



# BLAAUWBANK

GOLD MINING IMPACT ASSESSMENT

ELEMENT UNITED | [HTTPS://ELEMENTUNITED.COM](https://elementunited.com)





# SUMMARY

## Element's report\* provides

African Gold Artisanal Mining Environmental Impact Assessment for Blaauwbank Mine, South Africa

## Element's leadership

Scott Lomu • President

Over 25 years in the precious elements industry.  
A passionate voice for responsible, humane mining.  
Leading the digital gold rush to provide access for all.

David Kasteler • COO

FINSERV entrepreneur who has built multiple high-value organizations.  
Consulted for or represented over \$750M in mining assets.

## Element's purpose

Element is bringing the blockchain + metaverse revolution to gold and precious elements. We digitize precious elements by building digital economies on top of mines.

Why is it important to slow mining?

- End Hoarding
- Reduce CO<sub>2</sub> Emissions
- End Exploitation
- Corruption
- Free Access for All

\*Document information provided by a 3rd party. Data not verified by Element United.

# EXECUTIVE SUMMARY

This report was produced independently and resulted from Element United's ambition to mine differently, support future generations by protecting the planet, and reclaim land once destroyed by harmful practices, ultimately giving power back to the people most hurt by industrial mining.

Research is intended to give the reader of this report an overview of artisan gold mined near Magaliesburg, South Africa, and its impact on the sustainability framework surrounding underground mining. People, planet, and prosperity underline this report's themes, starting with the introduction of gold mining in the late 19<sup>th</sup> century, Johannesburg, South Africa, and its lifecycle.

We discuss gold as part of the materials economy, from extraction to processing and refining, followed by gold's variable three-tiered market structure of jewelry, investment, and industrial use. Each link in the chain contains some reference to the frameworks measuring the impact on the South African people, the land surrounding the claim, and opportunities provided by the mine—or their absence.

In brief, this report introduces the people most impacted by the mine, paleo archaeology considerations, and environmental impacts. References and keywords are indicated in **bold** for the reader of this report to continue independent research on the rich history of the South African region and its people.

Closing this report, we offer carbon reduction data related to Scopes 1, 2, and 3. Our team conducted no on-site testing. Instead, we used prevailing and relevant data, professional SME sources to include the airline industry, product retailers, and academics, as well as EPA calculators, and reliable, annotated, public, educational, and generally accepted resources to form estimations or conclusions.

Research notes and resources are provided at the end of this document.



# INTRODUCTION

South Africa (SA) mining<sup>1</sup> boomed after diamonds were discovered on a riverbed near Johannesburg in 1867; the Witwatersrand Gold Rush followed in 1886. Since then, more than 41,000 tons of gold have been mined in the Archaean Witwatersrand Basin (\$2.2 trillion), with more gold found in smaller, outlying areas. Much of South Africa's gold mining is primarily mined underground, as with the Mponeng gold mine, where gold deposits can run as deep as 3.84km or 2.87 mi.

One miner's income supports between 5 and 10 dependents.

Several factors contribute to market instability<sup>2</sup>, including South Africa's overall market size, whereas technological advancements and shifting job categories impact salaries, quality of living, and job security. Of the 93,000+ jobs in gold mining alone, it is estimated that one income supports between 5 and 10 dependents.

## BLAAUWBANK MINE<sup>3</sup>

Blaauwbank mine's first production of gold in 1913 amounted to 7200 pounds. (That would amount to \$6.5 million with today's gold market value when gasoline was 7 cents a gallon, bread 5 cents a loaf, and home was around \$2750.00.) As it is the oldest gold mine in the Gauteng province, tours are offered.

Geologist Al Joubert (2020) analyzed the alluvial and quartz reef gold found in the Blaauwbank mine, located 70 km NW of Johannesburg in the Witwatersburg Gold Basin. He observed additional metals, including nickel, copper, silver, and iron.

With a newly implemented technology, miners can blast three times daily to achieve 100% retrieval. After, the Blaauwbank mine itself will smelt the gold using green cyanidation, refine it, and supply its own energy using a Belgian solar energy grid. Any electricity balance can provide for the nearby town of Magaliesburg at discounted margins.

<sup>1</sup> Miner, H. (2018, September 23). *History of gold mining in South Africa*. How to Find Gold Nuggets. <https://howtofindgoldnuggets.com/history-gold-mining-south-africa/>

<sup>2</sup> Minerals Council South Africa. (n.d.). *Mining in SA*. <https://www.mineralscouncil.org.za/sa-mining>

<sup>3</sup> Show Caves. (n.d.). *Blaauwbank Historic Gold Mine*. Show Caves. <https://www.showcaves.com/english/za/mines/Blaauwbank.html>

The mine's location is in the "second thrust zone diagonal to the Rietfontein fault<sup>4</sup>." (This is a significant time in plate tectonic history when Australia, Africa, and others were linked end-to-end as one supercontinent.) Joubert's (2020) Initial asset valuation was conducted for a 5-year cash flow period (60 months) but had an extended valuation to condense 17 years into seven using more effective methods and a Scientific Innovations and Design (SID) team.

Such statistics from the SA Department of Mineral Resources and the US Geological Survey indicate that South Africa has more than US \$2.5 trillion in gold ore reserves.

— University of the Witwatersrand (ca. 2016)

## SA GOLD MARKET



PC: GETTY IMAGES

Now, "employee numbers have fallen 41%, and production has dropped by 67%" due to suspicion, hostility, and lacking progressive mining tactics—something for which the Blaauwbank mining actively sought remedy. Of the top ten physically producing gold mines (China, Russia, Australia, U.S., Canada, Ghana, Brazil, Uzbekistan, Mexico, and Indonesia), the final five nations do not retain enough gold internally for top listing on gold reserves. Note that South African gold is not on this list, though earlier estimations had placed it in the top 5 global producers of gold<sup>5</sup>.

<sup>4</sup> Joubert, A. (2020, September 24). *Technical Report On The Mineral Resource Assessment Of The Protea Gold Project, Gauteng, South Africa*. SID Scientific Innovations and Design (Pty) Ltd, South Africa

<sup>5</sup> Pocket Guide to South Africa (2012/13): Mineral Resources.

<http://www.gcis.gov.za/sites/www.gcis.gov.za/files/docs/resourcecentre/pocketguide/2012/15%20Mineral%20Resources.pdf>



Still, Blaauwbank and other artisanal or small-scale mining (ASM) operations generate 2500-3000 metric tons of gold worldwide, occupying three markets: jewelry, investments, and industrial, including electronics, medical, and dental applications. And controlling its value is the London Bullion Market, which trades in veritable secrecy, setting the price of one troy ounce of gold for the entire global economy.

### **Jewelry (48%)<sup>6</sup>**

Gold is a prestige item in many parts of the world, providing generational wealth. The most significant portion of gold is made into jewelry. Other and various cultures equate gold with religious symbology, some with power or office.

### **Investments (31%)**

As stocks plummeted during the COVID-19 pandemic, so did gold, highlighting gold's volatile trading market alongside the most recent pandemic. But with economic shutdowns, gold investments quickly rebounded, climbing above \$2000 for one troy ounce. Gold has since devalued, but it often fluctuates due to the breadth of the market it occupies. These quick, abrupt changes to valuation reveal how gold markets adjust to global goods trading—or a lack thereof.

### **Industrial (electronics, dental, medical) (21%)**

Gold is a noncorrosive conductor, working efficiently with lower voltages. Made less expensive, producers electroplate (bind) palladium with gold using  $\text{CuSO}_4$  (Copper Sulfate), which is highly toxic to humans, and our environment.



# UNDERGROUND MINING

## THE UNDERGROUND MINING LIFECYCLE<sup>7</sup>

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<sup>6</sup> Author notes: Some estimations suggest greater percentages for jewelry, and lower percentages for investments and industrial gold markets.

<sup>7</sup> Minerals Council South Africa. (n.d.). *The Gold Mining Lifecycle*. Mining for schools. <https://www.miningforschools.co.za/lets-explore/gold/the-gold-mining-life-cycle>



PC: WALDO SWIEGERS/BLOOMBERG

|                             |  |
|-----------------------------|--|
| <b>Exploration</b>          | Geochemical and geophysical techniques identify gold ore deposits; scientists drill for locations and quality of ore; SA governments regulate permitting for exploration and water use.  |
| <b>Construction</b>         | Site development includes shafts infrastructure, mining, milling, processing, and workshops  |
| <b>Going Underground</b>    | Mine cages in the vertical shaft transport miners, mining equipment & materials  |
| <b>Planning</b>             | Access to the gold-bearing reef requires tunnel development for earth and stope face openings  |
| <b>Drilling</b>             | Drilling begins after reefs are exposed in preparation for blasting.   |
| <b>Blasting and Hauling</b> | Rock is broken, the ore is collected (aka vamping & sweeping), and then hoisted through the shaft to the surface via conveyors and underground lifts   |
| <b>Transporting</b>         | Rock is conveyed to milling circuits, where the gold from the ore extraction process begins  |
| <b>Crushing</b>             | Crushers and grinding mills make smaller rocks smaller until it becomes sand   |
| <b>Processing</b>           | Cyanide and other chemicals combine with the grains of sand to extract the gold, separating it from carbon and leaving a slurry of tailings from which to extract additional elements such as remaining gold, uranium, and sulfides. |

Of Gauteng:

“Companies are also fearful of being caught between the state and its citizens or cast as a scapegoat for government inability to provide for its people.” —Vandome

|                                   |   |
|-----------------------------------|---|
| <b>Smelting</b>                   | Gold is heated to liquid form and poured into doré bars   |
| <b>Refining</b>                   | Doré bars are sent for further refining to 99.5% or 99.99% purity bullion   |
| <b>Closure and Rehabilitation</b> | Mine exhaustion (all ore is gone) is followed by rehabilitation of the site to its preexisting condition or another defined use |

Though an exceptional amount of energy is consumed upstream during the extraction and mineral processing stage, retrieving refined grains of gold, the grade or size of gold extracted has little impact on the refinery process downstream<sup>8</sup>.

## REFINING GOLD

Refining<sup>9</sup> requires hydrometallurgy and pyrometallurgy over several steps to separate, concentrate, and purify the gold.

- ✓ **Heap Leaching** (hydrometallurgy) removes gold from ore deposits and tailings with a cyanide concentration in water (spills cause environmental disasters in water supplies and watersheds alike).
- ✓ **Additional solutions** are used to separate and concentrate the gold, with electrolysis and other precipitation methods to return the gold to metallic form. After which, electrolysis plates out the gold. Copper, zinc, and other chemical compounds are likely employed in this process.
- ✓ **Pyrometallurgy** requires thermal treatment such as calcination, oxidation roasting, reactive gas refining, reduction melting, and fusion melting, stripping out silver and other metal alloys.

\*Blaauwbank’s gold target market requires on-site **green cyanidation**<sup>10</sup> to process the raw ore

Due to carbon (pollution) taxation, refineries now require carbon reduction emissions at the extraction point, refusing to work with some mining companies<sup>11</sup>. Moving away from diesel and toward renewables may advance carbon reduction efforts. Still, ecological damage, rampant corruption, and social constructs often fail to be mitigated, let alone addressed. In South Africa, communities may not understand that they have litigation options to address the pollution. Still, agencies exist to hold

<sup>8</sup> Norgate, T. and Haque, N. *Energy and greenhouse gas impacts of mining and mineral processing operations*. Journal of Cleaner Production, Volume 18, Issue 3, 2010, Pages 266-274, ISSN 0959-6526, <https://doi.org/10.1016/j.jclepro.2009.09.020>.

<sup>9</sup> TheIPMI. (2015). *Gold Refining*. YouTube. <https://www.youtube.com/watch?v=SfQxEKVx4xw>.

<sup>10</sup> *ACS Sustainable Chem. Eng.* 2021, 9, 1, 236–245 Publication Date: December 29, 2020 <https://doi.org/10.1021/acssuschemeng.0c06904>

<sup>11</sup> *Mining.com*. (n.d.). <https://www.mining.com/>



accountable mining companies that fail to support a mine's closure<sup>12</sup>.

Additionally, few refineries are willing to advertise the value or impact of harmful environmental “waste liquids” created by hydrometallurgy—fewer still conduct due diligence to identify human rights abuses<sup>13</sup>, conflict, or corrupt and ecological destruction<sup>14</sup>. That said, South Africa requires all mining companies to remediate pollution and rehabilitate the land impacted by the mines.



PC: MICHELE SPATARI/AGENCE FRANCE-PRESSE/GETTY IMAGES

## SUSTAINABILITY NEXUS

The sustainability nexus of people, planet, and prosperity are increasingly under pressure in South Africa from multiple sides, including governments that fail to protect the people and advocate on behalf of their citizens, as well as companies taking advantage of communities through pollution, displacement, or lack of pipeline advancements. Notable impacts for each of their pillars are:

<sup>12</sup> Global Data. (n.d.). *South Africa: Five largest gold mines in 2021*. Global Data. <https://www.globaldata.com/data-insights/mining/south-africa--five-largest-gold-mines-in-2090873/>

<sup>13</sup> Dunnebacke, A., & Barry, A. (2014, February 25). *Revealed: Why Dubai's First Conflict Gold Audit never saw the light of day*. Global Witness. <https://www.globalwitness.org/en/archive/revealed-why-dubais-first-conflict-gold-audit-never-saw-light-day/>

<sup>14</sup> Global Witness. (2020, July). *Beneath the shine: A tale of two gold refiners*. Global Witness. <https://www.globalwitness.org/en/campaigns/conflict-minerals/beneath-shine-tale-two-gold-refiners/>

## People<sup>1516171819202122</sup>.

- ✓ Mining statistics show human rights abuses, violence
- ✓ Companies illegally assault and detain protesters, causing social turmoil, protests
- ✓ Secondary and tertiary impacts result in property damage, robberies, looting of mines, residential spaces
- ✓ People experience increased Tuberculosis rates from silica dust
- ✓ People experience increased HIV rates
- ✓ Other physical impacts include fatigue from harsh working conditions and work overload
- ✓ Work results in poor nutrition, increased alcohol use
- ✓ People face production pressure even with resource limitations
- ✓ Communities experience environmental degradation-caused death from tailings dam instability, collapse
- ✓ Government chooses bottom-line protection over community safety; mining agencies choose the same
- ✓ Paleo-archaeology and paleo-anthropology limitations in the Cradle of Mankind

## Planet

- ✓ Freshwater and food source depletion affects biodiversity
- ✓ Cyanide and heavy water residue poison plants, animals
- ✓ Water pollution and water insecurity impact flora, fauna
- ✓ Soil pollution and food insecurity impact biodiversity, ecological health
- ✓ Poor mine waste management seeps into the soil, water systems
- ✓ Companies don't protect ecosystems, even with guidelines, and illegal mining operations, especially
- ✓ Smelting uses green cyanide, which further degrades the environment

## Prosperity

- ✓ Little to no educational opportunities exist to increase the skill set and earning potential of workers, and no options once mines shutter

<sup>15</sup> Earthworks. (2022, June 3). *Ahafo Gold Mine implicated in human rights abuses and irresponsible practices*. Earthworks. [https://earthworks.org/blog/wassa\\_ghana/](https://earthworks.org/blog/wassa_ghana/)

<sup>16</sup> Swart, A. (2022, January 18). *Violent crime, rising costs put South Africa's mining industry in a deep hole*. The Wall Street Journal. <https://www.wsj.com/articles/violent-crime-rising-costs-put-south-africas-mining-industry-in-a-deep-hole-11642517454>

<sup>17</sup> Vandome, Christopher. (2021, August 19). *Violence adds to uncertainty for South African mining*. Chatham House – International Affairs Think Tank.

<https://www.chathamhouse.org/2021/08/violence-adds-uncertainty-south-africas-mining>

<sup>18</sup> World Bank. (n.d.). *The Southern Africa TB in the mining sector initiative*. <https://www.worldbank.org/en/programs/the-southern-africa-tb-in-the-mining-sector-initiative>

<sup>19</sup> Pelders J, Nelson G. Contributors to Fatigue of Mine Workers in the South African Gold and Platinum Sector. *Saf Health Work*. 2019 Jun;10(2):188-195. doi: 10.1016/j.shaw.2018.12.002. Epub 2018 Dec 17. PMID: 31297281; PMCID: PMC6598803.

<sup>20</sup> Africa, S. S. (n.d.). *Improving lives through data ecosystems*. Statistics South Africa. <https://www.statssa.gov.za/?p=14682>

<sup>21</sup> McLaughlin, B. (2022, September 13). *South Africa tailings failure shows need for stronger guidelines*. Earthworks. <https://earthworks.org/releases/south-africa-tailings-failure-shows-need-for-stronger-guidelines/>

<sup>22</sup> John Francis Thackeray, « A History of Research on Human Evolution in South Africa from 1924 to 2016 », *Revue de primatologie* [En ligne], 7 | 2016, mis en ligne le 29 janvier 2017, consulté le 08 novembre 2022. URL : <http://journals.openedition.org/primatologie/2708> ; DOI : <https://doi.org/10.4000/primatologie.2708>

- ✓ Locals receive a lack of adequate compensation for displacement, sometimes nothing at all
- ✓ Companies bulldoze village schools to make way for mines as a show of force, intimidation, and violence against children
- ✓ One occurrence displaced 95000 subsistence farmers, which led to an absence of income with limited skillsets
- ✓ Contractor positions increase while worker positions decrease – a double-edged sword

## MINING REHABILITATION RULES AND HURDLES<sup>23</sup>

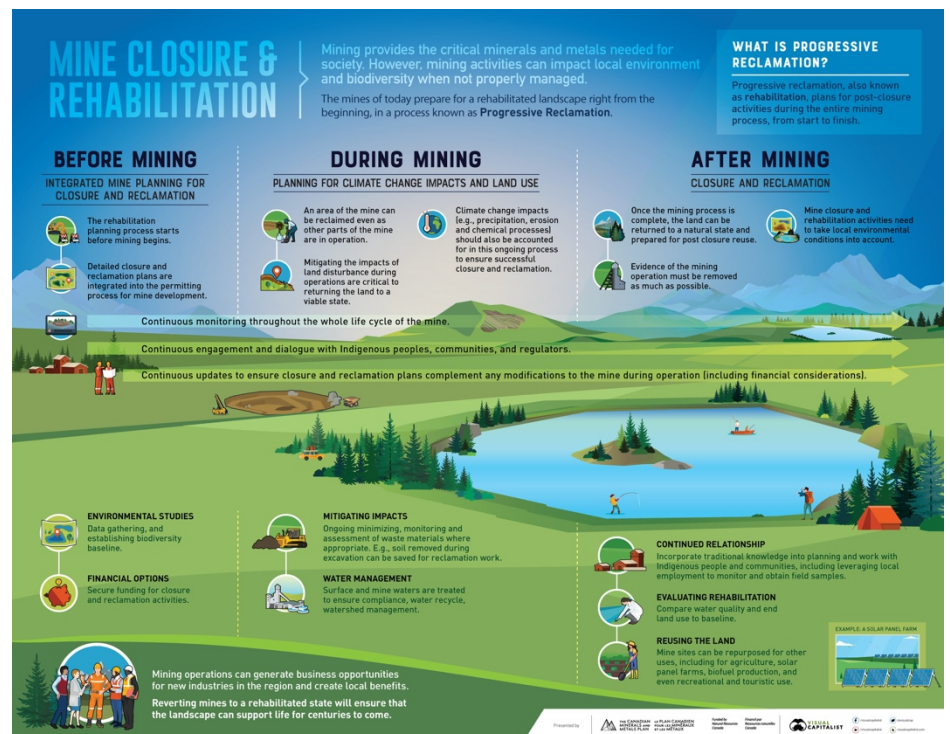


IMAGE CREDIT: NATURAL RESOURCES CANADA

New South African laws require mining companies to fund land rehabilitation when mines close. Funds must be used – at the end and not ongoing. If the company is unwilling to use the set-aside funds, the government can take over the money and project. However, until recently, several issues prevented mining companies from owning responsibility for land degradation.

### Previous legacy issues

A new concept of “rehabilitation.”

Multiple mines to rehabilitate

<sup>23</sup> Dambe, T. (2020, August 11). *ESG implications of Mine Rehabilitation in Africa*. DLA Piper Africa. <https://www.dlapiper.com/en/morocco/insights/publications/2020/08/africa-connected-issue-4/5mine-rehabilitation-in-africa/>

No provisions were made  
Locals previously shouldered the cost and burden

**Past governance**

No prevailing laws  
No regulations  
Corrupt officials

**Historically inadequate legislation**

No rules or regulations to address issues  
Lack of benefit for all stakeholders  
Backfill costs are not an option for some

## HUMAN RIGHTS ISSUES<sup>24</sup>

What became known as “forever mines” were those left derelict or ownerless, forcing South Africans to foot the cost of rehabilitation. So far, the government has rehabilitated 267 ownerless or derelict mines – a bill footed by the people. Human rights organizations have been watching these unrehabilitated mines, fighting on behalf of the locals impacted by their abandonment. Accidents, even death, have occurred at these mines, some by drowning in flooded mine shafts and others where pollution is a looming factor.

In some cases, artisanal miners, known as *Zama Zamas* (isiZulu for “try and try again”), will attempt to use underground mines to create a living. Without proper health and safety protection, some face peril. Of the 312 known deaths in these tunnels, most were by tunnel collapse, toxic air inhalation, and even explosives incidents. (See link below for impact video from locals.)

Secondary impacts include freshwater pollution, soil erosion, and additional pollution. Spontaneous underground fires will burn for a decade or more, emitting harmful gasses into the air for locals to breathe. Mines will sink, slide, and cause above-ground soil disturbances, becoming acres of potential harm to playing children and farming communities.

Notably, illegal mines often lack care or concern for water rights, water security, or water health, leaving communities with poisoned groundwater and flooding. The clean-up cost can weigh heavily on South African infrastructure, where the government chooses to mitigate the issues or abandon it to avoid paying hefty sums to rehabilitate the mines.

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<sup>24</sup> Human Rights Watch. (2022, July 14). *The Forever Mines*. <https://www.hrw.org/report/2022/07/05/forever-mines/perpetual-rights-risks-unrehabilitated-coal-mines-south-africa>



# GOLD EMISSIONS CLASSIFICATIONS<sup>25</sup>

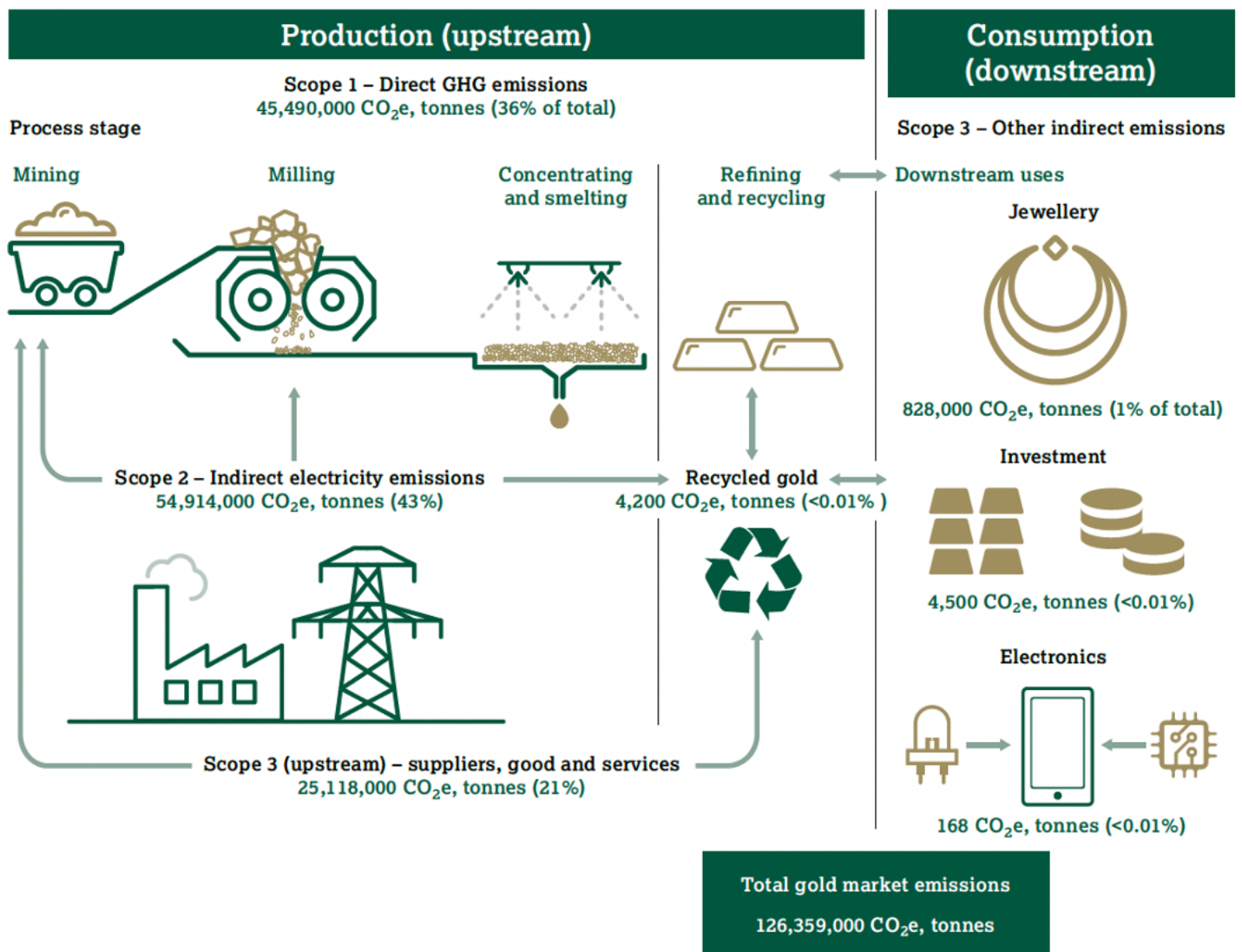


Figure 1 WORLD GOLD COUNCIL VIA KITCO NEWS

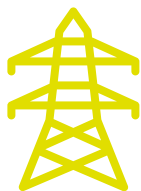
<sup>25</sup> Greenhouse Gas Protocol. (n.d.). <https://ghgprotocol.org/>

## MEASURE: LIFETIME



### SCOPE 1

- 792,656 LIFETIME MtC



### SCOPE 2

- 946,783 LIFETIME MtC



### SCOPE 3

- 462,382 LIFETIME MtC

# CARBON VALUE LIFETIME\*

## SCOPE 1

CAT 330B  
KOMATSU D65-E  
REFUELING TRUCKS  
ADDITIONAL MINING EQUIPMENT, I.E., GENERATOR  
MILLING MACHINES, CONVEYORS  
REFINING AND SMELTING  
BIOMASS DISTURBANCES

## SCOPE 2

INDIRECT ELECTRICITY CONSUMED

## SCOPE 3

(UPSTREAM)

SUPPLIERS  
GOODS  
SERVICES

(DOWNSTREAM - CONSUMPTION)

JEWELRY  
INVESTMENT  
INDUSTRIAL (TECH, DENTAL, MEDICAL)

BLAAUWBANK TOTAL  
CARBON PRODUCTION OVER  
A LIFETIME:

# 2,201,821 MtC

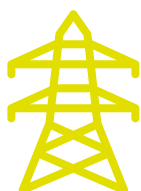
\* See legal notes, pg. 19

MEASURE:  
HALTED  
AFTER  
PROVEN  
SEASONS



SCOPE 1

- 634,124 MtC AS A SHUTTERED MINE



SCOPE 2

- 757,426 MtC AS A SHUTTERED MINE



SCOPE 3

- 369,905 MtC AS A SHUTTERED MINE

# CARBON VALUE MINE HALTED\*

## SCOPE 1

CAT 330B  
KOMATSU D65-E  
REFUELING TRUCKS  
ADDITIONAL MINING EQUIPMENT, I.E., GENERATOR  
MILLING MACHINES, CONVEYORS  
REFINING AND SMELTING  
BIOMASS DISTURBANCES

## SCOPE 2

INDIRECT ELECTRICITY

## SCOPE 3

(UPSTREAM)

SUPPLIERS  
GOODS  
SERVICES

(DOWNSTREAM - CONSUMPTION)

JEWELRY  
INVESTMENT  
INDUSTRIAL (TECH, DENTAL, MEDICAL)

BLAAUWBANK FULL CARBON  
SAVINGS AFTER  
SHUTTERING MINE

1,761,456 MtC

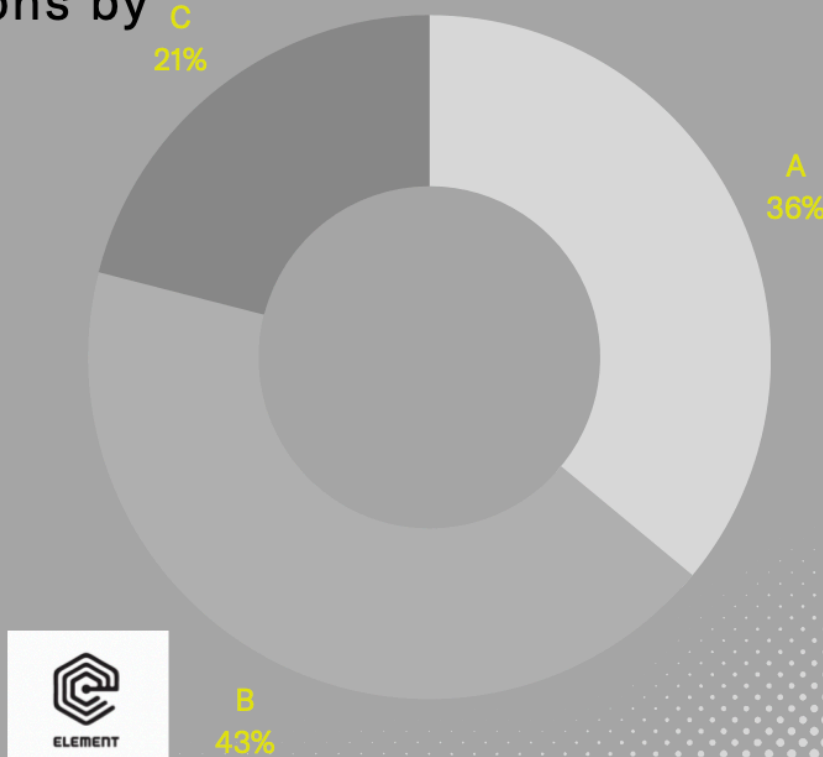
\* See legal notes, pg. 19

EST. **314,545** METRIC  
TONS OF CARBON  
PRODUCED ANNUALLY<sup>26</sup>

## Blaauwbank Gold Mining

Mine produces 314,545  
annual MtC - Emissions by  
activity

- A Scope 1 - Mining
- B Scope 2 - Electricity
- C Scope 3 - Consumption

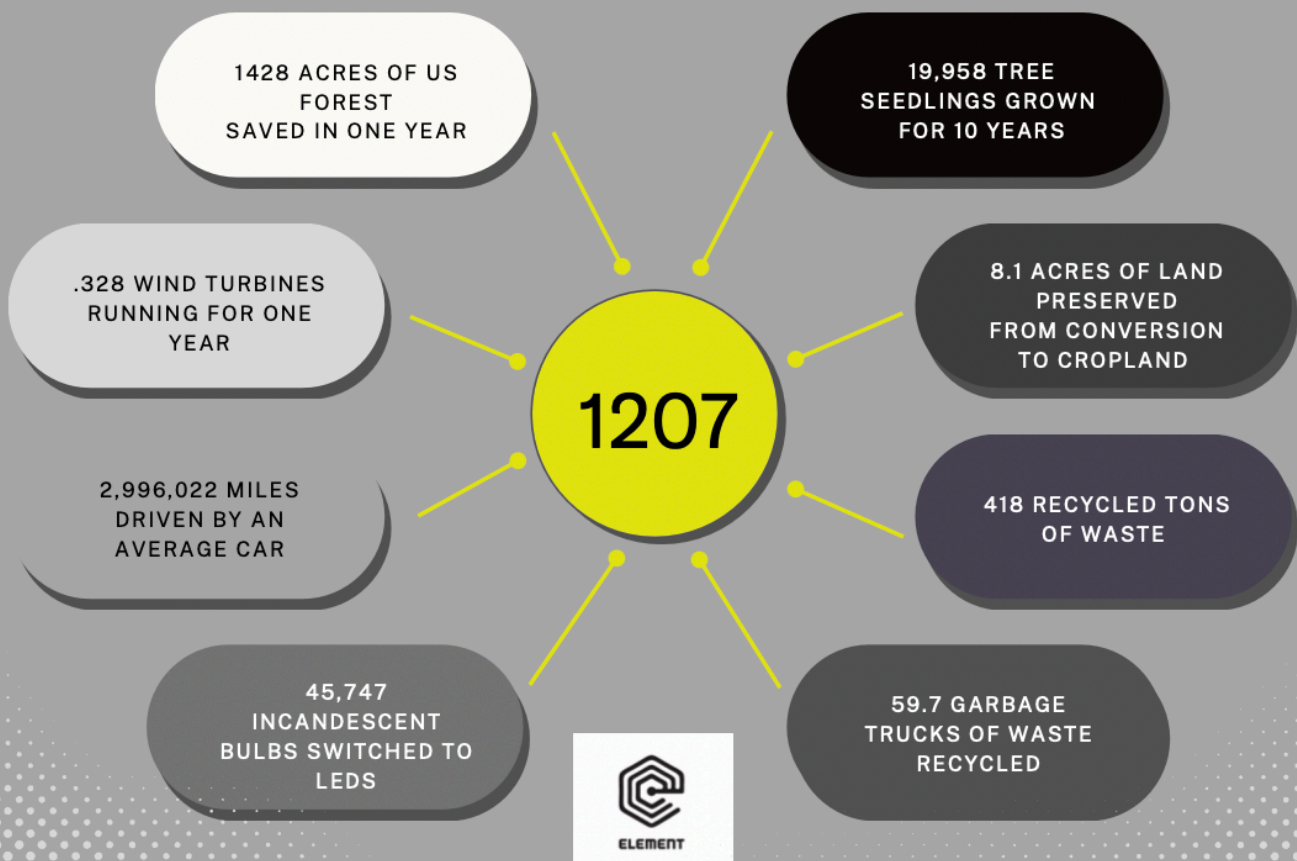


<sup>26</sup> See legal notes, pg. 19



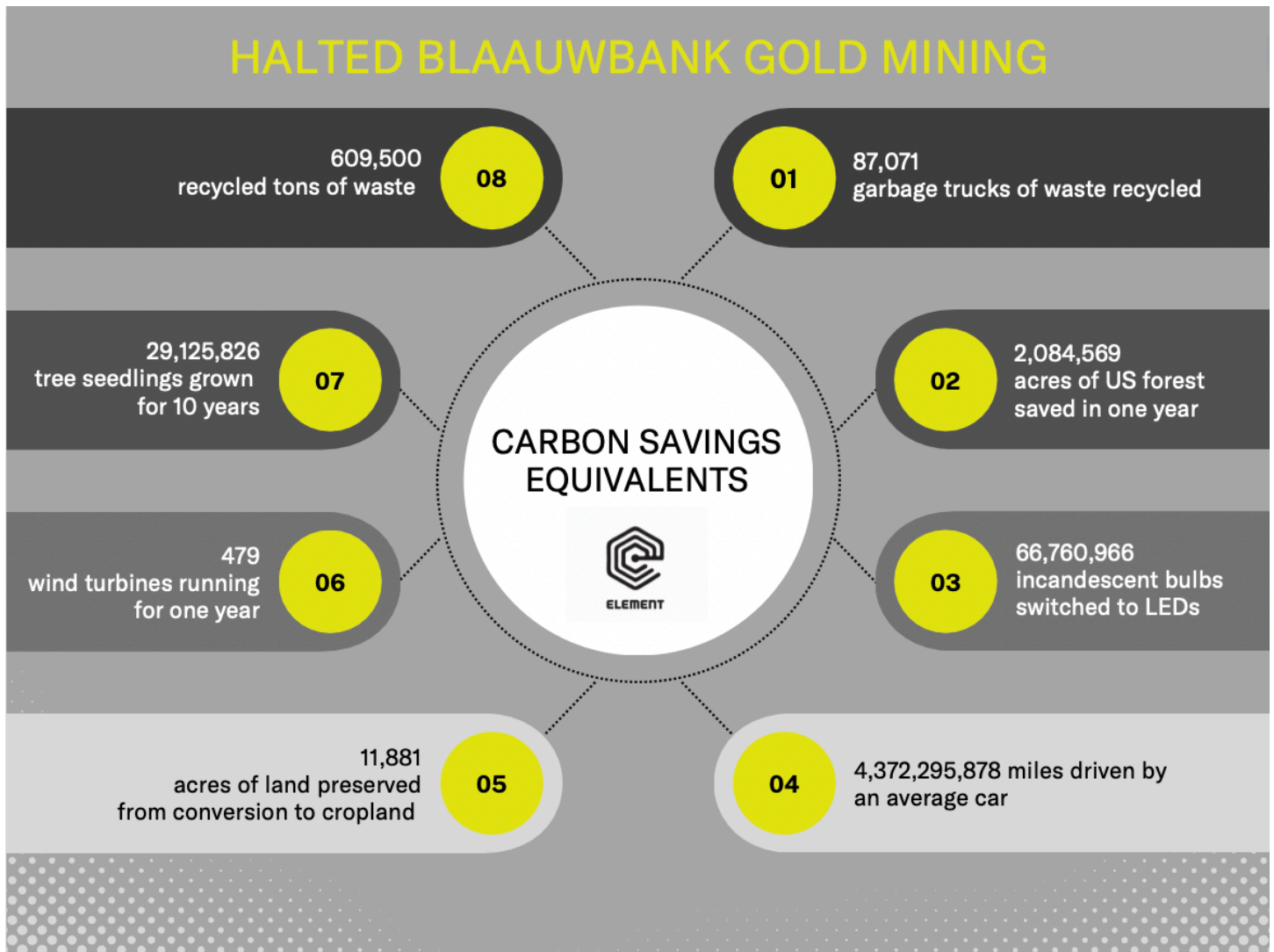
# EST. 1207 METRIC TONS CARBON SAVED DAILY<sup>27</sup>

## BLAAUWBANK GOLD MINE - DAILY GREENHOUSE GAS EQUIVALENCIES



<sup>27</sup> See legal notes, pg. 19

# SHUTTERED QUARRY SAVES EST. 1,761,456 METRIC TONS CARBON<sup>28</sup>



<sup>28</sup> See legal notes, pg. 19

# LEGAL NOTES

## FORWARD-LOOKING STATEMENT

This presentation may contain forward-looking statements that involve substantial risks and uncertainties. Forward-looking statements discuss plans, strategies, prospects, and expectations concerning the business, operations, markets, risks, and other similar matters. There may be events in the future that we cannot accurately predict or control. Any forward-looking statement in this presentation speaks only as of the date on which it is made. Factors or events that could cause our results to differ may emerge from time to time, and it is impossible for us to predict all of them. We do not plan to update or revise publicly any forward-looking statements except as required by law.

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**ELEMENT**



# RESEARCH NOTES

## SITE DETERMINATION

Data was collected from the Mining Technical and Progress reports in making site determinations

## LAND SIZE AND MINING OPERATION

Calculations based on the Mining Technical report

Significant annual potential for mining equals 365 days, 24/7

Maximum 10 tons carrying weight per load via trucking @ rate of 6.5 mpg fuel burn.

## PREVAILING DATA

Mining, extraction, refining, prime retrieval rate, and all other environmental estimations used prevailing data and gathered evidence from the U.S., Canadian, and other global agencies offering similar or general findings.

## SME FINDINGS

SMEs were contacted for earth mover equipment fuel capacity verification - Local Caterpillar Dealership

Diesel carbon burn was calculated at 22.38 lbs. carbon/gal. Aviation SME contacted (Pilot – Captain David Parlotz)

## OWNER'S MANUALS

Where such data as a fuel burn on Caterpillars and Komatsu earth moving machinery was unavailable, a general estimation of 7.5 diesel gallons per hour was used given retrievable owner's manuals.

## CALCULATIONS

Maximum machine/vehicle daily run times measured @ 12 hours.

Diesel carbon burn was calculated at 22.38 lbs. carbon/gal.

Online conversion calculators use for kWh to CO<sub>2</sub>, Btu to kWh, Lbs. to MtC

E.P.A. calculators were employed for compiling all other CO<sub>2</sub> scopes.



# RESOURCES

*ACS Sustainable Chem. Eng.* 2021, 9, 1, 236–245 Publication Date: December 29, 2020  
<https://doi.org/10.1021/acssuschemeng.0c06904>

Africa, S. S. (n.d.). *Improving lives through data ecosystems*. Statistics South Africa. <https://www.statssa.gov.za/?p=14682>

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<https://www.dlapiper.com/en/morocco/insights/publications/2020/08/africa-connected-issue-4/5mine-rehabilitation-in-africa/>

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