PACE-D Technical Assistance Program

HVAC Market Assessment and Transformation Approach for India

August 2014

This report is made possible by the support of the American People through the United States Agency for International Development (USAID). The contents of this report are the sole responsibility of Nexant, Inc. and do not necessarily reflect the views of USAID or the United States Government. This report was prepared under Contract Number AID-386-C-12-00001.

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ACRONYMS

Abbreviation	Definition
AIA	Airport Authority of India
ABT	Availability Based Tariff
AC	Air Conditioner
AHRI	Air-Conditioning Heating and Refrigeration Institute
AHU	Air Handling Unit
ASHRAE	American Society of Heating Refrigeration and Air-Conditioning Engineers
BEE	Bureau of Energy Efficiency
BPO	Business Process Outsourcing
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CHP	Combined Heat and Power
CII	Confederation of Indian Industry
COP	Coefficient of Performance
DISCOM	Distribution Company
DSM	Demand Side Management
DX	Direct Expansion
EAC	Evaporative Air-Conditioning
ECO	Energy Conservation and Commercialization
EE	Energy Efficiency
ECBC	Energy Conservation Building Code
EER	Energy Efficiency Rating
ESCO	Energy Service Company
ESEER	European Seasonal Energy Efficiency Ratio
FCU	Fan Coil Unit
FDI	Foreign Direct Investment
FY	Financial Year
GDP	Gross Domestic Product
GOI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
GW	Gigawatt
Gwh	Gigawatt hours
HRV	Heat Reclaim Ventilation
HS	Harmonized System
HV	High Voltage
HVAC	Heating Ventilation and Air-Conditioning
IGBC	Indian Green Building Council
IMTMA	Indian Machine Tool Manufacturers' Association
INR	Indian Rupee
IS Code	Indian Standard Code
ISHRAE	Indian Society of Heating Refrigeration and Air-Conditioning Engineers
IT	Information Technology
LBNL	Lawrence Berkeley National Laboratory
PACE-D TA	Partnership to Advance Clean Energy – Deployment Technical Assistance
PTAC	Packaged Terminal Air Conditioners
LEED	Leadership in Energy & Environmental Design
MNRE	Ministry of New and Renewable Energy
MOEF	Ministry of Environment and Forests

Abbreviation	Definition
MOP	Ministry of Power
NCR	National Capital Region
PTAC	Packaged Terminal Air Conditioner
RAMA	Refrigeration and Air-Conditioning Manufacturers Association
RTU	Roof Top Unit
SEER	Seasonal Energy Efficiency Rating
USAID	United States Agency for International Development
TR	Ton of Refrigeration
VAMS	Vapor Absorption Machines
VAV	Variable Air Volume
VRF	Variable Refrigerant Flow
VRV	Variable Refrigerant Volume

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EXECUTIVE SUMMARY

As India's economy and population continue to expand rapidly, meeting the nation's energy needs requires careful planning. India's building sector is forecast to experience large expansion, and the air-conditioning for this space would be a significant energy use. Given this scenario, the need to optimize energy use by heating, ventilating, and air-conditioning (HVAC) systems, takes on added urgency. In order to develop market transformation strategies and energy efficiency programs, the characteristics of the Indian HVAC market need to be defined.

Objective

The objective of this study is to characterize the Indian HVAC market. The study tries to outline the established practices in the HVAC industry as well as market response to energy efficiency. With the present situation as its base, estimates of the market share of energy efficiency (EE) technologies in the HVAC industry were arrived at. Furthermore, responses were sought regarding the perception and awareness of EE technologies amongst key decision makers, and perceived and actual barriers to deployment of energy efficiency.

Methodology

Extensive market research was conducted nationwide, with primary data collected through in-depth interviews and semi-structured questionnaires. Representation of a wide cross-section of stakeholders was ensured during the market research. Questionnaires were aimed at characterizing the current HVAC market, current and emerging technologies, future projections, and identifying barriers to energy efficiency. The research also included review of papers, journals, trade publications, and technical articles pertaining to the Indian HVAC market.

Market Characteristics

Based on the evaluation of current HVAC market, the following market trends are observed:

1. The market share of the common window air-conditioners and portable units is shrinking, and this trend is expected to continue.
2. Ductless split systems dominate the small commercial and residential market segment and their market is forecast to grow over the next few years.
3. Sales of Variable Refrigerant Flow (VRF)/Variable Refrigerant Volume (VRV) systems have grown by over 30 percent in value and total cooling capacity sold, despite reduction in average selling prices. The growth rates in market volume is higher. Growth rate of over 20 percent is projected over the next few years. The average selling prices of VRF systems are projected to decline by about 2.2 percent from 2010 prices by 2015. The market share of small chillers and packaged HVAC systems is being taken over by VRF systems.
5. Large centrifugal chiller sales decreased in 2012, primarily because of the global economic downturn and the resultant decrease in demand from Indian customers. Chillers with capacities greater than 700 kW are expected to grow 34 percent by 2016. Market value of air-cooled chillers is predicted to increase by about 36 percent by 2016. Water-cooled chillers are expected to follow the same trend but on a slightly lower scale.
6. The absorption chiller market has been affected by high gas prices, with residential, retail and office spaces reluctant about adopting the technology.
7. New approaches and technologies like district cooling plants have a potential market but the industry structure is not conducive to district plants and very few exist as of now. Coupling this system with solar thermal is an expensive option with a minimum payback period of 6 years.
8. AHUs (air handling units) are being increasingly used in HVAC systems.

Market Perspective

Some of the main findings from the study regarding the market decision-making process are shown below:

1. Building owners are the key decision makers for purchasing HVAC systems, followed by design engineers, and consultants.
2. In non-residential buildings, central chilled water systems are the preferred option for majority of the projects.
3. Energy efficiency and reliability prevail over other parameters during the purchase of HVAC systems across categories covering large systems. Interestingly, for smaller systems, maintenance and good after sales service are over-riding concerns. Reasonable price emerges as the next important reason for purchase consideration in the case of HVAC systems.
4. While heat recovery systems and passive dehumidification are expected to be in demand in the near future, the overall response to new technologies is lukewarm.

Market Transformation Approach

Based on the characteristics of the market, the broad framework for achieving market transformation is laid out. The market transformation approach for the HVAC sector in India needs to address the following major concerns in order to establish a market for high performance HVAC systems and equipment:

- Information Barrier
- Cost Barrier
- Policy
- Implementation

The steps needed to overcome the above barriers and achieve market transformation include:

1. Capacity building of independent institutions to test, verify and disseminate HVAC knowledge
2. Developing an HVAC test and demonstration facility to demonstrate and train
3. Mandatory enforcement of HVAC equipment efficiencies specified in the Energy Efficiency Building Codes
4. More stringent energy efficiency standards and labeling of HVAC equipment
5. Energy efficiency HVAC demonstration projects
6. Large scale renovation and energy efficiency design for HVAC systems in existing as well as new public buildings
7. Utility-driven HVAC energy efficiency programs targeting residential and commercial buildings.

1 INTRODUCTION

Building construction is projected to increase rapidly as India experiences rapid economic and population growth. Total constructed area in 2005 was around 2,100 million square meters and is predicted to grow five-fold to reach 10,400 million square meters in 2030.[2] Overall, the sector will achieve a compound annual growth rate of 6.6 percent.[3] This growth will be steered by the residential and commercial sectors, which will expand by four to five times from 2005 levels. Given this scenario, the need to optimize energy use by Heating, Ventilating and Air-conditioning (HVAC) systems, takes on added urgency.

HVAC: Potential for Improving Energy Efficiency

HVAC systems contribute to 31 percent of the energy used by commercial buildings in India.[4] An important objective of an energy efficient building, therefore, must be to optimize the air-conditioning systems.

Buildings account for more than 20 percent of total energy use in India. With market penetration for HVAC as low as three percent, it is estimated that the growth rate in this sector has been 20 percent per annum over the last decade, and is expected to accelerate to 30 percent per annum over the next five years.[5] Enhancing the efficiency of HVAC systems, powering these systems through renewable sources, and reducing heating/cooling loads are steps that are imperative for any building energy efficiency policy.

Institutional Framework

The country has a limited number of policy initiatives in place to mainstream energy efficiency and green buildings through control and regulatory instruments, including appliance standards, mandatory labeling and certification, energy efficiency obligations, and utility DSM (demand side management) programs; economic and market-based instruments; fiscal instruments and incentives; and information and voluntary action.

Thus far, the energy efficiency/building-related policy framework in India addresses and recognizes incremental reductions in energy use. The Energy Conservation Building Code (ECBC) was launched by the Bureau of Energy Efficiency (BEE), Ministry of Power, in 2007, on a voluntary basis. The code is applicable to commercial buildings or building complexes that have a connected load of 100 kW or greater or a contract demand of 120 kVA or greater. The ECBC stipulates minimum performance standards for building envelope, lighting, and mechanical systems. Green building rating systems like Green Rating for Integrated Habitat Assessment (GRIHA) and Leadership in Energy and Environmental Design (LEED) are also extensively used in India. The rating systems specify minimum performance criteria, while also allowing for a whole building performance approach. In addition to the measures mentioned above, the BEE is in the process of developing a chiller efficiency rating program. The Indian Society of Heating, Refrigerating, and Air Conditioning Engineers (ISHRAE), in partnership with the trade association Refrigeration and Air-conditioning Manufacturers' Association (RAMA), has been working towards modifying the Air-Conditioning, Heating and Refrigeration Institute (AHRI) standards to account for ambient conditions in India. Some of these organizations and policies are described in more detail in the following sections.

While these are important stepping-stones towards reducing dependence on fossil fuels for meeting energy needs of buildings, conventional systems continue to dominate the buildings sector. A few commercial buildings in the country are equipped with unconventional HVAC systems that are demonstrably energy-efficient or powered by renewable energy. Notable among these are the Pocharam campus of Infosys at Hyderabad that uses radiant

[2] PACE-D Research

[3] Reducing GHG Emissions in the Building Sector in India, A Strategy Paper by Environmental Design Solutions for Climate Works Foundation. April 2010.

[4] PACE-D Research

[5] http://docs.nrdc.org/international/files/int_12111201a.pdf

cooling and the Indian Machine Tool Manufacturers' Association (IMTMA) Exhibition Center in Bangalore that uses evaporative cooling. Several industrial and process buildings use two-stage evaporative cooling, while a few projects are experimenting with ground source heat pump systems. Such endeavors remain sporadic, tentative, and infrequent.

As mentioned earlier, the BEE, RAMA, and ISHRAE have been promoting energy efficiency and the establishment of standards for HVAC systems. The BEE, established in 2002, is already working towards adoption of the ECBC as a mandatory energy code. A minimum performance requirement for mechanical equipment forms an integral part of this code. Section on Current Policies related to HVAC further describes the pivotal role of the BEE in the advancement of energy efficiency goals. ISHRAE, established in 1981 as an associate of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), recognizes the need for, and is committed to, the establishment of a facility for reliable testing, rating, and certification of HVAC equipment. After the formation of its headquarters in Delhi, a subsequent Chapter was started in Bangalore in 1989. Between 1989 and 1993, ISHRAE Chapters were formed in all major cities in India and in the Middle East, firmly positioning it to pursue its objectives of technological improvements and supporting research related to HVAC. RAMA was formed in 1991 to promote the growth of the HVAC industry in India. One of its stated missions is to facilitate adoption of standards related to energy efficiency, manufacturing, and environmental management of HVAC systems and equipment.

Current Policies Related to HVAC

Several current policies or certifications related to energy efficiency, the environment, and standards and labeling directly or indirectly address the efficiency of HVAC systems. Some of these are:

- **Energy Conservation Building Code 2007**. The Energy Conservation Act, 2001 provides for the institutional arrangement and establishment of national and state-level energy conservation agencies to plan and execute energy efficiency programs. The Act led to the formation of the BEE that formulated the ECBC. It targets building energy efficiency and was introduced in the year 2007. This is the nation's first building energy code and aims to have a major impact on energy efficiency in buildings. It covers minimum requirements for building envelope performance as well as for mechanical systems and equipment, including HVAC systems, interior and exterior lighting systems, service hot water, electrical power and motors in order to achieve energy efficiency in different climate zones in India.

- **Environmental Impact Assessment (EIA) and Clearance from the Ministry of Environment and Forests (MOEF).** This is a mandatory requirement for all buildings with a built-up area above 20,000 sq. m. and such projects have to be appraised by the MOEF's Environmental Appraisal Committees (EACs) and the State Environmental Appraisal Committees (SEACs). The Ministry of New and Renewable Energy (MNRE) has initiated several programs focusing on the utilization of renewable energy sources in buildings.

- **Sustainable Habitat Mission under the National Action Plan on Climate Change (NAPCC).** This was launched on June 30, 2008. It encompasses a broad and extensive range of measures, and focuses on eight missions, which will be pursued as key components of the strategy for sustainable development. These include missions on solar energy, enhanced energy efficiency, sustainable habitat, conserving water, sustaining the Himalayan ecosystem, creating a "Green India," sustainable agriculture and, finally, establishing a strategic knowledge platform for climate change. For the habitat mission, the strategies proposed aim at promoting efficiency in the residential and commercial sector through various measures such as changes in building bye-laws, capacity building, research and development in new technologies, awareness, etc., management of municipal solid wastes, and promotion of urban public transport.

- **Energy Labeling of Appliances.** Launched by the BEE, it sets energy performance standards for refrigerators, air conditioners, motors and other appliances. Labeled products have been on the market since 2006. In a move to manage energy demand, the BEE made star rating for energy efficiency mandatory for a host of electrical appliances from September 20, 2008. The implementation of this mandate has resulted in increased adoption of energy efficiency amongst end users and the industry.

- **City Level Regulations.** These are a set of building guidelines in the form of building bye-laws, which are eventually implemented at the town and city level by the respective Development Authorities and Municipal Corporations/Municipalities. These bye-laws, however, currently have not been able to integrate the ECBC provisions and other sustainability parameters.

- **Green Building Rating Systems.** This is a popular tool to bring momentum in achieving energy efficiency and sustainability in buildings. The country has currently two rating systems, namely, LEED and GRIHA. The LEED Green Building Rating System™, developed and managed by the USGBC, is the most widely-used rating system in North America. Buildings are given ratings of platinum, gold, silver, or "certified", based on green building attributes. The Indian Green Building Council (IGBC) founded by the collaboration between the Confederation of Indian Industry (CII) and the private manufacturer Godrej, has taken steps to promote the green building concept in India. Currently, the IGBC is facilitating the LEED rating of the U.S. Green Building Council in India. LEED-India was launched in 2001, and rates buildings on environmental performance and energy efficiency during the design, construction and operation stages. The MNRE has adopted the GRIHA, which was developed by The Energy and Resources Institute (TERI). An indigenously-developed rating system, it accommodates climate variations, architectural practices, existing construction practices, and passive solar architecture. The GRIHA rating system takes into account the provisions of the National Building Code, 2005, the Energy Conservation Building Code, 2007 announced by the BEE, and other Indian Standard (IS) codes. This was developed with air-conditioned buildings sharing the emphasis with unconditioned and partially air-conditioned buildings.

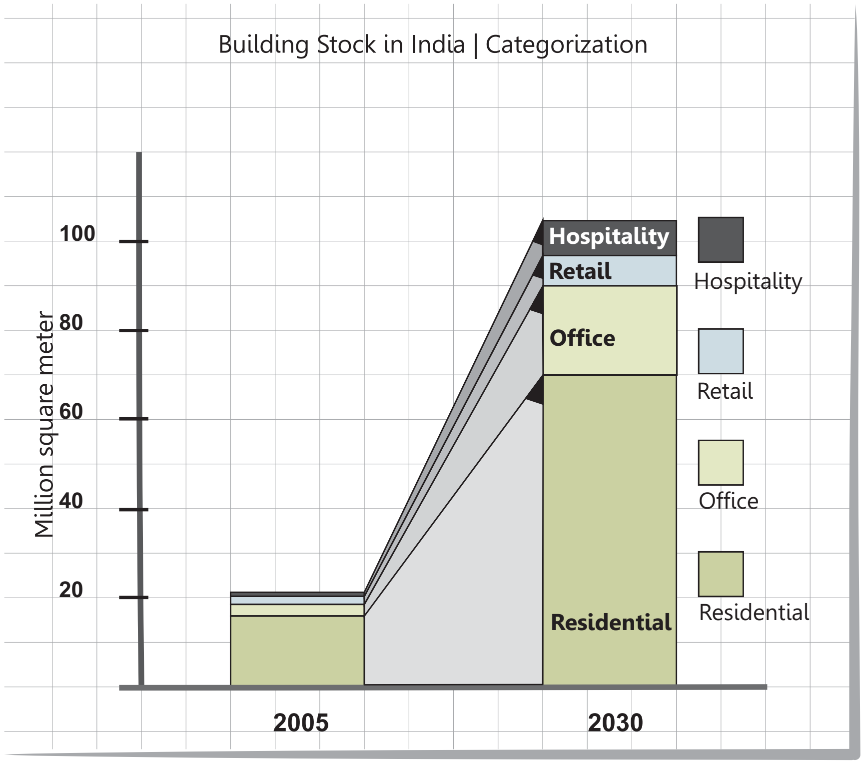
2 BUILDING STOCK AND GROWTH TRENDS

HVAC industry trends closely reflect the fluctuations within the buildings sector, as the latter provides the primary impetus to HVAC demand. Within this sector, the commercial, residential, and infrastructure subsectors extensively use HVAC systems for maintaining comfort conditions. A comprehensive examination of the current building stock, growth potential, and direction of growth, is therefore, vital to this study. HVAC systems are also one of the major consumers of energy within a building – accounting for approximately 31 percent of energy use in commercial buildings and 7 percent in residential buildings. The use of a particular HVAC technology is contingent upon the size, location, and occupancy of a building.

Current Stock and Growth

Very few studies in India have attempted to estimate the total residential and commercial space that currently exists in the country. The PACE-D TA Program reviewed the data from external sources and its own previous estimates to determine the existing building stock (for year 2005) and the projected (for year 2030). Total constructed area in 2005 was around 2,100 million square meters and is predicted to grow five-fold to reach around 10,400 million square meters in 2030 (Figure 1). Overall, the sector will achieve a compound annual growth rate of 6.6 percent.[6] This growth will be steered by the residential and commercial sectors, which will expand by four to five times from 2005 levels. Expanding population and greater economic activity will be the main triggers for this growth.

Figure 1: Building Stock in India – 2005 to 2030



[6]Reducing GHG Emissions in the Building Sector in India; A strategy paper by Environmental Design Solutions for ClimateWorks Foundation, April 2010.

Commercial

PACE-D TA Program research estimates commercial floor space to increase from a total stock of 458 million square meters in 2005 to 3,435 million square meters in 2030 (CAGR of 8.39 percent). This compares well with the USAID's Energy Conservation and Commercialization (ECO-III) study that estimated the total commercial floor space area to be approximately 516 million square meters in 2005, and expected this to expand three times to 1,930 million square meters by 2030.[7] It may be concluded, therefore, that about 70 percent of the 2030 commercial building stock is yet to be built.

Commercial space can be further divided into retail, offices, hospitality, hospitals, and educational/institutional buildings. Positive growth trends in the commercial sector will be led by retail and hospitality space, which will grow by 7 and 11 times respectively.

Retail

The retail sector in India started to expand during the period of economic liberalization after 1991. At present, the Indian retail sector is ranked amongst the top five in the world in terms of value. Retail floor space growth rates are high despite its smaller footprint compared to office space. Total retail space will likely grow from 95 million square meters in 2005 to about 643 million in 2030, achieving a CAGR of nearly 8 percent (Figure 1). As studies have shown, about 9.3 million square meters have been added from 2009 to 2012. In 2013, the Indian government opened Foreign Direct Investment (FDI) to international retail brands.[8] The resulting increase in penetration and rising purchasing power will boost construction activity in this sector. New retail space is likely to be concentrated in the largest urban centers of the country, as shown in Figure 2.

Offices

Existing office space area in India as of 2005 was estimated to be 290 million square meters and is expected to expand seven times to 2,000 million square meters by 2030, with a CAGR of 8 percent. Demand will be led by private sector entities in the Information Technology (IT) and Business Process Outsourcing (BPO) sectors.[9]

Educational and Institutional Areas

Total floor space area of educational and institutional areas was calculated to be around 79.5 million square meters in the USAID ECO-III study. The sector grew by an estimated 19 percent CAGR from 2009 to 2012, according to data from market studies.

Hospitality

The hospitality sector is projected to grow steeply, from 73 million square meters in 2005 to 791 million square meters, sustaining a CAGR of 10 percent. The present estimate of 114,000 hotel rooms in India across various categories falls short of the projected requirement by 150,000 rooms. The majority of market players have predicted a long-term preference for the budget and mid-market hotel segment.[10]

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[7] Total Commercial Floor Space Estimates, Energy Conservation and Commercialization (ECO-III), June 2010. Commercial floor space included retail, educational, hospitality, healthcare,
public and private offices, wholesale trade etc.
[8] Air-Conditioning Sector, Emkay Research, 2010.
[9] Air-Conditioning Sector, Emkay Research, 2010.
[10] Hospitality insights – From the Indian CEO's desk. PricewaterhouseCoopers (PWC), 2008

Healthcare

Total floor space for the healthcare sector (hospitals, clinics, nursing homes, and primary health centers) was estimated to be around 22 million square meters in 2005.[11] Market studies from 2010 suggest that the private players in this segment are planning to add 32,600 beds by 2015, which translates into a growth of 30 percent. Growth trends are also expected to be positive beyond 2015. Investment in healthcare infrastructure will come in the wake of the health care needs of a swiftly growing population.

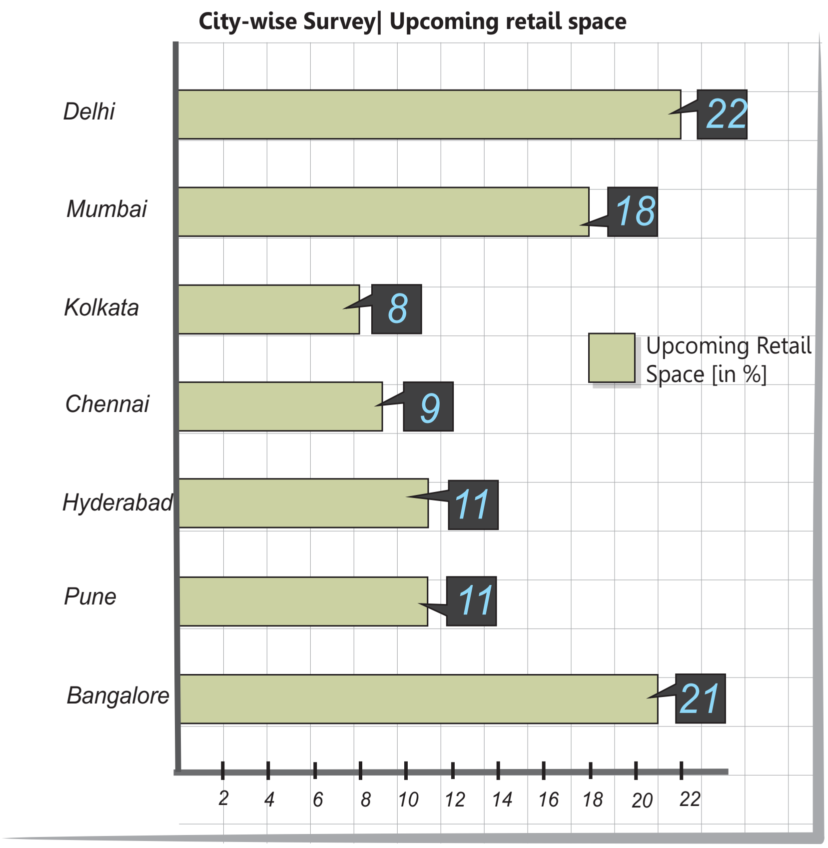
Residential

The residential sector is expanding due to population growth and migration from rural to urban areas for employment opportunities. Estimated to be around 1,630 million square meters in 2005, this sector is projected to swell to nearly 6,982 million square meters with a CAGR of 6 percent. Nearly 38 million new houses were built in urban areas in the 10 years between 2001 and 2011.[12] Multifamily housing is gradually becoming the predominant sub-sector in urban areas and will be a game changer as more high-rise residential developments install HVAC systems for comfort conditioning.

Infrastructure

Together with passenger and administrative facilities, retail spaces in airports and metro stations require HVAC systems for space conditioning. The Airport Authority of India (AAI) is planning to increase the total number of privately and publicly operated airports in the country from 436 to 500. Passenger traffic and cargo traffic grew at a CAGR of 15 percent and 20 percent respectively from 2007 to 2012. The Indian government has also announced modernization of four metro airports and the development of 35 new non-metro airport projects.[13] Existing metro and airport facilities are being expanded in the largest Indian cities, including the National Capital Region (NCR), Mumbai, Bengaluru, Chennai, Jaipur, Kolkata and Hyderabad.

Figure 2: Growth Rates for Retail Space in Indian Cities



[11]Total Commercial Floor Space Estimates, Energy Conservation and Commercialization (ECO-III), June 2010.
[12]Housing: Household amenities and assets – Census of India
[13]Infrastructure in India, A Vast Land of Construction Opportunity. PricewaterhouseCoopers (PWC), 2008.

Energy Use

India is the world's fifth largest electricity generating country, with an installed capacity of 249.48 Gigawatt (GW) (figures as in June 2014). Total electricity consumption in India during 2011-2012 was 772,603 Gigawatt Hours (Gwh).[14]

The breakdown in electricity consumption for 2011-2012 was as follows. The industrial sector consumed the major portion (44.8 percent) followed by the residential (22 percent), agricultural (17.3 percent) and commercial (9 percent) sectors.[15] The residential and commercial sectors together consume about 31 percent of the total, or about 239,506 GWh. Despite the huge energy generation capacity, the energy deficit in 2011-2012 was approximately 7.4 percent. The highest increase in electricity consumption was witnessed in the residential sector (9.4 percent CAGR from 1971 to 2012), followed by the commercial sector.

To estimate the projected demand from the different building sectors, the PACE-D TA Program relied on the previous studies and field experience in designing buildings to estimate the energy use due to HVAC systems in buildings. Average energy consumption in conventional residential buildings is nearly 60 kWh/square meter/year. Commercial buildings consume an average of 210 kWh/square meters/year.

Energy used for HVAC

Air-conditioning systems consume up to 31 percent of the total energy use in a conventional commercial building in the country (Figure 3). In residential buildings this share is comparatively less, at 7 percent of overall energy consumption. New and green buildings have systems that are more efficient and deliver better performance.

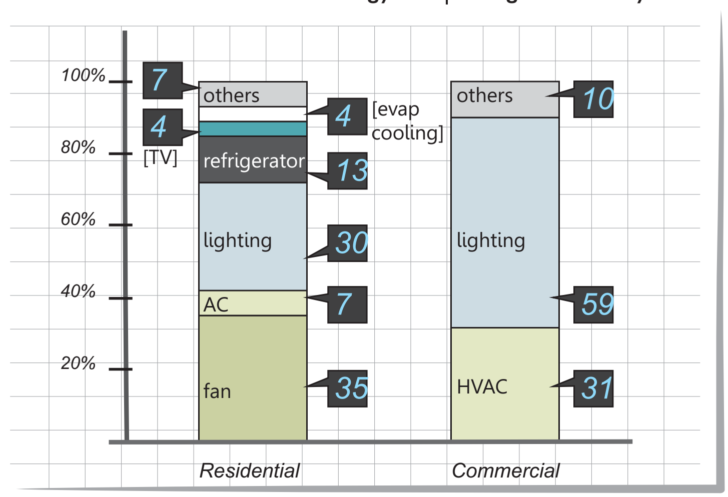
Applications for HVAC Systems

Cooling capacity, number and area of spaces or zones to be cooled (or heated), desired indoor temperature and humidity conditions determine the type of HVAC system used. A single residential unit will have lower cooling capacities and smaller spaces compared to commercial establishments.

The PACE-D TA Program documented common applications of HVAC systems through the survey. VRF/VRV systems have emerged as the most versatile, with substantial market share across residential, infrastructure and commercial sectors. Chillers are limited to large to medium-sized commercial and other infrastructure projects.

Figure 3: Residential and Commercial Energy End Use

Residential and Commercial Energy-use | Categorization by end-use



Source: PACE-D research

[14]All the building sub-sectors that are discussed in this report use electricity as the main source of secondary energy and consequently, this section will highlight the energy scenario and challenges in these building sectors in terms of electricity consumption and generation. Electricity is produced mainly from conventional primary energy sources in India – thermal energy (coal, petroleum, natural gas, etc.) and nuclear energy.

[15]Energy Statistics 2013, Central Statistics Office, National Statistical Organization, Ministry of Statistics and Programme Implementation, GOI.

Table1: Application of HVAC Systems by Building Type

Segments	Types of Chillers/HVAC Used
Residential	Predominantly window and un-ducted split systems. High-end residential buildings have also started using VRF/VRV systems.
Infrastructure (Airports/Metros)	Demand for water-cooled chillers (centrifugal and screw chillers specifically) is more because of higher tonnage requirements and greater efficiency. VRF systems are installed in smaller facilities and in buildings with specific space conditioning needs within large infrastructure projects.
Healthcare	Centrifugal, screw and water-cooled chillers are common.
Education	VRF systems are preferred in smaller establishments and centrifugal systems are more in demand in large projects.

PACE-D research

The PACE-D TA Program reviewed growth estimates for important sectors in the building industry. In terms of constructed area, the maximum growth will be seen by residential and commercial sectors, reaching four to five times the 2005 figures by 2030.

3 METHODOLOGY AND APPROACH

Market response to increased operational energy-use efficiency of HVAC products and systems formed the basis of this study. The market response helped determine the current trends and established practices in the HVAC industry. A clear understanding of the prevalent system sizes and types was obtained through the responses.

With the present situation as its base, estimates of the market share of EE technologies in the HVAC industry were arrived at.

Data Collection and Survey Structure

The assessment study findings are derived from primary and secondary research carried out as part of the PACE-D TA Program. A market research team[16] assisted the program in conducting an extensive survey of stakeholders along with one-to-one interviews – this constituted the primary data. Considerable effort was made to ensure that representativeness of a wide cross-section of stakeholders across the value chain were included in this study. Detailed survey questionnaires (attached in Annex 1 – Market Assessment Questionnaire) were developed for different categories of these stakeholders. The information sought included technologies, future projections, bottle-necks, and their suggestions on increasing energy efficiency in the market. Secondary research included conducting analysis of papers in peer-reviewed journals, publications, and technical articles pertaining to the Indian HVAC market.

Primary Research

Primary research for the project was conducted in two stages. At the first stage, in-depth interviews were conducted to obtain qualitative data from the industry. These were supplemented by semi-structured interviews with industry experts to obtain quantitative data. The primary interactions were undertaken with defined stakeholders with the objective of understanding the current market scenario and trends.

Several key manufacturers and vendors contacted initially (to assess the level of market penetration of EE technologies in the HVAC industry) were reticent about sharing information on the specific sale trends for the EE systems in their portfolio of products. To resolve this issue, the study determined diffusion of selected HVAC systems, the existing volume of sales, and growth potential, from manufacturers' brochures and information sheets. These were available more readily. The data obtained was eventually analyzed to determine the share of EE HVAC systems vis-à-vis conventional systems within the larger selected segments.

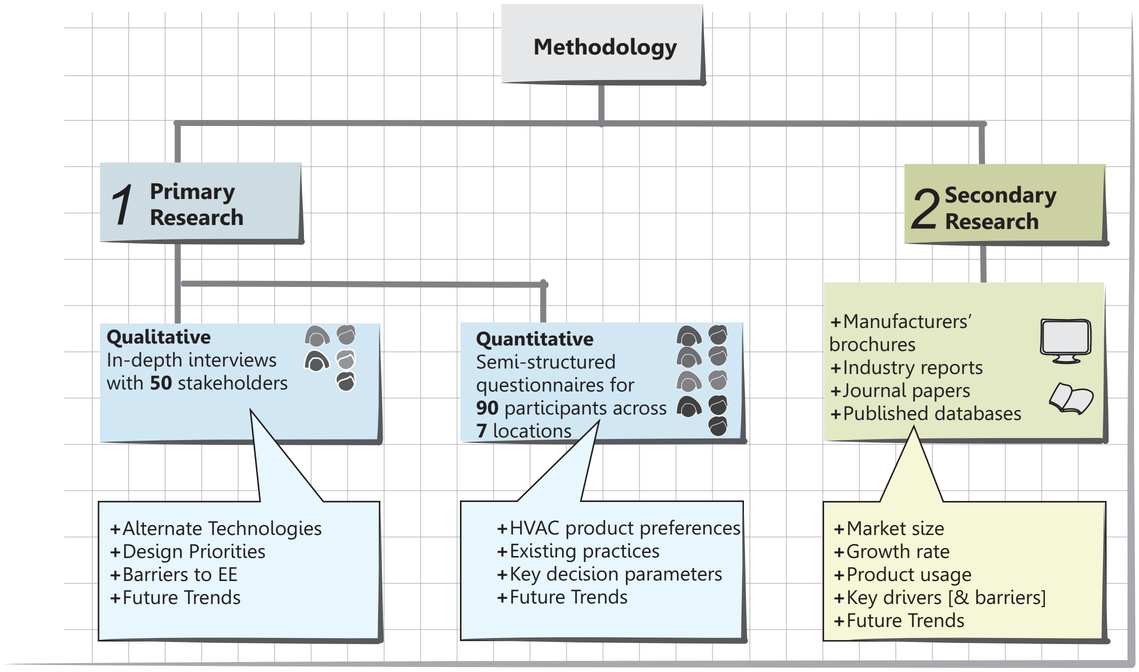
Identification of stakeholders

The key stakeholders interviewed and consulted during the process included:

- Manufacturers
- Distributors
- Consultants/Architects
- End-users
  - Hotels, Hospitals, Malls, Offices, Multiplexes
- Builders, Developers
- Manufacturing Associations
- Facility Management Companies

[16] Market Xcel conducted the surveys designed by PACE-D TA Program.

Figure 4: Market Research Methodology



Source: PACE-D research

The rationale behind selecting these stakeholders is highlighted below:
Manufacturers: An important group of stakeholders, as they are responsible for sourcing as well as testing of products. They undertake the design and testing of products in line with local and international test procedures.

Distributors: A key interface between manufacturers and end-users, distributors play a major role in influencing purchase decisions. The insight provided by this group was crucial in determining product, brand, type, or technology in demand. In addition, they provided insights on usage patterns across various segments.

Consultants/Architects: They provided a broad overview of market conditions and consumer demands. As they form an integral part of the design team, their perspective on how they view the current scenario, their understanding of energy efficiency, and their vision for its future, is important for understanding the market.

Builders/Developers: Builders/developers form a major user group as they install chillers in their own developed commercial and residential buildings. This end-users' group was also an important information source for understanding the decision-making process for selecting particular HVAC systems.

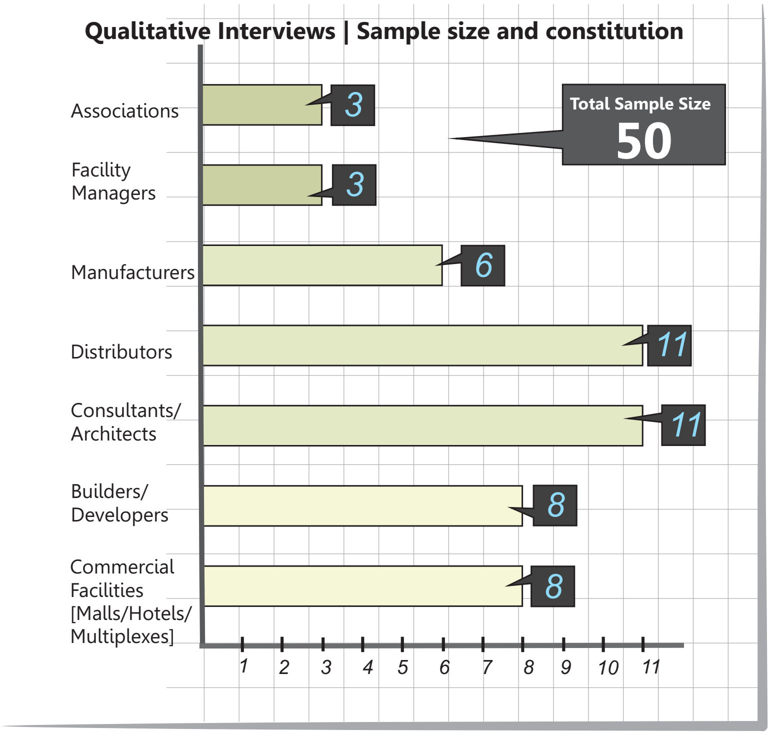
End-users: Product purchase decision-making in India is seen as a complex process, involving factors that go beyond performance-related issues. End-users provided important insights into these factors. They also provided data on performance, usage patterns, and maintenance issues. Most importantly, they allowed an analysis of prevailing attitudes and trends with respect to EE systems. Their responses covered the following issues:

- Current priorities of end-users when buying a specific appliance
- Influencing factors in purchase decision (advertisements, selling techniques, information sources, technologies, types, price, certifications)
- Role of operating cost economics in product selection
- Current possession and usage of said appliance
- Attitude and importance placed on energy issues and conservation (awareness)
- Future usage patterns
- Profiling data (occupation, turnover, usage behavior, purpose of usage)

Interviews

Face-to-face interviews were conducted so as to obtain qualitative data. Figure 5 highlights the sample size and breakdown of stakeholders interviewed in the process:

Figure 5: Qualitative Interviews: Sample Size and Breakdown

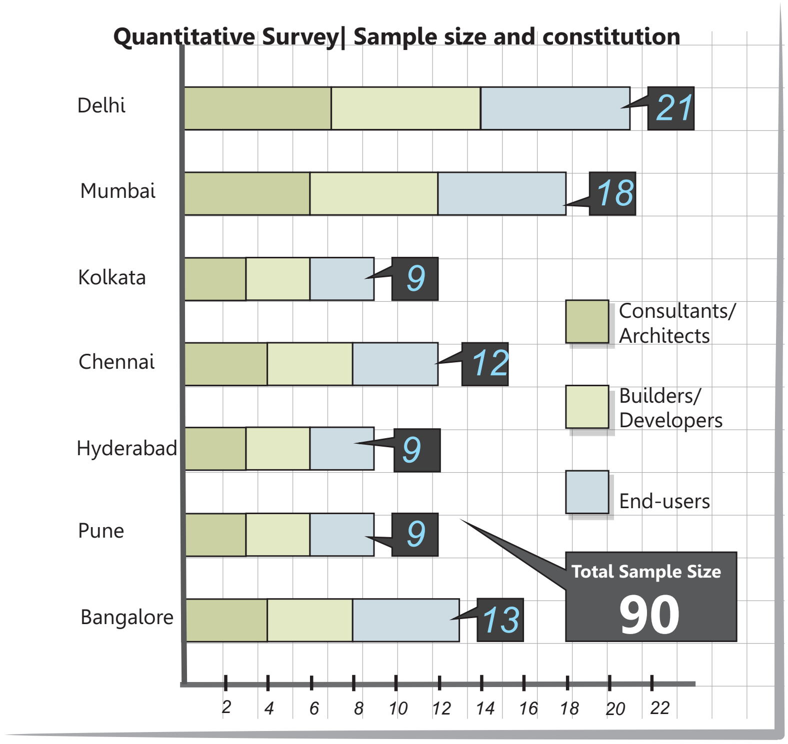


Source: PACE-D research

As summarized in the figure above, 50 interviews were conducted during the first phase of the primary research process to obtain qualitative data. For the second phase of the research, semi-structured interviews were carried out with identified experts located across five different climate conditions in India. The selection criteria covered the climate zone within which the city was located, the extent of urbanization, affordability factors, and the existence of respondent groups within the cities. Together, these cities account for a majority of the demand for HVAC equipment in the country. Although energy efficient products are vital for India as a nation, including small and large cities as well as rural areas, chillers are largely prevalent only in the Metro and Tier 1 cities of India.

Figure 6 highlights the construct for the second stage. A total of 90 interviews were conducted to obtain quantitative data. Penetration of large chillers in cold climate was found to be low during Stage 1 and preliminary discussions. They constitute a minor percentage of existing country-wide chiller stock and so the sample is not being distributed in these areas.

Figure 6: Construct for Semi-structured Interviews



Source: PACE-D research

Secondary Research

The study made extensive use of secondary research through a review of the available literature, including industry reports and database. The desk research involved collecting data from various secondary sources such as published reports, industry associations, manufacturers' product brochures, articles from leading journals, literature reviews, reports, etc.

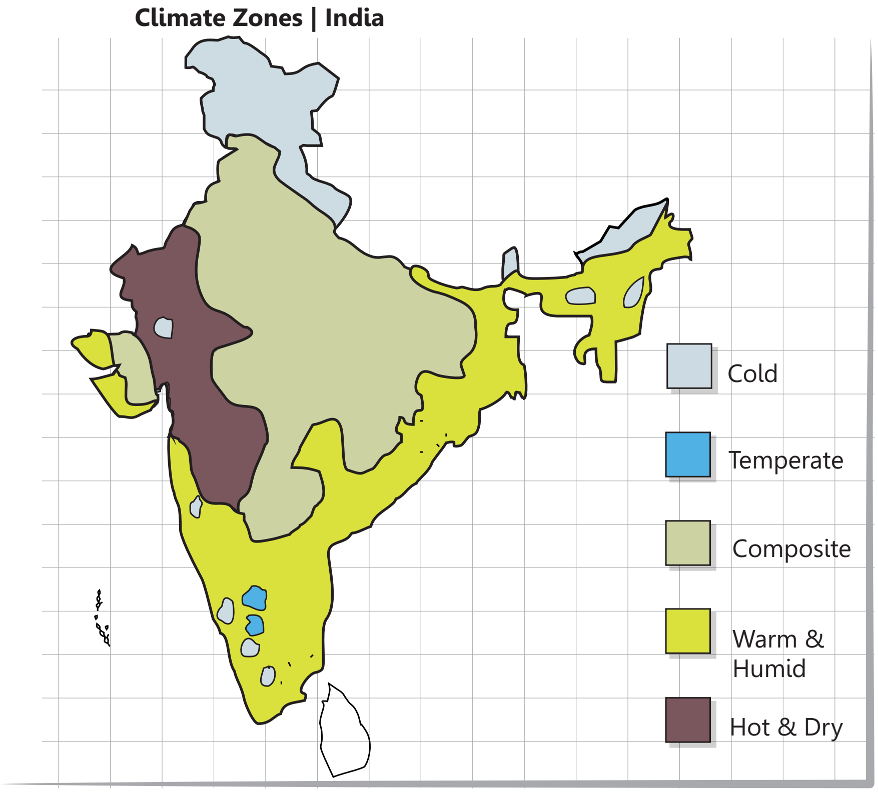
The study also focused on interpreting consumer behavior and response to EE HVAC technologies in order to understand the observed diffusion patterns and identify behavioral barriers. The surveys were designed to gauge the way energy efficiency is interpreted in the market versus the technically-correct definition of energy efficiency. Simultaneously, awareness about EE technologies amongst consultants, vendors and end-users was documented. Most importantly, current user priorities and influencing factors in making HVAC systems purchases were collected and analyzed. Sources of information for participants were analyzed to map the existing channels of information dispersion. Finally, the survey attempted to understand the expectations and experiences of consultants and end-users from EE technologies. This includes levels of satisfaction with the installed systems, frequency of maintenance-related activities, and problems encountered during operations.

Geographical Considerations

As mentioned above, the rationale behind city selection was to study region-specific trends across the largest segments of consumers. Put together, these cities account for a majority of the demand for HVAC systems in the country. The cities and the climate zones that they represent are:

- Composite – Delhi and Hyderabad
- Temperate – Bangalore and Pune
- Warm and Humid – Chennai, Mumbai, and Kolkata

Figure 7: Climate Zones in India



Source: PACE-D research

Selected HVAC Technologies

HVAC systems covered in the study are:

- Central systems – Chillers, condenser and chiller pumps, cooling towers, vapor absorption systems (VAMs), air handling units (AHUs), variable air volume (VAV) systems, radiant systems, geothermal and displacement ventilation systems
- Local/Direct Expansion (DX) systems – Splits, window ACs, multi-splits, roof top units, and VRF systems
- Ventilation systems – Evaporative cooling (single-, two- and three-stage)

4 FUNDAMENTALS OF HVAC SYSTEMS

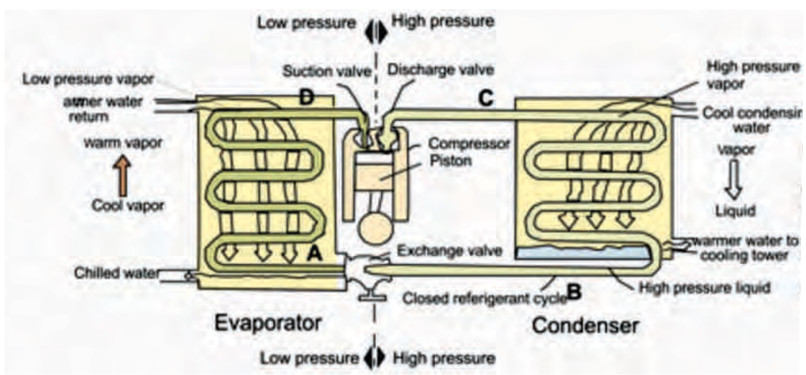
Buildings have cooling (or heating) loads due to sensible and latent heat gain. There are three primary sources for heat gain:

- Inward flow of heat due to higher outdoor temperatures
- Internal heat accumulation from equipment and people
- Direct solar radiation

A combination of these three factors leads to heat accumulation in buildings.[17] HVAC systems reject heat from building interiors to the outside through mechanical means, providing thermal comfort to its occupants. Passive cooling techniques also have the potential to provide this cooling.

The heat transfer process in an HVAC system, also called the refrigeration process or cycle, depends on the thermodynamic processes of evaporation and condensation. The refrigeration process transfers heat from one circulated medium (chilled air or water system inside the conditioned zone) to another system (condenser system, usually outside the conditioned zone). To do so, a refrigerant is evaporated to draw heat from a chilled medium, which is liquefied to transfer this absorbed heat outside. The chilled medium is circulated through the building to reduce its heat.

Figure 8: Schematic Diagram of a Compression Refrigeration Cycle



Mechanical systems use two types of refrigeration processes – vapor compression and absorption cycle. A complete vapor compression refrigeration cycle is explained in Figure 8. A compressor, evaporator, condenser and pumps are the mechanical equipment used to complete this heat transfer process. Refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor (A). Heat is transferred from the relatively warm air or water to the refrigerant, causing the liquid refrigerant to boil. The resulting vapor (B) is then pumped from the evaporator by the compressor, which increases the pressure and temperature of the refrigerant vapor. The hot, high-pressure refrigerant vapor (C) leaving the compressor enters the condenser where heat is transferred to ambient air or water at a lower temperature. Inside the condenser, the refrigerant vapor condenses into a liquid. This liquid refrigerant (D) then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. At this low pressure, a small portion of the refrigerant boils (or flashes), cooling the remaining liquid refrigerant to the desired evaporator temperature. The cool mixture of liquid and vapor refrigerant (A) travels to the evaporator to repeat the cycle.[18]

In absorption refrigeration, the condenser is replaced by an absorber, pump and generator. Absorption systems are discussed in further detail in the section on central HVAC systems.

[17] India is predominantly a warm country where HVAC systems primarily provide cooling. Often, discussions of HVAC systems in this document will be in terms of removing heat from (or providing cooling for) buildings, in order to avoid repetitive language.

[18] Water Chillers: Trane Air-Conditioning Clinic

Types of HVAC Systems in India

HVAC systems can essentially be divided into heating only, cooling only, ventilation only and air-conditioning systems. The next distinction, which is relevant from the perspective of applications in buildings, is based on the location of system components, cooling capacity of the systems, size of buildings, and number of zones[19] to be conditioned. HVAC systems can be classified as central and local/Direct Expansion (DX) systems using this criterion. Figure 9 illustrates the division of HVAC products within each category.

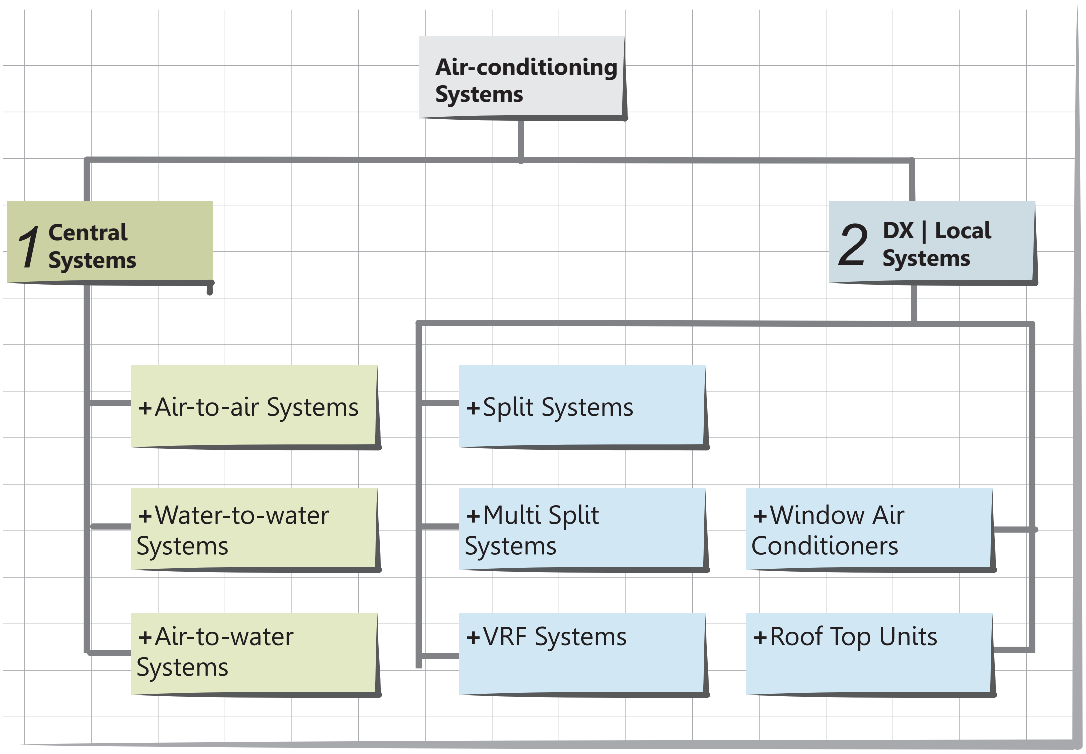
Local systems use DX technology and hence this report has termed local systems as DX systems. These systems heat or cool the air inside the zone through the refrigerant that flows directly from the compressor to the part of the DX system placed inside or adjacent to the zone. Central systems mostly cool or heat a heat transfer medium (water or air) that further transfers the heating or cooling to the zone.

Small DX systems can serve a single zone, and major components of the system are located inside or adjacent to the zone, or on the boundary of the zone and exterior space. Larger DX systems can serve multiple zones and be placed outside the zone. Generally, distribution systems (ductwork and terminal units) are not required because only refrigerant needs to be carried from the equipment to the conditioned zone or space.

While most DX systems are placed adjacent to or close to the conditioned space, major components of central HVAC systems are located outside the zone(s) served. These can be a central location inside, outside or near the building. Central HVAC systems are usually installed to serve multiple thermal zones (spaces or rooms) in larger buildings.

There are differences in the energy efficiency between the two systems, which are discussed later in this section.

Figure 9: Classification of HVAC Systems



Source: PACE-D research

[19] In HVAC terminology, thermal zone (or just zone) is a space or group of spaces with similar heating and cooling requirements. For DX systems, a zone usually has the same thermal and physical boundaries, i.e. each room is a zone by itself. Each zone must be controlled separately. For central systems, separate rooms can be combined to represent a single thermal zone.

[20] Ductwork and terminal units for carrying chilled air or water from the cooling equipment to the zones.

Direct Expansion (DX) Systems

In DX unitary systems, evaporators are in direct contact with the supply air stream and hence the cooling coil, which carries the refrigerant, is also the evaporator. The refrigerant is introduced through an expansion valve into the cooling coil.

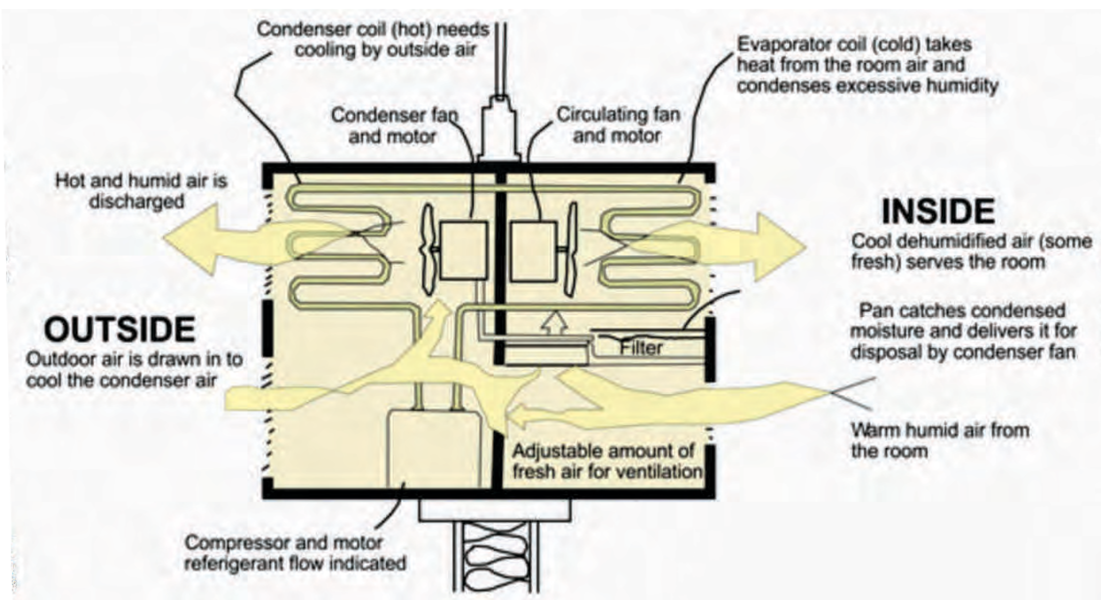
When the components of the refrigeration cycle–evaporator, condenser, compressor, and expansion device–are packaged together, the systems or unit is termed as packaged DX system. If the refrigeration cycle components are split, then the system is called a split DX system or more commonly, split air-conditioners/systems.

All the DX systems carry the essential components of a refrigeration cycle – compressor, condenser, expansion device, evaporator, cooling coils and refrigerant. DX HVAC systems cool the zone air directly, unlike central systems, which first cool a circulating medium that in turn cools the air supplied to the zone. Controls are provided either on the system itself or through a remote thermostat control.

Window air conditioners

Window air conditioners are packaged DX systems consisting of vapor compression refrigeration cycle components (evaporator, condenser, compressor, and expansion device), fans and controls. Units are placed on the boundary between the zone and external space because they carry both the exterior heat exchange element (condenser) and interior heat exchange element (evaporator) inside the same frame. Window air conditioners do not require any ductwork to circulate the cooling medium inside the zone and are more commonly used in residential buildings. Figure10 explains the heat transfer process in a window air conditioner.

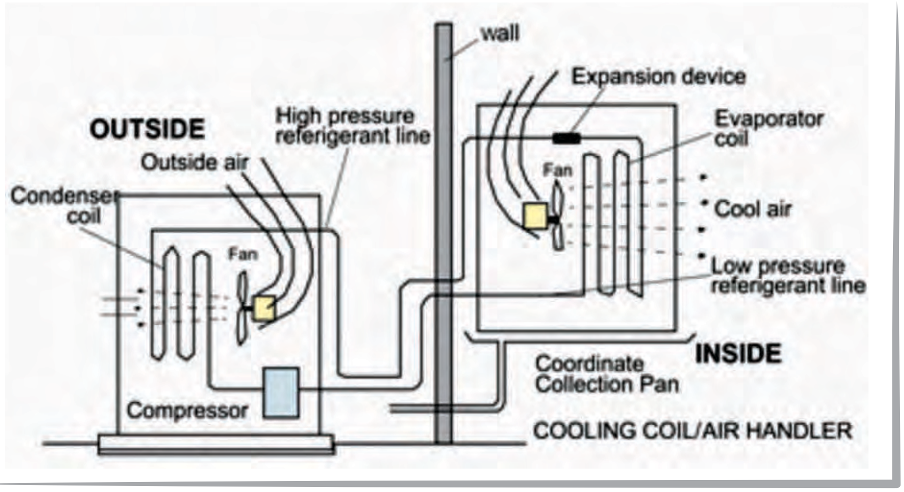
Figure 10: Schematic Diagram for a through-the-wall Window Air Conditioner



Split air conditioners

A typical split system contains an external unit housing the condenser and the compressor, and an internal air handler unit with the evaporator, expansion device and fan (Figure 11). The working principle is the same as for other DX systems, i.e. supply air for the zone is cooled by making it pass directly over the refrigerant-carrying cooling coil. Refrigerant is circulated between the units through insulated tubing.

Figure 11: Schematic Diagram of a Split Air Conditioner



Large DX Systems

Roof top units, multi-splits and Variable Refrigerant Flow (VRF) systems are larger DX systems in which single or coupled outdoor units are combined to send the refrigerant to multiple indoor units. In all these systems, only the refrigerant is sent to the evaporators contained in indoor units for heat transfer.

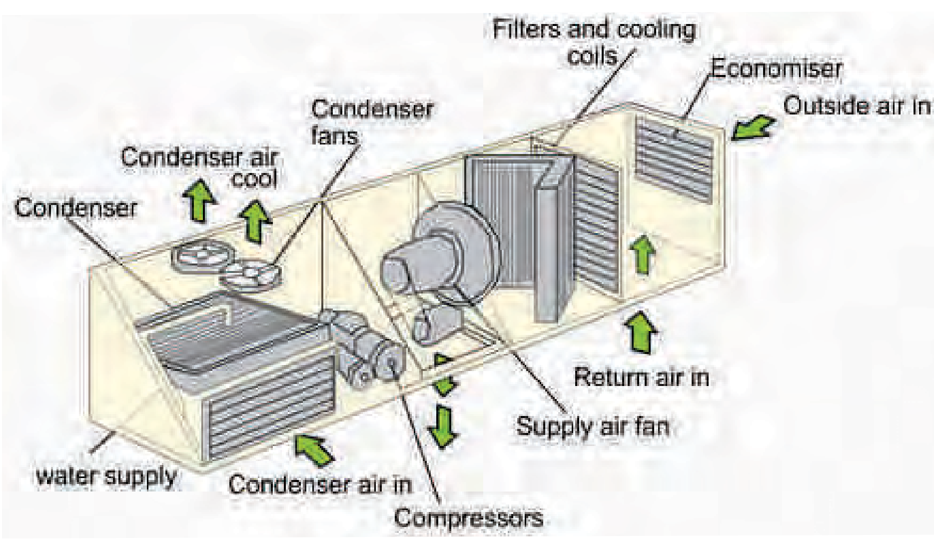
Multi-split systems

Split systems serve multiple zones through multiple indoor units connected to a single outdoor unit. When the distance between the zone air supply opening and the indoor unit is large, ducts may be introduced between the two. Split systems can be used in both residential and small commercial buildings.

Roof top units

Roof top units can be combined with ductwork in central systems or function as local systems to supply cooling. Standard components of the vapor refrigeration cycle – compressor, condenser, evaporator/cooling coils, expansion device, and fans are housed in an external unit placed on roof tops (Figure 12). Supply fans can be either packaged in a single unit with a compressor and condenser, or placed in a separate unit.

Figure 12: Schematic Diagram for Roof Top Units (RTUs)

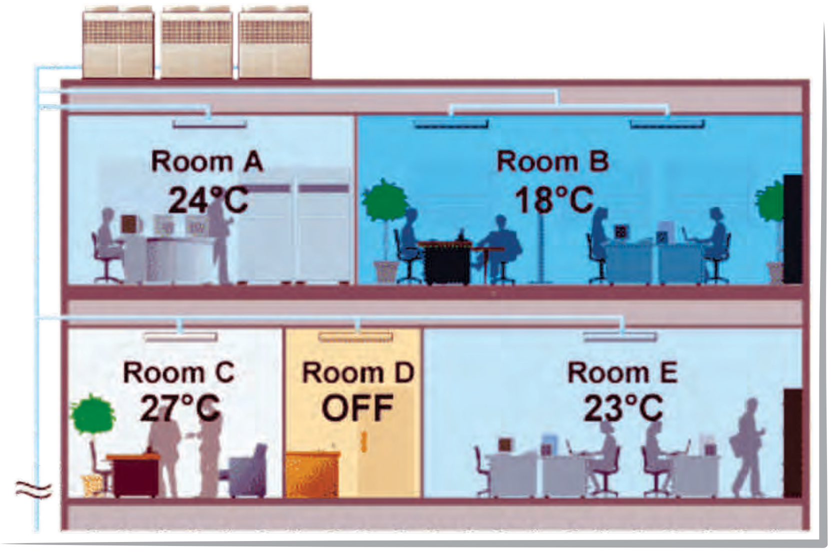


Variable Refrigerant Flow (VRF) systems

A single condensing unit placed outside the building can be connected to multiple number and types of indoor units in VRF or Variable Refrigerant Volume (VRV) systems.[21] VRF refers to the ability of controlling the flow or volume of refrigerant to the evaporator containing indoor units in response to requirements of different zones. This allows for greater efficiency as the system operates only on actual cooling demand. The operating principle is the same as other DX systems. The key difference is that the refrigerant flow is varied in VRF systems, whereas in other DX and central systems, the supply air volume is varied. Also, other systems can either switch on or off, whereas VRF systems continually adjust the flow. Variation in flow or volume is achieved through single or multiple inverter-driven variable speed scroll compressors that change their speed in response to an electronic expansion valve.

VRF systems can be combined with concealed, cassette, high-wall, floor, and ceiling indoor units. These systems can be used for cooling only, or as heat pumps, or for heat recovery.

Figure 13: Schematic Diagram of VRF System



Source: Fujitsu General Airstage VRF System (V Series)

Typical applications

DX systems are installed wherever a need for cooling spaces is felt in buildings that do not have central air-conditioning systems. This typically includes single and multifamily residential buildings, small offices and commercial establishments (hospitals, educational institutions, hotels, etc.).

Energy use issues

DX systems are less efficient than central systems. Waste heat cannot be utilized in DX systems as there is no unified network for collecting the air exhausted from zones. Separate units cannot be linked by a single unified control system and hence it is not possible to track or control operations. However, these need to be switched on only when the space requires cooling, and thus save energy by avoiding any pre cooling.

VRF/VRV systems are the most efficient compared with other DX systems. The former achieve greater efficiency due to the following reasons:

- Adjustment in volume of refrigerant sent to the indoor evaporator unit reduces the energy used by the compressor in air circulation.
- Refrigerant piping from the VRF outdoor unit to indoor units is less than other DX systems like multi splits or small central systems.
- Electronic expansion valves (for controlling the volume of refrigerant to the evaporator) used in VRF systems are more efficient than thermostatic valves used in other systems.

[21] VRF and VRF technology is the same. VRF is a trademark of Daikin Industries, the first developers of this technology. Hence other manufacturers use the term VRF for their products.

Central Systems

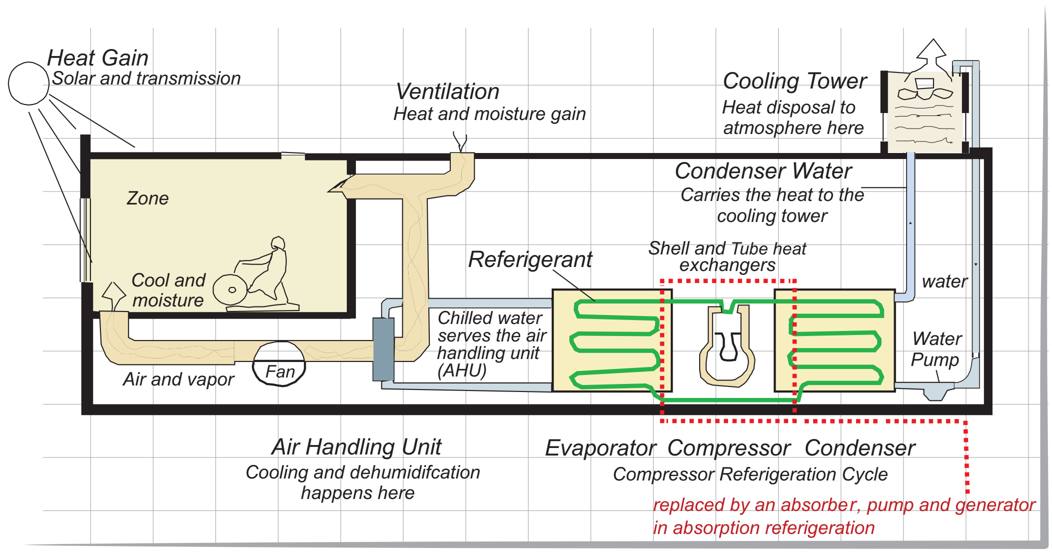
In central systems, the refrigerant is not circulated inside or near the zones. Rather it transfers the heat or cooled air to a 'chilled medium', usually water, which then circulates insides the zones. Components of the refrigeration cycle – compressor (or absorber plus generator), condenser, evaporator, heat exchanger and cooling coil are housed within a chiller unit. Inside the evaporator, the refrigerant takes the heat from the warm water coming from the building. Resultant chilled water is recirculated either back to the zones directly or cools supply air through an Air Handling Unit (AHU). Refrigerant in the evaporator needs to be cooled to repeat the cycle and is pumped to the condenser to transfer its heat to condenser water through a heat exchanger. The condenser water in turn rejects this heat to the environment through a cooling tower and returns to the condenser. Figure 14 explains this cycle and the role of different components.

All the components mentioned above are common across most sub-types of central systems and can be categorized by their function within the system as follows:

a) Central plant equipment – chillers, chiller pumps
b) Heat rejection equipment like cooling towers or air condensers
c) Distribution and delivery components – distribution ductwork or pipes, AHU and terminal delivery units like Fan Coil Unit (FCU), diffusers and personal delivery systems (wall and ceiling) for radiant systems

Mechanical, Electrical and Plumbing (MEP) consultants also refer to central equipment as high side/supply side components and distribution and delivery components as low side/air side components.

Figure 14: Schematic Diagram of a Central HVAC System with Main Components



Central system classification

Central systems are further classified on the basis of the refrigeration cycles – vapor compression and absorption refrigeration cycle. The former uses a mechanical compressor. Absorption systems, as the name implies, use the absorption process to transfer heat between the chilled water and the refrigerant.

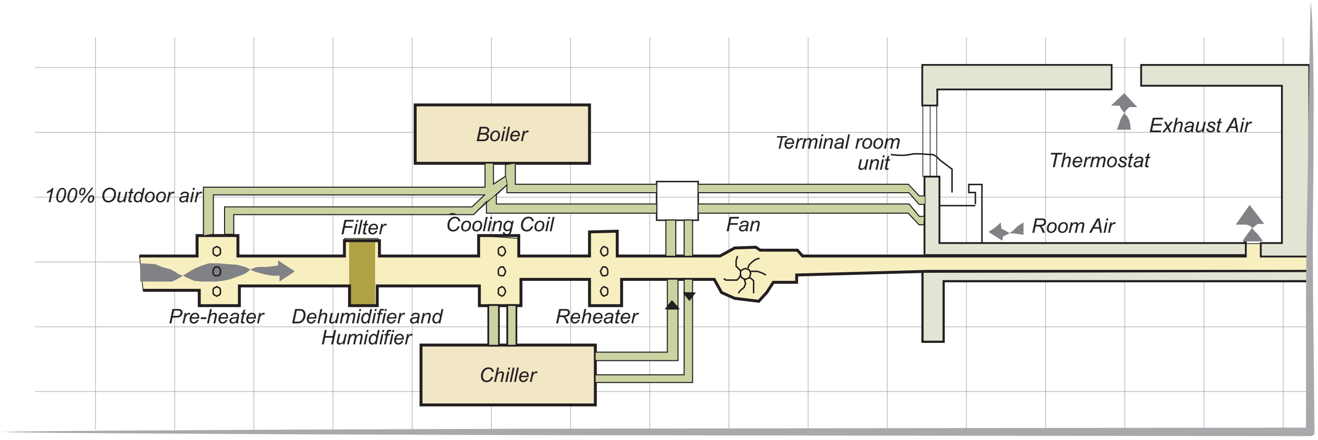
Sub-classification of central systems into all-air, all-water and air-water systems is decided by the nature of thermal energy transfer medium in the system. If only air is used for transferring heating or cooling to the zones, then the system is classified as an all-air system. All-water systems, as the name implies, use only water for heating and cooling the zones. In an air-water system, conditioning is transferred through a combination of heated/cooled air and hot/chilled water.

Layouts for all the three types of central systems are shown in Figure 15. All-air systems require ducts to carry the cool air to the zones. The main duct sizes can be very large as they have to carry the total volume of air required by all zones before it is distributed to smaller ducts. Thus volume-wise air to all-air systems is most inefficient. Typically, two duct networks, one each for supply and return air are required.

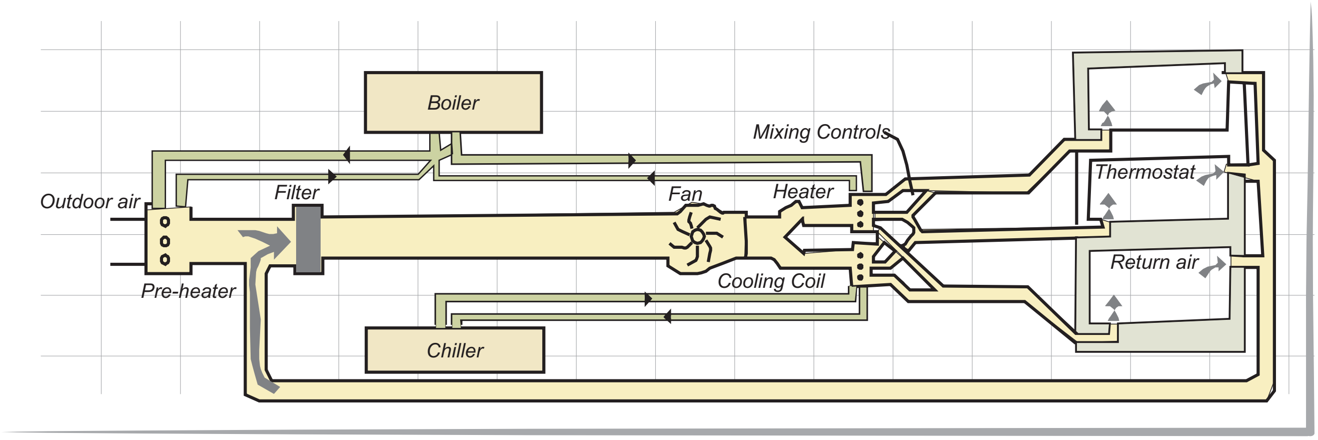
All-water systems are the most efficient in terms of space consumption because the main distribution channels are pipes which use very little space. A minimum of two pipes are necessary, one each for supply and return. These systems are also more energy-efficient compared to all-air systems as water is a more efficient medium of heat transfer. All water systems use AHUs and FCUs for delivery of the chilled medium to interior spaces.

Figure 15: All-air (a) and Air-water (b) Central Systems

(a)



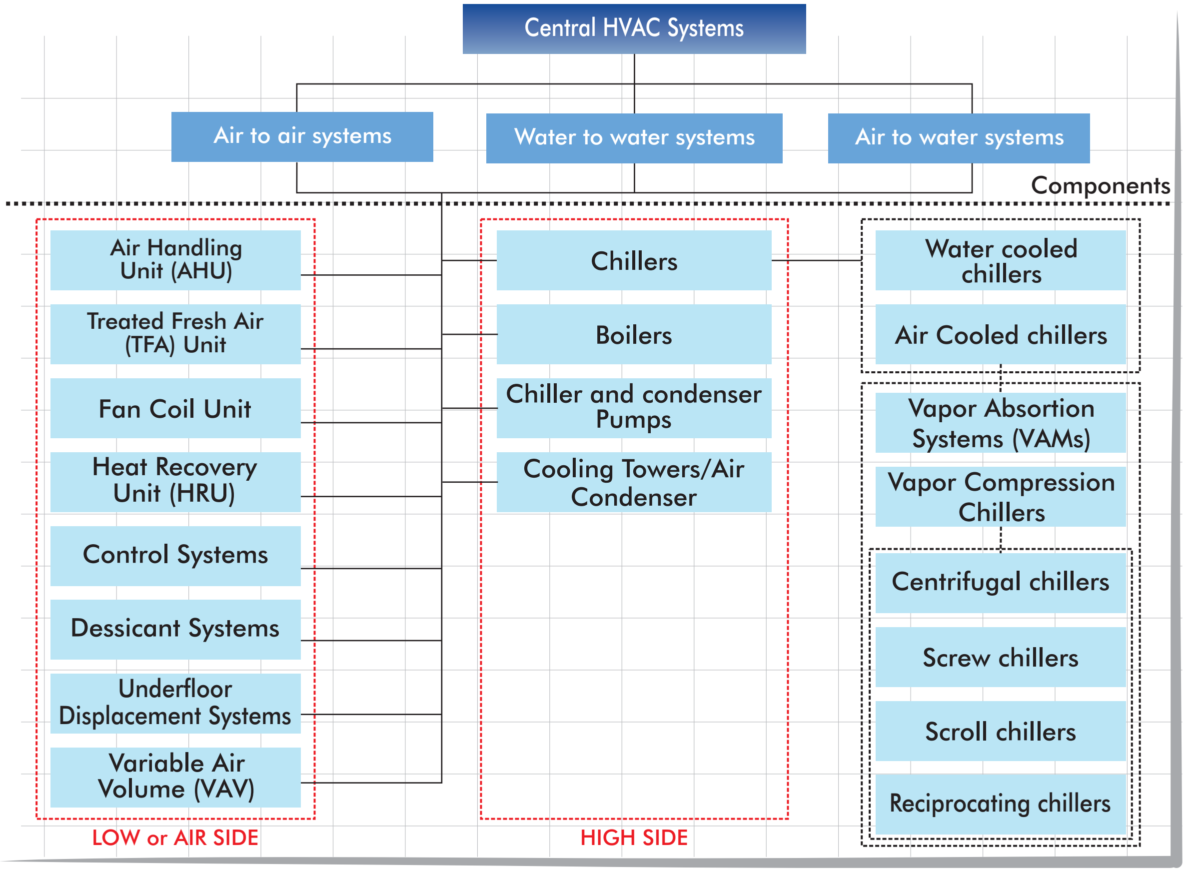
(b)



Air-water systems require both ducts and pipes for conditioning zones. Heating and cooling is met through chilled water and ventilation demands through an air supply system. These systems can use radiant panels, induction units and FCUs.

The types of central systems and important components are summarized in Figure 16.

Figure 16: Central HVAC Systems – Types and Components

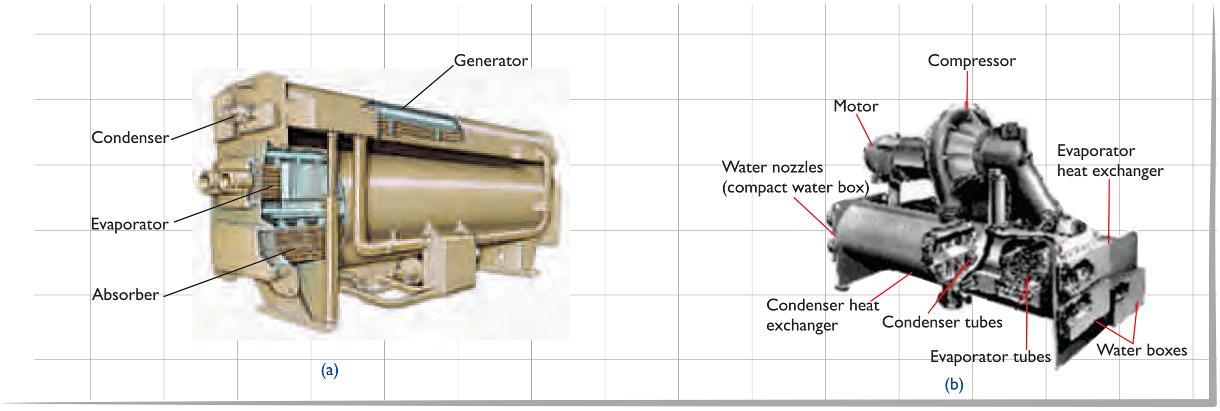


Source: EDS

Chillers

Chillers remove the heat accumulated in the circulated chilled water system as it cools the building. They can operate both on the vapor compression and absorption refrigeration cycle (Figure 17), and are accordingly categorized as positive displacement chillers and absorption chillers. The former uses a mechanical compressor, while the latter use the absorption process to transfer heat between the chilled water and refrigerant. Positive displacement chillers include reciprocating, screw, scroll and centrifugal chillers. Absorption chillers are also further classified on the basis of their efficiency as single-effect, double-effect and triple-effect absorption chillers. The difference is due to the additional condensers and absorbent generators used, for greater efficiency. Depending on the type of chiller, both water (cooling towers) and air (air condensers) can be used for rejecting the heat taken off from chilled water. Usually larger chillers use water and smaller chillers use air.

Figure 17: Absorption (a) and Vapor Compression (b) Chillers



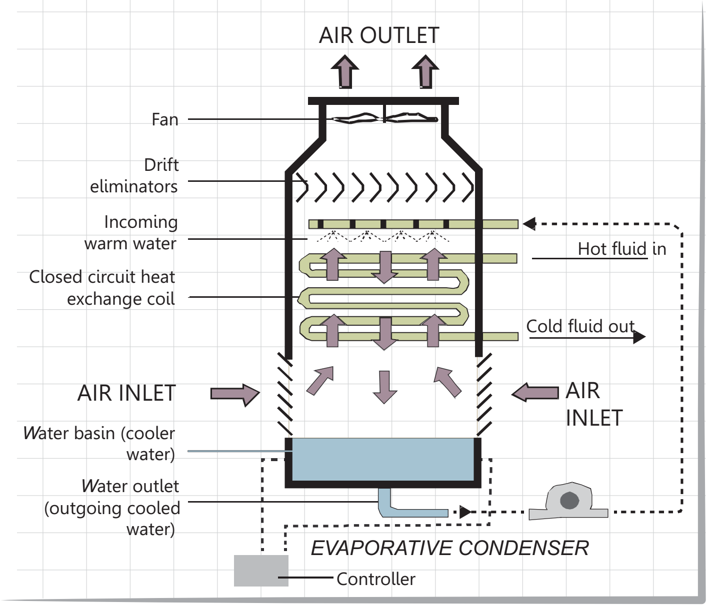
Source: TRANE Air Conditioning Clinic and York International

Cooling Towers

Chillers need to reject the heat removed from the chilled water circulating inside the building zones. In water-cooled central systems, the condensing water system consisting of condenser pumps, condenser, and cooling tower does this. Water in the condenser takes the heat from the heated refrigerant (Figure 8) and transfers it to the outside air through a cooling tower. Figure 18 describes the operating principle of a cooling tower. Warm condenser water is pumped to the cooling tower installed outside (on the roof or site perimeter). Heat from the pumped water is rejected to the cooler outside air through the process of evaporation and the cooled water is pumped back to the chiller.

The generic term "cooling tower" is used to describe both direct (open circuit) and indirect (closed circuit) heat rejection equipment. A direct or open circuit cooling tower is an enclosed structure with internal means to distribute the warm water fed to it over a packing or "fill." The latter provides a vastly expanded air-water interface for heating of the air and evaporation to take place. The water is cooled as it descends through the fill by gravity, while in direct contact with air that passes over it. The cooled water is then collected in a cold water basin below the fill, from which it is pumped back through the process to absorb more heat. The heated and moisture-laden air leaving the fill is discharged to the atmosphere at a point remote enough from the air inlets to prevent its being drawn back into the cooling tower. An indirect or closed-circuit cooling tower involves no direct contact of the air and the fluid, usually water, being cooled.

Figure 18: Cutaway View of a Cooling Tower



Chiller Pumps

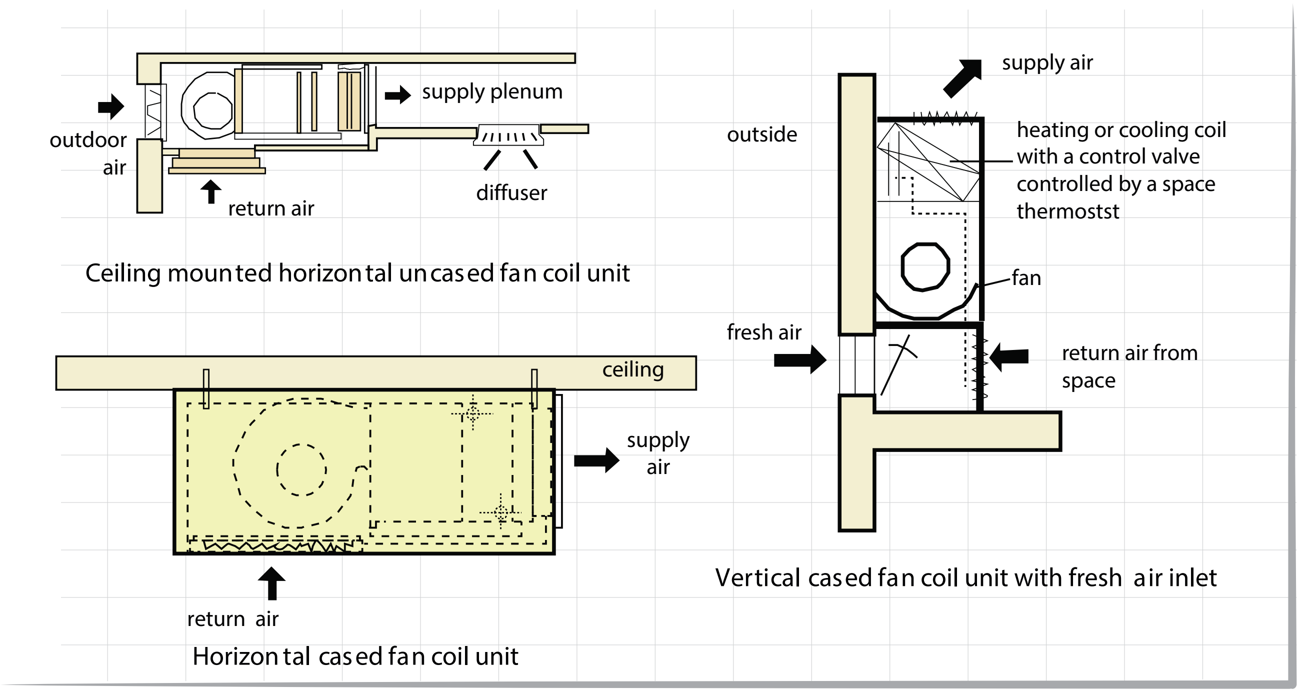
Chiller and condenser pumps are used to provide sufficient pressure to move the fluid through the chiller and condenser water distribution system at the desired flow rate. The pumps are broadly classified in two types: 1) centrifugal pump and 2) positive displacement pump. In HVAC services, centrifugal pumps are popular because of their design simplicity, high efficiency, wide range of capacity and head, smooth flow rate, low operating costs, varied sizes, and ease of operation and maintenance. Centrifugal pumps in chilled water HVAC plants are used for circulating chilled water through chillers and air handling units in closed loop, and for circulating cooling water through condensers and cooling towers in open loop.

Air Handling Unit (AHU)

Air Handling Units (AHUs) ensure that a building has optimal climate control, i.e. cooling, along with the necessary air pressure and air quality to make occupants in the building comfortable and safe. An AHU system supplies and circulates air around a building, or extracts stale air as part of a building's HVAC system. Essentially, an AHU comprises a large insulated metal box that contains a fan, heating and/or cooling elements, filters, sound controls, and dampers. Supply air passing through the unit is filtered and either heated or cooled, depending on specified zone requirements and the ambient weather conditions. Supply air from an AHU can use either fresh air or a mix of fresh and return air. To temper the supply air (cool as per the zone requirements), an AHU can either use chilled water from a central chiller plant or be fitted with an inbuilt DX refrigeration system.

An FCU is a small terminal device that consists of a heating/cooling coil and a fan. Thus FCUs are used in smaller and often local spaces only and are used to attain a desired temperature. In an air and water central system, FCUs are also supplied with pre-cooled fresh air coming from an AHU or Treated Fresh Air (TFA) unit. In an all-water system, FCUs are supplied with only chilled water from the central plant room. Either the room air or a secondary source of supply air is drawn over the cooling coil by an FCU fan to condition the zone. The desired temperature in the serving area is achieved by the simultaneous control of the control valve and the fan by a controller in response to room conditions. The control valve regulates the flow of cold water inside the cooling coil and the fan blows the supplied air through the cooling coil, further decreasing its temperature before it comes to the serving area.

Figure 19: Schematic Diagram of a Fan Coil Unit

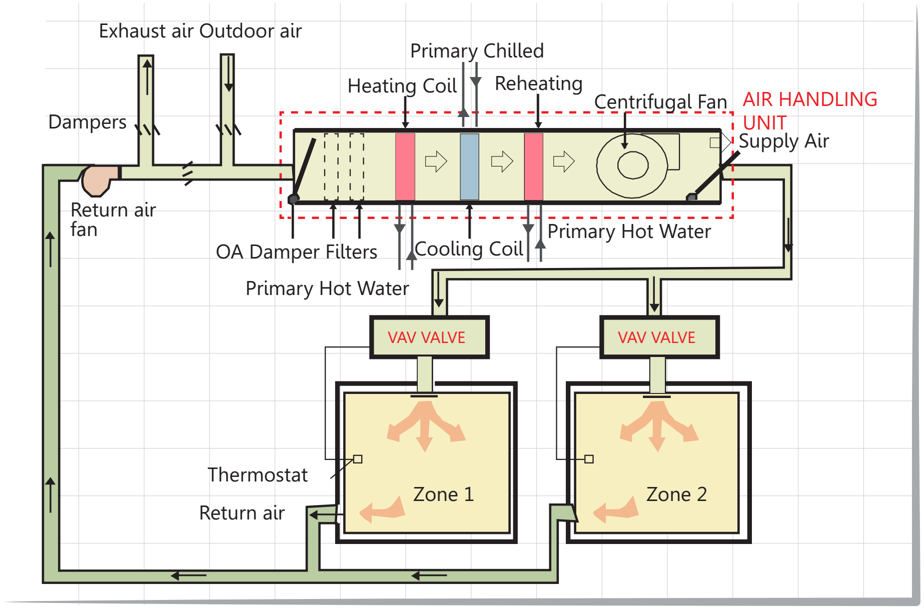


Variable Air Volume (VAV) system

In traditional control systems such as Constant Volume (CV), a constant volume of air is delivered to the space, and the temperature of supply is varied to meet cooling requirements of the zone. A CV system can serve only those building spaces with similar cooling loads as it responds to the demands of only one thermostat. Thus, it is rendered less useful if a building has many spaces with diverse cooling needs.

In contrast, a VAV system controls the temperature inside a space by modulating the amount of air supplied to it to maintain the required space temperature at all load conditions. A VAV system is capable of controlling space temperature in many spaces with dissimilar cooling and heating requirements while using only one AHU (Figure 20). By allowing the central system to run at part-loads, the VAV systems have a good potential for energy savings. Firstly, the air volume reduction creates an opportunity to reduce the fan energy required to move this air. Resultant reduction in supply airflow across the cooling coil also reduces the refrigerant that has to be pumped to the cooling coil, which further saves energy.

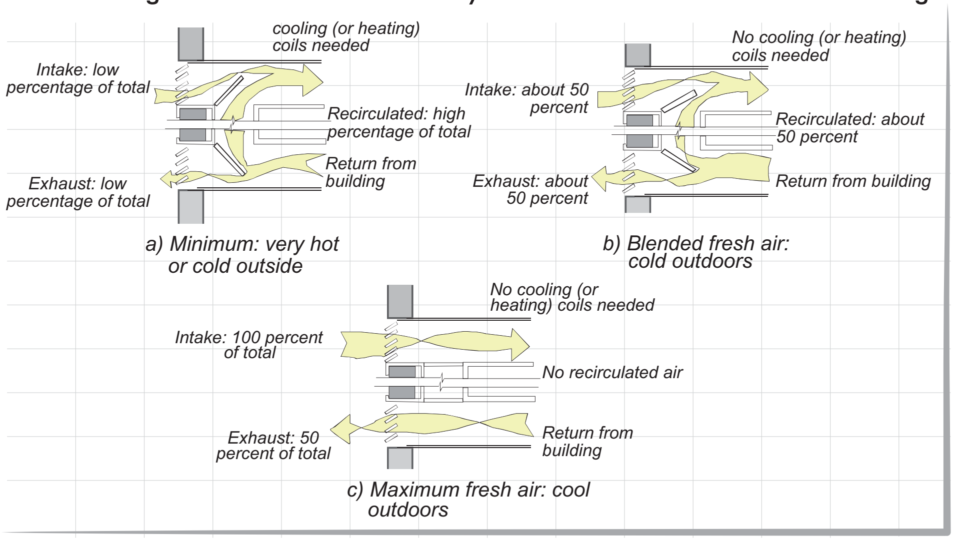
Figure 20: Variable Air Volume (VAV) Supply System with AHU



Air Economizer

Many air-conditioning systems operate with a fixed amount of outdoor air. Load on these systems can be reduced by modifying the system to include air economizers. These vary the volume of cool air added from the outside depending on the temperature difference between outdoor and indoor air. Figure 21 explains the different settings of an economizer. When outdoor air is cooler than supply air, economizers only allow outdoor air to enter the ducts. This outdoor air is filtered before entering the zone. No chilled water is required in this case and the supply air can be humidified and dehumidified locally. It also controls the quantity of fresh, exhaust, and re-circulated air. Adding an economizer cycle has several advantages including optimizing energy use in automatic thermal control, filtering of the fresh air, tempering of the cool outdoor air to avoid unpleasant drafts, and an orderly diffusion of fresh air throughout the building.

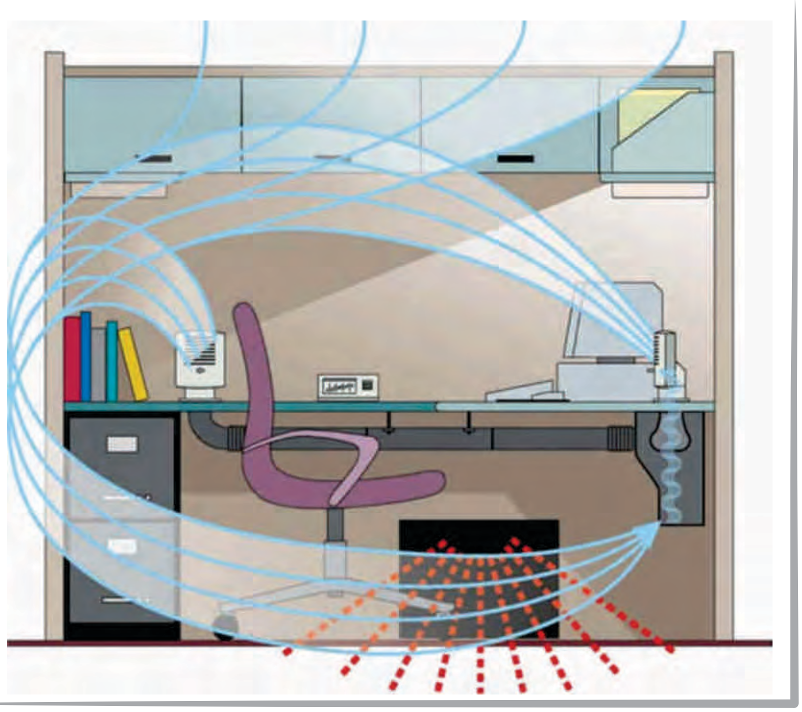
Figure 21: Air Economizer Cycle in Different Modes of Functioning



Workstation delivery systems

Rather than delivering cool supply air or water at some distance from occupants in the conditioned space, workstation delivery systems deliver to individual workstations in office spaces. Typical placement is shown in Figure 22. Workstation delivery systems (or personal climate control systems) can enhance efficiency by cooling only the space that demands it. By allowing more accurate and greater control, these can improve perception of thermal comfort of occupants. Typically, adjustable louvers and easily reachable controls are attached.

Figure 22: Workstation Delivery System



Source: Johnson Controls

Typical Applications

Central HVAC systems are applied wherever the required cooling tonnage and number of thermal zones are large. As such, these can be applied across multifamily residential, office, retail, and educational, institutional, hospital, hotels, and restaurants buildings. Central plants are also installed in infrastructure projects and industrial buildings.

Energy Use Issues

All water-cooled and air-water-cooled central systems are more efficient than all-air systems because water is a more efficient heat transfer medium than air. Heat recovery from return air or water is possible. This heat can be then transferred to supply air for the zones. However, the complete central system has to be switched on even if a single zone is to be conditioned, leading to waste of energy.

Overall Trends in HVAC Systems

Interactions with market players revealed that chillers, VRF systems, and AHUs are by far the most popular types of HVAC products in the country due to product durability and shift in the industry towards more sustainable solutions. Energy-efficient chillers, such as centrifugal and screw types, are expected to outpace reciprocating and scroll chillers, which are less energy-efficient. Industry-wise there is a paradigm shift towards Green Buildings and emphasis is being laid on energy-efficient equipment. In comparison with the other machines, VRV/VRF systems are the most popular ones currently and have a very good future in the market.

Radiant systems and geothermal cooling may become popular in future but are not preferred currently because of very high initial cost and long payback periods. VAM as technology is beneficial wherever waste heat is available freely through a process or availability of gas as a fuel is cheap. In the present scenario, where gas prices are high, it is not economical to use VAM for comfort cooling purposes. VAMs also consume a lot of water for operating, and this is a concern in areas where water resources are scarce.

[22]Mechanical and Electrical Equipment for Buildings"-9th Edition: Benjamin Stein and John S. Reynolds

5 MARKET CHARACTERISTICS

At the macro level, HVAC systems may be categorized as a) medium and large commercial; and b) residential and small commercial.

Medium and large commercial systems account for the largest of these categories, with 56 percent of the current HVAC systems falling under this category. Residential and small commercial constitute 44 percent of the current HVAC systems. This section contains an analysis and discussion of the current market share, growth potential, and documented trends of various systems that fall within the first two categories of HVAC systems.

DX SYSTEMS

DX systems include window air conditioners, split units (ducted, ductless and mini-splits), single packaged units [Roof Top Units (RTUs), indoor packaged] and Variable Refrigerant Flow (VRF) or Variable Refrigerant Volume (VRV) systems. Actual sales data by volume and value from 2010 to 2012, and projected sales from 2012 to 2015 have been used to understand the market conditions for all systems.[23 & 24]

Current Stock and Growth

Window Air Conditioner

Market Trends

Out of the types available in this segment, the market for through-the-wall window units and moveable units is nonexistent. Analyzing the sales trends comparatively, it is evident that there is a clear decline in the window air-conditioner market as customers are increasingly opting for split air conditioners (Figure 23). Sales by volume declined by 16.7 percent in 2010 to 2012 and are predicted to further decline by 6.9 percent from 2010 to 2015.

Split air conditioners are more energy-efficient and deliver higher comfort levels. Selling prices of window units are on the rise because the cost of manufacturing is steadily increasing. These two factors combine to negatively impact the market for window conditioners.

Supply Structure

The Indian window air-conditioners market has about 20-30 structured brands, and this makes it intensely competitive. There is a mix of international and national brands, and they are equally popular. Currently, the window air-conditioning market is under consolidation, with some brands like Videocon and Samsung exiting the market due to declining sales. Conversely, international brands like Daikin, Hitachi, and Panasonic are trying to increase their market share through aggressive pricing and marketing strategies.

Splits – ducted, non-ducted and multi-splits

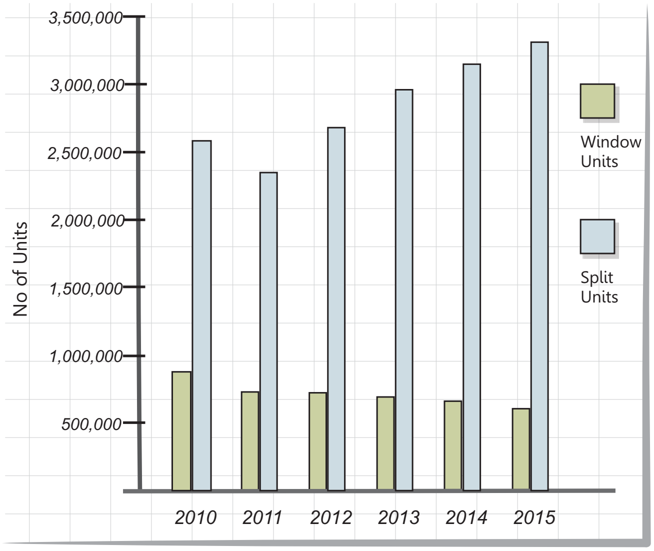
Market Trends

Ductless or non-ducted, ducted and multi-splits (both ducted and non-ducted) make up this segment. Single ductless splits dominate here, and their market is predicted to grow over the next few years, with the population rising and disposable incomes on the increase. The growth rate from 2010 to 2012 was 16 percent and is expected to reach 27 percent in the next three years, i.e. till 2015. Residential consumers are also shifting from using window units to relatively more efficient split systems.

[23] Product Policy Analysis Tool (PPAT) - India. Developed for Collaborative Labeling and Appliance Standards Program (CLASP) and Bureau of Energy Efficiency (BEE) by EDS.
[24] BSRIA – A multi-client study of chillers, windows and movables, single-packaged, AHU and fan coils, and split systems – India. November 2012.

Figure 23: Sales of Window ACs – 2010 to 2016

Split Units vs Window Units | Number of units sold and projected sales



Source: BSRIA - A multi-client study – India. November 2012

Ductless splits are available in smaller capacities of up to 7.5 kW. Ducted split units are available from 7.5 kW to 25 kW capacities. For both ducted and ductless systems, cooling-only options are more popular than heat pumps. Although sales of both heat pumps and cooling-only systems in all capacities are expected to grow, this preference pattern is not expected to be reversed. The market for ducted splits is tightening because consumers increasingly prefer VRF/VRV systems, at least in Tier 1 cities. VRF/VRV systems are more efficient; and fierce competition in the segment has driven down prices.

The market for multi-splits is negligible because cooling capacities of products offered in this sub-category are not sufficient for the extremely hot Indian summers. Capacity of outdoor units is the limiting factor. Preferred capacity for multi-splits is 4-5 ton of refrigeration (TR), whereas capacity of units available in the market is just 3 TR. Consequently, multiple units connected to a single outdoor unit of lesser capacity cannot function simultaneously at their full cooling capacity. Multi-splits will continue to cater to a niche market where space for installing outdoor units is restricted.

Supply Structure

Brands mentioned here represent around 80 percent of the total market share in their respective segments. Blue Star is more active in greater than 5 kW capacities. All these brands are equally popular and most of the international players are opting for localized production.

Table 2: Leading Market Players in Split Systems

Ductless Splits	Ducted Splits
LG	Carrier
Voltas	Blue Star
Samsung	Voltas
Daikin	Hitachi
Hitachi	LG
Panasonic	Daikin
Onida	ETA
Blue Star	

Source: PACE-D research

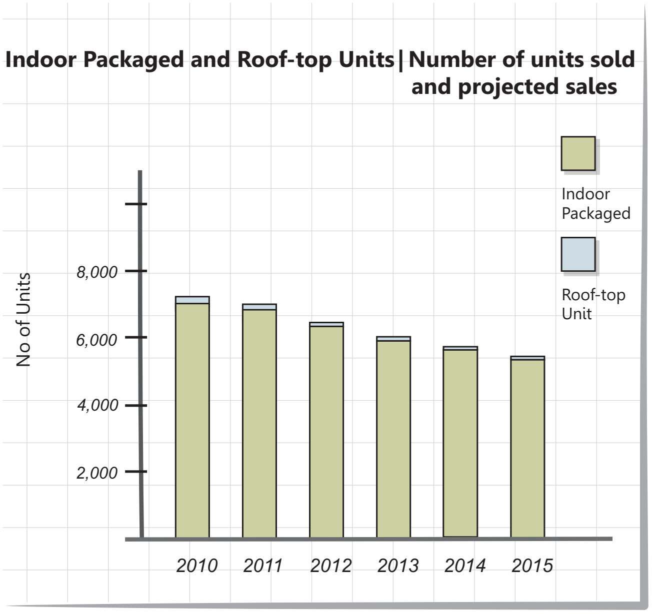
[25] Single indoor unit connected to a single outdoor unit

Single Packaged Units

Market Trends

The single packaged unit segment consists of indoor packaged, RTUs and Packaged Terminal Air Conditioners (PTACs). The market for PTACs is nonexistent in India. Indoor units take up space, which is at premium in urban centers of India, and hence are not preferred by either owners or tenants. RTUs are also not used commonly because of installation problems and high product prices. Sales for RTUs and indoor units are also declining. The market value of RTUs has contracted by 45.9 percent from 2010 to 2012 and this trend is not expected to be reversed.

Figure 24: Sales of Packaged Units



Source: BSRIA - A multi-client study – India. November 2012

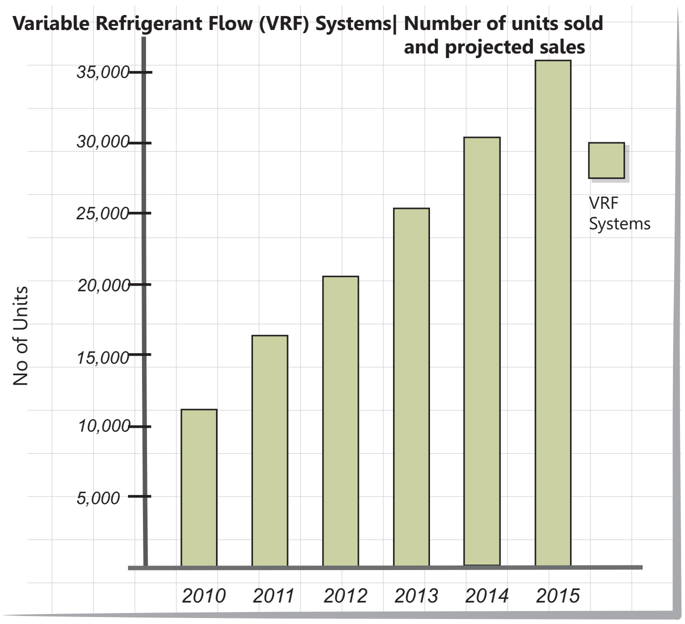
Variable Refrigerant Flow (VRF)/Variable Refrigerant Volume (VRV)

Market Trends

The market for VRF/VRV systems has grown by over 30 percent in value terms and total cooling capacity sold, due to a fall in average selling prices. The growth rate in market volume is higher. The growth rate till 2015 is predicted to be around 20 percent. Average selling prices of VRF/VRV systems by 2015 are projected to decline by 2.2 percent from 2010 prices.

This demand is driven both by greater energy savings provided by VRF systems and competitive prices. VRF/VRV systems provide higher part load efficiency. Installation capacity can also be reduced as these systems allow for diversity factor in design. For this reason, VRFs/VRVs are fast replacing ducted split systems in office, small commercial and high-end residential sectors. The price difference between VRF/VRV systems and similar but less efficient technology is small – and this is also an advantage for market growth. Some manufacturers are providing Heat Reclaim Ventilation (HRV) Systems with VRF/VRV systems.

Figure 25: Market Sales of VRF Systems



Source: BSRIA - A multi-client study – India. November 2012

Currently, VRF/VRV sytems sold in India use both scroll and inverter technology. Digital scroll technology, which offers better humidification and temperature control, is making inroads into the segment. Typical VRF/VRV sizes in use range from 300-400 HP. Larger capacities ranging from 800 to 1000 HP are also gaining popularity. VRF/VRV systems have a wide variety of applications in offices, hotels, retail stores, hospitals, high-end apartments, supermarkets etc. The top VRF/VRV market leaders, accounting for 93 percent of the market share, are Daikin, Toshiba, LG, Samsung, Voltas Media, and Blue Star.

Supply Structure

Daikin is the undoubted leader in the VRF/VRV segments. Voltas has increased its share of the VRF/VRV market. Other leading brands are Toshiba, LG, Samsung, and Blue Star. Put together, these players represent 93 percent of the market.

Geographical Variations

Region-wise, there is a clear preference for window air conditioners in the northern regions over the southern parts of the country. Summers are shorter and less extreme in north India and the cost benefits of installing split air conditioners are mitigated.

Central Systems

Central systems typically serve multiple zones or spaces in buildings with large cooling and heating loads. Unlike DX systems, central HVAC systems use chilled water to cool the air supply indirectly. This report has attempted to study the market configuration of chillers (water-cooled, air-cooled and absorption), Air Handling Units (AHUs), and Fan Coil Units (FCUs).

Chillers

Market Trends

The purchase process for chillers is determined by the required cooling capacity, refrigerant, and availability of water for heat transfer and rejection. Accordingly, chillers are classified in the market by cooling capacity, compressor type, and heat rejection methods. Current and projected sales trends for chillers are summarized below based on these classifications.

[26] Emerson Climate Technologies

Table 3 lists the capacity range in which various chillers are installed. While centrifugal compressors are used for higher capacities, screw chillers are used for smaller capacities. Reciprocating and scroll compressors are used for smaller capacities.

Table 3: Capacity Range of Different Chiller Types[27]

Chiller Type	Lower Range (kW)	Higher Range (kW)
Scroll and Reciprocating	52.5	700
Screw	87.5	140
Scroll	3.5	105
Centrifugal	525	8750
Absorption	17.5	4200

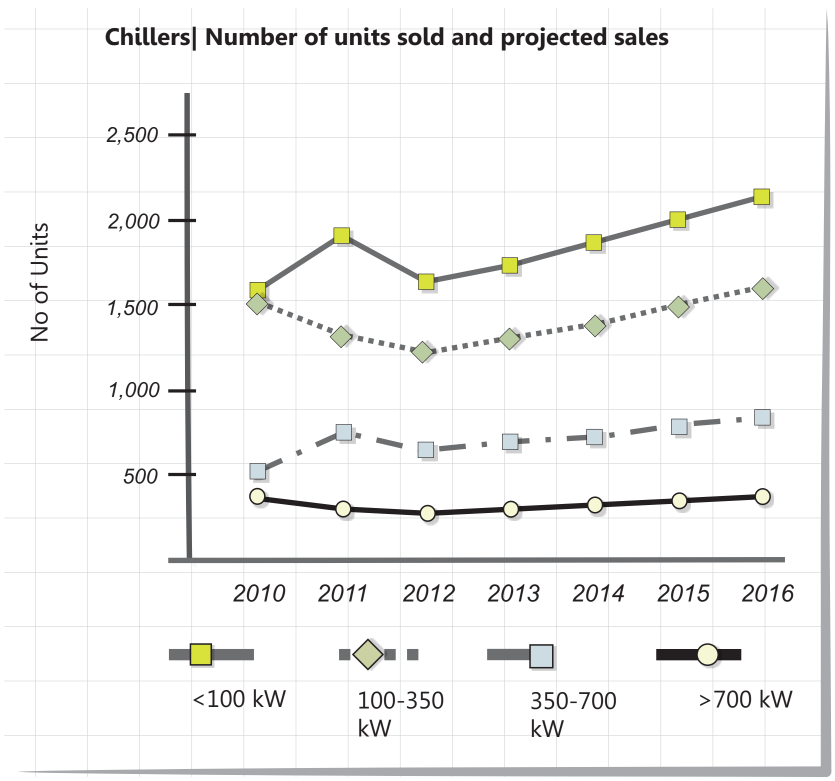
Source: PACE-D research

Sales of chillers in 101-350 kW and above 700 kW capacities dominate the market. Sales decreased in 2012 primarily because of the global economic downturn and the resultant decrease in demand from Indian customers. Chillers with capacities greater than 700 kW are expected to grow by 34 percent by 2016.

Reciprocating chiller

A downward trend is clearly discernible in this segment. Increasingly stringent regulations to limit the use of the R22 refrigerant and more efficient compressor types being available are the major factors for declining trends. Sales will probably decline to 100 units per annum and thereafter, growth trajectory will be flat.

Figure 26: Market Sales of Chillers – 2010-2016



Source: BSRIA - A multi-client study – India. November 2012

[27] UNEP 1998, JARN 11/01
[28] 1 kW = 0.28 TR. Conversely, 1 TR = 3.516 kW.

Scroll/Rotary helical (screw) chiller

Scroll compressor – scroll chillers face stiff competition from VRF/VRV systems. VRF/VRV systems can operate on demand based loads as low as 10 percent of unit capacity, are easy to install, and are less disruptive in retrofit applications. Earlier, scroll chillers were used to replace reciprocating types at the end of their service life. Now the capacities for which reciprocating and scroll chillers are used are mutually exclusive and this opportunity is also dwindling. However, sales of scroll chillers may grow in the process chilling segment because the cooling capacities required in process chilling match capacities available in scroll chillers.

Screw/rotary helical compressor – Screw chillers cater to medium to large capacities; and this is also the range of capacities in most new construction projects that are coming up in the country. Water-cooled screw chillers are also the best value for money option in the Indian HVAC market.

Centrifugal compressors

Standard and high efficiency (magnetic bearings) chillers are the two types available in the centrifugal chillers' segment. High-efficiency chillers were introduced recently into the market and almost all the leasing brands offering centrifugal chillers also offer those with magnetic bearings. At part-load conditions, magnetic bearing chillers can achieve a coefficient of performance (COP) of 9.5. However, the price differential between standard and magnetic bearing chillers is nearly 40-50 percent. As a whole, the centrifugal market is bound to grow. Buildings that have large cooling loads leading to single chiller module capacity of >900 kW invariably install centrifugal chillers. The infrastructure segment of the construction industry (airports, metro stations) depends exclusively on centrifugal chillers.

Absorption type (Vapor Absorption Machines)

Absorption chillers or Vapor Absorption Machines (VAMs) are thermally-driven chillers that use a heat source for cooling. This heat source can be natural gas, steam or waste heat. Absorption chillers are eco-friendly as they are run on waste heat and gas instead of electricity.

Natural gas prices are extremely high in India. High gas prices have led to residential, retail and office spaces being excluded from using absorption chillers. Coupling with solar thermal energy is an expensive option with a minimum payback period of 6 years. In a market where most consumers want a payback period of 1-3 years, this technology combination is untenable. Solar-coupled absorption chillers are installed only by clients who want to showcase and adopt green technologies irrespective of the returns on investment.

Thermax is the established leader in this segment, with 88 percent to 94 percent market share. Absorption chillers have a huge share of the process chilling market, where waste heat/steam is available, like thermal power plants, sugar mills, and pharmaceutical and chemical industries.

Despite narrow applicability due to gas pricing structure in the country, absorption chillers can be encouraged wherever CHP systems have been installed. As such, potential for absorption systems and CHP can be linked together. The technologies that must be encouraged are triple-effect and hybrid absorption chillers.

Figure 12 shows the market direction from 2010 to 2016 for all chiller types, based on the compressors used. The dip in market value for all types in 2012 can be explained by the slowdown in the economy. Screw and centrifugal chillers are predicted to grow positively. Though use of scroll chillers will decline in the comfort cooling segment, overall market for scroll chillers will grow due to sales in process chilling. While screw and scroll markets will grow by 61 percent and 25 percent respectively from 2010, centrifugal chillers will also register a growth of 17.4 percent over 2010 sales. Sales for reciprocating chillers will see a decline of 56.2 percent over 2010 levels by 2016; thereafter they are expected to remain stagnant for some years. Absorption chillers will lose customers on the back of the gas pricing issues discussed above. Their market value is expected to decline by 35 percent.

Table 4: Leading Brands – Chillers

All Chillers	Chillers < 350 kW	Chillers > 351 kW
Carrier	Blue Star	Carrier
Thermax	Voltas	Thermax
Blue Star	Carrier	Blue Star
Johnson Controls Inc.	Johnson Controls Inc.	Johnson Controls Inc.
Voltas	Daikin	Voltas
Daikin	Thermax	Kirloskar
Kirloskar	Others	Daikin
ETA		ETA
Others		CIAT
		Others

Source: PACE-D research

Supply Structure

Key brands in the chillers' market are Blue Star, Carrier, Daikin, JCI York, Kirloskar, Thermax, Voltas, Lloyd, Clivet, and Ciat. Most international manufacturers have shifted production to India to ensure competitive prices.

Barrier analysis conducted as a part of this study revealed that upfront cost is one of the primary reasons preventing purchase of more efficient HVAC systems. As such it will be an area of concern as to how rising prices will further affect the market for EE technologies. Minimum Sales Price (MSP) for reciprocating chillers is likely to fall by 8.7 percent between 2010 and 2016. MSP for screw and scroll chillers is predicted to rise by 4 percent and 30.5 percent respectively.

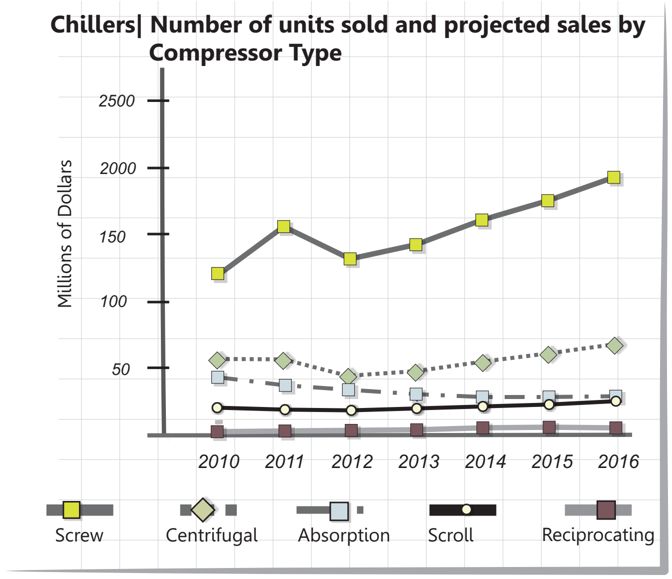
Table 5: Leading Brands by Compressor Type

Reciprocating	Screw	Scroll	Standard Centrifugal	High Efficiency Centrifugal	Absorption
Voltas	Trane	Blue Star	Johnson Controls Inc.	Blue Star	Thermax
Carrier	Daikin	Voltas	Carrier	Johnson Controls Inc.	Voltas
	Voltas		Trane		
	Blue Star				
	Johnson Controls Inc.				
	Carrier				

Source: PACE-D research

Table 5 summarizes the position of leading brands in the chiller market w.r.t. compressor type. JCI is a leader in the centrifugal chillers; segment. Trane and Carrier are also strong in the screw and centrifugal chillers market, while Daikin is gaining ground in the screw and scroll segments. The absorption chiller segment is led by Thermax.

Figure 27: Chiller Sales by Compressor Type 2010-2016 (value in USD million)



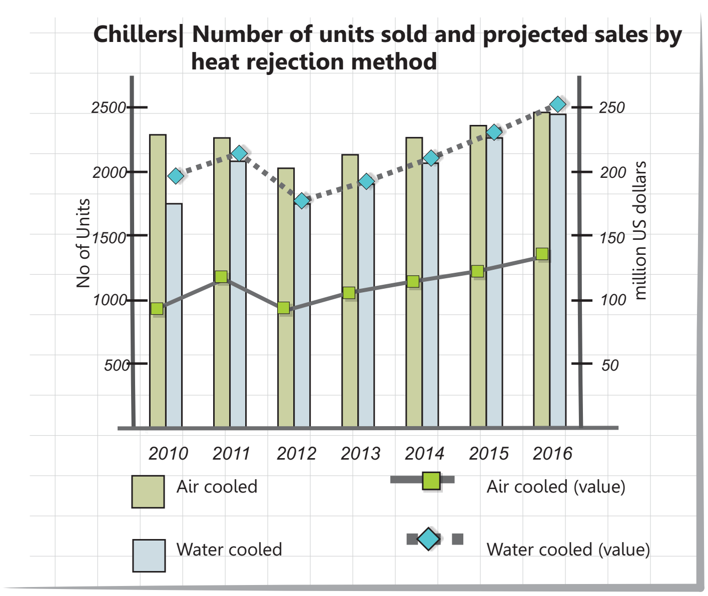
Source: BSRIA - A multi-client study – India. November 2012

Market Trends by Heat Rejection Method of Chiller

Heat from a chiller can be rejected by two methods: (a) cooling towers (water-based rejection), and (b) air condensers (air-based rejection). Water-cooled chillers are more expensive than air-cooled options, but are more efficient. Air-cooled chillers are generally used for smaller capacities. The share of water-cooled chillers (including absorption chillers) by value is almost 50 percent of the total chiller market value. The market value of air-cooled chillers is predicted to increase by 36.9 percent up to 2016. Water-cooled chillers are expected to follow the same trend but on a slightly lower scale. The segment is expected to grow by 27.3 percent up to 2016.

Proximity to water sources or access to sufficient water supply is required for using water-cooled chillers. A large number of city administrations have mandated use of recycled water in central plants due to increasing scarcity of water in Indian towns and cities. Cost of water recycling process will affect future sales of air and water-cooled chillers. Air-cooled chillers will be preferred in projects where water recycling cost is high.

Figure 28: Chiller Sales by Heat Rejection Method – 2010-2016[29]



Source: BSRIA - A multi-client study – India. November 2012

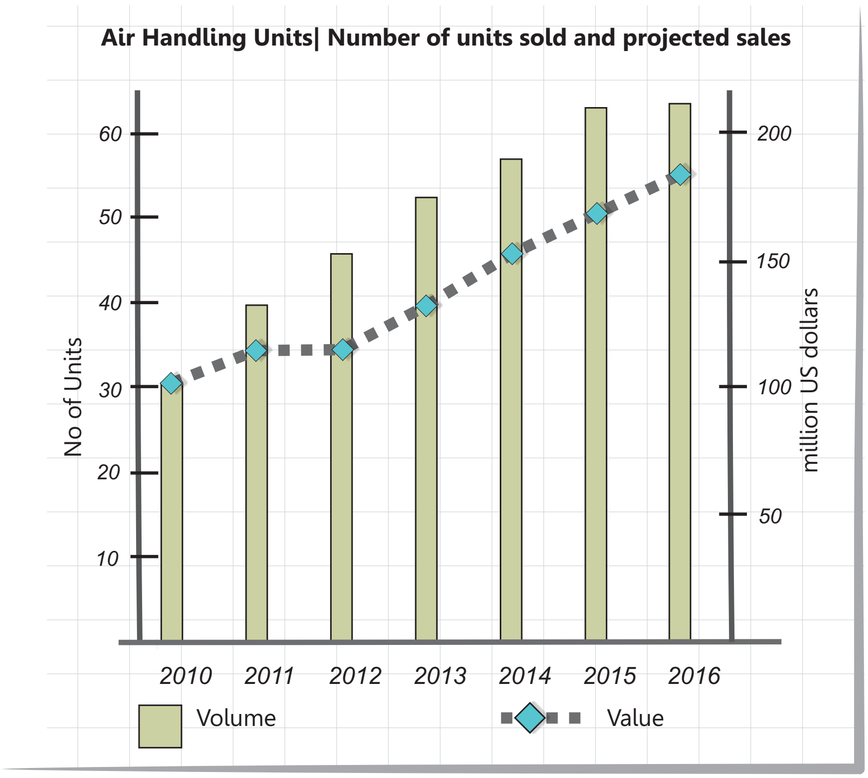
[29] Water-cooled chillers include absorption chillers

AHUs

Market Trends

The AHU market expanded by nearly 48 percent by volume from 2010 to 2012. Value of market share also increased from USD 89.3 million in 2010 to USD 113.1 million in 2012 – positive growth of 26.6 percent. The FCU market has echoed this trend, registering a growth of 33 percent in sales by volume and 43.9 percent by value. The bigger increase in value of the FCU market is because of rising prices. Average selling prices increased by 6 percent for concealed units and by 28 percent for cased units from 2010 to 2012. Meanwhile, average selling prices for AHUs dipped by 14.7 percent in the same period.

Figure 29: Sales of AHUs (USD million) – 2010-2015

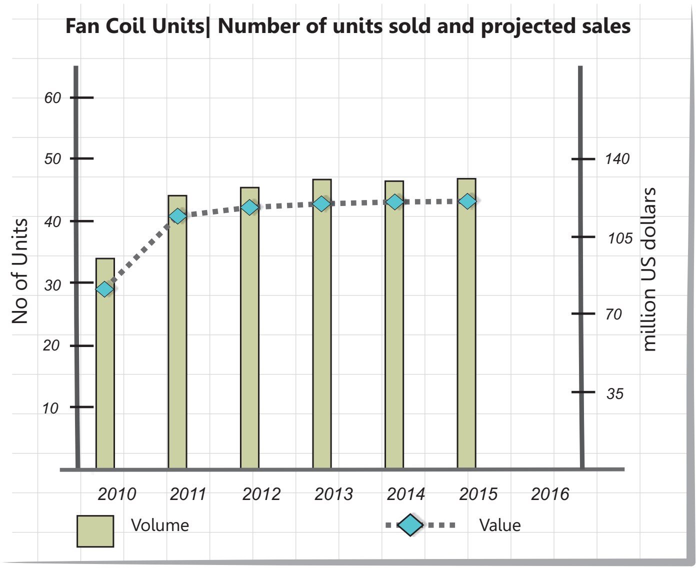


Source: BSRIA - A multi-client study – India. November 2012

There are various reasons for this trend for the two air side systems. AHUs are more popular among air side products in the Indian markets as compared to FCUs. Typical central systems' designs mostly use AHUs without any terminal units at the end of the ductwork. AHUs are also being increasingly used in ventilation-only systems as economizers and for free cooling in colder climates.

[30] Concealed FCUs are more popular than cased FCUs

Figure 30: Sales of FCUs (USD million) – 2010-2015



Source: BSRIA - A multi-client study – India. November 2012

Supply Structure

Lately, local brands have overtaken international brands in Indian markets, both in AHU and FCU sectors. By reducing manufacturing costs, these local brands have also driven the selling prices. Leading brands in the AHU segment are Zeco, Blue Star, ETA, Suvidha, Waves, Clivet, Flakt Woods, Edgetech and Netech. Sinko, JCI, Blue Star, Edgetech and Zeco lead the FCU market (in descending order).

6 Market Perspective

Quantitative semi-structured surveys have been undertaken with key stakeholders in order to understand current market scenario and trends. Further to garnering information on current usage patterns related to HVAC systems, the survey also explores the end-users' expectation from the next purchase, problems encountered with their current purchase, and their abstract understanding of energy efficiency and efficient products. The sample selection for the surveys is shown in the Table 6.

Table 6: Sample Construct for Quantitative Survey

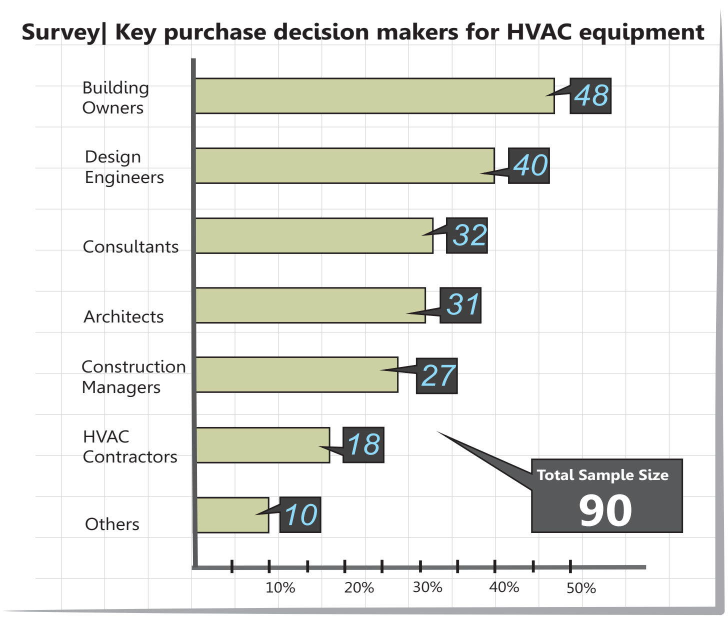
Climate	Geographical location	Consultants/ Architects	Builders/ Developers	End-users
Hot & Humid	Mumbai	6	6	6
	Kolkata	3	3	3
	Pune	3	3	3
	Chennai	4	4	4
Composite	Hyderabad	3	3	3
	Delhi	7	7	7
Temperate	Bangalore	4	4	4
Total		30	30	30

Source: PACE-D research

Although the energy efficiency of HVAC systems is a concern at the national level, the survey restricted itself to Tier I cities, keeping in mind the broader penetration of such products in these cities. Other factors that influenced the selection of the cities were diverse climate zones, purchasing power of end-users, robust construction activities, and the presence of respondent groups within the selected cities.

Figure 31: Key Decision Makers for HVAC Systems Purchase

[Indicates the percentage of people who identified themselves as key purchase decision makers within each category]



Note: Tables and graphs mentioned in this chapter have been derived from the market survey that was conducted in 2013.

Building owners emerge as key decision makers when purchasing HVAC systems for projects, followed by design engineers, and consultants. However, consultants and architects are nearly equally engaged in the decision-making process, and far more so than construction managers, contractors, or others.

Table 7: Reason for Current HVAC Purchase [Number/Count]

Parameters	All	Consultants/ Architect	Builders/ Developers	End-users
Chiller (Air-cooled/Water-cooled)	46	13	17	16
Good performance	20	8	4	8
Good cooling	18	6	4	8
Good service	12	3	3	6
Noise control	8	2	3	3
Reasonable price	8	-	-	8
Reduce energy cost	4	1	3	-
Good temperature control	3	2	1	-
Large Packaged Unit (Multi-split)	25	15	6	4
Low maintenance cost	8	6	1	1
Good performance	12	5	5	2
Occupies less space	5	4	-	1
Split	21	9	7	5
Good service	4	1	2	1
Good performance	2	-	1	1
Good cooling	3	1	1	1
Low maintenance cost	3	1	1	1
Reasonable price	2	1	1	-
Reduce energy cost	3	2	-	1
Noise control	2	1	1	-
VRF	16	7	4	5
Low maintenance cost	9	3	2	4
Reduced energy cost	8	3	1	4
Noise control	8	1	2	5

Good performance and good cooling prevail over other parameters during the purchase of HVAC systems across categories covering large systems. Interestingly, for smaller systems, maintenance and good service are over-riding concerns. Reasonable price emerges as the next important reason for purchase consideration in the case of chillers. Across all categories, good performance and good service claim precedence over other concerns. With VRFs, the key purchase criteria are equitably distributed across low maintenance cost, reduced energy cost, and good noise control.

Table 8: Features Considered at Latest HVAC System Purchase [Figures in Percentage]

Parameters	All			Consultants/ Architect			Builders/ Developers			End-users		
Ranking*	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3
Base		90			30			30			30	
Efficiency	28	49	64	27	40	53	30	60	80	27	47	60
The design and type of ductwork	26	36	50	23	37	47	30	37	57	23	33	47
The refrigerant	11	29	43	10	37	43	7	23	43	17	27	43
Location of the indoor unit	9	27	30	13	23	30	10	37	40	3	20	20
Location of the outdoor unit	9	14	21	17	27	40	3	7	10	7	10	13
A filter dryer	7	12	19	7	13	23	7	10	13	7	13	20
The condenser (outside) coil type	6	14	28	3	13	23	10	20	37	3	10	23
Balance dampers in the ductwork	3	10	20	-	10	20	3	7	13	7	13	27
Return-air considerations	2	6	19	-	-	20	-	–	7	7	17	30
Air-filter location	-	3	6	-	-	-	-	–	-	-	10	17

*R1 = No. of respondents who accorded the feature top rank
R2 = No. of respondents who accorded the feature second rank
R3 = No. of respondents who accorded the feature third rank

The efficiency of HVAC systems emerges as a top-ranked feature during the system purchase process across all categories. Efficiency, and the design and type of ductwork are the two most important features that are considered during the purchase process. Interestingly, refrigerant type is also an important consideration, ranked number three.

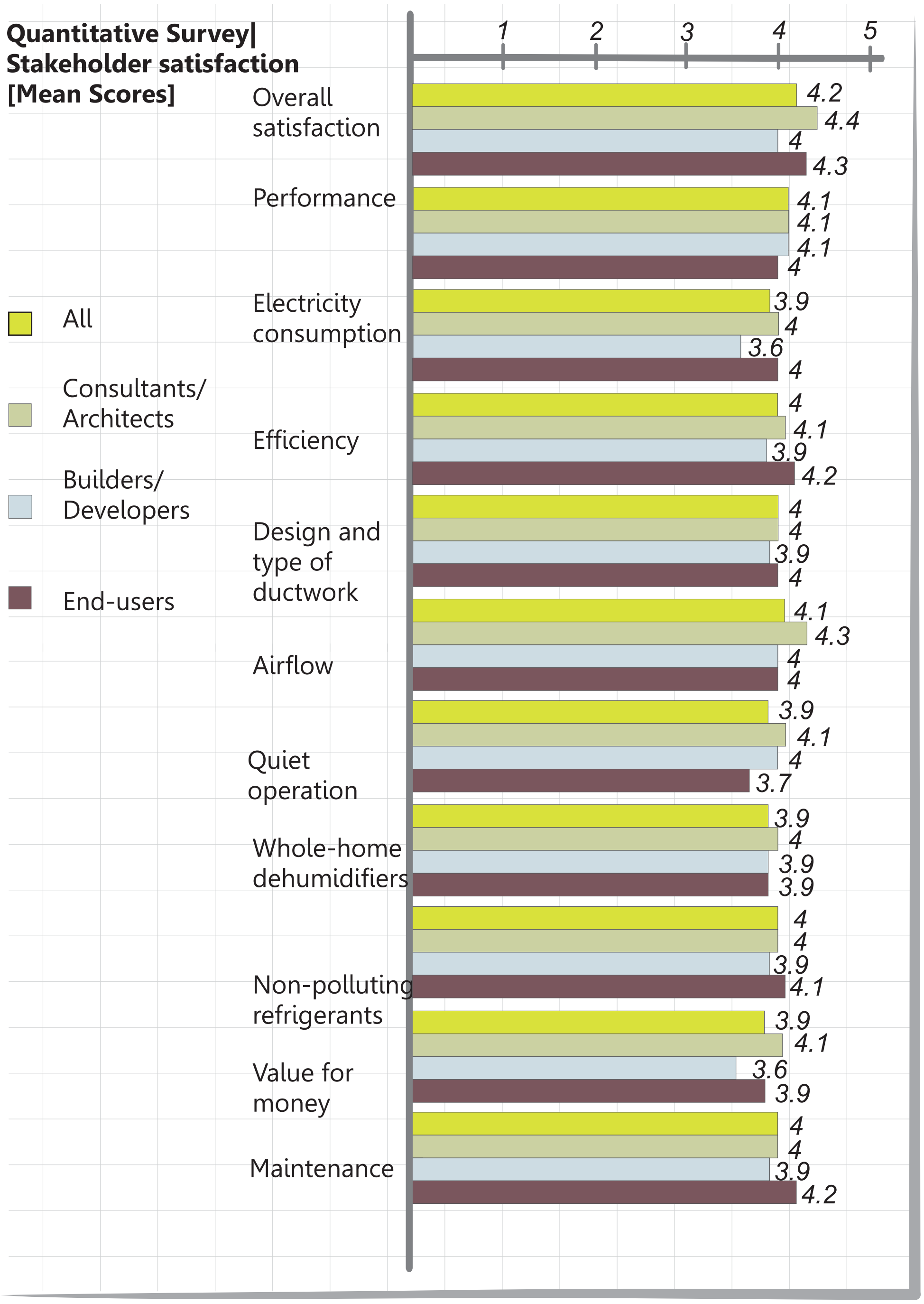
For consultants and architects, location of the outdoor unit is important, while for builders and developers the location of the indoor unit is accorded higher priority. This could be explained by architects and consultants sharing a deeper engagement with building aesthetics and developers, and builders being more concerned with economy of space.

Table 9: Sources of Information: HVAC System Purchase [Figures in Percentage]

Sources	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Engineers/Consultants/Architect	56	18	70	81
Contractor Referrals	47	33	69	39
Co-workers	39	48	27	42
Internet	27	58	15	8
Local Trade Organizations/ Dealers	15	27	12	-
Friends & Peer Groups	8	6	6	12

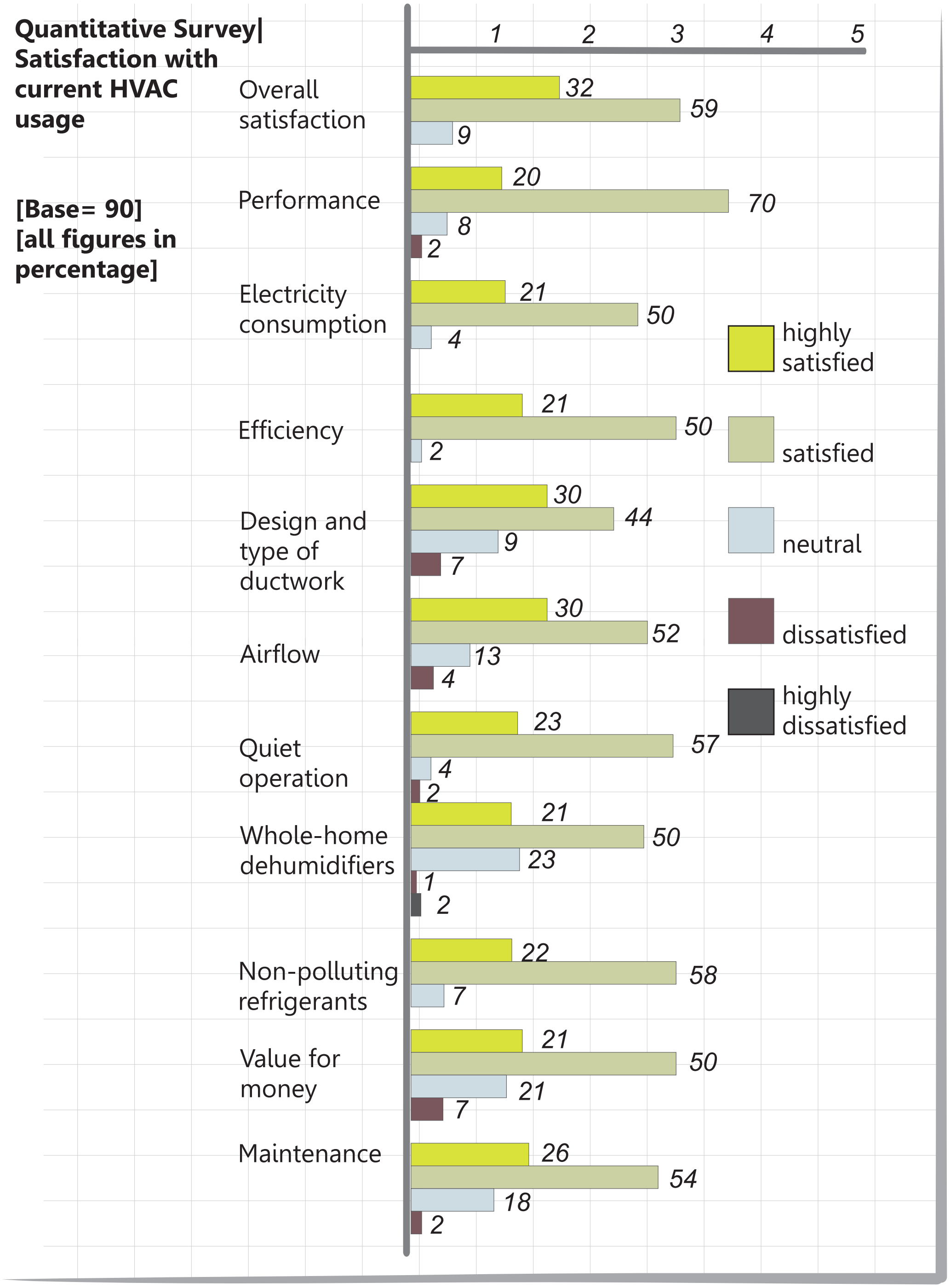
Engineers/consultants/architects rank as top sources of information during the HVAC purchase process. Other good sources for this information are contractor referrals and co-workers. In the case of consultants/architects, the internet has scored high as a robust source of information.

Figure 32: Satisfaction with Current HVAC [in Percentage]



Over 70 percent of the respondents expressed satisfaction with the current performance of HVAC systems, while 20 percent said they were highly satisfied. Overall too, an overwhelming majority (90 percent) have indicated satisfaction with the current status of HVAC systems.

Figure 33: Satisfaction with Current HVAC Usage



*Respondents indicated responses on a sliding scale of 1 through 5; 1 denotes highly dissatisfied and 5 denotes highly satisfied.

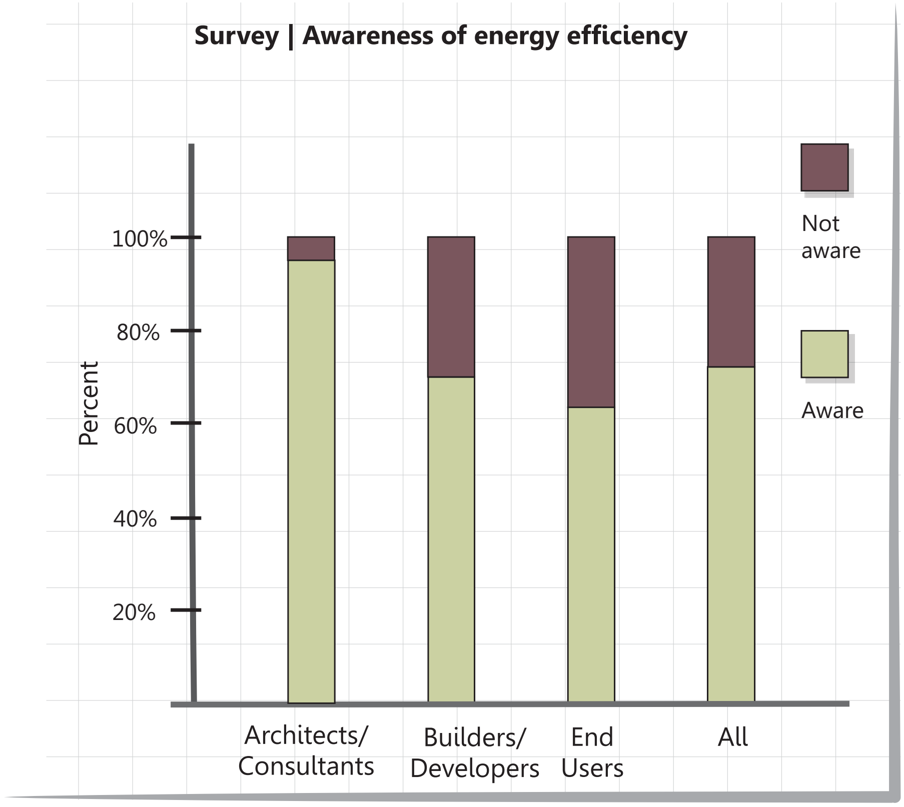
Mean scores of 3.9 and 4.0 are assigned to the parameters – electricity consumption and efficiency, respectively. Overall, respondents appear very satisfied with the current status of HVAC systems, assigning an average score of 4.2.

Table 10: Problems with Current HVAC System Usage [Figures in Percentage]

Parameters	All	Consultants/ Architect	Builders/ Developers	End-users
Chiller (Air-cooled/Water-cooled)	46	13	17	16
	24	54	12	13
Electricity consumption is high	17	8	6	31
Noisy operation	9	-	12	25
Gas leakage	7	-	12	6
High maintenance	20	8	6	31
Large Packaged Unit/Multi-split	25	15	6	4
None	36	40	33	25
Electricity consumption is high	16	13	17	25
Advance control system	8	8	17	-
Trips when overloaded	8	13	-	0
Split	21	9	7	5
None	70	33	14	
Electricity consumption is high	40	22	14	20
Noisy operation	20	0	29	
Maintenance is high	20	0	14	
Less cooling	30	11	0	20
VRF	16	7	4	5
None	50	57	25	60
Maintenance is high	6	14	-	20
Price is high	6	29	-	20

An overwhelming 70 percent reiterate that split systems do not entail inherent problems. VRF systems too, get a clear vote of approval for problem-free functionality. With chillers and large packaged units (multi-splits), respondents have a less enthusiastic response. High electricity consumption and maintenance were cited as common problems for chillers. For split systems too, high electricity consumption is a cause for concern, along with noisy operation and maintenance issues.

Figure 34: Awareness of Energy Efficient HVAC Systems [Base = 90, Figures in Percentage)



More than 70 percent of respondents are aware of energy efficient HVAC systems. The awareness is higher in the case of consultants/architects and relatively low in the case of end-users.

Table 11: Understanding of Energy Efficient HVAC Systems [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	64	24	21	19
Save power (electricity)	44	46	38	47
Low energy consumption	22	33	29	17
Related to new technology	22	29	14	63
Better machine efficiency	20	29	32	50
Less maintenance	11	17	14	-
Maintain temperature effectively	11	17	14	-
Star rating defines energy efficiency	3	4	5	-

A majority of respondents (44 percent) related energy efficiency in HVAC systems with saving power (electricity). Low energy consumption is ranked next. The purpose of this particular survey was to draw out the correlation that stakeholders have sub-consciously established between the term 'energy efficiency' and the listed parameters. Relationship to new technology and better machine efficiency, possibly the key drivers of an energy efficient HVAC market transformation strategy, received a moderate response (22 percent and 20 percent respectively). This highlights a gap that needs revisiting. Few respondents link energy efficiency with better functionality, with a lukewarm 11 percent relating energy efficiency to maintaining temperature effectively.

Table 12: Source of Information on Energy Efficient HVAC systems [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	64	24	21	19
Promoters of EE buildings	61	46	71	68
Internet	58	63	76	32
Consultants & Colleagues	45	46	38	53
Newspapers/publications	38	25	33	63
Government bodies	8	13	-	11
Others	14	25	5	5

According to the respondents, the main sources of awareness of energy efficient HVAC systems are promoters of energy efficient buildings and the internet. A market transformation strategy for such systems, then, should adequately provide for both - more information flow through a better institutional framework and better online information related to energy efficient HVAC systems (including vendor data, users' manuals, and technical manuals).

In the case of end-users, an overwhelming number derive this information through promoters of EE buildings, publications and printed matter, and consultants and colleagues – in that order.

Table 13: Awareness on Latest Technologies of HVAC Systems [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Heat Recovery Systems	64	80	70	43
Remote Diagnostic and Maintenance Systems	64	80	60	53
HVAC Functions with Computerized Controls	56	70	57	40
Combating Air Pollution with HVAC Technology	53	67	57	37
Complete Automation	52	67	60	30
Passive Dehumidification	48	70	43	30
Zones with Different Temperature Settings	46	50	43	43
Smart (Learning) Thermostats	41	47	47	30
Residential Zoning Systems	36	47	33	27
Noise Control Systems	34	40	33	30
Two-Stage Cooling Offers Efficiency, Extra Comfort	32	40	37	20
HVAC Software – may provide tools to help with scheduling, dispatching, billing, maintenance and inventory	29	30	37	20
DEVap (Dessicant Enhanced Evaporative Air Conditioning)	24	30	20	23

Predictably, consultants/architects are far more aware of energy efficiency technologies related to HVAC systems, compared to the other sub-categories of stakeholders. Heat recovery systems, remote diagnostic and maintenance systems, HVAC functions with computerized controls, combating air pollution with HVAC technology, and complete automation, appear familiar territory for the consultant community. End-users seem to have only a cursory knowledge of the parameters mentioned here.

Table 14: Technologies of the Future | Technologies most likely to be popular in the near-future [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Advance Heat Recovery Systems	27	20	30	30
Passive Dehumidification	21	23	13	27
Control HVAC Functions with Computerized Controls	13	23	10	7
Residential Zoning Systems	8	3	10	10
Home Automation	8	7	7	10
Noise Control	8	10	7	7
DEVAP	4	3	7	3
Combating Air Pollution with HVAC Technology	4	7	7	-
Nest Learning Thermostats	3	3	3	3
Zones with Different Temperature Settings	3	-	7	3

While heat recovery systems and passive dehumidification are expected to be in demand in the near future, the overall response to the listed parameters is lukewarm. This indicates that either the respondents are not well-versed with the terminology/technologies (and hence reluctant to predict a future for the same) or display a genuine apathy and lack of enthusiasm for the listed parameters. A market transformation strategy must address both scenarios.

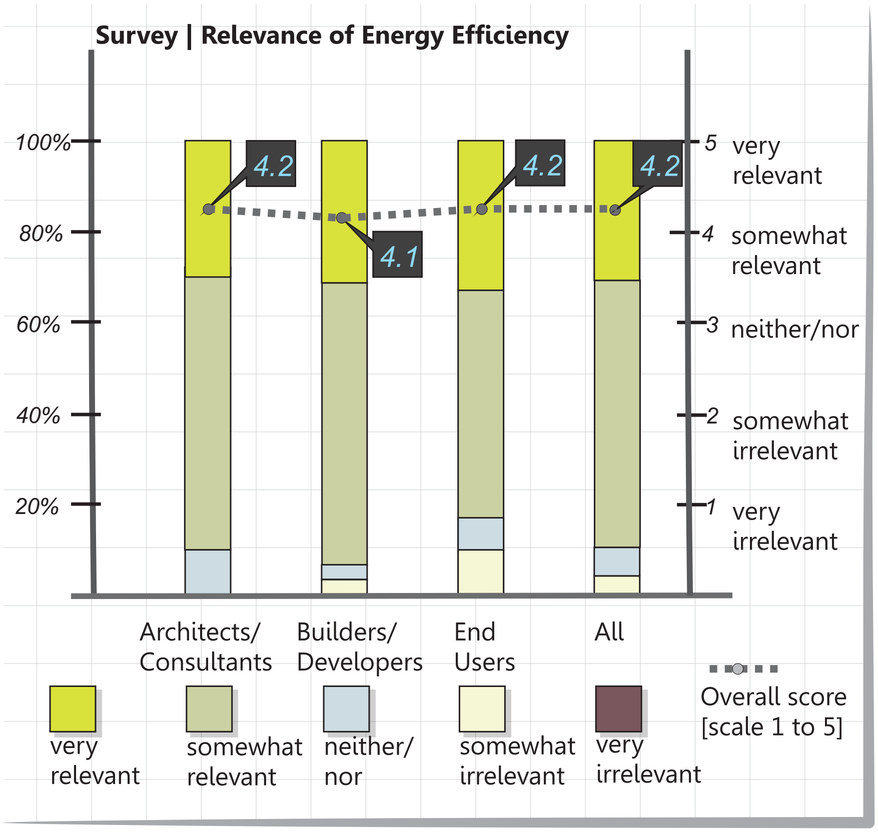
In addition, the respondents were asked to share their views on the following concept: 'HVAC systems in buildings play a major role in minimizing or increasing the energy consumption of a building.' In a conventional building, HVAC systems contribute nearly 60 percent of the annual electricity bills. The objective of most changes to HVAC systems will be to decrease energy cost and reduce greenhouse gas (GHG) emissions associated with building operations. HVAC accounts for a significant portion of the energy use of a commercial building and represents an opportunity for considerable energy savings. The responses have been summarized in Table 15.

Table 15: Reaction on the Proposed Concept [Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
It is a laudable concept	42	47	39	43
More energy saving	44	84	27	20
Low energy cost	10	17	10	3
Design keeping 'green' as a consideration	9	17	10	-
Less energy consumption	8	13	10	-
It is a new concept	7	7	10	3
Concept is already available in market	7	10	10	-
Low maintenance cost	7	7	13	-
Less electricity consumption	6	7	7	3
It is eco-friendly	6	10	7	-
It minimizes energy consumption	4	10	-	3

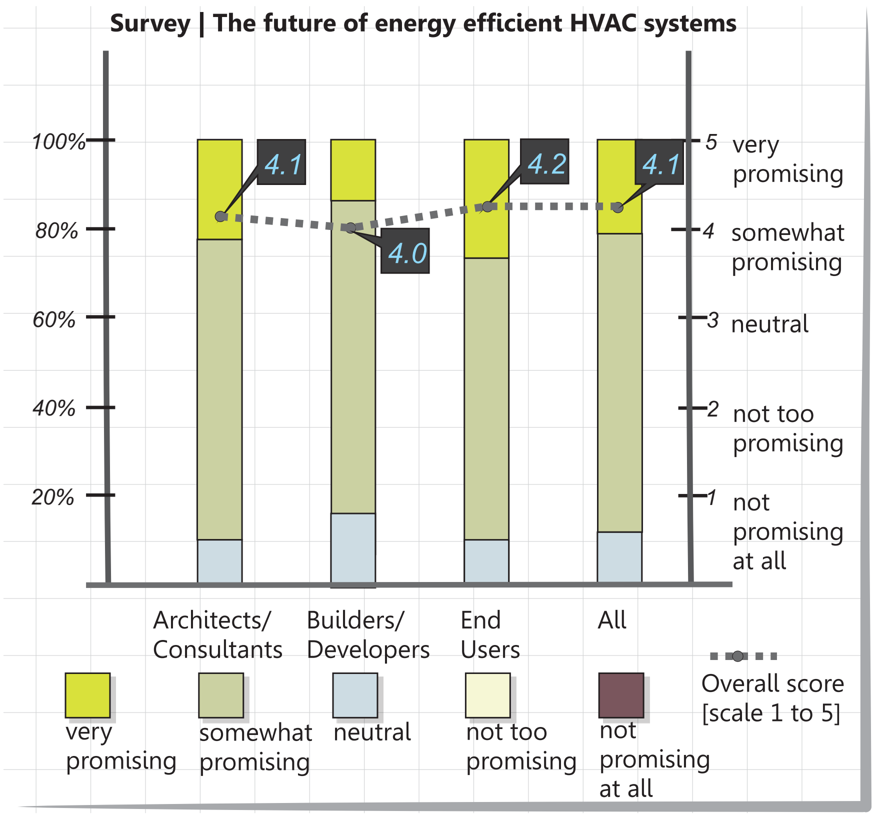
Many consultants/architects welcomed this as a laudable concept and acknowledged its potential for energy savings. However, the builders/developers and end-users responded in a more guarded manner, assigning moderate scores for its energy savings potential. Similarly, architects/consultants too responded in a restrained manner to other parameters related to design, keeping 'green' as the consideration, clearly demonstrating that the concept is yet to take root as a mainstream idea.

Figure 35: Relevance of the Proposed Concept [Number of respondents = 90]



Most of the respondents (90 percent) acknowledged that the concept of energy efficient HVAC systems was relevant, although in the score format, the score veered only moderately above (4.1 to 4.2) the score for somewhat relevant (4.0). This possibly indicates that the respondents are familiar with the concept at a superficial level.

Figure 36: Application of the Concept for Future Projects [Number of respondents = 90]



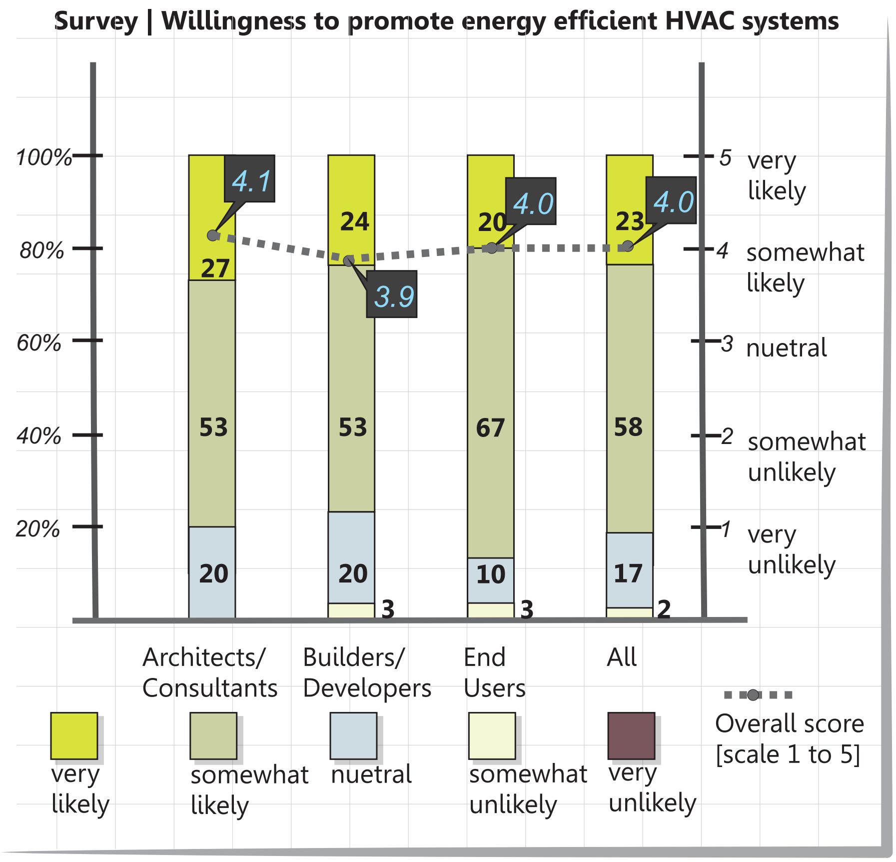
A moderate number of architects/consultants and end-users have said that the concept is very promising. Even fewer builders/developers have termed it very promising. However, nearly 88 percent of the respondents concur that the concept is at least somewhat relevant to their future projects.

Table 16: Expected Benefits from Energy Efficient HVAC [Figure in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Reduced energy cost	57	57	41	60
Energy efficient	49	43	23	42
Energy savings	48	53	45	52
Reduced maintenance cost	39	45	20	46
Reduction in GHG emissions	39	46	13	7
More effective cooling	27	35	3	7
Environment friendly	17	48	3	-
Combats global warming	12	50	-	30

Nearly all the perceived benefits of energy efficient HVAC systems have received robust ratings from consultants/architects. Understandably, builders/developers appear to value reduced energy cost and energy savings far more than the other parameters. End-users too, attach more value to these two parameters, in addition to reduced maintenance cost and combating global warming.

Figure 37: Willingness to Promote Energy Efficient HVAC Systems [Number of respondents = 90]



More than 80 percent are at least somewhat likely to promote energy efficient HVAC systems across all categories of respondents. This is marginally higher (87 percent) in the case of end-users. Within the category architects/consultants, 27 percent are very likely to promote energy efficient HVAC systems.

Table 17: Reasons for Promoting Energy Efficient HVAC [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	73	24	23	26
Saves electricity	40	40	17	27
Saves money	30	30	20	27
Saves energy	29	25	19	23
Reduces cost	20	30	22	26
Energy efficient	19	27	13	25
Advanced technology	16	23	7	17
Low maintenance	5	25	7	3
Protects environment	4	33	12	23
Eco-friendly	4	15	3	3

The primary reason for promoting energy efficient HVAC system is that such a system saves electricity, saves money, saves energy, reduces cost, is energy efficient, and uses advanced technology (with diminishing number of votes in that order).

Interestingly, there is a better correlation between the responses of the sub-categories architects/consultants and end-users. Possibly, the builders/developers category feels burdened with passing on the benefit of reduced energy costs to the end-user.

Table 18: Motivators for Promoting Energy Efficient HVAC [Figure in Percentage]

Parameters	All			Consultants/ Architect			Builders/ Developers			End-users		
Ranking*	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3	R1	R1+R2	R1+R2+R3
Base		90			30			30			30	
Reduced energy cost	50	66	76	57	63	67	47	63	77	47	73	83
Reduced maintenance costs	19	55	66	27	53	63	13	43	57	17	70	77
Environmental awareness	11	31	45	5	37	53	10	37	50	17	20	33
Increase reliability – fewer malfunctions	11	14	36	12	13	27	10	17	40	10	13	40
Improved occupant health	8	15	25	3	10	13	13	27	40	7	9	23
Benefits of going green	11	10	18	15	13	30			7	7	7	17
Increased economic benefits through job creation	7	12	28	-	-	27	7	13	30	-	10	27

*R1 = Percent of respondents who accorded the feature top rank
R2 = Percent of respondents who accorded the feature second rank
R3 = Percent of respondents who accorded the feature third rank

Reduced energy cost clearly emerges as the key motivator for promoting energy efficient HVAC systems across all categories. Reduced maintenance costs is the second-most cited factor, surprisingly, several notches above environmental awareness, benefits of going green, and improved occupant health. Overall, the responses are restrained.

Table 19: Barriers in Accepting/Promoting Energy Efficient HVAC Systems

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Lack of information/understanding of benefits of energy efficiency	72	80	67	70
Lack of awareness of the business case for energy efficiency	57	57	70	43
Absence of standardized measurements & verifications protocol	51	63	37	53
Perceived high initial investment costs	41	50	27	47
Absence of a common quantification method for energy savings benefits	40	43	30	47
Insufficient financial and regulatory incentives	36	43	27	37
Split incentives, wherein the capital investments for energy efficiency are made by the builders/owners but the benefits of lower operating expenses accrue to end-users	34	30	43	30
Limited technical expertise and products	34	23	40	40
Asymmetric access to information	27	27	37	17
Lack of promotion	20	20	17	23
Structural barriers	10	15	9	6

Lack of information/understanding about energy-efficient HVAC systems come across as major barriers (acknowledged by 72 percent of the respondents) in the acceptance and promotion of such systems. Lack of awareness of the business case for energy efficiency and standardized measurements/verifications protocol are a distant second and third, with 57 percent and 51 percent of the votes respectively. Perceived high initial investment costs, often cited as the primary barrier to the adoption of energy efficient systems, has been accorded a lower ranking here (fourth with 41 percent of the votes). This is an encouraging response with a view to framing a market transformation strategy for the adoption of energy-efficient HVAC systems, as it is relatively simple to address issues related to lack of information or insufficient information (in comparison to high cost of initial investment).

The absence of a common quantification method of energy savings benefits has also been voted (40 percent) as a major reason preventing early adoption of such systems.

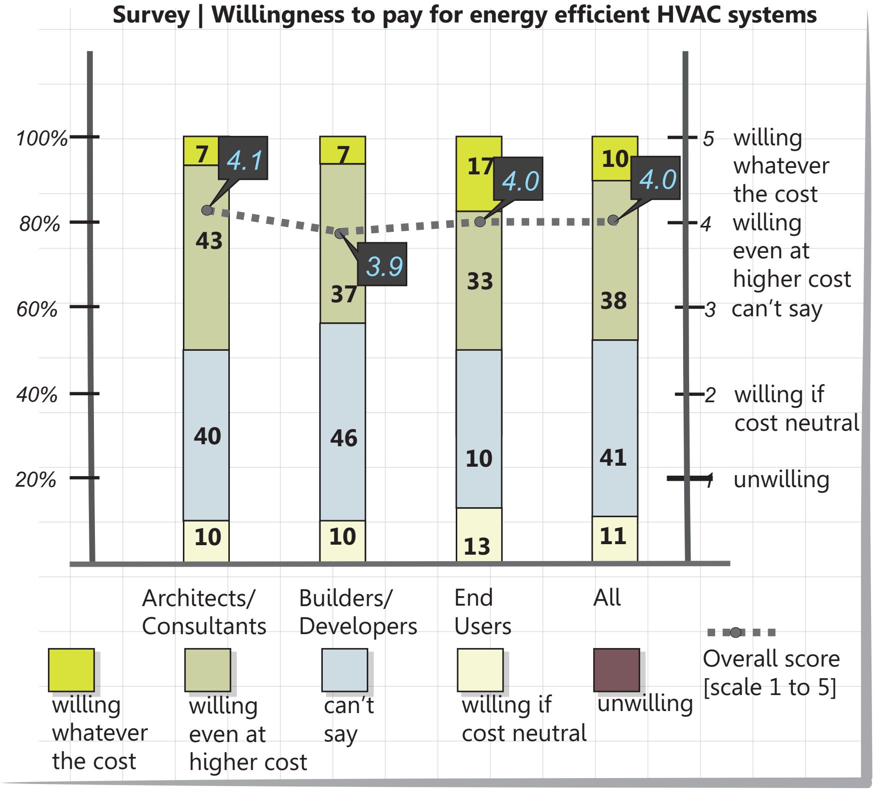
Overall, the architects/consultants' category has expressed more frustration with the listed barriers, followed by end-users, and developers/builders. This may indicate a larger engagement of architects/consultants with energy-efficient HVAC design compared to other sub-categories. Builders/developers cited lack of awareness of the business case for energy efficiency as the key barrier (70 percent) to adoption of energy-efficient systems.

Table 20: Preferred Method for Promoting Energy-Efficient HVAC Systems [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Advertisements	35	40	27	37
Through awareness programs	25	40	10	25
Knowledge dissemination – online	18	12	11	31
Through conferences & seminars	18	20	7	26
Direct promotion by meeting consultants	18	-	16	19
By providing more information in markets	18	15	-	20
Through government regulation	10	20	3	7

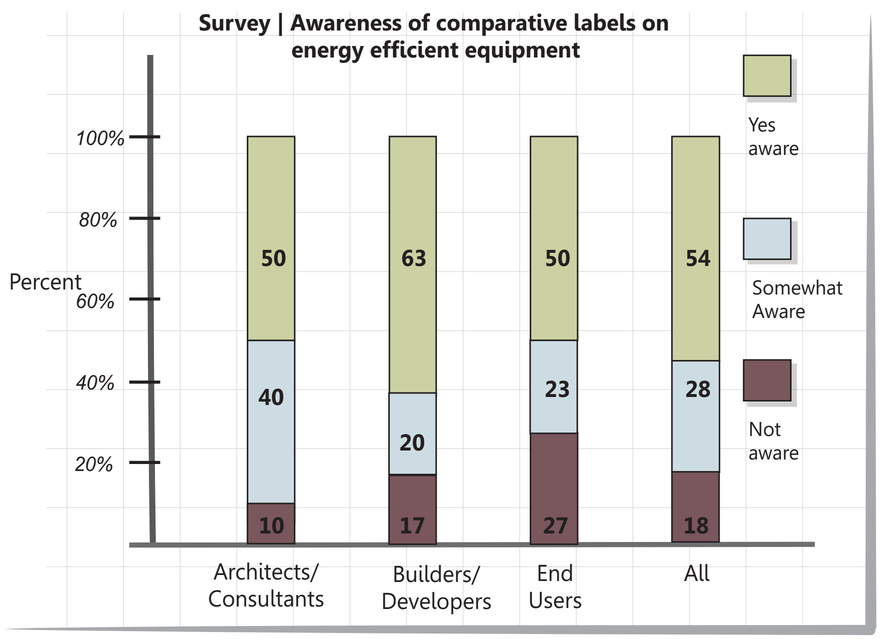
Though advertisements and awareness programs remain the most preferred methods for the promotion of energy-efficient HVAC systems, overall, the three sub-categories differ significantly in the way they prioritize various methods for promoting these systems. Architects/consultants find merit in government intervention through regulation as a way to promote these systems.

Figure 38: Willingness to Pay for Energy-Efficient HVAC Systems [Base = 90]



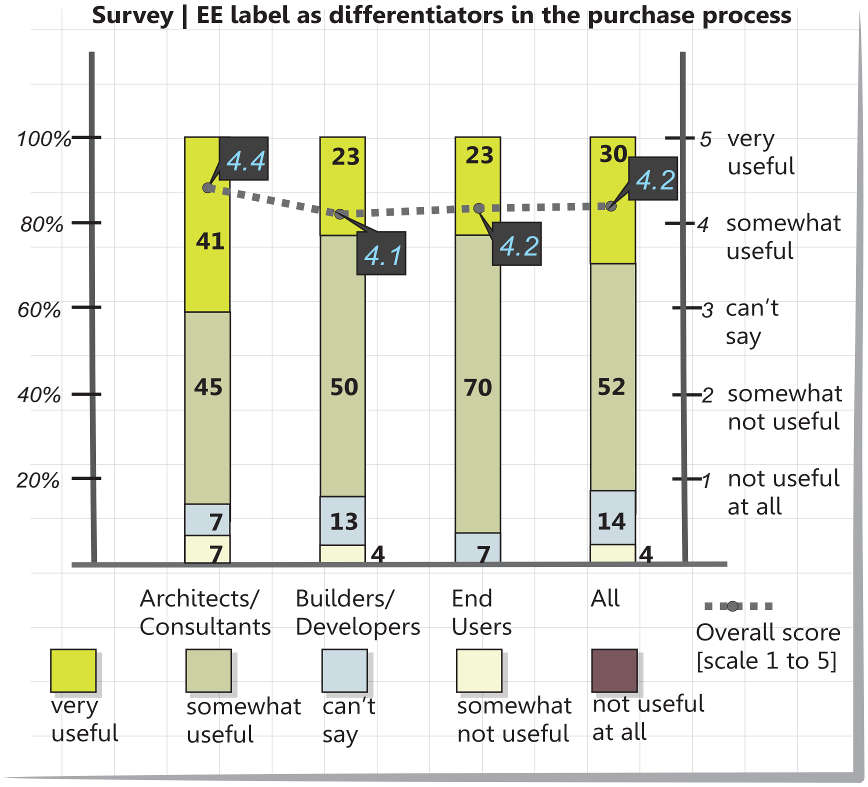
Overall, a significant number (48 percent) have indicated their willingness to pay for energy-efficient systems even if they cost more than their less efficient counterparts. A large number of respondents (41 percent) are still neutral (undecided) on the issue.

Figure 39: Awareness of 'Comparative Labels' on Energy-Efficient Equipment [Base = 90]



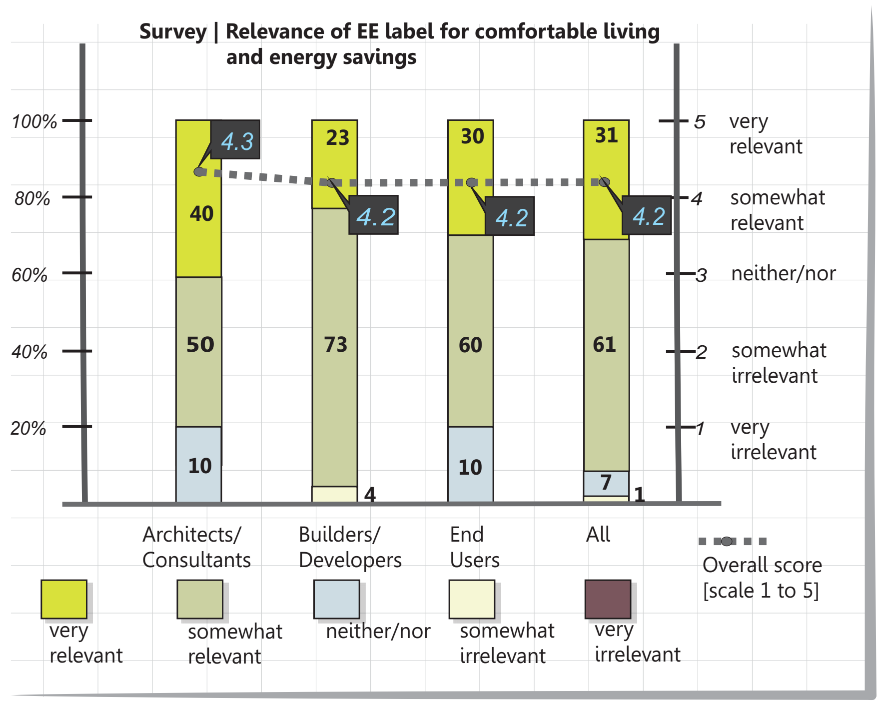
About 80 percent of the respondents are at least somewhat aware of the comparative labeling on energy-efficient HVAC systems. End-users are the least aware of such labels (27 percent).

Figure 40: Energy-Efficient Labels as Differentiators and their Usefulness in Purchase Process [Base = 74]



More than 75 percent attach value to labels as differentiators during the purchase of energy-efficient equipment. This practice is slightly less in the case of builders/developers.

Figure 41: Relevance of Energy-Efficient Label for Comfortable Living and Energy Savings [Base = 90]



More than 90 percent of respondents find HVAC systems with energy-efficient labels relevant for comfortable living and energy saving.

Table 21: Expectations from Energy-Efficient Label for Comfortable Living and Energy Saving [Figures in Percentage]

	All	Consultants/ Architects	Builders/ Developers	End-users
Base	83	27	29	27
Reduced energy costs	81	85	76	81
Environmental awareness	60	74	52	56
Reduced maintenance costs	59	67	55	56
Environmental benefits	58	67	52	56
Improved occupant health	53	63	52	44
Increased economic benefits through job creation and market development	43	37	45	48
Increased reliability – longer lifetimes than conventional products	37	41	38	33

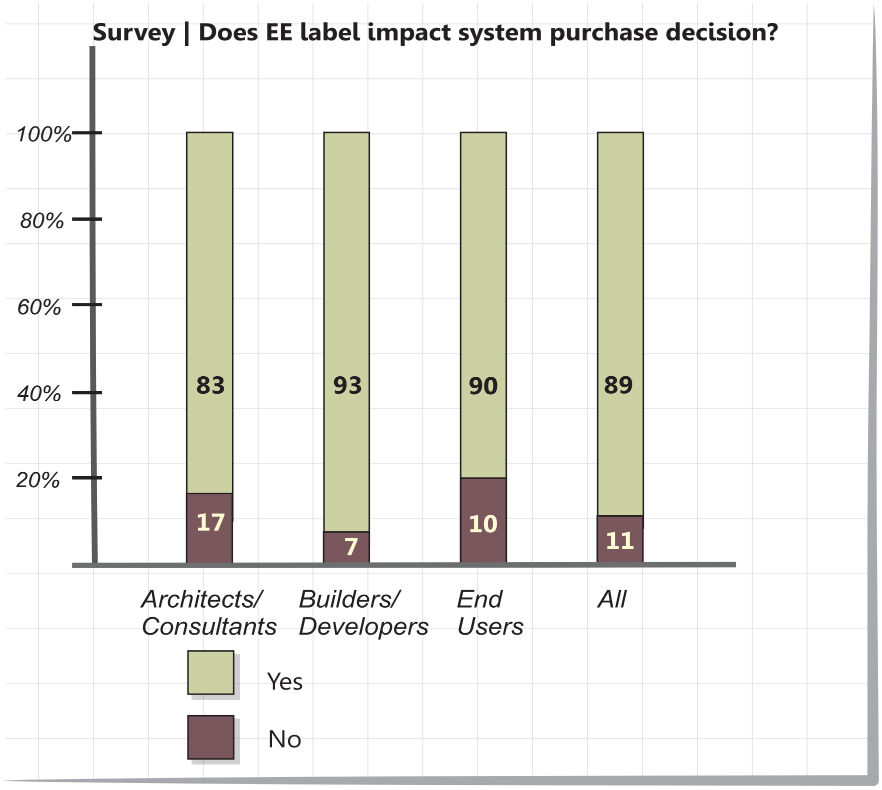
Reduced energy costs and environmental awareness are the primary expectations from energy efficiency labels, as listed by the respondents. Overall, architects/consultants have ranked the parameters in a more robust and enthusiastic manner than other categories.

Table 22: Reason for Irrelevance of Energy-Efficient Label for Comfortable Living and Energy Saving [Figures in Percentage]

	All	Consultants/ Architects	Builders/ Developers	End-users
Base	7	3	1	3
Nothing Specific	43	67	-	33
It is not relevant to me	14	-	100	-
It is highly technical	14	33	-	-
Difficult to analyze	14	-	-	33
Cost will be higher	14	-	-	33

On being further queried on why energy-efficiency labeling was not relevant, the answers given by some respondents were imprecise and ambiguous.

Figure 42: Effect of the Label on Particular HVAC System Purchase Decision [Base = 90]



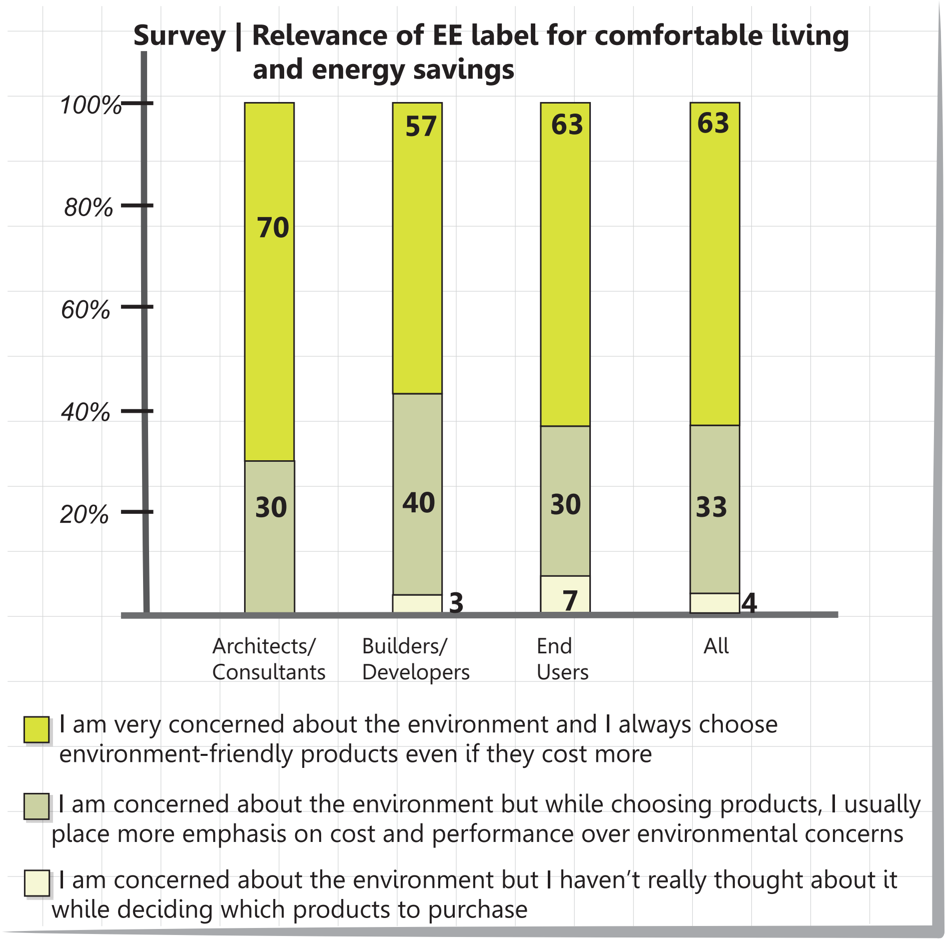
Energy efficient labels would affect the decision of HVAC purchase in almost 90 percent of the scenarios.

Table 23: Preferred Organization for Promoting Energy Efficient HVAC Systems [Figures in Percentage]

Parameters	All	Consultants/ Architects	Builders/ Developers	End-users
Base	90	30	30	30
Government	57	53	53	67
Independent organization	47	60	33	47
Organization set up by builders	35	29	60	17

The responses across categories were, on an average, in favor of government as the preferred organization for promoting energy-efficient HVAC systems. However, all three categories differed in the way they ranked the three parameters, with architects/consultants voting for independent organizations, builders/developers preferring organizations set up by builders, and end-users ranking government as their preference.

Figure 43: Opinion on Self-Image [Base = 90]



7 NEW TECHNOLOGY

Desiccant Cooling Systems

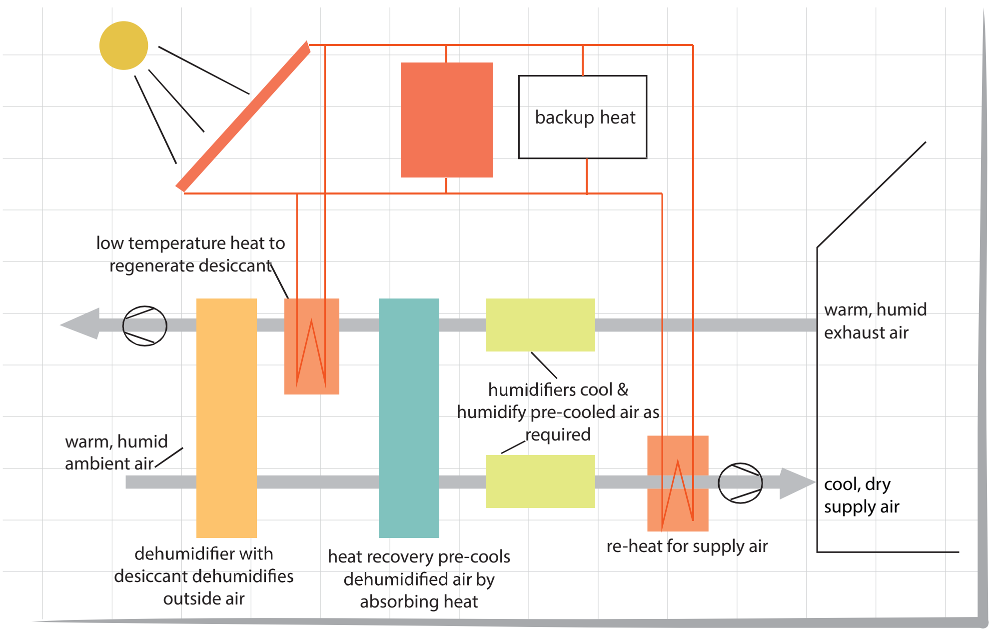
A desiccant is a substance, either solid or liquid, which absorbs water molecules from air and dehumidifies it. Initially used to absorb moisture from the air, the desiccant is later regenerated by heating it so that it releases the absorbed moisture. This phase change cycle is a continuous process that drives the operation of desiccant systems.

Two basic categories of desiccant systems are:

a). Open desiccant systems, where the desiccant comes into direct contact with the air for the process of dehumidification.

b). Closed desiccant systems, where the desiccant is confined to a closed chamber and dehumidifies air indirectly.

Figure 44: Schematic Diagram of Open Loop Desiccant Cooling



Based on the type of desiccant used, desiccant systems can be categorized as solid and liquid desiccant systems. In solid desiccant systems, a dry solid desiccant like silica gel or zeolite is used in a rotating bed or impregnated into a honeycomb-form wheel within the system. Liquid desiccant systems are a new emerging technology consisting of a contact surface, which is either a cooling coil or cooling tower, wetted with liquid desiccant like lithium chloride or calcium chloride.

Desiccant systems can be successfully used in regions with low heating demand but have limited application in high humidity areas where the desiccant fails to reduce the air moisture content to desired levels. In India, no commercial project is functioning on the concept of desiccant cooling. Research projects are underway to make the application more viable.

Note: Tables and graphs in this Chapter have been derived from the PACE-D TA Program's Energy Comfort Workshop Summary Report, February 28, 2013 to March 1, 2013.

Table 24: Features of Desiccant Systems

Pros	Cons
Improved air quality in interiors	High initial cost to set up the system
Less electric consumption as alternative energy sources can be used	Experienced professionals required to construct and service such systems
CFC, HFC, HCFC refrigerants are not used	Liquid desiccant can be corrosive and damage the system or components
Integration with conventional systems to remove latent heat load can reduce energy consumption	Cost-effective only when there is a source of waste heat available to regenerate desiccant
Low operational cost	

Three-stage Evaporative Cooling

Evaporative cooling is a mechanism traditionally used to provide thermal comfort in hot and dry regions. The mechanism involves sensible and latent cooling of air with water.

Direct evaporative cooling is most effective when the outside conditions are dry. Indirect evaporative systems are used during the seasons when little or no humidification is required, i.e. when outside air humidity is within a comfortable range. Fresh filtered air is made to pass through a dry section of the system to cool the air through sensible heat transfer.

Stage-wise evaporative cooling systems can be either two-stage or three-stage.

- Two-stage evaporative cooling systems (direct + indirect) – the direct system is functional during the dry season, when humidification of air is required, and the indirect system can be used when air needs to be primarily cooled.
- Three-stage evaporative cooling systems (direct + indirect + cooling coil) consist of direct and indirect evaporative cooling together with conventional cooling coils. The addition of cooling coils (chilled water or refrigerants) is helpful in the monsoon season when the humidity level is high and dehumidification is required. Fresh air passed through the coils controls both sensible and latent heat requirements. The coils are also useful in the winter when heating is required.

The drawback of the two-stage system is the high humidity level of the supply air. Over a period of time, indirect evaporative cooling systems that provide sensible cooling of the air without humidification have emerged in the market.

Table 25: Features of Evaporative Cooling Systems

Pros	Cons
Can be added to existing chilled water systems at low costs	Needs high purity water to prevent the build-up of salts
Reduces use of HFC refrigerants	Requires periodic maintenance
Reduces energy costs significantly	

Case study	Central University of Rajasthan
Location	Bandar Sindri, Ajmer, Rajasthan, India
Climate Type	Hot and dry
Building Type	Residential

System Description	Two-stage evaporative cooling system consists of a direct evaporative precooler, which provides cool and wet air to indirectly cool down the primary air in the tube bundle heat exchanger. The cool and dry air is then passed through a direct evaporative cooler to humidify it.
System Performance	Energy consumption in the hostel building is estimated to have been reduced to 1/3rd of a similar building with no major energy conservation measures and using conventional air-conditioning systems. Indoor temperatures were measured to be between 31 °C to 34 °C when the ambient was approximately 44 °C. Energy Performance Index was measured to be 60-65 kWh/m2/year (2012)

Solar Air Conditioning

Cooling loads in tropical countries like India peak during the hot summer season when solar heat gain through radiation is maximum. Solar cooling technology uses a renewable source of energy to reduce the cooling loads when air-conditioning demand is at its annual high. The principle behind the functioning of solar cooling is the use of solar heat/thermal energy to re-generate the refrigerant in an absorption chiller or the desiccant in a desiccant chiller.

Absorption chillers comprise of the following components:

1. Evaporator: Where the refrigerant evaporates at a very low pressure and temperature and is absorbed by the absorbent. The process results in extraction of heat from the refrigerant and provides chilled refrigerant as an output.
2. Generator: The mixture of absorbent and refrigerant is then introduced in the generator. Steam or hot water produced through the solar panel devices is used to vaporize refrigerant.
3. Condenser: The vaporized refrigerant is cooled down in the condenser and maintained at low pressure. This cooled refrigerant is then sent to the evaporator for generation of chilled water for air conditioning.

Figure 45: Schematic Diagram for Absorption Cycle

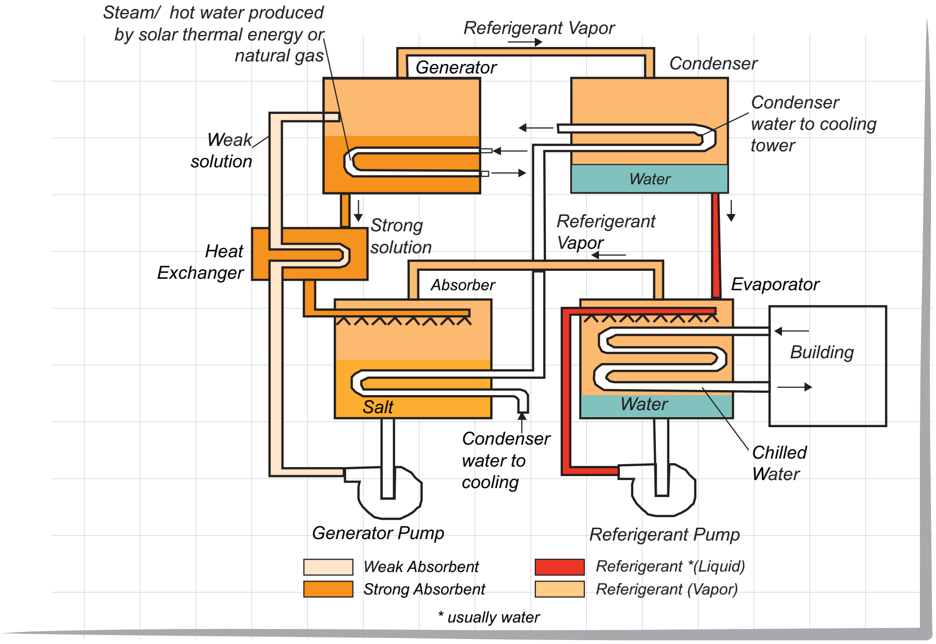


Table 26: Features of Absorption Chillers

Pros	Cons
Attractive payback when configured with power generation and hot water heating	Requires significant space for the solar panels and solar concentrators; thus suitable for projects with large building footprint or site area
Low distribution losses in the range of 5 to 10 percent; for conventional technologies, losses are between 75-80 percent	Capital cost is almost twice as much as conventional chillers
Eliminate the use of CFC, HFC, and HCFC refrigerants	Energy required for operating pumps is higher compared to energy for electric chillers
System operations generate less noise and vibration	Higher flow rate of condenser water required as absorption chillers have lower COPs
High efficiency in triple-effect absorption designs	Requires large cooling tower capacity compared to electric chillers as larger volume of water is circulated

Case study	Solar Energy Center
Location	Gurgaon, Haryana, India
Climate Type	Composite
Building Type	Office and residential
System Description	Solar air conditioning The 100 kW cooling capacity standalone system is integrated with a triple-effect Vapor Absorption Chiller (VAC) and solar parabolic concentrators. The system is designed to meet cooling loads of 13 rooms at the center. The VAC can use steam, hot water, gas, kerosene or oil to run continuously. Chilled water is supplied at 7 °C through FCUs to all rooms. Solar collectors, with area of 284 sq.mt., deliver water at temperatures between 140 °C and 210 °C.

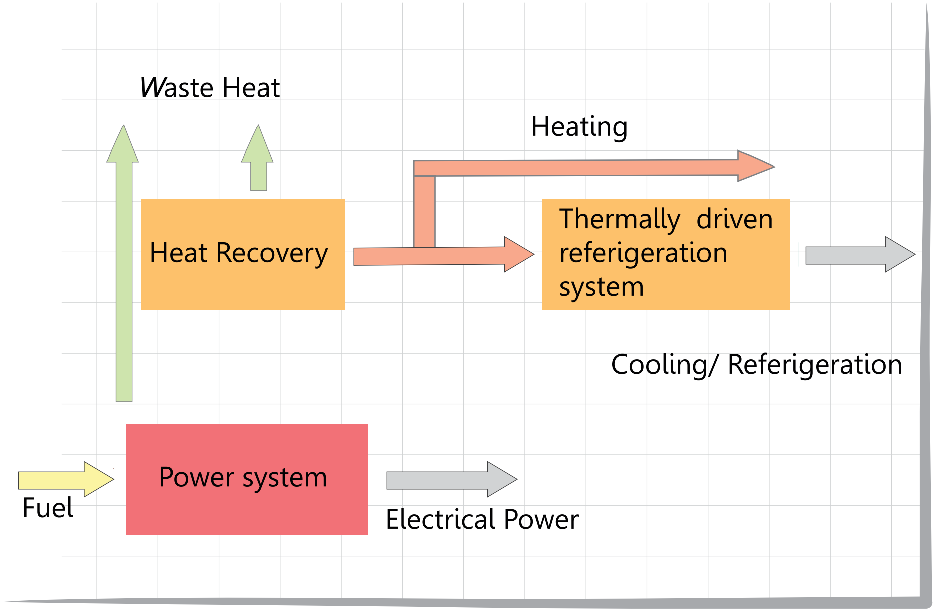
System Performance	The integrated system is estimated to be 20 percent more efficient than VACs with no solar component. Co-efficient of Performance (COP) is 1.7, which is the highest among vapor absorption technology coupled with eco-friendly energy resources. The system has built-in thermal energy storage using phase-change materials. This allows it to supply cooling continuously.

Tri-generation (Waste to Heat)

In a developing country like India, high volume of waste heat is generated, which could be used to produce electricity around the year. Tri-generation, which uses waste heat to provide cooling, could be a solution to the rising energy crisis. In many buildings like hotels, hospitals, and industries, there is a demand for hot water along with air cooling. Such a scenario is well-suited for the application of the tri-generation concept.

A tri-generation system produces three forms of energy, i.e. electricity, heating, and cooling, which could be used to generate power, hot water, and air conditioning with suitable equipment. The principle of tri-generation is based on generation of heat energy. Heat captured through burning waste or production of electricity with generators, or heat generated through solar panels could be used to generate hot water through heat transfer equipment. This heat can also be used to make cold/chilled water with absorption chillers. Potential for using tri-generation systems is estimated to be nearly 500 to 1,000 MW in India.

Figure 46: Schematic of a Tri-generation System



Tri-generation technology, also known as Combined Cooling, Heating, and Power (CCHP), comprises of a gas engine or a power system operated by burning waste, bio fuel, or fossil fuel to produce electricity. The connected heat recovery system is used as a heat exchanger to recover heat from the engine or exhaust. This recovered heat can be used for heating applications like hot water or a regeneration process in absorption chillers. The electricity produced within the tri-generation process could be used to power chillers during peak load periods. Thermal energy could be diverted to boilers to heat the water used in hospitals, hotels, and industries for numerous purposes. It could also be used in absorption chillers to heat the absorbent and refrigerant mixture and regenerate the absorbent.

Table 27: Features of Tri-generation Systems

Pros	Cons
Negligible use of CFC/HCFC-based refrigerants	Intense planning and research is required for designing systems for projects
System's efficiency is 90 percent in comparison to 25 percent for electricity produced in power plants	Applicability differs with each project; detailed feasibility studies are required for each new project
Huge benefits in terms of reduction of GHG emission (estimated at over 50 percent from the current GHG emissions levels in buildings with both cooling and heating load)	
Same equipment can be used to generate cooling, hot water and electricity in a building	
Has potential to double end-user productivity for gas-based systems (compared to a combined cycle power station)	

Case study	Pushpanjali Crosslay Hospital
Location	Ghaziabad, India
Climate Type	Composite
Building Type	Hospital; 400 bed tertiary care
Area	5000 sq. mt.
System Description	Tri-generation system 1000 TR air-conditioning load. Components to meet heating and cooling loads include a gas genset (1.7 MW), 600 TR capacity Vapor Absorption Machines (VAM) with heat recovery, and electrical chillers of 400 TR capacity.
System Cost	Total capital cost, including DG backup was INR 90 million (USD 1.5 million). Additional capital investment for the tri-generation system was nearly INR 34 million (USD 565,128). Cost of power generated through the tri-generation system (using natural gas) is INR 34 million (USD 565,128)/kW. Net savings of INR 3.8/kW or approximately INR 30 million (500,000) annually is achieved through this system.
System Performance	The system provides uninterrupted and reliable power supply, without any fluctuations to the hospital. Power supplied by natural gas is more environment-friendly than the coal-based power supplied through the grid. Operating cost of this system is INR 136,000 (USD 2,260) per day compared to INR 225,000 (USD 3,738) for using electrical chillers running on grid supply.

Source: Presentation by Mr. Vijay Agarwal, Pushpanjali Crosslay Hospital

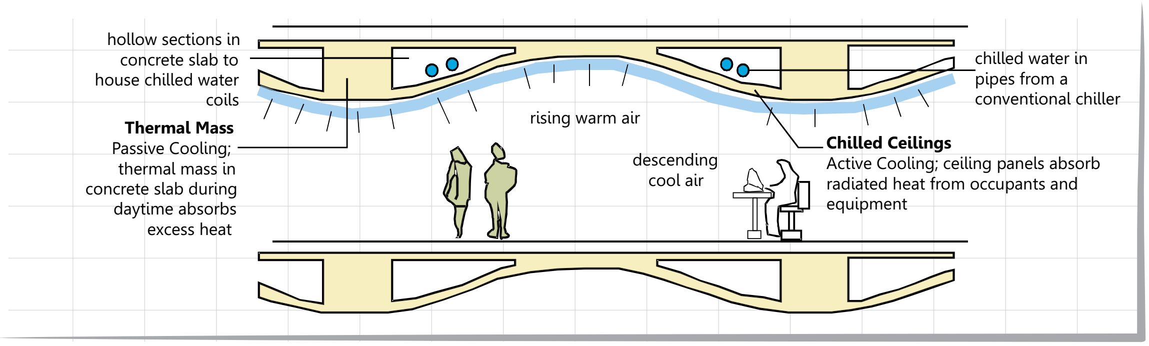
Radiant Cooling Systems

The guiding principle of a conventional air-conditioning system is convection whereas in a radiation system, the guiding principle is heat transfer through radiation. Heat transfer predominately occurs through surfaces like floors, ceilings, or walls, which in turn are heated or cooled by embedded coils. Radiant systems are installed in combination with large thermal mass to facilitate absorption and radiation. To optimize performance of the systems, coils should be installed in floors for heating purposes, and in ceilings for all cooling purposes. Application of radiant systems is limited to areas with high latent load and where chances of air leakage from adjacent humid areas are high. Improperly installed systems can lead to condensation on the building structural elements.

- Chilled slabs: These deliver cooling through the building structure, usually slabs, and are also known as thermally-activated building systems (Figure 47).
- Ceiling panels: These deliver cooling through specialized panels.

Systems using concrete slabs are generally cheaper than panel systems and offer the advantage of the thermal mass, while panel systems offer faster temperature control and flexibility. Capital expenditure of radiant systems is the same as a high-efficiency chilled water system; however, operational expenditure is less than chilled water systems.

Figure 47: Chilled Slab and Panel Radiant Cooling System



Radiant cooling systems consist of coils, which carry chilled water generated either through conventional electric chiller systems or low-energy chilled water generation systems like absorbent chillers/desiccant chillers. Chilled water in the coils cools down the slabs or panels, which in turn act as heat sinks for sensible heat loads of internal spaces.

Concrete structures typically used with radiant cooling systems also increase the thermal mass of buildings. This introduces inertia in the structure against temperature fluctuations and allows it to absorb heat from internal spaces more efficiently.

Table 28: Features of Radiant Cooling Systems

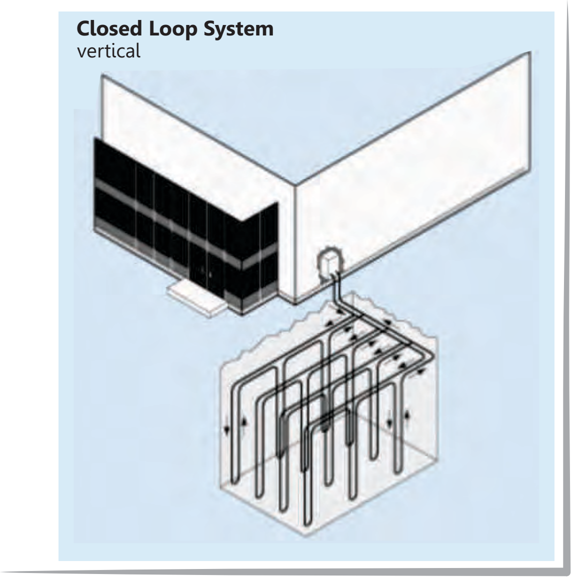
Pros	Cons
With a ventilation air system, thermal mass can significantly reduce the need for air-side systems. Fan power in HVAC systems is drastically reduced	Sections with leaking or blocked radiant pipes have to be closed, disrupting supply in the process
Noise and drafts of air movement are removed. There are no diffusers in the way of décor and cleaning	Condensation reduces cooling capacity. Hence an efficient envelope with "non-openable" windows is required
Additional savings due to lower supply temperature of chilled water (about 7-9 °C lower)	Condensate formation on the cold radiant surface results in water damage, mould, etc.
Better comfort conditions are maintained in zones	Complicated controls require skilled maintenance staff
	Not easy to maintain temperatures below 23 °C

Case study	Infosys Software Development Building (SDB-1)
Location	Hyderabad, India
Climate Type	Hot and dry
Building Type	Office
Area	11,600 sq. mt.
System Description	Radiant cooling system The two symmetric halves of the buildings are air-cooled with different technology. A conventional cooling system is implemented in one half, whereas the other half is cooled by a radiant system. The latter was designed for a cooling output of 75 W/sq. mt. Chilled water design temperatures for supply were 14 °C and for return 17 °C. Cooling tower approach temperature is 2 °C. Low-pressure piping and ducting distribution system is installed. An energy recovery system is also installed to provide dehumidified air to offices.
System Cost	Capital cost of the radiant system was INR 3,302 (USD 55.03) /sq.mt. The conventional system was installed at INR 3,327 (USD 56.45) /sq. mt.
System Performance	Energy index for the radiant system was 25.7 kWh/sq. mt. compared to 38.7 kWh/sq. mt. Thus, efficiency of the radiant system was 33 percent less than the conventional system. Average chiller plant efficiency for the radiant system side was .45 kW/TR compared to .6 kW/TR. Quantity of water required by the radiant system is one-fifth of that required by a conventional chiller of similar capacity. Air quality is also improved as there is no recirculation, so contamination is reduced. Comfort conditions measured inside the building are within the permissible limits of ASHRAE 55-2004 and ASHRAE 62.1-2007 for most of the time. The building has been operational for the last 3 years and the radiant system is functioning without any major complaints.

Ground Source Heat Pump (GSHP) Systems

A Ground Source Heat Pump (GSHP) system heats and cools buildings by using the earth as a heat source or heat sink. The system either extracts thermal energy out of the ground or transfers thermal energy from the building to the ground. Moreover, heat energy stored during the summer season could be extracted during winter to heat ambient spaces. On an average, 46 percent of the total solar energy received is stored in the ground. At 4-6 meters below ground surface[31], temperatures are more or less constant. Heat could be pumped in during the summer to the ground, where the temperature is lower than the ambient temperature.

Figure 48: GSHP System



The GSHP system has three major components:

1. **Earth connection**
   Earth connection is the connection between the GSHP system and the soil. Most popular connections are tubes, introduced either horizontally or vertically into the ground, or submerged in a lake or pond. The tubes carry an anti-freeze mixture and a suitable type of heat transfer fluid.
2. **Heat pump**
   This pump helps heat transfer from fluid in the earth connection to the distribution system. The pump consists of a heat carrier like water or air, which absorbs heat from heat transfer fluid through indirect contact and subsequently carries this heat energy to the heating/cooling distribution system. In a reverse cycle, the heat carrier transfers heat from the distribution systems to the heat transfer fluid in the earth connection.

[31]Depth below ground surface where temperatures are nearly constant is valid for India. It varies by latitude.

3. **Heating/cooling distribution system**
   This system delivers the heating or cooling from the heat pump to the ambient spaces. It consists of air ducts, diffusers, fresh air supply systems and control components, and circulates the supply air as per design conditions and occupants' requirements.

Table 29: Features of GSHP Systems

Pros	Cons
The system has high energy efficiency (50-70 percent) and provides heating, cooling and hot water	More suitable for composite climate as continuous pumping of heat to the ground could make the latter saturated in regions with minor differences between summer and winter temperatures
Low maintenance and low operational costs	Requires intense analysis at the concept design stage to check the feasibility of the system at a particular site
Additional savings due to lower supply temperature of chilled water (about 7-9 °C lower)	Condensate formation on the cold radiant surface results in water damage, mould, etc.
Uses renewable sources of energy	Requires skilled labor for designing and installing the system
	Government approval may not be available for all states
	High initial investment

Case study	Central University of Rajasthan
Location	Ajmer, Rajasthan, India
Climate Type	Hot and dry
Building Type	Residential – student hostel
System Description	Geothermal hybrid cooling system Water from the boreholes is used to cool the air before introducing the same in indoor spaces. Heat exchange between water from the boreholes and supply air takes place inside specially-designed AHUs. Air is further cooled after this through a two-stage evaporative cooling system. The system uses 100 percent fresh air and is designed to reduce temperature of the supply air by around 10 °C. Design temperature for the hostel rooms is 29°C.
System Performance	Average outlet water temperature from the boreholes is recorded at 25 °C. Outlet temperature in winter is around 19 °C. Energy Performance Index was measured to be approximately 78 kWh/m2/year (2012).

Boreholes in the Geothermal System at Central University of Rajasthan

8 Market Transformation Approach for India

The approach to market transformation in India needs to focus on the opportunities presented by growing demand and affordability of air-conditioning and fast growing domestic industry. The market research confirms that energy use in HVAC is an important concern for the end-users, but there is a lack of adequate reliable information for decision-making. The following sections summarize the insights from the market research and potential market transformation strategies.

Learnings from the Market Research

The HVAC Market Assessment Study has provided useful insights into the dynamics of HVAC industry, and design, operations and value of energy-efficient systems. Key observations from the market research are given below, and will serve as the context for developing a robust market transformation approach for HVAC in India:

1. The demand for high efficiency and new technology is being led by end users more than any other stakeholder in the process.
2. Energy efficiency considerations are already perceived as being factors in HVAC purchase decisions. At the first instance, most of the survey respondents felt that they have adequately incorporated energy efficiency considerations into the decision making process. Yet, most of them also felt that they were nor sure if they were actually getting the appropriate performance gains and savings benefit of energy efficiency in actual operations.
3. Decisions on HVAC purchases are heavily influenced by vendors and contractors. End-users are wary of such potential prejudiced sources of information, but they have limited access to objective information.
4. There is no clear understanding of cost benefit of energy efficiency in HVAC. Even though most of the end users, consultants and developers are concerned about energy used by HVAC systems, and they feel that high efficiency systems will yield savings, they rarely have the ability to do a life –cycle-costanalysis of different options. This often results in only a few equipment efficiencies being factored in decision making rather than the full system cost benefit.
5. Brand driven approach still predominates the large HVAC market. Advertising and branding seems to play an important role in market perception of energy use, which may not be substantiated by actual performance. Most manufacturers have a range of products with varying energy efficiency, but certain brands are automatically associated with high performance, even though a low efficiency system has bee selected.
6. Good cooling capability seems to be the most important factor for system selection amongst end-users and developers. Often, this translates to over sizing of equipment as well as a perceived down-side of energy efficiency in HVAC. The market perception is that energy efficiency in HVAC system may come at a cost to comfort.
7. Uncertainty about the total cost of ownership. There is a clear split incentive for developer and even amongst end-users there is insufficient information about the total cost of ownership of HVAC systems.
8. Capital cost is still the most important factor in decision making. Most of the respondents agree that awareness for energy efficiency is increasing in the market but still price plays an important role in buying decision as discussed in barriers to adoption. Most consumers do not prefer long-term benefits of saving energy, which they often are unsure of. They believe in the present, and the cost saved upfront. There is pressure to stay within predefined project budgets for HVAC systems, preset by previous experiences. The limited borrowing capacity of the owner also often outweighs long-term benefits.
9. There is focus on energy use, even if to a limited extent, in large buildings with chilled water systems, but for mid-size buildings where chiller systems are not installed, EE is not a perceived factor. Office, Healthcare, Educational and Industrial Buildings show big HVAC market potential in the coming years.

10. There is no independent monitoring of claims of energy efficiency by manufacturers and vendors. Energy efficient HVAC systems often don't show savings as advertised. Most common complain is that the running cost is very high, even in cases the HVAC system was selected for efficiency.
11. There is a lack of expertise in correct sizing and selection. Thumb rules are used for many decisions that are critical to system sizing and efficiency.
12. Many of the experts have concerns about ozone depleting substances (ODS) and future of chillers and HVAC systems from an environmental and regulatory perspective.
13. Lack of standardization of product efficiencies across different HVAC systems types makes it very difficult to compare different system options.
14. Product efficiency vs system efficiency is still not understood by most end-users, and they tend to make decisions based on individual equipment performance.
15. Lack of expertise in O&M is the most common reason for higher than expected energy use by the HVAC systems.
16. The perceived risks of changing technology, disrupting occupants, incurring debt, or entering into complicated agreements outside of core business areas for many owners and developers. The HVAC system is not updated or enhanced as long as there are no major complaints form the facility. The cost of energy is not clearly allocated to different end-uses in self occupied buildings.

Other considerations:

17. Inadequate knowledge of performance of non-traditional HVAC systems. This includes hybrid cooling systems, high efficiency equipment, as well as new types of cooling systems like radiant, and under floor systems.
18. ISHRAE has a good membership base, and HVAC fraternity needs to look up to it for information.
19. Knowledge of energy performance does not come from credible sources.
20. Even though there is a good awareness of the latest innovation through trade shows and international magazines, local experience and expertise is scant.
21. Even though cooling is acknowledged as the biggest concern, for utilities in India and they need to focus on HVAC DSM and energy efficiency programs at the utility level.

Market Transformation Potential Analysis

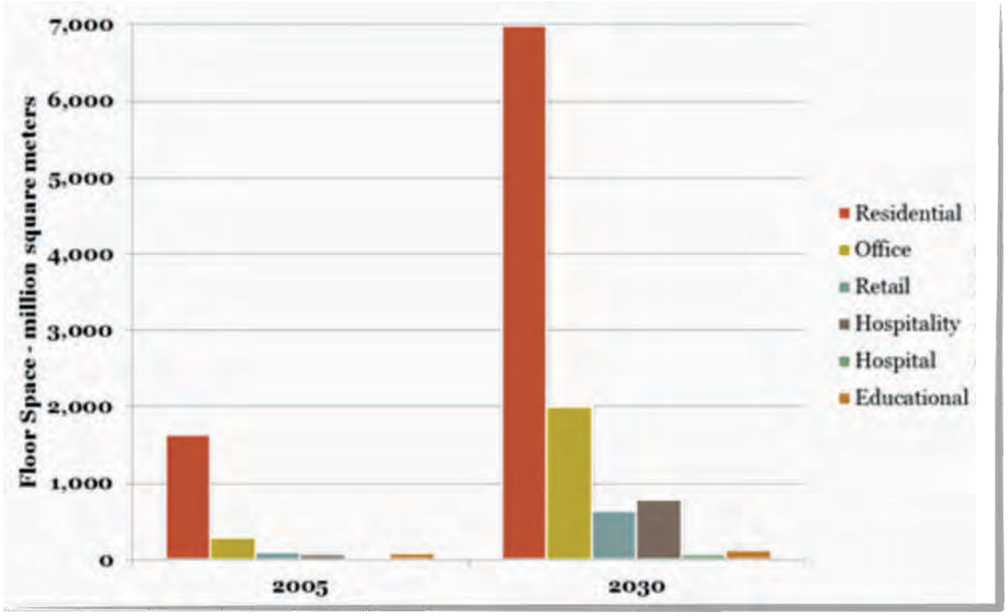
The analysis maps and the energy savings potential of various HVAC technologies, and sectoral and geographical intervention through the Market Transformation Plan.

Building Sector Expansion and HVAC Energy Use

Building floor area is undoubtedly bound to increase over the next few decades. Till 2030, residential sector is projected to lead this upward trajectory, followed by office and hospitality sectors (Figure 49). HVAC related energy consumption trends are closely linked to growth in floor space. Average energy use per unit area due to operating HVAC systems in conditioned buildings in India currently lies in the range of 120 – 290 kWh/ sq. mt./ year. If not improved, total energy usage for providing air conditioning in buildings is expected to grow to 1,547,129,000 MWh in 2030 (Figure 50).

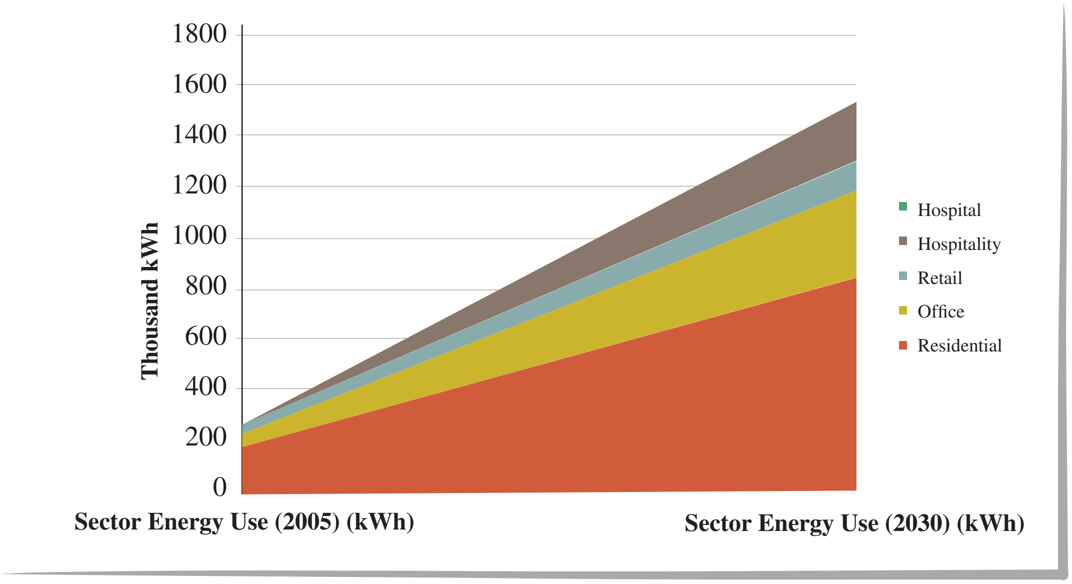
Residential, office, hospitality and retail will consume the largest share of the total energy consumption due to HVAC systems in the building sector. Magnitude of expansion in health and educational segments is expected to be smaller. The greatest impact of the market transformation will be felt if the market penetration of energy efficiency HVAC technologies can be improved in the three leadings sectors, i.e. residential, commercial and hospitality. It is crucial to inform and engage stakeholders from these three sub sectors to embrace energy efficiency in comfort systems.

Figure 49: Building Sector Growth Estimates (2030)



Source: EDS Analysis

Figure 50: Building Energy use due to HVAC Systems - Growth Estimates (2030)



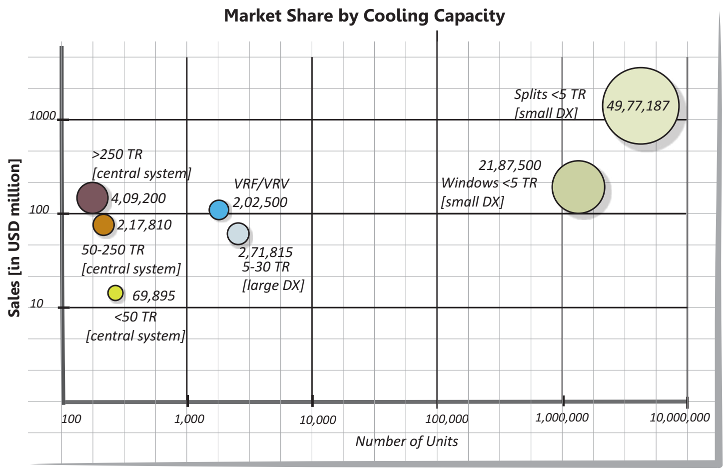
Source: EDS Analysis

HVAC Market Expansion

Total cooling capacity sold in 2010 was nearly 83,95,907 TR. Small DX systems, i.e. window air conditioners and split units with cooling capacity less than 5TR, cater to the bulk of cooling capacity demand. Sales of small DX systems dominated HVAC markets of India in 2010 (Figure 51), which was nearly 86 percent of total cooling capacity sold. Central systems, VRFs and large DX systems made up balance of 14 percent in the same year. Smaller DX systems are primarily used in residential and small commercial establishments; these can be a focus area for market transformation strategies because of the saving potential.

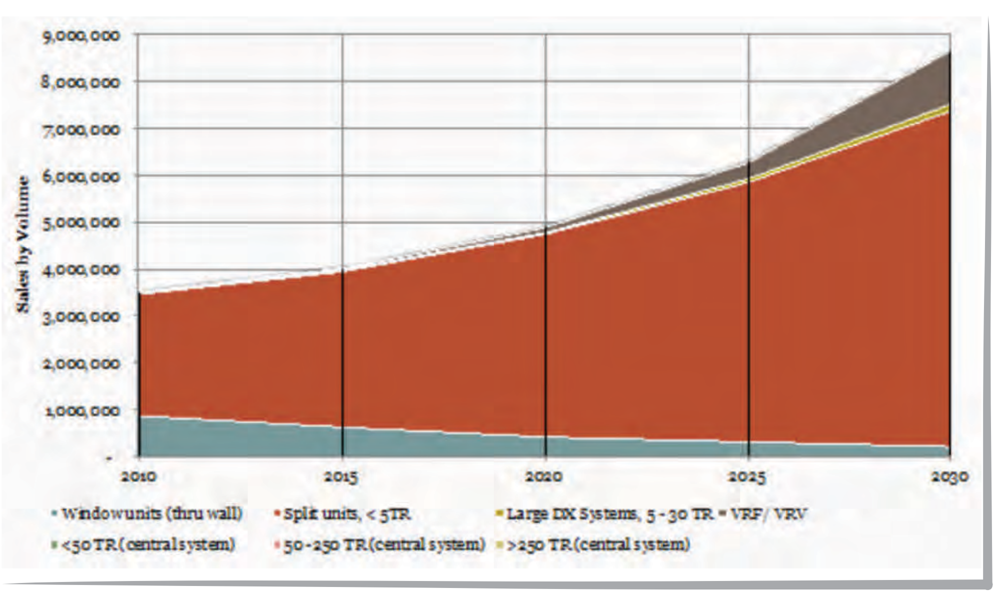
Market trends till 2030 for the HVAC products under study were also calculated and are summarized in Figure 52. Split units are expected to lead the HVAC market sales by volume. At the same time, market demand for window air conditioners is expected to decline over the next twenty years as consumers shift to greater efficiency and superior performance of split units in cooling spaces. VRF/ VRV market will also experience positive growth because of the flexibility of installing and of course, greater efficiency in energy use.

Figure 51: HVAC sales by Technology (2010). The size of the bubble indicates the annual sales by cooling capacity (TR)



Source: EDS Analysis

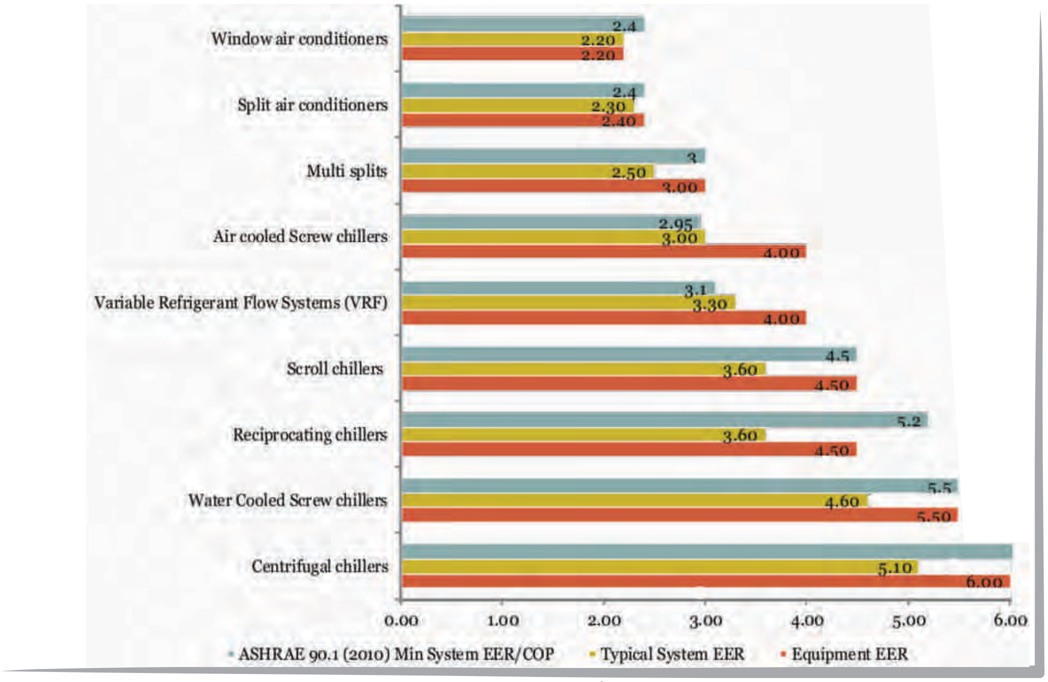
Figure 52: HVAC Market Growth forecast (2010-2030)



Source: EDS Analysis

While equipment efficiencies across all categories meet or exceed the minimum efficiency levels stipulated by ASHRAE 90.1 (2010), system efficiencies for central systems create a lag (Figure 53). Chillers available typically in the markets meet minimum COP/ EER ASHRAE 90.1 standards, but the ancillary system components do not. Equipment efficiencies of centrifugal, scroll and water cooled screw chillers either satisfy or exceed minimum COP/ EER requirements of ASHRAE 90.1

Figure 53: Relative efficiencies of HVAC technologies. The bars show the difference between the energy efficiency of the individual equipment, the overall HVAC system (including system losses), and minimum ASHRAE 90.1 (2010) requirements



Source: EDS Research

Figure 54 and Figure 55 summarize the findings from the analysis conducted to understand areas of intervention for the market transformation plan with respect to HVAC technologies. Expected savings potential till 2030 across all HVAC technologies assessed during the market study was calculated to identify top product categories that can deliver maximum energy savings.

Maximum savings are expected in the small DX segment comprising of ducted and unducted split units with cooling capacity less than 5TR, and window air conditioners. Potential savings from this segment will be nearly 670,700,000 MWh. Within large DX systems, which are ranked second highest, VRF/ VRVs lead with estimated savings of 225,000,000 MWh till 2030. Ducted splits greater than 5TR, also from this category, have an estimated potential of 22,350, 000 Mwh.

Central systems show the least potential for savings as an overall category, but closer review of various technologies within this group reveals that water cooled chillers with cooling capacity greater than 255 TR have energy savings potential of 36,000,000 MWh, the fourth highest amongst all technologies. Air cooled chillers with cooling capacity greater than 200 TR also have a combined savings potential of 20,000 MWh. By increasing market penetration of EE water cooled and air cooled chillers, maximum possible savings can be achieved in this group.

To summarize, in descending order, unducted splits, VRF/ VRF, water cooled chillers, ducted splits, air cooled chillers and window ACs can deliver maximum savings if the gap between typical equipment available now and optimal efficiency is closed by the Market Transformation Plan.

Figure 54: Cumulative Energy Savings Potential for HVAC Technologies (2010-2030)

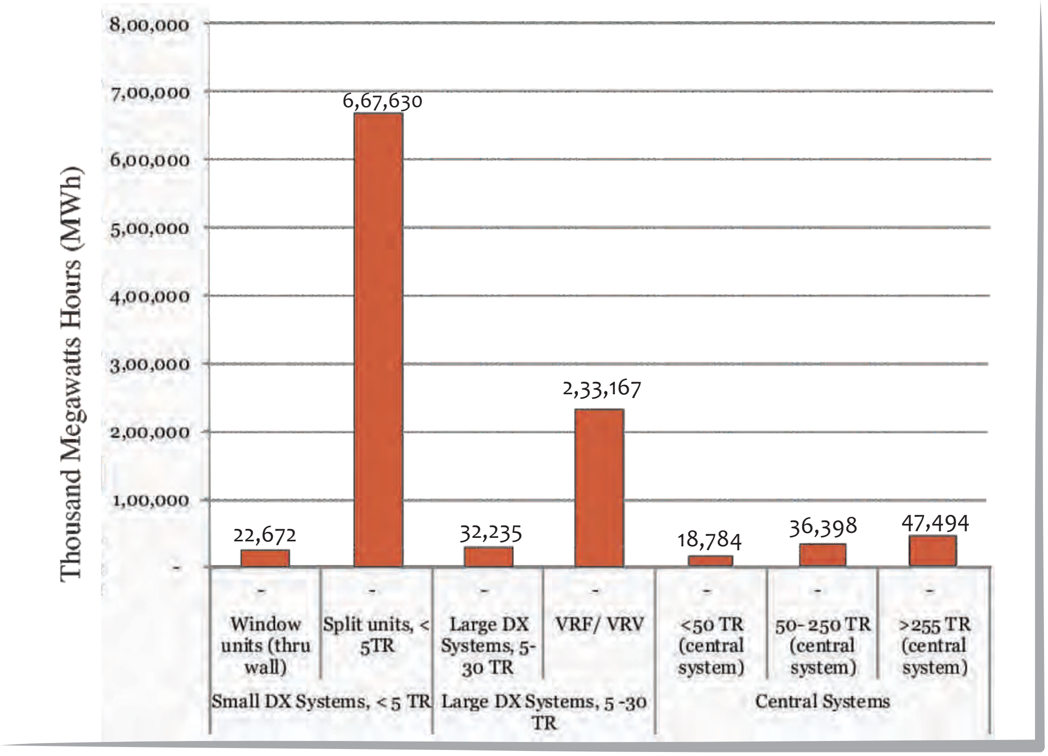
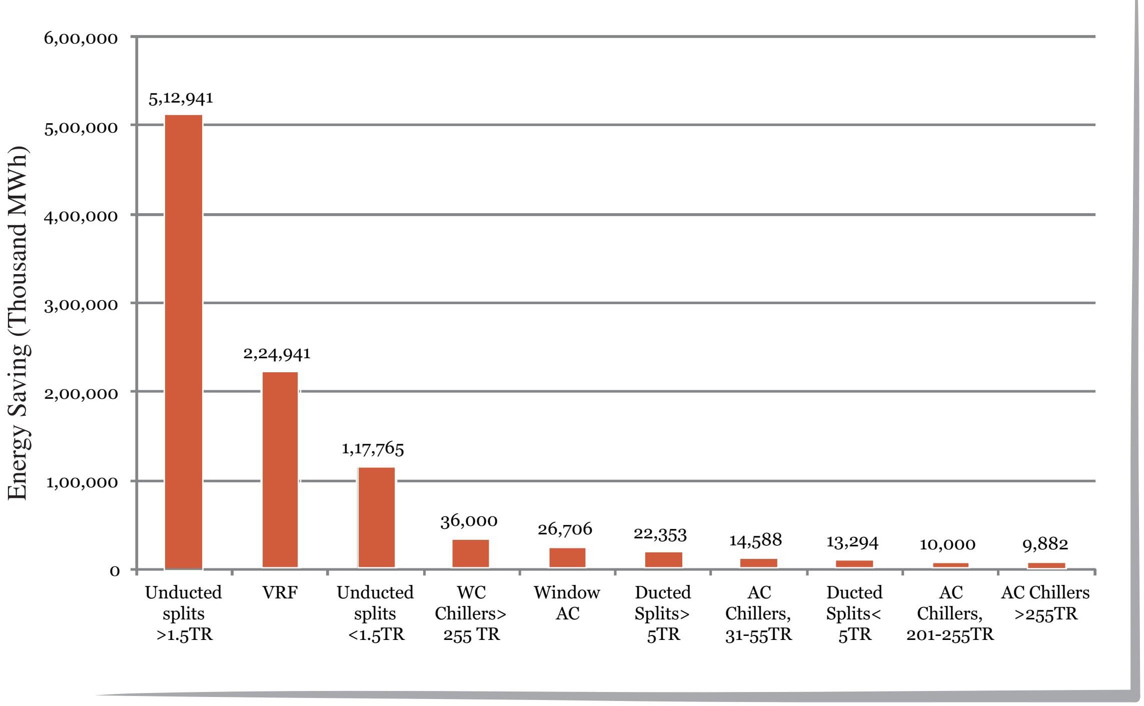


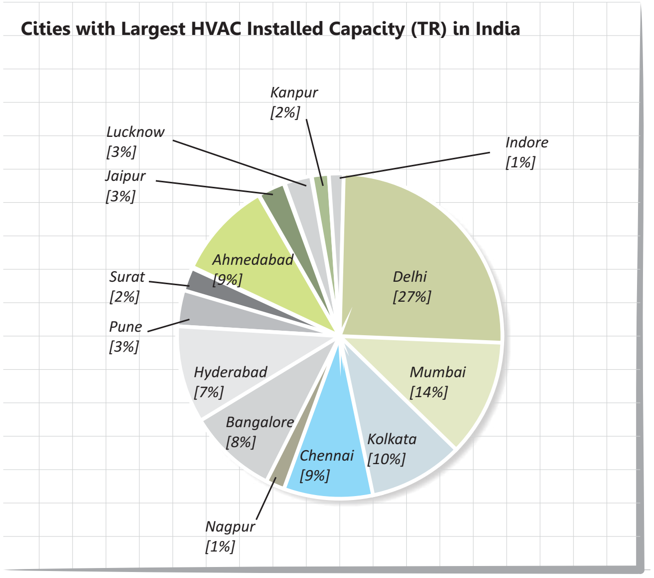
Figure 55: Cumulative Energy Savings Potential for Top 10 HVAC Technologies (2010-2030)



Source: EDS Analysis

Large population, urban lifestyles and commercial activity make the megacities of India the largest consumers of energy. For the same reasons, largest chunk of the total installed AC capacity is concentrated in the 14 mega cities of India. Out of these, Delhi and Mumbai together account for 40 percent of the total installed capacity (Figure 56), with Delhi leading the tally at 24 percent. Hyderabad, Bangalore, Chennai and Kolkata, with an estimated share of 7-9 percent each, are the next big consumers. Efforts at increasing penetration of EE HVAC products and systems should target these megacities as they are the largest consumers of HVAC driven energy consumption. As the most populated urban centers, they also hold significant impact potential for awareness raising campaigns amongst end users and key decision makers.

Figure 56: Cities with largest HVAC installed capacities (TR) (2010)



Source: EDS Analysis

Unducted splits (<5 TR), VRF/ VRF, water cooled chillers (> 255TR), ducted splits (> 5TR), air cooled chillers(> 200TR) and window ACs are some of the HVAC products that have maximum energy saving potential. Barring window ACs, rest are also expected to favourable market growth till 2030. The Market Transformation Plan must attempt to increase the diffusion of energy efficient products within these categories.

The market transformation plan should divest efforts sector wise across the building sector. Residential, commercial/ office and hospitality sector will experience maximum growth till 2030. Expected energy use will also be proportionately higher if efficiency of HVAC systems installed in these sectors is not improved.

Certain technologies like VRV/ VRFs are inherently more efficient than others; their average performance is superior to that of the most efficient products available in other categories. While a significant percentage of buyers are already opting for such advanced technologies, many more are discouraged from doing so because of high upfront costs, lack of technological expertise and lack of information on benefits. It is imperative to develop mature markets for these advanced technologies through the market transformation plans.

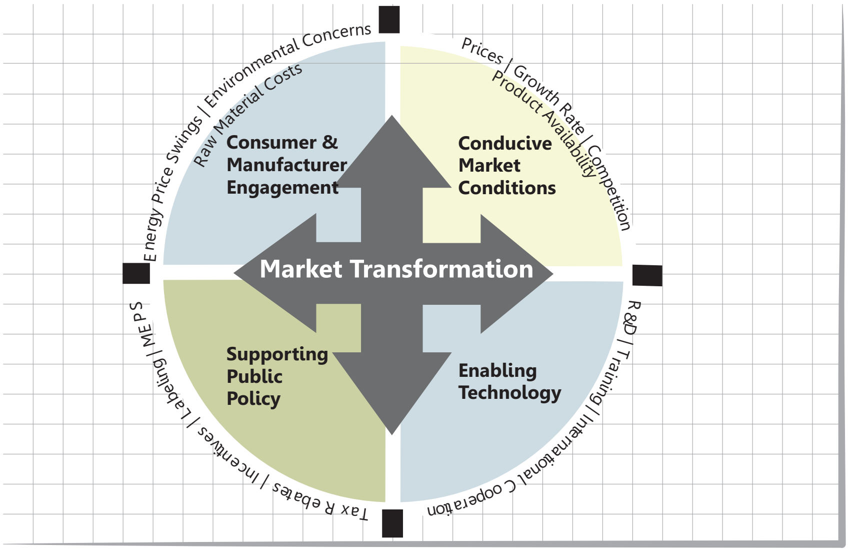
Geographical areas with maximum impact potential are the 14 megacities listed in Figure 57. Market transformation plan should focus on undertaking transformation strategies in these cities. This will eventually support formulation of city level policies that demand greater efficiency in HVAC system installed in buildings within the city jurisdiction.

Market Transformation Approach

According to ACEEE, Market Transformation (MT) is the strategic process of intervening in a market to create lasting change in market behavior by removing identified barriers or exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice. This will entail removing market barriers to broader adoption of energy efficiency, as well as accelerating adoption. The imperative is to prioritize long-term strategies rather than incentives or subsidies that may expire. The goal of the market transformation program is for energy efficiency to become standard practice in the HVAC marketplace.

A successful HVAC market transformation plan for India will need to address market barriers (including market uncertainty), price sensitivity, information barriers, technology barriers, financial barriers, and policy barriers.

Figure 57: Market Transformation Perspective



The market transformation approach for HVAC sector in India needs to address these concerns in order to establish a market for high performance HVAC systems and equipment (figure 57).

1. Information barrier
   a. Information on appropriate comfort standards and other design factors
   b. Information on appropriate design and LCC for HVAC systems
   c. information on actual performance of installed systems
   d. Information on high performance HVAC system design (considering variability and seasonality of usage)
   e. Information on correct installation and commissioning
   f. Information on operation and management practices
   g. Information on actual performance of conventional as well as new systems

2. Cost Barrier
   a. High capital cost of EE equipment
   b. Additional apace, water, or ancillary requirements of EE systems
   c. Split Incentive

3. Policy
   a. Expanding the coverage of the Mandatory EE standard
   b. Information on high performance system through branding and Labeling

4. Implementation
    a. Lack of on the ground agencies, which can design and maintain energy efficient HVAC systems
    b. HVAC efficiency sizing decisions are not integrated with overall building design process

The approach to implementing HVAC sector market transformation strategies will involve all the major stakeholders in the construction industry, the policy makers, the financial institutions, end-users, and the developer community. At the policy level, there is still not enough significance given to the building HVAC sector energy efficiency. The process of implementing the current ECBC, with its moderate stringency levels, itself is not going to dramatically effect the HVAC system efficiencies.

The near zero net energy building target, therefore, is a major leap forward in the policy approach. **A strategic advocacy impetus is needed to provide analysis to policy makers at the municipal and ULB level on the benefits of stringent standards for buildings and HVAC equipment.**

Integrated approach towards renewable energy generation, building energy efficiency, and design/construction industry is not commonly practiced. Vendor driven companies are not in a position to provide an integrated solution and most design/build firms do not have the capacity to do so either. Often, owners/developers, who are willing to invest in high performance HVAC systems, fail to get the desired results, because of the lack of this delivery mechanism. **Fostering an ethic of integrated design and performance-based design/build activities in the country will be the most important part of the strategy for India.**

Although the cost of electricity for commercial buildings in India is very high, and the cost of EE HVAC systems is coming down, the first cost of energy efficiency technologies is still a major barrier to widespread adoption. **A bigger market for such products and technologies, as well as a policy environment providing substantive incentives for development, implementation and import of energy efficient products/technologies** is a necessity for high performance buildings to be mainstreamed.

Potential Market Transformation Strategies

Capacity building of independent institutions to assess and disseminate HVAC domain knowledge

The biggest set of barriers to energy use reduction in the building sector is the lack of awareness and capacity to develop and implement energy efficiency HVAC projects. This lack of capacity to understand and implement extends from the policy makers to the financial decisions makers and the engineer and tradesmen on site. A number of capacity building and awareness measures need to be put together in order to overcome barriers at all these levels. These include demonstration projects, focused training programs and certification systems for professionals and practitioners.

The information dissemination and capacity building efforts need to
1. Focus on whole system based approach to design rather than equipment based as practiced currently.
2. Periodic HVAC system performance surveys and benchmarking
3. Professional training program and certification for practicing professionals
4. Training programs for Operations and Maintenance (O&M)

Different levels of training programs need to be delivered to address the information and awareness barriers. These range from workshops to provide in-depth design stage training to permit certification of “High Performance Building Design Consultants” to a compliance-oriented overview for manufacturers and other stakeholders in the building HVAC industry. There is a big gap in design intent and actual operations of HVAC systems in buildings. Engagement with facility management agencies and actual operators of HVAC and control systems is a must to achieve any actual improvement in performance.

High level workshops suitable for the building owners and decision makers along with details of cost benefit and implementation barriers based on the demonstration projects is also critical to adoption of EE HVAC systems.

Developing an HVAC application based test and demonstration facility for engineers, end-users.

Many EE technologies are niche or experimental due to lack of scaling opportunities. Access to HVAC systems of actual running buildings is extremely difficult. Independent demonstration facility where comfort applications are demonstrated with different HVAC types and cooling approaches is necessary to enable end-users and consultants to make informed decisions. Currently there is no such facility in the country imparting credible information on all kinds of HVAC systems and equipment. Many vendors and manufacturers have set up their own facilities to show case their products, but they are not perceived as unbiased by the market. Such facilities though, do provide valuable information and could be accredited, or supported to form a network of demonstration centers.

Mandatory enforcement of HVAC equipment efficiencies specified in the energy efficiency Building Codes

Energy Conservation Building Codes (ECBC) are one of the most effective ways of reducing energy use in new buildings. The EC Act has a provision to mandate ECBC for large non-residential buildings. The initial estimates indicate a saving potential of at least 40% in lighting and air conditioning for most new buildings. The saving potential can be even higher for buildings that operate 24 hours a day. The ECBC also specifies minimum efficiency standards for chillers and other HVAC equipment.

Although the ECBC is a big step forward for the current business as usual efficiency levels in HVAC equipment, there is potential to further improve on the performance levels and efficiency. This can be seen in a number of new green buildings coming up in the country. These high performance buildings exceed the ECBC requirements by as much as 40% within an acceptable payback period and initial investment limits.

The list of included HVAC equipment needs to be expanded, and the performance levels made mandatory in order to eliminate low efficiency equipment from the market.

Labeling of energy efficiency HVAC Equipment

There is a need to introduce labels for more HVAC systems and product types as well as to clearly distinguish the high-efficiency leaders.

Energy Efficiency HVAC Demonstration Projects

Alternate cooling technologies mentioned in the previous section have tremendous energy saving potential, and should be implemented in demonstration projects all across the country.

Utility-driven energy efficiency and DSM programs

Such incentive programs are typically operated by a local electric utility as part of the utility's Demand Side Management (DSM) program. These programs should use the same technical approach as Demonstration Building Program, but funded and administered by electric utility.

A successful DSM program will need to overcome the following barriers:

1. Market Barriers
    - Uncertainty about market demand of high energy efficiency HVAC equipment and systems
    - Uncertainty about cost-effectiveness of high energy efficiency models
    - Price dynamics in the domestic and medium-size HVAC market
    - High sensitivity towards first costs for HVAC equipment
    - Low margins for imported and high-performance HVAC systems due to low demand
    - Existing pool of products

2. **Market Uncertainty**
   - Understanding the demand and supply equilibrium for the energy efficiency HVAC appliances market
   - Undertaking market research studies for estimating the potential demand for high-efficiency models
   - Dissemination of information to manufacturers to assure the demand for energy-efficient appliances
   - Uncertainty over the cost-effectiveness of high-efficiency models - reluctance to commit the resources to develop and produce high-efficiency models

3. **Price sensitivity**
   - High sensitivity towards first costs of high energy efficiency products
   - **Reducing the purchase price –** reducing risk for consumers who are reluctant to buy a unfamiliar product, creating a marketing impact to consumers, an acting as a temporary market support until economies of scale reduce product costs
   - **Price subsidies –** decrease the risk to manufacturers reduce the risk to retailer propel sales as product costs come down Issues - Rebates and Subsidies should be able to be reduced and eliminated over time without a perceptible decline in market share

4. **Information Barriers**
   - Consumer awareness
   - Consumer purchasing behavior
   - Life-cycle benefits
   - Monitoring of program impact on the attitude of consumers
   - Effective energy efficiency communication camp

The electric utility can provide a portion of incremental cost of higher efficiency HVAC equipment as rebates. These can typically target "X" % better than code minimum requirements for specific equipment. The utility should cover enough cost that owner has a reasonable payback period for investment in efficiency, say 2-5 years, depending on the package of measures.

There are numerous models of utility driven DSM programs that have yielded good results. They range from low-cost no-cost O&M improvements to equipment replacement incentives and design incentives. Although such international experiences can be useful to learn from, they cannot be directly copied in the Indian context. The operating environment of the utilities in India is very different and with a high degree of variability in technical expertise and resources. The detailed approach for such programs needs to be piloted in selected urban centers with a high density of HVAC equipment and growth projections.. Some of the cities with a good potential for HVAC incentive programs is given below. These can then be expanded to other growth centers.

1. Delhi NCR
2. Mumbai
3. Chennai
4. Kolkata
5. Hyderabad
6. Bangalore

Energy Efficiency Design for HVAC Systems in all New Public and Government Buildings

All over the world, many federal as well as state governments have chosen to lead by example, by requiring new government buildings to meet strict energy standards. Government is by one of the largest developers of properties in India. Although there have been several efforts to improve energy performance of such buildings, most pilots have failed to scale up and realize the full energy saving potential. Lack of technical capacity for evaluation, implementation and monitoring has been one of the key reasons for this. Availability of financing for energy efficiency retrofits and upgrades is also an issue for several municipal and state level buildings. The misplaced perception that energy savings and comfort cannot be achieved simultaneously, is set even more in government projects than others.

In order for this program to succeed, the government buildings sector has to lead the movement by setting a high benchmark for the private sector to follow. The specifications for design, materials, and equipment selection for all new government buildings need to be at par with the best available energy efficiency technology and practices in the market. Incorporating specifications of design, comfort, and performance in the procurement documents of the government projects will have an effect in the overall building and HVAC market.

ANNEX 1: MARKET ASSESSMENT SURVEY - QUALITATIVE

Market Assessment Questionnaire – (Consultants/Architects)

Understanding of the product and its technology

1. How many types of HVAC systems are available in India? (both residential and commercial) [e.g. central chilled system, air-cooled/water-cooled, large package unit/multi-split, split, Variable Refrigerant Volume (VRV) and vapor absorption machine (VAM)]
2. In what type of building/industry are these being used the most? (Probe for reason)
3. What all technologies and brands of HVAC systems are widely used in the following building sectors? What are the major advantages of each type for the related building sector? (maintenance, cost, operational issues)

Segments	Changing market demand for HVAC
Real Estate (Residential→Apartments Commercial→Hotels/Retail)	
Infrastructure (Airports/Metros)	
Healthcare	
Education	

4. Which are the key products that are acting as triggers to growth and which are not in demand?
5. How is the demand for energy-efficient HVAC systems changing in comparison to less energy-efficient systems?
6. Are there any seasonal or regional differences in the demand of each type [central systems/Direct Expansion (DX) systems]? If yes, what factors are responsible for the same? (Weather condition, size of the buildings, popular type of industry/business in the region, supply of electricity, etc.)
7. How do consultants take decisions on the evolving category or technologies and any new product range added in the HVAC market?
8. What all technical and economic parameters are considered by consultants before taking decisions on HVAC systems (including chillers) or for making simulations?

Current market scenario and key traits

1. Who are the major players in the industry? Are these players specialized in specific HVAC systems or do they offer all type of systems?
2. How many popular brands are available in the market for HVAC systems? Does brand matter a lot in the eyes of end-users?
3. Comment on brand popularity as per the user segment – residential/commercial.
4. According to you which are the most popular brands in different HVAC systems categories? Which brand stands high on the following factors?

    a. Energy efficiency→Saves energy the most
    b. Compressor efficiency at part load
    c. Price→Adequate→Price as per features
    d. Performance
    e. After-sales service

5. In which segments is the demand for HVAC systems the most? (Pharmaceutical, Hotels, and Retail etc.) As per the industry, does the product vary in technical aspects? What are the brands that are popular in the market as per the various industry usages?
6. What is the perception of clients to test efficiency of HVAC systems before placing orders?
7. How relevant are the current energy standards like American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE), Energy Conservation Building Code (ECBC), etc. and how genuinely are they being followed in India?
8. Is the Air-Conditioning and Refrigeration Institute (ARI) testing of HVAC systems suitable for Indian conditions? Should there be provisions for separate test labs for testing in India? If yes, what will be the barriers to and economics of the same?
9. What is the client perception towards imported HVAC systems, imported parts of the system, and locally manufactured systems?
10. Are clients willing to pay for higher Coefficients of Performance (COPs)? What is the investment to savings ratio expected by the clients for subsequent higher COPs?
11. Is the market driven more by COP or Integrated Part Load Value (IPLV)? What would be more sensible parameter to consider?
12. Is the lifecycle analysis considering the capital cost and running cost with time, carried out before the system finalization?
13. How much do you promote the energy-efficient HVAC systems? If you promote them, then what are the barriers to energy-efficient HVAC selection?
14. Which of the energy-efficient HVAC system like radiant, displacement ventilation, geothermal cooling, Vapor Absorption Machines (VAM), solar cooling, etc., do you promote or think should be used in India. What are about the barriers/limitations to greater use of these systems. What is the scope for these systems in future?
15. Are your buildings energy-efficient? If yes, what energy efficiency measures have been adopted?
16. Have you designed/incorporated the following measures in HVAC design and installations:
    a. Variable Frequency Drives (VFDs) on pumps
    b. VFDs on cooling towers
    c. VFDs on Air Handling Units (AHU)/Treated Fresh Air (TFA) units
    d. Heat recovery ventilators
    e. Economizers
    f. Condenser water reset/relief
    g. CO_2 sensors based fresh air supply
    h. Carbon monoxide (CO) sensors in basement ventilation systems

Product type used and purchase process

1. On what basis do you decide which HVAC system type or brand is recommended for the end-users? What are the criteria used? [capital investment, compressor type, COP, IPLV, energy efficiency ratio, specific power consumption]
2. Which division from various organizations approaches your company for the HVAC systems? How do the requirements differ from organization to organization?
3. What are the requirements sent by the organizations? What are the energy-saving criteria set by the end users for installation of HVAC systems?
4. The important factor for installation of HVAC is Energy Efficiency. How does the type/brand of HVAC system differ in the amount of energy saved? What are the other factors that play an important role for the end-user?
5. Mostly it is seen that the clients/architects do not understand the IPLV or COP terms, which are different for different sizes and types of HVAC systems/chillers. Do you think that some standards and labeling of HVAC systems in each category and size is necessary to ease the selection problem?
6. If your answer to question 5 is yes, how do you think this should be done and what are the parameters to be considered?
7. What drives the choice of end-users the most? (changing market trends in terms of consumer behavior/attitude, entry of new products/technology, brands, changes in lifestyles, etc.). Arrange in order of priority/rank, i.e. mark 1 for highest priority, 2 for next highest priority, and so on.

Decision Parameter	Priority/Rank
Running costs	
Increase in product range with a range of features (style/ looks/color/compactness, etc.)	
Warranty/guarantee	
Acquisition cost	
Compressor efficiency at part load	
Energy efficiency ratio	
Coefficient of Performance	
Specific power consumption	
Ease of usage and installation	
Maintenance cost	
Area/space required for installation	
Energy efficiency	
Brand reputation for reliability/quality	
Environmental impact/greenhouse effect	
Technology used	
After-sales services	

8. At your end what factors act as triggers and what stops the end-users from opting for energy-efficient HVAC systems? (acquisition and installation cost, awareness level, promotions by the brand, technology used, greenhouse effect, rules and regulation levied by government agencies)
9. Is there any demand for energy-efficient HVAC systems? Who would be the potential client for energy efficient HVAC systems? What could be the reason for that?
10. According to you, what factors would act as key barriers towards opting for energy-efficient HVAC systems? (acquisition cost, installation cost, lack of knowledge, techno-economic factors)
11. Do you think the amount of technical data provided with the product is sufficient enough to make a sound decision on the efficiency and performance of the HVAC systems? What other data would help consultants and end-users in approaching better systems?

Future trends

1. What is the future for the HVAC market in India in the next 5 years? (for each listed type)
   Residential HVAC systems→window, split, multi-split, Variable Refrigerant Flow (VRF) and central-chilled water system Commercial HVAC→central-chilled system, air-cooled/water-cooled, large package unit/multi-split, split, VRV and VAM
2. How do you foresee the demand for each type? Which industries are looking forward to using HVAC systems?
3. How is the market shaping up in terms of new technologies and emerging consumer trends? (energy efficiency of the product) How can energy-efficient HVAC systems become affordable?
4. What are the new avenues where HVAC systems can be used?

1.1 Market Assessment Questionnaire (Associations)

Current market scenario and key traits

1. According to you what is the current status of the HVAC market and associated rise in energy demand?
2. What, according to you, could be the total market size of the HVAC category in your region and overall at the India level? (regional market size, markets that drive the segment, importers vs. manufacturers)
3. What changes have you experienced in the last 5 to 10 years? What could be the reasons for these changes? Currently, what are the key traits of this market?

4. According to you which are the most popular technology types in different HVAC systems categories? Which type stands high on the following factors?
   a). Energy efficiency→Saves energy the most
   b). Compressor efficiency at part load
   c). Price→Adequate→Price as per features
   d). Performance
   e). After-sales service

Policies & their implementation – HVAC systems

5. Which body/organization is responsible for framing policies for HVAC systems in India? Who implements the same and how?
6. What are the current energy-efficient standards for HVAC units? What all technical aspects govern the energy efficiency of the system? [refrigerant temperature, chilled water temperature, Coefficient of Performance (COP), Integrated Part Load Value (IPLV)]
7. Currently, are there any energy-efficient norms for HVAC systems? Do they differ for different technologies? Are there any norms for the operations also?
8. When a brand claims its products to be energy-efficient, on what basis is the claim made? Who audits their claim and how?
9. How can consumers ensure that the product is energy-efficient?
10. On a policy level, what could be done for the energy efficiency of HVAC systems?
11. As a key stakeholder of the industry, what measures have been adopted by you to enhance the sales of energy-efficient HVAC systems?
12. How relevant are the current energy standards like American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE), Energy Conservation Building Code (ECBC), etc., and how genuinely are they being followed in India?
13. Is the Air-Conditioning and Refrigeration Institute (ARI) testing of HVAC systems suitable for Indian conditions? Should there be provisions for separate test labs for testing in India? If yes, what will be the barriers to and economics of the same?
14. Is your building energy-efficient? If yes, what energy efficiency measures have been adopted?
15. Have you designed/incorporated the following measures in HVAC design and Installations
   f). Variable Frequency Drives (VFDs) on pumps
   g). VFDs on cooling towers
   h). VFDs on Air Handling Units (AHU)/Treated Fresh Air (TFA) units
   j). Heat recovery ventilators
   k). Economizers
   l). Condenser water reset/relief
   m). CO_2 sensors based fresh air supply
   n). Carbon monoxide (CO) sensors in basement ventilation systems

Understanding of the product and its technology

1. In what types of housing buildings/industries, are these products being used the most? What is the reason?
2. How does the policy formation of the following differ from each other? Which technical parameters are considered most important in each category for defining an energy-efficiency policy?

Segments	Changing market demand for HVAC
Real Estate (Residential→Apartments, Commercial→Hotels/Retail)	
Infrastructure (Airports/Metros)	
Healthcare	
Education	

3. Kindly shed light on the secondary market for HVAC systems. What is the product life of HVAC products? What happens to each type? How does the secondary market work? Which industry uses it further and how?

Take on the energy efficiency of HVAC systems

1. Are there different norms for residential and commercial HVAC systems? Kindly explain in detail.
2. Is there any demand for energy-efficient HVAC systems? Who would be the potential clients for energy efficient HVAC systems? What could be the reason for that?
3. According to you, what factors would act as key barriers in adopting energy-efficient HVAC systems? (acquisition cost, installation cost, lack of knowledge, techno-economic factors)
4. What is your opinion if the Bureau of Energy Efficiency (BEE) comes out with energy-efficiency labels for HVAC systems and chillers? Do you think these should be made mandatory or voluntary?
5. If you were to design labels for HVAC systems and chillers, what would be the basis for the same? Would they be comparative labels or endorsement labels? On the technical front, what are the desired efficiency norms you would suggest?
6. How can net zero buildings or near-to-net zero buildings be promoted in India?

Future trends

1. What is the future of energy-efficient HVAC systems? What are the steps that can be taken by you or can be supported by your organization to promote energy-efficient HVAC systems like radiant systems, displacement ventilation, VAM, etc.?
2. How is the market shaping up in terms of new technology and emerging consumer trends? (energy efficiency of the product)
3. What all are the new avenues where HVAC systems can be used?

1.2 Market Assessment Questionnaire (Manufacturers)

Understanding of the product and its technology

1. As you are into manufacturing HVAC systems, please tell us about their types? How many types are available in India? (both residential and commercial)
2. What are the dominating technologies in the following building sectors, and how is the demand for HVAC systems changing across these sectors in the past 2-3 years?

Segments	Changing market demand for HVAC
Real Estate (Residential→Apartments, Commercial→Hotels/Retail)	
Infrastructure (Airports/Metros)	
Healthcare	
Education	

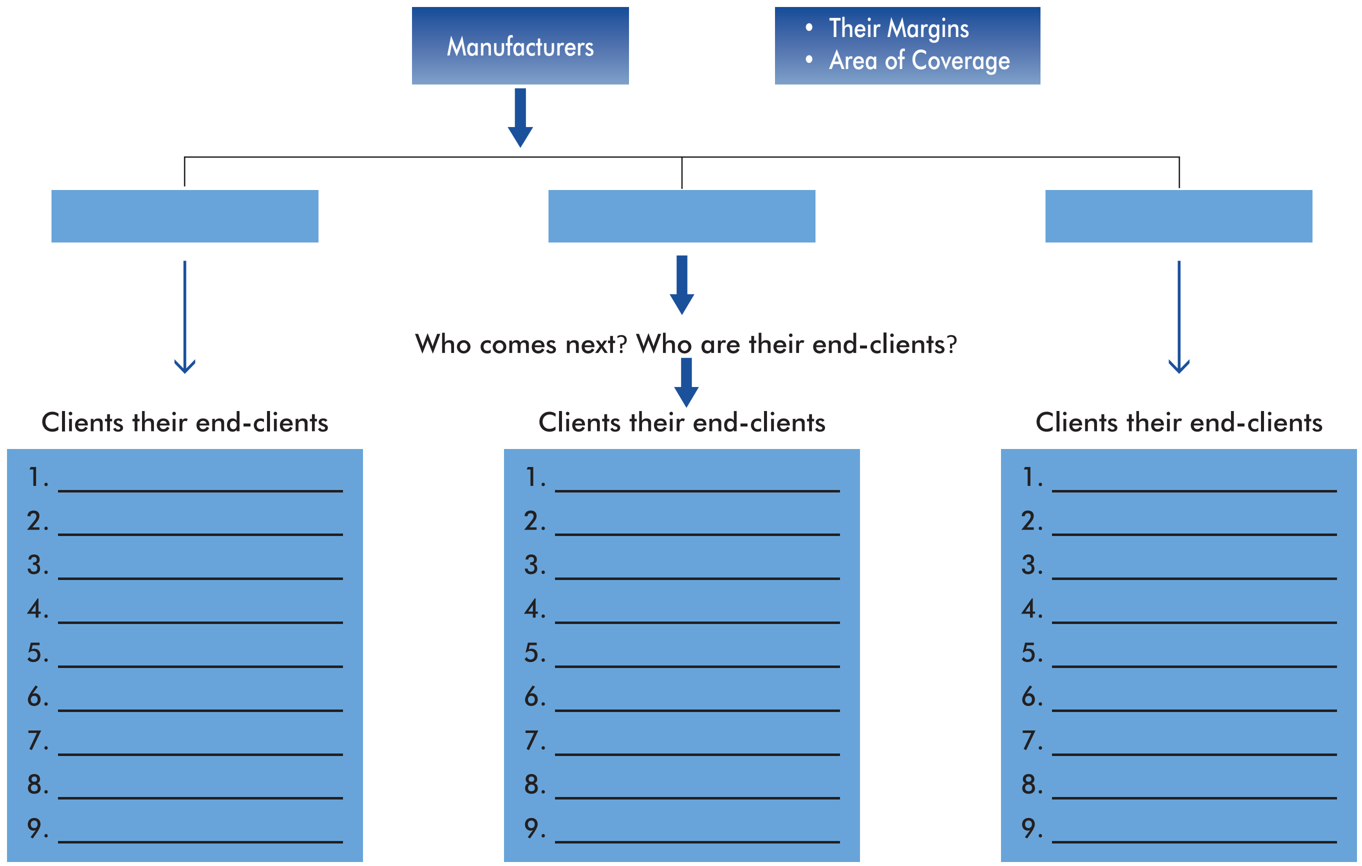
3. Is there any seasonal or regional difference in the demand for each of these technology? If yes, what factors are responsible for the same (weather condition, size of the houses, popular type of industry/business in the region, supply of electricity)
4. What are the major problems/reasons for the unpopularity of each of these technologies (maintenance, cost, operational issues)?
5. How can the efficiency of each of these technologies be enhanced? (mechanical parts/refrigerant/design changes)?
6. What is the lifecycle cost analysis of each system? What are the operational and maintenance costs associated with each type and in each sector?

Discussion on refrigerants

7. How important is the role of refrigerants in the energy efficiency of HVAC systems?
8. How do you think the new legislation on refrigerants would affect the HVAC market and energy efficiency?
9. What are the important factors for the choice of refrigerants?
10. What are parameters that should be considered to simulate the energy efficiency of HVAC systems more accurately with respect to practical performance?

Current market scenario and key traits

1. Now, let us talk about the overall HVAC industry in India. According to you, what is the current status of the HVAC market? Would you say the market is growing, stagnant or declining?
2. According to you, what is the total market size of different HVAC categories in your region and overall at the India level? (regional market size, markets that drive the segment, importers vs. manufacturers)
3. What are the market shares of international brands and Indian brands? What are the technical limitations of Indian brands over the international brands? What is the difference in the cost of HVAC system manufactured in India and that of an imported one?
4. How could the Indian market be helped in meeting international standards?
5. Is there any international product/technology that could help growing demand for HVAC systems in a more energy efficient way?
6. How is the market for energy-efficient HVAC systems different from less energy-efficient systems?
7. What changes have you experienced in market trends for energy efficient HVAC systems in the last 5 to 10 years? What could be the reason(s) for these changes? Currently, what are the key traits of this market?
8. Who are the major players in the industry? What is their market share? Are these players specialized in two to three types of HVAC systems or do they offer all types of products?
9. Kindly explain about each brand and the product they are popular for.
10. What is the percentage share of each brand as per their sales?
11. Who are your major clients? What type of HVAC systems do they purchase and for what purpose? Are they concentrated in a particular region or do you have clients from all over India?
12. Are you also into imports? If yes, which countries do you get supplies from? Is the import of parts more common in India or entire HVAC systems?
13. What are the barriers in the HVAC industry for energy-efficient HVAC system selection?
14. According to you, what factors would act as key barriers towards opting for energy-efficient HVAC systems? (acquisition cost, installation cost, lack of knowledge, techno-economic factors)
15. What is your opinion if the Bureau of Energy Efficiency (BEE) comes out with energy-efficiency labels for HVAC systems? Do you think these should be mandatory or voluntary?
16. If you were to design labels for HVAC systems, what would be the basis for the same? Would they be comparative labels or endorsement labels? On the technical front, what are the desired efficiency norms you would suggest?
17. From where do you think the problem in final energy-efficient HVAC system selection comes?
    a. Consultants
    b. Clients/Owners
    c. Distributors
    d. Manufacturers
18. Are there other manufacturers in the country that make similar equipment? Who all are your competitors?
    a. Tell us about each of them
    b. What is their approach and strategy with respect to their product?
19. Please draw the channel map by explaining the channel structure and its characteristics – separately for residential and commercial.
20. Who is at the next level? What are their margins and where do they further supply the product? (architects, consultants, distributors' dealers, etc.)



21. Which groups form the end-users? How does the product reach them? How do they use it, and for what purpose?
22. What drives the choice of end-user the most? (factors like changing market trends in terms of consumer behavior & attitude, entry of new products/technology, brands, changes in lifestyles, etc.). Arrange in order of priority/rank, i.e. mark 1 for the highest priority, 2 for next, and so on.

Decision Parameter	*Priority/Rank*
Running costs	
Increase in product range with a range of features (style/ looks/color/compactness, etc.)	
Warranty/guarantee	
Acquisition cost	
Compressor efficiency at part load	
Energy efficiency ratio	
Coefficient of Performance	
Specific power consumption	
Ease of usage and installation	
Maintenance cost	
Area/space required for installation	
Energy efficiency	
Brand reputation for reliability/quality	
Environmental impact/greenhouse effect	
Technology used	
After-sales services	

23. For the end-users, what factors act as triggers and what stops them from purchasing energy efficient HVAC systems? (acquisition and installation cost, awareness level, promotions by the brand, technology used, greenhouse effect, rules and regulation levied by government agencies.)
24. Is there any demand for energy-efficient HVAC systems? Who would be the potential clients for energy-efficient HVAC systems? What could be the reason for that?
25. According to you, what factors would act as key barriers towards opting for energy-efficient HVAC systems? (acquisition cost, installation cost, lack of knowledge, techno-economic factors)
26. Do shed light on the secondary market for HVAC systems. What is the product life of HVAC systems products? What happens to each type? How does the secondary market work? Which industry uses it further and how?
27. For the same technology, is a higher COP more expensive? For all technologies, formulate the following table (incremental cost of higher COP):

Technology name (e.g. water-cooled screw chiller 150 TR)	*Price*
Minimum COP offered by manufacturer	
Minimum + 1	
Minimum + 2 (etc.)	

28. How affordable are the higher COPs in terms of their paybacks? What is the investment-to-savings ratio trend for subsequent higher COPs?
29. Is the market driven more by COP or Integrated Part Load Value (IPLV)? What would be the more sensible parameter to consider?
30. How has the energy efficiency of systems offered by you changed over the past 4 years in terms of COP? Please answer using the table below.

System Type	*Compressor Type*	*Commonly used capacity(TR)*	*COP in 2008*		*COP in 2012*	
			Minimum	Maximum	Minimum	Maximum
		100				
		200				
		100				
		200				
		150				
		250				
		550				
		150				
		100				
		175				
		350				
		40				

31. How relevant are the current energy standards like American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE), Energy Conservation Building Code (ECBC), etc. and how genuinely are they being followed in India?

32. Is the Air-Conditioning and Refrigeration Institute (ARI) testing suitable for Indian conditions? Should there be provisions for separate test labs for testing in India? If yes, what will be the barriers to and economics of this?
33. According to you, how can the cost of HVAC systems be reduced for end-users? (For example, through local installation/local manufacturing/government subsidy/more technical research, etc.)
34. How interested are the end-users in India's market products?
35. What could be the possibilities of local testing of the HVAC systems in India?
36. Do you think the amount of technical data provided with the product is sufficient enough to make a sound decision on the efficiency and performance of the HVAC systems? What other data would help consultants and end-users in approaching better decisions?
37 Have you designed/incorporated the following measures in HVAC design and installations:
    a. Variable Frequency Drives (VFDs) on pumps
    b. VFDs on cooling towers
    c. VFDs on Air Handling Units (AHU)/Treated Fresh Air (TFA) units
    d. Heat recovery ventilators
    e. Economizers
    f. Condenser water reset/relief
    g. CO_2 sensors based fresh air supply
    h. Carbon monoxide (CO) sensors in basement ventilation systems

Future trends

38. What is the future of the HVAC systems market in India in the next 5 years?
    a. Residential HVAC systems→window, split, multi-split, VRF and central-chilled water system
    b. Commercial HVAC→central-chilled system, air-cooled/water-cooled, large package unit/multi-split, split, Variable Refrigerant Volume (VRV) and Vapor Absorption System (VAM)
39. How is the future of energy-efficient HVAC systems changing in comparison to less energy efficient systems?
40. How do you foresee the demand for each type? Which industries are looking forward to using HVAC systems?
41. How is the market shaping up in terms of new technology and emerging consumer trends? (energy efficiency of the product)
42. What all are the new avenues where HVAC systems can be used?
43. How could energy efficiency be improved in HVAC systems?
44. How are the categories/technologies evolving? What new product range is being added in the market?

1.3 Market Assessment – Questionnaire (Distributors)

Understanding of the product and its technology

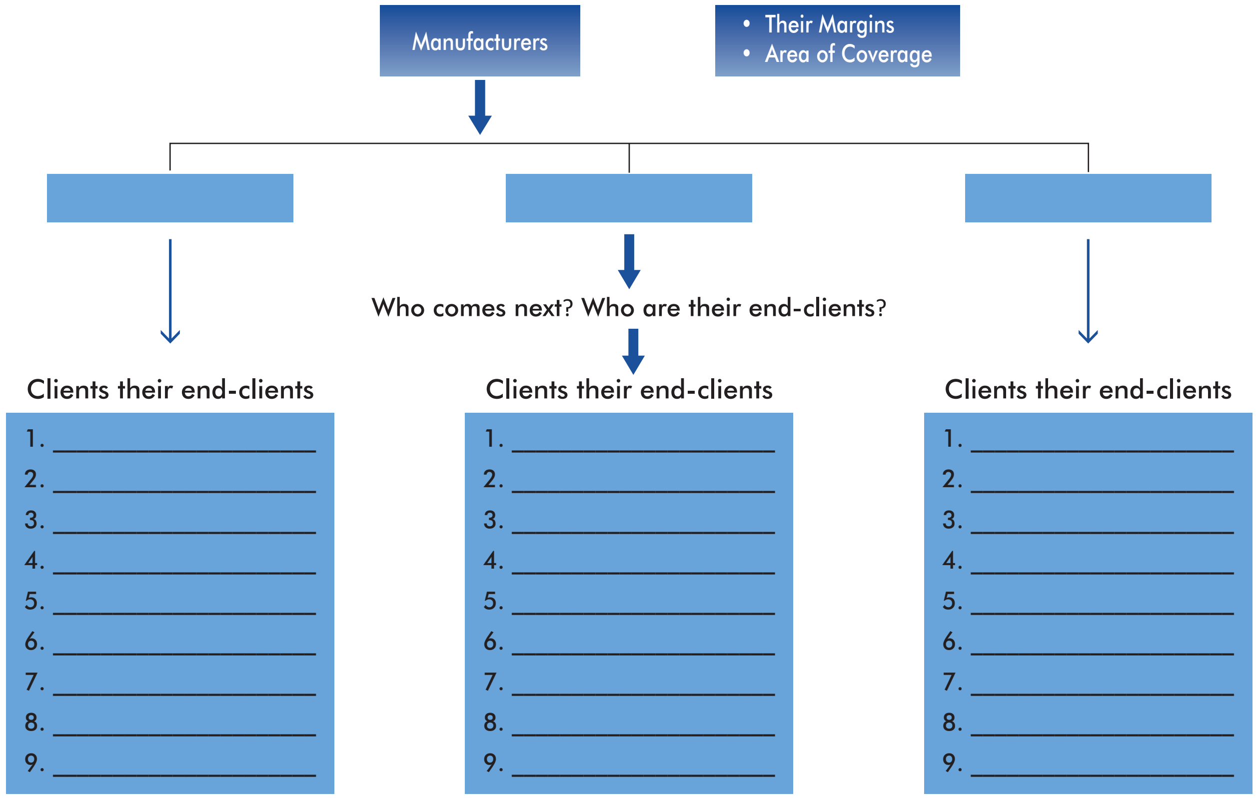
1. Please tell about the types of HVAC systems? How many types of HVAC systems are available in India? (both residential and commercial)
2. In what types of housing buildings/industries are they being used the most? (give reasons)
3. According to you, what is the current status of HVAC systems in the Indian market? Would you say the market is growing, stagnant or declining?
4. How has the demand for HVAC systems changed across the following segments in the past 2-3 years?

Segments	Changing market demand for HVAC
Real Estate (Residential→Apartments, Commercial→Hotels/Retail)	
Infrastructure (Airports/Metros)	
Healthcare	
Education	

5. Which are the key products that are acting as triggers to growth, and which of these are not in demand?
6. How is the demand for energy-efficient HVAC systems changing in comparison to less energy-efficient systems?
7. Are there any seasonal or regional differences in the demand of each type? If yes, what factors are responsible for the same (weather condition, size of the houses, popular type of industry/business in the region, supply of electricity, etc.)
8. What are the major features/parameters looked at by clients in HVAC systems?
9. What features make international products more in demand than Indian products?

Current market scenario and key traits

1. Being a mediator, who do you think drives the HVAC market in India – the client, manufacturers, associations or someone else?
2. What, according to you, is the gap between clients' demand and manufacturers' supply?
3. What, according to you, are the major factors of lag in energy-efficient HVAC demand? Are they related to the client or manufacturer?
4. How much gap is there in the demand from local HVAC system manufacturers and imported HVAC products?
5. Which all international countries'/companies' products dominate the Indian market?
6. What all international energy-efficient products are not popular in the Indian market? For what reasons?
7. How you think energy-efficient HVAC systems/products could be made more affordable for consumers?
8. What all taxes, duties, exemptions, etc. do Indian and international HVAC products bear?
9. According to you, what is the total market size of the HVAC category in your region and overall at the India level? (regional market size, markets that drive the segment, importers vs. manufacturers)
10. What changes have you experienced in the last 5 to 10 years? What could be the reasons for each change? Currently, what are the key traits of this market?
11. How relevant are the current energy standards like American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), Energy Conservation Building Code (ECBC),, etc., and how genuinely are they being followed in India?
12. Is the Air-Conditioning and Refrigeration Institute (ARI) testing of HVAC systems suitable for Indian conditions? Should there be provisions for separate test labs for testing in India? If yes, what will be the barriers to and economics of the same? Which are the major players in the industry? What is their market share? Are these players specialized in two to three types of HVAC system or do they offer all types?
13. Which areas have major concentration of HVAC systems distributors in India? Which are the big players in the market?
14. How many popular brands are available in the market for HVAC systems? Does brand matter a lot in the eyes of end-users?
15. Talking about end-users in residential and commercial segments, which are the most used brands and why?
16. What is the % share of each brand as per their sales?
17. What are the products that you offer?
18. As per the industry, does the product vary in technical aspects? What are the brands that are popular in the market as per the various industry usages?
19. Please draw the channel map by explaining the channel structure and its characteristics. (for both residential and commercial HVAC systems)



20. Who is at the next level? What are their margins and where do they further supply the product? (architects, consultants, distributors' dealers, etc.)
21. Which groups form the end-users? How does the product reach them? How do they use it, and for what purpose?
22. For the end-users, what factors act as triggers and what stops them from opting HVAC systems? (acquisition and installation cost, awareness level, promotions by the brand, technology used, greenhouse effect, rules and regulation levied by government agencies.)
23. Is there any demand for energy-efficient HVAC systems? Who would be the potential clients for energy-efficient HVAC systems? What could be the reason for that?
24. According to you, what factors would act as key barriers towards opting for energy-efficient HVAC systems? (acquisition cost, installation cost, lack of knowledge, techno-economic factors)
25. Do shed light on the secondary market for HVAC systems. What is the product life of HVAC systems products? What happens to each type? How does the secondary market work? Which industry uses it further and how?
26. What are the steps you think should be taken to promote energy-efficient HVAC system installation in the Indian market?
27. Who, as an organization, could be involved in the promotion of energy-efficient HVAC systems through a policy or a regulation, and how?
28. Have you designed/incorporated the following measures in HVAC design and installations:
    a. Variable Frequency Drives (VFDs) on pumps
    b. VFDs on cooling towers
    c. VFDs on Air Handling Units (AHU)/Treated Fresh Air (TFA) units
    d. Heat recovery ventilators
    e. Economizers
    f. Condenser water reset/relief
    g. CO_2 sensors based fresh air supply
    h. Carbon monoxide (CO) sensors in basement ventilation systems

29. What drives the choice of end-user the most? (factors like changing market trends in terms of consumer behavior & attitude, entry of new products/technology, brands, changes in lifestyles, etc.). Arrange in order of priority/rank, i.e. mark 1 for the highest priority, 2 for next, and so on.

Decision Parameter	*Priority/Rank*
Running costs	
Increase in product range with a range of features (style/ looks/color/compactness, etc.)	
Warranty/guarantee	
Acquisition cost	
Compressor efficiency at part load	
Energy efficiency ratio	
Coefficient of Performance (COP)	
Specific power consumption	
Ease of usage and installation	
Maintenance cost	
Area/space required for installation	
Energy efficiency	
Brand reputation for reliability/quality	
Environmental impact/greenhouse effect	
Technology used	
After-sales services	
Training for usage	

Future trends

1. What is the future for HVAC systems' market in India in the next 5 years?
   a. Residential HVAC systems→window, split, multi-split, VRF and central-chilled water system
   b. Commercial HVAC→central-chilled system, air-cooled/water-cooled, large package unit/multi-split, split, Variable Refrigerant Volume (VRV) and Vapor Absorption System (VAM)
2. How do you foresee the demand for each type? Which industries are looking forward to using HVAC systems?
3. What is the future of energy-efficient HVAC systems changing in comparison to less energy-efficient HVAC systems?
4. How is the market shaping up in terms of new technologies and emerging consumer trends? (energy efficiency of the product) How could energy-efficient HVAC systems become affordable?
5. What all are the new avenues where HVAC systems could be used?
6. Are there any government regulations for distributing HVAC systems? How favorable are these?

1.4 Market Assessment Questionnaire (End-User)

Understanding of the product and its technology

1. What energy efficiency measures have been adopted in your building?
2. Have you designed/incorporated the following measures in HVAC design and installations:
   i. Variable Frequency Drives (VFDs) on pumps
   j. VFDs on cooling towers
   k. VFDs on Air Handling Units (AHU)/Treated Fresh Air (TFA) units
   l. Heat recovery ventilators
   m. Economizers
   n. Condenser water reset/relief
   o. CO_2 sensors based fresh air supply
   p. Carbon monoxide (CO) sensors in basement ventilation systems
3. What parameters/features are looked into before making a decision for HVAC system selection?
4. What are your views about predicted performance through simulation analysis and operational performance of HVAC products?

Current market scenario and key traits

1. What have you experienced in the last 5 to 10 years in terms of HVAC performance?
2. According to you, which are the most popular brands in the HVAC category? Which brand stands high on the following factors?
   a. Energy efficiency→Saves energy the most
   b. Compressor efficiency at part load
   c. Price→Adequate→Price as per features
   d. Performance
   e. After-sales service→
3. Please list the reason(s) for which you use HVAC systems? What types of HVAC systems are used at your organization?
4. Do you favor more efficient HVAC systems over less-efficient but less-costly systems? How much return on investment (ROI) do you expect for such systems?
5. Please shed light on the decision-making process for finalization of HVAC systems.

Product type used and purchase process

1. Do you have enough information on the products to make a wise decision on energy-efficient HVAC selection? What are the parameters you consider before selection?
2. How do you evaluated HVAC systems in terms of their maintenance? Are repair parts easily available in the market?
3. How do you rate the availability of the desired products and cost of each HVAC category?
4. In which processes are HVAC system used in most in your organization? How do they actually help in saving energy?
5. What are the energy efficiency measures you use for energy savings in HVAC systems?
6. Please explain the entire process for purchase of HVAC systems. From where do you purchase? Manufacturer/Distributor or do you hire a consultant for the same? Does the in-house team decide the brand or type of purchase, or are external consultants hired? (compressor type, Coefficient of Performance, energy efficiency ratio, specific power consumption)
7. Which team in the organization is responsible for deciding the type of HVAC systems to be purchased?
8. How do the team/consultants evaluate various brands for purchase? What are the attributes that matter the most for the purchase?

9. How relevant are the current energy standards like American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE), Energy Conservation Building Code (ECBC), etc., and how genuinely are they being followed in India?
10. Is the Air-Conditioning and Refrigeration Institute (ARI) testing of HVAC systems suitable for Indian conditions? Should there be provisions for separate test labs for testing in India? If yes, what will be the barriers and economics of the same? At your end, what factors act as triggers and what stops the team from opting for HVAC systems? (acquisition and installation cost, awareness level, promotions by the brand, technology used, greenhouse effect, rules and regulation levied by government agencies.)
11. Let us talk about energy efficiency in detail. Currently, is there any demand for energy-efficient HVAC systems? Who would be the potential clients for energy-efficient HVAC systems? Why do you say so?
12. What drives your choice the most? (changing market trends in terms of consumer behavior & attitude, entry of new products/technology, brands, changes in lifestyles, etc.). Arrange in order of priority/rank, i.e. mark 1 for the highest priority, 2 for the next highest, and so on.

Decision Parameter	*Priority/Rank*
Running costs	
Increase in product range with a range of features (style/ looks/color/compactness, etc.)	
Warranty/guarantee	
Acquisition cost	
Compressor efficiency at part load	
Energy efficiency ratio	
Coefficient of Performance (COP)	
Specific power consumption	
Ease of usage and installation	
Maintenance cost	
Area/space required for installation	
Energy efficiency	
Brand reputation for reliability/quality	
Environmental impact/greenhouse effect	
Technology used	
After-sales services	

Future trends

1. How is the market shaping up in terms of new technologies and emerging consumer trends? (energy efficiency of the product) What all are the new avenues where HVAC systems can be used?

ANNEX 2: MARKET ASSESSMENT SURVEY - QUANTITATIVE

2.1 Market Assessment Questionnaire – (Consultants/Architects/ Builders/Developers)

Company	
Address	
Tel	
Contact Person	
Department	
Designation	

Could you please tell me since how long have you been in this profession?

	Code
Less than 1 year	1
1-5 years	2
5-10 years	3
More than 10 years	4

2. What is the total number of employees in your organization? (#)..
3. How many offices do you have in India?...
4. What was your company's total revenue for 2011? (Mn Rupees)? Rs ....
   (record verbatim and then code)

Less than 5,000,000	1
50,00,000 – 10,000,000	2
More than 10,000,000	3

5. What type of projects have you been a part of/undertaken?

Private and public housing	1
Factories	2
Offices and retail units	3
Schools	4
Hospitals and public buildings	5
Civil engineering and infrastructure projects	6
Others	7

6. Which are your current ongoing projects & your future projects? In which city are they being undertaken?

Current Projects	City	Future Projects	City

7. Are you using HVAC systems in your projects?

Yes	1	Continue
No	2	Terminate

8. Who is the key decision maker when purchasing HVAC systems for your projects?

	Key Decision maker
Building Owner	1
Construction Manager	2
Design Engineers	3
HVAC Contractor	4
Architects	5
Consultants	6
Any Other	7

9. What type of HVAC system are you using in your projects?
   a. Which brand of HVAC system are you using in your project?
   b. What is the installed capacity of the HVAC system you are using currently?
   c. Since how long you have been using the same?

Less than 1 year	1
1-3 years	2
3-5 years	3
More than 5 years	4

   d. What was the total cost incurred on the HVAC, excluding installation, during the purchase?

   e. Who usually takes care of the maintenance?

   f. How much does the AMC of your HVAC system cost?

   g. Which type of HVAC would you consider for your next purchase?

   h. What is the reason for considering the same for your next purchase?

   I. What will be the installed capacity of the HVAC system you plan to use for your projects?

		Q 9	Q a	Q b	Q c	Q d	Q e	Q f	Q g	Q h	Q i
		Currently Used	Brand	Current Installed Capacity		Cost Incurred	Maintained by	AMC	Next Purchase	Repurchase	Future Installed Capacity
Non Residential	Chiller (Air-Cooled/Water-Cooled)										
	Large Packaged Unit/Multi-Split										
	Split										
	VRV										
	Vapor Absorption System (VAM)										

10. What is the reason for purchasing the current HVAC brand?

Non Residential - Chiller (Air-Cooled/Water-Cooled)
Non Residential - Large Packaged Unit/Multi Split
Non Residential – Split
Non Residential – VRVNon Residential - Vapor Absorption System (VAM)

11. What is the percentage of utility of the HVAC system under different climatic conditions? Please ensure that the sum of usage should add up to 100%.

	%
Summer	
Winter	

12. Which, according to you, are the important features to be considered while purchasing a HVAC system?

    I. Of all the features that you mentioned below, which are the top 3 features that you will consider while purchasing a HVAC system? Rank 1 will be the most important feature followed by 2 & 3.

	Important Features	Rank-Top 3 Features
The design and type of ductwork		
The refrigerant		
Balance dampers in the ductwork		
Location of the indoor unit		
Location of the outdoor unit		
Efficiency		
A filter dryer		
The condenser (outside) coil type		

Return-air considerations		
Air-filter location		
Any other		

13. Can you explain the purchase process/procedure of buying an HVAC system? This includes the entire time from initial requisition to invoice processing. Which are the parties involved & what role do they play?

14. What is your role in the purchase process?

15. What are the sources of information referred to while purchasing your HVAC system?

Friends	1
Co-workers	2
Contractor referrals	3
Internet	4
Local trade organizations	5
Any other........................	6

16. What is the total time required for buying an HVAC system? This includes the entire time from initial requisition to invoice processing _______________?

17. Please rate your current HVAC on a scale of 1 to 5 for the parameters below:

	Highly Satisfied	Satisfied	Neutral	Dissatisfied	Highly Unsatisfied
Overall satisfaction					
Performance					
Electricity consumption					
Efficiency					
Design and type of ductwork					
Consistent and continual airflow					
Quiet operation					
Whole-home dehumidifiers					
Nonpolluting refrigerants					
Value for money					
Requires low maintenance					

18. What are the problems you are facing with your current HVAC system ?

Non Residential – Chiller (Air-Cooled/Water-Cooled)
Non Residential – Large Packaged Unit/Multi-Split
Non Residential – Split
Non Residential – VRV
Non Residential – VAM

19. Are you aware of energy-efficient HVAC systems?

Yes	1	Continue
No	2	Skip to Q22

20. What do you understand by energy-efficient HVAC systems?

21. Where did you come to know about energy-efficient HVAC systems?

Promoters of EE buildings	1
Friends/family/colleagues	2
Newspapers/publications	3
Internet	4
Government bodies	5
Others (specify)	6
Others (specify)	7

22. What are the latest technologies of HVAC systems that you are aware of ?

	Q18	Qa
Passive Dehumidification	1	1
Desiccant-enhanced evaporative air conditioning (DEVAP)	2	2
Heat Recovery Systems	3	3
Residential Zoning Systems	4	4
Home Automation	5	5
The Nest Learning Thermostat	6	6
Noise Control	7	7
Control HVAC Functions - with computerized controls	8	8
Combat Air Pollution with HVAC Technology	9	9
Remote Diagnostic and Maintenance Systems	10	10
Zone Rooms with Different Temperature Settings	11	11
HVAC Software - Software may provide tools to help with scheduling, dispatching, billing, maintenance and inventory	12	12
Two-Stage Cooling - Offers efficiency, extra comfort	13	13
Any other	14	14

Explain the concept of energy-efficient HVAC systems to the respondents-

Heating, ventilation and air conditioning (HVAC) systems in buildings play a major role in minimizing or increasing the energy consumption of a building. In a conventional building, HVAC systems contribute nearly 60 per cent of the annual electricity bills. The objective of most changes to HVAC systems will be to decrease energy cost. Because of rising energy prices and the drive to reduce greenhouse gas (GHG) emissions associated with building operations, HVAC accounts for a significant portion of a commercial building's energy use, and represents an opportunity for considerable energy savings.

23. Now can you please share your views about this concept? What do you feel about this concept?

24. How relevant do you find this concept? Please rate your thoughts on a scale of 1 to 5 where 5 is Very Relevant & 1 is Very Irrelevant.

Very relevant	Somewhat relevant	Neither//nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

25. How promising do you find this option if you plan to use this for your future projects?

Very much promising	Somewhat relevant	Neutral	Somewhat not promising	Not at all promising
5	4	3	2	1

26. What do you think would be the benefits of energy-efficient HVAC systems?

27. What is your likelihood of promoting an energy-efficient HVAC system for your projects?

Extremely likely	Somewhat likely	Neutral	Somewhat unlikely	Extremely unlikely
5	4	3	2	1

28. What is the reason for your response?

29. Can you please suggest some methods/ways you can use to promote energy-efficient HVAC systems?

30. If in future HVAC systems come out with energy-efficient features, how much extra would you be willing to pay?

Will pay whatever it costs	Even if it costs more than for any non-energy-efficient chiller	Neutral	Only if it costs the same as any other chiller	I wouldn't buy it at all
5	4	3	2	1

31. Suppose you were to start/promote an energy-efficient HVAC system tomorrow, what do you think can act as motivators for its success?

	CODE	RANK
Reduce energy costs	1	
Environmental awareness	2	
Increase reliability - less frequent periods of inactivity - longer lifetimes than conventional products	3	
Reduce maintenance costs	4	
Improve occupant health	5	
Increase economic benefits through job creation and market development	6	
Benefits of going green	7	
Other (specify)	8	

32. What are the barriers to accepting/promoting energy-efficient HVAC systems?

	CODE
Lack of Information/understanding of energy benefits	1
Asymmetric access to information	2
Lack of awareness on the business case of energy efficiency	3
Absence of standardized measurements & verifications protocol	4
Absence of a common quantification method of energy savings benefits	5
Split-Incentives - The "split" of responsibility for capital versus operating expenses leaves building owners and developers with little incentive to invest in efficient construction	6
Perceived high initial investment costs	7
Limited technical expertise and products	8
Insufficient financial and regulatory incentives	9
Structural barriers	10
Lack of promotion	11
Others (Specify)	12

Labeling Section

33. Are you aware of any 'Comparative label' on 'energy-efficient equipment?

Yes, just aware	1
Yes, have some knowledge	2
No	3

34. Do these labels act as differentiators and are they useful in the purchase process?

Very useful	Somewhat useful	Neither/nor useful	Somewhat not useful	Not at all useful
5	4	3	2	1

35. Now if HVAC systems come with energy-efficient labels that give you assurance on comfortable living & energy saving, how relevant would you find it?

Very relevant	Somewhat relevant	Neither/nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

36. You said the concept is relevant to you; what reasons do you attribute to your response?

Reduce energy costs	1
Environmental awareness	2
Increase reliability - less frequent periods of inactivity - longer lifetimes than conventional products	3
Reduce maintenance costs	4
Improve occupant health	5
Increase economic benefits through job creation and market development.	6
Benefits of going green	7
Other (specify)	8

37. You said that this concept is not relevant to you; why do you say so?

38. Would labels affect your decision to purchase a particular HVAC system?

Yes	1
No	2

39. Who do you think should endorse energy-efficient HVAC systems to generate interest/increase awareness among consumers?

Government	1
Independent organization	2
Organization set up by builders	3
Others (specify)	4
Doesn't make any difference to me	5

Profiling Information

40. What is the average monthly electricity bill that you pay? Approximate no. of units consumed in a month?

Average Month Bill	No. of Units Consumed (Per month)

41. What is the source for each?

Water heating	Current Source	
	Electricity-operated geyser	1
	Gas-operated geyser	2
	Solar energy	3
	Others (specify)	4
Lighting	CFL	5
	Bulb	6
	Tube light	7
	Solar energy	8
	Other (specify)	9
Cooking	Solar cooker	10
	Gas stove	11
	Electric cooker	12
	Microwave	13
	Other (specify)	14
Cooling/Heating	Fan	15
	Air Cooler	16
	Air Conditioner	17
	Heater/Blower	18
	Chillers	19
	Other (specify)	20

42. I have a few statements with me that certain people like you have used to describe these systems. Please have a look at these and tell me which one best describes you.

I am very concerned about the environment so whatever possible, I always try to choose environment-friendly products, even if they sometimes cost a bit more	1
I am concerned about the environment but when choosing products, I usually place more importance on things like cost and performance rather than whether they are environment-friendly, although I don't ignore it	2
I am somewhat concerned about the environment but I haven't really thought about it in deciding which products to buy	3
I am neither aware nor concerned about environmental issues	4

2.2 Market Assessment Questionnaire Hotels/hospitals/malls/ multiplexes

Company	
Address	
Tel	
Contact Person	
Department	
Designation	

1. Provide information for the categories listed below:

In case of Hospitals

Type:		Ownership and Occupancy:	
Corporate Hospitals	1	Nongovernment Owned	1
Large Hospitals	2	Government Owned	2
Midsized Hospitals	3		
Small Hospitals	4		
Nursing Homes	5		
City:		Year Constructed	
Type (Specialty):		No. of Beds	
No. of Intensive Care Units (ICU)		No. of Buildings	
No. of Coronary Care Units (CCU)		No. of OR (Operating Rooms)	
No. of Floors		No. of Elevators and Escalators	

In case of Hotels

Level of Service:			Ownership and Affiliations:	
World-class Service		1	**Independent Hotels**	1
Mid-Range Service		2	**Chain Hotels**	2
Economy//Limited Service		3		
City:		4	Year Constructed	
Star Category:		5	No. of Rooms	
No. of Buildings			No. of Floors	
No. of Lifts			No. of Elevators and Escalators	

In case of Malls

City:		Year Constructed	
Area in Sq Ft:		No. of shops in each floor	
No. of Floors		No. of Elevators and Escalators	
No. of Lifts			

2. What is the total number of staff in your Hospital/Hotel? (#) ________________________________
   Ask for Hotels:
   How many branches do you have in India? ____________________________________

3. What was your total revenue for 2011? (Million INR)? INR _______ (record verbatim and then code)

Less than 50,00,000	1
50,00,000 – 10,00,0000	2
More than 10,00,0000	3

4. Are you using HVAC systems in your projects?

Yes	1	Continue
No	2	Terminate

If coded 2, terminate, else continue

5. Who is the key decision maker when purchasing the HVAC systems for your projectss?

	Key Decision maker
Building Owner	1
Construction Manager	2
Design Engineers	3
HVAC Contractor	4
Architects	5
Consultants	6
Any Other	7

6. What type of HVAC system are you using in your projects ?

a. What is the installed capacity of the HVAC system you are using currently ?

b. Since how long you have been using the same ?

Less Than 1 year	1
1-3 years	2
3-5 years	3
More than 5 years	4

c. What was the total cost incurred on the HVAC, excluding installation, during the purchase ?

d. Who usually takes care of the maintenance ?

e. How much does the AMC of your HVAC system cost ?

f. Which type of HVAC would you consider for your next purchase ?

g. What is the reason for considering the same for your next purchase ?

h. What will be the installed capacity of the HVAC system you plan to use for your projects?

		Q 9	Q a	Q b	Q c	Q d	Q e	Q f	Q g	Q h	Q i
		Currently Used	Brand		Duration of usage	Cost Incurred	Maintained by	AMC	Next Purchase	Reason for next Purchase	Installed Capacity
Non Residential	Chiller (Air-Cooled/Water-Cooled)	1							1		
	Large Packaged Unit/ Multi-Split	2							2		
	Split	3							3		
	VRV	4							4		
	Vapor Absorption Machine (VAM)	5							5		

7. Could you please tell me the reason for purchasing the current HVAC brand ?

Non Residential - Chiller (Air-Cooled/Water-Cooled)
Non Residential - Large Packaged Unit/Multi-Split
Non Residential - Split
Non Residential - VRV
Non Residential - Vapor Absorption System (VAM)

8. Can you please tell me the percentage of utility of the HVAC system under different climatic conditions? Please ensure that the sum of usage should add up to 100%.

	%
Summer	
Winter	

9. Can you explain the purchase process/procedure of buying an HVAC system? This includes the entire time from initial requisition to invoice processing. Which are the parties involved & what role do they play?

10. What is your role in the purchase process?

11. Which according to you are the important features to be considered while purchasing an HVAC system?
    a. Of all the features that you mentioned below, which are the top 3 features that you will consider while purchasing an HVAC system? Rank 1 will be the most important feature followed by 2 & 3.

	Important Features	Rank-Top 3 Features
The design and type of ductwork		
The refrigerant		
Balance dampers in the ductwork		
Location of the indoor unit		
Location of the outdoor unit		
Efficiency		
A Filter dryer		
The condenser (outside) coil type		
Return-air considerations		
Air-filter location		
Any other		

12. What are the sources of information referred to while purchasing your HVAC system ?

Friends	1
Co-workersContractor referrals	2
Internet	3
Local trade organizations	4
Any Other	5
	6

13. What is the total time required for buying an HVAC system? This includes the entire time from initial requisition to invoice processing.

14. Please rate your current HVAC on a scale of 1 to 5 for the parameters below:

	Highly Satisfied	Satisfied	Neutral	Dissatisfied	Highly Unsatisfied
Overall satisfaction	5	4	3	2	1
Performance	5	4	3	2	1
Electricity consumption	5	4	3	2	1
Efficiency	5	4	3	2	1
Design and type of ductwork	5	4	3	2	1
Consistent and continual airflow.	5	4	3	2	1
Quiet operation.	5	4	3	2	1
Whole-home dehumidifiers	5	4	3	2	1
Nonpolluting refrigerants	5	4	3	2	1
Value for money	5	4	3	2	1
Required low maintenance	5	4	3	2	1

15. What are the problems you are facing with your current HVAC system ?

Non Residential - Chiller (Air-Cooled/Water-Cooled)
Non Residential - Large Packaged Unit/Multi-Split
Non Residential - Split
Non Residential - VRV
Non Residential - Vapor Absorption System (VAM)

16. Are you aware of energy-efficient HVAC systems?

Yes	1	Continue
No	2	Skip to Q21

17. What do you understand by energy-efficient HVAC systems?

18. Where did you come to know about energy-efficient HVAC systems?

Promoters of EE buildings	1
Friends/family/colleagues	2
Newspapers/publications	3
Internet	4
Others (Specify)	5
Others (Specify)	6
	7

19. a. What are the latest technologies of HVAC systems that you are aware of?
b. Which technology do you think will be in demand the most in the future?

	Q18	Q18
Passive dehumidification	1	1
Desiccant-enhanced evaporative air conditioning (DEVAP)	2	2
Heat recovery system	3	3
Residential zoning systems	4	4
Home automation	5	5
Nest Learning thermostat	6	6
Noise control	7	7
Control HVAC functions with computerized controls	8	8
Combat air pollution with HVAC technology	9	9
Remote diagnostic and maintenance systems	10	10
Zone rooms with different temperature settings	11	11
HVAC software - software may provide tools to help with scheduling, dispatching, billing, maintenance and inventory	12	12
Two-stage cooling offers efficiency, extra comfort	13	13
Any other	14	14

Explain the concept of energy-efficient HVAC systems to the respondents-

Heating, ventilation and air-conditioning (HVAC) systems in buildings play a major role in minimizing or increasing the energy consumption of a building. In a conventional building, HVAC systems contribute nearly 60 per cent of the annual electricity bills. The objective of most changes to HVAC systems will be to decrease energy cost. Because of rising energy prices and the drive to reduce greenhouse gas (GHG) emissions associated with building operations, HVAC accounts for a significant portion of a commercial building's energy use, and represents an opportunity for considerable energy savings.

20. Please share your views about this concept.

21. How relevant do you find this concept? Please rate your thoughts on a scale of 1 to 5 where 5 is Very Relevant & 1 is Very Irrelevant.

Very relevant	Somewhat relevant	Neither/nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

22. How promising do you find this option if you plan to use this for your future projects?

Very much promising	Somewhat promising	Neither	Somewhat not promising	Not at all promising
5	4	3	2	1

23. What do you think would be the benefits of energy-efficient HVAC systems?

24. What is your likelihood of promoting an energy-efficient HVAC system for your projects?

Extremely likely	Somewhat likely	Neutral	Somewhat unlikely	Extremely unlikely
5	4	3	2	1

25. What is the reason for your response?

26. Suppose, if tomorrow you were to start/promote an energy-efficient HVAC system, what do you think can act as motivators for its success?

	Code	Rank
Reduce energy costs	1	
Environmental awareness	2	
Increase reliability - less frequent periods of inactivity - longer lifetimes than conventional products	3	
Reduce maintenance costs	4	
Improve occupant health	5	
Increase economic benefits through job creation and market development	6	
Benefits of going green	7	
Other (specify)	8	
Other (specify)	9	

27. What are the barriers to accepting/promoting energy-efficient HVAC systems?

	Code
Lack of information/understanding of energy benefits	1
Asymmetric access to information	2
Lack of awareness on the business case of energy efficiency	3
Absence of standardized measurements & verifications protocol	4
Absence of a common quantification method of energy	5
Savings benefits	
Split-Incentives - The "split" of responsibility for capital versus operating expenses leaves building owners and developers with little incentive to invest in efficient construction	6
Perceived high initial investment costs	7
Limited technical expertise and products	8
Insufficient financial and regulatory incentives	9
Structural barriers	10
Lack of promotion	11
Others (specify)	12

28. Can you please suggest some methods/ways that you can use to promote energy-efficient HVAC systems?

29. If, in future, HVAC systems come out with energy-efficient features, how much extra would you be willing to pay?

Will pay whatever it costs	Even if it costs more than for any non-energy-efficient chiller	Neutral	Only if it costs the same as any other chiller	I wouldn't buy it at all
5	4	3	2	1

Labeling Section

30. Are you aware of any 'Comparative label' on 'Energy-efficient equipment?

Yes, just aware	1
Yes, have some knowledge	2
No	3

31. Do these labels act as differentiators and are they useful in the purchase process?

Very useful	Somewhat useful	Neither/nor useful	Somewhat not useful	Not at all useful
5	4	3	2	1

32. Now if HVAC systems come with energy-efficient labels that give you assurance on comfortable living & energy saving, how relevant would you find them?

Very relevant	Somewhat relevant	Neither/nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

33. You said the concept is relevant to you, what reasons do you attribute to your response?

Reduce energy costs	1
Environmental awareness	2
Increase reliability - less frequent periods of inactivity - longer lifetimes than conventional products	3
Reduce maintenance costs	4
Improve occupant health	5
Increase economic benefits through job creation	6
Market development.	
Benefits of going green	7
Other (specify)	8
Other (specify)	9

34. You said that this concept is not relevant to you. Why do you say so?

35. Would labels affect your decision to purchase a particular HVAC system?

Yes	1
No	2

36. Who do you think should endorse energy-efficient HVAC systems to generate interest/increase awareness among consumers ?

Government	1
Independent organization	2
Organization set up by builders	3
Others (specify)	4
Doesn't make any difference to me	5

Profiling Information

37. What is the average monthly electricity bill that you pay? Approximate no. of units consumed in a month?

Average Monthly Bill	No. of Units Consumed (Per month)

38. What is the source for each?

Current Source	
Water Heating	1
Cooking	2
Cooling	3
Lighting	4
Space Heating	5
Office Equipment	6
Ventilation	7
Refrigeration	8
Other (specify)	9

39. I have a few statements with me that certain people like you have used to describe themselves. Please have a look at these and tell me which one best describes you.

I am very concerned about the environment, so whenever possible, I try to choose environment-friendly products, even if they sometimes cost a bit more	1
I am concerned about the environment; but when choosing products, I usually place more importance on things like cost and performance rather than whether they are environment-friendly, although I don't ignore it	2
I am somewhat concerned about the environment but I haven't really thought about it while deciding which products to buy	3
I am neither aware nor concerned about environmental issues	4

2.3 Sample of Filled-up Market Assessment Questionnaire

HVAC Study Questionnaire- Consultant/Architects/Builders/Developers

Hello, this is ( ) from Market Xcel. We are conducting a study to understand the HVAC market & the acceptance of Energy Efficient HVAC system within India. May I request you to spare some time to answer my questions? I would be greatly appreciative of the time spared by you. I would like to assure you that the responses shared by you will not be shared in isolation but clubbed with responses from other players to generate results.

Company	Sai Properties & Developers
Address	# 11&12, 2nd floor, P.2 Plaza, [illegible]
Tel	8?? 4412095
Contact Person	Rajesh
Department	marketing
Designation	marketing manager

1. **Could you please tell me since how long have you been in this profession?**

	Code
Less than 1 year	1
1-5 years	2
5-10 years	(3) 6 year
More than 10 years	4

2. **What is the total number of employees in your organization? (#)** more than 100

3. **How many offices do you have in India?** 01

4. **What was your company's total revenue for 2012? (Mn Rupees)? Rs.** 60,00000 **(RECORD VEBATIM and then code)**

Less than 50,00,000	1
50,00,000 – 10,00,0000	(2)
More than 10,00,0000	3

5. **What type of projects have you been a part of/ undertake?**

Private and public housing	(1)
Factories	2
offices and retail units	(3)
Schools	4
Hospitals and public buildings	5
Civil engineering and infrastructure projects	6
Others	7

6. **Which are your current ongoing projects & your Future projects & which city are they being undertaken?**

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Current Projects	City	Future projects	City
office	B'lore	public & office	B'lore

7. Are you using HVAC systems in your projects?

Yes	1	Continue
No	2	Terminate

If coded 2, terminate else continue

8. Who is the key decision maker when purchasing the HVAC systems for your projects?

	Key Decision maker
Building Owner	1
Construction Manager	2
Design Engineers	3
HVAC Contractor	4
Architects	5
Consultants	6
Any Other ______	7

9. What type of HVAC system are you using in latest projects?
   a. Which brand of HVAC system are you using in your latest project?
   b. What is the installed capacity of the HVAC system you are using currently?
   c. Since how long you have been using the same?

Less Than 1 year	1
1-3 years	2
3-5 years	3
More than 5 years	4

   d. What was the total cost incurred on the HVAC excluding installation during the purchase?
   e. Who usually takes care of the maintenance?
   f. How much does the AMC of your HVAC system cost?
   g. Which type of HVAC would you consider for your next purchase?
   h. What is the reason for considering the same for your next purchase?
   i. What will be the installed capacity of the HVAC system you plan to use for your next project?

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		Q9 Currently Used	Q a Brand	Q b Current Installed Capacity	Q c Duration of usage	Q d Cost Incurred	Q e Maintained by	Q f AMC	Q g Next Purchase	Q h Reason for next Purchase	Q i Future Installed Capacity
Non Residential	Chiller (Air Cooled/Water Cooled)	1							1		
	Large Packaged Unit/Multi Split	2							2		
	Split	(3)	LG	0 1K	[illegible]	10K	LG	15000	(3)	Good brand image	C/B
	VRV	4							4		
	Vapour Absorption System (VAM)	5							5		

10. Could you please tell me the reason for purchasing the current HVAC BRAND for your latest project?

Non Residential- Chiller (Air Cooled/Water Cooled)
Non Residential- Large Packaged Unit/Multi Split
Non Residential- Split Good brand image in market
Non Residential- VRV
Non Residential- Vapor Absorption System (VAM)

11. Can you please tell me the percentage of utility of the HVAC system under different climatic conditions? Please ensure that the sum of usage should add up to 100%.

	%
Summer	70
Winter	30

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12. Which according to you are the important features to be considered while purchasing a HVAC system?

i. Of all the features that you mentioned below, which are the top 3 features that you will consider while purchasing a HVAC system? Rank 1 will be the most important feature followed by 2 & 3.

	Important Features	Rank-Top 3 Features
The design and type of ductwork	1	
The refrigerant	2	1
Balance dampers in the ductwork	3	
Location of the indoor uni	4	
Location of the outdoor uni	5	3
Efficiency	6	2
A filter dryer	7	
The condenser (outside) coil type	8	
Return-air considerations	9	
Air-filter location	10	
Any Other________	11	

13. Can you explain the purchase process/procedure of buying a HVAC system? This includes the entire time from initial requisition to invoice processing. Which are the parties involved & what role do they play?

Billings helps in having correct products & helps us to give comments

14. What is your role in purchase process?

one among decision makes

15. What are the sources of information referred to while purchasing your HVAC system?

Friends	1
Co-workers	2
contractor referrals	3
Internet	4
local trade organizations	5
Engineers/Consultants	6
Any Other	7

16. What is the total time required for buying a HVAC system? This includes the entire time from initial requisition to invoice processing 1 days to 10 days

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	Highly Satisfied	Satisfied	Neutral	Dissatisfied	Highly Unsatisfied
Overall Satisfaction	5	4	3	2	1
Performance	5	4	3	2	1
Electricity Consumption	5	4	3	2	1
Efficiency	5	4	3	2	1
Design and type of ductwork	5	4	3	2	1
Consistent and continual airflow.	5	4	3	2	1
Quiet operation.	5	4	3	2	1
Whole-home dehumidifiers	5	4	3	2	1
Nonpolluting refrigerants	5	4	3	2	1
Value for money	5	4	3	2	1
Required low maintenance	5	4	3	2	1

ASK THOSE CODED 1/2/3 IN Q17. Ask for type coded in Q9

18. What are the problems you are facing with your current HVAC system.

Non Residential- Chiller (Air Cooled/Water Cooled)
Non Residential- Large Packaged Unit/Multi Split
Non Residential- Split Less cool so more bills
Non Residential- VRV
Non Residential- Vapour Absorption System (VAM)

19. Are you aware of energy efficient HVAC systems?

Yes	1	CONTINUE
No	2	SKIP TO Q22

(Ask Q20 to those coded 1 in Q14)

20. What do you understand by energy efficient HVAC systems?

N/A

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... did you come to know about energy efficient HVAC systems?

Promoters of EE buildings	1
Friends/family/Colleagues	2
Newspaper/publications	3
Internet	4
Government bodies	5
Others (Specify)	6
Others (Specify)	7

22. What are the latest technologies of HVAC system that you are aware of?

    i. Which technology do you think will be in demand the most in the future?

	Q18	Qa
Passive Dehumidification	1	1
DEVAP	2	2
Heat Recovery System	3	3
Residential Zoning Systems	4	4
Home Automation	5	5
The Nest Learning Thermostat	6	6
Noise Control	7	7
Control HVAC functions with computerized controls	8	8
Combat Air Pollution with HVAC Technology	9	9
remote diagnostic and maintenance systems	10	10
Zone Rooms with Different Temperature Settings	11	11
HVAC Software-Software may provide tools to help with scheduling, dispatching, billing, maintenance and inventory	12	12
Two-Stage Cooling Offers Efficiency, Extra Comfort	13	13
Any Other	14	14

Explain the concept of energy efficient HVAC system to the respondents-

The heating, ventilation and air conditioning (HVAC) systems in buildings play a major role in minimizing or increasing the energy consumption of a building. In a conventional building, HVAC systems contribute nearly 60 per cent of the annual electricity bills. The objective of most changes to HVAC systems will be to decrease energy cost. Because of rising energy prices and the drive to reduce greenhouse gas (GHG) emissions associated with building operations. Heating, Ventilation and Air Conditioning (HVAC) accounts for a significant portion of a commercial building's energy use and represents an opportunity for considerable energy savings.

23. Now can you please share your views about this concept? How do you find this concept? What do you feel about this concept?

very good concept ... is environment friendly projects

24. How relevant do you find this concept? Please rate your thoughts on a scle of 1 to 5 where 5 is Very Relevant & 1 is Very Irrelevant.

Very relevant	Somewhat relevant	Neither / nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

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Very much promising	Somewhat promising	Neutral	Somewhat not promising	Not at all promising
5	4	3	2	1

26. What do you think would be the benefits of energy efficient HVAC systems?

NO Need of water leaking problems

27. What is your likelihood of promoting an energy efficient HVAC system for your projects?

Extremely likely	Somewhat likely	Neutral	Somewhat unlikely	Extremely unlikely
5	4	3	2	1

28. What is reason for your response?

Going green is one of the prime concern now

29. Supposedly if tomorrow you were to start/promote an energy efficient HVAC system, what do you think can act as motivators for its success?

	CODE	RANK
Reduced energy costs	1	
environmental awareness	2	1
Increase reliability- less frequent periods of inactivity - longer lifetimes than conventional products	3	3
Reduce maintenance costs	4	
Improve occupant health	5	2
Increase economic benefits through job creation and market development. S	6	
benefits of going green	7	
Other(Sp.)	8	
Other(Sp.)	9	

30. What are the barriers in accepting/promoting Energy efficient HVAC systems?

	Code
Lack of Information/understanding of energy benefits	1
Asymmetric access to information	2
Lack of Awareness on the Business Case of Energy Efficiency	3
Absence of standardized measurements & verifications protocol	4
Absence of a common quantification method of energy savings benefits	5
Split-Incentives- The "split" of responsibility for capital versus operating expenses leaves building owners and developers with little incentive to invest in efficient construction	6
Perceived High Initial Investment Costs	7
Limited Technical Expertise and Products	8
Insufficient Financial and Regulatory Incentives	9
Structural Barriers	10
Lack of promotion	11
Others (Specify)	12

31. Can you please suggest some methods/ways which you can use to promote energy efficient HVAC systems?

news'papers, dealers, & advertize boards

32. If in future the chillers come out with energy efficient feature…how much extra would you be willing to pay?

Will pay whatever it costs	Even if it costs more than for any non-energy efficient chiller	Neutral	Only if it costs same as any other chiller	I wouldn't buy it at all
5	4	3	2	1

Labeling Section -

33. Are you aware of any 'Comparative label' on 'Energy Efficient equipment?

Yes, Just aware	1
Yes, have some knowledge	2
No	3

34. Do these labels act as differentiators and are they useful in the purchase process?

Very useful	Somewhat useful	Neither / nor useful	Somewhat not useful	Not at all useful
5	4	3	2	1

35. Now if HVAC systems come with energy efficient labels that gives you assurance on comfortable living & energy saving. How relevant do you find it?

Very relevant	Somewhat relevant	Neither / nor	Somewhat irrelevant	Very irrelevant
5	4	3	2	1

(Ask Q36 to those coded 5 or 4 in Q35)

36. You said the concept is relevant to you, what reasons you attribute to your response?

Reduced energy costs	1
Environmental awareness	2
Increase reliability- less frequent periods of inactivity - longer lifetimes than conventional products	3
Reduce maintenance costs	4
Improve occupant health	5
Increase economic benefits through job creation and market development.	6
Benefits of going green	7
Other(Sp.)	8
Other(Sp.)	9

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37. You said that this concept is not relevant to you, why do you say so?

38. Would label effect your decision to purchase a particular HVAC system?

Yes	1
No	2

39. Who do you think should endorse the Energy efficient HVAC systems to generate interest/increase awareness among consumers?

Government	1
Independent organization	2
Organization set up by builders	3
Others (specify) ____________	4
Doesn't make any difference to me	5

Profiling Information

40. What is the average monthly electricity bill that you pay? Approximate no. of units consumed in a month?

Average Month Bill	No. of Units Consumed (Per month)
R1K	cls

41. What is the source for each?

	Current Source	
Water heating	Electricity operated geyser	1
	Gas operated geyser	2
	Solar energy	3
	Others(sp.)	4
Lighting	CFL	5
	Bulb	6
	Tube light	7
	Solar energy	8
	Other(sp.)	9
Cooking	Solar cooker	10
	Gas Stove	11
	Electric Cooker	12
	Microwave	13
	Other(sp.)	14

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	Fan	15
	Air Cooler	16
Cooling/Heating	Air Conditioner	17
	Heater/Blower	18
	Chillers	19
	Other(sp.)	20

42. I have few statements with me that certain people like you have used to describe them please have a look at these and tell me which one best describes you.

I am very concerned about the environment so whatever possible, I always try to choose environment friendly products, even if they sometimes cost a bit more	1
I am concerned about the environment but when choosing products, I usually place more importance on things like cost and performance rather than whether they are environmentally friendly, although I don't ignore it	2
I am somewhat concerned about the environment but I haven't really thought about it in deciding which products to buy	3
I am neither aware nor concerned on environmental issues	4

ANNEX 3: LIST OF RESPONDENTS

List of respondents for detailed interviews

S. No.	Name	Designation	Organization	Category	Centre	Tentative Day of Interaction
1	Mr. G.C. Modgil	CEO	Sterling India-Consulting Engineers	Consultant	Delhi	14th February 2013
2	Mr. N.C Gupta	CEO	Gupta Consultants and Associates	Consultant	Delhi	12th February 2013
3	Mr. Milind Gawde	Manager - Engineering	Breach Candy Hospital	End-user	Mumbai	28th March 2013
4	Mr. Atul	DGM, Facility	K. Raheja Corporation	End-user	Mumbai	22nd March 2013
5	Mr. Krishan Kumar	Manager - Maintenance	Ambience Mall, Vasant Kunj	End-user	Delhi	21st March 2013
6	Mr. Karan Raina	Manager – Utility	The Great India Place	End-user	Noida	2nd week April 2013
7	Mr. Vivek Gupta	Architect	Arvind Vivek & Associates	Architect	Delhi	2nd week April 2013
8	Mr. Santosh Shindane	Engineer	Bhabha Hospital	End-user	Mumbai	3rd week March 2013
9	Mr. Nitin Joshi	Senior General Manager	Blue Star Limited	Manufacturer	Mumbai	28th March 2013
10	Mr. S P Singh	G M - Services	Vipul Tech Square	End-user	Gurgaon	25th March 2013
11	Mr. Mukesh	Asstt. Manager - Engineering Division	Apollo Hospitals Enterprise Ltd.	End-user	Delhi	09th April 2013
12	Mr. Sanjay Koul	Manager - CHP Proposals	International Coil Ltd.	Manufacturer	Gurgaon	2nd week April 2013
13	Mr. Rohit Yadav	Asstt. Manager-Engineering	Phoenix Marketcity	End-user	Pune	2nd week April 2013
14	Mr. Praveen Kumar	Manager - Services	Omaxe Ltd.	Builder	Delhi	3rd week March 2013
15	Mr. Vineet Shukla	Head - HVAC systems	WSP Consultants	Consultant	Noida	11th April 2013
16	Mr. Vivek Maheswari	General Manager	ETA Engineering Pvt. Ltd.	Manufacturer	Noida	09th April 2013
17	Mr. Rahul Buliyan	Senior Manager-Commercial Projects	Amrapali Group	Builder	Noida	09th April 2013
18	Mr. Dhanprakash Garg	Head - Commercial Projects	Mvl Limited	Builder	Gurgaon	10th April 2013
19	Mr. Saurabh Singh Rathod	AVP - Commercials	Climaveneta Climate Technologies (P) Ltd.	Distributor	Gurgaon	10th April 2013
20	Mr. Rajesh	Head - Operations	SK Air Conditioner	Distributor	Pune	3rd week March 2013
21	Mr. Vikash Upadhyay	Project Manager	Jones Lang Lasalle (Jll)	Facility Management	Mumbai	12th April 2013
22	Mr. Amaan	Managing Director	Comfort Aircon	Distributor	Delhi	4th week March 2013
23	Mr. Rana	Co-Owner	Vitzer Enterprises	Distributor	Delhi	3rd week March 2013
24	Mr. Wilson	Project Manager	Kwality Air Tech Engineering Pvt. Ltd.	Distributor	Mumbai	4th week March 2013
25	Mr. Manoj Juneja	Managing Director	Harmony Inc.	Distributor	Delhi	3rd week April 2013
26	Mr. Lalit Bedi	Managing Director	Cool Breeze Aircon Pvt. Ltd.	Distributor	Delhi	4th week March 2013
27	Mr. Narender Gandhi	Team Leader - North	Trane	Distributor	Mumbai	2nd week April 2013
28	Mr. Mayank	Architect	Shift	Architect	Delhi	2nd week April 2013

S. No.	Name	Designation	Organization	Category	Centre	Tentative Day of Interaction
29	Mr. Raghvendra Bisen	DGM - Planning	Peninsula Land Ltd.	Builder	Mumbai	2nd week April 2013
30	Mr. Saurabh Diddi	Energy Economist	Bureau of Energy Efficiency (BEE)	Association	New Delhi	30th April 2013
31	Mr. Vijay Bali	VP - Sales & Marketing	Reynold India Private Limited	Manufacturer	Noida	16th April 2013
32	Mr. Rama Murti	Manager - Operations	Updater Services (P) Ltd. (UDS)	Facility Management	Delhi	4th week April 2013
33	Mr. Amit Gulwade	Sr. Engineer	RS Kulkarni and Consultancy	Consultant	Pune	3rd week April 2013
34	Mr. Naresh	Engineer	Vactal Engineers Pvt. Ltd.	Distributor	Delhi	1st week April 2013
35	Mr. Satish Yadav	Deputy Manager	Emerson Climate Technologies (India) Ltd.	Distributor	Gurgaon	18th April 2013
36	Mr. Rajiv	Managing Director	Kromatics	Consultant	Mumbai	1st week April 2013
37	Mr. Abdul Aziz S A	Managing Director	Peace HVAC Systems Pvt. Ltd.	Distributor	Bangalore	30th April 2013
38	Mr. Vijay Chawla	Technical Head	Bharti Realty	Builder	Gurgaon	2nd week April 2013
39	Mr. Umesh	Managing Director	Bright International Bright Freezer (India)	Manufacturer	Mumbai	4th week April 2013
40	Mr. Aryan Kaushik	Manager - Maintenance	Ajnara Grace	Builder	Noida	22nd April 2013
41	Mr. Joyti Parkash	Purchase Manager	Ascent Group Limited	Builder	Noida	22nd April 2013
42	Ms. Pallavi Priya	Sr. Architect	Dezlabs	Architect	Delhi	2nd week April 2013
43	Mr. Mahesh	Managing Director	McD Built Environment Research Laboratory Pvt. Ltd.	Consultant	Bangalore	4th week April 2013
44	Mr. Agnelo Rodricks	Managing Director	Weather Cool Sales Pvt. Ltd.	Distributor	Mumbai	2nd or 3rd week April 2013
45	Ms. Hemali	Senior Architect	KNS Architects Pvt. Ltd.	Consultant	Mumbai	2nd week April 2013
46	Mr. Karthik	Managing Director	Design Tree Service Consultants Pvt. Ltd.	Consultant	Bangalore	4th week April 2013
47	Mr. Ravinder Mehta	Secretary	Refrigeration and Air-Conditioning Manufacturers Association of India	Association	Delhi	4th week April 2013
48	Mr. Rishi Bagga	Manager - Business Development	Knight Frank	Facility Management	Gurgaon	4th week April 2013
49	Mr. Pradeep Kumar	Associate Director, Building Energy Systems	TERI (The Energy and Resources Institute)	Association	New Delhi	4th week April 2013
50	Mr. Sandeep Patil	Manager	Kolte Patil Developers Ltd.	Builder	Pune	3rd week April 2013

List of all participating organizations of survey

S. No.	Company	Location	Category
1	*SESCON BUILDERS PVT. LTD.*	*Delhi NCR*	*Consultants/ Architects*
2	*SPACE ART*	*Delhi NCR*	*Consultants/ Architects*
3	*UD ARCHITECTS PVT. LTD.*	*Delhi NCR*	*Consultants/ Architects*
4	*MR JAGDISH C MARWAHA*	*Delhi NCR*	*Consultants/ Architects*
5	*SOM PROJECTS PVT. LTD.*	*Delhi NCR*	*Consultants/ Architects*
6	*PRACHI ASSOCIATES AND CONSULTANTS*	*Delhi NCR*	*Consultants/ Architects*
7	*RSQR ARCHITECTS*	*Delhi NCR*	*Consultants/ Architects*
8	*SOMDUTT BUILDERS PVT. LTD.*	*Delhi NCR*	*Builders/Developers*
9	*JAGDAMBA ASSOCIATES*	*Delhi NCR*	*Builders/Developers*
10	*CHD DEVELOPERS LTD.*	*Delhi NCR*	*Builders/Developers*
11	*GIAN P MATHUR ASSOCIATES*	*Delhi NCR*	*Builders/Developers*
12	*OMAXE LTD.*	*Delhi NCR*	*Builders/Developers*
13	*ONE WAY BUILD ESTATE PVT. LTD.*	*Delhi NCR*	*Builders/Developers*
14	*J K ASSOCIATES*	*Delhi NCR*	*Builders/Developers*
15	*CLARKS INN*	*Delhi NCR*	*End-users*
16	*RG STONE UROLOGY & LAPAROSCOPY HOSPITAL*	*Delhi NCR*	*End-users*
17	*IDI PARAGON MALL*	*Delhi NCR*	*End-users*
18	*THE MUSE SAROVAR PORTICA*	*Delhi NCR*	*End-users*
19	*HOTEL CONCLAVE*	*Delhi NCR*	*End-users*
20	*NATIONAL HEART INSTITUTE*	*Delhi NCR*	*End-users*
21	*EROS HOTEL*	*Delhi NCR*	*End-users*
22	*DAIKIN AIR CONDITIONING INDIA PVT. LTD.*	*Mumbai*	*Consultants/ Architects*
23	*MALIKA APPLIANCES*	*Mumbai*	*Consultants/ Architects*
24	*RAJESH PATEL CONSULTANTS PVT. LTD.*	*Mumbai*	*Consultants/ Architects*
25	*3I INFOTECH*	*Mumbai*	*Consultants/ Architects*
26	*G 1 MINI VISION*	*Mumbai*	*Consultants/ Architects*
27	*DURACOOL*	*Mumbai*	*Consultants/ Architects*
28	*RASHMI HOUSING PVT. LTD.*	*Mumbai*	*Builders/Developers*
29	*RMC READY MIX INDIA*	*Mumbai*	*Builders/Developers*
30	*SHREE MORYA DEVELOPERS*	*Mumbai*	*Builders/Developers*

A1 S.No.	Company	Location	Category
31	*KANAKADHARA VENTURES PVT. LTD.*	*Hyderabad*	*Consultants/ Architects*
32	*SHIVA SHAKTI ENGINEERING*	*Hyderabad*	*Consultants/ Architects*
33	*GALACON INFRASTRUCTURE AND PROJECTS PVT. LTD.*	*Hyderabad*	*Consultants/ Architects*
34	*LANDMARK BUILDERS*	*Hyderabad*	*Builders/Developers*
35	*MODI BUILDERS*	*Hyderabad*	*Builders/Developers*
36	*INDU PROJECTS LIMITED*	*Hyderabad*	*Builders/Developers*
37	*YASODHA HOSPITAL*	*Hyderabad*	*End-users*
38	*GANGA HOTEL*	*Hyderabad*	*End-users*
39	*PANJAGUTTA CENTRAL*	*Hyderabad*	*End-users*
40	*CHANDRAGUPTA ARCHITECTS AND INTERIOR DESIGNERS*	*Pune*	*Consultants/ Architects*
41	*ALBUS ENGINEERING CONSULTANTS PVT. LTD.*	*Pune*	*Consultants/ Architects*
42	*AIM ENTERPRISES*	*Pune*	*Consultants/ Architects*
43	*V R ENGINEERING*	*Pune*	*Builders/Developers*
44	*S M GROUP*	*Pune*	*Builders/Developers*
45	*DSK DEVELOPERS*	*Pune*	*Builders/Developers*
46	*CITY PRIDE*	*Pune*	*End-users*
47	*CENTRAL MALL*	*Pune*	*End-users*
48	*HOTEL SAPNA*	*Pune*	*End-users*
49	*SAPPHIRE CONSULTANTS*	*Bangalore*	*Consultants/ Architects*
50	*MISKIN AND ASSOCIATES*	*Bangalore*	*Consultants/ Architects*
51	*DESYA ENTERPRISES*	*Bangalore*	*Consultants/ Architects*
52	*VASANT KUMAR ASSOCIATES*	*Bangalore*	*Consultants/ Architects*
53	*INVENTORE DESIGN*	*Bangalore*	*Builders/Developers*
54	*KLASSIK ENTERPRISES*	*Bangalore*	*Builders/Developers*
55	*SAN PROPERTIES AND DEVELOPERS*	*Bangalore*	*Builders/Developers*
56	*MODERNITY INTERNATIONAL*	*Bangalore*	*Builders/Developers*
57	*BANGALORE INSTITUTE OF ONCOLOGY*	*Bangalore*	*End-users*
58	*THE GRAND PAVILION*	*Bangalore*	*End-users*
59	*AGADI HOSPITAL*	*Bangalore*	*End-users*
60	*DEVA RESIDENCY*	*Bangalore*	*End-users*

S. No.	Company	A1 Location	A2 Category
61	*WADHWA GROUP*	*Mumbai*	*Builders/Developers*
62	*RIZVI BUILDERS*	*Mumbai*	*Builders/Developers*
63	*KAVYA*	*Mumbai*	*Builders/Developers*
64	*GURUNANAK HOSPITAL*	*Mumbai*	*End-users*
65	*SHOPPERS STOP*	*Mumbai*	*End-users*
66	*KOHINOOR HOSPITAL*	*Mumbai*	*End-users*
67	*HOTEL SUBA INTERNATIONAL*	*Mumbai*	*End-users*
68	*KUMARIA PRESIDENCY HOTEL*	*Mumbai*	*End-users*
69	*HOTEL SURESHATHE DESIGNERS*	*Mumbai*	*End-users*
70	*THE DESIGNERS*	*Kolkata*	*Consultants/ Architects*
71	*ANJAN GUPTA ARCHITECTS*	*Kolkata*	*Consultants/ Architects*
72	*ARCHIND CONSULTANTS*	*Kolkata*	*Consultants/ Architects*
73	*AVANI GROUP*	*Kolkata*	*Builders/Developers*
74	*HIGHLAND GROUP*	*Kolkata*	*Builders/Developers*
75	*SHRACHI GROUP*	*Kolkata*	*Builders/Developers*
76	*SOUTH CITY MALL*	*Kolkata*	*End-users*
77	*IRIS HEALTH SERVICES LTD.*	*Kolkata*	*End-users*
78	*HOTEL MAURYA INTERNATIONAL*	*Kolkata*	*End-users*
79	*JEAYAM SHELTERS PVT. LTD.*	*Chennai*	*Consultants/ Architects*
80	*MAYFAIR HOUSING PVT. LTD.*	*Chennai*	*Consultants/ Architects*
81	*ARCHITECT STUDIO7*	*Chennai*	*Consultants/ Architects*
82	*DREAMLAND DESIGN*	*Chennai*	*Consultants/ Architects*
83	*AHLUWALIA CONSTRUCTION INDIA LTD.*	*Chennai*	*Builders/Developers*
84	*JD CONSTRUCTIONS AND PROMOTERS PVT. LTD.*	*Chennai*	*Builders/Developers*
85	*RAYNU PROMOTERS*	*Chennai*	*Builders/Developers*
86	*UDHAYAM FOUNDATIONS*	*Chennai*	*Builders/Developers*
87	*HOTEL BENZZ PARK*	*Chennai*	*End-users*
88	*SELVARANGAM HOSPITAL*	*Chennai*	*End-users*
89	*KKR ENT HOSPITAL AND RESEARCH CENTRE*	*Chennai*	*End-users*
90	*BONE AND JOINT HOSPITAL*	*Chennai*	*End-users*

ANNEX 4: KEY MARKET PLAYERS

Holding Group	Brand	Importer/Distributor	Products
Blue Star	Blue Star	Blue Star	Minisplits, chillers, rooftops, indoor packaged, United States ducted splits
Ciat	Ciat	Ciat	Chillers
Citizen Industries	Citizen Industries	Citizen Industries	AHUs, fan coils
Daikin	Daikin, McQuay	Daikin, McQuay	Chillers, rooftops, indoor packaged, US ducted splits, VRFs, minisplits
Emicon	Emicon	Emicon	Chillers, AHUs
Fläkt Woods	Fläkt Woods	Fläkt Woods	AHUs
Fujitsu Group	Fujitsu	Fujitsu General	Minisplits, VRFs
Godrej	Godrej	Godrej	Room air conditioning
Hitachi Group	Hitachi	Hitachi Home and Life Solutions India	Minisplits, US ducted splits, indoor packaged, rooftops
Trane	Trane	Trane	Chillers, rooftops, indoor packaged, US ducted splits, minisplits
Johnson Controls	York	Johnson Controls York, India	Chillers, rooftops, indoor packaged, US ducted splits, minisplits
LG Group	LG	LG India	Minisplits, US ducted splits, rooftops
Melco	Mitsubishi Electric	Mitsubishi Electric India	Minisplits, VRFs
Onida	Onida	Onida	Room air conditioning
Panasonic	Panasonic	Panasonic India	Minisplits
Samsung	Samsung	Samsung, India	Minisplits
Sanyo	Sanyo	Sanyo, India	Minisplits, VRFs
Suvidha Engineers	Suvidha	Suvidha Engineers	AHUs, Fan coils
Thermax	Thermax	Thermax	Absorption chillers
Videocon Group	Videocon, Kelvinator, Electrolux, Kenstar, Whirlpool	Videocon Group	Room air conditioning
Voltas	Voltas	Voltas	Minisplits, chillers, rooftops, indoor packaged, US ducted splits
Zeco	Zeco	Zeco	AHUs, fan coils

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