Manual for Adaptation and Increasing Resilience of Industrial Parks to the Impacts of Climate Change

in Andhra Pradesh and Telangana State, India

Manual 2: Engineering Measures for Planning and Resilience Measures for Climate Change Adaptation in Industrial Parks

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List of Abbreviations

APIIC	Andhra Pradesh Industrial Infrastructure Corporation
APITCO	Andhra Pradesh Industrial and Technical Consultancy Organisation Ltd.
CCA	Climate Change Adaptation
CEAC	Central Environmental Appraisal Committee
CETP	Common Effluent Treatment Plant
CPCB	Central Pollution Control Board
CRA	Climate Risk Analysis
CZMA	Coastal Zone Management Authority
CFO	Consent for Operation
CFE	Consent for Establishment
DPR	Detailed Project Report
EIA	Environmental Impact Assessment
EIP	Eco-industrial Park
GoI	Government of India
IALA	Industrial Area Local Authority
IC	Industrial Corridor
IP	Industrial Park
IMD	Indian Meteorological Department
MoEF & CC	Ministry of Environment, Forests and Climate Change
MSME	Micro, Small and Medium Enterprises
NIMZ	National Investment and Manufacturing Zones
NLP	National Land Use Planning
PF&IC	Price Fixation & Infrastructure Committee
SAR	Site Analysis Report
SC/ ST	Scheduled Castes/ Schedule Tribes

SEA	Strategic Environmental Assessment
SEAC	State Level Environmental Appraisal Committee
SEZ	Special Economic Zone
SFC	State Financial Corporation
SPCB	State Pollution Control Board
ST/SC	Scheduled Tribes / Scheduled Casts
SMP	Site Master Planning
SLAC	State Level Allotment Committee
TSIIC	Telangana State Industrial Infrastructure Corporation
USP	(Unique Selling Proposition)
ZM	Zonal Manager

Glossary

Adaptation	Any activity that reduces the negative impact of climate change, while taking advantage of new opportunities that may be presented as a result of climate change.
Cloud Burst	A cloudburst is an extreme amount of precipitation, sometimes accompanied by hail and thunder, which normally lasts no longer than a few minutes but is capable of creating flood conditions. A cloudburst can suddenly dump large amounts of water e.g. 25 mm of precipitation corresponds to 25000 metric tons/km2 (1 inch corresponds to 72,300 short tons over one square mile). However, cloudbursts are infrequent as they occur only via orographic lift or occasionally when a warm air parcel mixes with cooler air, resulting in sudden condensation.
Coastal inundation	The flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coasts, estuaries, and adjoining rivers or caused by rise in mean sea level. The winds drive large waves and storm surge on shore, and heavy rains raise rivers and overall water level.
Conducted Strike	This occurs when lightning strikes a conductor and that in turn induces the current into an area some distance away from the ground strike point. Unprotected connected equipment can be damaged if they become an indirect path in the completion of the ground circuit.
Cyclone	A cyclone is an intense low pressure area or a whirl in the atmosphere over tropical or sub-tropical waters, with organised convection (i.e. thunderstorm activity) and winds at low levels, circulating either anti-clockwise (in the northern hemisphere) or clockwise (in the southern hemisphere). From the centre of a cyclonic storm, pressure increases outwards. The amount of the pressure drop in the centre and the rate at which it increases outwards gives the intensity of the cyclones and the strength of winds.
Direct Strike	This is the most dangerous form, wherein the structure is a direct path for lightning currents to seek ground. The extent of the current determines its effects.
Down-slope wind	These are the winds blowing at / with very high speed down the slope of mountains
Drought	Droughts are periods of abnormally dry weather that results in serious hydrological imbalance. Droughts can be divided within the different hydrological cycle that they affect the most. Agricultural drought refers to abnormally low soil moisture, and hydrological drought implies a reduced runoff and groundwater recharge. The Indian Central Water Commission defined drought as “a situation occurring in an area when the annual rainfall is less than 75% of the normal (defined as 30 years average) in 20% of the years examined and where less than 30% of the cultivated area is irrigated”.
Flood	A flood is an overflow of water that submerges land which is usually dry. Flooding may occur as an overflow of water from water bodies, such as a

	river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground.
Flood Plain	A lowland area, whether diked, flood proofed, or not, which, by reasons of land elevation, is susceptible to flooding from an adjoining watercourse, ocean, lake or other body of water and for administration purposes is taken to be that area submerged at the Designated Flood Level.
Heat Stress	Heat stress refers to the severe consequences of extreme heat for human health, affecting most strongly the vulnerable groups such as elderly, infants and children, as well as people with chronic heart or lung disease. Severe cases of heat stroke can cause death. It affects the labour productivity significantly in industrial parks.
Heat wave	Heat waves, also referred to as extreme heat events, are periods of abnormally hot weather, relative to the expected conditions of the area at that time of the year. IMD (India Meteorological Department) specifies heat waves by the maximum temperature of a station of at least 40°C for plains and at least 30°C for hilly regions.
Heavy Rainfall	Precipitation falling with an intensity in excess of > 7.6 mm (0.30 in) per hour, or between 10 mm (0.39 in) and 50 mm (2.0 in) per hour. Short periods of intense rainfall can cause flash flooding, longer periods of widespread heavy rain can cause rivers to overflow.
Lightening	Lightning is a sudden electrostatic discharge during an electrical storm between electrically charged regions of a cloud (called intra-cloud lightning or IC), between that cloud and another cloud (CC lightning), or between a cloud and the ground (CG lightning). The charged regions in the atmosphere temporarily equalize themselves through this discharge referred to as a strike if it hits an object on the ground, and a flash, if it occurs within a cloud. Lightning causes light in the form of plasma, and sound in the form of thunder. Lightning may be seen and not heard when it occurs at a distance too great for the sound to carry as far as the light from the strike or flash.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Comment: Resilience means the ability to “resile from” or “spring back from” a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need. (UNISDR, 2015). According to the IPCC: “The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.” ((IPCC, Climate Change 2014. Impacts, Adaptation and Vulnerability. Summary for Policy Makers. Working Group II, 2014), p. 5)

Risk	The latest IPCC report now focuses more on risks whereas earlier reports applied the concept of vulnerability. The IPCC defines risk as ((IPCC, Climate Change 2014. Impacts, Adaptation and Vulnerability. Summary for Policy Makers. Working Group II, 2014), p.5): “The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. (…) the term risk is used primarily to refer to the risks of climate-change impacts.”
Sea Dike	A dike, floodwall or any other thing that prevents flooding of land by the sea. As defined in the Dike Maintenance Act, “dike” means “an embankment, wall, fill, piling, pump, gate, flood box, pipe, sluice, culvert, canal, ditch, drain”
Sea level rise	An increase in the mean level of the ocean. Seal levels can rise at a global level through an increase in the volume of the world’s oceans or at a local level due to ocean rise or land level subsidence. Sea level rises can considerably influence human populations in coastal and island regions and natural environments like marine ecosystems. Sea level rise is expected to continue for centuries. Because of the slow inertia, long response time for parts of the climate system, it has been estimated that we are already committed to a sea-level rise of approximately 2.3 metres (7.5 ft) for each degree Celsius of temperature rise within the next 2,000 years.
Sediment Control	Any temporary or permanent measures taken to reduce erosion, control siltation and sedimentation, and ensure that sediment-laden water does not leave a site.
Setback	Means withdrawal or siting of a building or landfill away from the natural boundary or other reference line to maintain a floodway and to allow for potential land erosion.
Sewer Backflow Flood Event	This type of flood event is noticeable in places where the sewer system is combined. When both storm-water and sewage flows through a single pipe, there would be situations of sewer system backflow, resulting in underground flooding.
Sheet erosion	This is the uniform removal of soil in thin layers from the land surface by winds. It occurs in areas where loose, shallow topsoil overlies compact soil.
Shortages in Energy Supply	Shortages in energy supply refers to the problems occurring in the electricity sector due to heatwaves and droughts, which cause blackouts and brownouts.
Side Strike	This results from the disintegration of the direct strike when alternate parallel paths of current flow into the ground via structure. When the determined current path has some hindrance to current flow, a potential above ground develops and the structure's resistance to ground becomes the alternate path of conduction.

Splash erosion	This erosion occurs due to the impact of falling raindrop on the surface of soil.
SRI (Solar Reflectance Index)	SRI refers to the ability of the surface to keep cool under the sun by reflecting solar radiation and emitting thermal radiation. It is calculated according to ASTM E 1980 by utilizing solar reflectance and thermal emittance of a given material.
Storm Surge	A change in water level caused by the action of wind and atmospheric pressure variation on the sea surface. The typical effect is to raise the level of the sea above the predicted astronomical tide level, although in some situations, such as when winds blow offshore, the actual water level may be lower than that predicted. The rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides, reaching up to 20 feet or more in some cases.
Storm tide	Storm tide is the resulting water level produced by the combined effect of storm surge and astronomical tides. It is therefore an absolute water level as recorded. The storm tide level may be lower than a high astronomical tidal level if there is a storm surge that occurs at low tide. The storm tide therefore depends on the storm surge level, the astronomical tide level and the timing of the storm surge relative to the timing of the astronomical tides.
Straight-line wind	High winds associated with intense low pressure can last for approximately a day at a given location. The blow in a straight line
Surface flood	Here the flood event is noticeable above ground and it occurs mainly due to overflow of water from any nearby river, lake or as a result of storm surge, heavy rainfall, or coastal inundation
Surge Protection Device	SPD also known as a transient voltage surge suppressor (TVSS), is designed to divert high-current surges to ground and bypass your equipment, thereby limiting the voltage that is impressed on the equipment.
Thunderstorm	They can form rapidly and produce high wind speeds. Thunderstorms often create heavy rain and they move very rapidly, causing high winds for few minutes at a location.
U-value	U-value refers to the rate of heat transfer through a structure, with a unit of measurement of W/m2K. The u-value decreases as the insulation gets better. One can imply a simple calculation of the u-value by using the thickness and the conductivity (k-value) of the particular material.
Water scarcity	Water scarcity is the lack of water due to low water availability and water demand exceeding the supply capacity – affected by the severity and frequency of droughts. Water scarcity has significant impacts on industrial parks in terms of production and processes.

1. Introduction to the Manual

The The Ministry of Commerce and Industry (GoI), the Departments of Industries and Commerce of the then Govt. of Andhra Pradesh and APIIC along with GIZ took a decision in the year 2013 to take up the project of "Adaptation to Climate Change in Industrial Areas in India" to address the challenges of climate change with a focus on Andhra Pradesh and Telangana.

Andhra Pradesh Industrial Infrastructure Corporation Limited (APIIC), an undertaking of Government of Andhra Pradesh, is a premier organization, vested with the objective and responsibility of building and holding land banks, developing Industrial Parks/Estates and Special Economic Zones by providing necessary Industrial infrastructure. Over 201 Industrial Parks have been established throughout the State in eight (8) industrial zones covering an extent of 57, 836 Acres. These industrial parks are prone to various types of extreme climate events such as Cyclones, Drought, Floods, Heat Waves, etc.

Telangana State Industrial Infrastructure Corporation Limited (TSIIC), an undertaking of Government of Telangana State, is a premier organization in the state, vested with the objective of providing Industrial infrastructure through development of Industrial Parks and Special Economic Zones. Over 131 Industrial Parks have been established throughout the State of Telangana covered under 6 zones of the TSIIC. Telangana state is threatened by disasters like floods, drought, heat waves,

This manual is a part of set of documents prepared for climate risk assessment, adaptation planning, adaptation measures, best practices, legislative, regulatory and operational framework and CRA for Andhra Pradesh and Telangana. This document focuses on engineering adaptation measures for the industrial parks and industries considering various disasters like cyclones, floods, lightening, drought and heat waves. The following section gives the details of documents prepared under this manual. Document 4 corresponds on engineering measures for planning adaptation and resilience measures, which is explained in this document in detail.

1.1 Climate Change Adaptation Document Series

TSIIC/APIIC, in cooperation and with support from GIZ, developed a set of documents targeting adaptation to climate change of existing and upcoming industrial areas in Telangana States / Andhra Pradesh, India. The following table gives an overview on the various documents and their scope. The present document covers the engineering measures for climate change adaptation in industrial parks. Also, this document gives the details of master plan set up for new parks. This manual should be used along with Guidelines and Manual 1. The following figures 1 and 2 provides the linkages between Guidelines, Manual 1 and 2.

Table1: Documents for adaptation to climate change in industrial areas in [Telangana State / Andhra Pradesh]

	Document	Scope
1	Climate Change Adaptation Policy for Industrial Areas	The policy is setting the frame for APIIC's strategy to promote and implement adaptation of existing and upcoming industrial areas in AP to make the State industry and economy more climate resilient.
2	Guideline for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change	The guideline provides orientation and develops a standard approach and methodology on how to plan for adaptation and increasing resilience of existing and upcoming industrial areas.
3	Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change **Part 1: Tools for Planning and Resilience Measures**	Part 1 of the manual includes the tools required to execute a climate risk analysis for existing and upcoming industrial areas. The results of the risk analysis provide a sound baseline to further plan and implement concrete adaptation measures, both in terms of infrastructure and operation, management and maintenance of the industrial parks.
4	**Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change – Part 2: Engineering measures for planning adaptation and resilience measures**	**Part 2 of the manual includes the engineering required to translate the results of the risk analysis into concrete adaptation measures. According to the prevailing climate hazards in the state the tools focus on adaptation to heavy rainfalls and related impacts, and to heat waves and droughts and related impacts.**
5	Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change – Part 3: Best practice examples	Part 3 of the manual presents a collection of national and international best practice examples and lessons learnt on adaptation of industrial areas, urban areas and infrastructures to the impacts of climate change. This also includes best practices on law and policies on climate change adaptation.
6	Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change – Part 4: Financing of plans and measures	Part 4 of the manual includes a collection of financing instruments and best practices for financing of adaptation measures in existing and upcoming industrial parks.
7	Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change – Part 5: Ex-	Part 5 of the manual providers gives an overview on relevant actors and stakeholders and provides orientation on how the planning steps described in the guideline document are embedded in existing planning and working processes of APIIC.

	isting Planning and Implementation Procedure for Industrial Parks	
8	Manual for Adaptation and increasing Resilience of Industrial Parks to the Impacts of Climate Change – Part 6: Baseline studies in TS and AP	Part 6 of the manual presents the results of a pilot risk analysis and baseline study executed in selected industrial areas AP.
9	Training modules on execution of a climate risk analysis for existing and upcoming industrial parks and their adaptation to the impacts of climate change	To successfully implement the guidelines and even more important the respective adaptation measures in planning and refurbishment of industrial parks, APIIC has to develop the respective capacities in planning and operational departments. Furthermore, external capacities have to be supported and developed to be able to provide the required services to the infrastructure corporations and to individual industries and companies, particularly to (M)SMEs.

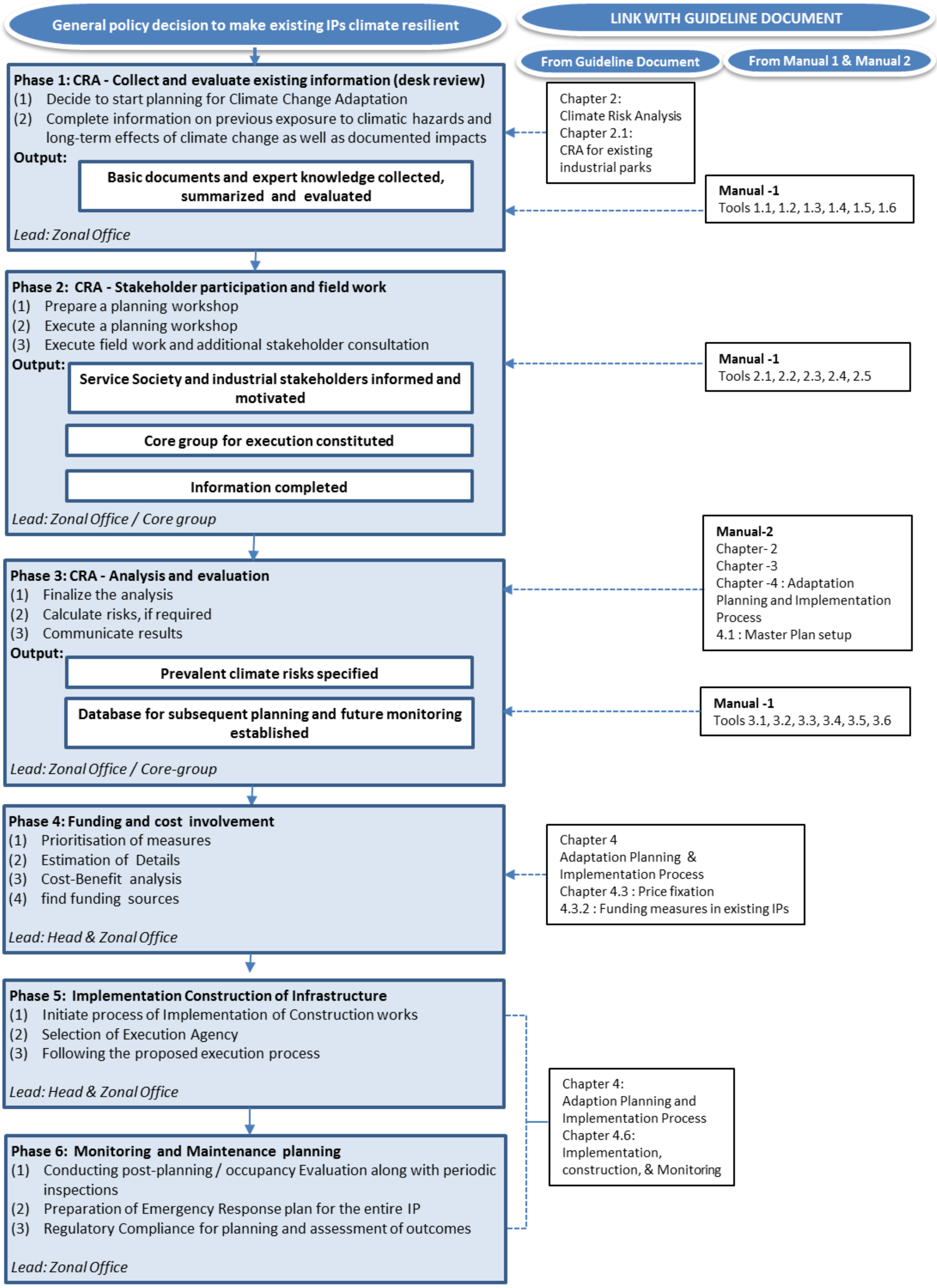


Figure 1: Flow Chart for Existing Industrial Parks

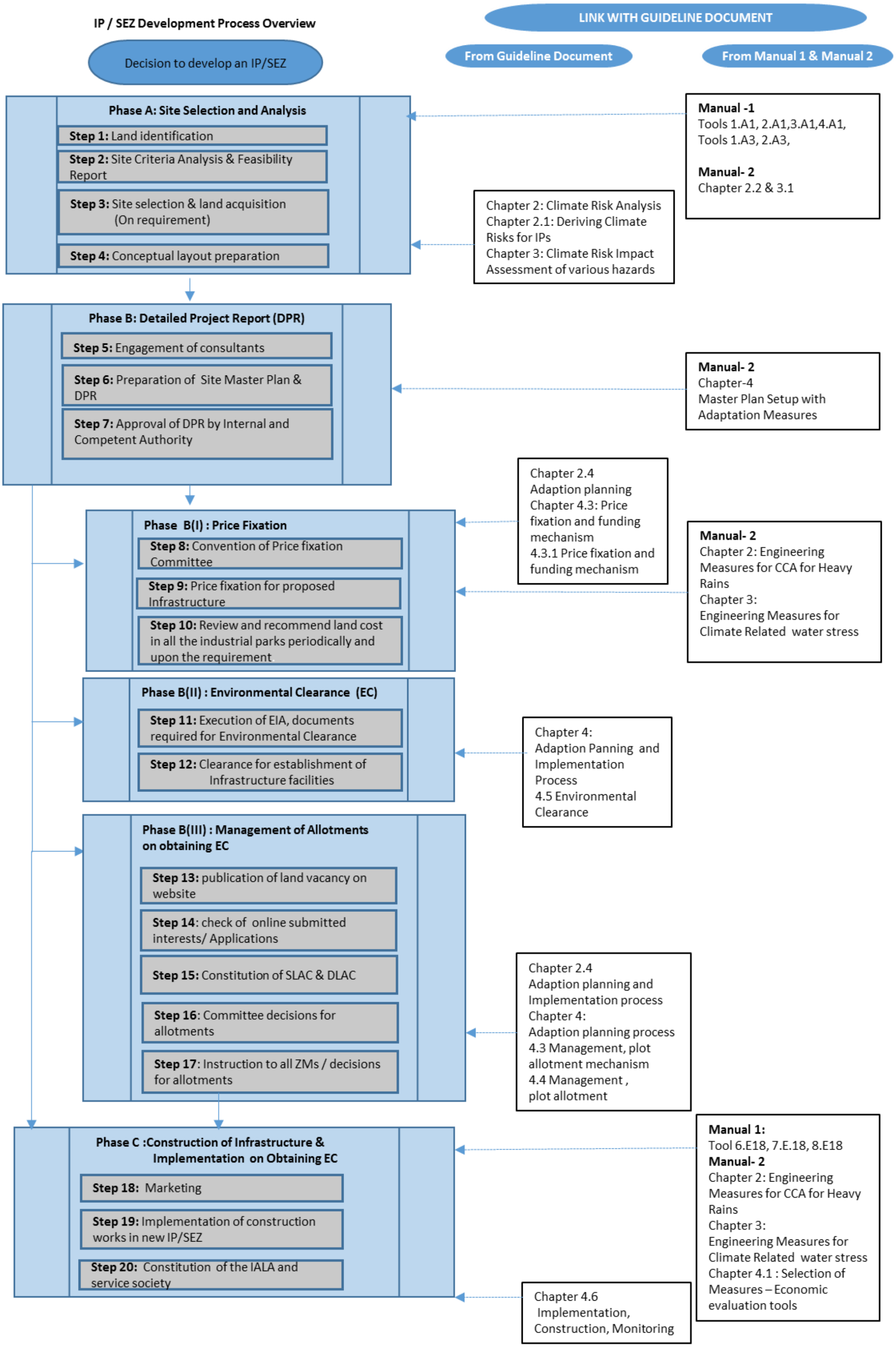


Figure 2: Flow Chart for Existing Industrial Park

2. Engineering Measures for Climate Change Adaptation for Heavy Rainfall

2.1 Connection between Heavy Rain and Flood Impact Risks and Measures

Heavy rainfall and flood related risks are the potential harm or danger anticipated in the future to the IPs and Buildings contained within. These risks could be mitigated or avoided by adapting the detail planning and engineering measures much before the occurrences of hazards in future.

Different mitigation measures applicable for different hazards are elaborated hereunder in Chapter 2.2.

2.2 Severity-based and Cost based prioritization matrix

The level of risks to various components in IPs and the buildings are dependent on the geo-climatic locations of the IPs, nature of hazards, and severity of risks.

During Climate Change Adaptation various measures are to be prioritized based on the severity level of the risks associated with corresponding hazards. Based on the past experience and observation a severity-based prioritisation matrix has been prepared for the Heavy rainfall and flood related risks, shown in figures below.

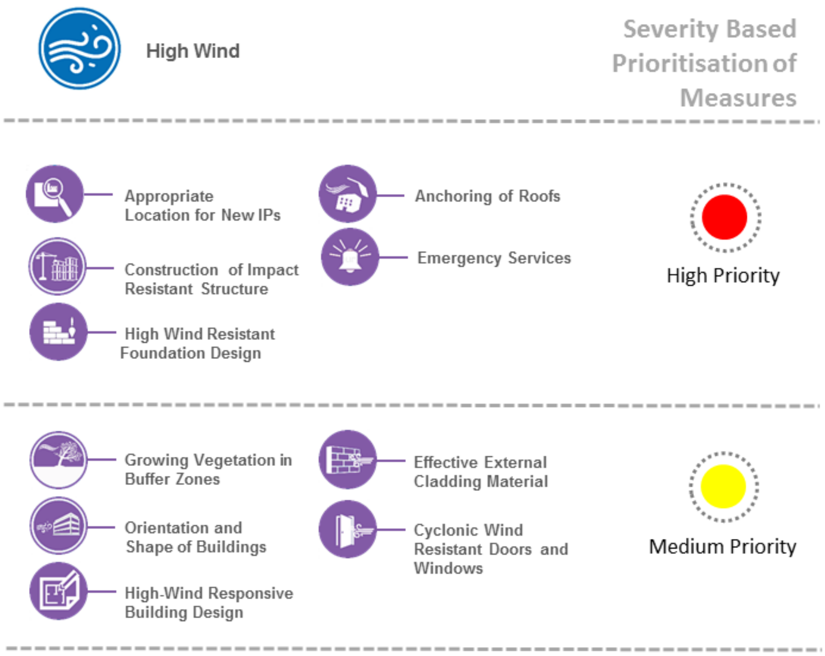


Figure 3: Severity based prioritisation of high wind impact

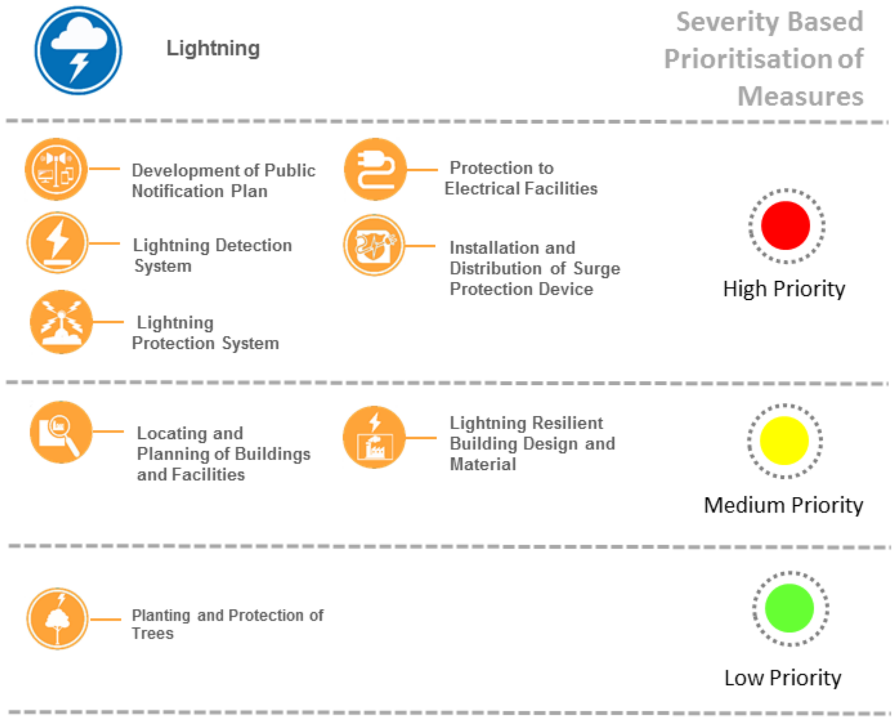


Figure 4: Severity based prioritisation of lightning impact

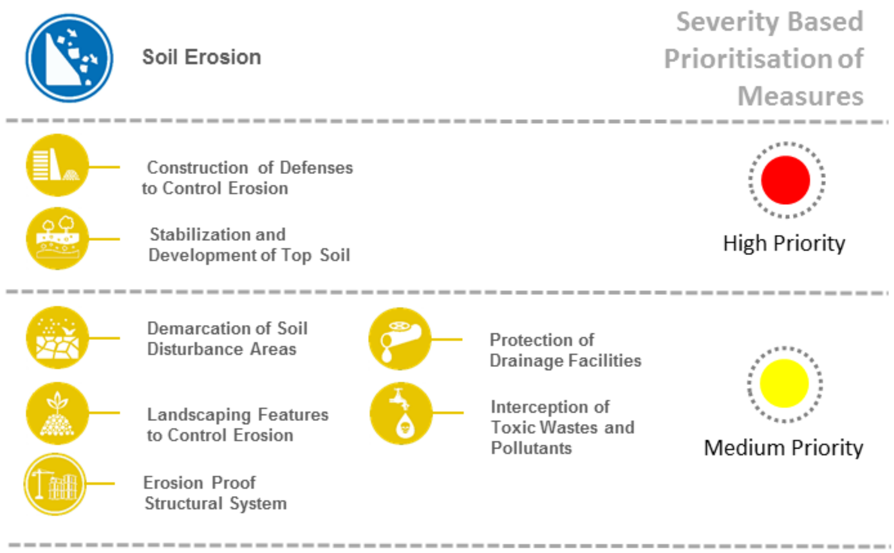


Figure 5: Severity based prioritisation of storm surge and coastal inundation

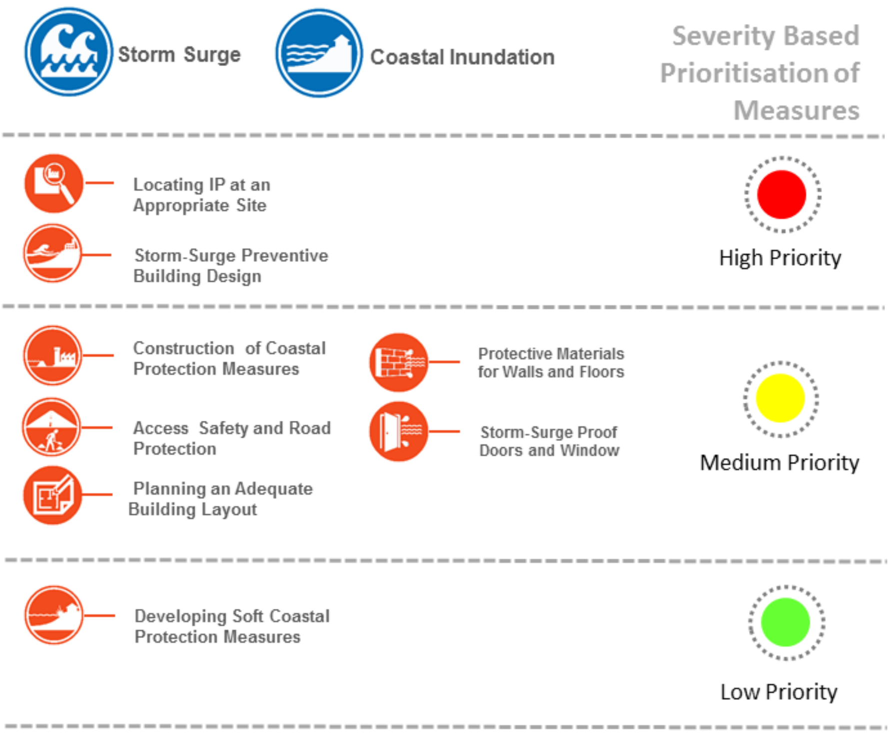


Figure 6: Severity based prioritisation of soil erosion impact

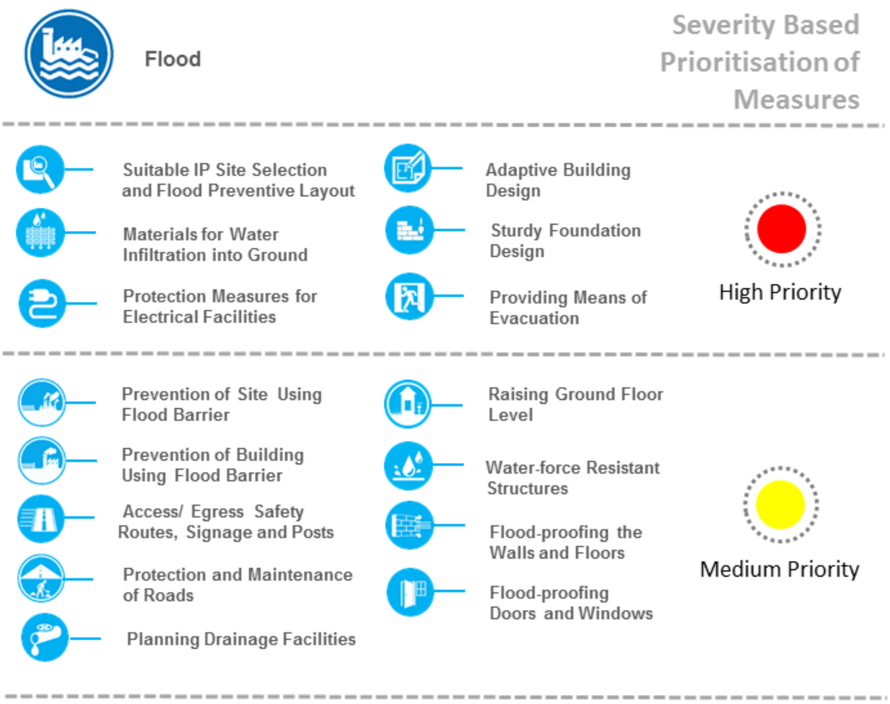


Figure 7: Severity based prioritisation of flood impact

Cost-Impact Prioritisation Matrix

The selection of the most applicable adaptation measures depends both on its cost and the severity of the risk that the Industrial Park is exposed to. In order to give an overview of the costs and impacts of the proposed adaptation measures, following matrices have been prepared.

The illustrations below summarize the costs and impacts of all the adaptation measures concerning high winds, lightning, storm surge, coastal inundation, soil erosion and floods.

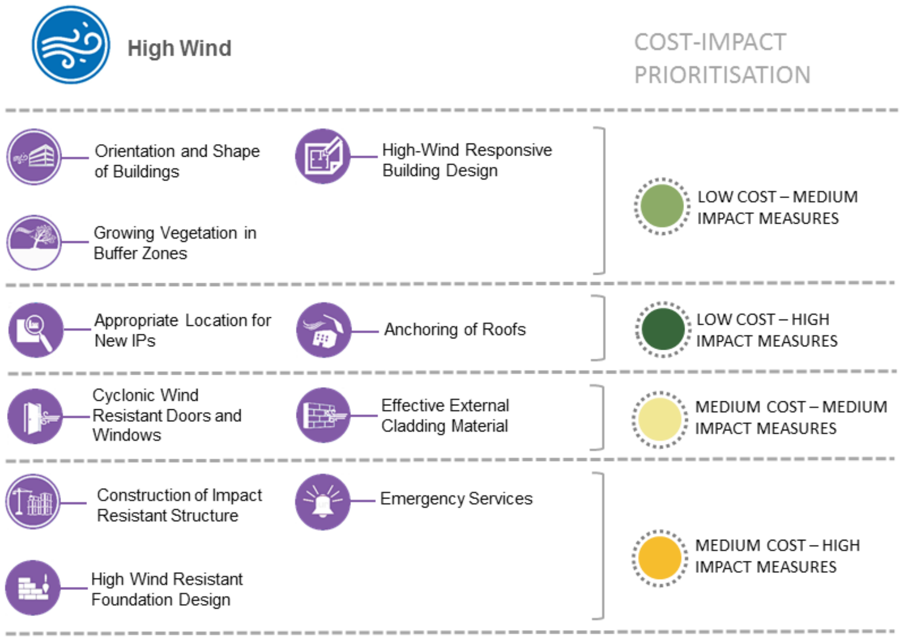


Figure 8 : Cost-impact prioritisation of high wind impact

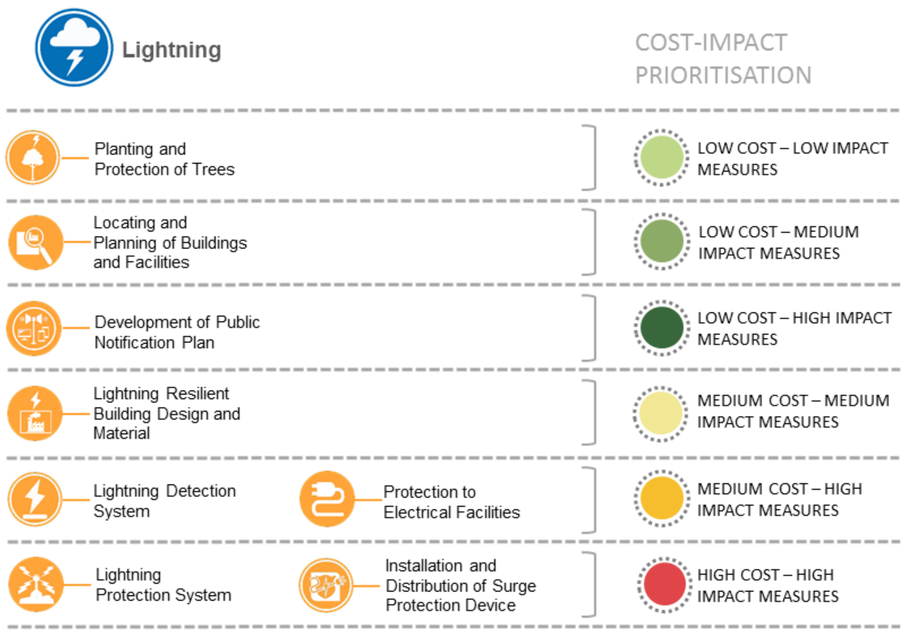


Figure 9 : Cost-impact prioritisation of lightning impact

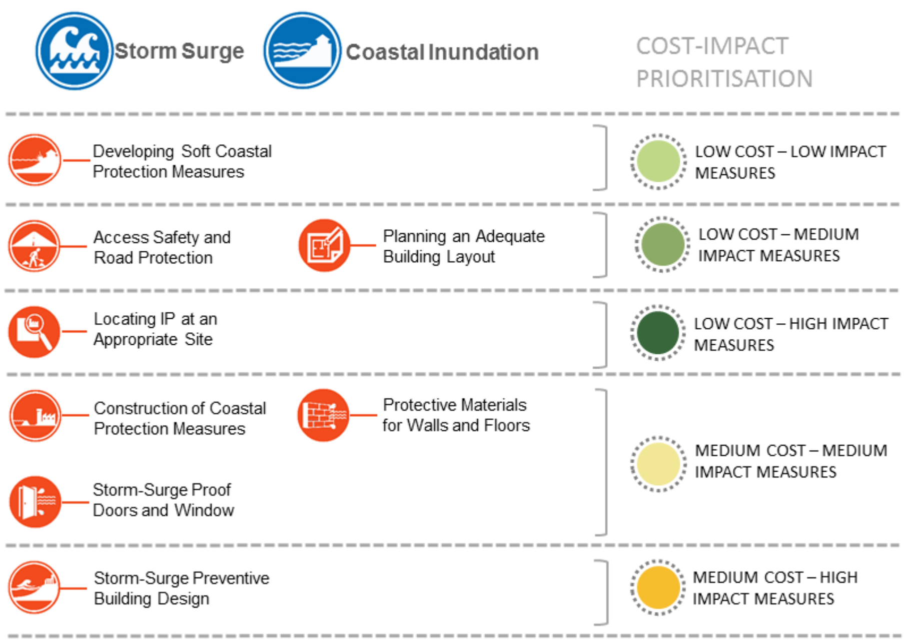


Figure 10: Cost-impact prioritisation of storm surge and coastal inundation impacts

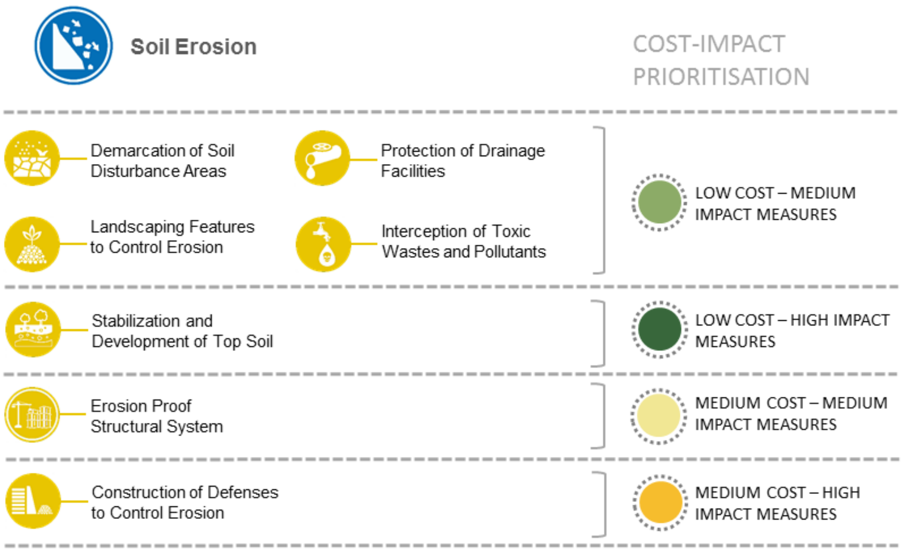


Figure 11 : Cost-impact prioritisation of soil erosion impact

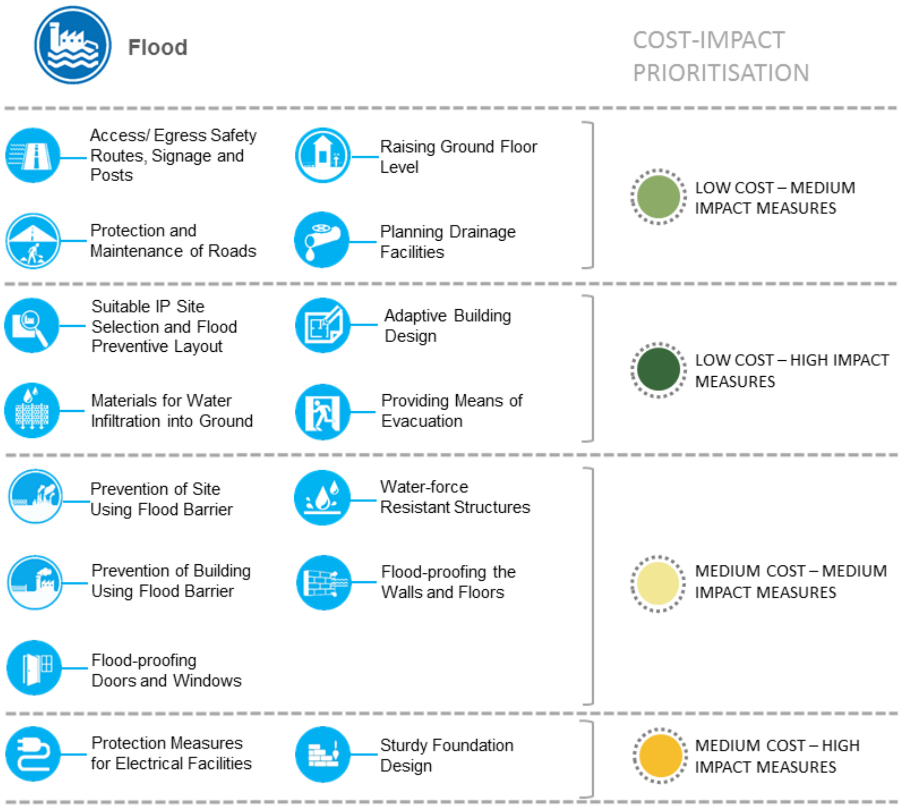


Figure 12: Cost-impact prioritisation of flood impact

2.3 Detail Engineering Measures of Heavy Rain and Flood Related Impact

Detail guidelines with respect to each impact have been enumerated in the subsequent sections, presented in the following order.

(1) High Wind

(2) Lightning

(3) Storm surge and Coastal Inundation

(4) Soil Erosion

(5) Flood

Various detail engineering measures for climate change adaptation to mitigate different impacts, at the site level as well as individual building level, have been elaborated applicable to new Industrial Parks or existing Industrial Parks or to both, depending on the level of impacts and probable degree of damages.

The engineering guidelines for each measure to be read in conjunction with the following, the detail contents of which are provided in the corresponding Annex VII, VIII and IX respectively of Manual 1.

a) Major applicable Codes and Standard (Refer Annex - VII)

b) Roles and Responsibilities (Refer Annex - VIII)

c) Planning and Analytical Tool (Refer Annex –IX)

The monitoring indicators for each measure are indicated along with the measures.

Further reading material related to each measure the Bibliography provided along with this document may be referred.

2.4 Impact : High Wind

CCA Measure 1: Evaluation of Appropriate Location for New IPs

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *No Regret*

Target Industrial Park: *New IPs*

(1) Engineering Details

Selecting a suitable location for the IP site is important. Though cyclonic storms always approach from the direction of the sea towards the coast, the wind velocity and direction relative to a building remain random due to the rotating motion of the high velocity winds. Therefore, it is rational to build a stronger-than-normal industrial building in an area where the high wind impact would be significant.

(2) Design Process/Specifications for on-site Execution

- Site located in areas adjacent to water surfaces, mud flats and salt flats should be avoided.
- In non-cyclonic region where the predominant strong wind direction is well established, the area behind a mound or a hillock should be preferred to provide for natural shielding.
- In cyclonic regions close to the coast, a site above the likely inundation level should be chosen. In case of non-availability of high level natural ground, construction should be done on stilts with no masonry or cross bracings up to maximum surge level, or on raised earthen mounds to avoid flooding/inundation but knee bracing may be used.
- In order to decrease the wind load, site can be selected in rough terrains or in open flat terrains with scattered obstructions.
- Avoid selecting sites located on an escarpment or the upper half of a hill as abrupt change in the topography may result in increased wind loads.

- There must be a provision of minimum two means of site egress. If one route becomes blocked by trees or other debris, or by floodwaters, the other access route could be used for evacuation and transportation.
- In hilly regions, construction along ridges should be avoided since they experience an accentuation of wind velocity whereas valley experiences lower speeds in general. Though some times in long narrow valleys wind may gain high speed along valley. If the IP is located in a valley, it would be protected from high wind velocities.

(3) Monitoring Indicator

- Estimation of Wind velocity
- Elevation and topography of the site
- Measurement Azimuth angle from the North

CCA Measure 2: Growing Vegetation in Buffer Zones

Type of Measure: *Low-Cost*

Impact Area: *Site and Land Use*

Adaptation Option: *Low Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

To resist the devastative impacts of cyclone it is necessary to develop natural protective barrier in a planned way changing coastal landscape considering all kind aspects as much as possible. Combined design of landscape from seashore to several kilometre inner lands may provide significant assistance to overcome almost all kinds of impacts of cyclone disaster. Creation of protective barrier in a planned manner inside IPs would be the responsibility of IIC, whereas, the similar actions beyond the IP boundaries would be the responsibilities of Regional planning or disaster management planning authorities.

(2) Design Process/Specifications for on-site Execution

The following actions would serve as appropriate measures for the existing IP sites.

- Position, height, width, continuity and density of vegetation and trees are very important to consider for the reduction of wind speed, strength and direction. Loosely dense and low height vegetation should be in the front position seaward side. The medium dense and moderate height plants should be in the middle position and finally most dense and tallest trees should be planned after the medium height *mangrove* row.
- Multiple rows of trees, e.g. *Casurina equisetifolia*, in three to four layers planted upwind would act as effective shield against high winds. The influence of such a shield will be over a limited distance, equivalent to 8 – 10 times the height of the trees. A tree broken close to the buildings might cause damage to the structures. Hence distance of tree from the buildings, must be kept 1.5 times the height of the tree.

- The Trees with trunks lesser than 6 inches in diameter would be appropriate for the site. Large trees can crash through pre-engineered metal buildings and wood frame construction.
- Falling trees with trunk more than 6 inches diameter, can cause severe damage to life, buildings and facilities and hence should not be placed near buildings. Falling trees can also rupture roof membranes and break windows.

(3) Monitoring Indicator

- Resistance potential of vegetative buffer belt against the wind force, in terms of height, spread, depth and density.

CCA Measure 3: Orientation and Shape of Buildings

Type of Measure: *Low-Cost*

Impact Area: *New Buildings*

Adaptation Option: *Low Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The shape of the building has a huge role in withstanding the pressure exerted by high wind. Building shape affects the value of pressure coefficients and, therefore, the loads applied to the various building surfaces The Building should be oriented in a direction opposite the direction of wind flow.

(2) Design Process/Specifications for on-site Execution

- The most suitable industry layout would generally be of circular, hexagonal, octagonal shapes. However, a regular square or rectangular layout with fewer amounts of cantilevers can serve the purpose. The peripheral corners must be rounded to improve aerodynamic properties. The rectangular plan would be better than the L-shaped plan.
- The best layout would be when the length would not be more than three times the width. (Length: width = 3:1).
- Non-load-bearing walls and door and window frames should be designed in line with the principles of rain-screen. This would minimize the damage caused by water and development of mold arising from the penetration of wind-driven rain.
- Building irregularities, such as re-entrant corners, bay window projections, a stair tower projecting out from the main wall, dormers, and chimneys must not be integrated in the design layout as it would cause localized turbulence. Turbulence would cause the wind speed to go up, which would increase the wind loads in the vicinity of the building irregularities.
- Trees with trunks larger than 6 inches in diameter, poles like, light fixture poles, flag poles, and power poles, or towers like, electrical transmission and large communication towers should not be placed near the building. Falling trees, poles, and towers could severely damage a facility and injure the occupants.

(3) Monitoring Indicator

- Realigned orientation angle of between building alignment with respect to the wind flow direction
- Level of safety of the components against the shear layer generation at the corners and edges of the buildings.

CCA Measure 4: Preparation of High-Wind Responsive Building Design

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *New and Existing Buildings*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

It is important to realize that a well-designed, constructed, and maintained building may be reducing the amount of damage caused by a wind event. Most damages occur because various building elements have limited wind resistance due to inadequate design, application, material deterioration, or roof system weakness. Wind speed would vary from region to region and the structural and non-structural components of buildings in IP must be designed with precision.

(2) Design Process/Specifications for on-site Execution

- Wind speed would increase with height above the ground. Taller buildings would be exposed to higher wind speeds and greater wind pressures. Therefore, an optimum height of 2 to 3 storey, of average height of 4m per storey) industrial building would be preferable.
- Every member and element must be designed to meet both the Allowable Stress Design and the Load and Resistance Factor Design specifications.
- The first main load to be calculated are the gravity loads. The first gravity loads to be calculated are the three dead loads, from roof, walls and floors. A dead load is the weight of structures and all the materials that are permanently attached to it.
- The second gravity loads to be calculated are the live loads. The analysis involves two live loads, one for the roof and another for the floors. Live loads are associated with the use or occupancy of a particular structure. Where dead loads are permanently applied, live loads tend to fluctuate with time and typically account for loads produced by people or furniture.
- The final load to be calculated is the wind load. Wind loads are not gravitational loads and it would have both a vertical and horizontal component.
- The pressure exerted by wind would be dependent on height of the building and the topography of the site.
- Walkway and entrance canopies are often damaged during high winds. Wind-borne debris from damaged canopies could damage nearby buildings and injure people, hence these elements should also receive design and construction attention.

- The services of electricity, water, communication and other facilities must be designed effectively to prevent interruption of industrial operations during temporary failure of municipal services.

(3) Monitoring Indicator NA

(1) Percentage efficiency of building design in terms of high-wind responsiveness.

CCA Measure 5: Construction of High Wind Resistant Superstructure

Type of Measure: *Retrofitting*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Designing a structure to withstand the devastating forces of cyclonic winds in the states of Telangana and Andhra Pradesh is a great challenge. The forces of the winds during cyclones like *Hud Hud* are so strong that structural failure is imminent. However, appropriate design details can contribute to the improvement of overall performance in the structure shell. Focus must be given on proper connection details to tie together exterior walls, roofs and floors.

(2) Design Process/Specifications for on-site Execution

- Availability of adequate load paths, chances of connection failures and level of wind resistance must be analysed in the structure.
- Sealing cracks in the foundation with epoxy would be necessary to reduce the chance of failure in the foundation. Additionally, ensuring correct installation of tie and bolt anchors from the wall frame deep into the foundation is necessary to diminish the probability of failures like overturning.
- Trusses or joists should be used to elevate the floor on piles. Sheathing with appropriate stainless steel nails and screws would be appropriate.
- The walls should have vertical and horizontal reinforcing and filling to resist wind loads. Along with this, constructing sheer walls would be necessary. Sheer walls would be made up of structural members that would combine to form vertical planes of the building.
- A minimum 150mm thick wall reinforced with bars at 300mm on centre-to-centre both way would be preferred.
- When using precast concrete panels, connections should be designed appropriately to have sufficient strength to resist wind loads.
- Buildings made of cast-in-place concrete would be suitable as they would provide high reliability and good wind-borne debris resistance.
- The connections are the most essential element of the design because they would keep the structure standing. To determine the necessary number of fasteners per connection, it would be necessary to compute the basic strength of a single dowel-type

fastener subjected to a lateral load. This would be known as the reference design value. This value when multiplied by the appropriate adjustment factors would provide the adjusted design value. The load per connection would then be divided by the adjusted design value to determine the required number of fasteners.

(3) Monitoring Indicator

- Level of Resistance against strong wind forces.
- Degree of resilience and durability against the strong wind impacts.

CCA Measure 6: High Wind Resistant Foundation Design

Type of Measure: *Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs (for further construction of new buildings)*

(1) Engineering Details

It is essential to construct a suitable foundation for industrial buildings as the stability of the structure would depend primarily on its foundation. Buildings usually have shallow foundation on stiff sandy soil and deep foundations in liquefiable or expansive clayey soils. It is essential that information about soil type be obtained. Estimates of safe bearing capacity may be made from the available records of past constructions in the area or by proper soil investigation.

(2) Design Process/Specifications for on-site Execution

- In flood prone areas, the safe bearing capacity should be taken as half of that for the dry ground. Also the likelihood of any scour due to receding tidal surge needs to be taken into account while deciding on the depth of foundation.
- Where a building would be constructed on stilts it is necessary that stilts must be properly braced in both the principal directions. This would provide stability to the complete building under lateral loads. Knee bracings would be preferable to full diagonal bracing so as not to obstruct the passage of floating debris during storm surge.
- The uplift forces from cyclone winds can sometimes pull buildings completely out of the ground. In contrast to designing for gravity loads, the lighter the building the larger or heavier the foundation needs to be
- The type of foundations adequate for high wind prone areas are:
    - Slab or raft foundation (Figure 13)
    - Stepped foundation (Figure 14)
    - Short bored pile foundation (Figure 15)
    - Pad foundation (Figure 16)

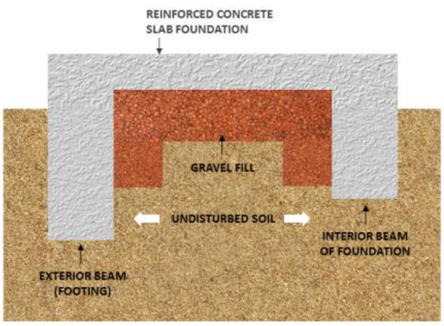


Figure 13: Slab or raft foundation

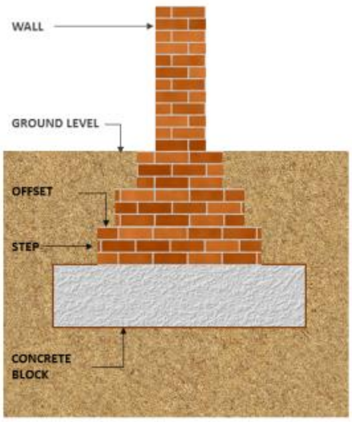


Figure 14: Stepped foundation

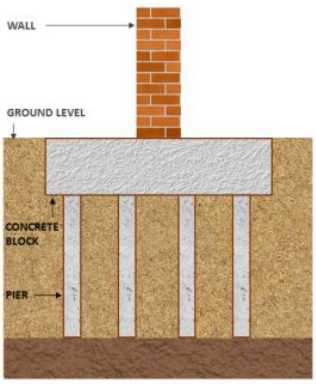


Figure 15: Short bored pile foundation

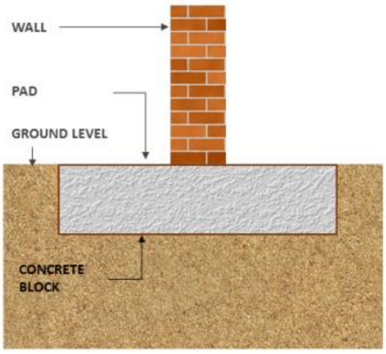


Figure 16: Pad foundation

- The specifications for footing design for a two-storeyed industrial building would be a continuous 12” wide footing, supporting light frame design and 8’ deep basement retaining walls.
- Weight of the footing would be determined by multiplying the density of concrete by the cross sectional area of the footing.

(3) Monitoring Indicator

- Degree of resistance, strength, and stability of foundation against over-turning due to strong wind forces.

CCA Measure 7: Use of Effective External Cladding Material

Type of Measure: *Retrofitting*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

It must be emphasised that good quality of design and construction is the single factor ensuring safety as well as durability in the cyclone hazard prone areas. Hence all building materials used must follow the applicable Indian Standard material Specifications.

(2) Design Process/Specifications for on-site Execution

- Exterior load-bearing walls should be made of masonry or precast concrete.
- Almost all wall coverings permit the passage of some water past the exterior surface of the covering, particularly when the rain is wind-driven. For this reason, most wall coverings should considered water-shedding, rather than waterproofing coverings. To avoid moisture-related problems, it is recommended that a secondary line of protection with a moisture barrier such as house wrap or asphalt-saturated felt and flashings around door and window openings be provided.
- Use of solid blocks with key-hole or hollow blocks with slots for keeping the reinforcing rod in the centre of cavity would be suggested. The filler element of micro-concrete must be applied.
- Appropriate sealants should be recommended for protection. Square shaped sealant joint would be recommended.
- Anchor ties or two-piece adjustable ties must be angled up or down or embedded between mortar joints In order to provide further strength to the building.

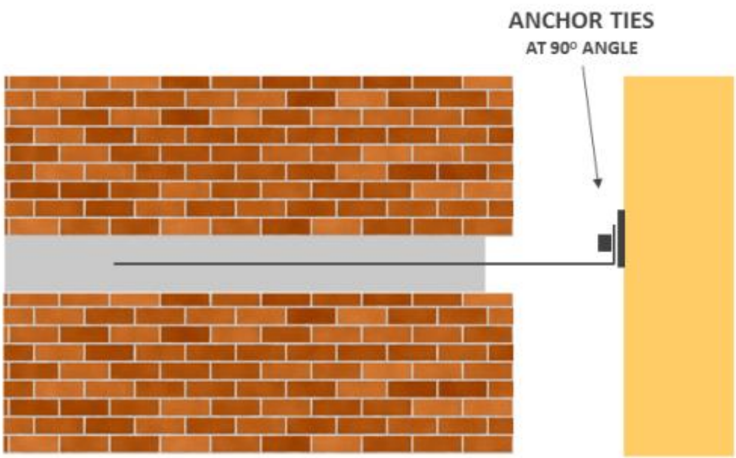


Figure 17: Angled up Anchor Ties

- The ties would provide good resistance to compressive loads.
- It is advisable to avoid the use of sealant as the first or only line of defence against water infiltration.
- Resistance to corrosion is a definite requirement in cyclone prone sea coastal areas. Painting of steel structures by corrosion-resistant paints must be adopted.
- In reinforced concrete construction, a mix of M20 grade with increased cover to the reinforcement has to be adopted. Low water cement ratio with densification by means of vibratos will minimise corrosion.

(3) Monitoring Indicator

- Holding capacity of the cladding materials with the wall surfaces or structural elements.

CCA Measure 8: Anchoring of Roofs to Prevent Uplifting

Type of Measure: *Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Roof failures occur most frequently during extremely severe cyclonic storms (180-200kmph) and super cyclonic storms (222kmph and above). The most vulnerable areas of a roof include the edges, corners, overhangs, and connections. Large overhangs allow the build-up of up-lift forces to generate under the overhang itself, which significantly increase the probability of the roof being torn off the rest of the structure. In order to reduce the damage level, strong roof to wall connections in the continuous load path is one of the basic and important step towards providing resistance to a building during high winds.

(2) Design Process/Specifications for on-site Execution

- Connections between roof and wall panels should be designed with adequate uplift load resistance to prevent the wall panels from collapsing.
- The design should limit the length of the overhang.
- Rafters to top plate and top plate to stud connections are needed to be developed in a continuous load path from the roof to the wall. The most common connection used to mitigate damage due to winds are straps, tie downs, roof clips, clinchers and fibre reinforced polymer.
- Hip roof (figure 18) layout would be most suitable for high wind affected areas. The hip roof would slope down to the walls on all four sides providing better resistance to wind pressure compared to other roof designs. This type of roof would be constructed with a series of trusses.

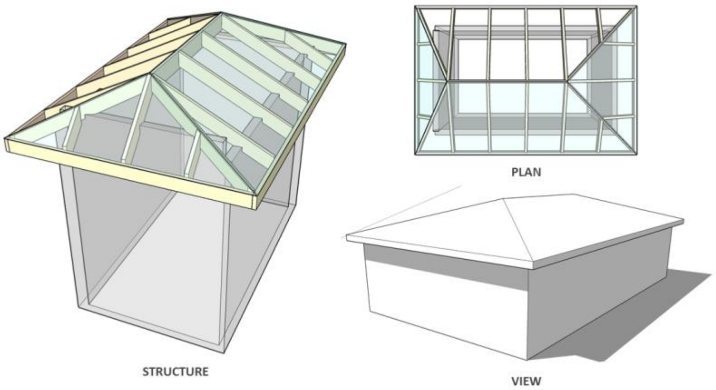


Figure 18: Hip Roof

- Hip rafters would come across diagonally from the corner and meet the ridge board a short distance from the ends of the building. Other shorter rafters would go from the wall plate to the hip rafter and are called jack rafters. The rafters would be attached to fit neatly onto the wall plate.
- Anchor plates can be used to provide additional resistance.
- For steel roof decks, it is recommended that a screw attachment be specified, rather than puddle welds or powder-driven pins. Screws are more reliable and much less susceptible to workmanship problems.
- If a continuous load path is developed from the roof to wall, the load must then be transferred from the wall to the foundation. The connections involved in this continuous load path are stud to sill plate and sill plate to foundation.
- Roofs with modified bitumen applied to a concrete deck can provide the required resistance to progressive peeling after blow-off.
- For precast concrete decks it is recommended that the deck connections be designed to resist the design uplift loads because the deck dead load itself is often insufficient to resist the uplift.
- Openings just below roof level be avoided except that two small vents without shutter should be provided in opposite walls to prevent suffocation in case room gets filled with water and people may try to climb up on lofts or pegs.

(3) Monitoring Indicator

- Anchoring strength of roof and parapet components with the structural elements.

CCA Measure 9: Cyclonic Wind Resistant Doors and Windows

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Blown-off doors and windows allow entrance of rain and tumbling doors can damage buildings and cause injuries. Blown off sectional and rolling doors are quite common. These failures are typically caused by the use of door and track assemblies that have insufficient wind resistance, or by inadequate attachment of the tracks or fixtures to the wall. Windows, curtain walls, and skylight assemblies (i.e., the glazing, frame, and frame attachment to the wall or roof) must have sufficient strength to resist the positive and negative design wind pressure.

(2) Design Process/Specifications for on-site Execution

- Openings in load bearing walls should not be within a distance of h/6 from inner corner for the purpose of providing lateral support to cross walls, where ‘h’ is the storey height up to eave level.
- Doors operable outward would be preferred as they would provide more resistance to the wind flow compared to the doors operable inward. Weather-stripping should be provided on the interior side of the door. Type of weather-stripping which could be used includes drips, door shoes and bottoms, thresholds, and jamb/heads.
- It is recommended to use exit door hardware for primary swinging entry/exit doors. This would minimize the possibility of the doors being pulled open by wind suction.
- The door, hardware, frame, and frame attachment to the wall should be of sufficient strength to repel the positive and negative wind pressure.
- Adding a vestibule would allow both the inner and outer doors to be equipped with weather-stripping. The vestibule could be designed with water-resistant finishes like, concrete or tile and the floor could be equipped with a drain. In addition, installing exterior threshold trench drains would be helpful.
- Windows, glazing, frame, frame attachment to the wall, curtain walls, and skylight must be designed to resist the positive and negative design wind pressure.
- Leakage can occur at the glazing/frame interface, in frame, or between the frame and wall. So window design should be done considering water infiltration issues. Sealants could be used as the secondary line of defence against water infiltration.
- The sealant joint should be designed to enable the sealant to bond on only two opposing surfaces i.e., a backer rod or bond-breaker tape should be specified. Butyl would be recommended as a sealant for concealed joints, and polyurethane for exposed joints.
- Sealant joints could be protected with a removable stop. The stop would protect the sealant from direct exposure to the weather and reduces the possibility of wind-driven rain penetration.

(3) Monitoring Indicator

- Anchorage strength against displacement of components.
- Strength against wind lateral thrust

CCA Measure 10: Emergency Services

Type of Measure: *Low-Cost*

Impact Area: *Technical and Social Infrastructure*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Responsive emergency measures would involve creation of plans through which the stakeholder would reduce vulnerability to hazards and cope with cyclone situations. Failure to prepare a working plan could lead to human mortality, lost revenue, and damage to industrial assets. It is favourable to provide backup facilities like emergency generators in the site for functioning of facilities.

(2) Design Process / Specifications for on-site Execution

- Providing at least two means of site egress would be necessary. If one route becomes blocked by trees or other debris, or by floodwaters, the other access route would still be available.
- In cases where multiple buildings, are occupied during a storm, it is recommended that enclosed walkways be designed to connect the buildings. The enclosed walkways would be used for protecting people moving between buildings during a cyclone (e.g., to retrieve equipment or supplies) or for situations when it is necessary to evacuate occupants from one building to another.
- Standby generators would be required for power supply to the standby circuits, to facilitate the local networks, telephone and other power automated emergency functions and services.
- The generators should be connected via manual transfer switches to allow for interconnectivity in the event of emergency generator failure.
- Emergency and standby generators should be placed inside wind-borne-debris resistant buildings and not outside or inside weak enclosures, to keep them safe from damage due to debris or tree fall.
- Fuel storage tanks, piping, and pumps must be placed inside wind-borne-debris resistant buildings, or in basement.
- For preparation of emergency-responsive plans catering to leakages of oils, effluents, hazardous substances into the vicinities, during flood or cyclone NDMA Disaster guidelines for chemical industries to be referred.
- On-site well or storage tanks should be provided for storing water of fire sprinklers.
- Pumps for onsite wells or storage tanks could be connected to an emergency power circuit with a valve for the municipal service line.

(3) Monitoring Indicator

- Percentage compliance level to mandatory provisions of standby facilities

2.5 Impact: Lightning

CCA Measure 1: Locating and Planning of Buildings and Facilities

Type of Measure: *Low-Cost, Tech-Change*

Impact Area: *Site Layout*

Adaptation Option: *No Regret*

Target Industrial Park: *New IPs*

(1) Engineering Details

The location, structure type and use of buildings and structures govern their degree of susceptibility to lightning strikes. If it is observed that the consequences suffered by the building can be serious in nature, permanent and efficient lightning protection system must be then installed. Protection system would be required in two situations. First, if the location, shape and height of the building is the susceptibility factor, or second, if the utility and type of construction of the building is responsible of lightning conduction.

(2) Design Process / Specifications for on-site Execution

- Outdoor Assembly zones for people reduce the level of safety from Lightning hazard. Therefore the zones must be located away from
  - Large structures
  - Group of trees
  - Under a single tree or a small group of trees
  - Large body of water
- Construction of small permanent and temporary structures like sheds, rain shelters and dugouts to be avoided.
- Small structures especially the metal structures are more susceptible to lightning activities.
- Dumping of metal wastes, scraps and other objects of metallic property in the open must be avoided as they have chances of conducting lightning. It is desirable to store them inside a building.
- Construction of high rise building could be avoided. Buildings with optimum 2 or 3 floors would be preferable.
- Storage of explosive or combustible material must be done in the areas demarcated as safe zones as per the risk assessment plan.
- Industries associated with manufacturing of paints, varnishes, chemicals and other combustible products would be highly susceptible to severe consequences of lightning activity. Therefore they must be located in or near the safe zones and they should carefully store their products and raw materials.

(3) Monitoring Indicator

- Frequency of expected lightning strikes based on the previous records.

CCA Measure 2: Development of Public Notification Plan

Type of Measure: *Low-Cost*

Impact Area: *Industrial Parks*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Public notification plans would be required to make the people aware of an upcoming or on-going lightning activity. The written notification should include safety policies, plans, emergency routes' demarcation, signage in various locations. Apart from this, radio address system, sirens and announcements should also be used to inform the people regarding the occurrence and degree of lightning.

(2) Design Process/Specifications for on-site Execution

- Notifications should comprise of the following aspects:
  - A written lightning safety policy
  - Designation of activities which must be suspended
  - Determination of when to suspend activities
  - Determination of safe/not safe shelters
  - Notification to persons in areas of maximum risk
  - Determination of when to resume activities.
- It is necessary to have a written emergency operations safety plan to evacuate the venue. Signs indicating where shelters must be located on venue property.
- Conducting awareness programs for the industrial labourers would be required to generate preparedness for hazards amongst them.
- There should be a public notification plan to notify the stakeholders present in the IP site regarding the lightning threats. It can be done in the following forms:
  - Public address system
  - Internal broadcast
  - Text/email message alerts
  - Use of social media
  - Staff announcements
- Fire safety measures must be notified. Location of hydrants and extinguishers must be provided.

(3) Monitoring Indicator

- Degree of effectiveness of the public notification system.

CCA Measure 3: Lightning Detection System

Type of Measure: *Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Lightning detectors are necessary to provide immediate information regarding a lightning strike. The detectors can give notice to shut down dangerous operations before the arrival of lightning. Detectors also may signal "all clear" conditions after the lightning threat has passed.

(2) Design Process/Specifications for on-site Execution

- The Industrial parks must install a locally-run lightning detection system with a display unit on site or subscribe to a commercial notification system.
- This facility must also have continuous access to information about thunderstorm warnings.
- Lightning protection system must be placed in close proximity to the electrical installation.
- The Detectors which can be installed are;
- *Radio Frequency (RF) Detectors.* These measure energy discharges from lightning. They can determine the approximate distance and direction of the threat. Operational frequency is important.
    - *Infero-meters.* These are multi-station devices, much more costly than RF detectors. They measure lightning strike data more precisely.
    - *Optical Monitors.* These can provide earlier warning as they detect cloud-to-cloud lightning that typically precedes cloud-to-ground lightning.
    - *Electric Field Mills.* These pre-lightning pieces of equipment measure the potential gradient (voltage) changes of the earth's electric field and report changes as thresholds build to lightning breakdown values, in the range of 15 KV.

(3) Monitoring Indicator

- Complexity and Accuracy level of the lightning detection system.

CCA Measure 4: Lightning Resilient Building Design and Material

Type of Measure: *Tech-Change*

Impact Area: *Existing and New Industrial Buildings*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

As Telangana and Andhra Pradesh are prone to lightning activities, the buildings in the IP must be designed to withstand lightning currents. Proper design and use of lightning impact resilient material would increase the efficiency of the building. The external structure, especially the roofs must be designed with precision.

(2) Design Process/Specifications for on-site Execution

- The classification of building as per height
    - Ordinary Building – A building of common or conventional construction used for commercial, industrial or residential purposes.
    - Class I Ordinary Building – A building that is not more than 75 feet (22.9 m) high.
    - Class II Ordinary Building – A building that is more than 75 feet (22.9 m) high or greater.
- Buildings with more height have higher chances of experiencing lightning strikes.
- It would be advisable to have buildings with metal façade or a concrete reinforcement, as it would make the structure perform like a natural down conductor system.
- Roofs of the building should be made of metal with proper grounding to earth. This would protect the entire roof superstructure against direct lightning strikes.
- Metal framed buildings where the building would have electrically continuous framing of sufficient size and conductivity would work as a part of lightning protection system.
- The structure should be constructed in complete coherence with the lightning effect mitigating technical documents.
- Equipotential bonding connections within the building must be kept in place and regular inspections of the connections must be done.

(3) Monitoring Indicator

- Degree of resilience against potential lightning occurrence.

CCA Measure 5: Lightning Protection System

Type of Measure: *Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The major risk associated with lightning strike is fire hazard. In order to mitigate the chance of fire, the building must be enveloped and properly guarded with lightning protection system.

This would help is conducting the lightning energy to the ground without causing any damage to the building.

(2) Design Process/Specifications for on-site Execution

- Zones for protection against lightning:
    - External zones:

      Zones like roof area of structure might be subjected to full lightning current.

      Zones like sidewalls of structure might not be subjected to direct current.
    - Internal zones:

      Zones where services enter structure or where the main power board is situated would be subjected to partial lightning currents.
- The lightning protection system can be arranged in mesh format. The 2 levels of mesh designs are (20m x 10m and 10m x 5m).
- The down conductor spacing must be 20m x 10m. Equipotential bonds could be used to minimise side flashing.
- The down conductors must take the most direct route from air termination system to the earth termination system. More number of down conductors would facilitate better distribution of lightning current.
- 10 ohm of overall earthing would be required, which could be achieved by 10 x number of down conductors. The conductors used must be either rod or ring type.
- Air termination conductors must be placed at roof overhangs, roof edges and on ridges of roof.
- If 10-inch air terminal is used then the interval spacing would not be more than 20 feet between air terminals. If a 24-inch air terminal is used, then the spacing may be increased to 25 feet. If the roof exceeds 50 feet in length or width or both directions the spacing can be increased up to 50 feet between terminals.
- There should be no metal installation protruding above the air termination system.
- Earth-termination system to be used should be, ring earth electrode, earth rod, foundation earth electrode.
- It would be necessary to bond all metallic services like water, electricity etc. to main equipotential bonding bar. Live electrical conductors like power lines, data and telecom lines could be bonded via Surge Protection Devices.
- The electrical conductivity of installations of the lightning protection system and earth resistance of the earth-termination system must be measured at regular intervals.

  Lightning protection system has been illustrated below in Figure 19

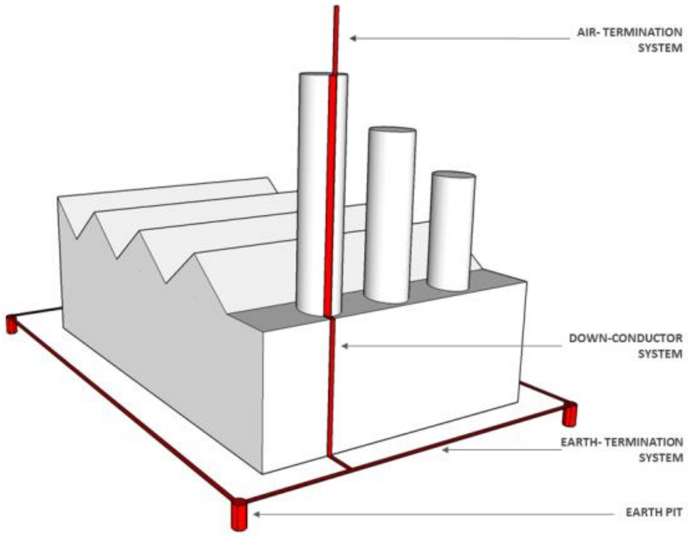


Figure 19: Lighting Protection System

(3) Monitoring Indicator

- Level of reduction of vulnerability against lightning.

CCA Measure 6: Protection to Electrical Facilities

Type of Measure: *Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The electrical facilities would be most prone to damage due to lightning activity. It is necessary for the IP to have a proper lightning protection system. In addition to this, surge protection devices must be installed to protect from gadgets and equipment from damage.

(2) Design Process/Specifications for on-site Execution

- It is critical that the Industrial Parks have a good, low-resistance grounding system, with a single ground reference point to which the grounds of all building systems are connected.
- Without a proper grounding system, protection against surges is difficult.
- Construction of substantial buildings with permanent wiring and plumbing would be preferable.
- All the units with mechanical protective function must be in working order. Also, all lines and system components must be completely secured.

- If a new supply connection would be installed or if an existing connection would be extended in the interior of building, then proper lightning equipotential bonding must be carried out.
- Such buildings would provide safe pathways for current from strikes to go to ground, making them the safest areas for shelter.
- When inside, one must stay away from windows and doors and anything that conducts electricity such as corded phones, wiring, plumbing, and anything connected to these.
- Apart from electrical distribution system, electrical transients can enter a facility through phone/fax lines, cable or satellite systems, and local area networks (LAN). Hence data lines must be protected from surge damage.
- In order to do this, SPDs should be installed on all systems susceptible to electrical transients.

(3) Monitoring Indicator

- Probability of service failure
- Technical soundness level of the electrical system

CCA Measure 7: Installation and Distribution of Surge Protection Device

Type of Measure: *Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Surge Protection Device (SPD) is a device designed to protect electrical devices from voltage variations. It attempts to limit the voltage supplied to an electric device by either blocking or shorting to ground any unwanted voltages above a safe threshold. SPD is required in the industries to protect the electrical equipment from irreparable damage due to lightning activity.

(2) Design Process/Specifications for on-site Execution

- It is advisable to install Surge protection that is properly sized.
- It is highly successful in preventing equipment damage, especially the sensitive electronic equipment found in most equipment today.
- The Surge Protection Device (SPD) must be installed after consulting with a licensed electrician.
- The licensed electrician would ensure that the electrical distribution system is grounded in accordance with the National Code.
- Considering that surges can originate from both internal and external sources, Surge Protection Devices (SPD) should be installed to provide maximum protection regardless of the source location.

- It is important to have a proper coordination of SPDs to avoid damaging of SPDs installed on distribution panels or locally at vulnerable equipment.
- SPDs must be inspected of regular intervals for maintenance and damage identification purpose.
- Surge Protection Devices (SPD) are required to be installed at three levels.
- Each level would add to the overall protection of the facility as it would further reduce the voltage exposed to the protected equipment.
    - **Zone 1:** The first level of protection would be achieved by installing an SPD on the main service entrance equipment, where the utility power comes into the facility. This would provide a shield against high energy surges coming in from the outside through lightning.
    - **Zone 2:** For the second level of protection, SPDs should be installed on all distribution panels that supply power to critical equipment.
    - **Zone 3:** The third zone of protection would be achieved by installing SPDs locally for each piece of equipment being protected, such as computers or computer controlled devices.
- If coordination is not achieved, excess energy from propagating surges can cause damage to Zone 2 and Zone 3 SPDs and destroy the equipment.

(3) Monitoring Indicator

- Percentage success of surge protection.

CCA Measure 8: Planting and Protection of Trees

Type of Measure: *Low-Cost*

Impact Area: *Site and Land Use*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The protection of trees against the effects of lightning is required to be considered where the preservation of the tree is especially desirable for environmental value. Proper functioning of the lightning conductors can be hindered due to existence of a tree in close vicinity. Therefore judicious planning of location and lightning conduction for trees in the IP site must be done.

In addition to the existing plantation guidelines being in use for Andhra Pradesh and Telangana industrial areas, the following measures may be adopted to address the impacts of lightning.

(2) Design Process/Specifications for on-site Execution

- Tall trees must be planted away from building structures and congregation areas.
- It should be seen that the trees planted in the sites do not obstruct the lightning conductors.

- Height of the trees planted around a building must not exceed the height of the building.
- The main down conductor should be run from the topmost part of the main stem to the earth termination.
- If conductors made of copper are used, then they should be insulated so as not to poison the tree.
- Large upper branches should be provided with branch conductors bonded to the main conductor.
- During fixing a conductor, allowance should be made for swaying in the wind and the natural growth of the tree.

(3) Monitoring Indicator

Mandatory height and distance clearance of the vegetation from the lightning arrestors

2.6 Impact: Storm Surge and Coastal Inundation

CCA Measure 1: Locating IP at an Appropriate Site

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *No Regret*

Target Industrial Park: *New IPs*

(1) Engineering Details

Storm generating from sea and its resultant surge tends to move inward toward the land. Therefore location of an IP needs to be ascertained with careful precision. Selecting an appropriate location would facilitate minimisation of overall cost of making the site resilient to the impacts of storm surge. Aspect of natural contour, vicinity to the coastline, slope of the site and existing drainage system must be analysed during site selection.

(2) Design Process/Specifications for on-site Execution

- The zones with lower ground level, experiencing high tides, within 10km from average coastline, must be identified with the help of the available contour maps of Survey of India.
- The site for IP should preferably be located on the available higher elevated land. In the absence of high elevated land, some of the buildings can be built on stilts.
- There should be appropriate isolation distance between the shelter belt and IP in order to avoid damage to the foundation of the building by the roots of the shelter belt.
- Re-designating and rezoning land of IP in coastal hazard areas for uses more consistent with the risk.
- Compulsory setback zones as per the Bye Laws are required to be provided.

- Encourage or permit land uses that are compatible with coastal flooding risks. The land should be allocated for such uses which would have minimum impact of flooding.
- Sections of the industries which would contain high-value economic and environmental assets, should be kept away from the predicted Sea Level Rise zone.

(3) Monitoring Indicator

- Physical distance from the sea coast edge
- Site elevation with respect to the nearby sea coast edge.

CCA Measure 2: Construction of Coastal Protection Measures

Type of Measure: *Low-Cost*

Impact Area: *Site and Land Use*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Constructing permanent protection measures in the buffer zone between IP site and coast line are extremely necessary. This would suffice in reducing the impact of storm waves on the buildings and infrastructures. The coastal protection measures also aim at restricting the sea water inflow due to rise in sea level from flooding the IP site. The types of coastal protection measures commonly constructed are breakwaters, groynes and gabions.

(2) Design Process/Specifications for on-site Execution

- Breakwater (as shown in Figure 20)
  - This structure would be built parallel to the coast.
  - It would involve in creating an area of shallow water in the buffer zone closer to coastline, so that the wave breaks against it before reaching the coast.
  - Breakwaters are generally made of granite and they cannot protect a large span of coastline. It is also cost-intensive.

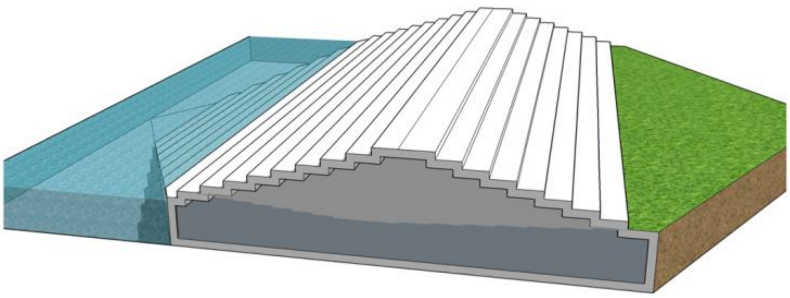


Figure 20: Stepped Breakwater Protection Measure

- Groins
  - These are low rigid hydraulic walls built at right angles to interrupt water flow.
  - They would facilitate deposition of preventive material from being carried away, on the side of the groin, facing the shore drift direction.
- Gabions(as shown in Figure 21)
  - They form wall on the coastline to protect the coast from erosion.
  - These are metal wire cages which would contain small rocks. They have a maximum span of 15 year.
  - These would absorb the shock of waves by diminishing the energy to minimum.

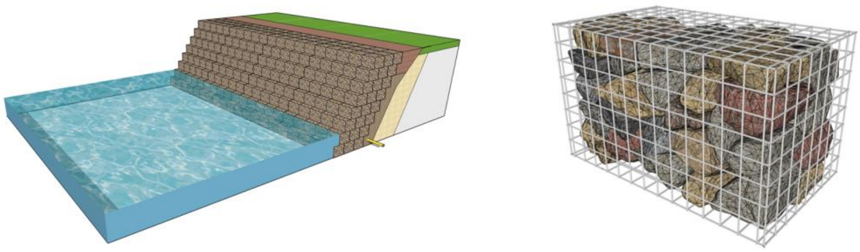


Figure 21: Gabion Protection Measure

(3) Monitoring Indicator

- Height, length and depth of the constructed barriers and embankments.

CCA Measure 3: Developing Soft Coastal Protection Measures

Type of Measure: *Low-Cost*

Impact Area: *Site and Land Use*

Adaptation Option: *Low Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Soft protection measures in the buffer zone between IP site and coast line are extremely necessary to prevent sand from eroding due to wave action. A combined effect of structural protection measures and soft measures would be of increased benefit in reducing the adverse effect of storm surge and coastal inundation.

(2) Design Process/Specifications for on-site Execution

- Beach Nourishment
  - This would create a wider beach by increasing the quantity of beach sediments artificially. Large amount of sand would be added to the beach which is being eroded.

- It is mostly used along with other hard structural measures like sea walls, dykes and groins.
- It generally lasts for maximum 10 years, requiring regular maintenance. The high cost of procurement and non-availability of good quality sand often makes this measure less favourable.

(3) Monitoring Indicator

- Length, height, density, depth and types of the selected vegetation covers.

CCA Measure 4: Access Safety and Road Protection

Type of Measure: *Low-Cost, Retrofitting*

Impact Area: *Site Layout*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Road protection, rehabilitation and redevelopment would have a high amount of positive contribution to reduction of cost of maintenance and road operation. An integrated approach must be followed while planning the access routes. Proper connectivity to inland regions would help in minimising the evacuation time for people from IP site to safe areas as well as the time required emergency supplies availability.

(2) Design Process/Specifications for on-site Execution

- The elevated approach-road to the buildings should be laid up with gravel / cement.
- The degree of damage following a storm surge situation must be analysed and immediate upgradation action must be taken to restore the road for temporary use.
- Vehicle parking zones should be located away from active flow areas and should have a means of evacuating safely.
- Access route to the local shelters must be demarcated with the help of emergency evacuation plans and signage.
- Drainage pits must be placed near the roads, in order to channelize the water to underground storage units.
- If the roads are situated at a close vicinity to the coastline, then the road must be equipped with embankments on the coast-ward side.

(3) Monitoring Indicator

- Signage location, size, visibility and expected outcome of the installations during the disaster.
- Tensile and compression strength, friction coefficient of the road surfaces.

CCA Measure 5: Planning an Adequate Building Layout

Type of Measure: *Low-Cost, Retrofitting*

Impact Area: *New Buildings*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The building layout should be planned in a manner such that the building can interact with the variability of wave action. Use of adaptive planning tools, standards and technologies which have been tested with time would provide further support to the industrial structures. Any development affected by storm wave flooding must be designed to withstand flood impacts with minimal damage. This would include foundations, sub floors, services (e.g. plumbing and electrical) and cladding.

(2) Design Process/Specifications for on-site Execution

- Development, subject to wave action, may be acceptable provided there are appropriate protection measures taken, such as, adherence to adequate design standards, higher floor levels or provision for setback.
- The shape of the building should preferably be square or rectangular with rounded peripheral corners in order to improve the aerodynamics of the structure.
- The total height of the buildings should meet the requirement of the design height of the storm surge and should be above the high tide line. The height of the building would be determined based on the following criteria.
    - Height between the ground level and the high-tide level should be of minimum 1m.
    - Plinth height should be about 1.2- 1.5m above the ground level.
    - If stilts are provided, the height should be 2.2 - 4.5m.
    - Height of each storey should not exceed 3.5m.
- Minor sheds and outbuildings may be constructed but attention must be paid to drainage issues.
- The space below the lowest horizontal structural member must be used for parking, access, or storage of less expensive items only.
- Renovations of existing buildings within the permissible limit which are not likely to be affected by the Sea level rise.

(3) Monitoring Indicator

- Level of storm surge resilience.
- Response capacity to the wave actions with minimum damage.

CCA Measure 6: Storm-Surge Preventive Building Design

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Buildings*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

In order to fully prevent the IP site from inundation impacts, the industry building design should be equipped with defence facilities. Reliable design specification must be followed during the construction phase. Installation of storm water harvesting options would increase the functionality of the industry.

(2) Design Process/Specifications for on-site Execution

- The roof should have parapet all around so that it can be used as a shelter space during flooding due to storm surge.
- Storm-water harvesting provisions must be built on the roofs and should be properly connected to the water storage tanks. Sedimentation-based water filters should be installed to purify the harvested rainwater for drinking purposes.
- The parapet should be up to the height of 0.8m, made of brick masonry and should have a strong pipe railing on top.
- The stairway should be spacious enough for the movement of the people. The width should be of 1.5 to 2 m.
- A ramp with a slope of 1:10 to 1:12 may be provided for the convenience of physically challenged people.
- Addition of up to 25% of the floor area, at the elevation of the existing building can be permitted, on condition that the addition is no closer to the existing natural boundary.
- No underground spaces or basement floors should be constructed, as it would be difficult to prevent flood water from entering those spaces.
- Louvered windows would be preferred. Doors must open outwards, so that water pressure pushes them into a seal and thus prevent the floodwater from entering the building.
- Use of open foundations (pile or pier) designed to resist all base flood conditions (waves, high velocity flow, erosion and scour, flood-borne debris) would be recommended.
- Where high velocity flow, scour, and erosion will not be experienced under base flood conditions, a traditional foundation may be acceptable.
- Adding sufficient clearance height of minimum 3.5m to allow parking beneath the building will not reduce future flood damages.

(3) Monitoring Indicator

- Level of resilience during the storm surge event.

CCA Measure 7: Use of Protective Materials for Walls and Floors

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Materials which would be used for building construction must be highly resilient to the force of water. The salinity of flooded sea water might have a corrosive action when they are in contact with metal. Hence the exterior elements should possess anti-corrosive, high drying capacity. Along with this, adequate waterproofing compounds must be applied on the claddings and in-between wall-slab joints to increase the durability of the structures.

(2) Design Process/Specifications for on-site Execution

- The structure should be made of load bearing brick masonry.
- In case of structures on stilt, the ground floor should be raised on RCC frame, and the upper portions (first floor and above) could be built with load bearing brick masonry structure.
- In order to increase the life of the buildings, Corrosion resistant steel can be used.
- Blended cement and high quality must be used to cover the steel to increase the durability of the structure.
- Pre-cast concrete blocks, fly-ash bricks and hollow bricks can be used for non-load bearing filler and partition walls. As they are light in weight, the overall weight on foundations would be reduced.

(3) Monitoring Indicator

- Corrosion resistance of the metallic components.
- Stability and strength of the non-metallic building components.

CCA Measure 8: Designing Coastal-Flood Proof and Storm-Surge Proof Doors and Window

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Waves generating from storm surge can have a devastating effect on the windows and doors. These building elements are most prone to damage amongst all the elements exposed to the initial impact of waves. Attention to detail must be given while placing the external opening points, and appropriate material, which would be able to withstand the pressure, must be used.

(2) Design Process/Specifications for on-site Execution

- Building entrances and other key outdoor access areas should not be affected by unsafe levels of flooding.
- Doors must open outwards, so that water pressure pushes them into a seal and thus prevent the floodwater from entering the building.
- Doors should be fixed firmly to the holding medium (walls / frames) with the help of heavy-duty stainless steel hinges.
- Designing a vestibule to protect a door entry is one method of managing water infiltration problems. In this approach, both the inner and outer doors can be equipped with weather stripping, and the vestibule itself can be designed to tolerate water.
- Windows should preferably be of louver type, made of non-breakable and non-brittle Fibre-Reinforced Plastics items.
- Laminated glazing must be used as they are non-porous and would not easily give away to tidal waves.
- Louvered vents should be provided with various walls just above floor level to drain water flowing in due to storm surge.
- Shutters should be anchored to the wall surrounding the window, and not to the window or door frame itself.

(3) Monitoring Indicator

- Strength and stability of the door-window and anchoring components in the building.

2.7 Impact: Soil Erosion

CCA Measure 1: Demarcation of Soil Disturbance Areas and Reduction of Land Disturbance Activities

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Various land use activities that involve disturbance of land can affect the environment adversely. Removal of vegetation, construction activities, digging for foundation construction can aggravate erosion activity. The effects may include induced erosion, damage to top soil, slope instability, generation and deposition of silt. Amount of soil disturbance (cut & fill) can be reduced through design development. Locations where high amount of soil erosion is observed must be identified in order to apply control measures and defences.

(2) Design Process/Specifications for on-site Execution

- Clearly identify the conditions where erosion is likely to occur regularly.
- Take notice of steep slopes, long slopes, light soils, bare soils, and include planning measures to reduce risk in those areas.
- Identify lower regions where runoff may accumulate and make the region vulnerable to temporary inundation or flooding, creation of gully erosions leading to permanent channelization due to accentuated runoff.
- Control Sedimentation due to land-disturbing activity through proper planning and execution in order to prevent off-site sedimentation damage to the extent required.
- Reduce soil erosion from unpaved roads, material handling tracks, and store yards.

(3) Monitoring Indicator

- Depth of soil, suspended sediment measurement
- Degree of reduction of Land Disturbance Activities

CCA Measure 2: Construction of Defenses to Control Erosion

Type of Measure: *Tech-Change*

Impact Area: *Site Layout*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Constructed defences focus on reducing the erosive power of the water. Energy dissipating structures force the water to yield its kinetic energy. Water with less kinetic energy has a slower velocity and is less erosive than that which has high kinetic energy. Defences constructed would help in reducing the velocity of water and cause lesser channel erosion.

(2) Design Process/Specifications for on-site Execution

- Drop Structures (Figure 22)
    - These structures would be used to maintain stable, non-erosive conditions in upstream and downstream reaches or to arrest head cutting.
    - Local scour could occur downstream of the drop structure and undermining must be prevented usually by constructing the drop structure foundation deeper than computed scour depths.
    - The structure must be able to withstand the high velocities and turbulence at its downstream end.
    - A series of drop structures could be used to minimize drop height and structure cost.

- Check Dams
  - These are effective in reducing channel or stream erosion by increasing the cross-sectional area of the stream and thus, reducing the velocity.
  - The decrease in the slope of the hydraulic gradient would reduce the shear stress, and this would minimise the erosive forces.
  - The dam should be anchored into bedrock material and should be designed to prevent undermining and overturning.
  - The area immediately downstream of the structure should be protected unless the formation of a scour pool is desired.
- Stilling Basins (Figure 23)
  - Stilling basins would be effective in reducing downstream erosion at the down-stream ends of check dams, drop structures and larger dams.
  - They would be designed to increase turbulence, reduce the total energy, and increase the downstream depth of flow

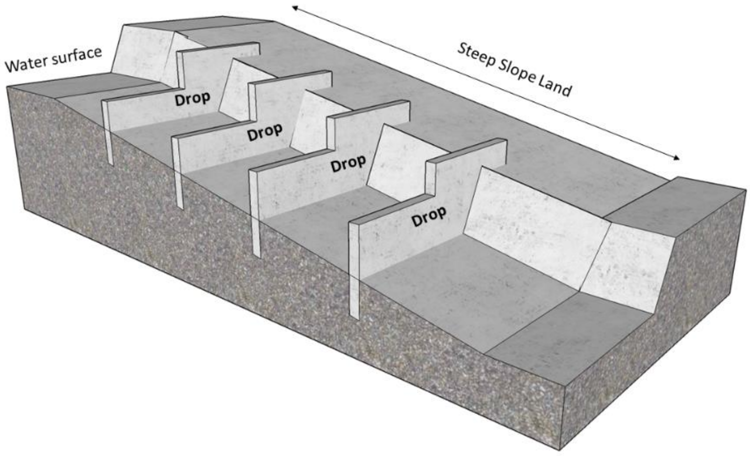


Figure 22: Drop Structure

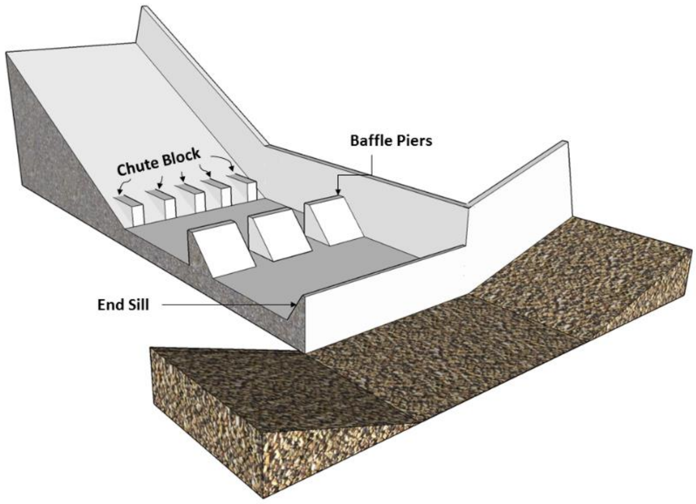


Figure 23: Stilling Basin

(3) Monitoring Indicator

- Strength of control erosion defence

CCA Measure 3: Landscaping Features to Control Erosion

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *Low Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Vegetation covers can act as the initial defence against erosion. Grasses, ground covers, shrubs and trees can efficiently protect the soil provided the slope is not much steep and the water velocity is not more than five feet per second. The plants must be compatible with the different habitats in the project area. Various landscaping features have been provided below.

(2) Design Process/Specifications for on-site Execution

- Retain existing vegetation wherever possible. Mulching can be done as a temporary erosion control measure and can be used alone or in conjunction with temporary seeding or permanent seeding and planting.
- Create permanent strips of grass or rough vegetation as buffer zones to slow down run off and trap soil at critical places on a slope or at the bottom of an open areas.
- Design the width of grass strips depending on soil type, slope and rainfall intensity.
- Create turfs or ground covers in the non-functioning open areas permitting ground water recharge.

- Plant hedges or build new ditches to restrict run off, or direct run off water away from areas prone to erosion.
- Type of landscape features which can be developed are:
  - Grass-Lined Channels

    Grass- lined channels are inexpensive, can be visually attractive and are relatively easy to establish and maintain if properly designed and installed.

    Grassed channels can often repair themselves unless the erosion damage is very severe.

    The permissible velocity in a grass-lined channel is that which can be sustained for reasonable lengths of time without experiencing severe erosion.

    The velocity would vary with type of grass, channel slope, and soil classification.

  a. Soil Retention Blankets

    Soil retention blankets of natural or synthetic materials could be used to hold the seed and soil in place.

    This would be of benefit till new vegetation cover emerges on channel banks or stream beds.

  b. Coconut Fibre Tubes

    Tubes of coconut fibre could be used to support plant growth along the edges of the water bodies.

    When these are used in conjunction with pre-planted pallets of aquatic plant species, they offer effective shoreline protection against erosion due to small waves.

(3) Monitoring Indicator

- Erosion resistance capacity of the plant root structures.

CCA Measure 4: Erosion Proof Structural System

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Structural system*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

The structural system of buildings situated in zones prone to soil erosion must be designed such that buildings retain stability even during the worst erosion situations. For this, buildings must be adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from exerted forces.

(2) Design Process/Specifications for on-site Execution

- The bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) must be elevated to or above the base flood level.
- The pile or column foundation and structure must be anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting on all building components.
- All structural systems of all buildings and structures should be designed, connected and anchored to resist flotation, collapse or permanent lateral movement due to structural loads and stresses from flooding equal to the design flood elevation.
- Structures erected in coastal high-hazard areas may be supported on pilings or columns and adequately be anchored to such pilings or columns as shown in Figure 24.

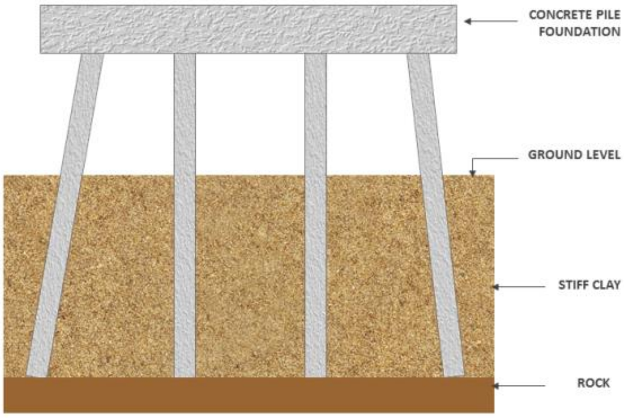


Figure 24: Pile Foundation details

- Pilings must have adequate soil penetration to resist the combined wave and wind loads (lateral and uplift). Water loading values must also be considered.
- Pile embedment shall include consideration of decreased resistance capacity caused by scour of soil strata surrounding the piling.
- Buildings and structures, and all parts should be constructed to support safely all loads, including dead loads, live loads, roof loads, flood loads, snow loads, wind and seismic loads.
- The construction of buildings and structures would result in a system that provides a complete load path capable of transferring all loads from their point of origin through the load-resisting elements of the foundation.

(3) Monitoring Indicator

- Level of resistance against uplifting.
- Strength of anchorage.

CCA Measure 5: Channelization and Protection of Drainage Facilities

Type of Measure: *Low-Cost*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

It is necessary to prepare proper designs for permanent outlet protection. Control Surface Water run-off originating upgrade of exposed areas to reduce erosion and sediment loss during the period of exposure.

(2) Design Process/Specifications for on-site Execution

- Construct land drains, pipe outlets, to ensure effective drainage.
- Drainage chutes must be built to intercept and direct the runoff water into a trapping device or stabilized area. These would mostly be built to protect the cut and fill slopes.
- Drainage chutes would generally comprise of concrete chutes and pipes. The dimension would be determined as per the location and estimated quantity of runoff.
- Roadside drainage ditches could also act a local drainage chutes.
- Regulate runoff velocities by keeping it low by appropriate surface textures.
- Soil around and under entrance and outlet must be well compacted along the length of the slope drain.
- When designing the outlet protection, consideration must be given to flow depth, roughness, gradient, side slopes, discharge rate, and velocity.
- Manage Storm Water Run-off in case of increase in the velocity resulting from a land-disturbing activity. As it is sufficient to accelerate erosion of the receiving watercourse.
- It can be done through planning measures to control the velocity at the point of discharge so as to minimize accelerated erosion of the site.
- Protect storm water outlet designed for post-construction velocity of the decadal (10-year) storm run-off in the receiving watercourse to the discharge point that does not exceed the limiting velocity.

(3) Monitoring Indicator

- Level of interception of eroded silt flow.

CCA Measure 6: Interception of Toxic Wastes and Pollutants

Type of Measure: *Low-Cost*

Impact Area: *Technical Infrastructure*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both New and Existing IPs*

(1) Engineering Details

Spillage or emission of toxic wastes must be avoided. If toxic materials combine with the surface water runoff, then the outcome can be fatal in nature. Toxic wastes must therefore be channelized to protect the IP for deadly damages.

(2) Design Process/Specifications for on-site Execution

- Channelize potential industrial toxic wastes such as oils, chemicals, metals to a treatment points.
- The channelization pipelines must be inspected at regular interval to check for chance of leakage occurrence and clogging of pipes.
- Intercept pollutants commonly transported by storm water from construction sites in industrial sites.
- Pollutant would include sediments, nutrients, petroleum products (e.g. oil storage, fuel facilities, leaks from crankcases and improper disposal of drain oil), chemicals (Paints, solvents, sealants, cleaning agents and caulks), metals (e.g. lead, zinc, copper, chromium, cadmium and nickel are found on industrial sites), pesticides, fertilizers and other potentially toxic chemicals.

(3) Monitoring Indicator

- Extent of toxicity of wastes in comparison to acceptable threshold level.

CCA Measure 7: Stabilization and Development of Top Soil

Type of Measure: *Low-Cost*

Impact Area: *Site and Land Use*

Adaptation Option: *Low Regret*

Target Industrial Park: *New IPs*

(1) Engineering Details

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or by combination of the two. Affected areas would include those which were susceptible to liquefaction and those covered with soft clay and organic soils.

(2) Design Process/Specifications for on-site Execution

- The simplest stabilization processes would be compaction and drainage because if water drains out of wet soil its strength would increase.
- The two broad categories are;
  - Mechanical stabilization

    Soil stabilization could be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing.

- Chemical stabilization

  Soil stabilization would depend mainly on chemical reactions between stabilizer and soil minerals to achieve the desired effect.

- The commonly used binders are:
  - Cement
  - Lime
  - Fly ash
  - Blast furnace slag

(3) Monitoring Indicator

- Quantity and time requirement of top soil stabilisation.
- Cost of top soil creation

2.8 Impact: Flood

CCA Measure 1: Suitable IP Site selection and Flood preventive layout

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *No Regret*

Target Industrial Park: *New IPs*

(1) Engineering Details

This is an essential step for planning new IPs. Prudently selecting an appropriate location can facilitate in minimisation of overall cost of making the site resilient to the impacts of flood. Aspect of natural contour, vicinity to existing water bodies and drainage system must be assessed while selecting the site.

(2) Design Process/Specifications for on-site Execution

- It is advisable to apply a sequential approach at the site level, where the individual industries would be developed on lower flood risk areas, lower grounds would be utilised for non-emergency access roads, amenity areas and other associated land uses.
- Areas of medium and higher hazard, and any wetlands or significant flow-paths, should be preserved for a recreational or other use that is consistent with its values.
- Greenfield sites may provide an opportunity for minor reshaping of the land to provide flood free lots and safe access.

- It is necessary to identify the location of overland flow routes either designed to divert floodwater away from property or designed to accumulate elsewhere.
- Existing drainage channels must be evaluated to plan for situation where there can be likelihood of overtopping.
- In order to reduce the effect of flood on the site, raising land to create high ground would be an effective solution. This should be planned in coherence with the existing flood management system present, if any.
- Land raising must be compensated by providing proper flood routes and additional flood storage areas.
- Raising the land should not be done in areas alongside watercourses. As it would give rise to reduction in flood storage capacity and increase in flow speeds and water depths in adjacent areas.
- The ground floor level should be set sufficiently high, wherever feasible, to prevent the buildings from impact of flood.

(3) Monitoring Indicator

- Physical distance from the large water sources
- Site elevation with respect to the nearby water sources
- Percentage of efficiency level of the layout in terms of desired functional objectives.

CCA Measure 2: Prevention of Site Using Flood Barriers

Type of Measure: *Low-Cost, Tech-Change*

Impact Area: *Site Layout*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

The flow of floodwater into the IP site needs to be restricted at the initial stage. For this, flood proofing the site is an essential step. It can be done by developing contours/ levees, utilising the natural contours of land or by constructing flood resistant walls.

Use of natural elements to prevent floodwater from gaining velocity, is a cost effective and environmentally sustainable approach. Growing dense vegetation, marshes and other deep-rooted plants can reduce the force of flood water.

(2) Design Process/Specifications for on-site Execution

- Landscape and vegetation barriers
    - The most economic approach would be to prepare the periphery of the site in ‘cut and mound’ manner. This would help to naturally divert the flood water from the site. The resulting terrain would facilitate in natural drainage of the accumulated floodwater from the site.
    - Construction of a typical low-cost earth embankment would be effective as a local flood defence. Pumping arrangements must be provided to remove potential rain-water or floodwater seepage.

- Recreate functional flood plains. Plan setback areas on each side of the river for overflow, with a buffer zone of grasses, trees, or shrubs.
- More amounts of permeable green spaces within the site must be promoted to reduce the runoff quantity. Plant marshes and trees with strong connected roots in the boundary region to intercept the floodwater flow.
- Dig shallow ditches to allow water to seep into the ground on site or to be transported through pipes. Ditches can be covered by a permeable surface like grass or rocks.
- Establish and protect open spaces in industrial parks, such as offset areas, roads, trees in site, outdoor facilities, recreation zones, and gardens to reduce water flow and decrease flash flooding.

- Constructed barriers
  - Installation of protection barriers of the right dimension and ready to be put in place in all the openings.
  - Solid gates with waterproof seals along with primary drains would act as a flood barrier. These can also be effectively used to mitigate low depth flooding from sewers.
  - Building of floodwalls at the periphery of the site is needed in order to prevent the flood water from damaging the buildings and infrastructure. This would be a free standing, permanent engineered and structured wall which would provide resistance to floodwater forces and inundation.
  - Floodwalls are generally up to a height of 3 to 4 feet. However they can go up till the height of 20 feet. As shown in Figure 25, the structural core of the floodwall comprise of Reinforced concrete with external cladding of cement concrete bricks.

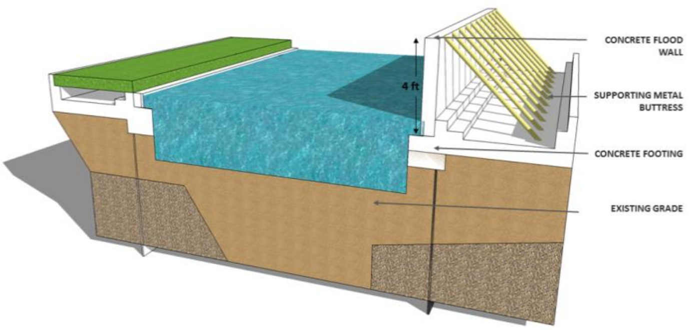


Figure 25: Flood Wall details

  - If the height of wall exceeds 20 feet, it would be advisable to provide transverse support bracing or buttress at regular intervals to support the flood wall.

(3) Monitoring Indicator

- Length, depth and height of vegetation for landscape barriers

- Density and type of vegetation required
- Required Length and Height of constructed barrier

CCA Measure 3: Preventing Floodwater from Entering Building

Type of Measure: *Tech-Change*

Impact Area: *Site and Building*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

This would involve the water exclusion strategy. Here emphasis would be given on minimising water entry and maintaining structural integrity. This strategy would be beneficial when low flood water depths are involved i.e. up to a maximum of 600mm. Use of materials and construction techniques to facilitate drying and cleaning would be preferred. By following this resistance measure, overall building resilience can be obtained.

(2) Design Process/Specifications for on-site Execution

- Individual industry plot may construct a flood wall as their boundary wall as depicted in Figure 26. This would help in reducing the initial velocity of flood water and would also prevent the building up to a limit till water reaches above flood wall level.

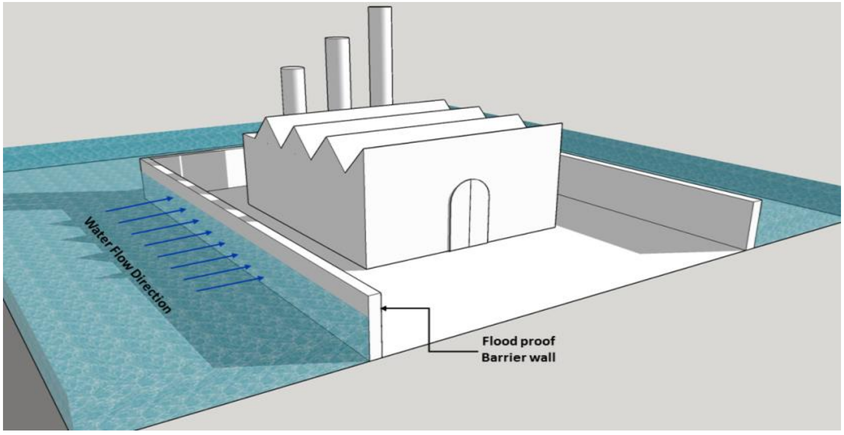


Figure 26: Floodwall around Building

- The risk of structural damage would become significant when the floodwater depth reaches 600mm. Therefore it is most advisable to raise the upper ground floor level to 1050mm and providing extra buffer space below for the floodwater to flow through.
- The ground floor level of each building may be split by cut and fill on the site to create different levels. The front half can be at a level 300mm and rear half can be at 1200mm above ground. This would result in flooding of only the front portion of the building and

would provide the occupants with sufficient time to move the necessary items to higher floors before the entire ground floor gets flooded.

- Constructing an industry on a natural slope would be beneficial as it would allow faster and easier drainage of flood water from inside of the building. This would reduce the effect of inundation on the structure and material and hence reduce the degree of damage.

(3) Monitoring Indicator

- Distance of the flood wall from the industry building
- Perimeter length and height of flood wall

CCA Measure 4: Access / Egress Safety Routes, Signage and Posts

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Access safety for evacuation during flood situation is a major aspect. Access routes must be planned in such a manner that it doesn't go through an area of high or extreme hazard

(2) Design Process/Specifications for on-site Execution

- Flood escape route located above the ground should be situated in publicly accessible land.
- Proper signage must be provided to demarcate the location of the escape routes.
- Vertical posts must be positioned on opposite sides at regular intervals along the roads which can be used as marker during emergency egress. The post can be made of metal coated with corrosion resistant paint and with fluorescent marking / retro reflector on the top. The height of the posts can be up to 1 meter. Figure 27 illustrates the positioning of vertical posts.

Figure 27: Vertical Posts for Road Safety

- It has to be ascertained that primary roads are located outside at-risk areas.
- The road networks to be used for emergency movement during flood must be properly designated.

(3) Monitoring Indicator

- Maximum distance from the farthest point of IP to the safe exit points
- Simplicity of road layout and adequacy of road width
- Evacuation time requirement (lesser the better)
- Effectiveness of signage location, visual clarity, size of the signage boards and Posts.

CCA Measure 5: Protection and Maintenance of Roads

Type of Measure: *Low-Cost*

Impact Area: *Site Layout*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

The transportation networks suffer a considerable amount of damage during floods. This may lead to isolating the IP from the region and can diminish accessibility to many zones within the site. This may also limit the movement of emergency services and essential supplies to and within the IP. Hence proper protection measures are required to keep the road in functioning condition.

(2) Design Process/Specifications for on-site Execution

- Increasing depressions to keep water from accumulating on roads.
- Replace fixed walkways by removable ones.
- Permeable materials must be used for construction of pavement. This would help in seeping of water into underground without flooding the roads.
- Sustainable drainage systems can be installed near the main roads which would divert the water into a storage area for release at a later safe stage.
- Give priority to repairing roads broken by heavy rainfall or flooding.

(3) Monitoring Indicator

- Level of service (LoS - A to F) in terms of maintenance quality, durability, and longevity.

CCA Measure 6: Using Permeable Materials for Surface Water Infiltration into Ground

Type of Measure: *Low-Cost, Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

The effect of flood can be reduced to a great extent, if the water can be percolated into the ground. The percolated water may either contribute to the underground water or may be diverted to storage tanks. Infiltration of water into ground would help in reducing the hydro-dynamic and hydrostatic forces on existing structures.

(2) Design Process/Specifications for on-site Execution

- Using permeable coating (instead of asphalt) around the building would help water infiltration into the ground. The water could be stored in a reservoir, and then slowly percolate down into the soil.
- The permeable bed could be lined with non-permeable clay.
- Use materials with low permeability at least up to 0.3m level of building
- Floodwater would create an upward pressure on the bottom of the building. Hence, the permeated water could be channelized to a tank below
- Improve the site-level storm water management system to control floodwaters
- Direct downspouts to roof-top storm water away from the building to encourage infil-tration in the ground, as well as to avoid water entering the foundation zone of the building through plinth regions.

(3) Monitoring Indicator

- Percolation rate measured through coefficient of runoff, and ultimate runoff quantity.

CCA Measure 7: Protection Measures for Electrical Facilities

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Protection to electrical facilities is necessary to minimise their damage, as they might be as-sociated with elements of high asset value. Continuous supply of electricity to emergency ser-vices to facilitate their hindrance free functioning is necessary. Essential electrical equipment must be isolated from the general equipment.

(2) Design Process/Specifications for on-site Execution

- Locating essential facilities (fire stations, power plants, water treatment plants, etc.) as well as new infrastructures to areas not at risk of flooding.
- Raising power plants to higher ground.
- Position the external electrical transformer at least 2m higher than the anticipated / recorded highest flood level.
- Do not run the electrical cables at the ground level in the site.
- Run the electrical cables through insulated conduits on elevation higher than the estimated flood level / above 6m for service vehicle clearance (wherever crossing the roads).
- Do not provide electrical joints in high / low tension electrical cable connection from the incoming point to the electrical receiving panels.
- Know the location of electrical panels, water supply and gas lines, and how to shut them off.
- Adopt inspection procedures and a maintenance schedule of infrastructures.

(3) Monitoring Indicator

- Height clearance of the substation, switchgears, main distribution panels from the expected level of flood water rise inside the building.

CCA Measure 8: Planning Suitable Drainage Facilities

Type of Measure: *Low-Cost, Tech-Change*

Impact Area: *Technical Infrastructure*

Adaptation Option: *Low Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

The drainage systems of new developments must be regulated to give them the capacity to support the expected increase in water quantity throughout the infrastructures' lifetime. Proper planning of drainage facilities would reduce the level of sewer flooding, overflow and other associated issues.

(2) Design Process/Specifications for on-site Execution

- Sustainable drainage systems can be used to interrupt floodwater flow from entering the site from adjacent zones. They would either store or divert the water into storage areas for later release when the level of floodwater has reduced.
- These drainage systems can be placed near infrastructure facilities, buildings, roads and pavements and in open green zones.
- Widen rainwater and sewer system pipes to increase drainage capacity.
- Ensure that drainage infrastructures can face heavy rainfall.

- Install a check valve in drains to control the flow of water through these pipes.
- Installing a sump pump to pump the water outside (far from the foundation) faster than it comes in.
- Inserting one-way valves into drains and sewage pipes to prevent backflow.
- Using expandable plugs to temporarily block pipes, drains, and toilets to prevent backflow.
- Setting up of screens to stop solid waste & debris from entering into drains from outside would be required.

(3) Monitoring Indicator

- Design capacity and flow characteristics in terms of cross-sectional area and flow velocity.
- Percentage chances of inundation / backflow / flash floods.

CCA Measure 9: Adaptive Building Design

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Buildings*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

An adaptive building design is building engineering that would interact with the variability in the climate due to climate change in a dynamic manner. Aspects of traditional building design would capitalise on technology and innovation to adapt to the flood hazard. Generally, available and dependable technologies are used to support an adaptive building design. Various design process for making buildings in IP adaptable to the impacts of flood have been given below.

(2) Design Process/Specifications for on-site Execution

- Building layout should be designed such that the lower floors can be flooded without too much damage.
- Create raised local flood walls or embankments around the building to protect building from the forces of flood water.
- Do not construct basement floors (full/partial) near the sites with high viability of flooding and coastal inundation.
- Components of lower storey wall structure and ground flooring should be given high priority as they are more susceptible to flood damages. Components like ceilings and roofing, located at a high level have lesser probability of being flooded, hence they can be assigned lower priority.
- Raise floor levels, electrical transformers, distribution panels above the anticipated flood level. Alternately, raise the electrical outlets and panels at least 1 meter above the normal floor.

- Adopt two storey building with double brick or masonry walls for lower storey in areas of higher risk from deep flooding.
- Adopt flood aware design for single storey buildings in areas where the ground level is higher but the risk from inundation is still high.
- Create buildings with lesser weight/Mass so that, there is less possibility of settlement of the foundation due to softening of soil during flooding.
- Create higher building volume at upper level for temporary relocation / rehabilitation of equipment, documents, and employees.
- Create higher building with provision for upper floors which can be used for shelter during the flooding.
- Locate the industrial process building where floors can be built above the nominal flood protection level. Consideration must be given to safeguarding the building entrances and their surroundings, and other main outdoor operational / access areas are not affected by unsafe levels of flooding.
- Any development affected by flooding must be designed to withstand flood impacts with minimal damage. This includes foundations, sub floors, services (e.g. plumbing and electrical) and cladding.

(3) Monitoring Indicator

- Percentage reduction of economic loss in term damage of the building asset.

CCA Measure 10: Adequate and Sturdy Foundation Design

Type of Measure: *Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Foundation is the key element in determining the strength, stability and durability of a structure. It would comprise of footing, foundation wall, slab, pier and pile. Foundation would be responsible for transferring loads from structure to the ground. Forces exerted by flood waters can cause extreme amount of adverse impacts on it, which could result in subsequent fall of the entire structure. Therefore utmost important must be given in designing the foundation system of buildings in hazard prone zones.

(2) Design Process/Specifications for on-site Execution

- Traditional type of foundation may be acceptable in places where high velocity flow, scour, and erosion will not be experienced under base flood conditions.
- Adopt open foundations (pile or pier), designed to resist all base flood conditions so that the flood water do not accumulate.
- For single or double storeyed buildings, raft foundation could be adopted. A shallow footing can be suitable for such buildings.

- Concrete blocks can be used as substructure elements and at least 25mm of clear cavity below damp proof course would be recommended for the rising water to pass through.
- Provide 2m wide plinth protection around the base of the building.
- If RCC structural system is used, high-quality waterproofing compound should be applied from the base of foundation up to 1m above the estimated / recorded flood level.

(3) Monitoring Indicator

- Stability, Load bearing capacity and safety levels of the foundation elements.

CCA Measure 11: Raising Ground Floor Level

Type of Measure: *Low-Cost, Retrofitting*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Flood water causes maximum amount of damage to the ground floor level. Preventing floodwater from entering the building might be difficult at times. In such cases measures like raising the ground floor level can reduce the impact of flood forces on the building. It would restrict the water from entering the building till a certain level.

A suspended floor would be constructed when high flood water depths, greater than 600mm are involved and where ground supported floors are not suitable. Such design would suit to a water entry strategy, where emphasis would be given on allowing water into the building, facilitating draining and subsequent drying.

In the case of a IP location, susceptible to both cyclone and flood, especially in the coastal areas, the raised floor would get the priority. However the overall height of the building has to be kept lower to minimise the cyclonic effects.

(2) Design Process/Specifications for on-site Execution

- Provide the ground floor slab at higher elevation. Raised floor (on fill, waffle pod, suspended slabs) minimises risk of water entering house when surrounding ground is flooded. Detailed design has been provided in Figure 28.

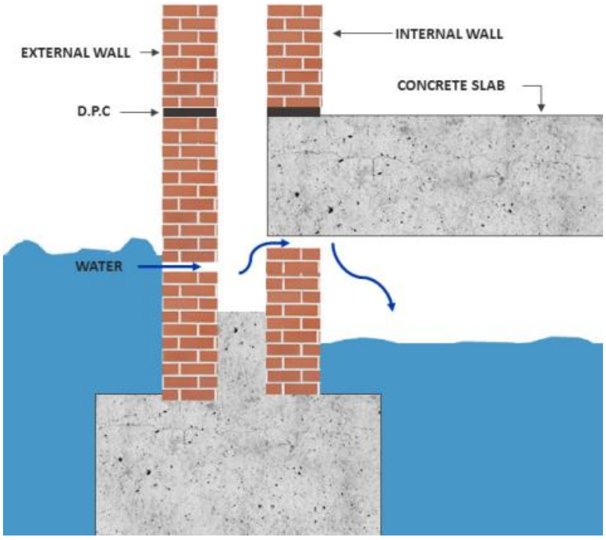


Figure 28: Raising Ground Floor Slab

- Make the ground floor slab heavy enough such that the additional weight and strength helps to resist buoyancy forces.
- Provide well compacted hard-core below the ground floor slab so as to minimize under-floor scouring.
- Concrete slabs of at least 150mm thickness should be used for non-reinforced construction. The use of hollow slabs would not be favoured if the elements are not properly sealed.
- Use of smaller tiles for the ground floor slab must be avoided to minimise the chances of loosening / displacement due to flood waves.
- Provide intermediate floors, above 4m constructed with RCC, steel metal sheet, composite floor with steel and concrete, with proper consideration to the overloading during emergency occupation due to flooding.
- In case of elevated suspended floor at the ground level, some extra elevation may reduce the flood risk.
- Regular assessment of the steel reinforcement in the concrete beams is required as they may be affected by corrosion following repeated or prolonged floods.
- The floor can be designed so that minor flooding and overland flow can pass under the floor.
- In case of elevated suspended floor at the ground level take special care of the potential uplift forces. Provide extra weights in such case as shown in the Figure 29 below.

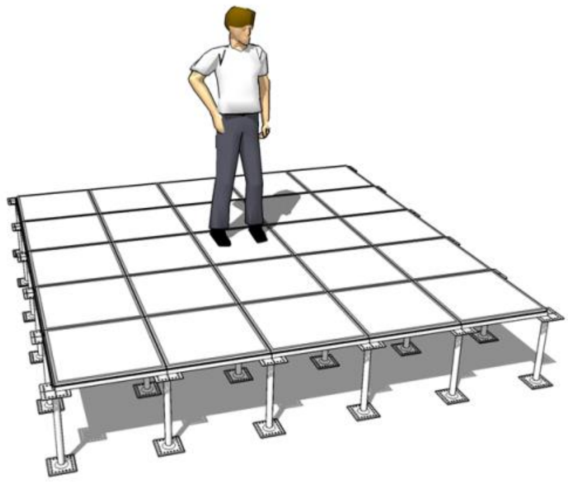


Figure 29: Suspended Floor

- Use ramps with high friction surface treatment instead of steps so that floor to ground access can be availed without any guidance.
- The subfloor space might require cleaning at regular intervals, especially after flood activity. Sewer flood, accumulated sediments should be removed to protect the structure from damage.
- Materials used should have proper drying and cleaning properties. Sacrificial materials can also be used for internal or external finishes; e.g. gypsum plasterboard.

(3) Monitoring Indicator

- Height clearance from the probable flood water level.

CCA Measure 12: Construction of Water-force Resistant Structures

Type of Measure: *Tech-Change*

Impact Area: *Structural System*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Materials used for building construction in flood prone zones must be highly resistant to the force of water. Additionally they should possess anti-corrosive, high drying capacity. Waterproofing compounds must be added to the building materials and applied on the claddings in order to increase the durability of the structures.

(2) Design Process/Specifications for on-site Execution

- Pay adequate attention to the properties of the soil types under potential flood inundation, drainage and the impact from flow velocities.

- Load bearing external walls should not be built of fly ash.
- Use Reinforced cast-in-site Cement Concrete for the structural framework. Provide tie beams linking supporting RCC columns wherever necessary at the plinth level / foundation pedestal level.
- Depending on the severity of flooding activity, provide RCC shear walls wherever necessary.
- Also, provide Steel framework and paint the steel members with anticorrosive paints from the base of foundation up to 1m above the estimated / recorded flood level.
- The steel members can be enclosed with PCC mixed with high-quality waterproofing compound from the base of foundation up to 1m above the estimated / recorded flood level.at the foundation level.

(3) Monitoring Indicator

- Strength and height of the water-force resisting structures.

CCA Measure 13: Flood-proofing the Walls and Floors

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Building and Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

In order to prevent the building from gradual disintegration and permanent damage, it is advisable to construct buildings from flood resilient materials. Such materials should be used, that can withstand direct contact with floodwaters without sustaining significant damages.

(2) Design Process/Specifications for on-site Execution

- Replace construction materials by water resistant materials (e.g., particle boards replaced by concrete or pressure treated / water resistant wood, carpets by ceramic tiles, and wooden doors by plastic).
- Replace mineral insulation within internal partition walls with closed-cell insulation, which is less likely to be damaged during flood. These boards are moisture resistant to a certain extent and their location enables easy replacement if damaged by prolonged floods. Details of wall section have been illustrated below in Figure 30.

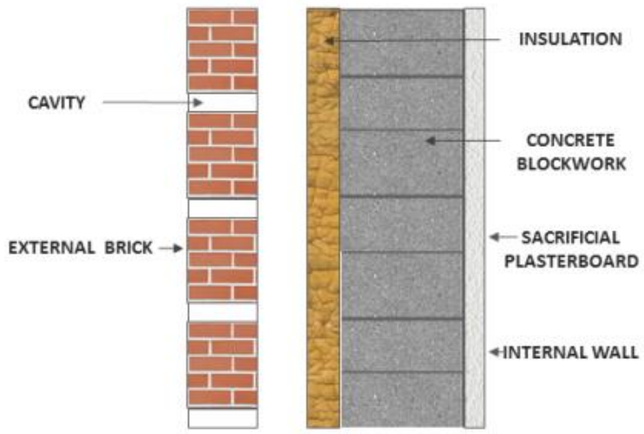


Figure 30: Wall section

- Taping or overlapping of 300mm membrane sections of Damp proof impermeable polythene membranes should be provided to minimise the water passage through ground floors.
- Ceramic tiles and closed-cell board insulation could also be fixed above the ground floor slab and on the internal faces of external walls.
- Use heavy and thick plinth walls to act as retaining walls to withstand the impact of flood water lateral loads.
- For external cladding engineering bricks, such as fireclay, are suitable as they have high water penetration and drying ability. Along with this, cement or lime plaster could be applied.
- For internal cladding, cement plaster with good bond with cement: sand: lime ratio of 1:6:1, could be beneficial as they dry rapidly.

(3) Monitoring Indicator

- Stability and strength levels of the wall components.

CCA Measure 14: Flood-proofing the Doors and Windows

Type of Measure: *Retrofitting, Tech-Change*

Impact Area: *Buildings and Technical Infrastructure*

Adaptation Option: *No Regret*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Designing doors, windows and their associated elements, is one of the most crucial step in flood proofing a building. They are highly susceptible to damages due to the flood water force. Breaking of these elements would result in flooding of the interior space at a higher rate. It is therefore prudent to design flood resilient doors and windows using adequate water resistant materials. This would provide them with enough strength to refrain the flood water from seeping in and damaging the inside.

(2) Design Process/Specifications for on-site Execution

- Install overhangs to prevent infiltration of heavy rain around doors and windows.
- Raising door thresholds would prevent low water entry. Use waterproof barriers and guides at doorways.
- The door could be set on drop hinges to self-close and during the event of flooding it could be pressed against the door frame sealing out the flood water.
- Use PVC sealant stoppers fitted at the bottom edge of the doors, to restrict water from entering the interior of the building.
- Add silicone sealants around doors and windows to limit water seeping in sealing gaps around pipes, cables and joints between walls and door and window frames.
- Replace doors, windows, skirting boards, and door and window frames by fiberglass, plastic, or other waterproof material. Timber doors should not be used.
- Escape windows must be provided for safe access to outside. No grills or openable grill panes should be provided for easy exit.
- Use of Structural Glazing up to 1m above the estimated / recorded flood level, and at the foundation level must be refrained from, to avoid damage and collapse of the glass splinters due to flood waves loads.

(3) Monitoring Indicator

- Degree of resilience of flood-proof materials for floors and walls.

CCA Measure 15: Providing Means of Evacuation

Type of Measure: *Low-Cost*

Impact Area: *Site Layout and social infrastructure*

Adaptation Option: *Win-Win*

Target Industrial Park: *Both new and existing IPs*

(1) Engineering Details

Urgent movement of people away from the area under threat during an emergency situation is the first and most important step in hazard prone zones. The most efficient evacuation measure would ensure safest evacuation and would require least time to transport people to a safe location.

(2) Design Process/Specifications for on-site Execution

- Audible sirens and visible warnings should be installed which would be triggered by Floodwater.
- Evacuation plans must be provided in every individual buildings.
- Considerations should be given to the safe movement of people in or out of the area, especially in the zones which are in the vicinity of potentially flowing water.
- Provide and designate open space for evacuation of people and emergency vehicle parking (Fire engines, ambulance etc.).
- Vehicle parking zones should be located away from active flow areas and should have a means of evacuating safely.
- Make provisions for inflatable boats for transportation use during flooding.

(3) Monitoring Indicator

- Estimated least evacuation time and convenience.
- Percentage of life saved / equipment saved.

3. Engineering Measures for Climate Related Water Stress

Heat waves and droughts pose particular harm to Industrial Parks due to increasing climate change conditions and their impacts. These potential damages depend on the frequency and the severity of the hazards. The implementation of appropriate adaptation measures would help coping with the changing climate conditions and adapting to the impacts of heat stress, water scarcity and shortages in the energy supply.

Different adaptation measures with detail engineering details and tools to aid the implementation process concerning heat waves and droughts are elaborated hereunder.

3.1 Severity-Based Prioritization and Cost based Matrix for Water Stress Measures

A severity-based prioritisation matrix has been established for adaptation measures concerning the impacts of heat waves and droughts, based on past experience and observation. The target is to prioritize and select the adaptation measures based on the severity level of the risks associated with corresponding hazards.

The matrices for each impact;

- Heat Stress,
- Water Scarcity, and
- Shortages in Energy supply,

are shown in the illustrations below.

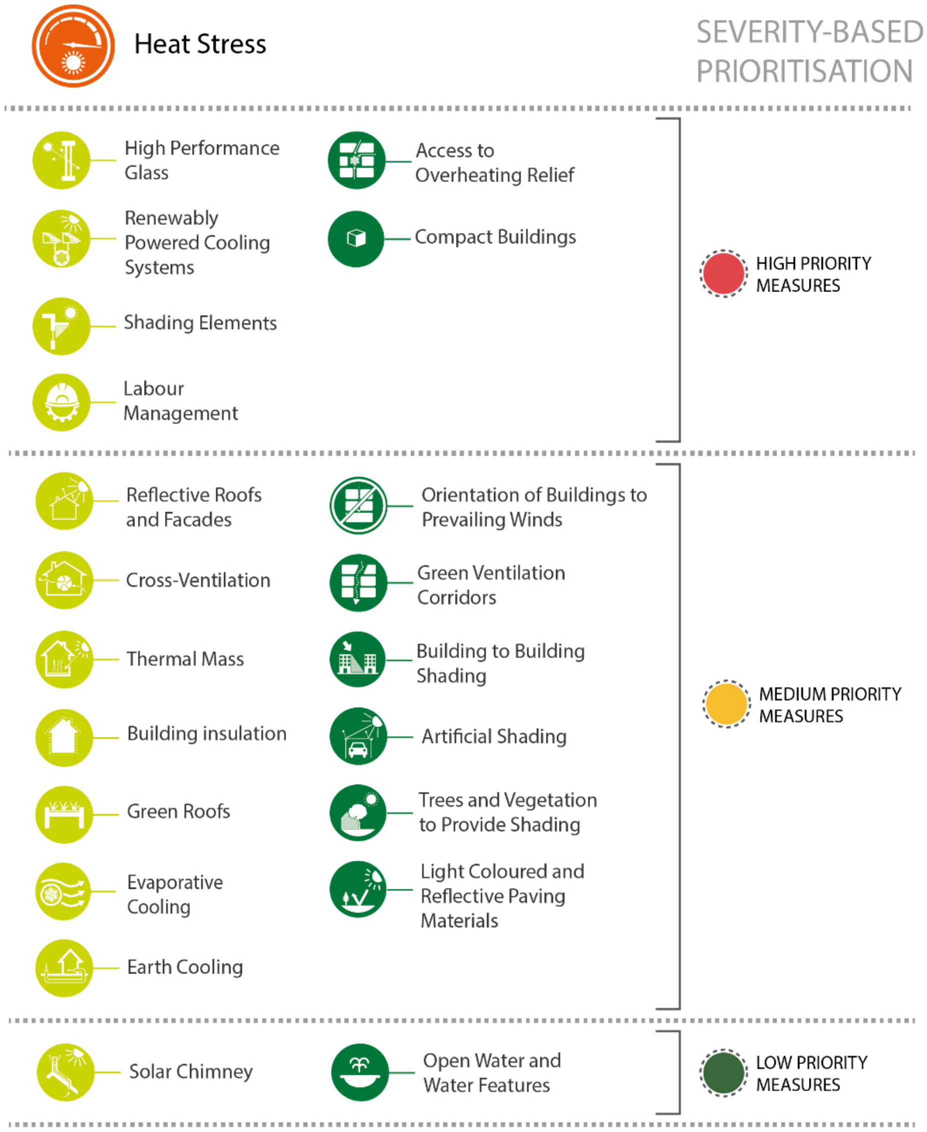


Figure 31: Severity-based prioritisation of the heat stress impact

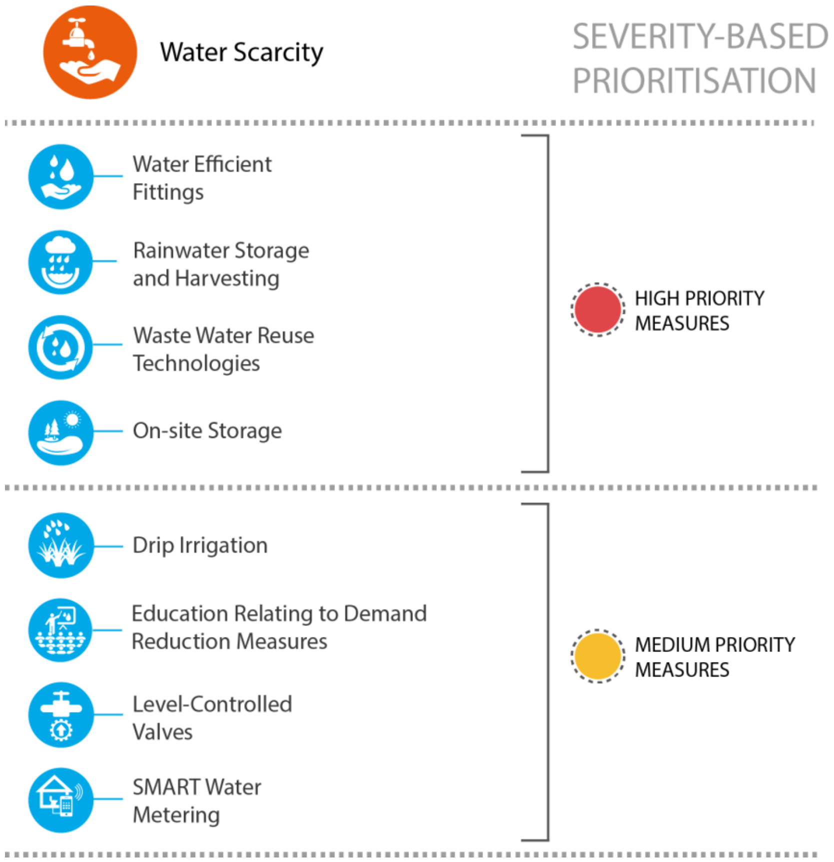


Figure 32: Severity-based prioritisation of water scarcity impact

Cost-Impact Prioritisation Matrix

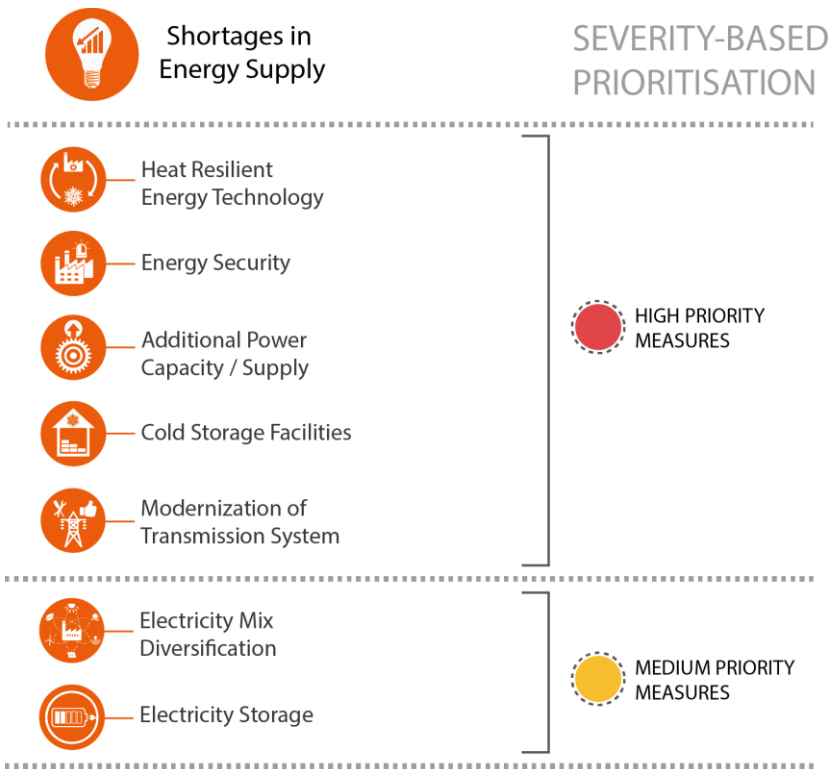


Figure 33: Severity-based prioritisation of shortages in energy supply impact

The selection of the appropriate adaptation measures depends both to its costs and the severity of the risk that the Industrial Park is exposed to. In order to give an overview of the costs and impacts of the proposed adaptation measures, following matrices have been prepared.

The illustrations below summarize the costs and impacts of all the adaptation measures concerning heat waves and droughts.

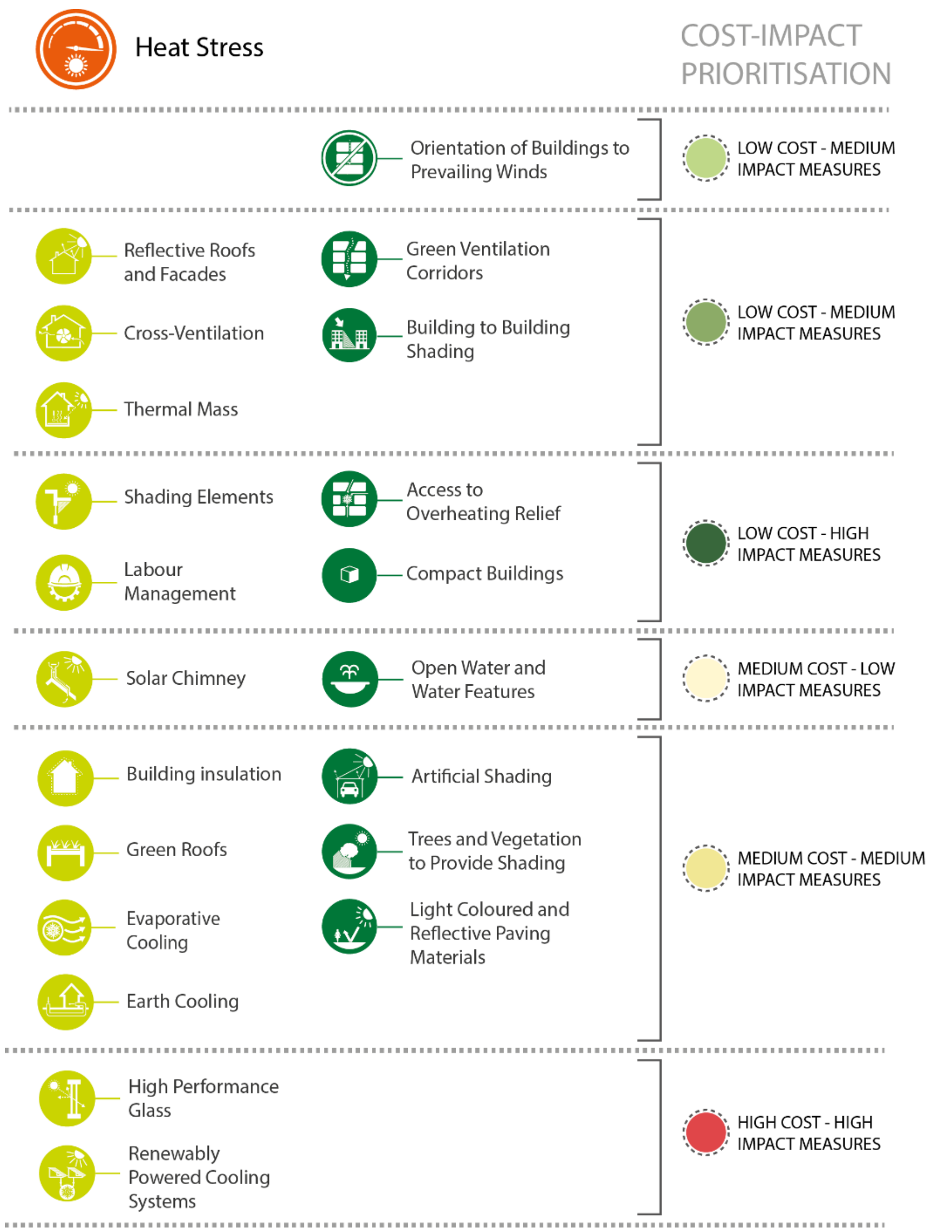


Figure 34: Cost-impact prioritisation of heat stress impact

3.2 Detail Engineering Measures of Heat Wave and Drought Related Impact

Detail guidelines with respect to each impact have been enumerated in the subsequent sections, presented in the following order:

(1) Heat Stress

(2) Water Scarcity

(3) Shortages in Energy Supply

The adaptation measures have various impact areas in Industrial Parks, ranging from the Site Layout to Buildings and Technical Infrastructure. The particular impact area is stated for each adaptation measure, as well as if the measure targets new and/or existing Industrial Parks.

The engineering guidelines for each measure to be read in conjunction with the following, the detail contents of which are provided in the corresponding Annex - VII, VIII and IX respectively.

a) Applicable Codes and Standard (Refer Annex - VII)

b) Roles and Responsibilities (Refer Annex - VIII)

c) Planning and Analytical Tool (Refer Annex – IX)

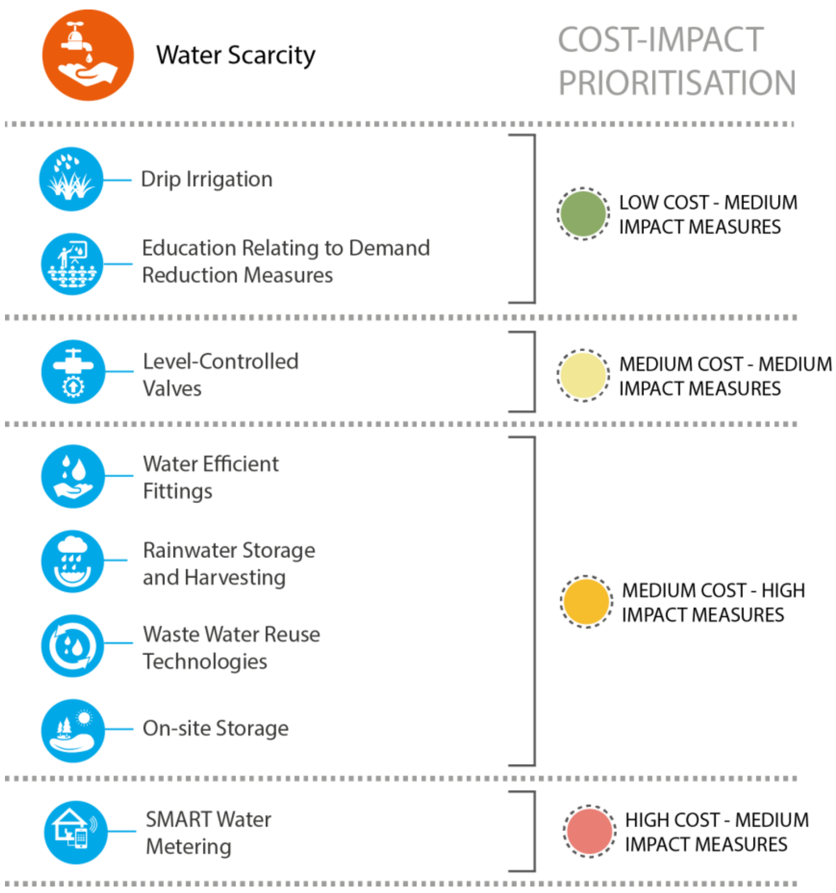


Figure 35: Cost-impact prioritisation of water scarcity impact

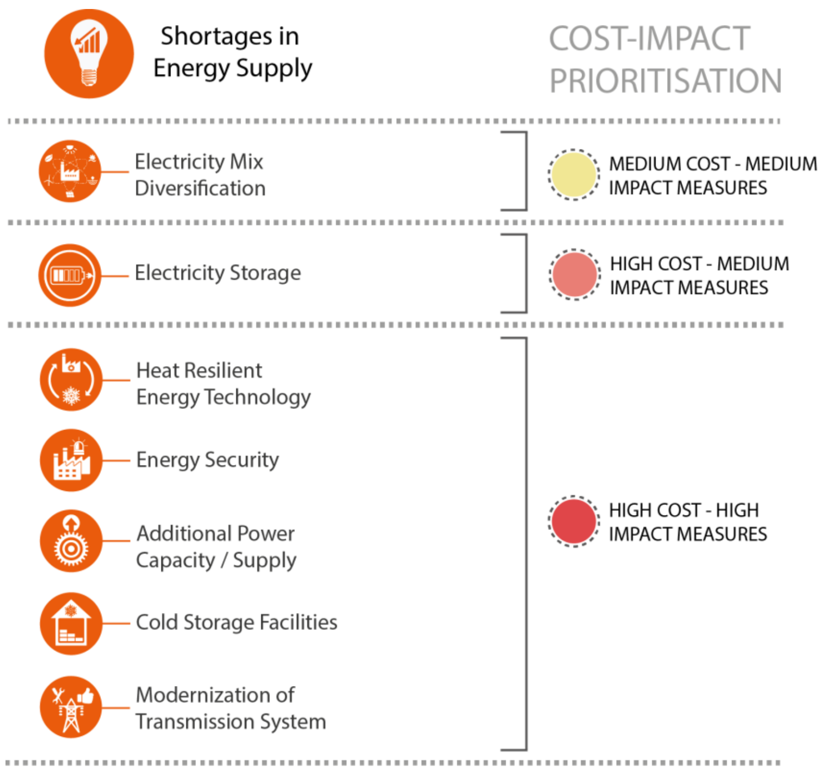


Figure 36: Cost-impact prioritisation of shortages in Energy Supply

3.3 Impact: Heat Stress – Cooling of Building

CCA Measure 1: Building Insulation

Type of Measure: *Retrofitting*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Insulating buildings can be a crucial strategy to reduce the heat gain of buildings. This is of importance especially during heat waves as insulation impedes the transmission of heat into internal building spaces. Insulation can hence lead to natural cooling of the building, with a subsequent reduction in energy consumption. Insulation can also reduce draughts caused by temperature differences between the building walls and the air and prevents structural damage. Building insulation is mainly suitable for office buildings in the industrial park.

b) Design Process/Specifications for on-site Execution

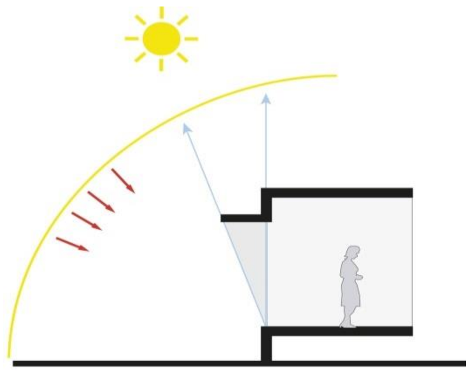
- The building walls could get insulation placed on the interior and the exterior side. Often it is easier to achieve higher thermal efficiency with external wall insulation.
- Rock, glass and slag wool are possible mineral insulation materials.
- The general standard is to use building materials that have low thermal conductivity and windows that have low u-values.
- When the u-values for the roof and the walls are 0.261 and 0.44 W/m^{2}K respectively (ECBC India), the reduction in heat in-flow through the roof is 90% and through the walls 70%.
- The thermal conductivity of the specific material determines the thickness of the insulation material – for example, 0.83 m thick porous brick would provide the u-value of 0.13 W/m^2.K.
- Since the use of insulation can prevent a building from losing heat, the risk of overheating must be addressed by an adequate design strategy, including external shading and high performance glass.

C) Monitoring Indicator

- Percentage of properties erected or retrofitted with building insulation

CCA Measure 2: Shading Elements

Type of Measure: *Retrofitting*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*



Shading Elements

a) Engineering Details

Internal and external shading elements can be an important strategy to naturally cool buildings in industrial parks. Shading elements will significantly reduce the surfaces exposed to direct sunlight (and hence reduce solar radiation penetrating the building), which helps to keep the building interior cool and lowers the energy need for air conditioning. It also improves the thermal comfort of the users in buildings. Shading elements are suitable for all the buildings in the industrial park, though technical solutions will depend on building typology and cost related to measure. Office buildings are suitable for more complex solutions (e.g. automated, internal shading devices), whereas production facilities will require simpler solutions (e.g. external shading devices).

b) Design Process/Specifications for on-site Execution

- The aim of this measure is maximum exclusion of solar gain in buildings during the hot season and heat waves.
- Generally, buildings should be designed with external shading devices such as overhangs, shutters and directional louvers at all openings of a building.
- Generally, a fixed horizontal shading device is appropriate for north oriented buildings and a vertical moveable device for east or west.
- Interior shading elements such as blinds are good ways of controlling glare and increasing the visual comfort, but not effective in terms of cooling the building as the solar gain has already entered the interior space.

c) Monitoring Indicator

- Percentage of properties erected with shading device

CCA Measure 3: Reflective Roofs and Facades

Type of Measure: *Retrofitting*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Roofs and facades with reflective materials help reducing indoor temperatures significantly and therefore help to lower the energy consumption required for cooling. Reflective roofs and facades are suitable for all the buildings in the industrial park. The effectiveness of this measures increases with the roof area.

b) Design Process/Specifications for on-site Execution

- Building materials for roofs and facades should have a high solar reflectance and a high thermal emittance.
- Using light coloured material will increase the heat reflection and help keeping the space cool, whereas dark coloured materials will absorb the heat.
- China mosaic, white cement tiles, paints with high Solar Reflective Index (SRI) values are typical examples of such building materials.
- Generally it is recommended that the Solar Reflectance Index (SRI) should be 29 or higher for steep slope (>2:12) roofing in IPs.
- For low slope roofing (more area exposed to the sun), the SRI values should be 78 or higher.

c) Monitoring Indicator

- Percentage of properties with reflective roofs and facades

CCA Measure 4: High Performance Glass

Type of Measure: *Technology-Change*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

The type and characteristics of the glass used for the building has a profound effect on the indoor temperature. In order to help cooling the building interior during high temperatures and heatwaves, it is highly recommended to use glass with improved solar g-value. G-value is a term that indicates how much solar heat can enter through the glass; the lower the g-value is, the less solar heat penetrated to the building. Solar control glass is a developed technology with low g-value, a recommended option for helping to cool the buildings. Solar control glass allows the sunlight to enter the window or facade in order to increase the day light and visual comfort inside the building, while radiating and reflecting away most of the heat. Due to the costs, such high performance glasses are mainly suitable for office buildings in the industrial park.

b) Design Process/Specifications for on-site Execution

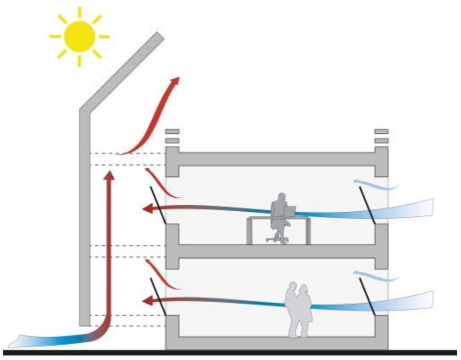
- There are coloured or mirrored solar control glasses available, as well as ones without.
- There are two main types of solar control glasses: absorbing and reflective glasses. In rejecting the solar heat gain – the increase in temperature in a space due to solar radiation, reflective glasses are to some extent better.
- The particular layers in the glass allow the light to come in, but prevent the heat to enter.
- Solar control glasses contribute to the insulation of the building too, as they are double-glazed.
- It is also possible to add solar control films onto flat glazing in existing buildings.

c) Monitoring Indicator

- Percentage of buildings with glass technologies

CCA Measure 5: Cross-Ventilation

Type of Measure: *Retrofitting*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*



Cross Ventilation

a) Engineering Details

Building ventilation is critical to employee comfort, because it can improve indoor environmental quality and reduce sources of heat related discomfort. Furthermore, natural ventilation reduces the energy demands generated by artificial climate control. Natural ventilation system comprises of an airflow circuit through a building, including windows, doors and other openings. Cross-ventilation is generally suitable for office buildings, for factories and industrial buildings. Mechanical ventilation is recommendable in order to extract war air, dust and fumes adequately.

b) Design Process/Specifications for on-site Execution

- In order to reach maximum pressure and air velocity, the building orientation should provide the largest openings to face the prevailing wind direction.
- Providing air intake windows at working level and exhaust windows (with support fans) at roof levels will maximize natural cross flow ventilation in buildings.
- Each room should have two separate openings for supply and exhaust.
- A small size inlet with a large outlet will provide the highest air velocity. However, large inlets let more air in, which will be useful when the wind direction is not constant.
- Wing walls can be used to provide pressure differences that cause ventilation, especially if the outdoor air velocity is not very high.

c) Monitoring Indicator

- Percentage of buildings with cross ventilation strategies applied.

CCA Measure 6: Green Roofs

Type of Measure: *Technology-Change*
Impact Area: *Buildings*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

The term green roof refers to roofs with plantation / vegetation on its surface. There are extensive (green roofs that are specifically designed for storm water management and insulation) and intensive (green roofs that are designed as functional living spaces and for aesthetic purposes) green roofs. Both flat and sloped roofs are appropriate for green roof implementation and it is possible and recommendable to combine them with renewable power generation, especially photovoltaics (PV). Including an improved rainwater management, green roofs can be important elements of temperature reduction in buildings by insulation of the roof and preventing urban heat island effect as well. Green roofs are applicable and recommended in office buildings, warehouses, and industrial halls in the industrial park.

b) Design Process/Specifications for on-site Execution

- Green roofs generally consist of an insulation layer after the roof deck, a waterproof membrane, roof drain, the substrate and vegetation on top.
- In hot climates, the planner should apply extensive green roofs, since they do not require irrigation. They also need only very little maintenance.
- For extensive green roofs, recommended vegetation is low-growing communities of plants and mosses selected for stress-tolerance qualities.[1]
- It is important to plan the green roofs with combination with solar energy (PV) wherever possible.
- In order to combine green roofs and solar energy effectively, PV Panels should stand above the substrate and vegetation.
- It is important to select vegetation that will not cause shading on panels.
- Extensive green roofs would provide an average of 70 to 170 kg per m^2 of weight to the roof and 130 mm in depth. The average substrate depth may vary from 2 cm to 20 cm. considering these features. The building and specifically the roof structure and strength need to accommodate the additional weight. For maintenance purposes, an internal or external access to the roof is necessary.

c) Monitoring Indicator

- Square meter and type of green roof installed per IP per year

CCA Measure 7: Thermal Mass Increase

Type of Measure: *Low-Cost*
Impact Area: *Buildings*
Adaptation Option: *No-Regret*
Target Industrial Park: *New IPs*

a) Engineering Details

Thermal mass is the ability of a solid or liquid material to absorb and retain heat. This slows down the process of heating of the building interior that can reduce the energy consumption. Research indicates that thermal mass saves energy in hot-humid climates and high-mass walls are more efficient than low-mass walls[2]. Thermal mass increase is mainly suitable for office buildings in the industrial park.

b) Design Process/Specifications for on-site Execution

- Concrete floor slabs and interior masonry are possible measures for increasing the thermal mass.

[1] Oberndorfer, E., et al., Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services BioScience 57(10):823-833. 2007
[2] Motamedi, S., Akhavan, M., Energy Analysis of Using Thermal Mass in a Hot Humid Climate, Recent Advances in Energy, Environment and Economic Development

- Stone, brick, concrete, unfired clay bricks, dense concrete block and gypsum plaster are some of the effective materials.
- Heavyweight material serves as thermal mass, with a form in the internal fabric – floor, walls or ceiling.
- Heat is absorbed during the day and “flushed out” through natural ventilation in the evening.
- Thermal mass is not an alternative to insulation, as the logic is storing the heat and releasing it later.
- It is necessary to consider thermal mass together with adequate shading and insulation of the building.
- Shading and insulation should also protect the thermal mass from the summer sun.

c) Monitoring Indicator

- Percentage of properties with thermal mass

CCA Measure 8: Renewably Powered Cooling Systems

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Win-Win*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

In hot and dry climates, it is essential to take advantage of the available solar radiation and use it for fulfilling at least a part of the energy demand in the building. In considering the impacts of climate change, demand for cooling systems will increase and renewable energies are a sustainable way to cover these growing demands.

b) Design Process/Specifications for on-site Execution

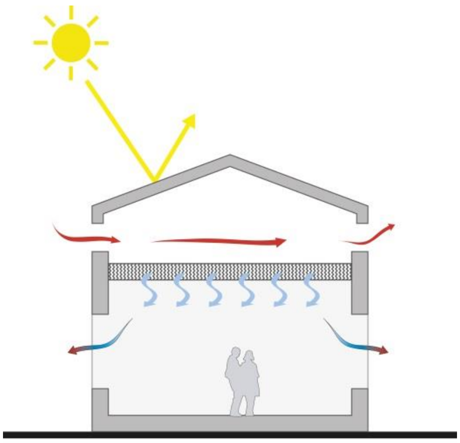
- Stand-alone PV systems could provide the needed additional energy demand.
- Both flat and sloped roofs are suitable for installing PV systems together with thermal insulations, however different installation technologies are necessary.
- In general, roofs should be south facing for maximum exposure to solar radiation.
- The PV cells or system should be adjustable in order to always adapt to the optimum angle.
- The weight of the PV System- which can vary from 9 to 160 kg/m2 must be considered in the construction stage of new buildings or when retrofitting buildings.
- Safe access to the roof and to the area with the PV System is needed.
- Feasibility studies and planning of PVs to be considered as part of a wider renewable energy system

c) Monitoring Indicator

- Square meters of photovoltaics installed per IP per year.

CCA Measure 9: Evaporative Cooling

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Low-Regret*
Target Industrial Park: *New IPs*



Evaporative Cooling

a) Engineering Details

Evaporative cooling is a passive cooling method that helps improving the inner air temperature through using natural processes. The evaporative capacity of water cools the incoming air, simultaneously increasing the relative humidity in buildings. It is a highly efficient method in hot and dry climates, but water availability is required in order to apply evaporative cooling in the industrial parks. Evaporative cooling is a suitable measure for office buildings, as well as warehouses in the industrial park.

b) Design Process/Specifications for on-site Execution

- There are several ways to incorporate evaporative cooling into buildings such as passive downdraft evaporative cooling (PDEC) or roof surface evaporative cooling (RSEC).
- In the first case wind towers with wetted columns, with wetted surfaces or wetted fabrics are used to cool the incoming air, which is sucked into the building by the gravity flow of air.
- RSEC means wetting roofs by spraying water over suitable water-retentive materials on roof surfaces. As the water evaporates, it draws most of the heat from the surface, thus lowering the temperature of the roof and hence reduces heat gain inside the building.
- Solutions need to be chosen based on a holistic energy concept for each building.

c) Monitoring Indicator

- Number of evaporative cooling systems applied within the IP (PDEC or RSEC)

CCA Measure 10: Earth Cooling

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Low-Regret*
Target Industrial Park: *New IPs*

a) Engineering Details

Earth air tunnels are underground heat exchangers. The temperature difference between the soil and the air leads to cooling of the inner spaces. It is important for this measure that the ground has good thermal conductivity. Soils with higher mineral content have higher conductivity. Moisture content increases the thermal conductivity as well as the dry density of the soil. Vegetation is also an effective insulation element to moderate the ground temperature. By utilizing earth-air tunnel systems, air to soil heat exchange is achieved, which cools the interiors in hot temperatures. Earth cooling is appropriate for office buildings, as well as the larger structures in the industrial park by increasing the capacity of the piping loops.

b) Design Process/Specifications for on-site Execution

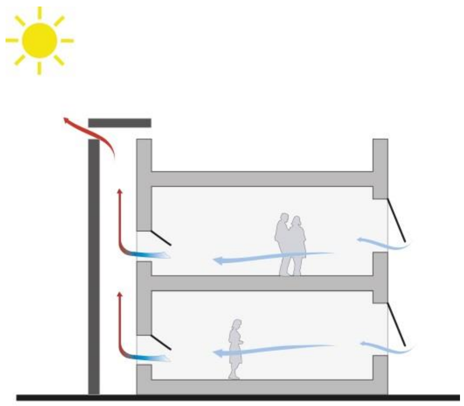
- Thermal conductivity of the soil, pipe diameter, length of tunnel and the air velocity in pipes are the performance parameters that will be determined while designing an earth-air tunnel system for a specific case.
- Already existing systems are indicating a pipe depth of 4 m and a diameter of 0.3 to 0.7 m.
- The length of the pipes should be appropriate for the air volume, that exists in the specific case.
- Increased length leads to increased heat transfer and high efficiency but then requires more energy for the fan.

c) Monitoring Indicator

- Number of earth air tunnel systems

CCA Measure 11: Solar Chimney

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*



Solar Chimney

a) Engineering Details

Solar chimney is another passive cooling method that utilizes natural processes to cool the building. During the day, solar energy heats the chimney and the air within it, creating an updraft of air in the chimney. This leads to suction in the chimney's base (convection effect) for ventilation and cooling of the building. The solar chimney can also be used in winter by closing the tip of the chimney and keeping the hot air inside the building by directing absorbed heat back into the building. Solar chimney is an appropriate measure for office buildings and production facilities in IPs.

b) Design Process/Specifications for on-site Execution

- There are several approaches to design solar chimneys, but in general, it is recommended to design solar chimneys tall and wide, and to orient them towards the sun.
- A solar chimney should have a dark and matt surface to absorb solar radiation, as well as a surface that allows solar heat to be transferred to the air.
- The greenhouse effect is commonly used for solar chimneys, with an absorber surface on one side, and a transparent surface like glass on the other side.

c) Monitoring Indicator

- Number of solar chimneys

CCA Measure 12: Labour Management

Type of Measure: *Low-Cost*
Impact Area: *Industrial Processes and social*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Applying management and operational measures will improve the productivity in the industrial parks during extreme temperatures and heat waves. The working schedules and hours can be rescheduled to fit the needs of the staff and the weather conditions the best. Supplying enough amenities in order to keep the working conditions and productivity in a high level is also essential.

b) Design Process/Specifications for on-site Execution

- Applying flexible working hours is one of the most efficient procedures.
- Physical demands in the peak hours should be reduced or rescheduled by shifting peak working hours (mainly between 1pm and 5pm) during a heat alert, essentially for outdoor workers and working near boilers / furnaces.
- Heavy work under direct sun or indoors when there is not enough ventilation should be minimized.
- Safe drinking water and shelters in industrial parks during heat alerts should be provided.
- Employees should be educated about the hazards of the heat stress and appropriate clothing should be encouraged.
- Rest periods in cool areas should be provided.

c) Monitoring Indicator

- Percentage of industries that have adapted shifts to climate

3.4 Impact: Heat Stress – Cooling of Urban Realm

CCA Measure 1: Green Ventilation Corridors

Type of Measure: *Low-Cost*
Impact Area: *Site Layout*
Adaptation Option: *Win-Win*
Target Industrial Park: *New IPs*

a) Engineering Details

Green ventilation corridors are connections of large open and connected green spaces. If adequately designed, green corridors can mitigate the heat island effects by improving urban ventilation, transporting colder and fresh air from outside into built up areas. In addition, green corridors are attractive open spaces for employees working in the industrial parks. Green corridors also have flood storage capabilities.

b) Design Process/Specifications for on-site Execution

- Green ventilation corridors designed along major prevailing wind directions will allow effective air movements.
- Green ventilation corridors should be continuous green spaces creating ecological connectivity and improving biodiversity and animal species dispersal.
- Provision and promotion of local species should be a priority.
- The design should offer multifunctional spaces deriving the maximum benefits for the costs.
- The irrigation requirements should be kept as low as possible using native trees and plants, as well as utilizing grey water or stored rain water.

c) Monitoring Indicator

- Green area (in square meter) completed

CCA Measure 2: Orientation of Buildings to Prevailing Winds

Type of Measure: *Low-Cost*
Impact Area: *Site Layout*
Adaptation Option: *Win-Win*
Target Industrial Park: *New IPs*

a) Engineering Details

To assure fresh air supply within Industrial Parks, both street pattern and buildings should be oriented to prevailing winds. Likewise, the design of buildings should avoid blocking prevailing winds.

b) Design Process/Specifications for on-site Execution

- Main streets aligned in parallel or up to 30 degrees to the prevailing wind direction could maximise the penetration of winds in industrial parks.
- The alignment of the longer frontage of plots should be in parallel to the wind direction in order to increase the ventilation.
- Roads should be wide enough to allow for good ventilation - hence non-building areas and setbacks are appropriate options.

- Shading considerations are essential when planning street orientation for ventilation.
- Site design should also allow for north south orientation of buildings for minimum heat gain.

c) Monitoring Indicator

Number of properties completed oriented to prevailing winds

CCA Measure 3: Artificial Shading

Type of Measure: *Retrofitting*

Impact Area: *Site Layout*

Adaptation Option: *No-Regret*

Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

If trees in public spaces are not applicable (e.g. due to ground/structural considerations), artificial shading might be a solution. Shading structures are both adequate to provide shade for people seeking protection from direct sunlight, e.g. at bus stops, walkways, public spaces within IPs or at construction work in IPs. Artificial shading might also limit overheating of vehicles at car parks.

b) Design Process/Specifications for on-site Execution

- Depending on the available budget, different constructions and technical solutions such as pavilions, tents or sun umbrellas can be used.
- Metal, wood or more advanced materials can be used.

c) Monitoring Indicator

- Square meter of artificial shading devices constructed per year

CCA Measure 4: Shelters for Access to Overheating Relief

Type of Measure: *Retrofitting*

Impact Area: *Site Layout*

Adaptation Option: *No-Regret*

Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Industrial parks should offer access to overheating shelters, which workers can use in case of heat waves. These facilities or “cooling centres” can be dedicated facilities within Industrial Parks or part of public buildings, service buildings or temples.

b) Design Process/Specifications for on-site Execution

- The location of the cooling centres should be in the walking distance (600m) from any point in the industrial parks.
- These shelters are cooled accordingly and offer cool drinking water.
- In case of heat alerts, cooling centres should also provide temporary night shelters for those working in the IP without immediate access to water and/or electricity.
- In a combination of artificial shading and access to overheating appropriate bus shelters with water centres might provide a good solution.

c) Monitoring Indicator

- Cooling Centres erected in an IP within a certain period

CCA Measure 5: Building to Building Shading

Type of Measure: *Low-Cost*
Impact Area: *Site Layout*
Adaptation Option: *Win-Win*
Target Industrial Park: *New IPs*

a) Engineering Details

The urban geometry can have a profound effect on the urban microclimate. The height of buildings and the dimensions between buildings will affect the shading situation between buildings (i.e. on roads or public spaces). The maximized shading between buildings will help to reduce temperatures and increase the thermal comfort.

b) Design Process/Specifications for on-site Execution

- The amount of direct radiation received in the space between buildings is determined by the street width and building height. Modulating both - street width and building height - can effectively control solar radiation, taking into account the orientation.
- The building height to street width ratio (H/W-Ratio) gives orientation. The higher the ratio, the more effective is the building layout to minimize heat gains.
- In hot climates, planning narrow streets surrounded by high buildings will minimize the heat gain. As this will be not applicable in all parts of Industrial Parks (esp. in the production zones with low buildings and broader streets), this strategy might be better applicable to service areas within Industrial Parks or at Office Parks.
- The exact dimensioning of the urban geometry can however only be determined by considering the solar geometry in combination with street and buildings orientation.

c) Monitoring Indicator

- H/W ratio within different properties

CCA Measure 6: Trees and Vegetation to Provide Shading

Type of Measure: *Retrofitting*
Impact Area: *Location (Land Use)*
Adaptation Option: *Win-Win*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Industrial parks offer various possibilities for providing shading through planting of trees. Shading and evapotranspiration from trees can reduce surrounding air temperatures by 5°C – hence planting trees is a crucial strategy in adapting to the effects of climate change. The careful selection of local trees species will reduce the maintenance and irrigation efforts.

b) Design Process/Specifications for on-site Execution

- Planting trees in front of buildings to block the sun will reduce temperatures around buildings (and hence reduce energy consumption for cooling). Planting trees 1.5 m to

3 m away from the building allows room for growth, but for shade trees should be no more than 9 to 15 m away.

- Trees can shade pavements to reduce their surface temperatures. Planting trees at regular intervals of 6 m to 12 m along both sides of a street, as well as along medians is a common way to provide valuable shading.
- Trees should have a wide and dense canopy.
- Trees should not block the ventilation.
- If choosing adequate types, irrigation need should be considered, together with irrigation with grey water and harvested rainwater.
- Generally, implementing local, drought tolerant species should be the priority.

c) Monitoring Indicator

- Number of trees planted

CCA Measure 7: Open Water and Water Features

Type of Measure: *Retrofitting*
Impact Area: *Location (Land Use)*
Adaptation Option: *Win-Win*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Water features such as ponds and fountains can reduce the air temperature of their surrounding through evaporation. Trees planted nearby will create higher thermal comfort and will enhance the cooling effect.

b) Design Process/Specifications for on-site Execution

- Water features can reduce air temperature as well as to create pleasant outdoor spaces.
- Planning water features in IPs will have to take into account the demand, which this will create.
- The water features should use local sources of water, such as harvested rainwater, and the water should have a subsequent use wherever possible.
- Net use should only include evaporative and other minor losses.

c) Monitoring Indicator

- Number of water features

CCA Measure 8: Light Coloured and Reflective Paving Materials

Type of Measure: *Tech-Change*
Impact Area: *Roads*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Majority area of IPs are paved, hence, selection of paving material is considered essential.. Both colour and material can have an impact on its cooling potential. If natural surfaces are covered with materials like concrete or asphalt (often because of new buildings, roads or parking facilities) the surface temperature will significantly increase and affect the microclimate significantly. This is because dark surfaces absorb much more solar radiation and hence heats the environment.

b) Design Process/Specifications for on-site Execution

- Paving considered for IPs can be porous asphalt for roads and light coloured brick for pavements.
- Coatings and grass paving are suitable pavement materials.
- Areas that expect high traffic turning forces and heavy goods vehicle traffic are not suited for its application.

c) Monitoring Indicator

- Share of reflective, bright surface realized per year

CCA Measure 9: Compact Buildings

Type of Measure: *Low-Cost*
Impact Area: *Buildings*
Adaptation Option: *Win-Win*
Target Industrial Park: *New IPs*

a) Engineering Details

Compact buildings lead to a low S/V ratio. The S/V ratio describes the rate between the surface of a building (S) and the volume (V) that needs to be cooled or heated according to climate. The lower the S/V ratio the higher the compactness of buildings and the lower the heat or cooling loss.

b) Design Process/Specifications for on-site Execution

- In hot and dry climate regions, the S/V ratio should be as low as possible to minimise the heat gain.
- Maximising the compactness of a building is balanced by creating permeable buildings that allow for natural ventilation.

c) Monitoring Indicator

- Percentage of properties completed with a S/V ratio below 2

3.5 Impact: Water Scarcity

CCA Measure 1: Level-Controlled Valves

Type of Measure: *Retrofitting*
Impact Area: *Industrial Processes*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Installation of level-controlled valves is an effective way of reducing the water consumption in industrial processes, as it helps in avoiding overflows. The valves shut off when the reservoir reaches a particular level or setting. It is possible to use these level-controlled valves in elevated tanks, or in storage tanks that are above or underground.

b) Design Process/Specifications for on-site Execution

- Control valves could detect the level of pressure changes. If the actual flow is different from the target the valve can decrease or increase it.
- The actuator that moves the disk can be a hydraulic, pneumatic, electrical or mechanical one.

c) Monitoring Indicator

- Number of utilized level-controlled valves

CCA Measure 2: Water Efficient Fittings

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Installations of water efficient fittings contribute to reducing water consumption. The installed fittings require less water to satisfy particular demands, which results in reduction of water use. It also helps reducing evaporation losses and contributes to water reduction.

b) Design Process/Specifications for on-site Execution

- Water efficient fittings should directly be an integral element of the technical infrastructure for new buildings.
- The retrofitting of the existing fittings into more efficient ones is relatively a simple process.
- Showerheads, toilet flushes, water tabs are options for water efficient fittings.
  For example, efficient fittings could reduce the water consumption of a showerhead from 15-20 litres per minute (lpm) to 6 or 7, (lpm) water taps from 15 to 18 lpm to 2 lpm and amount of water used by the toilet flush from 12 lpm to less than 4 lpm.

c) Monitoring Indicator

- Percentage of properties built incorporating water efficiency measures

CCA Measure 3: SMART Water Metering

Type of Measure: *Tech-Change*
Impact Area: *Technical Infrastructure*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

SMART Water Metering systems aim to optimize the operational and management processes in industrial areas, reducing costs and reducing the carbon footprint. SMART Water Metering are used for identifying leakages, detecting precisely the leakage, chargeable and non-chargeable water and preventing as many anomalies as possible. This help raising awareness of water consumption as well as helping to monitor the water use.

b) Design Process/Specifications for on-site Execution

- Smart water metering systems are water meters that could deliver data about water consumption, leakages etc. through a fixed-network communications system.
- Developing a measurement and verification plan is a recommended tool to compare the predicted savings and actual performance.

c) Monitoring Indicator

Percentage of properties incorporating SMART Meter

CCA Measure 4: On-site Storage

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Utilizing on-site water storage is a tool to manage the peaks in water demand, caused by extreme temperatures and heatwaves. This reduces also the risk of low water pressure.

b) Design Process/Specifications for on-site Execution

- Water can be stored in tanks and cisterns underground or above.
- Water can also be stored in main retention basins, which are also landscape elements in the industrial park.
- The capacity of the storage should be determined with respect to amount of precipitation and the water demand.
- Effective storage available in storage tanks should be considered while designing the capacity of the storage facility, as the actual usable water from the storage facility depends on different variables such as the location of the storage relative to the place of its use – distance and pressure zone.

c) Monitoring Indicator

- Percentage of properties incorporating on-site storage

CCA Measure 5: Waste Water Reuse Technologies – including a Grey Water Storage

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Wastewater treatment and reuse is one of the most essential components of water sensitive design and reduction of water consumption. Recycling water can reduce both water consumption and the volume of water entering the sewers. Water treatment is critical to any industrial park and should be an integral part of the concept of broader grey water and non-potable water strategies, with opportunities identified to capture and treat water on site.

b) Design Process/Specifications for on-site Execution

- Water treatment prepares water for an end-use, whether drinking, tertiary use or mechanical use. Processes can be natural or chemical, and remove physical or chemical disinfectants.
- Hydrocarbon interceptors, Reverse Osmosis and Membrane Bioreactor are possible technical solutions.
- Natural solutions include grey water treatment in grey water treatment plants recycling domestic wastewater for uses such as plant irrigation and toilet flushing and cooling tower.
- First step is to calculate the waste water volumes generated in the factory buildings.
- It is an important element of grey water reuse to ensure the quality standards of the treated water according to its targeted end-use.
- There should be appropriate signage to make it clear that the water is not potable.

c) Monitoring Indicator

- Percentage of properties incorporating waste water reuse technologies

CCA Measure 6: Rainwater Storage and Harvesting

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Rainwater usage, or rainwater harvesting, is a very important part of managing water stress and practicing water sensitive design in industrial parks. The practice comprises capturing, filtering and utilizing rainwater on site, whether for irrigation, water features, or industrial use after proper treatment. Conservation of rainwater provides an independent water source, thus reducing water usage and making the most of naturally available resources.

b) Design Process/Specifications for on-site Execution

- Firstly, the rainwater should be collected from roofs and from the landscape by directing and controlling the water with elements such as swales – a low tract of land, especially moist or marshy to catch and manage water runoff.
- The collected rainwater can be used for multiple functions, such as irrigation, industrial use or daily use such as toilet flushing after proper treatment.
- Care to be taken by not allowing industrial sewage mixing with rainwater.
- Tanks and cisterns are possible water storage facilities – protection from potential insect vectors to be considered.
- The design of the storage volume should take into account at least 2-3 days of rainfall.
- An approach to determine the size of the storage is to consider 5% of the annual rainfall and 5% of the annual demand. Commercial tanks may differ from 7000 litres to 300000 litres.
- Below ground storage tanks are generally cheaper and more suited for large volumes than above ground ones.
- Common construction materials for storage tanks are brickwork, reinforced cement concrete (RCC), Ferro Cement, plastic or polypropylene.
- It is recommended to use RCC or Ferro Cement for below ground tanks. These materials are generally cheaper than plastic and have high local material and labour availability.
- Underground tanks should not be very close to sewage chambers or lines.
- Another possible feature of storing water for irrigation is implementing water pools.

c) Monitoring Indicator

- Percentage of properties incorporating rain water storage

CCA Measure 7: Drip Irrigation

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Drip irrigation, or micro irrigation is an irrigation method that reduces water consumption and minimizes fertilizer use. It reduces water consumption by reducing evaporation and drainage. The method works by dripping water onto the roots of plants through a network of pipes having pores that reach the root base directly. Drip irrigation can also minimize exposure to diseases spread through irrigation water. The professionals who design these systems generally provide solutions to both design and implementation. One of the most important steps is having a plan of the green space with the plants and vegetation on it, the type of soil and the topographical conditions.

b) Design Process/Specifications for on-site Execution

- Uniformly spread water throughout the irrigated area would help achieving a uniform root growth.
- There should be separated bedding areas in the park as independent zones according to their different watering needs.
- The target should be a long, slow metering instead of short watering in order to enable the water to spread within the soil.
- The most appropriate time for irrigating the landscape areas and parks is morning and evening hours. Using Timers is recommendable in order to control this timing.

- Another important feature of drip-irrigation is installing a central shut off valve.

c) Monitoring Indicator

- Percentage of park area that is irrigated using alternative irrigation schemes

CCA Measure 8: Education Relating to Demand Reduction Measures

Type of Measure: *Low-Cost*
Impact Area: *Awareness Generation and social*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

One of the ways to decrease the water consumption is through changing the cultural and traditional methods of water use. Educational campaigns and awareness generation could achieve that. Education related to water scarcity and optimal use of water would lead to a decrease in water consumption.

b) Design Process/Specifications for on-site Execution

- Education about water use in daily use and operations as well as a general education about climate change hazards and water scarcity will increase the awareness of the industrial policy makers and staff.
- This results in a significant decrease in water consumption.

c) Monitoring Indicator

- Number of education sessions dedicated to water demand reduction measures

3.6 Impact: Shortages in Energy Supply

CCA Measure 1: Cold Storage Facilities

Type of Measure: *Retrofitting*
Impact Area: *Industrial Processes - Stock*
Adaptation Option: *No-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Extreme weather events such as heatwaves will affect storage facilities in industrial parks. This can lead to damage of materials, e.g. raw material that needs to be stored in a cool environment can get damaged.

b) Design Process/Specifications for on-site Execution

- Industrial Parks should provide cold storage for products and materials requiring to be stored at low temperatures.
- The power should be provided from renewable energy sources.
- For less sensitive materials, shaded storage facilities can be adequate.

c) Monitoring Indicator

- Percentage of storage facilities with a cooling measure

CCA Measure 2: Additional Power Capacity / Supply

Type of Measure: *Retrofitting*

Impact Area: *Technical Infrastructure (Power)*

Adaptation Option: *No-Regret*

Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

It is likely that heat waves will increase the demand for energy, especially for cooling to cater for both industrial processes and cold storage or products or materials. It is also possible that during a heat wave, electricity sector can suffer problems with generation, transmission and distribution, potentially causing a blackout. Hence, investments into existing power plants may be necessary to meet increased cooling demand, especially peak demand during heat waves. Renewable energy sources and bio fuels may provide the additional energy, although the priority of this measure is the reliability of the power supply.

b) Design Process/Specifications for on-site Execution

- Additional power sources (such as generators) that are synchronised with the main power supply are possible measures to meet the higher cooling demands and deliver enough power to meet the peak demand.
- There are different classifications for additional power supply, such as emergency and standby.
- An emergency power supply should be available in 10 seconds and a standby system ideally in 60 seconds.

c) Monitoring Indicator

- Percentage of properties with additional power capacity/supply

CCA Measure 3: Energy Security

Type of Measure: *Retrofitting*

Impact Area: *Technical Infrastructure (Electricity Generation / Power Supply)*

Adaptation Option: *No-Regret*

Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Acting as a quick-response backup system, the goal of a redundant power system is to mitigate the risk of unplanned outages and ensure continuity of operation by instantly responding to a blackout. For the newly built plants, it is recommended to implement bio gas powered turbines.

b) Design Process/Specifications for on-site Execution

- Building enhanced redundancy into networks, i.e. in building back up plants close to existing plants would contribute to the energy security, depending on the criticalness of the power supply.

- An appropriate location for newly planned power plants could be places close to the sea or where climate is projected to be cooler and water availability adequate.

c) Monitoring Indicator

- Number of back up plants implemented

CCA Measure 4: Heat Resilient Energy Technology

Type of Measure: *Retrofitting*

Impact Area: *Technical Infrastructure (Electricity Generation / Power Supply)*

Adaptation Option: *Low-Regret*

Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

To safeguard existing electricity generation and increase energy efficiency technological change is necessary. Technology should adapt to projected local climate changes and the design should allow operating at higher temperatures to avoid compromising the power output during heat waves.

b) Design Process/Specifications for on-site Execution

- Using heat-resistant technology and changing types of turbines will implement new technologies in existing systems.
- Heat resistant cells in PV Systems can be used to improve the airflow and keep them cooler.
- Conditions such as deposition of dust, bird droppings and water stains (salt) can significantly decrease the efficiency of solar thermal installations.
- For dry climates with dusty environments, a minimum weekly cleaning is recommended to maximise the efficiency.
- Self-cleaning solar panel coatings can be used to decrease cleaning needs drastically, but it is a costly measure unless the number of PVs is very high.

c) Monitoring Indicator

- Share of heat resilient energy technologies

CCA Measure 5: Electricity Mix Diversification

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure (Electricity Generation / Power Supply)*
Adaptation Option: *Win-Win*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Expanding the diversification of sources of power in the electricity mix by having both centralized and decentralized options will increase the energy security and the flexibility of the electricity sector.

b) Design Process/Specifications for on-site Execution

- Using a mix of renewable energy sources not just reduce GHG emissions, it also can possibly back up electricity when fossil-fuelled plants fail to generate.
- Mixed systems avoid overreliance to one type of source.
- Decentralized generation systems work independently from each other. If one system is defunct, the others still function.
- There will be a combination of regenerative systems with conventional systems.

c) Monitoring Indicator

- Share of renewable energy sources in energy supply

CCA Measure 6: Electricity Storage

Type of Measure: *Technology-Change*
Impact Area: *Technical Infrastructure (Electricity Generation / Power Supply)*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Both new and existing IPs*

a) Engineering Details

Energy from renewables can be stored and used when the demand increases or the production rate decreases.

b) Design Process/Specifications for on-site Execution

- In an energy generation system, electricity storage is necessary to secure constant electricity supply. The storage avoids the usage of fossil fuels in a backup situation.
- It has a high importance, in case of generation blackouts and increases the reliability of the supply.
- For storage, there are many different types of technologies (chemical, mechanical, compressed air, electrical) already developed or still in development.

c) Monitoring Indicator

- Percentage of utilities applied electricity storage

CCA Measure 7: Modernization of Transmission System

Type of Measure: *Retrofitting*
Impact Area: *Technical Infrastructure (Electricity Generation / Power Supply)*
Adaptation Option: *Low-Regret*
Target Industrial Park: *Existing IPs*

a) Engineering Details

The grid is the most weather-exposed part of the electricity supply chain. Improving the grid by retrofitting current structures and introducing new technologies and new design structures is a critical step for heat-proofing the electricity system.

b) Design Process/Specifications for on-site Execution

- Normally overhead lines bend and distort during the time of heat waves due to very high temperatures. That causes lower efficiency and higher loss of energy. To avoid this loss, the replacement of some overhead lines with underground cables should be used.
- The usage of smart technology can show exactly where an outage occurs as opposed to existing systems.
- Micro grids are associated with decentralized electricity systems. New grid structures and especially circular grids can be considered a better technology because they allow to reach end users through alternative routes.

c) Monitoring Indicator

- Share of modernized transmission systems

4. Master Plan Setup with Adaptation Measures

Climate Change Adaptation Planning is a geo-contextual, time-specific, and focus-based process. Therefore, CCA master planning for their corresponding potential impacts to be attempted and practiced as a process where *review, planning, detail engineering, implementation, monitoring,* and *mitigation* go on as a sequential process.

In this approach the decision to prepare a CCA plan is the leading step in the entire planning process. Following two varying contexts, A and B, portray the steps of CCA planning for the New IPs and Existing IPs respectively. They have been envisioned in line with the URDPFI master planning guidelines.

General Process of Climate Change Adaptive (CCA) Master Planning for New Industrial Parks (IPs)

(1) Pre-planning Stage

- Decision to set up New IP
- Decision to Prepare Plan for New IP
- Development of Aims and Objectives
- Decision on Type of IP and its constituent Industries
    - Analysis of Types of industries to be included in the proposed IP
    - Analysis of nature of building and infrastructure requirements within the proposed IP
- Decision on Scale of IP
- Site Selection (use of GIS and remote sensing data based search)
- Local Geo-climatic assessment
- Simplified Site and Hazard related Data collection
    - Hazard mapping
    - Climate Risk Assessment

(2) Awareness Stage

- Capacity Building (Awareness program for the stakeholders, nearby residents, IP managers).

(3) Planning Stage

- Risk Potential Assessment (GIS and remote sensing data based)
    - Analysis of potential Hazards
    - Analysis of potential Impacts on the identified site

- Land Suitability Analyses for the identified site
- Identification of an alternate site in lesser hazard potential region (in case of significant hazard potential in the selected site)
- Simplified Plan Preparation (Plot Layout, Infrastructure network alignment etc.) (Flood Management, Cyclone Management, Fire Services Management etc.)
- Alternative plan preparation
- CC Adaptation through inclusion of mitigations measures, based on the Hazard potential assessment (embedded in planning)
- Plan Evaluation (transparency through participation of Stakeholders)
- Adherence to Statutory Obligations (CRZ Notification, Environment Policies and Statutory Obligations, National Environment Policy 2006, EIA Notification 2006, Environment Protection Act 1986, Environmental Guidelines for Industries, Forest Conservation Act 1980, Guidelines for Buffer Zones for various types of development, Water bodies in urban areas, Advisory Report for Conservation and Restoration of Water Bodies in Urban Areas' & Repair, Renovation & Restoration)
- Plan approval

(4) Plot Allotment Stage

- Plot Allotment

(5) Implementation and Monitoring Stage

- Simplified Plan Implementation (including Monitoring)
- Clearly defining Roles and Responsibilities of all the stakeholders for implementation of the plan

(6) Overall Mitigation Management Stage

- Preparation of Climate-induced Disaster Management, Preparedness and Mitigation Plan for probable occurrences in future (Flood Management, Cyclones Management, Fire Services Management)

General Process of Climate Change Adaptive (CCA) Master Planning for Existing Industrial Parks (IPs)

(1) Pre-planning Stage

- Hazard / Climate Risk Assessment for all the existing IPs
  - Analysis of potential Hazards
  - Analysis of potential Impacts on the identified site
- Local Geo-climatic assessment
- Identification of specific existing IPs, based on the Base-line Risk Analysis

- Simplified Site and Hazard related Data collection
- Climate Risk Assessment
- Decision to Prepare CC Adaptation Plan for the existing IPs, and its constituent Buildings and Infrastructural Services
- Analysis of Types of constituent industries and Infrastructural Services in the selected existing IPs
- Analysis of Impacts on the IP
  - Site Layout Level
  - Infrastructure Network Level
  - Building Level

(2) Awareness Stage

- Capacity Building (Awareness program for the stakeholders, nearby residents, IP managers)
- Clearly defining Roles and Responsibilities of all the stakeholders for implementation of the plan

(3) Planning Stage and Detail Engineering Stage

- CC Adaptation Planning and detail engineering through incorporation of mitigations measures based on the Hazard potential assessment (Flood Management, Cyclone Management, Fire Services Management etc.)
  - Site Layout Level
  - Site Infrastructure Network Level
  - Building Level
- CCA Adaptation / Mitigation Plan Evaluation (transparency through participation of Stakeholders)
- Adherence to Statutory Obligations (CRZ Notification, Environment Policies and Statutory Obligations, National Environment Policy 2006, EIA Notification 2006, Environment Protection Act 1986, Environmental Guidelines for Industries, Forest Conservation Act 1980, Guidelines for Buffer Zones for various types of development, Water bodies in urban areas, Advisory Report for Conservation and Restoration of Water Bodies in Urban Areas' & Repair, Renovation & Restoration)
- CCA Adaptation / Mitigation Plan approval

(4) Implementation and Monitoring Stage

- Plan Implementation
  - Construction
  - Supervision
  - Compliance Monitoring

(5) Overall Mitigation Management Stage

- Preparation of Climate-induced Disaster Management, Preparedness and Mitigation Plan for probable occurrences in future (Flood Management, Cyclones Management, Fire Services Management)

4.1 Selection of Measures – Economic Evaluation Tools

Once all possible measures are identified the relevant adaption measures must be chosen. As resources are often constrained, it is crucial to select the adaptation measures, which are most effective for the particular situation.

There are various tools that aid the planners to select the adaptation measures that give the most efficiency in their specific case. Some very commonly used ones, and also in detail explained in the CCA Guidelines as methods of price fixation, are:

(1) Cost-Benefit Analysis (CBA)

(2) Cost-Effectiveness Analysis (CEA)

(3) Multi-Criteria Analysis (MCA).

Each approach has particular characteristics and therefore particular situations that they are appropriate for. The following are basic elements of the decision-making process about which tool to use:

- If all the costs and benefits of the adaptation measures are measurable in monetary terms, then a CBA will be the most logical tool.
- If it is possible to quantify the costs and benefits of adaptation measures, then a CEA can be considered.
- An MCA should be implemented, when it is not possible to define all the costs and benefits as monetary terms, but it is possible to rank them with respect to certain criteria.
- In situations when even a ranking is not possible, then other means of evaluation tools should be considered. This can be an expert panel, where an assessment of the measures is carried out. [3]

Multi-Criteria Analysis

As mentioned above, the particular characteristic of the Multi-Criteria Analysis (MCA) is that it allows the assessment of different adaptations options and measures against a number of criteria. Instead of expressing every cost and benefit of a measure in monetary terms, MCA allows the planners to give weighting to different criteria and rank the measures accordingly. By using this weighting, an overall score for each adaptation option is obtained, and the adaptation measure to choose would be the one with the highest score.

Multi-Criteria Analysis becomes very useful for the planners first of all when not all of the data is available, which can easily be the case in an uncertainty environment. It is also possible that various cultural and ecological considerations are involved in the selection of the measures and these are hard to determine as quantitative entities. Another situation where MCA becomes a suitable evaluation tool is when there are a lot of criteria to consider other than the monetary benefits and effectiveness.

[3] GIZ, Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty, 2013

UNFCC (United Nations Framework Convention on Climate Change) defines five main steps of a MCA:[4]

(1) Agree on the adaptation objective and identify potential adaptation options

(2) Agree on the decision criteria,

(3) Score the performance of each adaptation option against each of the criteria,

(4) Assign a weight to criteria to reflect priorities,

(5) Rank the options.

Cost-Effectiveness Analysis

The cost-effectiveness analysis (CEA), as also explained in the Guidelines Document as a method of price fixation, is the method to choose when there are several adaptation options available for reaching the same particular adaptation objective. The method is used to identify which adaptation measure would be the most cost effective one to reach the particular objective. In other words, it determines how a well-defined objective can be achieved in the most cost-efficient way.

In the cost-effectiveness analysis, the costs need to be quantified in monetary terms. When it comes to assessing the benefits, the monetary terms are not used – if benefits are also expressed in monetary terms, this would lead to a cost-benefit analysis. An example of a non-monetary benefit-demonstration is the number of animals preserved in a biodiversity program.[5]

Cost-Benefit Analysis

Cost-benefit analysis is the right tool to use when all the costs and benefits of an adaptation option can be quantified in monetary terms, and economic efficiency is the most important decision making criteria in the particular situation. This approach involves calculating and comparing all the costs and benefits of a measure, expressing all variables in monetary terms.

The cost-benefit analysis results with a Net Present Value (NPV) and a Cost-Benefit Ratio (BCR). NPV describes the difference between the present value of the benefits and the value of the costs. BCR describes the ratio of the present value of the benefits to the costs. Benefits and costs are each discounted at a chosen discount rate. The cost-benefit analysis also gives us a payback time, which indicates how much time has to pass until the investment pays itself with its savings.

These terms and steps of carrying out a cost-benefit analysis are demonstrated in an example calculation below.

Example of a Cost-Benefit Analysis

The following example demonstrates how to carry out a CBA for an adaptation measure. The adaptation measure Water Efficient Fittings is chosen for the demonstration.

Water Efficient Fittings are efficient ways of decreasing the water consumption in Industrial Parks, and so an important measure to consider under the increasing risk of water scarcity. When such fittings are installed, they require less water to satisfy particular demands, which results in reduction of water use. The vulnerability of the Industrial Park to the increasing water

[4] UNFCC, Assessing the Costs and Benefits of Adaptation Options, An Overview of Approaches, The Nairobi Work Programme

[5] GIZ, Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty, 2013

scarcity issues (concerning the climate change hazards of heat waves and droughts in Andhra Pradesh and Telangana) would also decrease, as the need for water will decrease in the buildings. Water Efficient Fittings should directly be an integral element of the technical infrastructure for new buildings. The retrofitting of the existing fittings into more efficient ones is also a relatively simple process. Showerheads, toilet flushes, water tabs are options for Water Efficient Fittings.

In order to be precise, the example chosen here covers the replacement of existing flushing systems of the toilets with new water efficient ones. This measure will be applied to an office building in the Industrial Park.

Water Efficient Fittings

Retrofitting Existing Toilets with Water Efficient Ones

Replacing the flush tanks in the toilets has an initial investment cost. This replacement will cause a radical decrease in the water use of the building, which will result with a decrease in the water costs of the Industrial Park, as well as the vulnerability to the water availability situation in times of water scarcity.

The hypothetical office building[6] covers an area of 1800 m^2 and has 300 employees. The building is actively used within working days for 239 days a year and receives in average 80 visitors per day. There are 10 toilets in the building.

The total annual water consumption in the building is 1116 m^3, and 61% of this consumption is done by the use of toilets in the building. The existing flush tanks in the toilets use 9 litres of water for each time flushing and in total 681 m^3 water in a year.

Replacing these flush tanks with new water efficient ones, which will use only 4 litres of water per flush, means a significant decrease in the annual water consumption. This will naturally decrease the water bills. The water tariff is accepted to be 120 INR/m^3. The expected lifespan of the new fittings are 5 years, and the discount rate is expected to be 9%.

Information about the new toilet fittings:

Water efficient flush tank – average rate flow:	4 litres per flush
Lifetime of new fitting:	5 years
Investment cost of replacing one flush tank:	1350 INR
Water supply and wastewater tariff:	120 INR/m^3
Discount Rate:	9 %

The costs of this measure are limited to the initial replacement of the flush tanks in the toilets. Directly after this replacement, the water consumption will decrease.

The exact cost-benefit analysis is as following:

Average flow rate of existing fittings	9 litres per flush

[6] This hypothetical example and the steps of calculation is based on the following publication: USAID & Jordan Ministry of Water and Irrigation, Chebaane and Hoffmann, Office Buildings Water Efficiency Guide

Percentage of water use	61%	
Annual water consumption	681 m^3	
Average flow rate of new fittings	4 litres per flush	
Number of fittings	10	
Cost of retrofitting each toilet	1350 INR	
Total cost of retrofitting	13500 INR	*Number of fittings*cost of retrofitting each fitting*
Percentage of saving per fitting	55,6%	*(Average flow rate of existing fitting – new fitting)/existing fitting*
Average annual water savings	378,3 m^3	*Percentage of saving per fitting*annual consumption*
Average annual savings	45400 INR	*Water tariff*average annual water savings*
Discounted benefits over life time*	192483,28 INR	*Calculated by adding the discounted value for each year (for 5 years with a discount rate of 9%)*
Benefit-Cost ratio	14,3	*Discounted benefits over life time/Total cost of retrofitting*
Payback period	3,57 months	*Total cost of retrofitting/Average annual savings*12*

***Discounted Benefits Over Life Time:**

Year	Dis-count Factor	Discounted Total Costs per Year			Discounted Total Benefits per Year		
		From	To	Average	From	To	Average
1	1,00	13.300	13.700	13.500	45.200,00	45.600,00	45.400,00
2	0,92				41.467,89	41.834,86	41.651,38
3	0,84				38.043,94	38.380,61	38.212,27
4	0,77				34.902,69	35.211,57	35.057,13
5	0,71				32.020,82	32.304,19	32.162,50
Sum		13.300	13.700	13.500	191.635,34	193.331,23	192.483,28
Net Present Value (NPV): 178.983,28				*discounted total benefits – discounted total costs*			

Retrofitting the existing flush tanks in an office building in the Industrial Park with more water efficient ones (using 4 litres per flush instead of 9) will pay itself back not 4 months after its replacement. The significantly high benefit-cost ratio also indicates the effectiveness of the measure.

The cost-benefit analysis concentrates solely on the economic benefits of the adaptation measures, and demonstrates the savings that the Industrial Park makes after going through with the initial investment. However, costs and benefits cannot be expressed in terms of monetary terms in every case. Climate change and corresponding hazards and impacts put human life and ecological system under risk, and all these different criteria should be thoroughly considered with experts before making decisions about adaptation strategies.

4.2 Funding of Engineering Measures

If costs are determined and the measure has been chosen according to their benefits, funding sources must be identified. Several sources are available to finance adaptation measures for industrial parks in India.

Generally, one can distinguish between:

- Funds, directly financing programmes or measures
- Governmental Incentives or compensation
- Privately financed measures

For detailed information please refer to the report “Climate Financing for Industrial Parks”, published by INTEGRATION GmbH in 2016.

Indian Funding Organisations / Programs

The most prominent fund on national level is the National Adaptation Fund on Climate Change (NAFCC) for India. The fund supports activities related to clime change not covered by other governmental funded initiatives. For the year 2016 and 2017 the NAFCCC had dedicated a budget of INR 3500 Million for the year 2016-2017, with a cap of INR 250 Million per program or project.

Other funds include:

(1) National Action Plan on Climate Change (NAPCC): A comprehensive NAPCC is prepared by India Government with a view to achieve sustainable development with co-benefit in terms of climate change.

(2) Green Climate Fund (GCF) NABARD (National Bank for Agriculture and Rural Development): Accredited by the NABARD has already taken various initiatives in addressing the challenges posed by Climate Change particularly in the areas of agriculture and rural livelihood sectors.

Apart from the above various nationalised bank, private banks and insurance agencies offer property insurance and accident insurance options which are to be explored, a portion of cost to be allocated for the same.

International Funding Organisations

Multiple funds financing climate change adaptation measures are available under the different programs in India. The INTEGRATION report identifies a number of funds, such as:

(1) Global Environment Facility,

(2) Green Climate Fund

(3) Climate Investment Fund of the World Bank

(4) Adaptation Fund under the UNFCCC

The Green Climate Fund seems to be the most suitable for CCA measures in IPs in India. The Green Climate Fund provides funding for projects in the sector “Infrastructure and Built Environment. More information can be found in the report “Climate Financing for Industrial Parks” and under the website of the Green Climate Fund: http://www.greenclimate.fund/home

Governmental Incentives

As part of the Indian National Action Plan on Climate Change (NAPCC) several energy incentives have been passed, mainly targeting the promotion and development of renewable energies such wind and solar power. This is especially important for adaptation measures targeting a more resilient energy infrastructure, such as diversifying the energy provision through renewable energies. More information on incentives available to business can be found on the website of the The Indian Renewable Energy Development Agency under the Ministry of New and Renewable Energy:

http://www.ireda.gov.in/forms/contentpage.aspx?lid=724

Private Sector Funding

The private sector can play a pivotal role in initiating and financing adaptation measures in Industrial Parks. One can identify two general approaches:

(1) Direct private investment, sometimes co-financed by loans or governmental incentives/programmes,

(2) And green bonds, as a means of raising private finance from capital markets. However, the focus of green bonds has been on mitigation activities, hence they are not highlighted in the following section.

Broadly speaking, direct private investments in adaptation measures can be differentiated between companies investing in to protect their assets and from climate change effects, companies generating a service/profit through financing measures and voluntary investment into climate adaptation measures through Corporate Social Responsibility (CSR) frameworks. More information including examples on private finance initiatives can be found within the Private Sector Initiative (PSI) of the Nairobi work programme:

http://unfccc.int/adaptation/workstreams/nairobi_work_programme/items/6547.php

4.3 Marketing, Evaluation and Supervision of Works

4.3.1 Marketing

Incorporating adaptation strategies and measures into the designs of Industrial Parks and premises can be a strong asset, if accordingly communicated and marketed. Marketing of adaptation measures can significantly increase the chances to develop the entire zone or promote singe plots. Marketing adaptation measures can incorporate the following actions:

(1) Developing a marketing and promotion strategy determining what channels will be used to communicate information on climate change risks and mitigation measures to the stakeholders

(2) Proactively show risk of climate change effects and potentials of adaptation measures to businesses and industries

(3) Market the zone or plot as “climate-proofed”, significantly reducing the investment risk for the buyer or tenant

(4) Indicate concrete adaptation measures in sketches, drawings or photos as part of due diligence materials provided to prospective tenants or purchasers

(5) Include both asset ratings (EPCs, BREEAM/LEED certificates) and operational ratings (Display Energy Certificates), alongside key indicators such as rental value, location and service charge.

4.3.2 Awareness Raising

The success of the CC adaptation would greatly depend on the implementation of the guidelines in appropriate manner. A vital step in the implementation process would be making the stakeholders as well as the common people aware of the hazards they are subjected to and the common approaches, minimum tools and guidelines and standard messages required to mitigate the impacts caused by the hazards.

Degree of awareness would differ for the new IPs and existing IPs depending on the level exposure to impacts. Preliminary guidelines for raising awareness for the different industry situations have been stated below.

(1) For New IPs

- Provide knowledge in simple terms (through handouts with illustrations and sketches) on the gravity of hazards and risk impacts to the stakeholders, and a brief idea of the probable financial loss on property, operation, people, and business.
- Implement frequent short-duration (1–2 days) awareness-raising interactive programs for the decision-makers and potential industry owners.
- Implement frequent medium-duration (3-5 days) training programs for the planners, engineers, and the representatives of the potential industry owners who would be responsible adaptation process.
- Highlight the properties as Climate Change Adapted along with the reduced risk potentiality and low investment requirement in future supported with simplified life-cycle cost-benefit analysis.
- Publicise the approved Govt. benefits, rewards and incentives to the potential investors, through social media.
- Transmit information to the population regarding emergency-response plans and measures for areas potential for hazard risks for their potential threat during the disaster.
- Develop and implement education and awareness-raising program for the public to stimulate people’s participation in preventing disasters, through public forums and workshops.

(2) For Existing IPs

One of the sub-committees of IALA (Industrial Area Local Authority) is environmental sub-committee. One of the roles of this sub-committee should be to include CCA measures into their industrial parks.

- Establish an exchange group involving decision-makers, planners, engineers, and existing industry owners, emergency response organisations.
- Develop media-based/online communication plans to disseminate information on climate change risks and probable mitigation measures to the stakeholders.
- Provide knowledge in simple terms (through hand outs with illustrations and sketches) on the gravity of hazards and risk impacts to the stakeholders, and a brief idea of the probable financial loss on existing property, operation, people, and business.

- Implement frequent short-duration (1 day) awareness-raising interactive programs for the decision-makers and existing industry owners.
- Implement frequent medium-duration (3-5 days) training programs for the planners, engineers, and the representatives of the existing industry owners who would be responsible adaptation process.

4.3.3 Industrial Environment Improvement Drive (IEID)

Every years industrial infrastructure corporation (APIIC and TSIIC) carry out one-month long environment improvement drive, since 2013. This is celebrated from June 5, World Environment Day till July 5. Many activities are carried out in the industrial parks which includes

(1) Awareness generation through experts in the industrial parks

(2) Carrying our rallied involving all the stakeholder

(3) Waste Management

(4) Plantation Drives

(5) Awareness Material and Banners

(6) Corporate Social Responsibilities

In addition, every year, three industrial parks are awarded for their contribution in implementing environmental measures in the industrial park. This concept was initiated in 2013 in united Andhra Pradesh, but now it is replicated in the industrial parks of Gujarat, Delhi and Uttarakhand,

CCA has been considered in these parks as part of awareness generation since 2015. This has to be one of the major topics from future IEID programmes.

4.3.4 Publicity

Publicity is the simplest mechanism by which a common mass can be reached for dissemination of information. The mode of publicity may be through print media (such as newspapers, brochures, handouts, bill boards etc.), digital media (such as social media, digital advertisements etc.). The basic objective of the publicity is to forward the information in the most easily comprehensible manner.

Some suggestive approaches to publicity are presented below.

(1) Communicate the required broad level adaptation measures along with the reduced risk potentiality and low investment requirement in future supported with simplified life-cycle cost-benefit analysis.

(2) Provide information on the approved Govt. benefits, rewards and incentives to the existing industry owners, through interactive workshops. Personal visit of the Govt. representatives/agents to the individual industries would be more effective.

(3) Publicise the names of the industry who have complied with the CCA frequently on the social media.

(4) Handholding the individual industries providing the detail engineering implementation guidelines and periodic supervision through consultative mode.

4.3.5 Evaluation and Supervision of Works

Supervision of the Works

(1) Project Management

The APIIC / TSIIC / IALA may decide to entrust the day-to-day management (monitoring and inspection) of the project to a third party as project management consultant.

(2) **Third Party Quality Inspection:**

A third party, with due competence and experience of performing similar nature and scale of works, to be appointed for periodic inspection and assertion of the quality and compliance as specified in the approved schedule of works, specifications, and various conditions the contract.

(3) **Field Inspection:**

After assessing the nature of critical elements to be observed, special inspection to be performed by the qualified in-house experts. In addition, qualified domain experts may be included in the team during inspection based on the experience and exposure to the similar situation.

Frequency of observation and need for special inspections will depend on the outcome of the risk assessment, complexity of the facility, material specification, and competence of the general contractor, subcontractors, and credibility of the material suppliers.

4.3.6 Monitoring

Success of all the CC adaptation approaches would depend on the efficacy of the monitoring process and appropriate implementation of the same. There are multiple facets of monitoring which are vital for effective CC adaptation, such as, legal enforcement, post-occupancy evaluation, periodic inspections, maintenance, repair & replacement, and emergency response & preparedness, as detailed below.

(1) Legal Enforcements

- Enforce regulatory / law and order mechanism to eliminate / minimise visible obstacles by the local community residents or individual industry property owners while implementing adaptation measures.
- Brainstorm and convince the stakeholders or decision-makers who may think that climate change poses less risk than other dangers and are therefore assigns low priority.
- Create and update ‘Knowledge Database’ on the options that would reduce climate risks and of the means to implement them.
- Eliminate, through funded research, the uncertainty about the future occurrence, and subsequent action plans (what to do / when to do). Irreversible consequences of some actions can delay choices until uncertainty is resolved.

(2) Post-Occupancy Evaluation

- The planning and engineering team, appointed by IALA, shall conduct post-occupancy evaluation of the newly built IPs, and advise IALA of the requirements periodic inspections, maintenance, and timely repair of specific sectors susceptible to deterioration.
- The planning and engineering team, appointed by IALA, shall conduct post-occupancy evaluation of the newly built industrial properties, and advise the industry owner of the importance of periodic inspections, maintenance, and timely repair, at the time of design, construction and maintenance.
- Post-occupancy evaluation of the property (building, services, landscape) to be carried out annually to ascertain the nature and trend of decay and deterioration of various components of the infrastructure and service conditions.
- A major repair and replacement planning to be initiated by IALA after a span of 5 years for the new buildings in the new IPs, even if no disaster during before that period.

(3) Periodic Inspections, Maintenance, Repair and Replacement

- IALA shall take the responsibility of providing technical support for mandatory periodic inspection and indicate that, failure of building components that are not maintained properly, repaired or replaced, can present a considerable risk of injury or death to occupants, and the continued operation of the industrial function may be jeopardized.
- It is important for the industry owner to understand that a property's / building's disaster impact resistance is likely to degrade over time due to weathering actions, and hence require regularly maintenance and repaired. The goal should be to repair or replace items before they fail during disaster. Periodic maintenance is less expensive than replacement after failure of the component and consequential damages.
- The building envelope and exterior-mounted equipment should require annual inspection and maintenance by competent persons. The items requiring maintenance, repair, or replacement should be identified, documented and scheduled for work.
- A special inspection is recommended following unusually immediately during early warning signal by the meteorology department, or after the disaster.
- In addition to inspecting for obvious signs of damage, the inspector should determine if cracks or other openings have developed that may allow water infiltration, which could lead to corrosion or dry rot of concealed components.

4.3.7 Maintenance

IALA shall provide an easily comprehensible and implementable Check List for in-house inspection, and basic-level maintenance Tips to every industry property owner at the time of allotment of the individual site.

IALA shall provide a list of competent and approved designers and contractors to the industry owners, on request.

Indicator-Based Assessment of Outcomes

Four areas of achievement that can be monitored and evaluated, as per UNDP framework (UNDP 2007):

- Coverage: Achievements regarding the involvement of stakeholders (viz. individuals, households, business, communities) in an intervention and the physical extent to which an intervention is implemented, (e.g. indicators include number of stakeholders implementing vulnerability reduction measures or length of coastline covered by interventions coupled with population of adjacent coastal areas)
- Impact: Outcomes of interventions
- Sustainability: Continuity of interventions in time scales beyond project implementation, (e.g. indicators include the perceived awareness of climate change within organizations compared to baseline levels)
- Replicability: Potential usefulness of results and lessons in comparable contexts, (e.g. indicators include the number of policies or guidelines incorporating project approaches and lessons learned)

Constitution of the IALA and Service Society

Indication on which sub-committee of IALA would be responsible for implementation.

4.4 Further Reading and References

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