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ENERGY EFFICIENCY SERVICES LIMITED
A JV of PSUs under the Ministry of Power

Chiller Energy Efficiency Program

Market Research and Feasibility Study

MAITREE
MARKET INTEGRATION AND TRANSFORMATION PROGRAM FOR ENERGY EFFICIENCY

eds
environmental design solutions

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John Smith-Sreeen

Director
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Growing energy use in buildings, especially for cooling, is a global concern. Our partnership with Energy Efficiency Services Limited (EESL) under the US-India bilateral Market Integration and Transformation for Energy Efficiency (MAITREE) program is focused on developing market-based solutions for energy efficiency in buildings and cooling.

USAID MAITREE has worked closely with EESL to accelerate adoption of building and cooling energy efficiency at scale, bolster markets, mobilize investments, and implement innovative business models. The first ever super-efficient air conditioner in India was launched by EESL, with technical assistance from MAITREE. This development has already catalyzed the market for higher efficiency products.

I am confident that the Chiller Energy Efficiency Program (CEEP), developed by EESL with support from USAID MAITREE, will have a similar impact, further increasing access to energy efficient technologies to a large number of energy intensive buildings. The objective of CEEP is to accelerate the replacement of old chillers with highly energy efficient chillers in India. In addition to the market transformation benefits, the project will lead to a significant direct reduction in greenhouse gas emissions.

I congratulate EESL for this initiative and pushing the envelope in this challenging sector towards greater efficiency. I also acknowledge the technical expertise, implementation experience, and market insights brought by our implementing partner Environmental Design Solutions [EDS]. I am certain that CEEP will contribute to realizing India's vision for Net Zero Emissions.

John Smith-Sreen

John Smith-Sreen

Arun Kumar Mishra

Chief Executive Officer
Energy Efficiency Services Limited

Energy Efficiency Services Limited (EESL) has always been the flag bearer in implementing energy efficient technologies at the end-user level, transforming the market with effective business instruments to support the cause of Government of India under National Mission for Enhanced Energy Efficiency (NMEEE) of the National Action Plan for Climate Change (NAPCC). NMEEE primarily focused on the energy efficiency enhancement of large energy intensive sectors by enabling accelerated adoption of low carbon technologies, appliances and equipment through market transformation strategies. EESL has been actively transforming the market through various programs by replacing incandescent and halogen bulbs with LED bulbs in residential and municipal bodies. It has resulted in estimated energy savings of 48.30 billion kWh, GHG emission reduction of 39 million tons of CO_2e per year with avoided peak demand of 9,768 MW.
Recently, NMEEE was revised and termed as ROSHANEE (Roadmap of Sustainable and Holistic Approach to National Energy Efficiency). ROSHANEE is an enhancement and consolidation of NMEEE activities implemented by Bureau of Energy Efficiency and climate mitigation attributes aligning with the NDC goals.

One of the major contributors to GHG emissions is the rapidly increasing cooling sector in India. The need of the hour is to improve energy efficiency and use of environment friendly refrigerants, as highlighted and recommended in the India Cooling Action Plan (ICAP). EESL has risen to address the growing cooling demand and resulting emissions by replacing the existing Air-Conditioners with 5 Star ACs in residential and commercial sector where demand for split and windows AC exist. Now, EESL aims to induce energy efficiency and avert GHG emissions in centralized air-conditioning system. The market potential for replacement of Chillers is 4.43 million TR in a decade's time. It is anticipated that the market for the central cooling system contributes to 26% of the total sales, with an annual growth rate of 8 - 10%. By Chiller Energy Efficiency Programme (CEEP), EESL targets to lower the cooling energy intensity in centralised air-conditioned buildings by just not focusing on the equipment replacement but with the intention of increasing the overall efficiency of the plant room. CEEP will also increase the demand for energy efficient chillers in the market and drive the industry to adopt environmentally friendly refrigerants. CEEP will be an enabler to overcome technological and financial barriers that may come.

The present study on the market on chiller replacement potential will not be limited to the usage of EESL but will cater to the policy makers & academia towards the promotion of energy efficient chillers. The replacement market of chillers would provide opportunities for the active involvement of ESCOs to implement energy efficient reforms, thereby, fulfilling the overarching goal of EESL of leveraging the growth of other private and smaller ESCOs. The study was jointly developed with USAID to improve the energy efficiency improvements in the central cooling systems.

Arun Kumar Mishra

S. P. Garnaik

Executive Director
Energy Efficiency Services Limited

Energy Efficiency Services Limited (EESL) is dedicated towards implementing innovative financial and technological solutions for market transformation in energy efficiency and believes in the ideology of exploring the energy saving potential of energy guzzling sectors. The demand for energy in the building sector has been on the rise and EESL has implemented schemes pertaining to improvement of energy performance of the building, by deploying energy efficient appliances and equipment. More specifically, Building Energy Efficiency Program (BEEP) and Super-efficient Air Conditioners (SEAC) Program focused on replacing air conditioners, lights and fans with efficient counterparts to improve the energy efficiency in the building sector.

EESL's SEAC program was successful in view of higher efficiency through technology upgradation and provides a larger opportunity for scaling-up. While the SEAC program shall continue to be intervened in various consumer categories, the Chiller Energy Efficiency Program (CEEP) aims to cater to the rapidly growing cooling demand of the centralised systems in the sector. The programme is designed to benefit end users so that CEEP is adopted in the market and the momentum to replace inefficient chillers quicky gains pace.

A stakeholder workshop on the chiller replacement program was held on 10th August 2019, the positive feedback from the stakeholders led to the formation of the Chiller replacement technical committee leading to the development of this market assessment report and the conceptualizing the CEEP as such.

This report on market research and feasibility establishes the opportunity to tap the chiller energy efficiency market and avert the carbon emissions due to low specific energy consumption. The report has estimated that around 4.3 million TR of chiller stock would be superannuated in the decade till 2030. Further, it has identified that replacement demand is most likely to be dominated by chillers between 150 TR to 500 TR with demand concentration for centrifugal and screw chillers.

Going forward, after the launch of CEEP, pilot projects with public and private sectors shall be explored to expedite the implementation of the scheme. EESL is grateful to USAID, under the Market Transformation and Integration for Energy Efficiency (MAITREE) program for being instrumental in developing the CEEP.

S. P. Garnaik

Apurva Chaturvedi

Senior Clean Energy Specialist
USAID

EESL and USAID are striving to create an environment that enables innovation and brings forward creative methods to counter climate change through energy efficiency. The ever-increasing demand for space cooling is an opportunity to transform the market for centrally air-conditioned buildings and enhance energy efficiency. Tapping such opportunities will play a pivotal role in lowering the energy intensity of existing buildings and help in achieving the intended nationally determined targets to reduce carbon emissions.

To address the growing energy demand in the building sector, an innovative retrofit program for replacing inefficient HVAC systems in buildings has been developed within the USAID MAITREE program. The Chiller Energy Efficiency Program (CEEP) focuses on consumer-oriented energy efficient business solutions to accelerate adoption of energy-efficient equipment - benefitting consumers, manufacturers, and the larger community.

Termed as the first fuel, “energy efficiency” is the most effective way to move towards securing a green economy. USAID partnership with EESL has been prolific in fostering transformative schemes to meet the large-scale demand for efficient technologies, averting carbon emissions in the process. USAID takes pride in its partnership with EESL and firmly believes that CEEP will improve the performance criteria of HVAC equipment market in India.

Apurva Chaturvedi

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ABBREVIATIONS

BEE	Bureau of Energy Efficiency
CFC	Chlorofluorocarbons
COP	Coefficient of Performance
EESL	Energy Efficiency Services Limited
ESCO	Energy Service Company
HCFC	Hydrochlorofluorocarbons
HVAC	Heating, Ventilation, and Air-conditioning
ICAP	India Cooling Action Plan
IPLV	Integrated Part Load Value
OEM	Original Equipment Manufacturer
PRSF	Partial Risk Sharing Facility
TR	Tonnes of Refrigeration

EESL Technical Committee

Name		Designation & Organisation
Mr S P Garnaik	Chair	Executive Director- Tech, EESL
Dr Anant Shukla	Convener	Additional General Manager - Tech, EESL
Mr Girja Shankar	Member	General Manager - Tech, EESL
Mr Tanmay Tathagat	Coordinator	Managing Director, Environmental Design Solutions
Mr Mohit Gupta	Member	Senior Manager - Tech, EESL
Mr Sameer Pandita	Member	Director, S&L, Bureau of Energy Efficiency
Mr Harish Sharma	Member	Trane
Mr Siddharth Salwan	Member	Trane
Mr A K Asthana	Member	GIZ
Mr Richie Mittal	Member	ISHRAE
Mr Bimal Tandon	Member	Carrier Midea India
Mr Hemant Kumar Singh	Member	Voltas
Mr P K Mukherji	Member	CLASP

Mr Shailash Nigam	Member	Daikin
Mr Bagath Singh	Member	Bluestar Limited
Mr Sandeep Kohli	Member	Johnson controls - Hitachi India
Mr Tosh Agrawal	Member	Assistant Manager - Tech, EESL

Market Research Participants

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Richie Mittal, Overdrive Engineering Pvt. Ltd.	Sandeep Dutta, Advance India Projects Limited (AIPL)
Sandeep Kohli, Johnson Controls India	Shailesh Nigam, DAIKIN Airconditioning Pvt. Ltd.
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Vikas Rawat, Nirlon Limited	

SUMMARY

The report on market research and feasibility establishes the opportunity to tap the chiller energy efficiency market and avert the carbon emissions due to energy intensity of chillers and chiller plant rooms in buildings. 4.3 million TR of chiller stock will be superannuated in the decade that has just started (until 2030). By value, it is equivalent to INR 11,000 crore or 1,600 million USD.

By size, replacement demand is most likely to be dominated by chillers between 150 TR to 500 TR with demand concentration for centrifugal and screw chillers.

The market study for CEEP focussed on understanding potential demand for replacement of chillers in terms of installed cooling capacity and monetary value, as well as consumer preferences and technology trends. The findings show that there is significant latent demand for chiller plant retrofit, accompanied by a competitive market. Details of the findings are covered below.

Market Demand

This study established both the market opportunity and business case for replacing chillers and central cooling plants.

0.75 million TR was ready for replacement in 2020 and 1.06 million TR is immediately ready for 2021. This represents a 377 million USD or 2,641 crore INR business opportunity for the year 2021 alone. 4.3 million TR of chiller stock will be superannuated in the decade that has just started i.e., till 2030. By value, it is equivalent to INR 11,000 crore or 1,600 million USD.

During the same period, chillers equalling about 11 million TR are expected to be sold in the market. Replacement will thus account for about 40% of the sales in the next decade.

Chillers within cooling capacity range of 150 TR to 300 TR will dominate demand. Screw and centrifugal chillers will constitute about 86% of estimated demand.

Average efficiency for energy efficient chillers in international markets for this size and technology type is about 6.7 (COP). Corresponding market benchmark for India is 6.3.

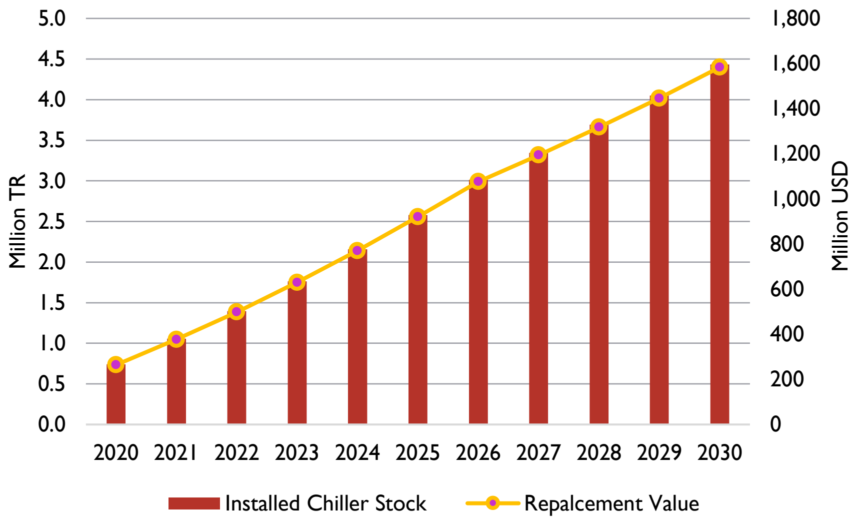

Figure 1 Replacement Market Size and Value Projections till 2030

Table 1 Demand Distribution of chillers by technology type

Short Term (1-3 Years)	Medium Term (1-5 Years)	Long Term (10 Years)
1.4 million TR	2.16 million TR	4.43 million TR
INR 1,850 crores (500 million USD)	INR 5,400 crores (770 million USD)	INR 11,000 crores (1,585 million USD)

Demand Distribution

Screw and centrifugal chillers will constitute about 86% of estimated demand. Small chillers of less than 55 TR, primarily deployed in process chilling, will also be a significant share of replacement market. By region, northern and southern India will offer a slightly bigger market for replacement.

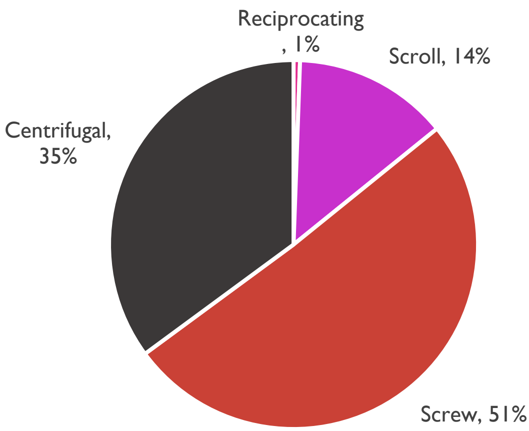

Figure 2 Screw and centrifugal chillers will form bulk of the replacement business both in short and long term

By size, replacement demand is most likely to be dominated by chillers between 150 TR to 500 TR. Analysis of HVAC industry sales trend from 2004 to 2030 indicate that, in year-on-year sales, chillers in this range have and will continue to have highest requirement.

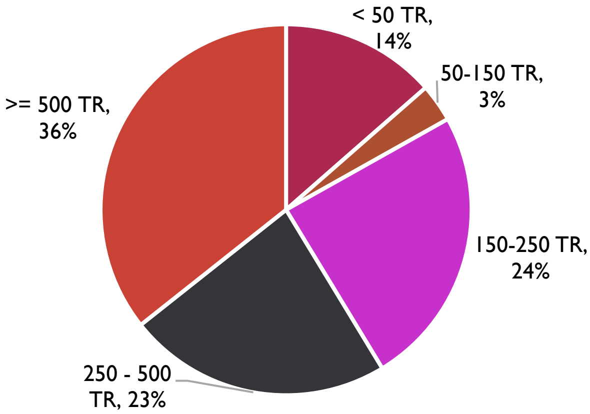

Figure 3 Replacement demand will be dominated by chillers in capacity range 150-500 TR. Average efficiency now available for models in this range is greater than 6.2.

Target Consumers

Government, public sector and hospitality and health care should be the target market segment to build a market for chiller replacement. Organizational commitments to environmental sustainability of the former and appreciation of efficiency driven monetary gains of the latter make them ideal customers.

Opportunity for Transformation

Chiller Energy Efficiency Program can save 2,750 GWh (2.8 million MWh) and avert 2.3 million tonnes of CO2e of GHG emissions. Projections are based on assumptions that CEEP will scale up at a moderate pace.

In parallel, CEEP can push the average central cooling plant efficiency. Chiller plant efficiencies in conventional buildings average at over 1.0 ikW/TR. Plant efficiency in green buildings range between 0.7-1.0 ikW/TR. The program can set technical specifications that ensure chillers and plants upgraded through CEEP remain in the highest percentile of high-performance central cooling plants and in time this range becomes the market norm.

R-134a and R-410a most commonly used refrigerants in chillers. Advanced refrigerants with GWP of less than 500 are only offered in high end, costly range of chillers. CEEP can be used to promote switch to low GWP refrigerants.

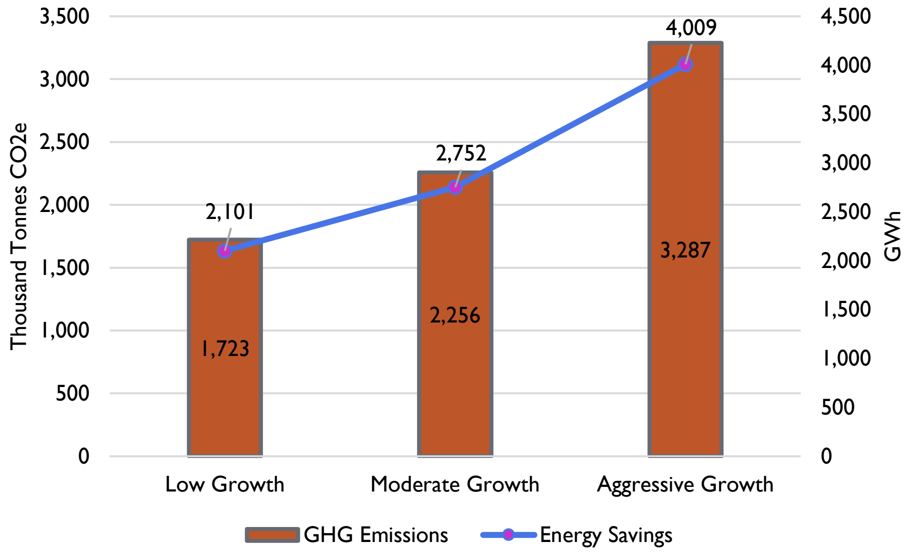

Figure 4 Cumulative GHG emissions abatement and energy saving potential of CEEP by 2030

Limited ESCO capacity: ESCOs have been unable to encourage chiller plant upgrades significantly. About 20 ESCOs retrofit chillers or chiller plants in India, the scope varying from complete plant retrofit to one-to-one replacement of pumps, motors etc. However, not all offer both financing and project execution to clients. ESCOs are technically equipped to undertake retrofits but not financially. Vendor ESCOs mainly design and execute projects whereas investment for equipment replacement is managed by owner. Business opportunities are thus restricted; since ESCOs are unable to assist chiller owners in overcoming one of the biggest barriers, that of fund constraints, the former simply advance replacement despite expertise available from ESCOs to advice replacement. CEEP can fill in this gap.

Challenges

Challenges deduced through this study include expectation of aggressive paybacks of less than 2- years amongst consumers. Extensive technical expertise is also required to undertake chiller plant retrofits. Some resistance from private sector customers on this account should be expected in initial stages of program implementation. Market is also extremely competitive, with manufacturers offering drastic margins during negotiations. Quotes received in a public tender are negotiable only to a certain extent. Implications of these challenges and strategy to circumvent are discussed in detail in the CEEP Business Model.

Market Characteristics: Technology and Efficiency Trends

Technology Costs

Upfront costs for installing or retrofitting a complete central cooling system with plant efficiency between .7 ikW/TR to .85 ikW/TR varies between INR 90,000 per TR to INR 1,20,000 per TR. Upfront unit cost of water-cooled systems is higher than that of air-cooled chillers. High side equipment constitutes about 40% of a central cooling system. Chillers can cost anywhere between 23-32% in water cooled systems.

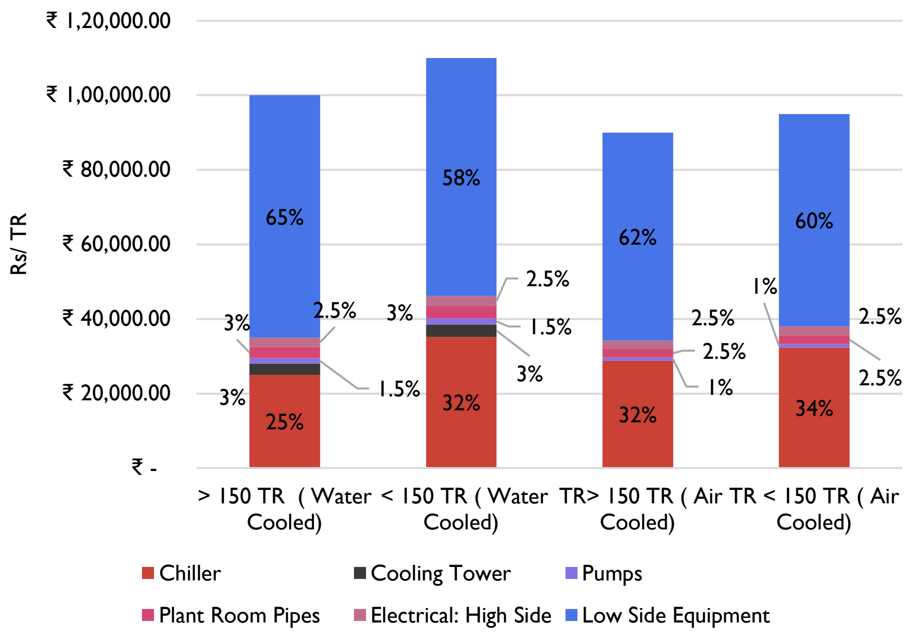

Figure 5 Central Cooling System Upfront Cost

Chillers between 150 TR to 300 TR are the most sold across any technology type or heat rejection method. Cost varied from per TR INR 20,000/TR to INR 25,000/ TR. Unit costs start reducing with cooling capacity from this point. Unit costs of super-efficient chillers in capacity range of 450 TR plus can be as low as INR 15,000/ TR to INR 22,000/TR. In the smaller capacities, unit costs are higher. Chillers with COP of 6.2- 6.3 are the most sold amongst consumers seeking energy efficient equipment. Maximum COP can reach upto 6.7. Unit cost differential however discourages most but those following extremely stringent efficiency goals to purchase chillers of this efficiency.

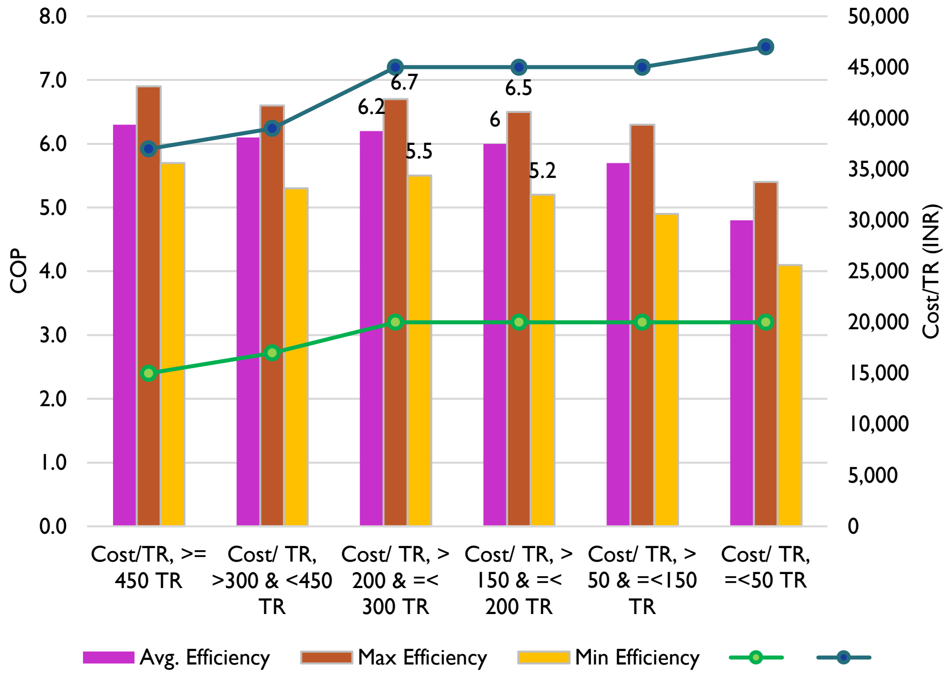

Figure 6 Higher capacity chillers, typically screw and magnetic bearing centrifugal chillers, also have higher efficiency ranges and lower prices per unit of cooling capacity.

Consumer Profile

1. Chiller plant owners prefer a payback of less than 2-3 years on investment in energy efficient upgrades.
2. Decision to replace chillers or other central plant components is decided by serviceability, performance, operation, and frequency of breakdowns. Presently, energy performance is not the sole criteria for replacement.
3. Chiller replacement is not a high priority/ critical action for clients. Multiple competing purchases that strengthen core functions of owners take precedence.
4. Consumers showed willingness to consider ESCO model for chiller plant upgrade, if it is accompanied by risk guarantee covers and attractive paybacks.
5. Chillers are typically replaced between 15-22 years. Manufacturer recommended replacement age is about 12-15 years considering that increase in efficiency between models manufactured in this timeframe is adequate for desired payback. Chillers more than 25 years old are also functioning but these are outliers of the existing population.

6. Pumps, cooling towers and other equipment in chiller plant is, on average, replaced within the lifecycles recommended by manufacturers. Increased expenditure on maintenance after this period encourages replacement.
7. HVAC system designers and chiller plant owners both agree that maintenance practices for continuous efficiency and overall environmental sustainability of plants is lacking.
8. Refrigerant is not a big priority in chiller purchase decision making because most manufacturers offer refrigerants within the same range of ozone depletion and global warming potential. Owners however welcome more environmentally sustainable refrigerants.

CEEP Scaleup Strategy

Super-ESCO Business Model

Fund shortage and competing expenditure delay chiller plant upgrades. ESCO model will be a key to turning around owners delaying replacement at manufacturer recommended end of life period. Partnership with ESCOs under a Super-ESCO framework to bring in business and implement Chiller Energy Efficiency Program will increase potential for demand aggregation, streamlined project execution and reduced program management costs.

Consumer sensitization to augment business opportunities

This study identified both low and high-cost technologies that enhance chiller plant efficiency but have not gained foothold in the market. Prime examples are condenser water treatment technologies that conserve water, prevent ground water pollution and increase chiller plant life. A consumer sensitization campaign on the side-lines of the chiller program to encourage consumer confidence in such technologies and, in general, the benefits of efficient chiller plant equipment will boost business opportunities.

Regular engagement with owners, ESCOs and technology providers

Marketing and awareness will be important for creating demand for chiller replacement. Engaging through industry associations like CREDAI, NAREDCO, RAMA, ISHRAE, First Construction Council will boost the program's profile and business opportunities. Platforms provided by industry associations are a more direct channel to inform potential consumers about program offerings and benefits while also encouraging participation from technology providers.

Demonstration projects

Pilots will confirm the commercial and technical viability of large-scale chiller replacement through ESCO business model.

1

Context and Approach

1. Context and Approach

India faces a conundrum in space cooling.

Its per capita cooling index of 62 kWh is one of the lowest and well below the global average of 272 kWh (IEA, 2018). This relatively low index has implications for health and productivity in a primarily warm climate. India is also expected to be most affected by heat stress caused because of global warming. Cooling degree days in India are expected to rise by 13% by 2050 due to global warming. Indian metropolises already count amongst the warmest cities with average cooling degree days above 3000. With a 1.5 °C rise in temperature, the country will lose 5.8% of the current working hours by 2030.[1] Cooling is also a sustainable development goal that cannot be ignored. Access to cooling therefore is imperative.

However, meeting the growing energy demand from space cooling is untenable in the long term. Total nationwide cooling demand is expected to increase eight-fold by 2038. Building sector will see an eleven-fold increase, the largest for any sector. Projected cooling demand, in combination with other energy end-uses, is expected to result in total energy use of 1,560 TWh/yr in buildings. About 65% will be expended in space cooling. 21% of the energy demand will be from commercial cooling applications. GHG emissions from such high energy use in space cooling will setback health benefits from cooling.

Installed stock of chillers is adding up since construction boom started in 2000. Chillers will consume 8% of total cooling energy demand. National strategies for controlling cooling demand identify central cooling systems as a focal area for reining in energy use due to space cooling. Regulations to regulate timely replacement with energy efficient models are non-existent. Chillers installed as recently as 2010 in India may thus be lagging in efficiency even though they have just crossed half-age mark.

A market-centric initiative to stimulate timely retirement of inefficient chillers and ancillary central plant systems can substitute inadequate policy drivers. Cooperating with market to build demand for replacement also holds potential for pushing deep changes in chiller markets towards energy efficiency.

Market conditions need to be understood and defined to design an implementable program.

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[1] Working on a warmer planet: The impact of heat stress on labour productivity and decent work. International Labour Organization, 2019.

The chiller market feasibility study was conducted to assess market demand for replacement of energy efficient chillers in commercial, industrial and residential establishments. It strives to answer three crucial questions to establish feasibility: *national chiller replacement demand in the short and long term, market characteristics and impact of proposed large-scale chiller replacement program*.

Chiller volume and distribution by age, type, regional location was studied to analyse demand in terms of cooling capacity ready to be replaced and investment required for enabling the proposed stock churn over. Most sold technologies and average efficiency of chillers were ascertained.

To understand market conditions, the study further profiles consumer's decision-making factors, preferences for technologies and services, and perceptions about ESCO to design and deliver chiller plant energy efficiency retrofits. It also delves into the state of ESCOs to gauge their capacity to upgrade chiller plants.

A cross section of stakeholders including manufacturers, owners or consumers, system designers, industry associations, contractors and ESCOs were interviewed to analyse latent demand for replacement and characteristics of replacement market. Interviews were structured around questionnaires focused on assessing replacement market size by cooling capacity (TR), distribution by technology, region, ownership, and financing models. Online surveys were also used to understand owner priorities in chiller plant replacement projects.

Environmental and economic impact of CEEP was modelled to understand program returns and value. The study finally evaluates and presents design approach for a large-scale chiller energy efficiency program attuned to market dynamics and independent of regulatory support.

1.1. Research Methodology

Bulk of the information and findings presented in this study is a result of interviews with industry stakeholders and data modelling conducted by MAITREE team.

Primary Research

HVAC system designers, manufacturers, ESCOs, HVAC contractors and end users from government, public and private sector were interviewed over a two-month period to gather intelligence on market size, technology trends, consumer behaviour, future of central cooling technologies and market opportunity for replacement. An online survey was also designed and shared with end users to gather data on consumer preferences.

Secondary Research

Data collected through screening of information in secondary sources supplements findings from interactions with industry experts. Sources for secondary research included online databases, articles published by technology experts in magazines and journals, market intelligence reports and product brochures. Environmental Design Solutions, implementing partner for MAITREE and authors of this study, also used data from their previous market studies on chillers and leveraged experience from designing high performance chiller plants in more than 250 green buildings in India and abroad.

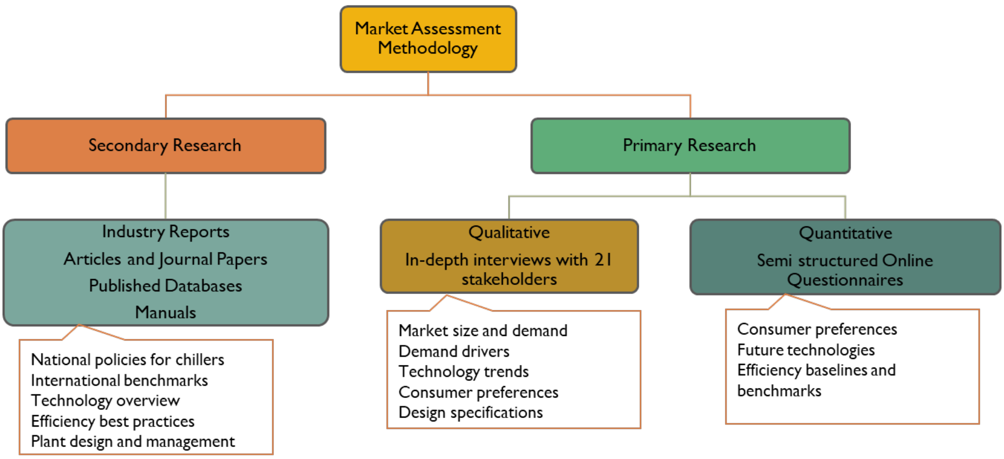

Figure 7 Methodology for Market Research

Forecasting

For the purposes of calculating market size, 2005 was assumed to be the base year to calculate capacity, in TR, of surviving stock ready for replacement. Volume and characteristics of installed population presently were estimated after calculating historical sales trend from 2005 onwards. Replacement market value was estimated till 2050. Future demand was derived by projecting market growth rates for the next two decades. Only electric chillers were considered for this study.

2

Chiller Energy Efficiency Program for India

Space cooling demand in India will increase eightfold by 2038, to reach about 1100 million TR. Chillers will constitute atleast 11% of the future national cooling demand and 8 % of energy use in buildings.

Energy efficiency in commercial buildings in India largely rests on low energy chiller plants. Commercial cooling and heating will account for 21% of total building energy use by 2038.

Energy Conservation Building Code, and Chiller Standard and Labelling Program are the primary drivers for chiller efficiency in India; but both are voluntary regulations. Additional measures are much needed to simulate supply and demand for energy efficient chillers and ensure timely upgrading of existing stock with market best technologies.

2. Chiller Energy Efficiency Program for India

Super energy efficient chillers, with a Coefficient of Performance of 6.3 and above, remain niche products. Muted demand discourages manufacturers from investing more in research and development of advanced technologies. Subsequent sections of this report also highlight a positive aspect of central cooling systems market: it is set to grow fast as cooling demand climbs from higher disposable incomes, increasing built floor space and rising global temperatures. Our study finds that central cooling systems represent 26% of HVAC market by sales; growth rates estimates are between 8% to 10%. Central HVAC system market is valued at 1,150 million USD as of 2018. Chillers are the highest value segment in central HVAC systems market, accounting for 35% of overall market value.

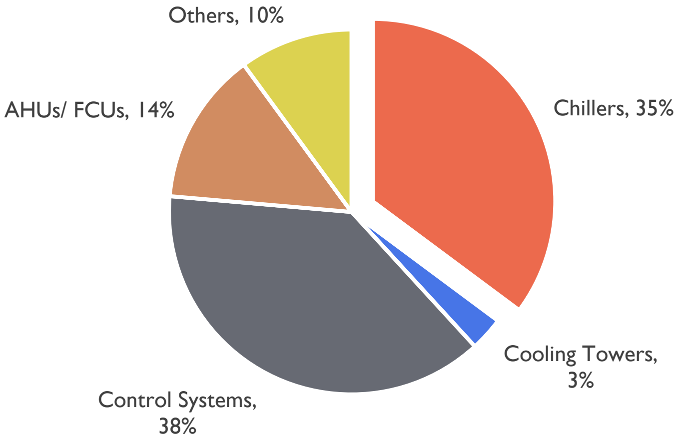

Figure 8: 1,150 Million USD Central System Market Composition

Hypothetically, a large-scale energy efficient chiller deployment program can ride on this growth momentum to accelerate market penetration of energy efficient chillers by creating demand and supply side pulls.

The program can also reinforce various national efficiency standards. Chillers and few other chillers plant technologies have entered the ambit of national energy efficiency policies recently. Most energy efficiency norms are in voluntary compliance phase (Energy Conservation Building Code, BEE Standard and Labelling Program), blunting their capacity to do a substantive course correction of markets towards energy efficiency. CEEP has the potential to improve the efficiency of existing chiller stock and push up baseline efficiencies of chillers in the market. Technology deployment programs such as CEEP also incentivize manufacturers to invest in research, development and deployment of more efficient technologies by creating a demand side pull.

Chiller Energy Efficiency Program should also fulfil interlinked national goals of meeting Intended Nationally Determined Contributions, sustainable cooling for all as recommended in India Cooling Action Plan and fostering a mature market for ESCOs.

Meeting India's Intended Nationally Determined Contributions of reducing Green House Gas (GHG) emissions to 33-35% of 2005 levels by 2030 depends on controlling emissions from space cooling. 30% to 40% of energy consumption in buildings is due to cooling systems.

India Cooling Action Plan stresses access to sustainable cooling for all and prescribes public or large-scale procurement of central cooling systems to achieve targets. The Action Plan estimates that installed capacity of chillers will increase by 7 times from 5.7 million TR to 38 million TR by 2037. Energy use will increase to 66 TWh. With energy efficiency interventions, there is a 30-32% energy saving potential. CEEP can support realization of this savings target by increasing market penetration of energy efficiency chillers. Other high priority interventions recommended by ICAP that can be achieved through CEEP are:

1. Thermal comfort for all, lower energy or electricity costs to users, higher user productivity and improved health as socio economic benefits of sustainable space cooling.
2. Mandatory public procurement guidelines for highest-efficiency ACs, fans, chillers, etc. and recommendations for low-GWP options where available
3. Programs to drive retrofitting of existing buildings to reduce cooling requirement and energy consumption.
4. Development and production of low-GWP alternative refrigerants to replace the widely used high–GWP HFCs.

Chiller replacement on large scale is an ideal vehicle for ESCO business model because of scale of expertise, services and financing required. ESCO market in India lags from low consumer confidence and biases, high investment recovery risks and financial crunch. CEEP is an opportunity to invest more capital in energy efficiency markets through ESCOs and eventually build a strong ESCO market.

3

Cooling Energy Demand: Chillers

Space cooling demand in India will increase eightfold by 2038, to reach about 1100 million TR. Chillers will constitute at least 11% of the future national cooling demand and 8 % of energy use in buildings.

Energy efficiency in commercial buildings in India largely rests on low energy chiller plants. Commercial cooling and heating will account for 21% of total building energy use by 2038.

Energy Conservation Building Code, and Chiller Standard and Labelling Program are the primary drivers for chiller efficiency in India; but both are voluntary regulations. Additional measures are much needed to simulate supply and demand for energy efficient chillers and ensure timely upgrading of existing stock with market best technologies.

3. Cooling Energy Demand: Chillers

Space cooling will increase its already large share of national cooling demand in India. Total nationwide cooling demand is expected to increase, in terms of Tonnage of Refrigeration (TR), 8 times by 2038 from 2017 baseline. In buildings the corresponding growth will be 11 times over the same time span, the fastest growth for any sector. 74% of total cooling demand will result from space cooling (India Cooling Action Plan 2019). Other studies reinforce estimates about an equally aggressive growth in cooling demand across all sectors and increased energy use from delivering this demand.

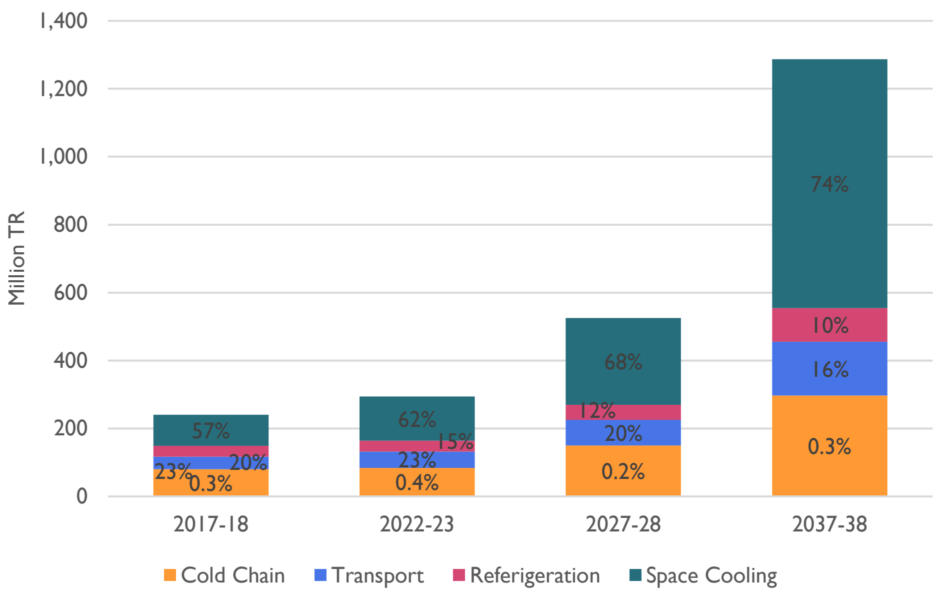

Figure 9 74% of national cooling demand of India will result from space cooling by 2038. Source: India Cooling Action Plan

In absence of intelligent and well implemented mechanisms for energy efficiency, the projected cooling demand, in combination with other energy end uses, is expected to result in total energy use of 1,560 TWh/yr in buildings. About 65%, 585 TWh/yr, will be expended in space cooling. 21% of the energy demand will be from commercial cooling applications (Figure 10). Chillers will alone consume 8% of this.

Demand for space cooling will be exacerbated because of warmer climate, increased commercial floor space, urbanization related heat stress, continuing sales of inefficient cooling technologies and increased purchasing power of end users.

Cooling degree days in India are expected to rise by 13% by 2050 due to global warming (Agency, The Future of Cooling: Opportunities for Energy Efficient Airconditioning 2018). Its metropolises already count amongst the warmest cities with average cooling degree days above 3000.

Commercial floor is expected to multiply 5 times to reach 1932 million square meters by 2030 (HVAC Market Assessment and Transformation Approach for India 2014). Centrally air-conditioned spaces are now becoming the new normal in commercial buildings. Architecture of commercial buildings is defined by thermally inefficient glass facades and little to no natural ventilation. Dependence on mechanical cooling is thus increasing.

India is experiencing the highest rates of urbanization globally. Urban areas experience high local temperatures in concentrated areas, or the heat island effect. This aggravates requirement for supplemental cooling to ensure occupant comfort in buildings.

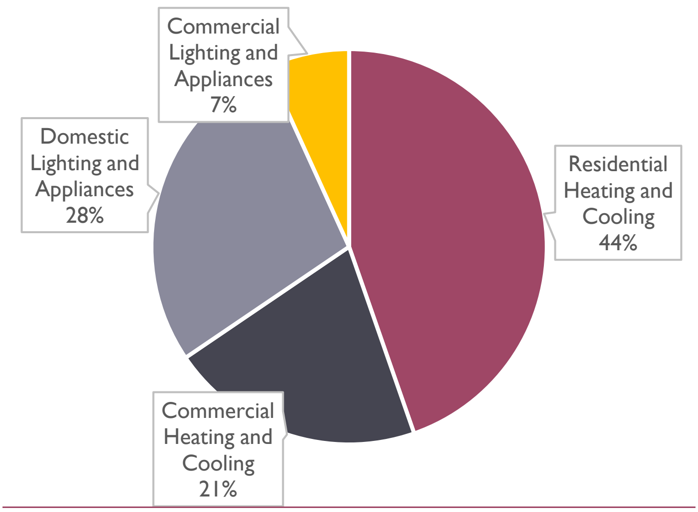

Figure 10 Building Sector Annual Energy Demand Breakup (TWh/yr) by 2037. Source: NITI Aayog India Energy Security Scenarios 2037

Low to moderate penetration of energy efficient appliances and limited compliance with energy regulations will also be equally strong drivers. Majority of national level regulations for controlling efficiency of cooling devices are voluntary. Updates to match international efficiency benchmarks or best in domestic markets are infrequent. The highest efficiency residential air conditioner in Indian market is half as energy efficient as the global best.

1.2. Drivers for Chiller Efficiency

Building energy codes and a labelling program are the main instruments of controlling and directing efficiency of chillers and other central cooling equipment. Compliance with both is voluntary unless state administrations decide otherwise.

1.2.1. Chiller Standard and Labelling program

Bureau of Energy Efficiency launched the Chiller Standard and Labelling program in 2018 for chillers running on vapor compression cycle. Chillers are rated on a 1-to-5-star rating defined in terms of Indian Seasonal Energy Efficiency Ratio and full load Coefficient of Performance (COP). Air and water cooled have different efficiency bands corresponding to their cooling capacity. Few manufacturers have started declaring ISEER values of their products. Most chiller manufacturers have not started declaring ISEER values despite launch of the Chiller Standard and Labelling scheme in 2018. The Scheme's voluntary status is a reason for the relatively slow rate of testing and declaration of ISEER values.

Table 2 Star Rating Plan for Water and Air-cooled Chillers in India

	Water Cooled Chillers					**Air Cooled Chillers***				
KW of cooling	ISEER									
	1 Star	2 Star	3 Star	4 Star	5 Star	1 Star	2 Star	3 Star	4 Star	5 Star
<260 (74 TR)	4.8	5.2	5.6	6.1	6.6	3	3.3	3.6	4	4.4
>=260 (74TR) & <530 kW (151 TR)	5	5.6	6.2	6.8	7.4	3.1	3.5	3.9	4.3	4.7
>= 530 (151 TR) & < 1050 kW (299 TR)	5.5	6.1	6.7	7.4	8.2					
>= 1050 (299 TR) & <1580 kW (449 TR)	5.8	6.5	7.2	7.9	8.7					
>=1580 kW (449 TR)	6	6.7	7.4	8.2	9					

* ISEER values for all air-cooled chiller of capacity >= 260 kW are same.

1.2.2. Energy Conservation Building Code

Energy Conservation Building Code was updated in 2017. Minimum efficiency for chillers, cooling towers, and pumps, and controls functionalities are defined in the code. Total central cooling system efficiency requirements are also recommended. This approach allows designers freedom to design energy efficient central cooling systems within site specific constraints. ECBC 2017 defers to the chiller S&L program in case the latter is updated to higher efficiency values.

Table 3 Efficiencies Proposed by Energy Conservation Building Code 2017

System		ECBC	ECBC+	Super ECBC
	Size	**COP**		
Chiller (By size)	**<260 kWr**	4.7	5.2	5.8
	>260 & <530kWr	4.9	5.8	6.0
	>530 & <1050kWr	5.4	5.8	6.3
	>1050 & <1580kWr	5.8	6.2	6.5
	>1580 kWr	6.3	6.5	6.7
		EER		
Pump power	**Chilled water pump**	18.2 W/kWr (with VFD)	16.9 W/kWr (with VFD)	14.9 W/kWr (with VFD)
	Condenser water pump	17.7 W/kWr	16.5 W/kWr	14.6 W/kWr
	Pump efficiency	70%	75%	85%
		Mechanical efficiency		
Fan power		60% (IE 2 type)	65% (IE 3 type)	70% (IE 4 type)

1.2.3. India Cooling Action Plan

The Action Plan estimates that installed capacity of chillers will increase by 7 times from 5.7 million TR to 38 million TR by 2038. With energy efficiency interventions, there is a 30-32% energy saving potential. High priority interventions recommended by ICAP include:

1. Mandatory public procurement guidelines for highest-efficiency chillers and recommendations for low-GWP options where available
2. Programs to drive retrofitting of existing buildings to reduce cooling requirement and energy consumption
3. Development and production of low-GWP alternative refrigerants to replace the widely used high–GWP HFCs

Efficient technologies and practices highlighted in India Cooling Action Plan include improvements in chiller efficiency with focus on part load efficiencies, lowering building cooling loads through thermally effective design and construction, improved operations and maintenance (O&M) through the use of data (building management systems) and more specialised HVAC staff, and, more efficient auxiliary systems (pumps, fans, pipe insulation, cooling towers, etc.) (India Cooling Action Plan 2019).

4

Chiller Efficiency Benchmarks

US and most other countries follow ASHRAE 90.1 and test standard AHRI 550/ 590.

European Union regulations for comfort and process chillers lead rest of regulations for energy efficient chillers. EU regulations evaluate and label environmental impact across the lifecycle. Refrigerants and other emissions are thus factored in evaluating environmental performance.

4. Chiller Efficiency Benchmarks

Most developed economies have instituted minimum energy performance standards (MEPS) to manage and incrementally improve efficiencies of comfort and process chillers entering retail markets. Other have integrated efficiency requirements in the building energy codes. Efficiency thresholds for MEPS from United States, European Union, Australia/ New Zealand, Canada and China are summarized in Table 4 to

MEPS from different countries is not comparable as metrics for efficiency are different. Chiller efficiency is referred to in terms of coefficient of performance (COP) at full load or part load, Integrated Part Load Value (IPLV), Non-standard Part Load Value (NPLV), Seasonal Energy Efficiency Ratio (SEER). More recently, EU has defined Seasonal Space Cooling Energy Efficiency and Seasonal Coefficient of Performance (SCOP) for EcoDesign regulations. Thresholds for rating under the Indian chiller standard and labelling scheme managed by BEE are defined in Indian Seasonal Energy Efficiency Ratio (ISEER).

California and United States

MEPS and test standards for chillers are defined in ASHRAE 90.1 and then integrated in state building energy codes for implementation. States with stringent energy efficiency milestones have adopted ASHRAE 90.1 2013, most recent version with revised performance levels. Others are still following previous versions.

Table 4 ASHRAE 90.1 2013 Chiller Minimum Energy Performance Standards

Vapor Compression Chillers	Capacity (kWr)	Minimum COP	Minimum IPLV
Air cooled, with Condenser	All Capacities	2.80	3.05
Air cooled, without Condenser	All Capacities	3.10	3.45
Water cooled, Reciprocating	All Capacities	4.20	5.05
Water Cooled (Rotary Screw and Scroll)	< 528	4.45	5.20
	>528 kW and < 1055	4.90	5.60
	1055 kW	5.50	6.15
Water Cooled, Centrifugal	< 528	5.00	5.25
	>528 kW and < 1055	5.55	5.90
	>1055 kW	6.10	6.40

Canada

Energy Efficiency Act of 1992 governs design and enforcement of minimum energy performance standards in Canada. MEPS or *Energy Efficiency Regulations* for chillers in buildings was introduced in 2004 and applies to Vapor compression chillers with cooling capacities less than 8,800 Kw (2,500 TR) with water condensers and less than 7,00 kW (200 TR) with air condensers, and absorption chillers of capacity less than 5,600 kW (1,600 TR). Energy efficiency is defined in terms of IPLV and full load COP. The Regulations were amended in 2016 to follow ASHRAE 90.1 2007. Chillers manufactured from January 2017 onwards are expected to follow ASHRAE 90.1 2013 values. Canada adheres to Chiller Test Standard CSA-C743-02 for determining performance rating chillers.

Australia

Chiller MEPS in Australia are framed under the National Appliance and Equipment Energy Efficiency Program. NCAEEEP follows the MEPS in Canada and USA as most of the chillers used in the country are imported from USA. Absorption chillers are exempt from the regulations. Higher efficiency levels have been also set in the Australian Standard to provide efficiency benchmark for chillers already over the minimum performance threshold. This is typically 15% more efficient than the corresponding minimum efficiency recommended value.

Table 5 International Minimum Energy Performance Standards for Water Cooled Chillers (Minimum Full Load COP)

	Reciprocating			Scroll			Screw		Centrifugal		
Capacity Range (kW)	**<500**	**500-1000**	**>1000**	**<500**	**500-1000**	**>1000**	**500-1000**	**>1000**	**<500**	**500-1000**	**>1000**
Australia and New Zealand	5	5.1/5.5	5.8/6.0	5.0	5.1/5.5	5.8/6.0	5.1/5.5	5.8/6.0	5.0	5.1/5.5	5.8/6.0
China	3.8	4.0	4.2	3.8	4.0	4.2	4.0	4.2	3.8	4.0	4.2

Table 6 International Minimum Energy Performance Standards for Air cooled Chillers (Minimum Full Load COP)

	Reciprocating		Scroll	Screw	Centrifugal
Capacity Range (kW)	**<400**	**>400**	**All ratings**	**All ratings**	**All ratings**
Australia & New Zealand	2.7	2.7	2.7	2.7	2.7
China	2.4/2.6	2.6	2.4/2.6	2.4/2.6	2.4/2.6

European Union

EU's EcoDesign and Energy Labelling Directives regulates efficiency of comfort chillers. Refrigerants are factored in the standard. Performance requirements of chillers are dependent on the global warming potential of refrigerant; GWP of 150 is the differentiating mark. Ecodesign is evaluates lifecycle energy and environmental performance of chillers. About 80% of chiller models in European markets are expected to be phased out to meet requirements framed in first phase of the directive.

5

Global Experience in Chiller Replacement

Chiller replacement programs in the past were initiated for meeting CFC phase out commitments in Kyoto and Montreal Protocols. Protracted project delivery processes, insufficient paybacks, inadequate knowledge, and confidence in proposed technologies resulted in moderately successful programs. CEEP must sidestep these issues for success.

5. Global Experience: Chiller Replacement Programs

Most chiller replacement programs implemented so far were guided by chlorofluorocarbon (CFC) refrigerant phase out under Kyoto and Montreal protocols. World Bank and United Nations, in partnership with governments, and public and private sector have financed or co-financed these programs. Multilateral Fund for the Implementation of the Montreal Protocol approved about 25 chiller replacement programs with a total funding of 19 million USD. Funds were allocated for investment in chiller replacement and for demonstration and technical assistance to create conducive conditions for large scale transition to low ODS refrigerants.

1.3. India

The World Bank led program entailed investment of 83.27 million USD, from three funding sources: Clean Development Mechanism, Multilateral Fund for the Implementation of the Montreal Protocol and Global Environment Facility. The program linked energy savings, air pollutions and GHG emissions abatement, ODS refrigerant phase out and carbon credit trading. Proponents could avail a subsidy on the upfront costs of chiller replacement and forego any benefits from generated Certified Emission Reduction certificates. Alternatively, they could forego upfront grants and benefit from revenues generated from trading of CERs.

With a target of replacing 370 CFC based chillers with non-CFC based chillers, 59 projects were registered, out of which 31 centrifugal CFC 11 chillers were replaced with HFC 134a screw chillers. Carbon trading component was stopped upon the termination of CDM midway through the program. Participation was low from public sector because of inability to avail of grants; Second option of availing CERs was more viable for public sector, but not feasible after CDM slowed down. Private sector participation was low because of complexities of financing mechanism proposed by World Bank (World Bank 2019).

1.4. Turkey

A performance based, multiyear, revolving fund mechanism was selected by World Bank and Government of Turkey to replace CFC chillers with HFC based centrifugal chillers. High upfront costs and commercial interest rates were found to major deterrents to chiller replacement or retrofit in a survey. 4 million USD was earmarked for the program, to be administered to shortlisted projects in a mix of grant and soft loan (zero interest rate) in the ratio of 25:75. Investment was recovered through 5 instalments in 3 years.

Program started in 2002 with two rounds of demonstration projects, totalling 18 replacement projects with equivalent capacity of 23 MW. The program then enlarged scope to annual budget of 1 million USD for supporting chiller replacements. By completion in 2008, 41 chillers had been replaced. Remaining balance in the revolving fund started with 4 million USD was 2.8 million USD.

A unique merit-based selection procedure was applied to identify projects. Owners or project proponent had to prove the cost effectiveness, and ozone depletion mitigation potential of the proposed replacement. Financial support required, chiller age and proposed chiller efficiency in terms of full load COP and NPLV determined eligibility for participation. Auxiliary central plant equipment was replaced along with chillers in many cases. Owners were charged 5% of the project costs to cover technical and financial monitoring costs. Technology Development Foundation of Turkey (TTGV), the main implementing agency, conducted pre and post replacement performance monitoring.

Challenges experienced by program teams included

1. appropriate, accurate measurement and verification of old chiller performance. ASHARE 827 “In-situ Performance Testing of Chillers for Energy Analysis” was mandated by World Bank for performance verification.
2. restricted access to new chiller technologies as energy efficient, HFC refrigerant based models in the market were limited.

1.5. Philippines[2]

The project introduced by International Finance Corporation (IFC) in the country gave leverage to the ESCOs by guaranteeing a favourable income upon investment from the energy savings, achieved due to the upgradation of systems towards energy efficient technologies. The key features of the project involved facilitation of investments in the replacement of inefficient chillers (in addition to the subsidies offered by the project), providing operating and maintenance services for the Chillers and associating ESCOs in the project. The replacement project with the partnership of ESCO developed a viable marketing strategy to expand the market nationwide for ESCO, generating employment opportunities in the process.

The chillers to be replaced had to be in use with an average cooling capacity of 330 TR, should have a residual technical life of more than 5 years and had to be installed post 1995. The CFC refrigerants recovered from the old Chillers were to be inventoried, stored and properly managed.

[2] http://documents.worldbank.org/curated/en/403971499652057103/pdf/ICR00004059-06302017.pdf

Table 7 Program Outcomes: Chiller Replacement Program in Philippines

Program Outcomes	
1.	Cooling capacity addressed by the project (Number of TRs)- The original target of 30,649 TR was exceeded by 49%. 45,687 TRs were achieved.
2.	ODP Consumption phase-out due to the replacement of chillers (ODP ton)-The project achieved 6.9 tons, and the revised target was exceeded by 21% of the revised target of 5.7 tons.
3.	Cumulative carbon emission reduction as direct benefits from the project (ktCO2)- The revised target was 62.4 ktCO2, which was exceeded by 136% when the project achieved 151.4 ktCO2.
4.	GWh savings and MW demand reduction (Gigawatt-hour (GWh))- The project achieved savings of 35 GWh/y.
5.	71 Energy Efficient (EE) Chillers installed to replace inefficient machines.

Less efficient chillers with large cooling capacity or specific energy consumption of more than 1 kW/TR were given priority so that such projects generate sufficient carbon finance revenue to scale up the chiller replacement programme initiated by the GEF funding, even if they were not eligible under the terms of CDM replacement. The project emphasized on the 4-year payback scenario and also stressed on the evaluation of Return of investment (ROI).

Post completion of the project, ESCOs continued with the maintenance and monitoring services. Some ESCOs provide guaranteed savings in the operation of Chillers as a part of the contract with the owner, with a validity till the end of the contract.

1.6. Singapore

The key highlights of the Singapore's Guaranteed Energy Savings Performance (GESP) in the country are listed below.

1. For Chillers with cooling capacity of more than 300 TR and less than 300 TR, the project guaranteed post retrofit efficiency of 0.62 kW/hr and 0.75 kW/hr respectively. If the efficiencies are not achieved, then full amount of lost energy savings are paid back to the Owners upto the 10^{th} year term.
2. The project also covers comprehensive cost of all new equipment and preventive cost for all the existing equipment.
3. At the Housing Promotion Board building the baseline efficiency before the retrofit were 1.01 kW/TR and 1.75 KW/TR, and the efficiency observed after retrofit were 0.617 kW/TR and 0.663 kW/TR.

4. At the Housing Development Board Building the post retrofit plant efficiency was evaluated to be 0.589 kW/TR; better than the committed efficiency.

ESCO which take up the project guarantees cost savings and provide comprehensive maintenance for a contract period of 3-5 years. GESP takes into consideration the equipment life cycle cost instead of 1-for-1 replacement, hence maximising energy and cost savings. The ESCOs are responsible for the entire project from audit to post implementation, monitoring and maintenance.

1.7. Thailand

In 2006, the World Bank worked with the Government of Thailand to help them achieve the following specific targets:

- The phase out of ozone depleting substances (ODS) by the early replacement of inefficient existing chillers with new systems and incorporating the use of non-CFC refrigerants.
- The reduction of emission of greenhouse gases by facilitating the installation of more efficient cooling equipment – chillers, pumps, fans, etc.

The project initially funded 24 building systems with the aim to replace 30% of the installed chiller capacity over a three-year period. The project did not manage to achieve its chiller equipment replacement goals. It did however achieve its ODS replacement goals, and of the chillers replaced, the average rate of return was calculated to be 30% with a range of 16% to 50% depending on type of chiller. This project thus was a very successful financial proof of concept.

1.8. Implementation Challenges

Challenges emerged from post implementation assessments. Almost all programs have experienced difficulties in engaging participants and completing projects.

1. Absence of policies and regulations to support chiller retrofit and replacement
2. Lack of competitive paybacks. Savings are inadequate in cases with small annual operational or running hours to repay the loan components
3. Both owners and suppliers shy away from complex performance and bank guarantees
4. Lack of confidence in newer technologies proposed under the programs
5. Lack of clarity about disposal guidelines and reticence to follow the disposal procedures as they are typically complex and time consuming
6. Chiller replacement was a less preferred investment for some owners; inclination was towards upgrades more visible to building users or occupants.
7. Site constraints that delayed chiller replacement discouraged owners from active participation.

1.9. Learning for CEEP

Feedback from participants of the CEEP study mirrored similar concerns about program implementation feasibility. The success of CEEP will depend on avoiding or resolving such barriers. Paybacks will have to match or surpass consumer expectations. EESL will have to undertake some degree of consumer sensitization about newer energy efficient technologies. Contractual agreements between vendors and clients must be concise with clear delineation of obligations and penalties. The program must piggyback on existing policies for efficiency i.e., Chiller S&L program and ECBC 2017, to acquire a robust project pipeline. These regulations are a big factor, as explained in detail in subsequent sections, for purchase of high efficiency central cooling systems.

6

Market Intelligence: Consumer Profile

There is a distinct difference amongst consumers by sector in perceived importance of efficiency and timely replacement of equipment to harness maximum of the efficiency potential. Owners of chiller plants in self-managed and operated facilities are more conscious of benefits of efficiency compared to owners passing on central plant operating costs to tenants. Healthcare and hospitality would then be most potent market for CEEP.

Consumers expect a payback of investment in replacement within 2-3 years. Median chiller replacement age is between 15 to 22 years. 80% of replacement and retrofits are self-financed. Gestation period ranges from 6 months to 1 year.

Real time, continuous performance measurement and monitoring is preferred. Refrigerants and additional performance parameters like noise, vibration, water quality etc. are less important in purchase decision making.

6. Consumer Profile

Consumer behaviour is somewhat segregated along nature of ownership. There is a distinct difference amongst consumers by sector in perceived importance of efficiency and timely replacement of equipment to harness maximum of the efficiency potential. This difference is dictated by nature of ownership, and occupancy profile of buildings. Owners of chiller plants in self-managed and operated facilities are more conscious of benefits of efficiency compared to owners passing on central plant operating costs to tenants.

1.10. Replacement Cycle

Manufacturer recommended replacement age for chillers and motors is 15 and 10 years respectively. For the more recently installed chillers, median replacement age is about 15-22 years. Retirement is also linked to maintenance regimes and chiller technology. Centrifugal chillers may be operated for 20 years or more; scroll chillers may be retired as soon as 10 years. Motors are mostly replaced after 10-12 years; the decisions again are mainly driven by increasing repair costs and downtime. Older chillers are known to be operating for upto 30 years. Cooling towers also reach end of efficient usability in 15 years.

1.11. Replacement Demand Factors

Consciousness about energy conservation and adherence with building energy codes are the most important influencers in inducing replacement of central cooling equipment. Product efficiency, operation and maintenance costs, and after sales service are other critical factors in purchase decision. Performance parameters like noise, vibration, refrigerants etc. are controlled in isolation and do not determine final specifications. Refrigerants specifically did not emerge to be a key decision-making factor during the surveys although owners acknowledged that chillers with zero ODS and low GWP refrigerants should be the future market norm.

1.12. Paybacks

Typical paybacks expected by owners is between 2-3 years, even in upgrades through ESCOs where upfront cost is zero. Customers from private sector, with aggressive returns on investment in their core businesses, may not agree to retrofits with payback of more than 1 year.

Customers are beginning to consider lifecycle costs in evaluating replacement value. Majority of lifecycle cost driven upgrades are either from the subset of owners that cannot pass on operational costs or are vying for tenants in a competitive rental market. Government or public sector customers, at least at the purchase decision making level, are less likely to be concerned with operational costs unless prompted to do so by organisational sustainability visions or policies set by senior management.

1.13. Service Agreements and Models

Most owners procure Annual Maintenance Contracts with the Original Equipment Manufacturer. Plants set up and managed by HVAC contractors also have back-to-back agreements with OEMs. 1 year in built warranty is provided for chillers. Owners sign Annual Maintenance Contracts (AMCs) thereafter for typically 2–3-year duration, capped at 5 years. AMC are either renewed annually with inflation or alternatively finalized for the entire contract period after adjustments for inflation. Manufacturers typically provide a 2-year inbuilt warranty on pumps and motors. Extended warranties are available for upto 5 years at additional costs. Thereafter, owners transfer repairs and upkeep into the scope of O&M service providers. Interviews with ESCOs and owners suggest that that the latter do not outsource O&M services to ESCOs; these are retained for the facility managers or O&M contractors.

1.14. Demand for Advanced Technologies and Performance

Majority of developers interviewed for this study indicated willingness to purchase chillers with third party certified environmental performance labels or “Ecolabels” if the incremental cost is negligible. Ecolabeling of chillers is picking pace in Europe and standards setting agencies in India are also considering introduction of a similar scheme for cooling systems in India.

Highly efficient chillers, pumps with VFDs, and advanced monitoring and control systems are considered as the most important technologies for ensuring a high efficiency plant room by end-users. Chillers and equipment with environment labels that holistically evaluate lifecycle performance with respect to energy use, refrigerant, manufacturing resource use, recycling potential etc. will be preferred if the incremental cost is moderate. Of these environmental sustainability parameters, low GWP and low ODP refrigerants and, low-waste and low-energy manufacturing processes are most significant for owners.

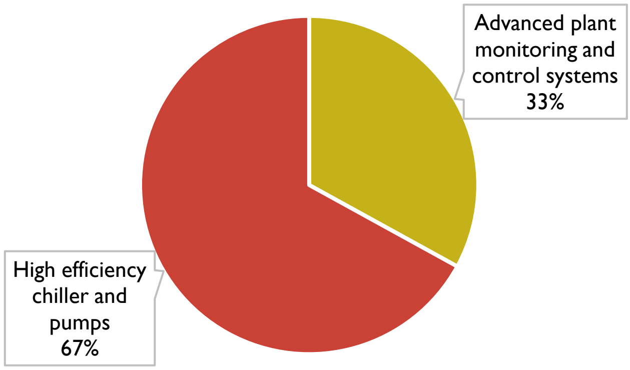

Figure 11 Highly efficient chillers and pumps and, advanced plant management systems are preferred technologies for enhanced plant efficiency

Willingness to invest in advanced technologies corresponds directly to perceived contribution of the equipment or operational practice in increasing plant efficiency. Super-efficient chillers, VFDs, energy management systems, water load optimization through design etc. are also the top technologies in which end users are likely to pay the incremental cost for incremental efficiency benefits.

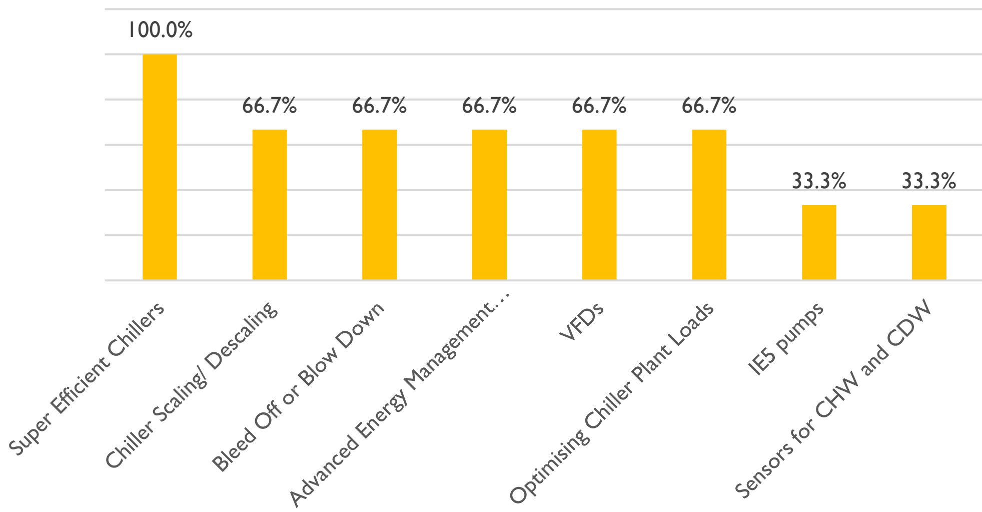

Figure 12 Consumers prefer to invest in highly efficient chillers, pumps and advanced plant management systems to gain plant efficiency

Super-efficient or IE5 pumps, sensors for monitoring system supply and return chilled water temperature are not high as the perceived benefits do not match the incremental investment. Investing in advanced technologies for condenser water treatment is not a high priority for end users even though system designers highlight this as a crucial for managing optimal performance of the cooling towers and overall environmental impact of chiller plants. It is attributable to little awareness about benefits of such technologies. Sensitization can increase market demand.

1.15. Business Models and Financing

80% of chiller replacements are self-financed. Lack of access to financing for upgrades, lengthy approval process and higher credit rates limit interest in using external funding. Among those potential customers who have capacity for self-financing, demand for retrofitting through ESCO models is ambiguous and depends on supplementary offerings. Partial risk guarantee facilitated by ESCOs enhances is one such value proposition that increases appeal of the business model for chiller replacement and plant upgrade to owners.

Scope of ESCO services is majorly confined to financing equipment cost, installation and commissioning and extended Annual Maintenance Contracts (AMCs) for the project duration. Servitization of chilled water or design, build and operate options as business model for building cooling is very much a niche segment in the market and not offered by ESCOs. Owners predominantly outsource operation and maintenance of plants to third party contractors that are different from the original equipment manufacturers. More about chiller and plant services is discussed in Section 1.17.

1.16. Retrofit Design Process

Replacement project gestation varies from 6 months to 1 year. Delays by owners in finalizing purchase decision can protract design and implementation. Large private and public sector organizations have comprehensive approval processes for risk assessment and finalizing technical specifications, legal obligations, and budgets for the proposed replacement scheme. Auditors and energy managers, HVAC system designers and owner's MEP teams coordinate throughout the replacement design and implementation. Audit for baseline development involves determining plant load, condition of systems, building load profiles and additional performance parameters from on-site studies. Collected data is used for analyzing energy conservation measures. Installation and commissioning can be in the scope of either the OEM, or the contractor or, an ESCO. Installation of equipment may vary by facility. Facilities that run through multiple daily shifts can have little downtime and leave a limited window for installation team

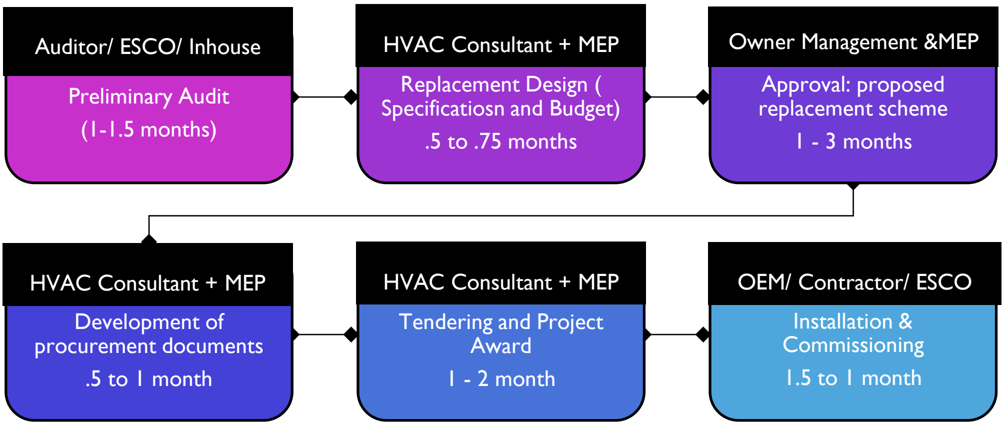

Figure 13 Chiller Plant Replacement Process: Major Steps and Timelines

1.17. Operations and Maintenance: Market Practices

Service agreements for operations and maintenance vary by end use. Hotels, hospitals and developers with portfolio or chain of properties typically employ inhouse O&M teams. Standalone public and private sector buildings rely on third parties for operating and maintaining plants. O&M of high and low side equipment may be given to separate contractors in larger facilities. Annual performance evaluation and penalties are increasingly figuring in O&M agreements with third parties. Typical O&M team configuration consists of 2 to 3-member technicians or junior engineers managing plants in 3 shifts. Larger plants may have a supervisor for the day shift. O&M contractors are expected to periodically assess operations and maintenance requirements of the plant. Costs of O&M packages are discussed in the next section.

O&M agencies are expected to provide the following resources and services:

1. Trained personnel, and equipment and instruments
2. Insurance of all equipment and personnel deployed to site
3. Remove all harmful substances or materials resulting from operation and maintenance of the plant
4. Provide quarterly comprehensive servicing, one of which must be rendered before onset of summer season
5. Attend break down calls as required
6. Checks for functioning of high and low side equipment at agreed intervals
7. Repair and replacement of worn-out parts, and monitoring equipment like meters, pressure gauges, flow switches, thermostats etc.
8. Condenser descaling

9. Top up or refill of refrigerant, oil, lubricants, chemicals etc.
10. Maintenance of buffer stock of spares

1.18. Plant Efficiency Measures

Highly efficient chillers are augmented with additional energy efficient equipment and operational efficiency measures in central plants. Efficiency measures most commonly integrated in plants are listed in Table 8.

Table 8 Energy saving potential for high performance in chiller plants

S. No.	Energy Efficiency Measures	Energy Saving Potential (%)
1	Provide secondary pump sets based on building load requirement. By this arrangement operational energy consumption can be reduced by shutting down the pumps of that zone where AC not required.	10-15%
2	During the building part load condition by running the chiller at 2°C higher outlet temperature will give the considerable power saving.	5%
3	Variable speed pumping system gives the best efficiency on partial loading	5%
4	Install a control system or chiller manager to coordinate multiple chillers & pumping system	
5	Make adjustments to minimize the refrigerant 'hot gas' bypass	2%
6	Chiller selection shall be on based on NPLV as maximum time chillers shall be running only partial loading also chillers should have VFD, this arrangement will give best efficiency on part load.	5%
7	Use free cooling or air side/water side economizer for catering the space cooling demand during favorable ambient condition.	6%
8	Reduce and optimize the piping valve quantities. This will reduce the pressure drop in pipes and tend to reduce the pump pressure head resulting reduction in pump power consumption.	2%
9	VAV boxes & VFD motor/EC fans in AHU to optimize the energy consumption at air side based on the building cooling profile.	10%
10	In air side should optimize the number of dampers in supply air ducts resulting reduction in AHU fan pressure drop and fan power consumption	1%
11	Descaling system or scale guard in chiller condenser inlet line which allow condenser water to pass through the system over the heat exchanger surface without depositing lime scale. Resulting heat exchanging capacity of condenser shall not drop down after a long run of period also this arrangement makes sure no decrement in chiller efficiency.	3%

12	By increasing the indoor pre-set temperature at 1°C will reduces the heat load in the space and electrical power requirement of plant room	6%
13	Fresh air flow shall be modulated based on CO2 or occupancy	2%
14	Continuous metering & regular maintenance of system like AHU/FCU filter cleaning, air purging from chilled water line & cooling tower sump etc. will ensure the optimum power consumption of the HVAC system	6%
15	Install only high efficient motor like IE3 & IE4 in the system	10%
16	Study part-load characteristics and cycling costs to determine the most efficient mode for operating multiple chillers.	-
17	Isolate off-line chillers and cooling towers	-
18	Establish a chiller efficiency maintenance program. Start with an energy audit and follow-up, then make a chiller efficiency-maintenance program a part of your continuous energy management program.	-
19	Eliminate excessive, simultaneous heating and cooling	-
20	Reset out-of-range or inappropriate setpoints during unoccupied periods	3-5%
21	Program equipment operating schedules to match building use	5-10%

1.18.1. Building Operational Profiles

Healthcare and hospitality buildings have maximum operating hours. Potential for savings is thus increased. However, variations in building loads are also more pronounced due to wider fluctuations in occupancy.

Table 9 Average Operational Profiles for Different Building Typologies[3]

Building Type	Institutional	Hospitality	Office	Commercial/ Retail	Healthcare
Annual Operational Hours	3500	6000-7000	3500	3000-6000	6000-7000
Diversity Factor	70%	60%	70-80%	60-70%	60%

[3] *EDS Analysis*

7

Market Intelligence: Market Characteristics

Current HVAC market is valued at 1.15 billion USD. 4 million TR stock was added in the last 5 years. Stable and moderate future growth rate of 7-10% is projected by most market players.

Screw and centrifugal chillers, with cooling capacity between 150-300 TR, dominate market sales. Metropolises lead demand pipeline. Variable refrigerant flow (VRF) systems are increasingly the default choice for comfort cooling where demand is less than 100 TR.

Domestic market is largely composed of international brands. Share of domestic brands in replacement is higher than that of international brands; the former has been supplying chillers much before international manufacturers entered India.

7. Market Intelligence: Characteristics and Size

This section analyses the characteristics for both new and replacement market.

Central Heating, Ventilation and Airconditioning (HVAC) system market was valued at 1,150 million USD in 2018. It is expected to grow at a CAGR of 8-10%. About 20,000 chillers, equivalent to 4 million TR capacity, were sold in the last five years alone. Market opportunity beyond this decade is also positive. Chillers are the highest value segment of central cooling system markets, accounting for 35% of the overall market value (Research 2022). Market feedback and research in external studies suggest process chilling to be primarily composed of scroll chillers. Chillers of smaller sizes, of upto 50 TR, form the bulk of sales stream in process chilling.

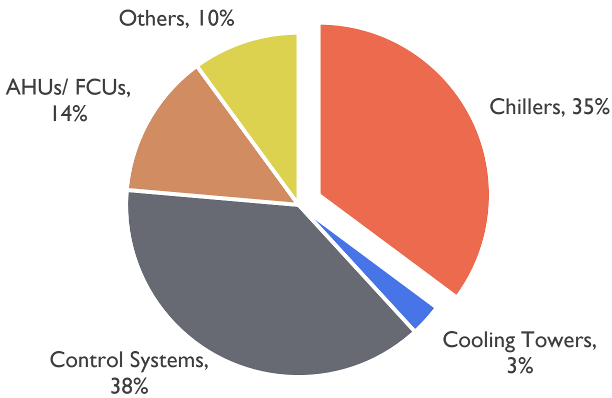

Figure 14 Market share, by value, of components in the central cooling system market

About 20% of the annual sales are for replacing retiring stock. This ratio might be higher than the market average for domestic brands. Both the brands are the oldest manufacturers and suppliers of chillers and have a larger share in existing stock compared to other brands.

Regionally, North India is the largest market for central cooling systems, followed closely by South, West and East India, in that order. Strong commercial sector construction growth rates in metropolises and Tier II cities, and, Construction of airports, metros, ports are also fuelling demand for chillers.

1.19. What is Most Sold? Market by Efficiency and Capacity

1.19.1. Technology

Screw and centrifugal chillers have dominated sales in the last decade and this trend is expected to continue as demand for smaller capacity and less efficient scroll and reciprocating chillers declines. Scroll chillers are used where cooling capacities of less than 55 TR (200 kW) are required; this is mainly in process cooling now. Space cooling with this small cooling loads is increasingly being met by Variable Refrigerant Flow systems because of higher efficiency, lower installation and operational costs.

Projects with larger cooling demands, of more than 400-450 TR, use centrifugal chillers.

1.19.2. Efficiency

Chiller efficiencies improve with increase in capacity beyond 1,400 kW (400TR). Coefficient of Performance (COP) for centrifugal chillers in the market varies from 5.3 to 6.7. Efficiency levels for water cooled screw chillers ranges from 4.2 to 6.2. Highest COPs are to be found in the 200-350 TR capacity range. Scroll chillers and air-cooled chillers have much lower COPs of less than 3.2.

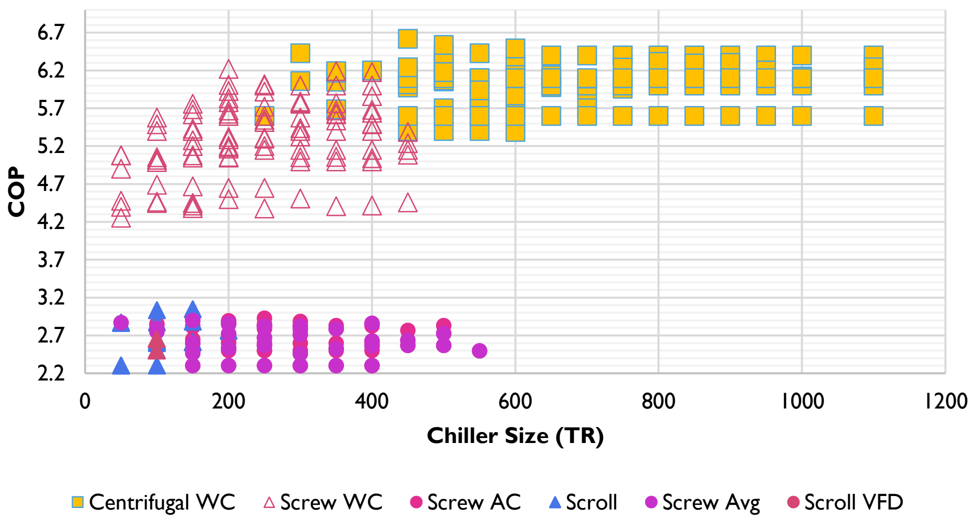

Figure 15 Chiller Efficiency Levels (COP at Full Load)
Source: EDS Analysis

Chillers with COP of 6.2- 6.3 are the most sold amongst consumers seeking energy efficient equipment. Maximum COP can reach upto 6.7. Unit cost differential however discourages most but those following extremely stringent efficiency goals to purchase chillers of this efficiency.

Chillers between 150 TR to 300 TR are the most sold across any technology type or heat rejection method (Figure 16). Cost varied from per TR INR 20,000/TR to INR 25,000/ TR. Unit costs start reducing with cooling capacity from this point. Unit costs of super-efficient chillers in capacity range of 450 TR plus can be as low as INR 15,000/ TR to INR 22,000/TR.

In the smaller capacities, unit costs are higher. Chillers less than 150 TR of 5.4 COP can have unit costs around INR 27,000/ TR. The same COP for a chiller of capacity 300 TR plus is priced at INR 17,000/TR.

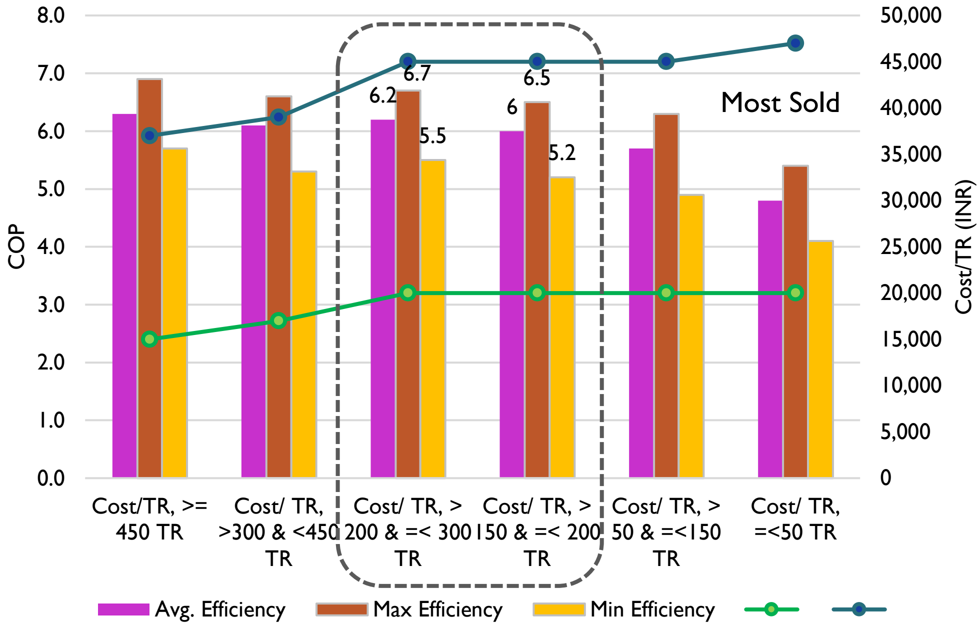

Figure 16 Higher capacity chillers, typically screw and magnetic bearing centrifugal chillers, also have higher efficiency ranges and lower prices per unit of cooling capacity

Chiller plant efficiencies vary between 0.7 ikW/TR to 0.85 ikW/TR in energy efficient or energy building code compliant buildings. In conventional buildings, performance may range above 1 ikW/TR. Highest performance chiller plants, with magnetic bearing centrifugal chillers, highly optimized building load management and advanced controls, can have efficiency as high as 0.5 ikW/TR.

Table 10 Chiller plant efficiency trends

Average Chiller Plant Efficiency in Energy Efficient Buildings ↓ (between 0.7 and 0.9 kW/TR)

Average Chiller Plant Efficiency in Conventional Buildings ↓ (between 1.0 and 1.2 kW/TR)

	Excellent						Requires improvement	
kW/TR	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
COP	7	5.9	5.0	4.4	3.9	3.5	3.2	2.9

1.20. Project Costs

Upfront costs for installing or retrofitting a complete central cooling system with plant efficiency between .7 ikW/TR to .85 ikW/TR varies between INR 90,000 per TR to INR 1,20,000 per TR. Upfront unit cost of water-cooled systems is higher than that of air-cooled chillers. High side equipment constitutes about 40% of a central cooling system (Figure 17). Chillers can cost anywhere between 23-32% in water cooled systems.

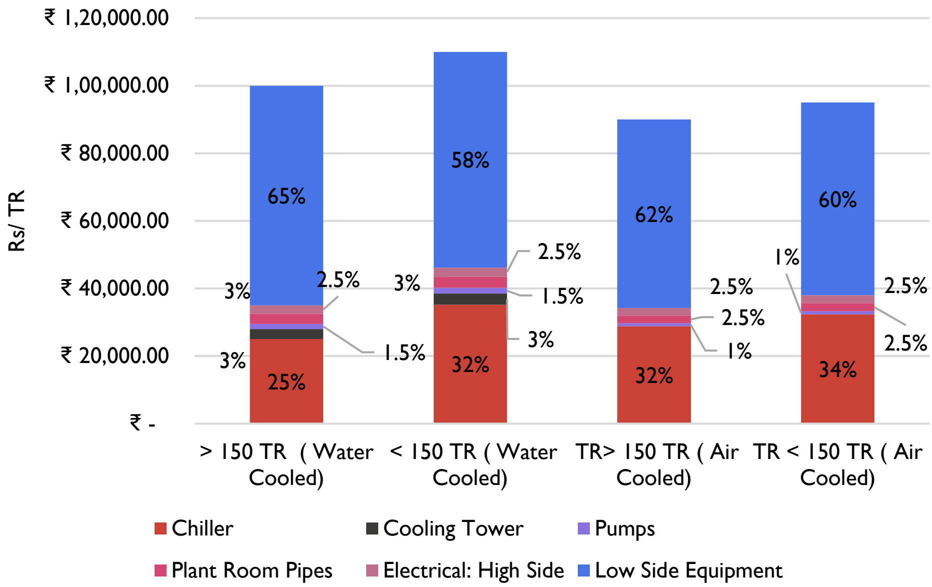

Figure 17 Central Cooling System Upfront Cost. *Source: EDS interviews with plant owners and contractors.*

Plant installation or first costs fluctuate with chiller technology and advanced controls. Non-magnetic bearing centrifugal chillers are almost half as costly as other technologies.

Unit chiller costs are inversely proportionate to size or cooling capacity. Average costs presented here are approximations normalized against site specific parameters. Actuals costs can be higher or lower for individual cases.

Table 11 Chiller Plant Project Cost Variations by Chiller Technology and Size.

< 100 TR	> 100 & < 300 TR (Non-magnetic chiller)	> 100 & < 300 TR (Magnetic chiller)	>300 TR (Non-magnetic bearing)	>300 TR (Magnetic bearing)
~ Rs. 1,15,000	~ Rs. 1,00,000 per TR	~ Rs. 1,15,000 per TR	~ Rs. 1,00,000 per TR	~ Rs. 1,10,000 per TR

Plant management costs vary more by size of the plant. Integration of advanced monitoring and energy efficient technologies result in incremental costs that are very project specific and cannot be loaded on average market costs. Larger private sector developers that own and commission multiple properties, with single plant size greater than 5,000 TR, for as less as 700 INR/ TR (10 USD). Servicing costs for chiller plants of less than 500 TR may vary from 1,200 INR/ TR (21 USD) to as high as 2,300 INR/TR (33 USD), depending on scope of services.

Lifecycle costs of a central cooling plant include acquisition costs, energy costs, servicing costs and cost of disposal at end of life. Energy costs constitute bulk of lifecycle costs. Servicing and energy costs are normalized for building types, building loads and climate. Maintenance and repair costs of centrifugal, screw and scroll chillers vary. Magnetic bearing centrifugal chillers have longer life, but on-site repairs are very challenging. Downtime is thus considerably increased in case of breakdowns and is more expensive.

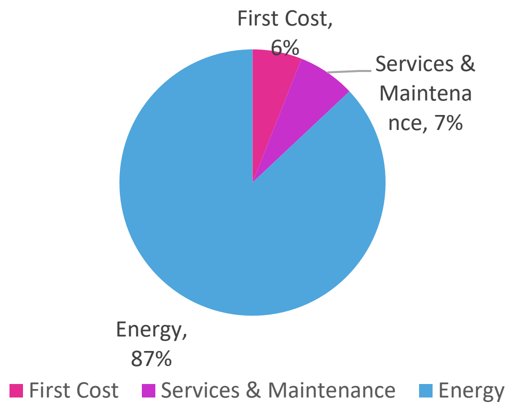

Figure 18 Lifecycle Costs of Chiller Plants.
Source: EDS projects and interviews with plant owners and contractors.

1.21. Refrigerants

R134A and R410A, with a GWP of 575 and 2000, are the two most used refrigerants in chillers in India. Most manufacturers provide low GWP refrigerants like R123zde only in product ranges with high environmental performance.

BEE expects a complete phase out of scroll chillers over the next 10-year period for more efficient screw and centrifugal systems. Increased use of non HFC refrigerants with minimal global warming potential (GWP) as compared to the current inventory of refrigerants can be expected (Table 9). This 2027 prediction is in line with the Kigali amendment.

Table 12 Chiller refrigerants are projected to transition to low GWP variants

Chiller type	2017	2027 (improved scenario)
Screw	100% R134A	60% R134A, 40% R513A
Scroll	95% R410A, 5% R407C	-
Centrifugal	90% R134A, 10% R123	45% R134A, 25% R1233zd, 15% RS13A, 15% RS14A

Coupled with the improvements in type of refrigerant, advances are also expected in their handling within the chiller system. The annual leakage rate is anticipated to drop from 2% (2017) to about 1% (2027) due to better operation and maintenance (O&M) practices and improvements in the chiller systems. Along with this reduced leakage, refrigerant recovery is also expected to increase from a current 50% (2017) to 90% (2027) due to better O&M practises at the end of chiller lifecycles.

Low GWP refrigerants and designs that reduce refrigerant consumption and leakage are performance parameters that EESL can promote through CEEP to nudge the market towards low GWP inventory.

1.22. State of the ESCO Market

ESCOs have been unable to encourage chiller plant upgrades significantly. About 20 ESCOs retrofit chillers or chiller plants in India, the scope varying from complete plant retrofit to one-to-one replacement of pumps, motors etc. However, not all offer both financing and project execution to clients. ESCOs are technically equipped to undertake retrofits but not financially. Vendor ESCOs mainly design and execute projects but investment for equipment replacement is managed by owner. Business opportunities are thus restricted; since ESCOs are unable to assist chiller owners in overcoming one of the biggest barriers, that of fund constraints, the former simply advance replacement despite expertise available from ESCOs to advice replacement.

1.23. Market Risks

Competitiveness of chiller markets, economic recession from COVID 19, and customer expectations of high return on investment are the biggest risks to CEEP. An aggressive and well-designed marketing plan will benefit Chiller Energy Efficiency Program by sensitizing consumers from high potential sectors (hospitality, healthcare, government, public sector) about benefits of replacement. Chiller market is extremely competitive. Manufacturers bid and negotiate aggressively, and plant owners are now accustomed to sharp negotiation margins. This is a mindset issue. CEEP can counter it by focusing on projects with higher energy savings to cost ratio such that cost markups over original prices quoted by manufacturers are balanced. Recent lockdown because of COVID-19 will aggravate economic slowdown and in turn, customers may advance replacement. Upfront investment by a third party may overcome this problem to some extent.

8

Market Opportunity

Numerically, replacement market potential is strong.

Chiller replacement is a 1,600 million USD untapped market. Chillers equivalent to 4 million TR will become superannuated by 2030. At present market prices, 377 million USD or 2,641 crore INR business opportunity is open in 2021.

Replacement of this stock with highly energy efficient variants is a dual opportunity to mobilize investment in energy efficiency markets.

8. Market Opportunity

Market opportunity was discerned from two perspectives: what is the appetite amongst owners to retire old, less efficient but functioning machines, and what is the quantum and capacity of the stock which will get superannuated during the next ten years by 2030.

Numerically, strong evidence emerged of a market that can be tapped with innovative financing models. Current installed capacity of chillers is about 6 million TR. This stock will grow to 38 million TR by 2050. Chillers installed from at least 2004 till now will reach the end of manufacturer recommended life in the next decade (Figure 19). 15% to 20% of current annual chiller sales, by volume, are for replacing existing stock; it is essentially the current replacement market size, and it will continue independent of any supplementary interventions. Balance of the market can be capitalized through active marketing and business models that discount cost of replacement for consumers.

By modelling stock replacement rates, a short-term market opportunity of 3 million TR is estimated for chiller replacement in space cooling. 0.75 million TR was ready for replacement in 2020 and 1.06 million TR is immediately ready for 2021. This represents a 377 million USD or 2,641 crore INR business opportunity for the year 2021 alone, and about 12% of the estimated total installed stock of chillers in 2021.[4]

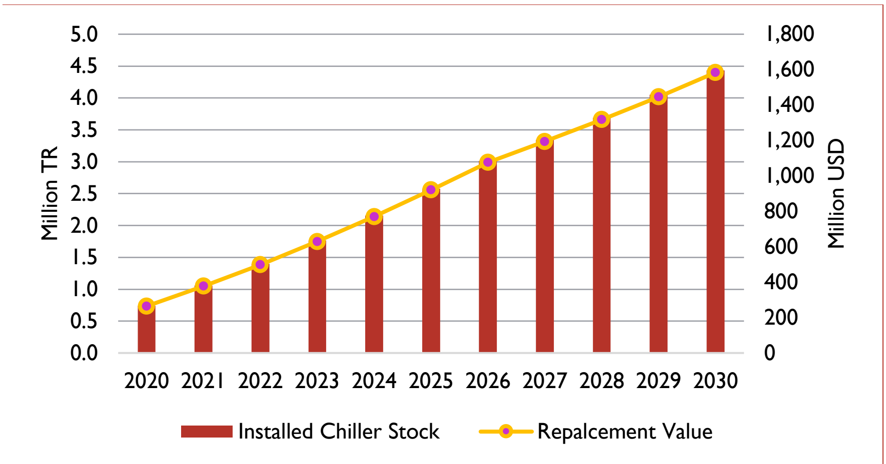

Figure 19 4.3 million TR of chiller stock will be superannuated by 2030. In the next ten years, replacement value will equal 1,600 million USD. *Source: EDS Analysis*

[4] This value is estimated by considering that half of retrofits will be chiller-only replacement and half high side equipment replacement.

Discounting existing market for replacing retired stock, 4.43 million TR of chiller stock will be superannuated over the next 10 years, i.e., till 2030. By value, it is equivalent to a 1,600 million USD market.[5]

Short, medium, and long-term prospects for CEEP are presented in Table 13.

Table 13 Market opportunity in replacing chillers will grow as equipment installed from 2004 onwards reaches retiring age.

Short Term (1-3 Years)	Medium Term (1-5 Years)	Long Term (10 Years)
1.4 million TR	2.16 million TR	4.43 million TR
INR 1,850 crores (500 million USD)	INR 5,400 crores (770 million USD)	INR 11,000 crores (1,585 million USD)

1.24. Replacement Demand Distribution

Screw and centrifugal chillers will constitute about 86% of estimated demand. Small chillers of less than 55 TR, primarily deployed in process chilling, will also be a significant share of the market. By region, western and southern India will offer a slightly bigger market for replacement.

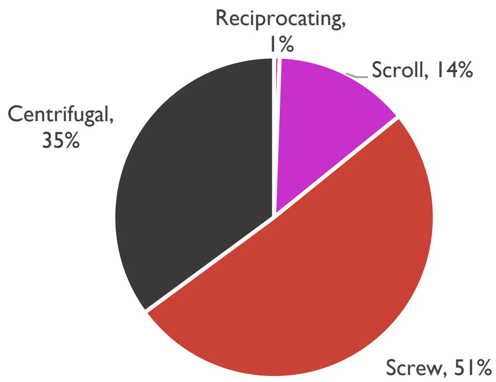

Figure 20 Screw and centrifugal chillers will form bulk of the replacement business both in the short and long term. *Source: EDS Analysis*

[5] At current prices for chillers and other high side equipment.

By size, replacement demand is most likely to be dominated by chillers between 150 TR to 500 TR. Analysis of HVAC industry sales trend from 2004 to 2030 indicate that, in year-on-year sales, chillers in this range have and will continue to have highest requirement.

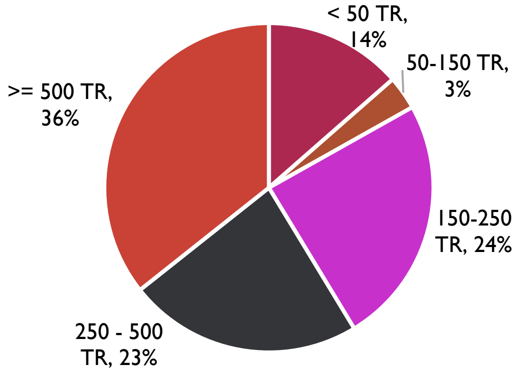

Figure 21 Replacement demand will be dominated by chillers in capacity range 150-500 TR. Average efficiency now available for models in this range is greater than 6.2. *Source: EDS Analysis*

1.25. Regional Distribution

Distribution is skewed slightly towards North and South India for replacement market. North and West have had a greater concentration of large industrial and commercial buildings which has resulted in older installations of central cooling and refrigeration systems. Going forward, North and South India will lead demand and hence the replacement opportunities of future will emerge from these regions. IT and ITES companies are largest aggregators of chillers, and these are primarily concentrated in southern cities of Bangalore, Hyderabad, Mysore and Chennai. Market in North India is meanwhile dominated by developer driven projects which may experience lag due to dip in real estate demand but will continue to be a major source of replacement projects.

Water cooled chillers dominate North and Western regions where their market share is estimated to be around 60-70%. Air cooled chillers are more common in coastal areas and South India because of water scarcity in metros in this part of the country and high ambient humidity.

Demand will be concentrated in the states of Delhi, Maharashtra, Karnataka, Gujarat, and Tamil Nadu. Comfort cooling through chillers is also largely limited to the 10-15 largest megacities in the country.

1.26. SWOT Analysis

STRENGTHS	WEAKNESSES
• Replacement incentive: 100% upfront financing model at lower credit rates will appeal to fund constrained owners • Price negotiation power with OEMs if procured in bulk • Comprehensive post retrofit M&V to measure impact and savings will increase consumer confidence in EESL offering	• Extensive support of external technical experts will be required for rollout. • Chiller market growth less aggressive than small direct expansion cooling systems (split and window ACs) • Market size restricted to non-residential buildings • Replacement behaviour: energy costs not paid by owner
OPPORTUNITIES	**THREATS**
• Stable growth rate projection (8-10%) for chiller market • Replacement opportunity of 20 million TR till 2030 • Both public sector owners and builders are facing fund shortages to invest in projects • Efficiency norms will drive demand for energy efficient chiller plant components • Boost Make in India campaign: domestic OEMs in central cooling market will be incentivized to develop more efficient models	• Direct Competition: OEMs can offer more competitive prices directly to owners • Default from consumers on payments • Alternate, more efficient technologies (e.g., VRFs) are taking over some segments of chiller market • Resistance from manufacturers to cannibalization of their market and clients

9

Project Design

CEEP aims to ease off the technological and financial burden of retrofitting chiller and chiller plant room equipment for the building owners by investing in the upfront equipment costs and providing project specific technical assistance to clients.

There are four business models based on which the implementation of CEEP will proceed, namely Project Management Consultancy (PMC), Engineering, Procurement and Construction, ESCO/Hybrid ESCO and Shared Savings ESCO models.

9. Program Design

CEEP is envisaged to be a zero-subsidy, zero-incentive, market centric initiative.

Financing emerged as the biggest roadblock in replacing and retrofitting chiller plant systems. Accessing financing from lenders is complicated and entails high-cost guarantee covers. Majority thus hesitate in borrowing funds. Interviews with consultants and consumers suggest that the program will unlock replacement market opportunity if it offers project finance, and, guarantees aggressive savings and return on investment on replacement. Third party financing can alleviate problems of fund paucity. CEEP must also offer option of deferred payments to owners, to be recovered from monetary savings. The program must also demonstrate project performance accurately and constantly to building owners through internationally followed methodologies.

Business model proposed for CEEP builds on this approach. Central plant systems, including chillers, will be replaced by Energy Service Companies (ESCOs) and investment recovered through rigorously monitored cost savings resulting from switch to more efficient models. ESCO market in India is underfunded. Majority have the technical expertise to undertake advanced retrofits but lack financing, this limits application of their actual technical capacity. To overcome this problem, it is proposed that a Super-ESCOs[6], brings necessary funding as an umbrella organization to ESCOs.

1.27. Business Model

Project specific deemed savings should be the basis of estimating returns on investment for Super-ESCO and customers. Super-ESCO will provide 100% financing for upfront costs and hire ESCOs or contractors to execute projects according to performance specifications framed jointly by the Super-ESCO and project owner. Real time monitoring and verification will determine actual energy savings and monetary savings resulting from the actual energy savings due to replacement or retrofit will be shared in a pre-determined ratio with the customer.

Prior to selecting this as the most viable model, EPC (upfront payment), ESCO/hybrid ESCO and shared savings model were analysed for CEEP. The strongest argument in favour of the Shared Savings + ESCO model is the provision of first cost financing to

[6] an entity that is established by the Government and functions as an ESCO for the public-sector market (hospitals, schools, municipalities, government buildings, and other public facilities); and also supports capacity development and project development activities of existing private sector ESCOs including helping create new ESCOs.

owners; financing crunch restricts chiller plant owners in replacing with more efficient machines.

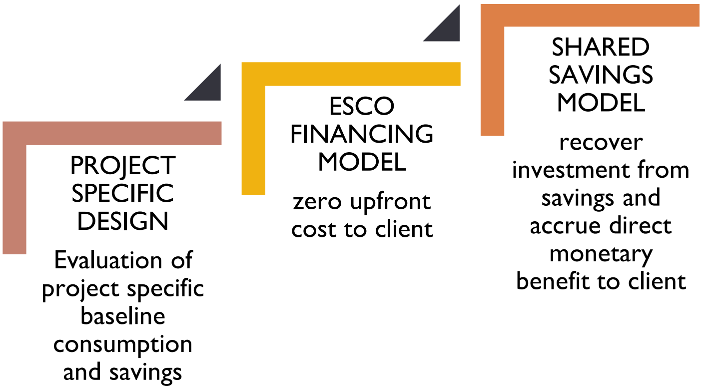

Figure 22 Program Benefits of Chiller Energy Efficiency Program

Table 14 Business Models for CEEP

	Project Management Consultancy (PMC)	Engineering, Procurement & Construction (EPC)	Actual Savings, ESCO/ Hybrid ESCO	Actual Savings, Shared Savings	Super ESCO
Model Description	Upfront cost is paid to OEM directly by the Client. Consultancy Charges are paid to Super ESCO. All savings accrue to the client.	Upfront cost paid by client. Super-ESCO charges PMC fee on a cost-plus model. All savings accrue to the client.	Clients make no upfront payments in ESCO and in Hybrid ESCO clients share upfront costs. Clients will payback via equated instalments	Upfront costs may or may not be shared between EESL and customer or manufacturer. Monetary Savings are shared in a pre-agreed ratio in tripartite agreement. Clients thus earn a 'nominal income' on the new chiller.	Super ESCO will bring projects to ESCOs with mutual risk and investment sharing. Upfront cost up to 30% applicable to Client.
Investment Risk	Lower risk of investment recovery	Lower risk of investment recovery	Higher risk of investment recovery; risk guarantee required	Higher risk of investment recovery; risk can be shared with partner, but exclusive	Lower level of risk

				risk guarantees still required	
Market Competitiveness	The model of consultancy services may hold strong for public sector clients, however for private sector clients, competitive edge is lost.	Equalizes market offering of Super-ESCO with other OEMs or contractors; competitive edge of project financing is lost	Gives Super-ESCO strong competitive edge over OEMs or contractors especially with consumers facing fund shortage	Competitive edge is retained	Upfront cost investment up to 30% may be a challenge for the Client

1.28. CEEP Services

Services to customers can be divided into three sequential packages, beginning from energy audit and culminating in comprehensive after sale support for replaced equipment during project duration.

1. **Project Design**
   a) Plant audit and baseline study
   b) Project Design (feasibility, specifications, service agreements)
   c) Equipment selection through public procurement
2. **Replacement or retrofit**
   a) Dismantling
   b) Supply, installation and third-party commissioning of equipment
3. **After Sales Support**
   a) Annual maintenance of equipment
   b) Operations and Maintenance of Plant
   c) Post retrofit performance measurement and verification

Table 15 Super-ESCO Services under Chiller Energy Efficiency Program

	Product or Service	Description	Scope
Project Design	**Plant or Chiller Energy Audit**	• Baseline energy consumption assessment • Analysis of ○ cooling or heating loads/ requirements, current facility requirements ○ system performance w.r.t. efficiency, operational efficacy	Super-ESCO → Third Party Accredited Auditors

	Chiller and Plant Design Optimization	• Feasibility Assessment • Design optimization: chiller/plant downsizing • Procurement and performance specifications, service level agreements	Super-ESCO → HVAC Consultants/ ESCOs/ OEMs/ HVAC Contractors
Replacement or Retrofit	**Chiller and Ancillary Components**	Energy efficient, low GWP chillers, pumps, cooling towers. EESL will decommission, dismantle, supply, install and commission.	Super-ESCO → OEMs/ ESCOs/ HVAC Contractors
	Chiller Plant Controls or Energy Management Systems	Automated monitoring and control devices to measure, monitor, diagnose performance and alter operational patterns to improve energy savings	Super-ESCO → ESCOs/ OEMs / HVAC Contractors
Services	**Plant Performance Monitoring**	Monitor plant and building cooling/ heating load profiles and energy consumption Measure and report efficiency	Super-ESCO → ESCOs/ OEMs / HVAC Contractors
	Plant Operations and Maintenance	Provide equipment and personnel to operate and maintain the plant	Super-ESCO → ESCOs/ HVAC Contractors

1.29. Procurement Specifications

Chiller procurement in CEEP should be guided by lifecycle costs. Clients will be able to get the best return on investment through this methodology.

Lifecycle Cost (LCC) = ∑ Capital Cost, Annual Maintenance Charges, Energy Costs, Residual Cost

LCC is usually calculated over product life. However, since the responsibility and/or service level agreements with the plant owner and ESCO or vendor will be restricted to the project period in CEEP, the LCC above is being modified to Project Period Cost (PPC), i.e.

Project Period Cost (PPC) = ∑ Capital Cost, Annual Maintenance Charges till project period, Energy Costs till project period

1.30. Target Consumers

Target customer base will be centred in commercial, hospitality, retail, health, institutional and infrastructure (airports, metros) buildings with central cooling systems. Since 2005, expansion in built floor space has been led by residential, office, hospitality and healthcare sectors. Central cooling systems will be predominantly installed in the last four sectors (Table 16).

Table 16 Types of commonly installed cooling systems by sector

Market segment	Predominant HVAC system
Residential	Primarily Split systems and window air conditioners. There is a slow trickle in of VRF/VRV systems in higher end apartment complexes.
Office	Split ACs and VRFs in small to medium sized buildings; screw or centrifugal chillers in large office buildings.
Infrastructure (Airports/Metros)	The high tonnage requirements in this segment see the use of water cooled (centrifugal and screw) chillers. Internally for smaller sections, VRF/VRV systems are installed.
Healthcare	Water cooled chillers – Screw and Centrifugal
Education	Large projects have centrifugal systems. Smaller projects use the VRV/VF systems
Hospitality	3-5 Star hotels primarily use chillers. Other use VRFs or split ACs.

Government and public sector will be the most easily convertible market for CEEP. HVAC consultants interviewed during this study indicated that about 1 to 1.2 million TR installed in government buildings is about to become superannuated. Manufacturers also suggested that 40% of installed stock is distributed in the public and government sector buildings. Priority target customers should be from this segment.

1. *Non-residential buildings managed or owned by Central Public Works Department*

1 million TR capacity is estimated to be installed in non-residential buildings owned or managed by CPWD. CPWD is a low hanging fruit. As a government agency faced with aging infrastructure and protracted approvals for funding retrofits, CPWD can be the most natural partner CEEP.

2. *Government hotels and hospitals*

There are about 1,300 3 stars plus hotels in India. Chillers equalling 1.5 to 1.7 million TR are estimated to be installed across hotels with rating of 3 star or above in India. Bulk of 5-star hotels are now complying with the most stringent green building certification and building energy codes. 3-star, 4 star and government hotels or resorts are lagging in integrating high performance cooling in their premises. Most follow an own and operate model; so, there is strong incentive for minimizing expenditure on plant operations. It has not been possible to quantify installed stock distribution between government or private sector hotels in the country.

3. *Airports and metros*

Metro stations and airport are cooled exclusively with central cooling systems. 13 metro networks across the country serve through nearly 750 stations. All of the cities with metro networks lie in warm climate zones requiring mechanical cooling and ventilation. 0.3 million to 0.5 million TR is estimated to be installed in metro stations and offices.[7] 0.2 million is estimated to be installed across 150 airports.

1.31. Program Rollout Strategy

Energy performance contracts, strong ESCO network, and procurement guided by lifecycle costs must be integrated in the program to guarantee best value for money for Super-ESCO and building owners.

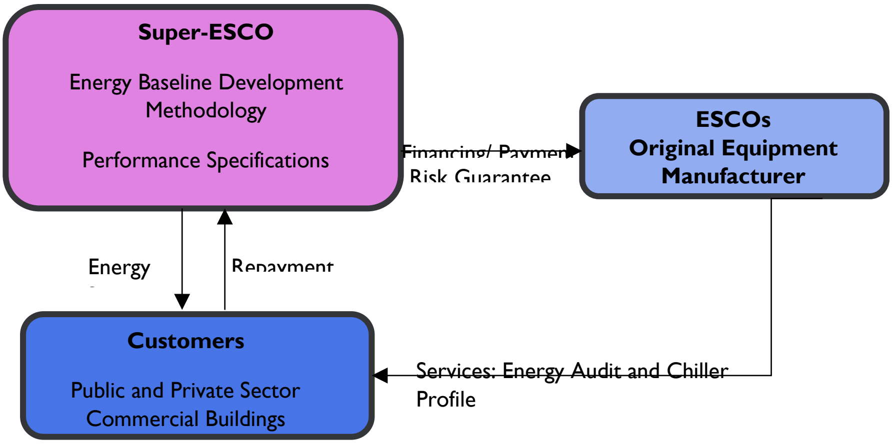

Table 17 CEEP Implementation framework through Super-ESCO Model

1. *Standardised Energy Service Performance Contracts*

Eligibility criteria for vendors, technology specifications, service terms, measurement and verification protocols, penalty clauses, procurement rules, evaluation criteria should be defined in standardized energy performance and service agreements. In parallel, standard methodologies for conducting audits and establishing baseline energy consumption must be developed.

2. *ESCO Empanelment*

CEEP can be executed on scale if ESCO are employed to determine project feasibility and implement retrofits. BEE has empanelled ESCOs across a five-point grading system. Grade 1 to 3 ESCOs can further BEE accredited ESCOs can be empanelled for CEEP retrofit design and execution as per standard methodologies.

[7] In a conservative scenario, assuming that even half of above-mentioned stations are cooled via chiller plants, with average plant capacity of 750 TR.

3. Facilitate Risk Coverage

Interviews with owners and ESCOs suggest that payment or risk guarantee coverage enhances appeal of retrofits through third party financing. World Bank, Bureau of Energy Efficiency and SIDBI have established multimillion-dollar partial risk guarantee funds for ESCOs, municipalities and government buildings. Chiller Energy Efficiency Program can be linked to these funds for expedited approval of guarantees for participating ESCOs.

4. Demonstration Projects

CEEP must begin with a series of pilots designed with public and private sector to check sector specific challenges and advantages. Pilots should also serve

- as confidence building measures for potential customers
- assess actual energy savings from chiller replacement
- evaluate validity of retrofit implementation processes proposed for CEEP

Marketing and Consumer Sensitization

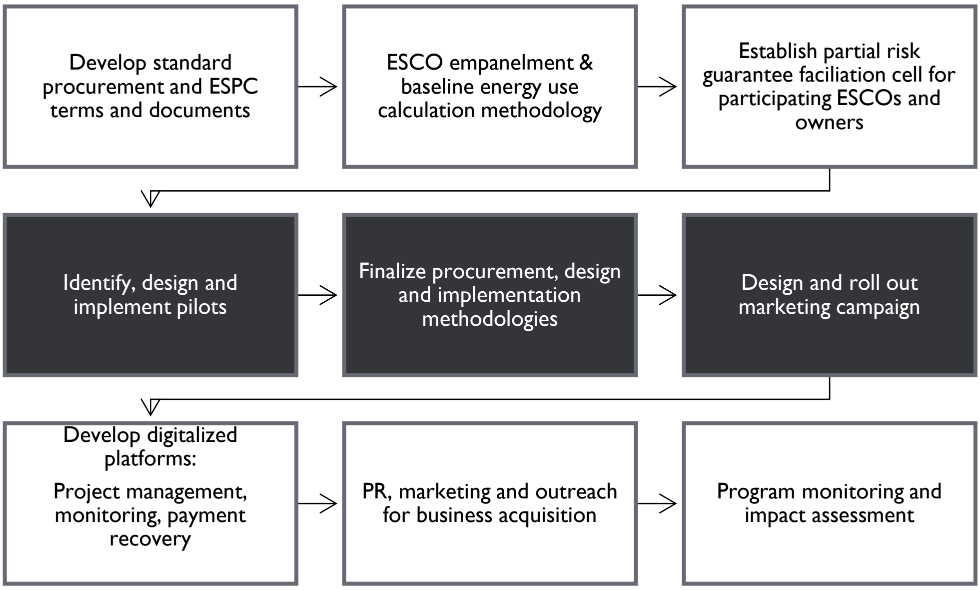

Figure 23 Chiller Energy Efficiency Program Rollout Strategy

Business acquisition in CEEP must draw on both mass outreach and face-to-face engagement with potential clients. Workshops with chiller owners from public and private sector, participation in building and construction industry trade shows and events, and targeted ads in electronic and print for CEEP marketing should be actively pursued in a systematic manner to create communication channels with potential customers and create a buzz in the industry. Consumer education through electronic and print media should also figure prominently in CEEP marketing campaign. CEEP services and benefit of business model should be propagated to public and private sector through outreach events in partnership with industry and builders' associations such as ISHRAE, RAMA, NAREDCO, CREDAI etc.

1.32. Replacement Process

A systematic plan to establish accurate baseline energy use and savings, define optimal performance specifications and study post retrofit performance as per international protocols should be followed to create a strong quality-conscious market perception for CEEP.

1. Baseline Study

Replacement must begin with development of baseline energy consumption and system downsizing or optimization studies by third parties, primarily accredited auditors and ESCOs contracted to develop, and, as per methodology determined by Super-ESCO.

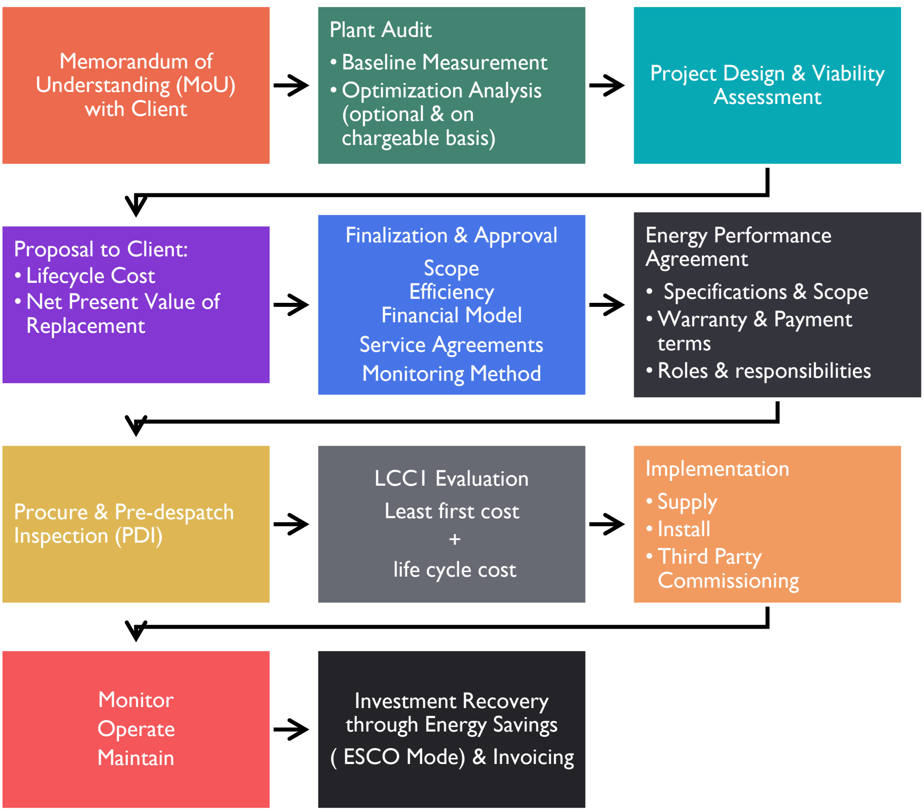

Figure 24 CEEP: Replacement Process Flow

2. *Project Design, Procurement and Implementation*

Findings from energy audit of chiller plant must inform cost benefit analysis and net present value of replacement costs to clients using standard calculation methods. Performance specifications can be framed for viable projects in request for proposals and energy performance service agreements (EPSCs). Empanelled ESCOs can then be solicited to bid to dismantle, supply, install and service energy efficient systems as per EPSC performance requirements. Annual maintenance contracts, insurance, penalty clauses will apply as per EPSC with customer and contracts with vendors.

3. *Performance Measurement and Verification*

Retrofit performance monitored as per international standards will build confidence of owners in viability and ROIs of chiller replacement; it will also validate performance and energy savings. Monitoring and Verification (M&V) paths prescribed in International Performance Measurement and Verification Protocol (IPMVP) for measuring retrofit impact are the most suitable methodology. In case of one-to-one chiller or pump replacement, *Option B -Retrofit Isolation: All Parameter Measurement* can be used to define M&V boundary around the replaced chiller (s). Key performance indicators will be measured and evaluated within this boundary only. *Option C – Whole Facility* is recommended for whole plant upgrades.

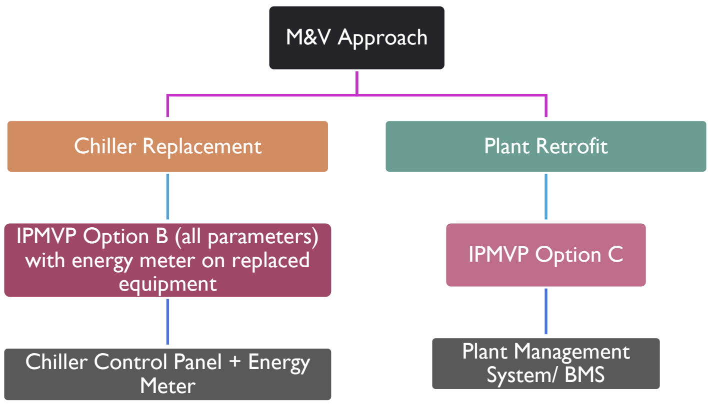

Figure 25 M&V Approach for Chiller Replacement Projects

10

Environmental & Economic Impact

CEEP can reduce gaps between international and Indian efficiency benchmarks for chillers. Against more measurable parameters of GHG emissions and energy use optimization, the program will avert 1,940 million tonnes of GHG emissions and save 2.4 million GWh of energy by 2030.

Indirectly, the program can boost market for ESCOs, high impact, efficient technologies, and chiller plant operation practices.

10. Environmental and Economic Impact

Chiller efficiency program is expected to lead to three immediate outcomes.

1. Supplement national targets such as meeting INDC commitments and sustainable development goals through savings in energy, reduction in peak demand and abatement of GHG emissions
2. Supplement India Cooling Action Plan objectives and national policies for regulating chiller efficiency
3. Market transformation by
    a. Increasing baseline efficiency of chiller inventories sold in markets
    b. Boosting ESCO market, build ESCO capacity to undertake replacement or retrofits, and mobilize private sector investment in chiller replacement
    c. Encouraging market supply of high-performance chillers, hitherto limited as niche segment of central HVAC market
    d. Preparing supply chains for product design as per nest generation of stringent, advanced standards such as Ecolabeling that encompass lifecycle environmental impact from production to disposal

Long term benefits, difficult to quantify and likely to be experienced beyond the 10-year scenarios modelled for this study, will be transition to best practices of timely replacement of chillers, adherence to good plant management practices and lasting consumer confidence in benefits of energy efficient cooling technologies.

1.33. Direct Impact

Replacement with energy efficient chillers result in savings of about 30% in full load conditions, and 50% in partial load conditions. This number is deduced form review of a large sample of past retrofits. The data was extrapolated to model long and short-term direct impact. Energy savings and GHG emissions are calculated assuming that all replaced chillers will be in the 5-star range under BEE's Standard and Labelling program.

By 2030, chiller replacement through CEEP will save 2,750 GWh and avert 2.3 million tonnes of CO_2e in a moderate growth scenario. Results for low and aggressive growth scenarios are presented in Figure 26

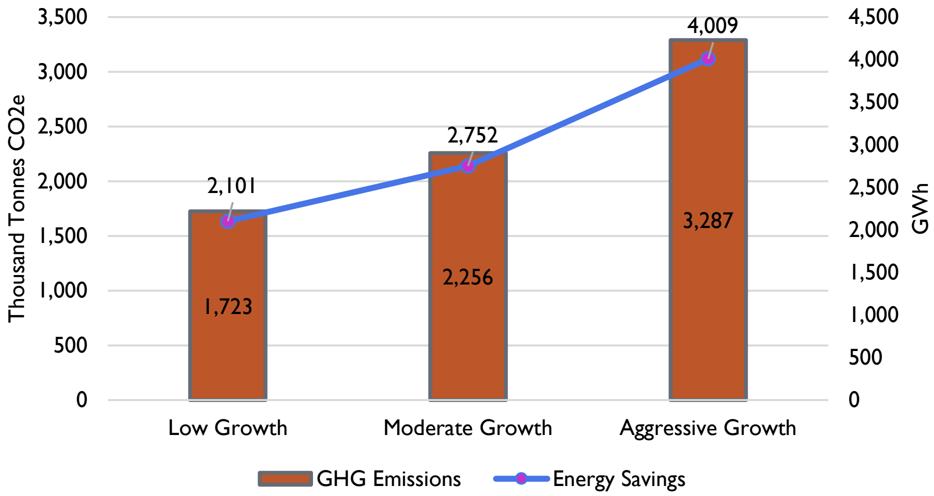

Figure 26 Cumulative GHG emissions abatement and energy saving potential of CEEP till 2030

In a moderate growth scenario, and the most likely one, CEEP will avert 30 thousand tonnes of GHG emissions and save 37 GWh energy in the short term i.e., 3 years (Figure 27). In the medium term, i.e., 5 years, 189 GWh will be saved and 270 thousand tonnes of CO2e will be averted.

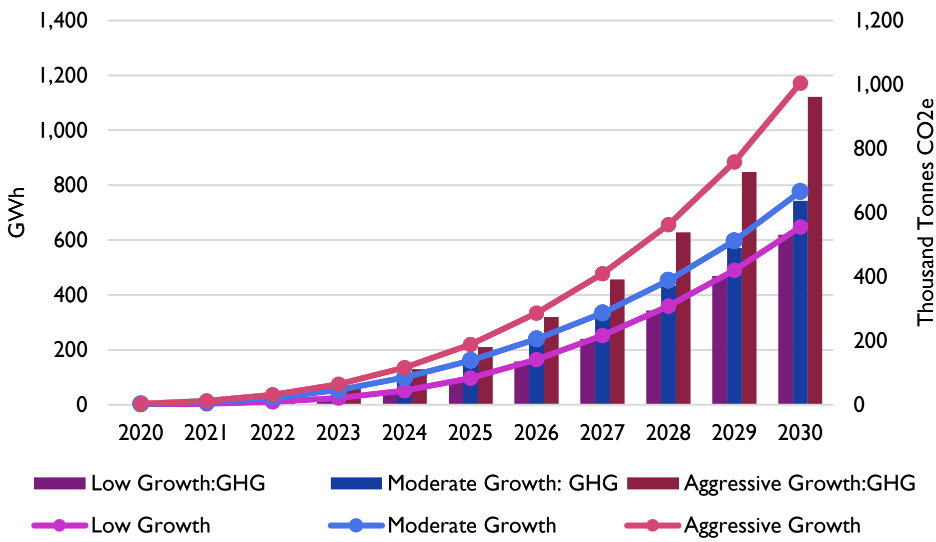

Figure 27 Cumulative, year-by-year, GHG emissions abatement and energy savings from CEEP

Across lifecycle of the replaced equipment, CEEP will save 11,650 GWh and avert 9.6 million tonnes CO2e in a moderate market penetration scenario (Figure 28). Lifecycle energy savings and averted emissions will rise to 17,580 GWh and 14.4 million tonnes CO2e respectively in case of aggressive business acquisition. In case of low growth, CEEP will avert 8 million tonnes CO2e.

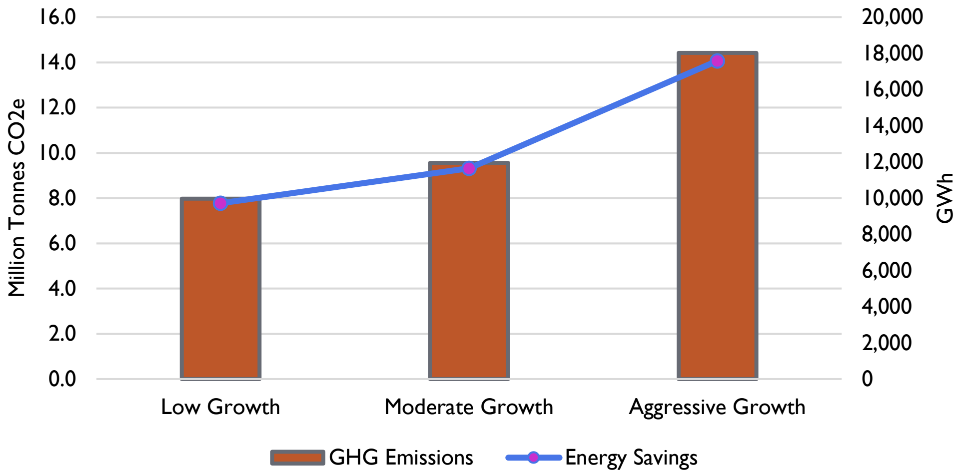

Figure 28 GHG emissions averted and energy saved from CEEP across lifecycle of replaced chillers

Costs for electricity are the highest in a chiller plant; once the first cost are overcome, plant upgrades deliver significant cost savings to clients. CEEP save 7,800 crores or 1050 million USD by 2030 in energy costs.

Appendices

Annex I: Questionnaire for Manufacturers and Consultants

Section 1: Demand drivers

1. What are the demand drivers for replacement? Please rank if possible:
    a. Operation or maintenance costs
    b. Energy efficiency/ environmental sustainability
    c. Mandatory regulations like ECBC, S&L, local laws for water and electricity use, refrigerant phaseout etc.
    d. Organization CSR/ green or energy efficient procurement policies
    e. Overall building or facility retrofit
2. Rank the performance parameters that end users prioritize in making a purchase decision (ask for each type of component/ technology)? 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
Energy efficiency/ Coefficient of Performance	
Payback	
Inbuilt AMCs/ warranties	
Technology fit/ suitability for the project	
Acquisition/ upfront cost	
Site constraints (Area /space required for installation etc.)	
Brand reputation for reliability / quality/ after sales services	
Familiarity of plant management team with a product or brand	
Other environmental performance indicators like water efficiency,	
Occupant comfort (sound/ vibration/ indoor quality etc.)	
Other (please specify)	

3. For the end users what factors act as triggers and what stops them from opting chiller or replacement of existing chiller with that of higher efficiency? (Probe: acquisition and installation cost, awareness level, promotions by the brand, technology used, rules and regulation levied by the Govt. agencies.)
4. How important is the refrigerant in the selection of energy efficiency chillers?

Section 2: Demand/ Market Profile

5. Which of the following sectors will have good opportunities, both in long and short term, for chiller replacement or central plant retrofit? Please rank.

Hotels	
Healthcare	
Office buildings	
Business/ Shopping	
Airports /Metros	
Residential	
Industrial	
Cold Storage	
Public Sector	

6. Which technology or product in a central plant has high market potential?
7. How is the demand for chillers segregated through the regions (North, South, East and West)?
8. Which are the top ten cities per annual sales or chiller installation/ replacement projects?
9. What is the potential in government sector?
10. Are there any sector specific barriers to replacement projects across commercial, residential, process chilling and cold storage?
11. What is the segmentation of annual demand for chillers between new installations and replacement?

Parameter	Annual demand of chillers Percentage (%) OR No. of units in a year
New installation	
Replacement of existing systems	

12. What percentage of retrofits are limited to only chiller replacement versus whole plant retrofit? Please specify, if possible, by
    a. owner type (public and private sector),
    b. sector (commercial, industrial, cold storage/ infrastructure, transport, residential),
    c. application (comfort and industrial cooling),

d. building typology (hotels, healthcare, office, business/ shopping, airports/ metros, residential, industrial, cold storage)

13. Is there any sector, season or region-specific preference for a particular brand, technology? If yes, what factors are responsible for the same (probe weather condition, size of the facility, popular type of industry/business in the region, regulations for water or electricity use, building norms etc.)

14. How is the market shaping up in terms of new technology and emerging consumers' trends? (Probe energy efficiency, VFDs etc)
15. What can prompt end users to select highly efficient systems and to retrofit pants or replace equipment? (probe sensitization and education, reduced costs, industry practices etc.)
16. What are the new technologies in the market for plant and equipment control that should be promoted to enhance plant performance?

17. Which manufacturers stand 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→

Section 3: Project Design

18. What are the most sold efficiency levels (COP or kW/ TR) that end users prefer to install?
    a. By capacity range (TR)
    b. By type (screw, scroll, reciprocating, centrifugal, magnetic bearing centrifugal, absorption)
    c. By application or sector???

19. What is the average equipment replacement age for?
    a. Chillers
    b. Pumps
    c. Cooling towers
20. What is the average gestation period for a retrofit project, from the beginning of the baseline study to commissioning of new equipment?

	Task	**Months**
1	Baseline development/ energy audit	

2	Selection of consultant for retrofit or new installation design and/ or implementation	
3	Project design and optimization	
4	Equipment Procurement (including preparation of technical specifications, BOQs and tender evaluation)	
5	Supply and Installation	
6	Commissioning	
7	Selection of AMC agency	

Please add tasks that maybe missing from this list.

21. What all technical and economic parameters are considered by consultants before making a decision on the chiller? Is the life cycle analysis considering the capital cost and running cost with time done before the chiller finalization?
22. What efficiency solutions, other than replacement of equipment, is typically advised or asked for by clients in a plant upgrade? Please select and/ or add to options: set point optimization, chilled or condenser water temperature reset, heat recovery etc.
23. What is the most typical agreement period for an AMC contract? 1, 3, 5 years or more?
24. Do end users prefer AMCs from OEMs or third parties? Are comprehensive AMC packages for central plant operations and maintenance by a third party preferred over service agreements for individual plant components? Please provide break-up of market, in percentage, if possible, along these options.
25. What is the standard services agreement/ AMCs packages provided for chillers and central plants?
26. What is the M&V protocols, methods and products preferred by end users?

Section 4: Project Costs

27. What is the average project cost for retrofitting?
    a. Retrofitting central plant (TR or kW), including design optimization. Costs can be provided separately for chillers, pumps, cooling towers, plant controls/ energy monitoring systems
    b. Chiller replacement (TR or kW)
28. How do these number vary by increments in a) efficiency, b) plant size/ chiller capacity?
    Estimates can be provided in the following table.

Type	Cooling Capacity (TR)	Minimum Efficiency (… kW/TR)	Most Sold Efficiency (… kW/TR)	Highest Efficiency (… kW/TR)
Screw/ Scroll…	< 100 Kw/ 30 TR			
	>= 100 kW & <350 Kw (>= 30 TR & <100 TR)			
	>= 350 kW & <700 Kw (>= 100 TR & <200 TR)			
	>= 700 kW & < 1050 kW (>= 200 TR & < 300 TR)			
	>= 1050 kW & < 1500 kW (>= 300 TR & < 425 TR)			
	>= 1500 kW (>= 425 TR)			

29. Is there any discernible difference in projects costs due to project location, building type or any other factor?
30. How affordable is the higher COPs in terms of their paybacks? What is the investment to savings ratio trend for subsequent higher COPs?
31. How do the above costs vary for a project under ESCO mode?

Section 5: Project Financing

32. What is the break-up of the replacement market by mode of financing? Models of financing being considered for this study are self-financing and energy performance contracts. Please explain end user preferences by sector, application and end user.
33. What is the most common source of funding for installation/ retrofit of chillers/ central plants?
34. Are financial institutions promoting financial products /loans for the end-users and/or manufacturers for installation of energy efficient systems?
35. What are the key challenges while implementing projects through ESCO based methods? How can they be circumvented? Do you foresee increase in demand for chillers/ central plant systems if financial support is provided through ESCO based models?
36. What value added services should ESCOs or equipment manufacturers add to encourage owners in retrofits? (probe: baseline development (can evaluation of water and other environmental and occupant health parameters be considered), after sales services, monitoring systems, equipment efficiency, extended warranties?

Annex II: ESCOs with Expertise for Central Plant Retrofit

No	ESCO	BEE Grade	Services
1	Amplebit Energy Solutions Pvt. Ltd.	4	HVAC optimization through automation and AI, power factor improvement
2	BOSCH	1	HVAC, Waste heat recovery, integrated heating and cooling, Steam distribution optimization
3	Development Environergy Services Ltd	1	Thermal measures, pumping systems
4	ENCON Energy Services	2	Compressed air optimization, lighting, HVAC
5	Energized Solutions	3	LED and HVAC retrofits
6	Enfragy Solutions India Pvt. Ltd.	4	Lighting, solar space heating system, HVAC
7	First ESCO Ltd.	5	Medium voltage variable frequency drives in fans and pumps, induction lighting systems, HVAC
8	Forbes Marshall		Boiler efficiency optimization as well as process heat recovery, boiler replacement andautomation, thermic heating/cooling
9	Honeywell	2	Building automation equipment, lighting, hot water generation, Chillers
10	Johnson Controls	2	HVAC, building automation, VFDs
11	Promethean	3	Waste heat recovery from chillers and compressors
12	Schneider Electric India Ltd.	3	Lighting, building envelope, building automation, HVAC
13	See-Tech	1	Lighting, HVAC, pumping
14	Siri Exaergy & Carbon Advisory Services Pvt. Ltd.	4	Lighting, drives/pumps/fans/ motor systems, solar hot water heating
15	Smart Joules	2	Operational central AC equipment, redesigning on site, automation
16	Stenum Asia	4	Thermal system, compressed air optimisation, lighting
17	Thermax	2	WHR with electricity generation/ steam (steam and process heat as a service), boiler retrofits, heat pumps
18	DESL/ Veolia	1	HVAC
19	Voltas Limited	1	HVAC
20	Carrier Airconditioning& Refrigeration Limited	2	HVAC
21	Blue Star Limited	2	HVAC

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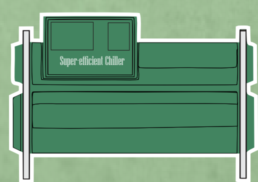
Super efficient Chiller

USAID MAITREE

United States Agency for International Development (USAID) Market Integration and Transformation Program for Energy Efficiency (MAITREE) is a bilateral program with the Ministry of Power, Government of India. MAITREE aims at accelerating uptake of cutting-edge technologies, innovative business models, and end-user engagement, for adoption of energy efficiency at scale. MAITREE works with a range of public sector, private sector, and international partners. Environmental Design Solutions [EDS] is the implementing partner for the program.