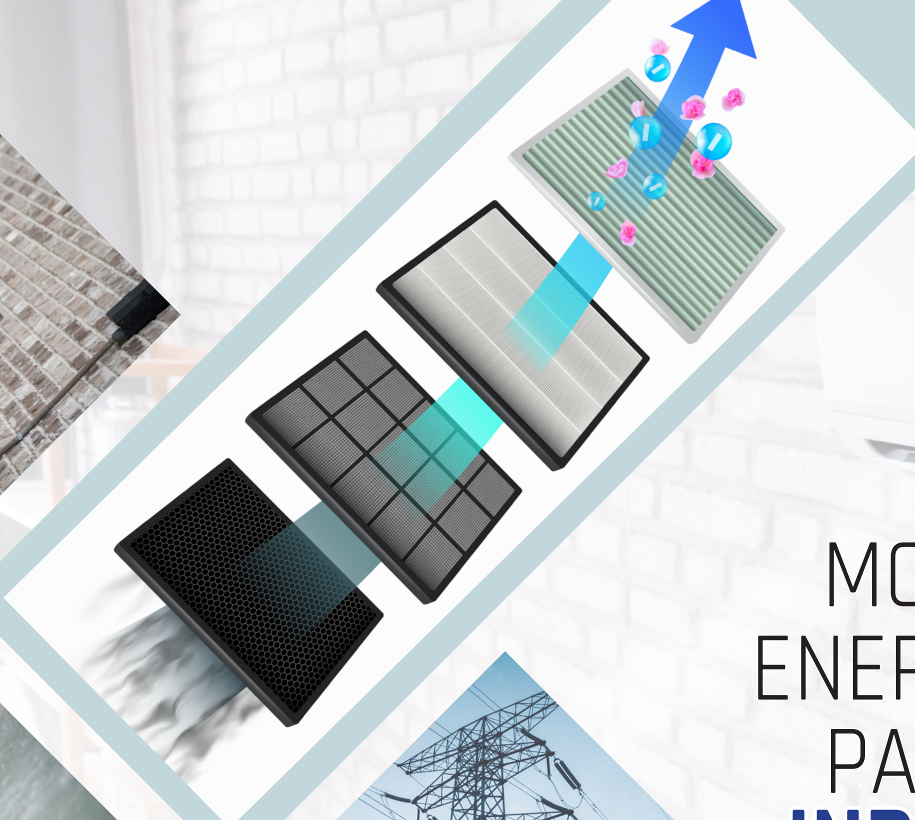

SHEETAL

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

MODELLING THE ENERGY EFFICIENCY PATHWAYS FOR **INDIA'S ROOM AC SECTOR**

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THE ENERGY AND RESOURCES INSTITUTE

Creating Innovative Solutions for a Sustainable Future

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LIST OF ABBREVIATIONS

BAU	Business as Usual
BEE	Bureau of Energy Efficiency
ECBC	Energy Conservation Building Code
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Limited
FT	Frozen Technology
GDP	Gross Domestic Product
GT	Giga ton
GW	Gigawatt
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbon
ICAP	India Cooling Action Plan
IESS	India Energy Security Scenario
ISEER	Indian Seasonal Energy Efficiency Ratio
MEPS	Minimum Energy Performance Standards
MoEF&CC	Ministry of Environment, Forest and Climate Change
MW	Megawatt
NAPCC	National Action Plan on Climate Change
NMEEE	National Mission for Enhanced Energy Efficiency

PAT	Perform Achieve and Trade
RAC	Room Air-Conditioner
S&L	Standards and Labeling Program
SEAD	Super-efficient Equipment and Appliance Deployment
tCO_2e	Tonnes of carbon dioxide equivalent
TEAP	Technology and Economic Assessment Panel
TWh	Terawatt hour

KEY FINDINGS

1. Improving income conditions, urbanization and frequent heat waves have transformed AC need as a developmental need and these would drive massive room AC demand in India. As per the modelling, Indian AC market is expected to witness 6.45% CAGR in next 3 decades as per the reference scenario.

2. The Room AC market is estimated to expand from 40 Mn installed AC in 2017-18 to 300-400 Mn AC stock by 2046-47

3. India's AC efficiency market has been improving at the rate of 2.76% annually. To achieve the ICAP implementation goals, the annual improvement in average efficiency in AC sector needs to be doubled.

4. There have been around 72% improvement in the efficiency of best available AC product in Indian market in last decade. This has outpaced the MEPS ratcheting up of 38% in last decade.

5. Increase in peak demand and electricity consumption from 2019 to 2047.

6. Successful ICAP implementation could avoid 187.016 GW capacity and save around 300 BU of electricity which would bring the 1.5 lakh crore rupees of monetary benefit for the economy as per the reference scenario.

7. In the BAU and Frozen technology scenario, the AC segment is expected to witness huge emission increase and it would reach up to 306.57 million tCO_2. Under the ICAP implementation scenario with Kigali amendment adjustments, 230.76 million tCO_2 of emissions could be avoided in reference scenario.

8. Aggressive MEPS upgradation through policy push coupled with ensuring skilled technicians' availability through training and capacity building of servicing sector along with robust consumer awareness campaign are the key intervention to achieve the ICAP goals and turn AC demand challenge in the opportunity.

1 INTRODUCTION

The comfort cooling or otherwise known as thermal comfort air conditioning is becoming a necessity year by year owing to the increase in the average temperatures all around the globe. The 2019 was the second warmest year in the record, wrapping up the hottest decade ever recorded (Climate central). It has been scientifically established that the isothermal air flow is directly linked to the productivity of the humans and plays an important role in providing comfortable working and living conditions (Akimoto et al., 2010). There are about 1.6 billion ACs currently in use throughout the world, of which USA and China has more than half of the share. The ownership of Air-Conditioners is still considered a luxury in India as the current penetration of Air-Conditioners in the residential sector is only 7-9% (ICAP, 2019). The demand for the cooling is growing rapidly in India which is propelled by the economic and population growth.

The expected enormous rise in the RAC units can put heavy strains on the electrical grid of the country. In the current scenario, the ACs are consuming over 2000 TWh of electricity every year globally which is two and half times higher than the total electricity use of the Africa. Over a fifth of the electricity use in the building is for the cooling and space cooling in buildings is responsible for 50% or more of residential peak electricity demand (OECD/IEA, 2018).

Every year the cooling demand in the metropolitans of India is growing rapidly because of increasing sweltering heat. Soaring temperatures and heat waves are common in northern plains of India and these are cited as main reasons behind the spurt in cooling demand. Delhi's peak power demand breaks its high every summer and the power distribution companies quote the Cooling load as the main reason behind the Delhi's power demand. DISCOMS estimates that almost 50% of the power demand in summers is due to the cooling comprising of air-conditioners, coolers and fans. According to the DISCOMs, the Delhi's peak power demand is more than the power demand of Mumbai and Chennai combined, and thrice that of Kolkata.

The energy efficiency has a tremendous potential in addressing the increasing the cooling demand to control the peak power demand. The energy efficiency has major implications for consumers, businesses and environment in terms of energy access, reducing greenhouse gas footprint and economic growth.

The energy efficiency has a critical role to play in the growth of RACs in India as it has the potential to address the growing cooling energy demand. The total potential energy savings from the RAC sector would reach over 100 TWH in 2030 which translates to potential demand saving of over 50 GW or equivalent 100 new coal fired power plants of 500 MW capacity (Phadke et al., 2014). The Bureau of Energy Efficiency (BEE) has shown its commitment to ratchet up the minimum energy performance standards (MEPS) continuously since including RACs under the Standards and Labelling programme (S&L). BEE through its regular notifications has been playing its role in the improvements of energy efficiency standards for various equipment and driving the market transformation towards energy efficiency. The energy efficiency initiatives synergized with policy actions can boost the uptake of energy-efficient ACs to address the increasing cooling demand (Singh & Phore, 2020). Electricity demand projections are an important element in the entire electricity supply chain mechanism (Negi & Kumar, 2019). In this report, econometric demand model has been developed to project the RAC stock which feeds into the power demand and emission estimations. The Montreal Protocol is the most successful and universally ratified treaty and it is designed to protect Ozone layer by phasing out various substances that are responsible for ozone depletion. From its inception, this treaty has undergone nine revisions and the latest was Kigali Amendment in 2016. Scientists believes that northern hemisphere is expected to be full recovered by 2040, southern hemisphere by mid-century and the Antarctica in 2060s. The Kigali Amendment, if implemented fully has the potential to reduce future global warming in 2100 due to HFCs from a baseline of 0.3-0.5 °C to less than 0.1°C. The Montreal Protocol has a prime role to play in combating climate change and to limit the global temperature rise to 1.5°C. In this report, we will explore the CO2e emissions from the RAC sector under various scenarios.

Room air-conditioning segment would have major impact on the implementation of India cooling Action Plan and achieving its targets. Keeping in the view to develop the sectoral implementation roadmap for ICAP implementation, we have conducted detail modelling exercise and analyzed the expected stock projections, energy efficiency pathways and its impact on electricity consumption and emissions. In the end, key interventions have been recommended to achieve the sustainable cooling goals.

2 OBJECTIVES

The objective of this study is to develop energy efficiency pathways for room AC sector to inform ICAP implementation through analyzing the room AC market in India based on macro-economic indicators and challenges associated with electricity demand and GHG emissions. Modelling energy efficiency gain associated with potential energy saving and avoiding the emission through identifying opportunities to inform ICAP implementation roadmap.

3 APPROACH AND METHODOLOGY

India is facing a rapid increase in the annual sales of the ACs and it is straining the electrical grids throughout the country by spiking the peak loads. The present work is a step towards estimating the room AC market through stock projections against macroeconomic indicators such as GDP and population and thereby evaluating the numbers for the electricity demand at generation and supply sides to operate the RACs in future. The methodology for the present work involves a data centric quantitative approach through conducting econometric modelling to form projections on the stock, electricity demand, and emission estimates. The detailed layout of the methodology is presented in the figure 1. The study also includes the refrigerant demand in the sector and analysis on the low-GWP transition under Kigali Amendment thereby its impact on direct emissions from RAC sector. Detail secondary literature has been reviewed to develop the baseline trends in the sector vis-à-vis current RAC stock and energy efficiency existing status as well as historical trends. Expert consultation has been conducted to finalize the modelling scenarios and assumptions. Subsequently, stakeholder engagement in the form of one-to-one meetings & expert interviews has been conducted to brainstorm on the modelling results.

The scenarios developed for this study have three dimensions – AC market and electricity demand growth, energy efficiency, and refrigerant transition. Aspirational and Reference scenarios are developed to account the GDP growth projections for India. The projections on the GDP and population growth are based on the GDP projections by NITI Aayog IESS analysis (IESS, n.d.) and World Bank's population estimates for India (World Bank, n.d.) respectively. Table 1 shows the macroeconomic factor under Reference and Aspirational growth scenarios. The energy efficiency scenarios take the ratcheting-up of MEPS in account and we have developed three sub-scenarios for the energy namely – Frozen technology (FT), Standards and Labeling programme (S&L) aligned and India Cooling Action Plan (ICAP) aligned. The refrigerant transition considers two scenarios for the refrigerant demand in India, namely – Business as usual (BAU) and Kigali. We hereby acknowledge that the ongoing pandemic would certainly have short-term impact on the global economy and India is no different as evident from its impact on economic growth. However, the analysis performed in this study has not taken the impact of COVID-19 on the RAC sector into consideration. Since the modelling activity performed here has a long-term outlook till 2047, based on the historical trends on the population & GDP growth and RAC penetration level growth, the effects of the ongoing pandemic[1] are difficult to predict at present for a long term impact on the market growth.

1 The projections carried out in the current report may need to be revised in the coming years to access the effects of COVID-19 pandemic on the growth of RAC market in India.

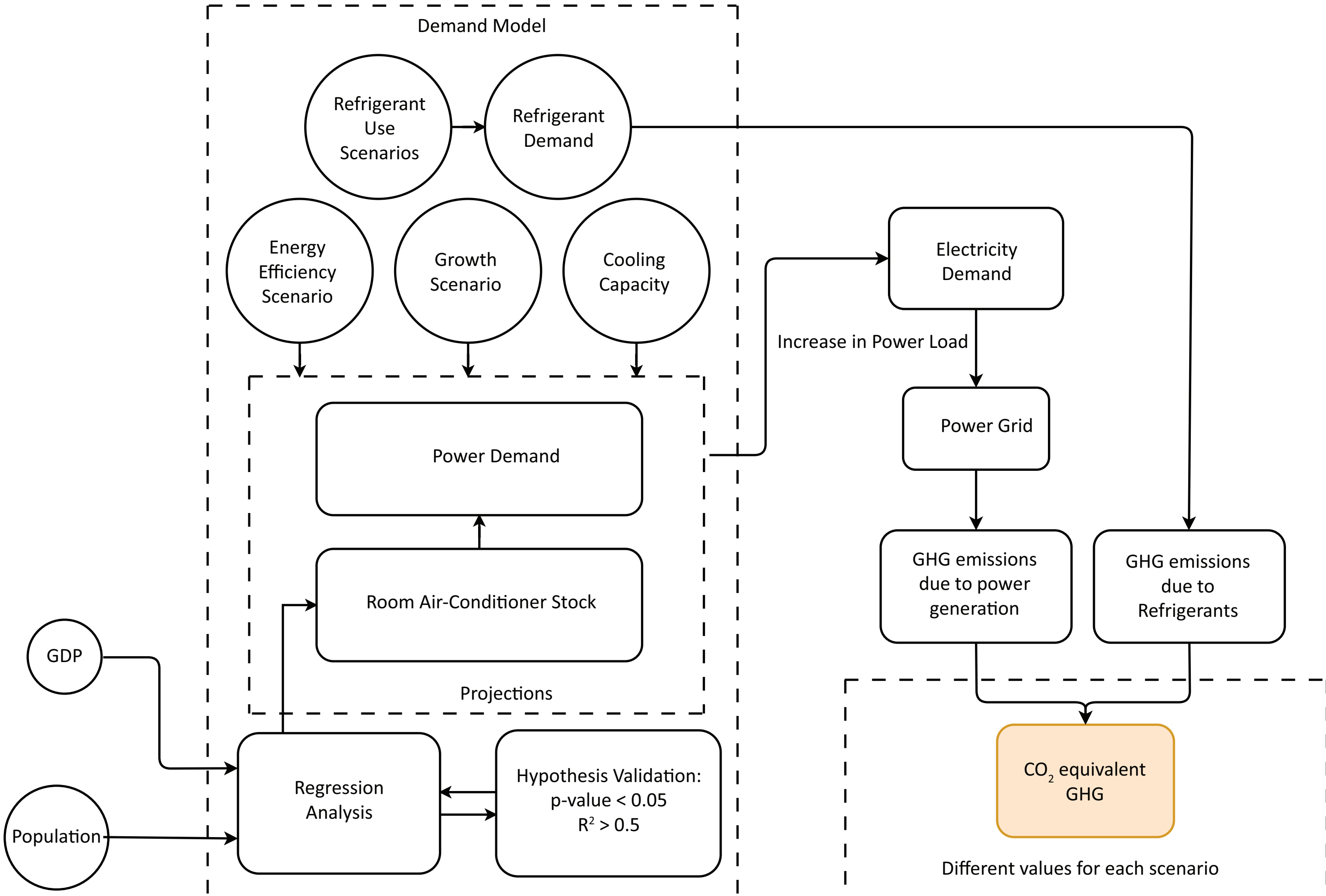

Figure 1 Methodology layout

Table 1 Macroeconomic factors

Reference Growth Scenario			Aspirational Growth Scenario	
Year	**GDP**	**Population (millions)**	**GDP**	**Population (millions)**
2011-12	4.50%	1228	4.50%	1228
2016-17	8.10%	1306	8.10%	1306
2021-22	6.20%	1388	8.10%	1388
2026-27	6.40%	1458	8.40%	1458
2031-32	6.40%	1526	8.40%	1526
2036-37	6.30%	1584	8.20%	1584
2041-42	5.20%	1639	6.50%	1639
2046-47	4.70%	1683	5.60%	1683

Figure 2 represents the combination of the scenarios developed for this study. Under the FT scenario, the average EER/ISEER of RACs remains stagnant at a constant value of 3.72 after 2019 till 2046-47. Higher the EER/ISEER rating value, more efficient the RAC system. The S&L scenario developed in this study is in-line with the Standards and Labeling programme and we have considered the rate of energy efficiency improvements same as the current rate of average efficiency improvement due to star rating program. There is a limitation to efficiency improvements as well and a constant continuous increase in the efficiency of an equipment should not be expected realistically owing to various constraints in the design of heat exchangers,

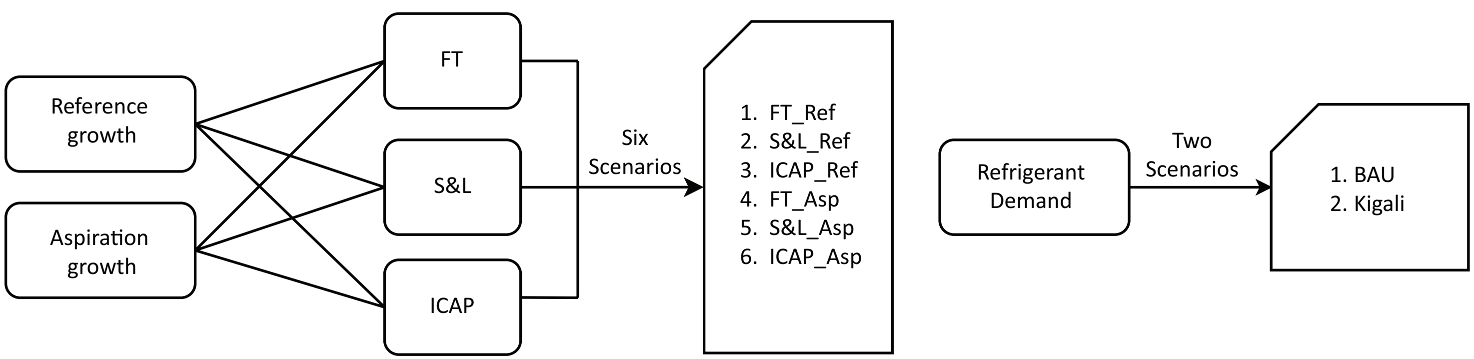

Figure 2 Developed scenarios

compressors, motors, etc. Similar to the S&L scenario, we have developed our third scenario – ICAP which takes the inspirations from the intend of the India Cooling Action Plan (ICAP, 2019) to double the MEPS upgradation rate.. In the ICAP scenario, the rate of efficiency improvement would grow at double the rate of S&L scenario throughout 2046-47 with the same step change in the rate of improvements with time. Under ICAP scenario, we have kept the EER/ISEER values a little bit ambitious, in order to achieve the broader targets and goals of the ICAP which are to reduce the electricity demand for cooling. Table 2 gives a detailed description of the developed energy efficiency scenarios. Figure 3 represents the average ISEER growth projections as per the table 2. Two scenarios are developed for the refrigerant use and demand, namely – Business as usual (BAU) and Kigali Amendment aligned (Kigali) scenario. Table 3 gives a detailed description about these scenarios. HCFCs would be phased out as per the India's commitment to the Montreal Protocol. The data on the refrigerant demand is based on the inputs from the various industry stakeholders on the refrigerant use and the available literature (Singh et al., 2019) (TERI et al., 2018) in the public domain. The forecasting has been performed on basis of the received inputs on the refrigerants under the BAU and Kigali scenarios.

Table 2 Energy Efficiency Scenarios

(Frozen Technology) FT	(Standards & Labelling)S&L	India Cooling Action Plan (ICAP)
ISEER remains stagnant at 3.72 till 2046-47	ISEER values follows the current growth trend i.e., ratcheting up of MEPS at a rate of 2.76% annually till 2029-30	Ratcheting up of MEPS happens at double the rate of current S&L programme, i.e., ISEER improves at a rate of 5.52% annually till 2029-30
	Rate of efficiency improvements in ISEER with a value of 1.7% annually between 2030-31 and 2039-40	Rate of efficiency improvements in ISEER with a value of 3.4% annually between 2030-31 and 2039-40
	Rate of efficiency improvements in ISEER with a value of 1% annually beyond 2040-41	Rate of efficiency improvements in ISEER with a value of 2% annually beyond 2040-41
ISEER value in 2046-47 would be 3.72	ISEER value in 2046-47 would be 6.37	ISEER value in 2046-47 would be 10.78
Average deterioration in efficiency of the units occurs at a rate of 2% annually	Average deterioration in efficiency of the units occurs at a rate of 2% annually	Average deterioration in efficiency of the units occurs at a rate of 2% till 2024-25 and gradually improves to 0.5% considering the efforts under ICAP implementation around training and certification of technicians and consumer awareness.

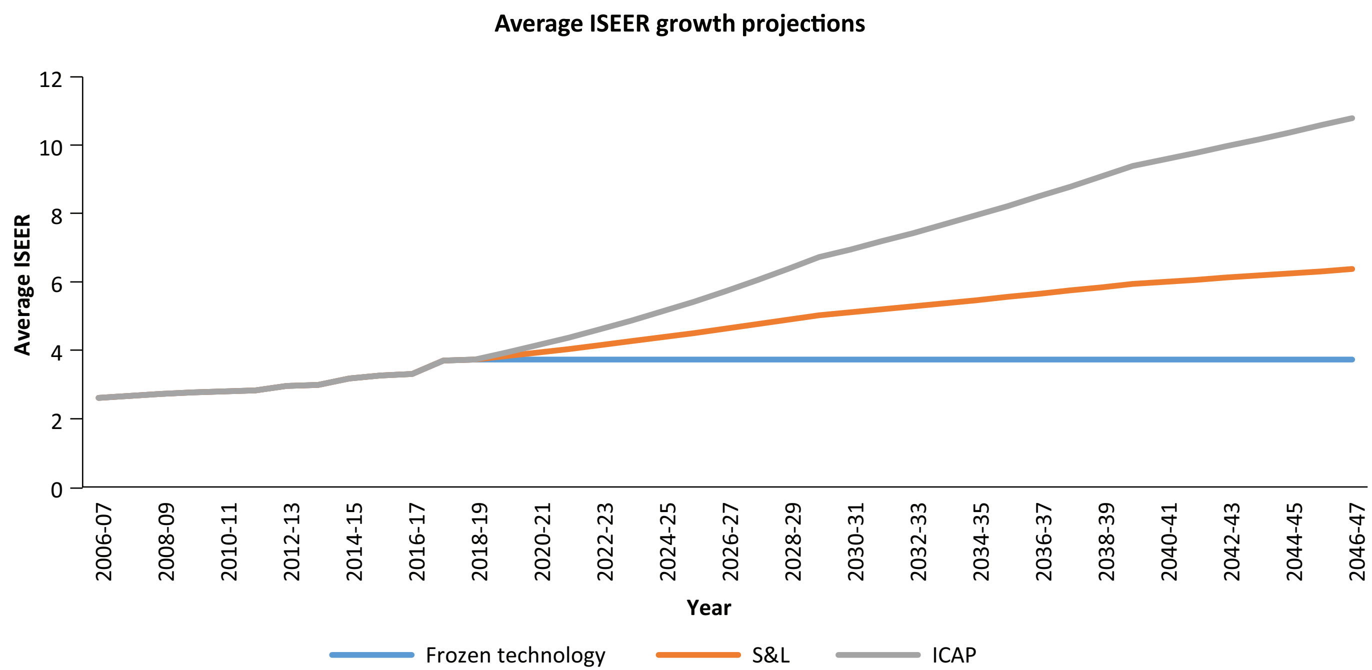

Figure 3 Average ISEER growth projection

Table 3 Refrigerant use scenarios

BAU	Kigali
HCFC will be phased out according to the Montreal Protocol and HPMP II	HCFC phase down in par with Montreal Protocol. Implementation of ICAP influences HFC use management
Predominantly HFC will replace HCFC	HFC rise not as steep as business as usual, owing to rise in low GWP refrigerant use and phase down of HFCs in par with Kigali Amendment
Increase in low GWP refrigerant's use shall remain gradual	Rapid rise in low GWP refrigerant

The approach for the econometric modelling activity is 3 layered involving the estimation of the RAC stock, the electricity and refrigerant demand; and the CO2e emissions from the RAC sector. The first layer of modelling estimates the stock of the air conditioners from the GDP and population growth as inputs. A top-down modelling approaches which includes regression and econometric analysis is used to evaluate the number of RAC stock. The second layer of the modeling is the demand model. The demand model is used to estimate the peak power demand, both at generation and consumptions end, and the electricity demand to operate the RACs and the refrigerant demand. Several important assumptions have been taken in accordance with the published literature such as life span of a RAC unit is taken as 10-year; peak coincidence factor of 0.7 (Phadke et al., 2014); T&D losses (Pachouri et al., 2018); and, annual operating hours for an RAC unit. The refrigerant demand model considers the refrigerant transition in accordance with India's commitments to the Montreal Protocol (Secretariat, 2020). The deterioration in the efficiency is considered as per the published literature (Matson et al., 2002), (Fenaughty & Parker, 2018) and aspects of expert servicing is taken into account under the ICAP scenario. The refrigerant market is expected to grow at a rate of 8.5% annually till 2026 and at a rate of 7.5% annually after 2027 (Singh et al., 2019). The third layer of the modelling estimates the CO2e emissions from the RAC sector. Both the direct and indirect emission are estimated in this study.

4
CURRENT STATE OF PLAY

There are various policy frameworks in place for promoting the energy efficiency in RAC sector. The programs run by government of India through BEE include S&L program, PAT scheme, ECBC and SEAD. The MoEF&CC launched ICAP to streamline the progress in cooling sector by clearly defining the goals. EESL is also running parallel programs to promote EE in RAC sector.

The Standards & Labeling (S&L) programme for equipment and appliances including RACs and 20 other equipment/appliances was initiated by the Bureau of Energy Efficiency (BEE) in 2006 to promote energy efficiency. This programme has played a pivotal role in transforming the outlook of Indian market towards energy efficiency of appliances and helped in establishing a clear viewpoint for the policy front to work towards energy efficiency and conservation policies. The MEPS and labeling program in India have contributed to about 43% of market average efficiency improvement for room air conditioners over the past 12 years. Additionally, a revised methodology for evaluating air conditioner performance in India has promoted better international market synergies and advancement in adoption of new energy-efficient technologies in the country. Even though, there have been substantial improvement in the Minimum Energy Performance Standards upgradation of around 38% in last 10 years as elucidated in the Figure 4, the efficiency improvement rate in the best available technology in India has been far more than MEPS ratcheting up. Indian market witnessed around 73% efficiency improvement in the best available room AC product from 3.6 EER in 2010-11 to 6.1 ISEER in 2019-20.

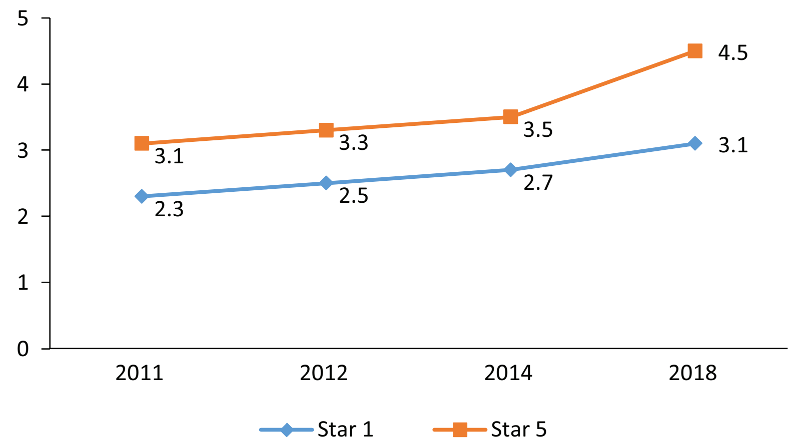

Figure 4 Standards upgradation trajectory in India
Source: BEE

The Energy Conservation Building Code (ECBC) by BEE provides the minimum requirements for the energy-efficient design and construction of buildings. ECBC is applicable for the new large commercial buildings with connected load of 100 kW and above or 120 kVA and above. The BEE is also looking up for scope of mandatory energy audits and implementation of energy efficiency upgrades in existing buildings as there is huge potential for energy conservation. There is rapid increase in residential building stock coupled with increase in electricity use for space cooling. BEE has launched energy codes for new buildings that are an important regulatory measure for ushering energy efficiency in the residential building sector (BEE, 2018).

The India Cooling Action Plan (ICAP) was released in March, 2019 by Ministry of Environment, Forest, and Climate Change (MoEF&CC) is a comprehensive document aimed to address the cooling requirements across sectors with recommendations for a 20-year time horizon. The ICAP lists out the actions required to reduce the cooling demand in the country. ICAP identifies the cooling requirements as cross sectoral and as essential part for the economic growth across sectors such as residential and commercial buildings, cold chains, refrigeration, transportation and industry. The plan provides an integrated vision towards cooling across sectors encompassing inter alia reduction of cooling demand, refrigerant transition, enhancing energy efficiency and better technology options.

The Super-Efficient Equipment and Appliance Deployment (SEAD) is an initiative by Clean Energy Ministrial and the International Partnership for Energy Efficiency Cooperation. SEAD aims to make it easier for governments and the private sector to capitalize on reducing energy demands and carbon emissions while lowering energy costs for consumers, businesses, and institutions. SEAD initiative fosters collaboration among its participating governments to strengthen their standards and labeling programs to more quickly keep pace with technology, and to work together on incentives, prizes, and procurement programs that can spur the development of super-efficient devices.

Energy Efficiency Services Limited (EESL) is a Super-Energy Service Company, which enables consumers, industries and governments to effectively manage their energy needs through energy efficient technologies. EESL's bulk procurement programs are step towards providing the super-efficient RACs to people at competitive prices using economy of scale. With the goal of integrating energy efficiency into India's cooling sector, EESL has initiated a first of its kind, Super-Efficient Air Conditioning programme. Consumers can buy the Super-Efficient Air Conditioners distributed by EESL at prices that are comparable to the most energy-efficient ACs in the market. These Super-Efficient ACs will provide 1.5-TR cooling capacity at high ambient temperature while also reducing the cost of cooling by 50%. Under the first phase, EESL will distribute 50,000 super energy-efficient and environment-friendly ACs accros India by partnering with different state discoms.

The Global Cooling Prize is rallying a global coalition of leaders to solve the critical climate threat that comes from growing demand for residential air conditioning. It is an innovative competition to develop a climate-friendly residential cooling solution that can provide access to cooling to people around the world without warming the planet. This groundbreaking competition is designed to incentivize development of a residential cooling solution that will have at least five times (5X) less climate impact than standard Residential/ Room Air Conditioners (RAC) units in the market today. This technology could prevent up to 100 gigatons (GT) of CO_2-equivalent emissions by 2050, and put the world on a pathway to mitigate up to 0.5˚C of global warming by 2100, all while enhancing living standards for people in developing countries around the globe. Daikin and Gree have won this competition and their technology intervention to improve the efficiency of the air-conditioning system is innovative as both have integrated evaporative cooling in their technologies.

The present technology available in the market for RACs dominantly use vapour compression refrigeration and keeps modernizing the features in the newer products. The major change in the RAC technology observed in the recent years is the introduction of inverter based compressors which have improved the efficiency of the RACs to a great extent. The transition from the fixed speed to inverter compressors has sharply increased in the last five years to meet MEPS requirements (TEAP, 2019). The improvement in the design of heat exchangers with the introduction of smaller diameter tubes and micro-channels has also contributed in the efficiency improvement of the RACs. The smaller diameter fin and tube type heat exchangers are enabling medium and lower GWP refrigerant RACs to comply with safety standards and reducing the refrigerant charge (TEAP, 2019). The majority of the R&D efforts are towards the development of energy-efficient equipment with low and medium GWP refrigerants that exceeds the MEPS by 10% or more. According to the TEAP 2019 report, the refrigerants available in new builds of RACs have 85% share of R-410A, 10% share of R-32 and 5% share of R-22 in south eastern Asian countries. Owing to the phase-out schedules of HCFC, new R-22 (ozone depleting) based units are not developed for higher efficiency grades and imports are not allowed in India. There is push in Indian market to leapfrog during the transition from R-22 to lower GWP alternatives and skipping the R-410A. The predominant alternative R-32 is considered market ready by nearly all manufacturers and it offers 75% reduction in climate impact compared to R-410A (TERI et al., 2018). The R-290 is already penetrating the Indian market which boasts its low GWP value of 3 (Calleja-Anta et al., 2020). The next big technological improvement in the RAC technology is going to be introduction of internet of things. Many manufacturers have started to offer products with app control of ACs through wifi. These mobile applications offer many control and monitoring options of ACs which can optimize the daily operations and can suggest schedules for timely and preventive maintenance of the equipment.

5 RESULTS AND DISCUSSION

In this section, we present an overview of aggregate results of various scenarios studied in this report. As mentioned in the methodology, direct and indirect emission are being projected from the RAC sector. Market growth and stock projections against the macroeconomic indicators have been conducted to assess the electricity demand at the supply side and demand side from the sector.

RAC stock growth

The figure 5 shows the projections of the RAC stock over the years under reference and aspirational scenarios. The projections clearly show the impact of economic and population growth on the access of cooling to the people in the country. The RAC stock under the reference scenario is projected to grow to over 265 million units in the year 2046-47, which is approximately 6 times the RAC stock in 2018-19. Whereas if look closely at the aspirational scenario, the growth projections for the RAC stock shows a whopping increase of about 9 times with a value of 402 million units in the year 2046-47 in comparison to 2018-19. The trend in the RAC stock growth projection shows a compound annual growth rate (CAGR) of 6.51% for the reference scenario and 8.09% for the aspirational scenario.

The RAC stock projections suggest that there is a need to monitor the huge increase in the equipment in terms of the energy-efficiency and environmental implications of the RAC units. Currently, RAC penetration in India is low and the results suggest massive growth in the stock numbers. Keeping in the view, it could be argued that most of the incoming pool of AC consumers would-be first-time buyers. Some of the studies suggest an abrupt increase in AC stock in the immediate future, however, our results suggest a high growth for a slightly longer duration of around 30 years.

Provided the large new ownership consumer pool might pose a challenge of locking in obsolete technologies as they would rather prefer cooling service with low cost over energy efficiency due to low awareness about operational cost challenges. As the figure 5 suggests, the stock of RACs is going to get doubled in coming 6-8 years of time, the need for a framework to influence the purchasing decision of the consumers towards the energy-efficient and low GWP based cooling

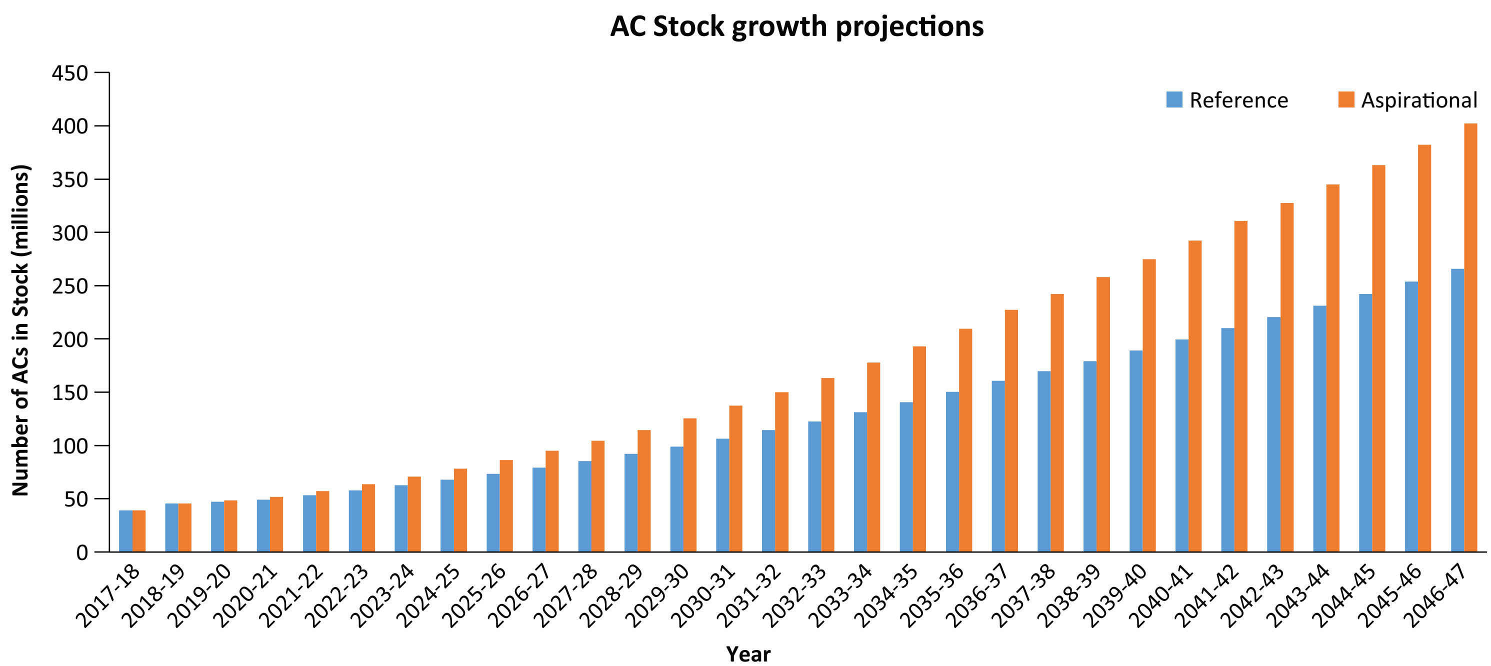

Figure 5 RAC stock growth projection

appliances and encouraging the manufacturers towards developing energy-efficient is imperative. The India Cooling Action Plan (ICAP) recognizes "cooling" as an important thrust area under national science and technology programme to support development of technological solutions and encouraging innovation challenges. The aspiration to make the cooling accessible for all can be made possible through the development of energy-efficient and not-in-kind cooling technologies which are not only affordable but should be omnipresent.

Demand model

Power demand at consumption end

The high growth of refrigerant based personal cooling equipment are expected to have high impact on electricity grid. Connected load and thereby the electricity demand have been projected with 0.7 coincidence factor. The figure 6 and 7 shows the power demand projections for the RAC sector at the

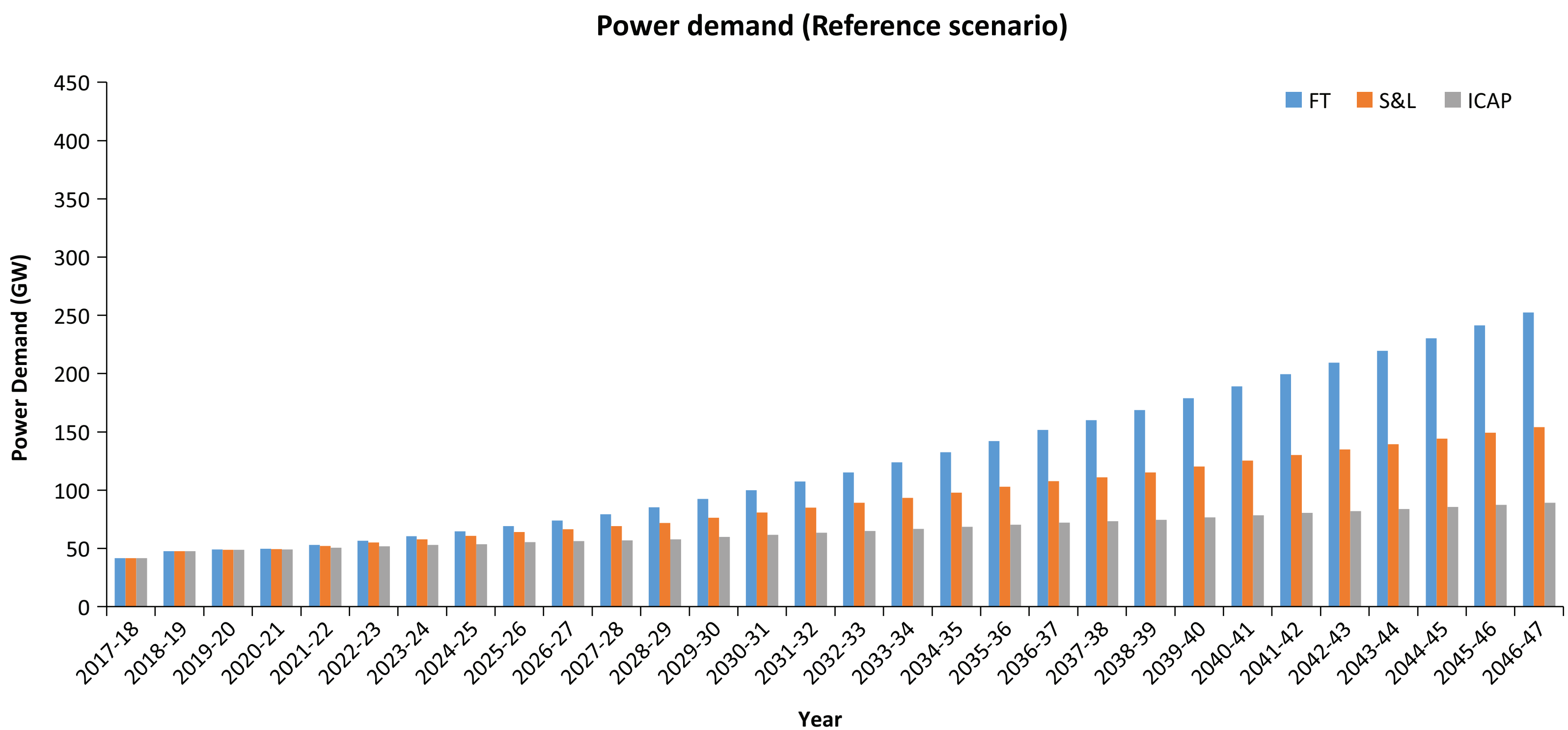

Figure 6 Power demand at consumption end (Reference scenario)

consumption end side for the reference and aspirational scenarios respectively. The Frozen technology scenario presents horrible picture and estimated to reach 400 GW power demand by 2047 in the aspirational scenario from room AC only, and yes, this is not the total HVAC demand. The number is even more than India's total installed capacity in 2018. Star rating scheme for ACs through its "Push-Pull" mechanism has resulted in substantial capacity avoid. Efficiency improvement through pushing standards upgradation and pulling the consumer demand for efficient products through providing energy information using labels, has been one of the most cost-effective tools to move the market towards efficiency.

However, the massive stock growth and thereby electricity demand provides opportunity to cater substantial gain from efficiency improvement, government has shown it's intend through promoting aggressive standards upgradation under India Cooling Action Plan.

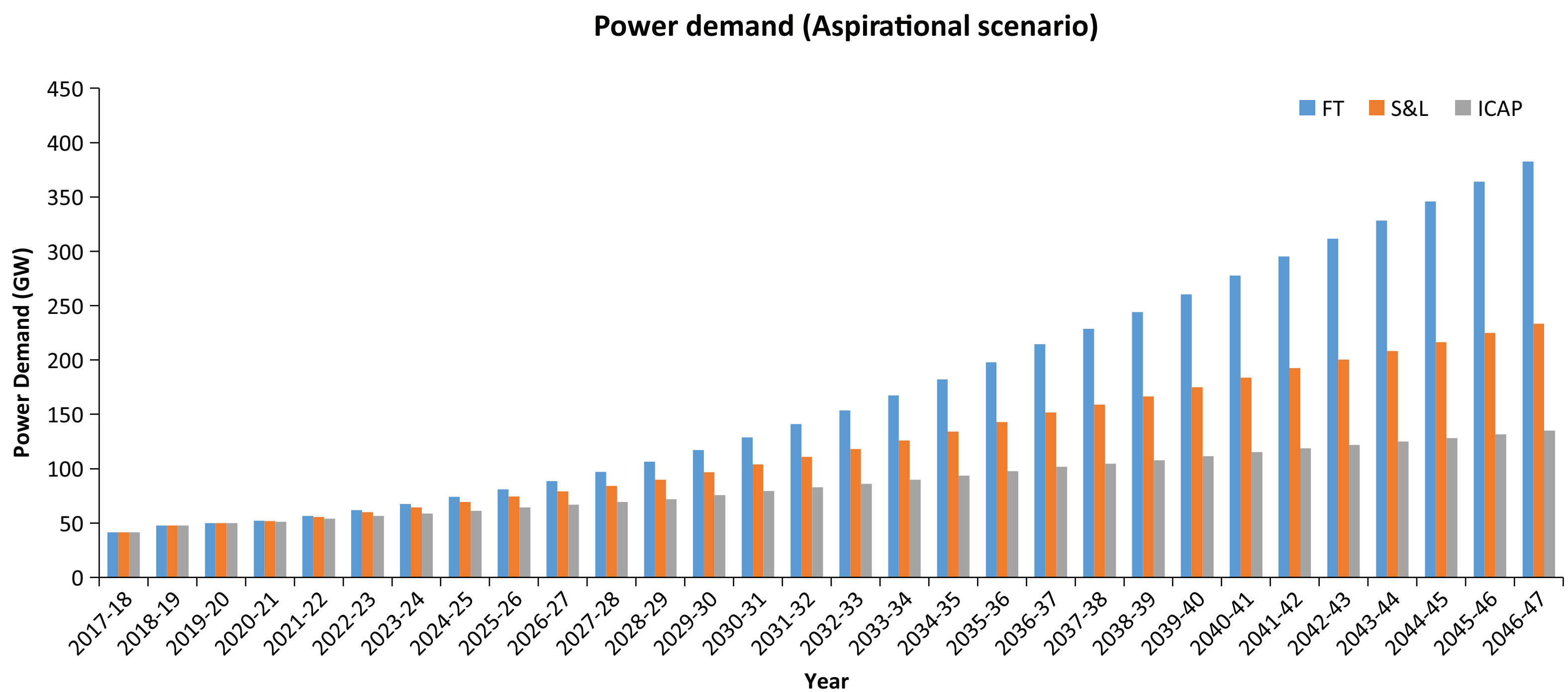

Figure 7 Power demand at consumption end (Aspirational scenario)

It is also evident from the ICAP scenario in the study as the ICAP scenario shows a reduction in power demand of 163 GW under the reference scenario and of 248 GW under the aspirational scenario in the year 2046-47. The objective of the frozen technology scenario used in this study is to benchmark the projections made from the S&L and ICAP scenarios. From the figure 6 and 7, we can observe that the reduction in the cooling energy requirements from the S&L scenario are over 30% and from the ICAP scenario are over 54% in the year 2037-38 under both the reference and aspirational growth scenarios respectively.

Power demand at generation end

The figure 8 and 9 shows the power demand projections for the RAC sector at the generation end side for the reference and aspirational scenarios respectively. The figure 8 and 9 have a similar interpretation as of figure 6 and 7. The ICAP scenario shows a reduction in power demand of 187 GW under the reference scenario and of 283 GW under the aspirational scenario in the year 2046-47. The objective of the frozen technology scenario used in this study is to benchmark the projections made from the S&L and ICAP scenarios. We have a similar reduction in the cooling energy requirements from the S&L and ICAP scenarios as the last section. One of the objective of the India Cooling Action plan is the reduction of cooling energy requirements by 25% to 40% by year 2037-38, and both of the S&L and ICAP scenarios developed in this study are able to achieve this target. It is interesting to note here that the ICAP scenario is able to overachieve the action plan's targets. The realization of the benefit from the adoption of the ICAP scenario in comparison of

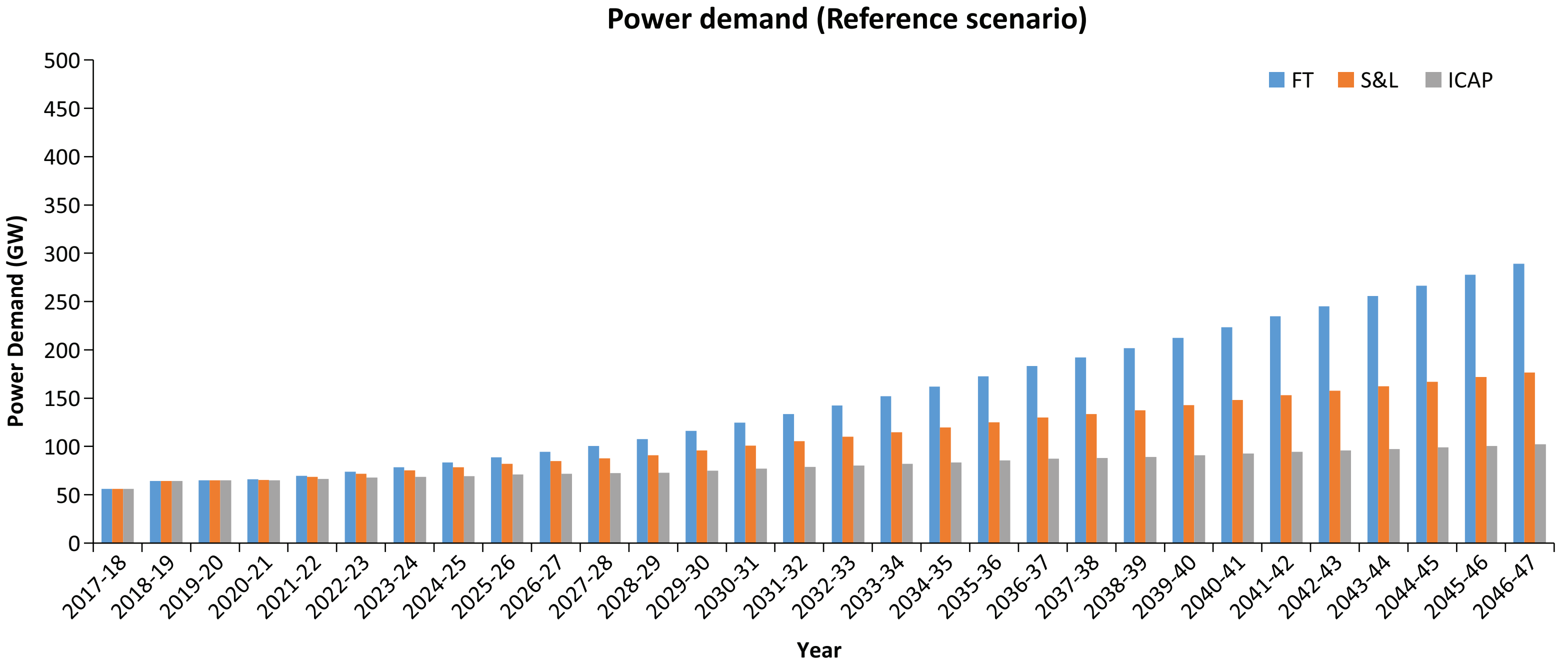

Figure 8 Power demand at generation end (Reference scenario)

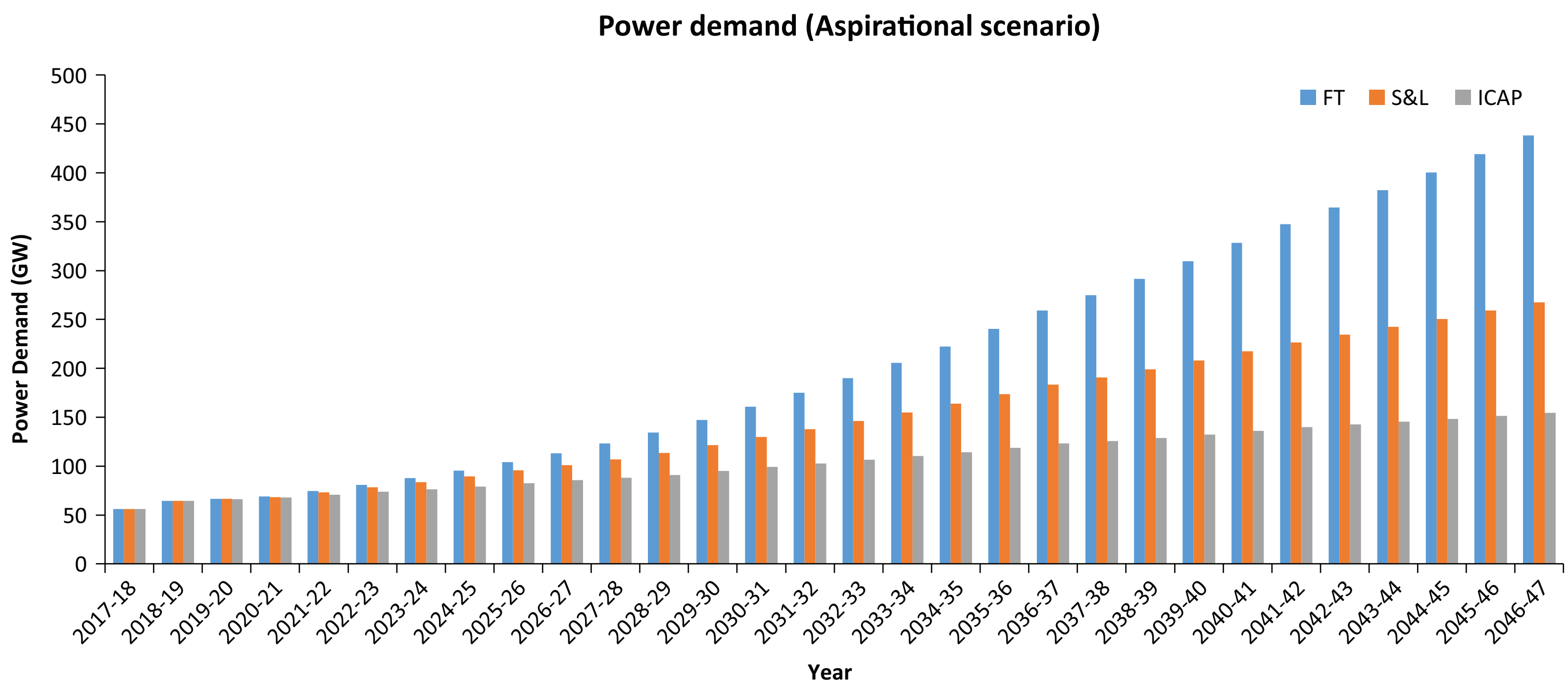

Figure 9 Power demand at generation end (Aspirational scenario)

S&L scenario can be understood from the potential of saving from the cost of developing new 225 power plants of 500MW generation capacity each by 2046-47 under aspirational scenario.

Electricity demand

The figure 10 and 11 shows the electricity demand projections for the RAC sector at the generation end side under the reference and aspirational scenarios respectively. The ICAP scenario shows a reduction in the electricity demand of 299 TWh under the reference scenario and 453 TWh under the aspirational scenario in the year 2046-47. The reduction in electricity demand by the ICAP aligned policy intervention show a very promising step forward towards the India's NDCs from the RAC sector and overall contribution of cooling towards Paris Agreement.

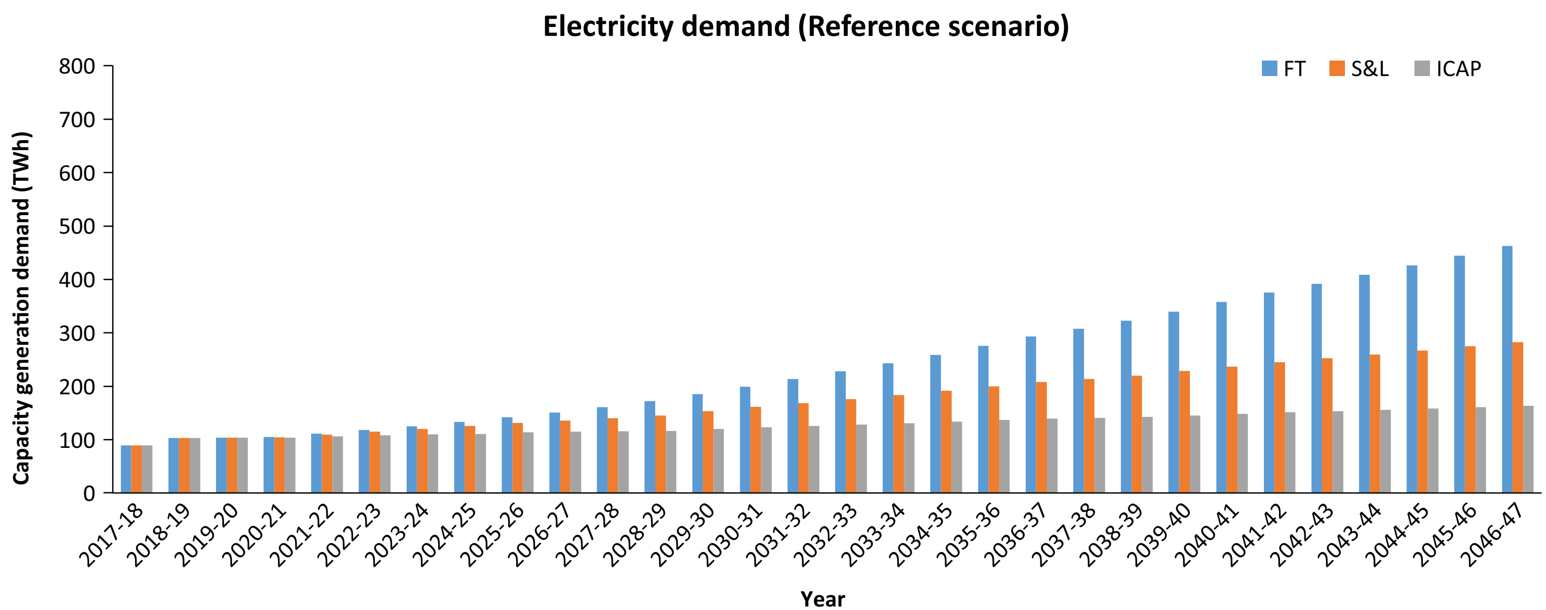

Figure 10 Electricity demand (Reference scenario)

The power demand analysis for operating the RAC holds a significant point of view on the energy security front for the country. Since the present contribution of the RACs power demand in the urban centers is substantial, it becomes an important area of consideration for the policy interventions to set the direction of energy use and reforms in the country. One of the objectives under the India Cooling Action Plan (ICAP) is to reduce the cooling energy requirements by 25% to 40% by the year 2037-38. Regularly ratcheting up of the MEPS can help support this target set by the ICAP provided enough thrust on the innovation and development of the energy-efficient cooling technologies with the collaboration of the industry and the academia. The scenarios developed in this study provides a background and perspective for the policy interventions required to meet the ICAP targets. The S&L and the ICAP scenarios are reflective of the intentions to promote the energy-efficiency initiatives in the cooling sector. The servicing of the cooling equipment plays a crucial role in maintaining the proper functioning of the appliance, preventive maintenance and ensure energy-efficiency over its lifetime. The aspect of the servicing is well incorporated in the ICAP scenario of the present analysis along with ambitious improvement in the MEPS of the cooling equipment. Both these factors project an optimistic view of the policy action by flattening the curve for the capacity generation by the mid-century. These actions can be realized through a well throughout framework to bring out a market transformation towards energy efficiency.

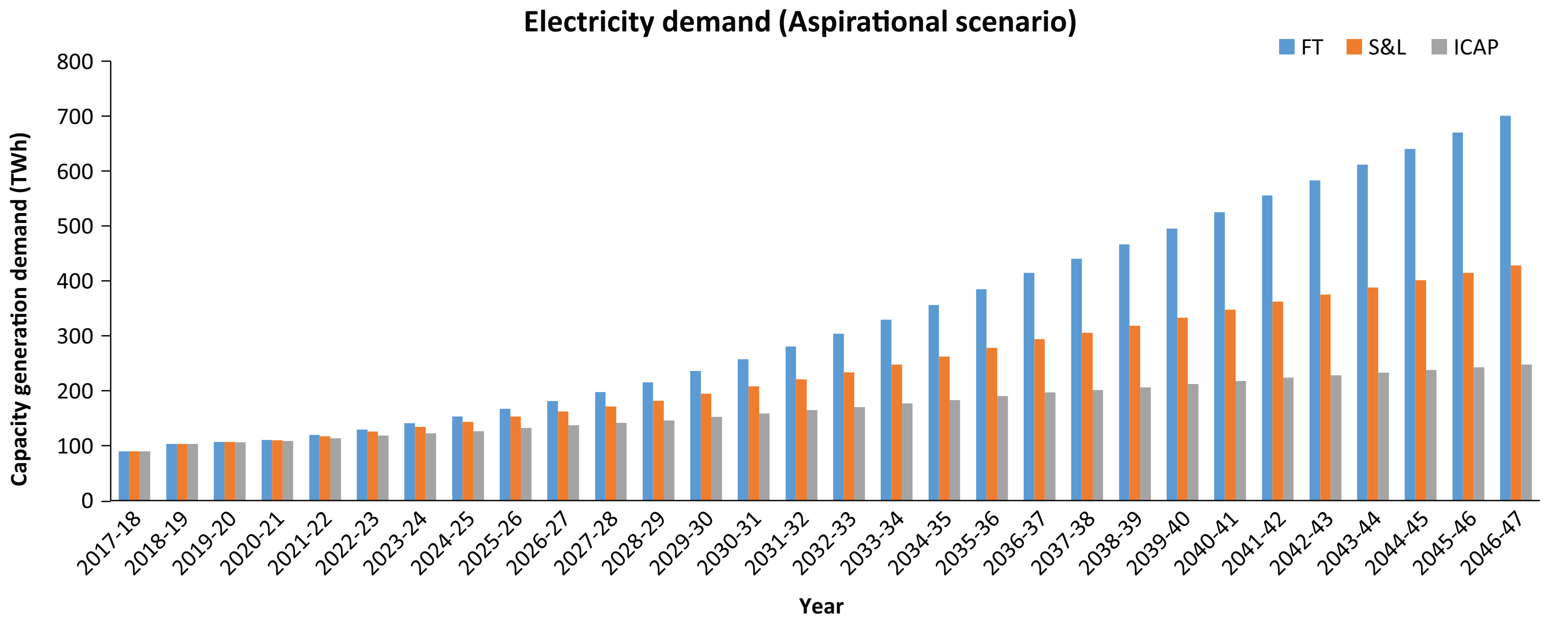

Figure 11 Electricity demand (Aspirational scenario)

Refrigerant demand

The figure 12 and 13 represents the refrigerant production trends for the RAC sector under the BAU and Kigali scenarios. The scenarios are described earlier in the methodology section. Under the BAU scenario the transition mainly happens from the HCFCs to HFCs with a low share of low GWP refrigerants. Figure 12 clearly shows that in 2046-47, almost every refrigerant used is a HFC under the business as usual scenario. The figure 13 brings out a more positive picture as the transition from the HFFCs supports both HFCs and other low GWP refrigerants. The low GWP refrigerants takes over the HFCs in terms of production capacity in mid 2030s, thanks to the phase down schedule of HCFs under the Kigali Amendment of the Montreal Protocol.

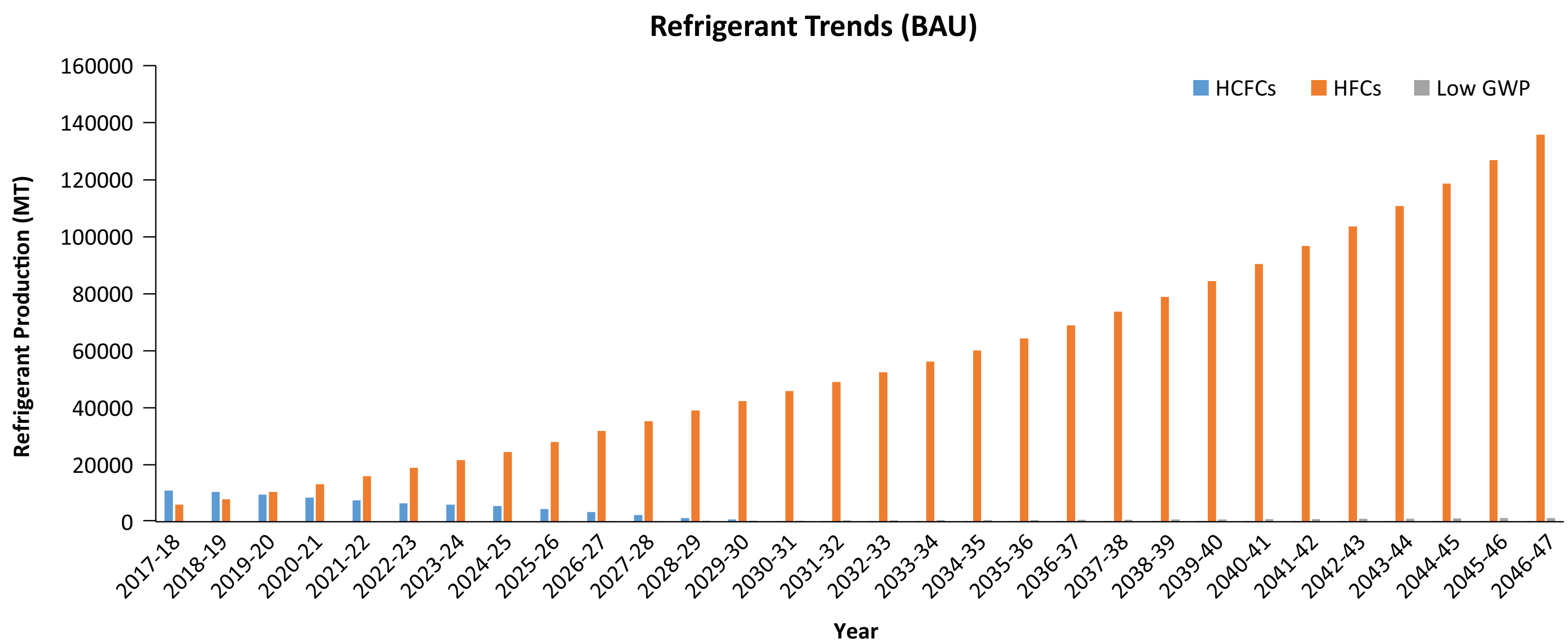

Figure 12 Refrigerant trends (BAU scenario)

The Kigali scenario developed in this analysis highlights the aspirational refrigerant transformation towards the low GWP refrigerants while phasing down the HFCs and phasing out HCFCs. The leapfrogging by India from HCFCs to low GWP refrigerants require a push from the government in terms of a clear refrigerant policy to support the low GWP refrigerants in terms of their development, domestic production and availability in the market. The ratifications status of Kigali Amendment of the Montreal Protocol for India is pending currently but the government has shown positive steps by realizing the India Cooling Action Plan (ICAP) which in principle follows the Kigali Amendment. The ICAP focuses on the development and indigenous production of the refrigerants and one of its target is to reduce the refrigerant demand to 25% to 30% by the year 2037-38. The average tonnage of the RACs is evaluated to be approximately 1.3 TR in this analysis and we believe that this figure can be reduced with the help of passively reducing the cooling loads in the buildings. The lower average tonnage of RACs can boost the ICAP target of reducing the refrigerant demand.

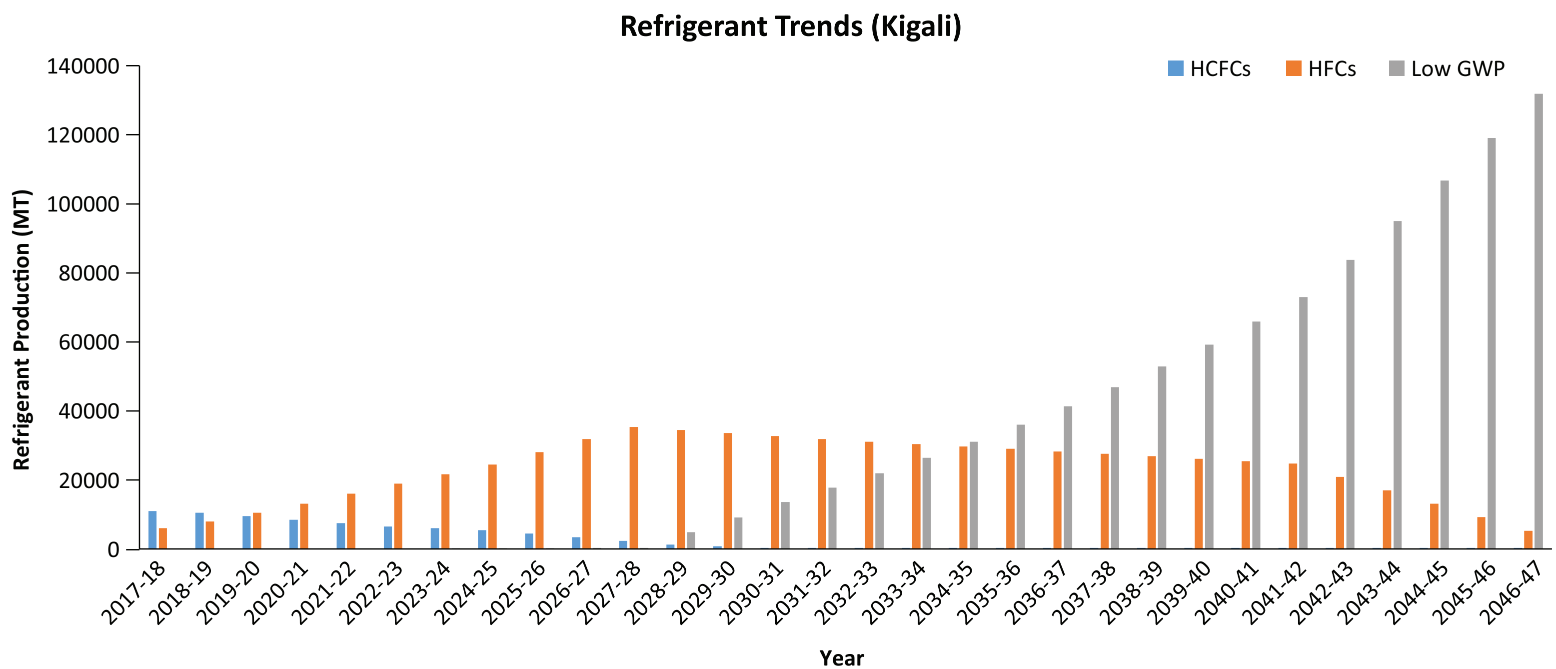

Figure 13 Refrigerant trends (Kigali scenario)

Emission estimations

Direct emissions

The figure 14 represents the CO_2 equivalent direct emissions from the RAC sector under the BAU and Kigali scenarios. The BAU scenario provides a benchmark for us to compare the effectiveness of the Kigali scenario in terms of environmental effects. The Kigali scenarios shows a very promising picture in controlling the direct emission from the RAC sector and there is huge difference in the levels of the emissions when compared with BAU scenario. The Kigali scenario is able to achieve the reduction in the emissions as per the Montreal protocol's phase out schedule supports the low GWP refrigerants.

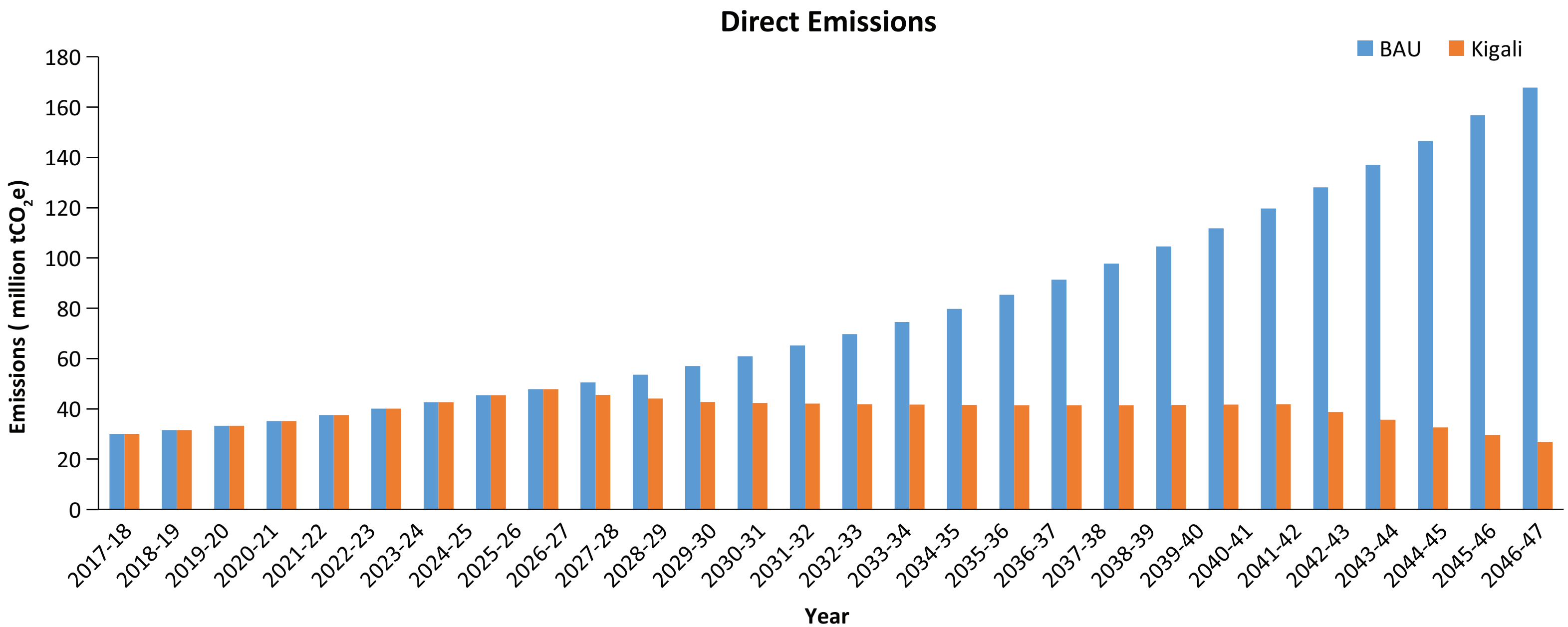

Figure 14 CO_2 equivalent direct emissions estimation for the RAC sector

Indirect emissions

The figure 15 and 16 shows the indirect emissions from the RAC sector with different energy-efficiency scenarios under reference and aspirational growth scenarios respectively. The reference scenario shows a very soothing picture for the RAC sector as the direct emissions are continuously decreasing under the ICAP policy intervention. Even the ICAP under the aspirational scenarios also highlights the decrease in the indirect emissions after 2037-38 and before this the curve for emissions flatten after a brief increase in emissions in 2020s. One thing from the figures 15 and 16 is clear that no matter which scenario we observe, the emissions always flatten before mid-century and even starts to decrease with the increase in number of RACs. There are huge benefits in terms for reduction of carbon emissions for opting the ICAP policy intervention as compared with the S&L programme. The analysis shows that ICAP scenario saves over 40% more than the S&L scenario after mid-2040s.

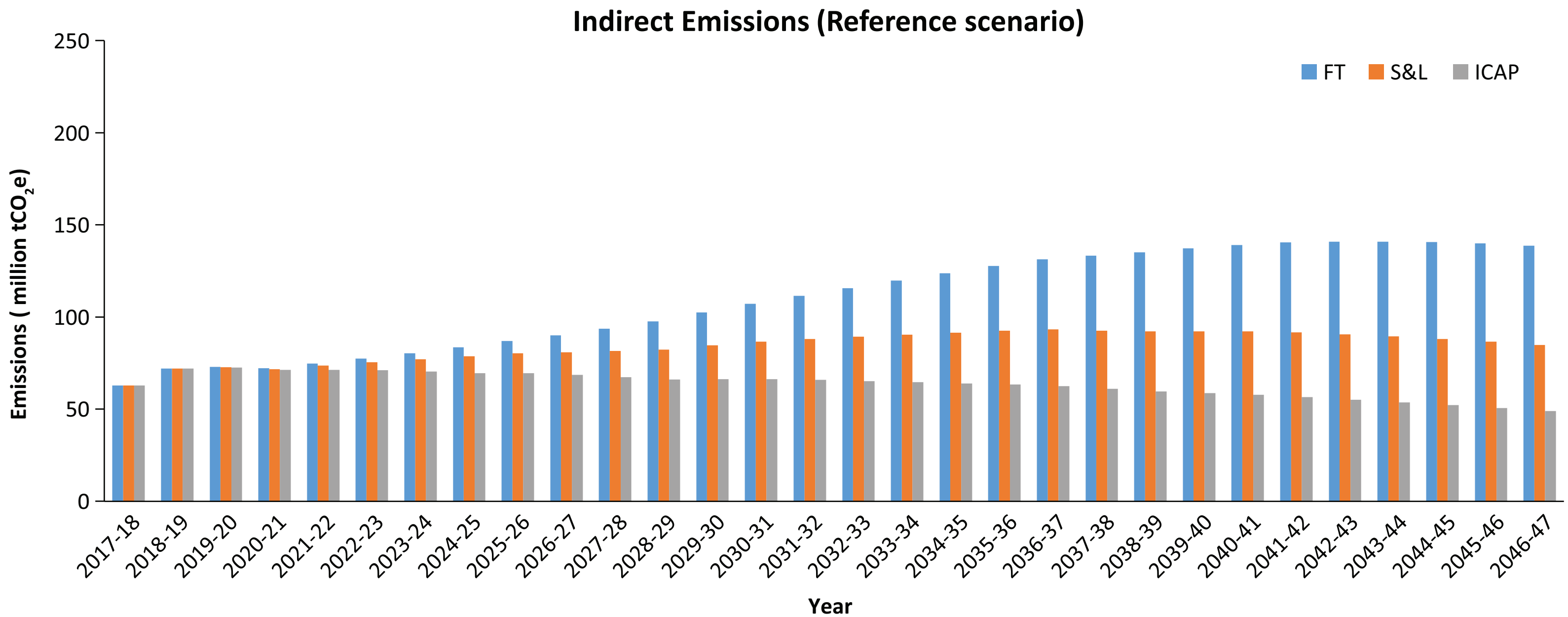

Figure 15 CO_2 equivalent indirect emissions estimation (Reference scenario)

The analysis carried in the above sections of the report has bought out the ICAP scenario to be the best way forward. The analysis has shown that the successful ICAP implementation could avoid 187.016 GW capacity and save around 300 BU of electricity which would bring the 1.5[1] lakh crore rupees of monetary benefit for the economy as per the reference scenario.

1 We have considered the rate of electricity as INR 5/unit for the purpose of easy calculation.

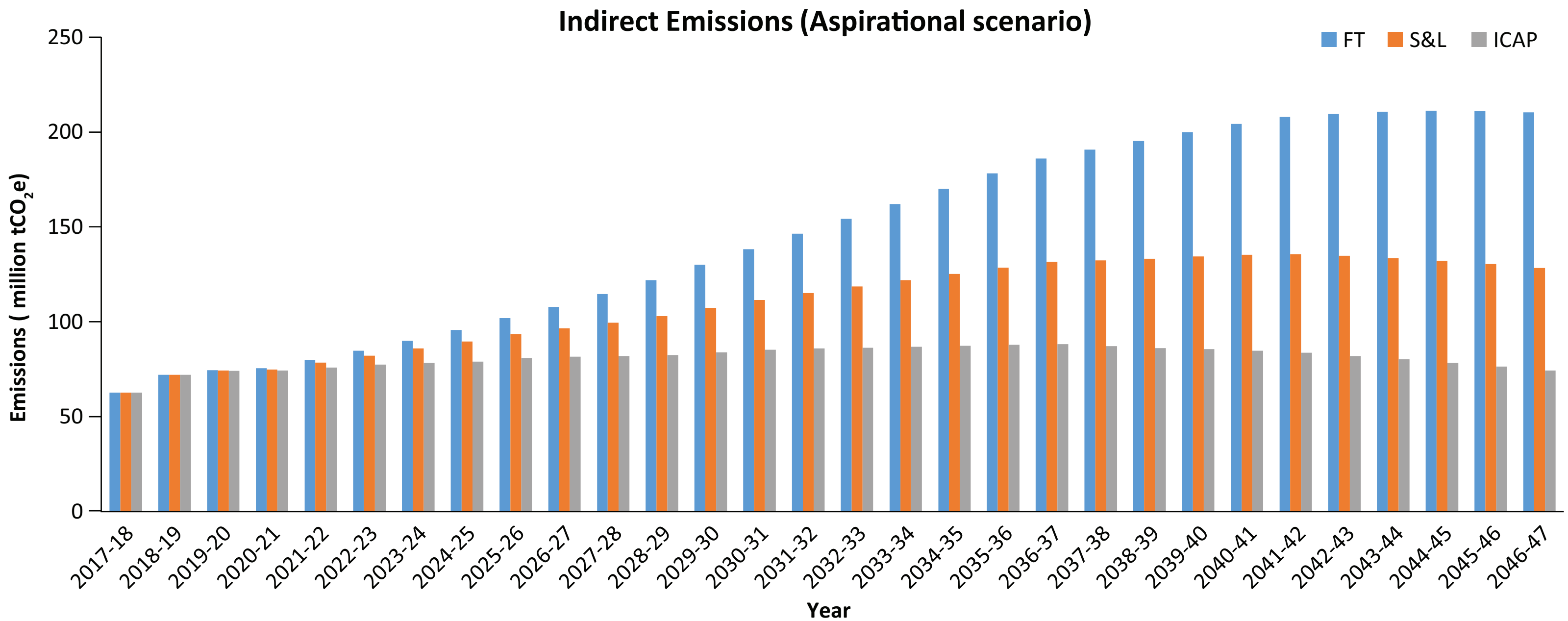

Figure 16 CO_2 equivalent indirect emissions estimation (Aspirational scenario)

6 RECOMMENDATIONS

The preceding sections have presented various projections and analysis which have led to a number of conclusions and recommendations. This section provides recommendations based on the qualitative and quantitative insights gathered in the course of the present study and may be helpful for various stakeholders engaged in the RAC sector.

The analysis in the previous sections suggests that the best case scenario to achieve the electricity savings, emission reduction and to promote the energy efficiency and low GWP refrigerant is the ICAP scenario. With rapidly growing economy and increasing global average temperatures, the demand for RACs in India is going to boom. Policies and programs promoting and supporting energy efficiency and sustainable cooling are needs of the present time. Synergetic actions to bring the market transformation towards energy efficiency in the RAC sector is required. Programs like the S&L from the BEE should be promoted more with inclusion of new parameters to classify the equipment. These classifications should include the aspect such as regular servicing plans with appliance, nature of refrigerant used, and recyclability of the appliance, etc.

The analysis has shown that there is a certainty of total RACs units in the country to get doubled in next 7-10 years. The energy efficient and right sized equipment with low GWP refrigerants might be the right strategy to promote sustainable technology if any disruptive technology is not developed in short term. Market transformation business models like the bulk procurement program can provide a necessary push to the newer cooling technologies that are energy-efficient. Such business models are effective in checking the affordability of the appliances and makes pathways for the newer technology to be taken up by the consumers. The analysis suggests that the adoption of energy efficient sustainable cooling technologies is best way forward both in terms of lower operational costs and environment.

There is need for recycling and refurbishment policy for the RAC equipment to ensure its safety and energy-efficiency. The industry in collaboration with the government can find ways to come up with such a recycle mechanism which is in the benefit of all the stakeholders. The cooling servicing sector has a large potential to provide employment and regulate the cooling sector. The institutional strengthening through the servicing can be achieved on the ground, and the energy efficiency of the appliances and proper handling of the refrigerant can be ensured. A universal certification program to train and skill the current and future servicing personnel workforce can equip the country with skill reliability in the cooling sector.

The following table recommends the actions required for various fronts in the RAC sector.

Policy
• Adoption of ECBC codes across all the local bodies in the country. • Promoting the adoption of low GWP refrigerants • Supporting the super-efficient appliance programs • Mandatory servicing plans for bigger establishments to ensure energy-efficiency.
Institutional strengthening
• Improvement in MEPS at double the current pace of ratcheting up. • Universal certification of the servicing personnel. • Time bound training programs to upskill the current workforce of service technicians.
Market transformation
• Successful implementation of the EESL bulk procurement program. • Deployment of super-efficient air-conditioners through bulk procurement model.
Industry
• Drive innovation in the development of the conventional and not-in-kind cooling technologies. • Design recycle models • Upgradation and refurbishment plans of existing RAC units.
Behavioural change and communication outreach
• Design and implementation of consumer awareness programs towards energy efficiency and low GWP refrigerants. • Promoting the India Cooling Action Plan among all the personnel in the cooling industry.

7 CONCLUSION

The RAC sector in India had been experiencing rapid growth in the recent years and our analysis suggests that it would further keep on increasing in the future as well and even at an accelerated pace. The rising average global temperatures, increasing population and economic growth of India indicates the high potential of growth of RAC sector. The present study has been able to model the RAC demand from the population, GDP and penetration data and further estimated the power, electricity, and refrigerant demand with the possible emissions from the RAC sector. The modelling study has developed various scenarios based on the growth, energy-efficiency and refrigerant transition to analyze the RAC sector.

The impact of S&L and the ICAP scenarios discussed in the previous sections in comparison with the frozen technology scenario in terms of electricity savings and emission reduction can be understood from the below table.

Year	S&L		ICAP	
	Electricity savings (TWh)	Emission reduction (million tCO_2e)	Electricity savings (TWh)	Emission reduction (million tCO_2e)
Reference Scenario				
2026-27	15.237	9.09	35.984	21.46
2036-37	85.221	38.19	153.609	68.84
2046-47	180.08	54.02	299.266	89.77
Aspirational scenario				
2026-27	19.034	11.35	44.017	26.25
2036-37	121.383	54.40	218.033	97.71
2046-47	273.174	81.95	453.567	136.07

There is a clear indication of the environmental benefits of the policy actions that are driven by the sustainability. The impact of these policy actions is very vast as it not only saves the electricity though the implementation of energy-efficiency, but highlights the scope of emission reductions which can help India achieve its NDCs in conformation of Paris Agreement.

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