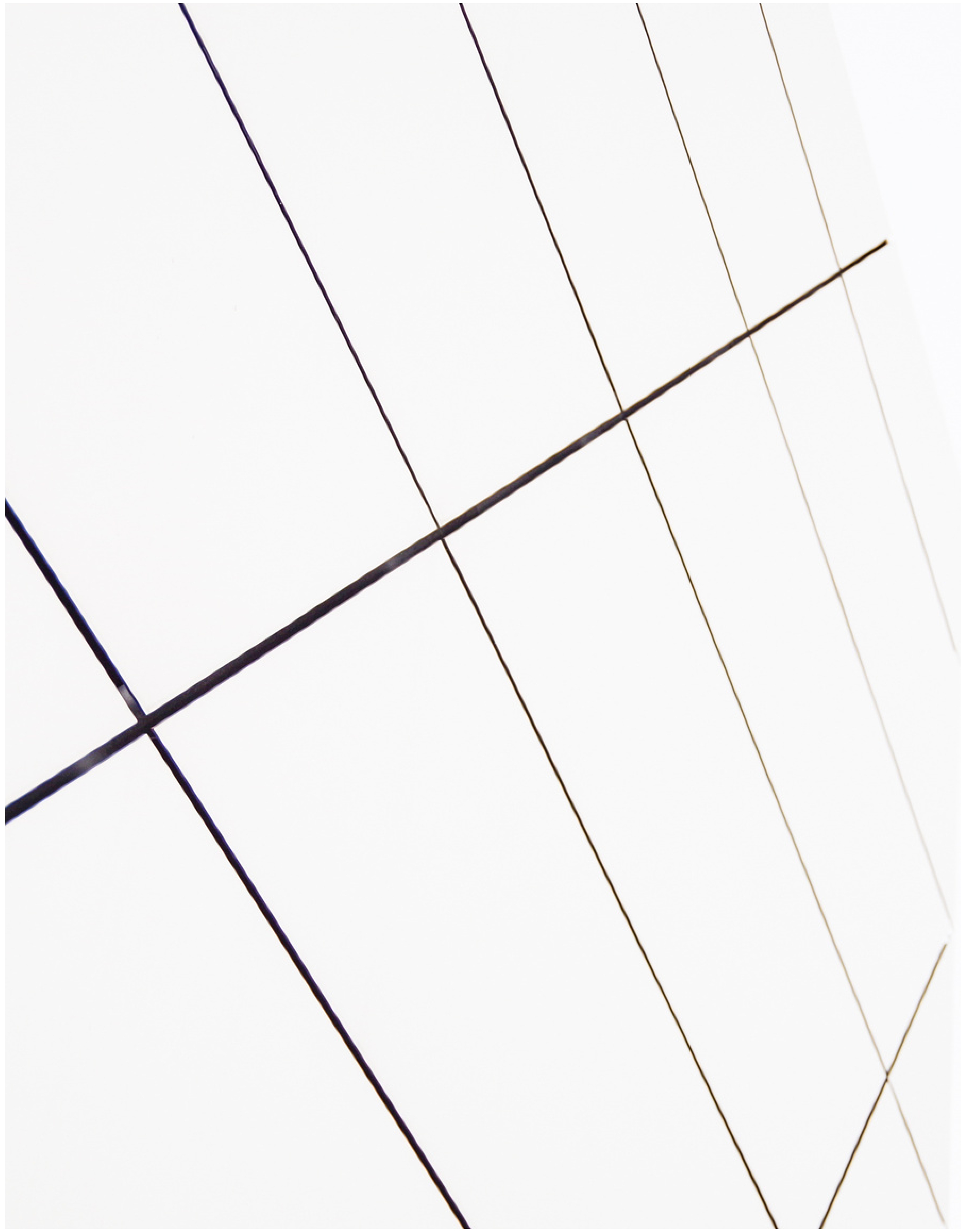


# Indian Case Challenge

THE SEMICONDUCTOR CONUNDRUM

# Table of Contents

# Strategic Roadmap

**Partnership**

TSMC and Tata join hands in pursuit of a cutting-edge semiconductor fab in India.

**Foundry is set up**

Orders for tools and equipment are sent out, and construction starts.

**Technology Transfer**

The technology transfer for the design and manufacturing of desired node sizes is completed.

**Design Process**

Research takes place to produce state-of-the-art semiconductors.

**Manufacturing**

The fab starts operation and produces it's first finished wafer.

**Order Fulfillment**

Supply chain is integrated and customers receive their orders.

**Expansion**

Establishing fabs, increasing capacity, and improving technology

# Market Positioning

Our recommendation to the company would be to move ahead as a manufacturer, firstly fulfilling the requirements of its subsidiaries and further becoming a domestic and international supplier.

### Why Fabrication?

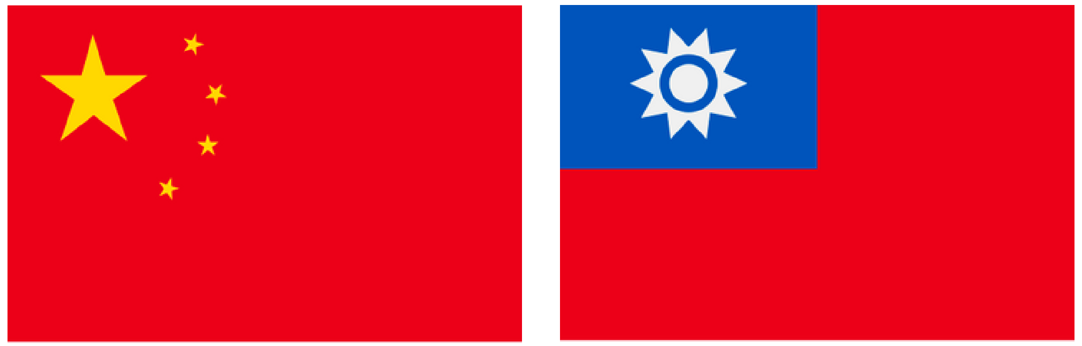
The **fabless** market is a **fragmented market** structure with a complete **oligopoly**.
It is a **highly saturated** by major players.

It is also a good time to enter the fabrication market due to the **geopolitical instability** in the current manufacturing hubs of China and Taiwan.

The **Government of India** has also been taking active measures for the ease of business and promoting **semiconductor fabrication** under its **Make In India** scheme.

With the **advent of EV and IoT** and the global push for carbon neutrality the demand for semiconductors will consistently hit all time highs.

# The Geopolitical Climate



The increasing tensions between west and China have opened an opportunity for new players in a highly competitive market.

As there are increasing fears of China invading Taiwan a semiconductor shortage is imminent.

### China and Taiwan

It is important to note the significance of these countries in the semiconductor space, **China the no. 1 exporter of Silica** and **Taiwan the no. 1 exporter of finished semiconductors**, prospectively being at war disrupts the already strained supply chains.

### Tradewar with the west

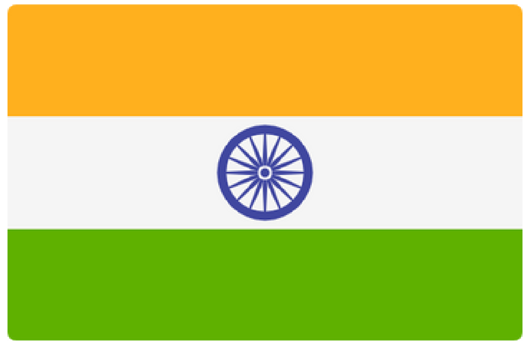
A large number of **companies are actively looking to move their base of operations from China** to more stable countries due to the ongoing trade war with the west.

### India's Benefit

India - a country with a large skilled workforce, and **a large potential customer base** - is one of the **top contenders for FDI** from top industry players.

# The Indian Jackpot

India is a high-paced ever-changing economy. With looser regulations and a government more accepting to newer industries, India is nothing less than a jackpot for any company looking to expand.



### Input Factors

A large base of skilled engineers, well-educated **cheap labor force**, a huge domestic market, and **abundant natural resources** have always portrayed India as a semiconductor hub.

### Contemporary India

The new **pro business government** has optimised the previous bottlenecks of excessive red tape and bureaucracy. Further, incentivising and **promoting fabrication units** has made the country a serious contender.

### Tata - The Indian Conglomorate

Tata has earned the trust of millions of Indians over the past century. Any product launched by the company is, without a question, the right quality and fairly priced. That is the kind of branding Tata has.

# Business Model

Getting into the semiconductor fabrication industry is an **expensive** affair. To **save on** huge **upfront costs**, and also to quickly grab **orders** and a larger **market share**, whilst establishing a resilient supply chain, **Tata should look into partnering** with one of the chip manufacturing giants.

### TSMC

With a market cap of over $400B, TSMC is the **top player** in the industry. The company would be **looking to avert risks by moving its fabs into more politically stable countries** amidst the geopolitical tensions between Taiwan and China. At the same time, this could also turn out bad for the company as a dissolution of the partnership could be plausible.

### Global Foundries

GF is the **only major company not based in China or Taiwan**. Trade ban with China all over the world make GF an attractive company to partner with, GF also wants to invest in non-Chinese foundry markets and hence talks can be initiated. Although its **lack of experience in 10nm and 7nm nodes eliminates a prospective partnership.**

### Intel

Intel wants to **invest aggressively in the foundry business**, Tata can offer help from subsidiaries to provide support from the same, diversifying investment risk. **Intel 10nm tech is better than TSMC 7nm tech (more transistor dense)**, and hence it might be a better partner in terms of quality

But they have been shaky on their con.

# Our recommendation for the partnership

Our recommendation to the company would be to partner with TSMC .

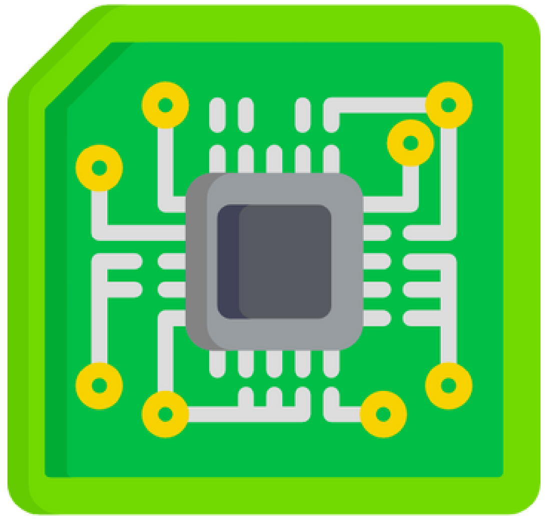
X

**Why TSMC?**

TSMC is a **market leader in the semiconductor space**, it has technological expertise in the node sizes of 130nm, 90nm, 65nm, 55nm, 40nm, 28nm, 22nm, 20nm, 16nm, 12nm, 10nm, 7nm, 6nm, 5nm, and 4nm. In a strategic partnership TATA would not only **benefit from the technology transfers, but also have ease of access to other node size chips**. TATA would also have a significant order base from the start of operations.

Intel would prefer to manufacture chips in the USA itself because the government there can provide them with better subsidies over raw materials as the government wants to keep the fabrications local to retain the soft powers associated with the semiconductor supply in the global market.

# Chip Sizes



There are a lot of chip options in the industry. Some have **better demands**, some have **better margins**,

**Our recommendation** to Tata would be to **grow as a supplier of the 7-10nm range chips**.

## Moore's Law

**Moore’s law has been slowed in the past few years,** shrinking the node sizes further generally leads to problems with quantum superposition of electrons among the gates, rendering them useless. Hence very intricate design is needed to further shrink the sizes unlike before which takes significantly more time.

**bigger chips are going to become obsolete because 7-10nm size range** has growing uses and cutting-edge applications, which is also a cost effective solutions. making these chips smaller, and further using smaller chips, is going to be an expensive affair for the industry and hence this is the **sweet spot for a manufacturer to target.**

# Future Prospects

The market for **≤7/10nm node sizes is expected to grow** to a **share of over $25B** while the other segments hold almost constant demand through the years.

From our quantitative analysis, one can derive that 7-10nm range has a colossal market demand that is posed at **increasing in the coming years.**

In automotives alone, the demand is expected to triple in the coming decade.

**The Indian government is set to** stop purchase of all fossil fuel based vehicles by 2025 and **phase them out completely by 2030.** This will create a demand of about 20 million **electric vehicles** every year that will use an **average of 3000 semiconductors each**. If we were to assume that the sales of cars were to remain constant for the next 5 years, even then we would be looking at 4 Million EV being sold.

With each electric vehicle containing a rough 3000 semiconductor chips, just the local Indian automotive market is expected to hence require about **12 billion chips per annum**.

With local demand growing to such extent it makes sense to go forward as a manufacturer.

**IGSS Ventures** → 28, 45, 65nm tech looking to set up in Tamil Nadu

**ISMC** → 65nm fab proposed

**Foxconn-Vedanta JV** → 28nm tech with investment of $19.5B already

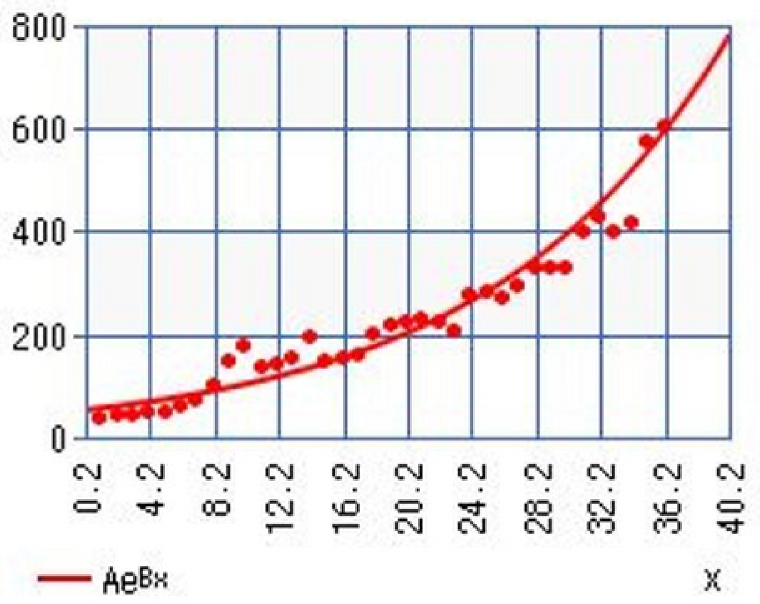
With many major companies planning on producing larger node sizes in India, **Tata's demand for larger chips, which will imminently decay, can be fulfilled locally,** whilst having our own **7-10nm** fabrication can help us **stay future proofed** for all our ventures while also enjoying the high demand and profit margins that accompany it.

# Quantitative Analysis

## From Exhibit 2

| function | value |
|---|---|
| mean of x | 18.5 |
| mean of y | 182.196664 |
| correlation coefficient r | 0.9566146 |
| A | 52.5935886 |
| B | 0.067161754 |

Year vs Sales (Billion USD)

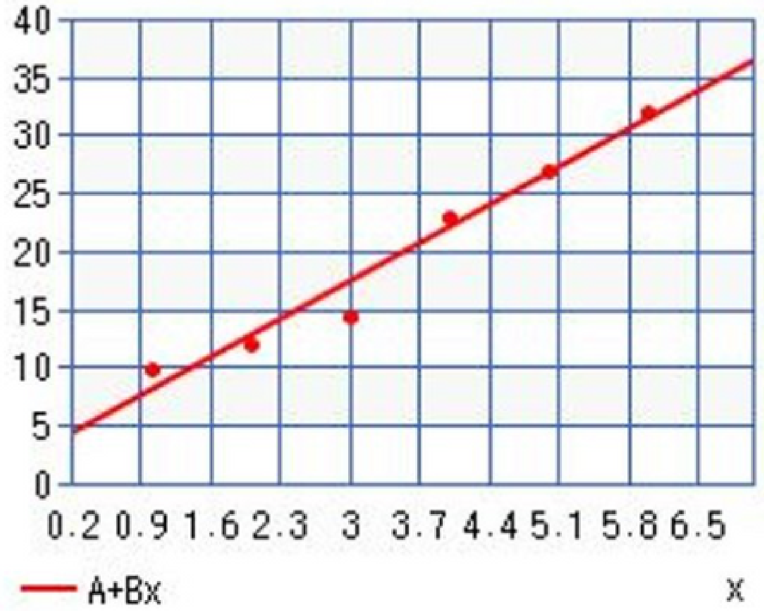



Growth of Semiconductor Industry

## From Exhibit 12

| function | value |
|---|---|
| mean of x | 3.5 |
| mean of y | 19.75 |
| correlation coefficient r | 0.982176862 |
| A | 3.4 |
| B | 4.67142857 |

In Billion (USD)




Year vs Foundry Market Size

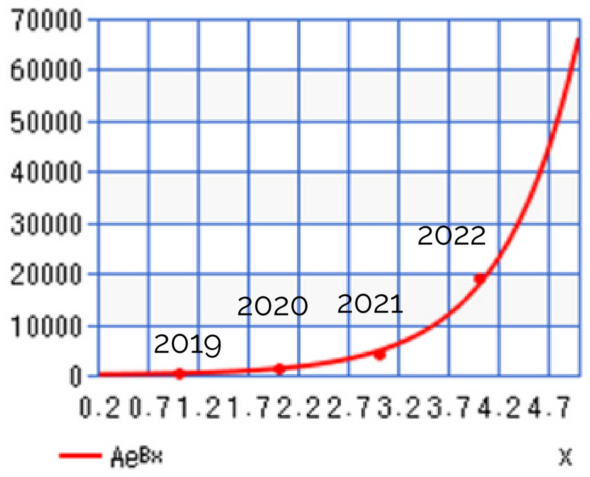
# Tata's Demand

TATA is currently a market leader in the electric vehicle industry in India. We can forecast the demand for the coming years using the same model. This model's accuracy stands for the next couple of years which would cater to the immediate demand for semiconductors. Electric vehicles and implementations of other subsidiaries would require more processing power within these appliances; hence, moving to our 7nm node-based chips will prove to be more energy and cost-efficient.

## Electric Vehicles

**The market share of Tata EVs is expected to grow** as the company plans to introduce newer, more affordable EVs to serve the Indian market. **Tata Elxsi has been working on autonomous driving**, and Google already has vehicles on US roads. This **technology will need top-of-the-line chips**, and TATA can be a market leader in meeting any needs it has.

| function | value |
|---|---|
| mean of x | 2.5 |
| mean of y | 2,470.460533 |
| correlation coefficient r | 0.998739319 |
| A | 91.906977 |
| B | 1.316553169 |




## Communication / Home Appliances

A skyrocketing demand for lower node chips is also expected with the **5G telecom services.** Tata Communications can make full use of this technology. **VOLTAS and home appliances** will want to incorporate AI in order to move towards smart homes. **Using ML models to optimize their efficiency**, using the latest learning techniques such as **federated learning** which minimizes privacy concerns and optimizes for each user's cases can be a great move.

# Breakeven Analysis

Even though it is cheaper to manufacture a 16nm die over a 7nm die, we must understand the fact that the **demand for a 16nm die** in the **coming years** (the time by which we start production) would be much l**ower than the demand for a 10nm or a 7nm die**. This in turn would lead for a lower revenue in case we decide on manufacturing a 16nm or greater chip.

Further, it is useful to understand that there are **a lot more manufacturers of bigger dies than those of smaller dies**, hence there is market **saturation and fierce competition in those markets**. There are very few companies across the world that possess the resources for manufacturing chips with higher technology requirement and hence gaining a step on the competitors will also help us monopolise the domestic market, apart from providing us an opportunity to become a large exporter of chips.

In light of the trade bans with China across the world, **India could prove to be a great option** for the fulfilment of the cutting-edge chip requirements. 5G technologies and autonomous driving are not too far in the future, and hence expecting a demand from those sectors is not absolutely wrong in the longer run.

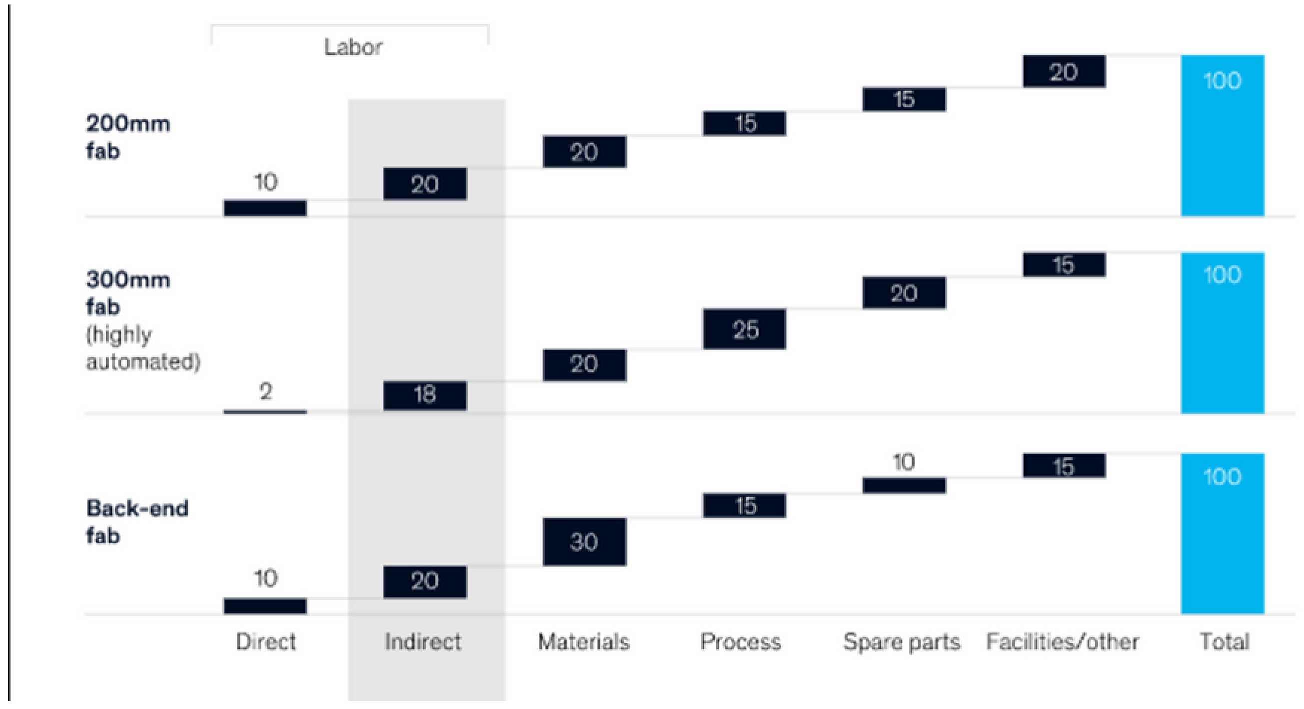



Figure 1: Yearly Manufacturing Cost for Fab in %

| | 16nm | 10nm | 7nm | 5nm | 3nm |
|---|---|---|---|---|---|
| Chip area (mm²) | 125.00 | 87.66 | 83.27 | 85.00 | 85.00 |
| No. of transistors (BU) | 3.3 | 4.3 | 6.9 | 10.5 | 14.1 |
| Gross die per wafer | 478 | 686 | 721 | 707 | 707 |
| Net die per wafer | 359.74 | 512.44 | 545.65 | 530.25 | 509.04 |
| Wafer price ($) | 5,912.00 | 8,389.00 | 9,965.00 | 12,500.00 | 15,500.00 |
| Die cost ($) | 16.43 | 16.37 | 18.26 | 23.57 | 30.45 |
| Transistor cost per 1B transistors ($) | 4.98 | 3.81 | 2.65 | 2.25 | 2.16 |

Analysis of Various Node Sizes

# Breakeven Analysis

The fabrication of **7-10nm node size** requires ASML Extreme Ultraviolet Machines (EUVs) that can have a cost ranging from **$120M to $200M .**

The cost of the general infrastructure and specialised support infrastructure can cost upwards of **$200M-$300M**.

Post this we would want to incorporate the license cost of the technology transfer, we already know that the license cost for 55-65nm technology is $300M-$400M, and that of 28nm is roughly $1B. Accordingly, we can estimate **the license cost for a 7nm chip to be about $1.98B using our trend analysis** (On the right).

ASML had projected that 1 EUV tool per layer supports 45,000 wafers per month. semiconductor have about 30 layers.

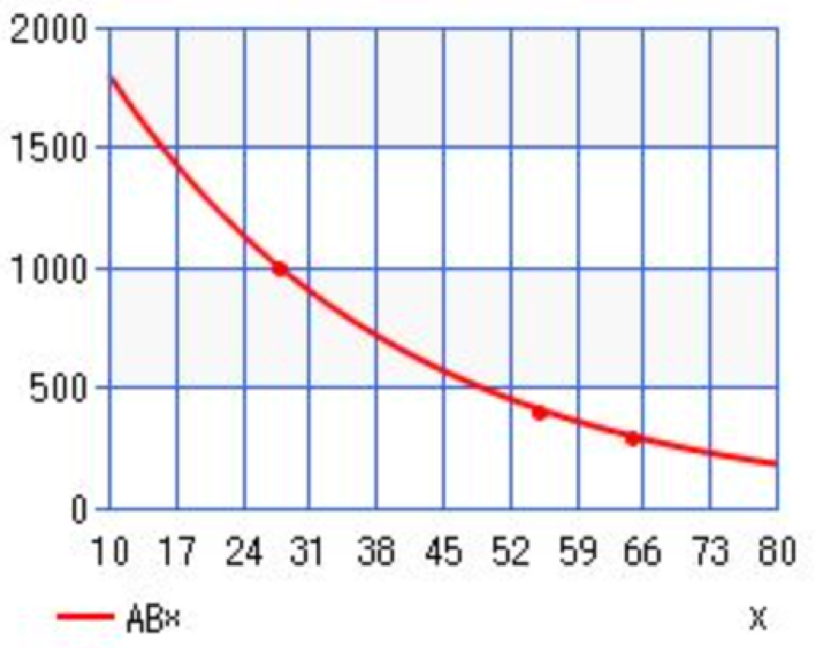
The government scheme focuses on setting up semiconductor fabs in India. The scheme will provide financial support to companies **investing a minimum of Rs 20,000 crore** in a logic/memory/analog/mixed-signal fab with **a capacity of 40,000 wafer starts per month.**

**The government will cover 50 per cent of project cost for firms covering 28 or lower nanometers (size of transistors produced),**

cost for **300mm wafer per sq. inch is $3  minimum.** so assuming our cost is a bit more, we can say that a wafer would cost us about 109.6*3.2 ~ **$350**

we cannot expect 100% utilization of the plant as soon as it starts manufacturing, so **assuming about 70% utilization**, we can say that **28000wpm are produced**. hence a **variable cost decrease of 20%** can be expected (this is because the labor, and other facilities are fixed variable costs).

| function | value |
|---|---|
| mean of x | 49.33333333 |
| mean of y | 493.2424149 |
| correlation coefficient r | -0.99943954 |
| A | 2,491.620826 |
| B | 0.9677015916 |




Quantitative Analysis of License Cost (Million USD vs Node Size)

# Breakeven Analysis

We need to **have a capacity of 40,000 wafers per month.** Assuming **30 layers per wafer** and each machine processing 45000 wafer layers per month,

40,000 wpm → 30*(40000/45000) = **27 EUV machines**

Cost of EUV lithography machines = **$4.05B**

Assuming the infrastructure cost = **$250M**

let us assume about 50% of the cost of lithography machines would also go in **other equipmen**t such as setting up UPW equipment, air conditioning, server rooms, clean room maintenance cost, insulation of the building, and other Important Equipment. ~ **$2.025B**

Licensing Cost = **$1.98B**

**Total fixed cost** = **$8.305B**

Cost for a 300mm Silicon Wafer = **$350/wafer**

Variable Material Cost for 40,000wpm → $350*40000*12 = **$168M**

considering material cost is 20% of the total cost**,**

**Total variable cost** = **$840M/annum**



The **selling price for one wafer** can be about **$P for breakeven assuming a 5 year breakeven.** We get fixed cost per year of $2.768B (because it will take 2 years to build the facility, while the next 3 years will recover the fixed cost)

**F = QP - V** [where V is the variable cost of operating the plant including production based on 70% utilization/year]

2.775B = 28000*12P - 0.672B [variable cost decrease of 20% as explained before]

P= $6238.095

For 50% gross profits, we can scale this number by 1.5, hence our final **selling price** ~ **$9357/chip**

Considering the market cost is about $10000, this helps us gain a larger market share due to competitive pricing without compromising on quality or profits.

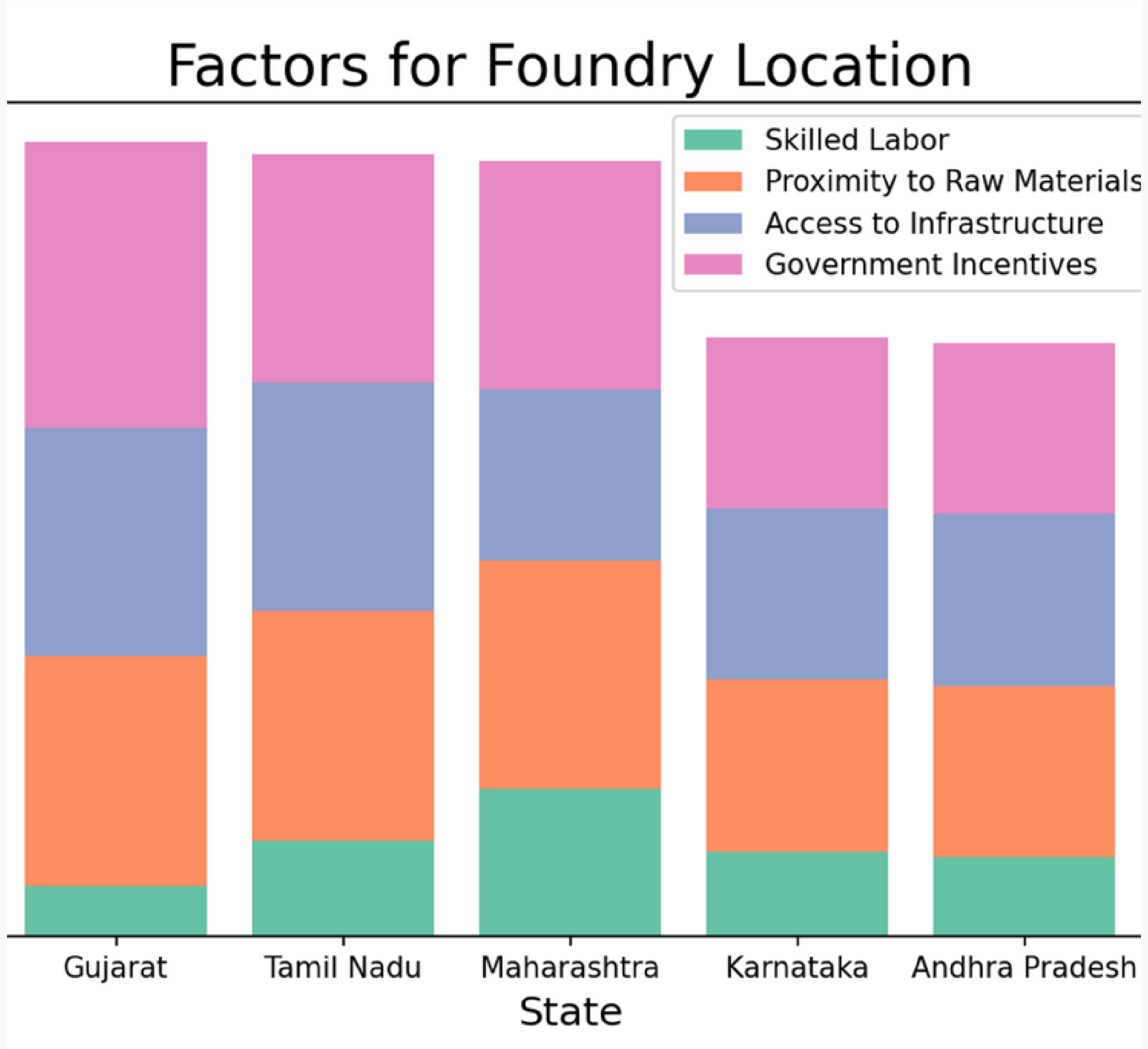
# Manufacturing Location

**Gujarat** has **several government incentives** in place, such as tax exemptions and subsidies, to draw investment in the manufacturing industry.

Gujarat **led all Indian states in terms of foreign direct investment (FDI)** in the manufacturing sector in 2020, per statistics from the Department of Industries and Mines.

Gujarat has **a well-developed infrastructure**, with **a large number of ports, airports, and transportation networks**. According to data from the Ministry of Road Transport and Highways, Gujarat has **a total road network of over 150,000 kilometers,** including a number of national and state highways.

Gujarat has a **number of ports and airports, which can facilitate the import of raw materials such as silicon and gases**. The state also has a number of industrial clusters and manufacturing hubs, which may provide access to local sources of raw materials. According to data from the Department of Commerce, **Gujarat is home to over 1,800 small and medium-sized enterprises (SMEs)** in the chemicals and petrochemicals sector, which could potentially provide access to raw materials for the foundry.



# Raw Materials

**Raw material sourcing** is one of the **most problematic bottlenecks** that semiconductor manufacturers face. A semiconductor fab requires **silicon wafers** and **ultrapure water (UPW)** as its main raw materials. A constant supply of high-wattage power supply is also a necessity for successful operations.

**Our recommendation** would be to **buy UPW equipment** for in house manufacturing, and **partner with Siltronic** for a steady supply of high-quality silicon wafers.

## Ultrapure Water

UPW is used at various steps in the processing of silicon wafers into desired chips. It is used for cleaning the wafer, and for multiple other chemical processes done on the wafers. The semiconductor industry has stringent standards for the UPW that is used, with specific conductivity, ionic content, and allowed dissolved gases to name a few.

## Silicon Wafers

Silicon Wafers are used as the input for a lithography machine. The transistors are etched onto the wafers. A good quality- properly polished and coated- wafer would lead to a high end product with better throughput for the semiconductor fab.

# Sourcing Strategy for UPW & Electricity

The International Technology Roadmap for Semiconductors (ITRS) in its 2015 roadmap stated that the target usage for UPW in 2020 would be about 4.5 liters/sq. cm. Assuming that this would be the requirement by the time our fab is functional-

for 40,000 wpm (at 80% efficiency,  for an 8-hour shift) → 40000*(area of wafer)*4.5/(30*8*0.8) liter/hours = 662,679.7 liters/hour

One piece of equipment that provides 20L of UPW per hour costs about $12,100 (Rs. 1M)

Number of machines required = 662679.7/20 ~ 33,134

Total cost of machines = $400.92M

Let us assume supporting infrastructure cost for a UPW plant to be 10% of the machinery cost.

So, **Total cost of UPW plant** ~ **$441M**

Electricity can be sourced from the state board itself-

Total fab electricity consumption (kWh/sq. cm) = 1.432

Total area of wafers = 40000*12*(area of wafer) = 339.29M sq. cm

Total electricity usage = 485.866 GWh

**Total cost** = **$26.88M** (at a rate of Rs. 4.57/unit)

# Sourcing Strategy for Silicon Wafers

Sourcing The Silicon Wafers is one of the harder challenges to solve, there are 3 plausible solutions for it.

## Greenfield Development

In this option we develop our own silicon wafer manufacturing from ground up.

**Tata Mining is already India's major Silicon miners of SiO2** (Quartz; The raw material required to make Silicon Wafers).

Tata also has the a wide array of highly skilled engineers, but in a specialised job like this they may lack experience.

This would also **require a large array of expensive machinery** and is a extensive process.

**We would not recommend this route due to its capital intensive nature.**

## Acquisition

There are **no significant companies** that are **locally manufacturing silicon wafers** of the caliber or size that we would require for our applications.

Major international suppliers are available but an **acquisition would not be a possiblity given the immense market caps.**

## Partnerships

There are many global players in Silicon Wafer manufacturing partnering up with them can be a beneficial way to make sure that we have a constant supply of high quality silicon wafers.

Some potential partners include Global Wafers and Siltronic.

**Our Recommendation would be to go ahead with Siltronic** instead of Global Wafers as it just invested $5B in a.

**Siltronic might also be interested in a potential partner for a joint-venture to manufacture in India.**

# Executive Summary

The problem at hand is for us to understand how Tata can enter into the semiconductor industry, and what the future holds for the Indian conglomerate. Another question is the avenue Tata should venture into, followed by choosing the specifics of the same.

**Our recommendation is for Tata to become a fab for the 7-10nm node size.**

The background of the problem is the highly saturated semiconductor industry with no fabs in India, and a history of failure. We firmly believe that this is a good time for Tata to enter the industry in light of the supply chain disruptions across the globe. The bullish 7-10nm market segment justifies capital investment for a sustainable, rewarding and self-fulfilling future.

**Our recommendation for a partner would be TSMC**, the global semiconductor manufacturing leader. The aligned interests of both TSMC and Tata, would be mutually fruitful. The other venture routes would not be feasible because of capital risks, low expertise, and lack of infrastructure for the chosen node sizes.

**Our analysis reveals a breakeven price/wafer of about $6000**. Even selling the product with a gross profit of 50%, enables sales at prices under market value. A lower price, along with the branding of Tata and TSMC would help us gauge a large market share.

For Tata **to solve the significant raw material bottlenecks** faced by semiconductor manufacturers, **Our recommendation would be to buy UPW machinery, and partner with Siltronic for a stable influx of raw materials.** Owning a completely independent venture would be more risk in the pot, considering the money Tata is already investing.

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- 300 mm wafer market share
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# Thank You