Ecological Comparison of Synthetic versus Mined Diamonds

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Abstract

The energy usage and emissions in mined versus lab-created diamonds was evaluated, based on industrial data, since these two factors are often a general indicator of environmental impact that can be useful in product comparisons. Depending on the process and the location of the mine, the data can be highly divergent and cannot be used as a singular measure of environmental impact. There is a need to develop life cycle analysis techniques from industrial ecology to conduct a detailed comparison of synthetic versus mined stones.

Introduction

Synthetic diamonds have come of age, and the year 2010 will be remembered as a landmark year in this regard since for the first time labs of the Gemological Institute of America (GIA) in New York were able to grade a gem quality near-colorless synthetic diamond (formed by chemical vapor deposition) , greater than 1 carat. The history of synthetic diamonds at the industrial level, goes back to patents for super-abrasives at General Electric can be traced back to several decades (Hazen, 1996). However, gem quality synthetic diamonds have only risen to prominence in the last decade with the rise of a few key companies who are taking on this growing market in concert with boutique jewelry brands. As jewelers consider environmental social responsibility more seriously in marketing their gemstone products, energy usage in mined versus lab-created gems can be an important factor in determining comparative environmental impact. The Kimberley Process for certifying conflict-free diamonds has also raised the prominence of consumer interest in the origin of diamonds and the production process (Smillie, 2010).

While there has been a general reluctance on the part of gemologists to embrace synthetic stones, since 2006 the GIA has been grading synthetic diamonds and has profile some of the research in this regard as well (Shigley, 2006). The comparison of mined diamonds with synthetic diamonds in terms of environmental and social concerns has risen to prominence within the last five years as public concerns over mining have gained increasing strength. However, the techniques for comparing synthetic and mined diamonds in terms of environmental impacts have yet to be fully refined.

There are two key methods for making synthetic diamonds – High-Pressure-High Temperature (HPHT) process and Chemical Vapor Deposition (CVD). The former is better suited for industrial diamond production and involves converting graphite (an allotrope of carbon as well) into a diamond, while the latter (involving gas to solid conversion on a substrate) is more suitable for gemstone manufacturing. However, both are used in gem production by various manufacturers. HPHT has the advantage of using fewer ingredients and is usually faster. Chemical vapor deposition is a method of growing diamond from a hydrocarbon gas mixture, similar to how diamonds are formed in astronomical processes. The advantages of CVD diamond growth include the ability to grow diamonds over larger areas and on various substrates, and a more refined control over the chemical impurities and thus properties of the diamond produced. Furthermore, unlike HPHT, CVD process does not require extreme pressures (Ferro, 2002).

Methods

This communiqué provides a synthesis of data provided by mines on energy consumption at diamond mines in comparison with diamond synthesis energy usage provided by manufacturers. Secondary data from earlier studies is also provided. However, the main purpose of this article to critique the paucity of data available for ecological impact comparison and to highlight the need for life cycle analysis in this regard.

An estimate of energy usage in the production of a synthetic gem versus a mined gem can provide a rough comparison of the relative impacts of both kinds. The problem remains that there is tremendous variation in energy usage among mines, depending on where they are located.

The Argyle mine in Western Australia, for example, has a fuel usage of 4.2 pounds per carat, whereas the Diavik mine in northern Canada uses fuel at 11.5 pounds per carat, thanks to its harsh climatic conditions as well as the geological location of ore bodies. Furthermore, Diavik has to produce its own electricity onsite from diesel fuel, because it is so far from the usual sources of power. The energy usage for synthetic diamonds on a per carat basis may still be considerably greater than for mined diamonds because of issues of scale.[1]

Energy use is again highly variable, however, depending on the site. The average energy needed to produce a medium- quality synthetic diamond of three to seven carats at Apollo Diamonds is around 28 kilowatt- hours (kWh) per carat for a diamond which can usually take 2 to four weeks to be deposited for marketable sizes. In contrast, the Argyle diamond mine uses on average 7.5 kilowatt- hours per carat, while Diavik uses 66.3 kilowatt- hours per carat. De Beers, which has a diversified mining portfolio that also includes marine diamond mining off the Skeleton Coast of Namibia, consumes an average of 80.3 kilowatt- hours per carat.[2]

A company which is using HPHT to produce gem-quality diamonds is Florida-based Gemesis. The process which they have perfected takes four days to grow a diamond of an average 2.5 carats. A microscopic diamond grain is placed in a 4,000-pound machine about the size of a kitchen range. Temperatures as high as 2,700 degrees Fahrenheit, and hundreds of thousands of pounds of pressure are used to grow the diamond nugget, one atom at a time. It uses about 20 kilowatt-hours per carat.

[1] Data collected by Mary Ackley, research assistant to the author. Diavik reported fuel consumption in liters per carat, so an average density for diesel fuel of 850 grams per liter was used for conversions.

[2] De Beers data reported by the company in its public reports in different units and converted by the author: 0.289 gigajoules per carat, converted to kilowatt- hours per carat. All other data collected by the author directly from contacts with sources at companies.

Concerns with earlier studies

Comparisons carried out by Martin (2010) reveal that if we are to use another corollary for environmental impact, greenhouse gas emissions, and convert those to a consumer-friendly metric of miles drive in an average car we get a stark comparison. Comparing the reported emissions from the Ekati mine versus the Gemesis process, Martin calculated that 483 million miles worth of auto emissions can be saved if the annual production of Ekati was switched to synthetic diamonds. This calculation was based on simple arithmetic which involved translating the energy usage data into the average greenhouse gas emissions from the energy source of the mine. This emissions number was compared with the greenhouse gas emissions of an average fuel economy car in the United States (25 miles per gallon).

However, this data may be misleading because we do not have any accurate metrics of the raw material used to make the synthetic diamonds. For proprietary reasons, the kinds of materials added to each process have not been revealed. For HPHT processes, various forms of transition metal catalysts are required to make the process efficient. Similar metallic constituents may also be required for CVD in the form of the substrate used for the deposition process to occur (Choudhary and Bellare, 2000). If relatively abundant and multi-use metals such as iron or copper are used, then the ecological impact will figure less prominently in the analysis, since they would be mined for other uses as well. On the other hand if the proprietary process involves using rare earth metals which might not have as many other uses and where economies of scale would develop for this particular industry as synthetic diamonds become more popular, then the mining impacts of those metals themselves would figure prominently. For example, platinum, which was historically a metal used for jewelry is now primarily mined for use in catalytic converters in cars (60% by volume, is used for non-jewelry related catalytic purposes).[3] The equipment durability is also a major unknown in this process. How often parts need to be replaced and what each of those constituents are made of would need to be figured into the calculations. Furthermore, since the use of gem-quality diamonds is inextricably linked to jewelry consumption, an accurate impact assessment needs to consider the impact of

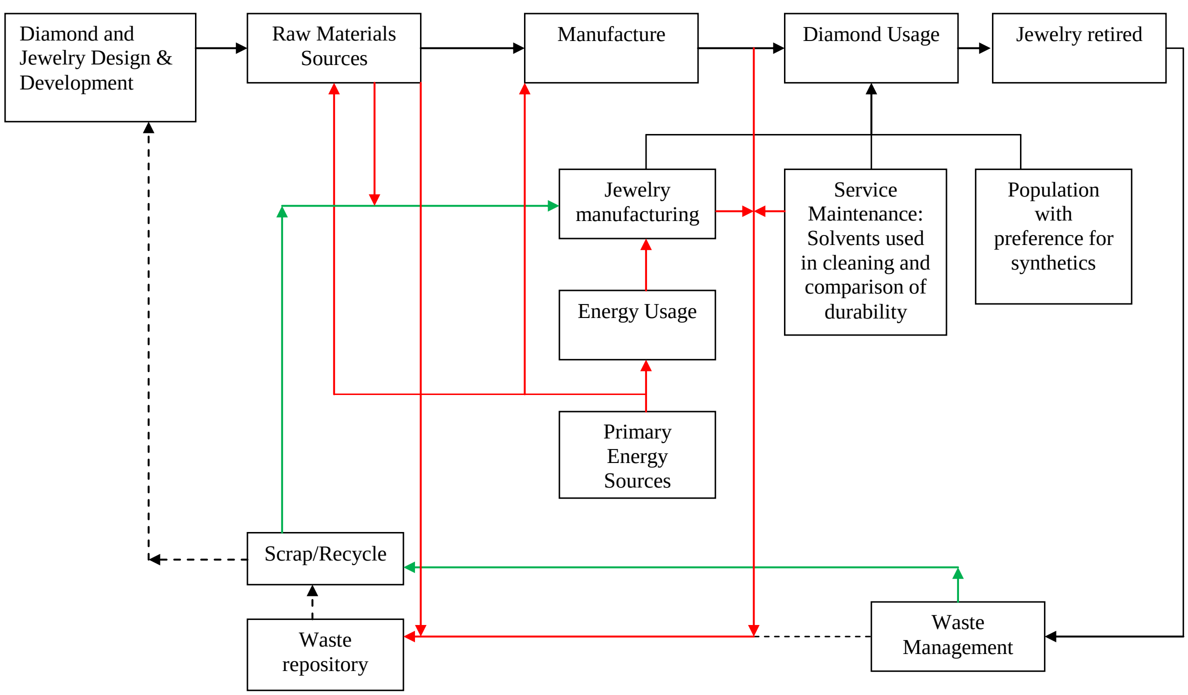
[3] International Platinum Groups Metals Association, www.ipa-news.com 2010

jewelry processing as well. This may remain constant in a comparison between synthetic and mind diamonds but in some cases, if synthetics are less expensive and a lower quality metal is used, there may be less incentives for take care and "save" the jewelry. Thus less expensive jewelry often ends up in the waste stream far more quickly than more expensive jewelry, even if it is just as durable.

Life Cycle Analysis

Given these aforementioned deficiencies in comparisons being offered, a more comprehensive analytical tool is needed. The emerging field of industrial ecology offers us the tool of "life cycle assessment" which can provide such a holistic analysis (Hendrickson, 2004; Horne et al, 2009). Figure 1 shows a general schematic of a life cycle assessment which would need to be carried out to have a comprehensive analysis of ecological impacts pertaining to synthetic diamonds.

Figure 1: Life Cycle Analysis Framework for synthetic diamonds



An important feature of this market is that the usual circularity of a life cycle assessment is broken in the context of gem-quality diamonds since there is not as much incentive to recycle but rather to accumulate. Thus, waste management is less of a concern with the product itself but the wastes that may accumulate along the processing need to be considered. The diagram shows the potential areas for accruing more negative impacts with red arrows and the areas where leveraging positive impacts by green arrows. The diamond industry will need to develop clear metrics along these various paths of the life cycle to get meaningful comparisons of impact.

Conclusion:

Consumer preferences for mined versus synthetic diamonds may change due to price, scarcity and perceptions of environmental and social impact. Social indicators in terms of conflict and livelihood potential for various kinds of diamond sources may be easier to determine than the environmental indicators of comparative impact. Although energy usage comparisons can provide a rough estimate of comparative impact, they vary considerably by the geographic location of the mine versus the kind of process used in the diamond synthesis. Life Cycle Analysis can provide a more comprehensive evaluation and should be actively pursued as means of accounting for ecological impacts.

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References

Choudhary, D, and J Bellare. 2000. Manufacture of gem quality diamonds: a review. *Cermacis International,* 26, no. 1: 73-85.

Ferro, Sergio. 2002. Synthesis of diamond. *Journal of Materials Chemistry* 12, no. 10 (9): 2843-2855.

Field, J. E. 1992. *Properties of Natural and Synthetic Diamond*. Academic Press.

Hazen, Robert M. 1999. *The Diamond Makers*. Revised. Cambridge University Press, August 28.

Hendrickson, Chris T., Dr. Lester B. Lave PhD, and H. Scott Matthews. 2006. *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach*. RFF Press, April 19.

Horne, Ralph, Tim Grant, and Karli Verghese. 2009. *Life Cycle Assessment: Principles, Practice and Prospects*. CSIRO Publishing, June.

Martin, Andrew 2010. "Q&A: Synthetic versus Mined Diamonds." *Stanford Alumni Magazine,* February.

Shigley, James E. 2008. *Gems & Gemology in Review: Synthetic Diamonds*. Gemological Institute of America, April 3.

Smillie, Ian. 2010. *Blood on the Stone: Greed, Corruption and War in the Global Diamond Trade*. First. Anthem Press, August 1.