CareEdge RESEARCH

Report on Global Opto-semiconductors Industry

September 2023

DISCLAIMER

This report is prepared by CARE Advisory Research and Training Limited (CareEdge Research). CareEdge Research has taken utmost care to ensure accuracy and objectivity while developing this report based on information available in CareEdge Research's proprietary database, and other sources considered by CareEdge Research as accurate and reliable including the information in public domain. The views and opinions expressed herein do not constitute the opinion of CareEdge Research to buy or invest in this industry, sector or companies operating in this sector or industry and is also not a recommendation to enter into any transaction in this industry or sector in any manner whatsoever.

This report has to be seen in its entirety; the selective review of portions of the report may lead to inaccurate assessments. All forecasts in this report are based on assumptions considered to be reasonable by CareEdge Research; however, the actual outcome may be materially affected by changes in the industry and economic circumstances, which could be different from the projections.

Nothing contained in this report is capable or intended to create any legally binding obligations on the sender or CareEdge Research which accepts no responsibility, whatsoever, for loss or damage from the use of the said information. CareEdge Research is also not responsible for any errors in transmission and specifically states that it, or its Directors, employees, parent company – CARE Ratings Ltd., or its Directors, employees do not have any financial liabilities whatsoever to the subscribers/users of this report. The subscriber/user assumes the entire risk of any use made of this report or data herein. This report is for the information of the authorised recipient in India only and any reproduction of the report or part of it would require explicit written prior approval of CareEdge Research.

CareEdge Research shall reveal the report to the extent necessary and called for by appropriate regulatory agencies, viz., SEBI, RBI, Government authorities, etc., if it is required to do so. By accepting a copy of this Report, the recipient accepts the terms of this Disclaimer, which forms an integral part of this Report.

Table of Contents

List of Charts

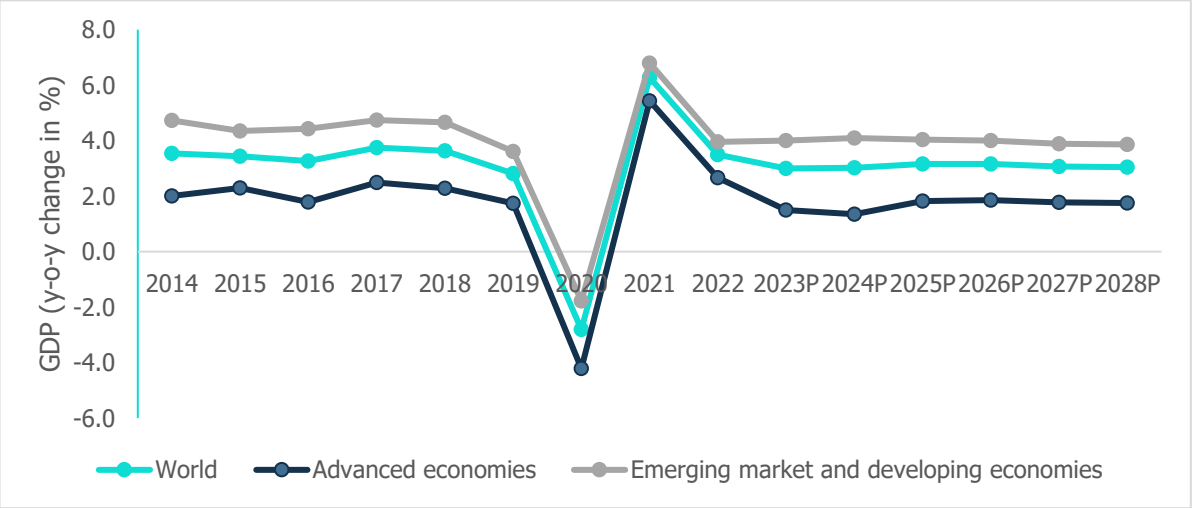
List of Tables

1. Economic Outlook

1.1 Global economy outlook

As per the International Monetary Fund (IMF)'s World Economic Outlook growth projections released in July 2023, global economic growth for CY22[1] stood at 3.5% on year on year (y-o-y) basis, down from 6.3% in CY21 due to disruptions resulting from the Russia-Ukraine conflict and higher-than-expected inflation worldwide. The global economic growth for CY23 is projected to slow down further to 3.0% mainly due to tightening global financial conditions, expectations of steeper interest rate hikes by major central banks to fight inflation and spill-over effects from the war between Russia and Ukraine with gas supplies from Russia to Europe expected to remain tightened. Growth in CY24 is projected to remain broadly stable at 3.0%, although with notable shifts across regions. For the next 5 years, the IMF projects world economic growth in the range of 3.0%-3.2% on a y-o-y basis.

Chart 1: Global Growth Outlook Projections (Real GDP, Y-o-Y change in %)



Notes: E- Estimated, P-Projection
Source: IMF – World Economic Outlook, July 2023 and April 2023

Advanced Economies Group

The major advanced economies registered GDP growth of 2.7% in CY22, down from 5.4% in CY21, which is further projected to decline to 1.5% in CY23. This forecast of low growth reflects rise in central bank interest rates to fight inflation and the impacts of Russia- Ukraine war. About 93% of advanced economies are projected to see decline in GDP growth in CY23. This growth is expected to decline further to 1.4% in CY24.

One of the major countries from this group is **United States**. United States registered GDP growth of 2.1% in CY22 compared to 5.9% in CY21. Whereas, growth for CY23 and CY24 is projected at 1.8% and 1.0%, respectively. This is reflective of declining real disposable income and savings impacting consumer demand with higher interest rates taking toll on spending.

Euro Area registered GDP growth of 3.5% in CY22 compared to 5.3% in CY21. However, the boost from reopening of economy after pandemic appears to be fading. For CY23 and CY24, the growth is projected at 0.9% and 1.5%, respectively. The accelerated pace of rate increases by the Bank of England and the European Central Bank is leading to tightening of financial conditions and resulting in cooling of demand in the housing sector and beyond.

[1] CY- Calendar Year

Emerging market and developing economies group

For the emerging market and developing economies group, GDP growth stood at 4.0% in CY22, compared to 6.8% in CY21. This growth is projected at 4.0% in CY23 and 4.1% in CY24. This expected improvement in GDP growth in CY24 is on account of anticipation of gradual recovery. The stable growth is contributed by about 61% of economies which are expected to grow at faster rate in CY23, while remaining economies including low income countries are expected to grow slower.

In China, growth is expected to pick up to 5.2% with the full reopening in CY23 and subsequently moderate in CY24 to 4.5%. Whereas, India's GDP projections for CY23 and CY24 stand at 6.1% and 6.3%, respectively, with resilient domestic demand despite external headwinds.

Table 1: GDP growth trend comparison - India v/s Other Emerging and Developing Economies (Real GDP, Y-o-Y change in %)

	Real GDP (Y-o-Y change in %)										
	2018	2019	2020	2021	2022	2023E	2024P	2025P	2026P	2027P	2028P
India	6.5	3.9	-5.8	9.1	7.2	6.1	6.3	6.2	6.1	6.0	6.0
China	6.8	6.0	2.2	8.4	3.0	5.2	4.5	4.1	4.0	3.6	3.4
Indonesia	5.2	5.0	-2.1	3.7	5.3	5.0	5.0	5.0	5.0	5.0	5.0
Saudi Arabia	2.8	0.8	-4.3	3.9	8.7	1.9	2.8	3.0	3.0	3.0	3.0
Brazil	1.8	1.2	-3.3	5.0	2.9	2.1	1.2	1.9	2.0	2.0	2.0

E- Estimated, P- Projections; Source: IMF, World Economic Outlook Database (July 2023 and April 2023)

The **Indonesian** economy is expected to register growth of 5% both in CY23 and CY24 with strong recovery in domestic demand and healthy export performance coupled with policy measures and normalization in commodity prices.

In CY22, **Saudi Arabia** was the fastest growing economy in this peer set with 8.7% growth. Factors such as strong oil production, non-oil private investments which includes wholesale and retail trade, construction and transport, and robust private consumption bodes well for overall economic growth of this economy. Saudi Arabia is expected to grow at 1.9% and 2.8% in CY23 and CY24, respectively.

On the other hand, economic growth in **Brazil** is expected to moderate to 2.1% in CY23 due to headwinds of inflation. Recovery is expected in the medium term with sound financial system, large cash buffers with the public sector, and adequate international reserves.

Despite the turmoil in last two-three years, India bears good tidings for becoming USD 5 trillion economy by CY27. According to the IMF dataset on Gross Domestic Product (GDP) at current prices, the GDP is estimated to be at USD 3.4 trillion for CY22 and projected to reach USD 5.2 trillion by CY27. The expected GDP growth rate of India for coming years is almost double compared to the world economy.

Besides this, India stands out as the fastest growing economy amongst the major economies. Outshining the growth rate of China, the Indian economy is expected to grow at more than 6% in the period of CY24-CY28.

Indian economy is paving its way towards becoming largest economy in the world. Currently, India is the third largest economy globally in terms of Purchasing Power Parity (PPP) with ~7% share in global economy with China [~18%] on the top and United states [~15%] being second. Purchasing Power Parity is an economy performance indicator denoting relative price of an average basket of goods and services that a household needs for livelihood in each country. Despite the impact of the pandemic, high inflationary and interest rate environment globally and the geo-political tensions in Europe, India has been one of the major contributors to world economic growth.

1.2 Indian Economy Outlook

1.2.1 GDP growth and Outlook

Resilience to external shocks remains critical for near-term outlook

India's GDP grew by 9.1% in FY22 and stood at Rs. 149.3 trillion despites of some spill overs of the pandemic and geo-political Russia-Ukraine. In Q1FY23, India recorded 13.2% y-o-y growth in GDP which can largely be attributed to better performance by agriculture and services sectors. Following this double-digit growth, Q2FY23 witnessed 6.3% y-o-y growth, while, Q3FY23 registered 4.5% y-o-y growth. This slowdown in growth during Q2FY23 and Q3FY23 compared to the Q1FY23 can be attributed to normalization of the base and a contraction in the manufacturing sector's output. Subsequently, Q4FY23 registered broad-based improvement across sectors compared to Q3FY23 with growth of 6.1% y-o-y. The investments as announced in the Union Budget 2022-23 on boosting public infrastructure through enhanced capital expenditure has augmented growth and encouraged private investment through large multiplier effects in FY23. Supported by fixed investment and higher net exports, GDP for full-year FY23 was valued at Rs. 160.1 trillion registering an increase by 7.2% y-o-y.

In Q1FY24, the economic growth accelerated to 7.8%. The manufacturing sector maintained the encouraging pace of growth gaining from favourable demand conditions and lower input prices. A supportive base along with continued strength in services and construction activities supported the growth.

GDP growth outlook

- During FY24, strong prospects for agricultural and allied activities are likely to boost rural demand. However, El Nino is being predicted in the current fiscal which may lead to deficit rainfall in the country and impact agricultural output. Rebound in contact-intensive sectors and discretionary spending is expected to support urban consumption.
- Strong credit growth, resilient financial markets, and the government's continued thrust on capital spending and infrastructure are likely to create a congenial environment for investments.
- External demand is likely to remain subdued with slowdown in global activity, thereby indicating adverse implications for exports. Additionally, heightened inflationary pressures and resultant policy tightening may pose risk to the growth potential.

Taking all these factors into consideration, in August 2023, the RBI in its bi-monthly monetary policy meeting estimated the real GDP growth of 6.5% y-o-y for FY24.

Table 2: RBI's GDP Growth Outlook (Y-o-Y %)

FY24 (complete year)	Q1FY24	Q2FY24	Q3FY24	Q4FY24	Q1FY25
6.5	8.0	6.5	6.0	5.7	6.6%

Source: Reserve Bank of India

1.2.2 Gross Value Added (GVA)

Gross value added (GVA) is the measure of the value of goods and services produced in an economy. GVA gives a picture of supply side whereas GDP represents consumption.

Industry and Services sector leading the recovery charge

• The gap between GDP and GVA growth turned positive in FY22 (after a gap of two years) as a result of robust tax collections. Of the three major sector heads, service sector has been fastest growing sector in the last 5 years.

• **Agriculture sector** was holding growth momentum till FY18. In FY19, the acreage for rabi crop was marginally lower than previous year which affected the agricultural performance. FY20 witnessed growth on account of improved

production. During the pandemic impacted period of FY21, agriculture sector was largely insulated as timely and proactive exemptions from Covid-induced lockdowns to the sector facilitated uninterrupted harvesting of rabi crops and sowing of kharif crops. However, supply chain disruptions impacted the flow of agricultural goods leading to high food inflation and adverse initial impact on some major agricultural exports. However, performance remained steady in FY22.

In Q1FY23 and Q2FY23, the agriculture sector recorded a growth of 2.4% and 2.5%, respectively, on a y-o-y basis. Due to uneven rains in the financial year, the production of some major Kharif crops such as rice and pulses was adversely impacted thereby impacting agriculture sector's output. In Q3FY23 and Q4FY23, the sector recorded a growth of 4.7% and 5.5%, respectively, on a y-o-y basis.

Overall, the agriculture sector performed well despite weather-related disruptions such as uneven monsoon and unseasonal rainfall impacting yields of some major crop and clocked a growth of 4% y-o-y in FY23 and stood at Rs. 22.3 trillion. In Q1FY24, this sector expanded at a slower pace of 3.1% compared to a quarter ago. Going forward, rising bank credit to the sector and increased exports will be the drivers for agriculture sector. A deficient rainfall may impact the reservoir level weighing on prospects of Rabi sowing. A downside risk exists in case the intensity of El Nino is significantly strong.

• **Industrial sector** witnessed CAGR of 4.7% for the period FY16 to FY19. From March 2020 onwards, nation-wide lockdown due to the pandemic had a significant impact on industrial activity. In FY20 and FY21, this sector felt turbulence due to the pandemic and recorded decline of 1.4% and 0.9%, respectively, on a y-o-y basis. With the opening up of economy and resumption of industrial activity, it registered 11.6% y-o-y growth in FY22, albeit on a lower base.

The industrial output in Q1FY23 jumped 9.4% on y-o-y basis. However, in the subsequent quarter, the sector witnessed a sharp contraction of 0.5% due to lower output across mining, manufacturing and construction sectors. This was mainly because of the poor performance by the manufacturing sector which was marred by high input costs. In Q3FY23, the sector grew modestly by 2.3% y-o-y. The growth picked-up in Q4FY23 to 6.3% y-o-y owing to a rebound in manufacturing activities and healthy growth in the construction sector. Overall, industrial sector is estimated to be valued at Rs. 45.2 trillion registering 4.4% growth in FY23.

The industrial sector grew by 5.5% in Q1FY24. The industrial growth was mainly supported by sustained momentum in the manufacturing and construction sectors. Within manufacturing (as captured by IIP numbers), industries such as pharma, non-metallic mineral products, rubber, plastic, metals, etc. witnessed higher production growth during the quarter.

• **Services sector** recorded CAGR of 7.1% for the period FY16 to FY20, which was led by trade, hotels, transport, communication and services related to broadcasting and finance, real estate & professional service. This sector was the hardest hit by the pandemic and registered 8.2% y-o-y decline in FY21. The easing of restrictions aided a fast rebound in this sector, with 8.8% y-o-y growth witnessed in FY22.

In Q1FY23 and Q2FY23, this sector registered y-o-y growth of 16.3% and 9.4%, respectively, on a lower base and supported by revival in contact intensive industries. The services sector continued to witness buoyant demand and recorded a growth of 6.1% y-o-y in Q3FY23. On the back of robust discretionary demand Q4FY23 registered 6.9% growth largely driven by trade, hotel and transportation. Overall, benefitting from the pent-up demand, service sector was valued at Rs. 20.6 trillion and registered growth of 9.5% y-o-y in FY23.

In Q1FY24, Services sector growth jumped to 10.3%. Within services, there was a broad-based improvement in growth across different sub-sectors. However, the sharpest jump was seen in financial, real estate and professional services. Trade, hotels and transport sub-sectors expanded at a healthy pace gaining from strength in discretionary demand.

Healthy growth in various service sector indicators like air passenger traffic, port cargo traffic, GST collections and retail credit are expected to support service sector going ahead.

Table 3: Sectoral Growth (Y-o-Y % Growth) - at Constant Prices

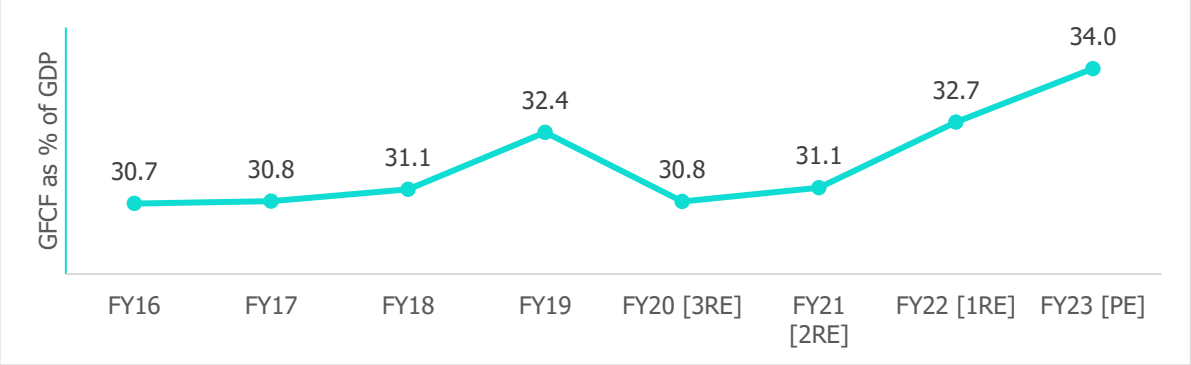
At constant Prices	FY18	FY19	FY20 (3RE)	FY21 (2RE)	FY22 (1RE)	FY23 (PE)	Q1FY24
Agriculture, forestry & fishing	**6.6**	**2.1**	**6.2**	**4.1**	**3.5**	**4.0**	**3.5**
Industry	**5.9**	**5.3**	**-1.4**	**-0.9**	**11.6**	**4.4**	**5.5**
Mining & quarrying	-5.6	-0.8	-3.0	-8.6	7.1	4.6	5.8
Manufacturing	7.5	5.4	-3.0	2.9	11.1	1.3	4.7
Electricity, gas, water supply & other utility services	10.6	7.9	2.3	-4.3	9.9	9.0	2.9
Construction	5.2	6.5	1.6	-5.7	14.8	10.0	7.9
Services	**6.3**	**7.2**	**6.4**	**-8.2**	**8.8**	**9.5**	**10.3**
Trade, hotels, transport, communication & broadcasting	10.3	7.2	6.0	-19.7	13.8	14.0	9.2
Financial, real estate & professional services	1.8	7	6.8	2.1	4.7	7.1	12.2
Public administration, defence and other services	8.3	7.5	6.6	-7.6	9.7	7.2	7.9
GVA at Basic Price	**6.2**	**5.8**	**3.9**	**-4.2**	**8.8**	**7.0**	**7.8**

3RE – Third Revised Estimate, 2RE – Second Revised Estimates, 1RE – First Revised Estimates, PE -Provisional Estimate; Source: MOSPI

1.2.3 Investment trend in infrastructure

Gross Fixed Capital Formation (GFCF), which is a measure of the net increase in physical assets, witnessed an improvement in FY22. As a proportion of GDP, it is estimated to be at 32.7%, which is the second highest level in 7 years (since FY15). In FY23, the ratio of investment (GFCE) to GDP inched up to its highest in the last decade at 34% as per the advanced estimate released by the Ministry of Statistics and Programme Implementation (MOSPI).

Chart 2: Gross Fixed Capital Formation (GFCF) as % of GDP (At constant prices):



PE: Provisional Estimates, RE: Revised Estimate, AE: Advanced Estimate; Source: MOSPI

Overall, support of public investment in infrastructure is likely to gain traction due to initiatives such as of Atmanirbhar Bharat, Make in India, Production-linked Incentive (PLI) scheme announced across various sectors etc.

1.2.4 Industrial Growth

Improved core and capital goods sectors helped IIP growth momentum

Index of Industrial production (IIP) is an index to track manufacturing activity in an economy. On a cumulative basis, IIP grew by 11.4% y-o-y in FY22 post declining by 0.8% y-o-y and 8.4% y-o-y, respectively, in FY20 and FY21. This high growth was mainly backed by low base of FY21. FY22 IIP was higher by 2.0% when compared with the pre-pandemic level of FY20, indicating that while economic recovery was underway, it was still at very nascent stages.

During FY23, the industrial output has recorded a growth of 5.1% y-o-y supported by a favourable base and a rebound in economic activities. During April 2023 and May 2023, IIP grew by 4.2% y-o-y and 5.3% y-o-y growth,

respectively. This growth in April and May 2023 was aided by encouraging performance of the mining and manufacturing sectors. However, in June 2023, the industrial output slowed to 3.7% mainly due to moderation in manufacturing sector's output. Overall, the industrial output grew by 4.5% in Q1FY24.

Chart 3: Y-o-Y growth in IIP (in %)

Source: MOSPI; P-Provisional

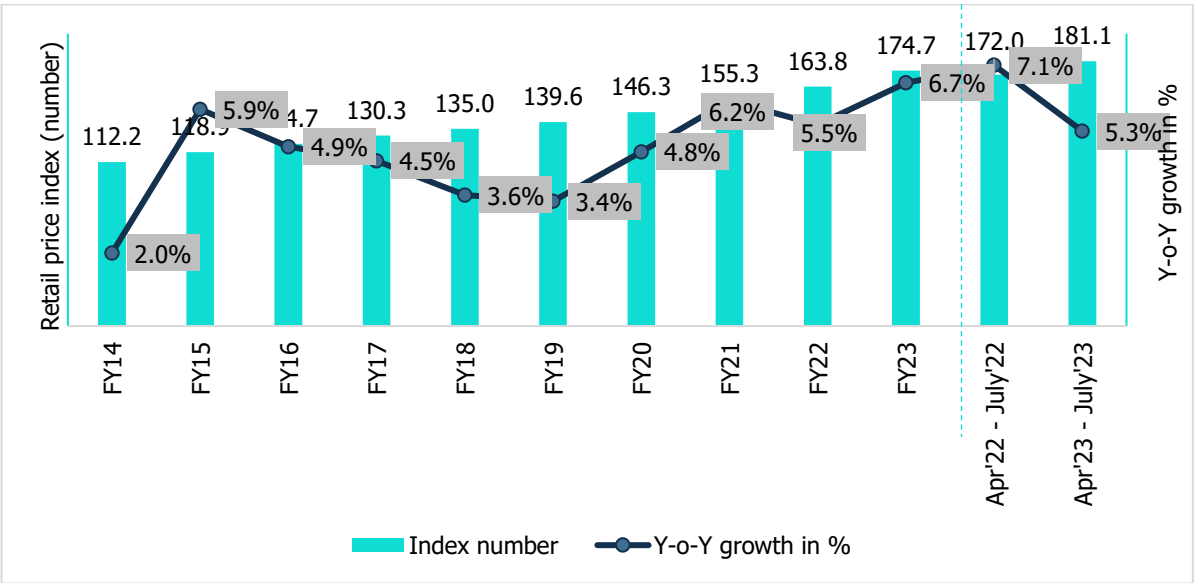
Going forward, it will be critical to maintain the current growth momentum in the industrial sector. In the environment of global slowdown, maintaining growth in industrial output will depend on the resilience and momentum of domestic demand. Pick-up in the investment demand is also expected to support segments like capital goods and infrastructure. However, challenges from an uncertain global economic scenario and weak external demand are likely to persist.

1.2.5 Consumer Price Index

India's consumer price index (CPI), which tracks the retail price inflation, stood at an average of 5.5% in FY22 which was within RBI's targeted tolerance band of 6%. However, the consumer inflation started to upswing from October 2021 onwards and reached the tolerance level of 6% in January 2022. Following this, CPI reached 6.9% in March 2022.

CPI remained elevated at an average of 6.7% in FY23, above the RBI's tolerance level. However, some relief was seen towards the end of the fiscal wherein the retail inflation stood at 5.7% in March 2023, tracing back to the RBI's tolerance band. Apart from a favourable base effect, the relief in retail inflation came from a moderation in food inflation. In the current fiscal FY24, the CPI moderated for two consecutive month to 4.7% in April 2023 and 4.3% in May 2023. This trend was snapped in June 2023 with CPI rising to 4.9% and 7.4% in July 2023 largely due to rise in food inflation. The CPI has breached the RBI's target range for the first time since February 2023. This marks the highest reading observed since the peak in April 2022 at 7.8%. The notable surge in vegetable prices and elevated inflation in other food categories such as cereals, pulses, spices, and milk have driven this increase. Further, the contribution of food and beverages to the overall inflation has risen significantly to 65%, surpassing their weight in the CPI basket.

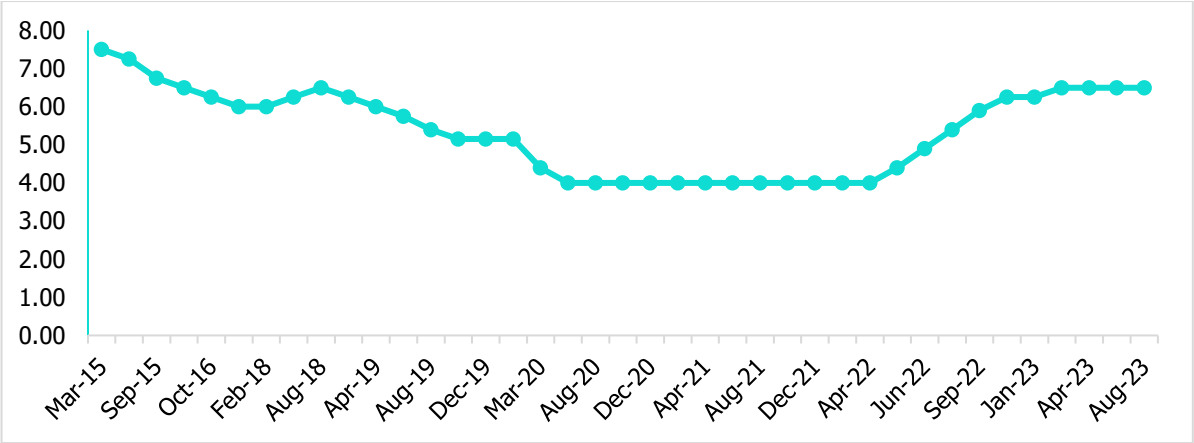
Chart 4: Retail Price Inflation in terms of index numbers and Y-o-Y Growth in % (Base: 2011-12=100)



Source: MOSPI

The CPI is primarily factored in by RBI while preparing their bi-monthly monetory policy. The RBI has increased the repo rates with the rise in inflation in the past year from 4% in April 2022 to 6.5% in January 2023.

Chart 5: RBI historical Repo Rate



Source: RBI

However, with the inflation easing over the last few months, RBI has kept repo rate unchanged at 6.5% in the last three meetings of the Monetary Policy Committee. At the bi-monthly meeting held in August 2023, RBI projected inflation at 5.4% for FY24 with inflation during Q2FY24 at 6.2%, Q3FY24 at 5.7%, Q4FY24 at 5.2% and Q1FY25 at 5.2%

In a meeting held in August 2023, RBI also maintained the liquidity adjustment facility (LAF) corridor by adjusting the standing deposit facility (SDF) rate of 6.25% as the floor and the marginal standing facility (MSF) at the upper end of the band at 6.75%.

The central bank continued to remain focused on withdrawal of accommodative stance. With domestic economic activities gaining traction, RBI has shifted gear to prioritize controlling inflation. While RBI has paused on the policy rate front, it has also strongly reiterated its commitment to bringing down inflation close to its medium-term target of 4%. Given the uncertain global environment and lingering risks to inflation, Central Bank has kept the window open for further monetary policy tightening in the future, if required.

1.2.6 Key Demographic drivers for Economic Growth

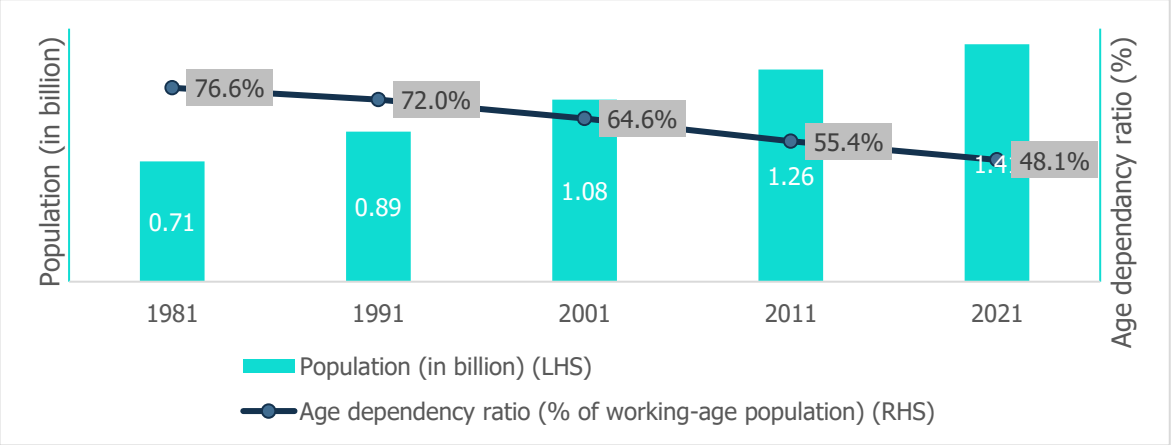
The trajectory of economic growth of India and private consumption is driven by socio-economic factors such as demographics and urbanization. Some of the key demographic drivers are as under:

- **Growing Population and Declining Dependency Ratio:**

With 1.41 billion people, India is the second most populous country in the world. The population has witnessed significant growth in the past few decades.

Age Dependency Ratio is the ratio of dependents to the working age population i.e. 15 to 64 years, wherein dependents are population younger than 15 and older than 64. This ratio has been on a declining trend. It was as high as 76.6% in 1981, which has reduced to 48.1% in 2021. Declining dependency means the country has improving share of working age population generating income, which is a good sign for the economy.

Chart 6: Trend of India Population vis-à-vis dependency ratio

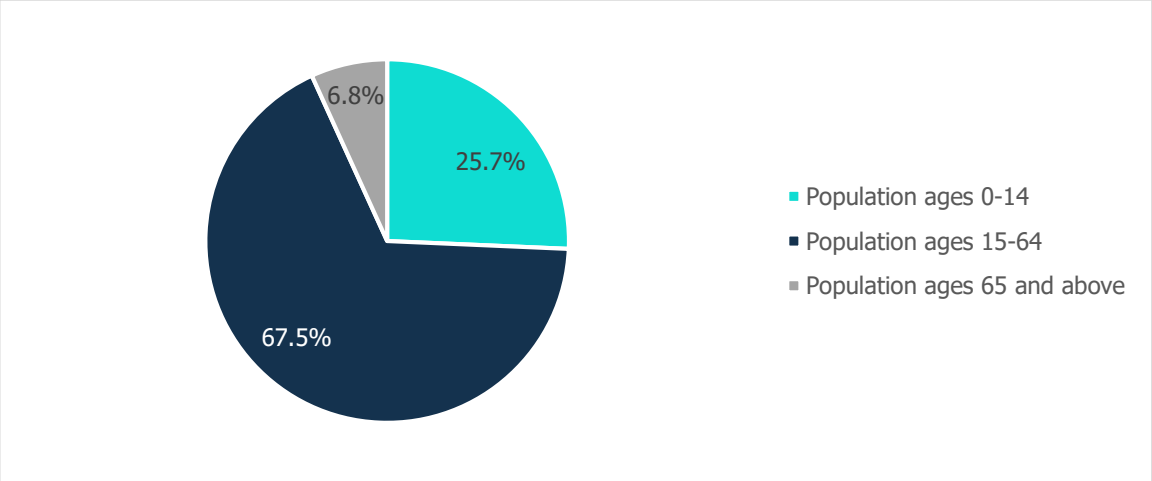


Source: World Bank Database

- **Young Population:**

With an average age of 29, India has one of the youngest populations globally. As a vast resource of young citizens enters the workforce every year, it is expected to create a 'demographic dividend'. India is home to a fifth of the world's youth demographic and this population advantage will play a critical role in economic growth.

Chart 7: Age-wise break up of Indian population

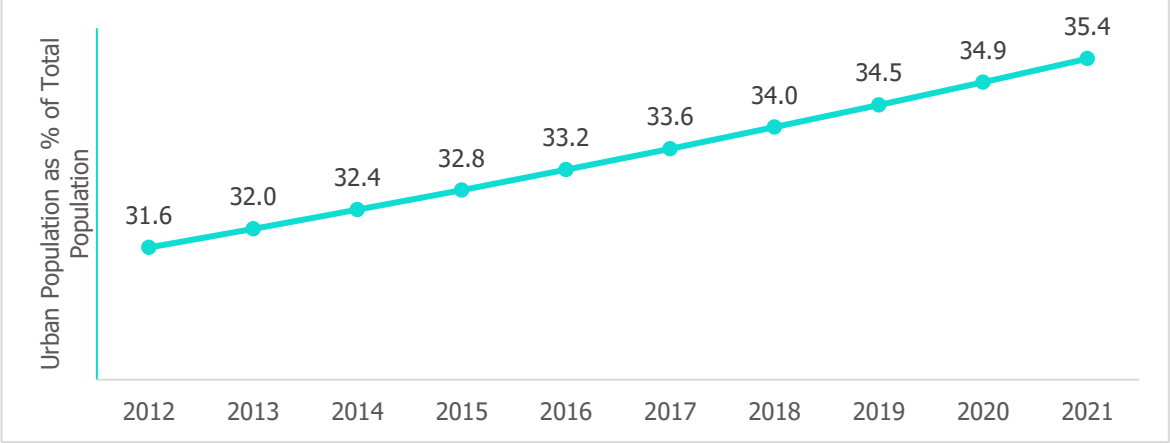


Source: World Bank Database

- **Urbanization**

Urbanization of India's population is growing on a larger population base. The urban population in India is estimated to have increased from 403 million (31.6% of total population) in the year 2012 to 498 million (35.4% of total population) in the year 2021. People living in tier-2 and tier-3 cities have greater purchasing power.

Chart 8: Trend in urbanisation in India

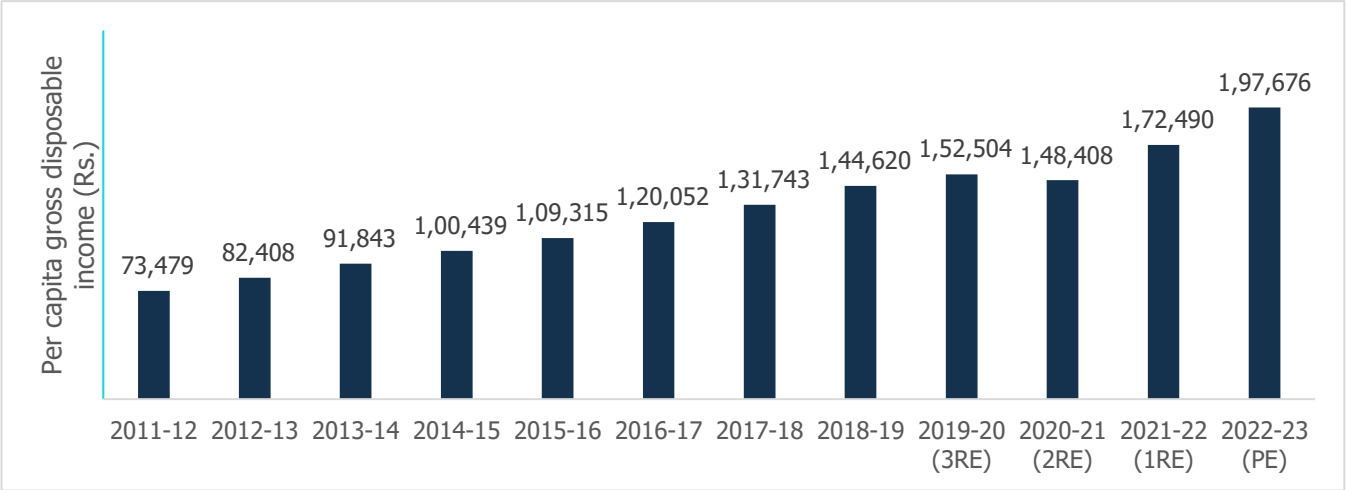


Source: World Bank Database

- **Increasing per capita disposable income**

Gross National Disposable Income (GNDI) is measure of the income available to the nation for final consumption and gross saving. Between the period fiscal 2012 to fiscal 2023, per capita GNDI registered CAGR of 9.4%. More disposable income, in turn drives more consumption, thus economic growth. Below chart depicts the trend of per capita GNDI in past 12 years:

Chart 9: Trend of Per Capita Gross National Disposable Income



Note: 3RE – Third Revised Estimate, 2RE – Second Revised Estimates, 1RE – First Revised Estimates, 2AE – Second Advanced Estimate; Source: MOSPI

1.2.7 Concluding Remarks

Despite the global growth uncertainties, Indian economy is relatively better placed in terms of GDP growth when compared with other emerging economies as it is expected to grow at 6.3% in CY24 compared to world GDP growth projection of 3%. The major headwinds to economic growth are escalating geopolitical tensions, volatility in global commodity prices and shortages of key inputs. However, the bright spots for the economy are continued healthy domestic demand, support from government towards capital expenditure, moderating inflation and improving

business confidence. Various high-frequency growth indicators including purchasing managers index, auto sales, bank credit, GST collections have shown improvement in the FY23. Moreover, normalizing employment situation after the opening up of economy is expected to improve and provide support to consumption expenditure.

In line with the India Meteorological Department's (IMD's) projection, the rainfall activity has been muted in August with cumulative rainfall deficit of 8%. Weak to moderate El Nino conditions are expected to lead to a prolonged dry spell.

Public investment is expected to exhibit healthy growth as the government has budgeted for strong capital expenditure of about Rs. 10 trillion for FY24. Private sector's intent to invest is also showing improvement as per the data announced on new project investments. However, the volatility in commodity prices and the economic uncertainties emanating from global turbulence may slow down the improvement in private capex and investment cycle.

Among sectors, the industrial segment is expected to perform better as the input costs are now moderating. With flagship programmes like 'Make in India' and the PLI schemes, the government is continuing to provide the necessary support to boost the industrial sector. Service sector is expected to see continued growth in FY24 with healthy economic growth. However, some segments like information technology in the services sector would feel the pinch of slowdown in the US and European economies.

2. Semiconductor Industry

2.1 Overview

Semiconductors are material whose conductive properties lie in between that of conductors and insulators. They can be pure metals like silicon or germanium or can be a compound like gallium arsenide or cadmium selenide. Doping is method used to introduce a small amount of impurity into the pure semiconductors to cause large changes in the conductivity of the material i.e. enabling conduction of electricity

Semiconductor's specific electrical properties enables it to be used in computers and other electronic devices. It can conduct electricity in specific conditions like temperatures, light etc. This makes it an ideal choice to control electricity in everyday electrical items.

Broadly, there are two types of semiconductors: -

- **N-type semiconductor**- It is used when the conductance is high with a large number of free electrons.
- **P-type semiconductor**- It is used when the inductance is high with a lower number of free electrons.

The electrical conductivity of a semiconductor device can be controlled over a wide range, either permanently or dynamically, making them highly versatile for various applications. Essential electronic components such as transistors, diodes, and photovoltaic cells contain semiconductors. These are also used in the development of electronic chips, computing components and devices, and integrated circuits.

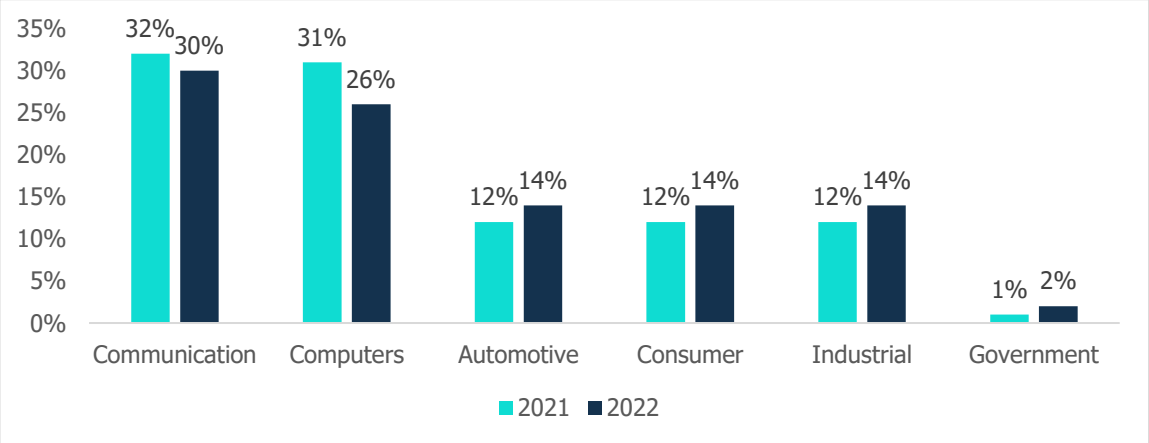
Elemental semiconductors include antimony, arsenic, boron, carbon, germanium, selenium, silicon, sulphur and tellurium. Silicon is best known semiconductor, forming the basis of most integrated circuits (ICs). Common semiconductor compounds include gallium arsenide, indium antimonide and the oxides of most metals.

2.2 Global Semiconductor Market Overview

Semiconductors are the integral part of the technology used in a broad range of products across almost all industries in the global economies. According to Semiconductor Industry Association, despite the downwards trend in the semiconductor market during the second half of 2022, the global semiconductor sales reached USD 574 Bn, a growth of 3.3% as compared to 2021.

Historically, end-user markets like computers and communication accounted for one-third of the total sales. However, according to World Semiconductor Trade Statistics Organization End-use Survey 2022, the automotive and industrial applications experienced the largest growth for the year despite computer and communication retaining the largest share.

Chart 10: Share of Global Sales Revenue by End Market for 2021-22



Source: World Semiconductor Trade Statistics, Semiconductor Industry Association

The semiconductor industry is very prone to shortages due to natural disasters, variations in supply chain of raw materials, changing economic conditions or geographical and political events.

Usually, the semiconductor manufacturing companies work at around 80% utilization and modify their capacities according to the demand. In the last 2 years, the operating flow of the semiconductor industry has been disrupted due to various reason as listed below-

- In the beginning of the pandemic in 2020, car manufacturers reduced their semiconductor demand drastically as they predicted sales downturn. But subsequently, the demand for digital infrastructure, laptops and IT equipment increased as people began working from home. This led to the production of expensive processors as per the IT industry needs and decrease in low cost car chips, leading to shortage of automotive chips.

- The trend of increasing use of cryptocurrency has added to the already high demand of high-end computing systems. Cryptocurrency mining requires large amount of data mining with specialized computers. The high demand for cryptocurrency mining machines led to lower availability of chips for other uses. The collapse of cryptocurrencies since first quarter of 2022 as however eased the problem.

- Taiwan is the leading producer of semiconductor chips. Severe drought conditions in the country led to unavailability of ultra-pure water needed to clean the silicon wafers which also affected the semiconductor chip supply.

- Neon is an essential part of the lasers used in chip manufacturing and Ukraine is the leading supplier of neon globally. The geopolitical issues between Russia and Ukraine led to disruption in supply of neon used for chip manufacturing.

India has seen huge growth in the consumer electronics market in the past few decades. Market for white goods like TVs, music systems and mobile phones started to see demand growth in the 1980s and 1990s. According to India Semiconductor Association, the electronic system design and manufacturing sector in India is estimated to grow to USD 220 Bn in FY25 from USD 78 Bn in FY18, with a CAGR of about 16%. This in turn is expected to push the electronics component market, which consists of semiconductor, to reach USD 72 Bn by FY25 from USD 27 Bn in FY18 at a CAGR of about 15%.

The key end-use industries for semi-conductor consists of mobile services, information technology, automation, telecommunication devices, industrial machinery, automobiles etc. All these industries are witnessing growing demand in India. The lack of indigenous semiconductor manufacturing has led to high imports to meet the domestic demand. According to the India Semiconductor Association, the total demand for wafer[2] is expected to grow to 17.6 million units in FY25 from 7.5 million units in FY19.

2.3 Opto-semiconductor - Overview

Opto-semiconductor are semiconductors that work by absorption and emission of light. They are based on the quantum mechanical effects of light on electronic materials. Photodiodes, light emitting diodes (LEDs), solar cells and semiconductor lasers are categorized as opto-electronics devices. The opto-semiconductor devices work on the basis of interaction of light and interaction of the electron-holes. They are advantageous over other semiconductors on the basis of conversion efficiency.

Opto-semiconductor can be made from a variety of materials which includes silicon, germanium, etc. dependent on the wavelength of the light that is to be generated or detected.

[2] A wafer is a thin slice of semiconductor usually made of crystalline silicon or other semiconductor material design in the form of a very thin disc to create integrated circuits.

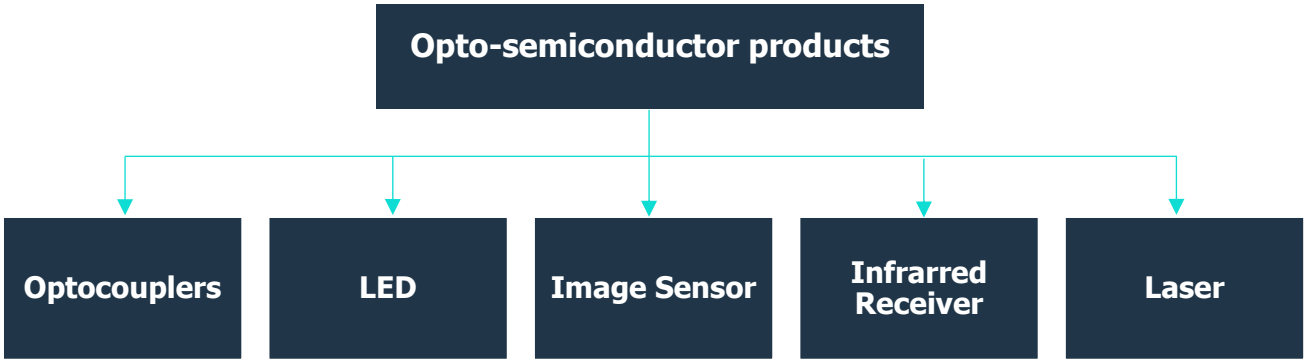
Properties of Opto-semiconductor Devices-

- Product using opto-semiconductor for emitting light have long wave length.
- These products can be easily fabricated and are cost-effective.
- The opto-semiconductor wafers are a size of nanometre.

The opto-semiconductor consists of light sensitive surface that absorbs and emits light. The light is incident on the p-n junction and is converted to charge called photocurrent. Hence the electricity flows through the semiconductor. Opto-semiconductors converts electricity to light and vice versa which is the key to LEDs.

Type of Opto-semiconductors

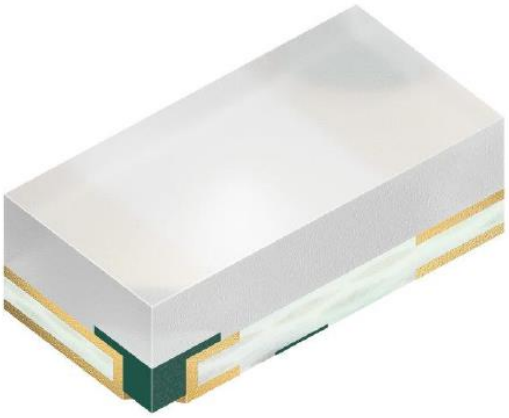
The opto-conductor semiconductor market consists of the following different products-



i. LED

An LED is a semiconductor device that emits light when electric currents pass through it. Light is produced when electric current-carrying particles (called electrons and holes) combine together in a semiconductor material. The holes in the p-type semiconductor recombine with the electrons in the n-type semiconductor, releasing energy in the form of photons. The photon energy determines the wavelength of the emitted light and thus the colour of the LED. Different semiconductor materials with different bandgaps produce different colours of light. The precise wavelength (colour) can be tuned by changing the composition of the emitting or active region.

Figure 1 : Light Emitting Diode



Source: Maia Research, CareEdge Research

With the rapid advancement of LED technology and the continuous increase of LED light efficiency, the uses of LED are becoming more widespread. As the worldwide energy constraint worsens, people are paying greater attention to

the development prospects of LED in the lighting business. LED lighting has the potential to replace incandescent, tungsten, and fluorescent lamps.

LEDs are very highly efficient and directional which make them ideal for many industries. They are ideal for street lights, parking garage lighting, walkways, offices, industrial areas, refrigerated case lighting, modular lighting, automobile lighting, general lighting, camera flashes, medical flashes, etc. Infrared LED are used in remote-control circuits used in electronics.

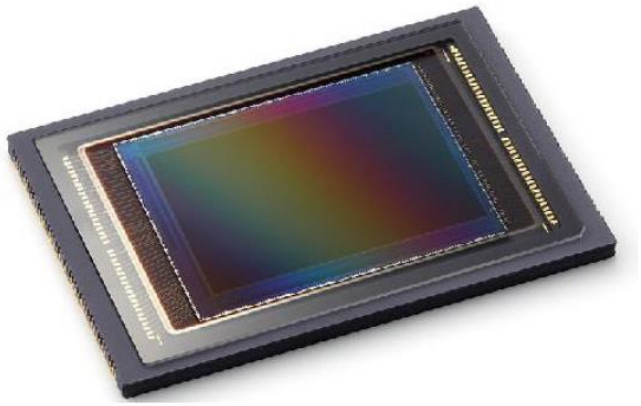
ii. Image Sensor

An image sensor is a semiconductor device that uses the photoelectric conversion function of an opto- semiconductor to convert the light image on the photosensitive surface into an electrical signal that is proportional to the light image. It is widely used in digital cameras and other electro-optical devices. It is the core module of the camera product and plays an important role in the camera's imaging quality.

The solid-state image sensor chip contains pixels which are made up of light sensitive elements, micro lenses, and micro electrical components. The chips are manufactured by semiconductor companies and cut from wafers. After light strikes on the photodiode in the image sensor, the picture is then converted into electrical signals and is sent to a series of internal devices like shift register, capacitor, amplifier, etc. Hence the image is converted from analog to digital. In this process, voltage signals are transformed into binary values and are stored and processed.

From the perspective of product categories, the current mainstream image sensors include two categories: Charge-coupled Device (CCD) image sensors and Complementary Metal-oxide Semiconductor (CMOS) image sensors. Among them, CCD image sensors are mainly used in professional cameras, industrial applications and other fields due to their performance advantages such as high resolution and low noise. Due to the performance advantages of lower power consumption and cost, smaller size, and ability to read random image information, CMOS image sensors have a wider range of applications. In addition to being used in digital cameras, they are also used in smartphones, automobiles electronics, mobile payment, security, medical imaging etc.

Figure 2: Image Sensor



Source: Maia Research, CareEdge Research

iii. Optocouplers

An optocoupler is a semiconductor device that allows electrical signals to be transmitted between two isolated circuits. It is a combination of an LED that emits infrared light and a semiconductor photosensitive device that detects the

emitted infrared light. There are two parts of an opto-coupler, LED that emits infrared light and a photosensitive device that detects the light. The photo sensor in the output circuit detects the light and converts it into AC or DC electric current dependent on the circuit.

The opto-coupler removes any electrical noise from the signal. It can isolate low-voltage devices from high voltage circuits i.e. it avoids disruptions from the voltage surges.

Some common market applications for optocouplers include microprocessor input/output switching, PC communications, DC and AC power control, signal isolation and power conditioning. Increasing adoption of optical technology in various end-user industries is an important factor attracting investments in the optocoupler market.

In addition to the above, manufacturers of industrial automation equipment (such as robot controllers, AC servos, and general-purpose inverters) and green energy systems (such as solar inverters and battery systems) are under intense pressure to significantly reduce the size to gain cost advantages. At the same time, new safety standards require longer creepage and clearance distances for electrical isolation components. These factors are also leading to incremental demand for optocouplers.

Figure 3: Opto-coupler

Source: Maia Research, CareEdge Research

The growing demand for advanced techniques, especially for advanced switching applications, is driving the development and adoption of digital opto-coupler. For example- CMOS (complementary metal-oxide semiconductor) digital isolators use magnetic coupling through thick insulation to provide high speed, high isolation and low power consumption at high data rates.

In addition, the shift from automobiles to electric and connected vehicles has also triggered the extensive development of electronic and safety components in the automotive field, thereby promoting the adoption of optocouplers. Optocouplers are also increasingly used in powertrain systems to enhance their functionality and efficiency.

iv. Laser Diode

A laser diode is an opto-semiconductor that converts electrical energy into light energy, producing high-intensity coherent light. In laser diodes, the pn-junction of a semiconductor diode acts as the lasing medium or active medium. They produce radiation with the same frequency and similar wavelength, hence the beam produced is very bright and focused. They might either produce a visible or infrared spectrum. Laser diodes work almost like LEDs. The key difference between LEDs and laser diodes is that LEDs emit incoherent light while laser diodes emit coherent light. Laser diodes are widely used in various devices like barcode readers, laser printers, security systems, fibre optic communications, Light Detection and Ranging (LIDAR) systems in autonomous vehicles etc.

Figure 4: Laser Diode

Source: Maia Research, CareEdge Research

Since the boom in data communication (datacom) and telecommunications, more and more devices have been used in materials processing applications. For more than a decade, laser diode revenue has been primarily driven by sensing applications. However, the overall laser diode market size is expected to grow significantly owing to booming optical communications and 3D sensing markets, as well as recent growth in medical laser systems.

Growth in optical communications is driven by data-centric applications such as cloud services from companies like Apple and Facebook, higher-definition 4k and 8k video streaming from companies like Netflix, and Disney+, and growing industrial automation traffic. The migration from 400G and beyond to higher-speed optical communications continues as cloud operators race to connect more and more data centers to keep up with the massive growth in IP traffic in India. In addition to optical communications, 3D sensing also offers great growth prospects for the laser diode market. All these factors are expected to push up the demand in laser diode market.

v. Infrared Receiver

The infrared receiver is an IC - based light-receiving component. It is a device that operates in the range of infrared light. Generally, it can receive infrared light in the 850~1,100 nm band. It receives light from an infrared transmitter and decodes the infrared signal. Together they form a complete infrared sensor for a variety of applications.

They typically generate infrared using LEDs, and the main component of a receiver unit is usually a photodiode. A remote control flashes a pattern of invisible light, which is picked up and then turned into an instruction by the receiver module. The infrared receiver receives the modulated infrared waves from the transmitter and changes it into output. After receiving the signals, the infrared receiver encodes and amplifies the signal into suitable transmission through low voltage wiring. The receiver and transmitter must be located in the same space as the process requires line-of sight transmission.

Infrared receivers are widely used in communication equipment, photographic equipment, automobile electronics, lighting, and other fields. It is also used in consumer electronics for remote control, in driverless vehicles for obstacle sensing, and military and aerospace monitoring and measurement systems. Apart from this, they are used in medical devices like in radiation thermometers and anesthesiology testing, night vision cameras, meteorology, flame monitors, gas detectors etc.

Figure 5: Infrared Receivers

Source: Maia Research, CareEdge Research

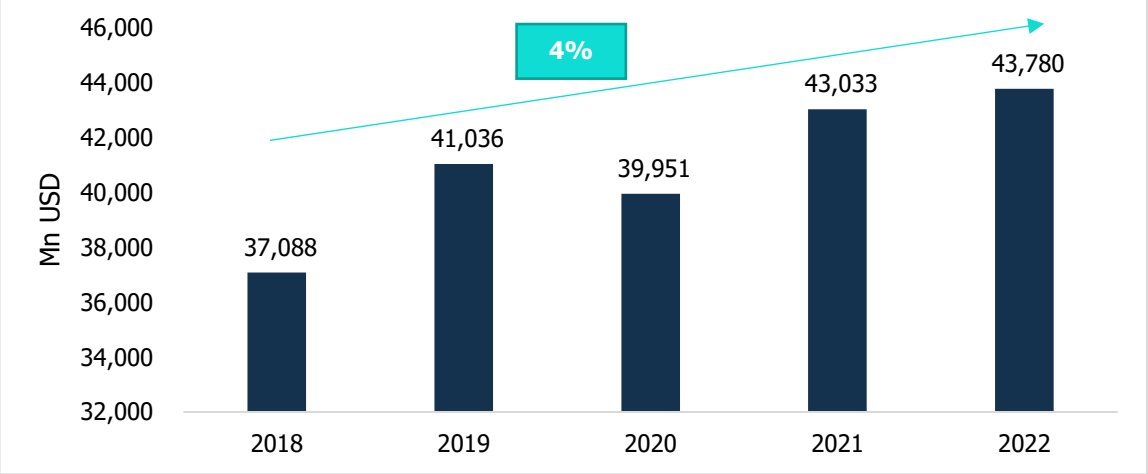
3. Global Opto-semiconductors Industry

Japan, Taiwan and Southeast Asia are the main producers of opto-semiconductors with Japan being the largest producer and China being the largest consumer of opto-semiconductors.

As China is the global manufacturing hub producing a wide range of auto parts and lighting products, it consumes the largest quantity of opto-semiconductors. Additionally, China is the world's largest market for consumer electronics, including smartphones, TVs and wearables. All these factors have resulted in China becoming the largest consumer of opto-semiconductors, with a strong domestic market and an important role in the global supply chain.

Japan, Taiwan, and South Korea are the main exporting countries, while China is the main importing country of opto-semiconductors in the world. The global opto-semiconductor market was estimated at USD 37,088 Mn in 2018 and has grown at a CAGR of 4% to USD 43,780 Mn in 2022.

Chart 11: Global Opto- Semiconductors Market Value

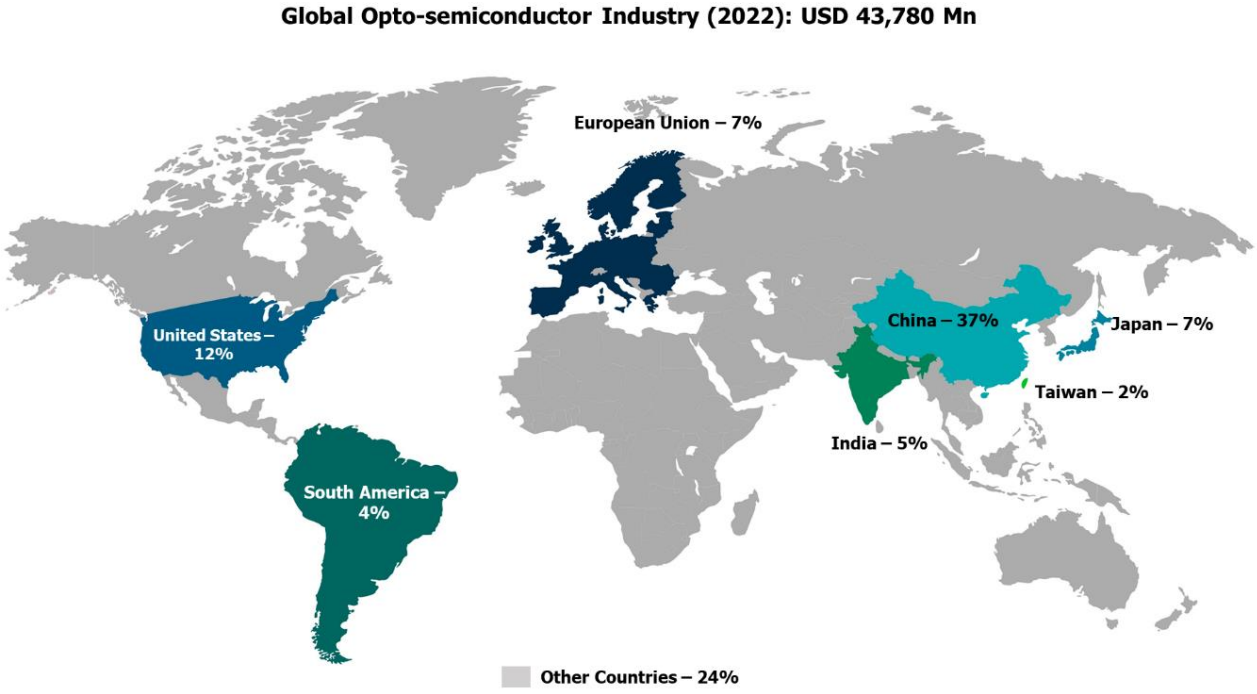


Source: Maia Research, CareEdge Research

3.1 Region-wise Consumption Market Size

China accounts for 37% of total global consumption of opto-semiconductors, followed by the U.S. which accounts for 12%, and by European Union and Japan, both accounting for 7%.

Chart 12: Opto- Semiconductors – Region-wise Market Share as on 2022

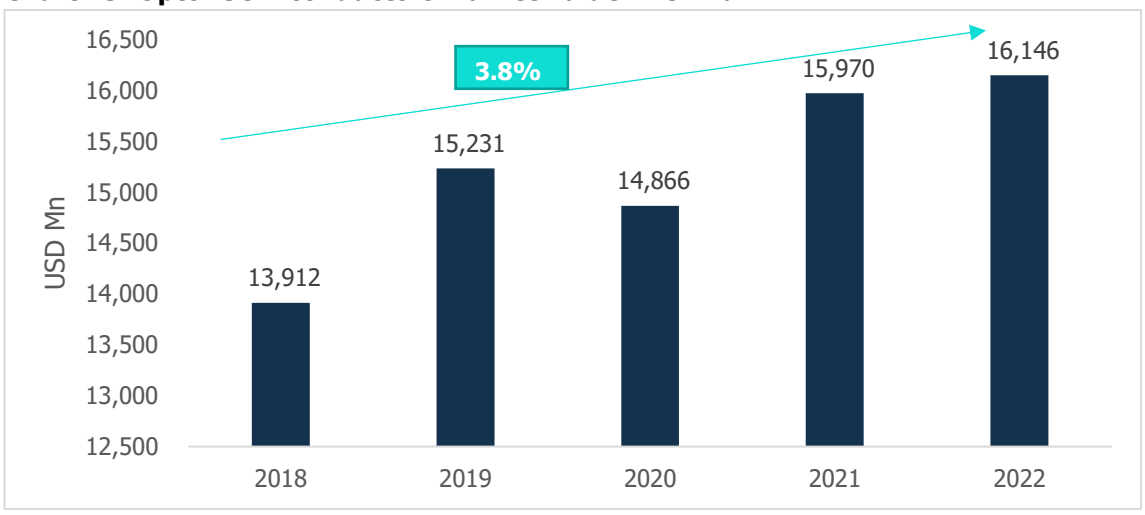


Source: Maia Research, CareEdge Research

i. China

The opto-semiconductor market in China was estimated at USD 13,912 Mn in 2018 and has grown at a CAGR of 3.8% to USD 16,164 Mn in 2022.

Chart 13: Opto- Semiconductors Market Value in China

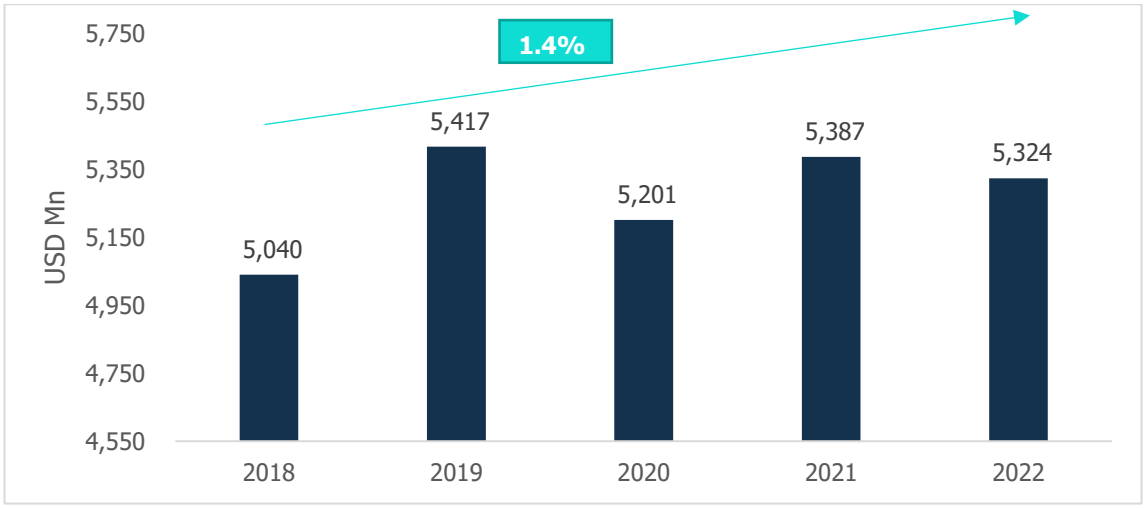


Source: Maia Research, CareEdge Research

The US

The opto-semiconductor market in U.S. was estimated at USD 5,040 Mn in 2018 and has grown at a CAGR of 1.4% to USD 5,324 Mn in 2022.

Chart 14: Opto- Semiconductors Market Value in USA



Source: Maia Research, CareEdge Research

The U.S. optoelectronic semiconductor market has been driven by growth in industries such as technology, telecommunications, automobiles, healthcare and consumer electronics.

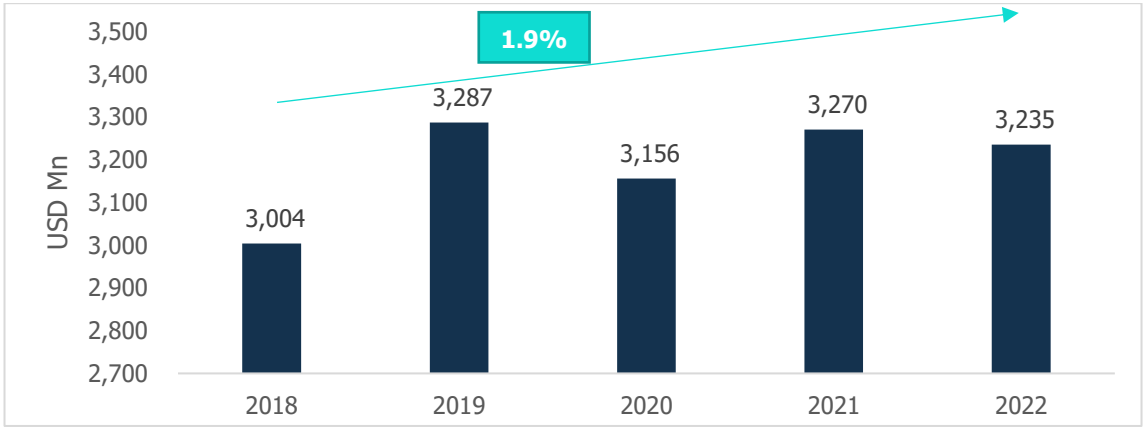
In the lighting segment, factors such as growing environmental concerns and energy efficiency are driving the demand for optical semiconductors in applications including LED lighting and renewable energy systems. Government policies and industry efforts being taken to reduce carbon emissions and improve energy efficiency are also aiding the market growth.

The U.S. also has a strong market for consumer electronics, including smartphones, televisions, wearables and smart home technology. Opto-semiconductors used in applications such as display panels; image sensors and lighting systems are important components of these devices. Growing consumer demand for advanced and innovative electronic products are some of driving factors for the opto-semiconductors market in U.S.

ii. European Union (EU)

The opto-semiconductor market in E.U. was estimated at USD 3,004 Mn in 2018 and has grown at a CAGR of 1.9% to USD 3,235 Mn in 2022.

Chart 15: Opto- Semiconductors Market Value in European Union



Source: Maia Research, CareEdge Research

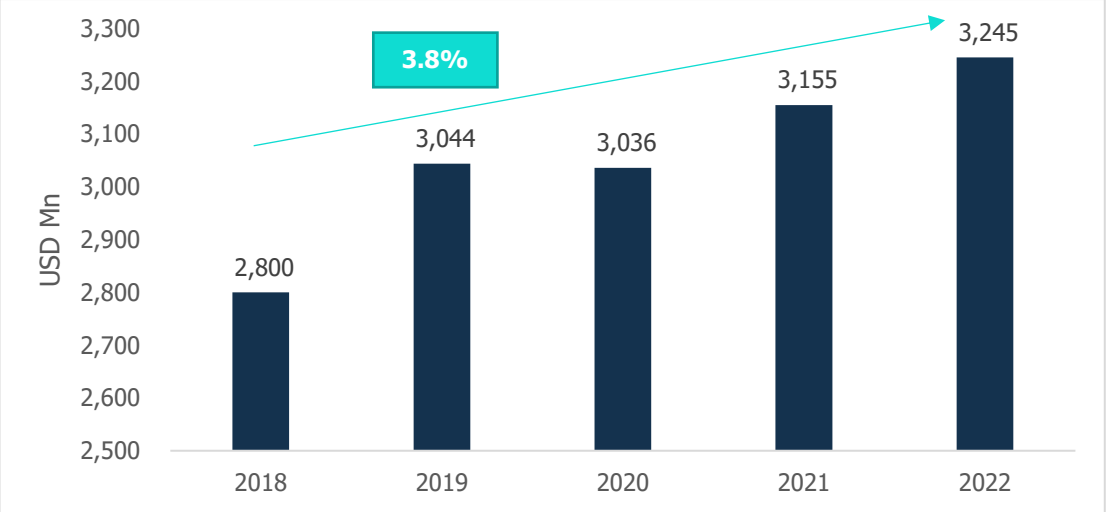
The E.U. optoelectronic semiconductor industry is driven by environmental and energy efficiency concerns. The EU attaches great importance to sustainability, energy efficiency and environmental protection. Opto-semiconductors, especially LED lighting solutions, offer energy-efficient alternatives to traditional lighting sources, driving demand in areas such as smart lighting, building automation and renewable energy systems.

The E.U. automotive industry is very focused on electric vehicles, advanced driver assistance systems (ADAS) and connected car technologies. Opto-semiconductors are an integral part of applications such as LED lighting, lidar sensors, image sensors and optical communications, driving demand in this segment.

iii. Japan

The opto-semiconductor market in Japan was estimated at USD 2,800 Mn in 2018 and has grown at a CAGR of 3.8% to USD 3,245 Mn in 2022.

Chart 16: Opto- Semiconductors Market Value in Japan



Source: Maia Research, CareEdge Research

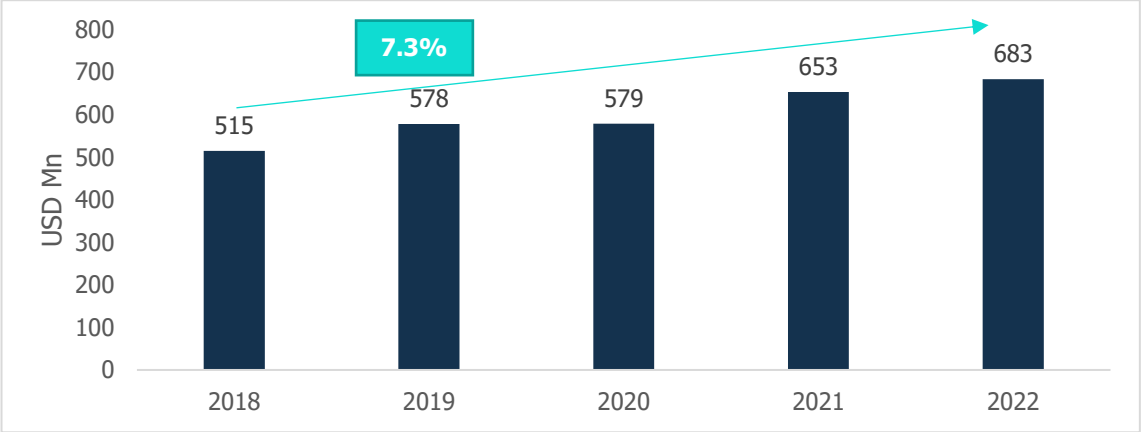
The Japanese opto-semiconductor industry is driven by manufacturing and exports. Japan is an important player in global manufacturing of opto-semiconductors, including LEDs, lasers and image sensors, and a wide variety of electronic devices, automotive applications and industrial equipment are produced in Japan. Demand is driven by both domestic consumption and export markets.

Japan is known for its automotive industry and the production of high-quality cars. Japan's focus on advanced safety features, electric vehicle and autonomous driving technologies is the driving factor for opto-semiconductors in automotive applications including lighting systems, sensors and communication components. In addition, Japan has a strong industrial sector that makes extensive use of opto-semiconductors in various applications such as factory automation, robotics, machine vision systems, and optical communications. Opto-semiconductors enable advanced sensing, imaging and data transmission functions in these industrial applications.

iv. Taiwan

The opto-semiconductor market in Taiwan was estimated at USD 515 Mn in 2018 and has grown at a CAGR of 7.3% to USD 683 Mn in 2022.

Chart 17: Opto- Semiconductors Market Value in Taiwan



Source: Maia Research, CareEdge Research

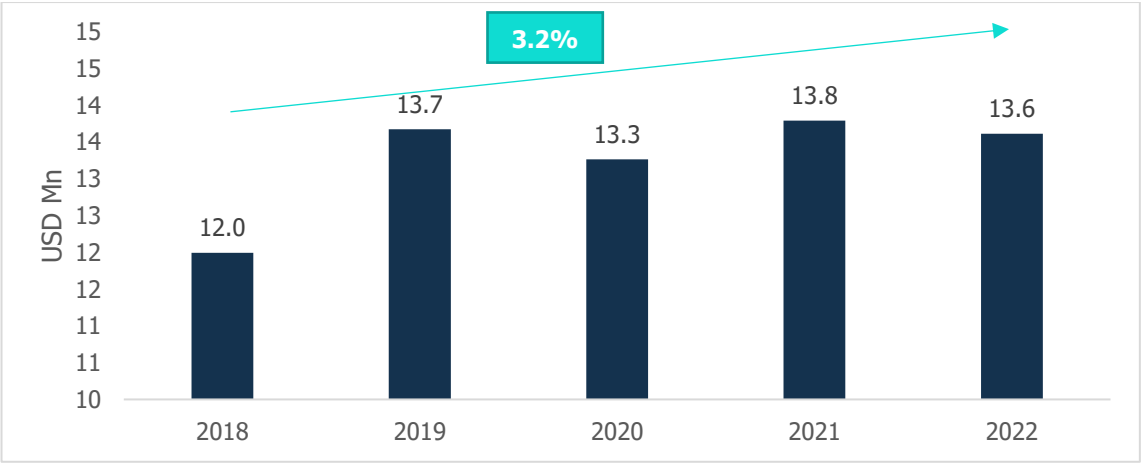
Taiwan is known for its expertise in opto-semiconductors. Demand drivers include strong manufacturing capabilities, an export-oriented economy, and the presence of leading semiconductor companies, which contribute to the demand for opto-semiconductors.

Taiwan has a strong manufacturing industry which includes LED lighting, display panels and optical communication components. Growth in opto-semiconductors market is driven by the production of these optoelectronic products, both for local downstream industry extension and for export to global markets. In addition, the consumer electronics industry is an important end user of Taiwan Opto-semiconductors. This market is driven by the production of smartphones, tablets, televisions and other electronic devices that require opto-semiconductors for display technology, sensors and lighting systems.

v. Finland

The opto-semiconductor market in Finland is currently small. It was estimated at USD 12 Mn in 2018 and has grown at a CAGR of 3.2% to USD 13.6 Mn in 2022.

Chart 18: Opto- Semiconductors Market Value in Finland



Source: Maia Research, CareEdge Research

Finland's demand for opto-semiconductors is mainly driven by the country's focus on developing advanced technologies in areas such as telecommunications, electronics, healthcare and industrial automation. Finland has a

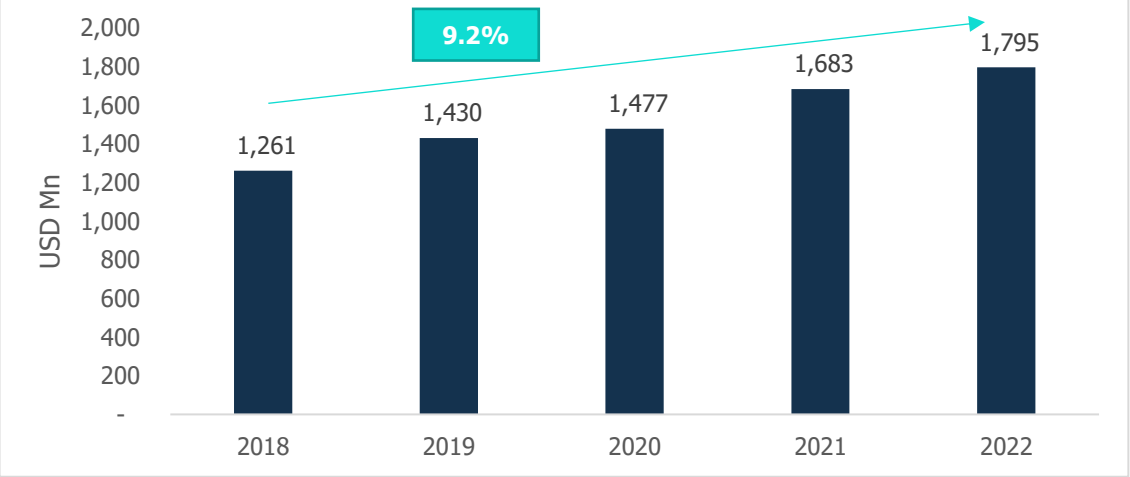
strong research and development culture, with active collaboration between academia, industry and research institutions.

In the lighting industry, Finland places great emphasis on sustainability and energy efficiency. Opto- semiconductors, especially LED lighting solutions, provide energy efficient alternatives to lighting and contribute to sustainable development. The demand for opto-semiconductors is also driven by the need for high speed communications, data transmission, networking equipment, and advanced electronics.

vi. South America

The opto-semiconductor market in South Africa was estimated at USD 1,261 Mn in 2018 and has grown at a CAGR of 9.2% to USD 1,795 Mn in 2022.

Chart 19: Opto- Semiconductors Market Value in South America



Source: Maia Research, CareEdge Research

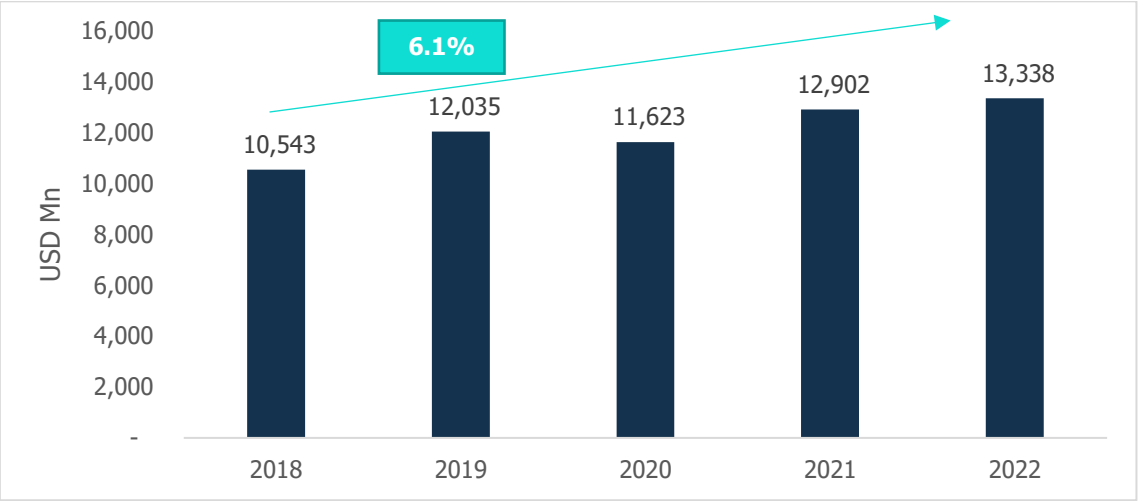
With the economic development of South America in recent years, the process of urbanization has accelerated leading to increase of disposable income and the expansion of middle-class population. As a result, consumer demand has surged for electronics, telecommunications, and automotive products, all of which rely on opto-semiconductors. Meanwhile, governments across South America are implementing policies and incentives to boost domestic manufacturing and attract investment in the semiconductor industry. These initiatives aim to strengthen the supply chain, encourage research and development, and create a favourable business environment for optoelectronic semiconductor manufacturers.

The automotive industry in South America has also been expanding, driven by factors such as increasing urbanization, rising disposable income, and government policies to promote electric vehicles. Additionally, the region is investing in infrastructure development, including expanding telecommunications networks and improving transportation systems. All these factors have been contributing to the growing opto-semiconductor market in the country.

vii. Other countries

The opto-semiconductor market in other countries was estimated at USD 10,543 Mn in 2018 and has grown at a CAGR of 6.1% to USD 13,338 Mn in 2022.

Chart 20: Opto- Semiconductors Market Value in other countries



Source: Maia Research, CareEdge Research

The most important market for opto-semiconductors among other countries is China. China has a huge domestic market from lighting, consumer electronics and automotive industries. The local optoelectronic semiconductor industry is well positioned to meet this demand and benefit from rising consumer spending. The Chinese government also provides strong support to the semiconductor industry through various policies, incentives and funding programs. These initiatives are aimed at boosting domestic manufacturing, improving technological capabilities and reducing reliance on imports.

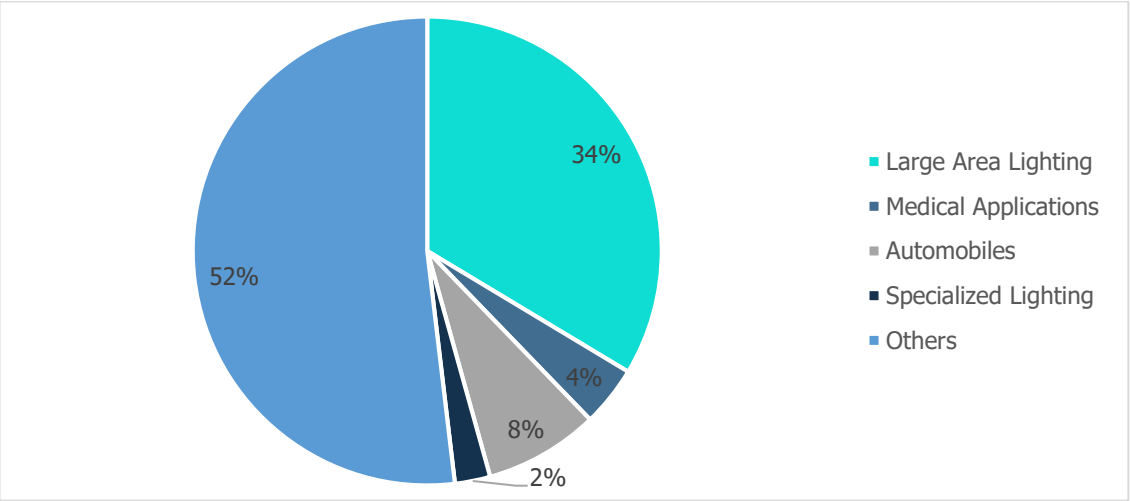
Apart from China, India, Middle East, Africa and Indonesia are among the growing markets for opto-semiconductors. The demand in these regions are driven by improving network infrastructure, rising consumption in consumer electronics goods etc.

3.2 Global Opto-semiconductor Market by Application

The global market for opto-semiconductor is majorly driven by applications which includes large area lighting, medical uses, automation of automobiles and specialized light like photosynthesis, aqua lightings, sanitization etc.

Large area lighting accounts for 34% of the total market followed by automobiles. The other applications which consists of more than 50% of the total market are consumer segment products like mobile phone, sensors, cameras, solar cells etc.

Chart 21: Global Opto- Semiconductors application market shares as on 2022

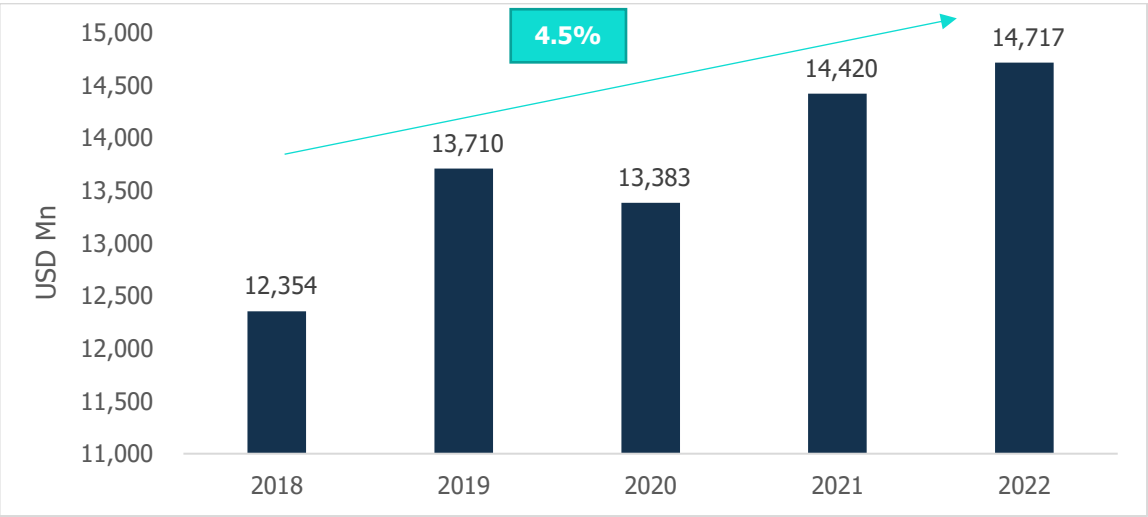


Source: Maia Research, CareEdge Research

i. Large Area Lighting

The global market size of opto-semiconductors used in large area lighting stood at USD 14,717 Mn in 2022, up from USD 12,354 Mn in 2018, implying a CAGR of 4.5%.

Chart 22: Global Opto-semiconductor Market - Large Area Lighting



Source: Maia Research, CareEdge Research

Opto-semiconductors are extensively used in large area lighting applications, such as street lighting, stadiums, industrial lighting and architectural lighting. LEDs and other opto-semiconductor devices offer energy-efficient and long-lasting lighting solutions for these applications.

Large area lighting requires cost reduction, sustainability and improved performance and use LEDs abundantly. Some large occupancy areas also have occupancy sensing lightings to save energy. LED lighting sensors are used in warehouses, where they help optimize the space and improve workflows. Intelligent light fixtures with the light sensing functionality can increase productivity by tracking the movements of goods and workers through the warehouse space and generating data for real-time optimizations. Motion sensing LED lights are also becoming popular in street lights and office buildings to reduce energy consumptions.

The market potential of opto-semiconductors for large area lighting in the Asia Pacific region is more as these are developing countries. Rapid urbanization, infrastructure development and need to upgrade outdated lighting systems

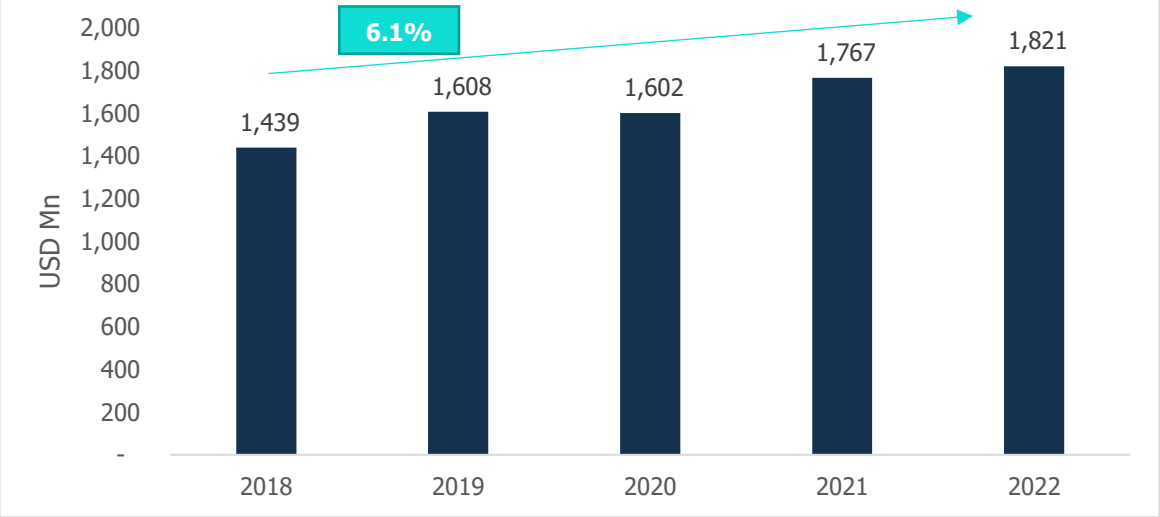
are the major demand drivers. Government initiatives to improve energy efficiency and cost savings are further boosting the adoption of optoelectronic semiconductor-based lighting solutions in this region.

The market for opto-semiconductors in large area lighting is stable in United States and EU. Developed countries place great emphasis on energy efficiency and reducing carbon emissions. Strict regulations and incentives to promote the use of energy efficient lighting have resulted in a huge demand for large area lighting solutions, including LED lighting, in commercial and industrial applications, and public infrastructure projects. In addition, the increasing adoption of smart city technologies and outdoor lighting control systems is also driving the demand for advanced large area lighting solutions in these regions.

ii. Medical Applications

The global market size of opto-semiconductor used in medical applications stood at USD 1,821 Mn in 2022, up from USD 1,439 Mn in 2018, implying a CAGR of 6.1%.

Chart 23: Global Opto-semiconductor market value in Medical Applications



Source: Maia Research, CareEdge Research

Opto-semiconductors play a crucial role in various medical applications, including medical imaging, surgical instruments, phototherapy and diagnostics. A large number of optical devices which use opto-semiconductors and sensors are used in imaging. Among these, optical coherence tomography (OCT), confocal microscopy (CM), and photoacoustic (PA) imaging, endoscopy and laparoscopy are the predominant one. In medical imaging, opto-semiconductors such as laser diodes are used in devices like laser scanners etc. LED-based light sources are also used in phototherapy for treating skin conditions.

Opto-semiconductor laser light sources have many advantages over other light sources for a variety of medical applications. These light sources of a given wavelength are chosen for a given application because of their ability to emit light to interact with the tissue so as to achieve the desired effect. This process is known as selective photothermolysis. Emphasis is on conversion efficiency, temperature sensitivity, and cost rather than beam quality and brightness, which tend to be the driving factors for opto-semiconductor light sources in medical industry. The power supply needed to generate the optical energy is significantly less, and the required cooling system is smaller because there is less waste heat. Opto-semiconductor lasers can also be used to produce a variety of monochromatic wavelengths and generate significant optical power in a small, compact footprint. Other medical applications of opto-semiconductors include pulse oximetry, heart-rate monitors, blood diagnostics like blood glucose monitoring, urine analysis and dental color matching.

In United States, a large healthcare industry coupled with substantial investments in R&D drive the demand for opto-semiconductors in medical applications. High quality healthcare standards and presence of leading medical equipment manufacturers also add to the demand.

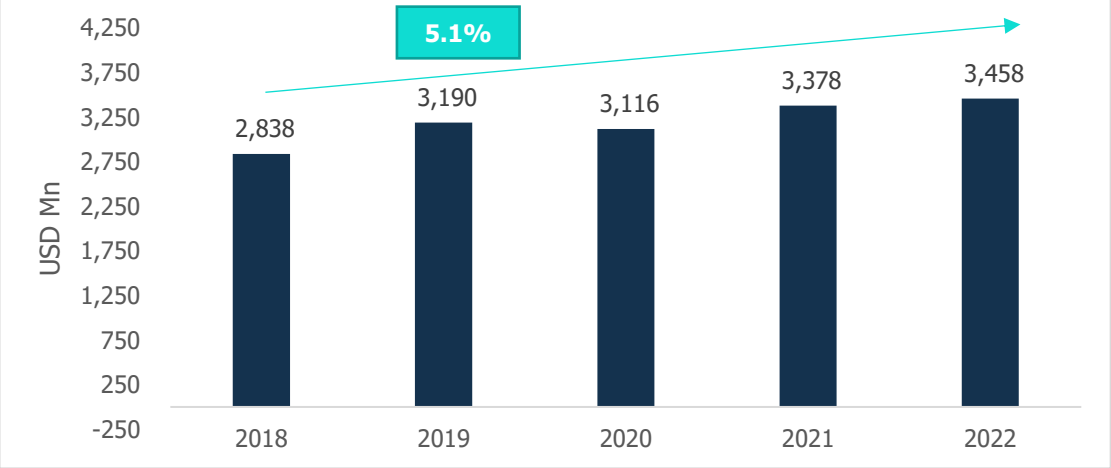
In EU, medical needs are on the rise as the population ages. A strong medical infrastructure, emphasis on innovation and collaboration between academia and industry drive the adoption of opto- semiconductor technologies for medical applications. Regulatory frameworks that promote patient safety and healthcare efficiency also aid the demand.

In Asia Pacific, the rapid growth of the healthcare market in developing countries, rising disposable income and increasing focus on healthcare infrastructure have increased the demand for optical semiconductors in medical applications. The well-established expansion of healthcare infrastructure in emerging countries such as China and India have further boosted the market. In addition, countries such as Japan and South Korea occupy an important position in the field of medical device manufacturing. Rising aging population, increasing healthcare spending, and advancements in medical imaging and diagnostics also add to the demand for optical semiconductors for medical applications in the region.

iii. Automobiles

The global market size of opto-semiconductor used in medical appliances stood at USD 3,458 Mn in 2022, up from USD 2,838 Mn in 2018, implying a CAGR of 5.1%.

Chart 24: Global Opto-semiconductor market value in Automobiles



Source: Maia Research, CareEdge Research

Opto-semiconductors are widely utilized in the automotive industry for various lighting applications. LED technology is extensively used in automotive lighting systems, including headlights, taillights, turn signals and interior lighting. Opto-semiconductors provide energy efficiency, improved visibility, and design flexibility for automotive lighting solutions. Opto-semiconductors also play a vital role in sensors and communication technologies.

The United States has a well-established auto industry that focuses on advanced technology and safety features. The integration of LED lighting systems, LiDAR sensors and other optical components in vehicles is driving demand for opto-semiconductors in vehicles to improve safety, driver assistance systems and support autonomous driving initiatives.

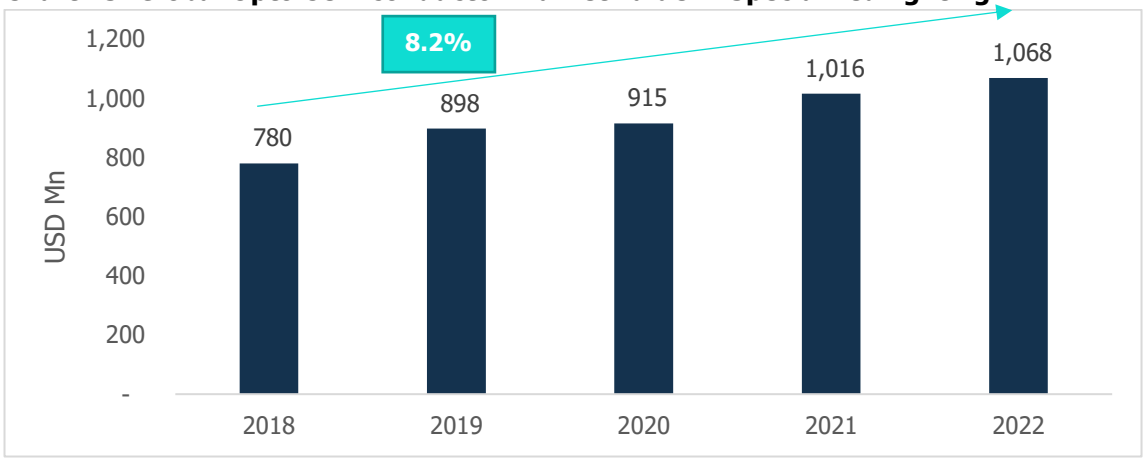
The European automotive industry is known for its emphasis on safety, sustainability and innovation. Automotive demand for opto-semiconductors is driven by the integration of advanced lighting technologies, optical sensors and imaging systems to meet safety standards, improve energy efficiency and support autonomous driving functions.

The Asia-Pacific region is the largest automotive market in the world, in which countries such as China, Japan and South Korea play an important role. India has also registered a big growth in the segment in FY23. The rapid growth of the automotive industry, increasing adoption of EVs and the implementation of stringent safety regulations drive the demand for opto-semiconductors in this region. Government initiatives to promote the adoption of electric vehicles and the development of intelligent transportation systems are further aiding market growth.

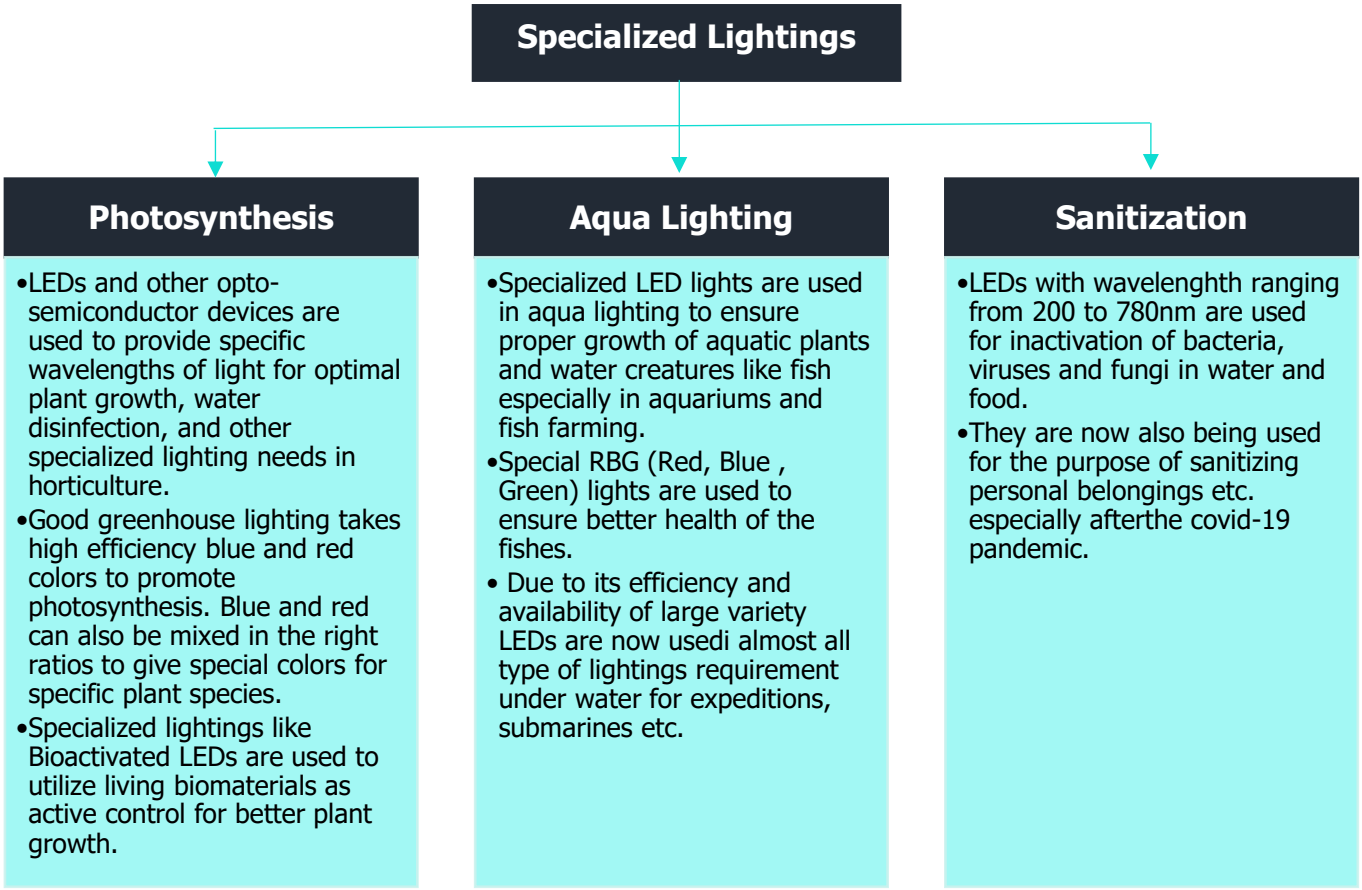
iv. Specialized lighting for photo synthesis, aqua lighting, sanitization etc.

The global market size of opto-semiconductor used in specialized lighting applications stood at USD 1,068 Mn in 2022, up from USD 780 Mn in 2018, implying a CAGR of 8.2%.

Chart 25: Global Opto-semiconductor market value in Specialized lighting



Source: Maia Research, CareEdge Research



In the United States, the field of greenhouse and indoor farming occupies a significant position. The demand for photosynthesis-specific lighting is driven by the adoption of advanced horticultural lighting solutions that enable year-round crop production, improve crop quality and maximize yield in a controlled environment.

In Europe, there is growing focus on sustainable agricultural practices and food security. The need to optimize crop growth in greenhouse agriculture, vertical farming and other controlled-environment farming systems drives the need for photosynthesis-specific lighting, thereby reducing reliance on traditional seasonal farming.

The Asia-Pacific region, especially countries such as China and Japan, places a lot of emphasis on high-tech agriculture and vertical farming. The need to address food security challenges, optimize resource use and improve crop quality and productivity within limited land areas drives the need for photosynthesis-specific lighting.

v. Others applications

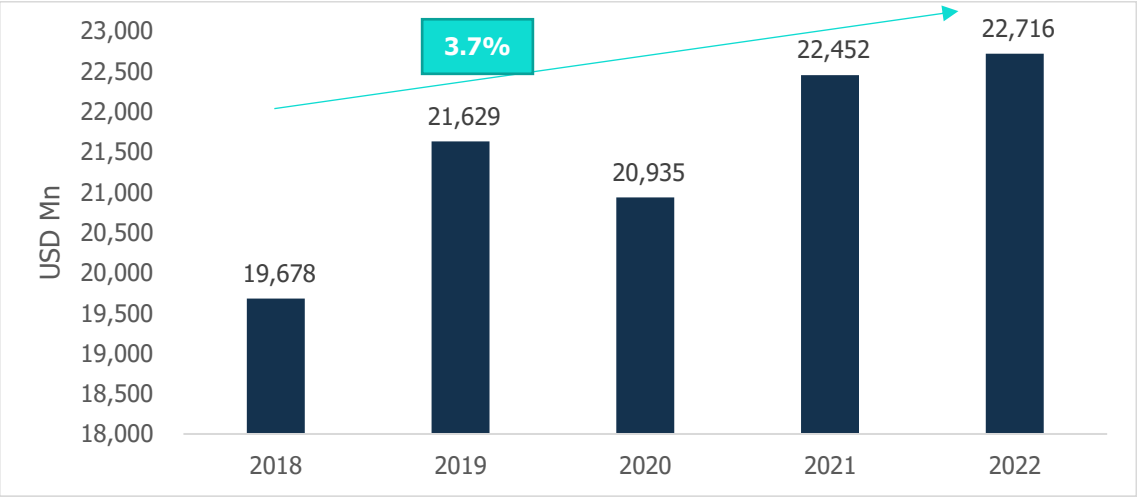
Opto-semiconductors have diverse applications beyond the mentioned categories. They are used in consumer electronics, communication systems, optical data transmission, optical sensing, display technology, smartphones, photovoltaic devices, wireless communications, aerospace, architectural lightings, data and computing centres and many other industries and applications.

Nowadays, a growing number of premium smartphone manufacturers are turning to iris recognition as biometric identification method, which is much more accurate and reliable than fingerprint recognition. When a user wants to unlock the device, he must have his iris irradiated by an infrared LED light and then shot by a camera in the front of the device. The phone's iris recognition system will check the iris image against the one stored in the system. If the two images are identical, the device will be unlocked for the user. In smartphone applications, iris recognition technology uses the phone's front-facing camera rather than a separate sensor to capture the user's iris image

Devices like optical repeaters and fibre optics which are use opto-semiconductors as their key building blocks are massively used in military and aerospace. They are used to transmit over-air radio frequency that is usually cannot reach their intended receivers due to many obstacles like confined spaces, tunnels etc.

The global market size of opto-semiconductor used in other applications stood at USD 22,716 Mn in 2022, up from USD 19,678 Mn in 2018, implying a CAGR OF 3.7%.

Chart 26: Global Opto-semiconductor market value in other applications

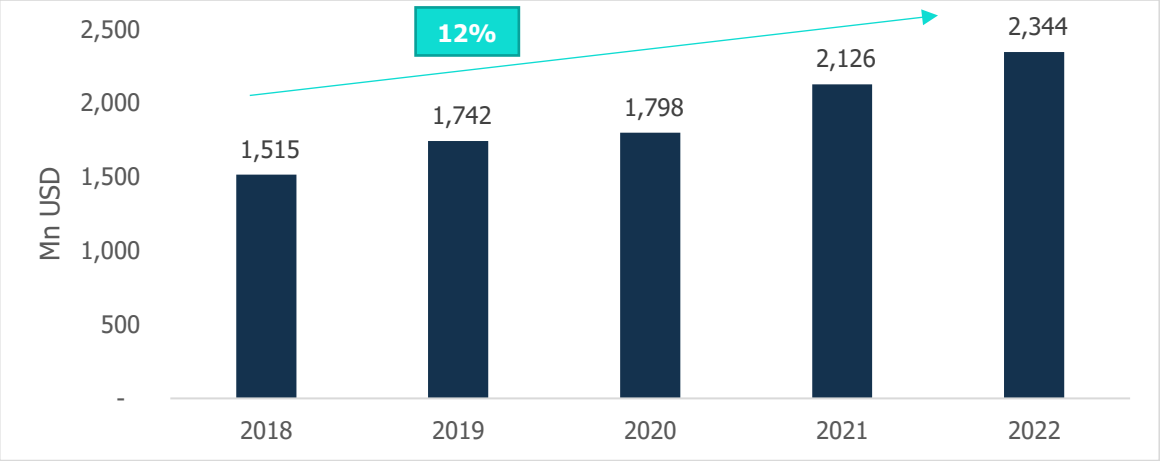


Source: Maia Research, CareEdge Research

4. Indian Opto-semiconductors Industry

The Indian opto-semiconductor market was estimated at USD 1,515 Mn in 2018 and has grown at a CAGR of 12% to USD 2,344 Mn in 2022.

Chart 27: India Opto- Semiconductors Market Value



Source: Maia Research, CareEdge Research

The Indian economy has high reliance on semiconductors because semiconductor-based sectors are in high demand. The Electronic Systems Design and Manufacturing (ESDM) sector in India is rapidly increasing. The Indian government is prioritizing the development of the ESDM ecosystem in India and is offering a variety of incentives and subsidies to companies looking to establish electronics manufacturing plants in India.

The industrial sector contributes significantly to India's economy and many enterprises in this area rely heavily on opto-semiconductor chips. India needs to lower its reliance on foreign supply and expand its production of opto-semiconductor chips. With the implementation of production-related programmes and other incentives for semiconductor makers, the Indian government has taken the right steps in this regard.

Mobile & wearable devices, information technology, industrial, consumer electronics, telecom, automotive etc. are the key consumers of opto-semiconductor in India.

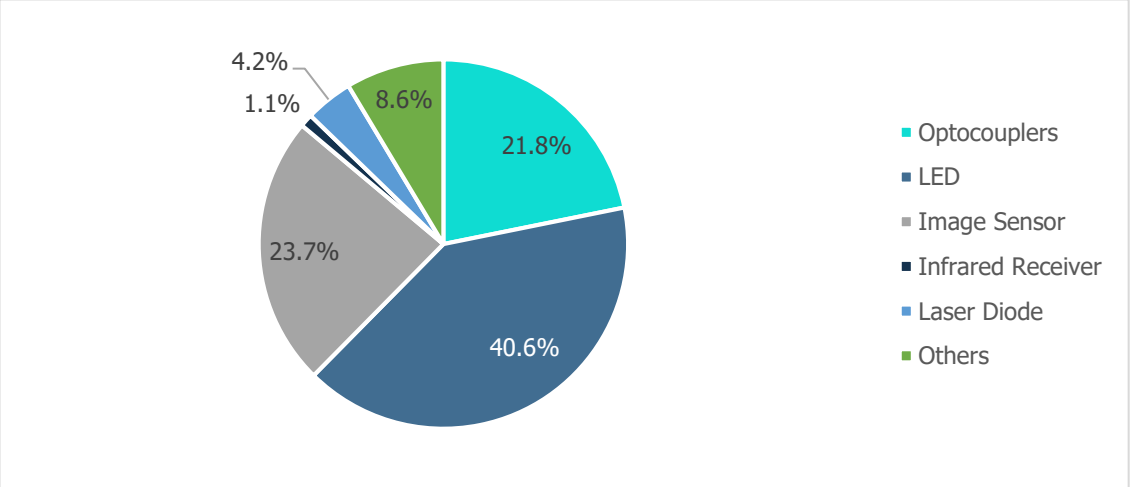
Currently, India is nearly entirely reliant on imports for its opto-semiconductors requirement. India imports opto-semiconductors mainly from China, Singapore, Japan, Germany, South Korea, Thailand, the United States, Malaysia, Vietnam and France.

Because of its high cost, high risk, time-consuming nature, and rapid technological progress, opto-semiconductor manufacturing is a highly complicated and technologically advanced sector that necessitates significant upfront and ongoing investment. Furthermore, the major materials used in the production of semiconductors include silicon, germanium, and gallium arsenide, which are not abundantly available in India.

4.1 Indian Opto-semiconductor Industry by Product

LEDs constitute 40.6% of the total opto-conductors market in India followed by image sensor opto-semiconductors. LEDs are replacing all the traditional plasma lighting as it is more efficient both in terms of life and cost. Image sensors are used in medical applications and mobile phones.

Chart 28: India Opto- Semiconductors Market share product-wise as on 2022



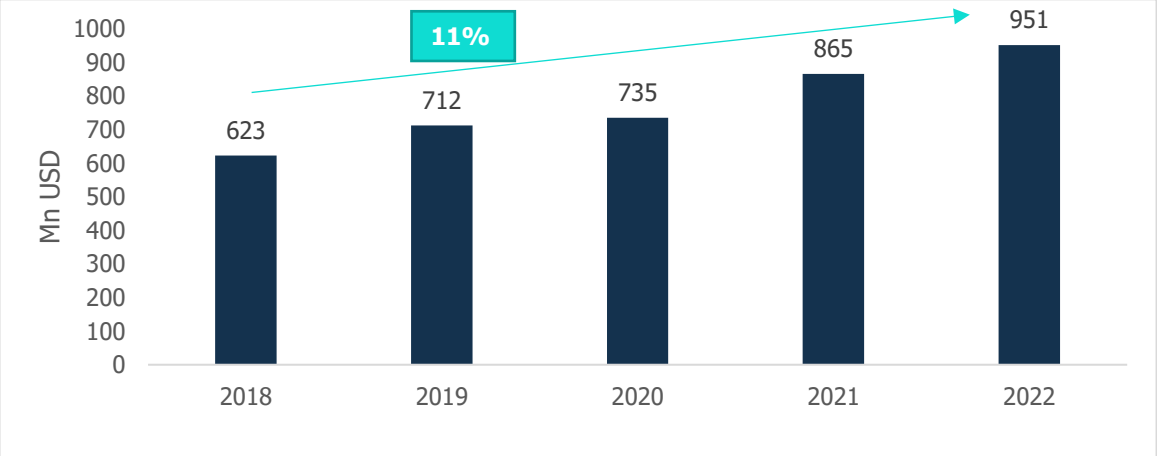
Source: Maia Research, CareEdge Research

i. LED

The LED lighting market in India has a lot of potential to grow. In recent years, with the increasing attention of the Indian government and people to energy conservation and emission reduction, traditional incandescent lamps have been gradually eliminated by the market, and the LED lighting industry has a strong development momentum.

The Indian LED market has grown from USD 623 Mn in 2018 to USD 951 Mn in 2022, implying a CAGR of 11%. This growth has been driven by growth in the end user industries, increase in replacement of incandescent lamps with LED lights, etc. LEDs form the largest subsegment of opto-semiconductors and their contribution has continued to remain around 41% in 2018 to 2022.

Chart 29: India LED Market Value



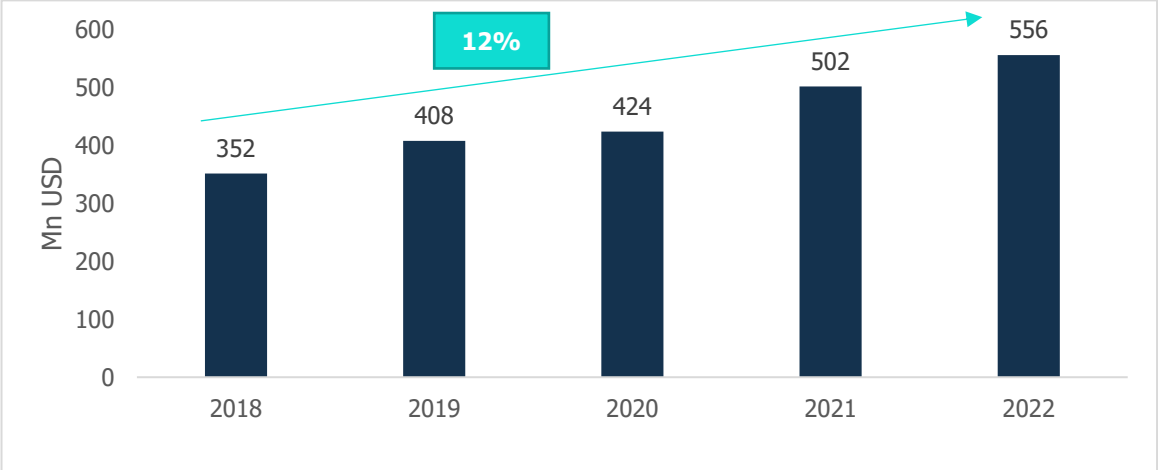
Source: Maia Research, CareEdge Research

ii. Image Sensor

The Indian image sensor market has grown from USD 352 Mn in 2018 to USD 556 Mn in 2022, implying a CAGR of 12%. This growth has been driven by demand of high-performance camera, artificial intelligence devices,

smartphones, increase in mobile payment applications etc. Image sensors form the second largest subsegment of opto-semiconductors and their contribution has increased from 23.2% in 2018 to 23.7% in 2022.

Chart 30: India Image-sensor Market Value

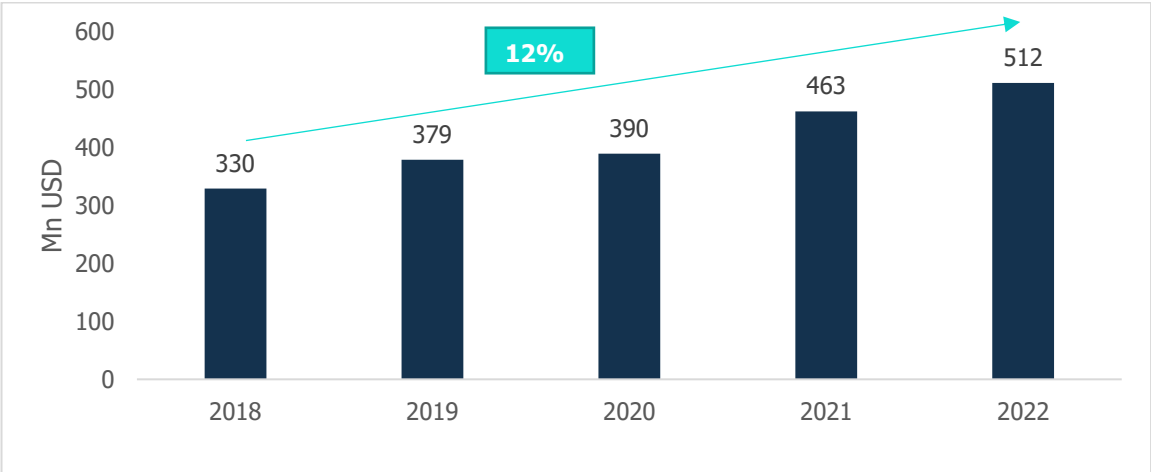


Source: Maia Research, CareEdge Research

iii. Optocouplers

The Indian optocoupler market has grown from USD 330 Mn in 2018 to USD 512 Mn in 2022, implying a CAGR of 12%. This growth has been driven by demand and popularity of advance technology driven products in all the segment. Opto-couplers accounted for 21.8% of the opto-semiconductor industry in 2022 compared 21.7% in 2018.

Chart 31: India Opto-coupler Market Value

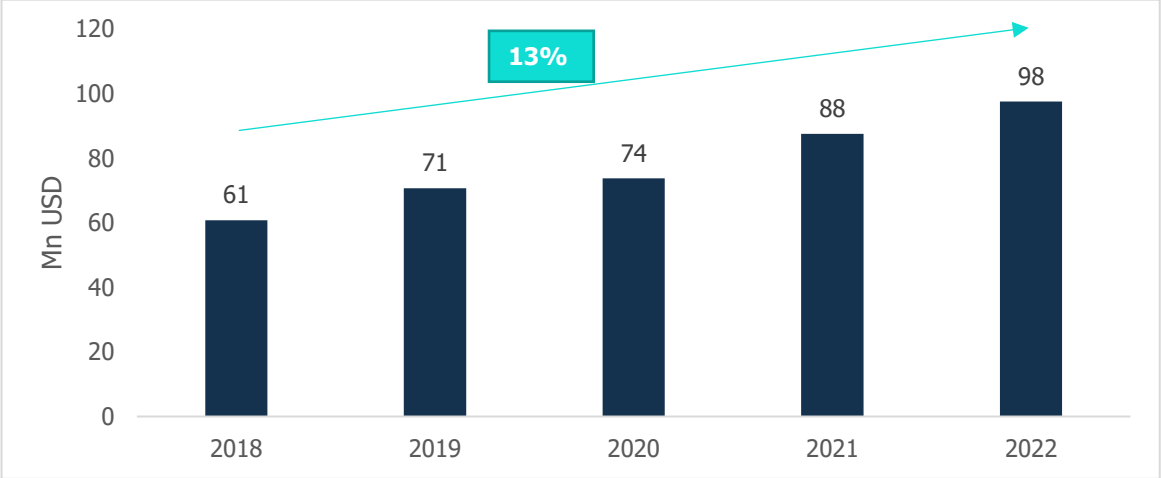


Source: Maia Research, CareEdge Research

iv. Laser Diode

The Indian laser diode market has grown from USD 61 Mn in 2018 to USD 98 Mn in 2022, implying a CAGR of 13%. Laser diodes accounted for 4.2% of the opto-semiconductor industry in 2022 compared to 4% in 2018.

Chart 32: India Laser Diode Market Value

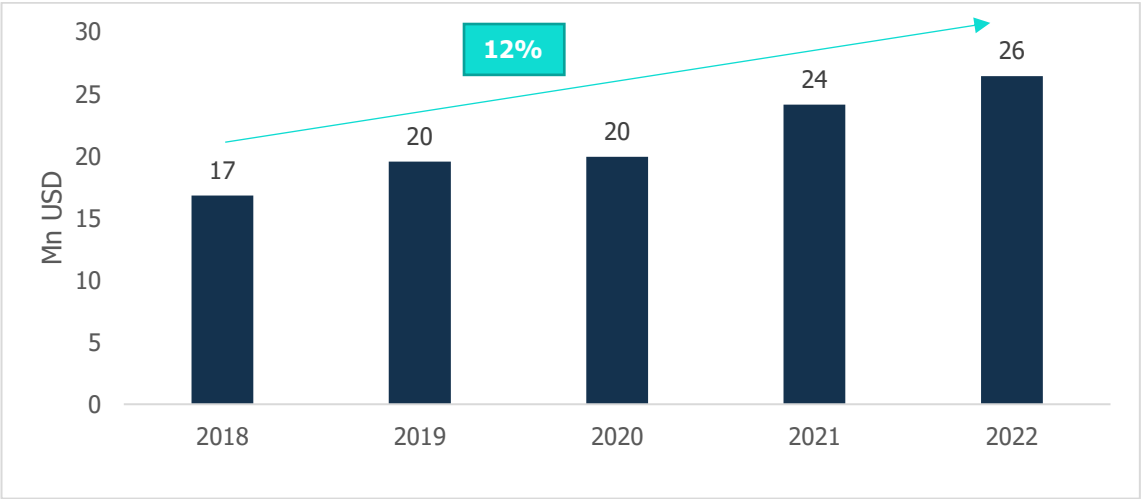


Source: Maia Research, CareEdge Research

v. Infrared Receiver

The Indian infrared receiver market has grown from USD 17 Mn in 2018 to USD 26 Mn in 2022, implying a CAGR of 12%. Infrared receivers are accounted for 1.1% of the Indian opto-semiconductor industry in 2018 and 2022.

Chart 33: India Infrared Receiver Market Value

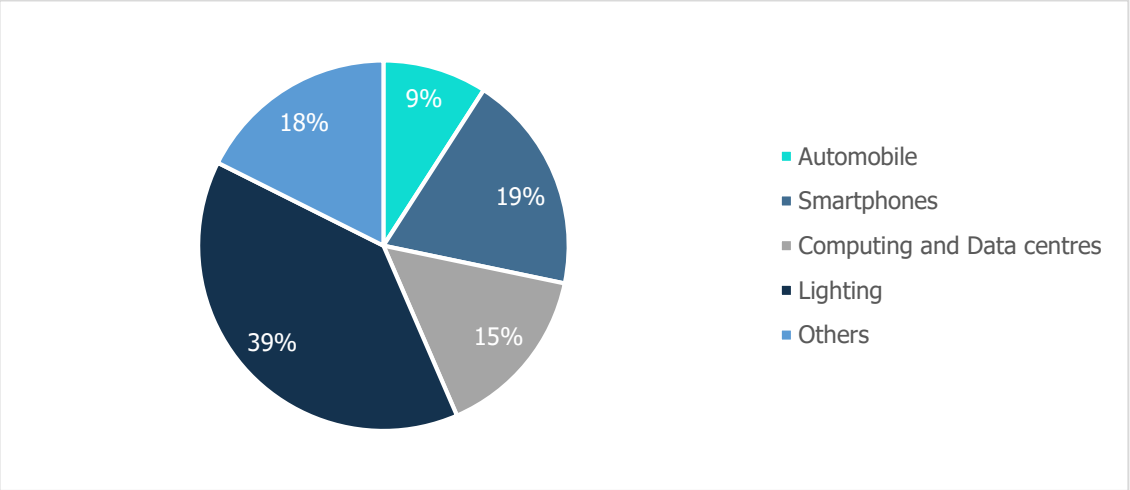


Source: Maia Research, CareEdge Research

4.2 Indian Opto-semiconductors Industry by Application

The opto-semiconductor industry in India has witnessed significant growth driven by various end-user segments such as automotive, smartphones, computing and data centers, and lighting. Opto-semiconductor is used in various other industries as well such as smartphones, automobile, computing and data centre and lighting.

Chart 34: India Opto- Semiconductors End-user Industries market share as on 2022



Source: Maia Research, CareEdge Research

The lighting industry is the key driver of the opto-semiconductor market in India. It accounts for about 39% of the total market share followed by smartphones.

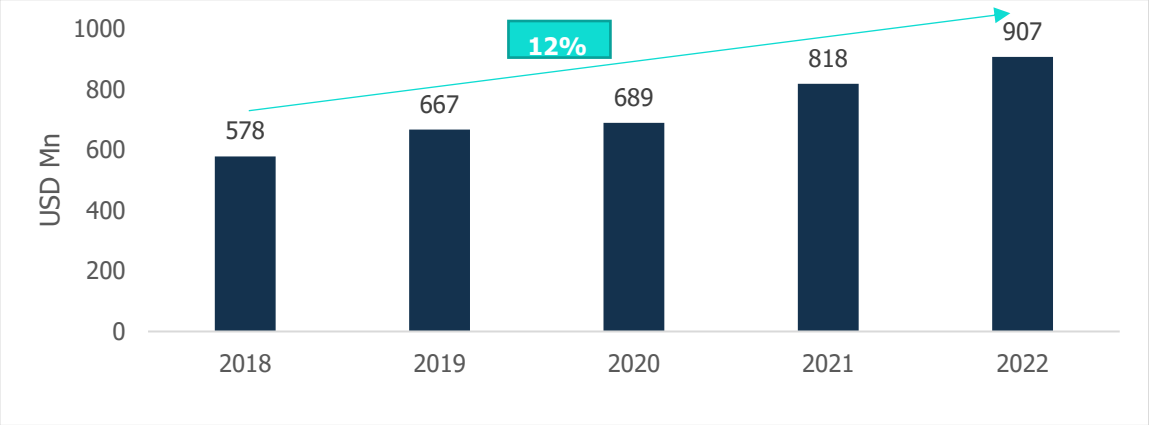
i. Lighting

India's lighting industry is shifting towards energy-efficient lighting solutions with an emphasis on LED technology. LED semiconductor light-emitting technology has gradually replaced the original incandescent lamp and gas discharge light source. LED technology has higher energy efficiency, lower cost, is more durable and is gaining popularity in the lighting industry scene. LED has both performance and pricing advantages. LED has diverse demands from home, commercial and professional lighting. LED is a lighting solution of choice as it is stable, continuous, efficient, changeable, flexible and portable. It has a lifespan of over 50,000 hours. LED lighting is more cost-effective and the overall cost of use is lower.

Government initiatives such as the UJALA program (Unnat Jyoti by Affordable LEDs for All) and the National Street Lighting Program (SLNP) have led to the widespread adoption of LED lighting in residential, commercial and street lighting applications.

Opto-semiconductor are most widely used in the lighting industry and this industry accounted for about 38% of the total opto-semiconductor market in India in 2022. The market size of opto-semiconductors used in the lighting industry stood at USD 907 Mn in 2022, up from USD 578 Mn in 2018, implying a CAGR of 12%.

Chart 35: Opto-semiconductor market value in Lighting Industry



Source: Maia Research, CareEdge Research

ii. Smartphones

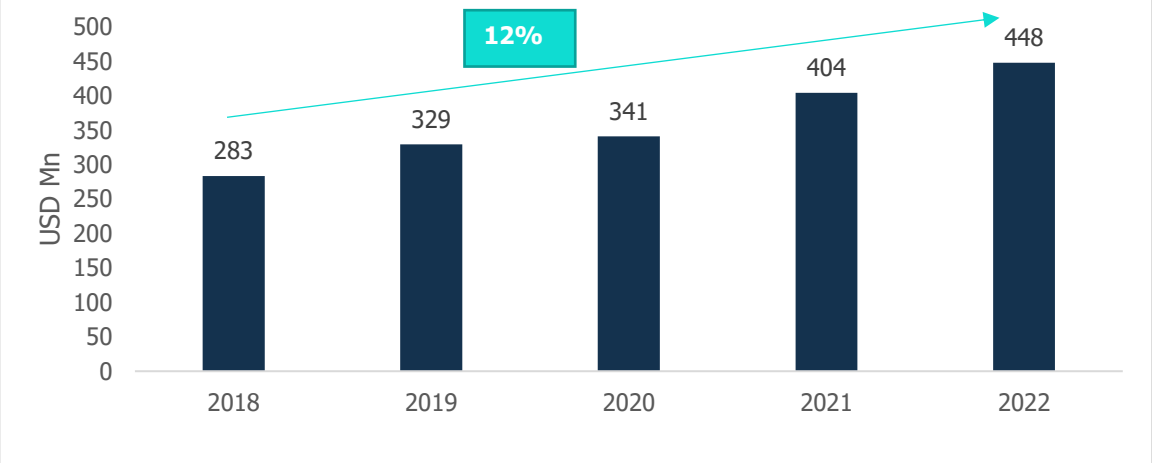
Smartphones use several opto-semiconductor technologies. Small packages, low power consumption, high integration, and ease of use are driving designers to increasingly adopt opto-semiconductors for consumer electronic devices. Among them, the common smartphone is a major application of opto-semiconductors. The application of opto- semiconductors in smartphones is mainly in two aspects of optics and sensing.

In recent years, camera has always been the focus area for mobile phone manufacturers and mobile phone manufacturers are constantly innovating and upgrading lens modules by upgrading the opto-semiconductor used. While the number of rear cameras continue to increase, the front cameras are also advancing.

In addition, most smartphones have a light sensor function - in a bright place, the brightness of the mobile phone screen will automatically increase and in a place with weak light, the screen will be automatically brightened. The photosensitive function of smartphones brings a lot of convenience to consumers in using mobile phones. It not only saves the battery consumption of mobile phones, but also facilitates consumers to use mobile phones under various light conditions and also protects the eyes.

Smartphones are the second highest contributor to the opto-semiconductor market in India with a share of 19.1% of the total market. The market size of opto-semiconductors used in domestic smartphones has increased from USD 283 Mn in 2018 to USD 448 Mn in 2022, implying a CAGR of 12%. The steady demand for smartphones and continuous demand for better camera performance are the driving factor for the opto-semiconductor market in this segment.

Chart 36: Market Size - Opto-semiconductors used in Smartphones Industry



Source: Maia Research, CareEdge Research

iii. Computing and Data Centres

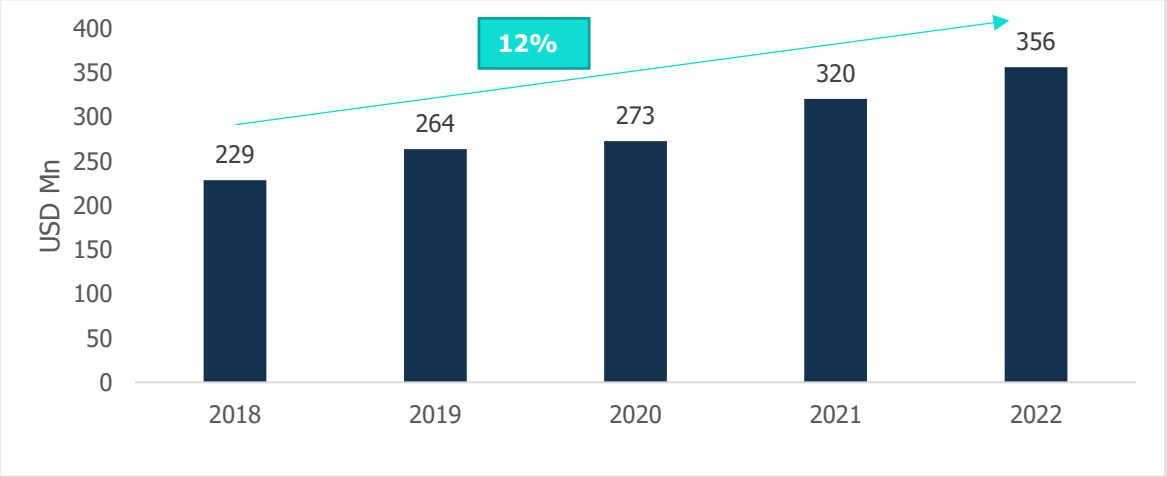
A data centre is a physical building complex that houses servers, switches, central processing units (CPUs), routers, cooling mechanism, high speed cables etc. for remote storage of data and computing. The servers are networked together in the data centre. The data centre may be part of private or public cloud and are fundamental to cloud system. A user can access these data centres through internet connections or network connections.

Data centres requires different types of semiconductors chips for different purposes. They are used for the purpose of processing, security, handling workloads, adapting to the current trend, storage, efficiency etc. The rapid development and wide application of cloud computing and big data have placed high demand on data centre networks and optical interconnection technologies. Opto-semiconductors are critical for optical interconnection within the data centre ecosystem.

With the intensification of digital transformation and vigorous development of cloud computing and artificial intelligence applications, upgrade of optical interconnection in data centres is underway. Silicon photonics technology (combination of semiconductor technology and optical technology) has become a recognized main direction to continue Moore's Law [3] and solve traffic problems through its advantages in power consumption, cost, structure, integration and other aspects. At present, silicon photonics integration technology is still in the early stage of development. Photonic chips need to be integrated with mature electronic chip technology, using advanced manufacturing technology and modular technology of electronic chips.

Computing and data centres accounted for 15% of the opto-semiconductors consumption in India in 2022. The market size of opto-semiconductors used in this segment stood at USD 356 Mn in 2022, up from USD 229 Mn in 2018, implying a CAGR of 12%.

Chart 37: Market Size - Opto-semiconductors used in Computing and Data Centre Industry



Source: Maia Research, CareEdge Research

The demand for high-performance computing and data storage continues to increase with effective data transfer. Optoelectronic components, such as optocouplers, enable high-speed, reliable data communication, making them critical for data centres and computing infrastructure.

[3] Moore's Law states that the number of transistors on a microchip doubles every two years. The law claims that we can expect the speed and capability of our computers to increase every two years because of this, yet we will pay less for them.

iv. Automobiles

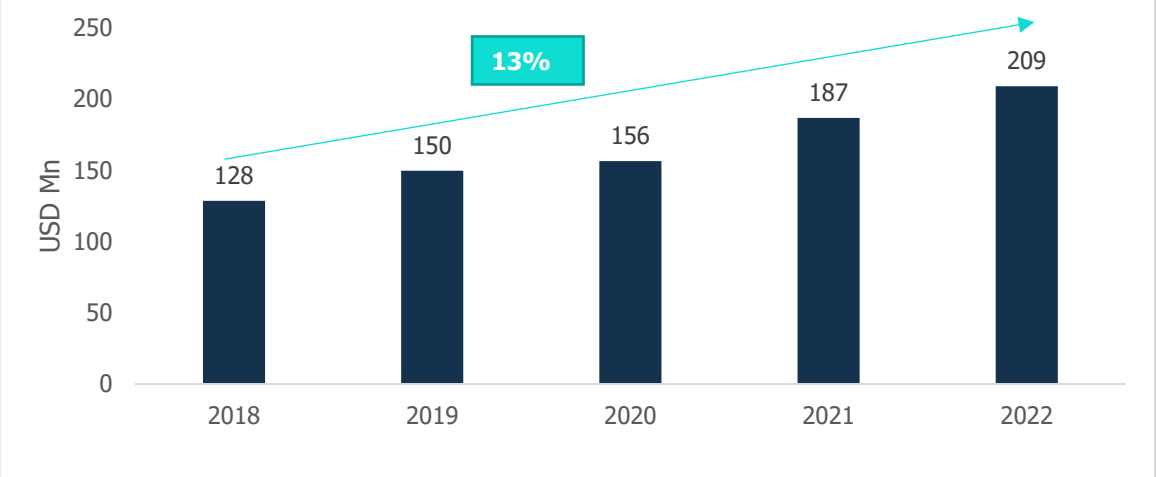
With the continuous rise in demand for automobiles and the rapid development of the automobile industry, the automobile ancillary industry has also witnessed good development opportunities. Among them, LED, as an emerging technology in automotive lighting, has received great attention from many companies. LEDs reflect road signs better than xenon, and high intensity discharge (HID) lights. In vehicles, LEDs can be used in lighting, security, convenience, and climate applications. In addition, LED products have outstanding advantages in volume, light source efficiency, price and cost, stable performance, energy saving, etc., which is gradually expanding their automotive application fields. LED lights are now widely used in automotive headlights, automotive taillights, window lighting, functional lighting, advanced lighting, etc.

In modern automobiles, semiconductors are used to enable safety systems and as driving assistance in semi-autonomous vehicles. Intelligent functions enabled by semiconductor devices are blind-spot detection systems, backup cameras, collision-avoidance sensors, adaptive cruise controls, lane-change assist, airbag deployment sensors and emergency braking systems. Additionally, with the increased popularity of driver assistance systems (ADAS) and LED lighting solutions is also adding to the demand for opto-semiconductor in automobiles.

The market size of opto-semiconductors used in domestic automobile industry has increased from USD 128 Mn in 2018 to USD 209 Mn in 2022, implying a CAGR of 13% and it accounted for about 9% of the total opto-semiconductor market in India in 2022.

The automotive industry is undergoing steady development and with continuous technological innovation and changing market demands, the future market potential of opto-semiconductors in the automotive industry is very large.

Chart 38: Market Size – Opto-semiconductors used in Indian Automobile Industry

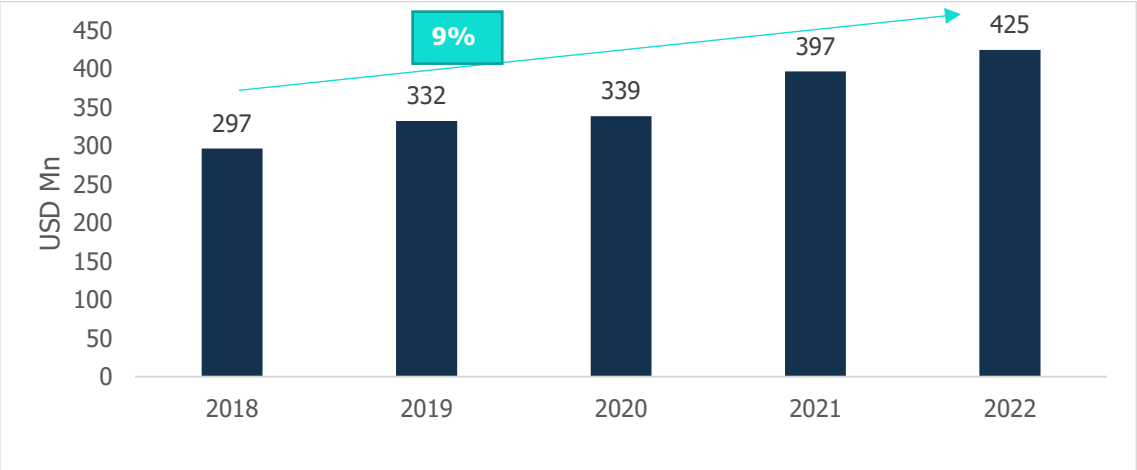


Source: Maia Research, CareEdge Research

V. Others

Overall, the opto-semiconductor industry in India is experiencing growth across several end-user segments. These user-industries consists of consumer electronics, telecommunication, healthcare, energy and power. All these industries are currently growing in India. These industries combined used about 19% of the total opto-semiconductor in 2022. The market size of opto-semiconductors used in these industries stood at USD 425 Mn in 2022, up from USD 297 Mn in 2018, implying a CAGR of 9%.

Chart 39: Opto-semiconductor market value in Other Industry



Source: Maia Research, CareEdge Research

5. Key Demand Drivers for Indian Opto-Semiconductor Industry

1. Infrastructure and industrial development (large area lighting)

One of the main applications of Opto-semiconductors are in large area lighting which includes lighting of airports, large commercial spaces, industrial establishments, street lights etc. As India outpaces the world in economic growth, significant infrastructure and industrial development is expected in the country.

The Government has envisaged investments of more than Rs. 1.43 trillion for airport sector under national infrastructure pipeline, over a period of 5 years. Further, the Ministry of Civil Aviation (MoCA) envisages 100 new airports to be built in the country over the next 10 to 15 years.

The growth in manufacturing and industrial activities is also expected to be healthy in the medium term driven by government's initiatives such as Make in India, Performance Linked Incentives, target to become a USD 5 trillion economy by FY27 and achieve exports worth USD 2 trillion by 2030.

Further, India has committed to reduce the carbon intensity of the economy by 45% by 2030 compared to 2005 levels and targets to achieve net zero emissions by the year 2030. In direction of this target, the government has taken multiple initiatives to promote use of LED lighting in the country.

The Street Lighting National Programme (SLNP) was launched in 2015 to replace conventional street lights with smart and energy efficient LED street lights across India. Under SLNP, 1576 Urban Local Bodies (ULBs) have been enrolled, out of these ULBs, work has been completed in 1060 ULBs. As on May 2022, 1.27 crore LED street lights have been installed in ULBs and Gram Panchayats across India.

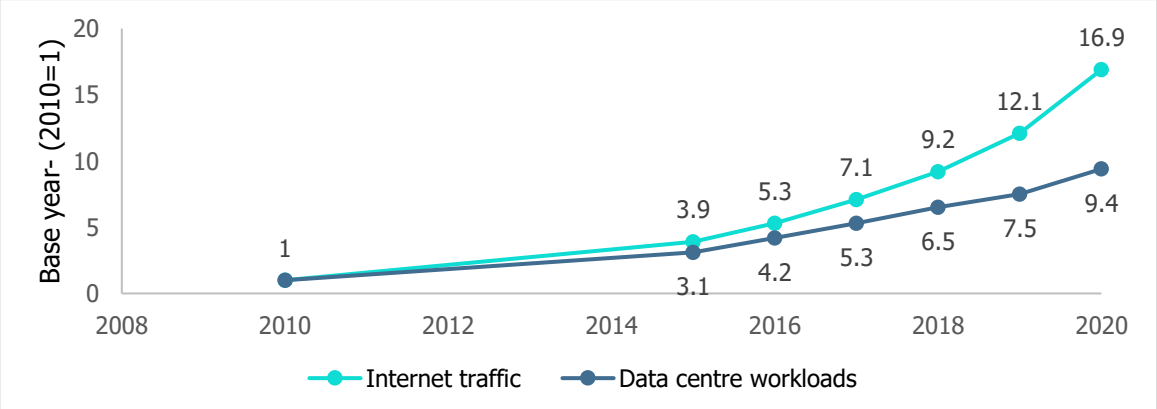
The above factors are expected to lead to an increase in demand for large area lighting in the country and in turn lead to a strong demand for opto-semiconductors in India.

2. Surging demand for data, transfer speeds

The need for computing power is rising as more and more data is created by digitalization and by the Internet of Things (IoT). Cloud computing has further increased the demand for fast data transfers. The global internet traffic has increased about 17-fold in 10 years from 2010 to 2020 and is expected to continue to increase exponentially in the coming years. This has also led to increase in workload on data centres. The same trend has been observed in India as well.

Continuously increasing demand and speed of data is a sizable opportunity for component manufacturers that have presence in optical communication products such as opto-semiconductors, which play a vital role in data transmission, fiber optic communications and high-speed connections within data centers.

Chart 40: Growth in global internet traffic and data centre workload (base year 2010)

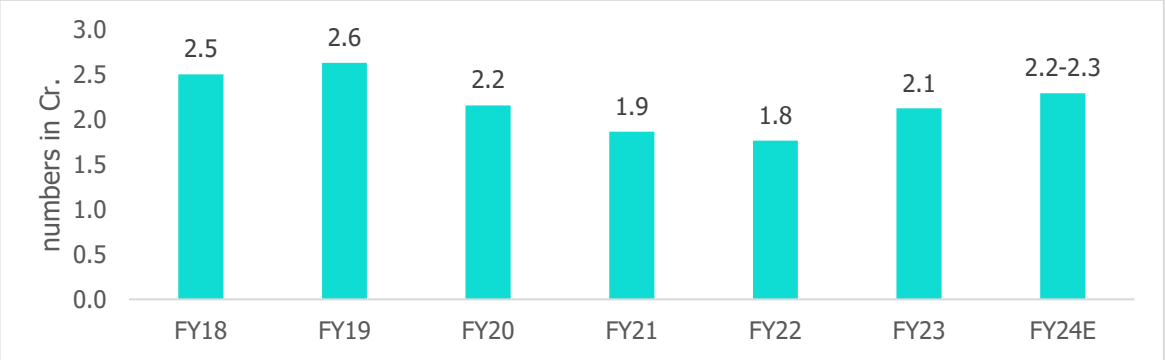


Source: International Energy Agency, CareEdge Research

3. Upward trajectory in the Indian Automotive Industry

The Indian automotive industry is witnessing rapid technological advancements driving the demand for opto-semiconductor components. The implementation of safety regulations and the adoption of advanced driver assistance systems (ADAS) require opto-semiconductor devices such as image sensors, LiDAR sensors and LED lighting systems. CareEdge Research expects the Indian auto industry to grow at 7-9% in FY24 driven by healthy demand in the urban areas, increasing replacement demand, growing demand for utility vehicles in the passenger vehicle segment and maintain stable growth trajectory in the medium-long term. As the auto industry grows and adopts technologically advanced features, it will drive the development and usage of opto-semiconductors.

Chart 41: Domestic Auto Sales Volumes



Source: Maia Research, CareEdge Research

4. Healthy demand, decreasing average replacement cycle of smartphones, laptops

Opto-semiconductor based components find applications in smartphones, laptops and tablets in light assembly, sensors etc. India is one of the leading consumers of these products and the demand is expected to increase driven by factors such as increasing disposable income, large youth population, growing workforce and rising aspirations to own premium brands.

Further, shrinkage of average replacement cycles and demand for upgraded products are further driving the growth in the segment. Factors of sophistication, safety, energy efficiency and convenience, the average number of electronic components across various products are constantly on the rise. This bodes well for the growth of opto-semiconductor markets in India.

5. Rise of digital manufacturing

3-D printers are being used to make everything from semiconductors to automobile parts and prototypes. The major driving factor for 3D- printing are surge in digitization, implementation of progressive technologies, smart factories, robotics, machine learning, etc. Photonics components are crucial in increasing the performance of this equipment and in reducing its cost.

6. Rapid adoption in non-invasive surgeries

Treatment of a wide range of conditions (including cancer and diabetes) has got a boost from non-invasive technologies. Such technologies may also help healthcare become more efficient and accessible. Most lasers that enable these procedures rely on photonic materials.

For example, laser technology uses photonics to achieve concentrated beam of light. In medical industry, laser technology is used widely for treatment of cancer, eye surgeries, endoscopy, removing stones from kidney, treating tumor etc.

7. Rising use of ultraviolet sanitizing lights

Ultraviolet (UV) irradiation particularly UV-C (wavelength of 180-280 nano meter) and far-UVC (wavelength of 200-235 nano meter), is increasingly being used as a disinfection technique to either kill or inactivate microorganisms. Opto-semiconductors are one of the key components of this technology. This technique can be used for air, surface and water disinfection and is finding increasing applications where people are not directly exposed including medical

fields for disinfection of critical surfaces and places such as the operation theatre, water treatment, food disinfection etc.

8. Transition to sustainable energy sources and hence demand growth in photovoltaic components in solar power projects

As the global consciousness towards the environment increases, the pressure to reduce harmful emissions and pollutants is going to intensify which will increase demand for renewable sources of energy all over the world.

Multiple countries including India have already commenced the transition to renewable energy driven by the COP 26 targets[4]. This has led to a significant increase in capacity of solar power generation. The pace of project bidding by the government has also remained strong in the recent years. Capacity expansions are projected to continue in the medium term, owing to increase in domestic manufacturing of solar modules, technological breakthroughs, interest from domestic and institutional investors, and the Government of India's sustained thrust on the sector.

Growth in solar power capacity is expected to lead to significant demand for photovoltaic components, which in turn will drive the demand for opto-semiconductor.

9. Advent of niche applications such as horticulture and aqua lighting

LED lights are being used in various horticulture processes such as photosynthesis, photo morphology etc. LED lights promote healthier plant growth by accelerating photosynthesis, strengthening plant immunity, and increasing nutritional value.

LEDs are also preferred for aquarium lighting as they are cost effective and greatly enhance the colours and esthetics of the objects and fish.

[4]The COP 26 target by Government of India states that by 2030, the non-fossil fuel energy capacity would be 500 GW, and 50% of the energy requirement would be fulfilled by renewable sources. Also, the aim is to reduce the carbon intensity of the economy by 45% and reduce the total projected carbon emission by 1 billion tonnes.

6. SWOT Analysis of Indian Opto-Semiconductor Industry

Opto-semiconductor is an emerging manufacturing sector in India. SWOT analysis of the opto-semiconductor industry in India is detailed below:

Strengths
- Indian government policy support
- Healthy growth prospects of end user industies
- Cost saving for consumers

Weakness
- High capital cost of estalishing manufacturing faciliies, limited technical knowledge
- Non-availability of requisite manpower

Opportunity
- Foreign investor interest
- Lower preference for China-made products
- Indian government's focus on scaling up local opto semiconductor manufacturing capacity

Threat
- Lack of cost-effective transport infrastructure
- Uninterrupted power and water availability

5.1 Strengths

- **Indian government policy support**

  The Government of India has announced an investment of USD 10 Bn for production incentive plan under the Program for Development of Semiconductors and Display Manufacturing Ecosystem. The Indian Government plans to provide incentive program for the semiconductor, display manufacturing, and design industries, creating a conductive environment for Indian electronics manufacturing. These initiatives have been taken in a bid to ensure that there will be no sudden shortage of chips needed in India in the next 3 to 5 years, and also avoid sharp rise in chip prices in various fields of electronic products, automobiles, and high-tech products caused by the shortage.

  Under this scheme, the Government will provide financial support of up to 50% of the project cost to eligible display and semiconductor manufacturers. Apart from this, the Government has also launched various programs like Indian Semi-conductor Mission, SEMICON India and National Electronics Policy, Make in India initiatives and Production Linked Incentive Schemes etc. to support the semiconductor production in India.

- **Healthy growth prospects of end-user industries**

  The key end user industries of opto-semiconductors include automobiles, smartphones, computing and data centers, consumer electronics and lighting. The automobile sector is expected to demonstrate steady growth with increasing consumer spending and demand for high performance and latest technology integrated vehicles. Further, developments in the automotive industry, including the development of autonomous vehicles, will drive demand for opto-semiconductors used in sensors and lighting systems.

  The smartphone market is expected to grow with growing demand for high-end cameras and decreased replacement cycle. Lighting has major market share in the opto-semiconductor market. The replacement of

incandescent lamps with LED lights is gaining momentum. In the consumer electronics, the demand for portable and efficient appliances are the key demand drivers.

- **Cost Saving for Consumers**

  Lighting:

  LED lighting is known for their high energy efficiency. They use significantly less electricity than traditional incandescent or fluorescent bulbs, reducing energy bills and operating costs, and reducing maintenance costs associated with bulb replacement. In addition, optoelectronic semiconductor lighting enables flexible and controllable lighting solutions, such as dimming, color changing and intelligent lighting systems. This enables energy-saving features and customization options that provide additional cost advantages.

  Smartphones and computing devices:

  Opto-semiconductor devices can be designed to be smaller and thinner, enabling thinner smartphones and computing devices. Optoelectronic semiconductor components such as high-speed fiber optic transceivers enable faster data transmission and improved network connectivity, enhancing the overall performance of smartphones and computing devices.

  Data Centers:

  Opto-semiconductor components enable data centers to efficiently expand their network infrastructure to support ever-increasing data transmission and storage needs, which can reduce data center energy consumption and operating costs.

  Automobile:

  Opto-semiconductors such as LED headlights and taillights are more energy efficient than conventional lighting technologies, reducing power consumption and fuel consumption in electric vehicles. In addition, opto-semiconductors enable compact and customizable designs, enabling automakers to optimize space utilization, reduce weight and potentially lower production costs.

5.2 Weakness

High capital cost of establishing manufacturing facilities, limited technical knowledge

Opto-semiconductor factories require significant capital investment which are typically in excess of USD 200 million for a commercial size opto-semiconductor unit. Further, the factories also have larger lead times and typically take 2-3 years to complete. Additionally, there are only a few Indian players with the requisite technology. Thus, there is high technical and capital entry barriers in this industry.

Non-availability of requisite manpower

India has limited availability of workforce required for setting up and operating an opto-semiconductor manufacturing unit. There are limited number of semiconductor engineers trained in the knowledge of device physics and process technology, which is essential for fabricating and manufacturing chips designed by the design engineers.

5.3 Opportunities

Foreign investor interest

According to data released by the International Monetary Fund, India will remain one of the fastest-growing economies in the world, with leading investors seeing India as the most attractive markets. Rising foreign direct investment is expected to provide lucrative opportunities for new entrants to raise funding for setting up manufacturing facilities.

Lower preference for China-made products

China is one of the largest producers and exporter of semiconductors in the world. The trade war between USA and China, which started in 2018, has shifted the focus towards other Asian countries for manufacturing and export of electronic components under China+1 policy. Many multinational companies have hence shifted to other Asian countries like Vietnam and India. This reduction in preference for China-made products is also expected to push the indigenous production of components like opto-semiconductor.

Indian government's focus on scaling up local opto-semiconductor manufacturing capacity

The Indian government is focusing on the development of semiconductor capacity locally. It has established a center of excellence in nanoelectronics at the Indian Institute of Technology, Bombay and the Indian Institute of Science. In addition, the Indian government is trying to introduce semiconductor-related courses in high schools. If semiconductor education for high school students is implemented effectively, then India's competitiveness in the opto-semiconductor talent pool will improve significantly. The growing talent pool is also expected to create lucrative development prospects for new entrants in the market.

5.4 Threat

Lack of cost-effective transport infrastructure

For the industry to be competitive, a strong and cost-effective transportation infrastructure is required. The logistics cost in India is higher compared to global averages which may impact the competitiveness of the opto-semiconductor industry. However, the government is taking multiple initiatives to reduce the logistics costs in line with global averages including development of highways, dedicated railway freight corridors etc., whose impact will be visible in the medium-long term.

Uninterrupted electricity supply and water availability

The opto-semiconductor manufacturing industry needs a stable and reliable power supply because the manufacturing process is very delicate, and even a short power outage or voltage instability can impact the process. Power disruptions in India, especially during the peak demand months, can impact the industry adversely. Further, as semiconductor manufacturing requires significant amount of water, there needs to be uninterrupted water supply at the plant location.

7. Key Challenges faced by the Industry

1. Availability of stable power and water resources

The opto-semiconductor manufacturing industry needs a stable and reliable power supply because the processing process is very delicate, and a very short-term power outage or voltage instability can cause shutdowns, however, not too many locations are available in India where this can be ensured. At the same time, the opto-semiconductor manufacturing industry has a significant requirement of pure water resources.

2. High capital investments

Semiconductor Fabrication Facilities requires a wide range of expensive devices in function. It also requires a non-contaminated clean room with controlled temperature, no dust as a single speck of dust will ruin the microcircuit. The clean room is to be maintained within a narrow band of temperature and humidity with is dampened against vibration.

The fabrication process requires a multistep series of photolithographic and chemical processing steps during which electronic circuits are created on a wafer made up semiconductor material. As a result, the fabrication facility requires huge initial capital investments and also needs to be kept up to date with evolution in technology.

3. Requirement of specific raw material

Silicon is most commonly used raw material in semiconductor fabrication. Apart from this, Germanium, Gallium arsenide and silicon carbide are also used in fabrication process. Silicon is made from sand but the sand needs to be clean and of the proper quality. Most of the world's silicon comes from the beaches of Australia. Many of the chemicals and gases required to manufacture semiconductors are also required to be imported and are not readily available in India.

4. Non-availability of requisite manpower

There is limited availability of skilled manpower required for semiconductor manufacturing in India such as semiconductor engineers trained in the knowledge of device physics and process technology. While foreign experts can be contracted initially for setting up operations in India, it is imperative to develop a trained work force in India in the long term.

8. Competitive Profile of Key Players

- **Polymatech Electronics Pvt. Ltd.**

Particulars	Details
Established	Incorporated by Polymatech Co., Ltd., Japan in 2007 and subsequently sold to current promoters in 2018
Headquarter	India
Business Distribution Region	Worldwide
Business Overview	Polymatech is India's first opto-semiconductor chip manufacturer. Polymatech is involved in the designing, manufacturing, packaging and assembly of semiconductor chips, chip modules, sensors, LED, Liquid Crystal Display, transducers, actuators, touch panels, Nano electronic components, etc.

Table 4: Polymatech Electronics Pvt. Ltd. - Revenue and PBT Margin

	FY20	FY21	FY22	FY23
Value (M USD)	0.2	6.1	17.0	80.82
PBT Margin	- 16.4%	15.4%	27.5%	25.7%

Source: Maia Research, CareEdge Research

- **Broadcom Inc.**

Particulars	Details
Established	1961
Headquarter	United States
Business Distribution Region	Worldwide
Business Overview	Broadcom is a technology company that designs, develops and delivers a broad range of semiconductor and infrastructure software solutions. The company's product portfolio includes memory adapters, controllers and ICs, wireless, wired and optical products.

Table 5: Broadcom Inc. Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	251.8	277.7	289.5	325.4	360.1
Gross Margin	32.3%	32.1%	31.9%	31.6%	32.6%

Source: Maia Research, CareEdge Research

- **OSRAM GmbH**

Particulars	Details
Established	1919
Headquarter	Germany
Business Distribution Region	Worldwide
Business Overview	OSRAM is a subsidiary of ams AG, a supplier of opto semiconductors and lighting products. The company provides luminaires, LEDs, light management systems and lighting solutions. OSRAM's Opto semiconductors business unit offers a wide range of LEDs for general lighting, automotive, consumer, and industrial applications as well as infrared, laser, and optical sensors. The company's automotive

	business unit develops and produces lights, light modules, and sensors for the automotive industry and the spare parts market.

Table 6: OSRAM Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	172.1	196.2	201.8	242.6	259.1
Gross Margin	31.7%	31.1%	30.8%	30.1%	31.4%

Source: Maia Research, CareEdge Research

- **Samsung Group**

Particulars	Details
Established	1938
Headquarter	South Korea
Business Distribution Region	Worldwide
Business Overview	Samsung is a South Korean multinational conglomerate headquartered in Seoul, South Korea. It was founded in 1938 and has grown to become one of the world's largest and most influential companies. Samsung operates in various industries, including electronics, semiconductors, information technology, and more. Samsung has a strong presence in the opto-semiconductor industry. It manufactures and supplies a variety of opto-semiconductor components, including LEDs, image sensors, and optical communication devices. Samsung is a leading manufacturer of LED products, including LED chips, LED packages, and LED displays. Its LED products are widely used in applications such as consumer electronics, automotive lighting, and general lighting. In display & mobile, Samsung LEDs was the first manufacturer to start mass production of Communication Service Provider (CSP) applied display LEDs and mobile flash.

- **Renesas Electronics Corporation**

Particulars	Details
Established	2002
Headquarter	Japan
Business Distribution Region	Worldwide
Business Overview	Renesas Electronics Corporation designs develops, manufactures, and sells various semiconductor products. The company's product portfolio includes microcontrollers and microprocessors, discrete and power devices, power devices, amplifiers, switches and multiplexers, DC/DC converters, RF amplifiers, flow sensors, gas sensors, power supplies, batteries management, data converters, automotive sensors, transistor arrays, and memory interface products. The company provides integrated circuits (ICs) for communications and mobile devices, factory automation, and motor drives. It serves the automotive, communications, healthcare, high-

	performance computing, home and building, industrial, personal electronics, and technology markets.

- **Table 7: Renesas Electronics Corporation Revenue and Gross Margin**

	2018	2019	2020	2021	2022
Value (M USD)	78.9	94.5	97.1	116.4	129.4
Gross Margin	31.8%	31.4%	31.2%	30.8%	32.1%

Source: Maia Research, CareEdge Research

- **LITE-ON Technology**

Particulars	Details
Established	1975
Headquarter	Taiwan
Business Distribution Region	Worldwide
Business Overview	LITE-ON manufactures and markets a wide range of computer components and Peripheral equipment. The Company's products include computers, digital home products, consumer electronics, communications products, key components and sub-systems, and optoelectronic components.

Table 8: LITE-ON Technology Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	69.9	81.0	82.8	101.9	116.1
Gross Margin	32.6%	32.9%	32.6%	31.9%	32.2%

Source: Maia Research, CareEdge Research

- **Lumileds Holding**

Particulars	Details
Established	1999
Headquarter	United States
Business Distribution Region	Mainly in Europe, North America and Asia
Business Overview	Lumileds is a global lighting solutions company helping customers around the world deliver differentiated solutions to gain and maintain a competitive advantage.

Table 9: Lumileds Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	57.4	67.9	69.9	81.6	89.1
Gross Margin	22.4%	22.5%	22.4%	22.5%	23.2%

Source: Maia Research, CareEdge Research

- **Toshiba Electronic Devices & Storage Corporation**

Particulars	Details
Established	2017
Headquarter	Japan

Business Distribution Region	Worldwide
Business Overview	Toshiba Electronic Devices & Storage Corporation provides semiconductor and storage products. It offers silicon carbide (SiC) power devices, diodes, microcontrollers, bipolar transistor products, and more. The company serves automotive, industrial, and consumer product applications. Toshiba Electronic Devices & Storage Corporation is a subsidiary of Toshiba Corporation.

Table 10: Toshiba Electronics Devices Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	47.2	50.9	51.6	57.2	59.4
Gross Margin	26.6%	26.2%	27.5%	28.5%	27.7%

Source: Maia Research, CareEdge Research

- **Mitsubishi Electric Corporation**

Particulars	Details
Established	1921
Headquarter	Japan
Business Distribution Region	Worldwide
Business Overview	Mitsubishi Electric Corporation develops, manufactures, and sells electrical and electronic products. The company provides products such as turbo generators, nuclear power plants, and power electronics equipment, electric motors, transformers, circuit breakers, gas-insulated switchgear, switch control, and display devices. It also provides surveillance systems control and safety systems, power transmission and distribution systems, electrical equipment for locomotives and rolling stock, elevators, escalators, building security and management systems, and more. The company provides logistics, real estate, advertising, procurement, financial and other services. Mitsubishi Electric serves the information processing and communications, space development and satellite communications, consumer electronics, industrial technology, energy, transportation, and construction equipment sectors.

- **Table 11: Mitsubishi Electronics Corporation Revenue and Gross Margin**

	2018	2019	2020	2021	2022
Value (M USD)	33.5	38.4	40.3	48.5	53.1
Gross Margin	31.4%	30.9%	30.1%	29.6%	30.5%

Source: Maia Research, CareEdge Research

- **ROHM Company Limited**

Particulars	Details
Established	1958
Headquarter	Japan
Business Distribution Region	Mainly in America, Asia and Europe

Business Overview	ROHM CO.LTD is a manufacturer of various electronic products. The company supplies ICs and other related semiconductors and electronic components to its customers worldwide. Its product portfolio includes monolithic ICs, power modules, power ICs, application-specific ICs, laser diodes, resistors, capacitors, transistors, diodes, LEDs, thermal heads, bipolar transistors, image sensor heads, LED displays, among others. ROHM products are used in various fields such as industrial, automotive, healthcare, infrastructure, computer, and consumer products.

- **Table 12: ROHM Revenue and Gross Margin**

	2018	2019	2020	2021	2022
Value (M USD)	35.4	40.9	41.9	50.3	52.9
Gross Margin	30.6%	30.3%	29.7%	30.1%	30.7%

Source: Maia Research, CareEdge Research

- **ON Semiconductor (Onsemi)**

Particulars	Details
Established	1999
Headquarter	United States
Business Overview	ON Semiconductor is a designer, manufacturer, and supplier of semiconductor products and solutions. The company offers products under the Power Solutions Group (PSG), Advanced Solutions Group (ASG), and Intelligent Sensing Group (ISG). It serves customers from the automotive, medical, aerospace and defense, industrial, Internet of Things (IoT), communications, 5G and cloud power, wireless, networking, consumer, personal electronics, medical and computing industries.

Table 13: On Semiconductor Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	21.4	25.1	26	28.9	33.7
Gross Margin	30.4%	29.5%	29.1%	28.7%	29.6%

Source: Maia Research, CareEdge Research

- **Vishay Intertechnology**

Particulars	Details
Established	1962
Headquarter	United States
Business Distribution Region	Worldwide
Business Overview	Vishay Intertechnology is a manufacturer of semiconductors and passive electronic components. The company's product portfolio includes MOSFETs, ICs, a wide range of diodes and rectifiers, and different types of optoelectronic products. These products perform the single function of switching, amplifying, rectifying, and transmitting electrical signals. Vishay offers passive components including resistors, inductors, magnetics, and capacitors. They can be used to store

	charge, resist current flow, and aid in filtering, surge suppression, measurement, timing, and tuning. Vishay's products and services serve a variety of industries, including automotive, computer, industrial, telecommunications, avionics, military, aerospace, consumer, and medical.

Table 14: Vishay Intertechnology Revenue and Gross Margin

	2018	2019	2020	2021	2022
Value (M USD)	16.6	19.9	20.8	25.9	28.8
Gross Margin	26.1%	26%	25.5%	25.1%	25.6%

Source: Maia Research, CareEdge Research

9. Indian Regulatory Policies and its implication on the industry

Government of India has taken various initiative to build the overall semiconductor ecosystem in the country to ensure India's dependency on imports reduces in the medium-long term. The government has also taken various steps to address the challenges faced by this sector, facilitate scale-up of local manufacturing capacity and increase the availability of skilled manpower required for growth of this sector. Following schemes have been announced by the Government to facilitate growth in semiconductor manufacturing:

1. Indian Semi-conductor Mission

Indian Semi-conductor Mission (ISM) is an Independent Business Division of Digital India Corporation. It has all the financial and administrative powers to catalyze the Indian semiconductor ecosystem in manufacturing, packaging and design. It is serving as a nodal agency to efficiently, coherently and smoothly implementing the developmental programme for semiconductor manufacturing ecosystem in India.

Objectives:

- To facilitate adoption of good microelectronics and developing trusted semiconductor supply chain which includes raw materials, specialty chemicals, gases and equipment for manufacturing.
- To enable multi-fold growth of Indian semiconductor design industry by providing required support in the form of Electronic Design Automation (EDA) tools etc.
- To promote and facilitate indigenous Intellectual Property (IP) generation and incentivize transfer of Technologies.
- To enable research in semiconductors and display industry through grants, global collaborations, academia, industry and through establishing Centres of Excellence.

The following 3 schemes have been introduced under the aforesaid programme:

i. **Modified Scheme for setting up of semiconductor fabs in India**
This scheme aims at attracting large investments for setting up semiconductor wafer fabrication facilities in the country to strengthen the electronics manufacturing ecosystem in India. The Scheme extends a fiscal support of 50% of the project cost on pari-passu basis for setting up of Silicon CMOS based semiconductor fab in India.

i. **Modified Scheme for setting up of Compound Semiconductors / Silicon Photonics / Sensors Fab / Discrete Semiconductors Fab and Semiconductor Assembly, Testing, Marking and Packaging/ OSAT facilities in India**
Under this scheme, fiscal support of up to 50% of the capital expenditure on pari-passu basis is extended for setting up compound semiconductors / silicon photonics / sensors fab / discrete semiconductors fab and semiconductor assembly, testing, marking and packaging/ OSAT facilities in India.

ii. **Modified Scheme for setting up of display fabs in India**
This scheme aims at attracting large investments for manufacturing Thin Film Transistor Liquid Crystal Display (TFT LCD) or Active-Matrix Organic light-emitting diode (AMOLED) based display panels in the country to strengthen the electronics manufacturing ecosystem. Scheme extends fiscal support of 50% of Project Cost on pari-passu basis for setting up of display fabrication facilities (Fabs) in India.

2. Semicon India Future Design: Design Linked Incentive (DLI) Scheme

Ministry of Electronics and Information Technology has announced the Design Linked Incentive (DLI) Scheme to offset the challenges in the domestic industry involved in semiconductor design in order to not only move up in value-chain but also strengthen the semiconductor chip design ecosystem in the country. Centre for Development of Advanced Computing (CDAC) is responsible for implementation of the DLI Scheme as Nodal Agency.

The DLI Scheme aims to offer financial incentives as well as design infrastructure support across various stages of

development and deployment of semiconductor design(s) for Integrated Circuits (ICs), Chipsets, System on Chips (SoCs), Systems & IP Cores and semiconductor linked design(s) over a period of 5 years in form of an incentive of 4-6% of net sales turnover over 5 years subject to a ceiling of Rs.30 Crore per application.

As on June, 2023, under the Modified Semicon India Programme, the government has decided to invite new applications for setting up of Semiconductor Fabs. The applications will be received by India Semiconductor Mission, the designated nodal agency entrusted with the responsibility of implementing the Modified Semicon India Programme for development of semiconductors and display manufacturing ecosystem in India.

Under the Modified Programme, Fiscal Incentive of 50% of the project cost is available to companies/consortium/joint ventures for setting up of semiconductor fabs in India of any node (including mature nodes). Similarly, fiscal incentive of 50% of the project cost is available for setting up of display fabs of specified technologies in India.

3. National Policy on Electronics

The National Policy on Electronics 2019 was announced on February, 2019. The vision of the program is to position India as a global hub for Electronics System Design and Manufacturing (ESDM) by encouraging and driving capabilities in the country for developing core components, including chipsets, and creating an enabling environment for the industry to compete globally. To attract and incentivize large investments in the electronics value chain and promote exports, following three schemes have been notified under the aegis of NPE 2019:

Production Linked Incentive Scheme (PLI) for Largescale Electronics Manufacturing was announced on April, 2020 to provide an incentive of 4% to 6% to eligible companies on incremental sales (over base year) involved in mobile phone manufacturing and manufacturing of specified electronic components, including Assembly, Testing, Marking and Packaging (ATMP) units.

The total outlay under the Scheme is Rs. 38,645 crores. Till date, 16 companies including 5 global companies (under category Mobile Phone), 5 domestic companies and 6 companies were approved under the scheme.

After the success of the First Round of PLI Scheme, 2nd round of the PLI Scheme which targeted Specified Electronic Components was announced in March 2021, incentivizing 5% to 3% on incremental sales to eligible companies, for a period of 4 years. A total of 16 companies were approved by the Competent Authority under this scheme. The tenure of the PLI Scheme has been extended by one year i.e. from 2024-25 to 2025-26. Out of total 16 companies, 15 companies opted for extension and has led to total production of more than Rs. 1,67,770 crore including exports of Rs 65,240 crore as of June 2022.

i. **Production Linked Incentive Scheme (PLI) for IT Hardware** was announced in March 2021 to provide an incentive of 4 % to 2 %/1 % on net incremental sales (over base year) of goods manufactured in India and covered under the target segment, to eligible companies, for a period of four years. The target segment under this PLI Scheme includes (i) Laptops (ii) Tablets (iii) All-in-One PCs and (iv) Servers. Support under the Scheme was to be provided for 4 years from FY22 with FY20 as the base year. Under this scheme, a total of 4 applications from foreign companies have been approved as on March 2021.

ii. **Production Linked Incentive Scheme 2.0 for IT Hardware** was announced in May 2023. Under this scheme, the manufacturing ecosystem for components and sub-assemblies and supply chain development is encouraged to be more localized in the country. Additionally, the scheme is expected to increase flexibility and options for applicants and is given on incremental sales and investments thresholds to further incentivise growth. Semiconductor design, IC manufacturing, and packaging are also included as incentivised components under the scheme.

- The PLI Scheme 2.0 for IT Hardware was approved with a budgetary outlay of Rs 17,000 crore.

- The scheme is expected to lead to total production of about Rs. 3.35 lakh crore, bring an additional investment of Rs. 2,430 crores in electronics manufacturing and will lead to generation of 75,000 additional direct jobs.
- The Scheme will promote large scale manufacturing in Laptops, Tablets, All-in-One PCs, Servers and Ultra Small Form Factor (USFF) devices and contribute significantly to achieve electronics manufacturing turnover of approximately USD 300 billion by 2025-26.
- Approved applicants of existing PLI will be allowed to apply under PLI 2.0.
- The scheme has three category of applicants, namely global companies, hybrid (global/domestic) companies and domestic companies.

iii. **Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS)** was announced in April 2020 to provide financial incentive of 25% on capital expenditure for the identified list of electronic goods that comprise downstream value chain of electronic products, i.e. electronic components, semiconductor/display fabrication units, ATMP units, specialized sub-assemblies and capital goods for manufacture of aforesaid goods.

As on February 28, 2022, the Executive Committee (EC) has approved 23 applications with total project outlay of Rs. 6,816 crore and committed incentives of Rs 1,245 crore.

iv. **Modified Electronics Manufacturing Clusters (EMC 2.0) Scheme** was announced in April, 2020 to provide support for creation of world class infrastructure along with common facilities and amenities, including Ready Built Factory (RBF) sheds/Plug and Play facilities for attracting major global electronics manufacturers along with their supply chain to set up units in the country. The scheme provides financial assistance for setting up of both Electronics Manufacturing Clusters (EMCs) projects and Common Facility Centres (CFCs) across the country.

As on March 2023, three EMCs over an area of 1,337 acres with project cost of Rs 1,903 crore, including central financial assistance of Rs 889 crore have been approved which projected investment target of Rs 20,910 crore.

v. **Program for Development of Semiconductors and Display Manufacturing Ecosystem**: India Semiconductor and Display Manufacturing Ecosystem Development Plan was announced in December 2021, under which Rs 760 Bn (USD 10 Bn) is to be spend to develop a sustainable semiconductor and display manufacturing ecosystem in India. The USD 10 Bn fund is to be provided over six years and is expected to bring in investments of up to Rs 1,700 Bn. Overall, the program will provide attractive motivation and support to companies engaged in silicon semiconductor fabs, display fabs, compound semiconductor/silicon photonics/sensors fabs, semiconductor packaging, and semiconductor design and manufacturing. Among other goals, India wants to build at least two greenfield semiconductor factories and two display factories under this scheme.

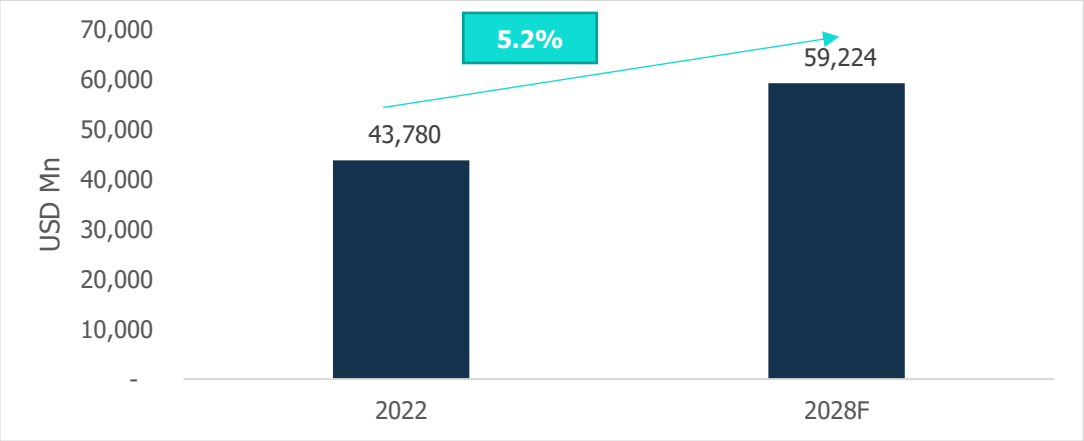
As on February 28, 2022, the Executive Committee (EC) has approved 23 applications with total project outlay of Rs.6,816 crore and committed incentives of Rs 1,245 crore. The total employment generation potential of the approved applications is 29,021.

10. Outlook

9.1 Global Opto-semiconductor Industry

The global opto-semiconductor industry is expected to reach USD 59,224 Mn by 2028, growing at a CAGR of 5.2% from 2022 to 2028. The growth is expected to be driven by growth in downstream industries like automotive sector, lighting both in community areas and households. Also, the growth of artificial Intelligence and automation of processes in all walks of life will also drive the demand globally.

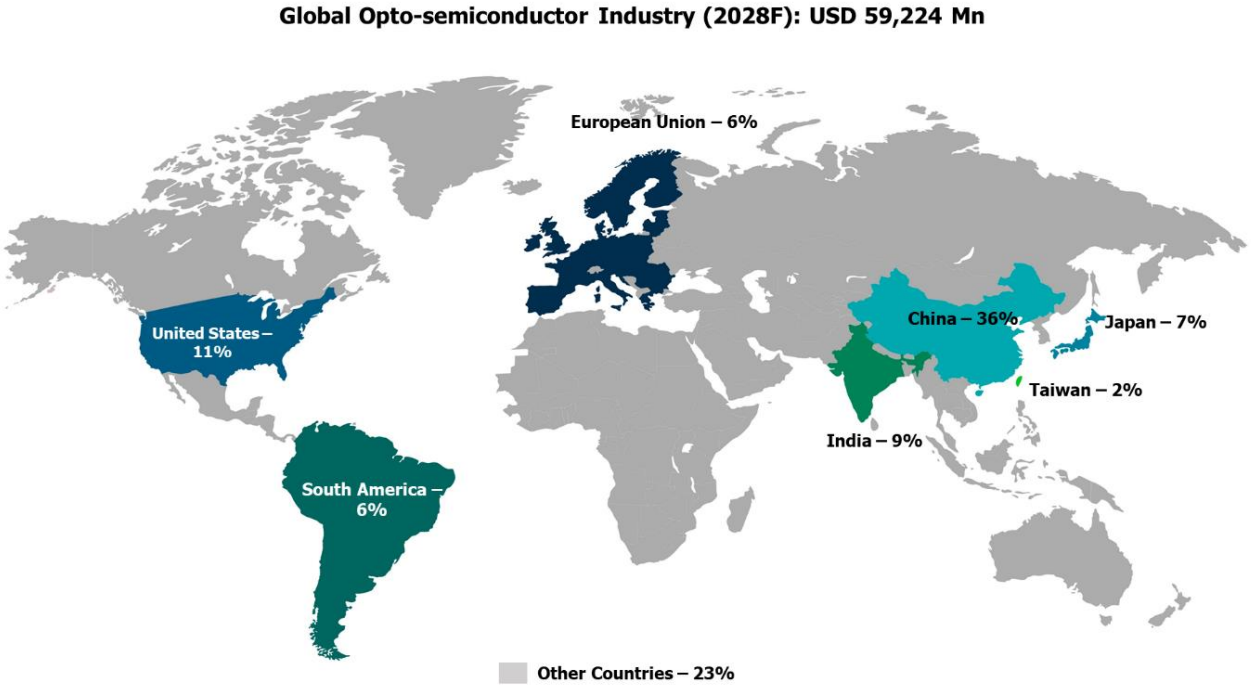
Chart 42: Global Opto-semiconductor market value forecast for 2028



F- Forecasted

Source: Maia Research, CareEdge Research

Chart 43: Region-wise market share for 2028



F- Forecasted

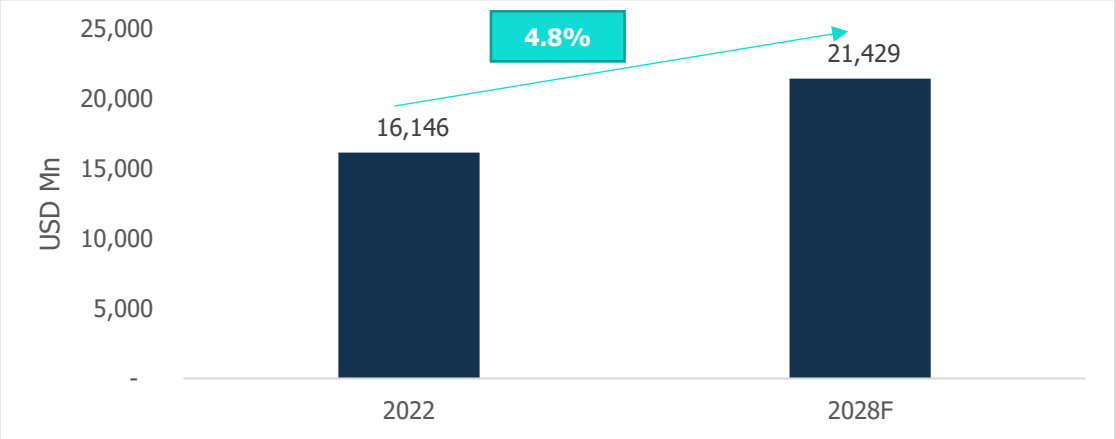
Source: Maia Research, CareEdge Research

9.1.1 Region-wise Outlook

- **China**

The Opto-semiconductor market in China is expected to reach USD 21,429 Mn by 2028 from USD 16,146 Mn in 2022, growing at a CAGR of 4.8%.

Chart 44: Opto-semiconductor market value of China Forecast for 2028

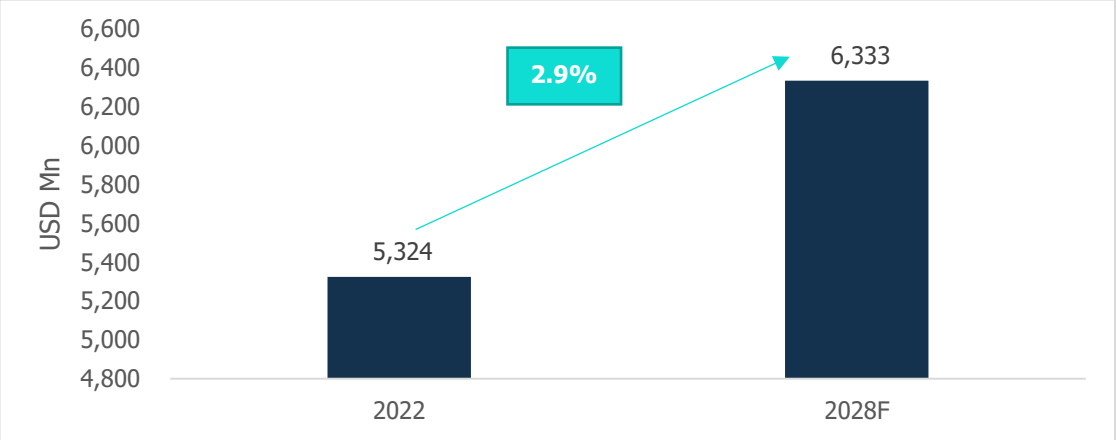


F- Forecasted
Source: Maia Research, CareEdge Research

- **United States**

The Opto-semiconductor market in United States is expected to reach USD 6,333 Mn by 2028 from USD 5,324 Mn in 2022, growing at a CAGR of 2.9%.

Chart 45: Opto-semiconductor market value of United States Forecast for 2028

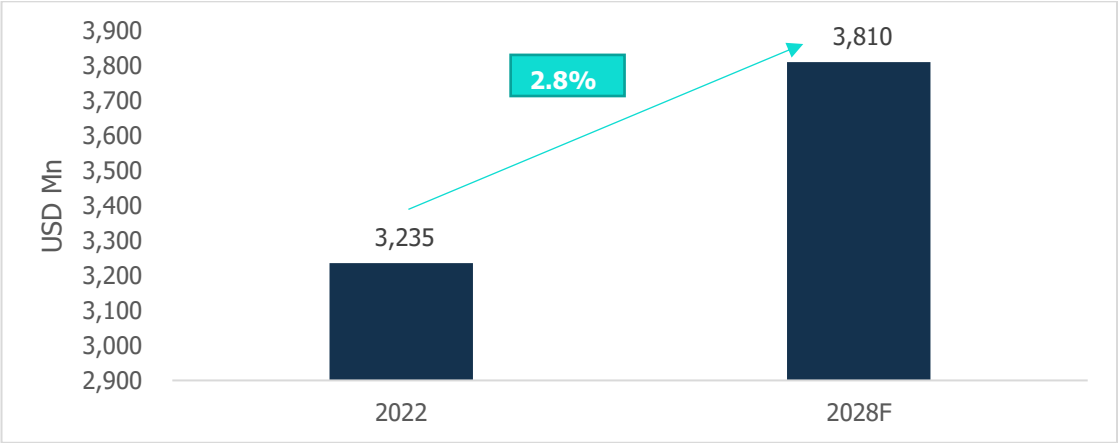


F- Forecasted
Source: Maia Research, CareEdge Research

- **European Union**

The Opto-semiconductor market in European Union is expected to reach USD 3,810 Mn by 2028 from USD 3,235 Mn in 2022, growing at a CAGR of 2.8%.

Chart 46: Opto-semiconductor market value of European Union Forecast for 2028

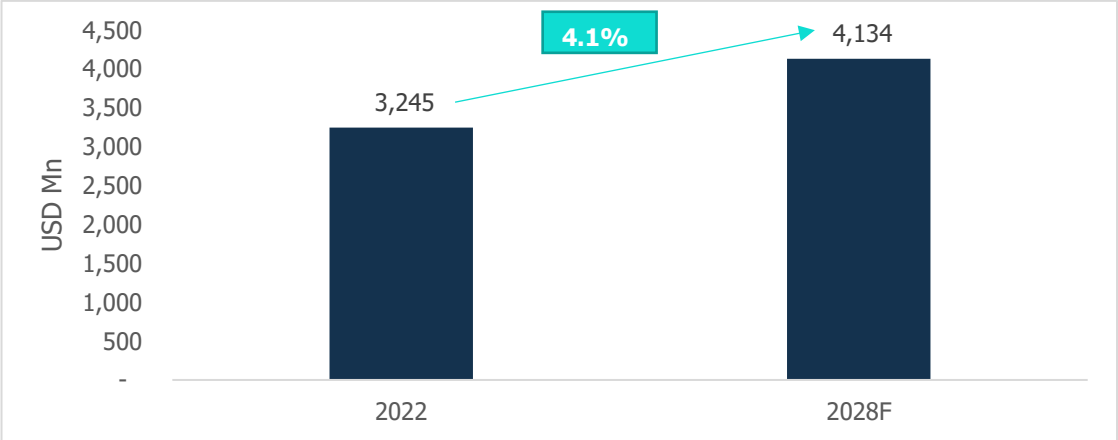


F- Forecasted
Source: Maia Research, CareEdge Research

- **Japan**

The Opto-semiconductor market in Japan is expected to reach USD 4,134 Mn by 2028 from USD 3,245 Mn in 2022, growing at a CAGR of 4.1%.

Chart 47: Opto-semiconductor market value of Japan Forecast for 2028

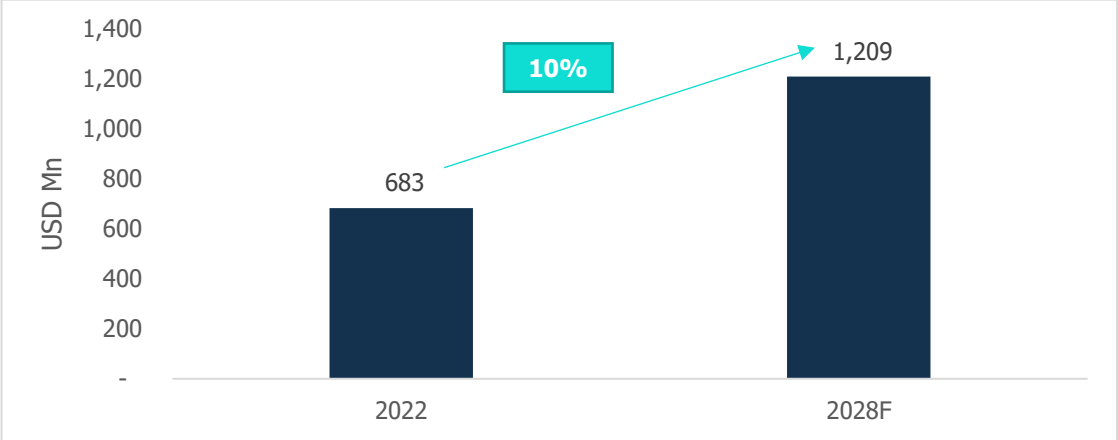


F- Forecasted
Source: Maia Research, CareEdge Research

- **Taiwan**

The Opto-semiconductor market in Taiwan is expected to reach USD 1,209 Mn by 2028 from USD 683 Mn in 2022, growing at a CAGR of 10.0%.

Chart 48: Opto-semiconductor market value of Taiwan Forecast for 2028

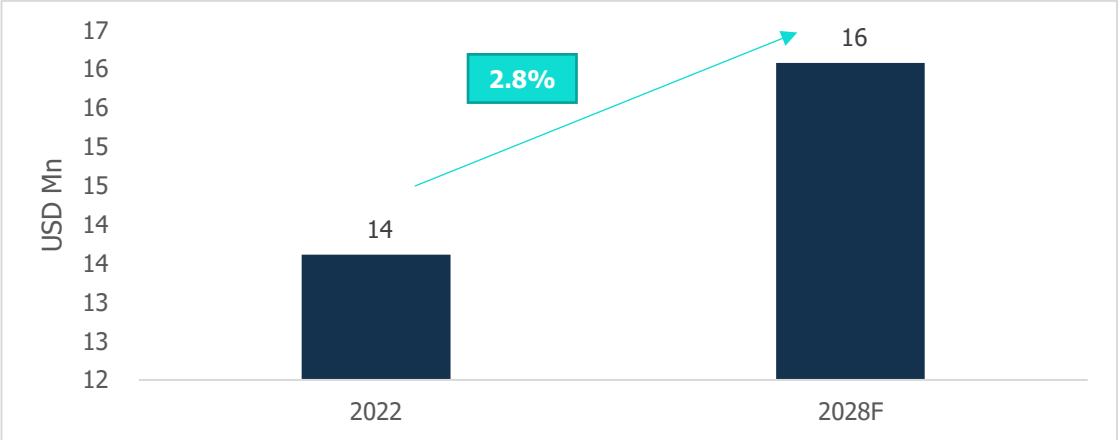


F- Forecasted
Source: Maia Research, CareEdge Research

- **Finland**

The Opto-semiconductor market in Finland is expected to reach USD 16.1 Mn by 2028 from USD 13.6 Mn in 2022, growing at a CAGR of 2.8%.

Chart 49: Opto-semiconductor market value of Finland Forecast for 2028

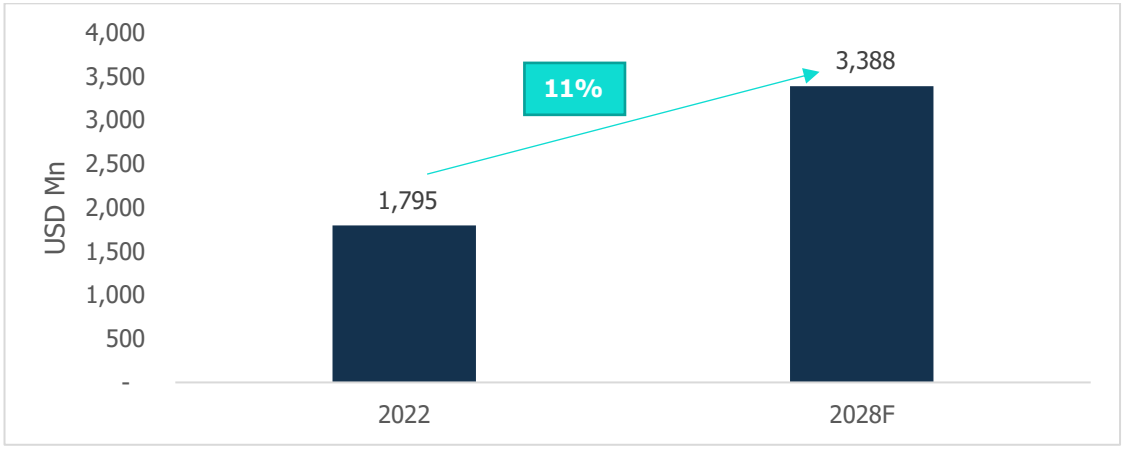


F- Forecasted
Source: Maia Research, CareEdge Research

- **South America**

The Opto-semiconductor market in South America is expected to reach USD 3,388 Mn by 2028 from USD 1,795 Mn in 2022, growing at a CAGR of 11%.

Chart 50: Opto-semiconductor market value of South America Forecast for 2028

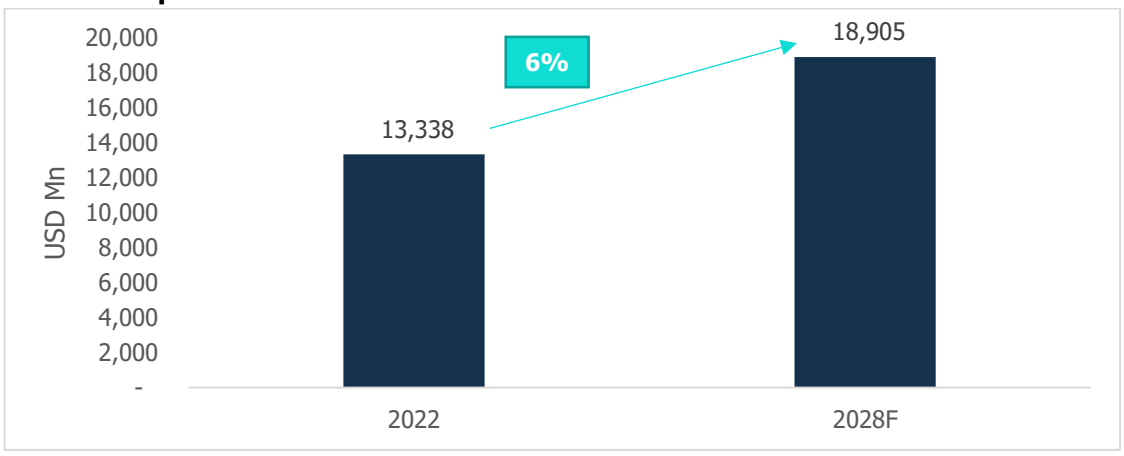


F- Forecasted
Source: Maia Research, CareEdge Research

- **Others countries**

The Opto-semiconductor market in other countries is expected to reach USD 18,905 Mn by 2028 from USD 13,338 Mn in 2022, growing at a CAGR of 6%.

Chart 51: Opto-semiconductor market value of other countries Forecast for 2028



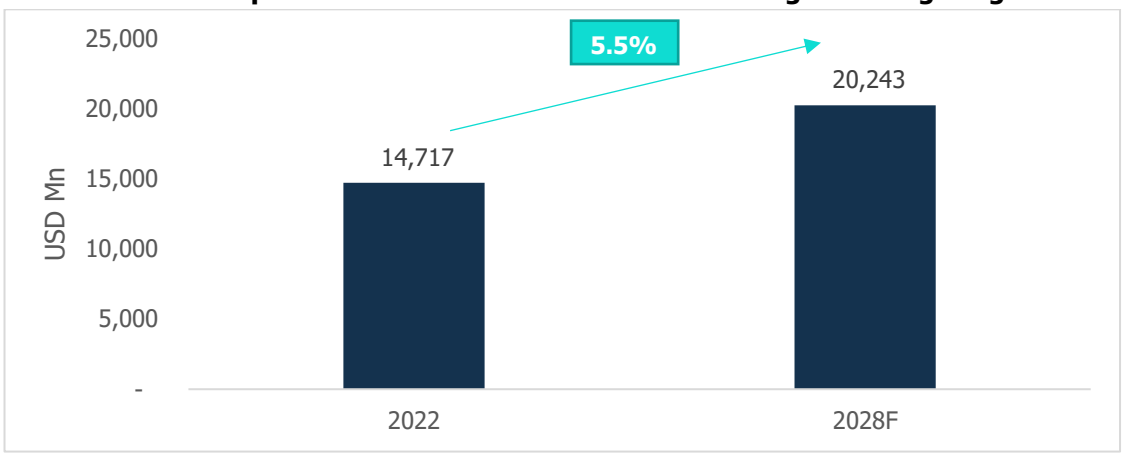
F- Forecasted
Source: Maia Research, CareEdge Research

9.1.2 Application-wise Outlook

- **Large Area Lighting**

The opto-semiconductor market for large area lighting is expected to reach USD 20,243 Mn by 2028 from USD 14,717 Mn in 2022, growing at CAGR of 5.5%.

Chart 52: Global Opto-semiconductor market value for Large Area Lighting Forecast for 2028

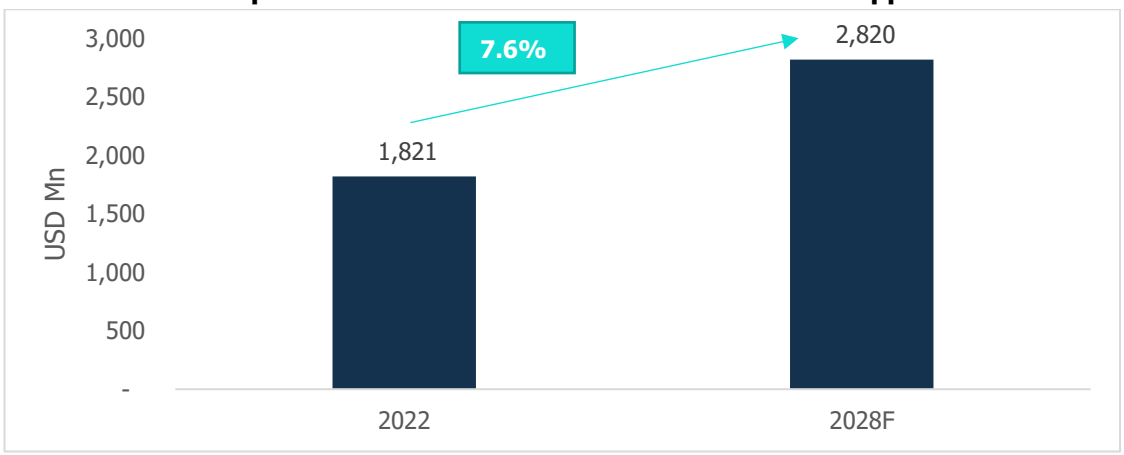


F- Forecasted
Source: Maia Research, CareEdge Research

- **Medical Applications**

The opto-semiconductor market for medical applications is expected to reach USD 2,820 Mn by 2028 from USD 1,821 Mn in 2022, growing at CAGR of 7.6%.

Chart 53: Global Opto-semiconductor market value for medical applications Forecast for 2028

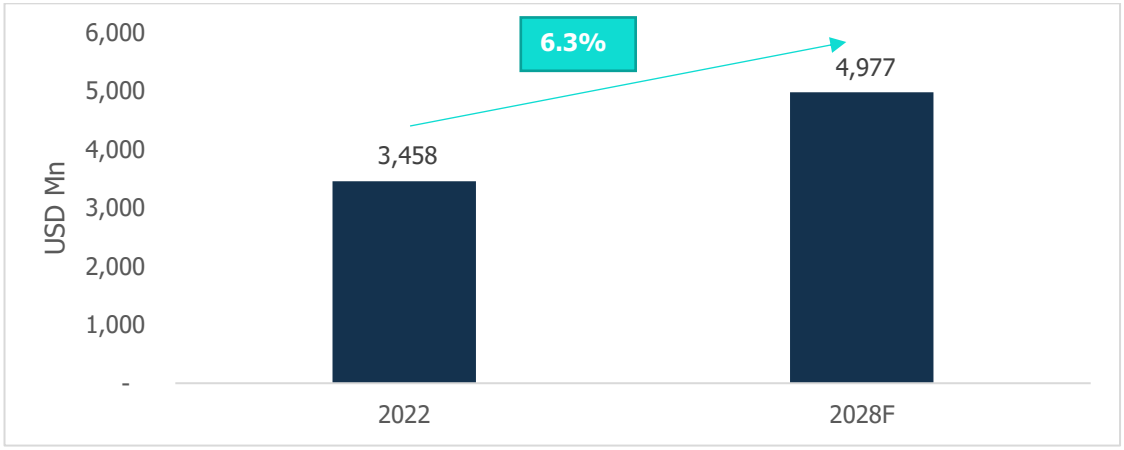


F- Forecasted
Source: Maia Research, CareEdge Research

- **Automobiles**

The opto-semiconductor market for automobiles is expected to reach USD 4,977 Mn by 2028 from USD 3,458 Mn in 2022, growing at CAGR of 6.3%.

Chart 54: Global Opto-semiconductor market value for Automobiles Forecast for 2028



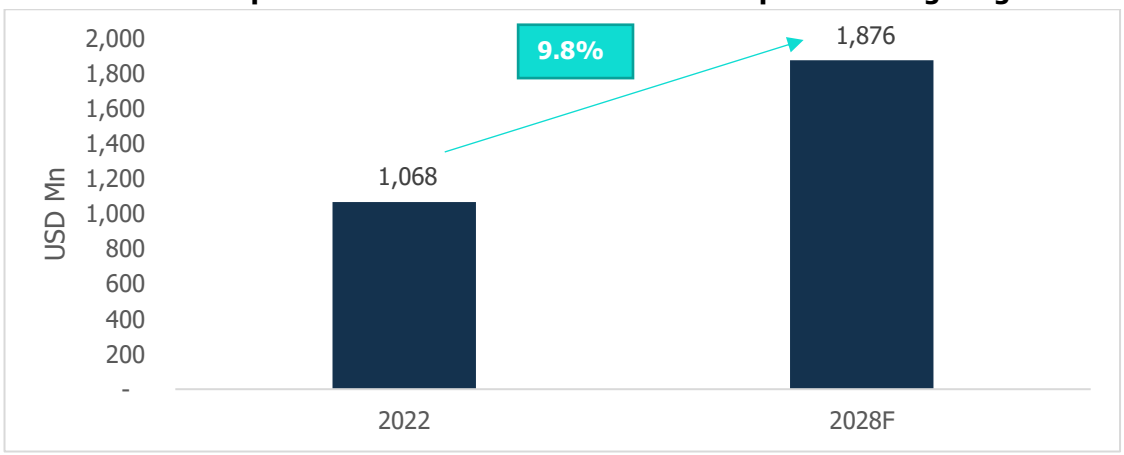
F- Forecasted

Source: Maia Research, CareEdge Research

- **Specialized Lighting**

The opto-semiconductor market for specialized lightings is expected to reach USD 1,876 Mn by 2028 from USD 1,068 Mn in 2022, growing at CAGR of 9.8%.

Chart 55: Global Opto-semiconductor market value for Specialized Lighting Forecast for 2028



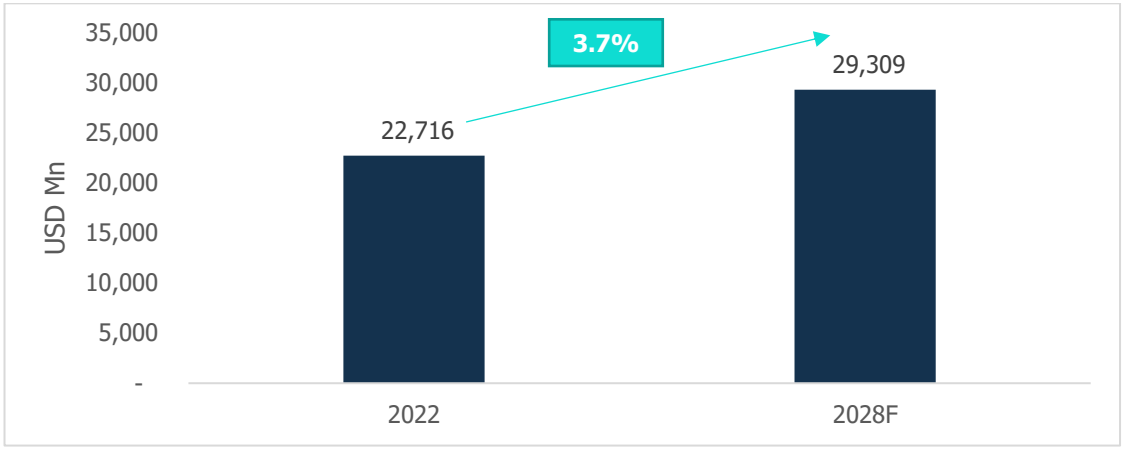
F- Forecasted

Source: Maia Research, CareEdge Research

- **Others**

The opto-semiconductor market for other applications is expected to reach USD 29,309 Mn by 2028 from USD 22,716 Mn in 2022, growing at CAGR of 3.7%.

Chart 56: Global Opto-semiconductor market value for other application Forecast for 2028

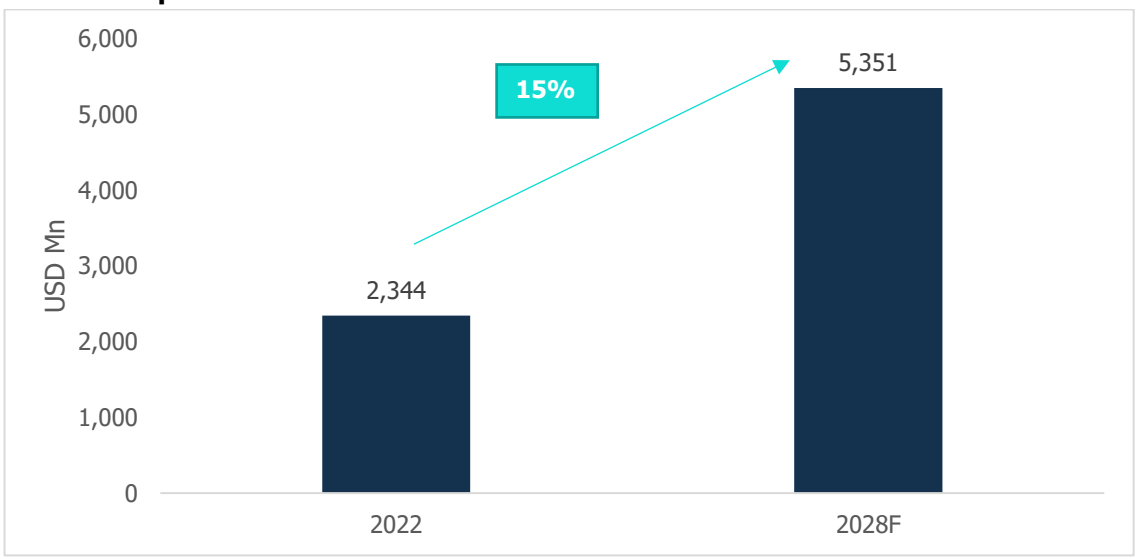


F- Forecasted
Source: Maia Research, CareEdge Research

9.2 Indian Opto-semiconductor Industry

The market of opto-semiconductor in India is expected to reach USD 5,351 Mn by 2028, growing at a CAGR of 15% from 2022 to 2028. The developments in this sector are expected to be driven by increased investment, supportive policies by the Government and increase in demand by the end-user industries.

Chart 57: Opto-semiconductor market value Forecast for 2028



F- Forecasted
Source: Maia Research, CareEdge Research

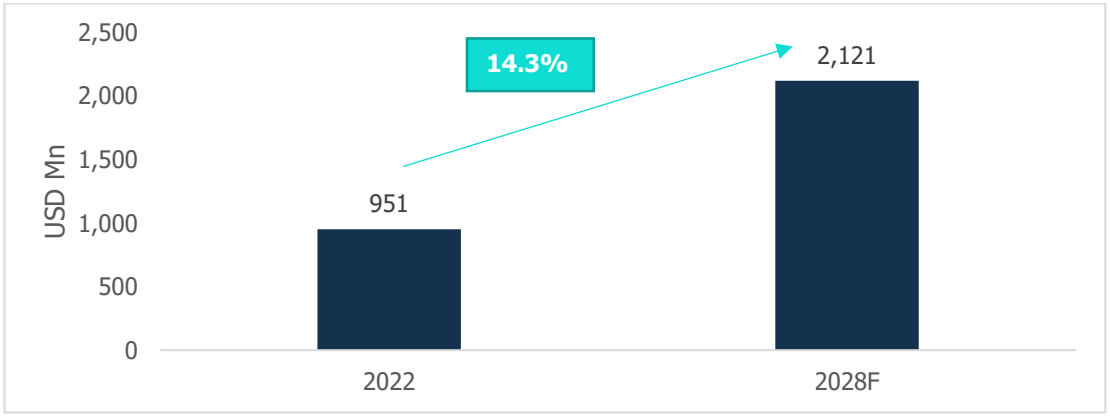
9.2.1 Product-wise Outlook in India

Outlook for the different types of opto-semiconductors in India are as follows:

- **Light Emitting Diode (LED)**

The Light Emitting Diode market is expected to reach USD 2,121 Mn by 2028 from USD 951 Mn in 2022, growing at a CAGR of 14.3%.

Chart 58: LED market value Forecast for 2028

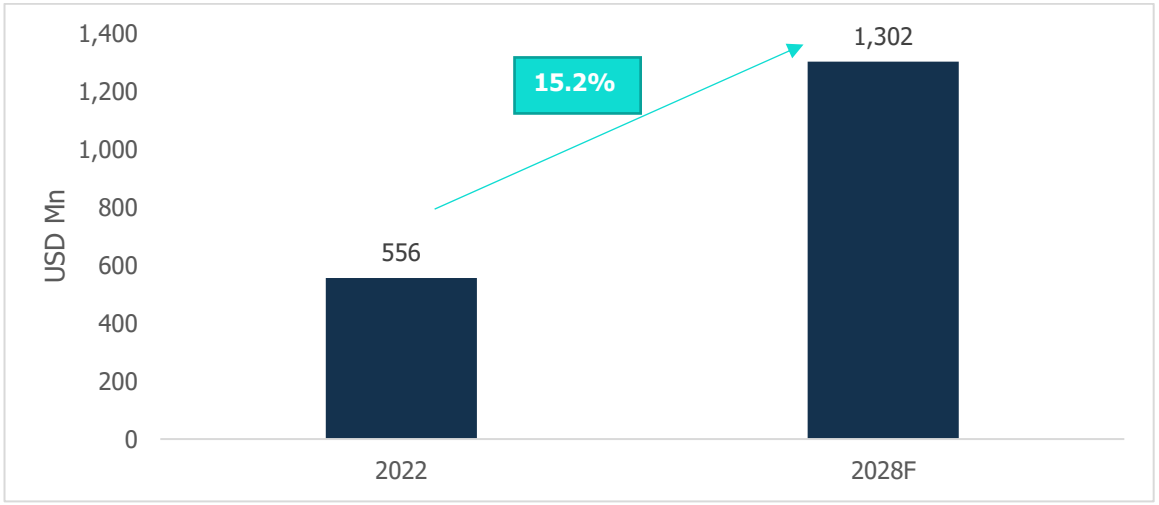


F- Forecasted
Source: Maia Research, CareEdge Research

- **Image Sensor**

The Image sensor market is expected to reach USD 1,302 Mn by 2028 from USD 556 Mn in 2022, growing at CAGR of 15.2%.

Chart 59: Image Sensor market value Forecast for 2028

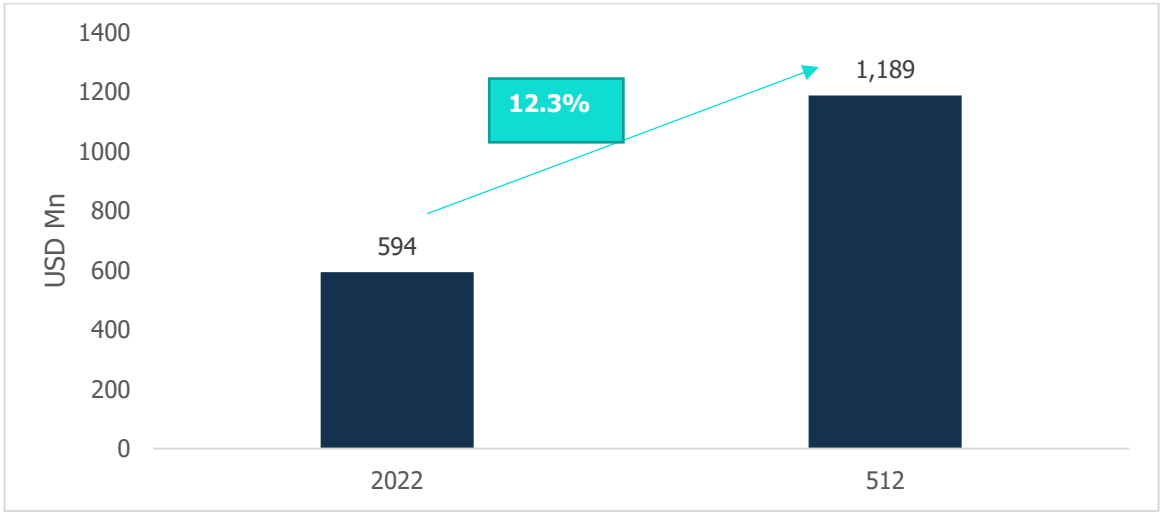


F- Forecasted
Source: Maia Research, CareEdge Research

- **Opto-coupler**

The Opto-coupler market is expected to reach USD 1,189 Mn by 2028 from USD 594 Mn in 2022, growing at CAGR of 12.3%.

Chart 60: Opto-coupler market value Forecast for 2028

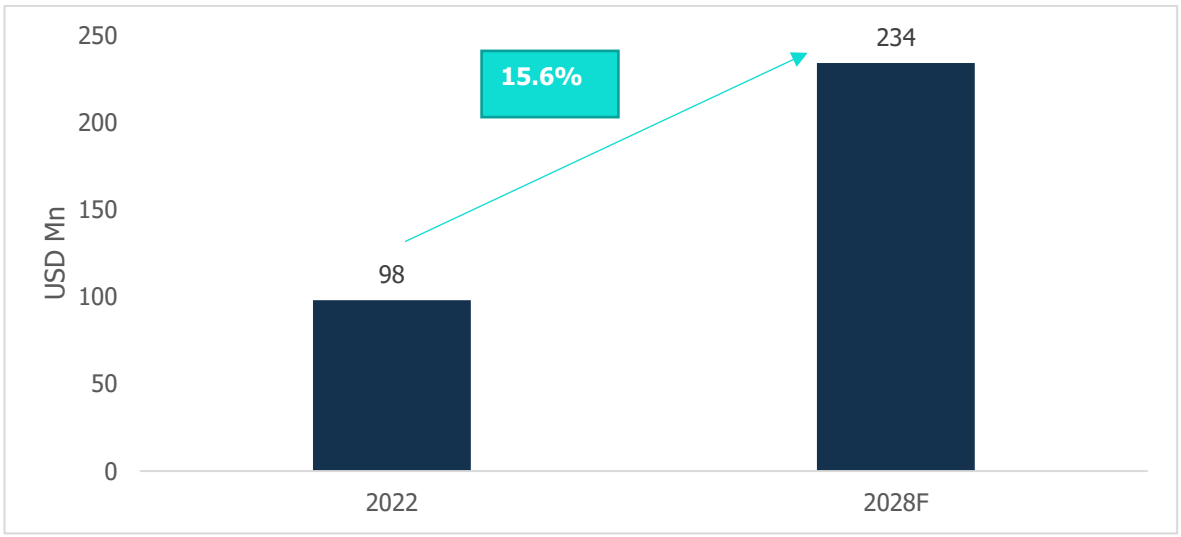


F- Forecasted
Source: Maia Research, CareEdge Research

- **Laser Diode**

The Laser Diode market is expected to reach USD 234 Mn by 2028 from USD 98 Mn in 2022, growing at CAGR of 15.6%.

Chart 61: Laser Diode market value Forecast for 2028

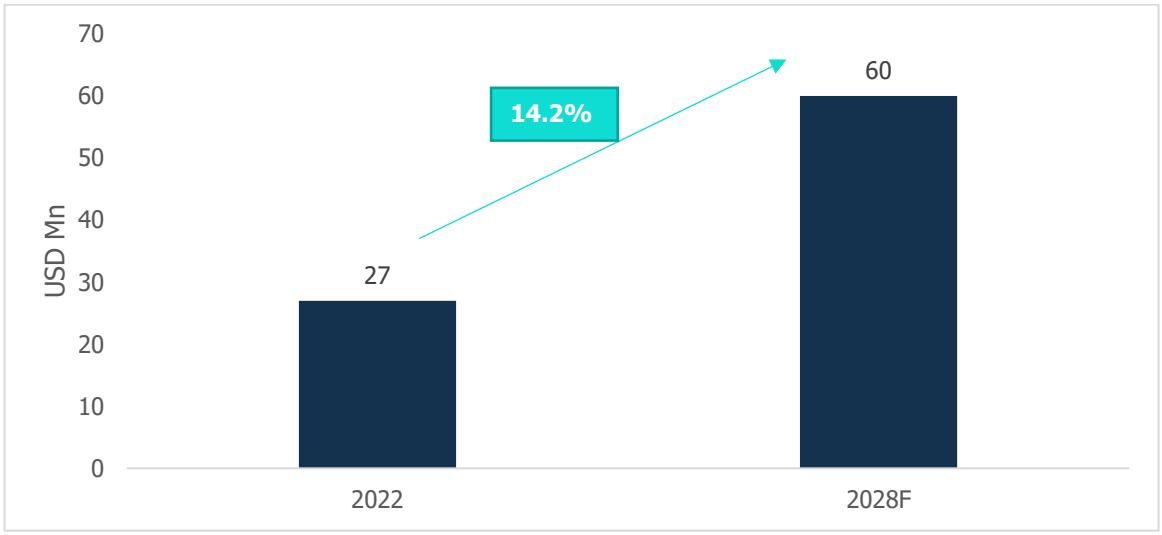


F- Forecasted
Source: Maia Research, CareEdge Research

- **Infrared Receiver**

The Infrared Receiver market is expected to reach USD 60 Mn by 2028 from USD 27 Mn in 2022, growing at CAGR of 14.2%.

Chart 62: Infrared Receiver market value Forecast for 2028



F- Forecasted
Source: Maia Research, CareEdge Research

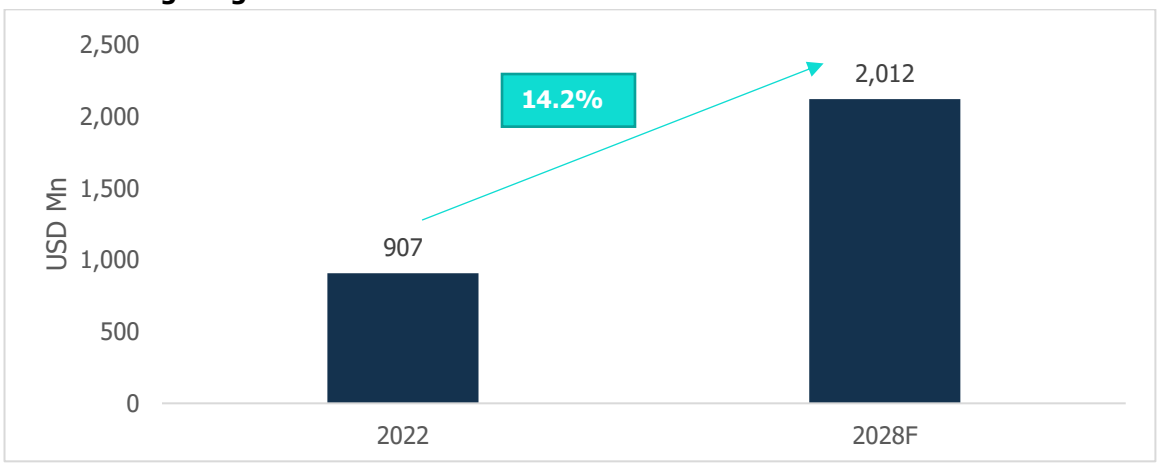
9.2.2 Application-wise outlook

Application-wise growth outlook for the Indian opto-semiconductors industry is as follows.

- **Lighting**

The opto-semiconductor market for lighting industry is expected to reach USD 2,012 Mn by 2028 from USD 907 Mn in 2022, growing at CAGR of 14.2%.

Chart 63: Lighting market value Forecast for 2028

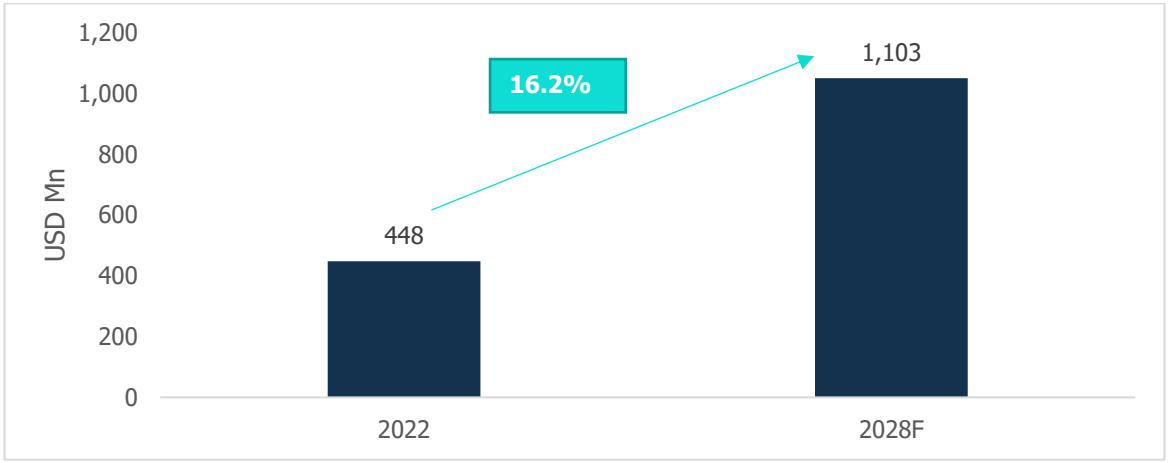


F- Forecasted
Source: Maia Research, CareEdge Research

- **Smartphone**

The opto-semiconductor market for smartphone industry is expected to reach USD 1,103 Mn by 2028 from USD 448 Mn in 2022, growing at CAGR of 16.2%.

Chart 64: Smartphone market value Forecast for 2028

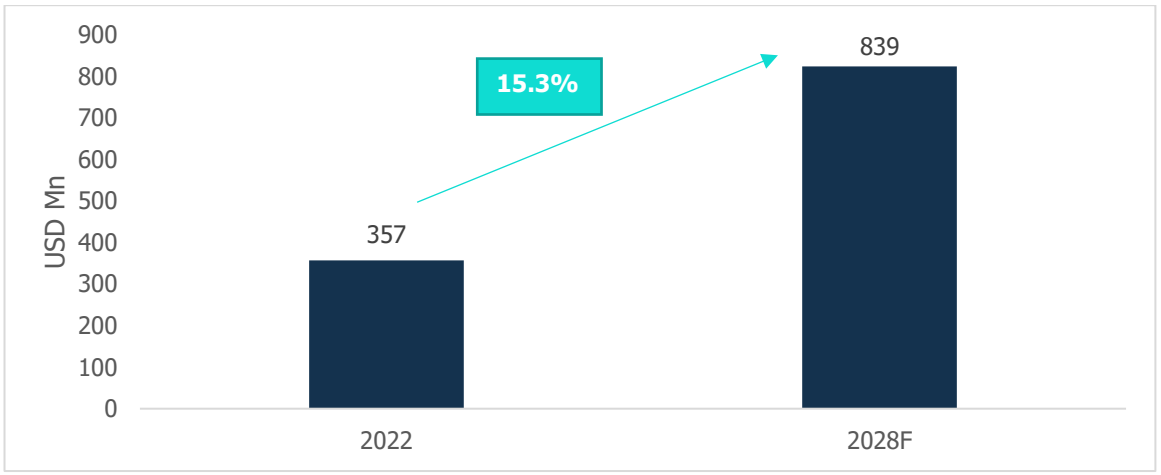


F- Forecasted
Source: Maia Research, CareEdge Research

- **Computing and Data centres**

The opto-semiconductor market for computing and data centre industry is expected to reach USD 839 Mn by 2028 from USD 357 Mn in 2022, growing at CAGR of 15.3%.

Chart 65: Computing and Data centres market value Forecast for 2028

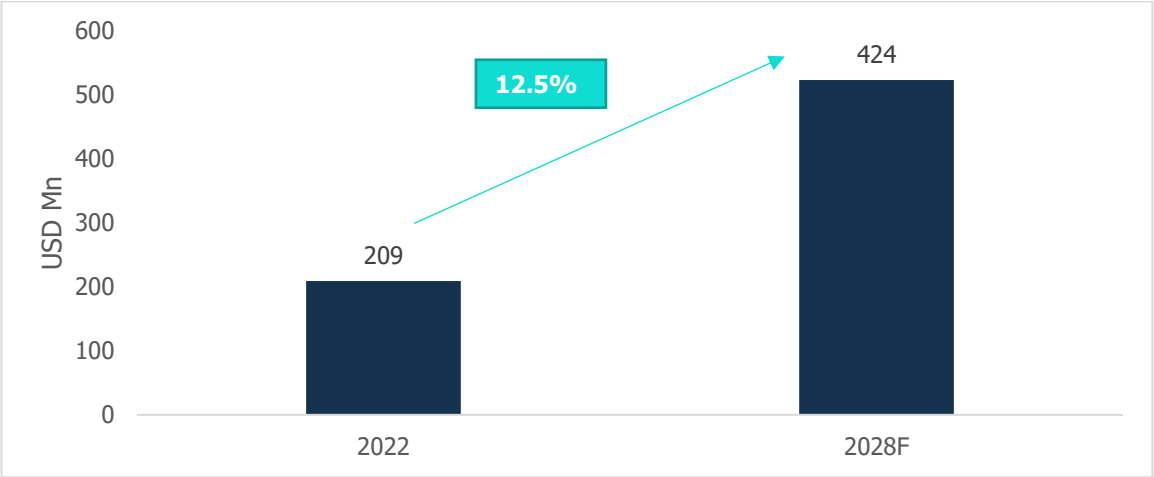


F- Forecasted
Source: Maia Research, CareEdge Research

- **Automobile**

The opto-semiconductor market for automobile industry is expected to reach USD 424 Mn by 2028 from USD 209 Mn in 2022, growing at CAGR of 12.5%.

Chart 66: Automobile market value Forecast for 2028

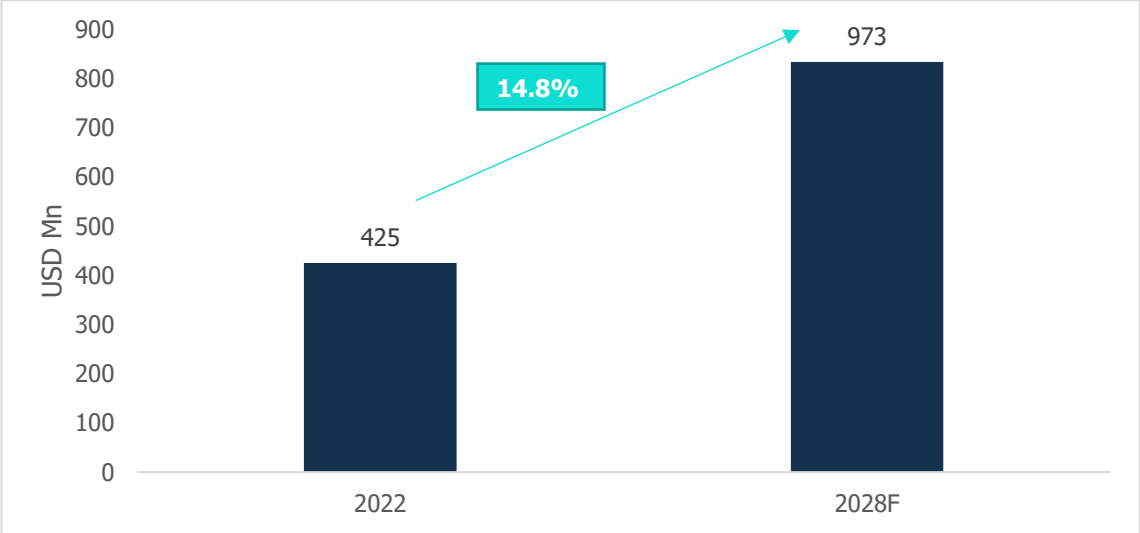


F- Forecasted
Source: Maia Research, CareEdge Research

- **Others**

The market size of opto-semiconductors used in other industries consisting of medical, telecommunication, consumer durables etc. is expected to reach USD 973 Mn by 2028 from USD 425 Mn in 2022, growing at CAGR of 14.8%.

Chart 67: Others market value Forecast for 2028



F- Forecasted
Source: Maia Research, CareEdge Research

CARE Advisory Research & Training Ltd
(Wholly-owned subsidiary of CARE Ratings Ltd.)
A-Wing, 1102-1103, Kanakia Wall Street, Chakala, Andheri-Kurla Road, Andheri East, Mumbai- 400093
Phone: +91-22-68374400

Connect:

About:

CareEdge is a knowledge-based analytical group that aims to provide superior insights based on technology, data analytics and detailed research. CARE Ratings Ltd, the parent company in the group, is one of the leading credit rating agencies in India. Established in 1993, it has a credible track record of rating companies across multiple sectors and has played a pivotal role in developing the corporate debt market in India. The wholly-owned subsidiaries of CARE Ratings are (I) CARE Advisory, Research & Training Ltd, which offers customised advisory services, credible business research and analytical services (II) CARE Risk Solutions Private Ltd, which provides risk management solutions.