OUTDOOR AIR POLLUTION

Assessing social and private benefits and costs for improved brick production in Andhra Pradesh

Cost-Benefit Analysis

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ANDHRA PRADESH PRIORITIES — AN INDIA CONSENSUS PRIORITIZATION PROJECT

INDIA CONSENSUS — A TATA TRUSTS & COPENHAGEN CONSENSUS CENTER PARTNERSHIP

This work has been produced as a part of the Andhra Pradesh Priorities project under the larger, India Consensus project.

This project is undertaken in partnership with Tata Trusts.

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An India Consensus Prioritization Project

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Working draft as of May 23, 2018

Policy Abstract

India is the second largest producer of bricks in the world, after China with a global production share of nearly 14 percent. Brick is also a major contributor to environmental pollution as it depends heavily on natural resources, like soil (e.g. top fertilie alluvial soil in the Indo-gangetic plains), and coal. There are often applications of biomass including agricultural wastes like cotton straw, mustard straw, wood chips, etc for firing.

Although there are many technologies that can be used for brick manufacturing, two technologies that are largely predominant in India are Clamp Kilns and Fixed Chimney Bull's Trench Kiln (FCBTK). The main process of brick making practised in Northern and Eastern region of India is FCBTK. These regions account for majority of the annual brick production largely because of access to alluvial soil in the Indo-Gangetic plains. The remaining production is based primarily on Clamp Kiln methods used across the Central, Western and Southern parts of India. Over the last 40 years brick production has increased by more than 8 times, due to growing demand from the housing and infrastructure sectors. Since these technologies are old, they are inefficient and generate a lot of pollution. Around 35 million tonnes of coal is consumed in the sector and is the third largest consumer of coal in the economy after thermal power, iron and steel. The average estimated CO2 esmission from the sector is more than 60 million tonnes.

The economic and social benefit-cost assessment undertaken in this study looks at two options of cleaner kiln technologies in the state of Andhra Pradesh. The two options involve improvement of existing Clamp Kilns and (and FCBTK technology) to the Zig-Zag Kilns, and Vertical Shaft Brick Kilns (VSBK) technology.

It is important to note that there may be marginal improvement in operating costs, but the biggest advantage of moving to these technologies is the increased production of class 1 bricks that will fetch substantial value from the market. Information on private benefits and costs of currently predominant and cleaner brick kiln technologies have been used based on review of recent literatures as well as interaction with selected experts. The key parameters for which information have been collected include investment, production value and operating costs, efficiency improvement and CO2 emissions. It has been found that the production of class 1 bricks can increase from 50 percent to 80 percent incase of Zig-Zag

technologies, while in VSBK, the production of class 1 bricks can be as high as 90 percent. Increased efficiency will reduce CO_2 emission between 22 percent and 47 percent thereby reducing global warming potential. At the same time emission of particulate matter will come down thereby improving ambient air quality reducing disease burden and mortality across population of different age groups. Social benefits of cleaner technologies are estimated based on recent advances in health assessments of fine particulate matter ($PM_{2.5}$) developed by Ostro (2004) as well as Global Burden of Disease (GBD) recent estimates for the state of AP. Table A1 presents the private benefits and costs as well as the environmental and social benefits from these technologies.

Table A1: Incremental present value (PV) of benefits and costs from shifting to proposed technologies

Rs million		Zig-Zag (VSL Approach)	VSBK (VSL Approach)	Zig-Zag (DALY Approach)	VSBK (DALY Approach)
Cost		24960	38400	24960	38400
Financial benefits					
	3%	145100	191488	145100	191488
	5%	126739	167257	126739	167257
	8%	104768	138262	104768	138262
CO2 benefits	3%	35,220	75,242	35,220	75,242
	5%	10,580	22,602	10,580	22,602
	8%	0	0	0	0
Health benefits					
	3%	100477	153374	62508	95416
	5%	86199	131579	47420	72385
	8%	69409	105950	32528	49652
Total benefits	3%	2,80,797	4,20,104	2,42,828	3,62,146
	5%	2,23,518	3,21,438	1,84,739	2,62,244
	8%	1,74,177	2,44,212	1,37,296	1,87,914
BCR	3%	11.25	10.94	9.73	9.43
	5%	8.96	8.37	7.40	6.83
	8%	6.98	6.36	5.50	4.89

Cost and benefits numbers in million INR
Source: Author's calculation

The studied options are financially (private costs and benefits) viable and economically (social costs and benefits) viable. As evident from the above table, the benfits costs ratios are relatively more for conversion or retrofitting of existing Clamp kilns to Zig-Zag kilns over VSBK. The BCR from conversion to Zig-Zag technology is in the range of 5 and 11 and for that of VSBK it is in the range of 4 and 10.

The studied options are financially (private costs and benefits) viable and economically (social costs and benefits) sustainable. As evident from the above table, the benfits costs ratios are relatively more for conversion or retrofitting of existing Clamp kilns to Zig-Zag kilns over VSBK. The BCR from conversion to Zig-Zag technology is in the range of 5 and 11 and for that of VSBK it is in the range of 4 and 10. The estimated incremental profits per kiln from shifting to Zig-Zag kiln is Rs 30 mn, Rs 26 mn and Rs 21 mn for three discount rates while for VSBK it is Rs 39, Rs 34 and Rs 29 mn under the three discount rate scenarios. The average number of lives to be saved per year is 629 in case of Zig-Zag technology and 961 in case of VSBK. The savings of carbon emission per year are 1.81 mn tCO2 and 3.86 mn tCO2 for these technologies. The total benefits due to conversion to Zig-Zag technology are Rs 280 bn, Rs 223 bn, and Rs 174 bn using VSL approach and Rs 242 bn, Rs 184 bn and Rs 137 bn using DALY approach respectively. The total benefits due to conversion to VSBK technology are Rs 420 bn, Rs 321 bn, and Rs 244 bn using VSL approach while using DALY approach the total benefits are and Rs 362 bn, Rs 262 bn and 187 bn using for the three discount rates.

It is important to note that there are many impediments to this shift. Interactions with selected stakeholders have revealed that despite having a business case, poor awareness among entrepreneurs, lack of concessional finance for buying these technologies and hand holding are areas that need utmost attention. While there are various programs undertaken by ministry of micro small and medium enterprises to create awareness among producers, often the reach has been limited and focused at specific locations. This can be minimized by engaging with state level and/or district level institutions/ agencies particularly, industry associations, polytechniques, Small Industries Development Bank of India, incubation centres of professional and technical institutions, etc. More importantly, such engagements need to focus on time adherence. Further delay in the transformation will put more people at risks thus jeopardizing some of the key development targets defined under the sustainable development goals (SDGs).

Academic Abstract

The analysis presented in this paper established that there are substantial financial, social and environmental benefits on account of reduced particulate matter (PM) and CO_2 emissions through technology interventions in India's brick kiln sector using Andhra Pradesh as a case study. Emissions largely arise from inefficient combustion of large quantities of coal, petcoke and agri-residues that are used in brick kilns which has serious health and mortality implications. Improved brick manufacturing technologies like Zig-Zag can save 629 deaths per year till 2030 The total benefits due to conversion to Zig-Zag technology are Rs 280 bn, Rs 223 bn, and Rs 174 bn using VSL approach and Rs 242 bn, Rs 184 bn and Rs 137 bn using DALY approach respectively using for the three discount rates (3%, 5% and 8%). The total benefits due to conversion to VSBK technology are Rs 420 bn, Rs 321 bn, and Rs 244 bn using VSL approach while using DALY approach the total benefits are and Rs 362 bn, Rs 262 bn and 187 bn using for the three discount rates. The estimated incremental profits per kiln from shifting to Zig-Zag kiln is Rs 30 mn, Rs 26 mn and Rs 21 mn for three discount rates while for VSBK it is Rs 39 mn, Rs 34 mn and Rs 29 mn under the three discount rate scenarios.

Introduction

Brick manufacturing is an estremely important economic activity in India. With an average annual production of 200 billion bricks per annum, India is the second largest producer of bricks in the world, after China. India's share is nearly 14 percent of the global brick production. Over the last forty years, brick production has increased by eight times, largely driven by growth in the housing and infrastructure sector (CSE, 2017). Fired clay bricks are still the first choice for building materials in the country. However, in recent years, alternate options are emerging largely in the form of fly ash hollow bricks that are used in various residential and commercial buildings and creation of public infrastructure. Nevertheless, with majority of the infrastructure development in India is expected to come up in the next 10 to 15 years, there would be a 3 to 4 times increase in demand for bricks in India. Clay fired bricks will continue to remain as the primary choice among consumers largely due cost and ease in their availability.

Brick is also a major contributor to environmental pollution as it depends heavily on natural resources, particularly soil (e.g. top fertilie alluvial soil in the Indo-gangetic plains), and coal as well as other agri residues for firing kilns, etc. Infact, 65 percent of India's bricks are produced from the fertile alluvial soil from the Indo-gangetic plain, while, it is the second largest consumer of coal in the industrial sector category, after iron and steel. Brick production operation is largely seasonal and is found to operate from 9 months of the year, particularly during the dry seasons. The brick manufacturing in most of the states starts after monsoons, from end of September/early October and continue till June/July, as clay extraction, moulding and drying are carried out in the open (Maithel, 2012). The brick kiln sector employs more than 10 million people, who are migrant labourers from eastern and south eastern states, working in more than 100000 bricks across different states in India. However, it is important to note that there are no official estimates on number of operating brick kilns in India, by state or region. Different studies have provided different estimates on the operating bricks which range from 1,00,000 to 1,50,000 kilns. The conditions under which these people work are extremely hazardous and they are often underpaid. There are also frequent reports on exploitation of child labour in major brick manufacturing states and clsuters.

The predominant technology that is used for brick manufacturing in India is Fixed Chimney Bull's Trench Kiln (FBTK).This accounts for nearly 70 percent of the total brick produced in the country. However, other technologies that find application include Clamp Kilns, which produce bricks in batches where operation might be happening at relatively smaller scales, and are widely used in the peninsular region, contributing to about 25 percent of the total brick production. There are extremely fewer application of improved and environment friendly/cleaner brick kiln manufacturing technologies like Zig-Zag Kilns, Vertical Shaft Brick Kiln (VSBK), or Hoffmann Kiln, in India. Their share is around two to three percent of the total total brick manufacturing technologies currently operational in India, although official estimates are not available.

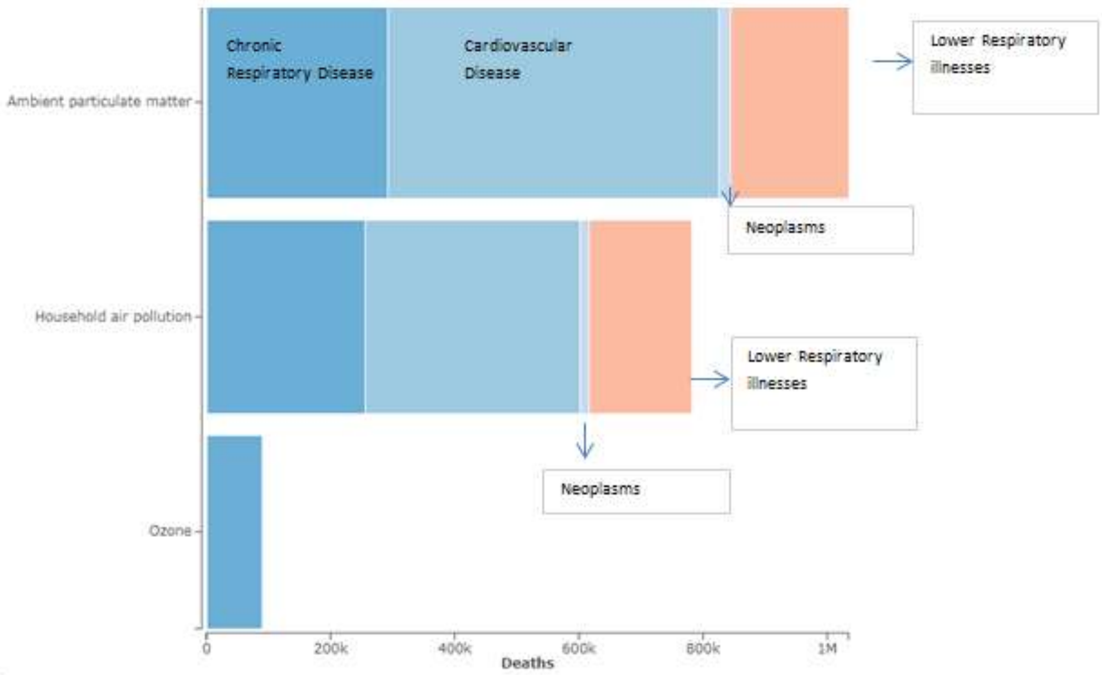
As mentioned above coal is the main source of energy for brick kilns. The use of large quantities of coal and petcoke in brick kilns contributes significantly to emissions of carbon dioxide (CO2), and particulate matter (PM). It is estimated that, around 35 million tonnes of coal is consumed in the sector and is eventually the third largest consumer of coal in the economy after thermal power, iron and steel. However, there is often application of biomass including agricultural wastes like cotton straw, mustard straw, wood chips, etc for firing. Because of these technologies, the poor and inefficient combustion of coal and other fuels lead to significant emission of particulate matter and CO2. The average estimated CO2 esmission from the sector is more than 60 million tonnes. In recent months, the growing emission from the brick manufacturing sector has drawn attention of the central pollution control board (CPCB), and as per the order received by the state pollution control boards, many of the brick kiln opertors have been ordered to convert to cleaner brick production methods as early as possible[i]. At the same time there are emissions of other environmentally polluting substances like sulphur dioxide, various oxides of nitrogen, and carbon monoxide. The pollutants not only have an adverse effect on the health of workers, local population, and vegetation, but also contribute to global warming.

Air pollution and health impacts in India

Air pollution is now widely known to have impacts over human health, agriculture, ecology, buildings, and climate. In terms of health some of the common impacts reported are respiratory, cardiovascular, cardiopulmonary, and reproductive systems (Steinle et al. 2015).

In a recent study by Indian Council of Medical Research (ICMR), air pollution was found as the second leading health risk factor in India after child and maternal malnutrition. This risk factor encompasses both outdoor air pollution from a variety of sources as well as household (indoor) air pollution that mainly results from burning solid fuels for cooking and domestic heating. While child and maternal malnutrition caused 14.6 percent of the country's total disability-adjusted life years (DALYs), air pollution was the second leading risk factor in India. Outdoor air pollution caused 6.4 percent of India's total DALYs in 2016, while DALY estimated from household air pollution was 4.8 percent. Air pollution was found to contribute significantly to India's burden of cardiovascular diseases, chronic respiratory diseases, and lower respiratory infections. Air Pollution led to over 2,750 cases of deaths or severe illnesses per lakh people in 2016. The key states that are most affected due to air pollution include Haryana, Delhi, Punjab, Bihar, Rajasthan, West Bengal and Uttar Pradesh. This is presented in figure 1. Around 41 deaths per 100000 population was estimated due to cardiovascular diseases arising from air pollution followed by chronic respiratory diseases (22 deaths) and other lower respiratory diseases (14 deaths) arising from ambiet air pollution. This indicates that chronic respiratory disease, largely caused due to air pollution, is the second largest cause of death after cardio-vascular diseases.

Figure 1: Deaths due to different diseases arising from air pollution in India



Source: ICMR, PHFI, IHM&E (2018)

Air quality in Andhra Pradesh

Andhra Pradesh Pollution Control Board is the agency responsible for collection and monitoring ambient air quality in the state. The state pollution control board have 3 three laboratories located at three zones viz. Visakhapatnam, Vijayawada & Kurnool and while there are nearly nine regional offices that carry out the functions of monitoring and assessing the ambient air quality in the state. In all 41 ambient air quality stations are reported to be in place across the state for real time air quality monitoring and tracking changes. These stations collect ambient concentrations data from residential as well as from industrial locations.

The brick kilns in the state are located in six major districts as has emerged from discussion with stakeholders. These include Krishna, Guntur, Vizianagram, Srikakulam, Kurnool, and Ananthpur. Ambient air concentration of particulate matter (PM 10) have been used for the year 2016 for nine months, as reported by the state pollution control board, in the above mentioned districts to capture the extent of impact on air quality in the sate due to operations of brick Kilns. The contribution from the brick kiln sector in the ambient PM concentration is discussed in the subsequent sections. Figures 2 to 7, provide the scattered plot of PM 10 concentrations for the year 2015-2016 (CPCB, open gov data). PM 2.5 monitoring has started very recently. A quick assessment of share of PM 2.5 and PM 10 provides an average estimate of nearly 0.5 for these districts. The central pollution control board has defined standards for PM10 ambient concentration for (industrial, Residential, Rural and Other Areas) at 60 microgram/m3 (for Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals), and 100 microgram/m3 (for 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Figure 2: Ambient PM 10 concentrations in Krishna district based on reported data from different monitoring stations

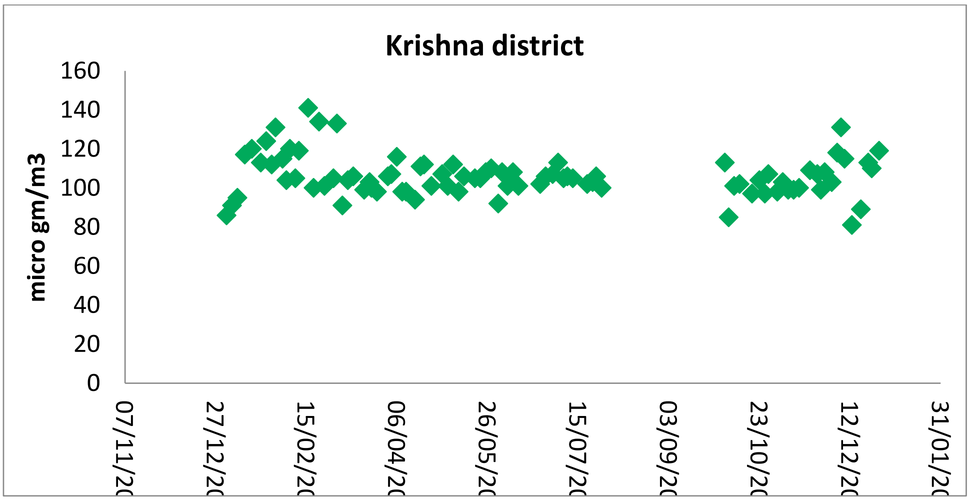


Figure 3: Ambient PM 10 concentrations in Guntur district based on reported data from different monitoring stations

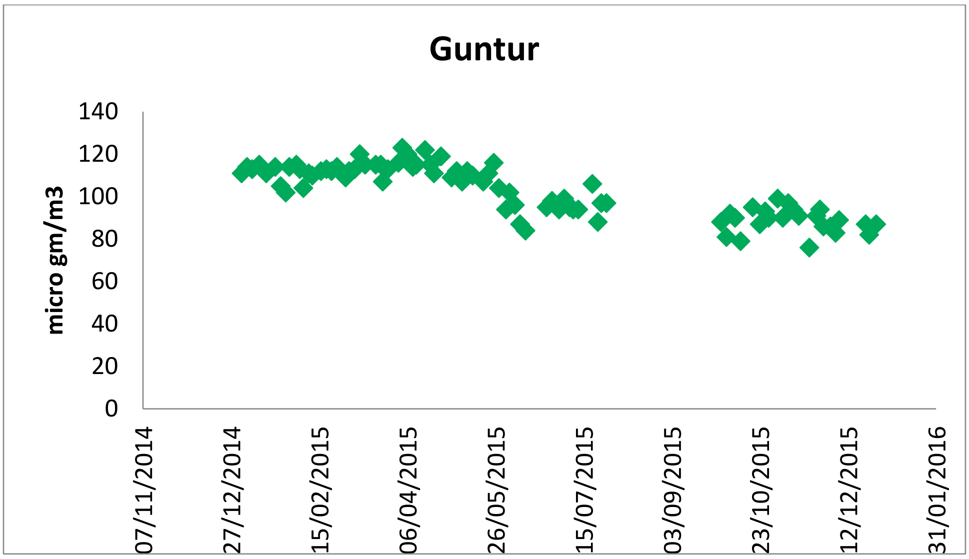


Figure 4: Ambient PM 10 concentrations in Vizianagram district based on reported data from different monitoring stations

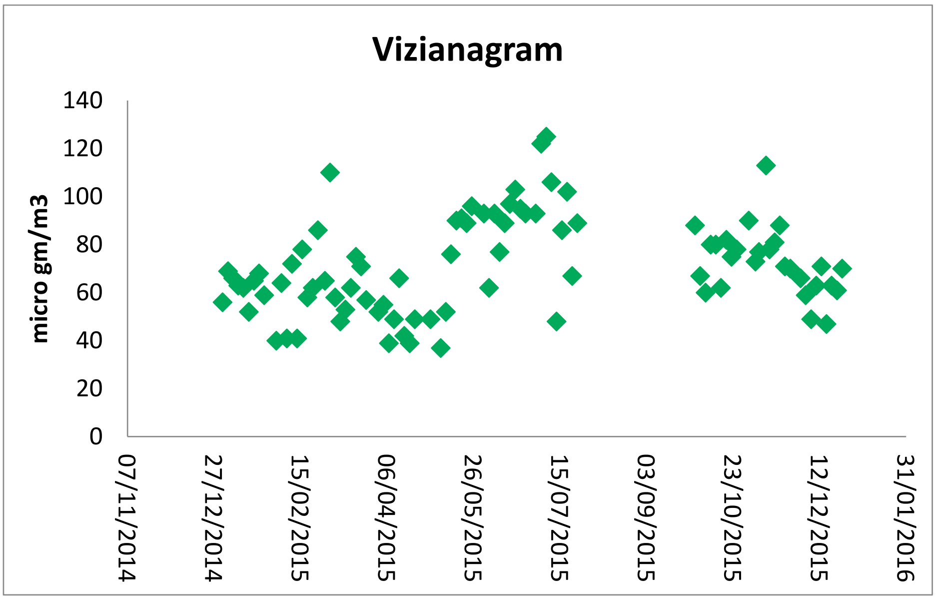


Figure 5: Ambient PM 10 concentrations in Srikakulam district based on reported data from different monitoring stations

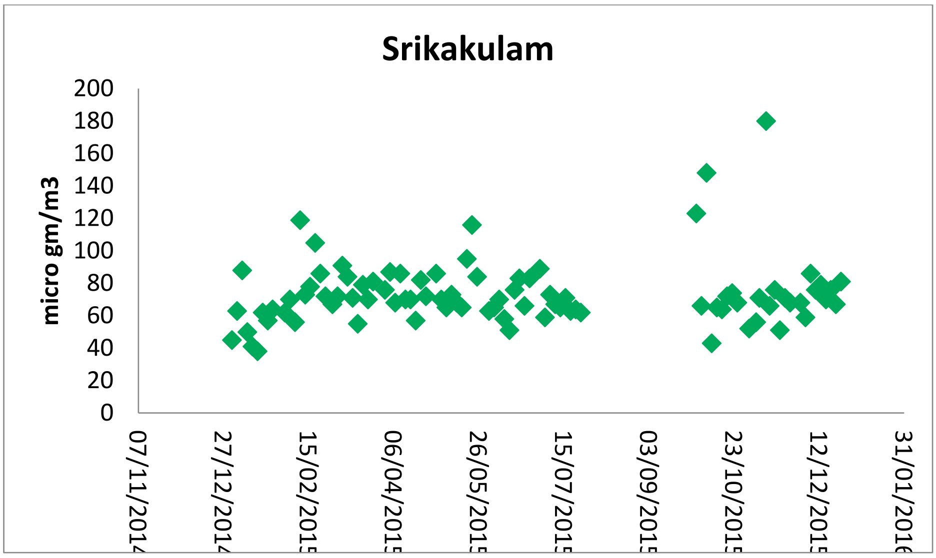


Figure 6: Ambient PM 10 concentrations in Kurnool district based on reported data from different monitoring stations

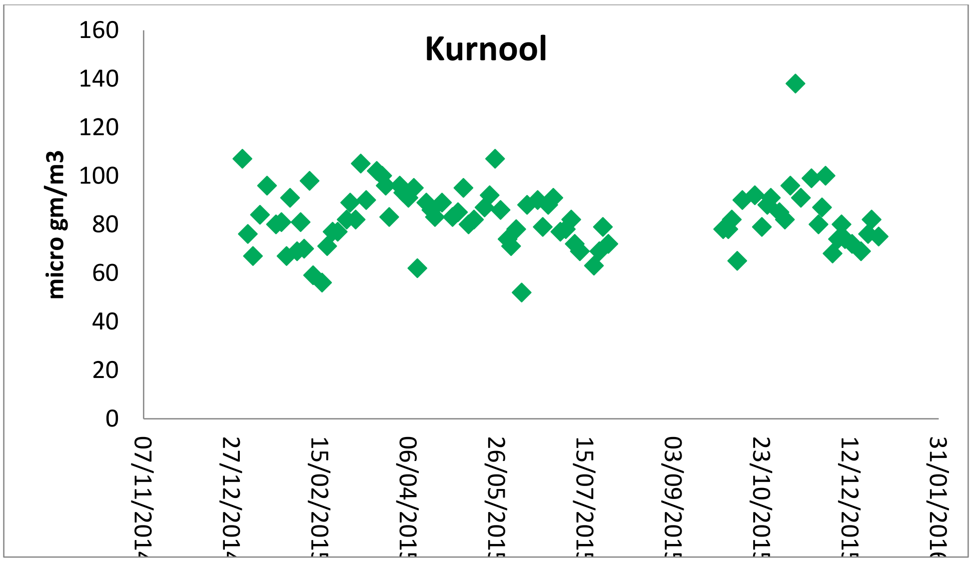
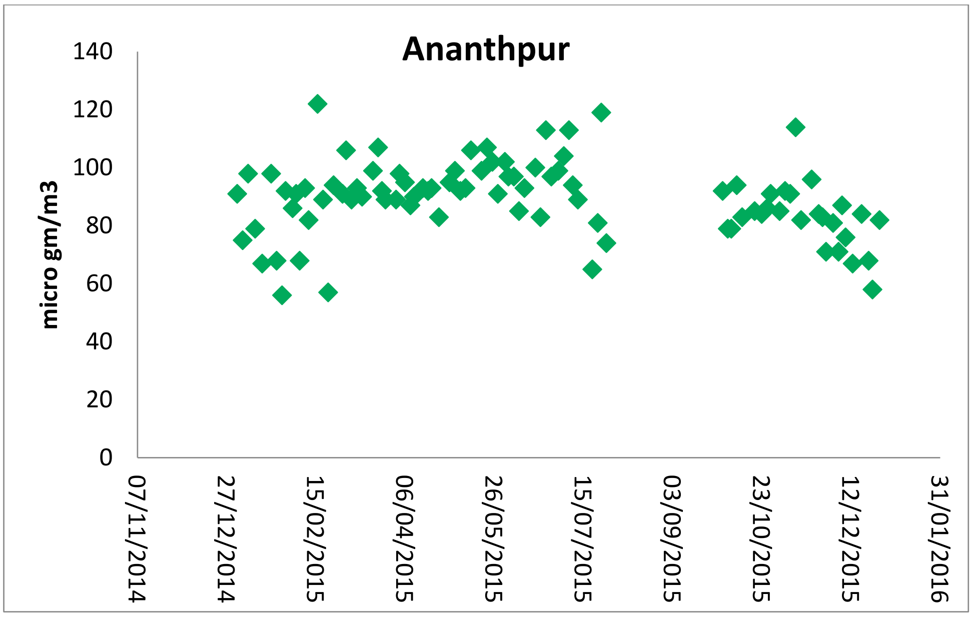


Figure 7: Ambient PM 10 concentrations in Ananthpur district based on reported data from different monitoring stations.



As observed from the above trend in ambient PM concentration, there are violations of PM 10 concentrations at most of the monitoring stations in these districts. Further, it is noted that there are variations in the average yearly concentration across six districts. For example, the highest average annual concentration has been observed in Krishna district (nearly110 µg/m3), while the lowest average annual concentration has been observed in Vizianagram (nearly 72 µg/m3). The ambient standard for PM 10 is 60µg/ m3 to 100 µg/m3, while that of World Health Organization Guidelines, the concentration is 20 µg/ m3 for the annual mean and 50 µg/m3 for 24-hour mean. Indian Standards are slightly less stringent as compared to WHO guidelines. However, the world's average PM10 levels, by region, range from 26 to 208 µg/ m3, with an average of 71 µg/ m3, as per WHO estimates published in 2014.

It is important to note that for certain disctricts the monitoring stations are located both in industrial locations, as well as residential locations, while for other districts the monitoring stations may either be situated in industrial location or only in residential locations only. Further, number of the monitoring stations is not uniform and varies across different districts. For example, air quality monitoring in Krishna district largely happens at Vijayawada city area and the monitoring stations are located in the residential as well as industrial locations, while in Vizianagram, monitored data is collected from industrial locations only.

Source apportionament studies in India are limited and largely available for regional/local level assessment or studies. Among them, most of the studies are for key urban locations, like Delhi NCR, Mumbai, Bangalore, etc. Selected review of literatures suggest that the average contribution from the the brick kiln is in the range of 15 to 25 percent. Hence an average concentration of 20 percent of the monitored data has been apportioned for the emission from the brick kiln sector in the state of Andhra Pradesh.

Brick Kiln sector in Andhra Pradesh

Although there are quite a few technologies that can be used for brick manufacturing, in India two technologies that are largely predominant are Clamp Kilns and FCBTK. The brick production methods and their geographic distribution are presented in the figure 8.

Figure 8: Brick Production Methods and Geographic Distribution (Maithel, 2012)

Kiln Type	Region	Brick production
Clamp/ Zig-Zag/Vertical Shaft Brick Kiln(VSBK)	Central, West and Southern India-Gujarat, Orissa, Madhya Pradesh, Maharashtra & Tamil Nadu	25%, 2-3%,1-2% (respectively)
Fixed Chimney Bull's Trench Kiln(FCBTK)	North and East India- Punjab Haryana, Uttar Pradesh, Bihar & West Bengal	70%

As evident from the above figure, the predominant technology in the Northern and Eastern region of India is FCBTK which is the most popular method of production, that account for majority of the annual brick production. The remaining production is based primarily on Clamp Kiln methods used across the Central, Western and Southern parts.

TERI (2016), estimated that 32 percent of the bricks in the country are manufactured using clamps, 61 percent are manufactured using FCBTK, 3 percent with moving chimney BTK and 1 percent for Holfmann kiln. The vertical shaft brick kilns (VSBK) contribute very little in the total share of the kilns across India.

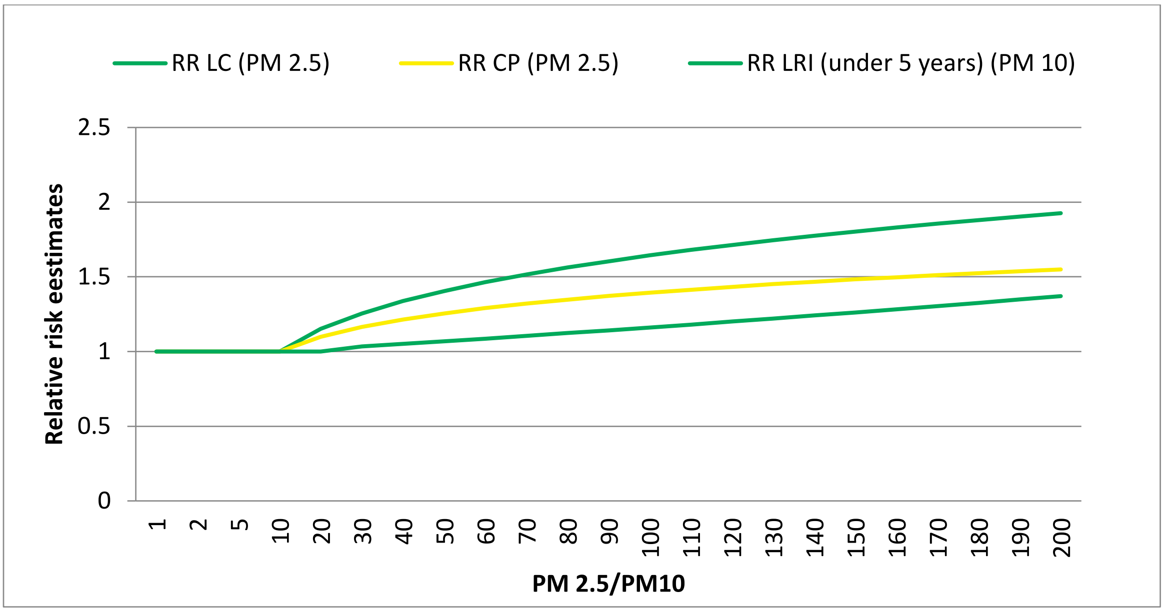
The state of Andhra Pradesh is one of the key brick producing states in South India. As mentioned earlier, there are very limited data on number of operational brick kilns in the state, as well as their break up by technology and production capacitities. For that matter few consultations with experts were undertaken which revealed that the estimated total number of brick kilns in the state of Telengana and Andhra Pradesh is approximately 8000. This estimate is based on earlier studies and estimates at a time when the state was not divided. However, after the formation of the new state, it is learnt that approximately 60 percent of total brick kilns are operational in Andhra Pradesh, while the remaining 40 percent is present in Telengana. Since there are no official estimates, this break up is largely a perception of the key experts. As mentioned earlier, in terms of their geographic distribution of brick kilns in different districts in the state of Andhra Pradesh, it was learnt that kilns are mostly operating in Krishna, Guntur, Vizianagram, Srikakulam, Kurnool, and Ananthpur. They account for nearly 70 to 80 percent percent of the total kilns operating in the state as revealed based on discussion. The intermittent kilns like clamp kilns, that manufacture bricks in batches are mostly functional in the peninsular region. They account to around 90-95 percent of the total brick kilns that are operating in the state.

Clamp kilns are predominant technology for producing bricks in the state. The stacked raw bricks are irregularly fired with different fuels in between them. There is no requirement of any permanent structure since the bricks are fired in the open and the kiln can be set up anywhere. The kiln base is made up of fired bricks having intervals of tunnels for feeding fuels. The top of the base contains a layer of fuel and on top of the fuel lies green bricks arranged in a pyramidal shape, for making the structure steady and stable. The firing happens from the bottom and as the heat goes up, the fuel in between gets ignited and in the process also burn the bricks. However, since kilns are randomly designed, and are open, it leads to improper burning of the fuel as well as loss of heat thus making some bricks being over burnt and some unburnt leading to wastages.

Health impacts of emissions of PM from the brick kilns

Exposure to air pollution is linked to a wide spectrum of health effects that can be acute or chronic in nature and will vary with concentration of pollutants. Particulate air pollution exposure can lead to lung cancer and other cardiopulmonary mortality. Health impacts of emissions from PM for AP has been analysed for cardiopulomonary disease, lung cancer and lower respiratory tract infection for children under the age of five years. The relative risks have been estimated based on Ostro (2004) for these health risks. The relationship between health risks and exposure to PM 10 or PM 2.5 is presented in figure 9.

Figure 9: Relative risks mortality due to lung cancer (LC), cardiopulmonary disease (CP) and lower respiratory infections (LRI) from exposure to PM 10 or PM2.5



RR (LC) = ((PM2.5+1)/(Threshold + 1))^(0.23218)
RR (CP) = ((PM2.5+1)/(Threshold + 1))^(0.15515)
RR (LRI (under 5 years) = EXP^(0.00166(PM10-threshold))*

Based on the estimates of the global burden of disease methrodolgy, AP recorded more than 34,000 deaths due to exposure to PM 2.5. Further, an estimated around 1500 deaths have been attributed due to brick kilns in the state. As mentioned above, there are limited source apportionments studies at the regional or local level. Review of selected studies (TERI, 2013, ICIMOD, 2016), reveal that PM 10 contribution from brick kilns to ambient PM concentration on an average ranges between 15 to 25 percent. Guttikunda et al. (2014) estimated share of PM 10 contribution from brick kiln in Patna city at 11 percent. A study by NRDC in Ahmedabad, estimated 6 to 15 percent contribution of PM in city's ambient concentration. However for the study a higer estimate of 20 percent has been used that was concluded based on discussion with experts. Table 1 presents the district wise population, average PM10 concentrations during the brick manufacturing months and the estimated deaths arising from brick kilns in the state.

Table 1: District wise population, average PM concentration during the brick manufacturing months (above standards) and the estimated deaths arising from brick kilns

Sl. No	Name of Districts	Population (2016)*	Mean concentration (PM10)	Estimated deaths due to brick kilns
1	Krishna	46,91,778	110	304
2	Guntur	51,13,922	112	332
3	Vizianagram	23,93,585	111	155
4	Srikakulam	27,89,880	139	185
5	Kurnool	43,32,907	108	280
6	Ananthpur	43,21,100	107	279

Estimated based on the annual population growth rate between 2001 and 2011 and calculated over 2011
Source: Author's estimation

Brick kiln interventions

The benefit-cost assessment undertaken in this study looks at two options of cleaner kiln technologies. One of the options involves an improvement of existing clamp kilns and FCK technology to the Improved Zig Zag Kilns, while the other option is Vertical Shaft Brick Kilns (VSBK) technology. The detailed benefits and costs of these technologies are presented in the following sections.

Intervention 1: Improved Zig-Zag Kiln

Clamp kilns and/or FCKs can be converted to Improved Zig-Zag Kilns at low costs in the low lands at the same site. This can be accomplished in less than half a year. Hence any intervention in 2018, will start reaping environmental benefits and social benefits from 2019. The production capacity is the same or higher compared to the Clamp kilns and/or FCKs. The brick quality is as good as or better than FCK, and with energy savings and PM emission reductions. Brick Kiln owners find this technology the most attractive because they neither need to relocate nor having to look for high land (Guttikunda and Khaliquzzaman, 2014), and there is no need for large investment cost that requires commercial financing.

Needless to mention, for Zig-Zag brick kilns, conversions must meet technological and operational standards. It is important to note that Zig-Zag brick manufacturing leads to 22 percent lower CO_2 emission than Clamp kiln/Down draught kiln brick manufacturing process. A comparative assessment of key parameters for both the technologies in the context of AP is presented in table 2.

Table 2: Key technical, financial and environmental parameters of clamp kilns and /or FCBK vis-à-vis Zig-Zag brick kiln technologies in the context of Andhra Pradesh.

Category	Unit	Clamp kiln/Down draught kiln	Zig-zag
Total registered brick kilns in AP	No	4800	4800
Average brick production capacity/ clamp kiln	No (in million)	4	4
Average annual production of bricks in AP	No (in million)	19200	19200
Capital Cost/Kiln	Rs (in million)	3.25	5.2
Total capital cost	Rs (in million)	15600	24960
Percentage of Class 1 bricks produced (clamp brick kiln)	Percent share	0.6	0.8
Percentage of Class II and other bricks	Percent share	0.4	0.2
No of Class 1 Brick produced	No (in million)	11520	15360
No of Class II and other bricks produced	No (in million)	7680	3840
Selling Price of Class 1 brick	Rs	4	4
Total revenue from selling class 1 brick	Rs (in million)	46080	61440
Selling Price of Class II and other bricks produced	Rs	1.5	1.5
Total revenue from selling Class II and other bricks produced	Rs (in million)	11520	5760
Total Revenue	Rs (in million)	57600	67200
Operating Cost/Brick - INR	Rs	2.35	2.068
Total operating Cost	Rs (in million)	45120	39705.6
Operating Profit	Rs (in million)	12480	27494.4

Source: Maithel (2013); Guttikunda (2014), Greentech (2012)

* Since production capacity of brick kilns are not available, the average annual production capacity per kiln is assumed at 4 million bricks.

As evident from the above table the Zig-Zag technology scores substantially over the conventional clamp kilns and/or FCBK brick kilns. Hence any intervention initiated in 2018 will start reaping environmental benefits and social benefits from 2019. It is important to note that there may be marginal improvement in operating costs, but the biggest advantage of moving to this technology is the increased production of class 1 bricks that will fetch substantial value from the market.

Finally, the financial benefits for Zig-Zag technology has been estimated for a period of 12 years (till 2030) using 3 discount rates viz. 3%, 5% and 8%. The incremental benefits and costs from shifting to Zig-Zag technology is presented in table in 3.

Table 3: Incremental present value (PV) of benfits (financial, health and environmental) achieved from shifting to Zig-Zag technology

Rs million		Zig-Zag (VSL Approach)	Zig-Zag (DALY Approach)
Cost		24,960	24,960
Financial benefits			
	3%	1,45,100	1,45,100
	5%	1,26,739	12,6,739
	8%	1,04,768	1,04,768
CO2 benefits	3%	35,220	35,220
	5%	10,580	10,580
	8%	0	0
Health benefits			
	3%	1,00,477	62,508
	5%	86,199	47,420
	8%	69,409	32,528
Total benefits	3%	2,80,797	2,42,828
	5%	2,23,518	1,84,739
	8%	1,74,177	1,37,296
BCR	3%	11.25	9.73
	5%	8.96	7.40
	8%	6.98	5.50

Source: Author's calculation

The cost of technology has been used based on literature review and discussion with subject matter experts. Using the estimated average production per kiln (table 2), and the capital cost per kiln, the total capital cost of intervention has been esimated. The adoption of Zig-Zag technology not only reduces cost of production but also leads to increase in share of class 1 bricks. The total incremental financial benefits are Rs 145 bn, Rs 126 bn and Rs 104 bn till 2030, for 3%, 5% and 8% discount rates respectively. The incremental profit per kiln for these disount rates are Rs 30.2 mn, Rs 26.4 mn and Rs 21.8 mn.

The incremental financial benefit thus captures these two benefits. The social benefits of cleaner brick kilns assessed in this study are health benefits of reduced PM10 emissions and global benefits of carbon dioxide (CO_2) emission reduction due to higher energy energy efficiency of Zig-Zag technology. Other social benefits of air emissions reductions - such as reduced material damage to buildings structures, reduced degradation of forest, soil and water, and reduced damage to agricultural crops – are not estimated as these benefits are found in most studies to be quite small compared to health benefits.

With regard to estimating the carbon benefits, the CO_2 savings from Zig-Zag technology have been used along with the baseline estimates from Clamp Kiln technology. A retrofitting with a Zig-Zag technology is estiamated to reduce CO_2 by 1.8 million tonnes. The social cost of carbon has been used from Tol (2018), in which Tol estimates the CO_2 value at US$ 25.3/tCO_2 for 3% discount rate and US$ 7.6 /tCO_2 at 5% discount rate. Combining CO_2 emission savings and cost of carbon, the present discounted value of carbon has been estimated at Rs 35 bn and Rs 10 bn respectively.

Finally, the health benefits have been estimated based on the risk function for cardiopulmonary disease, lung cancer and lower respiratory infection among children under 5 years. In the presence of Zig-Zag technology, an estimated 7,552 deaths can be avoided (between 2019 and 2030), thereby improving quality of life. This leads to saving of 629 deaths per annum. The average PM concentration for each district alon with the risks parameter, as provided by Ostro (2004), the relative risk above the threshold has been estimated. Assuming that nearly 60 percent of the population is exposed to the ambient condition, and using the estimated decline in PM concentration of the district concerned due to intervention, the risk weigthed share of impacted population fraction for each disease is estimated. The decline in the risk weigthed share of impacted population fraction for each disease, arising due to technological intervention, when multiplied by the disease specific incidence of death, provides the avoided death due to technological intervention. Avoided deaths and associated illness from cleaner brick kilns can be monetized by using various benefit valuation measures. The Copenhagen Consensus Center (CCC) methodology apply a value of GDP per capita per avoided “disability adjusted life year” or DALY. VSL per averted death is equivalent to 72 times GDP per capita in Andhra Pradesh, while DALYs are valued at 3 times GDP per capita in the state. .

The benefits from the VSL approach provide estimated net present value of incremental health benefits of Rs 100 bn, Rs 86 bn and Rs 69 bn based on 3 discount rates 3%, 5%, 8% respectively. The estimated incremental benefits using the DALY based valuation approach provides benefits of Rs 62 bn, Rs 47 bn, and Rs 32 bn, using the same set of discount rates. The total estimated benefits from VSL approach are Rs 280, Rs 223 and Rs 174 bn which is higher than the benefits obtained from DALY (i.e. Rs 242, Rs 184 and Rs 137 bn). The benefit costs ratios under these two approaches for three discount rates are 11, 8, & 7 and 9, 7 and 5 respectively.

Intervention 2: Vertical Shaft Brick Kiln Technologies (VSBK)

The VSBK technology uses hot exhaust gasses for the gradual preheating of the unfired bricks in a continuous process, thus reducing energy consumption and CO2 emissions compared to the more commonly used clamp kilns. There is no doubt that the VSBK technology is one of the most energy efficient and cost effective brick firing processes in the world, with the added benefit of providing a better working environment for staff members. The VSBK makes clay brick an even more sustainable building option by reducing the embodied energy of an average clay brick, at least by half. It is important to note that Zig-Zag brick manufacturing leads to 53 percent lower CO2 emission than Clamp kiln/Down draught kiln brick manufacturing process.

A comparative assessment of key parameters for clamp kilns and VSBK is presented in table 4.

Table 4: Key technical, financial and environmental parameters of clamp kilns and /or FCBK vis-à-vis VSBK brick kiln technologies in the context of AP.

Category	Unit	Clamp kiln/Down draught kiln	VSBK
Total registered brick kilns in AP	No	4,800	4800
Average brick production capacity/ clamp kiln	No (in million)	4	4
Average annual production of bricks in AP	No (in million)	19,200	19,200
Capital Cost/Kiln (possible replacement in 6 to 8 months)	Rs (in million)	3.25	8
Total capital cost	Rs (in million)	15,600	38,400
Percentage of Class 1 bricks produced (clamp brick kiln)	Percent	0.6	0.9
Percentage of Class II and other bricks	Percent	0.4	0.1
No of Class 1 Brick produced	No (in million)	11,520	17,280
No of Class II and other bricks produced	No (in million)	7,680	1920
Selling Price of Class 1 brick	Rs	4	4
Total revenue from selling class 1 brick	Rs (in million)	46,080	69,120
Selling Price of Class II and other bricks produced	Rs	1.5	1.5
Total revenue from selling Class II and other bricks produced	Rs (in million)	11,520	2,880
Total Revenue	Rs (in million)	57,600	72,000
Operating Cost/Brick - INR	Rs	2.35	2.068
Total operating Cost	Rs (in million)	45,120	39,705.6
Operating Profit	Rs (in million)	12,480	32,294.4

Source: Maithel (2013); Guttikunda (2014), Greentech (2012)

* Since production capacity of brick kilns are not available, the average annual production capacity per kiln is assumed at 40,00,000.

As evident from the above table the VSBK technology scores substantially over the conventional clamp kilns and/or FCBK brick kilns. It is important to note that there may be marginal improvement in operating costs, but the biggest advantage of moving to this technology is the increased production of class 1 bricks that will fetch substantial value from the market. While the number of class 1 bricks in Zig-Zag technology is approximtaly 80 percent, the share further increases to 90 percent in VSBK. With regard to financial benefit from VSBK technology, the increased revenue from selling additional class 1 bricks have been considered as the key benefit in the analysis.

The private financial benefits for VSBK technology has been estimated for a period of 12 years (till 2030) using 3 discount rates viz. 3%, 5% and 8%. The incremental benefits and costs from shifting to VSBK technology is presented in table 6.

Table 5: Incremental present value (PV) of benfits (financial, health and environmental) achieved from shifting to VSBK technology

Rs million		VSBK (VSL Approach)	VSBK (DALY Approach)
Cost		38,400	38,400
Financial benefits			
	3%	1,91,488	1,91,488
	5%	1,67,257	1,67,257
	8%	1,38,262	1,38,262
CO2 benefits	3%	75,242	75,242
	5%	22,602	22,602
	8%	0	0
Health benefits			
	3%	1,53,374	95,416
	5%	1,31,579	72,385
	8%	1,05,950	49,652
Total benefits	3%	4,20,104	3,62,146
	5%	3,21,438	2,62,244
	8%	2,44,212	1,87,914
BCR	3%	10.94	9.43
	5%	8.37	6.83
	8%	6.36	4.89

Source: Author's calculation

Use of VSBK can lead to an incremental financial benefit of Rs 191 bn, Rs 1687 bn and Rs 138 bn for 3 discount rates. The incremental profit per kiln for these disount rates are Rs 39 mn, Rs 34 mn and Rs 28 mn. The social benefits of cleaner brick kilns assessed in this study are health benefits of reduced PM10 emissions and global benefits of carbon dioxide (CO_2)

emission reduction from improved energy efficiency. A retrofitting with a VSBK technology is estimated to reduce CO_2 by 3.8 million tonnes.

Using the same approach discussed in the previous section the avoided CO_2 costs have been estimated to be Rs 75 bn and Rs 22 bn for 3% and 5% discount rates. In the presence of VSBK technology, an estimated 11528 deaths can be avoided, thereby improving quality of life between 2019 and 2030. This is equivalent to 961 deaths saved per annum.

The benefits from the value of statistical life approach provide estimated health benefits of Rs 153 bn, Rs 131 bn and Rs 105 bn based on 3 discount rates 3%, 5%, 8% respectively. The estimated benefits using the DALY based valuation approach provides benefits of Rs 95 bn, Rs 72 bn, and Rs 49 bn, using the same set of discount rates. The total estimated benefits benefits from VSL approach are Rs 420, Rs 321 and Rs 244 bn which is higher than the benefits obtained from DALY based approach (i.e. Rs 362, Rs 262 and Rs 187 bn). The benefit costs ratios under these two approaches for three discount rates are 10, 8, 6 and 9, 6 and 4.

Conclusion

The analysis presented in this paper confirms that there are substantial environmental benefits on account of reduced PM emission and the consequent health benefits through technology interventions.

Brick is also a major contributor to environmental pollution as it depends heavily on natural resources, like soil (e.g. top fertilie alluvial soil in the Indo-gangetic plains), and coal as well as other agri residues for firing kilns, etc. Infact, 65 percent of India's bricks are produced from the fertile alluvial soil from the Indo-gangetic plain, while, it is the second largest consumer of coal in the industrial sector category, after iron and steel. The use of large quantities of coal and petcoke in brick kilns contributes significantly to emissions of carbon dioxide (CO_2), and particulate matter (PM).

The level of penetration of improved and environment friendly technologies in the brick kiln sector have been very slow. As per certain estimates there is 3 percent moving chimney BTK and 1 percent Holfmann kiln in India operating in India. Two technologies that are largely predominant are clamp and FCBTK, which are less efficient in terms of energy consumption and quality brick production, than other technologies. However, penetration of technologies like Zig-Zag and VSBK are are both financially (private costs and benefits) and economically (social costs and benefits) viable when appropriately adopted in the state of AP.

It is important to note that there may be marginal improvement in operating costs, but the biggest advantage of moving to these technologies is the increased production of class 1 bricks that will fetch substantial value from the market. It has been found that the production of class 1 bricks cen increase from 50 percent to 80 percent incase of Zig-Zag technologies, while in VSBK, the production of class 1 bricks can be as high as 90 percent. Increased efficiency will reduce CO_2 emission thereby reducing global warming potential. At the same time emission of PM will also come down thereby improving ambient air quality.

The studied options are financially (private costs and benefits) viablity and economically (social costs and benefits) viablity. As evident from the above table, the benfits costs ratios are relatively more for conversion or retrofitting of existing Clamp kilns to Zig-Zag kilns over VSBK. The total incremental financial benefits are Rs 145 bn, Rs 126 bn and Rs 104 bn till 2030, for 3%, 5% and 8% discount rates respectively. The incremental profit per kiln for these disount rates are Rs 30.2 mn, Rs 26.4 mn and Rs 21.8 mn. A retrofitting with a Zig-Zag technology is estimated to reduce CO_2 by 1.8 million tonnes. The total estimated benefits (private+CO_2+health) from VSL approach are Rs 273, Rs 220 and Rs 174 bn which is higher than the benefits obtained from DALY (i.e. Rs 235, Rs 181 and Rs 137 bn). The benefit costs ratios under these two approaches for three discount rates are 11, 8.8, & 7 and 9.5, 7.3 and 5.5.

Use of VSBK can lead to an incremental financial benefit of Rs 191 bn, Rs 1687 bn and Rs 138 bn for 3 discount rates. The incremental profit per kiln for these disount rates are Rs 39 mn, Rs 34 mn and Rs 28 mn. A retrofitting with a VSBK technology is estimated to reduce CO_2 by 3.8 million tonnes. The total estimated benefits benefits from VSL approach are Rs 405, Rs 314 and Rs 244 bn which is higher than the benefits obtained from DALY based approach (i.e. Rs 347, Rs 255 and Rs 187 bn). The benefit costs ratios under these two approaches for three discount rates are 10.6, 8.2, 6.4 and 9, 6.7 and 4.9.

In the presence of Zig-Zag technology, an estimated 7,552 deaths can be avoided (between 2019 and 2030), leading to saving of 629 deaths per annum. VSBK can lead to avoiding 11,528 deaths (between 2019 and 2030), and will save 961 deaths per annum.

However, there are many impediments to this shift. Interactions with selected stakeholders have revealed that despite having a business case, poor awareness among entrepreneurs, lack of concessional finance for buying these technologies and hand holding are areas that need utmost attention. While there are various programs undertaken by ministry of micro small and medium enterprises to create awareness among producers, often the reach has been limited and focused at specific locations. This can be minimized by engaging with state level and/or district level institutions/ agencies particularly, industry associations, polytechniques, Small Industries Development Bank of India, incubation centres of professional and technical institutions, etc. More importantly, such engagements need to focus on time adherence. Further delay in the transformation will put more people at risks thus jeopardizing some of the key development targets defined under the sustainable development goals (SDGs).

References

- Tol, R. (2018). 'The Economic Impacts of Climate Change'. Review of Environmental Economics and Policy, Volume 12, Issue 1, 1 February 2018, Pages 4–25, https://doi.org/10.1093/reep/rex027, Published: 12 January 2018

- Ostro, B. (2004).Outdoor air pollution. WHO Environmental Burden of Disease Series, 5. Available at http://www.who.int/quantifying_ehimpacts/publications/ebd5.pdf, last accessed 2nd May, 2018

- CPCB (2017), 'Directions issued to District Magistrates/Collectorates of 22 NCR districts of 3 states, dated 24.10.2017, under section 5 of EPA, 1986, regarding Brock Kilns'. Available at http://cpcb.nic.in/uploads/direction/brick_kiln_haryana_13.02.2018.pdf, last accessed 2nd May, 2018

- Centre for Science and Environment (CSE) (2017), 'Overview of Brick Kiln Sector in the country', Available at https://cdn.cseindia.org/docs/photogallery/slideshows/TP-cleaner-brick-production-20171211-15-Overview-of-Brick-Kiln-Sector-Environmental-issues-Nivit-Kuma.pdf , Last accessed, 12th May, 2018.

- TERI (2016), 'Air Pollution Emissions Scenario for India', Sharma S., Kumar, A. (Eds). There Energy and Resources Institute, New Delhi- PP 1-76.

- Maithel, S., Uma, R., Bond, T., Baum, E., Thao, V.T.K., 2012. Brick Kilns Performance Assessment, Emissions Measurements, & a Roadmap for Cleaner Brick Production in India. Study report prepared by Green Knowledge Solutions, New Delhi, India

- Guttikunda, S.K. Goel, R. & Pant, P. (2014), 'Nature of air pollution, emission sources, and management in the Indian cities', Atmospheric Environment 95 (2014) 501e510

- ICMR, PHFI, IHM&E (2018), 'Global Burden of Disease India Database', available at http://www.healthdata.org/india, last accessed 30th April, 2018.

- Steinle, S. et. al (2015), 'Personal exposure monitoring of PM2.5 in indoor and outdoor microenvironments ',Science of The Total Environment, Volume 508, 1 March 2015, Pages 383-394.

- NRDC (2017), 'Issue Brief: Protecting Health from Rising Air Pollution in Ahmedabad, Supporting Research and Analysis for the Ahmedabad Air Information & Response (AIR) Plan', Available at https://www.nrdc.org/sites/default/files/ahmedabad_aqi_-_final.pdf, last accessed on 3rd May, 2018

- Location wise daily Ambient Air Quality of Andhra Pradesh for 2015-2016, https://data.gov.in/resources/location-wise-daily-ambient-air-quality-andhra-pradesh-year-2015. last accessed on 3rd May, 2018.

As a new state, Andhra Pradesh faces a bright future, but it is still experiencing many acute social and economic development challenges. It has made great strides in creating a positive environment for business, and was recently ranked 2nd in India for ease of doing business. Yet, progress needs to be much faster if it is to achieve its ambitions of becoming the leading state in India in terms of social development and economic growth. With limited resources and time, it is crucial that focus is informed by what will do the most good for each rupee spent. The Andhra Pradesh Priorities project as part of the larger India Consensus – a partnership between Tata Trusts and the Copenhagen Consensus Center, will work with stakeholders across the state to identify, analyze, rank and disseminate the best solutions for the state. We will engage people and institutions from all parts of society, through newspapers, radio and TV, along with NGOs, decision makers, sector experts and businesses to propose the most relevant solutions to these challenges. We will commission some of the best economists in India, Andhra Pradesh, and the world to calculate the social, environmental and economic costs and benefits of these proposals

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