Prefeasibility Report

for

Proposed Poly-Silicon Project
(30,000 TPA)

at

APSEZ, Kutch, Gujarat

Project Proponent

Mundra Solar Limited

Adani House, Near Mithakali Six Roads,
Navrangpura, Ahmedabad

1.0 Introduction to Project Proponent

Adani Group, currently the largest player in the Private Power sector through **Adani Enterprises Limited (AEL)** and **Adani Properties private limited (APPL)** is planning to expand its operations into renewable energy resources.

- **Adani Properties Private Limited (APPL)** registered in, 1995 is held by Mr. Pranav Vinodbhai Adani, Mr. Kamal Daulal Moondra and registered in Ahmedabad, Gujarat, India.
- **Adani Green Energy Ltd (AGEL)** is a Public Company incorporated in 2015. Directors of Adani Green Energy Limited are Mr. Gautambhai Shantilal Adani, Mr. Rajeshbhai Shantilal Adani and Mr. Vineet S Jain.

As part of this strategic plan, the Group plans to set up a State of the Art large-scale integrated manufacturing plant to produce Polysilicon, Crystalline Silicon Ingots and Wafers, Solar Photovoltaic Cells and Modules in India through **Mundra Solar Limited (MSL)**, a company with its registered Office in the State of Gujarat, incorporated to undertake, identify, formulate, design, develop, regulate, restructure, reorganize, participate and/or assist in the designing, development, construction, implementation, commissioning, operation and maintenance of solar photovoltaic equipments.

The Indian **Electronics System Design and Manufacturing (ESDM)** Industry is amongst the fastest growing sector driven by consistent increase in domestic demand of electronic products. The Indian Government has introduced several transparent and investment friendly policies to foster the growth of the Indian ESDM ecosystem that include **National Policy on Electronics (NPE); National Manufacturing Policy (NMP); Modified Special Incentive Package Scheme (M-SIPS); Electronic Manufacturing Clusters (EMCs)** to promote investment in manufacturing sector.

The EMC scheme has been notified on October 22nd 2012, to develop infrastructure in the **Electronics Systems Design and Manufacturing (ESDM) Sector**. The Government is offering a package of incentives to attract domestic and global investments into the ESDM sector within EMCs along with financial support for the development of infrastructure of EMCs.

Figure 1: Holding structure of MSL

Profile of Chief Promoters

- **Adani Enterprises Limited (AEL)** is a diversified conglomerate into coal mining and trading, which was listed in 1994. AEL over the years has transformed itself from a pure commodity player to a value enhancer with emphasis on asset creation for long-term sustainability. AEL on its own is the leading player in imported coal trading business in the country. AEL has more than two decades of experience in global trading with established business relationships with the global players. Currently, AEL is the largest importer of coal in India.

- AEL has leveraged on its star trading house experience and execution record of building mega projects to embark on an asset-backed diversification plan to exploit opportunities in infrastructure sector.
- AEL has been designated as Category I power trader (Highest Category in Power Trading Licenses) by CERC till June 9, 2029. AEL's power trading business involves making purchases of surplus power and selling this surplus to energy deficit electricity boards.
- **Adani Properties Private Limited (APPL**) was incorporated on 25th May 1995 as a Private Limited Company. APPL is mainly engaged in the business of let-out and/or lease of immovable properties and wholesale trading of commodities.
- APPL is part of promoter and promoter group of all the listed/to be listed entities of Adani group and holds strategic investment into Adani Enterprises Limited, Adani Ports and SEZ Limited, Adani Power Limited and Adani Transmission Limited.
- APPL has also invested in unlisted group companies which are mainly engaged in Real Estate and Green Energy Business.

2.0 Project Background

The project envisages setting up of **"30,000 MT Polysilicon plant"** located within a notified Electronic Manufacturing Cluster (EMC) facility of Mundra SEZ under the M-SIPS guidelines. This project will be one of the first such facilities located within an EMC facility to be set up in a Special Economic Zone (SEZ).

- The proposed Solar PV Manufacturing Unit within EMC facility will be located within existing Mundra SEZ, and benefits from the following common infrastructure already in place:
  - Mundra SEZ is equipped with a multimodal connectivity which includes road, air, sea and rail linkages.
  - Mundra SEZ is equipped with well-developed social infrastructure facilities for residential, commercial, education, health, recreational and others. In addition to these, the area has special infrastructure services like effluent treatment plants, desalination plant, water treatment plants and others which are ready for use based on the required capacity.
- Polysilicon is the most critical Raw material in the solar value chain. Approximately 90% of demand for Polysilicon comes from solar PV industry

2.1 Need of the project

Internationally, Polysilicon supplies are concentrated in China & US and hence there is a strong case for manufacturing in India. Due increasing demand of renewable energy; especially, there will be a huge demand for Polysilicon in future. Government has set up target for solar power capacity of 100 GW, by 2022. This target triggers the demand for large scale manufacturing of Solar PV components. Prevailing demand supply gap in manufacturing capacity creates a strong case for investments in domestic solar equipment manufacturing across the value chain.

2.2 Project-Salient Features

Features	Details
Land requirement	57.09 Ha
Land use	Entire land identified land for this project belongs to the APSEZL (An Adani Group Company) and is already designated for industrial purpose as per the local land use plan. There is no forest land involved in the project. No resettlement and rehabilitation is involved.
Proposed capacity	30,000 MTPA
Product	Polysilicone (Solar Grade Silicon)
Water requirement	25000 KLD Desalinated water will be sourced from APSEZL
Power	140 MW during operational phase from MUPL/Grid.

2.3 Project Cost

The approximate project cost is provided below:

Particulars	Cost *(In Rs. Crores)*
Land & Site Development	290
Building Cost	600
Equipment and Infra Cost (including EPC)*	5300
Research Equipment	50
Preoperative Cost	150
Contingency @ 5%	320
IDC Expenses @ 10%	671
Total Project Cost	**7381**

2.4 Employment generation

Manpower planning is very essential for 30,000 MT polysilicon plant of MSL given the fact that it has to consist of right number of people, right kind of people at the right phase and execution of the project and during operations to achieve business goals. MSL man power utilization rationale is based on the following approach.

- Analyze the current manpower inventory (industry) and make future forecasts based on the project phasing.
- Recruitment of best in the industry team for efficient management.
- Develop employment program for efficient use of resources.
- Design training programmes to enhance skills in line with the industry demands.

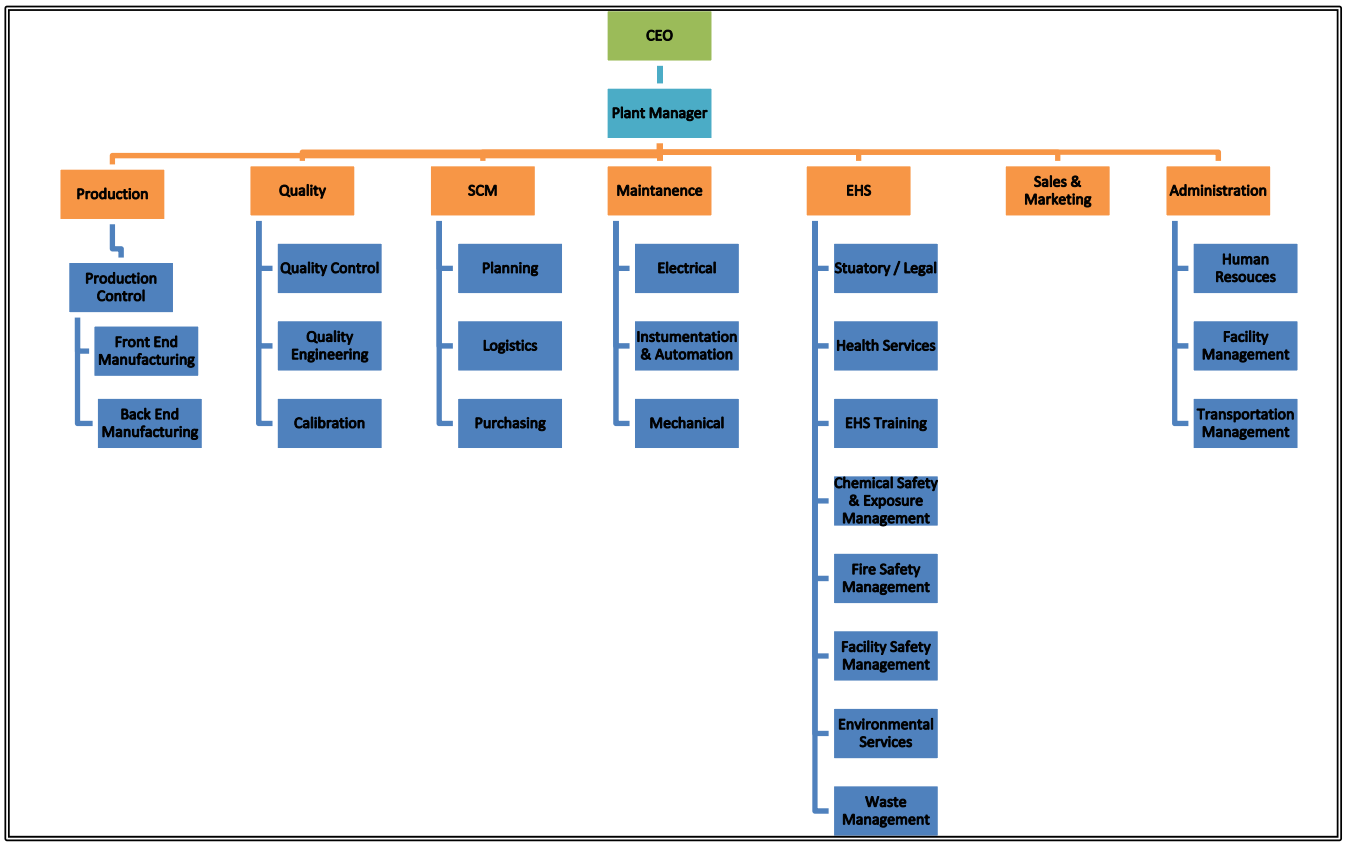
Manpower requirements

The manpower requirement includes a mix of Contractors, Engineer Staff and Workmen. The requirement proposed below is during the operation of plant after all the 3 phases are completely commissioned. The estimation of staff during the operation of plant is based on 3 shifts of 8 hour each as follows:

Manpower planning

Description	Polysilicon	Corporate
Contractors	300	-
Up -Front staff	600	-
Engineer staff	92	-
Management	40	46
Admin staff	62	6
Total	**1094**	**52**

Organogram:



3.0 Site Analysis

3.1 Locational benefits

The proposed 30,000MT polysilicon plant will be strategically located within north head of the approved EMC Unit which is being promoted and developed by MSTPL with in APSEZ. Located in the Gulf of Kutch, it is bounded by the sea in the south & west and by Rann (salt marshlands) in the east & North.

The proposed facility is located within an EMC facility of **640.89 acre** plot of land within the Mundra SEZ, about 60 KM from Bhuj airport and 65 KM from Kandla airport and well connected with State Highway No.6 and No.48, and National Highway 8A and NH 15 to key cities like Ahmedabad, Mumbai and Delhi.

APSEZ Mundra is also a gateway to Europe, the US, Africa and West Asia. Apart from location, competitive logistics costs to the customer's drives volumes at Mundra port. The Mundra Port has one of the deepest water draft depths on the west coast of India, ranging from approximately 16 meters to 20 meters berth side, and up to 32 meters at the single point mooring facilities, allowing APSEZ to accommodate capsize container cargo vessels of up to 10,000 TEUs, and VLCCs and ULCCs of up to 360,000 DWTs. The port also has world's largest coal unloading facility with capacity of 60 MMT. It handled 26.76 MMT in FY'13. It has fully mechanized fertilizer cargo complex and steel yard. APSEZ spread over 15,000 Ha out of which 6656 Ha had already been notified as SEZ in initial phase.

3.2 Multi-modal connectivity

APSEZ has multimodal connectivity and it is well connected with the region via existing National & State Highways i.e. NH-8A extension & SH-6. Existing APSEZ rail network from Adipur provide connectivity to the national rail network grid which any industrial setup requires; and would help the units in the EMC to reduce the operational cost and improve accessibility to the markets. APSEZ with port facilities has a natural advantage for being the most efficient gateway for land locked hinterland of the country, comprising North and North West India.

APSEZL has developed substantial infrastructure, including two inland container depots, 86 KM of railway track and a network of roads and flyovers connecting the Mundra Port to the regional road network. It is also connected by a railway line that is capable of handling double stack containers to Bathinda and the northern hinterland of India, and by branch lines to the Delhi-Mumbai freight corridor. Its two single-point mooring facilities are connected by pipeline to petroleum refineries in Panipat, Haryana and Bathinda, Punjab and the regional pipeline network, and port's liquid cargo storage and handling facilities are connected by POL pipeline to Bahadurgarh, near Delhi.

3.3 Port connectivity

Mundra Port, India's largest private port is the integral part of APSEZ, has a deep draft which enables large vessels like Panamax and super post Panamax to dock alongside its berth. The port has associate facilities like warehousing, container freight station (CFS), storage tanks etc. to add value to logistics needs.

3.4 Road connectivity

ASPEZ is connected to the National & State Highways Road network by NH-8A Extension and SH6 & SH 48. Broad four-lane roads ensure efficient movement of road traffic to and from the port. Four lanes ROB (Rail over bridge) in the SEZ Area of port ensure that the various modes of transportation do not impede each other's movement. APSEZL has developed road network within the SEZ with efficient designed for predominantly freight traffic, in order to provide high-level access to the various zones of APSEZ area like ports, warehousing, CFS, industrial establishments. The major spines run east-west and north-south of APSEZ area connected directly to State highways & National Highways via SH.

3.5 Rail connectivity

APSEZ is well connected with national railway network with the exiting BG link with Ahmedabad passing through Gandhidham and Viramgam. This has been facilitated by commissioning the 117 kms BG railway line and includes APSEZ and Adipur connectivity, situated at a distance of 8kms from Gandhidham.

APSEZL has developed and operates a private 64 KM double track railway line – largest private railway link in the country between Mundra and Adipur, connecting Mundra Port to the Indian Railways network at Adipur, Gujarat. It has also constructed and operates a 22 KM railway line through Mundra SEZ, connecting Mundra Port to Mundra-Adipur railway line and nearby power plants.

3.6 Air connectivity

Fully functional commercial airports are located at Bhuj (about 60 km) and Kandla (About 50km) from Mundra SEZ. A newly constructed airstrip at Mandvi is at a distance of 40 km. APSEZL has its own Airport at an approximate distance of 14.5 KM from the main port location. It is a licensed airport in 'Private Category' with Air Traffic Control (ATC) operated by the Airports Authority of India (AAI). The APSEZL airport has potential to develop commercial modern state-of-the-art international airport capable of serving requirements of cargo hub centre, MRO facilities, passenger/baggage handling facility, fuel refilling, aprons, hangers for various kind of aircrafts etc.

3.7 Logistics infrastructure

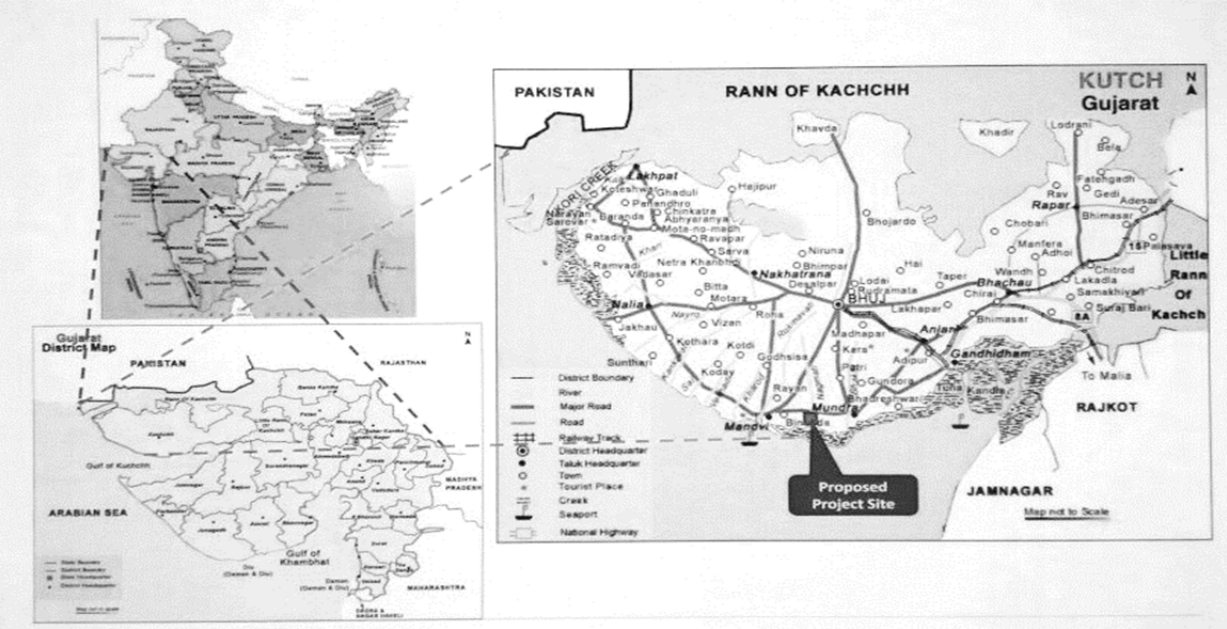
APSEZL also has logistics division which helps in integrating ports with industrial business hubs. It provides logistic services through its wholly owned subsidiary Adani Logistics Ltd. It currently owns and operates six trains of container cars across India. It also operates two rail linked Inland Container Depots (ICD) at Patli, Punjab and Kishangarh, Rajasthan. ICD Patli is a multi-functional logistics park, the single largest in National Capital Region (NCR). Company has developed two container freight stations at Mundra and Hazira. The proposed location of MSL facility within Mundra SEZ is having advantage of existing well established connectivity and accessible to the nearby region via road, rail and air.

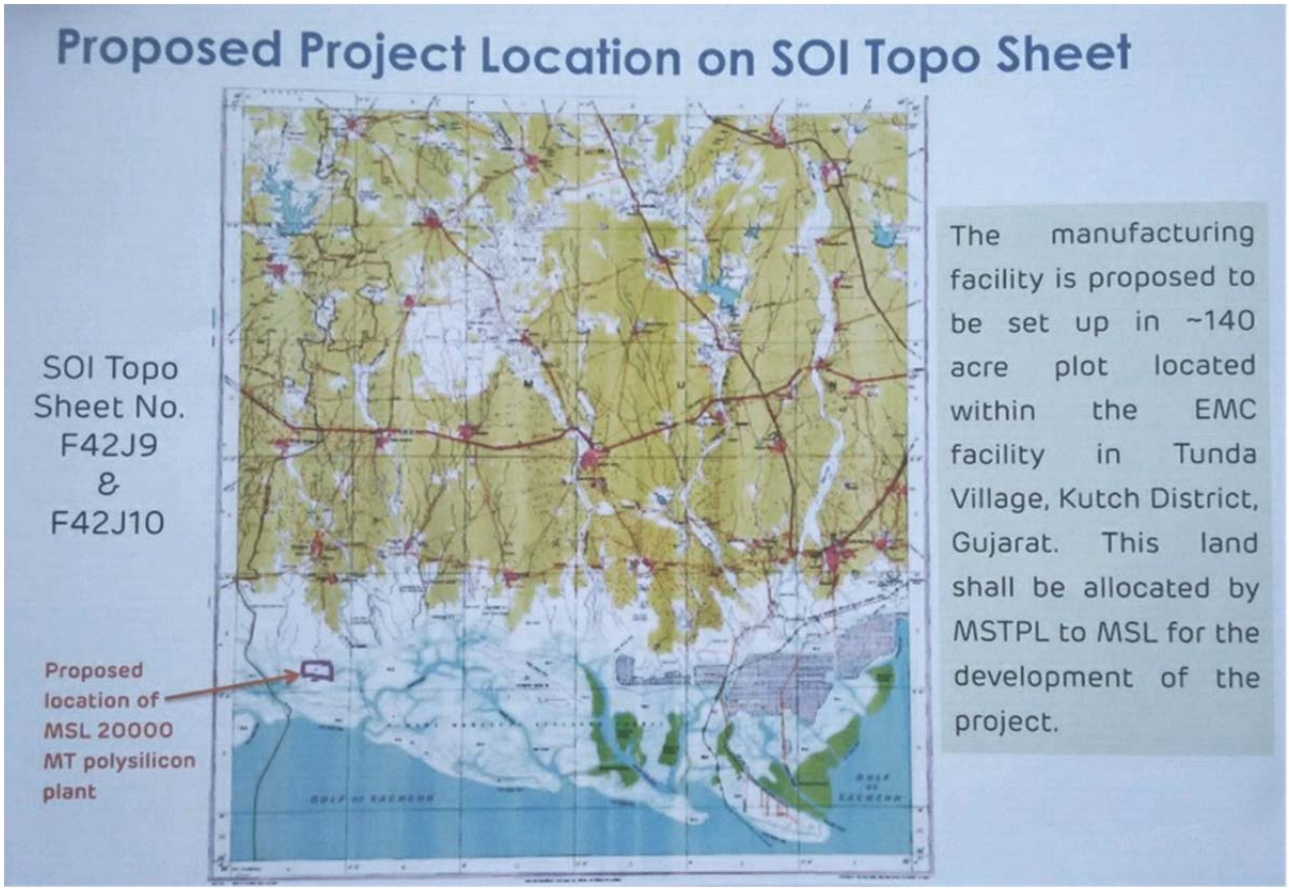
Environmental Setting

Sr. No.	Particulars	Details
1.	Latitude	$22^0$48'00.74"
2.	Longitude	$69^0$31'37.00"
3.	Location	Survey No. 180/P in notified APSEZ
4.	District	Kutch
5.	State	Gujarat
6.	Nearest Railway Station	Bhuj, 55 km
7.	Nearest other Airport	Bhuj, 55 km
8.	Forests	Dandedri RF (2.9 km) Mundra Mangrove RF (2.0 km) Navinal RF (5.7 km) Mundra Dhao RF (5.0 km)
9.	Water bodies	Kotri creek (1.5 km, E) Khari Nadi (1.3 km, NE) Gulf of Kutch (1.6 km, S)] Nagavanti Nadi (10 km, E)
10.	Inland, coastal, marine or underground waters	Gulf of Kutch (1.6 km, S) Kotri Creek (1.5 km, E)
11.	Densely populated or built up	Mundra (22 km)

Sr. No.	Particulars	Details
	area	
12.	Defense installation	Nil
13.	National Parks & Wild life sanctuaries	Nil
14.	Seismic Zone	The project area falls under Seismic Zone-V as per IS: 1893 (Part 1): 2002.

Location map





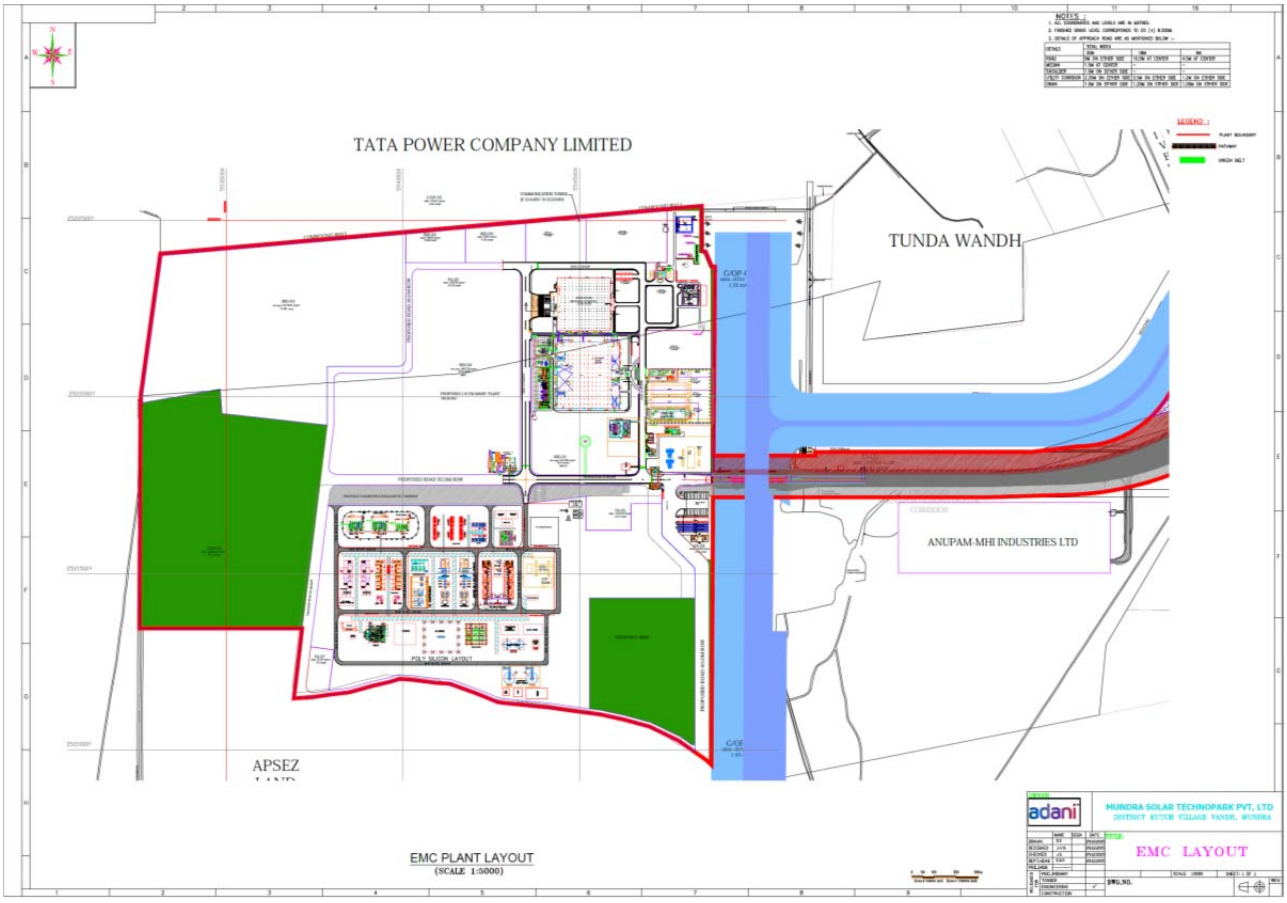
Project location on Google Map

Project surrounding within 5-km radius

3.8 Plant Layout

The manufacturing facility is proposed to be set up in 57.09 Ha plot located within the EMC facility in Tunda Village (latitude $22^0$48'00.74"N and longitude $69^0$31'37.00"E) Kutch District, Gujarat. The manufacturing unit is easily accessible by road from NH-8A with extension between Gandhidham and Mandvi towns.

The approach road to EMC facility is through an extension of existing SEZ road (near ANUPAM project) by 1.2 KM approx. including 300m Length Bridge over intake channel. The proposed manufacturing unit will get connected to State Highway (SH-6) via 3.5 KM APSEZ road to SEZ Gate (GATE no. 3A) and continuing up to SH-6 over a distance of 3.6 KM. Further connectivity from SH-6 to NH-8a ext. via Mota Kandagra village over a distance of 7.5 KM exists



Proposed location of MSL 20000 MT Polysilicon plant

3.9 Layout of EMC Facility

Proposed plant layout for Polysilicon manufacturing

MSL is planning to partner with an established technical company who can establish the process, supply technology, automation and control platform. MSL will use the supplier's experience and process knowledge systems to help MSL plant produce an estimated 30000 tons of Polysilicon annually. The recommended land area for a 30,000 tons state of the art Polysilicon plant allowing for use of setbacks, expansion of operations and green space to keep certain operations distant from each other is 325050 m^2.

MSL proposes to lease an area of approximately 57.09 Ha within an EMC facility in close proximity to water source availability. This will allow for future expansion into manufacture of silicon Polysilicon, ingots and wafers at a future date. This production facility will include the floor space optimized for plant

equipment's, change room, raw materials stores, finished goods stores and Waste water treatment plant to ensure a smooth and safe operation. The manufacturing facility will operate in three shifts throughout the year.

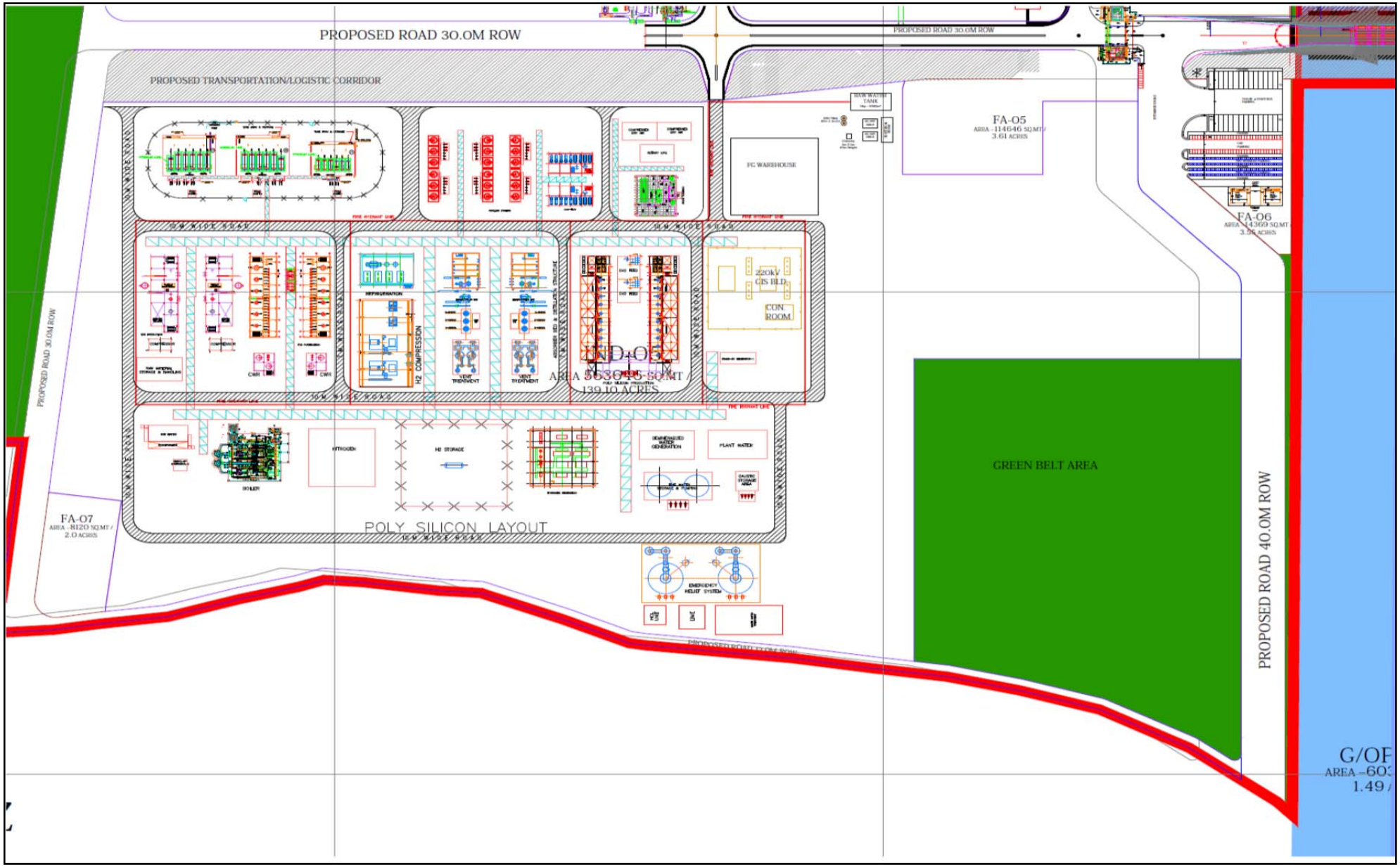
MSL as a Polysilicon producer is designing the plant with utmost plant safety as the processes are critical. Both the design and the execution of expansion and upgrades to projects are critical as MSL strive for minimal down time so that productivity is not affected in the downstream process. The plant brings in high level of automation - for automatic transport, crushing, classifying material tracking and storage system.

The basis of Polysilicon plant design is based on the following requirements.

- Final Process Design and technical partner selection
- Final plot plan
- Detailed Capex estimate
- Detailed Operating cost estimate
- Detailed Project Schedule
- Detailed data for utilities
- QC procedures
- Polysilicon products specifications
- Layout optimized for design capacity

List of buildings planned:

- Metallurgical grade Silicon milling
- HCl generation / Hydrogen generation and purification
- Administration building and quality control lab
- Ware housing- raw material. Finished goods
- Centralized control room
- Tank farm area
- Effluent treatment plant section
- TCS reactor building
- TCS purification
- Poly silicon deposition and STC converter room
- Vent gas recovery system buildings
- Utility Building
- Engineering workshop
- R&D building
- Captive / Emergency power supply



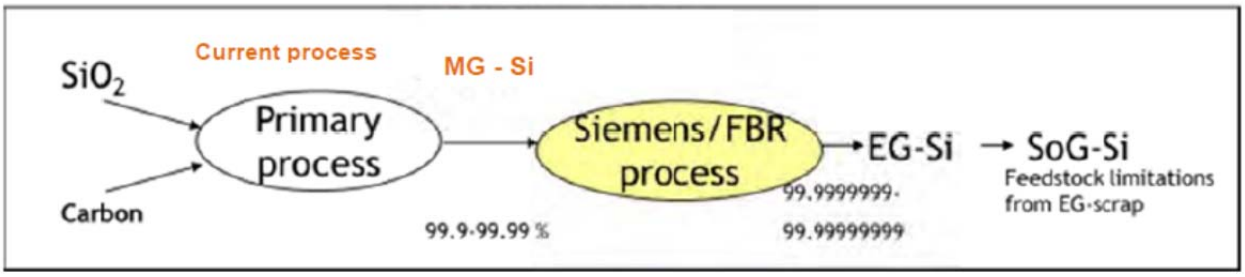
Polysilicon manufacturing plant layout

4.0 Project Description: 20000 MTPA Polysilicon Manufacturing

Polysilicon accounts for about 30% of the cost of a finished solar panel. Approximately 90% of demand or polysilicon comes from solar PV industry. Polysilicon process have been volatile earlier, until the construction of new plants in the recent times adding significant capacity supply to the market. Production requires large processing plants that may cost up to INR 3.5 million per MT to build.

Before silicon rod/Boule is cut into thin wafers, the raw material to be purified, so as to make the "photo volatile effect" efficient. The process of making low pure metallurgical grade silicon from basic raw material of quartz (sand) and carbon through a thermic reduction happens in a submerged arc furnace followed by production of Chlorosilanes (basic raw material) by reacting with HCl.

The final stage is Chemical Vapour Deposition (CVD) process, where chlorosilanes will be converted into pre silicon. Alternatively high Silane (SiH_4) gas is generated from TCS and then converted into high pure Si granules in Fluid Bed Reactors (FBR).



With the patented process of Dynamit Noble expiring, there are few players who offer the package for Hydro Chlorinated and Siemens based CVD process and FBR process in polysilicon manufacturing.

Major technology players - Siemens and FBR process

	Technology Providers	Technology	Region
1	GTAT (GT Advanced Technologies)	Siemens Based CVD reactor	USA
2	Centrotherm SiTec	Siemens Based CVD reactor	Europe
3	Poly Silicon Technologies (PST)	Siemens Based CVD reactor	USA
4	SCC (Silicon Chemical Corporation) Wacker	Siemens Based CVD reactor	
5	Virasa Technologies		USA
6	REC Silicon and	FBR	Norway
7	MEMC Silicon	FBR	Singapore

Major technology players in TCS manufacture and technology holders

	Technology Providers	Country of Origin
1	Wacker Chemie,GmbH	Germany
2	DOW Corning Corp.,	Michigan
3	Union Carbide,	Virginia
4	Dynarait Noble	(Later became Huls, Degussa and now Evonik)
5	Osaka Titanium	Japan
6	Chisso,	Japan
7	Shin Etsu Handotain	Japan

Details of product and raw materials:-

- **Products:-**

Sr. No	Name of the Product	production MT/Annum	Maxi Storage	Chemical formula	Physical State	Storage In (MOC)
1	Poly Silicon or poly crystalline silicon	20,000	1500 MT	Si	Solid	As 10 Kg PE Bags

- **Raw Material:-**

Sr. No.	Name of the Raw Material	Consumption MT/Annum	Maxi Storage	Chemical formula	Physical State	Storage In (MOC)	Source
1	Chlorine	4000	36 Tone (900 kg * 40 Tonner)	Cl_2	Gas	Tonner	Domestic
2	Hydrochloric Acid	1200	10000 L (1x1000L IBC)	HCl	Liquid	IBC	Domestic
3	Hydrogen Gas	3200	50 kg 12 kg pressure	H_2	Gas	Pipeline	In-house manufacturing
4	Tri Chloro Silane	107,200	1000 CuM	$SiHcl_3$	Liquid	SS Tank	Produced as part of the Poly Si process cycle by reaction of HCl with MG-Si
5	Silicon Tetrachloride	22500	1000 CuM	$Sicl_4$	Liquid	SS Tank	Produced as part of the Poly Si process cycle
6	Metallurgical Grade Silicon	21600	18000	MG-Si	Solid	Jumbo Bags	Import
7	Nitrogen	130,000	Two tanks of 200 m3 capacity each	N_2	Gas	Pipe Line	In-house Manufacturing

- **Intermediate product:-**

Sr. No	Name of the Raw Material	production MT/Annum	Maxi Storage	Chemical formula	Physical State	Storage In (MOC)	Source
1.	Silane	22500	1000 CuM	SiH_4	gas	--	In house
2.	Tri Chloro Silane	107,200	1000 CuM	$SiHcl_3$	Liquid	SS Tank	Produced as part of the Poly Si process cycle by reaction of HCl with MG-Si
3.	Silicon Tetrachloride	22500	1000 CuM	$Sicl_4$	Liquid	SS Tank	Produced as part of the Poly Si process cycle
4.	Hydrogen Gas	3200	50 kg 12 kg pressure	H_2	Gas	Pipeline	In-house manufacturing
5.	Nitrogen	130,000	Two tanks of 200 m3 capacity each	N_2	Gas	Pipe Line	In-house Manufacturing

Brief Description of Handling, storage and internal transportation at site for all raw materials, intermediate products and final product:

Production process of Poly Silicon is covered in four steps as follows,

1) Synthesis: metallurgical grade silicon reacts with Hydrochloric acid and produces Trichlorosilane.

$Si_{mg} + 3\ HCl \longrightarrow (HSiCl_3)_{crude} + H_2$

2) Distillation: the crude TCS will be purified by passing through the distillation towers,

$(HSiCl_3)_{crude} \longrightarrow (HSiCl3)_{hyperpure}$

3) Deposition: The hyperpure TCS will be passed in CVD reactors with mix up of hydrogen gas. There the pure silicon is deposited on the silicon slim rods,

$4(HSiCl3)_{hyperpure} \longrightarrow Si_{hyperpure} + 3SiCl_4 + 2\ H_2$

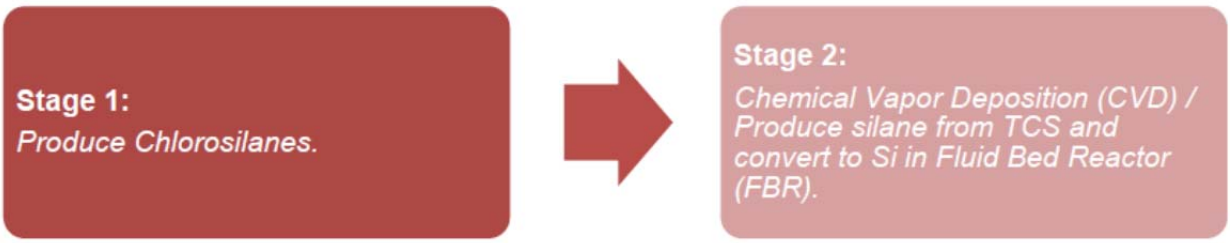
4) Off Gas Recovery: Unreacted gases will be collected back and treated. Then used for deposition with hyper pure TCS.

Once the Silicon deposition reaches certain limit, the CVD process stopped and the silicon rods will be harvested. The big silicon rods will be broken into small sizes called chunks. The chunks are packed in double layered PE bags with size of 10 Kg per bag. Generally the chunk sizes are categorised and same size chunks are packed in one bag.

Category	Chunk Size
Size 1	0 – 15 mm
Size 2	5 – 45 mm
Size 3	20 – 65 mm
Size 4	35 – 150 mm

These poly silicon bags are packed in a carton box of capacity 250 kg per box and moved to FG Ware house and stored.

The proposed manufacturing process for silicon is done in two stages as shown below



4.1 Stage 1.Production process of Chlorosilanes, Chemical Vapor Deposition

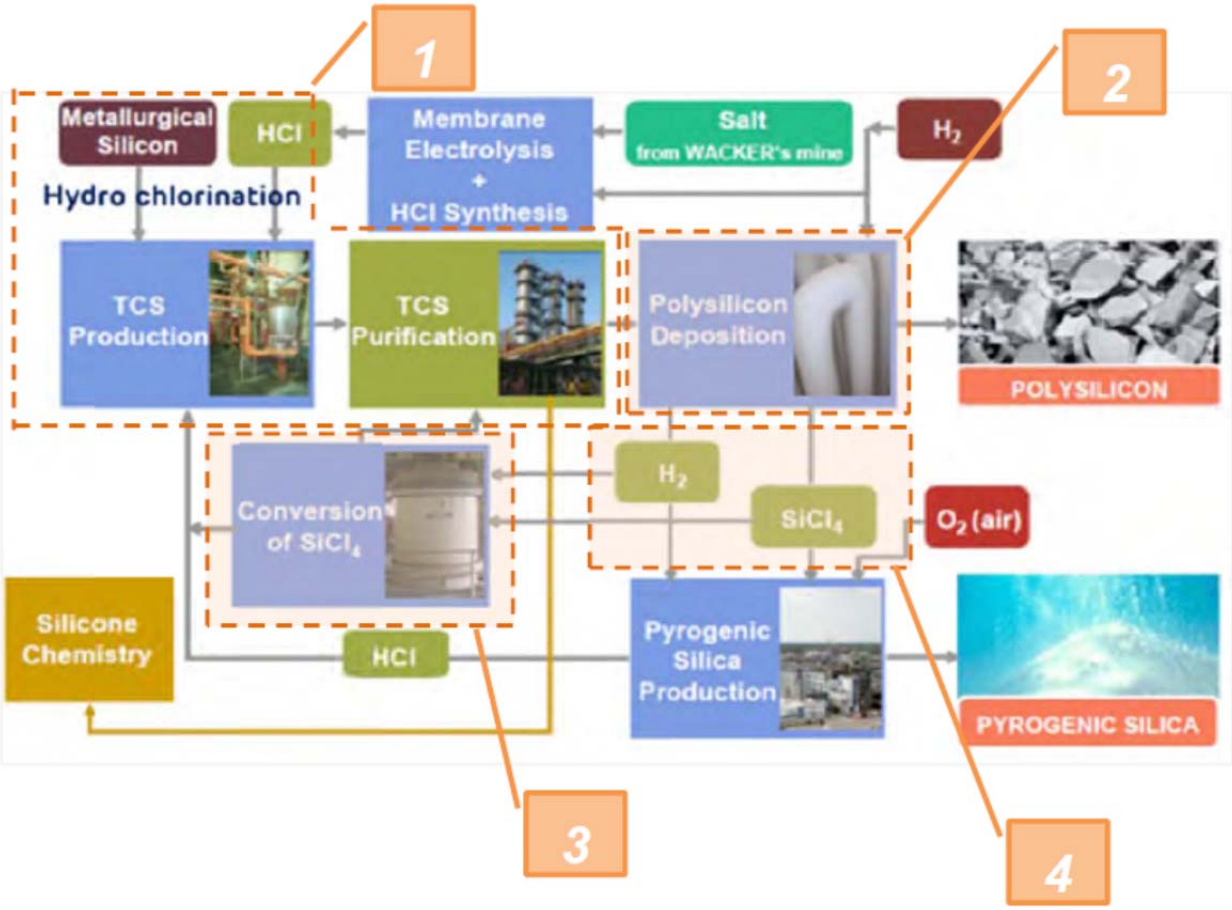
The starting material required for the CVD process is pure Chlorosilane (either silicon tetrachloride or trichlorosilane or a mixture of the two) and pure Hydrogen. The simplified chemical reaction with silicon tetrachloride as the source is as below.

$SiHCl_3 + H_2 \rightarrow Si + 3\ HCl$

For producing such high purity silicon the starting materials themselves should be very pure. The Solar/

Semiconductor grade poly crystalline silicon is obtained by the reduction of chlorosilanes with hydrogen in a chemical vapour deposition reactor. The reactor consists of electrical resistance, heated inverted U5 shaped thin rods, graphites or preferably silicon fixed to a base plate. The reactor is cooled with circulating distilled water to keep the walls at working temperature.

Production process and core stages identified



Chemistry of various stages of high pure polysilicon production

Synthesis	$Si_{mg} + 3\ HCl \rightarrow (HSiCl_3)_{crude} + H_2$
Distillation	$(HSiCl_3)_{crude} \rightarrow (HSiCl_3)_{hyperpure}$
Deposition	$4\ (HSiCl_3)_{hyperpure} \rightarrow Si_{hyperpure} + 3\ SiCl_4 + 2H_2$
Conversion	$SiCl_4 + H_2 \rightarrow (HSiCl_3)_{hyperpure} + HCl$
Pyrolysis	$SiCl_4 + 2H_2 + O_2 \rightarrow SiO_2 + 4HCl$

4 key stages are identified as in **Figure 13** and discussed in the following sections.

4.2 Stage 2: Production and Purification stage

4.2.1. Production of chlorosilane

Step 1: Production

Chlorosilanes are produced by direct reaction of Anhydrous Hydrogen chloride with Silicon metal of lesser purity levels (MG-Si grade) along with recycled Silicon tetrachloride for its conversion to Trichlorosilane. This is a cost effective integration of two process steps in to single one that conserves power usage, and same will be introduced in the process of MSL.

The reaction is endothermic and the constituents are required to be heated by external heaters and the resultant gas mixture is passed through for further processing. The chemical reaction in this stage is as below.

$$Si + 3HCl + SiCl_4 \xrightarrow{600°C} SiHCl_3 + SiCl_4 + H_2$$

- The heating and cooling are done with heat transfer fluids, from which the heat is recovered for use in other areas that requires external heat.
- The off gases containing primarily chlorosilanes and H_2 are subjected to condensation up to 60°C and then to a series of purification steps before subjecting to final scrubbing and disposal.

The product thus collected is subjected to distillation to remove the high boiling impurities and the chlorides of metal to a very low level for it to be used in the downstream process.

Step 2: Purification

The Chlorosilane, are purified by distillation and sedimentation / adsorption. The primary aim of distillation is to remove Chloride impurities such as $AlCl_3$, $FeCl_3$, $TiCl_4$ etc and also boron and phosphorous chlorides. The distillation train consists of number of columns. In the first column, the heavy impurities such as $TiCl_4$, $AlCl_3$ and $FeCl_3$ are removed as bottom products along with the higher boiling residues.

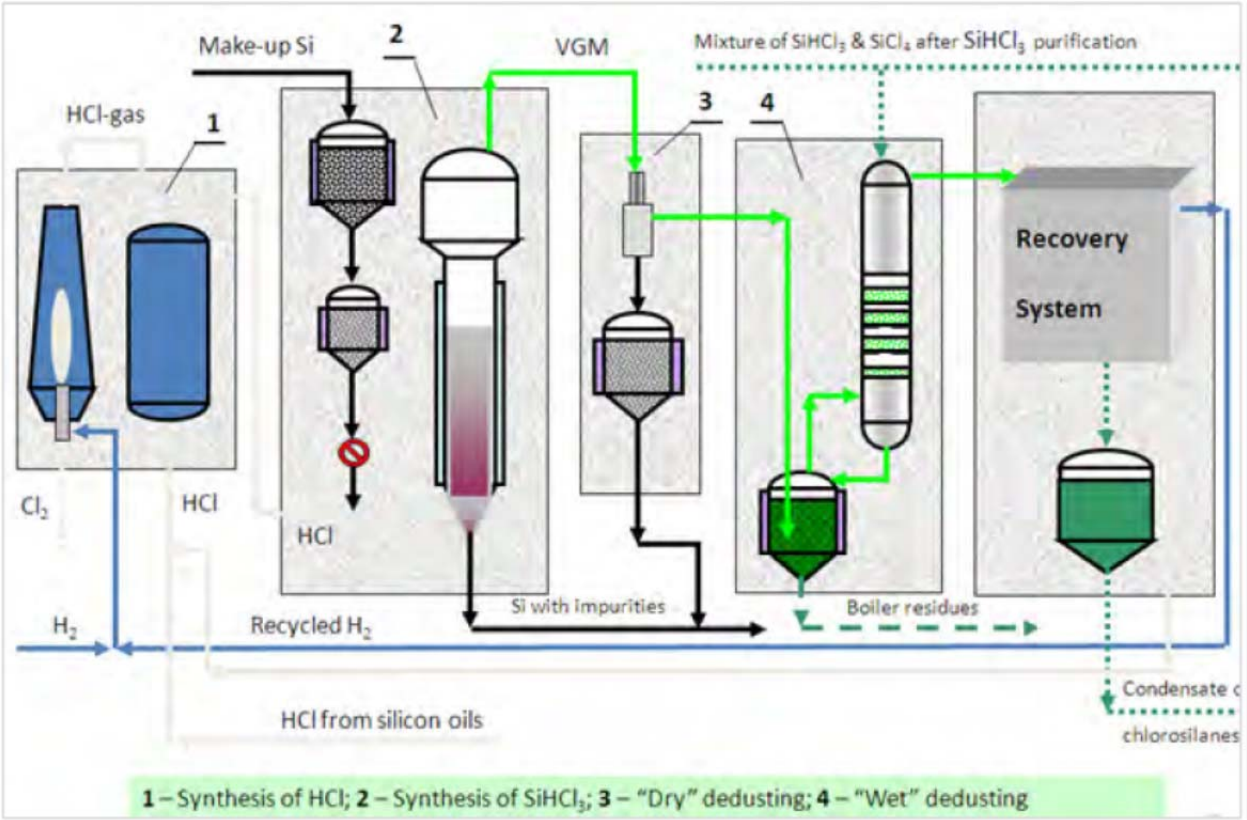
In the subsequent columns the chlorosilanes are further purified and all the chlorides are removed and taken to a high purity levels. Distillation alone may not result in complete removal of the impurities particularly boron and phosphorous. Final purification is achieved by passing the distilled chlorosilanes through a reactor containing activated alumina gel or Silicone gel formed in situ as adsorbent. The product coming out of the reactor will be of desired purity.

In order to remove any suspended adsorbent particles, the chlorosilane is subjected to a simple distillation and the pure product is stored in stainless steel storages.

4.2.2. Trichlorosilane (TCS) production

The TCS fed to the deposition reactors is produced by reacting finely ground metallurgical grade silicon with anhydrous hydrogen chloride (HCl) gas in a fluidized bed reactor. The reactor produces a mixture of chlorosilanes that are primarily TCS and STC with a small amount of dichlorosilane (DCS) up to a max of 2%.The reactions are:

- DCS reaction: $Si + 2\ HCl \rightarrow SiH_2Cl_2$
- TCS reaction: $Si + 3\ HCl \rightarrow SiHCl_3 + H_2$
- STC reaction: $Si + 4\ HCl \rightarrow SiCl_4 + 2\ H_2$



Block diagram for crude production of SiHCl3

Step 1: Production

This method to produce crude TCS is often referred to as the hydrochlorination process. The crude TCS exiting the reactor contains multiple impurities which must be removed prior to use. The hydrochlorination process produces higher molecular weight chlorosilanes and polysilanes while trace quantities of moisture react with the above compounds to produce siloxanes. Impurities in the metallurgical grade silicon and hydrogen chloride react to produce a number of metal chlorides (primarily aluminium and iron chlorides), hydrocarbons, chlorinated hydrocarbons, and a small amount of methyl chlorosilanes

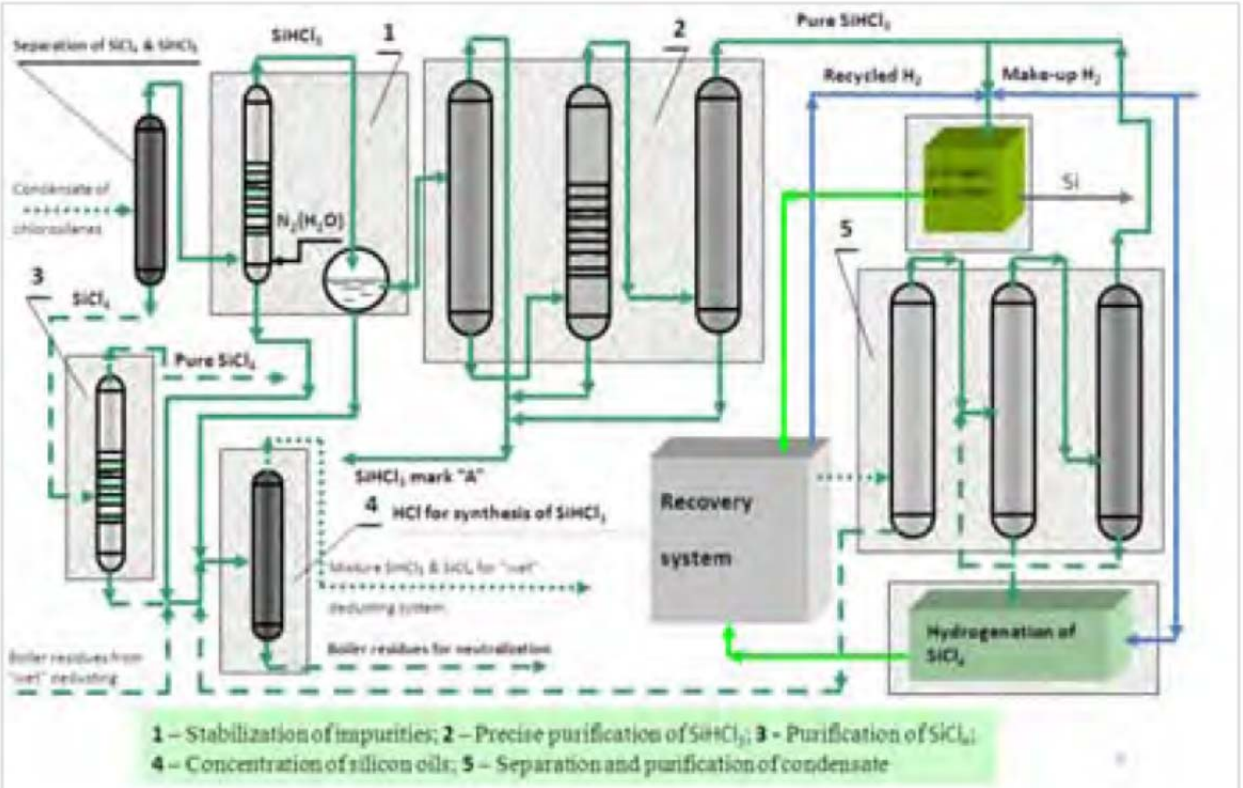
- The off gases from the reactors are first subject to "dry dedusting" by cyclone separators that ensures removal of the unreacted met. Silicon and sends it back to the reactors. Depending on the purity of the feed silicon a slip stream from this will be taken and the material will be purged out to waste.
- A similar purge from the bottom of the reactor will be made to ensure the impurities do not build inside the reactor and do not end in the chlorosilane and increasing the load on the purification stage.
- After the cyclone separators the gases are subjected to dry-dedusting to remove the $AlCl_3$ by maintaining the temp in such a way that they are removed here.
- The gases from the reactor is cleaned by scrubbing the effluent gas, which cools the gas and removes waste liquid and solids called "wet dedusting".

Off gases are subjected to a three stage condensation to condense all the chlorosilanes, called Crude TCS. The crude TCS liquid requires further purification before it can be fed to the PCS deposition reactors. Effluent gas exiting the scrubber consists of hydrogen, hydrogen chloride, and small amounts of chlorosilanes and reaction by-products. The TCS production effluent gas can be directed to a dedicated

effluent gas recovery system scrubber and dispose the HCl and vent the H_2 to a high point vent as they will not meet the purity levels required in the deposition process.

Step 2: Purification

The crude TCS must be purified before it can be used to produce polycrystalline silicon of sufficient purity for high conversion photovoltaic solar cell or electronic semiconductor manufacturing. The crude TCS is treated via a multiple step separation and purification process as indicated in the process diagram below.



Block diagram for separation of SiCl4 and SiHCl3

Purification of the crude TCS removes STC, metal chlorides, higher molecular weight chlorosilanes, polysilanes, siloxanes, and hydrocarbons. In addition the STC is purified for subsequent conversion into TCS. The purification process produces the following streams:

- Purified TCS
- Low grade TCS
- Purified STC
- Heavies waste
- Purification Vent Gas.

The purified TCS is fed to the deposition reactors to make polycrystalline silicon (PCS). The low grade TCS can be sold as a by product or further reacted to recover HCl for recycle to the polysilicon process. The purified STC feeds the conversion reactors (STC to TCS) for conversion to purified form of TCS. The heaviest waste goes to waste treatment for neutralization and disposal.

The small amount of vent gas from the purification processes is sent to the vent gas treatment system. To produce high purity TCS, the purification process necessitates that some of the TCS is lost with the un-separated impurities.

Several of these impurities have boiling points which are very close to that of TCS and difficult to separate. These impurities, and the lost TCS, are collected as low grade TCS, which can be either **sold**

as a by product or incinerated with sufficient hydrogen to produce a fumed **silica by product** and recover HCl for recycle to the polysilicon process or chlorinated to produce **silicon tetrachloride** for return to the polysilicon process.

Additional purification of the TCS is required to remove impurities containing phosphorus, boron, arsenic, and iron which can negatively impact the polysilicon product quality even at extremely low levels.

4.3 Deposition stage

The basic process equipment for production of polysilicon is intended for deposition of polycrystalline silicon on initial thin (7 x 7 mm) silicon slims of square section produced by longitudinal cutting of rods silicon of big diameter (80 mm - 90 mm). In total a reactor may be fitted with 36 - 48 slims.

Production of polycrystalline silicon is carried out by hydrogen reduction of trichlorosilane. Recirculation contour includes evaporators/vaporizers for preparation vapour gas mixture (hydrogen + Trichlorosilane), reactors for deposition of polysilicon and system of recovery off gases for separation and return chlorosilane, hydrogen chloride and hydrogen back to the process.

- The deposition rate increases with increase in temperature and needs to be controlled to avoid melting. Also the distribution of the TCS and H_2 properly insures better and uniform growth.
- As the surface area available for the growth increases, the reactant flow are to be increased to take the advantage or else it will result in to “starved growth" or “pop corn" patterns. Throughout the process the ratio of the TCS and H_2 is maintained and only the flow is increased as the surface area available for the growth increases.
- The deposition rate increase to the square root of the flow of the reactants into the reactor, In the typical process the deposition will be the highest towards the end and the lowest towards the startup.(If a simplified process reaction is looked at for every molecule of Si produced two molecule of $SiCl_4$ is produced and one molecules of HCl is produced and two molecules of $SiHCl_3$ is used up in the process).
- For all practical purposes the H_2 does not take part in any way in the reaction.

During the above high temperature reaction a small amount of polymers like silicone oils get formed which are flushed along with the Silicon tetrachloride and are better to be neutralized than separating them. A slip stream from the CVD off gas recovery system will be carrying such polymers which will need to be neutralized eventually.

A white to yellow syrupy oil that gets formed is dissolvable in $SiCl_4$ but in purest form is explosive when touched or rubbed in dry condition. This needs to be borne in mind during taking up the cleaning operation of the reactors. One more yellow powder that gets formed is very quiescent and non-dangerous. All these polymers can be doused with water to render them harmless.

Process of deposition of poly crystalline silicon is carried out in the water-cooled reactionary chamber. Distinctive feature of the given design in the above table is the application of hot water with temperature 80°C-90°C for cooling of internal wall of reactor, and also maintenance of pressure in the reactionary chamber up to 6 bar (g) during process of deposition of silicon. Increase of pressure in the reactionary chamber allows essentially (more than 2 times) to raise deposition rate of silicon in a reactor due to preliminary heating of the incoming gases and allows to increase quantity of initial raw material passed through a reactor.

Process of deposition of silicon is carried out on a surface of initial slims whose temperature is supported at a level 1090^0C – 1120^0C with help of electric current.

Preliminary heating of initial slims in a reactor before the beginning of process is to be carried out by

a Heating system (common for about 4 such reactors). After reaching the desired temperature of the conductor, the temperature on the surface of slim rod is supported by passing electric current the surface of slim rod is supported by passing electric current.

After heating slims, before silicon deposition, etching of surface silicon slims by a mixture of hydrogen and the hydrogen chloride, is to be provided to ensure good, surface for deposition.

During deposition the amount of feeding gas, moving in reactor is adjusted to the surface of silicon rods and changes from minimal to maximal values.

The control loops are to be programmed to ensure the flow and pressure is ensured in the circuit during start up every time.

Higher pressure in a reactor gives a number of advantages, first of all, an opportunity of essential increase deposition rate and, hence decreases of the electric power consumption during deposition of Polysilicon.

The high pressure in a reactor allows to increase amount of VGM in a reactor (in comparison with process at normal pressure), and as it was already marked above, moving of VGM to a reactor increases proportionally to growth of a surface of silicon rods. Thus in a reactor forms the significant excessive amount of VGM which is heated up to high temperatures due to a heat transfer by radiation from silicon rods and convection.

Bonds in molecules of trichlorosilane become less strong, that leads to decrease of an energetic barrier for dissociative adsorption of trichlorosilane with formation of chemisorbed layer of silicon dichloride on a surface of silicon rods. The high pressure in a reactor promotes preferable course of reaction as below.

$SiCl_2 + H_2 \rightarrow SiH_2Cl_2$

These effects lead to essential increase of deposition rate. Besides increased pressure in a reactor allows passing through a reactor a lot of initial VGM, that also leads to increase of deposition rate.It is necessary to note that increase of pressure in a reactor and in pipelines excludes formation of silicon oils.

The general level of energy consumption during deposition of polycrystalline silicon (kWh/kg) first of all depends on a level of energy consumption in reactor and the level in a reactor in turn depends of deposition rate of silicon. Therefore achievement of optimum of deposition rate of silicon in a reactor is the important technological problem, in many respects determining technical and economic parameters of process as a whole. The silicon filaments can be purchased or produced on site using vendor provided equipment.

The deposition unit process is supplied with purified TCS liquid and TCS liquid recycled from the PCS deposition and STC conversion effluent gas recovery systems. The TCS liquid is vaporized and mixed with hydrogen gas feed and recycled hydrogen gas from the PCS deposition effluent gas recovery system.

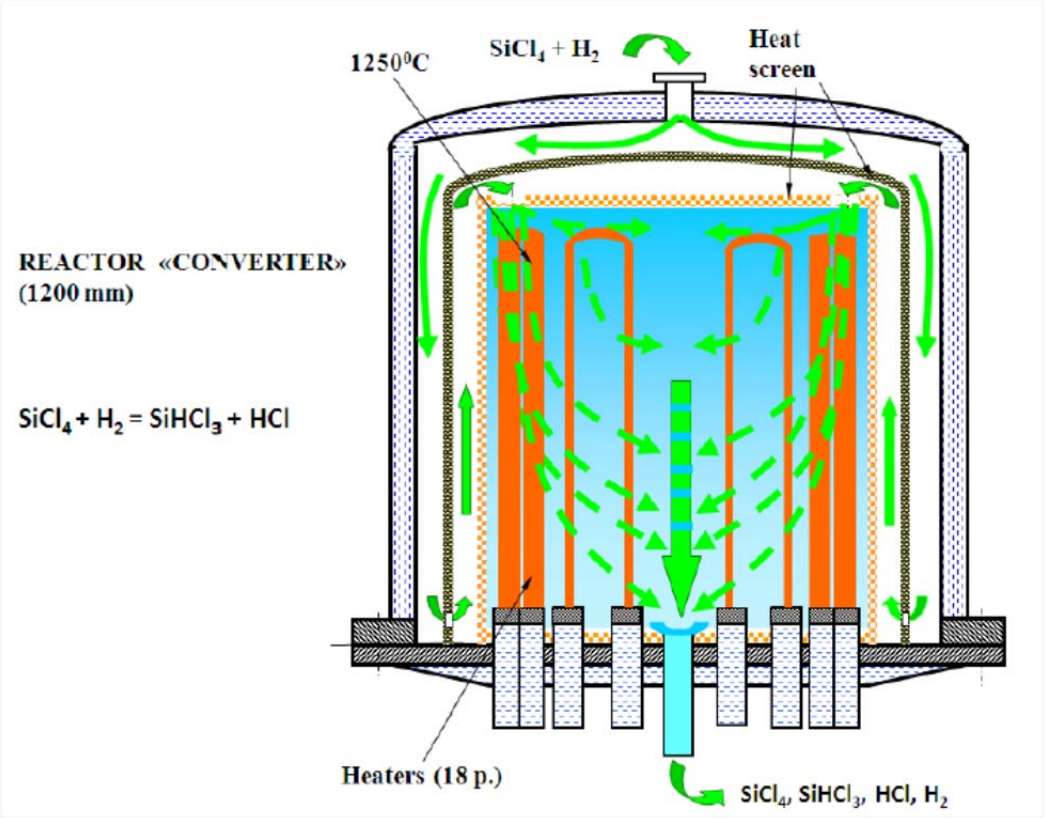
Silicon deposition yields a large quantity of gaseous HCl. The chemical reactions in the deposition reactors also produce a significant quantity of STC and smaller quantities of DCS and other chlorosilanes. Since the deposition reactors are fed with excess TCS and hydrogen, the PCS deposition reactor effluent gas consists primarily of TCS, STC, H_2, HCl, and DCS.

4.4 Silicon Tetrachloride conversion to TCS

Poly reactor outlet contains hydrogen, unreacted trichlorosilane, silicon tetrachloride (formed as a byproduct), dichlorosilane and hydrogen chloride, moves to a recovery system similar to the one in the TCS production stream where it separates into components.

Hydrogen and trichlorosilane after separation from silicon tetrachloride by distillation return in process of producing of polycrystalline silicon, hydrogen chloride return in process of synthesis trichlorosilane

and silicon tetrachloride moves hydrogenation to trichlorosilane. Additional STC is obtained from by product plant for conversion to trichloro silane here



Hydrogenation includes the following basic operation and equipment:

- Preparation of gas mixture containing hydrogen and silicon tetrachloride with mole ratio
- Installations of hydrogenation "Converter" in which on surface of carbon heaters at temperature 1250°C there is an interaction silicon tetrachloride with hydrogen to formation of Tri-Chloro-Silane system of recovery of off gases similar to the one in TCS plant, with return not reacted hydrogen and silicon tetrachloride in a head of process of hydrogenation, Trichlorosilane in process of Polysilicon production and hydrogen chloride to synthesis of Trichlorosilane.

The basic apparatus of hydrogenation process is "Converter" which consists of water cooled cylindrical chamber with an elliptic cover and the flat bottom. At the bottom two thermal screens are loaded for preliminary heating of VGM and 36 electrodes for fastening graphite heaters are located. On the surface of heaters at a temperature at 1250°C hydrogenation reaction takes place.

The characteristics of reactor "Converter" is as listed in the table below:

Sno	Characteristics	Measurement / Value
1	Working temperature on heaters	1250 °C
2	Material of heaters	carbon composite
3	Working pressure in a reactor	6 bar (g)
4	Atmosphere in a reactor	chlorosilane, H_2,HCl
5	Percent of $SiHCl_3$ producing by one pass	>17 %
6	Mole ratio	H_2:$SiCl_4$ = 3:1
7	Flow rate of VGM to "Converter	3000 kg/h
8	Number of heaters	48
9	Specific consumption of power	20 kWh/kg of Poly.

4.5 Recovery process

4.5.1. Deposition effluent gas recovery

At present the most reliable equipment supplier in this area are CDI who have the comprehensive equipments for separation and re use of various components. Installations of CDI will carry out recovery of off gases from reactors for producing polysilicon and hydrogenation, by consecutive passage through 4 modules.

- **Module 1**. Cools the incoming feed gas 45^0C and 1.2 kg/cm^2 in a scrubbing tower to condense the major portion of the chlorosilanes and silicon oils from the feed gas.
- **Module 2**. Compresses and cools the feed gas to prepare for module 3. Operating conditions are 45^0C and 8.9 Kg/cm^2. Additional chlorosilanes are condensed in this step.
- **Module 3**. Removes and recovers HCl from the feed gas. HCl is absorbed in a 45^0C chlorosilane stream at 8.9 Kg/cm^2. HCl is recovered from the liquid stream by distillation at 7.3 Kg/cm^2.
- **Module 4**. Removes the remaining HCl and chlorosilanes from the gas stream by adsorption on a special activated carbon. Hydrogen leaving this module contains small amounts of HCl and chlorosilanes. The activated carbon is regenerated by indirect heating and cooling with a heat transfer fluid. The regeneration gas stream is refrigerated to condense chlorosilanes, and then purged to a caustic scrubber for final treatment prior to being vented to the atmosphere.

4.5.2. Deposition effluent gas recovery

The off gases from the CVD reactor system is taken to condensers as explained in the TCS off gas section. The chlorosilanes that are condensed are stored in a storage tank of capacity 22 – 50m^3 of 5 nos.

- First one collecting the mixed chlorosilanes from the condensers
- One feeding the distillation column that is separating the TCS and STC for feeding the STC to the converters.
- One collecting the TCS from the fractionation column after further purification and absorption. This is sent back to the CVTJ vaporizers.
- One collecting the STC from the fraction action column.
- One feeding the STC to the Converters**.**

The purification columns in the CVD off gas recovery shall be in 12000 TPA two streams and shall be with two columns, one for macro separation and another for further polishing of TCS before it is fed to the vaporizers again.

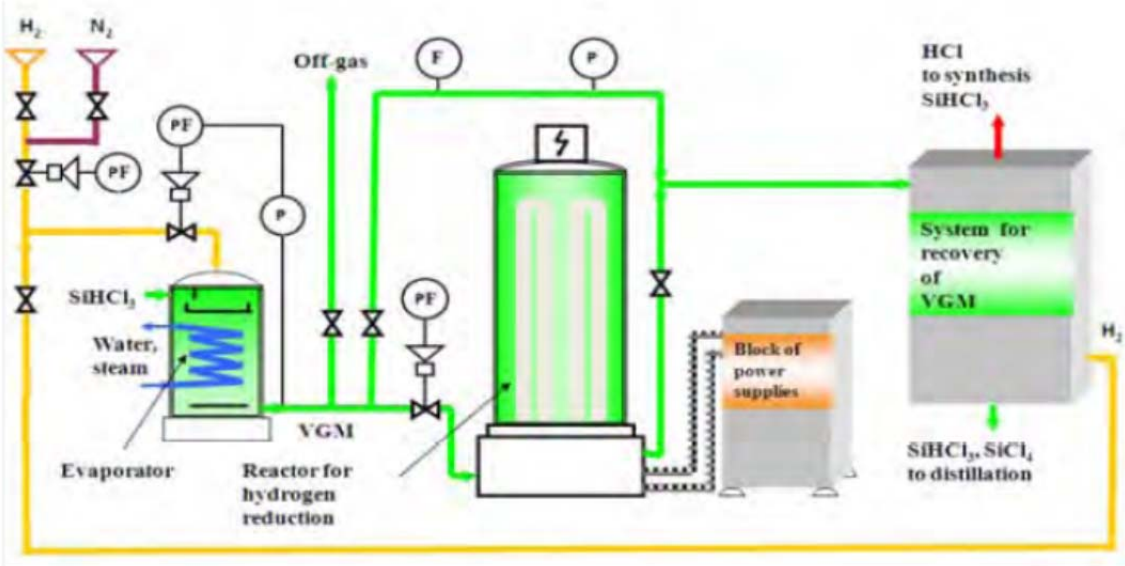
- The impurities at this stage will be very less the columns shall be of 11.5 m dia and about 20 - 25m tall max. Operating at about 3 kg/cm^2 and 70 - 80°C.

- The uncondensed gases leaving the condensers are subjected to CDI vent recovery package in two streams of 12000 TPA each and the HCI and H_2 are recycled back to the process. The stages and number of equipment's are similar to the one explained in the TCS section.
- The polysilicon deposition reactors are fed a mixture of TCS vapor and H_2 gas. A relatively low percentage (approximately 15%) of the TCS is deposited as polysilicon. About 30% of the TCS feed reacts to produce large amounts of STC and smaller amounts of DCS and other byproducts.
- Approximately 60% of the TCS feed exits the deposition reactors. This effluent gas contains large amounts of TCS and STC, and significant amounts of H2, HCl and DCS.

The PCS deposition reactor effluent gas is treated in a multiple step separation and purification processes to allow return of the valued components to the polysilicon production process. Recycle hydrogen is returned to the PCS deposition reactors with excess hydrogen going to the STC conversion reactors. Recycle HCl is sent to the TCS production reactor.

The condensed mixed chlorosilanes are sent to additional process equipment for separation and purification prior to recycle to the PCS deposition and STC conversion reactors. The TCS returns to the PCS deposition reactors. The STC returns to the STC conversion reactors. A low grade STC returns to TCS purification train for additional separation and purification.

Block diagram, process of hydrogen reduction



4.5.3. STC Conversion Effluent Gas Recovery

The off gases from the Hydrogenator (STC converters) system is taken to condensers as explained in the TCS off gas section. The chlorosilanes that are condensed are stored in a storage tank and tankage requirement for this section is as follows:

- One tank of 1000 cum receives the mixed chlorosilanes and the other one feeding the fractionation column
- One tank of about 1000 cum can be used for storing the STC separated and fed to the big tank in the CVD section or directly fed to the converters.
- One tank of 1000 cum can be used to store the separated TCS and fed back to the CVD section to the vaporizers directly.
- The rejects shall be taken directly to the rejects tank of the CVD distillation section.

The off gases leaving the condensers shall be taken to a two stream of 12000 TPA PCS trains and subjected to removal of HCI and H2 for recycle back to the process. Since this stream's H2 could contain some carbon impurities the H2 is recycled back only to the converters and fresh make up is taken in this

stream only as the H2 atom is added to STC to make it TCS. The HCl recovered at 9 bar (g) is returned back to the TCS FBRs.

The STC conversion process generates an effluent gas stream, which is recovered in a process similar to the deposition reactor EGR. Recycled hydrogen is returned to the STC convertors. Recycled HCl is sent to the TCS production reactor. The condensed mixed chlorosilanes are sent to additional process equipment for separation and purification prior to recycle to the PCS deposition and STC conversion reactors.

The TCS returns to the PCS deposition reactors. The STC returns to the STC conversion reactors. A low grade STC returns to TCS purification train for additional separation and purification.

A mixture of vaporized chlorosilane and hydrogen in suitable proportion is passed through the reactor. The reduction of chlorosilane takes place on the hot surface of the rod on which the silicon produced gets deposited. Thus the rod grows in size with time. Deposition is continued till sufficiently large diameter rods are obtained. The silicon thus obtained is broken down to “Chunks” and stored for further processing.

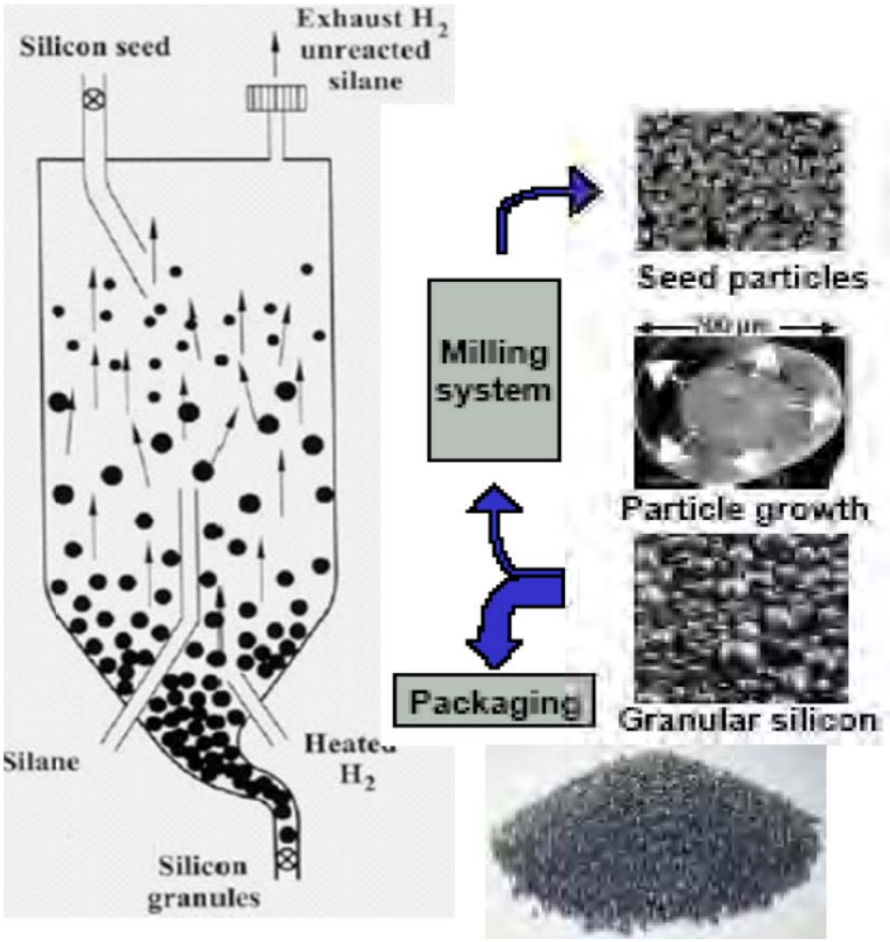
Once the sufficiently large rods are formed the reactor is taken out of production and purged with N2 before they are opened and got ready for the next process.

4.6 Fluid Bed Reactor Process (FBR)

A fluidized bed reactor consists of gas-solid mixture that exhibits fluid-like properties. The bed can be considered to be an inhomogeneous mixture of gas and solid that can be represented by a single bulk density. Furthermore, an object with a higher density than the bed will sink, whereas an object with a lower density than the bed will float, thus the bed can be considered to exhibit the fluid behaviour as expected by Archimedes' principle. In fluidized beds, the contact of the solid particles with the gas is greatly enhanced when compared to packed beds. This behaviour in fluidized beds enables good thermal and mass transport inside. Similarly due to the good heat transfer, which enables thermal uniformity analogous to that of a well-mixed gas, the bed can have a significant heat-capacity whilst maintaining a homogeneous temperature field.

The increase in fluidized bed reactor use in today’s industrial world is largely due to the inherent advantages of the technology.

Trichlorosilane gas produced in the Hydrochlorination process is passed, after purification, through a catalyst which is Amberlyst type which does redistribution of H2 molecule in the Silicon and yields SiH4 which is called silane. The silane is further subjected to purification process and then stored in tanks.



4.6.1 FBR Technology

In a FBR designed to produce granular polysilicon, tiny silicon particles are fluidized in a SiH4/H2 flow, and act as seed crystal onto which polysilicon deposits to form free-flowing spherical particles. The process is carried out at 650°C. The silicon thus growing on the tiny particles gains weight and travels down the fluid bed reactor and collected at the bottom as Granular Silicon which is known as FBR based high pure POLY SILICON. The size distribution of the particles thus formed is over the range from 0.4 to 3 mm in diameter.

4.6.2 Purification of Hydrogen:

The Hydrogen required for reduction is obtained from the in-house water electrolyser to ensure high purity levels in the H_2 gas. This hydrogen is of sufficient purity for Chlorosilane reduction purposes except that it contains some water vapor. The purification of hydrogen, therefore, involves the removal of this vapor. This in accomplished by compression of hydrogen to about 10 - 12 kg/cm^2 pressure in a two stage non- lubricated hydrogen gas compressor.

When the compressed hydrogen is cooled most of the water condenses and removed. Then they are passed through De Oxo towers to remove the Oxygen and then final traces of the impurity are removed in a dual column adsorption unit with molecular sieves as adsorbents. The hydrogen thus obtained is sufficiently pure to be used for the CVD of silicon.

4.7. Utility systems required to support the polysilicon production process

TCS Production Hot Oil

The Trichlorosilane Production Hot Oil system is a closed loop heat transfer utility used by the trichlorosilane fluidized bed reactors. The loop is designed such that two oil temperatures can be supplied. During initial reactor startup, oil at 350^{0}C is supplied to the reactor to initiate the reaction. The TCS synthesis reaction is very exothermic. Once the reaction is initiated, heating is no longer needed and the oil loop switches operation to become a cooling loop that operates at a temperature of approximately 250 to 300^{0}C. Note that the TCS reactors are a typical source of heat recovery for the plant.

The Trichlorosilane Purification Hot Oil system is used to supply hot oil to the distillation column reboilers. The typical operating temperature for this system is 200 to 250^{0}C. A portion of the heat load for this loop can be obtained from the Trichlorosilane Production Hot Oil loop. To support heat recovery from the PCS deposition and STC conversion cooling water systems, the high temperature TCS purification loads could potentially be supplied from the TCS production hot oil system and low temperature TCS purification loads could be supplied by an oil system at approximately 125 to 175^{0}C.

Process Cooling Water

Process cooling water is a process utility primarily used for the cooling medium in heat exchange processes such as distillation column condensers, process stream coolers, and compressor discharge coolers. The typical operating temperature is 25 to 30^{0}C. The temperature is maintained through the operation of evaporative cooling towers.

Refrigerated Cooling

A refrigerated cooling system provides low temperature heat exchange for the polysilicon production plant. The primary uses are for final condensers on various process systems and storage tank vents. The dual suction pressure system provides cooling at 10^{0}C and 60^{0}C.

PCS Deposition Cooling Water

The polysilicon reactors are serviced by two independent process cooling water systems. The systems recirculate high resistivity water and are supplied make up from the plant DI water system. The two process cooling water systems operate at different supply temperatures. The lower supply temperature system provides cooling for the electrodes and power supply equipment. The higher supply temperature system cools the reactor shell, base plate, and effluent gas. The supply temperature, resistivity, and flow demands for the process cooling water systems vary between the different deposition reactor providers.

STC Conversion Cooling Water

The STC convertors are serviced by two additional process cooling water systems similar to the systems described for the deposition reactors. The supply temperature, resistivity, and flow demands for the process cooling water systems vary between the STC convertor providers.

Nitrogen

Nitrogen is a plant wide utility used to provide an inert gas space and to purge process materials from equipment and piping prior to maintenance. Nitrogen is also used in the following locations in the polysilicon production process:

- Pressurizing the Metallurgical Grade Silicon Reactor Feed Tank
- N2 pad for chlorosilanes storage tanks (pressure control and inert gas space)

- Pressure control for certain distillation columns.

In addition, a major use of nitrogen is the purging of the bell jar reactors (both polysilicon deposition and STC conversion) prior to accessing the reactor internals. The bell jars are similarly purged with nitrogen following any activity which exposes the inside of the bell jar to the atmosphere. The nitrogen must be of very high quality since it does come in contact with process streams and process equipment.

Nitrogen Quality specification

Purity : ≥ 99.9999 % by volume

Impurities

Name	Formula	Concentration
Total Hydrocarbons	CH_4	0.1 ppmv max
Oxygen	O_2	0.5 ppmv max
Water	H_2O	1.0 ppmv max
Carbon Monoxide	CO	0.1 ppmv max
Carbon Dioxide	CO_2	0.1 ppmv max.

Effluent Gas Recovery Hot Oil System

The Effluent Gas Recovery Hot Oil system is used to supply hot oil to the mixed chlorosilanes distillation column reboilers. The typical operating temperature for this system is 175 to 225^{0}C.

4.8. Typical specifications of Polysilicon

Polysilicon is the essential raw material for the solar and the Electronics industry. Earlier the rejects of Semiconductors was used in the solar industry and the trend has been reversed due to huge capacity additions in the last decade and solar industry alone consumes 90% of the poly produced across the world.

It's one of the purest ever man made material in the world complex and capital intensive manufacturing process.

Based on the Quality/Purity of the silicon, it has categorized into various grades and handled as given below.

Polysilicon grading

Grade Impurities (ppm)	Si purity %	# N	Total	Applicable field
MG-Si	98.5-99	1-2	10000 –15000	For Steel application
Silgrain (HQ)	99.7	2	2500 – 3000	Major impurities C, Fe, Ca, Al,
UMG-Si	99.99	4	500 -1000	Same
SoG-Si	99.9999	6	4 – 6	Low amount of Impurities
Puri Si	**99.9999999**	**9**	**0.001 - 0.005**	**higgh Pure fro Solar Applications**

Packaging: Poly silicon is to be packed in polyethylene bag (no additives) of 5.0 Kg weight. A double bag system with clean room packing shall be done.

Surface condition: Product will be clean with no stains, grey, luster free, rough and visible contaminants except the amorphous.

High pure Polysilicon specification

Sno	Description	Specifications
1	**Size of Chunk**	
1.1	*<5mm*	*<1% by weight*
1.2	*5 - 45mm*	*max.25% by weight*
1.3	*20 - 65mm*	*max.35% by weight*
1.4	*10 - 150mm*	*min.75% by weight*
2	**Impurities**	**Maximum Concentration**
2.1	*Acceptor (B, Al)*	*< 0.2 ppba*
2.2	*Carbon*	*5.0 ppba*
2.3	*Donor (P, Sb, As)*	*< 5.0 ppba*
2.4	*Acceptor + Donor*	*< 10.0 ppba*
3	**Other Metals Impurities**	**Maximum Concentration**
	Total surface Metals	30.0 ppbw
3.1	*Aluminum(Al)*	*10.0 ppbw*
3.2	*Chromium(Cr)*	*2.0 ppbw*
3.3	*Copper(Cu)*	*2.0 ppbw*
3.4	*Iron(Fe)*	*10.0 ppbw*
3.5	*Nickel(Ni)*	*2.0 ppbw*
3.6	*Potassium(K)*	*10.0 ppbw*
3.7	*Sodium(Na)*	*15.0 ppbw*
3.8	*Zinc(Zn)*	*4.0 ppbw*
4	**Bulk Metals(Total)**	**Maximum Concentration**
4.1	*Fe, Cu, Ni, Cr, Zn, Na*	*10.0 ppbw*

5.1 Raw-material

5.1.1. Key raw materials identified in polysilicon manufacturing

5.1.1.1. Raw Material 1 - Metallurgical grade silicon (MGSi)

The polysilicon production process requires metallurgical grade silicon, anhydrous hydrogen chloride, and hydrogen. Metallurgical grade silicon (MG-Si) contains a minimum of 98.5% pure silicon. It is supplied as a finely ground powder and shipped in semi bulk (super sacks) or bulk quantities. The MSL plant will include a material handling system for removing the MG-Si from the shipping containers and transferring it to a storage site. The MG-Si will also be procured as lumps and ground at site to the required size.

Material specifications

Particle Size: 110,373 Micro

Purity: ≥ 98.5 % by weight

Impurities:

Name	Symbol	Concentration
Aluminium	Al	4000 ppmw max
Boron	B	100 ppmw max
Calcium	Ca	2000 ppmw max
Carbon	C	1000 ppmw max
Iron	Fe	4000 ppmw max
Phosphorous	P	100 ppmw max
Arsenic	AS	100 ppmw max

5.1.1.2. Hydrogen Chloride

This will be manufactured in-house using Hydrogen and Chlorine. High purity anhydrous hydrogen chloride gas (HCl) is needed for supply to the TCS fluidized bed reactor.

Material specifications

Purity: ≥ 99.99 % by volume

Impurities:

Name	Formula	Concentration
Hydrogen	H_2	30 ppmv max
Total Hydrocarbons	CH_4	1.0 ppmv max
Inorganic Carbon	CO_2	25 ppmv max
Nitrogen	N_2	50 ppmv max
Oxygen	O_2	2.0 ppmv max
Water		1.0 ppmv max
Chlorine	Cl_2	1.0 ppmv max
Chlorine/Bromine	Cl_2/Br_2	5.0 ppmv max
Hydrogen Bromide	HBr	20 ppmv max
Iron		0.5 ppmw max
Boron		2.0 ppbw max
Phosphorous	P	3.0 ppbw max

5.1.1.3. Various options on HCl generation units

Hydrogen and Chlorine burning unit:

This system has a very attractive proposition in terms of capital and operating cost as the unit has a pay back of just 3 years with steam generation option at 12 kg/cm^2 as offered by SGL.

The system's only disadvantage is that the excess H_2 admitted to ensure all the Chlorine is burnt leaves the AHCI with a 0.3% w/w of H_2 or a 56% v/v which may affect the reaction at the TCS fluid bed reactors.

Acceptability of such levels of H_2 in AHCl stream needs to be checked with TCS technology providers.

Desorption of aq. HCl 30% - 32%:

There are three options available in this:

- **18% - 20% HCl route:** The distillation unit will desorb HCl and leave a 18% - 22% aq. HCl as a byproduct which needs to be again enriched from some other source to 30% - 32% and returned back here.
- **1% route:** The azeotrope of 18% - 22% can be broken with $CaCl_2$ solution and further distillation is possible until a 1% aq. HCl solution is left for disposal.
- **Twin Tower system**: This system gives a dry HCl and leaves only water which can be taken directly for inland irrigation or for cooling tower make up and is capital intensive.

All the above desorption systems yield HCl with lot of moisture, which needs to be dried further. As the HCl outlet pressure in options1 and 3 will be at 22.5 kg/ $cm^2$the moisture levels will be at about 200 - 300 ppm. With option 2, the generation pressure is at 1 kg/c cm^2 and will have a moisture level of about 1000 ppm.

With the addition of a Sulfuric acid tower after this the moisture level can be dropped to a level of about 50 ppm but leaves one more effluent to be handled that is spent sulfuric acid. All the desorption options require a molecular sieve system to bring down moisture levels to 12 ppm. Capacity of one block shall be at 1.8 - 2.0 MT per hour.

The produced Anhydrous HCl shall be free of moisture and carbon with moisture less than as per the specification discussed, under Raw material and Utilities

- This HCl is mixed with recycled HCl from the plant and compressed in diaphragm compressor to about 5 to 8 kgf/sq.cm and fed to TCS FBR.

The reactor while start up may be required to be operated at peak load till full recycle is established. Till this equilibrium is reached depending on quantity of recycle balance is generated by this reactor. The reactor is capable of having these turn down ratios.

The reactor should be built with safety locks to avoid un reacted chlorine going along with the product by proper ratio controller, Emergency controls should instantly cut down chlorine to appropriate levels.

Hydrogen

The polysilicon production process requires high purity H_2 with very low levels of moisture and carbon containing compounds.

Nitrogen

Nitrogen is a plant wide utility used to provide an inert gas space and to purge process materials from equipment and piping prior to maintenance. Nitrogen is also used in the following locations in the polysilicon production process:

- Pressurizing the Metallurgical Grade Silicon Reactor Feed Tank
- N_2 pad for chlorosilanes storage tanks (pressure control and inert gas space)
- Pressure control for certain distillation columns.
- In addition, a major use of nitrogen is the purging of the bell jar reactors (both polysilicon deposition and STC conversion) prior to accessing the reactor internals. The bell jars are similarly purged with nitrogen following any activity which exposes the inside

of the bell jar to the atmosphere. The nitrogen must be of very high quality since it does come in contact with process streams and process equipment.

Material specifications

Purity: ≥ 99.9999 % by volume

Impurities:

Name	Formula	Concentration
Total Hydrocarbons	CH_4	0.2 ppmv max
Nitrogen	N_2	0.1 ppmv max
Argon	Ar	0.1 ppmv max
Oxygen	O_2	0.1 ppmv max
Water	H_2O	0.1 ppmv max
Carbon Monoxide	CO	0.2 ppmv max
Carbon Dioxide	CO_2	0.1 ppmv max

The raw material requirements & source details are tabulated below:

Raw Material	Quantity	Source	Logistics
Metallurgical Grade Silicon (MG – Si) through Containers	~21,600 MTPA	Import from China & other Asian countries	Imported at Mundra port in Jumbo bags and then by road to plant
Hydrogen	~3200 MTPA	In-house Manufacturing	NA
Chlorine	~4000 MTPA	Domestic	Through Chlorine tonners

6.1 Utility requirement for Polysilicon plant

Based on the basic engineering and design the connected peak load for the 20,000 MT Polysilicon plant is estimated to be around 1400 MU per annum. The power will be fed by EMC promoter based on the requirement and through the main substation and controlled through distribution transformers and different control centres.

Through a ring main network power will be distributed to the individual blocks of the process area and connected to the equipment. Individual equipment level power requirements at plant level is shown below.

Polysilicon plant power requirement

Load requirements for polysilicon plant.		
Equipment Name	**Unit**	**Power requirement**
24 Pairs CVD reactor	40	1400 MU
Column	40	
Hydrogen compressor	21	
Hydrochlorination FBR	4	
Adsorber	42	
Cooling tower	4	

Polysilicon plant other utility requirement

Utility type	UOM	Requirement
Water	KLD	25,000
Natural gas	NM^3/Year	16,400,000
Steam (1.3 MPa)	Tons / Year	1,300,000

The following plant utility systems required to support the polysilicon production process are provided as a part of the production facility.

- **Compressed Air**

  Compressed air is a plant wide utility used for general applications and maintenance activities. This utility will not come in contact with process streams or be connected to process equipment. The typical operating pressure is 650 – 700 kPa (gauge).
- **Instrument Air**

  Instrument air is a plant wide utility used primarily to drive valve actuators. This utility will not come in contact with process streams or be connected to process equipment.
- **Steam**

  Steam is a potential heat source to be used either directly (or indirectly via hot oil) for heating or vaporizing process streams in heat exchangers throughout the process (e.g. column reboilers).
- **Industrial Water**

  Industrial water is a plant wide utility used for processes such as cooling tower makeup, DI water system feed, process hose bibs, etc.
- **Potable Water**

  Water used for drinking, washing, eye baths and safety showers.
- **Fire Water**

  A dedicated fire water system is required to support the plant fire protection and firefighting systems. Fire water tank will be provided with capacity 3000 m^3 in 650 m^2 area
- **Hydrant System**

Medium velocity water spray system

- High velocity water spray system
- Low expansion foam system
- Mobile & portable fire extinguishing equipment
- Fire alarm & detection system

The system will be designed in accordance with the requirement for the plant. While designing the fire protection system for this power station its extreme ambient condition will be taken into account. The water for hydrant and water spray system will be met from a dedicated firewater storage tank. All fire hydrants will be provided with necessary accessories and hose houses.

An automatic medium velocity water spray system with heat detection system will be provided for fuel oil storage tanks, cable spreader / trench area. A manual type medium velocity water spray system will be provided for air heaters. Water for the spray system is drawn from the hydrant main ring.

- **Thermal Insulation**

  Thermal insulation will be provided wherever necessary to minimize heat losses from equipment, piping and other auxiliaries, to ensure personnel protection. Insulation will be held by adequate cleats, wire nets, jackets etc. to avoid loosening. Insulation thickness will be selected so that the covering jacket surface temperature does not exceed the surrounding ambient temperature by not more than 20°C.

- **Cranes, Hoists & Elevators**

  Electric Overhead Travelling (EOT) cranes will be provided CVD building & metal grade silicon handling area. The cranes will be used for handling heavy equipment during erection and maintenance of equipment. The cranes will be designed to handle the heaviest piece in that area. Mono- rail hoists of suitable capacity will be installed in areas where the approach of external crane is not possible.

- **Workshop Equipment, Stores & Laboratory**

  The additional instruments required for chemical laboratory, electrical & electronic instruments for Electrical laboratory and the workshop equipment and accessories as required for general maintenance works will be provided.

- **Protective System**

  For protection of equipment against abnormal system conditions, adequate protective devices will be installed in the respective switchgears and/or control and relay panels.

  A group of such protective devices would be installed to protect the equipment under different abnormal conditions, arising in the system. Each equipment will be provided with a unit as well as backup protection.

  Besides this, protection against lightning surges will be provided with lightning arresters at suitable locations for outdoor equipment over and above the shielding wires and lightning masts. In any case, proper discrimination and selectivity will be provided so as to isolate only the faulty elements, keeping the healthy part of the system in service.

- **Plant Communication**

  The plant communication system will be provided to facilitate operations by establishing quick communications among the operating personnel stationed at various locations of the plant. The communication system comprises of internal telephone system through an automatic exchange (EPABX), to facilitate communication among the operators, and a public address system for simultaneous transmission of information and instructions. In addition, wireless system will also be provided for operators on the move.

- **Distributed Control System (DCS)**

  The instrument and control system will be provided with a microprocessor-based distributed control system (DCS) and a few other analogue instruments and control devices. It will perform the functions of monitoring, control, alarm, protection and interlock, diagnosing, accident treatment and maintenance guidance of the unit to meet all requirements at various operational conditions.

  - The system will fulfil the following basic functions:
  - Monitor all major plant functions inputted to the DCS
  - Provide the operator with a central, universal and instantaneous means to monitor the plant.
  - Collect and store data for trending of various plant functions. Keep track of various plant events and log them for historical purposes
  - Perform required basic calculations for performance monitoring and optimization.
  - Produce operating logs for record purposes and post trip review reports.
  - Provide sequence of events monitoring and reporting.
  - Perform self-checking and self-diagnosis
  - Provide capability to add, delete and modify points from the system by means of conversional mode.

  The fundamental functions such as control, alarm, monitoring, interlock and protection will be segregated, so that the failure of one does not result in the failure of other functions.

  There will be two DCS considered in the project one for the Trichlorosilane Synthesis and for the other parts of the plant.

  Error checking will be provided to ensure that accepted message is just the same as that was sent. Redundancy and self-diagnosis will be provided for the control system and communication network. The functions of a failed component will be transferred automatically and bumplessiy to the standby processor. The CRT, and the alarm printer will display the failure message. The corresponding input and output circuits are to be programmed in the I/O module.

  Sufficient redundancy in the control system will be built to take care of any exigencies and any future requirement and for process optimization.

- **Clean Room - HVAC**

  Clean room of cl.10,000 will be made for the CVD reactor section. The ingot preparation room will be to class 1,000.

  The final product chunking and packing will be provided with a Clause 100 levels to ensure the product is not contaminated during packing operations. The Clean rooms will be provided with dedicated HVAC with sufficient back ups.

- **Deionized Water**

  A treatment system for production of deionized (DI) water purification is needed for reactor filament production, process cooling water makeup, QA lab use, and various other users.

- **Wastewater Collection and Treatment**

  Process wastewater from the Vent Gas Treatment final scrubber, the Batch Neutralizer, the Neutralizer Scrubber, and the Emergency Scrubber are sent to the wastewater treatment system.

  Wastewater treatment may include pH adjustment, separation of trace insoluble organics, and clarification (removal of suspended particles) as required to meet local discharge requirements.

- **Recycle Water**

  Certain waste water streams are segregated, collected, and fed to a recycle water treatment system within the waste water treatment plant. The recycle water is primarily used for

processes such as cooling tower makeup.

- **Sanitary Sewer**

  A separate sanitary sewer system will be required to service streams from lavatory locations.
- **Plant Cooling Water**

  Plant cooling water is a process utility primarily used for the cooling medium for systems outside the main process areas where temperature limitations or tight control is not required.
- **Normal Electrical power**

  The plant will be supplied by two independent high voltage electrical sources. The system will provide step down transformers and distribution switchgear to supply power at the appropriate voltages for process equipment. Portions of the electrical distribution system and equipment will be rated for use in a classified (hazardous) environment.
- **Emergency power**

  Emergency power will be provided to critical control, safety, and environmental protection systems to maintain operation in the event of a power outage. Selected users of emergency power will be provided with an uninterrupted power source (typically local or centralized battery backup) to ensure continuous operation.
- **Uninterruptable Power**

  Uninterruptable power should be considered on systems where a loss of power could result in the permanent loss of critical operating parameters or data. The Distributive Control System computer and compressor PLC's may utilize uninterruptable power.
- **Fuel Gas**

  Fuel gas will be used to fire the heating units on the Trichlorosilane Production Hot Oil and Trichlorosilane Purification Hot Oil systems.
- **Plant Safety and Environmental Systems**

  The following plant safety and environmental systems are required to support the polysilicon production process.
- ***Fire and Hazardous Gas Detection and Monitoring***

  Gas detection systems are installed in order to provide early leak detection of chemical releases. Early detection is important to prevent exposure and/or injury to personnel and to minimize releases to the environment. For the polysilicon plant, both flammable gas and acid gas detection should be installed.

  Typically, sensors within the process areas are placed in serviceable locations, away from sample points, in a quantity and density to ensure early detection. Additional sensors are placed on the plant perimeter in order to detect releases going outside the process areas and potentially off site. Gas detection inside buildings will be linked to building evacuation alarms.
- ***Liquid Leak Detection and Monitoring***

  Liquid leak detection in the process area containment areas are installed for early leak detection of not only process chemicals, but also cooling water and other process utility spills such as hot oil. Placement and activation of these systems must be carefully engineered so that rain water, for instance, will not cause false alarms.
- ***Spill Containment and Vapor Suppression***

  A spill involving one or more of the liquid chlorosilanes associated with the polysilicon process poses a significant safety and environmental risk to the production plant. Chlorosilanes are flammable and upon release will react with moisture to produce corrosive and toxic compounds. For example, TCS is consider highly flammable with a flash point of minus 28°C and carries the

following additional warnings concerning release and improper handling:

- Can form explosive mixture with air
- Reacts violently with water
- Reacts with water and moisture to form gelatinous silicic acid and other corrosive acid(s)
- With water causes rapid corrosion of some metals
- May react violently with oxidants

All areas where liquid chlorosilanes or other hazardous liquids are present will be provided with non-permeable spill containment barriers suitable for long term exposure to the chemicals to be contained. The height of the barriers will be based upon the maximum quantity of liquid which may be present within the containment area.

The area of the individual containment areas will be limited to provide for localized containment and prevent spills from spreading to otherwise unaffected areas of the plant.

The containment areas will be designed, as much as practical, to direct spilled fluids to collection sumps to minimize the surface area of exposed liquid (contributing to vapour release) and facilitate collection and treatment of the fluids. All spill containment areas will be provided with spill/leak detection and alarms.

The outdoor spill containment areas will be designed to address the effects of rainwater collection within the containment area and provide for transfer of collected rainwater to the storm water collection system.

- **Storm Water**

Storm water management systems need to be designed and put in place to handle the accumulation and possible treatment of potentially contaminated rain water.

7.1 Proposed Infrastructure by EMC

7.1.1. Basic infrastructure

a) Internal roads network

The entire road network is divided into four corridors to access any designated area within the entire EMC facility.

- Main arterial road comprising of 40 meter, 30 meter, 18 meter, 12 meter ROW approximately 12550 **meter** four lane/two lane carriageway
- Provision of street light is maintained for the road. The pavement will be designed for heavy traffic movement in arterial roads and light traffic movement in service road
- Pavement marking and road signs will be provided as per standard practice and project specific requirement
- The roads within EMC shall be of flexible pavement road (preferably) i.e. bituminous road. Wherever required, rigid pavement concrete road would be provided. The pavement thickness shall be designed to cater to the desired traffic intensity estimated approx. of 350 to 400 trailers per day. This traffic intensity is expected within EMC.
- Four lane bituminous roads with shoulders and RCC drains will be provided to access all parts of the EMC area. In addition to four lane road, the two lane roads will also be provided with divider as per IRC norms. All storm water drains will be RCC rectangular drains. This would be open at top except at road crossing where precast concrete cover slab will be provided. Kerb Stones are intended to separate surfaces providing physical or visual delineation and containment of the pavement construction and also on either side of roads.

b) Landscaping and Green Belt development

The proposed landscaping and green belt development plan will have an objective such as prevention of land degradation due to activities during construction phase; enhancing the forest cover for increasing the biodiversity of the region; providing aesthetic value to the project area and enhancing the ecological equilibrium of the area; and to a large proportion in combating soil erosion.

The development of green belt protects the natural flora and fauna of the area and provides cleaner, improved air quality. The greenbelt development plan aims at overall improvement in the environmental conditions of the region. Approach roads shall be covered under this plan by providing avenue plantation on both sides or at median of the road. Wherever required, guards and barbed wire fencing will be installed for protection of the plants. In addition there shall be roadside plantation in two rows on either side of new roads around the project area and also along existing roads. To maintain the plantation, organic manure and arrangement of water will be done.

c) Street lighting

11 kV/415V Compact Sub Stations (CSS) are proposed to cater power to street light and parking area. LED type lighting fixtures are proposed to save power. Tubular 9m height with single arm/double arm lighting pole are proposed to illuminate internal roads within EMC area. LED lights of 60 W are proposed for Street lighting purpose. Solar Street Lights have been considered over normal street lights due to the following advantages:

- No line voltage, trenching, or metering
- No power outages
- Battery backup for cloudy or rainy days
- Solar street lights are independent of the utility grid. Hence, the operation costs are minimized.

- No maintenance except for the battery: Solar street lights require much less maintenance compared to conventional street lights.
- Since external wires are eliminated, risk of accidents is minimized.
- Environment friendly - 100% powered by the sun, solar panels reduce fossil fuel consumption, eliminating pollution.
- Separate parts of solar system can be easily carried to the remote areas

The solar street lights shall have the following components:

- Solar Panel
- LED Lighting Fixture
- Rechargeable Battery
- Controller
- FRP Pole

d) Storm water drainage system

Storm Water drainage system within EMC shall be designed considering rainfall intensity of 75mm/hr and for 1 hour duration. The cross section and longitudinal slope of drains shall be designed such that the velocity of water shall be equal to or more than self-cleaning velocity. The proposed drainage design shall be revalidated from Indian Metrological data.

RCC rectangular drains shall be provided. At road crossings, cross drainage work either of RCC box culvert and/or pipe culverts of suitable diameter and class shall be provided.

e) Boundary wall

The boundary wall will be provided on the periphery of the EMC area for only 511.34 acres and the rest additional area would be demarcated along the periphery of the EMC without any boundary wall.

- Boundary wall shall be of 2.4m high and constructed with pre-stressed precast panels.
- The wall panels are designed for 2133 mm (L) X 50 mm (B) x 300 mm (D) , 7 no's
- Vertical post with pre-stressed precast concrete will be provided at regular interval.
- The foundation shall have 250 dia piles 6 m depth at 2.253 m^3
- The column sections are designed for 200 mm X 200 mm X 2700 mm high
- Metal angle post with RBT wire will be provided over boundary wall as additional protection.
- The total length of boundary wall is around 6.125 kms.

7.1.2. Essential infrastructure

To ensure that EMC facility has seamless access to essential basic services like water, power, sewerage and effluent effectively, it is proposed that the essential services be addressed in separate such as those required at the unit level and at the facility level. The requirements for the EMC facility shall be met by the infrastructure already available within the SEZ facility and such details are provided in the subsequent sections. Essential services required by respective units shall be designed and built by respective units as per their needs; however MSTPL will facilitate the requirement for power, water, ETP and other utility needs as when required.

a) Primary power distribution

The power infrastructure is planned to meet the requirements of EMC facility. Initially 11 kV and 66 kV voltage levels are proposed as receiving voltage from local distribution licensee *MPSEZ Utilities Pvt. Ltd.* ***(MUPL)*** and a 220 kV substation is envisaged for meeting the future requirement of the anchor and other units. In this regard, MSTPL has already filed an application with MUPL on 07th August 2015 to

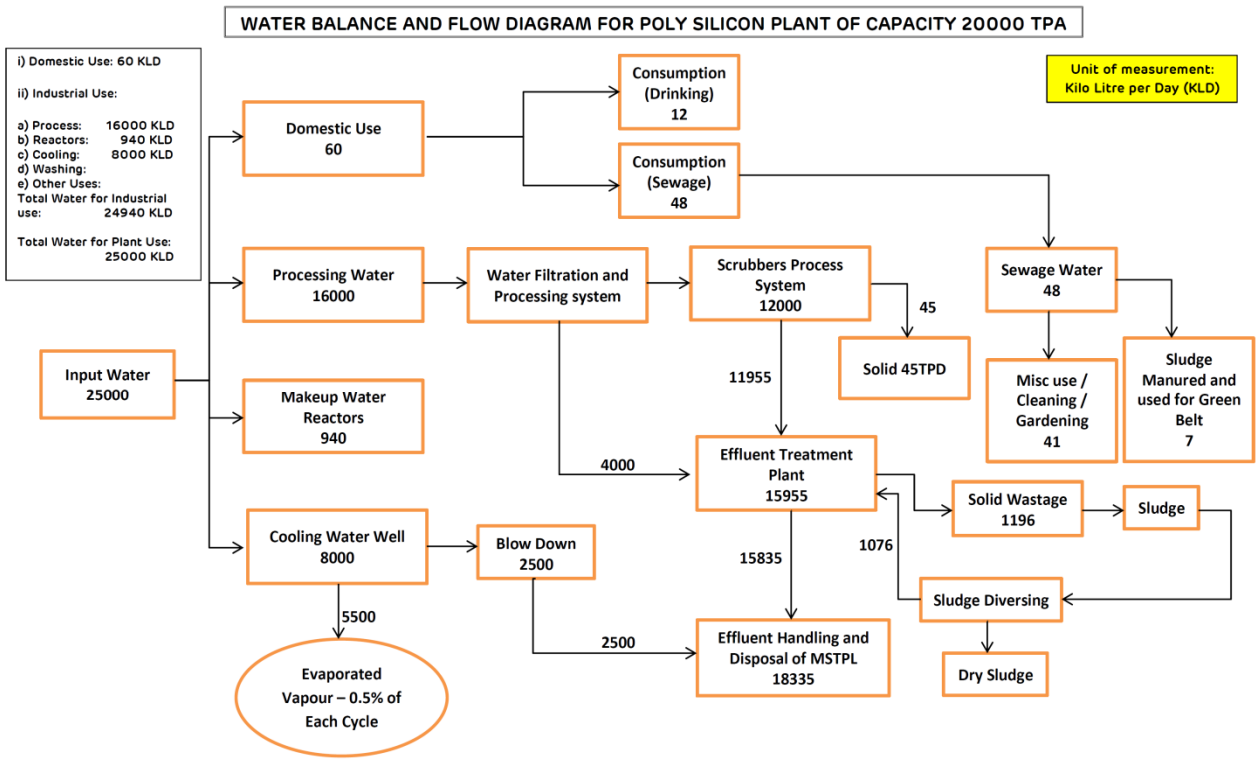
avail power supply at 11 kV and 66 kV voltage levels.

b) Water Supply

The overall water distribution infrastructure is planned to handle the water requirement estimated at 40 MLD. The initial infrastructure is planned to meet the EMC related water requirements estimated at 2 MLD. Desalinated water to the EMC facilities will be supplied from the existing 40 MLD desalination plant with suitable capacity augmentation.

- Desalinated water will be stored in RCC tank (partly below and partly above ground located within EMC facility area) of capacity 5000 cu.m. This tank capacity is derived considering buffer storage of 3 hrs of total process water requirement and one hour of total pumping capacity of fire water in line with TAC requirement i.e. 3000 cu.m water storage for fire protection system.
- The desalinated water tank shall be designed as per IS 3370.This also includes the water requirement for fire protection systems.
- From the storage tank, three (3) vertical turbine pumps (2W+1S) of capacity 840 m^3/hr at 40 mWC head will supply / distribute the desalinated water to various Units/ facilities located within the EMC facility from the storage tank.. The vertical pumps capacity is arrived based on 40 MLD of process water requirement for the EMC. Each facility will have their storage & further treatment & distribution network within their Unit.
- HDPE piping will be used for the water supply system considering high chloride content in desalinated water. This will eliminate internal corrosion in water supply piping.
- Water supply pipe is routed from existing power plant desalination plant to EMC complex via. Water tank located near Main Receiving Sub-Station (MRSS) which is approximately 5 Kms and the water pipe will be routed underground.
- MSTPL is also providing the internal pipeline distribution infrastructure for all the Units located within the EMC facility.
- The water shall be pumped in to the ring main to different units using piped water network.

Water Balance Diagram



c) Effluent storage and collection

Effluent/sewage shall be considered as 80% of the water supply. Effluent generated from the individual Units located within EMC facility will be treated by the individual Units and thereby meeting the environmental regulations stipulated by Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) norms/regulations.

- Treated effluent from all the Units located in EMC complex will be transferred to common collection RCC sump having approx. 5 hrs. Storage and will be located within EMC complex.
- The storage tank capacity of effluent is about 7000 cum. From common collection sump, treated effluent will be pumped to outfall channel through 3nos. (2W+1S) pumps vertical turbine pumps of capacity 700 cu.m. /hr and rated discharge head of 30 mWC.
- Effluent discharge shall be continuous .Treated Effluent meeting the relevant norms will be discharged to outfall through underground HDPE piping. The typical specifications of the HDPE piping are given below
    - Pipe Size : 500 NB
    - Pipe MOC : HDPE
    - Pressure Ratting : PN 6
    - Grade : PE 80
    - Design Standard : IS 14333
- In case the discharge norms are not met by individual units, then there will be a provision for retreatment of effluent at the individual units

d) Sewage Treatment System

The sanitary waste streams from toilets of different buildings will be conveyed either by gravity or by

pumping to the main sewage receiving sump cum lifting station. Final treated sewage will meet the norms of Environment. Sewage will be transferred to common sewage receiving station through sewage network which will be covered under civil scope.

STP capacity : 2 X 60 KLD (Packaged type)

Type : Aerobic

Raw Sewage Characteristics:

1	BOD_3 27ºC	:	350 mg/l
2	COD	:	500 mg/l
3	TSS	:	500 mg/l
4	Fecal Coliform	:	10^6 - 10^7, Number per 100 ml

Treated Sewage Characteristics: (Deleted)

1	BOD3 27ºC	:	30 mg/l
2	COD	:	100 mg/l
3	TSS	:	5 mg/l
4	pH	:	6.5-8.5
5	Fecal Coliform	:	<1000, Number per 100 ml
6	Residual Chlorine	:	0.5 mg/l

Treated sewage water will be used in horticulture.

e) Fire protection service

The Fire Detection and Protection System provide a means to control fire hazards in order to provide life safety and minimize property loss in the event of fire.

Water for the fire protection system is supplied from a water storage tank which will have dedicated water storage for fire water supply system. The system consists of water storage tank, main fire water pumps, jockey pumps and yard piping. The fire water mains are provided with necessary sectional isolation valves to permit isolation of a particular section for maintenance while keeping the rest of the system operational. Fire hydrants are installed along the fire main in accordance with TAC recommendations. External Hydrant System shall cover following facilities:

- Admin Building including auditorium and conference facility
- Gate Complex /Security building
- Fire Station
- Canteen
- Training Center
- Warehouses
- Switchyard

Detail of Fire pump, jockey pump, diesel pump with capacity:-

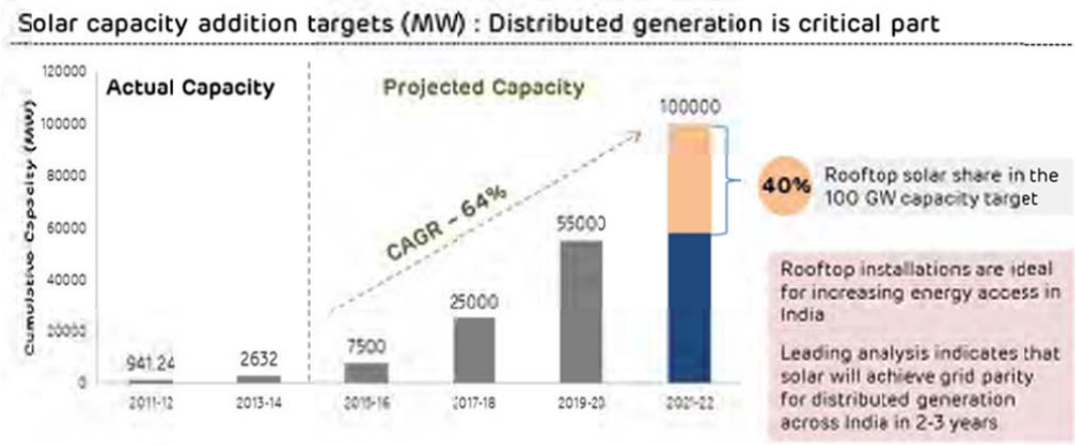
Sr. No.	Name of Pump	No. of Pump	Capacity
1.	Electrical Pump	2	273 m3/hr
2.	Jockey Pump	2	10 m3/hr
3.	Diesel Pump	2	273 m3/hr

Detail of fire extinguisher:-

Sr. No.	Type of Fire Extinguishers	Capacity	Qty.
1	ABC DCP STORED PRESSURETYPE	06 KG	30
2	ABC DCP STORED PRESSURETYPE	02 KG	15
3	DCP BC TYPE	06 KG	40
4	MECHANICAL FOAM	50 LITER	20
5	CO_2 TYPE	4.5 KG	15

8.1 Project rationale

GoI has recently revised the national target for solar power from 20 GW to **100 GW, to be achieved by 2022**. This target triggers the demand for large scale manufacturing of Solar PV components. Prevailing demand supply gap in manufacturing capacity creates a case for investments in domestic solar equipment manufacturing across the value chain if the national level targets are to be achieved.



India's aggressive plans for solar generation

Current installed capacity & Existing manufacturing capacities are extremely small & unintegrated, hence cannot support the desired Solar Power generation targets. This implies that the country would need significant manufacturing capacities to meet above demand.

India's current Solar PV manufacturing capacity shortfall

Projections in MW	FY16	FY17	FY18	FY19	FY20	FY21	FY22
Annual capacity projections	7,500	7,500	10,000	12,500	17,500	20,000	25,000
Cumulative installed capacity	-	15,000	25,000	37,500	55,000	75,000	100,000
Domestic production - cell manufacturing capacity	1,375	1,375	1,375	1,375	1,375	1,375	1,375
Shortfall in domestic capacity (Import dependency)	6,125	6,125	8,625	11,125	16,125	18,625	23,625

Current installed capacity & Existing manufacturing capacities are extremely small & unintegrated, hence cannot support the desired Solar power generation targets

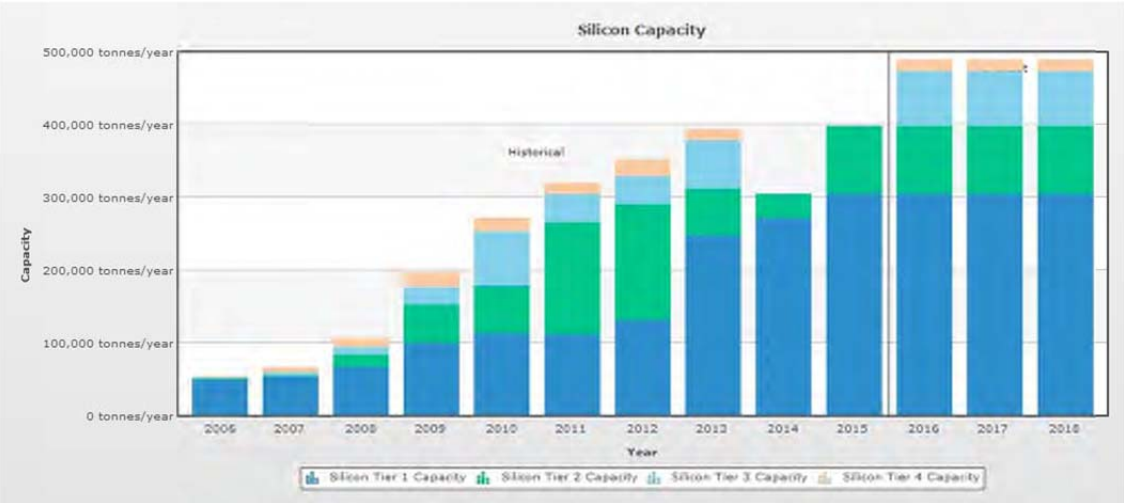
Launch of **"Make in India"** augments decisions to focus on domestic manufacturing.

Govt. Focus Area	Advantages for solar manufacturing
Growth in Manufacturing Sector (aligned with "Make in India")	• Reduces dependency on import of Solar components primarily from China. • Reduce imports to control current account deficit.
Increase in Manufacturing sector share in GDP	• Investment potential of $ 10 Bn and annual revenue of $ 7 Billion after 7 years.
Employment	• Direct employment of ~150,000 by 2022
Additional skill set development	• Creates skill enhancement opportunity through direct / Indirect employment for rural and urban population

MSIPS Policy	NCEF funds	SEZ benefits	State policies
• Upto 25% capital subsidy & upto 10% production subsidy for manufacturing across solar value chain	• Additional 15-20% capital subsidies for solar manufacturing	• Direct and indirect tax benefits • Customs duty exemption	• Power subsidy • Interest cost rebate • Tax exemptions

While poly silicon is the most critical raw material in the value chain, India does not have any polysilicon manufacturing capacity.

Internationally, polysilicon supplies are concentrated in China and US and hence there is a strong case for manufacturing in India.



Given strong solar demand, the polysilicon consumption is expected to increase in future.

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9.0 Environment Management Plan

A. INTRODUCTION

The Environment Management Plan (EMP) is required to ensure sustainable development in the area surrounding the proposed project/activity. Hence, it needs to be an all encompassive plan for which the industry, Government, Regulating agencies; like Pollution Control Board working and the local residents of the area need to extend their co-operation and contribution.

It has been evaluated that the proposed project will have no negative impacts on the surrounding areas. Mitigation measures at the source level and an overall Management Plan at the site level are elicited so as to preserve the surrounding environment.

Based on aspect/impact analysis and potential environmental impacts, mitigation measures are recommended in order to synchronize the economic development of the project area with the environmental protection of the region. The construction phase impacts are mostly short term, restricted to the plot area and not envisaged on the larger scale. In the operational phase, the environmental impacts are due to continuous operation of the project; hence, the emphasis in the Environment Management Plan (EMP) is to minimize such impacts. The emphasis on the EMP development is on the following:

- Mitigation measures for each of the activities causing the negative environmental impact
- Monitoring plans for checking activities and environmental parameters and monitoring responsibilities
- Role responsibilities and resource allocation for monitoring

B. THE PROJECT

M/s. Mundra Solar Ltd intends to set up First in India; “Polysilicon manufacturing plant” located within a notified Electronic Manufacturing Cluster (EMC) facility of Mundra SEZ under the M-SIPS guidelines. This project will be one of the first such facilities located at Mundra, Dist: Kutch, Gujarat.

The proposed Solar PV Manufacturing Unit will be located within EMC facility at existing SEZ, and benefits from the following common infrastructure already in place:

- Mundra SEZ is equipped with a multimodal connectivity which includes Road, Air, Sea and Rail linkages.
- Mundra SEZ is equipped with well-developed social infrastructure facilities for residential, commercial, education, health, recreational and other activities.

In addition to these, the area has special industrial infrastructure services like Effluent Treatment Plants, Desalination Plant, Water Treatment Plants and others which are ready for use based on the required capacity.

The proposed facility will be located within an EMC facility of 640.89 acre plot of land within the Mundra SEZ, about 60 KM from Bhuj airport and 65 KM from Kandla airport and well connected with State Highway No.6 and No.48, and National Highway 8A and NH 15 to key cities like Ahmedabad, Mumbai and Delhi.

In order to manage environmental issues, appropriate institutional arrangements along with suitable organizational structure need to be in place, with clear definition of a range of required activities, powers and responsibilities. The assessment of environmental impacts and mitigation measures have been identified for effective operation of environmental management activities in the pre-construction, construction, commissioning and Operation and Maintenance (O&M) activities.

Following sections describe the environment management plan proposed for construction and operation phases.

C. ENVIRONMENT MANAGEMENT PLAN

Environmental Management Plan (EMP) is a plan that seeks to achieve a required end state and describes how activities that have or could have an adverse impact on the environment, will be mitigated, controlled and monitored.

The EMP will address the environmental impacts during the design, construction and operational phases of a project. Due regard must be given to environmental protection during the entire project. In order to achieve this, number of environmental specifications/ recommendations has been made. These are aimed at ensuring that the proponent/contractor maintains adequate control over the project in order to minimize the extent of impact during construction, ensuring appropriate restoration of areas affected by construction, and preventing long term environmental degradation.

Environmental impact arising due to development activities are considered as the heart of Environment Management process. An equally essential element of this process is to develop measures to eliminate, offset, or reduce adverse impacts to acceptable levels and enhance the beneficial ones during implementation and operation of the projects. The integration of the project planning has been done by clearly defining the environment requirements within an Environment Management Plan (EMP). The Management Action Plan aims at controlling pollution at the source of generation itself to the maximum possible extent with the available and affordable technology followed by treatment measures before they are discharged.

Specifically, the EMP monitors and manages environmental aspects and issues of the project during operation phase by:

- Identifying potential environmental impacts;
- Recommending mitigation measures for the negative impacts;
- Identifying opportunities for enhancement measures;
- Providing an organizational framework for operating Environment

Management System and other functions of the project by assigning roles and responsibilities for environmental monitoring and management;

Formulating Environmental Management Plan, which specify mitigation, monitoring activities and indicators to be attached to Annual and periodic activity plans for project implementation.

D. COMPONENTS

In this section, Environmental Management Plan has been dealt for both construction and operational phase of the proposed 20000 MT Polysillicon manufacturing Plant. The following are the components of EMP:

- Mode of Implementation (Mitigation Measures and arrangements for Impacts)
- Institutional Arrangements

E. CONSTRUCTION PHASE:

Mode of implementation: Construction Phase

Mitigation Measures	Mode of Implementation	Task allotted to
Air Environment		
Water sprinkling in vulnerable areas	Daily twice or as Specified in civil construction package and site inspection	Civil Construction Group
Proper maintenance of vehicles and Construction equipment	Site Inspection	Construction Group
Transportation of construction material in covered trucks, wherever possible	Site Inspection	Construction Group
Noise Environment		
Proper maintenance of vehicles, equipment and machinery	Site Inspection and records	Construction Group
Provision of acoustic covers/ enclosures on equipment and machinery	Specified in contact award and Inspection	Environment, Health & Safety (EHS) Group
Provision of earmuffs/ earplugs to the workers in high noise areas and enforcement of its use	Specified in contact award and Inspection	Environment, Health & Safety (EHS) Group
Water Environment		
Channelization of effluents from construction area through existing network of drains	Site development and as specified in the contract award documents	Civil Construction Group and EHS
Construction of temporary sedimentation tanks for the effluents from construction area	Site development and as specified in the contract award documents	Civil Construction Group and EHS
Solid Waste Management		
Disposal of surplus earth and construction debris	Site development and as specified in the contract award documents	Civil Construction Group
Socio-economic Environment		
Provision of environmentally safe camping area for the migrant laborers	Site development and as specified in the contract award documents	Top Management
Arrangements for water supply and sanitation	Site development and as specified in the contract award documents	Civil Construction Group

MANAGEMENT:

Environment impacts during construction phase will be mainly due to civil works such as site clearing, foundation, construction, material and machinery transportation etc. The construction phase impact will be temporary in nature and localized phenomena except the permanent change in land-use pattern at the project site.

Based on the findings of the impact assessment and considering the necessity to limit environmental impact during construction, a general guideline has to be ascertained. Figure outlines the implementation of the EMP during construction phase for ensuring compliance with environmental rules, regulations and standards.

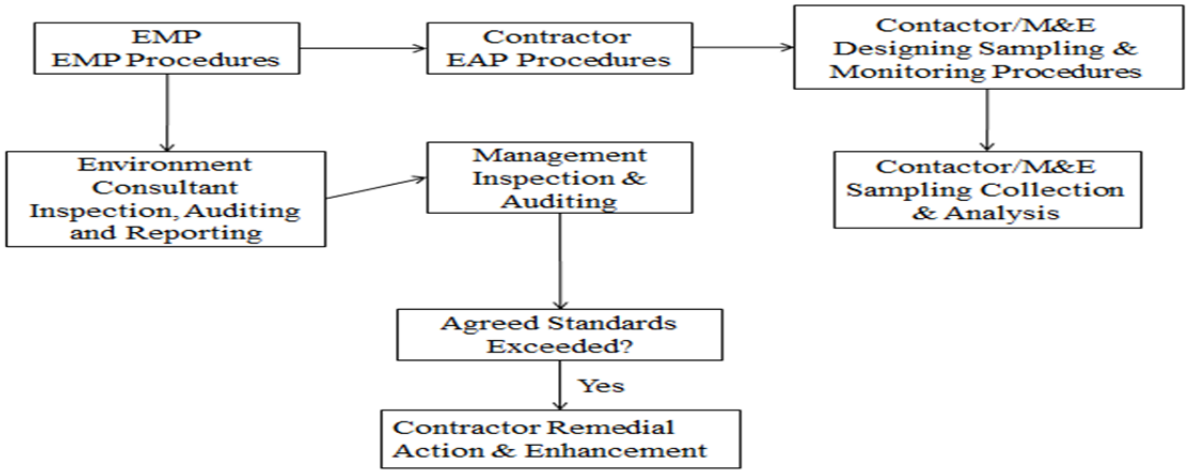

Figure: Outline for EMP implementation during construction Phase

Mitigation Measures Proposed during Construction

The mitigation measures for environmental control during construction are summarized in the following Table

Mitigation Measures Proposed During Construction Phase

Probable Source	Proposed Mitigation Measures	Targets to Achieve
Air Environment		
Increase in dust and NO_X concentration in ambient air due to Leveling and Heavy Vehicle movement	Water sprinkling in vulnerable areas Proper maintenance of vehicles and construction equipment Transportation of construction material in covered trucks, wherever possible	Control of fugitive dust from construction areas Control of NO_X Emissions Control of Fugitive dust from construction
Noise Environment		
Construction Equipment	Proper maintenance of vehicles, equipment and machinery Provision of acoustic covers/ enclosures on equipment and machinery wherever possible Provision of earmuffs / earplugs to the workers in high noise areas and enforcement of its use	Control of ambient and in-plant noise levels Control of ambient and in-plant noise levels Protection of workers
Water Environment		
Soil runoff and effluents from construction activities	Channelization of effluents from construction areas through existing network of drains Construction of temporary sedimentation tanks for the effluents from construction areas.	Control of suspended solids in effluents from construction area
Solid Waste Management		
Construction Activities	Disposal of surplus earth and construction debris Reclaiming of un-built area with appropriate vegetation / landscaping	Control of pollution Create a good visual environment
Ecology	Awareness training and camps	
Clearing of Vegetation	Soil enabling activities Afforestation and Green belt Development	-

Disposal of Solid & Liquid Waste

Adequate sanitation facilities on construction site would be provided. All waste from the sanitary system would be dispose off suitably to avoid environmental pollution. Wastewater should be routed through suitable designed Sewage Treatment Plants, without contaminating either ground or surface water or causing a health risk.
Earthwork involves removal of vegetation also due to the construction and transportation activities, a lot of dust will be generated. Water will be regularly sprinkled to reduce dust. Low-lying area, if any, will be filled with the earth excavated during the construction work.

Labor Colony
The following facilities are recommended for the labor camps:

- Labor camp site shall have electricity and ventilation system, water supply and community latrines with semi-permanent structures for their workers;
- Water must be treated and disinfected before consumption;
- Commissioning of community Latrines and Septic Tanks are proposed to be constructed;
- Adequate facilities for collection, conveyance and disposal of Solid Wastes shall be developed for Solid Wastes collection, conveyance and disposal.

F. OPERATION PHASE

Mode of Implementation (Mitigation Measures and Arrangements for Environment Impacts)

Mitigation Measures	Mode of Implementation	Agency
Air Environment		
Air pollution control device	Integral Part of Main Plant Package	O&M
Water Environment		
Cooling Towers	Part of Main Plant Package	O&M Group
Effluent Treatment Plant	Part of Main Plant Package	O&M Group
Sewage Treatment Plant		Township Administration
Noise Environment		
Provision of acoustic enclosures/ barriers/ shields to reduce noise	-	-
Provision of personal protective equipments (PPE)like ear plugs and earmuffs	-	Plant (O&M) and HSE Group
Solid Waste Management		
ETP Sludge	-	HSE Group
Township Solid Waste		Township Administration
Others		
Afforestation and Green Belt Development	-	Horticulture Group
Control of Fire and Explosion Hazard	Part of Main Plant Package	EHS (Safety Group)& O&M Group
Chemical Laboratory & Environmental Laboratory Equipment	-	Water Treatment Plant (WTP) under O&M Group

MANAGEMENT:

Each of the activities during operation phase is critically reviewed for deriving out the mitigation measures. Mitigation measures for the activities considered to be causing significant environmental impacts during production phase.

In general, the best housekeeping practices are incorporated in the design as well as in production phase to reduce the short terms impacts due to the proposed activities.

Activity	**Environmental Impacts**	**Mitigation**
Manufacturing of Products.	• Air • Land • Water • Noise	Ensure proper handling of all spillages/Leakages by introducing spill control procedures for various raw materials.
		Ensure use of PPE's by workers.
		MSDS of each chemical & finished product to be displayed at the storage area.
		Necessary leave and licenses for storage of chemicals and gas will be obtained from authority.
		Ensure segregation of strong & Weak Streams at the point of Generation.
		Effluent streams to be treated through primary and secondary treatment process. Some of the volume will be recycled to reduce the water consumption and rest will be utilized for dust suppression and gardening purpose.
Operation of Column Steam Boilers	• Air • Noise • Land	Preventive maintenance of fuel firing system and optimization of air fuel ratio.
		Preventive maintenance of machinery to reduce noise level
		Provision of Adequate Stack Height of 35m
		Ensure usage of PPE.
Operation of DG Sets	• Air • Noise	HSD to be used as fuel
		Acoustically enclosed for noise reduction.
		Preventive maintenance of machinery to reduce noise level
		Ensure usage of PPE
		Provision of Adequate Stack Height
Operation of ETP & STP	• Land • Water	Effluent to be treated in the in-house ETP and then disposed to the common disposal facility
Temporary Solid Waste storage and handling within the premises.	• Water • Land	Well demarcated Storage area marked as Hazardous Waste Storage area with Leachate collection system, impervious roof and floor
Storage of all the raw materials, products.	• Air • Water • Land	Ensure proper control measures for safe storage of hazardous chemicals
		Proper facilities to prevent rain / storm water contamination during monsoon
		MSDS for each chemical to be displayed at the storage area
		Fire Extinguishers to be installed at all vulnerable points within the plant

Activity	Environmental Impacts	Mitigation
		Dyke walls to avoid mixing of the chemicals in case of spillage / Leakage
Transportation of all the raw materials, finished products & hazardous wastes	• Air • Water • Land	Pucca roads to be provided for internal transportation. Vehicles to have PUCs. Spillages if any to be handled with proper care and put to use up to extent possible.
Toilets	• Water	Ensure proper sewage collection, conveyance & disposal.
		Sewage to be disposed off in soak pit.
Development and maintenance of green belt	• Air • Land	Ensure development and maintenance of proper green belt as proposed.
Direct/Indirect Employment	• Socio-economic issue	Continue policy of local employment

G. INSTITUTIONAL ARRANGEMENTS (Environmental Management Cell)

A Separate Environment, Health & Safety (EHS) Department comprising of a team of experienced and qualified personnel shall be established to look after the Environment, Occupational Health & Safety functions of the Project. The Environment / EHS Group shall be headed by a Senior Level executive preferably an Environment Engineer of the Project. The Head of EHS will be assisted by well-trained staffs comprising of environmental and safety specialists.

The responsibility of environmental management of the Project is mainly to acts as coordinator for environmental matters. This group acts as a nodal agency for various groups at projects and corporate level as well as outside agencies like State Pollution Control Board.

The functions of Environment Management Cell are

- Environmental monitoring for routine monitoring of emissions, ambient air quality, water and wastewater.
- Analysis of environment data, reports, preparations and transmission of report to statutory authorities, Corporate Center etc.
- Compliance with guidelines and statutory requirements.
- Coordination with statutory bodies, functional groups of the station, engineering department etc.
- Interaction for evolving and implementation of modification programmes to improve the availability / efficiency of pollution control devices / systems.
- Environmental Appraisal (Internal) and Environmental Audit
- Coordinate and manage the EMP implementation during pre-construction, construction and operation phase.
- Preparation, implementation and follow-up of Rapid Action Plans (RAPs).

Environment Management cell will be equipped with an Environmental Laboratory. There will be a dedicated in-house Environment Laboratory or the work shall be outsourced to approved laboratory. The HOD (Environment) submits the Environmental Analysis reports to the Station Head and Corporate Environment & Sustainability Head for reporting the results to the statutory authorities regularly. Further, Safety specialist will ensure safe working practices in all sections of the plant. The Staff will is well trained for environment control measures like air, water quality monitoring, solid waste management, noise abatement etc. The Staff would also be trained to operate ESP and other pollution control equipment at maximum efficiency.

H. ENVIRONMENTAL MONITORING PLAN

Environment monitoring plan is given in table 5.3 as follows:

Environment Monitoring Plan

Sr. No.	Activity	Schedule
AIR QUALITY MONITORING		
1	Ambient air monitoring of parameters specified by GPCB in their air consents from time to time within the **M/s. Mundra Solar Limited** premises.	Every month
2	Stack monitoring of flue gas stacks as given in air consent from time to time	Every month
WASTEWATER QUALITY MONITORING		
1	Monitoring of untreated and treated effluent wastewater. Parameters as mentioned in Water Consent	Daily
NOISE MONITORING		
1	Noise Monitoring and maintaining records	Monthly
SOLID WASTE GENERATION MONITORING / RECORD KEEPING		
1	Records of generation of solid & Hazardous waste and records of disposal.	To be updated daily
2	Records of generation, handling, storage, transportation and disposal of other solid, aqueous and organic hazardous wastes as required by hazardous waste authorization	To be updated daily
ENVIRONMENTAL AUDIT		
1	Environmental statement under the EP (Act) 1986	Once in a year

I. GREEN BELT DEVELOPMENT

The total area of the plot is 57.09 Ha. The greenbelt area along with plantation and lawn development with tree cover will be developed in around approx. 15 Ha. The company has planned to develop green belt in surrounding location also with help of local body.

Trees will also help in attenuate the ambient noise level. This will also acts as a barrier between inside & outside environment. This will help in preventing outside pollution to come in the factory premises.

Criteria for Selection of Species for Greenbelt

The plant species suitable for greenbelt development need to be selected based on the following criteria:

- Fast growing;
- Thick canopy cover;
- Perennial and evergreen;
- Large leaf area index;
- High sink potential ;
- Efficient in absorbing pollutants without significantly affecting their growth;
- Suitable for the local seasons.

A concept of three tier green belt development viz. rows of permanent trees in say 20m width, followed by avenue trees with medium canopy in a width of approximately 50 m shall be planted along the periphery of the plant, thereby developing approximately 50 m wide green belt all along the plant boundary.

The various services / utility areas within the plant would be suitably graded to different elevations. Natural features of the plant site would be retained as far as possible to integrate with the buildings to form a harmonious / pleasant environment. Areas in front of various buildings and the entrance of power

plant would be landscaped with ground cover, plants and trees based on factors like climate, adaptability etc. The green belt would consist of native perennial green and fast growing trees. Trees would also be planted around the site area to minimize the dust pollution.

The species of trees, plants, shrubs, grass to be planted shall be selected so that it grows easily in this region.

Guideline for Plantation

The design and implementation of greenbelt within and around the complex of proposed power project shall follow the guidelines published by CPCB Govt. of India. About 1500 trees will be planted per hectare. The species identified for greenbelt development would be planted using pitting technique. The filling of soil should be completed at least 5-10 days before actual plantation. Healthy saplings of identified species shall be planted in each pit. The plant species that may be useful for development of thick green cover in keeping view of the nature of pollutants expected from power plant and pollution attenuation coefficient of plants, the following plants species are short listed for plantation as per recommendation of Forest Department.

Trees Species as per recommendation of Forest Department

Common Name	Botanical Name	Remark
Neem	Azadirachtaindica	Medicinal, Evergreen & Timber
Siris	Albiziasp.	Ornamental & Evergreen
Gulmohar	Delonixregia	Ornamental & Evergreen
Kachnar	Bauhinia variegate	Ornamental & Deciduous in winter
Amaltas	Cassia fistula	Ornamental & Evergreen
Ashok	Polyalthialongifolia	Ornamental & Evergreen
Kaner	Nerium sp.	Ornamental & Evergreen
Anola	Emblicaofficinalis	Medicinal & Fruit
Mango	Mangiferaindica	Fruit, Foliage & Timber
Palas	Butea monosperma	Ornamental & Deciduous in winter
Shisham	Dalbergia sissoo	Timber & Deciduous in winter
Pipal	Ficus religiosa	Medicinal & Deciduous in winter
Banyan	Ficus benghalensis	Foliage & Canopy
Jamun	Syzygium cuminii	Fruit, Timber & Evergreen
China rose	Hibiscus rosa chinensis	Ornamental
Mahua	Madhuca latifolia	Fruit, Timber & Evergreen
Bahera	Terminallia bellarica	Fruit, Timber & Evergreen
Karanj	Poongamia pinnata	Evergreen
Arjun	Terminallia arjuna	Ornamental & Evergreen
Teak	Tectona grandis	Timber & Deciduous in winter
Bamboo	Dendrocalamus strictus	Evergreen
Tecoma	Tecoma stens	Ornamental & Evergreen

Cost of Green Belt Development

The cost of greenbelt development will mainly include the soil handling and sapling costs including preparation of agricultural soil and use of biocides and fertilizers and cultures of Azotobacter and Rhizobiu. The costs will depend on local edaphic factors including distance of nearest nursery and sapling survival rates. About 10crores of Rupees has been earmarked for the greenbelt development.

J. RAIN WATER HARVESTING

It may be possible to construct Recharge Structure construction in form of "Recharge Percolation Well" at the site.

Rainfall is one of the important Parameters that contribute water for the purpose of its recharge into ground water reservoir and therefore estimating the likely quantum of it for the purpose of recharge is of prime importance.

Long term rainfall data is used for its analysis, probability of rainfall occurrence, rainfall intensity, analysis of daily rainfall, average evaporation. Moreover, hydraulic parameters like porosity and permeability values indicate the availability of underground space for storing recharged water if given opportunity. Opportunities may be created by planning for rainwater harvesting. Therefore, the application of concept of availability and opportunity has been considered.

Rainwater Aquifer has three main functions, namely;

- Storage,
- Transmission &
- Mixing.

The company currently has 57.09 Ha land in its possession and is available for rainwater harvesting.

Estimation of Effective Runoff Volume
Area x Rainfall x Runoff Coefficient
566580 x 550 mm/1000 x 0.5=155809 m^3

Recharge Structure; Like Recharge Pond/Tank Need To Be Constructed. By creating necessary infrastructure of drainage to divert & collect runoff water towards recharge structure like recharge pond for recharging ground water aquifer.

Comments:

1. The hydro geologic setting plays an important role in determining the degree to which recharge water can alter the quality in local aquifer system. The type of soils and their ability to absorb the salts in recharge water and the hydraulic properties of the aquifer contribute to or reduce salt concentrations.
2. Relevant information of various input parameters was collected, compiled, analyzed and interpreted of all relevant information of various input parameters to assess the present status on ground water conditions with special emphasis on ground water flow direction in and around the present study area Selecting Suitable recharge structure for its construction.
3. Recommending the specification for recharge structure construction and its maintenance.
4. The soils of the district are broadly classified as Saline alkaline soil in the Southern strip of the study area comprising the coastal area; which are generally not suitable for cultivation in their present state. The other type of soils: such as loam, silt, silty clay are also found at certain places.
5. Geo-morphologically the study area comprises of coastal area which is characterized by sand mounds and narrow plain strip
6. The ground water in and around the study area is mainly confined in unconfined and semi confined conditions. In general the ground water quality is inferior (saline), except at places where such wells are located near surface water bodies are yielding relatively good quality water.

For recharging ground water Aquifer /Reservoir, Rainfall is one of the important Parameters that contribute water for the purpose of its recharge into ground water reservoir and therefore estimating the likely quantum of it for the purpose of recharge is of prime importance. Long term rainfall data is used for its analysis, Estimation of Effective Runoff Volume 155809 m^3

Recharge Structure Like; Recharge Pond/Tank Need to Be Constructed By creating necessary infrastructure of drainage to divert & collect runoff water flow towards recharge structure like Recharge Pond/Tank for recharging ground water aquifer.

K. CLEANER PRODUCTION

The following objective would be adopted for effective implementation of Cleaner Production (CP):

- The concept of Four -R's- reduce, reuse, Recover and recycle would be implemented as much as possible.
- Appropriate Fuel handling system would be installed to minimise wastage
- Treated effluent would be partially recycled.
- The feeding of solid raw material would be done by hopper so that there is least spillage due to fugitive emission.
- Optimum operating conditions would be maintained to get maximum yield.

L. ENVIRONMENTAL IMPACT STATEMENT AND SUMMARY OF ENVIRONMENTAL IMPACTS

AMBIENT AIR

M/s. Mundra Solar Limited will not adversely affect the ambient air quality in surrounding area.

The following air pollution control measures have been recommended for implementation at the proposed plant:

- Boilers shall be operated with minimum excess air so that fuel consumption is reduced and NOx emissions are minimized. Low NOx burners shall be installed for further reduction in NOx emission.
- The Stack and the ID Fans with adequate capacity shall be provided to take care of emergency release conditions and for additional load of flue gas under Boiler start up and shutdown periods.
- All the internal roads shall be asphalted to reduce dust emission due to vehicular movement.
- The combustion units shall be maintained properly for obtaining optimum efficiency and to ensure that the emission rates remain within estimated levels.
- The fugitive emissions should be reduced by adopting appropriate measures.
- Adequate Plantation of trees shall be done to absorb the dust released in these areas.

WATER RESOURCES

Water will be supplied by MPSEZ and no ground water shall be withdrawn from the bore wells. It follows that ground water quality is not adversely impacted due to activities of **M/s. Mundra Solar Limited**.

Water is required for makeup to the closed cycle re-circulation system. It is proposed to reuse the water wherever possible to achieve minimum discharge concept. It is envisaged to utilize process waste water after treatment further back into process and for gardening.

The treated waste-water will be recycled for plant use and for green belt development. Therefore, there will be no impact on the ground water resources because of contamination due to discharge of wastewater.
The major waste-water generated from the plant like DM Plant discharge will be treated in a Waste Water Treatment Plant and recycled for its reuse in the Plant. No discharge of liquid waste to the other public boundaries and water bodies is foreseen for the proposed plant.

In the plant, some specific locations require washing, to maintain good plant housekeeping and prevent build-up of dirt and waste material, which generates waste water. This waste water containing oil along with process drain will be led to an Oil Water Separator for separation of oil. The clear water will be led to the Monitoring Basin. The separated oil will be recovered separately in a drum and shall be recycled and reused.

NOISE LEVELS

Considering the Mitigation measures, the Noise levels shall be within limits specified by statutory authority at plant boundary, Moreover, the Preventive Maintenance of the equipments shall also be carried out regularly. Hence, there shall be no adverse impact on noise levels due to operations of **M/s. Mundra Solar Limited.**

Manufacturers and suppliers of noise generating devices/machines like Steam Turbine Generator, Compressors and other rotating equipment shall be asked to provide acoustic enclosures for noise control by adopting appropriate design and state of art technology for fabricating/assembling machines.

Proper noise barriers/ shields etc. shall be provided around the equipment wherever required. Noise from equipment shall be adequately attenuated by providing soundproof enclosure and insulation to minimize the noise level.

Recommendation for Noise Management
To reduce the impact of noise, shock absorbing techniques may be adopted;

- All openings like covers and partitions shall be acoustically sealed
- The Operator's Cabin (Control Rooms) shall be properly insulated with special doors and observation windows
- The operators working in the high-noise areas would be strictly instructed to use earmuffs/ ear plugs
- Noise levels shall be reduced by the use of absorbing material on floors, walls and ceilings
- Development of thick vegetation in the plant premises shall be done to attenuate continuous noise.

SOIL QUALITY

M/s. Mundra Solar Limited will take all reasonable precautions to make its solid waste and effluent storage / treatment areas impervious to water and leachate migration. This will prevent soil contamination. It follows that the soil quality shall not be adversely impacted by proposed plant operations.

FLORA & FAUNA

The proposed project is situated within the notified industrial estate & looking to the Environmental Management Plan, there shall not be any significant impact on the flora and fauna of surrounding area.

SOCIAL ENVIRONMENT

The proposed project is expected to contribute towards uplift of local people's quality of life and it shall generate inputs for industrial/economic development in the region. Following guidelines are given to proponents for protection of workmen likely to be engaged from the nearby villages, as also a discussion towards the end covering community benefits. The project proponent should take adequate steps to get local people into confidence so as to avoid any misconceptions amongst the people in future. The following measures are suggested for minimizing the adverse impacts on Socio - Economic & Human interest:

- Communication with the local community should be institutionalized as done on regular basis by the project authorities to provide an opportunity for mutual discussion.

- Social welfare activities may be undertaken by the project authorities in collaboration with local administration, gram panchayat, block development office etc. for better co-ordination.

For the workers in the plant, facilities such as sanitation, fuel, restroom, canteensetc.will be provided. This will be also applicable to contractual workers during constructionas well as operation phase. Medical facilities and provision of safety appliances will also be made available to all categories of workers. Where natural lighting is not adequate to ensure safe working conditions, and during night time, adequate and suitable solar lighting, including portable lighting, would be provided at every workplace.

CORPORATE SOCIAL RESPONSIBILITY

Corporate Social Responsibility for the Adani Group is handled by Adani Foundation. Since its inception in 1996, Adani Foundation has been working in a number of prominent areas to extend its support to people in need. Working closely with the communities, the foundation has been able to assume the role of a facilitator by creating an enabling environment for many. With the human-centric vision the foundation has always thrived to make the processes sustainable, transparent and replicable. Adani foundation is currently operational in 7 states and is working towards an integrated development of the entire society with its core focus on Education, Community Health, Sustainable Livelihoods Development and Rural Infrastructure Development.

CONCLUSION

The following points shall be noted:

1. Ambient air quality, ground water quality and noise levels shall remain within acceptable limits after the proposed manufacturing activities due to effective design and implementation of environmental management plans.
2. Risk to flora/fauna and soil is negligible due to effective management and handling of hazardous wastes and wastewater.
3. Socio-economic benefits due to creation of direct / indirect employment.

Thus, it can be concluded on a positive note that after the implementation of the mitigation measures and Environmental Management Plan, the regular operations of **M/s. Mundra Solar Limited** will have negligible impact on environment and will benefit the local people.