MINISTRY OF NATURAL RESOURCES
CO-OPERATIVE REPUBLIC OF GUYANA

POLICY BRIEF #1

Bauxite mining in Guyana: future economic pillar?

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A. SCOPE

This policy brief is the first in the series of seven such documents. It seeks to forecast the trend of Guyana's bauxite industry in the coming decades by assessing the implications for the industry of (i) the world market outlook for bauxite and its value-added products, (ii) the country's comparative advantages and disadvantages as a destination for investments in bauxite mining, and (iii) corporate strategies of bauxite companies. The brief then outlines policy recommendations.

B. BACKGROUND

(i) Policy context: In 2016, Guyana commemorated 100 years of bauxite mining under the theme "Is Bauxite going to be an economic pillar for Guyana for the next centennial?" This policy brief and the others in the series take up this question.

As an initial matter, to achieve conceptual harmony, the brief fits the question in the theme within the National Mineral Sector Policy Framework and Actions- 2019-

2029 (NMSPFA), prepared for the Ministry of Natural Resources in December 2018. Policies #3 and #4 of the NMSPFA and their strategic goals fully enfold the bauxite-as-a-future-economic-pillar question.

NMSPFA policies	Relevant strategic goals
#3: Expanding mining's contribution to national and sub-national economic development.	SG 8: to increase tax revenues from mining operations without adversely affecting the investment climate and the cost of doing business in Guyana.[1] SG 9: to increase revenue collection by more effective monitoring of mineral payloads.[2] SG 11: To expand the number of businesses and economic activities that serve the mining sector (backward linkages) and that use the outputs of mining (forward linkages).[3] SG 13: To expand the impact of CSR of large mining enterprises on community and regional development.[4] SG 14: To more directly distribute government proceeds of mining to regions and communities that host and hosted mining operations.[5]
#4: Raising the attractiveness and competitiveness of Guyana's mineral sector for large investments.	SG 18: To enhance the availability, quality and dissemination of suitable data on Guyana's geology and mineral potential (inclusive of coastal and shallow marine areas) in line with the information needs of mining investors.[6] SG 19: To continuously improve Guyana's mining investment climate by minimizing hard risks and risks perception from the perspective of investors, especially large ones.[7]

Further, the NMSPFA advises in Context #5 (Role of mining in the national economy) that Guyana's mineral-based economy will remain vulnerable should:

[1] Addressed in Policy Brief #4 in this series

[2] Addressed in Policy Brief #5 in this series.

[3] Addressed in Policy Brief #2 in this series.

[4] Addressed in Policy Brief #6 in this series.

[5] Addressed in Policy Brief #6 in this series.

[6] Addressed in Policy Brief #3 in this series.

[7] Addressed in Policy Brief #4 in this series.

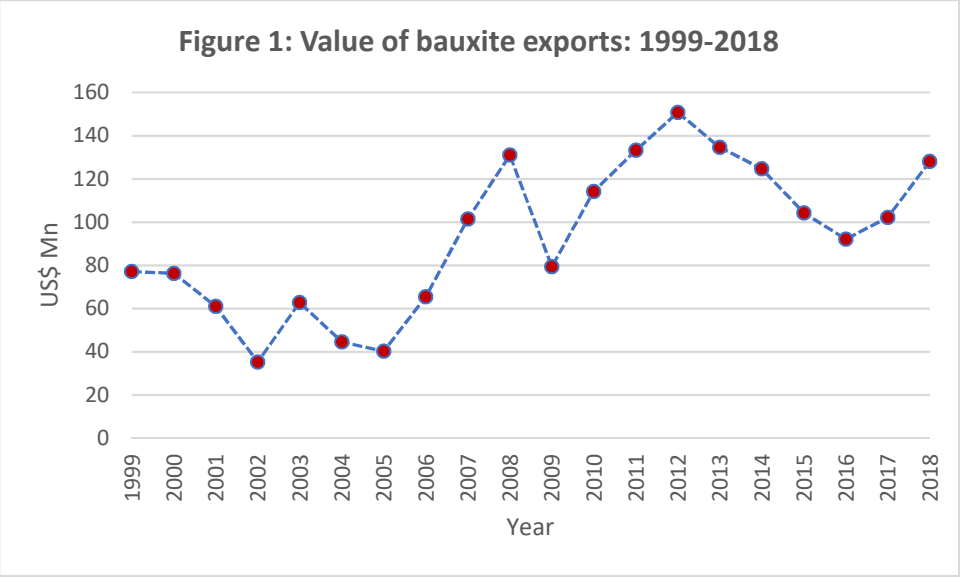
- the mining base remain narrow and mineral-based forward linkages are underdeveloped;
- new discoveries remain few and far apart due to low investment in exploration or over-rated mineral endowment;
- mining revenues not be judiciously employed for sustainable development.

Accordingly, we see the bauxite industry not a stand-alone pillar but as part of the foundation of a multi-faceted and expanding national mineral sector.

Guyana's share of world bauxite output
1925 - 1929
11.3%
1935 - 1939
8.8%
1945 - 1949
21.5%
1955 - 1959
9.6%
1965 - 1969
5.0%
1985 - 1989
2.8%
2017
0.5%

(ii) Historic snapshot. In the previous centennial, Guyana was among the world's top three producers of bauxite until the mid-1950s. Until the late 1970s, the industry remained a major and often the main contributor to the economy in terms of share of GDP, export earnings, employment, and contribution to government revenue in the form of import duties, taxes, and dividends. After nationalization in the 1970s, the industry began to experience severe and existential challenges. Private ownership returned in the early 2000s, but the industry has not regained its former glory. Its production and market share have dwindled from their historic heights; it remains vulnerable to price fluctuations; its marquee product (refractory-grade calcined bauxite) faces stiffening competition from substitutes and improved technology; and it is still beset by several deep-seated internal disadvantages, such as high freight costs and thick overburden.

Since 1999, the value of exports of all types of bauxite from Guyana averaged US$ 91 million. Between 2010 and 2018, yearly contribution of bauxite to total export receipts averaged 9.8%, down from an average of 43.4% between 1971 and 1980. The industry's contribution to GDP over the last decade hovered around 1.5%, down from 13.9% between 1971 and 1980.



(iii) Governing economic philosophy: Since 1985, successive Guyana governments have moved the country's economy away from state-owned entities as the dominant segment to an economy driven by the private sector. Privatization of state entities and the reversal of the nationalization (through management contracts, leases, joint ventures and outright sales) have been the most dramatic result of this philosophical shift.

Bauxite's share of export earnings
1971 - 1980
43.4%
2010- 2018
9.8%

For the bauxite industry, since the early 2000s, ownership and management have been transferred from the state over to foreign-owned companies. A national consensus has now long emerged that the future of the industry will depend on maintaining and attracting overseas attention and investments. In this new dispensation, government's main role includes that of investment seeker and facilitator and minority shareholder.

C. POTENTIAL INVESTORS IN BAUXITE MINING IN GUYANA

Companies willing to invest in bauxite mining in Guyana will likely include:

i) foreign-owned bauxite companies already in Guyana;

ii) large integrated bauxite companies not currently operating in Guyana, with their own supply chain from bauxite mining to alumina refining to aluminum smelting;

iii) Chinese-owned companies as a subset of those in (ii) above that are seeking to supply their own local markets by investing overseas;

iv) Small third party or independent operators, looking to satisfy niche markets.

Whether these companies invest in Guyana depends mainly on three pivotal sets of investment factors:

i) Their assessment of the world market outlook for bauxite.

ii) Their assessment of Guyana's comparative advantages and disadvantages in this context.

iii) Their corporate strategies.

D. ASSESSMENT OF INVESTMENT FACTORS

D1: World market outlook for bauxite and implications for Guyana

The policy brief discusses here the outlook of the global bauxite industry in terms of the main types of bauxite Guyana produces or could potentially produce. These include:

i) Metallurgical-grade or metal-grade bauxite ("MAZ")[8]

ii) Refractory-grade calcined bauxite ("RASC")

iii) Cement-grade bauxite ("CeGB")

iv) Chemical-grade bauxite ("CGB")

v) Abrasive-grade bauxite ("AAC" or "AGB")

This disaggregation recognizes that for each bauxite grade or end use, different economic, geo-political/strategic, market, and technological drivers operate. The

[8] Locally-assigned acronyms used for marketing purposes.

THE THREAT TO NON-METALLURGICAL BAUXITES

The one long-standing hallmark of Guyana's bauxite industry that persists today is its nature as a diversified bauxite producer. Guyana continues to mine both metallurgical-grade and non-metallurgical-grade bauxites. Non-metallurgical-grade bauxites in Guyana include refractory-grade, abrasive-grade, chemical-grade, and cement-grade ores. By volume, production of metal-grade bauxite (MAZ) dominates, accounting for 60 -70% of local output over the last several years. By monetary value of exports, however, Guyana's non-metallurgical bauxites match that of MAZ. It is important therefore to understand the potential of these bauxites to secure the future of the local industry.

Worldwide, non-metallurgical bauxites account for only 4% of total bauxite production, putting it within the range of 12 – 20Mtpa. As a group, however, these bauxites continue to face relentless and growing competition from two sources. The first relates to other Al-containing material such as clays, andalusite, and bauxite residue (red mud). The second source poses a greater threat to the non-metallurgical bauxite market. It is based on the products generated from processed metal-grade bauxite, such as aluminum trihydrate (ATH), fused alumina, calcined alumina, and high-purity and ultra-high-purity alumina. ATH, for example, is the material produced in the Bayer alumina refining process, a step before the production of alumina. These alumina-based products (non-metallurgical alumina) are also used as feedstock for the manufacture of refractories, abrasives, cements, and chemicals and directly compete with raw non-metallurgical bauxites, replacing them to a large extent in the market. They offer superior, custom-made, and consistent quality; more reliable availability, lower prices, and fewer environmental issues. To illustrate the extent of the competition: in 2015, 2Mt of aluminum sulphate (used mainly as alum for water treatment, and in paper manufacturing) was made directly from chemical-grade bauxite, but 5.5Mt from ATH.

These two sources of competition for non-metallurgical bauxites (other Al-containing material and non-metallurgical alumina) have resulted in declining use of such bauxites. This reality is stressed throughout this policy brief.

interplay of these drivers determines the market outlook for each product; that is, its long-term demand trend (flat; down or up; slow or rapid), and the hard limits to its potential market size.

For each bauxite grade, therefore, this policy brief assesses its market demand and its production, supply and use. Under market demand, we assess separately the influences that both favor and restrict growth in demand. Likewise, for production and supply, we examine the influences separately that both favor and restrict increases.

From the perspective of Guyana's future as a bauxite producer, the influences that (i) favor the growth in world demand for bauxite and (ii) those that restrict growth in production in and supply from other countries point to the POSITIVE (good for Guyana). On the other hand, those influences that (i) are likely to restrict the growth in world demand for bauxite and (ii) those that favor growth in production in and supply from other countries point to the NEGATIVE (not good for Guyana).

With this analytical framework, the brief examines below each grade of bauxite in turn.

Metal-grade bauxite

(i) Definition and specifications: Metal-grade bauxite is the term applied to bauxites used in the production of alumina, which is mostly used as the feedstock for aluminum smelters and, to a small extent, also for a number of chemical and refractory applications. Guyana's metal-grade bauxite carries the commercial name MAZ.

In terms of chemical and mineralogical composition, the specifications for metal-grade bauxites have changed over the decades with the requirements for AL_2O_3 dropping from over 50% to 30%. The preferred specifications

require a pure gibbsitic ore with high AL_2O_3, low SiO_2 and high Fe_2O_3. The higher the reactive silica content[9], the higher the alumina refining costs. Gibbsitic bauxite is preferred because it requires less energy during refining (see Annex I). Bauxites with lower AL_2O_3 and gibbsitic content, however, have become acceptable and now dominate the world market.

(ii) Uses: More than 85% of the bauxite mined globally is converted to alumina for the production of aluminum. An additional 10% goes to non-metal uses in various forms of speciality alumina, while the remainder is used to produce chemicals, abrasives and refractories. The United States Geological Survey (USGS) reports that world production of bauxite in 2018 was 300 million tonnes (Mt), By calculation, over 255Mt of metal-grade bauxite was therefore mined in that year.

(iii) Local production: Figure 2 gives Guyana's metal-grade bauxite output from 2009 to 2018 based on data from the Bureau of Statistics. Since 2009, production has averaged around 1,133,000 tonnes per annum (tpa). Almost all production comes from the Berbice operations of Bauxite Company of Guyana Inc. (BCGI), majority-owned by UC Rusal. Bosai Minerals (Guyana) Inc. in Linden produced only 26,600 tonnes (t) of MAZ over the last ten years combined.

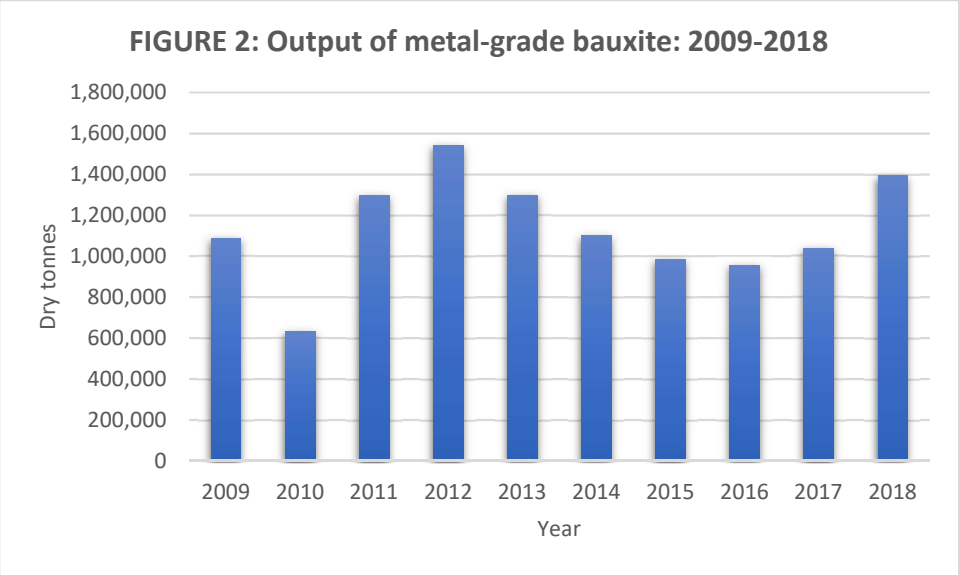
Guyana has one of the best metal-grade bauxites in the world in terms of its high recoverable alumina content and its near pure gibbsitic mineralogy. The iron content is however below specifications. In addition, BCGI reports that the high reactive silica content of 7% of its bauxite from Berbice raises alumina refining cost.[10] In its monthly operational statement for its Kurubuka operation in 2015, however, average yearly silica content is reported at 4.14%.

This operation supplies Rusal's Aughinish refinery in Ireland and its Nikolaev alumina refinery in the Ukraine with high-quality bauxite used for "sweetening" lower-grade Guinean bauxite.[11]

[9] Reactive silica refers to that part of the silica content in bauxite ore that reacts with and consumes the caustic soda in alumina refining, thereby increasing refining costs.

[10] Company report prepared for the MNR.

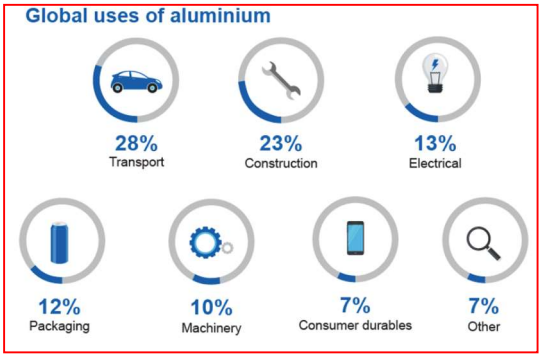
[11] As a result, Ukraine accounted for US$78,239 or 5.7% of all Guyana's exports in 2018.



85%
Share of bauxite used to make alumina.

(iv) World demand: Over 85% of bauxite is used to produce alumina and about 94% of alumina is smelted to produce aluminum. The fate of metal-grade bauxite therefore is dictated by aluminum demand and supply. Aluminum is the second most used metal in the world after steel. The prosperity of aluminum manufacturing depends on the demand for the metal by several end users. As shown below, the largest of these are the transport (vehicle manufacture) construction and electrical sectors.

94%
Share of alumina used to make aluminum.



Source: Resources and Energy Quarterly December 2018. Aust gov.

83Mt
China's bauxite imports in 2018.

China, the world's biggest aluminum producer, relies heavily on bauxite imports, shipping in around 83 million tonnes in 2018, up from 69 million tonnes in 2017. The increase in bauxite import was also driven by China's depleting domestic reserves and stiffening environmental regulation, which kept the domestic supply tight and prices high in 2018.

(v) World production and supply

As most of the world's bauxite output is destined for alumina refineries, a country's total output is a direct measure of its share of world metal-grade bauxite output.

Selected world's bauxite producers, 2018		
Country	**Bauxite output** (mil tonnes)	**% of world total**
Australia	75	25.0
China	70	23.3
Guinea	50	16.6
Brazil	27	9.0
Jamaica	10	3.3
Guyana	1.5	0.5
WORLD	300	100

Source: USGS Mineral Commodity Summaries 2019

(vi) World market outlook for metal-grade bauxite

Factors favoring growth in demand

- increasing industrialization and urbanization, especially in India and China. China is expected to increase bauxite imports as its own deposits become depleted and the discovery of new reserves fails to keep pace. CM Group forecasts that China's bauxite imports would rise from around 50Mt in 2015 to over 100Mt in 2025.
- the increasing use (in relative and absolute terms) of aluminum in vehicle manufacturing. Today, plug-in hybrid and full battery electric vehicles use 25-27% more aluminum than the typical internal combustion engine car. By 2030, aluminum demand from Electric Vehicles (EVs) will near 10 million tonnes, a ten-fold increase from 2017. For the entire auto industry, total aluminum content for 2020 will reach 466 pounds per vehicle, an increase of 69 pounds from 2015.
- Increased construction of greenfield and brownfield alumina refinery plants worldwide. Most of these will depend on captive or domestic bauxite sources (see Policy Brief #2).

Factors likely to restrict growth in demand

- Slow down in the Chinese economy. While China's economy is still expected to grow, its growth rate will likely decrease as the economy matures.
- Recycling of aluminum and other metal scraps. As the idea of a circular economy takes hold, increasing emphasis on minimizing waste will reduce demand for virgin bauxites.

- macro risks, such as slowing economic growth; though commodity demand has outpaced GDP growth on average since 2000.

Factors favoring growth in production and supply

- The less stringent chemical and mineralogical requirements for metal-grade bauxites have widen world reserves and have put in play a larger number of countries as suppliers. Required AL_2O_3 content has dropped from over 55% to as low as 30% and a higher content of diaspore and boehmite (monohydrate bauxites) is now accepted as ore, alongside reserves of the previously-dominant pure gibbsitic ore.
- The large number of bauxite projects recently commissioned or in the pipeline. For example, Rio Tinto's world-class Amrun bauxite project in Australia commenced production this year and is expected to ramp up to an estimated full production rate of 22.8 Mtpa by the end of 2019. Also, continued investments in Guinean bauxite will see its exports grow in 2019 to 62Mt, which is 13% over 2018 and 66% over its 2017 output.
- Continued investments in large untapped bauxite reserves in countries in West Africa, Australia, and South-east Asia. The Boke region in Guinea, for example, with reserves estimated at 23Bt continues to attract massive investments.
- Re-entry of Indonesia (previously China's largest bauxite supplier) and Malaysia into the world market as bauxite exporters.[12]
- Continued penetration of China's Belt and Road Initiative into Africa and Latin America will bring more mining projects online.

Factors restricting growth in production and supply

- Depletion of bauxite reserves both in terms of quantity and quality, especially in China. China has large bauxite resources (c 3.5-4Bt), but only about 25% of the bauxite can be classified as reasonable quality, with the balance low quality.[13] Higher grade deposits are rapidly declining in China. Suriname has also seen depletion of its high-quality deposits,
- Environmental and land-use conflicts. Governments are more willing to issue cease-work orders on bauxite mines and to delay or reject approvals for new operations. The Malaysian government, for example, in early 2016

[12] In 2014, the Indonesia government imposed a ban on bauxite exports to force private investment towards alumina production. In 2016, Malaysia imposed a ban on bauxite mining over concerns for unchecked environmental damage and illegal mining.

[13] Edison Investment Research (2015) -" Opportunities for Australian suppliers". https://www.edisoninvestmentresearch.com/research/sector

banned all bauxite mining after unregulated mining and run-offs from unsecured stockpiles in the eastern state Pahang contaminated water sources, turning roads, rivers, and coastal waters red. The country was once the biggest bauxite supplier to top-buyer China. China itself has significantly toughened environmental requirements for bauxite mines and plants.

- Protectionist trade policies, especially in the US. Under the Trump administration, the US government has moved to protect the country industries by withdrawing and/or renegotiating trade agreements, blacklisting countries and companies, and imposing tariffs on imports. The situation has created greater uncertainty among investors, causing some to postpone investment decisions.

Implications for Guyana

On balance, the factors that favor the growth in demand for metal-grade bauxite outweigh those that are likely to retard such demand (good for Guyana). But the factors that promote the growth in production and supply from countries other than Guyana outweigh those likely to restrict such production and supply (not good for Guyana). The widespread and growing availability of metal-grade bauxite in Australia, West Africa, South-east Asia and elsewhere makes Guyana a low-priority source for large volumes of the ore. In this global frame of analysis, increased exports of Guyana's MAZ will be minimal if they do occur.

At another scale of analysis, other considerations exist. The high alumina content of Guyana's MAZ makes it attractive as an additive or sweetener for alumina feedstock. Its below-spec iron content and relatively high reactive silica, however, mitigate against it being used as the total feed for a refinery. The fact also that alumina refineries are built to handle a specific and narrow range of bauxites serves to reduce market penetration of Guyana's MAZ.

Continued mining of MAZ will likely depend on the desire of an integrated operator, such as UC RUSAL, who may wish to guarantee its own raw material supply for its alumina refineries. As these integrated companies own and run several mines globally and do buy ore from other parties, the extent to which Guyana can emerge as a main source of supply is accordingly constrained.

Furthermore, most of the recent and planned greenfield and brownfield alumina refinery projects have locally captive bauxite mines, eliminating the need for imported ores.

Guyana does possess massive potential for metal-grade bauxite. Development of this potential would require extensive financial investments to conduct work at the levels of reconnaissance, target appraisal and evaluation, and reserve estimation. Additionally, the development of resources, such as those in the Pakaraimas, will depend on the existence of an interior transportation network of paved roads and/or railways, none or little of which is currently on the national planning

agenda. When one adds to the above equation the factors of mining costs and freight costs (discussed below), it is not expected that Guyana will climb to the next level as a supplier of metal-grade bauxite in the foreseeable future.

Refractory-grade calcined bauxite

73%
Share of refractories used in the steel sector, the largest market.

(i) Definition and specifications: Bauxite suitable for refractory applications must meet very stringent requirements, such as high alumina (59% to 61%), low iron oxide (> 2.5%) and low titania content (no higher than 4%). Silica can range between 7% and 10%. This grade specification rules out bauxite from the majority of bauxite producing countries.

(ii) Uses: Refractories include a wide range of products that differ by input raw materials and industrial end uses. Raw materials used to manufacture refractories include bauxite, silica, fireclays, chromite, carbon, magnesite and dolomite. Industrial end uses and users include steel making, power generation, non-ferrous metals production for the automotive and aviation industries; and the cement, ceramics, glass, chemical and petrochemical and hydrocarbon sectors. The largest consumer of refractories is the iron and steel sector, accounting for approximately 73%, followed by cement (12%).

The bauxite-based products are referred to as high-alumina refractories and are of two types by input raw material: those directly manufactured from refractory-grade calcined bauxite and those produced by the Bayer alumina refining process.

0.9%
Share of bauxite used to make refractories.

(iii) World demand, production and supply: In 2015, 3.08Mt of bauxite was used to make refractories. Of this total, refractory-grade calcined bauxite directly accounted for 49% (1.88Mt). The remainder was manufactured from preliminary products in the Bayer process. All told, only about 0.9% of bauxite produced annually is used for refractories.

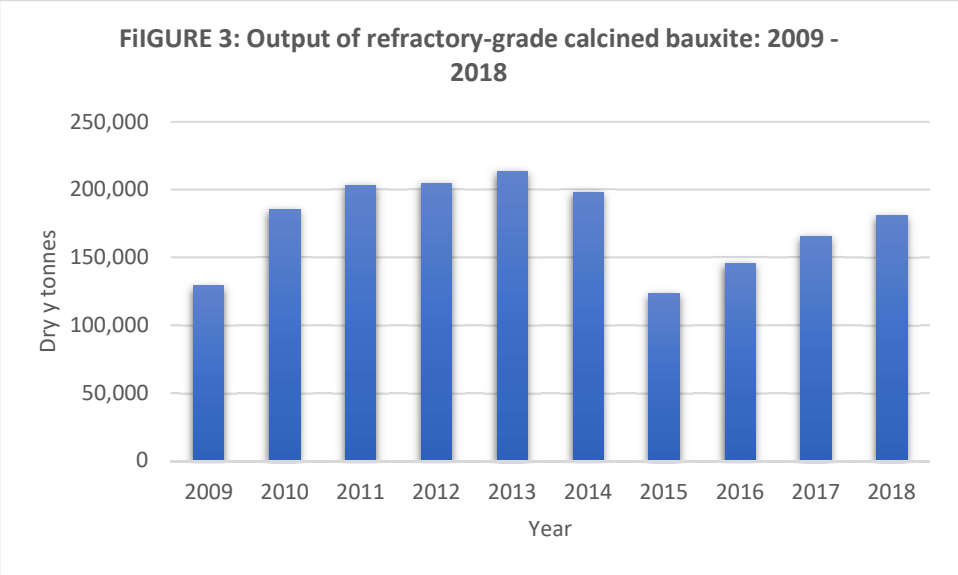
1.88Mt
Amount of calcined bauxite used in refractories in 2015.

Most of refractory-grade calcined bauxite is used in China, Russia and India. China, Russia, India and Guyana are the main raw material sources. However, production from India and Russia ordinarily cannot meet strict quality specifications and is mainly used domestically. China and Guyana therefore dominate trade in the material. China produces over half of global steel output and is therefore the most significant driver of refractories consumption.

(iv) Local production. Figure 3 gives Guyana's refractory-grade bauxite output from 2009 to 2018 based on data from the Bureau of Statistics. Guyana's fall from its near monopolistic position as a supplier of refractory-grade calcined bauxite to its lowly position today is widely documented. Since 2009, production of RASC has averaged 175,000 tpa. Mining and processing occur in Linden by China-

headquartered Bosai Minerals Group, which has ownership of over 200 million tonnes of high alumina and low iron bauxite deposits worldwide.[14]

In 2016, shipments of calcined products from Guyana (RASC and AGB) were valued at around US$39.5m.



(v) World market outlook for refractory-grade calcined bauxite.

Factors favoring growth in demand.

- The growth of the iron & steel, glass, non-ferrous, and cement industries is expected to drive the market growth. Steel production consumes roughly 70% of the world's refractories. Demand from major steelmaking countries is expected to drive demand for refractories. Foremost among these countries are China and India, where industrialization and urbanization continue apace.

- The likely increase in use of refractory-grade bauxite in ceramic proppants, the largest consumer of non-metallurgical bauxites. Use of proppants grew by nearly 40% per year between 2011 and 2015, and is expected to pick up further from 2018 onwards in tandem with a forecast recovery in oil prices. Oil prices however remain finicky and bauxite-based proppants face stiffening competition from sands and other refractories.

- The expected commencement in the US of large-scale multi-year infrastructure rebuilding projects. New and rehabilitated bridges, utilities,

[14] http://en.cqbosai.com/index.php/company/show/115.

railroads, roads, and tunnels are expected to increase demand for steel and therefore for refractories. In February 2018, US President Donald Trump unveiled plans to fix his nation's infrastructure. The proposal called for $200 billion in new federal funds that the administration anticipates will "stimulate $1.5 trillion in new investment in infrastructure," with the involvement of states, local governments and private partnerships.[15]

- Growing shift in use of high-quality refractories, a market where bauxite raw material enjoys an edge.

 Factors likely to restrict growth in demand.

- Improved manufacturing technology has significantly reduced the amount of refractories required for a unit volume of steel.
- Competitive from other refractory products limits the market for bauxite refractories. Clay and magnesia are the most widely-used minerals in refractories production.
- Major steel producing countries, such as Japan, have reduced their use of bauxite-based refractories.
- Uncertainty in the supply of refractory-grade bauxites has forced a shift towards other types of refractories.
- A slowdown in China's economic expansion.
- Macro risks, such as slowing economic growth; though commodity demand has outpaced GDP growth on average since 2000.

 Factors favoring growth in production and supply.

- The desire by users of refractory-grade bauxites for a more diversified list of suppliers.
- Increased bauxite exploration in China.

 Factors restricting growth in production and supply.

- Limited resource endowment worldwide. Only two countries (China and Guyana) have the required quality of bauxite to produce refractory-grade calcined bauxite. Bauxite for refractory products can also be obtained from Russia, India and Brazil, but these sources

[15] The Trump plan has so far failed to materialize.

ordinarily cannot meet strict quality specifications for refractories applications or mainly serve domestic markets.

- China's bauxite resources are declining, particularly its high grade refractory bauxite. Efforts by the Chinese government to boost resources through exploration will add new resources, but the quantity of refractory grade material is not expected to grow significantly.
- Strong pressure on domestic Chinese producers of calcined bauxite to divert production to the flourishing alumina industry as part of the government's policy to reduce dependence on foreign imports of alumina.

6.6%
Guyana's share of calcined bauxite world market in 2015.

- Chinese refractory bauxite producers and calciners are not part of integrated companies; they have different owners. Chinese calcined bauxite supply is therefore prone to disruptions as producers and calciners confront separate problems. Calciners have, for example, to contend with decreasing bauxite quality, high energy cost, slow approval process for new plants, and environmental crackdowns.

  In addition, the government has forced the closure of small plants, leaving production in the hands of only a few large companies (> 50,000 tpa), inclusive of Bosai Minerals Group Inc.
- Obligations to meet government environment protection standards in China are forcing its calciners to close operations or introduce costly plant upgrades. Government's efforts to integrate the highly-segmented industry may cause further closures and capacity reductions among Chinese calciners throughout 2019.[16]

Implications for Guyana

On balance, the factors that restrain the growth in demand for refractory-grade calcined bauxite outweigh those likely to spur such demand (not good for Guyana). But the factors that are likely to curb the growth in production and supply in countries other than Guyana outweigh those likely to favor such production and supply (good for Guyana), as Guyana is only one of two countries with exportable refractory-grade calcined bauxite. In addition, much of China's calcined bauxite

2
Number of countries that export refractory-grade calcined bauxite (China and Guyana).

[16] Refractory Windows, Dec 2018. – "Calcined bauxite industry is meeting change in 2019".

supplies domestic refractory companies - either in the form of refractory bauxite, or abrasive bauxite for brown fused alumina.[17]

As First Bauxite Corp has shown with its operations at Bonasika, the potential exists for the country in the foreseeable future to capitalize on its unique position of hosting rare occurrences of this type of bauxite. The company has apparently been able also to capitalize on the desire among purchasers to reduce their over-reliance on Chinese-own supplies. One of its market studies in 2011 predicted an additional yearly demand for refractory bauxite of 1 million tonnes by 2025, most of which likely to be sourced outside of China. With the company's production of 320,00Mta scheduled to begin at the end of 2019, the company can overtake Bosai as the world's largest producer of the product.

On the flipside, over the decades, the share of RASC of total refractory bauxite consumption has significantly declined. RASC has few remaining exclusive applications and is no longer used as a bulk material in refractory production. It competes with several alternative raw products and holds only a small share of the total refractory market. It is now mainly a product for niche markets.

Guyana's refractory-grade bauxite can also serve as a feedstock for the manufacture of calcined proppants used for hydraulic fracturing in the petroleum industry. This market however remains uncertain in light of fluctuating oil prices and technological advances in the use of cheaper proppants.

The country has resources to last a further 50 years.[18] Therefore, the future profile of Guyana's bauxite industry will be intricately bound to the fate of its refractory calcined bauxite sector. But total production is unlikely to surpass 800,000 tpa in the foreseeable future from a projected output of 450,000 to 500,000 tpa by 2020.

Cement-grade bauxite

(i) Definition and specifications: Chemical composition can range. The typical industry requirement for high alumina/low iron cement is for a minimum Al_2O_3:SiO_2 of 10:1 (which normally excludes bauxite having a silica content of more than 6%) and a minimum Al_2O_3:Fe_2O_3 ratio of 20:1. For high-iron cement, this latter ratio is set at 2.5:1. In cement products, the higher the alumina content, the more rapid the hardening rate and the better the refractory properties. A high silica content, however, hampers the rapid hardening property of the cement.

(ii) Uses. In terms of volume used, cement applications have become the largest market for non-metallurgical-grade bauxite, accounting for 1% of bauxite production. Cement-grade bauxite is used (i) to produce low-medium grade aluminous cements (calcium aluminate cement or CAC) , and (ii) to upgrade the

[17] As a measure of the internal demand for all types refractories in China, the country produced in 2016 23.91 million tons of refractory products, but exported only 1.64 million tons.

[18] Bosai, for example, reports reserves of 70Mt.

alumina content of ordinary Portland cement (the most frequently used binder in the commercial production of concrete).

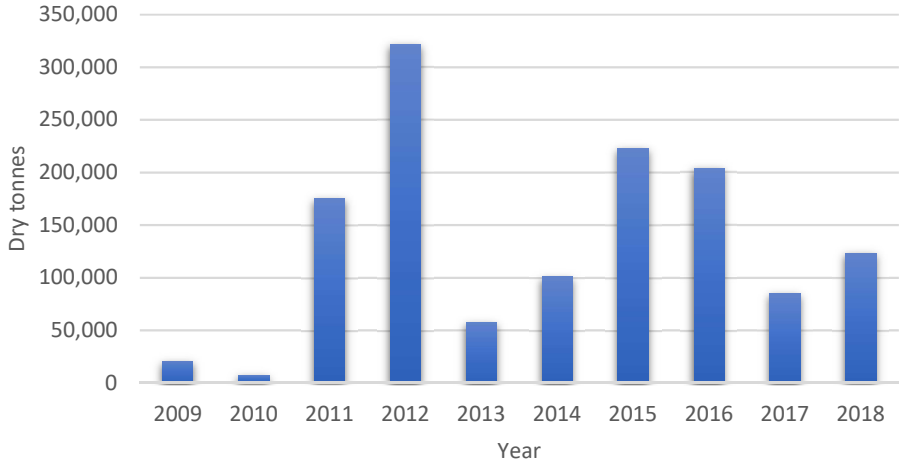
(iii) World demand, production and supply: The cement market mainly serves the construction industry. China is the main driver of the cement market both in terms of cement production and consumption, accounting for over 50% of global production.

In 2015, an estimated 450,000t of bauxite (compared to 600,000t in 2011) was used to produce low to medium-alumina cements (CAC). For Portland cement, between 2-3Mt of non-metallurgical bauxite is used annually.

(iv) Local production. Figure 4 gives Guyana's cement-grade bauxite output from 2009 to 2018 based on data from the Bureau of Statistics. Local production comes from both Bosai's and Rusal's operations, the former being by far the larger and the more consistent producer. Production shows wide fluctuations most likely due to market demand and local operational difficulties. Rusal's BCGI entered the market between 2014 and 2017, producing a combined 280,000t.

In 2016, Bosai's shipments of cement-grade bauxite (80,783t) and chemical-grade bauxite (119,077t) were valued at around US$ 9.5m.

FIGURE 4: Output of cement-grade bauxite: 2009-2018



(v) World market outlook for cement-grade bauxite.

Factors favoring growth in demand.

- Continued investments in construction and infrastructure, especially in India and China. The World Cement Association (WCA), however, forecasts that in 2019 world cement demand will grow only by 1.5%. China's dwindling

needs are a significant factor, but even excluding this, overall demand will only rise by 2.8% in 2019, according to the WCA.

- The expected start by the US government of the long-overdue nation-wide rehabilitation and rebuilding of America's infrastructure, such as bridges, energy infrastructure, railroads, roads, and waterways. In February 2018, US President Donald Trump unveiled plans to fix his nation's infrastructure. The proposal called for $200 billion in new federal funds that the administration anticipates will "stimulate $1.5 trillion in new investment in infrastructure," with the involvement of states, local governments and private partnerships.[19]

 Factors likely to restrict growth in demand.

- Increasing preference for high-alumina CAC (which uses alumina) over low to medium-grade CAC (which directly uses chemical-grade bauxite) especially in refractory applications.
- The use of calcined alumina as a substitute for chemical-grade bauxite. In cement products, the higher the alumina content, the faster the hardening rate and the better the refractory properties (resistance to corrosion, abrasion, and extreme temperatures). These factors have led to the added use of calcined alumina instead of chemical-grade bauxite in the production of high-quality cements.
- Cement-grade bauxite is considered an expensive additive in the manufacture of Portland cement, forcing manufacturers to seek cheaper alternatives.
- Significant and increasing competition from fly ash wastes and aluminous slag as additives to Portland cement.
- Significant quantities of cement are recycled for use as construction aggregate. As the idea of a circular economy takes hold, increasing emphasis on minimizing waste will reduce demand for virgin bauxites.
- Macro risks, such as slowing economic growth; though commodity demand has outpaced GDP growth on average since 2000.

 Factors favoring growth in production and supply.

- Cement demand is expected to grow in tandem with increased infrastructure development worldwide.

[19] The Trump has so far failed to materialize.

- Cement-grade bauxite offers quality advantages over other additives in the manufacture of Portland cement (the most frequently used binder in the commercial production of concrete).

Factors likely to restrict growth in production and supply.

Use of cement-grade bauxite in industry.

- The significant and increasing use of bauxite residue ("red mud") as a replacement for virgin bauxite in Portland cement.[20] With improved technology and stricter environmental requirements on the disposal of red mud, it is likely to substantially cut down the use of cement-grade bauxite as an additive to Portland cement.
- Expected decline in demand for low to medium-alumina CAC.
- Bauxite is not a major ingredient in cement manufacture. Portland cement is composed of only 2 – 3% of bauxite.
- Competition from concrete substitutes such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum, steel, stone and wood.
- General lack of supply gaps for cement raw materials.

Implications for Guyana

On balance, the factors that retard the growth in demand for cement-grade bauxite outweigh those likely to spur such demand (not good for Guyana). In addition, the factors that likely to favor growth in production and supply in countries other than Guyana outweigh those likely to restrict such production and supply (not good for Guyana).

Though the cement industry is large, its use of cement-grade bauxite is relatively small. Exports from Guyana are expected to remain flat.

Chemical-grade bauxite

650Kt

World output of chemical-grade bauxite (CGB) in 2015.

(i) Definition and specifications. Bauxite used directly in the chemical industry is high-quality material and is, in some cases, regular uncalcined refractory-grade bauxite. Chemical-grade bauxite accounts for less than 0.3% of bauxite production. The most significant requirement for chemical-grade bauxite is that its acid-soluble iron oxide content must be low. The preferred market specification is for gibbsitic bauxite with a maximum Fe_2O_3 content of 2.5% or a Al_2O_3:Fe_2O_3 ratio of 23:1 or higher.

[20] Bauxite residue is the main by-product of the Bayer process used in alumina refineries.

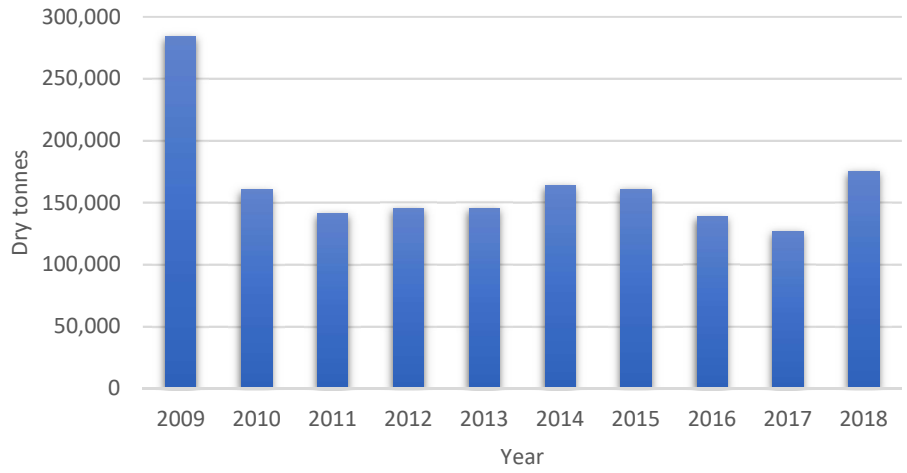
(ii) Uses. The main market for chemical-grade bauxite in aluminum chemicals is as a feedstock in the production of aluminum sulphate, which is mainly used in water treatment to clarify water[21], but also in pulp and paper production, and leather tanning.

(iii) World demand, production and supply: World output of chemical-grade bauxite in 2015 was 650,000t.

25%
Guyana's share of world production of CGB in 2015.

(iv) Local production. Figure 5 gives Guyana's chemical grade bauxite output from 2009 to 2018 based on data from the Bureau of Statistics. Guyana is one of the world's top producers, producing about 25% of 2015 world output. Local CGB comes from both Bosai's and Rusal's operations, with the former accounting for 62% of local production since 2009. Since 2010, production has averaged around 150,000 tpa. In 2016, Bosai's shipments of cement-grade bauxite (80,783t) and chemical-grade bauxite (119,077t) were valued at around US$ 9.5m.

FIGURE 5: Output of chemical-grade bauxite: 2009 - 2018



(v) World market outlook for chemical-grade bauxite.

Factors favoring growth in chemical-grade bauxite demand include:

- None detected.

Factors likely to restrict growth in demand include.

[21] In its hydrated variety known as alum.

- The market share of chemical-grade bauxite as a feedstock in aluminum chemical production is declining due to competition from alumina trihydrate (ATH) feedstock. Of the aluminum sulphate produced in 2015, 5.5Mt was produced from alumina trihydrate (ATH) feedstock,[22] 2Mt from chemical-grade bauxite (accounting for 25% of the total), and 1Mt from other feedstocks such as clay, syenite and aluminum scrap.
- Decreasing use of aluminum sulphate in pulp and paper manufacturing.
- Aluminum sulphate, the main market for chemical-grade, is also produced from clay, syenite and other materials, further reducing the market share of chemical-grade bauxite as a feedstock.

 Factors favoring growth in world production and supply.

- None detected.

 Factors likely to restrict growth in world production and supply.

- General lack of supply gaps for raw materials for the manufacture of aluminum chemicals.
- Declining demand for alum.
- Growing use of Bayer alumina.
- Small market share even within the global water treatment sector.
- Stricter environmental standards in China for cement plants.

Implications for Guyana

On balance, the factors that retard the growth in demand for chemical-grade bauxite outweigh those likely to spur such demand (not good for Guyana). In addition, the factors that likely to favor growth in production and supply in countries other than Guyana outweigh those likely to restrict such production and supply (not good for Guyana).

Quality specifications, however, give Guyana's refractory grade bauxites a competitive edge as a feedstock for the chemical industry. The market however is small and shrinking in the face of competition from other more-widely available raw materials. Guyana's production and exports of CGB are therefore predicted to remain flat.

[22] ATH is produced in the penultimate step in the Bayer process that produces alumina.

Abrasive-grade bauxite

(i) Definition and specifications: Producing calcined abrasive-grade bauxite is equivalent to producing refractory-grade material (such as RASC), except that abrasives are calcined (fired) at a lower temperature. The main bauxite used in abrasive-grade bauxite is gibbsite, though mineralogy is not of major significance. Alumina content must be as high as possible (>80% on a calcined basis). Silica content should be less than 6% because of the cost of removal. High levels of iron are required to maintain the silica-iron ratio if excessive quantities of silica are present. Titania needs to be between 2 -4%, so that the hardness of the alumina grains is not impaired.

Abrasive-grade bauxite must also meet strict physical criteria. Particle size is especially critical, as too large a particle will inhibit calcination (thus allowing reabsorption of water) and too fine a particle size will create dust problems.

(ii) Uses. Abrasives are materials used to smooth, roughen, polish or clean surfaces or to remove materials for the purpose of altering surface shape and size. Only 0.7% of bauxite production is used for abrasives. Some of this calcined material is used directly as an inexpensive abrasive product (less than 100,000tpy). The bulk of it, however, is used to manufacture brown fused alumina (BFA), which has uses both as a special abrasive and as a refractory product.

Abrasives consumption is greatly influenced by activity in the manufacturing sectors, in particular the aerospace, automotive, furniture, housing, and steel industries.

(iii) World demand, production and supply: World production of fused alumina in 2018 was 1.3Mt, with China as the world's leading producer. [23] In 2015, around 900,000t of BFA was used in abrasives, which consumed about 1.2Mt of calcined abrasive grade bauxite.

(iv) Local production. In the 1950s, Guyana started the production of abrasive-grade bauxite. The material is considered as a byproduct of RASC production. Production since then has been intermittent, ranging from 2,000 to 81,000 tonnes between 1955 to 1995, with zero production between 1971 and 1981.

Presently, Bosai Minerals Group (Guyana) Inc., is the country's single producer of abrasive-grade bauxite, producing an average of 41,000 tpa from 2015 to 2018.

(v) World market outlook for abrasive-grade bauxite.

Factors favoring growth in demand.

- Growth in heavy manufacturing, construction and the automobile/aviation sectors, the largest consumers of all types of abrasives, as industrialization progresses mainly in China and India.

[23] U.S. Geological Survey, Mineral Commodity Summaries, January 2018

Factors likely to restrict growth in demand.

- Natural and manufactured abrasives, such as garnet, emery, or metallic abrasives, can be substituted for fused alumina in various applications.
- Substitution of abrasive-grade bauxite by higher-quality products made from zirconia and alumina.
- Increasing use of plastics and better casting technology in the automobile industry, one of the main consumers of abrasives.

Factors favoring growth in production and supply.

- None detected.

Factors likely to restrict growth in production and supply.

- Declining consumption of abrasive grade bauxite.
- Reduced production capacity in China, the world's largest producer of brown fused alumina (BFA), due to stricter environmental requirements and lack of good quality bauxite feedstock.
- BFA demand in abrasives is expected to reach 1.1Mt by 2021, requiring only 1.45Mt of bauxite.

Implications for Guyana

On balance, the factors that restrain the growth in demand for abrasive-grade bauxite outweigh those likely to spur such demand (not good for Guyana). In addition, the factors that likely to favor growth in production and supply in countries other than Guyana outweigh those likely to restrict such production and supply (not good for Guyana).

The abrasive-grade bauxite market is a small and mature one. Exports from Guyana are expected to remain flat and intermittent. An American firm, Metallica Commodities Corp., has however showed interest in re-opening the idled 125,000 tpa calcining kiln in Everton, Berbice, for the production mainly of abrasive bauxite.

The company has not publicly disclosed the factors that make this project feasible.

D2: Guyana's comparative advantages and disadvantages

With regards the development of bauxite resources, most of Guyana's comparative advantages and disadvantages are well documented. On balance, they tend to make bauxite mining in Guyana highly vulnerable to cost increases and/or price decreases. Main issues include:

Comparative advantages	Comparative disadvantages
Government offer of several fiscal incentives. These include a low royalty rate, tax holidays, waiver of import duties and withholding taxes, rapid depreciation, and other concessions.	High freight costs (due to low river depths for large ships and to long distance from main markets).
Long history of bauxite mining. This leads to entrenched social acceptance (social licence) for bauxite mining as part of the economic landscape. Also leads to availability of experienced labour force.	High stripping ratios. Overburden thicknesses can reach as high as 30m.
High-quality resources. The country still possesses world-class refractory-grade and chemical-grade bauxites.	High energy costs. Leads to high cost of drying and calcining operations. Also a major impediment in the way of alumina refining and aluminum smelting.
Political stability	Mostly incomplete assessment of bauxite occurrences countrywide. Companies must therefore take on the high risk and financial burden of conducting their own exploration.
	Large transportation infrastructure gap. Lack of adequate penetration into the hinterland makes development of inland bauxite resources prohibitive.
	High cost of dewatering mines to ensure drainage control.

D3: Corporate strategies and implications

Typical corporate goals and strategies	Implications for Guyana
For security reasons, bauxite companies strive to own their own supply of raw materials. Rusal's self-sufficiency in bauxite, for example, is reported to be around 90%, half of which produced outside of Russia.	Positive (Good)
Third party operators may seek a market advantage in presenting themselves as a more reliable or an alternative supplier. This is the strategy currently employed by First Bauxite Corp in assessing the feasibility of its Bonasika operation.	Positive (Good)
Large bauxite companies seek to assure themselves of uninterrupted bauxite supply over the long-term and therefore seek to expand their bauxite portfolios.	Positive (Good)
Diversification of bauxite investments towards South-East Asia, India and Africa.	Negative
Companies in the bauxite value chain seek to improve efficiencies and reduce costs through assets consolidation, research into new technologies, and waste reduction and reclycling.	

E. POLICY RECOMMENDATIONS

From the early 1990s unto today, the government posture towards the bauxite sector has aimed to:

- Encourage foreign direct investment and ownership of existing mines,
- Encourage participation of companies and exploration of non-traditional areas, such as in the Canje and Pakaraima deposits.
- Ensure that existing mines remain open in the face of challenges such as market volatility, internal labour disputes and, more recently, aggressive US international trade policy.
- Minimize or avoid the social and economic fallout caused by any closure or contraction of bauxite operations in Linden, Kwakwani and elsewhere.

- Encourage value-added production.
- Address the environmental and natural hazard threats posed by previous and ongoing bauxite mining.

These goals are captured in the National Mineral Sector Policy Framework and Actions of the Ministry of Natural Resources. In addition, in line with this national framework, it is recommended that the development of the bauxite industry be seen as an integral part of a regional development strategy in bauxite mining regions.

Absent, arguably, from the list of government measures is the objective of increasing tax revenues for the national treasury. Arguably, keeping the mines open has far outweighed revenue gathering and other considerations.

The main policy tools to realise these objectives have been fiscal instruments in the form of tax incentives (such as tax holidays and waivers of duties) and the ready granting of exploration concessions outside of the traditional bauxite mining districts, such as in Canje and the Essequibo.

Little progress has been made in creating a "total investment climate" through, for example, building new road and railway links, deep-water port facilities, and cheap energy sources; or through bauxite geo-data acquisition and dissemination. To the extent that these measures require large government financial outlays, the country may soon reach a position where it can so invest using its expected oil revenues. Creating a total investment climate that includes a range of facilitating factors and conditions is the overarching recommended policy approach.

F. FINAL WORD: the next centennial

For the local bauxite industry in the next centennial, starting from 2016, it is anticipated that the industry would be geared more towards satisfying small, dedicated non-metallurgical overseas markets. The country will remain mainly a niche or speciality supplier of refractory-grade and chemical-grade bauxite. But, as demand for these products is likely to remain flat or grow only modestly in the face of technological advances and growing use of substitutes, the local industry is not expected to see large increases in output beyond those already planned. Ceramic proppants, as the largest and an expanding user of refractory bauxite, do offer much potential if oil markets can remain stable.

The country will remain mainly a niche or speciality supplier of refractory-grade and chemical-grade bauxites.

Of all bauxite grades, metal-grade bauxite holds the largest and the most assured growth potential worldwide. While, on one hand, this is good news for Guyana. On the other, there is abundant supply of metal-grade bauxite from Guinea,

Australia and elsewhere that enjoy better comparative advantages relative to Guyana.

The lack of interest in the Pakaraima bauxites and the poor exploration results from the northern portion of the coastal bauxite belt further mitigate against the country significantly increasing production in the foreseeable future.

The possibility exists that the feasibility and profitability of bauxite mining could be increased if mining of the associated materials, such as clays (including kaolin) and sands, could be undertaken. The option remains open.

G. ANNEXES

ANNEX I: Types of bauxite by mineralogy

(i) Gibbsite (Alumina Trihydrate or simply 'Hydrate' - $Al_2O_3.3H_2O$): The most abundant economic source of alumina. Gibbsite is the most soluble aluminium oxide and therefore has a lower temperature (c 140°C) and energy requirement during refining. Refineries that operate on other bauxite ores may have to operate at temperatures of up to 300°C. Gibbsitic bauxite possesses the highest commercial and industrial quality. Guyana's bauxite reserves and those in other tropical countries are of this type.

(ii) Boehmite (Alumina Monohydrate $Al_2O_3.H_2O$): this is not as soluble as gibbsite. It requires more energy than gibbsite in the refining process. Requires higher refining temperatures, typically 240-260°C

(Iii) Diaspore ($Al_2O_3.H_2O$): this has the same composition as boehmite but is denser and harder. It requires more energy in refining than either gibbsitic or boehmitic bauxite. It does not occur in tropical bauxites but is of importance in Europe and China. A lot of the bauxite in China is of the diaspore type. Requires the highest refining temperatures to process, typically +260°C.

ANNEX II: Types of bauxite by chemistry and end use (after J.W. Shaffer, 1975)

Metal Grade Bauxite requires a high alumina content and a reactive silica content of less than 5% so as to decrease the consumption of caustic soda to enhance alumina recovery. Iron and titanium oxides are diluents and there are no generally accepted maximum limits of these impurities.

Refractory Grade Bauxite requires a high alumina content with low iron oxide and low silica content. The requirements for this grade are most rigid. Bauxite for refractories is calcined (heated) to produce a product with maximum density and minimum porosity and shrinkage. A typical analysis for refractory grade bauxite is: more than 58% Al_2O_3, less than 2% Fe_2O_3, less than 5% SiO2and less than 3% TiO_2.

Chemical Grade Bauxite may be comprised of several differing grades of bauxite for the manufacture of aluminous chemicals. Iron content should be low and the alumina should be readily soluble in sulfuric acid. The range of chemical characteristics is: 56.50% to 60.50% Al_2O_3; 4.25% to 9.00% SiO_2; 2.25% to 3.50% TiO_2; 1.50% to 3.00% Fe_2O_3; 28.00% to 31.00% LOI.

Abrasive Grade Bauxite is a calcined product and specifications are less stringent because more iron is tolerated. A titania content of 3% to 5% is desirable as it

imparts a greater toughness to abrasive products. The range of chemical characteristics is: 85.00%to 87.00% Al_2O_3; 6.00% to 10.00% Fe_2O_3; 3.00% to 5.50% SiO_2; 3.0% to 4.50%TiO_2; 1.00% to 2.00% LOI.

Cement Grade Bauxite for the manufacture of high-alumina cements may have variable silica and iron contents depending on the refining capabilities of the buyer. Iron content may be relatively high and it is actually desirable because iron compounds in the cement contribute to hardening and act as fluxes in the manufacturing process. The typical range of chemical characteristics is: 45% to 58% Al_2O_3; 20% to 30% Fe_2O_3; 2% to 6% SiO_2; 2.50% to 3.50% TiO_2; 0.50% to 3.00% CaO; 11% to 20% LOI.

General note: The bauxite used for producing abrasive, chemical, and refractory products must fulfill much more rigid compositional requirements than the crude ore that is commonly used for aluminum metal production. The natural chemical impurities that exist within these raw materials are not chemically removed from the ore during product processing, as in the case of the Bayer process in alumina refineries. These non-metallurgical grade bauxites are utilized in an essentially unrefined form, as direct feedstocks for the production of their ultimate end products.[24]

ANNEX III: Types of bauxite by ore quality

By ore quality, bauxites are classified into grades based on (i) aluminum content (generally the higher the better), (ii) reactive and non reactive silica content[25], and (iii) the presence of impurities such as iron oxides/hydroxides, kaolinite, titanium oxide (titania), organics and sulphur. All of these must fall within specific limits to qualify as feedstock in various manufacturing processes.

ANNEX IV: Types of bauxite by geological formation.

By geological formation, bauxite deposits are either (i) lateritic (formed in situ from weathering of aluminous parent rocks in tropical and temperature regions), or (ii) Karstic (partially transformed bauxite materials washed and accumulated in eroded limestone cavities where further transformation can occur). Guyana lateritic bauxites can be further subdivided into (i) buried deposits (formed mostly in the Coastal Plain), and (ii) plateau or upland deposits (formed on lateritic capped hills mostly in the Pakaraimas).

[24] Refractory Grade Bauxite. https://www.911metallurgist.com/refractory-grade-bauxite/

[25] Reactive silica is the proportion of silica in the ore that will react with the caustic soda during alumina refining, driving up the cost of production.