institutional support, as summarised in the recommendations.

Table 11: Challenges, opportunities, and recommendations

S.No	Challenges	Opportunities	Recommendations	Institution
1.	**R&D** Facilitating the use of 5mm copper tubes requires redesigning heat exchangers, running simulations on refrigerant flow and temperatures changes, and optimising the overall heat transfer performance.	The R&D ecosystem will enable domestic technological innovations that are aligned with policy goals and promote resource optimisation, including the use of locally made greener refrigerants. International collaborations can also accelerate the development of globally competitive technology.	**Recommendation 1:** Set up a national R&D facility such as the Centre for Sustainable Cooling to promote energy efficiency and greener refrigerants in cooling technologies by bolstering national and international collaboration.	MoEF&CC, with support from the Department of Science and Technology (DST) Industry associations: ISHRAE & RAMA Private businesses: RAC manufacturers
2.	**Investment** Manufacturing heat exchangers with 5mm IGTs requires a separate assembly line, entailing investment in a new set of tools and machinery and significant rework for OEMs to switch from an existing 7mm setup to a new 5mm setup.	The policy support can enable existing OEM setups in the country to adopt technology that can lead to enhanced production for indigenous consumption and export purposes.	**Recommendation 2:** Special incentives should be devised under the PLI scheme and multilateral funds on refrigerant and/or clean energy transitions can be catalysed to facilitate the growth of new manufacturing setups.	Department for Promotion of Industry and Internal Trade (DPIIT) MoEF&CC BEE Ministry of Commerce and Industry
3.	**Skill Development** The wall thickness of the 5mm IGT is very low (~0.20 mm), making it fragile and difficult to handle during the heat exchanger manufacturing process and also at the time of final product assembly.	The manufacturing and exclusive assembly lines of 5mm IGTs would accelerate the transition of copper tubes in RACs and help create additional employment in the downstream copper and refrigeration industry.	**Recommendation 3:** Drive skill-building in the sector through training and national certification schemes.	Ministry of Skill Development and Entrepreneurship Ministry of Education

Recommendation 1

Set up a national R&D institutional framework for refrigerants and heating, ventilation, and air conditioning (HVAC) technology innovation by bolstering national and international collaboration.

The incorporation of smaller diameter IGTs requires the redesign of heat exchangers. In particular, it requires redesigning the fin and tube circuit, optimising the number of passes between headers, performing computer simulations on refrigerant flow and temperatures changes, and optimising the overall heat transfer performance.

To enable a complete transition towards small diameter IGTs, we therefore recommend that R&D be promoted and accelerated in this segment through collaborations between domestic and international firms engaged in the HVAC manufacturing space. As mentioned in ICAP, we further put forward a recommendation to set up regulatory frameworks that can guide the pace and direction of the R&D effort in the technology space.

Proposed rollout strategy for Recommendation 1

1. Under the aegis of MoEF&CC, with support from DST's Science and Technology Programme, dedicated R&D funding can be earmarked to establish a Centre for Sustainable Cooling focused on promoting energy efficiency and greener refrigerants in cooling technologies. The centre shall support ICAP implementation through innovation in AC technology and enabling component level efficiency gains and environmental benefits while reducing the cost of technology to make it widely accessible.

2. A steering committee to guide the activities of the centre, with representatives from DST, R&D institutes, MoEF&CC (Ozone Cell), BEE, industry associations, Refrigeration and Air-Conditioning Manufacturers Association (RAMA) and Indian Society of Heating, Refrigeration and Air-Conditioning Engineers (ISHRAE), and private companies (such as those involved in refrigerant development and HVAC and refrigeration (HVAC&R) appliance and equipment manufacturing), shall be constituted to promote R&D on cooling-related challenges in India.

3. The funding for the centre's activities can be leveraged by establishing R&D consortiums using development aid from multilateral funds earmarked for the refrigerant transition and climate action. In addition, the public-private partnership (PPP) model can also be leveraged, wherein a combination of development aid and private finance can be clubbed to ensure the centre's long-term sustainability. Further, the centre can leverage the expertise available in academic and research institutes of excellence within the country like Council of Scientific & Industrial Research Indian Institute of Chemical Technology (CSIR-IICT), Indian Institutes of Technology (IITs), Indian Institute of Science (IISC), and National Institutes of Technology (NITs) that promote R&D in HVAC technologies.

Recommendation 2

Special incentives should be devised under the Product Linked Incentive (PLI) scheme, and multilateral funds on refrigerant and/or clean energy transitions can be catalysed towards facilitating the growth of new manufacturing setups.

To manufacture heat exchangers with 5mm IGTs, a separate assembly line needs to be created, which requires a significant amount of investment in a new set of tools and machinery.

Further, on the OEM side, switching from an existing 7mm setup to a new 5mm setup will also require a significant rework.

In order to encourage the domestic players engaged in the industry to make these investments, we recommend that additional incentives be devised under the ambit of the PLI scheme. Since the transition to small diameter IGTs will enhance the transition to lower-GWP refrigerants, we also recommend that multilateral funds on clean energy transitions be redirected to such innovations.

Proposed rollout strategy for Recommendation 2

1. DPIIT's Startup India Seed Fund Scheme can be leveraged, within which financial assistance may be given to the component manufacturers for the funds spent on R&D and innovation for tube manufacturing and design tweaks for RAC and component manufacturing.

2. Seed funding should be earmarked by MoEF&CC for domestic RAC manufacturers to accelerate the transition to small diameter 5mm copper tubes by catalysing the finance from multilateral funds on refrigerant and/or clean energy transitions.

3. BEE can be consulted to create a separate category of super energy-efficient RACs through the doubling of MEPS. Consultation within the Ministry of Commerce and Industry should be initiated to integrate the new line of RACs into its existing programmes and devise tax and subsidy benefits to accelerate its penetration in global and domestic markets.

Recommendation 3

Drive skill-building in the sector through training and national certification schemes.

The wall thickness of the 5mm IGT is very low (~0.20 mm), which makes it fragile and difficult to handle during heat exchanger manufacturing and also at the time of final product assembly.

As advocated by ICAP, we therefore recommend that an exclusive skill development programme on the inner grooving of small diameter and plain tubes be integrated into the government's ongoing initiatives under Skill India Mission and Pradhan Mantri Kaushal Vikas Yojana. The skills imparted can create a class of trained and skilled personnel required for precision manufacturing of small diameter IGTs.

Similar initiatives on skill enhancement programmes for the cooling industry have also been highlighted as a key policy measure in ICAP.

Proposed rollout strategy for Recommendation 3

1. MoEF&CC, together with the Ministry of Skill Development and Entrepreneurship, can support the upskilling of workers in refrigeration, air conditioning, and heat pumping under Skill India Mission and Pradhan Mantri Kaushal Vikas Yojana.

2. Ministry of Skill Development and Entrepreneurship, in collaboration with National Skill Development Corporation, should register industry training centres under the Ministry of Education's National Skills Qualification Framework (NSQF) and make linkages with MSME Development Institutes. This will create a class of trained and skilled personnel required for precision manufacturing of small diameter IGTs.

5.2 PROMOTE THE DEVELOPMENT OF DOMESTIC SMALL DIAMETER IGT MANUFACTURING FACILITIES

Table 12 highlights the existing challenges related to domestic manufacturing of small diameter IGTs for RACs in India. It also illustrates the potential opportunities that can be leveraged with the right policy and institutional support, as summarised in the recommendations.

Table 12: Challenges, opportunities, and recommendations

S. No	Challenges	Opportunities	Recommendations	Institution
1.	Import duties The existing duty-free imports of finished products such as copper tubes and pipes from Vietnam, Malaysia, and Thailand under the FTA with ASEAN discourages investment in domestic manufacturing of small diameter copper tubes.	Rationalisation of duties under FTA can stimulate the revival of domestic manufacturing and generate socioeconomic benefits for the country. It can also potentially accelerate the country's mission to achieve the clean energy transition through the notion of Atmanirbhar Bharat or "Self-Reliance."	**Recommendation 4:** Rationalise the component of import duty on copper cathodes and finished copper goods in the downstream copper industry to create a level playing field for domestic manufacturers.	**Nodal agency:** Department of Commerce Supporting agency: Ministry of Finance Ministry of Micro, Small, and Medium Enterprises (M/o MSME)
2.	Complete dependence on imports poses business risks, as witnessed during the COVID-19 pandemic when major supply chain disruptions took place.			
3.	Initial cost Setting up an IGT manufacturing facility requires a high CAPEX, posing a huge investment challenge for small, medium, and large industry players.	A domestic manufacturing facility will facilitate access to available technology and address the prohibitive investment costs in setting up new manufacturing lines. FDI from leading countries can be an important channel to proliferate the tech exchange and pave the way for "Make in India."	**Recommendation 5:** Formulate a cluster on value-added copper products.	**Nodal agency:** M/o MSME Supporting agency: DPIIT

			Recommendation 6: Attract multinational companies to bring in investment through the FDI route and establish joint ventures for small diameter IGT and component manufacturing.	Nodal agency: DPIIT Supporting agencies: Private businesses such as RAC, copper tube, & heat exchanger manufacturers
4.	Skill development IGT manufacturing requires a higher degree of sophistication and precision, which is difficult to achieve with the domestic plain copper tube manufacturers' current technologies and skill level.	Formal skill development relevant to IGT manufacturing would boost production, accelerate the transition to high-value copper products in RACs, and help create additional employment in the copper and end-use products in the refrigeration sector.	**Recommendation 7:** Drive skill-building of the sector through training and national certification schemes.	**Nodal agency:** Ministry of Skill Development and entrepreneurship Supporting agency: Ministry of Education

Recommendation 4

Drive Rationalise the component of import duty on finished copper products to create a level playing field for domestic manufacturers.

Within the India-ASEAN FTA, copper cathodes attract a basic customs duty of 5%, while the finished copper tubes and pipes are imported from countries like Vietnam, Malaysia, and Thailand at 0% duty, which has eliminated most domestic manufacturing. The remaining domestic plain tube manufacturers are not willing to set up IGT manufacturing facilities until the FTA and inverted duty structure issue is resolved.

We thus recommend that the inverted duty structure be changed so that the copper products manufactured in the downstream copper industry, such as copper tubes and pipes, are kept outside the ambit of the FTA. In particular, we recommend that downstream copper goods such as copper tubes and pipes be categorised in the negative list of the FTA agreement between India and ASEAN.

Proposed rollout strategy for Recommendation 4

1. Ministry of Commerce and Industry, in collaboration with the M/o MSME and Ministry of Finance, can collect data on the loss of employment and value addition suffered by the copper products manufacturing industry and assess foreign exchange loss from imports of finished copper goods with industry stakeholders.

2. A review of the India-ASEAN FTA in goods should be initiated and the possibility of keeping downstream copper goods in the negative list negotiated.

3. A gradual reduction in import duties levied on copper cathodes should be implemented.

Recommendation 5

Special Formulate a cluster on value-added copper products.

The Indian copper plain tube manufacturing industry comprises SMEs. Setting up an IGT manufacturing facility requires a high CAPEX, which poses a critical challenge for the SMEs. Traditionally, they have relied on bank lending for their cash flow requirements and investment. However, there are still major barriers to financial access for SMEs, including their low credit scores, weak accounting systems, collateral requirements from banks, high interest rates, and banks' preferences for large companies over SMEs, among others.

We thus recommend that a specialised zone termed "value-added cluster" for copper goods be created in the country, wherein SMEs get access to land, capital, and raw materials at reasonable and affordable costs. The cluster zone can also encourage partnerships between OEMs and other private players. This will ensure a sizeable flow of private capital to cover the initial capital expenses for copper tube manufacturers' small-scale manufacturing units. The flow of these funds can be incentivised by extending tax exemptions.

Proposed rollout strategy for Recommendation 5

1. M/o MSME should run consultations with state-led MSME departments to explore the possibility of creating a value-added cluster on copper-related products.

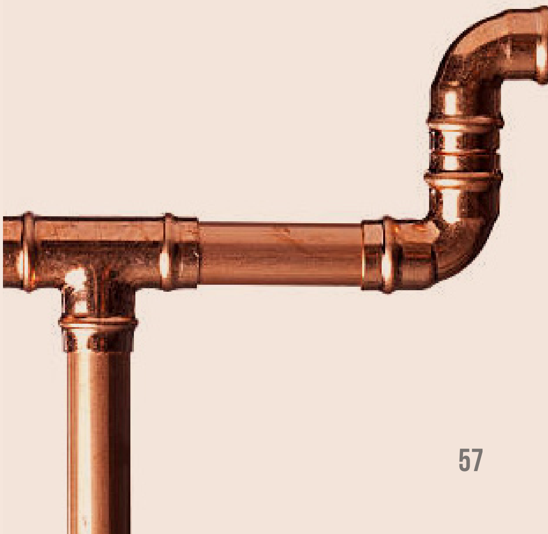
2. A cluster programme support agency can be formulated to coordinate, manage, and provide technical guidance for undertaking the cluster development initiative.

3. M/o MSME, in consultation with DPIIT, should examine ways to promote investment in the cluster, such as through Start-Up India funds and the FDI route.

4. The existing programmes supporting cluster development, such as the MSME Cluster Development Programme and National Manufacturing Competitiveness Programme, can be leveraged to get support for hard and soft interventions, along with enhancing the competitiveness of the potential firms to compete globally.

5. The departments may further encourage partnerships between OEMs and other private players wherein the private players can take the lead and cover the initial capital expenses for copper tube manufacturers' small-scale manufacturing units.

6. Tax rebates should be earmarked for the private players and multinational firms that make the initial investment.



Recommendation 6

Attract multinational companies to bring in investment through the FDI route for component manufacturing.

To deal with the high CAPEX issue, we recommend that foreign investments in the sector be encouraged. In particular, joint ventures with domestic players in the industry should be formed. The investment funds can lead to an expansion of domestic manufacturing and assembly lines integrating small diameter copper tubes into RAC components.

Proposed rollout strategy for Recommendation 6

1. The FDI route may be leveraged to initiate investments in AC component manufacturing, and a network of domestic downstream copper industry and foreign firms can be established.

2. The DPIIT should review FDI applications for the AC industry on a fast-track basis in order to enable greater impact on the local value addition and employment envisaged under the PLI scheme.

Recommendation 7

Drive skill-building of the sector through training and national certification schemes.

The Indian copper plain tube manufacturing industry is unorganised and fragmented. The industry still uses outdated technology and is severely lacking in the skills required for the higher precision work involved in IGT manufacturing. Further, there are quality concerns and higher rejection rates in domestically manufactured plain tubes compared to imported tubes.

IGT manufacturing requires a higher degree of sophistication and precision, which would be difficult to achieve with domestic manufacturers' current technology and skill level. We therefore recommend that an exclusive skill development programme on the inner grooving of small diameter and plain tubes be integrated into the governments' ongoing initiatives under Skill India Mission and Pradhan Mantri Kaushal Vikas Yojana. The skills imparted can create a class of trained and skilled personnel required for precision manufacturing of small diameter IGTs.

Proposed rollout strategy for Recommendation 7

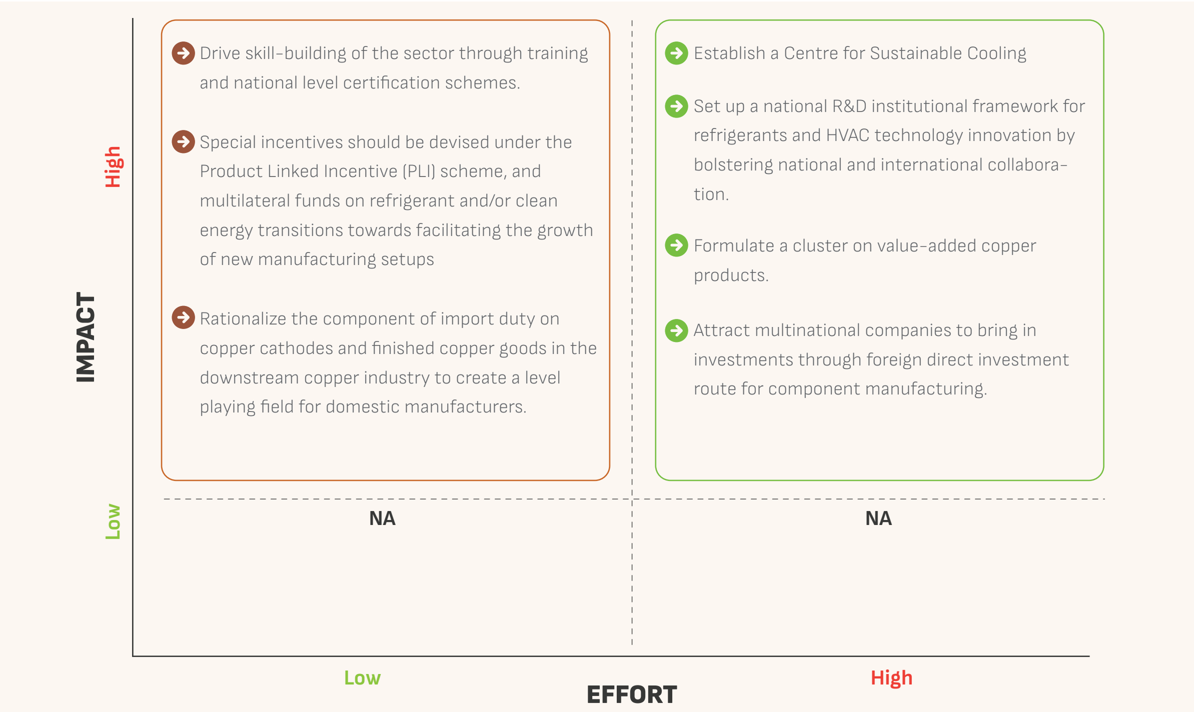
1. MoEF&CC, together with the Ministry of Skill Development and Entrepreneurship, can support the upskilling of workers in refrigeration, air conditioning, and heat pumping under Skill India Mission and Pradhan Mantri Kaushal Vikas Yojana.

2. Ministry of Skill Development and Entrepreneurship, in collaboration with National Skill Development Corporation, should register industry training centres under the NSQF and make linkages with MSME Development Institutes. This will create a class of trained and skilled personnel required for precision manufacturing of small diameter IGTs.

5.3 IMPACT EFFORT MATRIX

While all the recommendations together form a conducive environment for accelerating the transition to small diameter IGTs in appliances and promoting an ecosystem for domestic manufacturing, Figure 28 classifies the recommendations in an impact effort matrix with four quadrants: low effort-low impact, low effort-high impact, high effort-low impact, and high effort-high impact.

Figure 28: Impact effort matrix for strategic prioritisation of recommendations



The matrix has been developed based on a qualitative categorisation and the experience and insights gained in this study. However, the final prioritisation will be contingent on government priorities, an enabling environment, and the institutional capacities in India to initiate domestic IGT manufacturing.

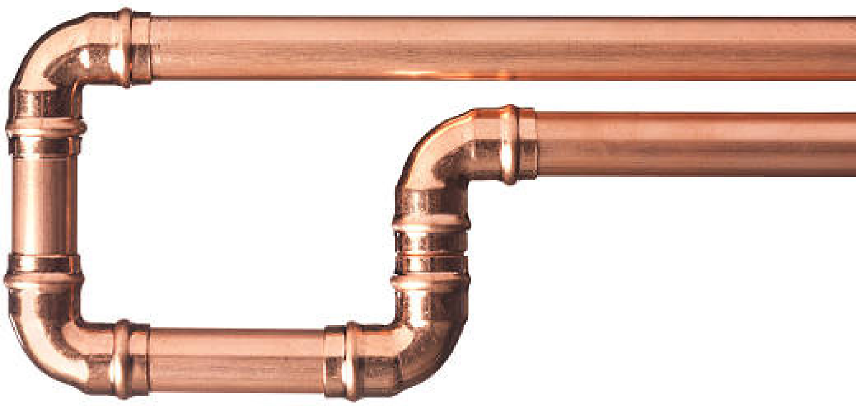
5.4 THE WAY FORWARD

With soaring temperatures, rising incomes, and rapid urbanisation in India, RAC adoption is projected to increase significantly over the coming years. Through the launch of ICAP in 2019 under the aegis of MoEF&CC, the country has escalated its climate goals and positioned itself as a nation that is committed to achieving its global and national targets on climate action. A framework of imperatives and strategies to reduce the emissions from increased RAC and refrigerants use has been clearly laid out in ICAP. Standards and labelling has been identified as a crucial policy reform that India can continue to leverage to further strengthen its actions in this space and thus ensure compliance to its Nationally Determined Contributions.

However, another crucial aspect of the expanding cooling needs is the opportunity to enhance the country's position in the value chain space and establish India as a leading manufacturer of energy-efficient cooling appliances, particularly RACs. Energy efficiency interventions have various co-benefits, such as employment creation, improved health and productivity, etc. This report clearly establishes the substitution of aluminium and copper tubes with small diameter copper IGTs as one such intervention that not only promises efficiency gains for RAC technology, but also various socioeconomic benefits for the country.

India has a number of policies in place to strengthen the domestic manufacturing ecosystem of components and end-use equipment. However, the policy support does not always enable competitive advantage for the country to produce and trade this equipment on both the domestic and global markets. There are specific challenges to establishing a robust value chain of small diameter copper IGTs in India, ranging from raw material limitations to lack of financing and sub-optimal productivity.

Transitioning to 5mm IGTs provides a wide range of opportunities; however, there is a considerable lack of policy push to enable domestic copper tubing manufacturing in India. In this context, examples from enabling policies adopted globally should be examined, in order to create a pro-manufacturing ecosystem and promote design innovations for component level efficiency gains in India.



As a way forward, it is crucial for the decision-making entities in the country to establish complementarities between climate and economic policies and create enabling mechanisms for the downstream sub segments within industries such as tube manufacturing. This can be achieved by establishing a Centre for Sustainable Cooling that provides a platform to enable climate cautious yet profitable business propositions and solutions best-suited for the space cooling industry. The centre shall focus on building capacity and knowledge enhancement of stakeholders w.r.t. R&D, financial measures, policy & regulatory instruments, and skill development to establish a favourable domestic manufacturing ecosystem and accelerate the adoption of components that improve the energy efficiency of space cooling appliances. This, in turn, could bolster international collaborations in innovation and enable key manufacturers and traders of downstream copper products to develop state-of-the-art technologies and enhance their position in the global market.

Establishing a Centre for Sustainable Cooling to promote domestic manufacturing ecosystems for super energy-efficient and climate-friendly space cooling technologies can be a way forward for India to position itself as a global catalyst of climate action and will further strengthen the ethos and relevance of domestic actions to fulfil the international commitments made in COP26.

Further, as the creation of a domestic manufacturing ecosystem for copper-based industries is crucial, there is a need for a study to create a roadmap for decarbonisation of the copper industry. The study can produce a compendium of technologies and global best practices that minimise negative environmental impacts and a resulting set of recommendations to internalise the potential externalities from the production process.

Annexure 1: Copper Tube Types and Uses

There are different types of copper tubes, such as plain, inner grooved, hard drawn, and soft drawn. Based on the application, a particular type of tube of a certain thickness is used. Table 13 presents a comparison of the different types of tubes based on their properties, application, and other factors.

Table 13: Comparison of hard drawn, soft drawn, and inner grooved tubes

Parameter for comparison	Hard drawn plain tubes	Soft drawn plain tubes	Inner grooved tubes
Manufacturing process*	Not annealed	The additional process of annealing is done	Online annealing and inner grooving are done
Physical characteristics	Hard and inflexible	Soft and flexible	Soft and flexible, better heat transfer coefficient, can withstand higher pressure as required with modern environment-friendly refrigerants
Applications	Shell and tube heat exchangers, underground piping, pressurised water systems, medical gas piping system, piped natural gas application, cable lugs, small-sized heat exchangers, etc.	Connecting tube for refrigeration and air conditioning applications, connecting the pressure gauges and control valves, flared fittings and connections, etc.	AC and refrigeration system evaporators and condensers
Cost	Less expensive than the other two	More expensive than hard drawn tubes due to additional annealing process	Most expensive option, as inner grooving requires sophisticated machinery and skilled labour
Domestic manufacturing capacity	Manufactured domestically	No domestic manufacturing-only imported	No domestic manufacturing due to low profit margins and high required investment-only imported

** The initial manufacturing process for all types of tubes of is the same; the only difference is an additional annealing process in some cases, depending on the type of tube.*

Copper tube classification

Types K, L, M, DWV, and Medical Gas tubes are specified ASTM standard sizes, with the actual outside diameter always 1/8-inch larger than the standard size. Each of the types represents a series of sizes and with varied wall thicknesses. Type K tubes have thicker walls than Type L tubes, and Type L walls are thicker than those of Type M for any given diameter. All inner diameters depend on tube size and wall thickness.

The tubes that are being used in the HVAC and cooling industries are as follows:

Table 14: Types of copper tubes used in the cooling industry[42]

Tube type	Color code	Standard	Application	Commercially available lengths		
				Nominal or standard sizes	**Drawn**	**Annealed**
Type K	Green	ASTM B 88[3]	• Domestic water service and distribution • Fire protection • Solar • Fuel/fuel oil • HVAC • Snow melting • Compressed air • Natural gas • Liquified petroleum (LP) gas • Vaccum	**Straight Lengths:**		
				1/4 inches to 8 inch	20 ft.	20 ft.
				10 inch	18 ft.	18 ft.
				12 inch	12 ft.	12 ft.
				Coils:		
				1/4 inch to 1 inch	-	60 ft.
					-	100 ft.
				1-1/4 inch to 1-1/2 inch	-	60 ft.
				2 inch	-	40 ft.
					-	45 ft.
Type L	Blue	ASTM B 88	• Domestic water service and distribution • Fire protection • Solar • Fuel/fuel oil • Natural gas • Liquified petroleum (LP) gas • HVAC • Snow melting • Compressed air • Vaccum	**Straight Lengths:**		
				1/4 inch to 10 inch	20 ft.	20 ft.
				12 inch	18 ft.	18 ft.
				Coils:		
				1/4 inch to 1 inch	-	60 ft.
					-	100 ft.
				1-1/4 inch to 1-1/2 inch	-	60 ft.
				2 inch	-	40 ft.
					-	45 ft.
Type M	Red	ASTM B 88	• Domestic water service and distribution • Fire protection • Solar • Fuel/fuel oil • HVAC • Snow melting • Vaccum	**Straight Lengths:**		
				1/4 to 12 inch	20 ft.	N/A

42 Copper Development Association, https://www.copper.org/applications/plumbing/techref/tpf_stds/tube_pipe_stds.html

DWV	Yellow	ASTM B 306	• Drain, waste, vent • HVA • Solar	**Straight Lengths:**		
				1/4 to 8 inch	20 ft.	N/A
ACR	Blue	ASTM B 280	• Air conditioning • Refrigeration • Natural gas • Liquefied petroleum (LP) gas • Compressed gas	**Straight Lengths:**		
				1/4 to 8 inch	20 ft.	N/A
				Coils:		
				1/8 inch to 1-5/8 inch	-	50 ft.

The IGT standards are compiled under the umbrella of ASTM B68, GB/T 20928. IGTs have the following characteristics:

- Inner diameter range: 4.3-14.22 mm
- Bottom wall thickness range: 0.20-0.50 mm
- Total wall thickness range: 0.35-0.83 mm

Table 15: IGT specifications

• Relevant standards: ASTM B68, GB/T 20928, JIS H3300
• Inner diameter: 4.3-14.22 mm
• Outside diameter: 5.0-15.8 mm
• Grade: C11000, C12200, C2680, C27200,
• C27000, etc.
• Bottom wall thickness: 0.20-0.50 mm
• Total wall thickness: 0.35-0.83 mm
• Fin groove depth: 0.15-0.33 mm
• Unit weight: 34-270 kg

Applications: Widely used in the air conditioning, refrigeration, gas, & water sectors.

Table 16 General manufacturing dimensions of IGTs (ASTM B68, GB/T 20928, JIS H3300)[43]

Specification	OD		ID	Wall-thickness		HF	TWT	Number of Grooves	Apex Angle	Helix Angle
	(Inches)	(mm)	(mm)	(Inches)	(mm)	(mm)	(mm)			
5.00 × 0.21 + 0.14 – 18	0.197	5.00	4.32	0.008	0.200	0.14	0.34	40	40	18
7.00 × 0.25 + 0.18 – 18	0.276	7.00	6.14	0.010	0.250	0.18	0.43	50	22	18
7.00 × 0.305 + 0.165 – 18	0.276	7.00	6.06	0.012	0.305	0.165	0.47	65	38	18
7.94 × 0.28 + 0.20 – 18	0.313	7.94	6.98	0.011	0.280	0.20	0.48	50	40	18
7.94 × 0.30 + 0.20 – 18	0.313	7.94	6.94	0.012	0.300	0.20	0.50	50	40	18
7.94 × 0.41 + 0.20 – 18	0.313	7.94	6.72	0.016	0.410	0.20	0.61	50	40	18
9.52 × 0.30 + 0.20 – 18	0.375	9.52	8.52	0.012	0.300	0.20	0.50	60	25	18
9.52 × 0.33 + 0.20 – 18	0.375	9.52	8.46	0.013	0.330	0.20	0.53	60	25	18
9.52 × 0.355 + 0.20 – 18	0.375	9.52	8.41	0.014	0.355	0.20	0.555	60	25	18
12.70 × 0.355 + 0.20 – 18	0.500	12.70	8.41	0.014	0.355	0.20	0.555	60	25	18
15.88 × 0.355 + 0.20 – 18	0.625	15.88	8.41	0.014	0.355	0.20	0.555	60	25	18

43 GD copper Mexico, Available at: http://www.gdcobre.com/copper.html, February 2022

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