

# **Lab-Grown Diamonds: Reshaping the Gemstone Market**

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## **I. INTRODUCTION**

Historically rooted in the demand for natural diamonds, the gemstone industry is experiencing a shift with the rise of lab-grown diamonds. These diamonds, created through advanced techniques like CVD and HPHT, share the same optical and physical characteristics as natural ones but come at a lower cost. This trend is changing traditional perceptions within the industry, influencing price-sensitive and environmentally conscious customer bases, and impacting market dynamics, such as changes in the pricing structure and demand patterns of natural diamonds. These artificial stones have created fierce competition in an already cluttered market.

This paper explores the economic effects of lab-grown diamonds, analyzing factors such as low COGS (cost of goods sold) and manufacturing overheads, market expansion, and supply disruption and how they might be reshaping market structure into two major segments of quality and ethical consideration, making reasonably priced luxury stones more attainable. Lab-grown diamonds may redefine an industry once centred on exclusivity and scarcity, potentially leading to a more sustainable and eco-friendly approach than traditional diamond mining practices. The affordability of these LGDs has appealed to a whole new unexplored market of middle-class customers and first-time buyers looking to make a budget-conscious decision.

### **GROWING DIAMONDS: CVD & HPHT –**

CVD stands for Carbon Vapor Deposition, which is a complex production process involving highly advanced and scientific technology that has been grown and perfected for decades to minimize the cost and maximize the production output.

A fine piece of ‘diamond seed’ is chosen and heated in a sealed chamber at roughly 800 degrees Celsius. The chamber is flooded with carbon-rich gas, causing an ionization process leading to the transformation of pure carbon. Then a connection is formed by these pure molecules with the original seed, inhibiting the growing process. The time required to grow a diamond depends upon the efficiency of the machine and the size of the stone desired. A one-carat diamond can be grown in less than a month, and a smaller diamond can be grown in less than two weeks.

The high Pressure and High Temperature (HPHT) process is a lab procedure in which artificial diamonds are formed by replicating the conditions under which a natural diamond is formed deep within the earth’s crust. As the name suggests, the technique involves putting carbon in the form of graphite under extremely intense temperature and pressure. The seed that is passed through this procedure melts, and a diamond begins to form around it. Then this substance is carefully cooled in special conditions.

The first successful artificial diamond experiment was conducted in 1955. Since then, numerous advancements have been made to ensure that high-quality LGDs can be produced in a cost-efficient manner. The producers follow the traditional strategy of ‘bulk production’ coupled with cutting-edge technology to secure a commercially viable operation without compromising standards.

It is almost impossible to differentiate the physical properties of an LGD from a natural diamond through the naked eye. The four C’s—*Color, Cut, Clarity, and Carat Weight*, which make up the physical characteristics—can be replicated perfectly in an LGD; even the flaws within a real diamond can be mirrored. Similarly, the chemical composition is also identical to the mined ones, both being constituted of pure, unadulterated carbon. The molecular structure of both these diamonds is based on the tetrahedral lattice arrangement of carbon atoms. Thus, there are very few distinguishable indicators that can only be identified by experts in laboratories with specialized equipment.

### **ECONOMIC IMPACT ON THE GEMSTONE INDUSTRY –**

#### ***Cost Structure and Pricing Dynamics –***

The first gem-quality synthetic diamonds were not made until the 1980s. Since only one diamond seed could go through the CVD process at that time, the process was far from being commercially viable and efficient. So, it took tens of thousands of dollars per stone to be manufactured. With technological innovations in this field, according to expert industry analysts, the cost came down to almost 4000 dollars per stone in 2008. After 15 years, the cost is estimated to be a mere 200-300 dollars per stone, as dozens of seeds can go through the CVD process at once.

The gemstone market, which was already highly volatile before the introduction of synthetic diamonds, was yet again jolted by its affordability. The costs associated with mining—exploration, labour, government fees, and royalty expenses—keep the natural diamond prices elevated. On the other hand, the prices of LGDs-per-carat keep on sinking; typically, in today's market, the price of an LGD is 80-95% less than that of a natural diamond. As these stones are physically and optically nondifferentiable, high-priced diamonds face stiff competition from their artificial counterparts.

#### ***Market Expansion and Consumer Behavior –***

Diamonds were a luxury that could be afforded only by a small, well-off part of society; middle-class customers could only dream of attaining it. This traditional perception changed with the boom of LGDs in the gemstone market. CVD diamonds tapped into an unaddressed consumer segment that the original industry could never get hold of. Budget-restrained mainstream end users were instantly attracted by these economically accessible luxury items.

Even the members of upper-class society are tempted to reconsider their decision to purchase real stones, as the CVD diamonds offer the lucrative opportunity of 'Larger Stones for Less.' High-quality and larger artificial stones can be bought either in the same price range or less in comparison to natural diamonds of small size and lower clarity grade. Such features are altering the purchasing behaviours of the loyal real diamond's customer base.

On average, 130 million carats of rough diamonds were mined in the last decade, out of which almost 20% are considered gem quality, meaning almost 25 million carats flooded the market. This means that the supply chain of the gemstone industry is massive, and huge amounts are polished and cut each year, making the industry extremely competitive and saturated. On top of this, 6-7 million carats of CVD diamonds were produced by 2020. But out of these, most were high-grade stones, making the competition more intensive. Thus, the local manufacturers face strong contenders who have already taken 20% of the marketplace share in the gemstone industry.

To survive and flourish amid this revolutionary change, many traditional diamond producers have introduced an LGD jewellery line. In 2018, the De Beers group launched the Lightbox brand to bring forward affordable LGDs. Similarly, Pandora, one of the largest jewellery makers, adopted a 100% LGD use in its jewellery in 2021. Yet many conventional companies refused to embrace synthetic diamonds by promoting and marketing the unique allure of natural diamonds.

### **ETHICAL AND ENVIRONMENTAL CONSIDERATIONS –**

#### ***Environmental Impact Comparison –***

Diamond mining exerts a profound impact on the environment, leading to water contamination, habitat destruction, and significant greenhouse gas emissions. The process consumes vast amounts of water, with up to 7.3 cubic meters per carat used during extraction, while acid mine drainage and the leaching of heavy metals pollute local water supplies. Air pollution from mining machinery and the burning of fossil fuels worsens climate change, with emissions reaching as high as 160 kg of CO<sub>2</sub> per carat. The removal of topsoil and overburden not only degrades land but also contaminates it with chemicals, making it unsuitable for agriculture. Additionally, deforestation and ecosystem disruption displace wildlife like caribou and grizzly bears, putting pressure on biodiversity.

When compared to natural diamonds, LGDs have a lower ecological impact. It involves no habitat destruction, no soil erosion, and less pollution in water and air. However, LGD industries run on a large amount of energy. The source of this energy leaves a large carbon footprint on the environment. A large amount of water is also involved in cooling processes, as well as chemicals like methane, hydrogen, and argon are also involved. These chemicals are generally nontoxic, but their transportation and storage can have an impact on the environment.

In the modern-day world, sustainability is no longer a trend; it's becoming a central part of a consumer's decision-making. A recent study by NielsonIQ found that 78% of US consumers say that a sustainable lifestyle is important to them. The supply chains of these synthetic products are transparent, with no ties to conflict zones or human rights abuses. LGDs are a guilt-free choice for customers wanting to make an ethical choice.

#### ***Reduction of Ethical Concerns –***

By aligning their branding with ethical sourcing, the companies not only fulfill their Corporate Social Responsibility but also attract Gen Z and Millennials who look for sustainable brands. Companies have been leveraging third-party certificates to authenticate the green credentials of LGDs. Advertisements and branding narratives of the retailer often compare the smaller environmental footprints of LGDs with the destructive practices of traditional mining, and some brands highlight how their use of LGDs supports initiatives such as renewable energy projects or reforestation programs.

## **RESHAPING MARKET STRUCTURE AND QUALITY SEGMENTATION –**

### ***Transformation of Industry Segments –***

The perception of Exclusivity and Prestige has been the cornerstone of the value of natural diamonds. The deep-rooted notion of diamonds being a sign of sophistication makes it a wanted luxury amongst the elites. However, the LGD campaigns are focused on changing this common viewpoint, showcasing diamonds being available for all. Through this, the man-made stones take away all the distinctiveness and rarity associated with the natural stones.

“A Diamond is Forever,” the famous advertising slogan of De Beers Group in the 1950s, unimaginably changed the gemstone industry. It was through this marketing campaign that diamonds were publicized as symbols of eternal love and commitment. It instilled a sense of security and romance that comes with owning a diamond. Soon, a marriage proposal was incomplete without a diamond-studded ring, and a wedding was imperfect without diamond jewellery. Such clever marketing inspired generations to come and propelled the gemstone industry into the \$32.6 billion industry it is today. Similarly, “Breakfast at Tiffany’s” and Bulgari’s Serpenti were other successful advertising campaigns introducing creative jewelry lines.

Pandora’s “Diamond for All” is one of the most successful modern-day revenue-generating campaigns in the lab-grown market sector. This move broke the conventional diamond story and transformed Marilyn Monroe’s famous dialogue, “Diamonds are a girl’s Best Friend” to “Diamonds are everyone’s best friend” and “Diamond on ring finger” to “Diamond on all fingers.” This initiative highlighted that these precious stones were not for a few, not for once-in-a-lifetime occasions, but gave personal meaning to each user.

### **CASE STUDY: De Beers Group's Entry into Lab-Grown Diamonds with Lightbox Jewelry –**

De Beers Group has dominated the industry since its foundation in 1888, monopolising almost 80-85% of the rough diamond distribution from the early 1890s till the beginning of the 21st century. Currently, De Beers controls roughly 30% of the supply, owning mines in four different countries: Canada, Botswana, Namibia, and South Africa. Foreseeing the shift in the market dynamics, De Beers launched its jewellery brand in 2018, “Lightbox,” to offer synthetic diamonds. Historically, the company had downplayed the importance of LGDs, emphasising the emotional value of natural diamonds, marking the first time that the industry giant sought to acknowledge synthetic diamonds.

### ***Economic Impact –***

De Beers focused on capturing the segment share by entering the market with competitive pricing. A transparent pricing model was established, clearing all the complexity and ambiguity relating to original diamond pricing.

***A Quarter carat at 200 US Dollars***

***A Half carat at 400 US Dollars***

***A Full carat at 800 US Dollars***

The additional cost of metal on jewellery and setting charges amounted to almost \$100-\$400. Therefore, the total cost for a carat was at \$1200, independent of factors like cut, clarity, and colour. In comparison, other CVD producers positioned the same size diamonds at \$1500-\$4000. This gap was capitalised by the Lightbox brand, which created a new benchmark for affordable diamonds.

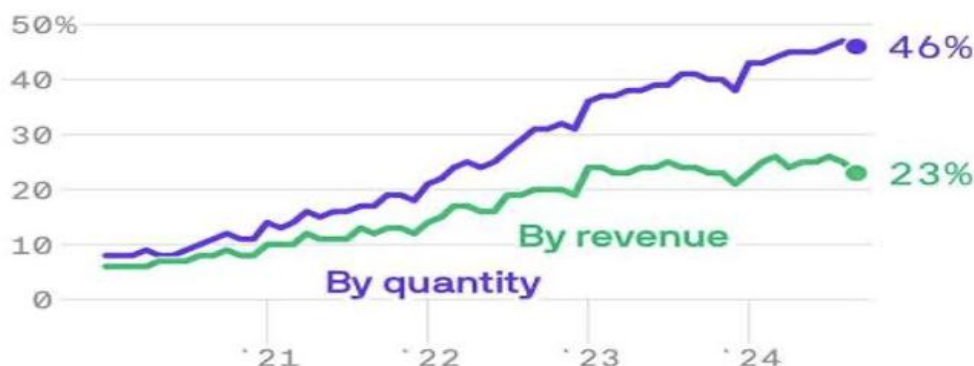
Lightbox’s pricing strategy positioned LGDs as non-competitors of natural diamonds by removing the grading system and certification requirements for synthetic stones, suggesting that these stones have no in-centric value. This supported the new narrative of De Beers that lab diamonds are non-luxury items that were steered clear from traditional associations of natural diamonds like engagements and weddings. Lightbox created a product line that unveiled LGDs as accessories for everyday use, targeting younger generations with their stylish and versatile pieces.

### ***Cost Structure and Pricing Dynamics –***

De Beers leveraged advancements in the Chemical Vapor Deposition strategy and huge capital resources at their disposal to make an impactful entry into the LGD segment. The company invested \$94 million in a state-of-the-art production facility using its subsidiary Element Six near Portland, Oregon. The facility, once fully operational, can produce 500,000-carat stones annually. The high output and a streamlined process will significantly lower the average price per carat. De Beers is involved in each stage of manufacturing and market selling, meaning this facility could procure raw diamond seeds from the company itself and sell the product through the channels of the sales team. With the absence of a grading system, which accounts for a major portion of the overhead expenses, Lightbox gained an edge over its competitors.

**Transformation of Industry Segments –**

To survive in the market, many LGD brands moved away from traditional offerings and aimed at establishing these diamonds as fast fashion. Clear segmentation was made between both by marketing as a luxury and the other as an accessory.



**^ Lab-grown diamonds' share of total U.S. diamond jewellery sales; Monthly January'20 to September'24**

The above graph showcases that LGDs have a continuous rise in volume sales, but the revenue share is not increasing. This proves that consumers have majorly purchased small and fine LGD jewellery pieces.

**LONG-TERM ECONOMIC IMPLICATIONS FOR THE GEMSTONE INDUSTRY –**

**Market Saturation and Price Dynamics –**

There are roughly 1.7 billion carats of diamond reserves in the world right now, and more are yet to be mined. This challenges the notion of diamonds being rare, having almost 120 million mined last year. On top of this, the CVD and HPHT production does not seem to slow down anytime soon, which puts the overall gemstone market at risk of oversaturation. Natural diamond prices have been falling since the start of the Russia-Ukraine War, and so even CVD diamonds have been losing their value over the last few years. However, the technological discoveries in this field indicate that both cost and time taken for production will decrease over the years, with Element Six's facility proving this point. The LGD retailers, depending upon the high margins, may struggle to protect their profitability, which could lead to a price war between producers and retailers. Thus, the possible unlimited production capacity could not only make the competition more cutthroat but would also affect the emotional value associated with a diamond.

As the supply of gemstones has overtaken the demand for them, both the market prices and the in-centric value have been eroding. This has not only affected the profitability but also the sustainability of the business. Oversaturation has created an intense rivalry; companies have heavily invested in marketing and discounts, affecting the margins. Due to reduced profit margins, small retailers are either potentially opting to exit the market or are on the verge of bankruptcy.

A diamond seed is the epicentre of all CVD and HPHT processes, the only raw material in both productions, serving as the starting point. Recent innovations in the seed have resulted in improved seed quality. This, in turn, enhances the overall quality of final products. A high-quality seed results in a defectless diamond with consistent results. Ongoing research in algorithms and artificial intelligence is exploring how to optimise the properties of seeds further. This would give the producers the ability to control the colour and clarity of the diamonds completely, catering to orders that require more personalised demands. If successful, the technology could help minimise wastage and further drive down the production cost.

**FUTURE DIRECTIONS AND AREAS FOR RESEARCH –**

**Economic Modeling and Market Forecasting –**

Robust forecasting methods are essential to capture the multi-layered dynamics of **supply, demand, and pricing** in a market increasingly shaped by **new production technologies** and **evolving consumer sentiment**. By integrating **macroeconomic indicators** such as global income trends and consumer confidence indices alongside **production cost variables** (e.g., energy prices, technological efficiency), researchers can develop **scenario-based models** that predict outcomes under various growth trajectories for both **natural and lab-grown diamonds**. Additionally, **big data analytics** and **AI-driven forecasting** offer the potential to continuously refine projections, adjusting for sudden shifts in consumer behaviour—like spikes in sustainability concerns or new social media

trends—and **regulatory changes** that influence the cost structure of mining or the carbon footprint of lab-based production. Such **holistic models** would not only aid businesses in **strategic pricing** and **inventory management** but also inform policymakers seeking to mitigate the **economic risks** and **social impacts** tied to the industry's rapid transformation.

#### ***In-Depth Consumer Psychology Studies –***

A consumer faces a psychological dilemma while choosing between the two options; some may feel conflicted about buying natural diamonds because of their unethical history, while they struggle to view LGDs as equally valuable due to their synthetic origin. An analysis should be done on how emotional triggers like social norms or environmental awareness impact decision-making. Due to the deep-rooted philosophy of natural diamonds being rare and exclusive, they are perceived to carry higher social status. Research could be done on how societal views evolve as LGDs become more mainstream. Regions having deeply engraved traditions with natural diamonds view it as the only option due to their cultural and emotional instincts.

#### ***Socio-Economic Impact on Mining Communities –***

At present, 40 mines worldwide account for 90% of the world's diamond production, but only 13% of them have a lifespan of more than 30 years and not more than 50 years. Thus, countries like Botswana, Russia, and Congo will soon face a crisis at their hands as their economies are heavily dependent on the diamond mine. With almost no possibility of discovering a mega mine, such countries will have to look for alternative options. More initiatives like the Kimberley Process need to be taken to foster mining with human rights exploitation and ecological disruption. For a more sustainable approach, the economies should compare the effects of underground mining with open-pit and marine mining, as the first one has a lesser impact on the environment. More such strategies should be explored and studied for a change in this industry.

## **II. CONCLUSION**

In conclusion, lab-grown diamonds have emerged as a viable alternative to natural gemstones, propelled by technological breakthroughs in CVD and HPHT processes. Their identical characteristics, coupled with drastically reduced production costs, have attracted budget-conscious consumers who previously viewed diamonds as out of reach. Simultaneously, the ethical and eco-friendly advantages of these stones resonate with buyers seeking a transparent supply chain and a smaller environmental footprint. Established industry leaders, illustrated by De Beers' entry with Lightbox Jewelry, are redefining value propositions and market segmentation—framing synthetic stones as accessible fashion items while preserving natural diamonds' exclusivity.

However, this democratization of diamond ownership raises critical questions about market oversaturation, shifting price dynamics, and the long-term viability of diamond-dependent economies. As new technology reduces production costs further, companies risk a race to the bottom in pricing, potentially diminishing the emotional appeal once tightly bound to diamond rarity. Future research should delve deeper into consumer psychology, economic modelling, and the socio-economic impact on mining communities. Collectively, these developments will influence how natural and lab-grown diamonds coexist, shaping both the business strategies of gemstone producers and the evolving consumer mindset in this rapidly transforming industry.

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