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IIEC

Market Assessment of Heat Pumps in India

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Development Environergy Services Ltd. (DESL)

Foreword

Energy efficiency stands at the forefront of India's energy transition and climate action strategy. As a Joint Venture of Public Sector Undertaking under the Ministry of Power, EESL has consistently led market transformation initiatives for energy efficient technologies through innovative business models and large-scale implementation programs. Our commitment to promoting sustainable technologies aligns perfectly with India's ambitious climate goals and energy security objectives.

This comprehensive assessment of India's Market for heating solutions based on Heat Pump technology comes at a crucial time when the nation is actively seeking sustainable heating and cooling solutions. The study reveals significant potential for adoption, with projected market capacity expanding from 43,416 MW_{th} in 2024 to 141,403 MW_{th} by 2030. The findings highlight substantial opportunities across residential, commercial, and industrial sectors, promising potential for both energy savings and emissions reductions.

As move forward towards promotion of energy efficient technologies, this report will serve as a decisive guidepost for concerned stakeholders. The detailed analysis and recommendations provided here will help in shaping policies, inform investment decisions, and drive technological innovation in the heat pump applications. We believe these insights will catalyze accelerated deployment of heat pumps and contribute meaningfully to India's broader climatic obligations energy efficiency goals while creating new opportunities for sustainable heating solutions.

We hope this report serves as a valuable reference for the concerned stakeholders working towards advancing clean energy solutions for heating applications in India.

(Vishal Kapoor)
Chief Executive Officer

Preface

Heat pumps represent a transformative technology capable of significantly reducing energy consumption and greenhouse gas emissions from heating processes across India's diverse sectors. This market assessment study comes at an opportune moment as India advances towards its climate commitments while seeking efficient solutions for heating and cooling needs. The study provides a thorough examination of the current landscape, technology maturity, market dynamics, regulatory frameworks, and supply chain aspects to identify promising applications and deployment strategies.

The assessment was undertaken with the primary objective of providing a strategic roadmap for accelerating heat pump technology adoption in India. Through extensive stakeholder consultations, detailed data analysis, and comprehensive market research, the report identifies key opportunities while highlighting barriers that need to be addressed through policy interventions, technology standardization, and capacity building initiatives.

This report represents a significant milestone in understanding India's heat pump market potential and the pathways for its development. The findings will serve as a valuable resource for policymakers, technology providers, end-users, and other stakeholders in understanding and realizing the transformative potential of heat pump technology in India. We believe this report with comprehensive analysis will contribute substantially to advancing the adoption of energy-efficient heating and cooling solutions based on the heat pump technology across the country.

22/5/2025

(Prashant Kumar)
CGM & Head CDP

Acknowledgement

The development of the report "Market Assessment of Heat Pump in India" marks a critical step in evaluating the role of heat pump technology in supporting India's Nationally Determined Contributions (NDCs) especially within commercial and industrial space. This will support in establishing a national program strategy for the large-scale adoption of Heat Pump Solutions. But taping into the signification, underutilized energy saving potential in commercial and industrial applications.

EESL expresses its sincere appreciation to the International Institute of Energy Conservation (IIEC) in conducting this comprehensive market assessment study of heat pump technology in India under GEF funded project with the technical assistant of UNEP. We extend our special thanks to Development Environergy Services Ltd. (DESL) for thorough analysis, technical expertise, and wider consultation with experts, academia working in heating & cooling domain in preparing this detailed report that will guide future initiatives in this sector.

We are particularly grateful to the various stakeholders including technology solution providers, faculty of academia (IIT Madras, Anna University), industry associations (ISHRAE, RAMA), designers & consultants of cooling/ heating projects, building developers, and end-users who generously shared their time and insights through consultations. Their practical experience and market understanding have been invaluable in developing a holistic perspective of India's heat pump market potential.

Special thanks to the Bureau of Energy Efficiency (BEE) and Ministry of Power for their continued guidance and support in promoting energy efficient technologies in India. The collaborative spirit demonstrated by all participants has been instrumental in making this study comprehensive and actionable. We also acknowledge the contributions of international organizations whose best practices and policy frameworks helped inform the recommendations in this report.

(Girja Shankar)
General Manager (Technical)

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Abbreviations

A2W	Air-to-Water
AC	Air Conditioner/ Air Conditioning
AHRI	AHRI - Air-Conditioning, Heating, and Refrigeration Institute
APF	Annual Performance Factor
ASHP	Air Source Heat Pump
ASME	American Society of Mechanical Engineers
AUD	Australian Dollar
BEE	Bureau of Energy Efficiency
CAGR	Compounded annual growth rate
COP	Coefficient of performance
CT	Cooling tower
CTC	Cut, Tear, Curl (tea processing method)
DC	Designated consumer
DESL	Development Environergy Services Ltd
ECBC	Energy Conservation Building Code
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Ltd
EN	European Norm
EPA SNAP	Environmental Protection Agency Significant New Alternatives Policy
ErP	Energy-related Products
ETP	Energy technology perspectives
ESCO	Energy Service Company
EU	European Union
EVI	Enhanced Vapour Injection
FY	Fiscal year
GB	Guobiao (Chinese National Standard)
GEF	Global Environment Facility
GHG	Greenhouse gases
GOI	Government of India
GWP	Global Warming Potential
HDD	Heating degree days
HFC	Hydrofluorocarbon
HSD	High speed diesel
HSN	Harmonized System Nomenclature

HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air Conditioning
IBEF	India Brand Equity Foundation
IEA	International Energy Agency
IIEC	International Institute for Energy Conservation
IISC	Indian Institute of Science
INR	Indian Rupees
IPCC	Intergovernmental Panel on Climate Change
IPLV	Integrated Part Load Value
IS	Indian Standards
ISEER	Indian Seasonal Energy Efficiency Ratio
JIS	Japanese Industrial Standards
kW_{th}	Kilo Watt Thermal
LPD	Litres per day
LPG	Liquefied Petroleum Gas
METI	Ministry of Economy, Trade and Industry (Japan)
MHP	Mechanical Heat Pump
MoEFCC	Ministry of Environment, Forest and Climate Change (India)
MoSPI	Ministry of Statistics and Programme Implementation
MVC	Mechanical Vapour Compression
MVR	Mechanical Vapour Recompression
MW	Mega Watt
MWth	Megawatt thermal
NATMO	National Atlas and Thematic Mapping Organization
NIC	National Industrial Classification
NITI	National Institution for Transforming India
NPLV	Non-Standard Part Load Value
NZE	Net Zero Emissions
PAT	Perform-Achieve-Trade
PLI	Production Linked Incentive
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photo Voltaic
R&D	Research and Development
RE	Renewable Energy
SEER	Seasonal Energy Efficiency Ratio
SME	Small and Medium-sized Enterprises

tCO_2	Tonnes of Carbon Dioxide
TL	Temperature lift
toe	Tonnes of oil equivalent
TRL	Technology Readiness Level
TVC	Thermal Vapour Compression
UNEP	United Nations Environment Programme
VRF	Variable Refrigerant Flow
W2W	Water-to-Water
y	year

Executive Summary

This report examines the market potential for applications of heat pumps in India's residential, commercial and industrial sectors for space heating and water heating applications. Heat pumps are devices which transfer heat using mechanical energy rather than generating heat directly, offering high energy efficiency and opportunities for reducing greenhouse gas (GHG) emissions compared to fossil fuel-based systems. Heat pumps can provide up to 3-4 times more energy than they consume, making them highly efficient for both heating and cooling applications. Recent technological innovations have enhanced heat pumps' efficiency and economic advantages, making them increasingly attractive across different applications.

In the Indian context, heat pumps present a promising solution to address the country's energy efficiency and GHG emissions reduction goals. Buildings and industries account for approximately 55% of India's primary energy consumption, resulting in 67.5% of GHG emissions. At the 26th Conference of Parties, India committed to reducing its emission intensity of its GDP by 45% by 2030 from 2005 levels and achieving net-zero emissions by 2070. Additionally, the country aims to reduce total projected carbon emissions by 1 billion tonnes by 2030. Heat pumps align with these targets by providing cost-effective heating and cooling options while significantly lowering emissions. The potential for widespread adoption of heat pumps in the building (residential, commercial) and industrial sectors can support India's ambitious climate objectives and offer a pathway to more sustainable energy use.

This report is the outcome of a comprehensive market assessment study of heat pump applications across residential, commercial and industrial sectors in India to inform strategic pathways for accelerating their adoption and maximizing energy savings potential. The report examines current technology maturity levels, market dynamics, regulatory frameworks, and supply chain aspects to identify the most promising applications and deployment strategies.

The approach adopted for the study involved a comprehensive evaluation of heat pump technology; assessing applications that demonstrate significant potential for energy savings and emission reduction in the building and industrial sectors, the results of the assessment were validated by a thorough analysis of historical data (imports), extensive stakeholder consultations, and review of global best practices. A comprehensive analysis of heat pump market segments indicated multiple classification approaches, with the most relevant categorization illustrated in the accompanying figure:

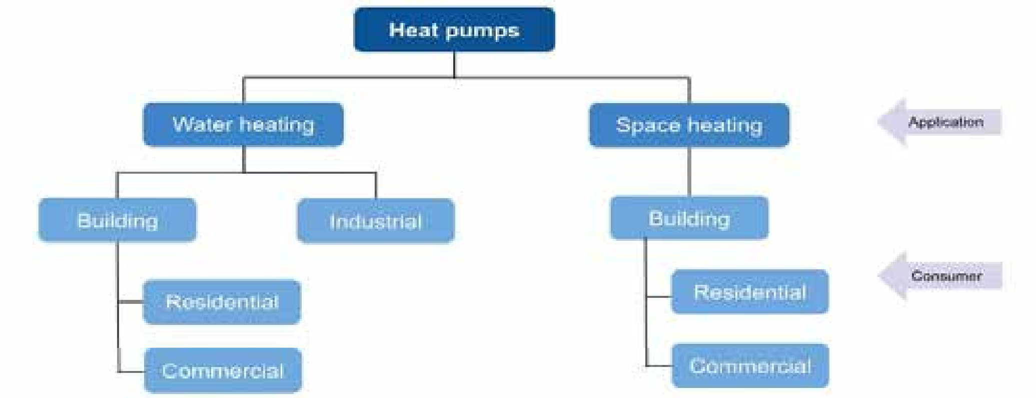

Figure 1: Market classification of heat pumps

The report provides baseline energy consumption, technical feasibility and investment requirements for each sector. To offer a forward-looking perspective, the analysis projects the market potential from 2024 to 2030.

The market analysis employed a three-tier temperature classification (<150°C, 150-400°C, and >400°C), with heat pumps, currently, being most suitable for low-temperature applications (<150°C) across residential, commercial, and industrial sectors. Heat pump systems in buildings provide versatile temperature control ranging from 25-70°C, delivering multiple functions including climate control and hot water supply for everyday needs like laundry, bathing, and kitchen use. Industrial applications present greater opportunities which can be tailored to requirements of diverse manufacturing processes. Specific industries identified which offer immediate opportunities for heat pump implementation are chemical, food and beverage, metal & auto components, automobile and textiles. The focus on applications below 150°C aligns with current commercially available heat pump technology capabilities, ensuring practical implementation potential across these sectors.

Approach for market assessment

- **Selection of applications for heat pump**: Based on the status of technology, two applications were selected- space heating and water heating
- **Shortlisting of sub-sectors**: Based on the potential for the above-mentioned applications in buildings and industries.
    - ***Space heating applications*** were evaluated only for buildings in North Indian states. Buildings considered included hotels, educational institutions (i.e. hostels), health care (i.e. hospitals with > 100 beds), retail (organized) and residential (super rich households).
    - ***Water heating applications*** were considered in both buildings and industries, pan India. The buildings considered included hotels, educational institutions (i.e. hostels), health care (i.e. hospitals with > 100 beds) and residential (households with electricity consumption of more than 100 kWh per month).
    - ***Industries*** considered include chemical, food and beverage, metals and auto components, automotive and textile. Industries using natural gas and diesel were only considered from a techno-economic perspective.
- **Assessment of market potential:** Baseline energy consumption was estimated using information from primary and secondary sources corresponding to space heating and water heating as applicable. From the baseline the heat pump potential, energy saving (in tons of oil equivalent) and GHG emission impact were calculated. Based on the barrier analysis, industrial sectors were evaluated and filtered to identify those using primary fuels that would make heat pump systems economically feasible.

Currently, India's heat pump sourcing is diverse, with suppliers from over sixteen (16) countries. Both international suppliers and domestic companies are involved in the supply and installation. Both fully assembled units and compressors for local assembly are imported. Analysis of import data indicates that nearly 90% of heat pumps are imported from China. However, 50-55% of importers are Indian companies.

Stakeholder consultations indicate that the heat pump business in India gained significant momentum after 2021, particularly in buildings, likely due to increase in high end built space and rising fuel prices. The residential sector dominates import (quantity), while the commercial sector dominates in terms of relative heating capacity. The industrial sector has a smaller market share due to various technical and economic challenges.

The summary of market potential for the heat pump technology is presented for the commercial sector, residential sector and the industrial sectors in India in the table below:

Table 1: Market potential

Parameter	Unit	2025	2026	2027	2028	2029	2030
Commercial sector							
Energy saving potential - Technical	MTOE	0.20	0.21	0.24	0.26	0.29	0.33
Energy saving potential - Monetary	Mn INR	22,738	24,975	27,579	30,623	34,194	38,401
Heat pump capacity	MW_{th}	11,048	11,777	12,602	13,541	14,617	15,861
Emission reduction potential	$MtCO_2$	1.9	2.0	2.3	2.5	2.8	3.1
Investment	Mn INR	192,843	208,076	225,489	245,497	268,603	295,411
Residential sector							
Energy saving potential - Technical	MTOE	1.18	1.36	1.56	1.79	2.06	2.36
Energy saving potential - Monetary	Mn INR	110,204	126,458	145,129	166,581	191,232	219,561
Heat pump capacity	MW_{th}	64,605	73,667	84,006	95,804	109,267	124,633
Emission reduction potential	$MtCO_2$	11.30	12.96	14.88	17.07	19.60	22.50
Investment	Mn INR	1,099,392	1,256,645	1,436,550	1,642,396	1,877,950	2,147,534
Industrial sector							
Energy saving potential - Technical	MTOE	0.20	0.22	0.23	0.25	0.27	0.29
Energy saving potential - Monetary	Mn INR	7,161	7,707	8,298	8,939	9,635	10,392
Heat pump capacity	MW_{th}	647	692	740	792	848	909
Emission reduction potential	$MtCO_2$	0.45	0.48	0.52	0.55	0.59	0.63
Investment	Mn INR	30,920	33,109	35,473	38,037	40,816	43,832

The market potential for heat pumps through 2030 is expected to be dominated by the commercial and residential sectors, driven by the major influx of commoditized air source heat pumps through imports. The residential sector is projected to represent approximately 85% of the overall market potential (In terms of heat pump capacity), reflecting the significant demand growth in building applications. However, the industrial sector's market potential by 2030 is expected to be more constrained, primarily due to three key factors: the necessity for specialized engineering design in industrial applications, the cost advantage of existing primary fuels, and the limited number of market players capable of providing engineered industrial heat pump solutions.

The estimated current adoption of heat pumps (relative to potential) in terms of cumulative heating capacity is as follows

Figure 2: Estimated adoption of heat pumps in 2024

The unpredictable nature of industry responses to emerging carbon market trends and possible modifications to the Perform, Achieve and Trade (PAT) scheme creates uncertainty in forecasting heat pump technology adoption across industrial applications. These changing market mechanisms and regulatory frameworks could change the financial viability and attractiveness of heat pump investments. The adoption of heat pumps in industrial settings will be driven not only by the techno-economic feasibility but also the broader ecosystem in which each sector operates. The latent market potential and actual adoption rates will therefore depend on how businesses evaluate and react to these emerging opportunities and requirements. These estimates are based on macro-economic conditions at the time of the study. The impact of the adoption of the technology by 2030 is presented in the figures below:

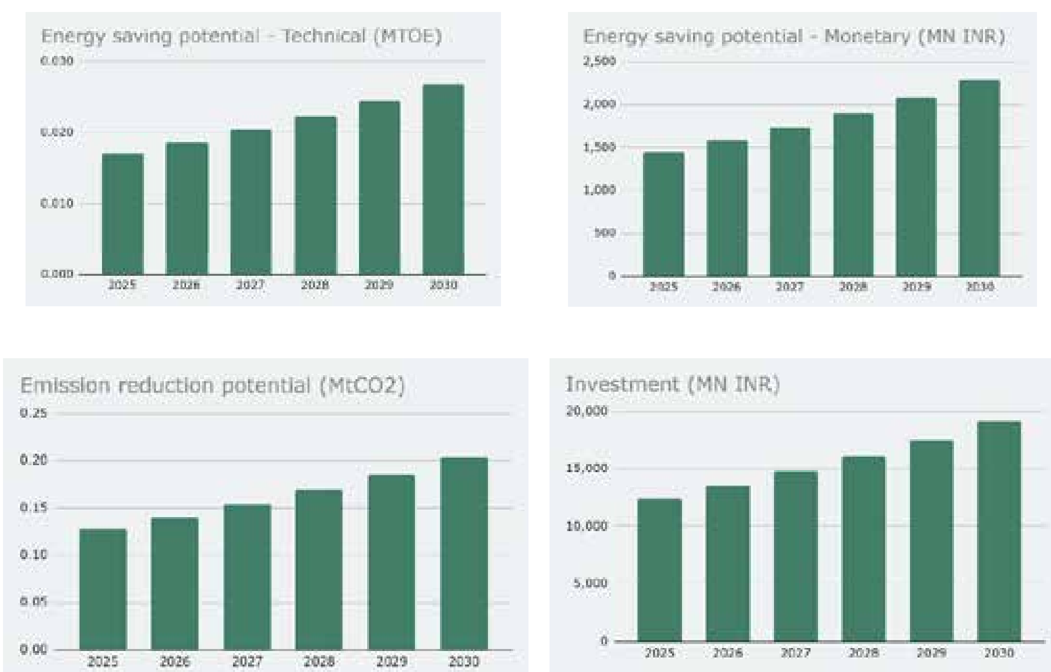

Figure 3: Impact of adoption of heat pump technology

In conclusion, this comprehensive market assessment of heat pump technology in India reveals significant potential across commercial, residential and industrial sectors. The analysis projects substantial growth opportunities, with total market capacity expected to expand from 43,416 MW_{th} in 2024 to 141,403 MW_{th} by 2030. The residential sector emerges as the dominant market segment, anticipated to represent approximately 85% of the overall potential, highlighting the significant role of building applications in driving adoption.

The study identifies key market dynamics, including the current low adoption rates ranging from 1% to 3.3% across sectors, with China dominating imports at 89% of market value. The analysis emphasizes the need to address critical barriers such as high initial costs, limited awareness, and a fragmented supply chain heavily dependent on imports. To accelerate adoption, the report recommends focusing on developing domestic manufacturing capabilities, enhancing technical expertise, and expanding distribution networks.

Introduction

Many households unknowingly possess a type of heat pump, often in the form of common appliances. For instance, refrigerators function as heat pumps, albeit with a different primary purpose. While refrigerators prioritise the cooling aspect, traditional heat pumps focus on the heating side. A heat pump operates by extracting thermal energy from its surroundings, such as the ground, water or air. It then elevates the temperature of a working fluid, typically referred to as a refrigerant. This process allows the heat pump to transfer heat to a particular application. In essence, both refrigerators and heat pumps utilise similar principles, but their applications differ based on whether the emphasis is on cooling or heating. Heat pumps are energy-efficient because they transfer heat rather than generate it, allowing them to provide more energy in heating than they consume in electricity. Their efficiency is measured by the Coefficient of Performance (COP), which is typically between 2 and 6, meaning that they produce 2-6 units of heat for every unit of electricity consumed. This efficiency makes them an environmentally friendly option for climate control. Heat pumps come in various types, including air-source, ground-source (geothermal), and water-source models, each suited to different environments and needs.

Basic working principle

Heat pumps work on the principle of transferring heat from one location to another, rather than generating heat directly as shown in the below Figure-1 . They can be used for both heating and cooling purposes.

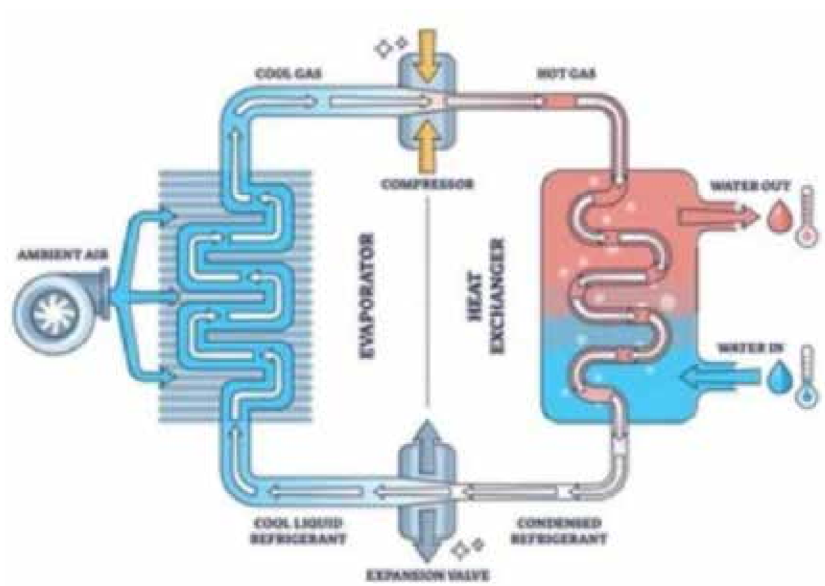

Figure 4: Heat pump working principle (Courtesy: Shutterstock)

Key components of a heat pump system include compressor, evaporator coil, condenser coil, expansion valve and reversing valve (for switching between heating and cooling modes). Here is a basic explanation of how heat pumps work:

- Refrigerant cycle: Heat pumps use a refrigerant that circulates through the system, changing from liquid to gas and back again.
- Evaporation: In heating mode, the liquid refrigerant absorbs heat from the outside air (or ground/water source) and evaporates into a gas.
- Compression: The gaseous refrigerant is then compressed, which increases its temperature significantly.
- Condensation: The hot, high-pressure gas passes through a heat exchanger (condenser) inside the building, where it releases its heat and condenses back into a liquid.
- Expansion: The liquid refrigerant then passes through an expansion valve, which reduces its pressure and temperature, preparing it to absorb heat again.
- Reverse cycle: For cooling, the process is reversed, with the heat pump extracting heat from inside the building and releasing it outside.

History of heat pumps

The history of the development of heat pump technology has seen significant advancements over the years. Initially, heat pumps for heating only (or mainly) profited from cheap components of air conditioning and refrigeration origin produced in large quantities. The main focus of development was on vapour compression systems (reverse Rankine cycle). In the 1990s, cheaper, more efficient, and more reliable heat pumps became available[1]. The growing environmental problems favoured the idea of saving primary energy by heat pump heating. The development focus shifted from component innovations to system optimization and cheaper mass production. There was a tendency towards natural refrigerants, mainly ammonia, and higher efficiencies due to low-temperature floor heating systems. From the early 1990s, hermetic scroll compressors began to outperform hermetic piston compressors and became the common choice for smaller heat pumps. The efficiency of small compressors significantly improved. New developments started for CO_2 compressors worldwide. Heat pumps were reported to have been implemented in the late 1990s in India. In 2008, the Infosys campus installed heat pumps to reduce their power demand by about 4 MW[2].

Relevance of heat pumps

Heat pumps will be the central technology used to cut heating's climate impact, predicts Yannick Monschauer, an energy analyst at the International Energy Agency[3]. The heat pumps as a technology have gained relevance for the diverse benefits, especially for a country with exponentially growing energy demand as predicted by NITI Aayog[4] and presented in the figure below:

[1] History of heat pumps: Swiss contributions and international milestones, Martin Zogg, 2008,
[2] National Mission on Sustainable Habitat 2021-2030, Ministry of Housing and Urban Affairs (Link)
[3] Everything you need to know about the wild world of heat pumps | MIT Technology Review (Link)
[4] NITI Aayog releases Analytical Tools for managing Climate Change and exploring Net Zero Pathways, NITI Aayog (Link)

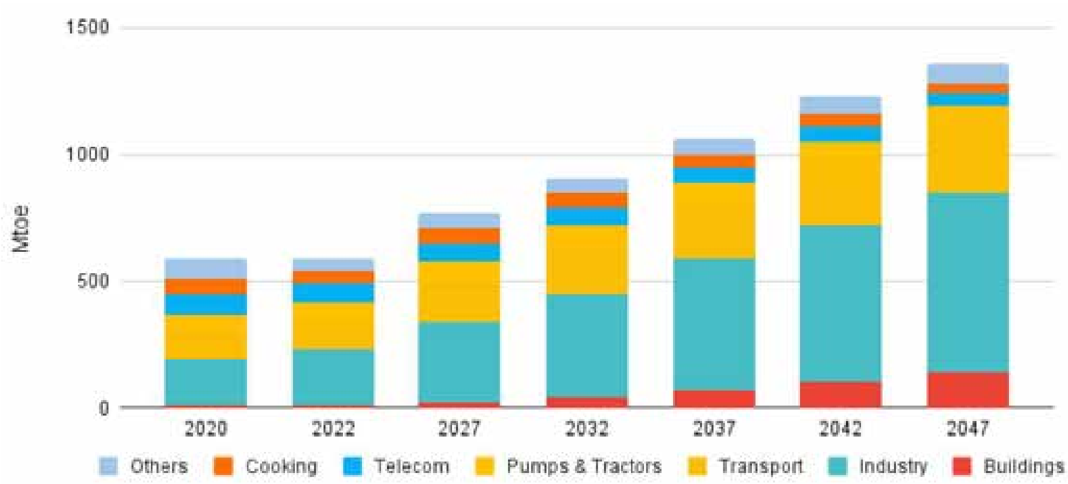

Figure 5: Energy demand projections

The energy demand is set to double in 2047 as compared to 2022 levels, dominated by the growth in the industrial and building sectors. Heat pump is, therefore, considered as a relevant technology. Heat Pump is considered as a breakthrough technology as described in the textbox below:

Textbox 1: Heat pump technology recognised as a strategic technology

Heat pump was recognised as a promising technology by the Planning Commission in 2013, envisaged to be promoted under the Electrical appliance programme[5]. A few other references related to the recognition of the heat pump technology are as follows:

- Buildings sector: In the Energy Conservation Building Code (ECBC) document, BEE notified the use of heat pumps in "Hotels, Hospital Patient Rooms, Hotel Guest Rooms, Resorts, Villas, Sleeping Quarters in Mixed use Buildings, Schools, Classrooms/Lecture Rooms" and "Buildings with Less than or equal to 12,500 m² of conditioned area" to install heat pumps to replace fossil fuel or electric hot water generator[6]
- Industrial sector: BEE and NITI Aayog recognised the heat pump technology as an existing decarbonisation solution for the industrial sector[7,8].

Even the International Energy Agency (IEA) has illustrated heat pumps as a strategic technology in the Energy Technology Perspectives 2023 (ETP-2023)[9]. It aims to assist decision-makers in understanding and navigating the ongoing changes in the energy sector. The Net Zero Emissions by 2050 Scenario (NZE Scenario) outlines a roadmap for the global energy sector to eliminate net CO_2 emissions by mid-century. The scenario aligns with the goal of restricting global temperature increase to 1.5°C (with at least 50% likelihood), conforming to the emission reduction assessments presented in the

[5] Twelfth Five Year Plan (2012-2017) Faster, More inclusive and Sustainable Growth, Planning Commission, GOI (Link)
[6] Energy Conservation Building Code (ECBC), BEE, 2017 (Link)
[7] Report of the inter-ministerial committee on low carbon technologies, NITI Aayog, 2022 (Link)
[8] Energy conservation guidelines for the industries (Category A), Bureau of Energy Efficiency (Link)
[9] Energy Technology Perspectives 2023 – Analysis - IEA (Link)

Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report.

In the NZE Scenario, heat pump is one among the six clean energy and technology supply chains that holds the potential to unlock around 50% of cumulative emissions reductions to 2050 in the NZE Scenario.

The scale and speed of deployment of heat pumps and associated supply chains needs to accelerate dramatically in line with the NZE Scenario.

However, the approach for developing the market needs to be reviewed from a National context. A review of the recent data to establish the context of heat pumps in the Indian market was conducted:

- Energy consumption
    - Energy Balance of India for 2020-21 (Data source: Energy Statistics India 2024 by the Ministry of Statistics and Programme Implementation, MoSPI)
    - Energy product consumption of various end use sectors for 2021-22 (Data source: National Energy Data: Survey and Analysis)

- GHG emissions
    - Distribution of GHG emissions by sector, 2016 (Data source: India - Third Biennial Update Report to the United Nations Framework Convention on Climate Change, 2021)
    - Energy Emissions in 2019 (Data source: India Climate and Energy Dashboard, NITI Aayog)

The contribution for the end-use sectors using the latest available data is depicted in the figures below[10]:

[10] Power generation sector was eliminated for this assessment

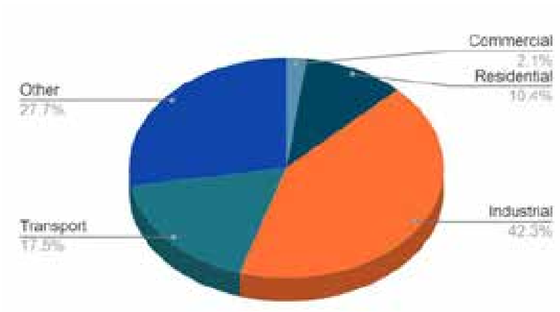

Figure 6: Contribution in the energy consumption (2021)

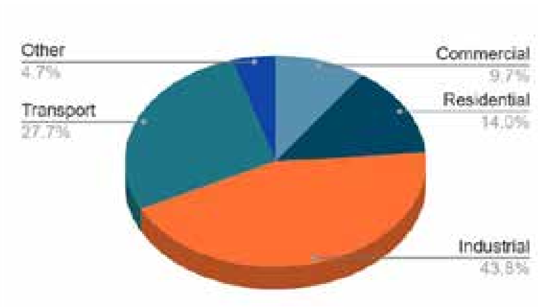

Figure 7: Contribution in the GHG emissions (2019)

The commercial, residential and industrial end use sectors contribute to about 55% in the energy consumption and 67.5% in GHG emissions. The "Other" category includes agriculture and miscellaneous.

Classification of heat pumps

Heat pumps can be categorised based on various factors, offering a diverse range of solutions for different applications. When classified by heat source/sink, we have air-source, ground-source, water-source and hybrid heat pumps. Compressor types include reciprocating, rotary, scroll, and screw compressors, each with unique characteristics. Capacity control methods encompass single stage and multi-stage technologies. The classification based on operating principle includes mechanical vapour compression and vapour absorption systems. Supply temperature ranges classify heat pumps into low-temperature (up to 55°C), medium-temperature (55-80°C), and high-temperature (above 80°C) systems. Refrigerant flow categorization includes single-stage, cascade, and multi-stage systems. Lastly, vapour recompression methods include mechanical (MVC) and thermal (TVC) vapour compression. These classifications help in selecting the most appropriate heat pump system for specific requirements, considering factors such as efficiency, capacity, and environmental conditions. The various types of heat pump classifications are summarised pictorially in the figure below:

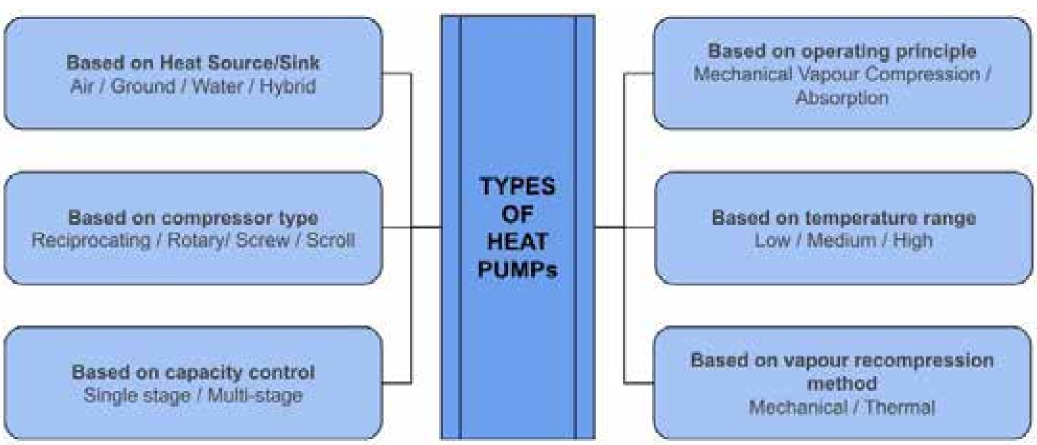

Figure 8: Types of heat pumps

However, the most practical classification is based on heat pump application followed by the end use segments as depicted in the figure below:

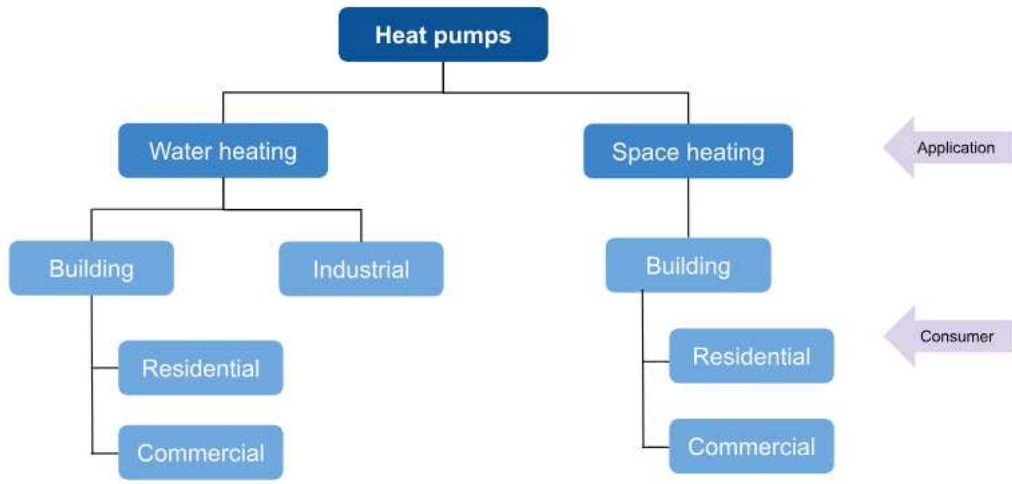

Figure 9: Market classification of heat pumps

The market assessment in this report will attempt to follow the above classification.

Structure of this assessment

This report aims to provide an update on developing a better understanding of the market potential of heat pumps in India. Accordingly, the report has been structured as follows:

- Section 1: Industry trends - This section covers the overview of the heat pump technological aspects (including the options for renewable energy integration)
- Section 2: Market definition and scope - This section reviews and prioritises the sectors/applications relevant for the heat pump technology
- Section 3: Overview of Indian market – This section reviews the profile of heat pumps market in terms of key players and the inferences from import data
- Section 4: Market Dynamics - This section presents the analysis of drivers and barriers in the heat pump market
- Section 5: Market size and forecast - This section presents the market size for the technology along with the forecast for 2030
- Section 6: Policy options – This section presents the prevailing policies from the global and the Indian perspectives
- Section 7: Regulatory landscape - This section presents the global perspective of key regulatory aspects with a view to gather learnings for the Indian context
- Section 8: Supply chain mapping - This section presents the key stakeholders in the supply chain along with a list of initiatives for each stakeholder
- Section 9: Gap assessment - The section presents the various gaps to be overcome for the faster development of the heat pumps market in India

CHAPTER 1:
Industry Trends

- Technology maturity
- Water heating application for the building sector
- Water heating application for the industrial sector
- Renewable energy integration

1. Industry Trends

The efficiency parameters for heat pumps play a significant role in the development of a market for heat pump technology. The key parameters for air source and water source heat pumps are as follows:

Table 2: Efficiency parameters for heat pumps

Air Source Heat Pumps

1. Coefficient of Performance (COP):
    - Measures instantaneous heating efficiency
    - Ratio of heat output to energy input
    - Typically ranges from 2.5 to 4 for modern air source heat pumps in Indian conditions[11]
2. Indian Seasonal Energy Efficiency Ratio (ISEER):
    - Measures cooling efficiency over an entire season
    - Adapted from SEER but tailored to Indian climate conditions
    - Used in the Bureau of Energy Efficiency (BEE) Star Rating system
3. Heating Capacity:
    - Measures the heat output at specific conditions
    - Typically measured in kilowatts (kW) or British Thermal Units (BTU)
    - Critical for proper sizing in Indian climate zones

Water Source Heat Pumps

1. Coefficient of Performance (COP):
    - Measures heating efficiency
    - Generally higher and more stable for water source heat pumps due to consistent water temperatures
    - Typically ranges from 3.5 to 5.5 for modern water source heat pumps[12]
2. Energy Efficiency Ratio (EER):
    - Measures cooling efficiency at full load
    - Ratio of cooling output to electrical energy input
    - Typically higher for water source heat pumps compared to air source
3. Integrated Part Load Value (IPLV):
    - Measures efficiency over a range of operating conditions
    - Particularly important for commercial applications
    - Provides a more realistic measure of seasonal energy efficiency

The technology maturity, renewable energy integration and technological developments for target sectors are discussed in this section.

1.1 Technology maturity

Given the diversity of applications, the market for heat pumps needs to be reviewed for each application separately. Moreover, since heat pumps are a capital-intensive technology as

[11] https://beeindia.gov.in/sites/default/files/ctools/Space%20Cooling%20Roadmap%20for%20India.pdf
[12] https://www.ashrae.org/technical-resources/bookstore/heat-pump-systems

compared to conventional heating technologies, there is a need to carefully design heat pumps for higher operational savings. While the operational savings are dependent on many parameters, the heat supply temperature plays an important role. The technology maturity for various levels of supply temperatures are presented in the table below:

Table 3: Technology readiness based on heat pump supply temperatures[13]

Temperature range	Technology readiness level (TRL)
<80°C	TRL 11 : Proof of market stability
80°C to 100°C	TRL 10 : Commercial and competitive, but large scale deployment not yet achieved
100°C to 140°C	TRL 8 to 9 : First of a kind commercial applications in relevant environment
140°C to 160°C	TRL 6 to 7 : Pre-commercial demonstration
160°C to 200°C	TRL 8 to 9 : First of a kind commercial applications for small scale MVR systems and heat transfers TRL 4 to 5 : Early to large prototype

The heat pumps with supply temperatures of <80°C have been confirmed to have attained market stability. However, the heat pumps with supply temperatures of 80-100°C and 100-140°C have a very selected presence in the market at commercial scale. A closer review of the commercially available heat pumps has been done to understand the most popular classification of the technology.

Textbox 2: Research developments in Heat pump technology

Heat pumps were reported to have been implemented in the late 1990s in India. In 2008, the Infosys campus installed heat pumps to reduce their power demand by about 4 MW[14]. In India, some of the innovations focused on the following aspects:

- In response to environmental concerns and regulatory pressures, heat pump manufacturers are increasingly shifting towards more eco-friendly refrigerants. R32, a refrigerant with a relatively low Global Warming Potential (GWP), is gaining significant traction in the market. Additionally, other refrigerants with similarly low GWP values are being adopted by suppliers
- Introduction of the Enhanced Vapour Injection (EVI) technology to cater to the air source heat pumps to operate in very cold climates
- Danfoss and Indian Institute of Science (IISc) signed an MOU[15] in 2021 to develop a research and training centre focused on promoting the use of CO_2-based refrigerants. They have come up with prototypes for the utilisation of ambient water as heat source in heat pumps and deliver temperatures 85°C

Globally, the trend of innovations in the field of heat pumps resulted in the following developments[16]:

[13] The Future of Heat Pumps, IEA, 2022 (Link)
[14] National Mission on Sustainable Habitat 2021-2030, Ministry of Housing and Urban Affairs (Link)
[15] Danfoss takes CO_2 refrigeration to India (Link)
[16] Cold Climate Heat Pumps Improving low ambient temperature performance of air-source heat pumps (Link)

- Supply temperature increase: 55°C → 160°C+
- COP improvement: 2-3 → 5-7
- Refrigerant evolution: CFCs → HFCs → Low-GWP/Natural refrigerants
- Application expansion: Residential → Commercial → Industrial → District Energy
- Renewable integration: Solar thermal → PV → Smart grids → Multi-source systems
- Cost reduction: 1000-1500 €/kW → 400-800 €/kW (residential systems)

1.2 Water heating application for the building sector

The building sector heat pumps are predominantly air source heat pumps. Rotary vane compressors are the most prevalent type of compressors[17]. The graph below illustrates the Seasonal Energy Efficiency Ratio (SEER) of multiple air source heat pumps. These heat pumps were monitored for a full year in a country with a cold climate. The SEER values are shown in relation to the varying ambient weather conditions experienced throughout the year. This visualization helps demonstrate how the efficiencies of these heat pumps fluctuate with changes in the surrounding environment.

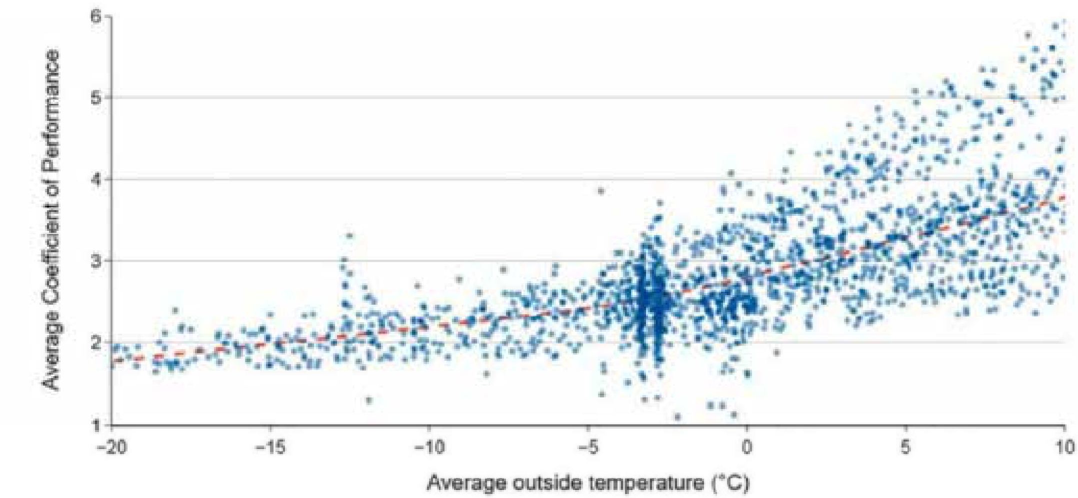

Figure 10: Average COP values for residential heat pumps[18]

The study revealed an annual average Coefficient of Performance (COP) of 2.8 for the heat pumps in the cold climate. It is important to note that India's climate conditions are generally more favourable for heat pump operation, potentially resulting in higher COP values. Moreover, technology providers in India claim that their heat pump systems can achieve up to 70% energy savings compared to traditional hot water systems. This suggests that the performance and efficiency of heat pumps in weather conditions prevalent in India could be significantly better than those observed in colder climates.

[17] A review of recent progress in the design and integration of domestic heat pumps, Next Energy Journal (Link)
[18] Coming in from the cold: heat pump efficiency at low temperatures, Joule Journal (Link)

1.3 Water heating application for the industrial sector

Currently, there are no standardized, commercially available heat pump systems specifically designed for industrial waste heat recovery. Instead, these solutions are typically custom-built and engineered to address the specific needs of each individual application. This tailored approach is necessary due to the diverse nature of industrial processes and the dynamic profile of waste heat characteristics.

Furthermore, integration of absorption and adsorption heat pumps into industrial processes require specific thermodynamic conditions to operate efficiently. Specifically, they need pinch temperatures (the smallest temperature difference in heat exchanger design) above 80°C as a driving force. This temperature requirement is crucial for achieving a thermodynamically reasonable and effective integration of heat pump technologies in industrial settings.[19] Given these considerations, mechanical vapour compression heat pumps emerge as the most appropriate heat pump technology for industrial waste heat recovery applications. The selection of specific components for these systems, particularly the refrigerant and compressor, is largely determined by the required supply temperature of the heat pump.

The figure below illustrates this relationship, showing how different refrigerants and compressor types are suited to various temperature ranges. This visual guide helps in understanding which combinations are most effective for achieving specific supply temperatures, ensuring optimal performance and efficiency in the industrial heat recovery scenarios.

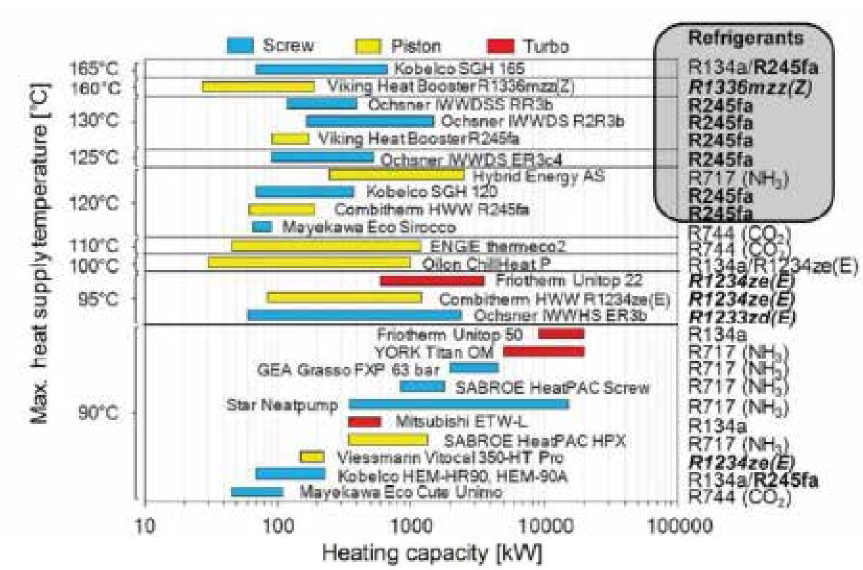

Figure 11: Refrigerants and compressors to meet industrial heat supply temperature[20]

The efficiency and cost-effectiveness of heat pumps are directly influenced by the temperature lift, which is the difference between the source and supply temperatures. This relationship can

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[19] Large-scale heat pumps: Applications, performance, economic feasibility and industrial integration, Renewable and Sustainable Energy Reviews Journal (Link)

[20] Arpagaus C, Kuster R, Prinzing M, Bless F, Uhlmann M, Büchel E, et al. High temperature heat pump using HFO and HCFO refrigerants - system design and experimental results. IIR International Congress of Refrigeration 2019

be observed in two key performance indicators: the Coefficient of Performance (COP) and the specific investment value.

Distinct empirical relationships can be established for heat pumps operating in different temperature ranges. Specifically, one set of relationships applies to heat pumps with supply temperatures below 100°C, while another set is applicable for those with supply temperatures above 100°C. These empirical relations help in predicting and optimizing heat pump performance across various temperature ranges, aiding in the design and selection of appropriate systems for a given application. As the market adoption of heat pumps continues to grow, particularly in industrial applications, it is expected that more comprehensive and refined empirical relationships will be established. This increased adoption will provide a larger dataset of real-world performance metrics across various operating conditions and applications. These expanded datasets will enable researchers and engineers to develop more accurate and nuanced empirical relations, further improving the ability to predict and optimize heat pump performance in diverse scenarios.

1.4 Renewable energy integration

Renewable energy integrated heat pumps offer a compelling opportunity for India to significantly reduce its carbon footprint and enhance energy efficiency, particularly in the industrial sector. While the initial investment for solar-assisted and geothermal heat pump systems (₹20-30 lakhs for a 25-kW solar-assisted system and ₹6-8 crores for a 1 MW solar thermal heat pump system) represents a current challenge, the potential for long-term cost savings and environmental benefits is substantial. These systems can deliver energy savings of 20-40%, and the integration of solar thermal energy has demonstrated a promising increase in COP from 2.33 for a standard air source heat pump to 2.95[21]. However, payback periods of 5-7 years can be a barrier, in particular, for small and medium enterprises (SMEs) which contribute significantly to India's industrial output. Several promising pathways exist to accelerate adoption.

These pathways include exploring government incentives and innovative financing models like leasing or Power Purchase Agreements (PPAs) to offset the requirement of upfront investments. Highlighting the long-term value proposition through life-cycle cost analysis can further showcase the economic advantages. Key barriers for solar integrated heat pumps include technical constraints like intermittency of solar energy, space requirements, system complexity; economic constraints like high initial cost, long payback period; awareness barriers. Strategic targeting of industries with high energy demands, such as dairy and textiles, can optimize the impact of these systems. Continued support for research and development, coupled with standardization and modular design, hold the key to reducing manufacturing and installation costs. Investing in skill development and training programs will ensure proper implementation and maximize system efficiency. Raising public awareness about the advantages of these technologies can stimulate market demand and drive wider adoption. By proactively addressing these opportunities, India can unlock the transformative potential of renewable energy integrated heat pumps and pave the way for a sustainable and energy-efficient future.

[21] Exergetic performance evaluation of heat pump systems having various heat sources

CHAPTER 2:

Market Definition & Scope

- Market analysis for heat pump application
- Selected heat pump applications

2. Market Definition and Scope

Heat pump technology is being considered as a strategic technology for improving the energy efficiency and decarbonisation across the world.

2.1 Market analysis for heat pump application

The heat demand is traditionally classified under 3 categories based on the temperature[22] as follows:

- < 150°C
- > 150°C and < 400°C
- > 400°C

Thermal applications that typically fall under the above temperature categories are depicted in the figure below:

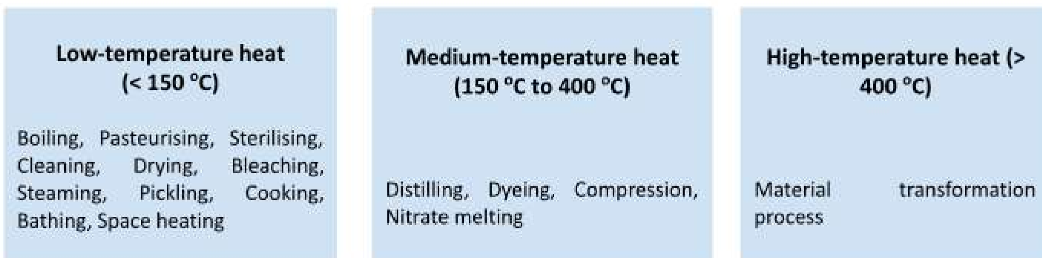

Figure 12: Classification of heat demand

As outlined in the preceding section, heat pumps are capable of meeting low-temperature heat (<150°C). Applications for residential and commercial segments include the following:

Table 4: Temperature profile for hot water application in building sector

Sector	Application	Temperature range (°C)
Residential	Bathing	35 - 45
	Space heating/cooling	25 - 30
Commercial	Bathing	35 - 45
	Laundry	60 -65
	Kitchen	60 - 70
	Hotel/Hospital - Space heating/ cooling	25 - 30
	Hotel - Swimming pool	30 - 35

Applications in the industrial segment are more complex due to the diverse nature of manufacturing processes. As an illustration, the figure below indicates the heat demand at different temperatures in key industrial sectors.

[22] IEA-SHC-Technology-Position-Paper--Solar-Heat-Integrations-Industrial-Processes--May 2020.pdf

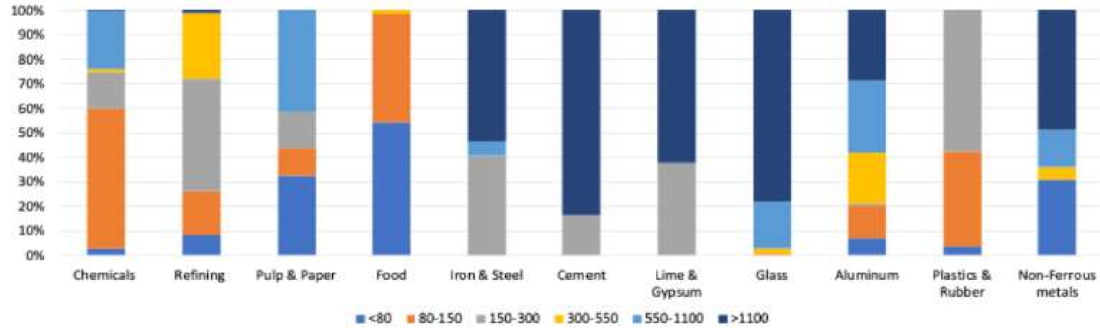

Figure 13: Industrial heat demand by temperature in selected industries[23]

Based on a detailed analysis of process flow, the following industrial sectors with heat demand less than 150°C have been identified - Chemical, Refining, Pulp & Paper, Food, Metal (Aluminium), Plastic & rubber.

International case studies for heat pump use cases were reviewed to validate the above shortlisted categories. A summary of the key takeaways is presented in the table below:

Table 5: Review of international case studies for industrial heat pump

Sector	Type of heat pump	Heat Pump supply temperature (°C)	Temperature lift (°C)	Heat pump capacity (kW_{th})	Energy savings (%)
Chemical	Water source - MHP & MVR	60 -115	32-70	5-23,000	50%
Food & Beverage	Air and Water - MHP	25 -120	5-78	6 -3,250	60%
Metal & Auto Component	Water source - MHP & MVR	35-130	15 -78	30 -10,000	50%
Paper	Water source - MHP	75	45	320	45%
Textile	Water source - MVR	65 -80	30- 40	98 -195	65%
Commercial	Air, Water and Ground - MHP	35-90	11-80	60 - 15,000	41%
Residential	Air, Water and Ground - MHP	35-90	11-80	60 - 15,000	41%

The case studies reviewed covered applications in Chemical, Food & Beverages, Automobiles, Metal, Machinery and Textiles industries. The shortlisting of sectors is in line with the report “IEA’s Annex 58 Task 1 Technologies report”.

2.2 Selected heat pump applications

The suitability of heat pumps can be analysed by reviewing the availability of sufficient heat

[23] Manufacturing Thermal Energy Use in 2014, *National Renewable Energy Laboratory (NREL)*, 2014, (Link)

source and heat sink. A few specific applications were analysed as presented in the below table:

Table 6: Review of heat pump applications

Sector	Product	Size of factory (Plant capacity)	Application	Heat pump capacity	Remarks
Metal	Auto-parts	Small (1.8 million pieces/y)	Phosphating section. Supply temperature 80°C. Present system: Diesel based hot water generator	Water source: CT cooling water at 27.3 °C Heat pump of 58 kW_{th}	Approximate payback period of 1.0 year; GHG emission reduction – 18%
Metal	Hand Tools	Small	Electroplating section. Supply temperature 50ºC. Present system: Furnace oil fired hot water generator	Air source heat pump	Approximate payback period of 3 years
Metal	Auto- Casting	Medium (71,462 t/y or 4.8 million piece/year)	Auto parts Washing. Supply temperature 80°C. Present system: Electric heater	Water source: CT cooling water at 31°C Heat pump of 295 kW_{th}	Approximate payback period of 1.5 years; GHG emission reduction – 1.5%
Food & Beverages	Food	Small	Cooking pasta, blanching vegetables, or rehydrating dehydrated ingredients, cleaning kitchen tools. Supply temperature 80°C. Present system: HSD based hot water generator	Water source: Feed water at 30°C Heat pump of 120 kW_{th}	Approximate payback period of 1.1 years; GHG emission reduction – 6%
Chemical	Rubber manufacturing	Small (83,000 pieces/months)	Steam for curing at a pressure of 5 kg/cm2 and 165°C. Present system: HSD Fired Boiler	Heat source was not found sufficient	-
Food & Beverages	Tea	Small (CTC: 420,702 kg/y, Orthodox: 85,089 kg/y)	Hot air for withering (25°C) and Drying at 90°C. Present system: LPG fired hot air generator	Air source: Ambient air 20°C Heat pump of 60 kW_{th}	Approximate payback period of 4.0 years; GHG emission reduction – 18.2%
Textiles	Dyers and processors	Small (2,324 t /y)	Hot water for dyeing and washing process at 80°C. Present system: Rice husk based hot water generator	Water source: Feed water at 55°C Heat pump of 97.7 kW_{th}	Payback period was long
Dairy	Milk & Milk Product	Medium	Hot water for preheating , Filtration	Water source: CT return water	Approximate payback period

Sector	Product	Size of factory (Plant capacity)	Application	Heat pump capacity	Remarks
			(40-50 °C) and pasteurisation for 15 sec process at 76°C+/- 2°C. Present system: HSD based steam boiler and hot battery	at 40°C Heat pump of 1,160 kW_{th}	of 1.1 years
Commercial building	Hotels	3 star (30 rooms, Only tap arrangement)	Water heating for sanitary purposes. Present system: Each washroom with 1 geyser of 15 litre capacity (2.5 kW rating)	Air source: 12 kW_{th}	Approximate payback period of 2-3 years
Commercial building	Hotels	7 star (60 rooms, luxury washrooms)	Water heating for sanitary purposes. Present system: Centralised gas fired hot water system of 5,000 litre capacity	Air source: 80 kW_{th}	Approximate payback period of 1.5 years
Commercial building	Hostels	Students - 1,100 count, over 300 washrooms	Water heating for sanitary purposes. Present system: Each washroom with 1 geyser of 15 litre capacity (2.5 kW rating)	Air source: 20 kW_{th} x 15 numbers	Approximate payback period of 2 -2.5 years
Commercial buildings	Hospitals	20 beds, 22 washrooms	Water heating for sanitary use Present system: Each washroom with 1 geyser of 15 litre capacity (2.5 kW rating)	Air source: 6 kW_{th}	Approximate payback period of 2 -2.5 years
Residential	Independent house/Villa /Apartments	5 to 6 washrooms with luxury fittings, 5 habitants	Water heating for sanitary use. Present system: Each washroom with 1 geyser of 15 litre capacity (2.5 kW rating)	Air source: 4 kW_{th}, (300 litres storage capacity)	Approximate payback period of 2 -2.5 years

CHAPTER 3:
Overview of Indian Market

- Key players
- Review of import data

3. Overview of Indian Market

3.1 Key players

The market for heat pump suppliers in India consists of a diverse array of companies originating from various countries. A few key heat pump market players are presented in the following table:

Table 7: Key heat pump market players

Country of origin	Names of a few companies
Denmark	Danfoss Industries Pvt. Ltd.
Germany	Bosch Limited ; Certoplast India Pvt. Ltd.
India	Aiwasun Green Technologies ; Aqvastar Smart Flow Solutions ; Benchmark Agencies Pvt. Ltd. ; Inter Solar Systems Pvt. Ltd. ; Sakar India Pvt. Ltd. ; Suntec Energy Systems ; Thermax Ltd., V Guard Industries Ltd. ; Waaree Energies Ltd.
Italy	Ariston Group India Pvt. Ltd. ; Climaveneta Climate Technologies Pvt. Ltd. ; Swegon Bluebox Pvt. Ltd. ;
Japan	Daikin Airconditioning India Pvt. Ltd. ; Mitsubishi Electric India Pvt. Ltd.
United States	A O Smith India ; Armstrong International Pvt. Ltd. ; Johnson Controls Hitachi AC Ltd. ; Pentair Water Treatment Pvt. Ltd. ; Trane Technologies India Pvt. Ltd.

Consultations were carried out with a few technology suppliers including the leading importers in India. The key takeaways from the consultations are as follows:

- **Start of heat pump business**: Earliest business in this sector started in 2008. However, the sales for heat pumps picked up only after 2021. The possible reasons for this sudden rise in the residential/commercial segment is the rise in built space post COVID and the rapid rise in the fuel prices for the industrial sector
- **Sectoral focus**: Water heating market for the buildings and industrial sector (dominantly for the building sector). Space heating market is very limited
  - Focus on residential markets: Residential: 90%, Commercial: 10%
  - Focus on commercial markets: Residential: 40%, Commercial: 60%
  - Focus on industrial markets: Residential:0%, Commercial: 10%, Industrial:90%
- **Business model**: Most of the building sector water heating suppliers are operating with the import and sale. There are a few suppliers who are operating with the import, assemble and sale.
- **Type of facilities**: Building sector (Greenfield - 90% and Retrofit - 10%); Industrial sector-Dominantly retrofit.

To supplement the stakeholder consultations, which are largely subjective, information from several secondary sources were reviewed and the findings are described below.

3.2 Review of import data

India's increasing demand for heat pumps, particularly in the residential and commercial sectors, is largely met through imports. There is a high reliance on foreign suppliers and heat pumps are sourced from nations with well-developed manufacturing capabilities and cutting-edge technologies in this industry. The approach for import is two-fold: import of fully assembled heat pump units; import of compressors for local assembly. This approach allows for some flexibility in meeting market demands while potentially supporting some level of domestic manufacturing.

To gain insights into the current market trends and patterns, India's import data[24] over the past two-year period was reviewed. This review indicates critical market dynamics, which are detailed in the following sub-sections. These findings provide valuable information about the nature of India's heat pump market, its dependencies, and potential areas for growth or change in the industry.

3.2.1 Market analysis - HSN Codes

Harmonized System Nomenclature (HSN) is an internationally standardized system of names and numbers for classifying traded products. The HSN codes that are dominant in the import of heat pumps in India are presented in the figures below:

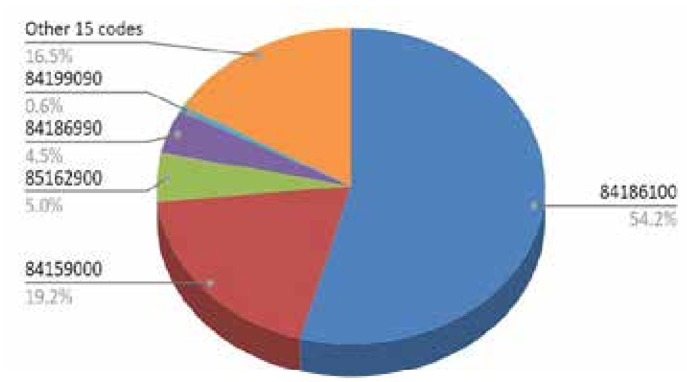

Figure 14: Share of HSN codes by heat pump value

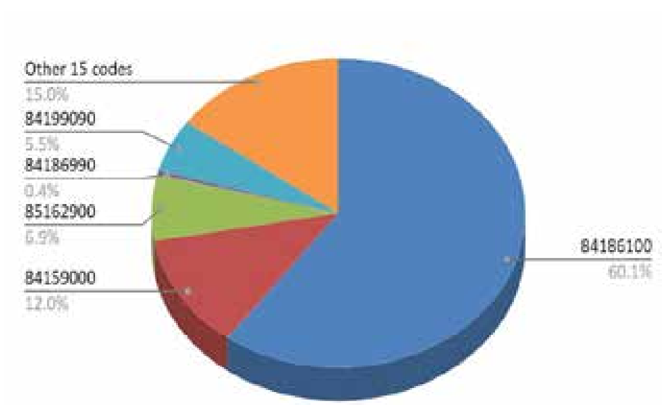

Figure 15: Share of HSN codes by heat pump numbers

The following five (5) HSN codes cumulatively account for over 80% in terms of value and count. The relevant HSN codes and the description of commodity imported are as follows:

[24] Commercial market research database developed by Eximpedia, 2024

Table 8: Heat pump import - Key HSN codes (Ministry of Commerce)

HSN Code	Description of commodity
84186100	Heat pumps other than air conditioning machines of heading 8415
84159000	Parts of air conditioning machines, including heat pumps
85162900	Other electric space heating apparatus and electric soil heating apparatus
84199090	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof - Other parts
84186990	Other refrigerating or freezing equipment, which can include certain types of heat pumps

3.2.2 Market analysis - Country of origin

The heat pumps imported in India are being shipped from various countries as presented in the figures below. The data is for the period Dec-22 to Nov-24.

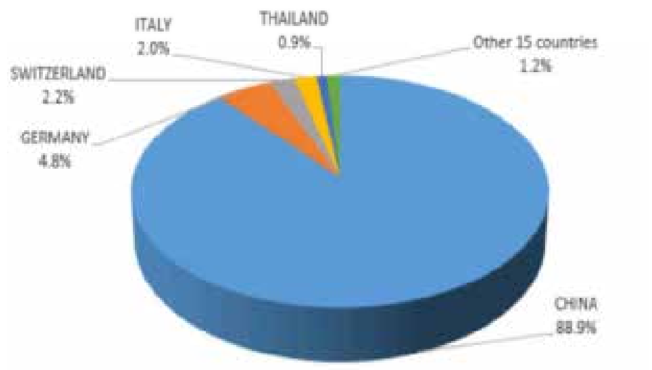

Figure 16: Share of country of origin by heat pump value

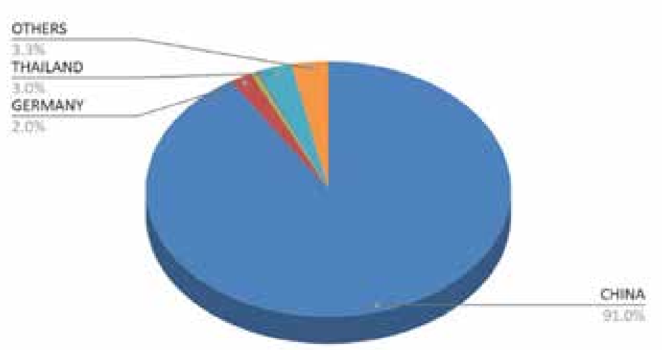

Figure 17: Share of country of origin by heat pump numbers

The import of heat pumps is dominantly from China, both in terms of value (89%) and in terms of quantity (91%).

The importers' countries of origin (companies that have offices in India, but headquartered in other countries) that are dominant in the import of heat pumps in India are shown in the figures below:

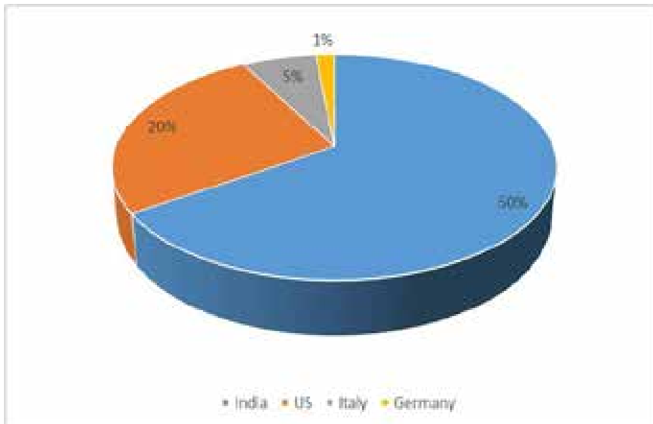

Figure 18: Share of importer's country of origin by heat pump value

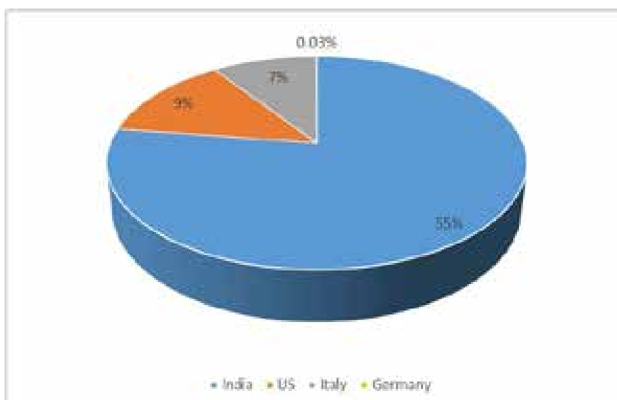

Figure 19: Share of importer's country of origin by heat pump numbers

The importer's country of origin for the import of heat pumps is dominantly India, both in terms of value (50%) and in terms of quantity (55%).

3.2.3 Market analysis - Application

Analysis from the perspective of application in terms of quantity and cumulative heating capacity imported is presented in the figures below:

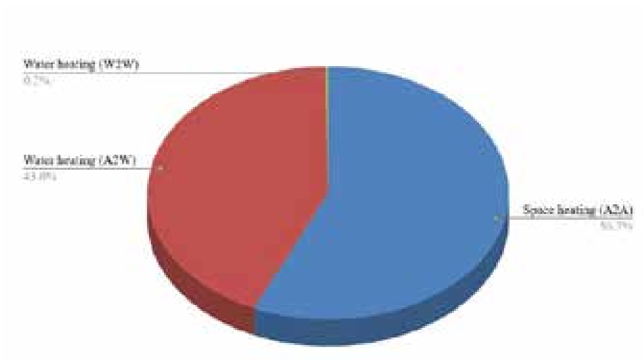

Figure 20: Market share of heat pumps by application - Number of heat pumps

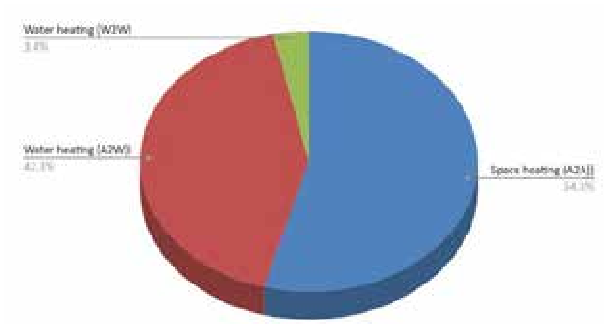

Figure 21: Market share of heat pumps by application - Cumulative heating capacity

When analysing applications in terms of both unit numbers and cumulative heating capacity, space heating emerges as the dominant market segment, followed by water heating. Within the water heating segment, air-to-water (A2W) systems has a larger share as compared to water-to-water (W2W) heating systems.

3.2.4 Market analysis - End use sectors

Analysis from the perspective of end use sectors in terms of number of quantity and cumulative heating capacity imported are presented in the figures below:

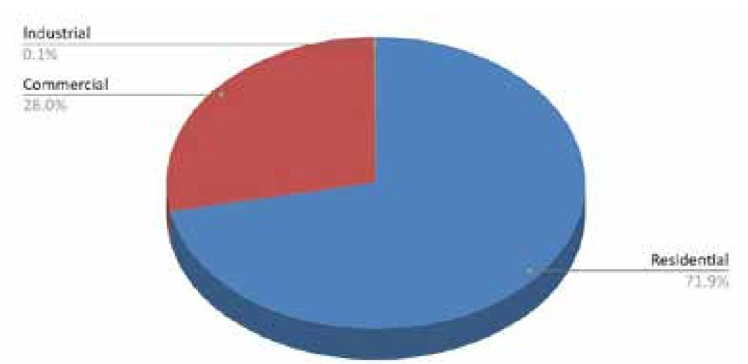

Figure 22: Market share of heat pumps by end use sectors - Number of heat pumps

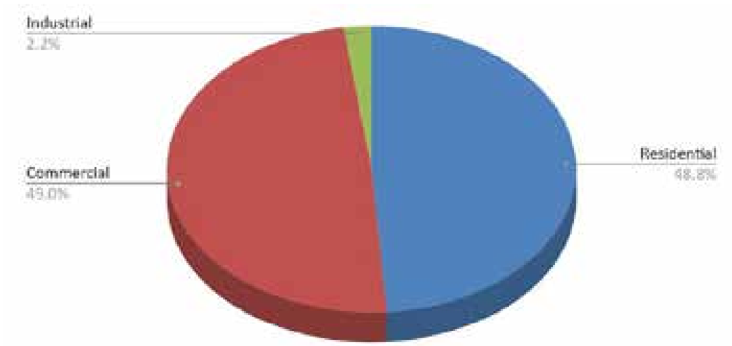

Figure 23: Market share of heat pumps by end use sectors - Cumulative heating capacity

Regarding the end-use sectors, the market share distribution varies depending on the metric used. When considering the number of units, the residential sector leads the market. However, when evaluating heating capacity, the commercial sector takes the top position. The industrial end-use sector, in comparison, has a significantly smaller presence in both aspects of the market due to various reasons. These include the limited maturity of high supply temperature heat pumps, which are often necessary for industrial processes, and the relatively economical use of primary fuel in the base case, which poses challenges to the financial attractiveness of heat pump adoption. Furthermore, the inherent complexity of industrial processes may not always align well with current heat pump capabilities. Additionally, there are specific challenges associated with water-to-water heat pumps, which require a simultaneous and steady source of water as a heat source—a condition not always easily met in industrial settings. These factors collectively contribute to the slower adoption of heat pump technology in industrial applications, resulting in a smaller market share both in terms of the number of units and the cumulative heating capacity.

3.2.5 Market analysis - Past trend

The past trends for heat pump imports in India in terms of heating capacity (MW) was reviewed for the selected HSN codes over a period of 16 years (FY 2008-09 to FY 2023-24) and presented in the figure below:

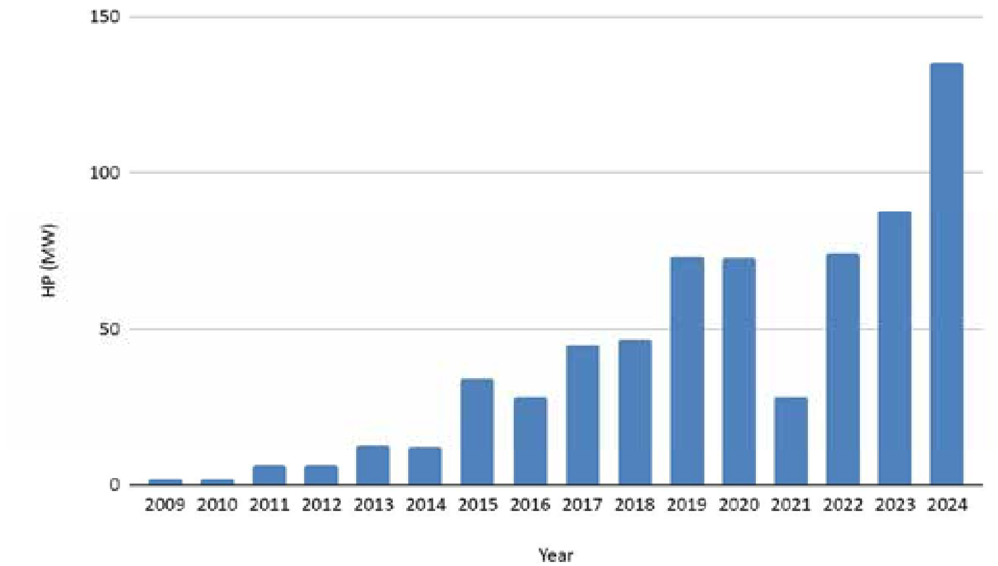

Figure 24: Estimated growth in heat pump installed capacity in India

The demand has an increasing trend at a near steady pace. Further estimates of the market adoption based on end use sectors is presented in the figure below:

RESIDENTIAL	COMMERCIAL	INDUSTRIAL
46,000 units	18,000 units	150 units
320 MW Installed capacity	320 MW Installed capacity	25 MW Installed capacity

Figure 25: Estimated market adoption for heat pumps - By end use sector

The total installed base of heat pumps is estimated to have reached approximately 64,150 units. In terms of overall heating capacity, these installations collectively represent about 665 megawatts (MW) of cumulative heating capacity.

CHAPTER 4:
Market Dynamics

- Market drivers for heat pumps
- Market barriers for heat pumps
- Drivers for industrial applications

4. Market Dynamics

An extensive review of published research, industry reports, and expert analyses were conducted to identify and assess the primary factors driving and hindering the adoption of heat pumps in the market.

4.1 Market Drivers for Heat Pumps

The key factors that drive the global heat pump market is described below:

1. Energy efficiency and decarbonisation objectives: Demand for energy efficient heating systems is increasing due to the need to comply with decarbonisation goals. Heat pumps deliver more heat than electricity.
2. Environmental concerns: Increasing awareness of climate change and the need to reduce carbon emissions. Awareness of environmental concerns has influenced the use of heat pump systems for heating systems. The designated consumers (DCs) under the Perform Achieve and Trade (PAT) scheme may have a motivation to invest in the heat pump technology in spite of the high upfront cost barrier and possible long payback period.
3. Government policies: Incentives, regulations, and building codes promoting energy-efficient technologies.
4. Rising energy costs: Motivating consumers to seek more efficient heating and cooling solutions.
5. Integration with renewable energy: Compatibility with solar PV systems and smart grids. The rising demand for solar energy is rapidly increasing the adoption of heat pumps for excess energy. These heat pumps help store energy and convert it into electricity, expanding the market.
6. Urbanisation and construction boom: New buildings incorporating more efficient technologies. Increase in population and urbanisation are influencing the demand within a minimum of 20 years.
7. Standardisation: Higher level of standardisation can drive increase in installations.

4.2 Market Barriers for Heat Pumps

The key factors that impede investments in heat pump include:

1. Competitive price of primary fuel used in the baseline scenario as compared to the price of electricity has a major impact on the project viability as shown in the figure below:

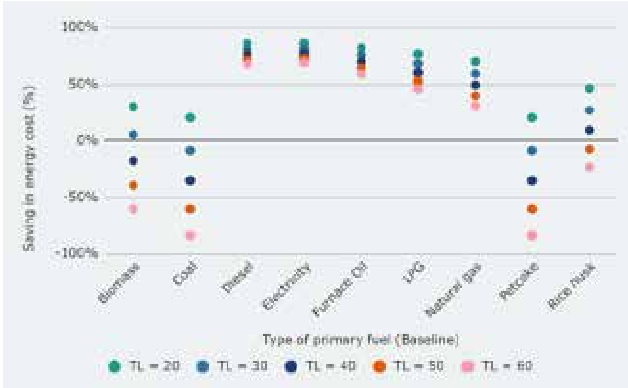

Figure 26: Estimated energy cost saving with heat pumps

The figure illustrates that energy cost saving is a function of temperature lift (TL), price of primary fuel (baseline) and price of electricity (which will be incurred when a heat pump is installed) (which will be incurred when a heat pump is installed). It is evident that heat pumps are viable for a minor temperature lift for biomass, coal, pet coke and rice husk, whereas diesel, electricity, furnace oil, LPG and natural gas are suitable for heat pump applications. The combination of primary fuel type and temperature lift are, therefore, very critical for the financial viability of heat pumps

2. High initial costs: Heat pumps often have higher upfront costs compared to traditional technological solutions
3. Lack of awareness: Many consumers are unfamiliar with heat pump technology and its benefits
4. Installation complexity: Careful design of heat pumps, especially for the industrial heat pumps, the ground source heat pumps and solar assisted heat pumps are necessary for getting benefited from the high capital cost of the technology
5. Economy of scale required for reducing manufacturing cost: The industrial heat pumps are a customised solution, where the technology supplier has to review process reliability to develop a process-specific design, which needs high efforts. Aggregation of demand of similar nature is necessary to motivate the heat pump technology suppliers to provide solution for the industrial customers
6. Existing infrastructure: Difficulty in replacing established heating systems, particularly in older buildings
7. Skilled labour shortage: Lack of technicians trained in heat pump installation and maintenance
8. Refrigerant regulations: Ongoing changes in refrigerant policies can affect heat pump design and costs
9. Limited space: Some properties may not have sufficient space for certain types of heat pump systems
10. Competition from other technologies: Other emerging heating and cooling technologies may compete for market share
11. Cultural preferences: In some regions, traditional heating methods are deeply ingrained in the local culture

4.3 Drivers for Industrial Applications

A study by McKinsey[25] provides the following insights for the development of heat pumps in the industrial market

Textbox 3: Key considerations for developing industrial heat pumps

- There is no one-size-fits-all solution for the industrial heating solutions. Less demanding applications can utilise standard, cost-effective, and modular heat pump systems. However, industries with intense heat needs, such as the chemical sector, may require significant research and development to create suitable heat pump solutions. This disparity in applicability highlights the need for continued innovation in heat pump technology to meet diverse industrial heating demands.
- When developing new industrial heat pump solutions, it is crucial to prioritise advanced control software as a key component, as it plays a vital role in optimising system performance and efficiency.
- Selecting the ideal refrigerant for a heat pump requires collaboration between manufacturers and end users. The choice depends on various factors, including the target temperature, regulatory compliance, and safety requirements specific to each project.
- Despite their name, heat pumps offer both heating and cooling capabilities in a single unit. This dual functionality often results in more cost-effective and efficient applications, making them an attractive option for various settings.
- As the industrial heat pump market expands, manufacturers need to diversify their product range. This growth phase requires collaboration across the industry, combining expertise to create tailored solutions for various applications.

[25] Industrial heat pumps: Five considerations for future growth

CHAPTER 5:
Market Size and Forecast

- Market size - Commercial sector
- Market size - Residential sector
- Market size - Industrial sector
- Market size - All sectors
- Market adoption

5. Market Size and Forecast

The market size for the following identified heat pump target applications is presented in this section:

- Space heating and water heating for the commercial sector
- Space heating and water heating for the residential sector
- Water heating for the industrial sector

5.1 Market size - Commercial sector

5.1.1 Context

The commercial building sector in India accounts for approximately 2% of the country's total energy consumption[26]. The demand for energy in a commercial building is fulfilled through various sources as depicted in the figure below:

Figure 27: Energy consumption in commercial sector

Electricity is the dominant energy source, accounting for 78.5% of energy consumption, which underscores its critical role in powering lighting, equipment, and HVAC systems in commercial settings. LPG remains a significant source, accounting for 21.5% of the energy consumed[27]. Electricity is the dominant primary fuel for the space heating and water heating segments in the commercial sector and supports the financial viability of heat pumps.

5.1.2 Energy profile

The type of commercial building will determine its design, construction, and operational characteristics. While there are many approaches for categorising commercial buildings, the following classification by Bureau of Energy Efficiency (BEE) in the Energy Conservation Building Codes (ECBC)[28] has been considered.

[26] National Energy Data: Survey and Analysis, *Bureau of Energy Efficiency,* 2021-22, (Link)
[27] National Energy Data: Survey and Analysis, *BEE,* 2023 (Link)
[28] Itkelwar, S. et al.,Commercial Energy Data Management: *Alliance for an Energy Efficient Economy,* September 2020, (Link)

Figure 28: Categorisation of commercial building sector

The following types of buildings have been considered for assessment of the market size for heat pumps:

- Hospitality is limited to hotels as per the statistics by the Ministry of Tourism
- Educational is limited to hostels
- Healthcare limited to hospitals >100 beds
- Shopping complex limited to organised retail

The rationale for eliminating business (offices) and assembly (multiplex, theatre, etc.) was low hot water and space heating requirements.

→ Hospitality sector

Hotels are significant energy consumers, with energy use varying depending on factors such as size, location, occupancy rate, and amenities offered. The typical end use pattern in hotels[29], is indicated in the figure below:

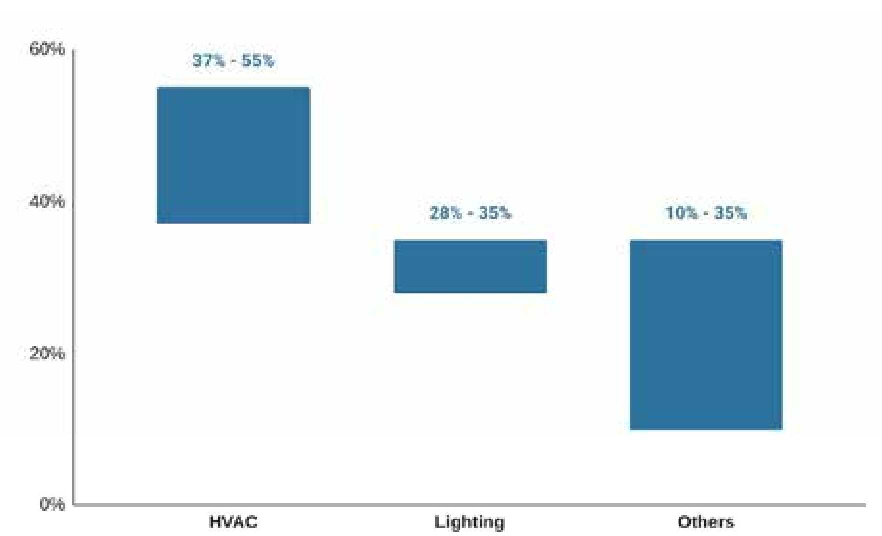

Figure 29: Typical energy end use in hotels

[29] Energy management in your hotel, *Bureau of Energy Efficiency,* December 2008, (Link)

The primary energy end-uses in hotels include HVAC, lighting, water heating, appliances such as refrigerators, televisions, and kitchen equipment, etc.

→ Educational sector (Hostel)

Within educational institutes, hostels are significant thermal energy consumers due to the longer occupancy as compared to academic areas. The number of students, faculty, and staff occupying the buildings directly influence energy consumption. The typical end-use pattern in educational institutions[30] is indicated in the figure below:

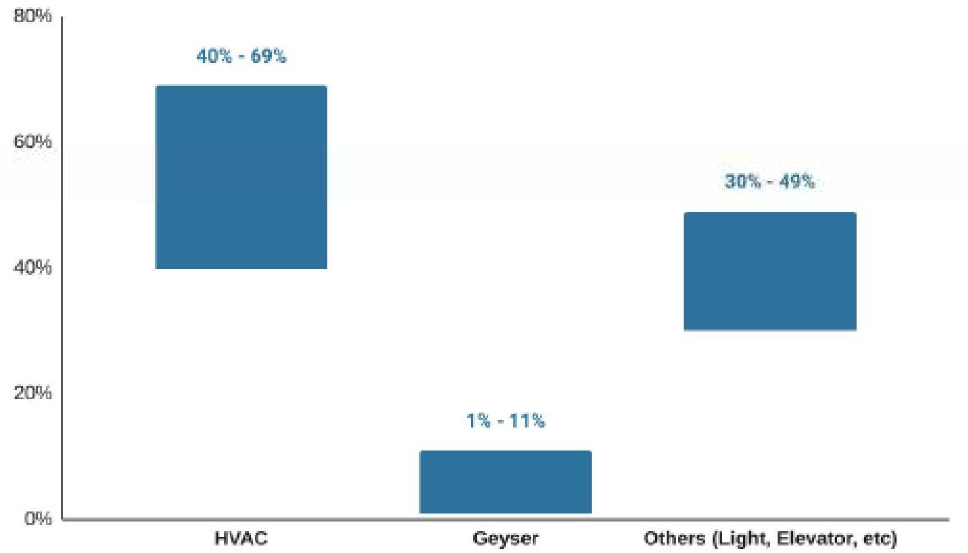

Figure 30: Typical energy end use in hostels

HVAC is the dominant energy end use, accounting for 40% - 69% of the total consumption, followed by others including fans, lighting, elevators, etc. which account for 30% - 49% and electric geysers for water heating, which accounts for 11% of energy use.

→ Healthcare sector

In hospitals, electricity consumption varies significantly across end uses, reflecting the unique operational demands of healthcare facilities.

[30] Abraham, C. et al., Energy audit of IIT Bombay campus, IIT Bombay, May 2008, (Link)

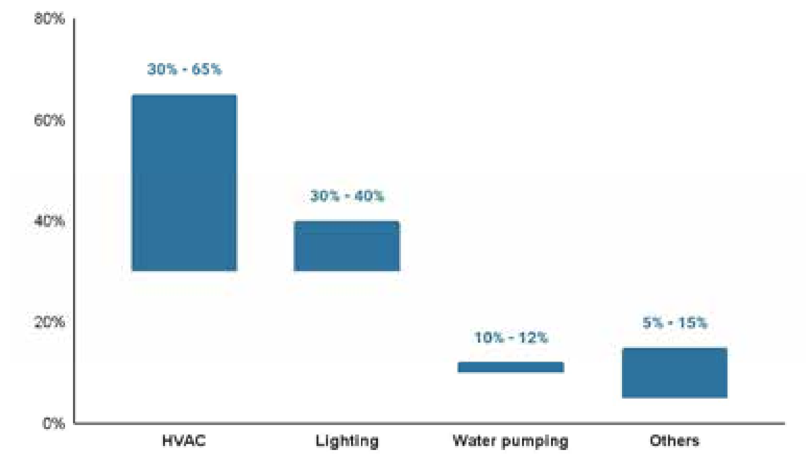

Figure 31: Typical energy end use in hospitals

The largest share of electricity is consumed by HVAC systems, which account for 30-65% of the total electricity usage. This wide range is due to the need for precise temperature and humidity control in various areas of the hospital, such as operating rooms and patient wards. Lighting is the next significant consumer, utilizing 30-40% of the electricity usage. Water pumping, essential for sanitation, heating, and cooling processes, uses about 10-12% of the electricity. The remaining 5-15% is attributed to other miscellaneous uses, which can include medical equipment, administrative operations, and other facility needs. This breakdown highlights the energy-intensive nature of hospital operations and the potential areas for energy efficiency improvements[31].

→ Retail Sector

The distribution of energy consumption by end use in the retail sector is shown in the figure below:

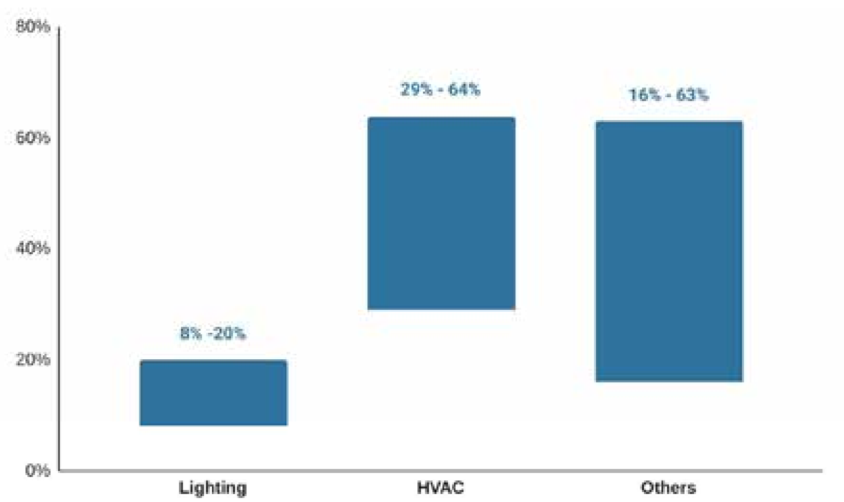

Figure 32: Typical energy end use in a retails

[31] Energy efficiency in hospitals: Best practice guide, Bureau of Energy Efficiency, March 2009, (Link)

According to various reports from the previous studies carried out, HVAC, which is crucial to maintaining indoor temperature, is the largest energy end use in the retail sector, accounting for 29% - 64% of the electricity usage. Lighting also accounts for a significant amount of energy use. Other equipment including ceiling fans, exhaust, computers, geysers, etc. also consume 16% - 63% of the electricity.

5.1.3 Market potential for 2024 - Commercial

The potential has been assessed for space heating and water heating applications in the commercial sector.

→ Heat pumps for space heating - Commercial

The potential of heat pumps for space heating in the commercial sector has been carried out as follows:

Step 1: Identify the target market

The identified target markets for heat pump adoption were determined based on the climatic conditions. The list of states in the Northern part of India with a "Cold climatic zone" and/or "Composite climatic zone" were considered suitable for the space heating market. The states/union territories thus selected were Jammu, Kashmir, Himachal Pradesh, Punjab, Uttarakhand, Haryana, Chandigarh, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Assam, Arunachal Pradesh and Nagaland.

Step 2: Estimate the number of facilities

Within the commercial building sector, the following data were critical to assess the market size:

- Hotels: Number of rooms
- Educational institutions: Number of rooms in hostels
- Health care: Number of beds
- Retail: Built space[32]

Table 9: Number of commercial facilities for space heating

Facilities	No. of facilities	Rooms/beds/Mn ft^2	Remarks
Hotels	424	26,658 (Rooms)	India Tourism Statistics 2023, Ministry of Tourism, GOI, (Link)
Educational institutions	Information not available	15,580 (Rooms)	Sustainable Space Heating Solutions in The Himalayan Region - TERI Report, 2020 (Link)
Healthcare	39,304	714,593 (Beds)	RBI publication, 2023 (Link)
Retail	Information not available	31.3 (million ft^2)	Knight Frank (Link)

[32] NCR region only

Step 3: Baseline Energy Consumption

The baseline energy consumption was estimated based on the number of heaters of 1 kW capacity currently being used for space heating and the corresponding operating hours.

Table 10: Number of space heaters (Normative)

Sector	Number of heaters	Remarks
Hotels	1 per room	Sustainable Space Heating Solutions in The Himalayan Region - TERI Report, 2020 (Link)
Educational institutes	1 per room	
Healthcare	0.5 per bed	
Organised retails	1 per 150 sft	DESL database

The yearly baseline energy usage was calculated by combining two factors: the heater's power requirement and the average yearly operational duration, which is measured in heating degree days (HDD). For cities in North India, the average HDD was determined to be 896 hours per year (computed as per ASHRAE 90.1). This figure was then used to estimate the total annual energy consumption for heating purposes. A diversity factor (0.8) was considered in line with ASHRAE 90.1.

Table 11: Baseline energy consumption - Commercial - space heating

Facilities	Baseline energy consumption (MWh/y)
Hotels	19,108
Educational institutions	11,168
Healthcare	256,110
Retail	149,573

Step 4: Estimate the heat pump market size

The supply temperature for space heating is suitable for air source heat pumps (ASHP). The annual average COP for ASHP was considered at a conservative level of 2.8[33]. The market size for heat pumps was derived using the baseline electrical load of conventional space heaters and the COP.

Table 12: Heat pump market size - Commercial - space heating

Facilities	Heat pump capacity (MW_{th})
Hotels	10
Educational institutions	128
Healthcare	6
Retail	75

[33] Interim Heat Pump Performance Data Analysis Report, Department for Energy Security and Net Zero, 2023 (Link)

Step 5: Estimate Energy Savings

Further, the annual energy consumption is calculated using the operating hours in the baseline. The difference between annual baseline energy consumption and the estimated annual heat pump energy consumption will be the total annual energy saving potential.

Table 13: Estimated energy saving - Commercial - Space heating

Facilities	Energy Savings (toe/y)
Hotels	910
Educational institutions	532
Healthcare	12,193
Retail	7,121

Step 5: Estimate GHG Reduction Potential

The greenhouse gas (GHG) reduction potential was determined using a grid emission factor of 0.82 kgCO_2/kWh

Table 14: Estimated GHG emission reduction - Commercial - Space heating

Facilities	GHG Reduction Potential (Mn tCO_2/y)
Hotels	0.009
Educational institutions	0.005
Healthcare	0.116
Retail	0.068

→ Heat pumps for water heating - Commercial

The potential of heat pumps for water heating in the commercial sector has been carried out as follows:

Step 1: Identify the Target Market

Water heating applications were identified to have demand in hotels, hospitals and hostels. Organised retail was not considered due to very limited demand for hot water.

Step 2: Estimate the number of facilities

The number of facilities and the corresponding rooms/beds/built area across pan India is provided in the table below:

Table 15: Number of commercial facilities - Commercial - Water heating

Facilities	No. of facilities	Number of rooms/ students/beds	Remarks
Hotels	1,716	107,795 (Rooms)	India Tourism Statistics 2023, Ministry of Tourism, GOI, (Link)

Facilities	No. of facilities	Number of rooms/ students/beds	Remarks
Educational institutions	50,477	4,026,221 (Students)	All India Survey on Higher Education, 2022, Ministry of Education, GOI, (Link)
Healthcare (Hospitals >100 beds	901	139,625 (Beds)	RBI publication, 2024 (Link)

Step 3: Calculate Baseline Energy Consumption

For each facility type, based on the occupancy rate, the total hot water demand was calculated. With reference to brochures from the technology suppliers, the specific power consumption to generate hot water was derived. Baseline daily energy consumption was calculated by multiplying the hot water demand per day and specific power consumption. Further, the annual energy consumption was calculated by multiplying the daily energy consumption with the annual number of days.

For the annual operating days, assumptions are made:

- Hotels = 6 months = 180 days
- Hostels = 6 months = 180 days
- Hospitals = 12 months = 365 days

Table 16: Baseline energy consumption - Commercial - Water heating

Facilities	Baseline energy consumption (MWh/y)
Hotels	180,313
Educational Institutions (Hostels)	1,437,021
Healthcare (Hospitals)	445,441

Step 4: Estimate the heat pump market size

The supply temperature for water heating is suitable for air source heat pumps (ASHP). The market size for heat pumps was derived using the estimated hot water consumption and the average temperature rise.

Table 17: Heat pump market size - Commercial - Water heating

Facilities	Heat pump market size (MW_{th})
Hotels	952
Educational Institutions (Hostels)	7,584
Healthcare (Hospitals)	1,159

Step 5: Calculate Energy Savings

The estimated electricity consumption in the heat pumps was calculated using the annual hot water quantity and the specific electricity consumption of the heat pumps. Further, the energy savings was calculated by the difference of the annual electricity consumption in the baseline and the heat pump scenario.

Table 18: Estimated energy saving - Commercial - Water heating

Facilities	Energy Savings (toe/y)
Hotels	12,061
Educational Institutions (Hostels)	96,121
Healthcare (Hospitals)	29,795

The difference between annual baseline energy consumption and the estimated annual heat pump energy consumption will be the total annual energy saving potential.

Step 6: Estimate GHG Reduction Potential

The analysis calculates the baseline GHG emissions associated with space heating using the baseline electricity consumption and a standard emission factor. It then estimates the annual GHG reduction potential by subtracting the emissions associated with heat pump electricity consumption from the baseline emissions.

Table 19: Estimated GHG emission reduction - Commercial - Water heating

Facilities	GHG Reduction Potential (Mn tCO_2/y)
Hotels	0.11
Educational Institutions (Hostels)	0.92
Healthcare (Hospitals)	0.28

5.1.4 Market potential for 2030 - Commercial sector

As mentioned in the preceding sections, the commercial sector is expected to witness robust growth in the coming years, driven by several key factors (i.e. population growth, economy growth, growing urbanisation, etc.). The energy demand for each sector will also increase. The increasing environmental concerns and the need for sustainable heating solutions will drive the adoption of heat pumps. Technological advancements and rising energy costs will make heat pumps more efficient and affordable.

The market potential for heat pumps is, therefore, expected to grow significantly in the next six years (2030) as summarised in the table below:

Table 20: Market growth - CAGR for Commercial

Commercial sector	Projection (CAGR %)	Remarks
Hotels	5%	2023 Indian Hospitality Trends & Opportunities (Link)
Educational institutions	3%	Education and Training, IBEF (Link)
Healthcare	22%	Investment opportunities in India's Healthcare Sector, NITI Aayog (Link)
Retail	12%	Study of the rise and growth of the Indian retail industry (Link)

It is estimated that the potential for heat pumps for space heating in the commercial sector can increase from 217 MW_{th} in 2024 to 954 MW_{th} in 2030. The corresponding investment required will be INR 16,403 Mn in 2024, increasing to INR 71,801 Mn in 2030. For water heating in the commercial sector, the market potential can increase from 9,695 MW_{th} in 2024 to 14,907 MW_{th} in 2030. The corresponding investment required will be INR 145,430 Mn in 2024, increasing to INR 223,610 Mn in 2030. The break-up by sector is as follows:

Table 21: Heat pump potential - Commercial sector

Type of facility	Space Heating				Hot water			
	Potential (MW_{th})		Investment (Mn INR)		Potential (MW_{th})		Investment (Mn INR)	
	2024	2030	2024	2030	2024	2030	2024	2030
Hotels	10	13	717	1,008	952	1,340	14,275	20,095
Hospitals	128	491	9,604	36,934	1,159	3,883	17,391	58,239
Educational Institutions	6	7	419	563	7,584	9,685	113,764	145,277
Retail	75	438	5,664	33,295	-	-	-	-
Total	**217**	**954**	**16,403**	**71,801**	**9,695**	**14,907**	**145,430**	**223,610**

The overall potential for GHG emission reduction can increase from 0.20 million tCO_2/y to 0.87 million tCO_2/y in the space heating segment and from 1.32 million tCO_2/y to 2.28 million tCO_2/y in the water heating segment.

In summary, the anticipated impact of heat pumps in the commercial sector is presented in the table below:

Table 22: Market potential for the Commercial Sector

Parameter	Unit	2025	2026	2027	2028	2029	2030
Energy saving potential - Technical	MTOE	0.20	0.21	0.24	0.26	0.29	0.33
Energy saving potential - Monetary	Mn INR	22,738	24,975	27,579	30,623	34,194	38,401
Heat pump capacity	MW_{th}	11,048	11,777	12,602	13,541	14,617	15,861
Emission reduction potential	$MtCO_2$	1.9	2.0	2.3	2.5	2.8	3.1
Investment	Mn INR	192,843	208,076	225,489	245,497	268,603	295,411

5.2 Market size - Residential sector

5.2.1 Context

India's residential sector accounts for approximately 10% of the country's total energy consumption. The demand for energy in a residential building is fulfilled through various sources as depicted in the figure below:

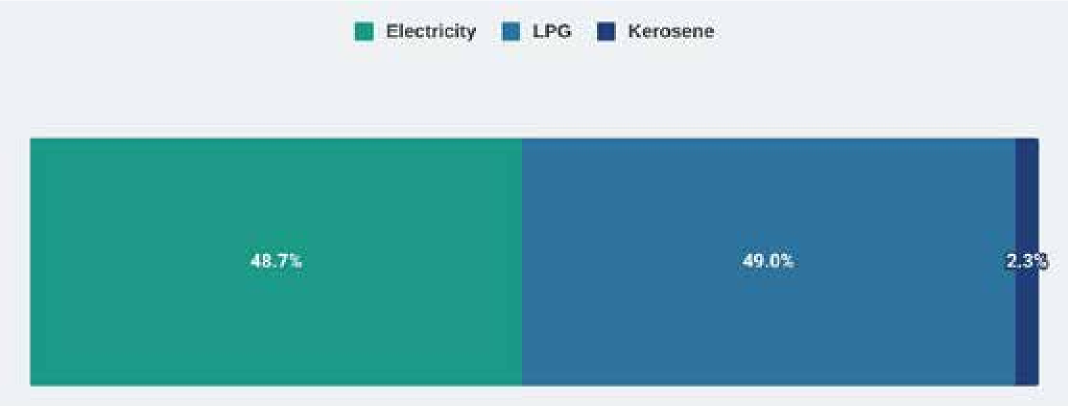

Figure 33: Energy consumption in residential sector

LPG and electricity are the dominant energy sources in India's residential sector, accounting for almost equal share of 49.0% and 48.7% respectively. Kerosene is also used in some amount, accounting for 2.3%[34]. Electricity is the dominant primary fuel for the space heating and water heating segments in the residential sector and supports the financial viability of heat pumps.

5.2.2 Energy profile

India's energy landscape has undergone a significant transformation in recent decades, driven by a burgeoning population and rapid economic growth. Energy consumption has more than doubled since 2000, propelling the country to become a major force in the global energy economy. This growth has been accompanied by a remarkable achievement: near-universal household access to electricity, attained in 2019. This milestone signifies that over 900 million citizens have gained access to electricity in less than two decades, marking a significant improvement in living standards[35].

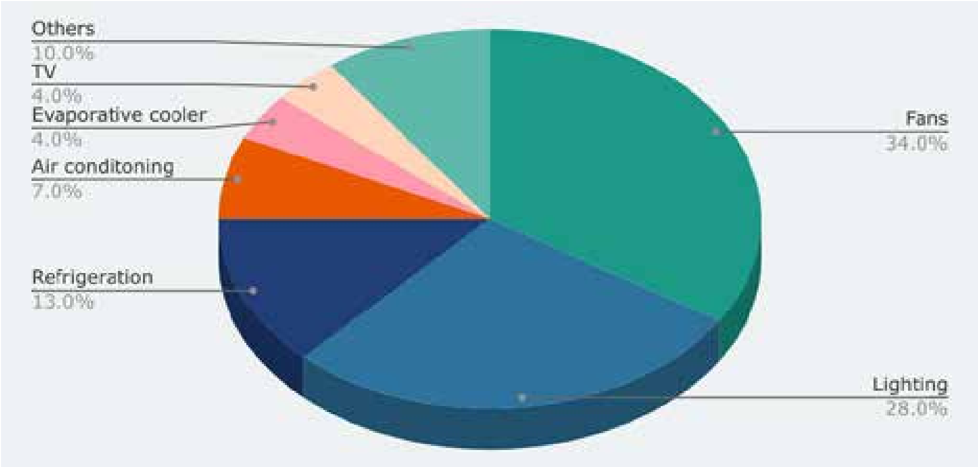

Figure 34: Electricity end use in a typical residential facility [36]

[34] National Energy Data: Survey and Analysis, *BEE,* 2023 (Link)
[35] Energy in India today, *India Energy Outlook 2021 : International Energy Agency*, 2021, (Link)
[36] A review of energy consumption in residential sector in India ; Possibilities for energy conservation, 2018 (Link)

Figure 31 showcases the distribution of energy consumption within the residential sector, which accounts for 21% of total electricity use. Notably, ceiling fans and lighting emerge as the primary energy guzzlers, collectively consuming a substantial 62% of the electricity demand. This underscores the significant role these appliances play in shaping residential electricity consumption patterns.

5.2.3 Market potential for 2024 - Residential

The potential has been assessed for the space heating and water heating applications in the residential sector

→ Heat pumps for space heating - Residential

The potential of heat pumps for space heating in the residential sector has been carried out as follows:

Step 1: Identify the target market

The identified target markets for heat pump adoption were determined based on the climatic conditions. The list of states in the Northern part of India with a "Cold climatic zone" and/or "Composite climatic zone" were considered suitable for the space heating market. The states/union territories thus selected were Jammu, Kashmir, Himachal Pradesh, Punjab, Uttarakhand, Haryana, Chandigarh, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Assam, Arunachal Pradesh and Nagaland.

Step 2: Estimate the number of households

Within the residential building sector in the above states, 25% of the houses were assumed to fall in the category of super rich households, i.e. 833,099[37].

Step 3: Baseline energy consumption

The baseline energy consumption was estimated by assuming three (3) heaters currently being used per household for space heating and the corresponding operating hours.

The annual baseline energy consumption was estimated by multiplying the heater load by the average annual operating hours (i.e. HDD). For cities in North India, the average HDD was determined to be 896 hours per year. This figure was then used to estimate the total annual energy consumption for heating purposes. A diversity factor (0.8) was considered in line with ASHRAE 90.1. It is estimated as 3,582,336 MWh/y

Step 4: Estimate the heat pump market size

The supply temperature for space heating is suitable for air source heat pumps (ASHP). The annual average COP for ASHP was considered at a conservative level of 2.8[38]. Further, the heat pump market size was calculated using the estimated annual baseline electricity consumption, the COP and the operating hours in the baseline. The estimated market size for residential space heating was 3,999 MW_{th}.

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[37] Sustainable Space Heating Solutions in The Himalayan Region - TERI Report, 2020 (Link)
[38] Interim Heat Pump Performance Data Analysis Report, Department for Energy Security and Net Zero, 2023 (Link)

Step 5: Estimate energy savings

The difference between annual baseline energy consumption and the estimated annual heat pump energy consumption was the total annual energy saving potential, which is 198,052 toe/y.

Step 6: Estimating GHG reduction potential

The greenhouse gas (GHG) reduction potential was determined using a grid emission factor of 0.82 kgCO_2/kWh. The estimated GHG reduction potential will be 1.89 Mn tCO_2/y.

→ Heat pumps for water heating - Residential

The potential of heat pumps for water heating in the residential sector has been carried out as follows:

Step 1: Identify the water heating potential

The pessimistic estimate for hot water through solar water heating in the residential sector in India was estimated as 552,288,081 LPD (Source: UNDP SWH Potential report, 2020).

Step 2: Calculate baseline energy consumption

Referring to the technical data sheets of technology suppliers, the temperature lift was taken as 45°C, based on which heat output was calculated. Baseline daily energy consumption was calculated considering electric geysers operating at 95% efficiency. The annual baseline energy consumption was calculated considering 180 days of operation, i.e. 5,475,561 MWh/y.

Step 3: Estimate the heat pump market size

The supply temperature for water heating is suitable for air source heat pumps (ASHP). The market size for heat pumps was derived using the estimated hot water consumption and the average temperature rise. The estimated market size for residential water heating is 28,899 MW_{th}.

Step 4: Calculate energy savings

The specific electricity consumption for the heat pump was considered based on the data provided by technology suppliers. The annual energy saving potential was calculated as 366,254 toe/y.

Step 5: Estimate GHG reduction potential

The annual GHG reduction potential was calculated by subtracting the emissions associated with heat pump electricity consumption from the baseline emissions. GHG reduction potential calculated was 3.49 Mn tCO_2/y.

5.2.4 Market potential for 2030 - Residential sector

The Indian residential sector is poised for significant growth in the coming years. Consequently, the energy demand from the residential sector is anticipated to rise at an accelerated pace over the next few years. The market potential for heat pumps is, therefore, expected to grow significantly in the next six years (2030) as summarised in the table below:

Table 23: Market growth - CAGR for Residential

Residential sector	Projection (CAGR %)	Remarks
Households	17%	PRICE Survey (Link)

It is estimated that the potential for heat pumps for space heating in the residential sector can increase from 3,999 MW_{th} in 2024 to 21,185 MW_{th} in 2030. The corresponding investment required will be INR 112,468 Mn in 2024, increasing to INR 595,819 Mn in 2030. For water heating in the commercial sector, the market potential can increase from 28,899 MW_{th} in 2024 to 103,448 MW_{th} in 2030. The corresponding investment required will be INR 433,482 Mn in 2024, increasing to INR 1,551,715 Mn in 2030.

Table 24: Heat pump potential - Residential sector

Type of facility	Space Heating				Hot water			
	Potential (MW_{th})		Investment (Mn INR)		Potential (MW_{th})		Investment (Mn INR)	
	2024	2030	2024	2030	2024	2030	2024	2030
Residential	3,999	21,185	112,468	595,819	28,899	103,448	433,482	1,551,715

The overall potential for GHG emission reduction can increase from 1.89 million tCO_2/y to 10 million tCO_2/y in the space heating segment and from 3.49 million tCO_2/y to 12.50 million tCO_2/y in the water heating segment.

In summary, the anticipated impact of heat pumps in the residential sector is presented in the table below:

Table 25: Market potential for the Residential Sector

Parameter	Unit	2025	2026	2027	2028	2029	2030
Energy saving potential - Technical	MTOE	1.18	1.36	1.56	1.79	2.06	2.36
Energy saving potential - Monetary	Mn INR	110,204	126,458	145,129	166,581	191,232	219,561
Heat pump capacity	MW_{th}	64,605	73,667	84,006	95,804	109,267	124,633
Emission reduction potential	$MtCO_2$	11.30	12.96	14.88	17.07	19.60	22.50
Investment	Mn INR	1,099,392	1,256,645	1,436,550	1,642,396	1,877,950	2,147,534

5.3 Market size - Industrial sector

5.3.1 Context

India's industrial sector is the largest energy-consuming sector, accounting for approximately 41% of the country's total energy consumption. The sector is dominated by energy-intensive industries such as iron and steel, cement, and chemicals. Coal is the primary source of energy in the industrial sector, followed by electricity and naphtha[39].

Figure 35: Energy consumption in Industrial sector

The industrial sector's energy consumption is driven by factors such as industrial growth, technological advancements, and the increasing demand for manufactured goods.

5.3.2 Energy Profile

As discussed in Section 2 by reviewing the potential sectors for heat pump case studies was discussed. Further, the primary fuel mix was reviewed to analyse commercial suitability as shown in the figure below[40]:

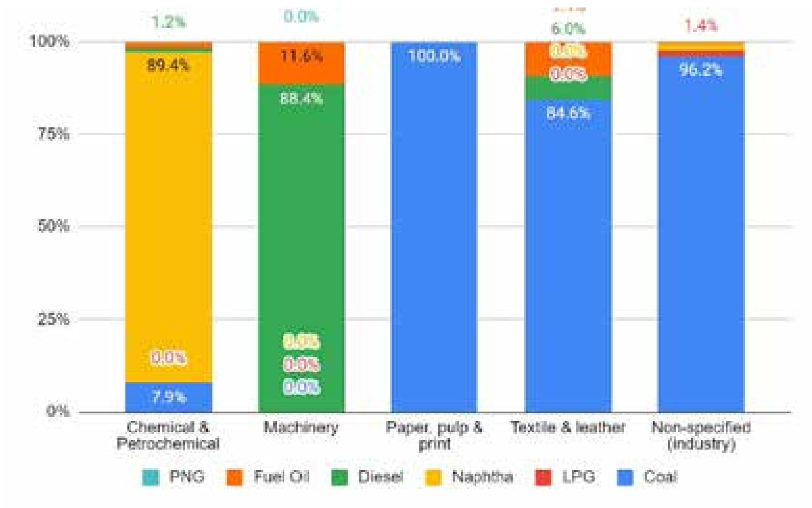


Figure 36: Primary fuel used in industries

The graph above illustrates the typical distribution of primary energy sources used across various sub-sectors. It is important to note, however, that individual industries may deviate from these general trends. For instance:

- Paper production and Non-specified industries rely almost exclusively on coal for their energy needs.
- The textile industry shows a more diverse energy profile, with significant portions of its consumption coming from coal and only some portion from diesel and fuel oil.

[39] National Energy Data: Survey and Analysis, *BEE,* 2023 (Link)

[40] https://www.mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_22/Chapter%207-Energy%20Balance.pdf

- The machinery manufacturing sector presents a potential opportunity for the adoption of heat pump technology, which could alter its energy consumption pattern.
- Chemical and petrochemical segment seems to have been dominated by the petrochemical sub-sector.

5.3.3 Market potential for 2024 - Industrial

The potential of heat pumps for space heating in the industrial sector has been carried out as follows:

Step 1: Identify the Target Market

The target market for heat pumps in the industrial sector was finalised based on the energy profile and the criteria for commercial attractiveness. After elimination of the sectors which have coal, biomass, pet coke and rice husk, the following target market was identified including machinery (metal/auto components, etc.), a part of the textile sector, chemical sector and non-specified (covering the food and beverage) sectors.

Step 2: Estimate the number of facilities

The estimated number of industries that can be targeted for heat pump technology was derived by reviewing the number of industries as per Annual Survey of Industries 2021, further adjustment of the number based on the NIC codes classification and past knowledge of the hot water demand.

Table 26: Estimated number of facilities - Industry

Industries	No. of industries	Remarks
Chemical (Non-DC)	2,100	Annual Survey of Industries, 2021; Further adjusted for the estimated industries with thermal energy demand
Food & Beverage	17,350	
Metal & Auto Component	14,900	
Textile (Non-DC)	2,300	

Step 3: Calculate Baseline Energy Consumption

For each industry type, based on the previous studies, the proportion of thermal energy consumption, average baseline energy consumption of industries and average thermal to total energy consumption ratio was used to calculate the baseline energy consumption.

Table 27: Baseline energy consumption - Industries

Industries	Baseline energy consumption (toe/y)
Chemical (Non-DC)	66,604
Food & Beverage	186,295
Metal & Auto Component	54,869
Textile (Non-DC)	39,458

Step 4: Estimate the market size

The heat pump market size was calculated using the estimated annual baseline electricity consumption and the operating hours.

Table 28: Heat pump market size - Industries

Industries	Heat pump market size (MW_{th})
Chemical (Non-DC)	129
Food & Beverage	361
Metal & Auto Component	106
Textile (Non-DC)	76

Step 5: Calculate Energy Savings

The annual average COP for the heat pump was considered at a conservative level of 3.6[41]. The analysis determines the average thermal energy saving with heat pump by referring to the several heat pump case studies and estimates the annual energy savings by the heat pump.

Table 29: Energy savings - Industries

Industries	Energy savings (toe/y)
Chemical (Non-DC)	33,300
Food & Beverage	107,120
Metal & Auto Component	31,550
Textile (Non-DC)	19,730

Step 6: Estimate GHG Reduction Potential

The GHG emissions from the proposed heat pump project was calculated and subtracted from the baseline emissions to derive the reduction potential as summarised in the table below:

Table 30: GHG emission reduction - Industry

Industries	GHG emission reduction (Mn tCO_2/y)
Chemical (Non-DC)	0.07
Food & Beverage	0.22
Metal & Auto Component	0.08
Textile (Non-DC)	0.06

[41] Interaction with heat pump suppliers

5.3.4 Market potential for 2030 - Industries

Stakeholder consultations were conducted to assess the increase in the demand for heat pumps in the industrial sector. It is understood that the demand from the industries in India has only taken off very recently. The metal based (auto components) and food & beverage industries are the only sectors where there have been some enquiries for heat pumps.

The data on import of heat pumps was also reviewed. However, as provided in Section 3.2.4, the adoption in the industrial sector has been very low.

In view of these data sources, growth trend was analysed through secondary research as summarised in the table below:

Table 31: Market growth - CAGR for Industrial

Industrial sector	Projection (CAGR %)	Remarks
Chemical	12%	India: The next chemicals manufacturing hub, McKinsey & Company (Link)
Food and Beverages	5%	Food processing, IBEF (Link)
Metal based	8%	Metal based industries, NATMO Geoportal (Link)
Textile	5%	Textile and Apparel, IBEF (Link)

It is estimated that the potential for heat pumps for water heating in the industrial sector can increase from 606 MW_{th} in 2024 to 909 MW_{th} in 2030. The corresponding investment required will be INR 28,897 Mn in 2024, increasing to INR 43,832 Mn in 2030. The break-up by sector is as follows:

Table 32: Heat pump potential - Industrial sector

Industrial Sub-sector	Hot water			
	Potential (MW_{th})		Investment (Mn INR)	
	2024	2030	2024	2030
Chemical (Non-DC)	129	255	6,196	12,229
Food & Beverage	361	484	15,164	20,321
Metal & Auto Component	106	169	4,785	7,593
Textile (Non-DC)	76	102	2,753	3,688
Total	**606**	**909**	**28,897**	**43,832**

The overall potential for GHG emission reduction can increase from 0.42 million tCO_2/y to 0.63 million tCO_2/y.

In summary, the anticipated impact of heat pumps in the industrial sector is presented in the table below:

Table 33: Market potential for the Industrial Sector

Parameter	Unit	2025	2026	2027	2028	2029	2030
Energy saving potential - Technical	MTOE	0.20	0.22	0.23	0.25	0.27	0.29
Energy saving potential - Monetary	Mn INR	7,161	7,707	8,298	8,939	9,635	10,392
Heat pump capacity	MW_{th}	647	692	740	792	848	909
Emission reduction potential	$MtCO_2$	0.45	0.48	0.52	0.55	0.59	0.63
Investment	Mn INR	30,920	33,109	35,473	38,037	40,816	43,832

5.4 Market size - All sectors

The overall market potential for heat pumps in India was estimated for the three types of facilities as summarised in the table below:

Table 34: Overall market potential - All 3 facilities

Type of facility	Space Heating				Hot water			
	Potential (MW_{th})		Investment (Mn INR)		Potential (MW_{th})		Investment (Mn INR)	
	2024	2030	2024	2030	2024	2030	2024	2030
Commercial	217	954	16,403	71,801	9,695	14,907	145,430	223,610
Residential	3,999	21,185	112,468	595,819	28,899	103,448	433,482	1,551,715
Industrial	-	-	-	-	606	909	28,897	43,832
Total	**4,216**	**22,139**	**128,871**	**667,620**	**39,200**	**119,264**	**607,809**	**1,819,157**

The contribution of the residential sector in the heat pump market potential (MW_{th}) is expected to be about 85% of the overall potential, followed by the commercial sector and the industrial sector.

5.5 Market adoption

The estimated current adoption of heat pumps in terms of cumulative heating capacity is as follows:

Figure 37: Estimated adoption of heat pumps in 2024

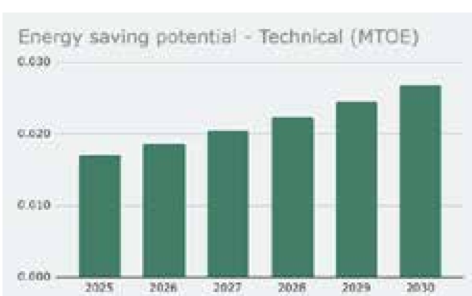
The market adoption of heat pumps in the residential water heating sub-sector has been assessed based on the adoption of solar water heaters. Similarly, the adoption rate of traditional HVAC products has been used to determine the adoption rate for residential space heating sub-sector. The adoption of heat pumps in the commercial and industrial sectors is based on the growth in the Asian market. A few pointers on the adoption of these products are as follows:

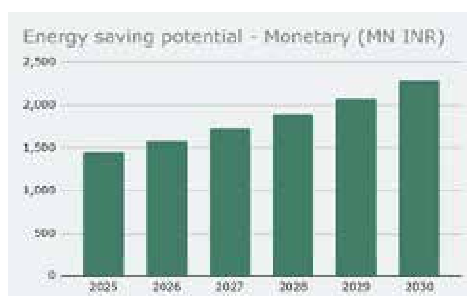
- Traditional HVAC products
  - Many consumers, particular to the Tier 2 and Tier 3 cities are still reluctant to switch to more efficient systems due to higher price tags[42]
  - Demand for residential ACs grew by a CAGR of 15.5%[43] for the period 2021-23 in India

- Solar water heater
  - Solar water heater market in India is expected to growth at a CAGR of 7.20% for the period FY2025- FY2032[44]

- Heat pumps
  - The sales in Asia for the period 2021-23 have grown at a CAGR of 8.5% However, 97.7% of the market is in China and Japan[45]

The unpredictable nature of industry responses to emerging carbon market trends and possible modifications to the Perform, Achieve and Trade (PAT) scheme creates uncertainty in forecasting heat pump technology adoption across industrial applications. These changing market mechanisms and regulatory frameworks could change the financial viability and attractiveness of heat pump investments. The adoption of heat pumps in industrial settings will be driven not only by the technical-economic feasibility but also the broader ecosystem in which each sector operates. The latent market potential and actual adoption rates will, therefore, depend on how businesses evaluate and react to these emerging opportunities and requirements. These estimates are based on the macro-economic conditions at the time of the study. The impact of the adoption of the technology by 2030 is presented in the figures below:





[42] Impact of energy efficiency and sustainability regulations on the HVAC&R industry in India (Link)
[43] Market assessment for super-efficient air conditioners, UNEP, 2021 (Link)
[44] India solar water heater marker assessment (Link)
[45] Global heat pump market report 2024 (Link)

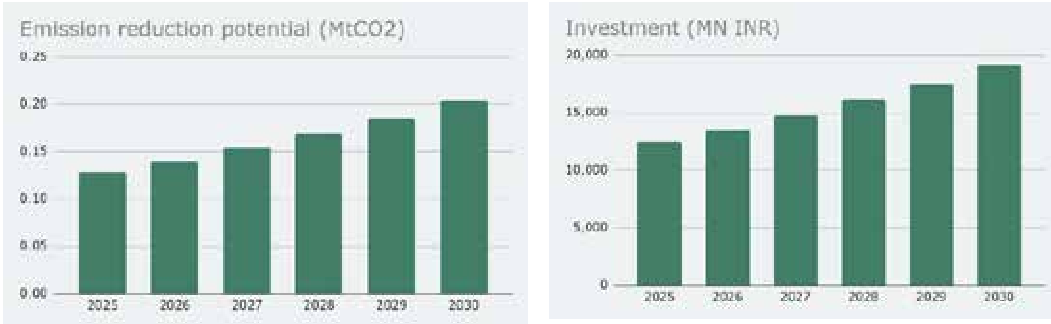


Figure 38: Impact of adoption of heat pump technology

The concept of technology adoption stages, also known as the Technology Adoption Lifecycle or Innovation Adoption Curve, is a model that describes how different groups of people adopt new technologies or innovations over time. The technology adoption stages are typically divided into five main categories:

Table 35: Technology adoption stages

Stage	Percentage	Characteristics
Innovators	First 2.5%	● First to adopt new technologies ● Risk-takers and tech enthusiasts ● Willing to try unproven products
Early adopters	Next 13.5%	● Opinion leaders and trendsetters ● Quick to recognize the potential of new technologies ● Often influential in their social circles
Early majority	Next 34%	● Pragmatic and practical adopters ● Willing to adopt new technologies after seeing proven benefits ● More cautious than early adopters
Late majority	Next 34%	● Sceptical and conservative ● Adopt new technologies only when they become mainstream ● Often influenced by peer pressure and necessity
Laggards	Final 16%	● Traditional and resistant to change ● Last to adopt new technologies ● May only adopt when forced to or when the technology becomes unavoidable

This model is often represented as a bell curve, with each group occupying a different section of the curve. The concept is useful for businesses and marketers to understand how new products or technologies might be adopted over time and to develop strategies for reaching different consumer segments. Additionally, the model highlights the importance of "crossing the chasm" – the challenging transition between early adopters and the early majority, which is often crucial for the widespread success of a new technology.

The current adoption of heat pumps for the commercial end use sectors falls in the category of Early adopters, whereas the residential and industrial sectors are in the Innovators category.

CHAPTER 6:
Policy Options

- Global policy experience
- Review of Indian policy experience
- Summary of policies

6. Policy Options

6.1 Global policy experience

The adoption of heat pumps has been rising rapidly in the global market as compared to the Indian market. An analysis of the key policy levers used to promote heat pumps in the global market is presented in the table below:

Table 36: Analysis of global policies for heat pump

Country	Key facts	Key lessons for India
China	● China's heat pump market grew from 1.23 million units in 2015 to 3.42 million units in 2020[46]. ● Government subsidies of up to 50% on air-source heat pumps in northern regions. ● The "Coal to Electricity" policy in Beijing led to 150,000 heat pump installations between 2016-2020.	● Strong government support and clear policies can rapidly accelerate adoption. ● Targeting specific regions with tailored policies can be effective. ● Linking heat pump adoption to air quality improvement can increase public acceptance.
Japan	● "EcoCute" CO_2 heat pump water heaters reached 6 million installations by 2019[47] ● High efficiency standards: COP of 4.0 or higher for air-to-water heat pumps. ● R&D focus led to the development of the world's first CO_2 refrigerant heat pump.	● Invest in R&D for technology suited to local conditions. ● Set high efficiency standards to drive innovation. ● Create a recognizable brand (like "EcoCute") for consumer awareness.
European Union	● Heat pump sales in the EU grew by 13% in 2020, reaching 1.62 million units[48] ● EU's Renewable Energy Directive recognizes heat pumps as renewable energy technology. ● Comprehensive installer certification programs like EU CERTiFLASH[49]	● Develop standardised training and certification programs for installers. ● Integrate heat pumps into broader renewable energy and energy efficiency policies. ● Foster a supportive regulatory environment across diverse member states.
United States	● Federal tax credits of up to $2,000 for qualified heat pumps[50]. ● State-level incentives, e.g., Massachusetts offers up to $10,000 for ground-source heat pumps. ● Heat pump shipments increased by 19% in 2020 compared to 2019[51].	● Implement multi-level incentive structures (Central and State). ● Tailor incentives to different heat pump types (air-source, ground-source). ● Leverage existing HVAC distribution networks for rapid market adoption.
Australia	● Heat pump water heaters have a 23% market share (2020). ● Rebates of up to AUD 1,000 in some states for heat pump water heaters ● Mandatory energy labelling system for	● Implement clear energy labelling for consumer awareness. ● Develop solutions for varied climatic conditions (tropical to temperate). ● Use rebates to overcome higher

[46] https://heatpumpingtechnologies.org/market-report/china/
[47] https://www.ejarn.com/detail.php?id=59738
[48] https://www.ehpa.org/market-data/
[49] https://www.ehpa.org/quality/hp-keymark/certified-hp-installers/
[50] https://www.energystar.gov/about/federal_tax_credits/air_source_heat_pumps
[51] https://www.achrnews.com/articles/144230-2020-heat-pump-shipments-up-19-percent

Country	Key facts	Key lessons for India
	heat pumps.	upfront costs.
Sweden	• Over 60% of buildings use heat pumps for heating. • Ground-source heat pumps are popular, with over 500,000 installations[52]. • Integration with district heating systems in urban areas.	• Explore ground-source heat pumps for consistent year-round efficiency. • Consider integration with district energy systems in urban planning. • Focus on long-term energy security as a driver for adoption.
United Kingdom	• Government target: 600,000 heat pump installations per year by 2028[53]. • Boiler Upgrade Scheme offers £5,000-£6,000 grants for heat pump installations[54]. • Retrofitting focus: 80% of 2050 building stock already exists today.	• Set ambitious, long-term targets to drive market growth. • Focus on retrofitting existing buildings, not just new construction. • Develop policies to transition from traditional heating/cooling systems.
Germany	• 40% subsidy on heat pump costs through federal funding[55]. • 35.4% year-on-year growth in heat pump sales in 2021. • Emphasis on combining heat pumps with solar PV systems.	• Integrate heat pumps with rooftop solar promotion programs. • Use substantial subsidies to overcome high initial costs. • Develop industrial heat pump applications for the manufacturing sector.

6.2 Review of Indian policy experience

A review of the Indian policy experience in the promotion of energy efficient technologies to analyse the response to specific policies was conducted and summarised separately for the end-use sectors as follows:

6.2.1 Commercial Sector

Table 37: Promotion of EE technologies in Commercial sector

Technology	Primary Barrier	Elaborated Policy Incentive	Growth in Adoption	Technology Adoption Stage (Start → End)	Stakeholder Engagement Approach
Energy Efficient Buildings (ECBC)	Lack of standardization	Mandatory standards, green building ratings[56]	Potential savings of 300 billion kWh by 2030	Early Adoption → Early Majority (projected)	Workshops for architects/engineers, developer engagement
Variable Refrigerant Flow (VRF) Systems	High initial cost	Included in ECBC, energy efficiency ratings[57]	25% CAGR from 2015-2020	Early Adoption → Early Majority	Training for HVAC engineers, case studies
District	High capex,	Pilot	3-4 major	Innovators →	Urban planner

[52] https://heatpumpingtechnologies.org/market-report/sweden/
[53] https://www.gov.uk/government/publications/heat-and-buildings-strategy
[54] https://www.gov.uk/guidance/check-if-you-may-be-eligible-for-the-boiler-upgrade-scheme-from-april-2022
[55] https://www.bafa.de/DE/Energie/Effiziente_Gebaeude/effiziente_gebaeude_node.html
[56] https://beeindia.gov.in/sites/default/files/ECBC%20Impact%20Analysis%20Report_Final.pdf
[57] https://ishrae.in/newsdetails/VRF-Market-in-India-to-Grow-at-25-CAGR/637

Technology	Primary Barrier	Elaborated Policy Incentive	Growth in Adoption	Technology Adoption Stage (Start → End)	Stakeholder Engagement Approach
Cooling Systems	complex implementation	projects, technical assistance[58]	projects implemented by 2020	Early Adoption	engagement, PPP models
Building Energy Management Systems	High implementation cost	Energy Service Company (ESCO) model promotion[59]	5% annual growth in ESCO market	Early Adoption → Early Majority	Training for facility managers, ESCO partnerships

6.2.2 Residential Sector

Table 38: Promotion of EE technologies in residential sector

Technology	Primary Barrier	Policy Incentive	Growth in Adoption	Technology Adoption Stage (Start → End)	Stakeholder Engagement Approach
Inverter ACs	High upfront cost	Mandatory energy efficiency ratings, awareness campaigns[60]	30% market share by 2020	Early Adoption → Early Majority	Consumer awareness, manufacturer engagement
Solar Water Heaters	High upfront cost, system design	Capital subsidy, soft loans[61]	9.01 million sq. meters installed by 2019	Early Adoption → Early Majority	Installer training, partnerships with housing developers
Energy Recovery Ventilators	High cost, low awareness	Included in green building ratings[62]	Limited adoption, mainly in premium housing	Innovators → Early Adoption	Integration in green building projects

6.2.3 Industrial Sector

Table 39: Promotion of EE technologies in industrial sector

Technology	Primary Barrier	Policy Incentive	Growth in Adoption	Technology Adoption Stage (Start → End)	Stakeholder Engagement Approach
Waste Heat Recovery Systems	High capex, technical complexity	Capital subsidy, accelerated	500 MW capacity by 2020	Early Adoption → Early Majority	Technical workshops, demonstration

[58] https://www.unep.org/resources/report/district-energy-cities-unlocking-potential-energy-efficiency-and-renewable-energy
[59] https://beeindia.gov.in/sites/default/files/ESCO%20Market%20Report.pdf
[60] https://beeindia.gov.in/sites/default/files/AC%20Market%20Study%20Report.pdf
[61] https://mnre.gov.in/img/documents/uploads/file_f-1597797108502.pdf
[62] https://igbc.in/igbc/redirectHtml.htm?redVal=showGreenHomesnosign

Technology	Primary Barrier	Policy Incentive	Growth in Adoption	Technology Adoption Stage (Start → End)	Stakeholder Engagement Approach
		depreciation[63]			projects
Tri-generation Systems	High capex, lack of awareness	Demonstration projects, technical assistance[64]	30 MW capacity installed by 2020	Innovators → Early Adoption	Industry workshops, case study dissemination
Industrial HVAC Optimization	Operational challenges, lack of expertise	Energy audit support, training programs[65]	Part of overall industrial energy efficiency improvements	Early Majority → Late Majority	Energy auditor certification, best practice sharing

6.3 Summary of policies

The global and Indian policy schemes were re-grouped under six (6) types of incentives, as summarised in the table below:

Table 40: Summary of global & Indian policies

Type of incentive	Global practices for heat pumps	Indian practices for EE technologies/schemes
Capital subsidy or tax subsidy	Australia, China, Germany, US	Inverter AC, Solar water heater, Waste heat recovery systems
Subsidy linked to either replacing a certain fuel, equipment or retrofit focus or innovation focus	China, Germany, Sweden, UK	-
Introduce standards & gradually improve the performance; Mandatory labelling; Certification of installers	Australia, EU, Japan	VRF
Integrate the heat pump as a prominent technology in broader EE & RE policies	EU	Energy recovery ventilators
Pilot projects & Technical assistance		District cooling systems, Trigeneration systems
ESCO model		Building Energy Management Systems, Industrial HVAC optimisation

To foster the growth of heat pump markets in India, a combination of policy incentives needs to be implemented. The specific strategies to be adopted should be determined following comprehensive discussions with relevant stakeholders. Further, the aspects related to regulations and supply chain are discussed in the following sections.

[63] https://www.teriin.org/sites/default/files/2018-02/2017IE02.pdf
[64] https://www.teriin.org/sites/default/files/2018-02/2017ER02.pdf
[65] https://beeindia.gov.in/content/energy-managers

CHAPTER 7: Regulatory Landscape

- Testing standards
- Market standards - Performance and efficiency
- Refrigerant management
- Comparison of heat pump standards & regulations in India v/s key global markets

7. Regulatory Landscape

7.1 Testing standards

Testing standards, such as those set by AHRI in the US and EN in the EU, ensure that heat pumps meet established performance, efficiency, and safety criteria. These standards include rigorous testing protocols that simulate various environmental conditions, confirming that heat pumps will perform as claimed. This process helps in verifying the reliability of heat pumps across different scenarios, ensuring that consumers receive products that meet their expectations. The table below details the laboratory testing standards in the selected countries.

Table 41: Testing standards for heat pumps

Country/ Region	Standard Name	Coverage (Air, Water, Ground Source)	Testing Protocols	Thresholds	Testing Conditions	Testing Parameters
United States	• AHRI[66] 210/240 • AHRI Standard 340/360 • AHRI Standards 13256-1 and 13256-2.	• AHRI 210/240 for Unitary Air-source heat Pumps with capacities less than 65,000 Btu/h • AHRI 340/360 for Air source heat pumps with capacities more than 65,000 Btu/h • AHRI 13256-1 and 13256-2 for Water-source Heat Pumps, Ground Water-source Heat Pumps, or ground-source closed-loop Heat Pumps	Performance testing	Change in standards after 65,000 Btu/h	Heating mode at 8°C, cooling mode at 35°C	IPLV, NPLV both
European Union	EN 14511-1:2022/09, EN 14511-2:2022/09, EN 14511-3:2022/09	All Types	Seasonal efficiency testing	Varies by type	Heating mode at -7°C, cooling mode at 35°C; part load testing conditions detailed in EN 14825	IPLV, NPLV both
Japan	JIS B 8616	All Types	APF testing	No specific threshold	Standard conditions: heating at 7°C, cooling at 35°C	Not specified
China	GB/T 18430	All Types	Energy	Varies by type	Heating mode at -	IPLV, NPLV

[66] Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment, *AHRI Standard 210/240,* 2023 (Link)

Country/ Region	Standard Name	Coverage (Air, Water, Ground Source)	Testing Protocols	Thresholds	Testing Conditions	Testing Parameters
			efficiency and safety testing		5°C, cooling mode at 35°C	both
India	IS 1391 (Part 1 & 2) *Derived from ISO/D1S 5151 'Room air conditioners and heat pumps — Testing and rating' issued by the International Organization for Standardisation*	Air Source	Performance testing	No specific threshold	Standard conditions: typically 7°C for heating and 35°C for cooling	Not specified
India	IS 8148: 2018 *'Ducted and Package Air Conditioners'*	Air Source	Performance testing	Graphs for corelation	Heating Mode (if applicable): - Indoor: 20°C DB - Outdoor: 7°C DB, 6°C WB Additional conditions for maximum and minimum operating temperatures	- Heating capacity (if applicable) - Power input - EER and COP
India	IS 18728: 2024 *'Multiple split-system air conditioners and air-to-air heat pumps (VRF air conditioners) – Specification'*	Air source	Performance testing	- Minimum COP - Maximum power consumption - Maximum noise levels - Minimum hot water output	- Ambient air temperature: typically 15°C to 43°C - Water inlet temperature: typically 10°C to 30°C - Target hot water temperature: typically 55°C to 60°C - Relative humidity: typically 30% to 70%	- Heating capacity - COP at various ambient temperatures - Energy consumption - Hot water output volume - Recovery time - Standby power consumption - Sound power level - Safety parameters (electrical, pressure, etc.)
India	IS 18154: 2023 *'Air-cooled air conditioners and air-to-air heat*	Air source	Performance testing	- Minimum Coefficient of Performance	Heating Mode: - Indoor: 20°C DB - Outdoor: 7°C DB, 6°C WB	

Country/ Region	Standard Name	Coverage (Air, Water, Ground Source)	Testing Protocols	Thresholds	Testing Conditions	Testing Parameters
	pumps'			(COP) for heating - Minimum Seasonal Energy Efficiency Ratio (SEER) - Minimum Heating Seasonal Performance Factor (HSPF) - Maximum sound power levels - Minimum part-load efficiency	Additional conditions for part-load and extreme temperature testing	

In summary, the country specific laboratory testing standards are as follows:

- **United States:** The AHRI 210/240 standard covers all heat pump types with performance testing up to 19 kW and temperature delivery up to 50°C. Testing includes IPLV and NPLV values, with heating mode at 8°C and cooling mode at 35°C.
- **European Union:** The EN 14511 series applies to all heat pump types with seasonal efficiency and performance testing. The standards allow up to 60°C temperature delivery. IPLV and NPLV testing is included, with specific conditions of heating mode at -7°C and cooling mode at 35°C. Detailed part load testing conditions are outlined in EN 14825.
- **Japan:** JIS B 8616 covers all heat pump types with APF testing and allows up to 60°C temperature delivery. IPLV and NPLV testing are not specified, with standard conditions of heating at 7°C and cooling at 35°C. There is no specific size threshold.
- **China:** GB/T 18430 includes all heat pump types with energy efficiency and safety testing. Size thresholds vary, with temperature delivery up to 60°C. IPLV and NPLV testing is included, with heating mode at -5°C and cooling mode at 35°C.
- **India:** IS 1391 (Part 1 & 2) applies to air-source heat pumps with performance testing and temperature delivery up to 50°C. IPLV and NPLV testing are not specified, with standard conditions of heating at 7°C and cooling at 35°C. There is no specific size threshold.

7.2 Market Standards - Performance and Efficiency

Market standards, including SEER (Seasonal Energy Efficiency Ratio) and APF (Annual Performance Factor), play an important role in maintaining high-performance levels in heat pumps. These standards ensure that only energy-efficient products enter the market, helping consumers make informed decisions. By setting minimum efficiency criteria, these standards drive manufacturers to manufacture more efficient products. The table below outlines the key market standards in the selected countries.

Table 42: Market standards for heat pumps

Country/ Region	Standard Name	Coverage (Air, Water, Ground Source)	Size Threshold (Heating kW, Temperature Range)	Manufacturer Threshold	Industrial/ Commercial Application	Future Plans
United States[67]	SEER, HSPF	Air Source	Up to 19 kW	Minimum SEER of 14, HSPF of 8.2	Residential units; No specific threshold for industrial heat pumps in SEER/HSPF	Increase in minimum SEER values by 2025
European Union[68]	ErP Directive	All Types	Varies by type	Efficiency requirements vary by type	Includes industrial and commercial applications	Stricter eco-design requirements
Japan[69]	APF	All Types	No specific size threshold	Minimum APF of 3.2 for heating and 4.0 for cooling	Covers residential, commercial, and industrial sectors	Continued promotion of high-efficiency products
China[70]	GB Standard	All Types	Varies by type	Minimum COP of 3.0 for heating and 2.5 for cooling	Applicable for residential, commercial, and industrial uses	Gradual adoption of stricter standards
India[71]	IS 1391	Air Source	Up to 10.5 kW (based on general practice)	Minimum COP of 3.0	Primarily residential; industrial and commercial standards in development	Development of standards for water and ground source

In summary, the country specific market standards for benchmarking performance are as follows:

United States: The SEER (Seasonal Energy Efficiency Ratio) and HSPF (Heating Seasonal Performance Factor) are regulated by the Department of Energy (DOE) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Specific thresholds include a minimum SEER of 14 and HSPF of 8.2 for residential heat pumps. Industrial heat pumps do not have a specific SEER/HSPF threshold.

European Union: The ErP (Energy-related Products) Directive specifies efficiency requirements for all types of heat pumps, including industrial and commercial applications. Efficiency requirements vary by product category and application.

[67] Air-conditioning, heating and refrigeration institute (AHRI)

[68] The Eco-Design Directive ErP for refrigerator systems and heat pumps, *robatherm,* 2018 (Link)

[69] Heat Pumps, Long Awaited way out for Global Warming, *The DENKI SIMBUN*, 2007, (Link)

[70] GB Standards, Website (Link)

[71] Room air conditioners — Specification part 1 Unitary air conditioners, Bureau of Indian Standards, 2000, (Link)

The **ErP (Energy-related Products) Directive**, specifically through the **Regulation (EU) No 813/2013** (Ecodesign) and **Regulation (EU) No 811/2013** (Energy Labelling), sets efficiency requirements for heat pumps across various applications, including residential, commercial, and industrial uses.

- **Size Thresholds**: The ErP Directive does not specify a uniform size threshold; instead, it sets requirements based on the type and application of the heat pump. For instance, residential heat pumps might have different efficiency criteria compared to industrial units.
- **Temperature Range**: The ErP Directive allows temperature delivery up to 60°C for certain heat pumps, including those used in industrial applications.
- **Manufacturer Threshold**: For residential and light commercial applications, the Directive specifies minimum Seasonal Coefficient of Performance (SCOP) values, which can vary based on the climate zone and the type of heat pump. For example, the SCOP must be at least 3.0 for air-to-water heat pumps in moderate climates.

Japan: The APF (Annual Performance Factor) is regulated by the Ministry of the Environment and the Japanese Industrial Standards (JIS). The minimum APF is 3.2 for heating and 4.0 for cooling. The standards cover residential, commercial, and industrial heat pumps.

China: The GB (Guobiao) Standard specifies a minimum Coefficient of Performance (COP) of 3.0 for heating and 2.5 for cooling. These standards apply to residential, commercial, and industrial heat pumps.

India: IS 1391 applies primarily to air-source heat pumps with a typical size threshold of up to 10.5 kW and a minimum COP of 3.0. Standards for industrial and commercial heat pumps are still under development.

7.3 Refrigerant Management

Regulations on refrigerant selection, such as the F-Gas Regulation in the EU and the EPA SNAP program in the US, are critical in minimising the environmental impact of heat pumps. These regulations phase out high-GWP refrigerants like R-410A and encourage the adoption of more environmentally friendly alternatives, such as R-32 and R-290. This transition is important for reducing the global warming potential associated with heat pump operations on account of refrigerant leakage. The table below shows the regulations on refrigerant selection in the selected countries.

Table 43: Regulations on refrigerant selection

Country/ Region	Standard/Regulation	Applicable Heat Pump Type	Specific Refrigerants Allowed or Restricted
United States	EPA SNAP Program[72]	All Types	R-410A restricted, R-32 encouraged
European Union	F-Gas Regulation	All Types	Phasing out HFCs, R-32 preferred
Japan	METI Guidelines	All Types	R-32 preferred, R-290 considered

[72] Significant New Alternatives Policy (SNAP) Program, *EPA,* (Link)

Country/ Region	Standard/Regulation	Applicable Heat Pump Type	Specific Refrigerants Allowed or Restricted
China	GB 9237	All Types	R-410A restricted, R-32 promoted
India	MoEFCC Regulations	All Types	R-410A restricted, development of R-32 and R-290

Refrigerant regulations in the selected countries focus on reducing the environmental impact of heat pumps by phasing out high-GWP refrigerants like R-410A and promoting lower-GWP alternatives like R-32 and R-290.

Service life and material of construction

While specific service life regulations for heat pumps are uncommon, standards like the EU's Ecodesign Directive encourage the design of durable and repairable products. Safety regulations, such as those for electrical integrity and structural materials make sure that heat pumps are reliable over the long term.

The table below shows the standards and regulations related to the service life, material of construction and safety for heat pumps:

Table 44: Material of construction standards

Country/ Region	Material of Construction Standards	Applicable Heat Pump Type
United States	ASME Standards for Pressure Vessels	All Types
European Union	EN 378, EN 303	All Types
Japan	JIS B 8603	All Types
China	GB 150	All Types
India	IS 1391, IS 1239	Air Source

While there are no specific laws governing the service life for heat pumps, the materials of construction are regulated to ensure safety and durability. The standards mentioned are applicable to all types of heat pumps, with India's material of construction standards limited only to air-source heat pumps.

7.4 Comparison of heat pump standards & regulations in India v/s key global markets

India's heat pump market is still in its nascent stages, with existing standards primarily focused on air-source heat pumps, such as IS 1391 (Part 1 & 2). This standard outlines performance testing and safety criteria but lacks the detailed scope seen in other global markets. For instance, unlike the European Union's EN 14511 series, which covers air, water, and ground-source heat pumps with stringent efficiency requirements, India has not yet developed equivalent standards for water and ground-source heat pumps. Additionally, India's standard does not address critical aspects like seasonal efficiency, which is regulated in the US through AHRI 210/240 and in the EU through the ErP Directive.

India also lacks detailed regulations on refrigerant selection. In contrast, countries like Japan and the EU have implemented strict controls on high-GWP refrigerants, such as the phase-out of R-410A under the EU's F-Gas Regulation. Furthermore, India's testing protocols do not include metrics like the Integrated Part Load Value (IPLV) or Non-Standard Part Load Value (NPLV), which are critical for assessing performance under variable load conditions, as seen in US and EU standards.

CHAPTER 8:
Supply Chain Mapping

- Review based on heat pump type and end use
- Review of initiatives for stakeholders
- Identified need for strengthening the supply chain

8. Supply Chain Mapping

The key players in the supply chain for heat pump solutions in India include:

- Manufacturers
- Installers and contractors
- Consumers
- Utilities
- Building developers and owners
- Local and regional governments
- Energy Services Companies (ESCOs)
- Distributors and retailers
- Research institutions
- Financing institutions
- Environmental groups
- Industry associations

These stakeholders represent various aspects of the heat pump market, from production and installation to end-use and policy-making. Each group has specific roles and potential initiatives to contribute to the development and growth of the heat pump industry in India.

The supply chain mapping for heat pump solutions in India presents a complex and fragmented landscape, influenced by several key factors:

1. Type of Heat Pumps: The market is segmented primarily into space heating and water heating applications. Each type has its own unique supply chain characteristics, component requirements, and distribution channels.
2. End-Use Sectors: The diverse end-use sectors, including residential, commercial, and industrial, each present distinct challenges and requirements. This segmentation leads to:
    - Varied technical specifications and performance needs
    - Different scales of operation and capacity requirements
    - Sector-specific regulations and standards compliance
3. Solution Complexity: Providing heat pump solutions often involves:
    - Customization based on specific application needs
    - Integration with existing HVAC or process heating systems
    - Consideration of local climate conditions and energy infrastructure
4. Import Dependency: A significant portion of heat pump components and sometimes complete units are imported, creating:
    - Supply chain vulnerabilities to global market fluctuations
    - Potential for delays in procurement and project implementation
    - Challenges in after-sales service and maintenance
5. HSN Code Analysis: To understand the import landscape, several Harmonized System Nomenclature (HSN) codes were reviewed as detailed in Section 3.2.1.

6. Domestic Manufacturing: While there's a growing push for domestic manufacturing, the industry still relies heavily on imports for advanced components and high-efficiency systems.
7. Distribution Networks: The distribution of heat pumps varies by sector and application, involving:
    - Direct sales from manufacturers for large projects
    - Distributor networks for smaller commercial and residential applications
    - Specialized HVAC contractors for installation and maintenance
8. Technological Advancements: The rapid evolution of heat pump technology, especially in improving efficiency and expanding application ranges, necessitates continuous updates to the supply chain.

This fragmented and complex supply chain landscape presents both challenges and opportunities for the heat pump industry in India. It underscores the need for a more integrated approach to manufacturing, distribution, and service provision, as well as policies that can support the growth of domestic capabilities while ensuring access to advanced global technologies.

8.1 Review based on heat pump type and end use

The supply chain mapping can be revised from the following perspectives:

- By heat pump type:
    - Space heating: There are about 20 importers of such heat pumps of heating capacity less than 20 kW. The major importers are dominated by the traditional air conditioning suppliers. A review of the major importers in the past 2 years with the HSN code 84159000 was conducted to identify the major players in the market. There were 9 importers, and the top 3 importers were catering to over 98% of the import during the period as depicted in the figure below:

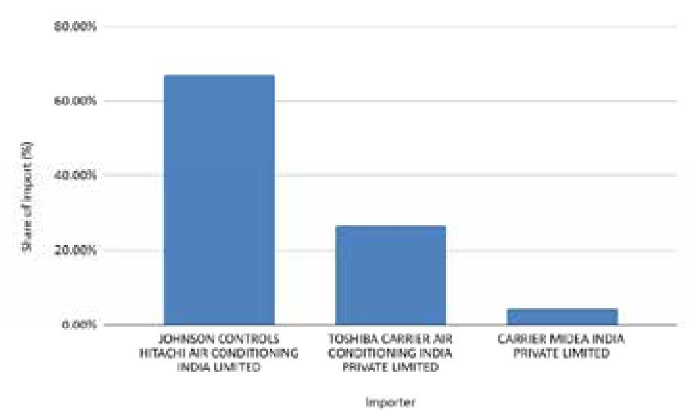


Figure 39: Key importers for space heating heat pumps

The heat pump market in India is predominantly led by major air conditioning suppliers who have expanded their product offerings to include heat pump technologies. These key players have adopted a versatile sales strategy that combines both direct sales and channel partner models. Through direct sales, they engage with large-scale projects and significant commercial or industrial clients, offering specialized attention and customized solutions. Simultaneously, they utilize a network of channel partners, including distributors, dealers, and authorized resellers, to expand their market reach, cater to smaller commercial and residential customers, and provide local support and after-sales services. This dual approach allows these companies to maintain a strong market presence, ensure comprehensive coverage across various customer segments and regions, and effectively address the diverse needs of the heat pump market, from standardized residential units to complex industrial applications.

- Water heating: There are about 100 importers of such heat pumps of heating capacity from a few kWs to 450 kW. The major importers are dominated by the suppliers in the business of providing water heating solutions (including solar water heaters), electric appliances etc. A review of the major importers in the past 2 years with the HSN codes 84186100, 85162900 and 84186990 was conducted to identify the major players in the market. There were 82 importers and the top nine (9) importers were catering to over 80% of the import during the period as depicted in the figure below:

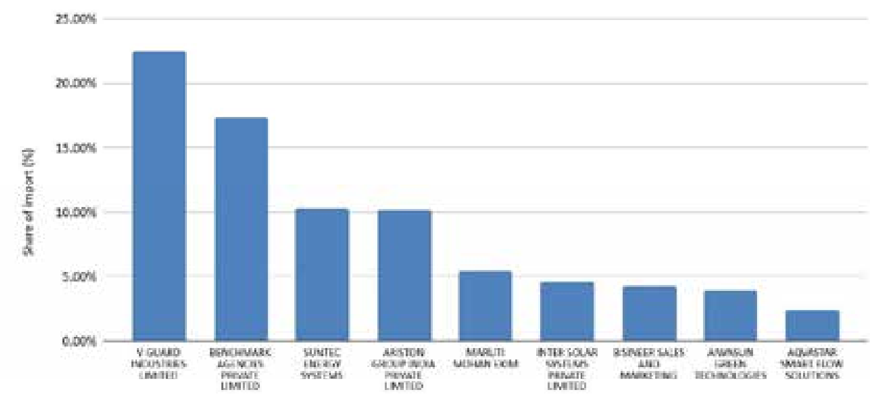


Figure 40: Key importers for water heating heat pumps

The key players comprise four (4) water heater/boiler manufacturers, two (2) electrical appliance suppliers, one (1) water solutions provider and one (1) swimming pool solutions provider. Most of these suppliers are operating their businesses through direct sale. However, another prominent player in this segment, A O Smith, operates through the channel partner model of implementation.

- By end use sectors: The complexity of the solution varies between the heat pump solutions in the end use sectors. However, for the water heating segment, there are mainly two (2) patterns for the delivery of heat pumps depicted in the figure below:

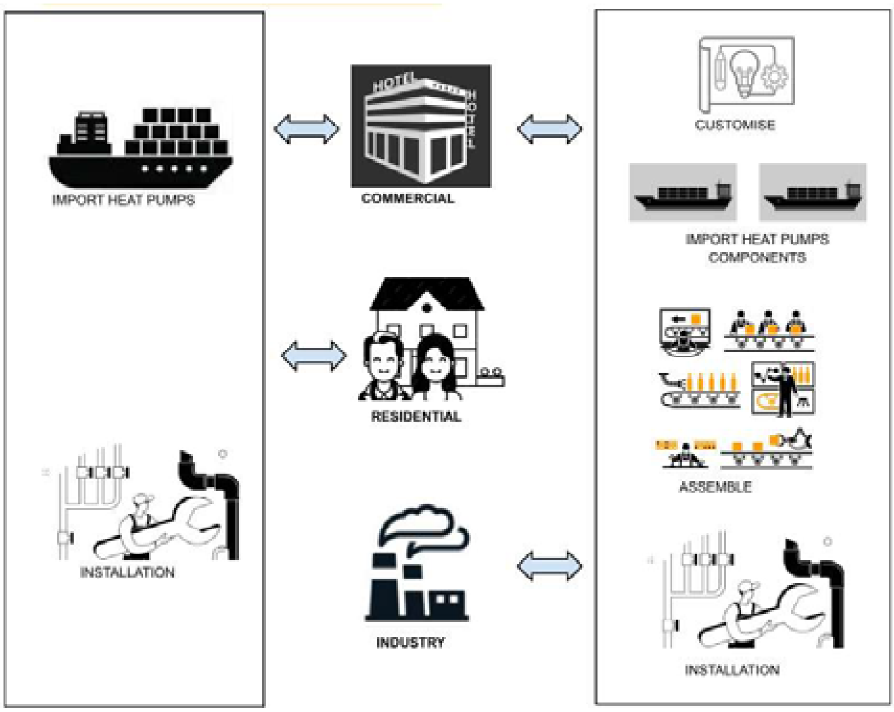


Figure 41: Heat pump activities for end use sectors

The heat pump market in India is characterized by distinct supply chain patterns across different segments:

1. Residential Segment: This sector is predominantly served by heat pump suppliers who import complete, skid-mounted units. These pre-assembled systems are then installed directly at the residential sites, offering a turnkey solution for homeowners.
2. Commercial Segment: The commercial market employs a hybrid approach to meet its heat pump needs: a) some projects utilize imported complete heat pump sets, similar to the residential segment. b) Others opt for a more customized approach, where individual components of the heat pump are imported separately. These parts are then assembled and installed on-site, allowing for greater flexibility in system design and adaptation to specific commercial requirements.
3. Industrial Segment: The industrial sector primarily relies on a component-based approach. This involves: a) Importing individual parts and components of heat pump systems. b) Assembling these components into complete units, either at a local facility or directly at the industrial site. c) Installation and integration of the assembled system into the industrial process.

This segmented approach reflects the varying complexity, scale, and customization needs across different end-use sectors. The residential market benefits from standardized, ready-to-install solutions, while the commercial and industrial segments often require more tailored systems to meet their specific heating and cooling demands. The reliance on imports, whether of complete units or individual components, underscores the current state of the Indian heat pump industry and its integration with global supply chains.

Of the components for the heat pump, many of the parts are imported in India. The most notable component which is the major cost head is the gas compressor. The refrigeration compressors are often imported under collaboration agreements or for special types or capacities that are not manufactured in the country[73]. Some compressors are also imported as part of projects awarded to foreign companies. Major air conditioner manufacturers like LG, Daikin, and Panasonic are starting or expanding production of AC compressors in India and is likely driven by the Production Linked Incentive (PLI) scheme for white goods[74]. On similar lines, PLI schemes for boosting compressors specific to heat pumps are necessary.

8.2 Review of initiatives for stakeholders

A non-exhaustive list of initiatives to boost the supply chain market and relevant for each stakeholder is presented in the table below:

Table 45: Stakeholders in the supply chain and preliminary list of initiatives

Manufacturer	Installers and contractors	Consumer
• Research and development grants • Product efficiency standards • Refrigerant regulations • Manufacturing tax incentives • Export promotion policies	• Training and certification programs • Installation standards and guidelines	• Purchase rebates and tax credits • Low-interest financing programs • Energy labelling and rating systems • Building energy performance standards • Utility bill savings guarantees
Utilities	**Building developers & owners**	**Local and regional government**
• Demand-side management programs • Time-of-use pricing schemes • Renewable energy integration policies	• Building codes and standards • Green building certification incentives • Property tax abatements for efficient buildings • Energy performance disclosure requirements	• Climate action plans • Clean energy targets • Zoning laws for heat pump installations • Public building retrofit programs
Energy Services Companies (ESCOs)	**Distributors and retailers**	**Research institutions**
• Performance contracting frameworks • Energy savings insurance programs • Measurement and verification standards	• Stocking incentives for efficient models • Sales training support • Marketing assistance for energy-efficient products	• Public-private research partnerships • Academic research grants • Technology demonstration project funding

[73] Review of refrigeration compressors, Department of Scientific and Industrial Research (Link)
[74] Import dependency for AC compressors may fall to 15% by 2027-28 | Company News - Business Standard

Financing institutions	Environmental groups	Industry associations
• Green financing guidelines • Risk mitigation instruments for energy efficiency loans • Carbon pricing mechanisms	• Public awareness campaign support • Policy advocacy frameworks • Community engagement program funding	• Standards development support • Market data collection and sharing policies • Industry representation in policy-making processes

8.3 Identified need for strengthening the supply chain

The areas that need strengthening in the heat pump supply chain in India include:

- **Component Supply/ Domestic Manufacturing**: Reduce the reliance on imports for advanced components and high-efficiency systems. Strengthening domestic manufacturing capabilities, especially for critical components like compressors, is crucial.
- **Customization and Integration**: Improving capabilities to customize heat pump solutions for specific applications and integrate them with existing HVAC or process heating systems.
- **Distribution Networks**: Enhancing the distribution networks, particularly for smaller commercial and residential applications, and specialized HVAC contractors for installation and maintenance.
- **After-sales Service**: Improving after-sales service and maintenance capabilities, particularly for imported systems.
- **Skilled Workforce**: Developing a skilled workforce for installation, maintenance, and customization of heat pump systems.
- **Standards and Regulations**: Developing comprehensive standards and regulations specific to the Indian market and climate conditions.
- **Technological Advancements**: Keeping pace with rapid technological evolution in heat pump efficiency and application ranges.
- **Research and Development**: Increasing R&D efforts to develop heat pump technologies suited to local conditions and requirements.

Strengthening these areas would help in developing a more robust and self-reliant heat pump industry in India

CHAPTER 9:
Gap Assessment

9. Gap Assessment

While heat pumps offer a promising solution for sustainable heating and cooling in India, several gaps hinder their rapid deployment.

Area	Gap
Market and Policy	• Energy costs are low (e.g., when using coal and biomass), which makes heat pumps a less attractive investment. As a result, specific financial incentives are unavailable, which are needed to encourage end-users to adopt heat pumps. • The high upfront cost of heat pump technology remains a significant deterrent to its widespread adoption in India, particularly given the country's price-sensitive market. This initial investment barrier is especially challenging in a nation where many households and businesses prioritize immediate affordability over long-term energy savings, despite the potential for reduced operational costs and environmental benefits that heat pumps offer. • Absence of reliable data on the performance of heat pumps for different applications. The absence of standardised testing procedures for performance assessment of heat pumps is a deterrent. • A supporting policy along with financial incentives encouraging the deployment of heat pumps is also absent.
Technology	• Limited domestic manufacturing capacity, with high reliance on imports, resulting in longer delivery times and higher capital expenditure. • The domestic supply chain is weak, with fewer players dominating components like compressors and refrigerants. • The extent of RD&D for heat pump technologies which are suitable for applications across the different climatic zones in the country is limited.
Capacity	• Limited availability of skilled technicians who can install and maintain heat pumps. • Limited awareness and understanding. There is limited understanding amongst the entire value chain, which is a deterrent. Further, the perception of air source heat pumps' effectiveness is often sceptical due to the region's extreme temperature swings • At present, there are no training programs to inform relevant stakeholders of the benefits of heat pump adoption or build a skilled workforce for its installation and maintenance.

By addressing these gaps and taking proactive measures, India can unlock the potential of heat pumps for sustainable heating and cooling, contributing to energy efficiency and environmental protection.

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