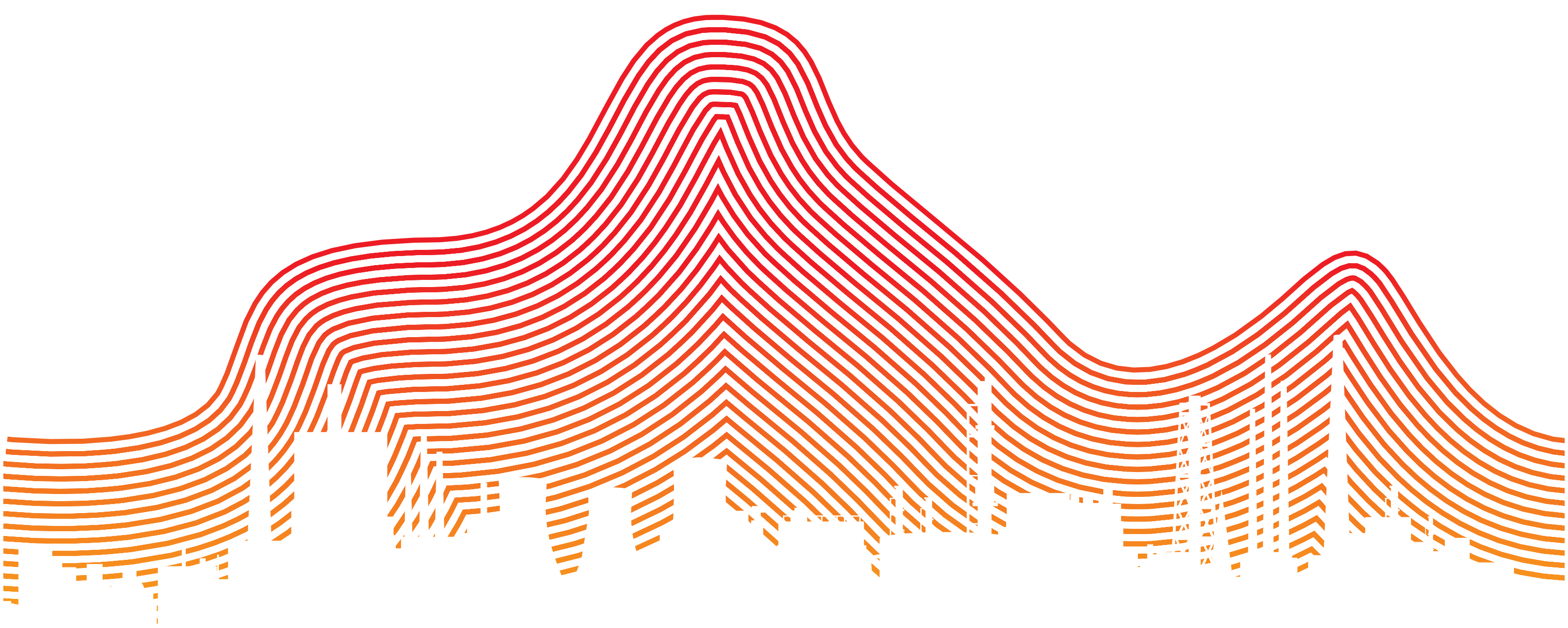
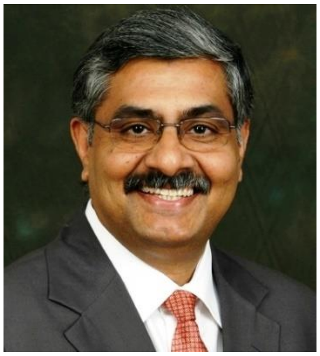
Heat Island Effect
in an Industrial Cluster

Identification, Mitigation
and Adaptation





R. Balakrishnan, IAS

FOREWARD

Human induced Climate Change, at present, is in the centre-stage of global discourse. In this backdrop, incidents of high summer-temperature in some of the industrial clusters of the state have received a very high public and media attention. The State Action Plan for Climate Change also has pointed out for a study to examine the cause of heat-islands in industrial clusters to help formulate an appropriate mitigation and adaptation policy.

Although globally a few Urban Heat Island Studies have been carried out successfully, such heat-island study for industrial cluster is rather novel and challenging. We are thankful to DFID for initiating such a complex study under the Climate Change Innovation Program and the TERI University for carrying out the study.

The study report and the policy-brief that delineates mitigation and adaptation measures for extreme-heat condition in Jharsuguda IB Valley area, will be extremely helpful for the policy makers and planners to effectively address the problem of high summer temperature in Jharsuguda industrial area.

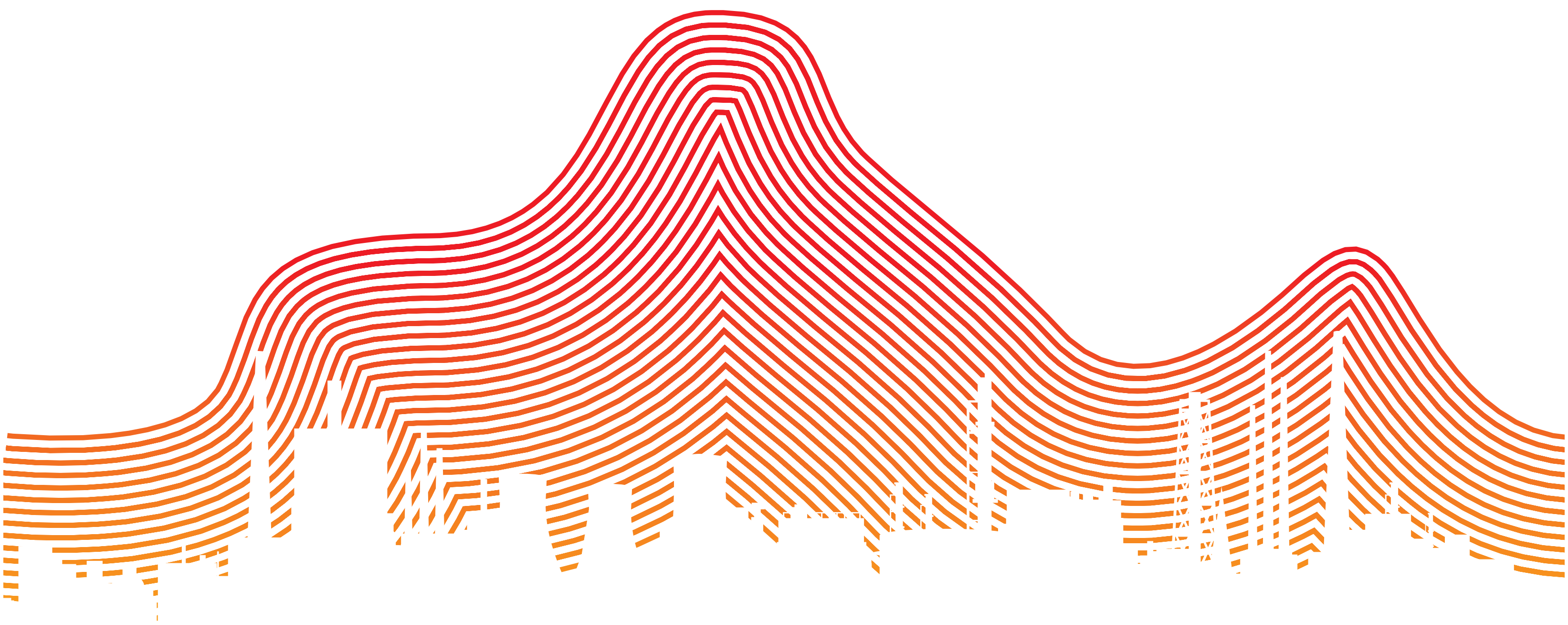
I appreciate the efforts of Mr. Soumik Biswas, State team leader of DFID, Dr. Prasoon Singh and his team from the TERI University, Forest & Environment Department and Shri Debidutta Biswal, IFS, Member Secretary, Dr. Nihar R. Sahoo, Senior Environmental Engineer and Shri Simanchal Dash, Senior Environmental Engineer of the State Pollution Control Board, Odisha, in bringing out this report.

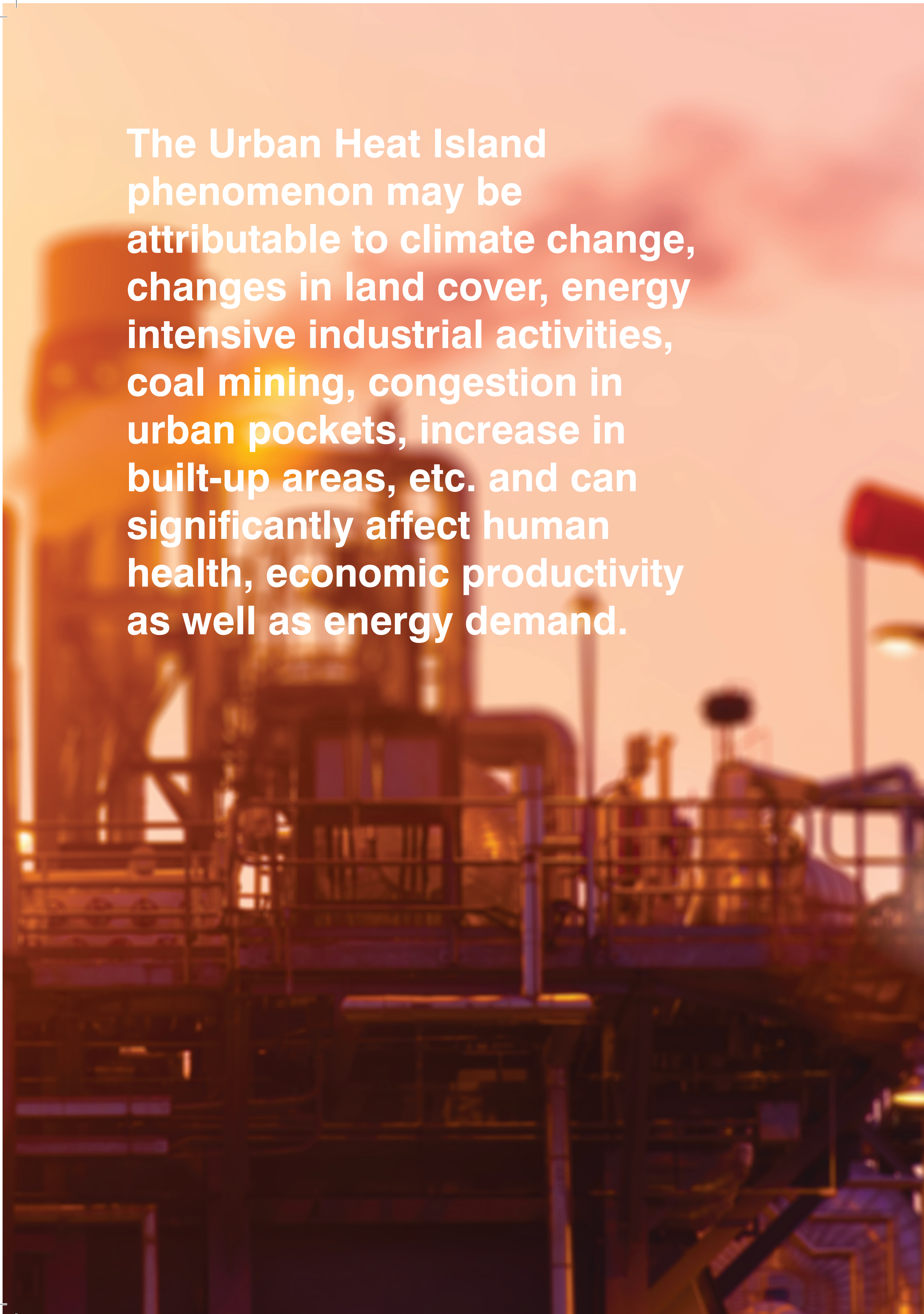
R.Balakrishnan, IAS
Addl. Chief Secretary-cum-Development Commissioner,
Govt. of Odisha-Cum-Chairman,
State Pollution Control Board, Odisha

Heat Island Effect in an Industrial Cluster

Identification, Mitigation and Adaptation

Briefing Paper





The Urban Heat Island phenomenon may be attributable to climate change, changes in land cover, energy intensive industrial activities, coal mining, congestion in urban pockets, increase in built-up areas, etc. and can significantly affect human health, economic productivity as well as energy demand.

Introduction

Urban Heat Island (UHI) is a situation with elevated air temperatures in urban areas in contrast to their non-urban rural vicinities. The phenomenon is present in all big and small cities around the world with varying intensity. The industrial agglomeration of Ib-valley in Jharsuguda faces the problem of heat island effect which may be attributed to changes in land cover, energy intensive industrial activities, mining, etc. The Ib-valley region of Jharsuguda is one of four identified UHIs (Jharsuguda, Titlagarh-Balangir, Angul-Talcher, Bhubaneswar) in the state of Odisha. It was found that there has been a steady built-up of heat in the study area over the years resulting in higher night time temperature which can be attributed to increase in industrial activities, coal mining, urban growth, deforestation and increase in open non-vegetated surface.

The UHI phenomenon may be attributable to climate change, changes in land cover, energy intensive industrial activities, coal mining, congestion in urban pockets, increase in built-up areas, etc. and can significantly affect human health, economic productivity as well as energy demand. Therefore, it is important to develop mitigation strategies to reduce the causes of UHI and adaptation strategies to cope with the heat stress.

The key challenges to implement these strategies are primarily related to proper execution of industrial and institutional framework and requires focussed drive, capacity and awareness among the institutions and in the affected population.

This briefing paper outlines the UHI mitigation and adaptation strategies based on the study conducted in this region. It provides a comprehensive strategy for mitigation and adaptation of the heat island effect. The sectoral contribution of different sources and sinks to heat islands has been analysed to determine where actions can be targeted. Sector specific measures to reduce the heat island effect over the Ib-valley region in Jharsuguda have been recommended on the basis of analysis of the contribution of each measure to the reduction in heat release.

An indicative potential of the impact of each measure along with the cost of implementation were estimated, wherever sufficient data was available. However, the execution of these plans requires investment, commitment and coordination from each sector, community group, and local and state government agencies. To strengthen the institutional mechanism and coordination, the roles and responsibilities of each institution have been worked out and documented.

Key Findings

The key methodologies followed in the study were:

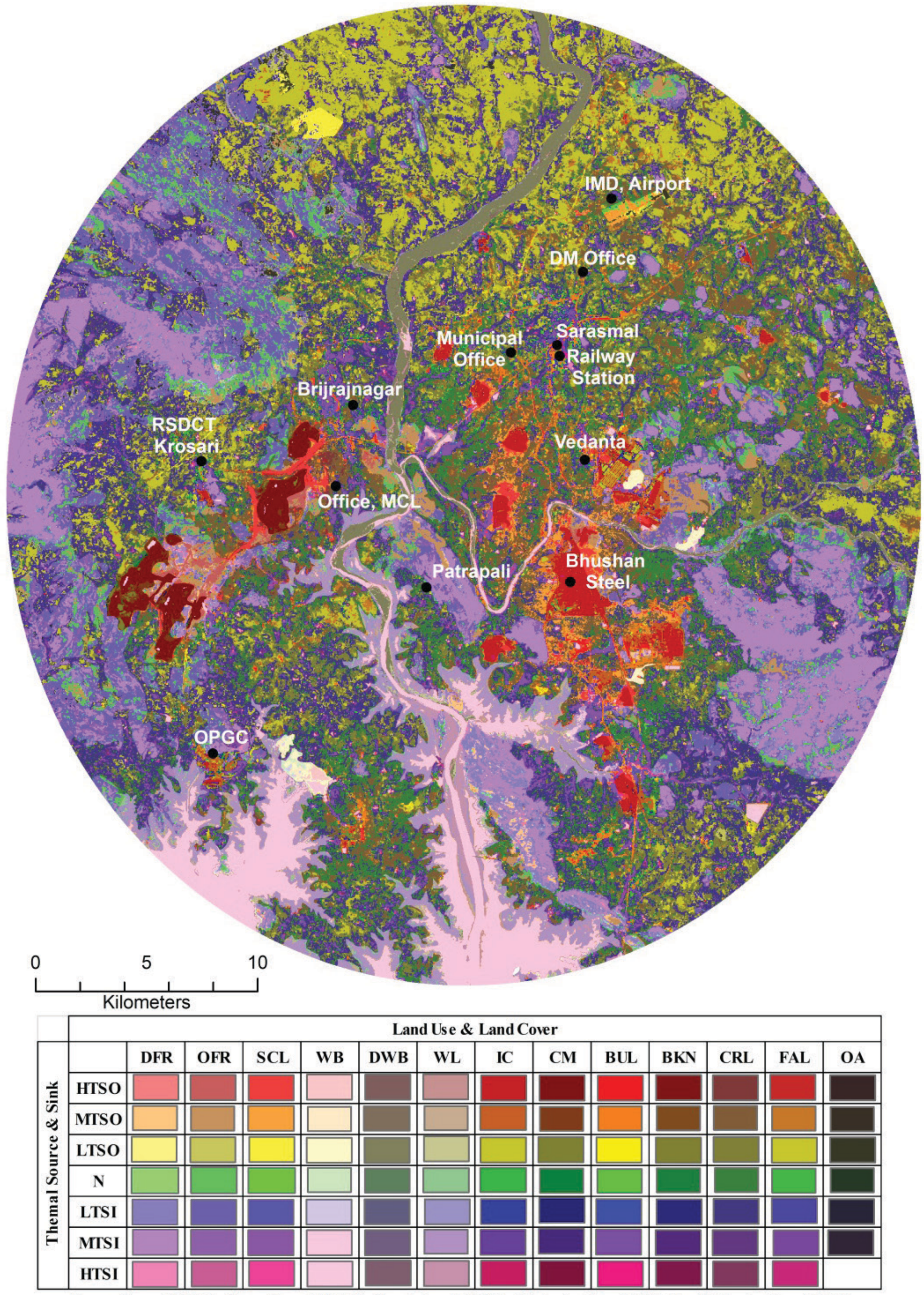
- Identification of thermal hotspots using **satellite remote-sensing**,
- Direct monitoring of ambient air temperature and humidity in 12 locations of the district and statistical analysis using **thermal retentivity** and **heat index approaches**,
- Assessment of **bio-physical parameters** to identify the key thermal sources and sinks, and
- Estimation of **net heat release** from coal mining and industrial activities using IR camera imaging.

The key findings for each of these models are summarised in Table 1. These methodologies individually resulted in independent findings and also in some cases re-inforced the findings of another methodology (as seen in the table below).

Model	Key Findings
Remote Sensing – Land Surface Temperature Model	There has been a steady build-up of heat in the region over the years resulting in higher night time temperatures. Coal Mining, Industries, Urban settlements and open non-vegetated surface have been identified as thermal hotspots
Ambient Air Temperature – Thermal Retentivity Model	'Bhushan Steel Area' and 'Market Road' are hotspot locations in summer; 'Market Road' is hotspot location in monsoon as well as combined period (summer and monsoon). This is likely because of the high built-up are on market road
Ambient Air Temperature – Heat Index Model	'Bhushan Steel Area', 'Municipality', and 'Market Road' are hotspot locations in summer; 'OPGC', 'Market Road', 'Municipality' are hotspot locations in monsoon; 'Bhushan Steel Area', 'Market Road', 'OPGC' are hotspot locations in the combined period. Higher heat sources, combined with higher built-up as well as more rotating population contributes to the higher heat index
Remote Sensing – Biophysical Model	Coal Mining, Industries and Urban settlements are high thermal sources; forests, vegetation and water bodies are high thermal sinks
Heat Release Model	Coal Mining – Impact of bio-reclamation of de-coaled area (in terms of heat release per unit de-coaled area) highest for Lajkura and Lakhanpur, least for Lilari

Table 1: *Key findings in the study.*

Thermal Source & Sink and Land Use/ Land Cover Matrix



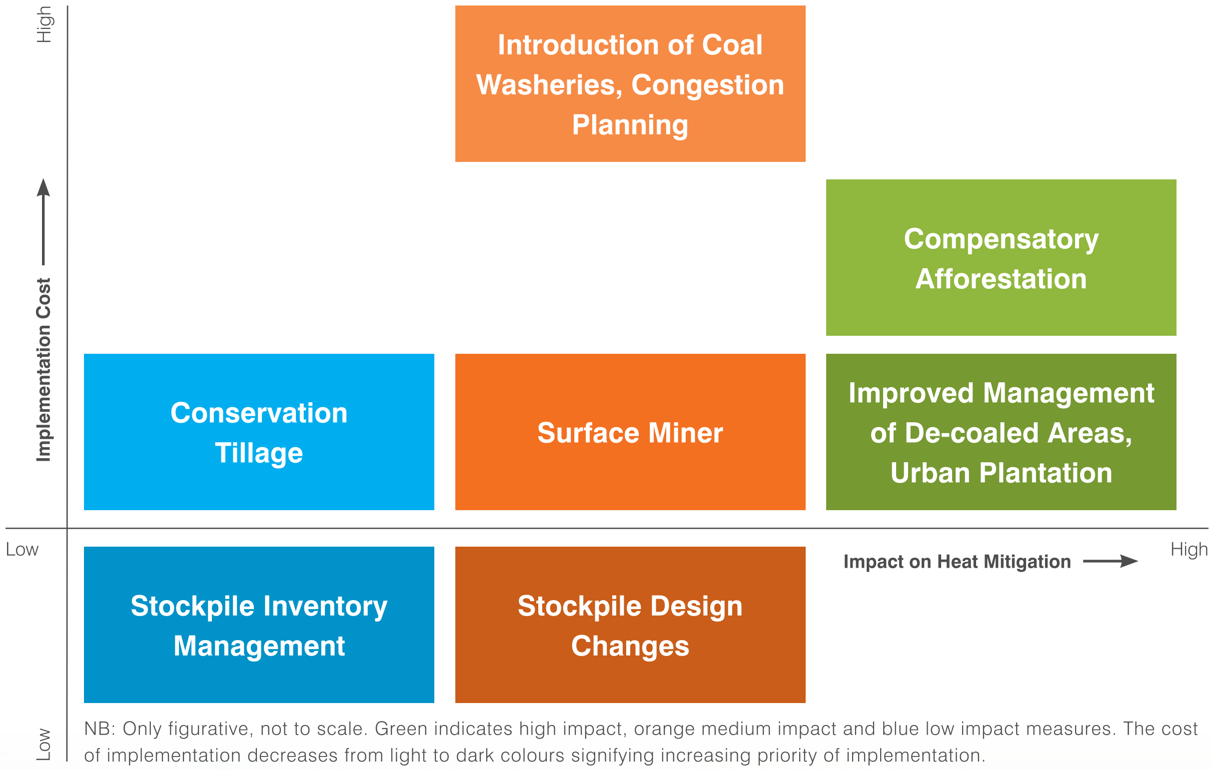
Dense forest (DFR); Open Forest (OFR); Scrub Land (SCL); Water Bodies (WB); Dry Water Bodies (DWB); Wet Land (WL); Industrial Cluster (IC); Coal Mine (CM); Built Up (BUL); Brick Kiln (BKN); Crop Land (CRL); Fallow Land (FAL); Open Area (OA);

High Thermal Source: HTSO (> 45°C); Moderate Thermal Source: MTSO (40°C - 45°C); Low Thermal Source: LTSO (35°C - 40°C); Neutral: N (30°C - 35°C); Low Thermal Sink: LTSI (25°C - 30°C); Moderate Thermal Sink: MTSI (20°C - 25°C); High Thermal Sink: HTSO (<20°C);

Figure 1: *Thermal heat sources and sinks plotted in a spatial map along with their land use classes to suggest what and where heat mitigation plan should be implemented. Total geographical area is classified in terms of thermal zones (source and sinks)—high, moderate, neutral, and low based on land use practices and function. 40% area out of total geographical area is under thermal sources, 13% area is under neutral category (neither a source nor a sink), and rest 48% are thermal sinks.*

Mitigation Measures

The most suitable set of heat mitigation measures have been recommended based on modelling and prioritized based on analysis of information collected from stakeholders' consultation using Multi-Criteria Decision Analysis (MCDA) through Analytic Hierarchy Process (AHP) approach. The sectors covered include coal mining, industries, cropland and urban planning. The recommended interventions along with their description, heat mitigation potential, priority ranking (based on impact to cost ratio), indicative costs and the responsible implementing agencies are provided in Table 2.



NB: Only figurative, not to scale. Green indicates high impact, orange medium impact and blue low impact measures. The cost of implementation decreases from light to dark colours signifying increasing priority of implementation.

***Figure 2:** Cost vs. Impact plot of heat mitigation measures*

Sector	Description of Intervention	Impact of Intervention
 **Coal Mining**	Improved management of de-coaled areas through increased bio-reclamation as well as creation of water bodies in mine void spaces.	Reduction in net heat release Impact per unit de-coaled area highest in Lajkura, Lakhanpur.
	Introduction of 4 new coal washeries.	Reducing self-oxidation by reducing ash content of coal.
	Complete penetration of surface miner technology.	Reduction in the amount of loose coal susceptible to self-oxidation.
	Speedy and transparent afforestation.	Increase in heat sink potential.
 **Industry**	Management of coal stockpile (reduce inventory in summer months keeping production schedule constant).	Reduction in coal purchase cost as follows: Plant A: Rs. 60 to 190 lakh (136878 MTPY sponge iron), Plant B: Rs. 36.7 crore (0.8 million MTPY pig iron), Plant C: Rs. 152 crore (0.5 million MTPY aluminium), Plant D: Rs. 95.5 crore (960 MW), Plant E: Rs. 55 crore (360 MW)
	Change of coal stockpile design	Heat released can be lowered by 11%.
 **Urban Planning**	New flyover on the left flank of the existing flyover in the NH-49 after crossing the railway line.	Reduced traffic flow can ease congestion and avoid fugitive and idling vehicular emissions which increase the ambient temperature of the region.
	Shifting of the entire bus stand from the southern part of the railway line to the northern part.	
	Develop two approach roads – a) From NH-49 and b) SH-10 to the proposed bus stand.	
	Plantation of short height trees and trees with higher LAI bordering the pavements of NH, SH and newly proposed roads. **Highway & Road Dividers:** *Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Bougainvillea, Cascabela thevetia* **Highway Sides:** *Ficus religiosa, Ficus recemosa, Syzygium cumini, Ficus benghalensis, Alstonia scholaris, Azadirachta indica, Tamarindus indica* **Municipal Roads:** *Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Alstonia scholaris, bouganvillea, cascabela sp, oleander plants, etc.*	Reduction of influx of solar radiation and amount of heat absorbed by the asphalt material.
 **Agriculture**	Increased adoption of conservation tillage in the agricultural areas.	Increase in surface albedo by 0.2 over that of the normal tilled crop land, decreasing temperature by 2°C.

Table 2: *Sectoral Intervention Options for Heat Mitigation*

Adaptation Measures

Odisha has been one of the leading states to address the problem of heat wave through a systematic heat wave action plan involving all stakeholders. The state's action plan outlines the responsibilities of the different wings of the state government. Additional roles have been proposed for these agencies over and above their current roles in the heat wave action plan as elaborated in Table 3.

An institutional Framework has also been designed to coordinate the different adaptation response strategies as shown in Figure 3. An institutional framework along the lines of heat wave action plan for implementing and tracking the progress of measures for heat island adaptation will go a long way to address this challenge.

Name of Dept./ Agency	Relevant Role
Level: Central	
Indian Meteorological Dept.	• Installation of more Automatic Weather Stations (AWS) in heat-wave prone districts • Analyse data from the different AWS to obtain real-time spatial distribution of temperature and heat index in each of the heat-wave prone districts • Provide zone-wise or block-wise early warning forecasts for each of the heat-wave prone districts.
Level: State	
Special Relief Commissioner (SRC)	• In addition to disseminating warnings through AIR (All India radio), Doordarshan and other private TV channels, SRC could help create local radio networks in Sambalpuri and organize discussions and other programs for creating public awareness on specific regions in the district which are more vulnerable to heat stress. Information on 'do's and 'do not's during heat stress should be highlighted in several strategic and heat stressed locations as posters, billboards and hoardings in the local language ensuring information is widely accessible amongst different groups of people. • To deploy adequate number of water tankers in water-scarce areas based on a careful analysis of the heat-stress prone regions and the population density of these regions within the district. The Department of Water Resources to be mobilized for release of water in the canals.
OSDMA	• To arrange for drinking water supply arrangements and access to medical facilities that are equipped to cater to both genders. • To reschedule working hours in educational institutions, for those doing physical labour, veterinary measures, etc. • Distribute leaflets among school children to educate them on heat stress and its prevention

Name of Dept./ Agency	Relevant Role
	• To reschedule timings of public transport, etc. in accordance with early warning forecasts. This should be done only if timings for works, schools and different government and non-government offices are also rescheduled simultaneously in the summer months.
Dept. of Housing & Urban Development	• Give directives to urban local bodies (ULBs)/Development Authorities to create more public parks and water bodies in hotspot areas for the general public. • Give directives to ULBs to identify temperature hotspots in the built-up areas and incentivize white painted roofs (albedo paint) in these regions. • Give directives to ULB/Development Authorities for the use of K-glass, doubly glazed glass in buildings and vehicles which prevent extra entry of heat inside, especially in the built-up areas which are located in hotspot regions.
Dept. of Labour and Employee Welfare	• Increase awareness among construction workers and factory labourers working in temperature hotspots through lunchtime meetings and labour union meetings.
Dept. of Woman and Child Development	• Sensitize female agriculture and brick labourers about the health effects of walking long distances to fetch water in the summer months. • Understand the concerns of the women labourers better with regard to working long periods in the heat and design guidelines to optimize such prolonged exposure. • Create awareness among female labourers on the locations of water kiosks in the district

Name of Dept./ Agency	Relevant Role
Dept. of Health	• Setting up of additional health dispensaries in heat stress zones in the district as well as equipping existing dispensaries with additional facilities such as life saver ambulances, available mobile personnel, 24 hour back-up power supplies, air conditioned rooms, availability of cold drinking water, appropriate housing design, etc. • Ensure adequate training and supply of health professionals (doctors, nurses, etc.) to meet the demand of heat stress induced morbidity cases, due to long hours of exposure in heat stress prone areas. • Capacity building of District Medical Officers (DMOs) on their roles and responsibilities towards heat stress and heat islands.
Level: Local Govt.	
Urban Local Bodies (Municipalities)	• Conduct Focus Group Discussions (FGDs) at a block-level to identify vulnerable regions in the municipality to implement immediate coping measures. The FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. • Providing public shelter structures in highways and crowded areas such as open markets. • Providing drinking water through jal chhatras (water kiosk) at strategic points. It is to be ensured that more number of kiosks is located at hotspot regions and their maintenance takes place at a healthy frequency. • Alert public transport systems on the heat-stress prone regions, especially in the summer months, to enable them plan alternate routes, if feasible. • Exploring light coloured concrete roads as an option to replace asphalt roads near hotspot regions.
Panchayats	• Conduct Focus Group Discussion (FGDs) at village level to identify the heat-stress vulnerable regions to implement immediate coping measures. Similar to the ULBs above, FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. • Provision of water kiosks at strategic as well as heat-stress vulnerable points based on the FGDs.

Table 3: *Proposed roles for adaptation in heat island for different govt. agencies*

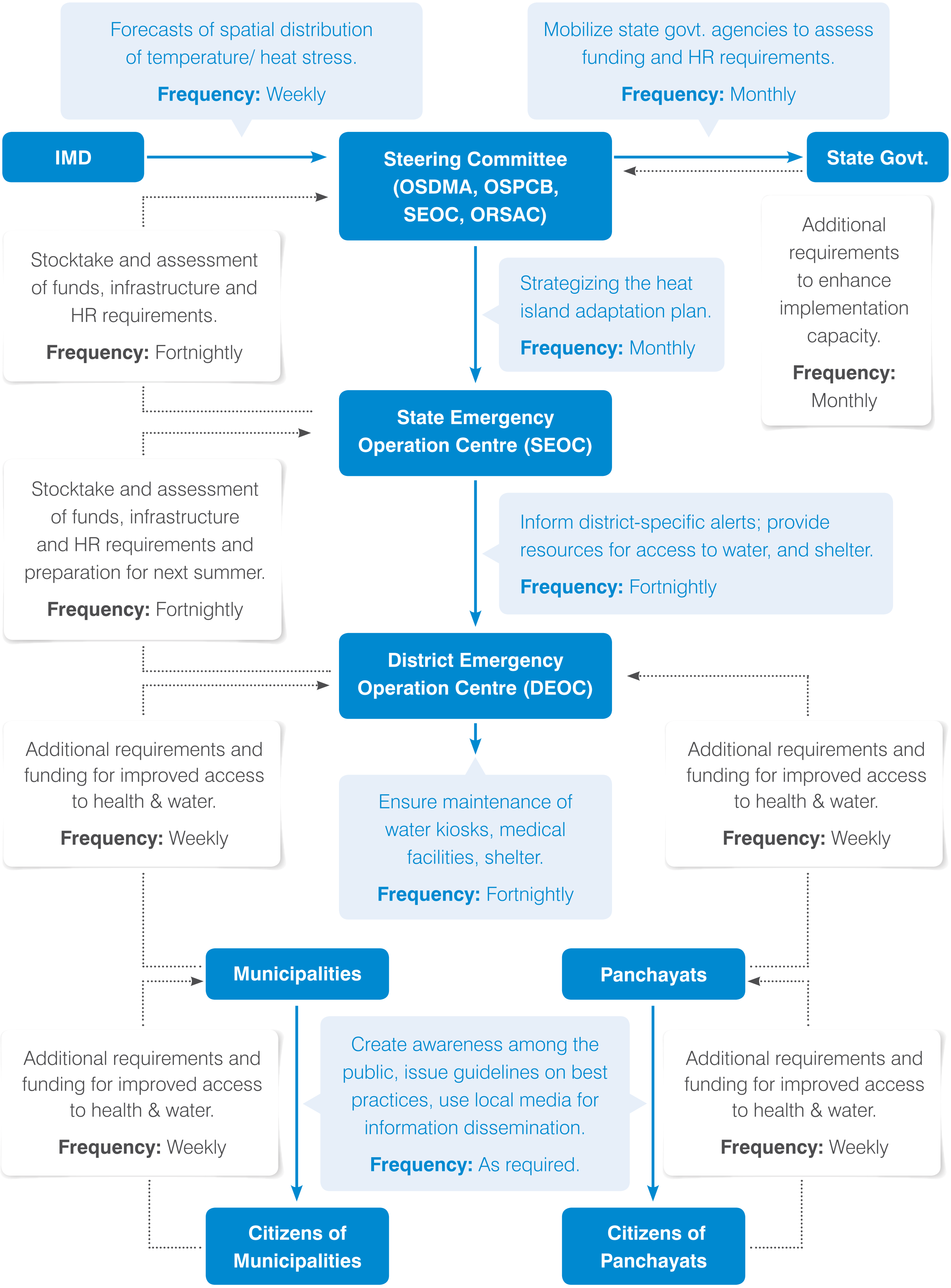
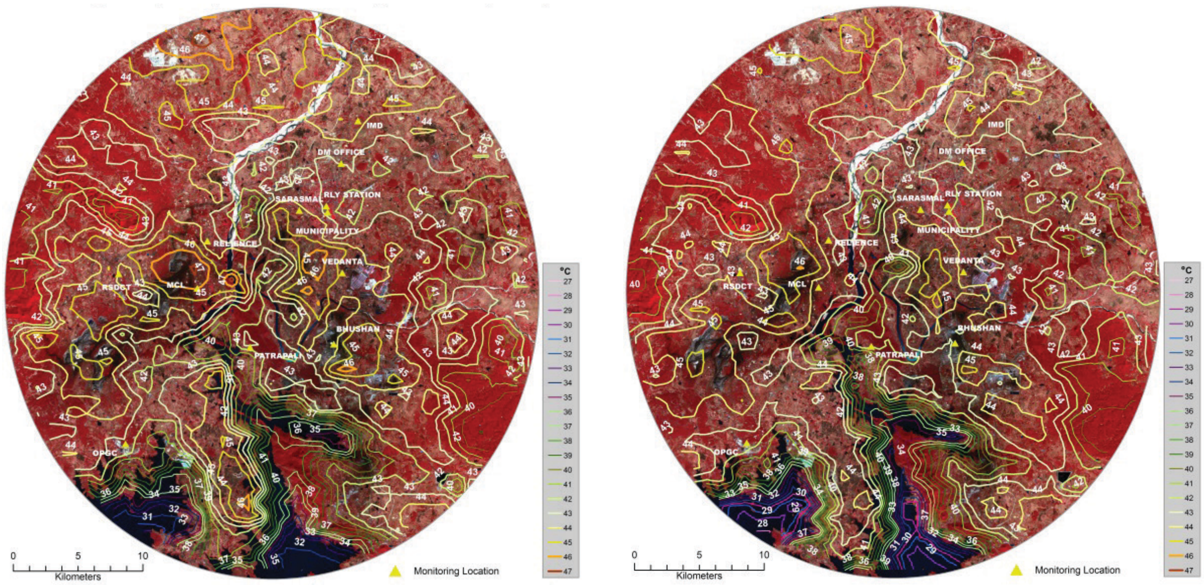


Figure 3: *Institutional implementation framework for coordinated adaptation response*

Appendix - Detailed Methodology

The following key methodologies were adopted to establish the UHI phenomenon in Jharsuguda.

Indirect satellite based measurements: Development of daily mean temperature contour map averaged over one month for the entire area using MODIS 7 Thermal Infrared (TIR) band data at 1 sq km resolution to identify thermal hotspots based on land surface temperature (Figure 4).



Average Daily Temperature - March (MODIS Daily Data)

Average Daily Temperature - April (MODIS Daily Data)

Figure 4: *Daily average Land Surface Temperature (LST in °C) in March and April 2016 using MODIS daily data. Yellow contours indicate hotspot regions. Ambient temperature trend-lines were plotted for the years 2005 to 2010 using IMD data. It was found that T_{max} increased by 0.36 °C, T_{min} increased by 0.55 °C, and the diurnal temperature difference $T_{max} - T_{min}$ decreased by 0.15°C, implying that minimum temperature has increased more than the maximum temperature during this period, at a confidence interval of 99%. This establishes a steady build-up of heat in the study area over time.*

2. **Direct monitoring at predetermined locations based on satellite data analysis:** Identification of the thermal hotspots in the area using thermal retentivity and heat index indicators[1] – calculated based on the real-time data recorded in the temperature-humidity data loggers installed at eleven locations [A. Brajraj Nagar, B. Patrapali, C. Bhushan Steel Area, D. Municipality Office, E. Market Road – Railway Station, F. Krosaki, G. Odisha Power Generation Corporation (OPGC) Area, H. Airport/IMD Station, I. DM office, J. Sarasmal Village, K. Mahanadi Coalfields Ltd. Office Area].

[1] **Thermal retentivity:** Refers to the extent of retention of heat in a given location during the course of a day, i.e. lower the difference between maximum and minimum ambient air temperature, higher the thermal retentivity.
Heat index: It is a composite index which takes into both account ambient air temperature and relative humidity of a given location; also called "feels like" temperature

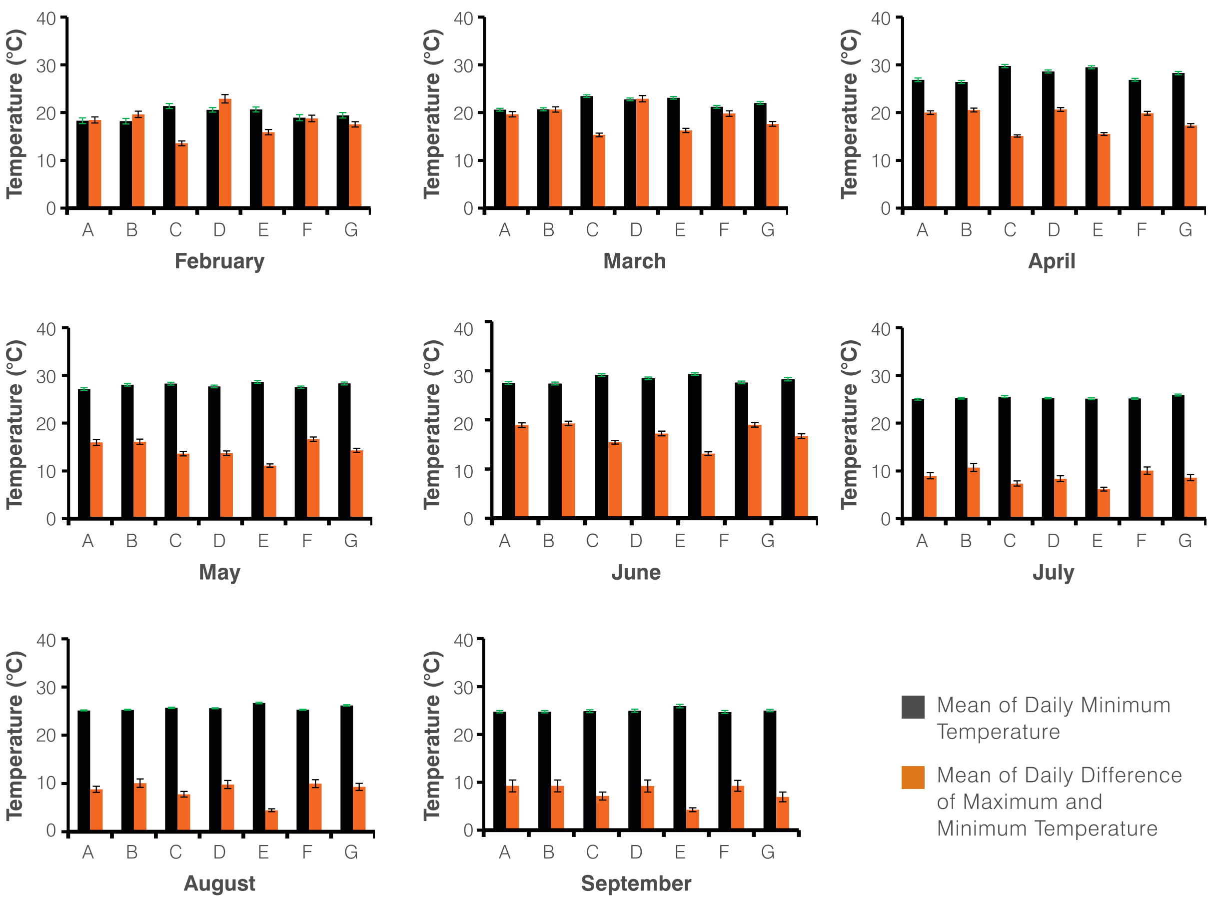


Figure 5: *Monthly variation of Tmin and (T_{max} – T_{min}) from February to September at different sampling locations A to G (X axis). Higher the T_{min} and lower the T_{max}-T_{min}, higher is the thermal retentivity of the region. Monthly averages of these parameters have been computed for each location and categorized based on Tukey's Honest Significant Difference (HSD) test. Lower case letters above the black bars indicates same statistical class for minimum temperature while upper case letters above the orange bars indicate same statistical class for diurnal temperature difference.*

Estimation of heat release from various anthropogenic activities: Heat release from different industrial activities such as open-cast coal mining (OCP), storage of coal in industry stockyard, etc. based on the surface area under different land use types (quarry area, barren land, de-coaled area, reclaimed area, backfilled area, etc.)[2] and surface temperature (obtained from IR camera) of each of the heat sources and sinks has been estimated as shown in figure 6.

[1] **Water Body:** Refers to the area within the mine boundary (typically void spaces) filled with inflowing groundwater.
Stockpile Area: Refers to the storage area for mined coal typically just outside the quarry.
De-coaled Area Exposed: Refers to the area within the mine boundary from which extractable coal has already been removed.
Area under Self-Oxidation: Refers to the parts of the de-coaled area as well as fractures within the quarry area undergoing partial combustion in the limited presence of oxygen at high ambient temperatures.
Vegetation Exposed: Refers to the vegetated area within the mine boundary, typically reclaimed from de-coaled areas.
Backfill Material Exposed: Refers to the de-coaled area which has been technically reclaimed through sand, gravel, etc.
Quarry Area Exposed: Refers to the area within the mine boundary which is currently under excavation.
Barren Land Exposed: Refers to the area covered with exposed rocks or thin soils within mine boundary.

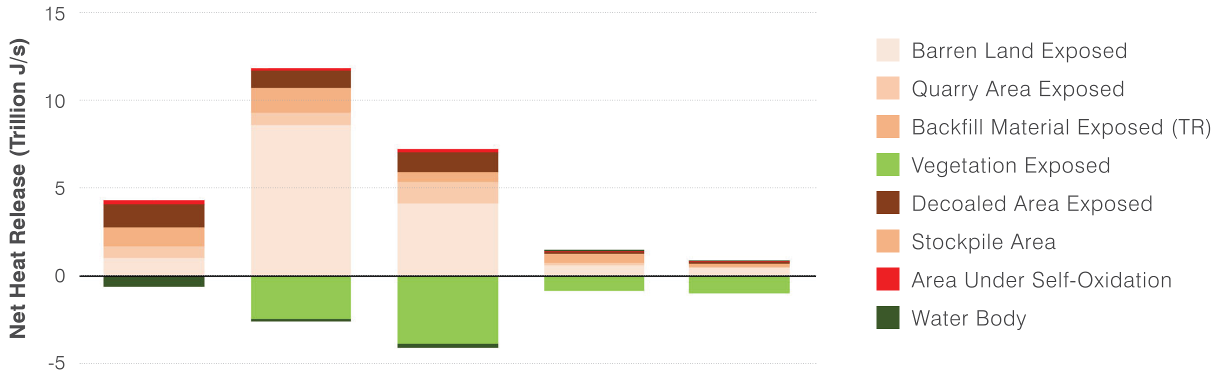


Figure 6: *Heat release in 5 OCPs by land use type. Net Heat released is highest for Lakhanpur OCP followed by Belpahar OCP due to large quarry area (area under excavation), and least for Lilari OCP due to the relatively small area within mine boundary. Area under vegetation is largest in case of Belpahar OCP, followed by Lakhanpur OCP.*

Assessment of biophysical parameters of land uses to identify thermal sources and sinks: In this model, the total geographical area is classified in terms of thermal zones (source and sinks)—high, moderate, neutral, and low based on land use practices and function. 40% area out of total geographical area is under thermal sources, 13% area is under neutral category (neither a source nor a sink), and rest 47% are thermal sinks.

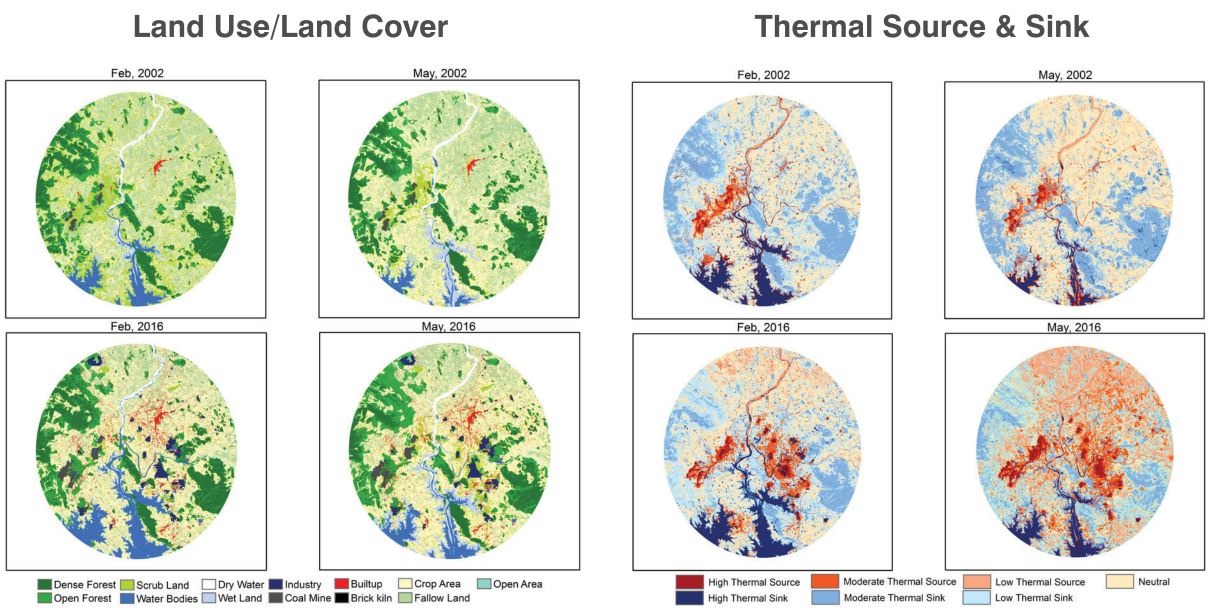


Figure 7: *Temporal change in a) land use/land cover and b) thermal sources and sinks in Ib-valley from 2002-2016. Built-up area has increased from 0.30% to 4.14% of total geographical area, which is more than 12 times with respect to the baseline of 2002. Similarly, coal mine area has increased twice and industrial area has increased 10 times than the base year. It has been observed that dense forest cover has decreased and open forest has increased during this period. Seasonal effects were observed on water bodies and fallow land, while agriculture land shows an increase of 14%.*

ACT (Action on Climate Today) is an initiative funded with UK aid from the UK government and managed by Oxford Policy Management. ACT brings together two UK Department for International Development programmes: the Climate Proofing Growth and Development (CPGD) programme and the Climate Change Innovation Programme (CCIP). The views expressed in this leaflet do not necessarily reflect the UK government's official policies.

Heat Island Effect
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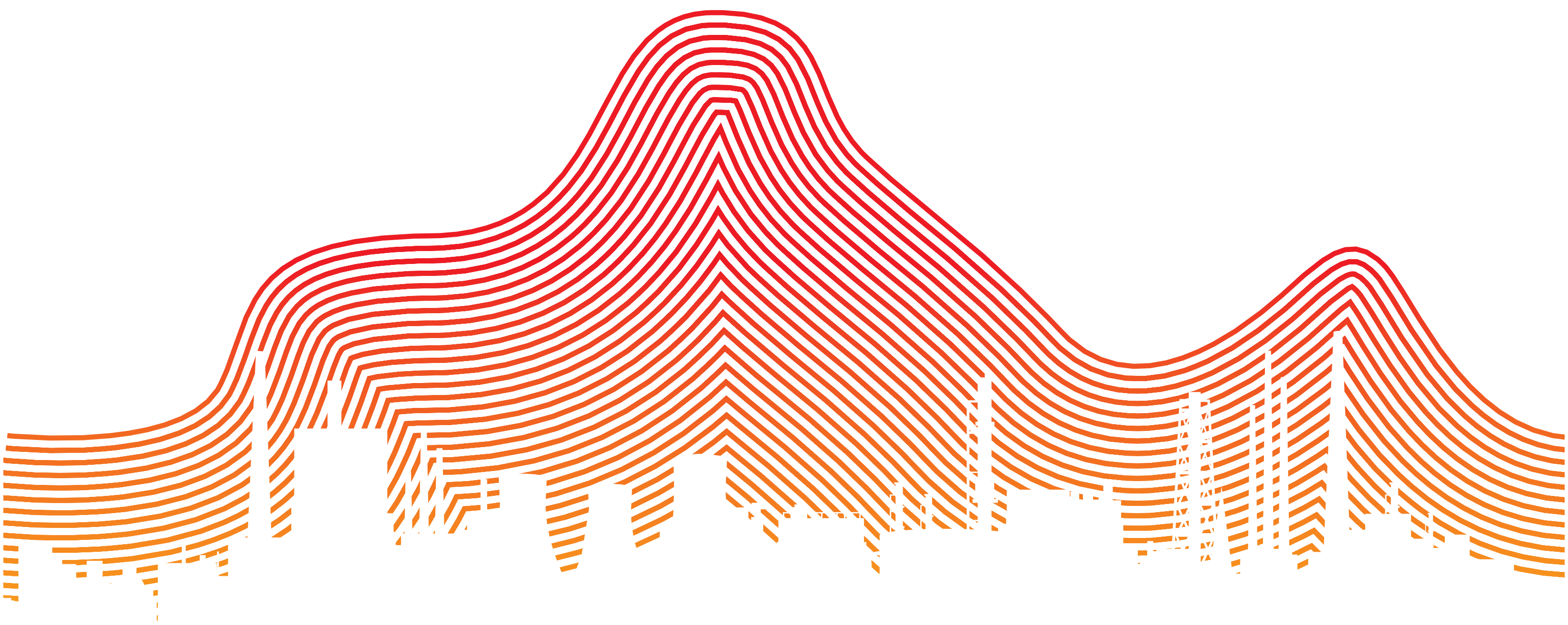
Action Plan



This report has been prepared by The Energy and Resources Institute (TERI)[a] in collaboration with TERI University[b] under the Climate Change Innovation Programme funded by Department for International Development (DFID).

Lead authors: Mr Prasoon Singh[a], Principal Investigator (PI); Mr Barath Mahadevan[a], Co-Principal Investigator (Co-PI); Dr Arindam Datta[a]; Ms Neha Pahuja[a]; Dr Vinay S P Sinha[b], Internal Advisor and Mentor
Reviewers: Dr Prodipto Ghosh[a]; Ms Suruchi Bhadwal[a]
Data Management and Monitoring: Mr Ved Prakash Sharma[a]

All efforts have been made to ensure the accuracy of the data used in the report. The consultants have provided objective and analytical inputs.

This material has been funded by UK aid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies.

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Abbreviations and acronyms

OCP	Opencast Project
BAU	Business as Usual
UHI	Urban Heat Island
SH	State Highway
NH	National Highway
LAI	Leaf Area Index
GHG	Greenhouse gas
MCL	Mahanadi Coalfields Ltd.
OSPCB	Odisha State Pollution Control Board
CAMPA	Compensatory Afforestation Management and Planning Authority
DM Office	District Magistrate Office
SRC	Special Relief Commissioner

Acknowledgement

The study team would at the outset like to thank all organizations and people who have provided crucial inputs during the various stages of the study to allow us to complete it successfully. Primary among them is Odisha State Pollution Control Board (OSPCB) and DFID (Department for International Development) who supported the study; Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India and Study Partners, Oxford Policy Management Limited.

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We would also like to thank the three municipalities of the district, viz. Jharsuguda, Brajrajnagar and Belpahar for their constant support in data collection and field work. Our thanks to Mr. Harish Ganatra of Jharsuguda Municipality for providing us relevant information needed for this study. Our gratitude also extends to the District Magistrate, Assistant District Magistrate, District Forest Officer, Deputy Director (Agriculture), District Medical Officer, and other officials for their valuable inputs.

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We would also like to extend our gratitude to the residences and commercial establishments, carpenters and furniture salesmen, and others who helped us to install data-loggers for temperature monitoring in various parts of the district. Lastly, we extend our warm gratitude to the citizens of Jharsuguda who have greatly enriched our understanding of their day-to-day lives.

Executive Summary

Urban Heat Island (UHI) is a situation with elevated air or surface temperatures in urban areas in contrast to their non-urban rural vicinities. The phenomenon is present in all big and small cities around the world with varying intensity. UHI has adverse effect on human health can also significantly affect the economic productivity. Based on combined macro and micro level evidence, it has been estimated that productivity increases as a function of temperature until approximately 13 ^{0}C and starts decreasing thereafter. Higher surface air temperature, particularly during summer months, is associated with increases in electricity demand, air pollution, and heat stress related mortality and morbidity.

The industrial agglomeration of Ib-valley in Jharsuguda faces the problem of heat island effect which may be attributed to changes in land cover, energy intensive industrial activities, mining, etc. Based on the time-series analysis it was found that the locations 'Bhushan Steel', 'Municipality Office' and 'Market Road' were hotspots for UHI during the summer period, and 'OPGC', 'Market Road' and 'Municipality Office' were hotspots in the monsoon period. The effect of UHI is amplified in the summer months when the temperature reaches ~ 50 ^{0}C. The total affected population in Jharsughuda and Lakhanpur blocks are 221,440 of which 108,344 are females. More than 90% population in these blocks reside in the rural areas and hence female labourers engaged in the agricultural or road construction activities are especially vulnerable to the heat stress situation in these areas.

This action plan is a framework to develop comprehensive strategies for mitigation and adaptation of the heat island effect. Experts and local stakeholders, including representation from women, were extensively consulted during the course of the study to come up with strategies that account for local priorities and constraints and their suggestions were incorporated to finalise this action plan report.

The sectoral contribution of different sources and sinks to heat islands has been analysed to determine where actions can be targeted. Sector specific measures to reduce the heat island effect over the Ib-valley region in Jharsuguda have been recommended on the basis of analysis of the contribution of each measure to the reduction in heat release. An indicative potential of the impact of each measure along with the cost of implementation were estimated, wherever sufficient data was available. However, the execution of these plans requires investment, commitment and coordination from each sector, community group, local and state government agencies. To strengthen the institutional mechanism and coordination, the roles and responsibilities of each institution have been worked out and documented.

Coal Mining

Key measures recommended for the five open cast coal mining projects viz. Samleshwari, Lakhanpur, Lajkura, Lilari and Belpahar include: a) Improved management of de-coaled areas through creation of water bodies in void spaces to reduce self-oxidation as well as act as a heat sink as well as through increased bio-reclamation area within the mine boundary; b) Setting up of more coal washeries which would reduce the ash content of coal, thereby reducing its self-oxidation potential – an exothermic process which releases heat into the ambient atmosphere; c) Moving from 95% to 100% surface miner technology for coal removal which would completely replace the conventional blasting operations, thereby improving the stability of benches and high-walls. This would consequently result in reduced self-combustion of loose coal due to the limited presence of oxygen; and d) Large-scale afforestation of the diverted forest area.

Industries

Key measures recommended in industries include: a) Stockpile inventory management which would enable optimizing coal purchase and keeping the stockpile inventory at an optimum level, thereby not only resulting in cost savings but also environmental benefits; b) Stockpile design changes from cuboidal to dome-shaped so that lesser surface area is exposed to environment, consequently resulting in lower heat radiation.

Urban Planning

Traffic congestion in certain parts of the district has been identified as a key issue to be addressed. Some of the measures that can be taken in this regard include shifting the bus terminus away from the market road, construction of flyover at strategic points, construction of new approach road to SH10 (Sambalpur-Jharsuguda bypass road), etc. In addition, plantation of trees with higher LAI (Leaf Area Index) bordering along the pavements of national highways, state highways and newly proposed roads, have also been included under the urban planning section. Species specific recommendations have been provided for national and state highways, city artillery roads and the municipal areas. Jharsuguda airport has been identified as a priority area for undertaking plantation activities due to extreme barrenness of the area. In the buildings sector, green roofing has been recommended as a voluntary measure to reduce ambient air temperature as well as cooling demand of air conditioners. Adopting higher albedo road surface materials such as concrete, where possible, can also go a long way to mitigate the rise in temperature.

Agriculture

In the agriculture sector, the key recommendation includes moving towards conservation tillage, which not only improves the productivity of land but also increases the surface albedo of the land mainly during the fallow period, thereby reflecting most of the incoming solar radiation back into the atmosphere.

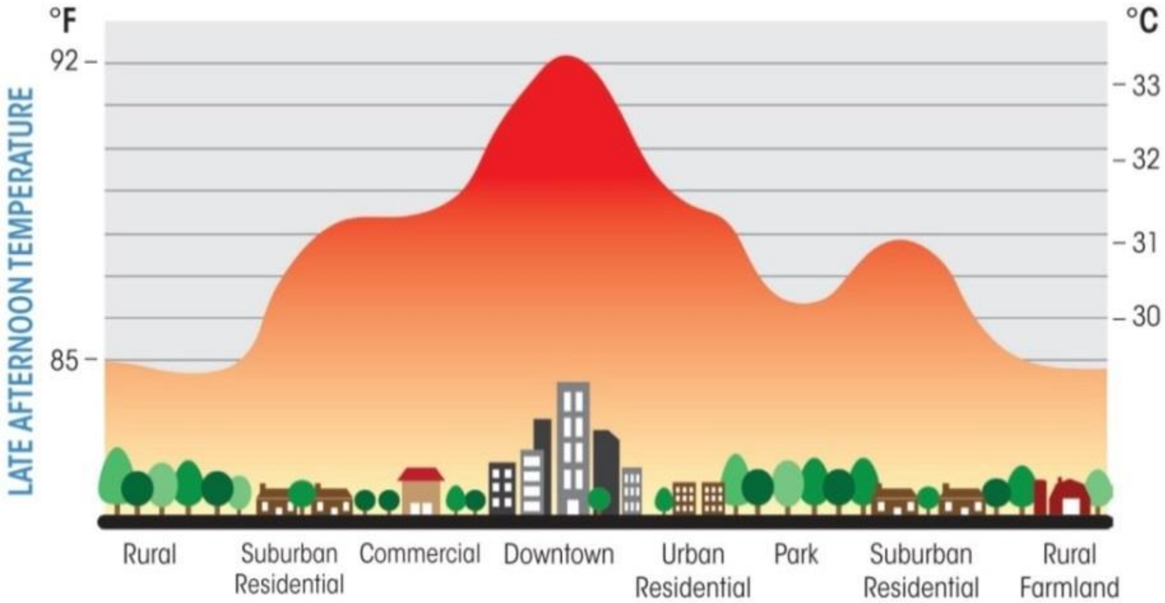
Adaptation

On the adaptation front, the focus is on developing coping mechanisms to deal with heat stress in the hotspot regions. This involves coordination among agencies such as Indian Meteorological Dept. (IMD), state government agencies, and urban local bodies. Apart from the government establishment, civil society also plays a key role in creating public awareness and knowledge dissemination. Additional roles have been recommended for the various government agencies over and above their current role in heat wave action plan. It has been recommended to increase the number of AWS especially in the heat-wave prone districts to obtain a spatial distribution of temperature. This would improve the quality of early warning forecasts sent by IMD to the state government. Odisha State Disaster Management Authority (OSDMA) must undertake capacity building measures to deal with emergency response and preparedness for heat wave and heat island effects, especially among the health workers and district medical officers. The DM office is the key point to implement emergency response measures. This must be equipped with information on heat-stress vulnerable regions in the municipality and villages. In addition, they must ensure water availability in kiosks at strategic points; create public awareness through newspapers and radios on hotspot zones, direct municipalities and panchayats to ensure the safety of women and children in the vulnerable zones, etc.

Chapter 1. Heat Mitigation Measures

Literature Review of the Urban Heat Island (UHI) Effect

The Urban Heat Island (UHI) phenomenon was first coined by Luke Howard in 1818 to describe the excess heat in London city compared to the country side. UHI is the situation with elevated air or surface temperatures in urban areas in contrast to their non-urban rural vicinities (Figure 1). The phenomenon is present in all big and small cities around the world with varying intensity. Urban centres have their typical morphology, materials and geometry that bring changes in the surface and atmospheric properties. These changes include alterations in the reflective and thermal properties of the surface. As a result, the new materials (e.g. asphalt, concrete etc.) abundant in urban setup have higher heat capacity or lower albedo, i.e. Urban areas tend to reflect less and store more heat for longer periods. Along with modifications in surface properties, atmospheric changes, such as higher emission of GHG, accumulation of air pollutants, and other factors including urban geometry (due to buildings, skyscrapers, etc.) and increased anthropogenic heat generation, greatly contribute to accumulation of large amounts of heat in the urban centres (Gartland, 2008). Further, higher energy demand for cooling (especially during summer months) in tropical countries also results UHI. UHI creates discomfort for humans and adversely affects the health[1] of elderly and other vulnerable sections of the society who work in unorganized or informal sectors and have prolonged exposure to heat.



(Source: Giridharan et al., 2004)

Figure 1 Temperature profile of a typical city depicting the Urban Heat Island (UHI) phenomenon

The reported studies on UHI around the globe are focussed on developed countries in North America and Europe. These studies broadly fall under the following categories, viz. a)

[1] *Our muscles generate heat which must be shed to the environment to maintain our core temperature at about 36.7 ^{0}C. Evaporation of sweat helps in cooling human bodies. However, in extreme heat conditions, too much sweating leads to dehydration with consequent rise of core body temperature, which is fatal. This is particularly problematic for people who could be of weaker constitution, or already mal-nourished or of already weaker health with different other ailments.*

estimating the heat island index based on spatio-temporal monitoring of ambient air temperature, b) using remotely sensed data to map the land surface temperature of the area, and c) analysing the health impacts and vulnerability indicators due to this phenomenon.

Rao (1972) had demonstrated the idea of using satellite data for studying UHI. Since then, several researchers have explored this concept to analyse UHI in various cities across the globe. In spite of India being one of the fastest growing countries of the world (IMF, 2016), there is paucity of reported studies on UHI. This indicates general lacuna in the knowledge of the policy developers on the UHI effects of growing urbanization. Most reported studies on UHI from India were carried out in Delhi (Mohan et al., 2011; Punia et al., 2011; Sokhi et al., 1989; Wentz et al., 2008). Surprisingly, there was no reported study on UHI effect in Mumbai and Kolkata despite being large metropolises. The following table summarizes some of the major heat island studies done nationally and internationally.

Table I Study of Heat Island Effect in Cities Around the World and in India

City	Study Conducted / Results Reported
New York	Heat island index of 4^0C in the summer and 3^0C in the winter was reported for based on meso-scale analysis (Gedzelman et al., 2003). Additional studies have indicated effect of HI on pollution, energy requirement and heat related mortality and morbidity (Rosenfeld et al. 1995; Nowak et al. 2000; Sailor et al. 2002; Hogrefe et al. 2004)
Atlanta	UHI induced convergence zone initiated convective thunderstorms in the city (A. Bornstein et al., 2000)
Seoul	Spatio-temporal structure of Urban Heat Island effect was studied for the city and it was established that the average maximum urban heat island intensity is 2.2°C over one year (Kim et al., 2005)
Birmingham, UK	Impact of UHI on human health was strongest in the city center and some pockets randomly scattered throughout the city (Tomlinson et al., 2011)
New Delhi	Heat island intensity (UHI) for the city of Delhi was observed to be higher in magnitude both during afternoon hours and night hours (maximum up to 8.3˚C) and that the top three high urban heat island locations in the city are within commercial and/or densely populated areas (Mohan et al., 2011)
Bengaluru	The increase in UHI effect in the city over last 45 year can be attributed to shrinkage of lakes and water bodies, decrease in vegetation areas as well as increase in built-up areas. (Ramachandra, et al., 2005).
Bhubaneswar	Increase of temperature in the city was closely associated with population growth, increasing number of vehicles and the changing land use of the city (Santosh et al., 2011)

Apart from its adverse effect on human health, UHI can also significantly affect the economic productivity. In recent years, global warming and the risk of climate change has generated renewed interest in this area (Dell et al. 2014; Heal et al. 2015). Micro-level studies have reported the effect of heat stress on cognitive and physical performance of workers vis-à-vis macro-level impacts of heat stress on per capita income (Wyon, 1974; Ramsey, 1995; Horowitz, 2009). Empirical models have also tried to correlate labour supply decisions to heat stress and the willingness to pay for heat mitigation, using country-level and household data (Heal et al., 2005). Macro and micro level evidences suggest that productivity increases with temperature until approximately 13^0C and starts decreasing thereafter (Burke et al., 2015).

Brief background on the Heat Island phenomenon in Jharsuguda

Jharsuguda is situated at 21.31^0 N and 83.27^0 E in the agro-climatic zone of western plateau. Jharsuguda is one of the most industrialised districts of Odisha. The total geographical area of the district is 2081 sq km with total population of 579,499 (India census, 2011). There are five blocks in the district, namely Jharsuguda, Lakhanpur, Kolabira, Laikera and Kirimira and comprises 353 villages. The District headquarters is Jharsuguda city located in the Jharsuguda block. Detail block-wise population of the districts is given in Table II.

Table II Block-wise population (total and rural) for the district of Jharsuguda

Name of Block		Male Population	Female Population	Total Population
Jharsuguda	Total	41,046	38,394	79,440
	Rural	38,777	36,359	75,136
Kirmira	Total	21,663	21,234	42,897
	Rural	21,663	21,234	42,897
Laikera	Total	24,780	25,212	49,992
	Rural	24,780	25,212	49,992
Lakhanpur	Total	72,097	69,950	1,42,047
	Rural	66,905	65,407	1,32,312
Kolabira	**Total**	24,037	23,966	48,003
	Rural	24,037	23,966	48,003
Total District		2,96,690	2,82,815	5,79,505

Source: District Census Handbook (2011)

Table III Block-wise number of Gram Panchayats and villages in Jharsuguda

Sl. No.	Name of CD Block	No. of Gram Panchayats	No. of Villages
1.	Lakhanpur	33	146
2.	Jharsuguda	17	73
3.	Kirimira	08	42
4.	Laikera	11	45
5.	Kolabira	09	47
Total		**78**	**353**

Source: District Census Handbook (2011)

A brief industrial profile of the district is given in table IV below.

Table IV Brief Industrial profile of Jharsuguda

Industry Type	Number	Industry Type	Number	Industry Type	Number
Cement	1	**Thermal Power**	5	**Coal Mines**	11
Iron and Steel	16	**Aluminium**	1	**Coal Washeries**	3

The heat island phenomenon in the district was analysed using two approaches a) Remote sensing based Land Surface Temperature (LST) analysis, and b) time-series analysis of the ambient temperature using temperature-humidity data loggers. Based on the time-series analysis it was found that the locations 'Bhushan Steel', 'Municipality Office' and 'Market Road' were hotspots for UHI during the summer period, and 'OPGC', 'Market Road' and 'Municipality Office' were hotspots in the monsoon period. The effect of UHI is amplified in the summer months when the temperature reaches ~ 50 ^{0}C. The vulnerable population to heat stress during different seasons were calculated based on these data (Table V).

Table V Block-wise vulnerability of population to heat stress during different seasons

<table>
<tr><th>Season</th><th>Hotspot Location</th><th>Name of Block</th><th>Total Population Vulnerable</th><th>Female Population Vulnerable</th></tr>
<tr><td rowspan="3">Summer</td><td>Bhushan Steel</td><td>(NA as in Sambalpur)</td><td>-</td><td>-</td></tr>
<tr><td>Municipality</td><td rowspan="2">Jharsuguda</td><td rowspan="2">79,440</td><td rowspan="2">38,394</td></tr>
<tr><td>Market Road</td></tr>
<tr><td rowspan="3">Monsoon</td><td>OPGC</td><td>Lakhanpur</td><td>1,42,047</td><td>69,950</td></tr>
<tr><td>Market Road</td><td rowspan="2">Jharsuguda</td><td rowspan="2">79,440</td><td rowspan="2">38,394</td></tr>
<tr><td>Municipality</td></tr>
</table>

In the summer season, the Jharsuguda block is found to be the most vulnerable to heat stress, due to the presence of hotspots in Municipality and Market Road ('Bhushan steel' is not considered as it lies in Sambalpur jurisdiction). The total population affected is 79,440 of which 38,394 are females. However, in the monsoon season, the Lakhanpur block is the most vulnerable due to the presence of hotspot location OPGC. It has a population of 1.42 lakh of which 69,950 are female. It may also be noted that more than 90% population in these blocks reside in the rural areas. Due to mal-nutrition and added pressure of household chores, the women suffer from more adverse health effects than the men and hence female labourers engaged in the agricultural or road construction activities are especially vulnerable to the heat stress situation in these areas.

The effect of physical characteristics of the landscape of a city such as aspect ratio, surface albedo, plan density ratio, green density ratio, fabric density ratio and thermal mass play an important role in the mitigation of heat island effect (Kolokotroni et al., 2006). In this action plan report, the most suitable set of heat mitigation and adaptation measures have been recommended based on modelling as well as stakeholder consultation. A comprehensive mitigation strategy was developed for each sector based on the results of the Decision Support System (DSS). The heat mitigation potential of different recommended measures were categorized as low, medium and high based on their relative reduction in radiative heat release with respect to BAU. The heat mitigation potential has been quantified, wherever possible in the DSS report. The initial capital cost of implementation of different mitigation strategies was analysed where sufficient information was available. “High cost” signifies > INR 100 crore, medium costs is in the bracket of INR 1 crore to INR 100 crore and low costs are <INR 1 crore. It is to be noted that the implementation costs of different measures are only indicative. Detailed feasibility studies need to be carried out to assess the exact costs. However, the execution of these strategies will require investment, commitment and coordination between different sectors and community groups. The roles and responsibilities of each institution have been documented to strengthen the institutional mechanism and coordination.

The following section analyse the effectiveness of different heat mitigation strategies as developed in the DSS report for different sectors.

1.1 Coal Mining

1.1.1 Improved management of de-coaled areas

a) Creation of water bodies (pit lakes) in void spaces to control self-oxidation and increase heat sink potential in de-coaled areas

A mine void is an open pit created after completion of extraction operations in a quarry. After mine operations are discontinued in an area and dewatering ceases, most of the void catchment is filled up by inflow of ground water, direct rainfall and runoff from adjacent drainage basins. A substantially large pit lake was observed only in one of the five Ib-valley OCPs, viz. Lajkura. The IR image below shows the difference in temperatures seen in the pit lake vis-à-vis other land use types within the mine boundary (such as technically reclaimed areas and de-coaled areas). It can be seen that the temperature difference observed between the water body and area under self-oxidation can reach upto 90-100^{0}C.

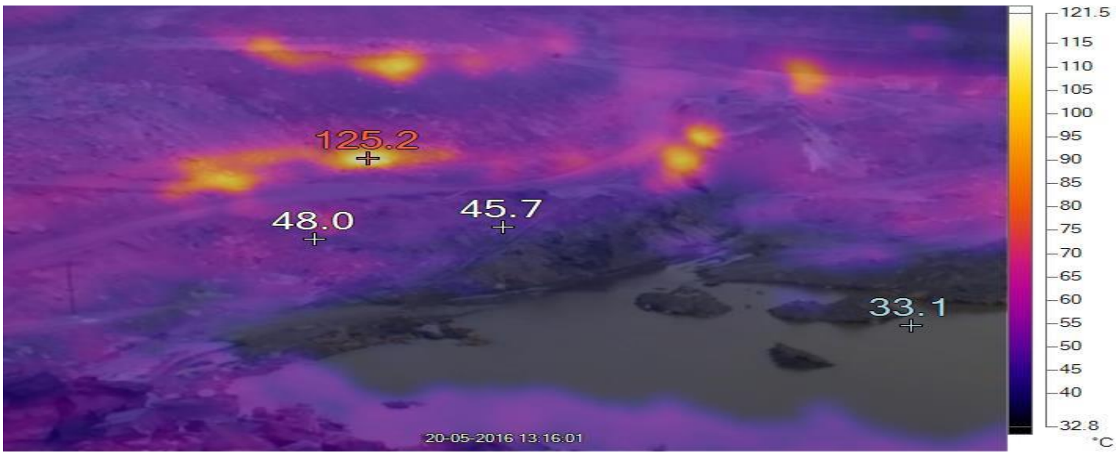


Figure 2 IR camera image of Lajkura OCP showing temperature profile of water body, de-coaled area and area under self-oxidation.

Given that water bodies act as a major heat sink, it is proposed that pit lakes be created in the void spaces of OCPs which currently do not have a substantial area covered by water body. Further, it is proposed that such a measure be prioritized on the basis of the total de-coaled area of the OCP as that can serve dual purposes of a) acting as a heat reservoir and b) providing a source of water to mitigate self-oxidation in the exposed coal seams through hose pipes and sprinkler systems. For modelling this intervention, it is assumed that the creation of water bodies/pit lakes in all the OCPs will result in a 75% reduction of self-oxidation in the de-coaled areas (refer pg. 77-79 of the DSS report).

b) 100% of the technically reclaimed area converted to bio-reclaimed area

Reclamation of land after removal of coal through open cast mining - can be done either technically or biologically. The former involves filling the de-coaled area with sand and gravel, while the later involves re-vegetation of the de-coaled area. Currently, most of the de-coaled area in the five OCPs is reclaimed technically. However, if the technically reclaimed area is converted to plantation or bio-reclaimed area, it can significantly add to the heat sink potential. The OCP with the largest heat release is Lakhanpur OCP (9.36 trillion J/s), followed by Belpahar OCP (3.17 trillion J/s), while the lowest value is observed for Lilari OCP (–0.11 trillion J/s) (for details see the analysis included in the DSS report). This can be explained by the fact that Lakhanpur has the largest mine boundary. Consequently, the quarry area exposed and de-coaled area, which are the key heat sources, are also larger for Lakhanpur as compared to other OCPs. It may also be noted that Belpahar OCP, though not as large in area as Lakhanpur OCP, has a significant heat sink potential due to the post-mining biological reclamation of land. Finally, the Lilari OCP acts as a net heat sink due to the fact that a large part of the de-coaled area has been biologically reclaimed. The prioritization of the OCPs in terms of bio-reclamation potential is given below.

The priority ranking of the OCPs for the above mentioned interventions, along with their individual and combined impacts are given in the table below.

Table VI Impact of Improved management of de-coaled areas and priority ranking of OCPs

Name of OCP	Net Heat Release in BAU (trillion J/s)	% Drop wrt. BAU in Scenario 1	Priority Ranking for Scenario 1	% Drop wrt. BAU in Scenario 2	Priority Ranking for Scenario 2	% Drop wrt. BAU in Scenario 3	Priority Ranking for Scenario 3
Lajkura	0.64	1.5%	3	510%	1	514%	1
Samleshwari	3.75	4.8%	1	180%	2	218%	2
Belpahar	3.17	4.7%	2	134%	3	139.1%	3
Lakhanpur	9.36	1.3%	4	93.7%	4	96.6%	4

**Scenario 1 refers to reduced self-oxidation by 75%, Scenario 2 refers to 100% bio-reclamation, Scenario 3 refers to implementation of Scenarios 1 and 2 combined (refer DSS report (pg. 77-79) for detailed estimation of heat release in the three scenarios).*

***Lilari OCP is excluded as it is already a net sink due to the large fraction of biologically reclaimed area.*

Thus, the highest drop in heat release is achieved in the case of Lajkura OCP, followed by Samleshwari OCP and Belpahar OCP. The mine with the lease potential for heat mitigation is Lakhanpur OCP. It may be noted that 100% adoption of bio-reclamation (as opposed to technical reclamation) in the first three OCPs converts the entire area within the mine boundary into a net heat sink which is reflected in the negative values of net heat release in the above table. However, in the case of Lakhanpur OCP, even 100% adoption of bio-reclamation will result in a positive net heat release, as indicated in the above table.

Responsible agency: Mahanadi Coalfields Ltd., Ministry of Coal, Odisha State Pollution Control Board (OSPCB).

Heat mitigation potential: High. (90-500% with respect to BAU)
Initial Implementation Cost: Medium

1.1. 2 Introduction of Coal Washeries

The ash content of Indian coals is among the highest in the world (42-44%). Coal handling and beneficiation through washeries can reduce the ash content up to four times (Sharma et al., 2015).

It has been estimated that mean increase in crossing point temperature (CPT) as a result of the introduction of coal washeries is 2.5^{0}C (Jena et al., 2011). This would in turn increase the ignition temperature of the coal, making it much less susceptible to self-oxidation. Higher the number of coal washeries, the total volume of coal undergoing self-combustion would be reduced with increasing number of coal washeries.

The existing coal washery in the Ib-valley region has an annual raw coal throughput of 10,000 kT with a processing capacity of 1.7 kT/hr. The sources of coal for the washery are Lakhanpur, Belpahar and Lilari OCPs (CMPDI, 2016). Total annual production of the five OCPs in Ib-valley during 2015 was 40751 kT, whereas the existing washery services only 10000 kT of coal produced which represents about 24.5% of the demand (MCL, 2015).

Table VII Capital Cost of Ib-valley coal washery

Particular	Total Estimate (Lakh INR)	Year-wise Phasing (Lakh INR)		
		Year 1	Year 2	Year 3
Civil Works	14723	0	8834	5889
Plant and Machinery	18337	0	11002	7335
Furniture and Fitting	30	0	18	12
CR Preparation, Bid Process, Scrutiny of Drawing, etc.	600	265	255	80
Total Initial Capital	33690	265	20109	13316

(Source: CMPDI, 2016)

It is to be noted that installation of at least four more washeries can help convert the existing raw coal to beneficiated coal. The average cost of each coal washery is taken to be INR 336.90 crores. (Table VII). Thus, the total cost of four washeries amounts to INR 1347.6 crores.

Responsible Agency: Mahanadi Coalfields Ltd. (MCL), Ministry of Coal (Govt. of India), Odisha State Pollution Control Board (OSPCB), Ministry of Environment and Forests (Govt. of India).

Heat Mitigation Potential: Medium
Initial Implementation Cost: High (INR 1347.6 crore)

1.1.3 Complete penetration of surface miner technology for coal removal

The conventional system of removal of coal takes place through drilling, blasting and crushing of the ore particles, which not only causes adverse impact of the environment through dust pollution, but also results in greater fractures in coal bearing rocks which increases the susceptibility to self-oxidation due to the increased penetration of ambient oxygen through the fractures. Conventional methods such as drilling and blasting can also create loose material on high-walls, thereby again increasing the susceptibility to self-oxidation. Further, coal cannot be mined in areas where blasting is restricted. As a result, selective mining and thin seam mining is not possible.

The principle of a surface miner is to cut, crush and load in one pass as opposed to the conventional method where drilling, blasting, crushing and loading are performed as three different operations. The surface miner can also produce solid and stable high-walls. Thin seam mining is possible and as a result, previously non-workable seams become workable.

About 95% of the removal of coal in Ib-valley OCPs already takes place through surface miner. It is proposed that remaining 5% of coal removal which takes place through conventional blasting be phased out and that entire coal production happens through surface miner technology. The costs of coal production with surface miner technology vis-à-vis. the conventional technologies are given in the table VIII below.

Table VIII Cost comparison of surface miner and conventional blasting techniques for OCPs

Parameter	Production through Surface Miner	Production through Conventional Drilling and Blasting
Unit Cost*	INR 35/ton	INR 64.75/ton
Total Amount of Coal Produced in 5 OCPs (2015)	40751 kT	2145 kT
Savings due to phasing out of conventional blasting	INR 63,814	-

*Source: Dutta, et al. 2016. Application of Surface Miner for Indian Coal Mines

Responsible Agency: Mahanadi Coalfields Ltd, Ministry of Coal (Govt. of India).

Heat Mitigation Potential: Medium
Initial Implementation Cost: Low*

*Savings incurred on operational expenditure however, additional surface miners may be required to excavate coal previously removed through conventional blasting.

1.1.4 Compensatory Afforestation

As per the Forest Conservation Act (1980), compensatory afforestation is one of the critical conditions stipulated by the central government while approving proposals for the reservation or diversion of forest land for non-forest use. Afforestation planning must assess the potential cooling effect that the plantation can bring about. Species growth rate as well as the rate of evapo-transpiration should be taken into account to ensure optimum cooling effect in least time.

The current plantation system is based on tendering process, leading to lot of delays in awarding projects and implementation. Since land is owned by the state government, it is leased out to mining companies for coal excavation. The lease boundary consists of forest areas which have to be diverted for coal mining operations. However, as mentioned by the mining officials and local citizens in the stakeholder meetings in which at least 25% of the respondents were women, once land is allotted it is still difficult to continue with the plantation activities due to frequent delays. Hence a specialized agency to perform these activities is required to make it speedy and transparent. Un-used land from other sectors – like railways, barren land, etc. can be pooled in for plantation activities and a clear demarcation of land for plantation is required. The use of private plantation agencies may also be explored for afforestation activities.

It may be noted that in addition to heat sink potential, forest cover also adds significantly to the carbon dioxide sequestration from the atmosphere. The double benefits incurred in afforestation make it an important area to consider for the policy-makers.

Responsible Agency: Mahanadi Coalfields Ltd. (MCL), District Forest Office (Jharsuguda)

Heat Mitigation Potential: High
Initial Implementation Cost: Medium (INR 4.38 lakh/ha)

1.2 Industries

In general, improving electrical and thermal efficiency as well as reducing station heat rates will contribute to the bottom line of the industries as well as to mitigation of heat island effect. Industries are encouraged to take such measures as appropriate and wherever possible. In addition, the following low-cost measures also contribute to mitigating heat generation and could be considered.

1.2.1 Stockpile Inventory Management

Coal stockpile is a key source of heat release in a large industrial unit such as steel manufacturing, thermal power plant, aluminium smelting, etc. The coal stockpile inventory typically fluctuates based on the monthly variation in production. From an environmental perspective, care must be taken to ensure minimum stockpile inventory in the summer months while still ensuring optimum output. The heat release from the stockpile is directly proportional the volume of coal stored and the fourth power of the surface temperature, as per Stefan-Boltzmann law. Thus, reduction in stockpile inventory would have a proportional reduction in ambient heat release. It may be noted that more the heat released from the stockpile, greater is the loss of usable coal for product manufacturing and hence, the higher would have to be the coal purchase to produce a unit ton of the product. Five plants in the

Ib-valley region have been analysed in terms of monthly variation in coal stockpile inventory, coal consumption and production. The cost savings incurred by these plants due to reduction in stockpile inventory in the summer months have been estimated using different statistical methodologies (refer pg. 89-106 of DSS report). The tables below summarize the key methodologies and parameters analysed in each of the plants as well as the cumulative cost savings that could be incurred through stockpile inventory management.

Table IX Model description for stockpile inventory management analysis for 5 plants in Ib-valley

Plant Id	Plant Type	Parameters Analysed	Time Period	Methodology
A	DRI plant	Coal stockpile, coal purchase, steel production	Monthly from January 2011 to December 2015	Time-lagged linear regression model relating coal purchase with coal stockpile and steel production
B	Integrated steel plant	Coal stockpile, sponge iron production	Monthly from January 2015 to September 2016	Based on variation of stockpile to production ratio with respect to yearly mean
C	Aluminium smelter plant	Coal stockpile, aluminium production	Monthly from January 2010 to December 2016	Based on variation of stockpile to production ratio with respect to yearly mean
D	Thermal Power Station	Coal stockpile, electricity generation	Monthly from January 2010 to December 2016	Based on variation of stockpile to generation ratio with respect to yearly mean
E	Captive Power Plant (of aluminium smelter)	Coal stockpile, electricity generation	Monthly from April 2014 to December 2016	Based on variation of stockpile to generation ratio with respect to yearly mean

Table X Summary of cost savings through stockpile inventory management in five plants of Ib-valley

Plant	Major Product	Production Capacity	Specific Coal Consumption	Cumulative Cost Savings
A	Sponge Iron	Sponge Iron – 136878 MT	1.55 MT coal/MT steel	Rs. 60 to 190 lakh
B	Steel	Sponge Iron – 1.3 million MT/year Pig Iron – 0.8 million MT/year	0.9 MT coal/MT sponge iron 0.76 MT coking coal/MT pig iron	Rs. 36.7 crore
C	Aluminium	0.5 million MT/year	13.3 MT coal/MT aluminium	Rs. 152 crore
D	Electricity	960 MW	0.84 to 0.934 g/kWh	Rs. 95.5 crore
E	Captive Power Plant	360 MW	0.68 ± 0.099 g/kWh	Rs. 55 crore

Responsible Agency: Industry (Steel Plant, Aluminium Plant, Thermal Power Station)

Heat Mitigation Potential: Medium

Initial Implementation Cost: Net savings for the plant (varies from Rs. 0.6 to 152 crore)

1.2.2 Changes in coal stockpile design

Changes in the design of the coal stockpile can bring about quite significant reduction in the ambient heat release from the stockpile. The variation in heat release was analysed for three possible coal stockyard geometries:

1. Cuboidal
2. Cylindrical
3. Dome-Shaped

Change in base area has a much larger impact on ambient heat release than change in height for all shapes. In other words, for a given base area, the lowest heat release is achieved in the case of dome-shaped stockpile. These have been analysed in the modelling report [3].

Responsible Agency: Industry (Steel Plant, Thermal Power Station, Aluminium Smelting)

Heat Mitigation Potential: Low. 11-13% w.r.t. BAU

Initial Implementation Cost: Nil

1.3 Urban Planning

1.3.1 Congestion Planning

Traffic congestion in the city can reduce the flow of the traffic and this might lead to increase in the local ambient temperature. Survey of the Jharsuguda Township during the study period indicates higher traffic congestions mainly in the railway station and bus stand area. The Station Road was also identified as one of the temperature hotspot during the present study.

It has been identified that the highest traffic congestion zone lies between the bus stand and Jhanda chowk on the station road. There is only one outlet of the Jharsuguda Railway station, which makes the area much congested. NH-49 has a sharp curve near the bus stand, which force the vehicles on the NH-49 to approach towards the bus stand. Introducing a new fly over in the left flank of the existing flyover in the NH-49 after crossing the railway line can divert the traffic on the NH-49 away from the Jharsuguda bus stand and reduce the congestion near the bus stand area.

The possibility of shifting the entire bus stand from the southern part of the railway line to the northern part and develop an approach road to the bus stand from the NH49 in the northern side of the main railway line. A northern exit road from the Jharsuguda railway station to the proposed bus stand in the northern side of the railway station would help to decongest the station road area in the southern side of the Jharsuguda railway station.

A new approach road to SH-10 (Sambalpur-Jharsuguda bypass road) from the proposed bus stand needs to be developed, to divert the traffic towards Sambalpur and Rangali from NH-49. Buses towards Chhattisgarh via NH-49 may also use this route to save time and avoid congestion on NH-49. While implementing both these measures, it would be pertinent to consider the ease of access and security implications for women, children and infirm section of the population.

Traffic island (round-abouts) should be introduced at cross roads on NH-49 and SH-10 and at the two intersections of NH-49 and NH-10 to maintain free flow of vehicles.

Responsible agency: Jharsuguda and Belpahar municipalities, Ministry of Commerce and Transport, Public Works Department (PWD), National Highways Authority of India (NHAI), State Highways Authority of India (SHAI), Ministry of Forest and Environment, State Pollution Control Board (OSPCB).

Heat Mitigation Potential: Medium
Initial Implementation Cost: Medium (Indicative: INR 50-100 crore)

1.3.2 Urban Plantation

The township of Jharsuguda has built up in the southern part of the Jharsuguda railway station. This area is close to the major temperature hotspots in the study area (market road). It is proposed that Jharsuguda Municipality plan future expansion of the township towards the northern (viz. Ekatali) and north-eastern (viz. Bhuliatikra, Bhuljhori, Airport) side of the railway station. While the forest department needs to increase tree plantation in the south and south-eastern part of the Jharsuguda municipality area. Plantation of trees with higher LAI should be bordering the pavements of NH, SH and newly proposed roads. This will prevent the influx of solar radiation and amount of heat absorbed by the asphalt material. Plantation of short height trees should be included in the median-island of wider roads like NH-49 and SH-10. Rainwater harvesting through creation of artificial water bodies should be introduced in both sides of the NH-49 and SH-10 where ever possible to provide required water for the plantation during the dry periods. Immediate plantation is required in the Jharsuguda Airport area. This could also have positive effect on the livelihood of the labourers, both male and female, who will be engaged in the implementation of these activities.

The species-wise recommendation for urban plantation in different parts of Jharsuguda is given in the table below:

Table XI Urban plantation options for Jharsuguda In-valley

Type of Urban Setting	Locations in Jharsuguda	Plantation Species
Highway and Artillery Road Dividers	NH-49 and SH-10, Market Road, etc.	*Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Bougainvillea, Cascabela thevetia*
Highway Sides	NH-49 and SH-10	*Ficus religiosa, Ficus recemosa, Syzygium cumini, Ficus benghalensis, Alstonia scholaris , Azadirachta indica, Tamarindus indica*
Municipal Roads	Jharsuguda, Belpahar, Brajrajnagar municipalities	*Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Alstonia scholaris, bouganvillea, cascabela sp, oleander plants, etc.*

Responsible Agency: Jharsuguda and Belpahar municipalities, Ministry of Commerce and Transport, Public Works Department (PWD), National Highways Authority of India (NHAI), State Highways Authority of India (SHAI), Ministry of Forest and Environment, State Pollution Control Board (OSPCB).

Heat Mitigation Potential: Medium
Cost: Low (Indicative - INR 20-50 lakh)

1.3.3 Green Roofing

Due to increasing urbanization in the district, the built-up area in Jharsuguda has seen a rapid increase from 0.3% of the total area in 2002 to 4.14% in 2016, signifying more than a 10-fold increase over a span of 14 years. Given the fact that the built-up area is also one of the top three thermal source categories contributing to the heat island phenomenon, the implementation of green roofing can go a long way in addressing this challenge. Both reflective roofing and green roofing are proven measures to reduce peak indoor air temperature with respect to conventional uncoated RCC roofing designs. It is understood that the amount of heat flux in case of high reflective RCC roofs is almost 77% less compared to uncoated RCC roof during peak time. This is attributable to application of maintenance-free reflective white coating which have insulation property due to the higher albedo value (0.9) of the coating material. Further, greening the roof through vegetation is also an effective option to reduce peak cooling demand.

A study conducted by TERI for the city of Bangalore compared the ambient air temperature and peak cooling demand for three roofing designs, viz. a) conventional uncoated RCC roofing, b) reflective white coated roofing, and c) vegetated green roofing. The results are given in the figures below.

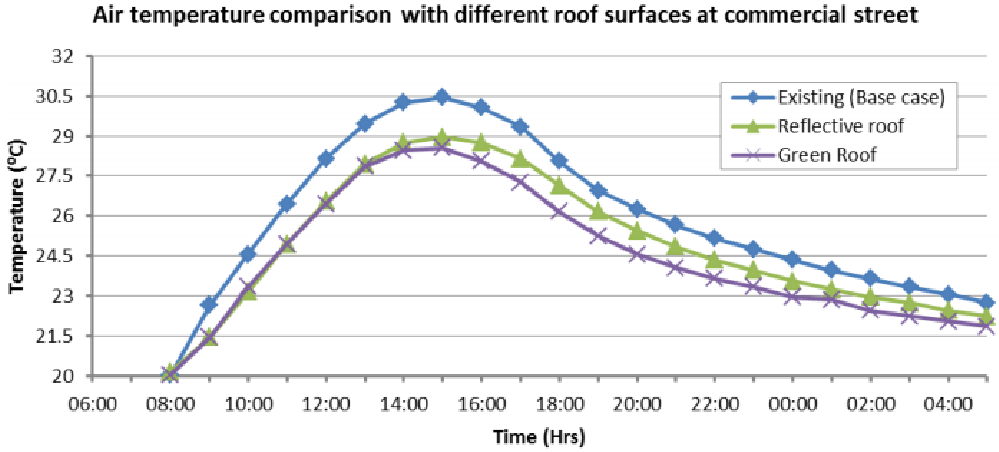


Figure 3 : Diurnal profile of ambient air temperature in three roofing designs, viz. a) existing uncoated roof, b) reflective white coated roof, and c) green roof. Source: TERI (2013)

It can be seen that implementation of reflective and green roofing can result in a peak temperature drop of 1.5^{0}C and 1.9^{0}C, compared to uncoated conventional RCC roofs. It is recommended that they be implemented starting with government buildings in the district. Based on results achieved, it can then be rolled out for commercial and residential establishments.

Responsible Agency: Jharsuguda, Belpahar and Brajrajnagar municipalities

Heat Mitigation Potential: Medium
Cost: Low

1.3.4 Reflective Road Surface Materials

The increasing concentration of high density built-up area in parts of Jharsuguda and other municipalities over the last 14 years has led to an increase in the usage of concrete and asphalt as road surface materials. As the biophysical model indicates, built-up area is one of the three most important contributing factors to the heat island phenomenon. Engineered road materials such as concrete and asphalt tend to have higher solar energy absorption and therefore tend to trap a relatively higher incoming solar radiation, which allows them to retain heat during the day and slowly release at night contributing to the urban heat island effect. With urbanization spreading to other parts of the district, it is therefore important to pay closer attention to the choice of road surface materials that will be considered in the city's expansion plans. A map of the district of Jharsuguda depicting the spatial spread of different road surface materials is shown below.

Figure 4: Map of Jharsuguda district depicting the locations of bitumen, concrete and kuchha roads. Source: Jharsuguda municipal office.

It can be seen that most of the highly urbanized parts of the district (such as the area between location 4 and 6) have concrete roads. The artillery roads are typically bitumen/asphalt whereas the rural areas adjoining the municipality still have kuchha roads (gravel or mud).

Although it is well known that higher albedo road surface materials reflect more heat to the environment, it is important to take into account other factors such as wind speed, wind direction, solar radiation, etc. of the location while looking at the effect on near-surface ambient air temperature. The diurnal variation in albedo or reflectance for 6 different kinds of road surfaces, viz. Portland Cement Concrete (PCC), Porous Hot Mixed Asphalt (PHMA), Hot Mixed Asphalt (HMA), turf, gravel, Pervious Portland Cement Concrete (PPCC) is given in the figure below.

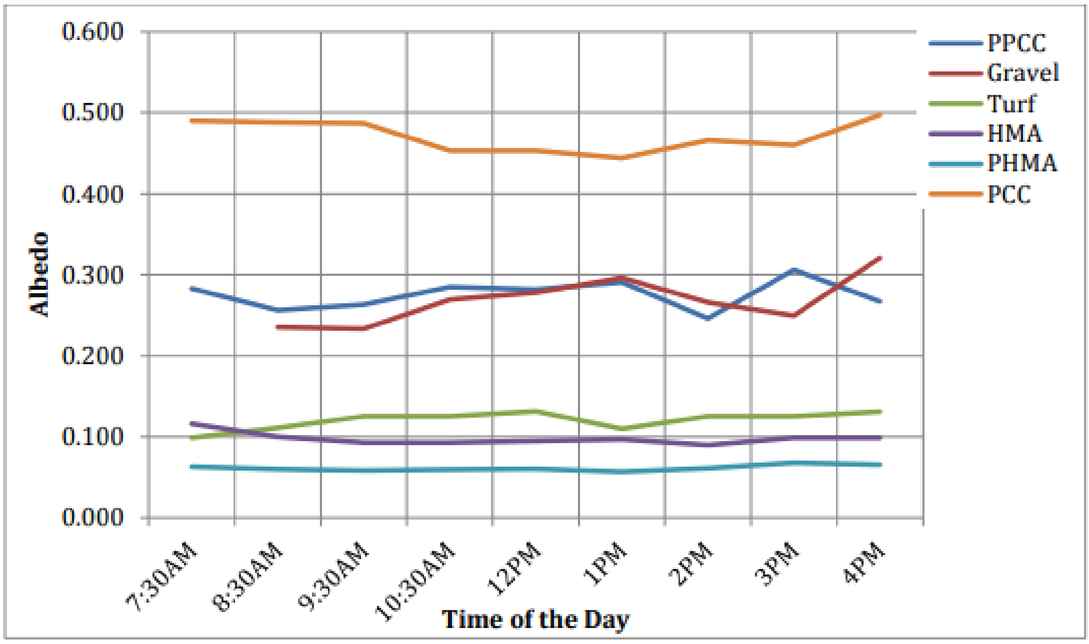


Figure 5: Diurnal variation of albedo for 6 different road surface materials. Source: Manzouri (2013)

As can be noticed, the albedo of PCC is consistently higher than that of other road surface materials, making it environmentally favourable. Further, the bitumen based materials such as PHMA and HMA have the lowest albedo, thus making them less suitable.

It is thus recommended that keeping cost and maintenance factors in mind, PCC material must be preferred in new road construction wherever possible.

Responsible Agency: Public Works Department (PWD), National Highways Authority of India (NHAI), State Highways Authority of India (SHAI)

Heat Mitigation Potential: Medium
Cost: Medium

1.4 Agriculture and Cropland

1.4.1 Conservation tillage

The entire district of Jharsuguda has more than 87,000 ha of crop land area. Lakhanpur and Jharsuguda panchayats have the largest share in the crop land area.

Land surface albedo decreases during the fallow period. Conservation tillage provides the best opportunity for halting degradation and for restoring and improving soil productivity. No tillage, minimum tillage, reduced tillage and mulch tillage are terms synonymous with conservation tillage. Conservation tillage or mulch tillage increases the surface albedo of the land mainly during the fallow period, increases the moisture level in the soil, improve the water and fertilizer penetration to the soil and above all increases the productivity of the crop land (Devin et al., 2013). Studies suggest that the conservation tillage increases the surface albedo in the range of 0.1 – 0.2 over that of the normal tilled crop land and 0.1 unit increase in albedo decreases the ambient temperature by 2°C (Devin, et al., 2013). Farmers do not need to invest large amounts of money to adopt the conservation tillage/no tillage.

Studies have demonstrated that the cost of adoption of conservation tillage is of the order of $10-15 per acre (Harper et al., 2017) However, local authorities need to plan awareness campaigns among the farmers and support systems to help farmers to adapt the conservation tillage practice. Panchayats, pani panchayats, BDO, district agriculture officers may be involved to conduct meetings (for example, at trysting trees) at a time when all the farmers, male or female are available to attend such meetings.

Most of the cropland areas in the Jharsuguda district are deprived of irrigation water during the rabi (winter) season. Rainwater harvesting pond in each farm to support the crop production during the rabi season would help increase the crop productivity as well as reduce the length of the fallow period in crop land.

To protect the crop from the extreme heat stress of the summer, plantation of broad leaved trees might be promoted on the bunds of the crop lands.

Responsible agency: Municipality, Panchayat, local agriculture research team.

Heat Mitigation Potential: High
Cost: Low (Indicative INR 14-20 crore)

The summary of recommended different heat mitigation action plan for different sectors is presented in Table XII for a better comparison of respective implementation cost and UHI mitigation potential. The measures are colour coded for high impact as green, medium as yellow, low as blue, and capital cost as green if low, yellow if medium and blue if high.

Table XII Summary of heat mitigation action plan for different sectors

Sector	Name of Measure	Impact on Heat Mitigation*	Capital Cost**	Responsible Agency
Coal Mining	Improved Management of De-coaled Areas	High	Medium	Mahanadi Coalfields Ltd., Ministry of Coal, Odisha State Pollution Control Board (OSPCB), Jharsuguda Municipality
	Introduction of coal washeries	Medium	High	Mahanadi Coalfields Ltd. (MCL), Ministry of Coal, Odisha State Pollution Control Board (OSPCB), Ministry of Environment and Forests (GoI).
	Phasing out blasting though surface miner	Medium	Negligible	Mahanadi Coalfields Ltd, Ministry of Coal
	Compensatory afforestation	High	Medium	Mahanadi Coalfields Ltd. (MCL), District Forest Office (Jharsuguda)

Industry	Stockpile inventory management	Medium	Negligible	Steel, Aluminium, Thermal Power, etc.
	Stockpile design changes	Low	Negligible	Steel, Aluminium, Thermal Power, etc.
Urban Planning	Congestion Planning	High	Medium	NHAI, SHAI, State Department of Commerce and Transport, Department of Forest and Environment, OSPCB, etc., Municipalities
	Urban Plantation	High	Low	NHAI, SHAI, State Department of Commerce and Transport, Department of Forest and Environment, OSPCB, etc., Municipalities
	Green Roofing	Medium	Low	Jharsuguda, Belpahar and Brajrajnagar municipalities
	Reflective Road Surface Materials	Medium	Medium	Public Works Department (PWD), National Highways Authority of India (NHAI), State Highways Authority of India (SHAI)
Agriculture	Conservation Tillage	Low	Low	Municipality, Panchayat, local agriculture research team.

*For impact of heat mitigation, low, medium and high are on the basis of relative reduction in radiative heat release with respect to BAU.

**For costs, high signifies greater than INR 100 crore. Medium costs fall in the bracket of INR 1 crore to INR 100 crore and low costs are below INR 1 crore. However, they are only indicative. Detailed feasibility study needs to be undertaken to assess the exact costs for these measures.

The above-mentioned measures have been mapped on a cost vs. impact graph as shown in the Figure 3 below. The diagram can be used as a decision-making tool which can help prioritize the order of implementation of these measures. Measures which are of negligible cost may be implemented first. This may be followed by implementing either high impact measures or low cost measures, depending upon their political and social feasibility. The measures which have the least impact and highest cost can be considered to have the least priority in the order of implementation.

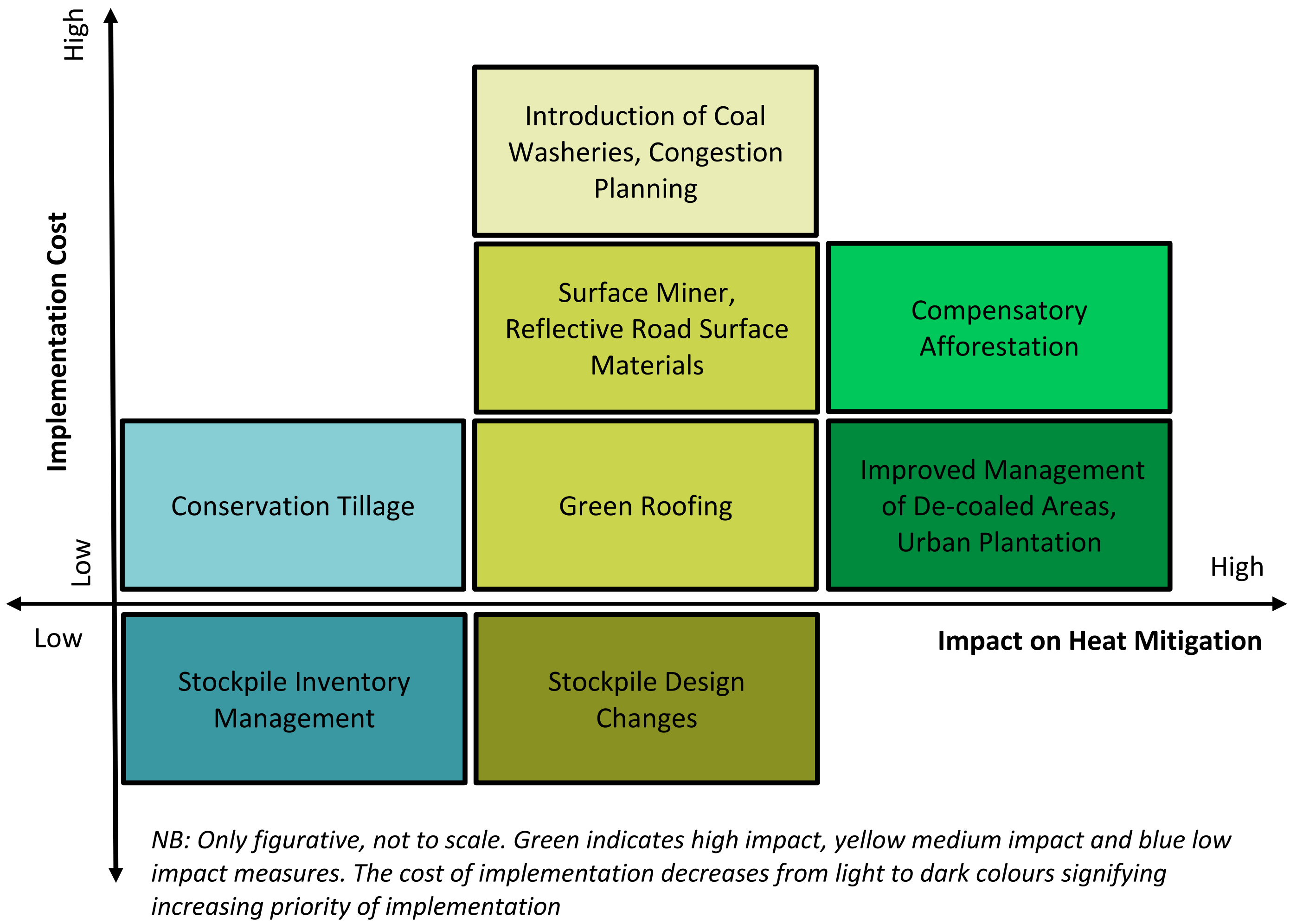


Figure 6 Cost vs. Impact plot of heat mitigation measures

Based on the above cost-impact plot, the measures have been ranked on the basis of feasibility of implementation. A thumb rule has been taken to arrive at the categorization of impact to cost ratios. Higher the impact and lower the cost, the more feasible is a particular measure. Such measures should be implemented as top priority. A priority ranking of the measures has been developed as given in the table below.

Table XIII Feasibility ranking of the heat mitigation measures

Name of Measure	Impact to Cost Ratio	Priority Ranking
Stockpile Inventory Management	Extremely High	1*
Stockpile Design Changes	Extremely High	1*
Phasing out Blasting through Surface Miner	Extremely High	1
Improved Management of De-coaled Areas	Very High	2
Green Roofing	Very High	2

Urban Plantation	Very High	2
Compensatory Afforestation	High	3
Reflective Road Surface Materials	High	3
Introduction of Coal Washeries	Low	4
Congestion Planning	Low	4
Conservation Tillage	Low	4

* *The benefits outweigh the costs in these cases. Hence, these have net negative costs and higher ranking*

Apart from the location-specific recommendations provided in this action plan, a number of other interventions that minimize the ambient heat release from different heat sources can be considered. These more general measures are typically effective for metros, large Tier 1 and Tier 2 cities as well as for industrial agglomerations. They are summarized in the table below.

Table XIV General Recommendations to mitigate urban heat island

Sector	General Recommendations	Comment
Industry	Improving electrical and thermal Energy Efficiency, Reducing station heat rate (SHR), etc.	To decrease the coal consumption and thereby reduce stockpile inventory volumes
Buildings	Using Energy Efficient ACs and refrigerators, Heat insulation and thermo-shielding of buildings, Indoor ventilation, Improvement in the reflectivity of walls and roofing materials, etc.	To increase the surface albedo of the city and thereby increase the heat reflectance back to the atmosphere
Urban Planning	Traffic demand management, introduction of low-emission vehicles and anti-heat coating of roads, etc.	To decongest the city and to increase the surface albedo of the roads which reflect more heat to the atmosphere.

Chapter 2. Heat Island Adaptation Strategies

Odisha has been one of the leading states of India to address the problem of heat wave through a systematic approach involving all levels of the government machinery (state, district, and blocks) as well as civil society organizations and industries.

The state has developed a heat wave action plan which outlines the roles and responsibilities of the different wings of the state government such as Special Relief Commissioner (SRC), Odisha State Disaster Management Authority (OSDMA), Department of Housing & Urban Development, Health and Family Welfare, Panchayati Raj, School and Mass Education, Commerce & Transport, Labour and Employees' State Insurance, Energy, Public Information & Relation, Water Resources, Fisheries & Animal Resources, Forest and Environment, Women and Child Development, ST & SC and Backward Classes Welfare, etc. The OSDMA is the key state nodal agency which convenes the state Steering Committee meetings to review and update the heat action plan annually.

The SRC issues directives to the concerned departments for taking precautionary measures such as availability of water in Jal Chhatras, access to medical facilities, regulating timings for schools and public transport, etc. in coordination with the relevant ministry in the state government. In addition, roles have been allotted for urban local bodies (ULBs) including District Collectorate office, municipalities and gram Panchayats for coordinated implementation of the emergency response measures. The Indian Meteorological Department (IMD) also has a key role to play in terms of disseminating early warning forecasts for heat-wave prone regions.

In this section, we identified additional roles that these agencies can take on, above their current roles in heat wave action plan. These roles would focus particularly on coping with the heat stress in heat islands and high temperature hotspots within the district.

2.1 Central Agencies

2.1.1 Role of Indian Meteorological Dept. (IMD)

- Installation of more Automatic Weather Stations (AWS) in heat-wave prone districts
- Analyse data from the different AWS to obtain spatial distribution of temperature and heat index in each of the heat-wave prone districts
- Provide zone-wise or block-wise early warning forecasts for each of the heat-wave prone districts.

2.2 State Agencies

2.2.1 Role of Special Relief Commissioner (SRC):

- In addition to disseminating warnings through AIR (All India radio), Doordarshan and other private TV channels, SRC could help create local radio networks in Sambalpuri and organize discussions and other programs for creating public awareness on specific regions in the district which are more vulnerable to heat stress. Information on 'do's and 'do not's during heat stress should be highlighted in several strategic and heat stressed locations as posters, billboards and hoardings in the local language ensuring information is widely accessible amongst different groups of people.

- To deploy adequate number of water tankers in water-scarce areas based on a careful analysis of the heat-stress prone regions and the population density of these regions within the district. The Department of Water Resources to be mobilized for release of water in the canals.

2.2.2 Role of Odisha State Disaster Management Authority (OSDMA)

- To ensure drinking water supply arrangements and access to medical facilities that are equipped to cater to both genders.
- To reschedule working hours in educational institutions, for those doing physical labour, veterinary measures, etc.
- Distribute leaflets among school children to educate them on heat stress and its prevention
- To reschedule timings of public transport, etc. in accordance with early warning forecasts. This should be done only if timings for works, schools and different government and non-government offices are also rescheduled simultaneously in the summer months.

2.2.3 Role of Department of Housing and Urban Development

- Give directives to urban local bodies (ULBs)/Development Authorities to create more public parks and water bodies in hotspot areas for the general public.
- Give directives to ULBs to identify temperature hotspots in the built-up areas and incentivize white painted roofs (albedo paint) in these regions.
- Give directives to ULB/Development Authorities for the use of K-glass, doubly glazed glass in buildings and vehicles which prevent extra entry of heat inside, especially in the built-up areas which are located in hotspot regions.

2.3.4 Role of Labour and Employee's State Insurance Department

- Increase awareness among construction workers and factory labourers working in temperature hotspots through lunchtime meetings and labour union meetings.

2.3.5 Role of Dept. of Women and Child Development

- Sensitize female agriculture and brick labourers about the health effects of walking long distances to fetch water in the summer months. Understand the concerns of the women labourers better with regard to working long periods in the heat and design guidelines to optimize such prolonged exposure.

- Create awareness among female labourers on the locations of water kiosks in the district.

2.3.6 Role of Department of Health

- Setting up of additional health dispensaries in heat stress zones in the district as well as equipping existing dispensaries with additional facilities such as life saver ambulances, available mobile personnel, 24 hour back-up power supplies, air conditioned rooms, availability of cold drinking water, appropriate housing design, etc.
- Ensure adequate training and supply of health professionals (doctors, nurses, etc.) to meet the demand of heat stress induced morbidity cases, due to long hours of exposure in heat stress prone areas.
- Capacity building of District Medical Officers (DMOs) on their roles and responsibilities towards heat stress and heat islands.

2.3 Local Government

2.3.1 Role of Urban Local Bodies (Municipalities and District Collectorate)

- Conduct Focussed Group Discussions (FGDs) at a block-level to identify vulnerable regions in the municipality. This can act as rapid assessment in order to implement immediate coping measures. The FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. This will ensure that specific health issues due to effect of extreme heat exposure is highlighted and preventive measures taken for the local population most likely to be affected by heat.
- Providing public shelter structures in highways and crowded areas such as open markets.
- Providing drinking water through jal chhatras (water kiosk) at strategic points. It is to be ensured that more number of kiosks is located at hotspot regions and their maintenance takes place at a healthy frequency.
- Alert public transport systems on the heat-stress prone regions, especially in the summer months, to enable them plan alternate routes if feasible.
- Exploring light coloured concrete roads as an option to replace asphalt roads near hotspot regions.

2.3.2 Role of Panchayats

- Conduct Focussed Group Discussion (FGDs) at village level to identify the heat-stress vulnerable regions. This can act as rapid assessment to implement immediate coping measures. Similar to the ULBs above, FGDs should have representation from all strata of the society and specific representation from women, women with children, aged and daily wage labourers. This will ensure that specific health issues due to effect of extreme heat exposure is highlighted and preventive measures taken for the local population most likely to be affected by heat.

- Provision of water kiosks at strategic as well as heat-stress vulnerable points based on the FGDs.

Table XV summarises the roles of these agencies.

Table XV Role of nodal agencies (central, state & local) in heat island adaptation response

Level	Name of Dept./Agency	Relevant Role
Central	Indian Meteorological Dept.	Heat Stress Forecasts, Early Warning System
State	Special Relief Commissioner (SRC)	To provide relief in the event of disasters and natural calamities, including heat waves.
	OSDMA	To direct disaster relief management activities at the state level.
	Dept. of Housing and Urban Development	To direct ULBs to increase access to parks, open spaces and water bodies.
	Dept. of Labour and Employee Welfare	To issue guidelines to labourers to minimize exposure to heat-stress related risks.
	Dept. of Woman and Child Development	To incorporate gender equity in heat wave action planning
	Dept. of Health	To set up additional health dispensaries in heat stress zones, equip existing and new health dispensaries with comfort facilities; adequate training and supply of health professionals; training and capacity building of DMOs.
Local Govt.	Urban Local Bodies (Municipalities)	To implement the various heat-stress adaptation measures in the Municipalities upon guidelines from the District Collectorate.
	Panchayats	To implement the various heat-stress adaptation measures in the villages upon guidelines from the District Collectorate.

Chapter 3. Institutional Framework for Monitoring Progress of Implementation

A coordinated institutional framework for the periodic review of the progress of these measures is proposed. An institutional framework along the lines of heat wave action plan for implementing and tracking the progress of measures for heat island adaptation will go a long way to address this challenge.

The roles of the various bodies involved are described below:

3.1 Steering Committee

The steering committee shall consist of representatives from Odisha State Disaster Management Authority (OSDMA), Odisha State Pollution Control Board (OSPCB), State Emergency Operating Centre (SEOC) and Odisha Space Applications Centre (ORSAC). The steering committee would be tasked with the following roles:

- Direct IMD to develop more spatially granular forecast and early warning system in the month of April to June for the heat-wave prone districts.
- Prepare a region-wise vulnerability map with the help of ORSAC.
- To provide guidelines and support to State Emergency Operation Centre (SEOC) for implementing different adaptation measures.
- To direct the District Collectorate office to conduct FGDs in municipalities and gram panchayats to assess the implementation of adaptation measures.
- To perform a monthly stock-take of the progress and evaluate the measures undertaken by the urban local bodies.

3.2 Urban Local Bodies (ULBs)

- To nominate sufficient human resources who would be accountable for the upkeep and maintenance of water kiosks (jal chhatras) and public shelters installed at various strategic points in the district.
- To ensure detailed records of heat mortality and morbidity patients are maintained at government hospitals and health dispensaries. The records would contain their address, place of work, type of occupation, age, gender, health status, etc.

Information Flow

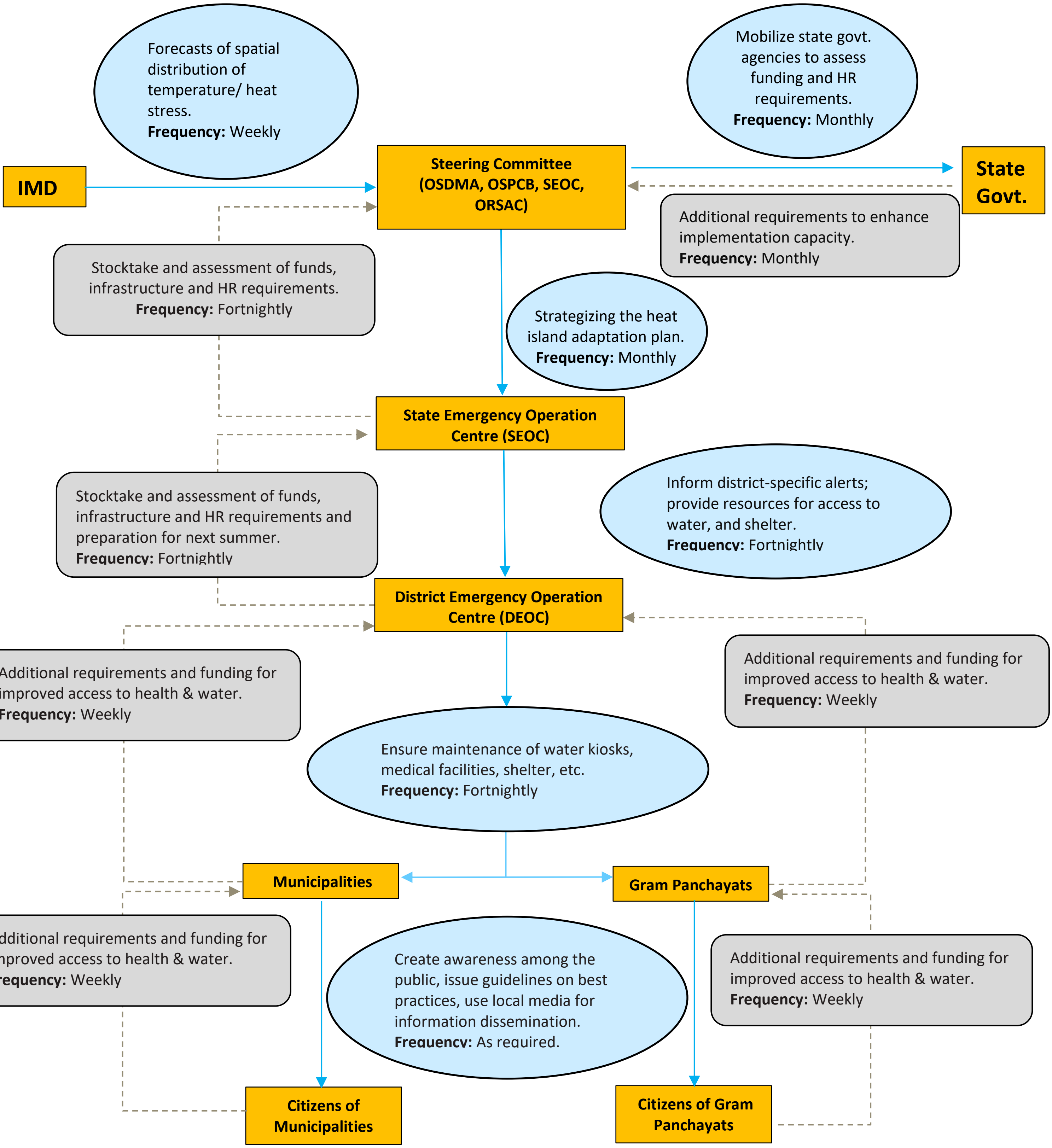


Figure 7: Information flow for heat island adaptation response strategy

(Note: Blue oval boxes indicate directives or guidelines, grey boxes indicate feedbacks and yellow boxes indicate institutions or groups.)

Way forward for action plan

The mitigation strategies described in the action plan have been ranked based on the indicative costs and heat mitigation potential quantified only for some measures. Indicative ranges have been taken for other measures from the concerned stakeholders. A better picture would emerge upon conducting a detailed cost feasibility and mitigation impact study for each of the measures, which would help prioritize the order of implementation. These feasibility studies would also have associated costs comprising of monitoring programs, pilot projects, modelling exercises, etc. In addition, an institutional body involving key stakeholders from industry, state government and urban local bodies can be created to track the implementation of the measures. A broad idea of the total costs associated with each of the listed measures is provided in the table XVI below.

Table XVI Heat mitigation measures by sector and indicative capital cost of implementation

Name of Sector	Name of Measure	Indicative Capital Cost*	Source
Coal Mining	Increased Bio-Reclamation of De-coaled Area		Not available
	Introduction of Coal Washeries	INR 1347 crore	CMPDI (2016)
	Phasing out Blasting through Surface Miner	Low	-
	Compensatory Afforestation	INR 4.38 lakh/ha	CAMPA (to be borne by user agency)
Industry	Stockpile Inventory Management	Negligible	-
	Stockpile Design Changes	Negligible	-
Urban Planning	Congestion Planning	INR 50-100 crore	Working Group on Transport, Planning Commission (2012)
	Urban Plantation	INR 20-50 lakh	Guidelines for Green Highways Project, National Highways Authority of India (2015)
Agriculture	Conservation Tillage	INR 14-20 crore	Based on crop area (pg. 42, DSS report) and Harper (2017)
Adaptation	Early Warning Forecasts	INR 2 crore	-
	Health Dispensaries	INR 200-500 crore	Inputs from DM Office
	Water Kiosks	INR 40-80 lakh	Amazon/IndiaMart

*Indicative capital costs include not only cost of implementation but also feasibility and pre-feasibility studies, modelling exercises, pilot projects, etc. The ranges stated here have been obtained based on expert consultations and workshops. Health dispensary costs include setting up of new health dispensaries and upgrading existing dispensaries with better facilities and include costs related to land acquisition, building design and infrastructure, purchase of medicines, refrigeration and air conditioning, etc.

The adaptation section of the action plan outlines the roles and responsibilities of the key government agencies involved in the implementation of coping strategies to ensure access to water, health and shelter facilities during the summer season. An institutional framework has been proposed to streamline the flow of information from the highest levels of the state government all the way to the individual citizens across different socio-economic groups. A mobile-based app can be created to keep track of the feedback received from citizens on parameters such as availability of water in water kiosks, access to medical facilities in health dispensaries and hospitals, upkeep and maintenance of public shelters, etc. The crowd-sourced feedback to the district collectorate office would not only hasten the decision-making process but also help assess the requirements at block-level. The specific municipal ward members or panchayat can then be informed to take corrective measures.

A community radio network can be set-up in the local language Sambalpuri. The radio network would disseminate information on heat stress vulnerable regions at a regular frequency, issue alerts on which routes to avoid, issue notices on changes in public transport timings, etc. The present analysis outlines the possible measures that can be taken with regard to decongestion of crowded areas like market road, such as construction of flyover, shifting of bus terminus, and plantation along road pavements and highways. For further improvement of the action plan and future planning in Jharsuguda, remote sensing based approach can be adopted to inform decision-making on city expansion, location of residential and commercial areas, industries, etc. This would help minimize the vulnerability of the population to heat stress.

In the realm of health and gender, a vulnerability mapping may be undertaken to look at the impact of heat stress through gender lens. In addition, an analysis of heat related morbidity and mortality will be useful in developing a more coherent adaptation response strategy.

Way forward for research based solutions

The current study has provided a good starting point for carrying out further research on industrial heat islands and related aspects.

In the ambient temperature section of the modelling report, the temperature hotspots of the district have been identified using temperature-humidity data-loggers. However, the spatial variation in temperature has not been attributed to the heat sources and sinks. A detailed source apportionment study can be undertaken to better understand the causative factors of temperature increase. This can be modelled using source-transport-receptor framework. The heat release from sources and heat absorbed by sinks can be quantified using the laws of radiation and convection. Dissipation can be modelled by looking at the convective heat transfer through air, using spatially disaggregated data on wind velocity. On the receptor side, the number of temperature-humidity data loggers can be increased to improve the spatial resolution.

Detailed assessment of land reclamation of de-coaled areas in local mines can be undertaken. As per the current analysis, there is a wide variation in the technically reclaimed and biologically reclaimed areas vis-a-vis the total de-coaled area in the five opencast projects. Understanding the nuances of different land reclamation strategies will provide a useful indicator of the heat mitigation potential. In addition, the phenomenon of self-oxidation of coal has not been fully understood. Controlling this phenomenon is a key challenge for coal mining practitioners, especially in India. While secondary literature has been used to quantify the self-combustion indicators for the various coal seams, computational fluid dynamics must be employed to assess the actual volume of coal undergoing oxidation. This would require information on not only the coal seam properties from proximate and ultimate analysis but also meteorological parameters such as ambient temperature, humidity and wind velocity at the coal seam locations.

In the modelling report the coal stockpile inventory management in a particular steel plant has been looked at in detail and a regression model has been developed relating the coal purchase with stockpile inventory and steel production. However, the quality of the model can be improved by analysing data from more steel plants. A comparative analysis of steel, aluminium and thermal power plants can also be undertaken to assess the variation in coal purchase savings based on their respective stockpile inventory patterns. In addition, flue gas dispersion from stacks has not been considered in detail in the present analysis. The heat content of flue gases released from stacks due to the combustion of coal may possibly be an important contributing factor to the increase in temperature in the district.

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