Manufacturing of 20 tonnes per annum Graphene at Main steel Works of Tata Steel Limited

A Pre-Feasibility Report

Tata Steel Limited, Jamshedpur, East Singhbhum, Jharkhand

July 2017
INTRODUCTION TO THE PROJECT

Executive Summary

Tata Steel is an Indian Multinational Steel industry headquartered in Mumbai, India. It is one of the top steel producing companies globally with an annual crude steel capacity of 23.88 million tonnes (in FY17), and the second largest steel company in India (measured by domestic production) with an annual capacity of 11 million tonnes. Its largest plant is located in Jamshedpur, Jharkhand and it was the seventh most valuable Indian brand in 2013 as per Brand Finance.

The Research and Development Division of Tata Steel Limited was set up in 1937 and is one of the oldest R&D Centres in India. Since its inception this Centre has played a pivotal role in the development of steel products and process routes that have given the Company a competitive advantage in both local and global markets. The innovativeness of the centre can be measured in terms of the number of filed patents (around 900) and granted patents (around 300).

Recently, the R&D division of Tata Steel Limited (TSL) has invented a process to produce Graphene from a naturally occurring resin, Shellac. Shellac is an organic resin secreted from an insect Laccifer lacca. These insects are bred on the leaves of selected trees such as ber and kusum. Owing to the climatic and habitat conditions required, Shellac farming is restricted to few areas in the world. Incidentally, India is the leading producer of shellac in the world. Tata Steels’ invention makes use of Shellac as a carbon source for synthesis of Graphene. The Patent number WO2015/040630A1 published on 26/03/2015 details Tata Steels’ invention of making Graphene starting from Shellac as the Raw Material.

The products developed using graphene has shown promising properties such as anti-corrosion, higher strength, higher conductivity, light weighting. Based on these results, Tata Steel now proposes to setup a production facility for Graphene manufacturing which will include scaling up of the lab process to the Industrial process level.

The proposed Graphene project aims at producing high quality product in India that will boost of international quality standards along with development of new Products using graphene; Hence It is in line with the three prominent policies launched by the Honourable Prime Minister of India, Shri Narendra Modi, namely ATAL INNOVATION MISSION, MAKE IN INDIA & ZERO DEFECT ZERO EFFECT (ZEZD)

The proposed plan for production is as follows in the Table 1.1:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Saleable Product</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Graphene Powder</td>
<td>20 Tonnes per annum</td>
</tr>
<tr>
<td>2</td>
<td>Graphene Liquid</td>
<td>60000 kL per annum</td>
</tr>
<tr>
<td>3</td>
<td>Graphene Vapour</td>
<td>1000 m3/hr</td>
</tr>
</tbody>
</table>

Table 1.1: Proposed plan for production
Employment generation (direct and indirect) due to the project

- **Indirect Employment**: Close to 1000 numbers of people over the next five years will be benefitted with respect to their employability. There is also an assumption that indirect employment will further increase with increase in demand of the graphene based product. In addition, more than 500 numbers of workers shall also be employed during the project phase.

- **Direct Employment**: 50 numbers of employees including officers, supervisors and workers.

**Location**

**General Location**: Tata Steel is located in Jamshedpur, east Singhbhum district of Jharkhand, ranging between 22°40’47” and 22°53’21” North latitude and 86°05’21” to 86°18’50” East longitude. The city is located in the basin areas of two principal surface streams, namely, the Subarnarekha River and its tributary, Kharkai River.

**Specific Location**: The proposed project will take place in the existing and established premises of main steel works of Tata Steel Limited in Jamshedpur to take advantage of the existing infrastructure, utilities and other resources. The location is approx. 1 Km towards North of R&D division. The specific coordinates of the site are 22°46’28”N and 86°11’54”E.

**Project Description with Process details**

Graphene Powder will be made from the raw materials - Shellac, Intercalated Graphite or Coal Tar. Any one of three or combination of these three raw materials can be chosen for making Graphene Powder. The process involves heating in inert atmosphere for at least 60 mins to produce Graphene Powder.

The produced Graphene Powder will be utilized for

a- Saleable Product to other companies/institutes

b- Used for production of Graphene Liquid – The process will be conducted in a set of three reactors in which graphene powder, Shellac and few other chemicals will be added (complete list of chemicals is shown below). The mixture will then be heated and stirred.

c- Used for production of Graphene Vapor

Graphene powder will be heated in a vacuum chamber to produce Graphene vapors which will be condensed on Cu/Ni base.

**Raw Material Requirement**

The Shellac is processed form of Lac cultivated largely in Jharkhand. Coal Tar is generated as a by-product of Iron making process in TATA Steel works. Intercalated Graphite and other chemicals are readily available in the market.
Availability of water, its source, Energy/power requirement and source
There will not be any use of water in the industrial purpose for the proposed project, however approx. 1100 m$^3$/day of water will be required for drinking and other washing purpose. This volume of water will be sourced from the existing water network of steel works. Power requirement for the proposed project will be approx. 370 kVA per annum, which will also be taken from the existing captive facility at TATA Steel.

Quantity of waste generated and scheme for their disposal
Solid Waste generated from the above process shall be reprocessed in the coke plant of main works. Apart from above, no other process solid waste generation is envisaged from the proposed process. No liquid waste generation is envisaged from the proposed project. However, there will be approx. generation of 100m3/day of sewage from the toilets, which will be connected to the existing sewage network of steel works for further treatment.

Project Cost
Total cost of project will be approximately Rs 8.25 Cr

Rehabilitation and resettlement
Tata Steel Limited (TSL) has planned to Produce Graphene Liquid and Powder from a new facility that will be installed within existing premises. As this expansion would take place within the boundary of the existing Tata Steel Works at Jamshedpur. Hence the issue of rehabilitation & Resettlement (R&R) would not be applicable to the purview of this proposed project. However, being one of the pioneers of Indian Industry and a responsible corporate house, Tata Steel has endeavored to improve the quality of life of the people of Jamshedpur and its adjoining areas over all these years.

Socio-Economic Development
The Corporate Social Responsibility (CSR) activities of Tata Steel, which is regarded as a global benchmark, have taken up a mammoth social outreach program covering the city of Jamshedpur and far beyond covering more than 600 villages. The principal initiative areas are income generation, health & medical care, education, sports, etc. With the help of this project, Shellac/Seedlack farmers will gain significantly as Shellac is one of the major Raw material for this project. In the current scenario, the demand for Shellac is not consistent which imposes loss to farmers. With a consistent supply all year round, TATA Steel will develop ARC agreements with local Shellac suppliers which in turn will benefit the farmers.
Financial and Social Benefit

The Graphene business has been identified as a potential link between the suppliers of seedlac (a naturally occurring cultivated product) and the potential to create good quality graphene that can have applications in various industries e.g. steel, automotive etc.

The Financial benefit has been evaluated based on the uniqueness of home grown technology which has the potential of delivering the lowest cost of Graphene Production. The financial benefit also depends upon successful application development with new customers.

Success of this business will also bring value addition to the social life of villagers and other stake holders in the supply chain.

ii) Benefit to local people including tribal population

Most of the production and processing of lac happens in Jharkhand, Chattisgarh and West Bengal. Through this project, the tribals engaged in cultivation of lac will be indirectly benefited as we will purchase shellac (processed seedlac) as our raw material, hence this proposed project will directly benefit people at the Bottom of the Pyramid. As the application development with various customers grows, the benefits will also grow proportionally to the tribal population in the coming years.
Chapter 1 - Introduction

1.1) Identification of Project and Project Proponent

For the Past few years, the world economy has struggled to be on a path of uniform and ensure widespread economic stability. Most emerging markets and developing economies have shown moderate growth, whereas the developed economies have moved on divergent paths, with slow pickup of growth in the US and prevailing weak economic conditions in the euro zone area.

The Indian economy has slowed down in the last few months and some of the sectors including the automotive and capital goods are facing demand slowdown. The Chinese economy too has witnessed a moderation in its growth rate. A clear industrial policy with special emphasis on manufacturing competitiveness and infrastructure spending will be the key requirement for revival of demand in markets like India.

The Government of India, realizing the need of setting up high Class facilities with suitable infrastructure, in terms of capital equipment and operating facilities that enhance innovation, manufacturing, transport, education etc., has set up 3 major initiatives as listed below:

- **ATAL INNOVATION MISSION**: The purpose of this mission is to enhance the culture of innovation and entrepreneurship in India.

- **MAKE IN INDIA**: This policy was launched by the Current Prime Minister of India, Respected Mr Narendra Modi, with the aim of improving India's economy by transforming into a manufacturing Hub.

- **ZERO DEFECT ZERO EFFECT (ZEZD)**: The ZEZD slogan given by Current Prime Minister of India, Respected Mr Narendra Modi, aims at high quality manufacturing that is also Green and sustainable. The scope of the model spans across all sectors of manufacturing and service industry with a special focus on micro, small and medium enterprises (MSME). The ZEZD model is meant to raise the quality levels in the unregulated MSME sector. The MSME sector is the engine of Indian economic growth. The MSME sector contributes around 38% of the country's GDP and around 110 million Indians are employed in the sector.

Tata Steel is an Indian Multinational Steel industry headquartered in Mumbai, India. It is one of the top steel producing companies globally with an annual crude steel capacity of 23.88 million tonnes (in FY17), and the second largest steel company in India (measured by domestic production) with an annual capacity of 11 million tonnes. Its largest plant is located in Jamshedpur, Jharkhand and it was the seventh most valuable Indian brand (as of 2013 Brand Finance publications).

The Tata Steel R&D division at Jamshedpur was set up in 1937 and is one of the oldest R&D centres in India. Since its inception, this Centre has played a pivotal role in the development of steel products and process routes that have given the Company a competitive advantage in both local and global markets. The Group's advanced Research and Development centre gives it the competitive edge to meet emerging challenges and
Manufacturing of 20 tonnes per annum Graphene at Tata Steel Limited, Jamshedpur, Jharkhand

ensure that the Company always stays on the path of innovation. Owing to special emphasis on its R&D division, Tata Steel has filed more than 900 patents globally and has been granted around 300 patents.

Recently, the R&D division of Tata Steel Limited (TSL) has invented a process of producing graphene from Shellac. Shellac is an organic resin secreted from an insect *Laccifer lacca*. These insects are bred on trees of some special tress only. Owing to the climatic and habitat conditions required, Shellac farming is restricted to few areas in the world. India is a leading manufacturer of Shellac. Tata Steels invention makes use of Shellac as a carbon source for synthesis of Graphene. The Patent number WO2015/040630A1 published on 26/03/2015 details the Tata Steels invention of making Graphene starting from Shellac as the Raw Material.

As the Graphene products developed from this method have shown some promising properties which can be utilized in either development of new products or improving the performance of existing products, Tata Steel has now proposed to setup a production facility for Graphene manufacturing which will include scaling up of the lab process to Industrial process.

The proposed Graphene project aims at producing high quality product in India that will boost quality standards of existing Steel products along with development of new Products; Hence It is in line with above mentioned 3 policies ATAL INNOVATION MISSION, MAKE IN INDIA & ZERO DEFECT ZERO EFFECT (ZEZD)

Graphene is an allotrope of carbon that exists in the form of a hexagonal lattice and with a thickness of the atomic order. Its existence was known to for many years, however it was successfully isolated and studied only in 2004 when Andre Geim and Konstantin Novoselov successfully isolated sheets of graphene by Scotch tape method at the University of Manchester. Ever since the first isolation of Graphene, many research groups are working worldwide to exploit its properties and companies are working to develop techniques for commercial and economical production methods of graphene.

TSL also produces coal tar as a byproduct. It has been a long wish that TSL is able to find out value added products out of coal tar. Additionally, graphite crucibles are commonly used in the steel industry for various experiments and are disposed off. In this connection, TSL has also discovered that in addition to shellac, a mixture of coal tar and expanded graphite can also result in graphene of various qualities. As the horizons appear expanded with the discovery of Graphene, Tata Steel Limited (TSL) intends to prepare finished good Graphene in amounts that will enable “MAKE IN INDIA” possible. The proposed plan for production is as follows in the Table 1-1:(I feel we need to introduce the rationale of producing graphene from other sources e.g. coal tar and graphite here)

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<tr>
<td>3</td>
<td>Graphene Vapour</td>
<td>1000 m3/hr</td>
</tr>
</tbody>
</table>

Table 1-1: Proposed plan for production
1.2) **Brief Description of the Nature of Project**

The proposed products Graphene Liquid (GFX), Graphene Powder (GPOW) and Graphene Vapour do not attract Environment Clearance from Ministry of Environment, Forest & Climate Change (MoEFCC) Govt. of India.

However, the process of making Graphene powder through Polymer granules / Organic compound (other than cracking) falls under category 5e and the process of making Graphene liquid and vapour through synthetic organic chemicals falls under Category 5f of EIA (Environment Impact Assessment) notification, 2006 and hence it is required to get environment clearance from MOEFCC, Govt. of India.

(both the above paragraphs seem to contradict each other – maybe I am unable to understand)

Graphene is prepared by heating either Intercalated Graphite, Coal tar or Shellac or a mixture of these three in inert atmosphere. The resulting Graphene powder will be used both as a saleable product as well as in manufacturing of Graphene liquid and Graphene Vapour in the same plant. The process of manufacturing Graphene Liquid involves addition of Graphene powder to a solution of Shellac resin and other chemicals. All the additives are then heated and continuously stirred in a reactor. The process of Manufacturing Graphene Vapour involves heating Graphene Powder on a Cu/Ni substrate.

1.3) **Need for the project and its importance to country and or region**

Due to Unmatched properties of Graphene (High Mechanical strength, Electrical and thermal conductivity, transparency) there is no limit to applications that can be developed with this wonder material. A list of potent applications with Graphene is shown in Table 1-2 below:

<table>
<thead>
<tr>
<th>S No</th>
<th>Property of Graphene</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High mechanical Strength</td>
<td>Composite materials with plastics/metals</td>
</tr>
<tr>
<td>2</td>
<td>High Thermal conductivity</td>
<td>Heat Sinks in electronic circuits, Thermal foils, Solar cells</td>
</tr>
<tr>
<td>3</td>
<td>High Surface Area</td>
<td>Batteries, super capacitors, fuel cells</td>
</tr>
<tr>
<td>4</td>
<td>Inert</td>
<td>Corrosion protection</td>
</tr>
<tr>
<td>5</td>
<td>High Electrical conductivity</td>
<td>Conducting inks, Bio medicals, Sensors</td>
</tr>
<tr>
<td>6</td>
<td>High transparency</td>
<td>LCD’s, Electronics</td>
</tr>
</tbody>
</table>

*Table 1-2- Graphene properties and applications*

For the country, the following benefits will be accrued:

a. Indirect employment of villagers who are involved in the lac cultivation and its supply chain.

b. Will help in making value added steel for all steel industries.

c. Will encourage Make in India initiative by manufacturing new material and exploring its application in manufacturing sector like optical, defense, steel, electronics etc.
d. Value added products from by products from the steel industry e.g. coal tar, graphite crucibles.

1.4) Demand Supply Gap

Although more than 7000 patents have been filed in last 10 years for Graphene based applications, the earliest commercial successes are being observed now. The early adapters are the composites and bio-sensors industry. The adoption in other segments e.g. steel industry has been slow because of the non-availability of good quality graphene consistently and economically. This challenge is being worked upon in many institutes/corporates worldwide.

The market study for Graphene based products by Tata Group marketing team is shown below in table 1-3:

<table>
<thead>
<tr>
<th>SN</th>
<th>Focus Area</th>
<th>Areas of interest</th>
<th>Market opportunity for Graphene (Rs Cr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Membrane Technologies</td>
<td>Corrosion Protection</td>
<td>7,320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low friction conductive conductors</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polymers with reduced permeation</td>
<td>4,330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water purification</td>
<td>1,330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transparent Solar Collectors</td>
<td>660</td>
</tr>
<tr>
<td>2</td>
<td>Heat Transfer Technologies</td>
<td>Nano-fluids, coatings</td>
<td>5,020</td>
</tr>
<tr>
<td>3</td>
<td>Energy Generation and Storage Technologies</td>
<td>Fuel Cells - bipolar plates, catalyst</td>
<td>1,450</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solar energy active materials</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OLED displays</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Printable batteries, super capacitors</td>
<td>3,600</td>
</tr>
<tr>
<td>4</td>
<td>Functional Structure Technologies</td>
<td>Structural Composites, EMI/ EMC Shielding</td>
<td>380</td>
</tr>
<tr>
<td>5</td>
<td>Electronics and Sensing Technologies</td>
<td>Printed Electronics and sensors</td>
<td>5,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>30,210</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FY' 20</th>
<th>FY' 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,640</td>
<td>9,980</td>
</tr>
<tr>
<td>1,660</td>
<td>2,660</td>
</tr>
<tr>
<td>2,990</td>
<td></td>
</tr>
<tr>
<td>8,450</td>
<td></td>
</tr>
<tr>
<td>8,650</td>
<td></td>
</tr>
<tr>
<td>2,660</td>
<td></td>
</tr>
<tr>
<td>6,650</td>
<td></td>
</tr>
<tr>
<td>11,300</td>
<td></td>
</tr>
<tr>
<td>3,060</td>
<td></td>
</tr>
<tr>
<td>10,770</td>
<td></td>
</tr>
</tbody>
</table>

Table 1-3: Market opportunity for Graphene based products
(Source: Group Technology and Innovation Office Report, 2016)

A list of companies actively working on Graphene and its products is presented in Table 1-4 below: Table 1-4 shows a list of companies who are actively working on graphene and its products.
The work done at Tata Steel R&D shows that
A. The trials using graphene show promising results. This has given adequate confidence to pursue this opportunity and set up a small production unit as a pilot project.
B. The raw material used for manufacturing Graphene is a naturally occurring fauna product, Shellac. Jharkhand and Odisha are the largest producers of Shellac in the world making it a favourable opportunity for Tata Steel (TSL).
C. There is also an opportunity to find value added products from the steel plant by products e.g. coal tar, graphite crucibles.
D. Graphene will add value to the product mix of Tata Steel

1.5) Imports Vs Indigenous Production
Tata Steel intends to produce Graphene in vapour, Liquid and powder form and the capacity of plant has been decided after a proper survey and business forecast. The aim is to ensure 100% Indigenous production and 0% Import. The aim is in line with Prime Ministers of India’s goal on “Make in India” initiative.

1.6) Export Possibility
Due to versatile property of Graphene and the present stage of application development in various fields, there is a strong possibility of exporting Graphene to foreign countries.

1.7) Domestic /Export Markets
Graphene as a product has potential in many applications. Table 1-5 represents the opportunities in various markets for Graphene business

<table>
<thead>
<tr>
<th>Field</th>
<th>Domestic Market</th>
<th>Export Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composites</td>
<td>Plastics, Defense, Rubber, metals</td>
<td></td>
</tr>
<tr>
<td>Bio medics</td>
<td>Gluco sensors, Pregnancy kits</td>
<td></td>
</tr>
<tr>
<td>Flexible Electronics</td>
<td>LCD’s</td>
<td></td>
</tr>
<tr>
<td>Filtering</td>
<td>Water filters</td>
<td></td>
</tr>
<tr>
<td>Corrosion inhibitors</td>
<td>Steel Products</td>
<td></td>
</tr>
<tr>
<td>Heat Dissipaters</td>
<td>Automobiles</td>
<td></td>
</tr>
</tbody>
</table>

Table 1-5: Opportunities for Graphene Business

Table 1-4: List of companies working on Graphene

<table>
<thead>
<tr>
<th>S No</th>
<th>Company</th>
<th>Country</th>
<th>Major Graphene Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ceal Tech</td>
<td>Norway</td>
<td>Single Layer Graphene Sheets</td>
</tr>
<tr>
<td>2</td>
<td>Haydale</td>
<td>Korea</td>
<td>Inks, Sensors, Energy storage, composites</td>
</tr>
<tr>
<td>3</td>
<td>Versarien</td>
<td>UK</td>
<td>Composites</td>
</tr>
<tr>
<td>4</td>
<td>Graphenea</td>
<td>Spain</td>
<td>Single Layer Graphene Sheets</td>
</tr>
<tr>
<td>5</td>
<td>Nanxplore</td>
<td>Canada</td>
<td>Electronics, Composites, Thermal Sinks</td>
</tr>
</tbody>
</table>
1.8) Employment generation (direct and indirect) due to the project

- **Indirect Employment**: It is estimated that close to 1000 people over 5 years will get benefited with respect to their employability by the proposed project. There is an assumption that the indirect employment will further increase with a corresponding increase in demand of the graphene based products. More than 500 numbers of workers shall be also employed during project phase.

- **Direct Employment**: 50 numbers of employees including officers, supervisors and workers.

**REFERENCES**

1. The properties of Graphene – Graphenea
   "https://www.graphenea.com/pages/graphene-properties#.WT4FCuuGPIU"
4. https://www.graphene-info.com/companies
Chapter 2-Project Description

This Chapter describes the major plant facilities required for the production of Graphene Liquid, Graphene Powder and Graphene Vapor

2.1) Type of Project including interlinked and interdependent Projects

The project involves manufacturing of Graphene from Raw materials, namely Intercalated Graphite, Shellac and Coal Tar via Thermal Cracking process. The Graphene powder thus produced will be a saleable product and will also be used for manufacturing of Graphene Liquid via a Chemical process.

There will be no interlinked project with this project within Tata Steel

2.2) Location

General Location: Tata Steel is located in Jamshedpur, east Singhbhum district of Jharkhand, ranging between 22°40'47" and 22°53'21" North latitude and 86°05'21" to 86°18'50" East longitude. The city is located in the basin areas of two principal surface streams, namely, the Subarnarekha River and its tributary, Kharkai River. The map showing site located in presented in Fig. 2-1 below.

![Site Location Map](image)

Fig. 2-1 - Site Location Map
**Specific Location:** The Graphene Project will be located inside premises of TATA Steel Jamshedpur Works. The location is approx. 1 Km towards North of R&D division. The specific coordinates of the site are 22°0’46”28”N and 86°0’11”54”E. The map showing specific location of the Graphene plant is shown in figure 2-2 below.

![Figure 2-2- Location of Graphene Plant inside TATA Steel, Jsr](image.png)

The General layout of the site is attached in Annexure 1

2.3) **Details of alternate Sites considered and the basis of selecting the proposed site , particularly the environment consideration:** The proposed project will take place in the existing and established premises of main steel works of Tata Steel Limited in Jamshedpur so as to take advantage of the existing infrastructure, utilities and other resources. No other alternate site was examined for the proposed project.

2.4) **Size or magnitude of operation**

The Graphene project will be located in an area of 3600 sqm near R&D building inside main works of TSL. This proposed building was being used as a warehouse, which will be customized as per the requirement of the basic design and engineering of the proposed project.
The proposed project will contain an Office, a Conference room, Basic amenities, two labs for quality testing, customer approval and development, Processing area, Raw material storage and finished goods storage areas etc.

A Furnace in the plant area will be utilized for making Graphene powder and Graphene Vapor. A set of Reactors will be utilized for making Graphene liquid.

The output from the plant is proposed to be as:

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2.5) Project Description with Process details

Graphene Powder will be made from raw material Shellac, Intercalated Graphite or Coal Tar. Any one of three or a combination of these three raw materials can be chosen for making Graphene Powder. The process involves heating in inert atmosphere for at least 60 min to produce Graphene Powder.

The project flow diagram is as shown in fig 2-4 below

![Process flow for Graphene Powder](image)

Figure 2-4- Process flow for Graphene Powder

After this, the produced Graphene Powder will be utilized for

A-Saleable Product to other companies/institutes

b- Used for production of Graphene Liquid – The process will be conducted in a set of three reactors in which graphene powder, Shellac and few other chemicals will be added (complete list of chemicals is shown below). The mixture will then be heated and stirred. The process flow diagram is shown in figure 2-5
Manufacturing of 20 tonnes per annum Graphene at Tata Steel Limited, Jamshedpur, Jharkhand

Fig 2-5) Process flow line for Graphene Liquid

c- Used for production of Graphene Vapor

Graphene powder will be heated in a vacuum chamber to produce Graphene vapors which will be condensed on Cu/Ni base. The process flow diagram for this is shown in Figure 2-6 below

Fig 2-6) Process flow line for Graphene Vapors

2.6) Raw material required along with estimated quantity, source, marketing area of final Product, Mode of transport of raw and finished food products

The Shellac is processed form of Lac cultivated largely in Jharkhand. Coal Tar is generated as a by-product of Iron making process in TATA Steel works. Intercalated Graphite can be obtained from used graphite crucibles in the steel plant or can be bought from the market. Other chemicals are readily available in the market.
<table>
<thead>
<tr>
<th>Product</th>
<th>Mode of transport of Finished Material</th>
<th>Raw material</th>
<th>Annual requirement</th>
<th>Source</th>
<th>Mode of transport of Raw Material</th>
<th>Marketing Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphene Powder</td>
<td>Road</td>
<td>Shellac</td>
<td>200 tons</td>
<td>Road</td>
<td></td>
<td>1- Composites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intercalated Graphite</td>
<td>10 ton</td>
<td>Road</td>
<td></td>
<td>2- Biomedicals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coal Tar</td>
<td>20 ton</td>
<td>Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Road</td>
<td>Formaldehyde</td>
<td>300 kL</td>
<td>Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyclohexylamine</td>
<td>240 kL</td>
<td>Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Epichlorohydrin (Epoxy)</td>
<td>1200 kL</td>
<td>Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IPA</td>
<td>6600 kL</td>
<td>Road</td>
<td>Corrosion Inhibiting Paint for Steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BYK 3441</td>
<td>600 kL</td>
<td>Road</td>
<td>1-Rebars</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2-Sheet</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-Tubes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4-Others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Road</td>
<td>Graphene Powder</td>
<td>600 Kg</td>
<td>None</td>
<td>Flexible Electronics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Graphene Powder</td>
<td>10 ton</td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-1) Raw material for producing Graphene powder, liquid and vapour
2.7) **Resource Optimization /recycling and reuse envisaged in the project**

Coal Tar generated as a by-product in the Iron making process inside TATA Steel works shall be utilised for making Graphene Powder. Graphite crucibles are discarded after usage in experiments. This can be used to generate intercalated graphite.

2.8) **Availability of water, its source, Energy /power requirement and source**

There will not be any use of water in the industrial purpose for the proposed project, however approx. 1100 m$^3$/day of water will be required for drinking and other washing purpose. This volume of water will be sourced from the existing water network of steel works.

Power requirement for the proposed project will be approx. 370 kVA per annum, which will also be taken from the existing captive facility at TATA Steel.

2.9) **Quantity of waste generated and scheme for their disposal**

Solid Waste generated from the above process shall be reprocessed in the coke plant of main works. Apart from above, no other process solid waste generation is envisaged from the proposed process.

No liquid waste generation is envisaged from the proposed project. However, there will be approx. generation of 100m3/day of sewage from the toilets, which will be connected to the existing sewage network of steel works for further treatment.
Chapter 3 – Site Analysis

The proposed New Graphene Project of Tata Steel Works would be undertaken within the existing Works boundary land area at Jamshedpur, owned by Tata Steel Limited (TSL). The total area allocated to the new project is 3600 m².

3.1) Site Location and Connectivity

Jamshedpur plant area is located in east Singhbhum district of Jharkhand, ranging between 22°40’47” and 22°53’21” North latitude and 86°05’21” to 86°18’50” East longitude. The nearest railway station is Tatanagar on the South-Eastern Railway line connecting Howrah-Mumbai. The Jamshedpur City is well connected with National Highway #33 (NH#33) and other road network. The Graphene Project will be located inside premises of TATA Steel Jsr Works. The location is approx 1 Km towards North of R&D division. The specific coordinates of the site are 22°46’28”N and 86°11’54”E. The site is surrounded by Roads from 3 directions.

3.2) Land Form, Land Use and Land Ownership

The Graphene Project site is located inside premises of TATA Steel. Land form consists of plain area. The site was earlier used as a warehouse. As described earlier, the premises of TATA Steel are under the ownership of TATA steel Ltd.

3.3) Topography

The Graphene project site is inside premises of TATA Steel located in Jamshedpur which is a part of Chhota Nagpur plateau. The Site is located on a plain area at an elevation of 150 m from sea level.

3.4) Existing Land Use Pattern

The existing land is an industrial site within main works premises of TATA steel Works

3.5) Existing Infrastructure

Existing Infrastructure within the proposed site shall be used for proposed project
Chapter 4 – Planning Brief

4.1) Planning Concept

The Project was planned along with external consultants. Site analysis, civil framework, power and utility requirement, water requirement, sewage system was included in planning of project. For safety issues, a complete HAZOP study was done along with TATA Steel safety department.

4.2) Population Projection

This project being small in size and complexity has no impact on population of Jamshedpur

4.3) Land Use Planning

As mentioned earlier, the site is located within existing TATA Steel premises. The land is currently used as a warehouse. The land will be modified to accommodate a Reactor area, Furnace area, Office and other general utilities

4.4) Assessment of Infrastructure Demand

The assessment has been completed in consultation with external agency

4.5) Amenities/Facilities

Amenities will include Rest rooms and toilets for contractors and workers of project and operation team. Employment will be provided during project phase to local people hence no housing facility is included.
Chapter 5 – Proposed Infrastructure

5.1) Industrial Area

The proposed area for Graphene project lies inside premises of TATA Steel Ltd. No external Industrial Area is involved.

5.2) Residential Area

There is no residential Area currently occupied at Site location.

5.3) Green Belt

Green belt development is being done in and around TATA Steel works.

5.4) Social Infrastructure

No Social Infrastructure is applicable to this project.

5.5) Connectivity

The Site is reachable from 3 sides by internal works road. Burmamines gate of TATA Steel is within 1 Km distance.

5.6) Drinking Water Management

1100 m³ of drinking water will be annually required for the new facility. The supply will be taken from the existing facility at TATA Steel only hence no other supply is required.

5.7) Sewerage System

The Site sewerage system will be connected to the main sewerage system for further treatment at Sewage treatment plant.

5.8) Industrial Waste Management

Solid Waste generated from the above process shall be re processed in the coke plant of main works. Apart from above, no other process solid waste generation is envisaged from the proposed process.

No liquid waste generation is envisaged from the proposed project. However, there will be approx. generation of 100m³/day of sewage from the toilets, which will be connected to the existing sewage network of steel works for further treatment.

Any small quantity of waste that will be generated during laboratory work/accidental spillage of chemicals will be first treated and then disposed of as per norms. Waste bins for collection of wastes will be provided in laboratory and plant area.
5.9) Power Requirement & Supply

370 kVA of electrical power will be annually required for the proposed site. The supply will be taken from the existing facility at TATA Steel hence no other direct supply is required.
Chapter 6 – Rehabilitation and Resettlement

Tata Steel Limited (TSL) has planned to Produce Graphene Liquid and Powder from a new facility that will be installed within its existing premises. As this expansion would take place within the boundary of the existing Tata Steel Works at Jamshedpur, hence the issue of rehabilitation & Resettlement (R&R) would not be applicable to the purview of this proposed project. However, being one of the pioneers of Indian Industry and a responsible corporate house, Tata Steel has endeavored to improve the quality of life of the people of Jamshedpur and its adjoining areas over all these years.

Socio-Economic Development

The Corporate Social Responsibility (CSR) activities of Tata Steel, which is regarded as a global benchmark, have taken up a mammoth social outreach program covering the city of Jamshedpur and far beyond covering more than 600 villages. The principal initiative areas are income generation, health & medical care, education, sports, etc. With the help of this project, Shellac/Seedlac farmers will gain significantly as Shellac is one of the major Raw material for this project. In the current scenario, the demand for Shellac is not consistent which imposes losses to farmers. With a consistent supply all year round, TATA Steel will develop ARC agreements with local Shellac suppliers which in turn will benefit the farmers.
Chapter 7 – Project Schedule and Cost Estimates

7.1) Likely date of start of construction and Likely date of completion

Likely date of start of construction will be subjected to grant of environment clearance from MOEFCC and it will take approx. 12 months to complete the project.

7.2) Estimated cost of project and analysis in terms of economic feasibility of the project

Total cost of project will be approximately Rs 8.25 Cr. The economic feasibility will be derived from the sales of Graphene powder, Graphene liquid and Graphene vapour related products to different customers.

The cost projections for the Graphene Project is listed in table 7-1 below:

<table>
<thead>
<tr>
<th>S No</th>
<th>Particulars</th>
<th>Capex including Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Civil and Structure</td>
<td>4.17</td>
</tr>
<tr>
<td>2</td>
<td>Utility, Electrical ITS and others</td>
<td>2.52</td>
</tr>
<tr>
<td>3</td>
<td>Processing Equipment</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8.25</td>
</tr>
</tbody>
</table>

Table 7-1 Cost projections for Graphene Project
8.1) Financial and Social Benefit

The Graphene business has been identified as a potential link between the suppliers of seedlac (a naturally occurring cultivated product) and the potential to create good quality graphene that can have applications in various industries e.g. steel, automotive etc.

The Financial benefit has been evaluated based on the uniqueness of home grown technology which has the potential of delivering the lowest cost of Graphene Production. The financial benefit also depends upon successful application development with new customers.

Success of this business will also bring value addition to the social life of villagers and other stakeholders in the supply chain.

8.2) Benefit to local people including tribal population

Most of the production and processing of lac happens in Jharkhand, Chattisgarh and West Bengal. Through this project, the tribals engaged in cultivation of lac will be indirectly benefited as we will purchase shellac (processed seedlac) as our raw material, hence this proposed project will directly benefit people at the Bottom of the Pyramid. As the application development with various customers grows, the benefits will also grow proportionally to the tribal population in the coming years.