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Can ICAP's residential cooling electricity demand projections be met: An assessment using PIER

June 2022

Saurabh Lale[1], Shweta Kulkarni, Prayas (Energy Group)[2]

Important policies like the ICAP have the potential to channelize energy efficiency efforts in the desired direction while also meeting India's developmental needs. In this exercise, we tried to decode ICAP recommendations for the residential cooling electricity demand to derive actions required to achieve the targets specified by ICAP. Further we analysed the impact of these recommendations on electricity demand for space cooling appliances like ceiling fans, air conditioners, and refrigerators using the PIER model. The results of the same have been shared in this article

Introduction

The India Cooling Action Plan (ICAP) was introduced by the Ministry of Environment, Forests and Climate Change (MoEFCC) in September 2019. ICAP provides a 20-year perspective and recommendations to address the challenges of increasing energy demand for cooling and refrigerant usage.

Rumi is an open-source energy-systems modeling platform developed by Prayas (Energy Group) with a focus on demand-oriented modeling. PIER (Perspectives on Indian energy based on Rumi) is an India energy model built with Rumi. Both Rumi and PIER are available publicly as github repositories. PIER includes a detailed bottom-up residential demand projection model, which currently estimates demand up to FY31.

The objective of this analysis is to model the impact of ICAP recommendations specific to residential cooling electricity demand using PIER. The results of this effort can help to evaluate the relative

[1] The authors thank their colleagues Srihari Dukkipati, Ashok Sreenivas, Narendra Pai, Atul Kharabe, Aditya Chunekar for their valuable inputs and review of the draft.

[2] This article is part of an ongoing series called Power Perspectives which provides brief commentaries and analyses of important developments in the Indian power sector, in various states and at the national level. The portal with all the articles can be accessed here: https://prayaspune.org/peg/resources/power-perspective-portal.html. Comments and suggestions on the series are welcome and can be addressed to powerperspectives@prayaspune.org.

impact of ICAP recommendations on reduction in overall residential cooling electricity demand and the feasibility of their implementation. ICAP has provided specific targets which are to be achieved by 2037-38, along with recommendations that can help achieve these targets (see Table 1). In this analysis, impact of recommendations for the residential sector related to building envelope, space cooling appliance ownership and efficiency of air conditioners, ceiling fans and coolers, and effect of AC set point temperature on electricity demand have been modeled using PIER.

Area	Target	Recommended actions	Remarks
Overall Target	Reduction of cooling energy requirements by 25% to 40% by year FY38.	This reduction is to be achieved through various measures like improved stock efficiency, encouraging usage of 5 star appliances, adapting to new technologies which are more efficient, and ensuring proper operation and maintenance of cooling equipment.	
ECBC	Reduction of cooling demand across sectors by 20% to 25 % by year FY38	The reduction in demand across sectors is expected to be achieved by improvements in building envelopes etc.	
AC	Steady growth of 3% p.a. in room air conditioner efficiency levels		We have assumed 3% p.a. efficiency improvement in newly purchased appliances.
Fan	Energy saving of 10-15% possible in FY28	If BEE S&L for ceiling fans is made mandatory, energy efficient ceiling fans of 35-45W as compared to ordinary fans of 70W will become the norm.	We have assumed there are no replacements and efficiency improvement apply to new purchases.

Cooler	It is estimated that 10-20% energy savings is possible in the next decade		We have not modelled usage of cooler in this exercise.

Table 1 ICAP targets verbatim from the ICAP document, a summary of the recommendations and remarks which describe our interpretation of the targets.

As mentioned earlier, ICAP provides recommendations for reduction of cooling energy demand across multiple sectors and end uses. A subset of these end uses specific to residential cooling electricity demand are modelled in a bottom-up manner in PIER, and are included in this analysis. The scope of work is as shown in Figure 1.

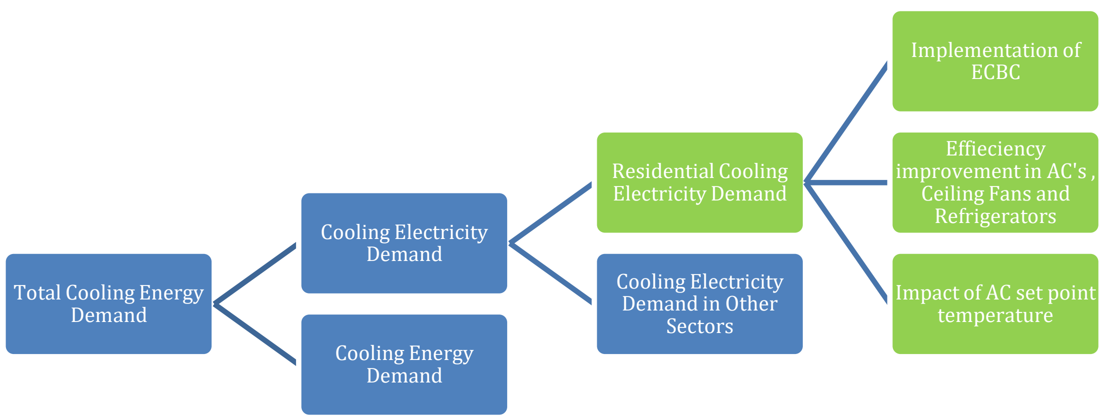


Figure 1 Scope of this analysis (in green)

Modeling ICAP recommendations in PIER

ICAP recommendations specific to residential cooling have been modelled by creating ICAP scenarios in PIER. Demand estimated in the ICAP scenarios are compared with the Reference scenario of PIER. This comparison can help to evaluate the relative impact of the recommendations and feasibility of their implementation.

Details specific to the residential sector for the Business as Usual (BAU) scenario in ICAP are not available. Hence, baseline assumptions used for estimation of residential electricity cooling and refrigeration demand have been inherited from the PIER reference scenario. Details of these assumptions related to appliance ownership numbers and their split by efficiency level etc. are available in the PIER report. Further, in this exercise ICAP recommendations have been modeled in two scenarios, conservative and optimistic. The Optimistic estimation assumes aggressive compliance towards ICAP recommendations. This involves higher improvement in AC EER, adaptation of ECBC in more than half constructions that exist and higher set point temperature for AC. Assumptions for optimistic scenarios are derived from upper bounds in ICAP reports and some other relevant documents. The Conservative scenario is developed using minimum improvements recommended by ICAP for electricity demand reduction. The following Table 2 provides details of the difference between the two scenarios.

<table>
<tr><th></th><th>PIER-Reference</th><th>PIER-ICAP-Cons</th><th>PIER-ICAP-Opt</th></tr>
<tr><td>AC-EER-Improvement</td><td>Improvement in average efficiency in PIER results from the assumption that AC stock is likely to grow by over 4 times between 2021 and FY31, and all of the new purchases will be as per notified star ratings in 2020 which are higher than the average stock efficiencies in that year.</td><td>Improvement of 3% per year for newly purchased appliances</td><td>Improvement of 6% per year for newly purchased appliances.</td></tr>
<tr><td>Refrigerator-rating improvement</td><td>Hard coded efficiency improvement of 0.5% every year in the stock of refrigerators</td><td colspan="2">Recommendation is to ratchet up efficiency level by 1 star after each 2-3 years. The improvement of efficiency has been included in the analysis. This impacts the overall stock efficiency.</td></tr>
<tr><td rowspan="2">ECBC recommendation</td><td>Standard construction material (brick) and standard thickness is considered, and appropriate thermal conductivity is considered.</td><td>Compliance U values (thermal transmittance) values taken from eco niwas samhita which is ECBC for residential buildings
18% buildings are compliant in FY38</td><td>Compliance U values (thermal transmittance) values taken from eco niwas samhita which is ECBC for residential buildings
60% buildings are compliant in FY38</td></tr>
<tr><td colspan="3">Building envelope related changes only affects the calculation of cooling energy demand for AC, and not for fans and coolers</td></tr>
</table>

Fans	70W fan assumed in first year (FY21). Each year, newly purchased stock will have 4% improvement in efficiency. This results in a reduction of 1% annually in average consumption over the entire stock.		
AC ref temperature	24 deg C	25 deg C	26 deg C

Table 2: Implementation of recommendations

Lastly, the current version of the PIER model provides estimates of electricity demand until FY31, whereas the target year for ICAP recommendations is FY38. For the ICAP scenarios, the electricity demand estimated in PIER is until FY31. Percentage reduction with respect to reference shows a fairly linear trend for both the ICAP scenarios. Hence as simple linear regression technique was used to project percentage reduction in cooling electricity demand from FY21 to FY38 which is the target year for ICAP goals.

Findings

In this section, we present the impact of ICAP recommendations on electricity demand for residential cooling and refrigeration, as estimated in the ICAP scenarios for space cooling appliances like ceiling fans, air conditioners, and refrigerators applied to the PIER model. The PIER reference scenario already considers efficiency improvement in ceiling fan stock in future years which has been retained as a part of this analysis. Hence the overall reduction in electricity demand for residential cooling and refrigeration in the PIER reference as well as ICAP scenarios includes the efficiency improvement in ceiling fans.

The ICAP recommendations which show greatest reduction in residential electricity cooling demand between PIER reference and ICAP scenarios are the use of energy efficient air conditioners and stricter implementation of the energy conservation and building codes (ECBC). Observations from this analysis have been discussed below.

Reduction in overall residential cooling and refrigeration electricity demand

The Chart 1 below shows the overall reduction in residential cooling and refrigeration electricity demand in the ICAP conservative and optimistic scenarios, compared to the Reference scenario.

Reduction in total residential cooling and refrigeration electricity demand as compared to PIER reference in the ICAP conservative and optimistic scenarios is ~12% and ~18% respectively for year FY31, and ~18% and ~30% respectively by FY38.

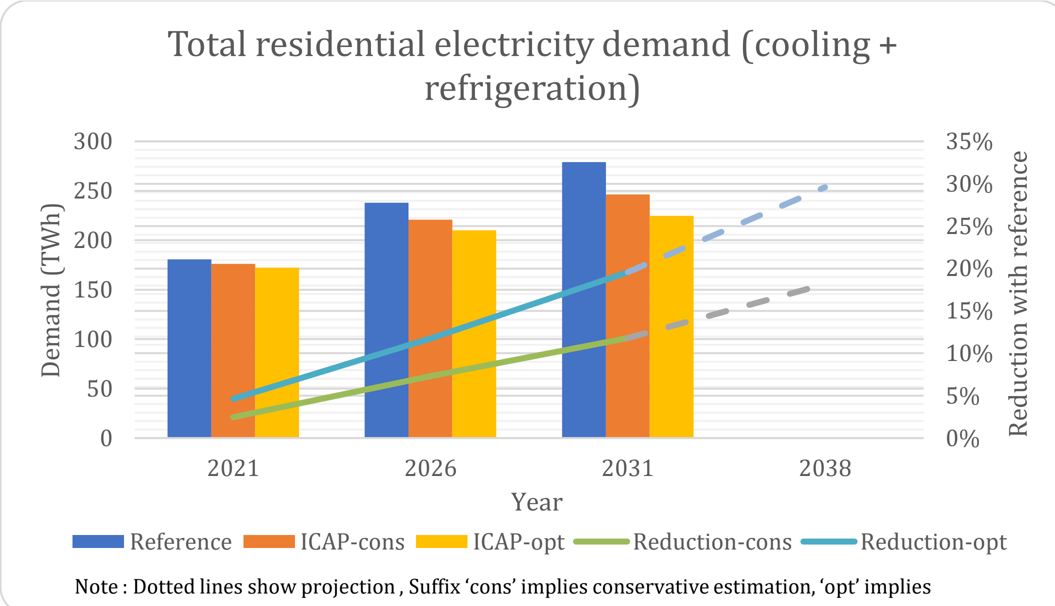


Chart 1: Total residential electricity demand (cooling + refrigeration) reduction

Effects of specific recommendations

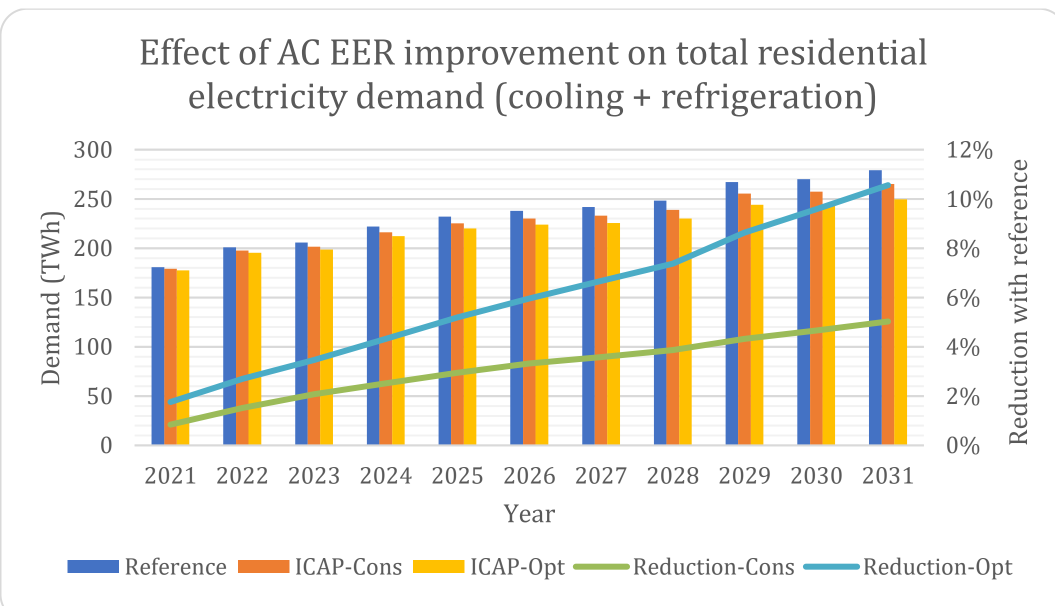
In this section, we share the impact of individual ICAP recommendations. Of the recommendations listed in Table 2, the building envelope improvements, AC EER improvements and efficiency improvements in ceiling fans play a significant role. The PIER reference scenario already considers an optimistic improvement in efficiency of ceiling fans in line with the ICAP recommendations; hence the change in demand is not observed in this comparative analysis. A separate attempt made to estimate the impact of ceiling fan efficiency improvement in the PIER reference scenario shows a demand reduction of ~2.5% in FY31 (see Annexure 2). Considering this, the total savings in residential cooling demand by implementing the ICAP recommendations may be ~15% and ~21% by FY31.

Reduction with AC EER improvement

The penetration of ACs in the residential sector is expected to increase multifold over the next decade, the assumption that these ACs will be energy efficient results in increasing combined EER over the years. For purposes of comparison, the table below shows the difference in the EER calculation formula between the Reference and ICAP scenarios. In the ICAP scenario, EER progressively improves year over year, whereas EER was assumed to be constant through the model period in the PIER Reference scenario. This leads to significant reduction of overall electricity demand in the ICAP scenario since new ACs form a big share of the AC stock by FY31. The observed overall average weighted EER improvement is 1.78% for PIER and 3.68%[3] for ICAP conservative and 5.6% for ICAP optimistic scenarios.

PIER	PIER-ICAP
$$E_{weighted} = E_{FY20} \times \frac{P_{FY20}}{P_{FY31}} + E_{FY21} \times \frac{(P_{FY31} - P_{FY20})}{P_{FY31}}$$ $E_{weighted}$ = Weighted EER for FY31 E_{FY20} = EER for FY20 E_{FY21} = EER for future (which is FY21 EER) P_{FY20} = stock in FY20 P_{FY31} = stock in FY31	$$E_{weighted} = E_{FY20} \times \frac{P_{FY20}}{P_{FY31}} + \sum_{i=FY21}^{FY31} E_i \times \frac{(P_i - P_{i-1})}{P_{FY31}}$$ Where $E_i = E_{i-1} \times (1 \times r)$, EER of year i r = appliance EER improvement each year which is 0.03 (3%) P_i = Stock of year i

Chart 2 below shows the electricity demand of the PIER reference scenario, and the ICAP scenarios for conservative estimation and optimistic estimation considering only AC-EER improvements, with other parameters being the same as PIER-reference scenario. The improvements result in residential electricity cooling demand reduction of ~5% and over 10% by FY31 in the ICAP Conservative and Optimistic scenarios respectively.



[3] As the stock of air conditioners increases significantly over the later years the weighted EER of ACs is observed to be much higher than the rate of EER growth per year.

Chart 2: Effect of AC EER improvement

Reduction with ECBC compliance

A similar analysis was performed to assess individual impact of ECBC on the residential cooling electricity demand. The building envelope related changes is modelled in PIER to only impact the calculation of cooling energy demand for ACs, through improved U value or thermal transmittance value. All other inputs are kept the same as in PIER reference scenario. As per table 2, the percentage of ECBC compliant buildings is 18% and 60% in 2037-38, in the ICAP conservative and optimistic scenarios respectively. As seen in the Chart 3 presented below, ECBC compliance results in a reduction of residential electricity cooling demand by over 3.5% and 9.5% respectively by FY31 in the two scenarios.

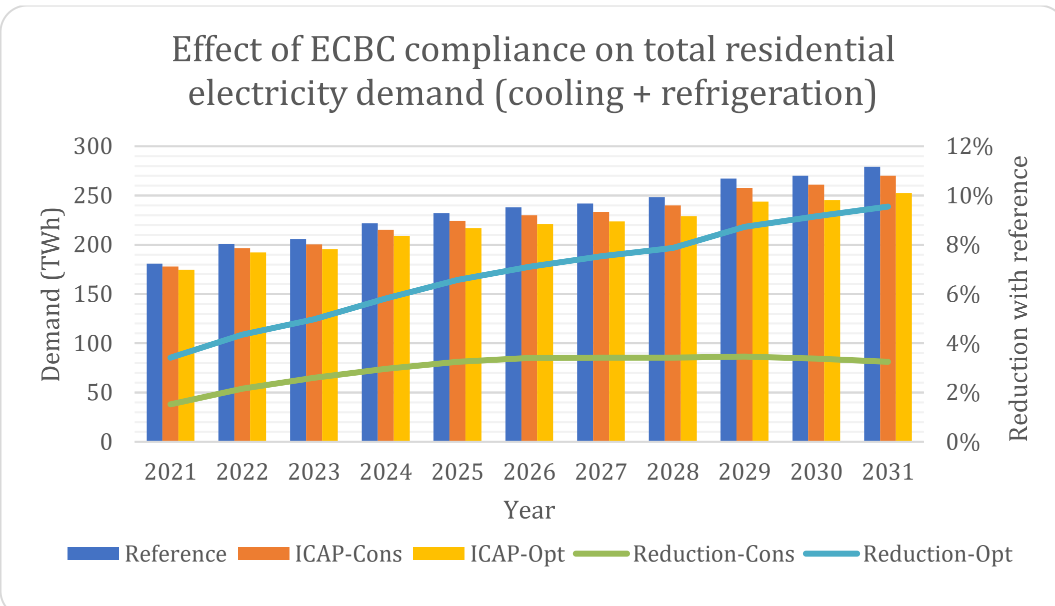


Chart 3: Effect of ECBC compliance

Finally, we also analyzed the impact of recommendations for refrigerators and AC set point temperature. The results from these interventions are shared in the Annexure 1. It is observed that there can be a reduction of 3.4% in residential cooling demand in FY31 by including recommendations for refrigerators and changes in AC set point temperature can result in reduction of electricity demand in FY31 by 3.3% and 6.6% respectively in the conservative and optimistic scenarios.

The effect of individual appliances or recommendations are not equal to the overall combined effect or reduction. This is because there are several interdependencies between recommendations. For example, enhanced ECBC implementation in buildings aids in reducing the cooling energy demand and hence lowers the AC energy requirement. Hence the total reduction in electricity demand for residential cooling is lower than the sum of reductions from individual recommendations for appliances or buildings.

Conclusion

ICAP has provided a list of short- and medium-term recommendations towards its broader objective of sustainable cooling and thermal comfort for all. It is important to identify the energy saving potential of each of the recommendations to prioritize the recommendations and develop an effective strategy. This would require a detailed bottom-up modelling of the relevant sectors and quantification of the recommendations. We conducted such an exercise in this analysis using the open-source PIER model developed by Prayas. The analysis is based on several assumptions we made related to building envelope, thermal comfort, appliance efficiency and other factors. Some of them have been mentioned here and others in the PIER documentation. Several scenarios can be developed using a different set of assumptions in an open-source model like PIER. Analysis based on these scenarios can also help in periodically revising the ICAP which was intended to be a 'living document'.

Important policies like the ICAP have a potential to channelize energy efficiency efforts in the desired direction while also meeting India's developmental needs. However, inadequate information and data can prevent direct action. Through this exercise, we tried to decode ICAP recommendations for the residential cooling electricity demand to better understand impact of each of the recommendations and hence derive action. From the findings shared above we observe that two ICAP recommendations namely stricter implementation of ECBC for buildings and efficiency improvement in Air Conditioners play a crucial role in reduction of residential cooling electricity demand. Strong actions from several stakeholders will be required to support these.

Therefore, this analysis suggests that, in order to achieve the ICAP target of 25%-40% reduction in residential cooling electricity demand by FY38, the following steps need to be taken:

- Developing policy mechanisms and a clear roadmap to accelerate ECBC adoption to reach at least 18% of ECBC compliant buildings by FY38
- Provide advance information and plan to ensure that AC efficiencies will be ratcheted up by 1 star every five years, this will help manufacturers plan their production lines in advance and help achieve the target
- Develop mechanisms to transform the fan market so that a significant share (at least 20%) of new fans purchased each year are of the highest efficiency standard

If India has to provide thermal comfort to all its citizens in a warming world while also reducing electricity demand and meeting its own climate goals, it needs to take aggressive and proactive measures. This analysis has provided a few such recommendations based on a rigorous analysis. More such analyses using other models can help in improving overall understanding of the relative impact of such policies and recommendations on energy demand across sectors and provide a clear action plan based on the efforts determined by the results in proportion to the impacts of the different instruments under consideration.

Annexure 1

ICAP recommendations and impacts

Overall residential electricity demand for cooling + refrigeration: Chart 1

% Reduction in comparison with reference	FY31	FY38
Conservative	11.79	18.15
Optimistic	19.56	29.59

Effect of AC EER improvement: Chart 2

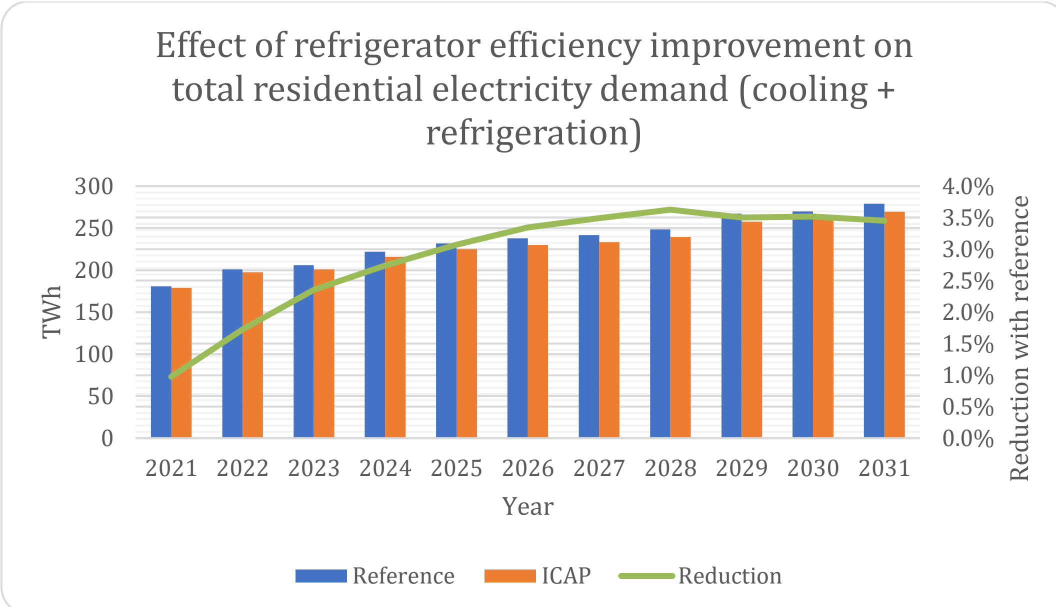
% Reduction in comparison with reference	FY31	FY38
Conservative	5.02	7.9
Optimistic	10.55	16.34

Effect of ECBC compliance: Chart 3

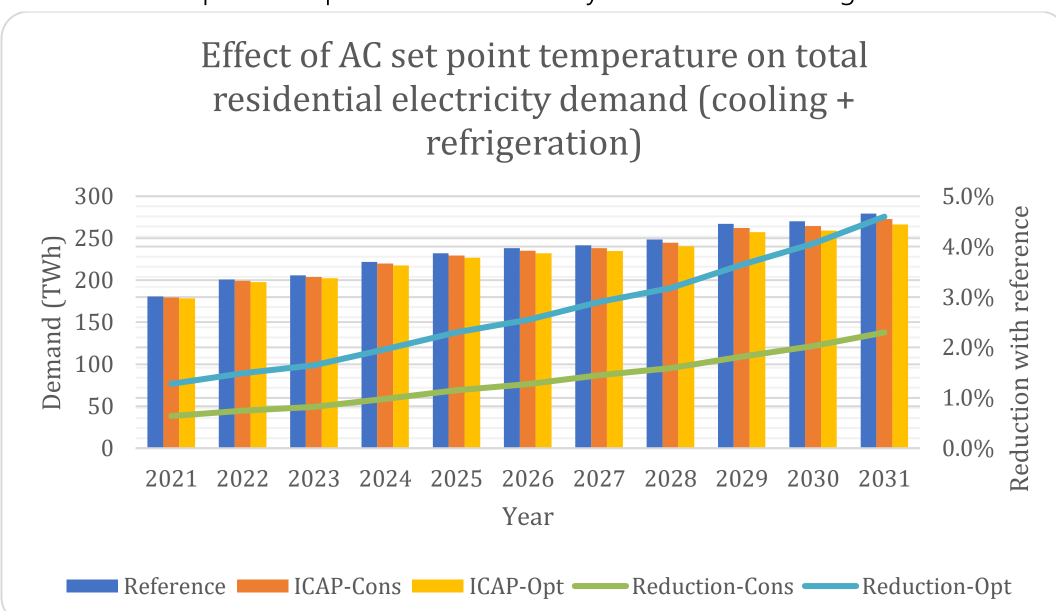
% Reduction in comparison with reference	FY31	FY38
Conservative	3.25	4.86
Optimistic	9.55	14.05

Effect of efficiency improvement in Refrigerator

% Reduction in comparison with reference	FY31	FY38
Only one scenario	3.4	5.6



Effect of AC set point temperature on electricity demand for cooling



% Reduction in comparison with reference	FY31	FY38
Conservative	2.29	3.3
Optimistic	4.59	6.6

Annexure 2

Quantification of fan efficiency improvements in the PIER reference scenario

PIER reference scenario already considers efficiency improvement in ceiling fan stock in future years. Following chart represents the BAU scenario where considerations for ceiling fans are modified from the PIER reference scenario. They are set to default very low improvement factor which as close as removing it.