FROST & SULLIVAN

ENVIRONMENTAL IMPACT ANALYSIS

PRODUCTION OF ROUGH DIAMONDS

ENVIRONMENTAL IMPACT ASSESSMENT

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Background

Growing Significance of Environmental Impact

In 2013, Frost & Sullivan had published a report "Grown Diamonds – Shaping Future of Diamond Industry". The report focused on technology impact assessment of the recent enhancements in the innovative technology of growing diamonds and it received significant industry interest.

However, one of the key areas when it comes to diamond industry is the impact that production of diamonds has on the environment. Environmental concerns have been on the forefront of discussions globally across industries and it is an area that no longer can be ignored or put on the back burner. Be it the World Economic Forum or United Nations Climate Summit, terms such as 'green economies' and sustainable development are fast taking center stage. Diamond mining has been one of the industries that have often been brought to light for environmental reasons and a lot of work is being done in the areas of sustainability especially for the environment.

Although, Grown Diamonds have received industry acclaim as a technological innovation, their environmental impact has not been analyzed in detail. This report deals with the environmental impact of diamond production covering in detail analysis for mined as well as Grown Diamonds.

This report is a result of extensive Frost & Sullivan analysis based on industry player interviews, publicly available and data shared in interviews and other available secondary information.

1 Introduction

Environmental Impact for Grown Diamonds

The environmental impact of diamonds is increasingly becoming a key factor in evaluation of diamonds. Even for Mined Diamonds, along with the 4 Cs, i.e. Cut, Clarity, Carat and Color two additional Cs have been added – which are Conscience and Carbon[1]. This illustrates the increasing awareness in buyers about diamond origins and about impact on environment.

A new source of diamonds known as Grown-diamonds or Cultured Diamonds is now available. These diamonds are grown in, what are referred to as, 'diamond-growing greenhouses'[2] above the earth under 'sustainable conditions'. Greenhouses provide a controlled environment for growing diamonds from a diamond seed. These grown-diamonds are physically identical to mined-diamonds and service a much wider range of applications when compared to mined ones. This is because they can be grown in consistent qualities and scalable quantities to meet the unique requirements of varied applications. Though Grown Diamonds have been recognized for their widespread applications and high degree of innovation, it is important to note that the technology involved in growing these diamonds, have a certain level of impact on the environment. This study captures the overall environmental impact of Grown Diamonds right from the preparation of a diamond seed to recovering completely Grown Diamonds from greenhouses, thus ensuring comprehensive measure of the impact.

[1]Source: Andy Martin, Stanford Alumni, April 2010, https://alumni.stanford.edu/get/page/magazine/article/?article_id=30348

[2] Source: Frost and Sullivan Report – Diamond Growing Greenhouses, http://www.frost.com/sublib/display-market-insight.do?id=289565507

Mined diamond production starts with exploration of diamond deposits beneath the surface of earth, followed by a suitable mining method (open-pit, alluvial, marine) based on the location of deposits to extract rough diamonds. Each of these mining methods involves application of heavy machinery, explosives, hydraulic shovels and trucks to extract diamonds from deep below the surface of the earth. This study captures the overall impact of various mining processes to extract each carat of diamond from the earth's surface.

This report also evaluates all the parameters for mined and Grown Diamonds together to provide an overall benchmarking to demonstrate relative impact.

2 Methodology and Scope of Study

Environmental Impact: Methodology

This study uses environmental impact framework to capture the key environmental consequences (positive or negative) of the process of producing a single crystal gem quality rough diamond. This framework primarily looks at a range of parameters related to environmental impact such as carbon emissions, water usage, energy usage, waste generated, land disturbed, etc. in the process of diamond production for both Mined Diamonds as well as Grown Diamonds. The parameters have been rated using a benchmarking framework to illustrate an overall comparative impact.

To ensure completeness and to incorporate the 'humane aspect often associated with such mining activities, the framework used also incorporates certain Human Impact factors. These are some of the key factors (not a comprehensive list) that have a direct impact on the workforce involved in mining activities. This is not inclusive of the other indirect factors such as human capital recruitment, training and development, employee benefits and other associated factors, which are common for both the sources.

The data for these parameters for the mined diamond providers have been gathered from sustainability reports publicly declared by different companies. Out of the key mined diamond producers, De Beers and ALROSA release environmental reports exclusively for their diamond mining operations. Together their production constitutes 67% of the total world mined rough diamonds sales[3]. The Grown Diamond industry does not have publicly available information due to the confidential and proprietary nature of processes involved in their operations. For the purpose of this study three key lab Grown Diamond producers were approached– IIa Technologies, Scio Diamonds and Chatham Diamonds. We have considered data from IIa Technologies, an ISO 14001 certified company, which has been verified as part of our research.

[3] The Global Diamond Report 2013: Bain and Company

After procuring data for key impact parameters, values have been compared for grown and mined diamond producers using a benchmarking framework. This framework uses an average value for the various players in both categories (mined and grown). The benchmarking framework gives a comparative weighted score on each of the impact parameters to provide an overall rating for environmental impact per carat of diamond produced.

The parameters considered for the environmental impact are listed below:

- Total Diamond Production:
  This number represents the total carats of rough diamonds produced in a year. Values considered here are for 2012 production and these are taken as the base for obtaining the per carat values for various environmental parameters

- Land Impact
  - *Land disturbed for mining*:
    This factor measures the overall land disturbed due to mining, exploration and construction operations. For the Grown Diamond producers, this covers the entire area for growth. For both cases, it takes into account land actually disturbed or used for production – not the entire licensed area.
  - *Mineral waste disposed or stored*
    This parameter measures the total mineral waste generated in the process which is either disposed or stored. For mining operations, it includes wastes across hazard classes 1 to 5 (Where Class 1 – extremely hazardous, Class 2 – highly hazardous, Class 3 – moderately hazardous, Class IV – low hazard, Class 5 – practically non-hazardous)[4]

[4] The Russian system of chemicals management - Antonia Reihlen, Juhan Ruut
http://hs.befgroup.net/glossary/texts/The_Russian_system_of_chemicals_management.pdf

- Water Impact:
  - *Water usage*

    This factor measures the total amount of water (potable and non-potable) used in production activities across operations for both grown and Mined Diamonds.

- Air Impact:
  - *Carbon emissions:*

    This takes into account the total carbon emissions in the production process – any greenhouse gases ($C0_2$-equivalent) released. A greenhouse gas (GHG) is any gas in the atmosphere which absorbs and re-emits heat, and thereby keeps the planet's atmosphere warmer than it otherwise would be. An increasing presence of GHGs in the earth's atmosphere leads to an increase in the average temperature globally (Global Warming) which subsequently influences weather patterns. The main GHGs in the Earth's atmosphere are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone.[5]
  - *Energy usage:*

    This parameter covers energy used in the process of production – both direct and indirect. Direct energy consumption refers to the energy used from various fuels directly for the process of mining/growth. Indirect energy used is in the form of electricity generated from various sources e.g. coal fire plants, hydro electric plants etc. used in the mining or growth process. Energy used includes energy from various sources including natural gas, oil, diesel fuel, coal, hydro power, etc.
  - *Sulphur oxide emissions (SOx emissions)*

    These mainly include sulphur dioxide emissions generated in the process of production.
  - *Nitrous oxide emissions (NOx emissions)*

    This factor accounts for mainly nitrogen oxide emissions during the process of mining or lab production of diamonds.

[5] Ecometrica – Paper on Greenhouse Gases, CO2, CO2e, and Carbon: What Do All These Terms Mean?

- Number of environment related incidents
  This constitutes the number of environment related incidents in a year of production. Incidents are mainly pollution-related (spills and releases) and, to a lesser extent, are linked to resource wastage, biodiversity or archaeological impacts. The measurement parameter is based on number of cases of non-compliance with environmental legislations and regulatory requirements.

Human Impact factors considered include Lost Time Injury Frequency Rate (LTIFR), Lost Time Injury Severity Rate (LTISR) and Occupational Disease Rate (ODR). These factors simply illustrate the level of direct impact in terms of accidents, fatalities and occupational diseases for employees involved in diamond production.

3 Environmental Impact Analysis

The environmental impact analysis focuses on key quantifiable areas of impact during the production of rough diamonds. The analysis will be represented for each parameter, highlighting the performance of both mined and Grown Diamonds. This is then followed by a benchmarking framework for an overall comparative analysis. All the environmental impact parameters have been considered on a per carat basis to ensure an equitable comparison of these parameters for grown and Mined Diamonds.

Process for obtaining per carat values

Mined Diamonds

Total Diamond Production: Total diamond production values have been used for the year 2012 based on officially and publicly declared numbers by leading diamond providers across all of their operations combined. Overall for all the parameters, per carat values have been obtained by using below formula:

$$V_D = V_{TD} / N_D.$$

Where,

V_D = Value of parameter per carat of diamond produced,

V_{TD} = Total value of parameter for entire diamond production process for the year,

N_D = Total diamond production in a year (in carats).

Grown Diamonds

Total Diamond Production: Total diamond production values have been used for the year 2012 based on numbers shared by leading Grown Diamond producers in the industry. The Grown Diamond production process involves growing a diamond using a diamond seed – production of these seeds has also been taken into account during the environmental impact calculations as well as overall production numbers. Overall, the parameters for impact have a general base formula that is followed:

$$V_S = V_{TS} / N_S.$$

Where,

V_S = Value of parameter for seed production process per carat of seed,
V_{TS} = Total value of parameter for entire seed production process for the year
N_S = Total carats of seeds produced in a year

Thereafter,

$$V_D = (V_{TD} + (V_S * N_{SD})) / (N_D + N_{SD})$$

Where,
V_D = Value of parameter for per carat of diamond grown,
V_{TD} = Total value of parameter for entire growth process for the year
V_S = Value of parameter for seed growth process per carat of seed (formula above)
N_{SD} = Total carats of seeds used to grow V_{TD} number of diamonds
N_D = Total diamonds grown in a year in carats

The value V_D is then used for each parameter for the Grown Diamonds.

Land Impact

Parameter Name	Mined Diamonds (per carat)	Grown Diamonds (per carat)
Land disturbed for mining/excavation	0.00091 hectares	0.00000071 hectares
Mineral waste disposed/stored	2.63 tonnes	0.0006 tonnes

Mined Diamonds

Excavation and mining activities lead to disturbance of land often leading to biodiversity destruction in the area and making the land unusable for any future uses even after the mining operations are closed. The nature of impact can vary based on the type of mining process being conducted[6]:

Open Pit and Underground mining - In open pit mining, geological structures called Kimberlite pipes (funnel-like tubes of rock which extend far into the depths of the Earth) are mined to extract the diamonds. Because they are so deep and so old (the youngest known Kimberlite pipes are several tens of millions of years old), they are found in the ground often

[6] Diamond Mining and the Environment Fact Sheet – by World Diamond Council

beneath overburden (such as sand and soil). This kind of mining can be done near the surface and up to, and in some instances, over 1km below ground. This means that large quantities of surplus waste rock, sand, soil and processed Kimberlite can accumulate in the immediate vicinity of such areas which need to be managed accordingly and rehabilitated.

Coastal and inland alluvial mining - When diamond deposits are found in coastal areas, mining companies may be required to remove soil and plant life before they begin mining. Mining of beaches and inland alluvial diamond deposits can also require the removal of overburden (such as sand and soil) and the construction of sea-walls. This kind of mining does result in large-scale excavation along coastal areas and modification of the land

Marine mining - Diamond deposits are sometimes found on the seabed, seabed matter needs to be removed from marine diamond mining sites to access the diamonds beneath.

Informal Diamond Digging -Small-scale informal alluvial diamond digging (artisanal diamond mining) is usually undertaken by individuals, families or small groups operating with the simplest equipment on unlicensed and unregulated land. Due to the very nature of this mining, it has little or no regard to the environmental impact or associated impacts on biodiversity and future agricultural land use.

Key diamond manufacturers are committed to carrying out rehabilitation efforts to compensate for the damage caused by mining operations. Such efforts are focused on rehabilitating equal and more area of land as has been disturbed by mining activities. The environmental management process also varies based on type of mining activity. For example in case of Open Pit and underground mining, plans are put in place by the mining companies for the removal, storage and return of topsoil/waste to return the area to its previous state. In case of marine mining to minimize the impact on the environment, the seabed matter is replaced in its original position. Additionally there are projects undertaken to conserve the biodiversity such as ensuring the native plant life around a site is harvested and the seeds replanted. Mining companies work with Millennium Seed Bank (run by The Royal Botanic Gardens at Kew Gardens in London, UK) on a global seed conservation

programme which collects, conserves and researches the world's seed-bearing plants[7]. There are also initiatives such as the Diamond Route which aims to develop mutually beneficial relationships with recognized academic institutions to initiate, coordinate and conduct research which will generate information required for decision support and information directly in line with management objectives for the conservation and sustainable utilization of biodiversity[8]. There are regulations governing the rehabilitation of land post mine closure and big diamond manufacturers outline a detailed mine closure process to covering environmental and social aspects.

However, even though there are strict norms and a lot of activity that is happening to ensure land conservation and preservation of biodiversity, a lot of environmental concerns still remain – especially in the area of mine closure. Many of the famous mines such as the Mirny Mine in Russia (second largest excavated pit on earth) continue to pose hazards. It has been declared a no-fly zone for helicopters and aircrafts owing to the potential currents that can be created due to the size of the open pit. Though the mining areas may see rehabilitation efforts but the land disturbed by mining operations become unusable large pits leaving a permanent dent in the earth's surface.

Grown Diamonds

The land used for production for Grown Diamonds covers both the facilities used in seed production as well facilities employed for diamond growth process. However, these facilities are often located in areas that have negligible impact on environment and have almost no impact on biodiversity in the area of operation. Moreover, these diamond facilities are at a nascent stage of production and are generally not producing to full capacity. This implies a scope of increased production from already existing infrastructure in terms of land and equipment. Generally the machinery and equipment used has a life span of at least 10 years. The land used also encapsulates the area used for administrative and management purposes by the companies. The seed production process is often carried out separately with some of the technologically superior companies having advanced methods to re-use these diamond seeds for multiple cycles of growth.

[7] Diamond Mining and the Environment Fact Sheet – by World Diamond Council
[8] The Diamond Route- Research - http://www.diamondroute.com/research.htm

The mineral waste that is generated is not from the diamond growth process but only from the seed production process. The growth process due its very nature does not have any mineral wastes generated.

Water Impact

Parameter Name	Mined Diamonds (per carat)	Grown Diamonds (per carat)
Water usage	0.48 m3	0.07 m3

Mined Diamonds

This parameter for Mined Diamonds quantifies the total water consumed (potable and non-potable) across mining operations. Considering the volume of usage, mining companies are involved in initiatives to reduce the total fresh water usage in mining activities – both for operations and housing consumption purposes. This is often done by deploying processing plants that are using zero-discharge water supply systems. The use of recycled water in operations often exceeds the use of fresh water in order to ensure minimal discharge and pollution of water bodies.

However, there continues to be an impact on water bodies though it is aimed to be reduced. There is constant discharge of waste water and pollutants in surface water bodies. Additionally there are environmental incidents such as repeated water pollution incidents recorded at Snap Lake Mine in Canada, which involved water with elevated nitrate concentrations seeping from the mine into Snap Lake.

Grown Diamonds

For Grown Diamonds, this parameter covers the entire usage of water in the process of diamond production both for growth process as well as associated seeds growth. It also encapsulates the water usage within office premises. Moreover, there is no detrimental impact associated with water usage such as the discharge of waste water or pollutants in water bodies.

Air Impact

Parameter Name	Mined Diamonds (per carat)	Grown Diamonds (per carat)
Carbon emissions	57000 grams	0.028 grams
Energy usage	538,577,900 Joules	250,750,487 Joules
Sulphur oxide emissions (SOx emissions)	0.014 tonnes	-
Nitrous oxide emissions (NOx emissions)	0.042 tonnes	0.09 mg

Mined Diamonds

The impact on air has been considered only in terms of the harmful emissions caused during the process of production. This covers carbon emission – any greenhouse gases emitted in the process, energy usage – overall energy used from all different sources, sulphur oxide emissions and nitrous oxide emissions. Carbon emissions though a recognized environmental concern have been on the rise for most of the companies. This is primarily due to expansion of operations, greater mining activities and additional water purification methods that are energy-intensive in nature.

Thus, with Mined Diamonds, though companies strive to reduce overall carbon footprint but it remains a challenge with increase in production and implementation of initiatives to handle waste or recycle water. For emission of air pollutants, companies have a consistent focus on trying to reduce the atmospheric pollution – however, due to the very nature of the process the improvements remain in the range of 5-10% each year with intermittent setbacks caused due to new emission sources or other unexpected reasons.

Grown Diamonds

In terms of overall gaseous emissions, the growth process involves little or no emissions of significance. In terms of energy used in the process, the energy used per carat is the only notable value in terms of impact. However, this energy consumption can be any form of energy up to 100% renewable energy. Also, this energy consumption takes into account the energy utilized in the production of seeds used in the growth process as well.

For the emissions, the values considered are the highest possible emissions in the process and not actual values which could be much lower. This is due to the emission level being below the lowest recordable limit of equipment used for such measurements. For example, carbon emissions are recorded as <125 mg/m3 - this being the lowest recordable value of the equipment used for such measurement. Hence, 125 mg is taken as carbon emission value to assume it the highest possible in the range. However, in reality the emissions could be much lower than this number.

Environment Related Incidents

Parameter Name	Mined Diamonds (per year)	Grown Diamonds (per year)
Number of environmental incidents	4.5 incidents	Nil

Mined Diamonds

This parameter covers various cases of breach of environmental legislation or regulatory requirements as recorded by relevant authorities. These incidents though smaller in terms of numbers are often significant in nature of impact created. Mining has a constant impact on its surrounding environment and as time goes on the cumulative impact caused could be irreversible. For example, at Snap Lake and Victor Diamond Mines in Canada, effluents have caused Total Dissolved Solids (TDS) concentrations to increase which results in a significant impact not only on water quality but on marine life as well. This is not limited to the lake where the mines are situated but go on to affect downstream water bodies as well[9]. Mining of diamonds poses a constant threat to the surrounding environment. This change is expected by companies in the industry but the extent of this impact over the life of the mine cannot be determined or completely eliminated.

[9] Environment Canada Technical Report to the Mackenzie Valley Environmental Impact Review http://www.reviewboard.ca/upload/project_document/EA1314-02_EC_Technical_Report.PDF

Grown Diamonds

Growing of diamonds in “Diamonds Greenhouses” is a completely indoor process with infrastructure comparable to semi-conductor industry where chances of any environmental hazard taking place is non-existent. Therefore, there is no recorded environment related incident during production of Grown Diamonds.

4 Human Impact Perspective

Diamond Mining involves working under extremely difficult conditions and is highly manpower intensive. There have been many cases of human rights violation which have been repeatedly voiced by advocacy groups around the world. Working conditions in mines have often been brought to light as being inhumane in many aspects. Complete and accurate statistics are not available because many of these accidents are not reported[10]. There are other issues such as child labor and exploitation of workforce which continue to plague the mined diamond industry. In certain regions, there have also been persistent concerns about the source of diamonds with illegally traded diamonds being used to fund conflict in war-torn areas, particularly in central and western Africa (known as 'conflict' diamonds).

The extent of hazards in diamond mining is quite intense ranging from mine explosions trapping miners and equipment accidents, to workplace induced illnesses such as tuberculosis, permanent hearing loss, slow poisoning and increased cancer risk. Considering these hazards, this section briefly discusses the key direct impact factors from a human perspective. The analysis focuses only on the key factors that are measurable in terms of direct impact; other factors such as social and cultural impact have not been considered.

Key Parameters that have been measured are

- *Lost Time Injury Frequency Rate*
  A lost-time injury is defined as an occurrence that resulted in a fatality, permanent disability or time lost from work of one day/shift or more[11]. This parameter measures the number of lost time injuries multiplied by 200,000 divided by the number of man hours worked. 200,000 hours worked are calculated as 50 work weeks, 40 hours each for 100 employees.

[10] ACP-EU Joint Parliamentary Assembly - http://www.europarl.europa.eu/meetdocs/2009_2014/documents/acp/dt/882/882645/882645en.pdf
[11] Definition of lost time injury – Safe work Australia - http://www.safeworkaustralia.gov.au/sites/swa/statistics/ltifr/pages/lost-time-injury-frequency-rates

- *Lost Time Injury Severity Rate*

  Lost time Injury Severity Rate shows the extent of safety anomalies by revealing how critical the injuries or illnesses caused at workplace are. It is usually calculated as: (Number of work days lost + Light duty days lost) x 200,000 / Total hours worked[12]

- *Occupational Disease Rate*

  Occupational Disease Rate is the rate of occurrence of employee's disease that originated and developed under the influence of a regular and long-term impact of industrial factors attributable to this profession, or a combination of working conditions characteristic only of the specific production. In the case of diamond mining, some of the occupational diseases include tuberculosis, systemic poisoning and even lung cancer.

Table 1 – Human Impact Parameter Values for Mined and Grown Diamonds

Parameter Name	Mined Diamonds (per 100 employees per year)	Grown Diamonds (per year)
Lost Time Injury Frequency Rate	0.115 injuries per 100 employees per year	Nil
Lost Time Injury Severity Rate	8.015 days per 100 employees per year	Nil
Occupational Disease Rate	0.075 incidents per 100 employees per year	Nil

Diamond growing facilities are designed similar to those in the semiconductor industry. The conditions of growth necessitate maintaining a clean room environment. Facilities using CVD equipment, for other than diamond growth are found in developed nations like Singapore, Japan, Taiwan, etc. These countries are members of the International Labor Organization and have formed and enforced standards for Work Health and Safety based on ILO's conventions. The CVD process is a safe process to begin with and has no life hazards or occupational hazards to their employees.

[12] Injury Severity Rate – Safeopedia - http://www.safeopedia.com/definition/392/injury-severity-rate

For Mined Diamonds, though these parameters are being constantly focused on via various initiatives and better compliance to safety regulations; it continues to remain an accepted concern. The key mined diamond companies follow strict policies on controlling injuries and fatalities and constantly strive to achieve zero harm. However, accidents and loss of life incidents continue to shadow the industry.

As for the issue on conflict diamonds, companies in the mined-diamond are bound by the Kimberley Process Certification Scheme developed by the United Nations to combat this issue. The Kimberley Process Certification Scheme (KPCS) imposes extensive requirements (*) on its members to enable them to certify shipments of rough diamonds as 'conflict-free' and prevent conflict diamonds from entering the legitimate trade[13]. However, this process at the onset has been narrow in its focus largely ignoring issues such as worker exploitation and fair play. Moreover, with tracking under the certification scheme limited to rough diamonds the end to end visibility is still an elusive scenario. Though this process intends to target sourcing issues in the jewelry industry, but it has hardly been successful in changing the opaque nature of operations in the industry[14].

[13] Kimberley Process - http://www.kimberleyprocess.com/en/about
[14]The Kimberley Process is a 'perfect cover story' for blood diamonds - http://www.theguardian.com/sustainable-business/diamonds-blood-kimberley-process-mines-ethical

5 Benchmarking Framework

The benchmarking framework provides an overall comparative view of the environmental impact and key aspects of the human impact for Mined Diamonds and Grown Diamonds. Although the parameters considered for evaluating these impacts are quantifiable independently, in order to assess their joint impact, we need to represent them on a common scale. While this common scale may not be able to reflect the absolute magnitude of difference for each parameter, it will represent this difference on a relative scale.

To start with benchmarking, a summary of all parameters is presented in the table below, highlighting the actual values for parameters along with the ratio indicator depicting the gap in the impact caused.

Table 2 – Benchmarking using Actual Values

Parameter Name	Mined Diamonds	Grown Diamonds	Ratio
Land disturbed for mining/excavation/production of rough diamonds	0.00091 hectares	0.0000007 1 hectares	1281:1
Mineral Waste Disposed or Stored	2.63 tonnes	0.0006 tonnes	4383 :1
Water Usage	0.48 m3	0.07 m3	6.9 :1
Air Emissions (Carbon emissions, NOx emissions, SOx emissions)	42071000	0.0289	1.5 billion:1
Energy Usage	538.6 mn Joules	250.8 mn Joules	2.1:1
Number of environmental incidents	4.5	Nil	4.5:0
Lost Time Injury Frequency Rate	0.115 injuries per 100 employees per year	Nil	0.12:0
Lost Time Injury Severity Rate	8.015 days per 100 employees per year	Nil	8.02:0
Occupational Disease Rate	0.075 incidents per 100 employees per year	Nil	0.075:0

The ratio indicator in the above table gives us an idea of the scale of difference in terms of environmental impact. For example, air emissions for a carat of mined diamond are 1.5 billion times that of air emissions for a Grown Diamond.

To further summarize an overall impact, weights were allocated to various parameters and relative ratings were assigned for mined and Grown Diamonds. For this purpose, the Analytic Hierarchy Process (AHP) framework has been used. The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977and 1994). The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives. The pertinent data are derived by using a set of pair wise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency[15].

To better understand the use of AHP framework, the key steps that were carried out have been listed below.

1. The nine key environmental parameters were placed as the column and row headers of a 9X9 matrix and thereafter pair wise comparisons for all possible options.
2. Thereafter the eigenvector for the matrix was calculated by multiplying the elements in each row with each other and then taking the n-th root (where n is the number of elements in the row)
3. Next the numbers were normalized by dividing them with their sum. This gives the final weights for the parameters
4. To check the consistency of the comparisons, two key parameters – Consistency Ratio (CR) and Consistency Index (CI) were calculated.

[15] Using the Analytic Hierarchy Process for Decision Making in Engineering Applications - Inter'l Journal of Industrial Engineering: Applications and Practice, Vol. 2, No. 1, pp. 35-44, 1995;
Analytic Hierarchy Process - Geoff Coyle: Practical Strategy. Open Access Material. AHP;
The Analytic Hierarchy Process – What it is and how it is used – R.W. Saaty.

5. Consistency Index (CI) is calculated by first adding the columns in the judgment matrix and multiply the resulting vector by the vector of priorities (i.e., the approximated eigenvector) obtained in step 2 above. This yields an approximation of the maximum eigenvalue, denoted by λ_{max}. Then, the CI value is calculated by using the formula: $CI = (\lambda_{max} - n)/(n - 1)$.
6. Next, the Consistency Ratio (CR) was obtained by dividing the CI Value by the Random Consistency Index (RCI) as given in table below:

Table 3 - RCI values for different values of n (n is number of parameters)

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

7. Values of Consistency Ratio (CR) lower than 0.1 indicates that the comparisons are consistent and need not be re-evaluated.

Using this framework, the weights obtained for various parameters have been listed below:

Table 4–Benchmarking Framework Parameter Weights

Parameter Name	Weightage
Land disturbed for mining/excavation/production of rough diamonds	21%
Mineral Waste Disposed or Stored	4%
Water Usage	10%
Air Emissions (Carbon emissions, NOx emissions, SOx emissions)	27%
Energy Usage	19%
Number of environment related incidents	5%
Lost Time Injury Frequency Rate	5%
Lost Time Injury Severity Rate	5%
Occupational Disease Rate	5%
Consistency Index	**0.03**
Consistency Ratio	**0.02**

After computing the weights for the parameters, each parameter was then rated based on actual values. For example – hectares of land disturbed by mined v/s Grown Diamonds was used as a basis to evaluate the actual ratings. However, the ratings themselves are not directly proportional to the difference in values, but represent a relative comparison of impact of all the parameters on a common scale.

Based on above benchmarking framework, the comparative benchmarking of Grown Diamonds and Mined Diamonds gives results shown in table below.

Table 5 – Benchmarking Results for Mined and Grown Diamonds

Parameter Name	Impact Ratings	
	Mined Diamonds	Grown Diamonds
Land disturbed for mining/excavation/production of rough diamonds	1.78	0.36
Mineral Waste Disposed or Stored	0.36	0.05
Water Usage	0.90	0.13
Air Emissions (Carbon emissions, NOx emissions, SOx emissions)	2.46	0.27
Energy Usage	1.62	0.23
Number of environmental incidents	0.44	0.02
Lost Time Injury Frequency Rate	0.41	0.05
Lost Time Injury Severity Rate	0.41	0.05
Occupational Disease Rate	0.41	0.05
Overall Comparative Rating (Impact scale of 1-10)	**8.8**	**1.2**

Overall Mined Diamonds represent more than 7 times the level of impact as compared to Grown Diamonds. However, this figure is indicative of relative impact and doesn't reflect actual magnitude of impact as explained earlier. The framework also takes into account key initiatives taken to reverse the environmental impact caused by mining of Diamonds especially in areas of land rehabilitation. Overall mining of Diamonds has a significantly larger environmental and human impact.

6 Building of Sustainable Practices

Sustainability continues to be a key concern for companies in the mined diamond industry. There is a constant focus on building economic, environmental and social aspects of sustainability in their operations. These measures have been briefly covered in the report to highlight the efforts of the mined-diamond companies to compensate for the overall environmental and social impact caused.

The sustainability initiatives across the mined-diamond industry broadly fall under the following categories:

People-Focused:

These initiatives are intended to contribute to the society in which these companies operate. One of the key pillars is often health and medical services. Companies often fund and support hospitals located near the mines and also provide for medical services to their employees. Often there are HIV and AIDS programmes supported by mined diamond companies through social investment funds.

Another key pillar to these sustainability measures is investment in education for the community. They do this by supporting schools and educational programmes in the region. Often specialized training programmes focused on imparting business skills are carried out to develop local talent that can be used in the business later.

Environment-Focused:

Environment is another key area of focus from a sustainability perspective. Companies carry out a range of activities to support the environment such as supporting biodiversity protection programmes and developing programmes to protect endangered wild life in the region. Often biodiversity initiatives also extend to protection and rejuvenation of marine life impacted by marine activities.

The diamond industry has established a number of Nature Reserves, where there are breeding programmes for rare and endangered species which have introduced antelope, disease-free buffalo and white rhino calves into the population. Programs have also been set-up to re-introduce native wildlife, including the African elephant, wild dog and black rhino. Companies in this industry have also worked with the South African National Parks and Peace Parks Foundation to develop a trans-frontier park (a protected conservation area that straddles international boundaries) incorporating large areas of land around the Venetia diamond mine in northern South Africa[16].

Economy-Focused:

The key highlight of diamond mining activities is the economic activity and development it brings to the region. Due to large scale infrastructure being built for diamond mining, it brings in socio-economic development in the region often reflected in the domestic product of the country of operation. Additionally the taxes paid by mining companies constitute a major contribution in the overall tax revenues for the governments in countries of operation.

Additionally, most companies try to prioritize local suppliers over foreign for procurements throughout the value chain. This preferential procurement process ensures growth opportunities for the local suppliers and pushes further economic activity in the region.

There is a focus on ensuring economic sustainability of a region post mining. The economies of regions with large diamond production often become quite dependent on diamond mining and related activities for generating employment and income. In planning for a mine closure, companies are increasingly trying to keep this as a key pillar by supporting the creation of diverse local economies and providing an impetus to non-mining activities and other industries.

[16] Diamond Mining and Environment – DiamondFacts.org by World Diamond Council

7 Analyst Opinion

Environmental Impact: This report has focused on analyzing the environmental impact of single crystal gem quality diamond production for both Grown Diamonds as well as Mined Diamonds and conducting a comparative analysis on key impact parameters. Based on the analysis and related study, in our opinion the following key results emerge from the study:

Intense impact v/s negligible impact

Mined diamonds overall show a much higher environmental impact on all parameters. In fact by the very nature of the processes involved, the intensity of the impact will continue to remain significant. On considering any parameter – be it land displaced for mining activities or emissions generated in the mining process, the impact levels can never reach near-zero or negligible levels. Additionally, there is a constant threat of one-off accidents or unexpected events such as seepage in groundwater that could cause even more high intensity impact. On the other hand, for cultured diamonds even scaling up production is not likely to generate any significant environmental impact.

Challenges in ascertaining impact

Grown Diamonds are produced in a “Greenhouse” setup, one that can grow diamonds by replicating nature-like favorable conditions. This setup is easy to track, monitor and control in terms of environmental, social or any other kind of impact. However in case of Mined Diamonds, the nature of impact is widespread, far reaching and often continues after the mining process is completed. A constant challenge to the industry and regulators remains that of measuring the impact itself. There are areas of impact that may still not be recorded due to differing laws and regulations across countries. Also the measured impact is often only direct in nature and it is very difficult to quantify and evaluate the indirect nature of impact. Moreover, there could be elements in the value chain where the impact is indirect and not being tracked.

Impact cannot be reversed

Any kind of environmental impact that is generated can be managed or controlled or measures can be taken to reverse it to the best extent possible. However, completely restoring the environment to a state of no impact is highly improbable if not impossible, especially if the impact is continuous rather than one time. This means that though mined diamond producers consistently strive to balance or negate environmental impact caused, it will always remain a challenge to completely reverse the damage caused.

Human Impact Perspective: The human impact perspective is a more easily visible component as compared to environmental impact. Loss of life incidents, occupational diseases or any other associated human harm caused in the process has been a key area of concern for mined-diamond producers. Overall, in our opinion some key points that can be highlighted are:

Exposure to potential hazard

Due to the nature of the mining process, a certain set of employees will continue to face exposure to potential hazards with a risk of fatality involved. Even as mined-diamond companies strive for zero harm, uncertainty continues to pose a challenge causing curable and incurable injuries to employees each year.

Challenge in ascertaining social Impact

Mined diamond production has a far reaching social impact – due to rehabilitation, environmental changes, economic change, etc. The nature of this impact is quite difficult to ascertain completely – be it positive or negative. Some of the scenarios such as conflict diamonds may be under the surface for years before they are addressed.

The Last Word

Growing diamonds causes significantly less environmental impact as compared to mining diamonds .This report has attempted to identify key environmental and human factors that can be quantified in order to equitably compare the two. Diamond is a unique material where, after decades of research, a grown choice is available that gives consumers and trade members an opportunity to provide an eco-friendly and human friendly diamond.

For the future, sustainability will be very important for the diamond industry as it will impact our natural environment and based on consumer trends will impact buying patterns as well. Growing Diamonds gives the Diamond Industry a distinct advantage over any other luxury commodity. It can now cater to a growing segment of consumers to whom eco and human friendly are important attributes. Diamonds, like any other resource, is finite and diamond growing provides a new sustainable source of raw material that will have a far smaller environmental impact.

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