Multiple Benefits of Improving Energy Efficiency

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) report states that buildings account 32 percent of the energy use and 19 per cent of the global emissions out of which almost a third can be attributed to the cooling sector. The aim of this paper is to establish the energy efficiency benefits and discuss health benefits from energy efficiency improvements in the emerging economies such as India. Air conditioners are important in targeting the improvement of energy efficiency policies and are the low-hanging fruit of climate policy in India because of its size and rapidly increasing market due to the aspirations of people in the country to improve their standard of living. Montreal Protocol's latest Amendment, that limits the use of a super-greenhouse gas Hydrofluorocarbons (HFCs) will provide an impetus to the energy efficiency innovations, and has historically catalyzed energy efficiency improvements of up to 35 per cent. Projected growth in power demand for cooling could have a crippling effect on India's fiscal status and prospects for economic growth to the extent it becomes necessary to further increase fossil fuel imports to maintain pace with high demand for electricity in the cooling sector. Modest energy efficiency improvements saves India billions of US dollars annually, several scores of Gigawatts (GW) of electricity, improved health outcomes in terms of reduced mortality and respiratory diseases and also indirect social impacts from improved health.
Thus this paper sheds light on these benefits and establishing a clear unmistakable link between these energy efficiency improvements and health.

Keywords: Air-conditioner, energy efficiency, coal emissions, health

Introduction

India plans to increase its generating capacity from a current 200 GW (gigawatts) to 800 GW by 2030 in order to sustain an economic growth rate of 8 per cent to 10 per cent for human resource development and poverty eradication. Since an excessive and increasing percentage of domestic power generation is used for air conditioning and refrigeration, improvements in

energy efficiency would significantly reduce demand. The Bureau of Energy Efficiency (BEE) has found that air-conditioning (AC) use represents the major share of peak demand in Indian cities. While the Maharashtra Electricity Regulatory Commission (MERC) study identified power demand from ACs at 40 per cent of the total demand for the city of Mumbai in a peak summer month, the BEE study estimates that 60 per cent of peak demand is for AC in dozens of Indian cities. Some studies state that Indian AC companies reported sales growth of 30 per cent on average on a year-to-date basis, with 50% growth in some regions. A 2013 Super-efficient Equipment and Appliance Deployment (SEAD) initiative found that deploying super-efficient air conditioners could significantly reduce energy use by 2020, avoiding the need for more than 100 medium-sized (500-megawatt) power plants. Past transitions to superior refrigerants/technologies, driven by the regulatory regime of Montreal Protocol on Substances That Deplete The Ozone Layer have been associated with improvements in energy efficiency of up to 60 per cent. The best available AC technology can already reduce energy use by 35 per cent to 50 per cent compared to market averages. These energy efficient technologies are also cost-effective as energy savings over unit lifetimes more than pay for any additional initial consumer costs. Adopting AC technology that is both cost-effective and more energy-efficient could save over 118 TWh (Terawatt hours) in 2030 and potential peak demand saving is found to be 60 GW by 2030; this is equivalent to avoiding 120 new coal fired power plants of 500 MW each. Efficiency improvements for the far larger number of refrigeration applications with their even greater power demands would also yield significant energy savings, further reducing the domestic demand for power generation and delivery.

Montreal Protocol bridges AC efficiency and climate change. Hydrofluorocarbons (HFCs) are '*super greenhouse gases*' that if left unchecked will by 2050 contribute from 14-27 per cent as much annually to global warming as CO_2, and effectively negate critical and anticipated reductions in CO_2 emissions [Velders et al., 2012]. They are growing at the rate of 10-15 per cent per year [Velders et al., 2012]. HFC are mainly used as refrigerants in air conditioning and refrigeration applications and have Global Warming Potential (GWP) that is several thousand times that of carbon dioxide (CO_2). Phasing out high- GWP HFCs is set to present gains between 87-146 $GtCO_2e$ (Gigatons of carbon dioxide equivalent) emission reduction by mid-century and avoid up to 0.5 degrees of warming by 2100 [Velders et al., 2014]. The energy efficiency improvements for the aforementioned appliances run parallel to the refrigerant transition that will be brought around with Kigali Amendment to the Montreal Protocol for the exact same appliances. This gives us an opportunity to understand not

simply the climate and energy benefits to be gained by such a two-pronged approach, but also the health benefits in vulnerable populations in a country like India, generated by modest improvements in energy efficiency of ACs.

Linking AC Efficiency and Climate Change

In 2010 buildings accounted for 32 per cent of total global final energy use, 19 per cent of energy-related GHG emissions (including electricity-related), approximately one-third of black carbon emissions, and an eighth to a third of fluorinated gases (largely used in cooling appliances) that are regulated under the Montreal Protocol on Substances that Deplete the Ozone Layer. [IPCC AR5, 2014] Globally, the cooling energy use is set to grow by 83 per cent by 2050 [IPCC AR5, 2014]. The finance and mechanisms under the Montreal Protocol provide for a transition for the AC industry from high GWP, HFC-based refrigerants to lower GWP refrigerants. The new generation of refrigerants have a positive impact on the energy efficiency of the ACs. Therefore, countries, especially India, with growing power demand and AC market must avail this unprecedented opportunity to address the phase-down of high GWP HFCs while addressing energy efficiency. Such efforts will by and large contribute to its emission reduction targets while providing health benefits from the reduced emissions.

Current status of AC market

The AC demand is growing at a dramatic rate of 20 per cent per year over the last decade, powering these energy intensive appliances is going to lead to a stress on the power demand, and will be a contributing factor to the need to add new coal fired power plants. In 2010 the dissemination of air-conditioners stood at a mere 3 per cent in India as opposed to 100 per cent in China amongst the urban households [NSSO, 2007; NSSO, 2012; Zhou et al., 2012]. This means an abundance of ACs in India have yet to be installed and would benefit the energy security, emission reductions and health of the people of the country vastly if the air conditioners that would introduced were energy efficient. The increased demand for AC can be attributed to various factors such as rising purchasing power and rapid urbanization, falling AC prices, and a hot and humid climate.

Future AC stock projections

The case of China helps in understanding the substantial growth in household appliance ownership due to its rising incomes and urbanization. The saturation of air conditioners in urban China went from nearly zero in 1992 to about 100% by 2007 i.e. within a span of 15 years [Zhou et al., 2012]. Similar growth may be expected in India due to the factors mentioned in the foregoing section. According to **Table 1**, the total number of ACs in

2030 will reach a saturation of 73 per cent in urban households bringing the total number of ACs to 116 million, which will consume about 239 TWh of electricity.

Table 1: Projected AC stock in 2020 and 2030

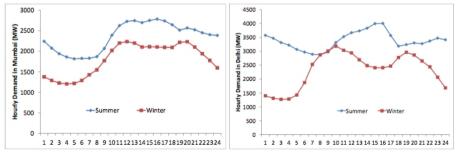|	2020	2030
Electricity consumed by ACs in business-as-usual in TWh/yr	77*	239*
Total stock of room ACs in millions	37	116
Total stock as percentage of urban households	30%	73%

Source: NSSO 2012; Letschert et al. 2012; Shah et al. 2013; author's calculations
*The electricity consumed in calculated by assuming the average EER of 2.89

Impact of AC growth on the electricity demand

Studies show that the cooling demand in India is coincident within a sector and with the peak demand [N. Abhyankar and Phadke, 2012; A. Garg et al., 2010; NDPL, 2011]. These studies show the following: (a) If a household or a commercial establishment owns an AC, its contribution to the peak demand is significant, (b) Residential and commercial space cooling demand has a significant seasonal correlation, (c) diurnally, residential AC demand peaks at night and commercial AC demand peaks in the afternoon. But during the afternoon, there are a few hours where residential and commercial demands coincide, and (d) space cooling is the only end-use that shows significant seasonal variation [Shah et al. 2014]. We can take the instance of two cities during the summer and winter: Mumbai and Delhi; these cities have low penetration of ACs and most of the load is either commercial or residential. It can be seen from **Figure 1** below that the usage is increased during peak afternoon hours of summer and drops during winter months; the drop is more evident, about 40 per cent in Delhi due to its propensity to have colder winters than Mumbai.

Figure 1: Average Hourly Demands on the Electricity Grid in Summer and Winter in Mumbai and Delhi

(a) Mumbai   (b) Delhi

Source: Shah et al. 2014; MSLDC 2012; DSLDC 2012

Further it can be seen from **Figure 2** below that the average heat index pattern during the summer months in India does not deviate drastically based on the geographic region, and thus it can be said that the cooling demand may have a high peak coincidence across geographic regions.
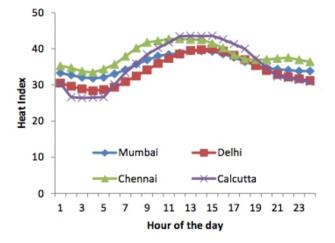

Figure 2: Average hourly heat indices across 4 Indian cities in May
Source: ASHRAE 2012; Shah et al 2014

Energy Saving Potential

The average EER of the AC in the Indian market is 2.89, which is 16 per cent lower than even China's lowest energy performance standards. Given the estimated stock, the efficiency gains associated with improving AC efficiency depend climate and usage factors. In India, a room air conditioner is assumed to run for about 8 hours every day for 6 months in a year i.e. 1440 hours/year.

If the efficiency is improved through compressor efficiency, compressor control, heat exchanger performance, expansion valves, crankcase heaters and controls, and standby power use, the total technical potential for saving electricity by improving efficiency of the room ACs in India is found to be 118 TWh at bus-bar in 2030 [Shah et al 2014]. Even a small percentage of improvements in energy efficiency of ACs per year, through the options mentioned in **Table 2** helps saves nearly 60 GW of peak demand that is equivalent to saving nearly 120 power plants of 500 MW each. As stated earlier the estimated electricity demand from ACs is set to increase to 239 TWh/yr by 2030, which translates to a peak demand contribution of about 143 GW. Meeting this demand requires construction of nearly 300 new coal fired power plants of 500 MW each [Shah et al 2014].

Table 2: Options for EE improvement from base case scenario

Compressor efficiency	6.5-18.7%
Compressor control	20-24.8%
Heat exchanger	9.1-28.6%
Expansion valve	5-8.8%
Crankcase heater efficiency and crankcase heater control	9.8-10.7%
Standby	2.2%

Source: Author's adaptation of Shah et al 2014

It can be seen from **Figure 3** below that the measure of potential savings is significantly comparable to India's renewable energy targets of 100 GW solar power and 75 GW wind power generation capacity.
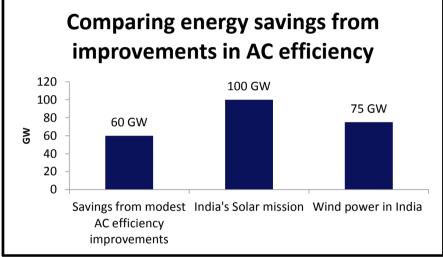

Fig 3: Comparing energy savings from improvements in AC efficiency
Source: Author's adaptation of Shah et al 2014

In the above section, it may be seen that improving energy efficiency could save up to 120 coal-fired power plants from being built. In the next section, the health impacts of coal- fired power plants are discussed.

Health benefits from avoiding the coal-fired power plants
Coal in India

Out of the 210 GW electricity generation capacity in India, 66% is derived from coal, with planned additions of 76 GW and 93 GW during the 12th and the 13th five year plans, respectively [Guttikunda and Jawahar 2014]. The analysis above shows that out of such capacity, making small improvements in energy efficiency of ACs alone may save 60 GW. Given that generating electricity from coal results in high human health costs

boosting AC efficiency for reducing health impacts and improving air quality is the low hanging fruit.

Indian coal-fired power plants are not efficient when compared to their western counterparts, and their average net efficiency is currently below 28%. Thermal efficiency is expressed as percent of the heat input used or by the heat input in kilo-calorie (kcal) required to produce a kilowatt-hours (kWh) of electricity. Approximately 0.770 kg of coal when burnt, produces 1 kWh of electricity in India, whereas the values are half that of India in western countries [Cropper et al 2012].

Grams of pollutant per kWh or the 'pollution intensity' also depends on the ash and sulfur content of the coal burned. Indian coal has high ash content, between 35 and 50 percent by weight, and lower sulfur content: about 0.5 percent by weight [Cropper et al 2012]. The high ash content and low calorific of the Indian coal means that the power plant's operational efficiency is adversely affected and this increases emissions per kWh electricity generated.

Pollution from coal-fired power plants

The emissions from coal-fired power plants depend upon various factors. Sulphur dioxide (SO_2) and CO_2 depend on variety of coal used at the plant. On the other hand, Nitrous oxides (NO_x) emissions depend upon the operating conditions and the design of the power plant. The total annual emissions from the 111 power plants in India is given below in **Table 3.**

Table 3: Total annual emissions from coal-fired power plants in India

	$PM_{2.5}$	SO_2	NO_2	VOCs	CO_2
Total in tons	580,000	2,100,000	2,000,000	100,000	665.4 million

Source: Guttikunda and Jawahar, 2014

While the combustion of coal releases SO_x, NO_x, CO_2, CO, volatile organic compound (VOCs), dangerous amounts toxic substances like of mercury, lead, cadmium, arsenic, etc. all of which are tremendously detrimental to human health are also emitted; the 2010 global burden of disease (GBD) study states that outdoor air pollution from particulate matter ($PM_{2.5}$) and ozone is one of the top 10 health risks in India, with an estimated 695,000 annual premature deaths from respiratory illnesses, compromised immune systems, and cardio-vascular conditions [IHME, 2013].

Of the estimated annual anthropogenic emissions in India, the thermal power plants account for 15 per cent for $PM_{2.5}$, 30 per cent for NO_x, and 50 per cent of SO_2. $PM_{2.5}$ is the only pollutant that is regulated in India. **Table 4** below gives an overview of prescribed limits of the pollutants in India and compares them with other countries.

Table 4: Overview of Indian emission standards and comparison with other countries

	PM	SO_2	NO_2	Mercury
India[a]	350 mg/Nm^3 (< 210 MW) 150 mg/Nm^3 (210 MW)	-	-	-
China[b]	30 mg/Nm^3 (proposed all) 20 mg/Nm^3 for key regions	100 mg/Nm^3 for new 200 mg/Nm^3 for old 50 mg/Nm^3 for key regions	100 mg/Nm^3	-
USA[c,d]	37 mg/Nm^3 for old 6 mg/Nm^3 for new	245 mg/Nm^3 for old 50 mg/Nm^3 for new	61 mg/Nm^3 for old 42 mg/Nm^3 for new	-
USA [c,e]	6.4g/GJ	640g/MWh	720g/MWh for old 450g/MWh for new	0.08g/MWh for lignite 0.01g/MWh for IGCC

[a]:From Central Pollution Control Board, India
(http://cpcb.nic.in/Industry_Specific_Standards.php);
[b]:From standards information in Chinese
(http://www.zhb.gov.cn/gkml/hbb/qt/201109/t20110921_217526.htm). Prior to 2011, the
standards were based on commissioning year (before 1996, 1997 to 2004, and after 2004);
[c]:Power stations emissions handbook (http://www.ccsd.biz/PSE_Handbook);
[d]:Emission rates are translated to mg/Nm3 based on assumed plant efficiency;
[e.] In official units; for mercury this is based on 12 month rolling average.
Source: Guttikunda and Jawahar, 2014

The high ash content of Indian coal may lead to high PM emissions. Although all coal plants in India have electrostatic precipitators (ESPs), the high ash content of coal and its chemical composition reduce their removal efficiency (Cropper et al, 2012). There are no emission control regulations for sulfur dioxide or for nitrogen oxides or mercury for coal-fired power plants.

Box 1: Best Practices

Best Practices: Dahanu

SO_2 concentrations are affected primarily by minimum stack height requirements and the requirement that electricity generating units of 500 MW or more leave space for a flue-gas desulfurization (FGD) unit as mandated by the then Ministry of Environment and Forests (MoEF). However, still not many plants in India use FGD units (7 are listed as using FGDs). The law states that generating units between 210 and 500 MW must have stacks of at least 220 meters; units greater than 500 MW must have stacks at least 275 meters in height.

Currently only Dahanu plant of 500 MW has installed a flue-gas desulfurization unit.The plant is located in an ecologically sensitive zone and its SPM emissions are among the lowest in our database (32.5 mg/Nm^3 in 2008). Assuming coal with 0.5 percent sulfur content and an SO2 removal rate of 80 percent, the FGD at Dahanu saves 123 lives per

Source: Cropper et al., 2012

The heavy metals such as arsenic, cadmium, mercury, lead, copper zinc are also present in the particulate matter of flue gas. They contribute towards a myriad of health hazards [Finkleman, 2007] and reduce the efficiency of ESPs. The percentage of the various metals after chemical analysis was found to be zinc: 1-7 per cent; copper: 2-7 per cent; manganese: 5-8 per cent; cobalt 7-10 per cent; cadmium: 12-18 per cent; selenium: 60-70 per cent; mercury: 70-80 per cent and traces of arsenic, iron, lead and chromium were found [Reddy et al, 2005].

Ozone pollution, also known as smog, is formed when NOx reacts with VOCs in the presence of sunlight.

Coal Cluster Problem

Coal-fired power plants are generally located in the coal mining areas of the country such as western Maharashtra, northern Andhra Pradesh, northern Chhattisgarh, Orissa West Bengal, Jharkhand and Bihar. Some power plants are in the coastal regions, due to the availability of water for cooling from the sea and ease of importing coal due to the ports. In such cases, the coastal winds are beneficial, however certain cities like Chennai and Ahmedabad host coal-fired power plants within the city limits (impact of pollution is alleviated in case of Chennai since it is a coastal city) [Guttikunda and Jawahar, 2014]. The pollution caused by emission of $PM_{2.5}$ from the coal-fired power plants in certain key regions, and its impact on mortality in the region is given below in **Table 5**.

In Delhi, up to 8 per cent of the ambient PM pollution can be attributed to the coal-fired power plants of 2000 MW, operated within 60 km from the city center [Guttikunda and Goel, 2013], thus the NCR with its highest population density of more than 21.5 million inhabitants in Delhi and its satellite cities, is exposed to higher PM pollution from coal-fired power plants. These land locked power plants pose a serious threat to the health of the inhabitants of the cities. While the impact of the emissions is felt within 200 km of the power plants, under windy conditions the influence can be tracked to distances as far as 400 km from the source region [Guttikunda and Jawahar, 2014].

Table 5: Health Impacts of $PM_{2.5}$ in selected areas

Cluster (size in degrees)	No. of plants (those more than 1000 MW)	Installed capacity in MW	Modeled $PM_{2.5}$[a]—median (95th percentile) $\mu g/m^3$	Estimated premature mortality within the region[b]
Delhi-Haryana (2.5° x 2.5°) (in land)	8 (5)	8,080	3.9 (7.7)	6,400-8,800
Kutch (Gujarat) (2.5° x 2.5°) (coastal)	5 (2)	9,900	1.0 (2.8)	100-120

Western Maharashtra (2.5º x 2.5º) (coastal)	3 (1)	2,780	0.9 (2.3)	1,700-2,400
Eastern Maharashtra and Northern Andhra Pradesh (3.0º x 4.0º) (inland)	10 (6)	14,800	3.2 (5.1)	1,100-1,500
Madhya Pradesh, Chhattisgarh, Jharkhand, Orissa (4.0º x 4.5º) (inland)	21 (10)	29,900	9.1 (23.1)	7,900-11,000
West Bengal, Jharkhand, Bihar (3.0º x 4.0º) (inland)	19 (7)	17,100	3.7 (5.6)	10,700-14,900
Eastern Andhra Pradesh (2.5º x 2.5º) (coastal)	2 (2)	3,000	0.8 (1.8)	1,100-1,500

[a] The PM2.5 concentrations are modeled grid averages and is the concentration due to the emissions from the coal-fired power plants only, which is incremental to pollution from other sources in the region. For these sub-regional domains, the CAMx dispersion modeling was repeated @ grid resolution of 0.1_ , equivalent of 10 km. Median and 95th percentile value is based on averages for all the grids in the select sub-regional domain.
[b] This is the estimate for the exposed population in the select geographical sub-region, but the influence of the power plant emissions reaches farther

Source: Adaptation of Guttikunda and Jawahar, 2014

Health Impacts

The direct link between air pollution and human health has been widely documented under the 2010 GBD study (IHME, 2013). Various epidemiological studies conducted in India have consistently demonstrated higher rates of respiratory and cardiovascular diseases in populations exposed to PM, NO_x, and ozone pollution [Guttikunda and Jawahar, 2014; Chhabra et al., 2001; Pande et al., 2002; Gupta et al., 2007; Wong et al., 2008; CBHI, 2010; Siddique et al., 2010; Balakrishnan et al., 2013].

Missing working days, loss of productivity, morbidity and mortality rate connected with air pollution has been converted to loss of gross domestic product (GDP) by a World Bank study of 2012, the study shows that the health impacts cost the nation USD 23.4 billion that is about 1.7 per cent of the GDP.

The water runoff from coal washeries carries pollution loads of heavy metals that contaminate ground water, rivers, and lakes thus affecting aquatic flora and fauna [Finkelman, 2007]. Very few coal-fired power plants desulfurize the flue gas. SO_x contributes to formation of small acidic particulates that penetrate into human lungs and are absorbed by the blood stream. It causes acid rain that damages the crops, forest and soil.

Smog can also cause many health problems such as coughing, wheezing, shortness of breath and chest pain. Ozone, a precursor to smog causes lung tissue damage, reduced lung capacity, asthma exacerbation, as well as increased risk of hospitalization for asthma, bronchitis and other chronic respiratory diseases [US EPA, 2007]. Some studies have also shown that prolonged ozone exposure may lead to premature death [Bell et al., 2005; Ito et al., 2005].

The health impacts of these pollutants emitted by coal-fired power plants are summarized below in **Table 6**.

Table 6: Summary of health impacts of emissions from coal-fired power plants

Effect	Health Impacts
Total premature mortality	80,000-115,000
Child mortality under 5	10,000
Respiratory symptoms	625 million
Chronic bronchitis	170,000
Chest discomforts	8.4 million
Asthma attacks	20.9 million
Emergency room visits	900,000
Restricted activity days	160 million

Source: Guttikunda and Jawahar, 2014

In countries like India and China that have a moderate life expectancy, research suggests that coal burning reduces life expectancy by 2.5 and 3.5 years in those countries respectively [Burt et al 2013].

Box 2: Case in China

A recent study in China highlighted significant differences between two communities that were of comparable socio- economic status but one was exposed to high levels of airborne particulate matter through the use of coal-fired boilers in town, whereas the other was not. Researchers [Chen et al 2014] found that exposure to high levels of particulates 184 $\mu g/m^3$ led to an increase in cardiorespiratory causes of death (resulting in a 14 per cent increase in overall mortality) and a reduced life expectancy at birth of about three years.

Although not necessarily at a level that demonstrably increases mortality at the same rate as in the China case study, particulates that are smaller than 2.5 microns travel deeper into the bronchial passages and lungs causing increased negative heath impacts. These can include decreased lung function, asthma, for example, every 10 $\mu g/m^3$ increase in $PM_{2.5}$ is associated with a 1 to 3.5 per cent decrease in measured lung function [Burt et al 2013].

Source: McDaid, 2014

Toxic mercury is emitted from coal-fired power plants and it mainly accumulates in water bodies. It causes neurological problems; children under age of six years are susceptible to brain and spinal cord damage. In adult it causes cardiac problems and affects vision, speech and hearing. Environmentally, deposit of mercury in lakes can make the fish unsafe to eat.

Conclusion

Carbon dioxide emissions from coal-fired power plants, in India constitute about 70 per cent of the energy sector emissions [INCAA, 2010]. In India, the amount of power generated from coal will remain high at least through 2030 and unless a better way is proposed to manage pollution from the coal-fired thermal power plants, the environmental effects and human health costs will be high [Prayas, 2011, 2013]. AC energy consumption is set to increase from 8 TWh in 2010 to 239 TWh by 2030. Such growth would inflict undue stress on the Indian power sector that would lead to unprecedented construction of new power plants. By enhancing energy efficiency 40 per cent of the energy consumed by room ACs could be saved cost- effectively. This renders energy savings of 118 TWh or a peak demand saving of 60 GW by 2030. Achieving such an extensive level of energy saving is equivalent to avoiding the construction of 120 new coal-fired power plants of 500 MW each.

Merging the upcoming HFC phase-down, recently agreed under the Montreal Protocol, with accelerating energy efficiency will not only help achieve emission reductions for India, but also deeply and positively affect the energy demand. It would also result in economic gains from reduced fossil fuel imports. These economic gains may be better suited to be utilized for powering over 400 million Indians that yet do not have access to electricity.

Indian energy efficiency standards are some of the lowest in the world. The stringency of the standards and labeling program in India by the Bureau of Energy Efficiency needs to be improved vastly. It is also important to pursue efforts such as improved building design and cool rooms to reduce or postpone the electricity demand from ACs [Shah et al., 2014]. This will consequently, prevent the building of unnecessary coal-fired power plants and open opportunities for investments in cleaner technology.

While the carbon dioxide emissions produced by coal-fired power plants by themselves may have no known direct effects on human health, they are a very significant contributor to global warming which itself poses one of the greatest threats to environment public health in the long term [USGCRP, 2016].

The adverse and intensive effects of climate change impacts individual and societal health, mental health, and well being. Rising

greenhouse gas emissions and its resultant rise in temperature, changes in precipitation patterns, increases in the frequency and intensity of some extreme weather events, and rising sea levels. Such incidences and impacts of climate change endanger our health by affecting our food and water sources, the air we breathe, the weather we experience, and our interactions with the built and natural environments. Thus the scientific understanding of how climate change affects and imposes risks to human health must be explored in greater depth, evaluated and monitored [USGCRP, 2016].

Though coal remains main fossil fuel for power generation, realizing energy efficiency will convey greater health and environment benefits as well as mitigate climate change.

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