

Africa—A wealth of resources and aspirations

Credit: SANSA

The South African National Space Agency (SANSA), established in 2010, coordinates South Africa's involvement with space research and activities through four program areas: Earth Observation, Space Engineering, Space Operations, and Space Science. Pictured is one of the full-motion telemetry, tracking, and command antennas that SANSA Space Operations manages and maintains at the Hartebeesthoek Radio Astronomy Observatory.

By Alex Talavera and Randy B. Hecht

Africa sees its future in technological advance—and actively seeks global partners to help achieve its research and economic development potential.

Africa is home to 1.38 billion people, more than one-seventh of the world's population. From a foreign trade perspective, it is an enormous market—one whose potential large global economies are beginning to fully appreciate.

For example, in the United States, the U.S. Chamber of Commerce urged the Biden Administration to “make Africa engagement a presidential priority...[and] enhance the competitiveness of U.S. business in Africa.” The organization endorses free trade agreement negotiations with Kenya and “capacity building to support a trade agenda in the African Continental Free Trade Area.”¹

Africa has long been mined for its raw materials.² The African continent, for example, is the preeminent source of critical materials such as nickel, cobalt, and rare-earth mineral ores and gold. Other valuable ores found in Africa include bauxite, iron ore, and uranium ore. But as international research and development collaborations demonstrate, Africa can be more than a node on the supply chain or a target for increased export activity.

R&D, with emphasis on development

France's National Centre for Scientific Research (CNRS) is collaborating with researchers in South Africa on INFINITE-CELL,³ a project focused on developing next-generation solar cells. According to its website, the project “proposes extending the very high efficiency tandem device concepts to emerging thin film PV technologies with high potential for reduction of costs and avoiding the use of critical raw materials.” The goal is to bring to market “cost-efficient photovoltaic tandem devices based in the combination of wide band-gap kesterite absorbers as top cell, and low-cost c-Si [crystalline silicon] thin film as bottom cell”—and its performance targets include “using only fully sustainable materials and processes.”

Throughout Africa, researchers are working on strategies for converting agricultural waste from an ecological problem

to a sustainable materials solution. In Madagascar, the French National Research Institute for Sustainable Development hopes to use a “large supply of organic materials and waste, coming mainly from the fruit industry.” Its initiative for identifying and recycling agro-industrial waste and biomolecules seeks to address the challenge that “Madagascar does not have a developed chemical industry and it imports most of its drugs but also a large number of compounds and active ingredients in special chemicals (surfactants, cosmetics, paints, pesticides, dyes, polymers, etc.).”⁴

CNRS issues rolling calls for proposals⁵ to support “development of long-term scientific partnerships with African institutions” and has worked with academic institutions worldwide (including the University of Chicago and the University of Arizona) on Ph.D. joint programs.

China is also prominent among international actors seeking to tap Africa’s research potential. In September 2019, the Chinese Academy of Sciences signed a memorandum of understanding with the African Academy of Sciences in Nairobi to promote “collaborative research, skills development, and technology transfer.”⁶

The Academy’s Sino-Africa Joint Research Center is collaborating in Kenya on an effort to address the increasing use of treated and untreated wastewater for irrigation in farming as freshwater resources dwindle.⁷ The wastewater is often polluted with heavy

metals that build up over time in soil and plants and may reach toxic levels.

U.S. interest in the region is not exclusively economic. The U.S. Geological Survey’s international programs in Africa include mitigating carbon dioxide build-up in Cameroon’s Lake Nyos; conducting geochemical mapping in Morocco; and, in partnership with the Department of State and the Geothermal Energy Association, developing Africa’s geothermal energy resources.⁸

Developing foreign trade and homegrown talent

Kenya, which is in the early stages of negotiating a Free Trade Agreement with the U.S., launched Vision 2030 “to transform Kenya into a newly industrializing, middle-income country.”⁹ Integral to this initiative is its Nano-Sciences, Material Science and New Production Technologies Programme,¹⁰ which calls for the establishment of the Kenya Institute of Technology and the National Physical Science Research Laboratory for Engineering and New Production Technologies.

Similarly, Nigeria’s Federal Ministry of Science and Technology seeks to integrate science, technology and innovation within the country’s socioeconomic development efforts through advocacy, capacity building and commercialization of R&D outcomes.¹¹ Its National Board for Technology Incubation operates 27 incubation centers located throughout Nigeria,¹² while the Nigerian Institute for Science Laboratory Technology seeks to

provide researchers with a “bridge between the laboratory and the economy.”

Most of these are early-stage initiatives that will need bilateral cooperation in know-how, market access, and basics such as equipment and supplies to come to fruition. We spoke with ceramic innovators to get their insights on where the sector stands in Africa today—and how they see its future on this continent. Their interviews appear on the following pages.

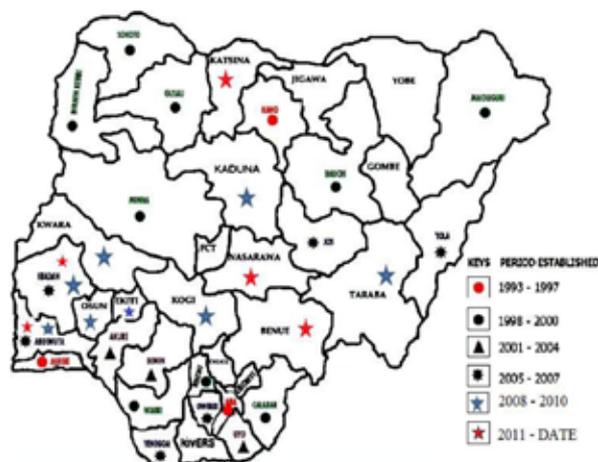
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Learn more about Haile in the September episode of Ceramic Tech Chat at <https://ceramictechchat.ceramics.org>.

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A 2013 map of incubation centers operated by the National Board for Technology Incubation. At that time, the Board operated 29 incubation centers; they currently operate 27.



Example of terraced agricultural land in Madagascar.

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ACerS International Chapters —Serving members in their local communities

Nearly 40% of ACerS members are located outside the United States. To better serve members around the world, ACerS supports the formation of International Chapters where concentrations of ACerS members reside outside the U.S.

Learn more about ACerS International Chapters at <https://ceramics.org/international-chapters>. ¹⁰⁰

Phylis Makurunge, researcher inspired by South Africa space program

If you express surprise that her native South Africa has a space program that inspired a young woman to become a materials engineer working on aerospace composite materials, Phylis Makurunge does not hesitate in her response. “South Africa is one ambitious country,” she says. “Ambitious in that it’s serious about research and development and how it plays in the ecosystem of the economy and industry.”

Her own ambitions led her to pursue a Ph.D. in materials engineering at the University of the Witwatersrand in South Africa, working with ceramics for aerospace applications. After completion, she moved to Wales to join the Nuclear Futures Institute at Bangor University as a post-doctoral research officer, where she explores how aerospace materials and nuclear energy can converge.

Although her research at Bangor has its genesis in a request from a commercial entity in the military and security industry, that company ultimately opted out of the collaboration. Makurunge continued the research in collaboration with the Council for Scientific and Industrial Research (Pretoria, South Africa),¹³ which has “a department that specifically looks at commercializing aerospace materials composites efficiently.”

“I focus on ultrahigh-temperature ceramics that have an unusually high melting point. We’re talking about above 2,000°C, but especially above 3,000°C,” she



Phylis Makurunge

says. “Few materials can withstand those temperatures without melting or even without vaporizing. So, that’s the leading quality that we look for, but also related to that quality is the robustness.”

Those characteristics are priorities because they help to identify which materials may be candidates for reuse in aerospace vehicles. Increasing the number of reusable materials and components furthers progress toward commercializing space travel.

That awareness of commercial potential hints at Makurunge’s dual ambitions for her future work. “I see myself in an industrial kind of setting more than an academic one. I’ve always loved the real engineering side of things,” she says. “In the academic field, you get the opportunity to really try out new things—anything that you can think of most of the time—and that is an amazing opportunity and something that I love. But I also love seeing the ideas going commercial. That’s what really drives me to, at some point be in industry again.”

That career shift may entail a return to South Africa. “We have a lot of new space players coming from the African continent, and already South Africa is a leading player in for a number of decades in the space arena,” she says. “A lot of changes are happening. A lot of developments are happening globally from countries that were not there. That means that anything can happen, really.” ¹⁰⁰

Aron Shonhiwa, business development manager, Cermalab Materials Testing Laboratory

Mining is the single biggest component of South Africa’s GDP. With mining/metallurgical operations and refractories in such a prominent position, quality assurance for those sectors plays an important role in the country’s continued development.

Cermalab Materials Testing Laboratory¹⁴ is engaged in materials testing, improving process technology, and evaluating final products. Its focus within the sphere of ceramics is cement and concrete.

“There are a lot of refractories being used in South Africa—some made locally and some imported,” says Aron Shonhiwa. “We assist our clients in testing their materials, researching new products, and ensuring that their materials are conforming to the required standards and specifications.”

One of the challenges the company faces is a shortage of professionals in ceramics. “Not many colleges or universities around us offer ceramics as a discipline,” Shonhiwa says. “Companies like ours have been sourcing some young professionals with chemical, metallurgical, materials science, or engineering training, and then we groom them. At the end of the day, it’s a question of training them into the real testing of ceramics.” Cermalab’s affiliated Institute of Ceramic Education offers a 16-week brick-making course and a three-day quality control course.

Some of South Africa’s refractories are subsidiaries of companies based abroad. Although that sets the stage for Cermalab to engage in cross-border

collaboration, those opportunities go untapped when the companies send samples overseas for testing.

“This is both time consuming and a financial constraint,” Shonhiwa says. “It would be ideal if we collaborate with the mother company overseas, so that we do the product development in testing for their subsidiaries in Africa, instead of shipping raw materials all the way to Europe or America.”

He notes that Cermalab’s equipment conforms to global standards and that the company conducts most of its tests in accordance with ASTM and European standards. With that in mind, he sees the company as offering companies in the U.S. and Europe a locally based resource that will allow them to attain their testing and quality assurance standards without having to set up a testing facility on the continent.

The company uses proficiency testing to promote that strategy. “You compare results and do statistical analysis to see if there is any discrepancy. That is the only way you can be in a position to say there’s no compromising quality if the testing is done in Africa or in the States,” Shonhiwa says. “There won’t be any compromise as far as procedures are concerned.”

See Cermalab’s accreditations page for further details, <https://cermalab.co.za/Pages/Accreditation.asp>. ¹⁰⁰



Aron Shonhiwa

Oluwagbenga Johnson, mechanical and metallurgical engineering professor, School of Engineering and the Built Environment, The University of Namibia

While challenges such as agricultural waste may be more acute in Africa, these issues transcend borders and require a global perspective. “We can see the local problems. We can adapt science and technology to help our people,” says Oluwagbenga Johnson. But equipment and facility limitations constrain his research capacity, so he has looked abroad for collaboration support.

“I see what they present, and I see what I’m presenting,” he says of his experiences at conferences in Europe. “It’s not that we can’t reach that height that they have. But unfortunately, we don’t have those capacities in terms of equipment.” He believes that multilateral collaboration would make better use of Africa’s mineral wealth, provide a better job market within engineering, and secure the continent’s future.

Johnson is no stranger to working across borders. Born in Nigeria, he earned his M.S. and Ph.D. in South Africa and now works in Namibia. One area of focus in his ceramic material research is cutting tools applications, and he believes his team was among the first in the world to conduct extensive research for this purpose into boron suboxide (B_6O).

“We were basically looking at improving some of the properties of the fracture toughness of the material,” he says. His work continues to explore “the relationship between the processes, structure, properties, and performance of these engineering materials.”

One recent area of emphasis in his work is developing engineering materials from locally sourced raw materials such as rice husks. The university’s agricultural campus operates a rice farm, and the husks presented a waste management challenge. Johnson and his colleagues developed a process for converting those husks into silicon carbide, which they then combine with aluminum to create a composite. In this way, they simultaneously reduce agricultural waste and make silicon carbide—which does not occur in nature—more economically accessible on the local market.

While the U.S. eyes Africa as an export market, Johnson notes that the continent has equally strong potential as a supplier of goods in demand. Namibia, for example, has the largest deposit of uranium oxide. “But if we produce the uranium cake, there’s nothing much we can do with it,” he says. “It has to



go overseas.” As a result, he recognizes that moving from research to commercialization requires value-added steps that depend on cross-border partnerships.

To ensure that its students keep pace with industry developments and can contribute meaningfully to those partnerships, the university revamps its curriculum every five years, a process that it completed most recently in August. The latest enhancements focus on problem-solving and digital skills as well as the soft skills necessary to keep pace with changes in the industry and the work environment. This focus is intended to help students and next-generation professionals meet international expectations and take their place in the global market. 

AFRICA MARKET SNAPSHOTS

A wealth of contradictions: in Africa, resource-rich countries seek an end to their economic struggles

By Alex Talavera and Randy B. Hecht

We look at six of the continent’s biggest economies and the challenges they face in converting national wealth to household prosperity

Africa is home to a formidable collection of natural assets: 30% of the world’s mineral reserves, 12% of its oil reserves, and 8% of its natural gas. Add to that 40% of the global supply of gold and as much as 90% of the world’s chromium and platinum—plus the largest reserves of cobalt, diamonds, and uranium on the planet.^a

But while these resources could be engines of development throughout the continent, the United Nations Environment Programme notes that a “significant share of these resources” is “used unsustainably” or “lost through illegal activities,” with the result that “the stream of benefits generated from these resources is being reduced over time.” The UN agency estimates that each year, Africa loses \$195 billion of its natural capital “through illicit financial flows, illegal mining, illegal logging, the illegal trade in wildlife, unregulated fishing and environmental degradation and loss.”^a

That lost revenue reduces Africa’s investment in its own development—with consequences that further hamper its capacity for economic growth and progress. For example, the World Bank notes that in recent decades, Africa’s food import bill has more than tripled to \$35 billion a year, even though

“much of this imported food could be produced locally, creating much needed jobs and incomes.”^b

The global pandemic dealt a further blow to African countries’ plans for development and economic growth. Despite that, Statista reports that for 2020, there were six countries in Africa that had a GDP in excess of US\$100 billion: Nigeria, Egypt, South Africa, Algeria, Morocco, and Kenya.^c Here, we look at market conditions in each of those countries. Note that we have eliminated GDP reporting because as throughout the planet, 2020 figures are not representative.

If your company is considering doing business with a partner in Africa, you may also find it useful to consult the U.S. Africa Business Center’s Investor Confidence Indicator for Africa. (<https://www.usafricabusinesscenter.com/investor-confidence-indicator-for-africa>)



Algeria: Hydrocarbon-fueled foreign commerce

Algeria’s fortunes rise and fall with hydrocarbons, which generate approximately 30% of GDP, 60% of budget revenue, and nearly 95% of export earnings, according to the

CIA’s *World Factbook*. The country has the world’s tenth-largest reserves of natural gas and third-largest reserves of shale gas, ranks 16th in proven oil reserves, and is the sixth-largest gas exporter.

While oil prices were high, these assets “enabled Algeria to maintain macroeconomic stability, amass large foreign currency reserves, and maintain low external debt,” the *World Factbook* notes, but “since 2014, Algeria’s foreign exchange reserves have declined by more than half and its oil stabilization fund has decreased from about \$20 billion at the end of 2013 to about \$7 billion in 2017.” Since 2015, the country has instituted protectionist policies—including import restrictions—and in 2018, the government announced the indefinite suspension of 850 products.

Services account for 47.4% of GDP, followed by industry (39.3%) and agriculture (13.3%). The industrial sector is led by petroleum, natural gas, light industries, mining, electrical, petrochemicals, and food processing. The labor force of 10.8 million is employed in services (58.4%), industry (30.9%), and agriculture (10.8%).

Exports of crude and refined petroleum, natural gas, fertilizers, and ammonia generated \$34.37 billion in 2017. Leading export partners include Italy, France,

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AFRICA MARKET SNAPSHOTS A wealth of contradictions (cont.)

Spain, the United States, the United Kingdom, India, and South Korea. Imports for the year totaled \$48.54 billion, led by refined petroleum, wheat, packaged medical supplies, milk, and vehicle parts. Principal import partners include China, France, Italy, Spain, Germany, and Turkey.

To learn more about this market, see the U.S. International Trade Administration's *Algeria Country Commercial Guide*,^d the World Bank's Doing Business guide for Algeria, and resources available through the U.S.–Algeria Business Council,^f which is hosting a Green Economy Forum & Expo on Nov. 15–17, 2021, in Algiers.



Egypt: Facing economic hurdles to manufacturing progress

Although hydrocarbons are a factor in Egypt's finances, the country's economy is more diverse than Algeria's; drivers also include agriculture, manufacturing, tourism, and other service sectors. However, that diversity does not translate to freedom from significant economic challenges that have created manufacturing and business difficulties.

"In late 2016, persistent dollar shortages and waning aid from its Gulf allies led Cairo to turn to the IMF for a 3-year, \$12 billion loan program. To secure the deal, Cairo floated its currency, introduced new taxes, and cut energy subsidies—all of which pushed inflation above 30% for most of 2017, a high that had not been seen in a generation," the CIA *World Factbook* notes. "Since the currency float, foreign investment in Egypt's high interest treasury bills has risen exponentially, boosting both dollar availability and central bank reserves. Cairo will be challenged to obtain foreign and local investment in manufacturing and other sectors without a sustained effort to implement a range of business reforms."

Services generate 54% of GDP, followed by industry (34.3%) and agriculture (11.7%). Chief industrial sectors include textiles, food processing, tourism, chemicals, pharmaceuticals, hydrocarbons, construction, cement, metals, and light manufacture. The labor force of 24.11 million is employed in services (49.1%), industry (25.1%), and agriculture (25.8%).

Egypt's 2018 export volume was \$87.89 billion. Crude and refined petroleum, gold, natural gas, and fertilizers are among the chief exports, and leading export partners include the United States, United Arab Emirates, Italy, Turkey, Saudi Arabia, and India. Imports for the year were \$115.34 billion. Refined and crude petroleum, wheat, cars, and packaged medicines lead import activity, and major import partners include China, Russia, the United States, Saudi Arabia, Germany, and Turkey.

To learn more about this market, see the U.S. International Trade Administration's *Egypt Country Commercial Guide*,^g the World Bank's Doing Business guide for Egypt,^h and resources available through the U.S.–Egypt Business Councilⁱ and the American Chamber of Commerce in Egypt.^j



Kenya: High rates of GDP growth—and unemployment

In 2014, Kenya achieved a milestone: its per capita GDP rose above a World Bank threshold that earned the country for status as a lower-middle-income country. It was a qualified victory for the country the *World Factbook* dubs "the economic, financial and transport hub of East Africa."

Although the authors note that Kenya had achieved real GDP growth that averaged over 5% for a decade and that it "has a growing entrepreneurial middle class," negative indicators are equally striking. Estimates of under-employment/unemployment have been as high as 40%. Weak governance, corruption, and inadequate infrastructure are cited as obstacles to improved annual growth and capacity to "meaningfully address poverty and unemployment." The government's planned growth initiatives focus on universal healthcare, food security, affordable housing, and expansion of manufacturing.

Services generate 47.5% of GDP, followed by agriculture (34.5%) and industry (17.8%). Agriculture provides at least part-time employment to approximately 75% of Kenyans, and the *World Factbook* notes that "small-scale, rain-fed farming or livestock production" is responsible for 75% of agricultural output. Services provide employment to 32.2% of the labor force, while industry employs just 6.7%. Strongholds of the industrial sector include small-scale consumer goods (plastic, furniture, batteries, textiles, clothing, soap, cigarettes, and flour), agricultural products, horticulture, oil refining, aluminum, steel, lead, cement, commercial ship repair, tourism, and information technology.

In 2019, Kenya's export volume was \$10.07 billion, led by tea, cut flowers, refined petroleum, coffee and titanium. Uganda, the United States, the Netherlands, Pakistan, the United Kingdom, United Arab Emirates and Tanzania are Kenya's biggest export partners. Import volume for the year was \$18.73 billion, driven by imports of refined petroleum, cars, packaged medicines, wheat, and iron products. Leading import partners include China, United Arab Emirates, India, Saudi Arabia, and Japan.

In 2020, the U.S. and Kenya announced that they had entered into free trade negotiations. These negotiations marked the first time the U.S. had launched trade talks of this kind with a country in sub-Saharan Africa. The U.S. Chamber of Commerce published *U.S.–Kenya Trade Negotiations*:

Implications for the Future of the U.S.–Africa Trade Relationship in April 2021; the report is available for free download at <https://www.uschamber.com/report/us-kenya-trade-negotiations>.

To learn more about this market, see the U.S. International Trade Administration's *Kenya Country Commercial Guide*,^k the World Bank's Doing Business guide for Kenya,^l and resources available through the American Chamber of Commerce Kenya.^m



Morocco: Free trade champion faces poverty challenges

At its narrowest point, the Strait of Gibraltar separates Morocco from Spain by just 8 miles.ⁿ This geographic proximity is complemented by the nation's efforts to build a diverse, open, market-oriented economy—one that emulates those found in Europe. Investments in its port, transportation, and industrial infrastructure and development of a free trade zone near Tangier have enabled Morocco to become more competitive and "position itself as a center and broker for business throughout Africa," the CIA *World Factbook* notes. A bilateral Free Trade Agreement with the U.S. has been in force since 2006, and Morocco entered into an Advanced Status agreement with the European Union in 2008.

Its future development plans include expansion of its renewable energy capacity toward a goal of generating more than 50% of installed electricity from renewable sources by 2030. But alongside these sophisticated targets are more traditional and entrenched challenges—high unemployment, poverty, and illiteracy rates, which are particularly acute in rural areas—and priorities include reform of the education system and the judiciary.

Agriculture, tourism, aerospace, automotive, phosphates, textiles, apparel, and subcomponents are among Morocco's key economic sectors. Services generate 56.5% of GDP, followed by industry (29.5%) and agriculture (14%). Dominant industries include automotive parts, phosphate mining and processing, aerospace, food processing, leather goods, textiles, construction, energy, and tourism. Within the labor force of 10.4 million, services employ 40.5%, followed by agriculture (39.1%) and industry (20.3%).

In 2019, Morocco's export volume was \$48.56 billion, led by cars, insulated wiring, fertilizers, phosphoric acid, clothing, and apparel; Spain and France are its key export partners. For that year, import volume was \$64.12 billion. Key imports were refined petroleum, cars and vehicle parts, natural gas, coal, and low-voltage protection equipment, and leading import partners were Spain, France, China, the United States, Germany, Turkey, and Italy.

AFRICA MARKET SNAPSHOTS A wealth of contradictions (cont.)

To learn more about this market, see the U.S. International Trade Administration's *Morocco Country Commercial Guide*,⁶ the World Bank's Doing Business guide for Morocco,⁷ and resources available through the American Chamber of Commerce in Morocco.⁸



Nigeria: Strong in fundamentals—and in need for reform

Oil-rich Nigeria, the largest economy in sub-Saharan Africa, has sought to diversify its engines of economic growth since the global financial crisis of 2008–2009. However, growth in agriculture, telecommunications, and services since that time have not delivered prosperity at the household level: “over 62% of Nigeria’s over 180 million people still live in extreme poverty,” the CIA *World Factbook* reports.

“Despite its strong fundamentals,” the authors add, “Nigeria has been hobbled by inadequate power supply, lack of infrastructure, delays in the passage of legislative reforms, an inefficient property registration system, restrictive trade policies, an inconsistent regulatory environment, a slow and ineffective judicial system, unreliable dispute resolution mechanisms, insecurity, and pervasive corruption.”

Services generated 56.4% of GDP in 2017, followed nearly neck-and-neck by industry (22.5%) and agriculture (21.1%). Leading industries include crude oil, coal, tin, columbite, rubber products, wood, hides and skins, textiles, cement and other construction materials, food products, footwear, chemicals, fertilizer, printing, ceramics, and steel. The labor force numbers 60.08 million, with 70% employed in agriculture, 20% in services, and 10% in industry.

Export volume was \$34.54 billion in 2020, down sharply from \$62.52 billion in 2019 (which had seen a rise from \$60.54 billion in 2018). Leading export commodities are crude petroleum, natural gas, scrap vessels, flexible metal tubing, and cocoa beans. Chief export partners include India, Spain, the U.S., France, and the Netherlands. The most recent data for import volume is \$32.67 billion in 2017, led by refined petroleum, cars, wheat, laboratory glassware, and packaged medicines. China, the Netherlands, the United States, and Belgium are major import partners.

To learn more about this market, see the U.S. International Trade Administration's *Nigeria Country Commercial Guide*,⁹ the World Bank's Doing Business guide for Nigeria,¹⁰ and resources available through the Nigerian–American Chamber of Commerce¹¹ and the Nigerian–USA Chamber of Commerce.¹²



South Africa: Can this emerging economy continue to ascend?

This middle-income emerging market has both

natural resource wealth and well-developed financial, legal, communications, energy, and transport sectors. Its stock exchange is Africa's largest and ranks in the top 20 globally. But South Africa also is distinguished by having one of the world's highest persistent inequality rates. The pandemic exacerbated the country's chronic problem of unemployment, which reached 32.5% at the end of 2020—and that rate skyrockets to 63% for workers age 24 or younger.

The CIA *World Factbook* lauds South Africa's “modern infrastructure,” which “supports a relatively efficient distribution of goods to major urban centers throughout the region,” but also notes the negative impact of “unstable electricity supplies” as well as “skills shortages, declining global competitiveness, and frequent work stoppages due to strike action.”

South Africa is the world's largest producer of platinum, gold, and chromium. In addition to mining, major industries include automobile assembly, metalworking, machinery, textiles, iron and steel, chemicals, fertilizer, foodstuffs, and commercial ship repair. For 2017, services generated 67.5% of GDP, followed by industry (29.7%) and agriculture (2.8%). The majority of the labor force of 14.68 million is employed in services (71.9%), followed by industry (23.5%) and agriculture (4.6%).

In 2019, export volume was \$123.86 billion, driven by gold, platinum, cars, iron products, coal, manganese, and diamonds. The biggest export partners are China, the United Kingdom, Germany, the United States, and India. Import volume for the year was \$131.72 billion, led by crude and refined petroleum, cars and vehicle parts, gold, and broad-casting equipment. Chief import partners include China, Germany, the United States, and India.

To learn more about this market, see the U.S. International Trade Administration's *South Africa Country Commercial Guide*,¹³ the World Bank's Doing Business guide for South Africa,¹⁴ and resources available through the U.S.–South Africa Business Center¹⁵ and the American Chamber of Commerce in South Africa.¹⁶

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¹³American Chamber of Commerce Kenya, <https://amcham.co.ke>

¹⁴World Atlas, “Strait of Gibraltar,” <https://www.worldatlas.com/straits/strait-of-gibraltar.html>

¹⁵International Trade Administration, “Morocco Country Commercial Guide,” <https://www.trade.gov/morocco-country-commercial-guide>

¹⁶The World Bank, “The ease of doing business in Morocco,” <https://www.doingbusiness.org/en/data/exploreeconomies/morocco#>

¹⁷American Chamber of Commerce in Morocco, <https://amcham.ma>

¹⁸International Trade Administration, “Nigeria Country Commercial Guide,” <https://www.trade.gov/nigeria-country-commercial-guide>

¹⁹The World Bank, “Ease of doing business in Nigeria,” <https://www.doingbusiness.org/en/data/exploreeconomies/nigeria#>

²⁰Nigerian–American Chamber of Commerce, <https://nigerianamericanchamber.org>

²¹Nigeria–USA Chamber of Commerce, <https://nusacc.us>

²²International Trade Administration, “South Africa Country Commercial Guide,” <https://www.trade.gov/south-africa-country-commercial-guide>

²³The World Bank, “Ease of doing business in South Africa,” <https://www.trade.gov/south-africa-country-commercial-guide>

²⁴U.S.–South Africa Business Center, <https://www.usafricabusinesscenter.com/u-s-south-africa-business-council>

²⁵American Chamber of Commerce in South Africa, <https://amcham.co.za>

Africa—A wealth of resources and aspirations

Directory of ceramic and glass enterprises, institutes, universities, and government agencies in Africa

REGIONAL

African Academy of Sciences

Website: <https://www.aasciences.africa>

Contact page: <https://www.aasciences.africa/contact-us>

This pan-African nonprofit has no political affiliations and seeks to use science to transform lives on the continent. Its mission is threefold: to grant fellowships and awards; provide “advisory and think tank functions for shaping Africa’s Science, Technology, and Innovation strategies and policies”; and implement programs that address Africa’s developmental challenges. The Academy has five strategic focus areas: environment and climate change, health and wellbeing, natural sciences, policy and governance, and social sciences and humanities. Its initiatives include the Alliance for Accelerating Excellence in Science in Africa (<https://www.aasciences.africa/aesa>).

Mining Review Africa

Website: <https://www.miningreview.com>

Contact page: <https://www.miningreview.com/info/contact-us>

Webinars: <https://www.miningreview.com/webinars>

ALGERIA

Abdelhafid Boussouf University—Mila

Website: <http://www.centre-univ-mila.dz/?lang=en>

Natural Sciences and Materials Research Laboratory:
http://lsnm.centre-univ-mila.dz/?page_id=208&lang=en

Email: lab.lsnm@centre-univ-mila.dz

The lab’s 14 teacher-researchers and two Ph.D. students are assigned to research teams focused on sedimentary basins and natural resources, natural plant substances, bioecology and means of control, and materials sciences and application processes.

Center for Development of Advanced Technologies

Website: <https://www.cdta.dz/en>

Email: contact@cdta.dz

The CDTA “supports at the national level the development of state-of-the-art technologies in multi-disciplinary thematic fields.” Among these are optics, photonics, and lasers; materials sciences; microelectronics and microsystems; design and development of integrated circuits; and nanomaterials and nanotechnology. It targets six areas of impact: health, energy, environment, water, digital, and industrial technologies.

University of Bejaia Algeria

Website: <http://univ-bejaia.dz/en>

Website of *Algerian Journal of Natural Products*:

<http://univ-bejaia.dz/ajnp/index.php/ajnp>

Email of journal director Kamel Belhamel:

kamel.belhamel@yahoo.fr or ajnp2014@gmail.com

This free, open-access journal is published twice annually by the University’s Laboratory of Organic Materials. Topics it covers include phytochemistry; antimicrobial, antiviral, or antiparasite activities; biopolymers and biocomposites; electrochemical processes using natural products; separation processes using natural products; and environmental impact and risk assessment.

EGYPT

British University in Egypt

Website: <https://www.bue.edu.eg>

Email: info@bue.edu.eg

Nanotechnology Research Centre website: <https://www.bue.edu.eg/nanotechnology-research-centre>

The Nanotechnology Research Centre focuses on nanoscience advances that reflect “critical community needs, such as water and medicine.” Links from <https://ntrc-info.wixsite.com/ntrc/research> lead to information about work by the NanoMaterials & Biosensing, Biomaterials for Medical and Pharmaceutical Applications, Applied Nano-Catalysis and Polymeric, Advanced Nanomaterials, and Industrial Catalysis research groups. The University’s Centre for Advanced Materials provides a list of its projects at <https://www.bue.edu.eg/research/research-centers/centre-for-advanced-materials-cam>.

Cairo University

Website: <https://cu.edu.eg/Home>

Email: fnt@cu.edu.com

The College of Graduate Studies for Nanotechnology is a regional leader in this field of study and offers research and consulting services through “alliances with major economic entities in the local, regional and global market.”

Egypt Nanotechnology Center

Website: <http://www.egnc.gov.eg/egnc>

Email: inquiry@egnc.gov.eg

The Center is working with IBM teams in the U.S. and Switzerland with an initial research focus on thin film silicon photovoltaics, graphene transparent electrodes for thin film photovoltaics, energy recovery from concentrator photovoltaics for water desalination, computational model-

ing and simulation, and biosensors. “These areas have been selected because of their scientific relevance and their potential impact on the economic development of Egypt.”

El Nasr Glass & Crystal Co.

Website: <https://www.elnasrglass-eg.com/en-gb/home>

Contact page: <https://www.elnasrglass-eg.com/en-gb/Contact-us>

Founded in 1932, this subsidiary of Metallurgical Industries Holding is “one of the first specialized companies in the production of glass tools.” In 2012, the company “replaced and renovated all its production lines using the latest European technology” (from Germany and Italy) to remain competitive and keep pace with the sector’s technological developments.

The General Co. for Ceramic and Porcelain Products

Website: <http://www.sheeni-egypt.com/en>

Contact page: <http://www.sheeni-egypt.com/en/contact-us.html>

A subsidiary of Metallurgical Industries Holding, this Egyptian Stock Exchange-listed company manufactures porcelain tableware, sanitaryware, and ceramics for floors and walls.

German University in Cairo

Website: <https://www.guc.edu.eg>

Contact page: <https://www.guc.edu.eg/en/contact.aspx>

Studies and research clusters in advanced engineering materials cover materials processes and analysis, structure–property relationship in engineering materials, and engineering polymers and advanced materials.

NanoTechnology and Advanced Materials Central Lab

Website: <http://www.arc.sci.eg/InstsLabs/Default.aspx?OrgID=627&TabId=0&lang=en>

Email: abdo@claes.sci.eg

“NAMCL is the first specialized lab in Egypt work in the nano agro field,” designs nano systems for agricultural and food applications, and “plays an official monitoring role through the full characterization of the manufactured nanomaterials including the safety evaluations.”

National Research Centre

Website: <https://www.nrc.sci.eg>

Email: info@nrc.sci.eg

Egypt’s largest multidisciplinary R&D center is devoted to basic and applied research. Its Engineering Research Division has departments for chemical, civil, and mechanical engineering as well as solar energy and systems and information.

KENYA

Dedan Kimathi University of Technology

Website: <https://www.dkut.ac.ke>

Contact page: <https://stp.dkut.ac.ke/contacts>

The University is establishing a Science and Technology Park as “an engine for innovation, incubation, development and commercialization of technology” that will integrate academic and entrepreneurial pursuits on campus. Its goals include employing research and innovation “to create intellectual property rights, spin-off companies and entrepreneurship” in three thematic areas: agri-tech (food bioresources and natural products value-addition), information and communication technology and design, and materials and manufacturing. Its initial anchor clients are



Credit: Ahmed El Annine Nakab, Unsplash

Directory of ceramic and glass enterprises, institutes, universities, and government agencies in Africa (cont.)

Snowcap Development Limited, Asytec, and Semiconductor Technologies Limited.

Jomo Kenyatta University of Agriculture and Technology

Website: <http://www.jkuat.ac.ke>

SMARTec staff page: <http://jkuat.ac.ke/departments/smartec/staff>

The University's Sustainable Materials Research & Technology Centre engages in research related to chemical analysis of concrete cores, DCP testing of subbase and subgrade layers, and extraction of aggregates in chemical analysis.

STL Semiconductor Ltd

Site: <https://stlsemiconductor.com>

Mail: info@stlsemiconductor.com

STL Semiconductor and the BG Ndegwa Center for Nano-Materials and Semiconductor Technologies is "the first of its kind advanced nano-technology and semiconductor laboratory in Kenya and indeed in Africa... a first-generation materials sciences facility offering scientific innovations targeted for semiconductor, agri-technology, biotechnology, energy, and any other large verticals. We aim to be the catalyst for cutting edge R&D innovation, intellectual property and proof of concepts for the semiconductor and related industries."

Technical University of Kenya

Website: <http://tukenya.ac.ke>

Email: vc@tukenya.ac.ke

The University is home to faculties of Applied Sciences and Technology, Engineering and the Built Environment, and Social Sciences and Technology.

MOROCCO

The International University of Rabat

Website: <https://www.uir.ac.ma/en>

Email: contact@uir.ac.ma

The University's College of Engineering and Architecture offers programs in automotive, aerospace, and energy engineering.

Kessy Beldi

Website: <https://kessybeldi.com/en>

Contact page: <https://kessybeldi.com/en/contact>

"A genuine Moroccan institution," the beldi tea glass was created in 1946 and is mouth blown from recycled glass.

Le Verre Beldi

Website: <http://en.verrebeldi.com>

Contact page: <http://en.verrebeldi.com/contact.php>

"Respecting the essential standards of recycling, job creation for craftsmen with strong skill, and quality products, Le Verre Beldis upgrades traditional Moroccan handmade and blown glass."

NIGERIA

University of Nigeria

Website: <https://www.unn.edu.ng>

Email: camillus.obayi@unn.edu.ng

The Faculty of Engineering encompasses departments of agricultural and bioresources, civil, electrical, electronic, mechanical, and metallurgical and materials engineering. From July 19–23, the University hosted the fourth Africa Nano Conference/Workshop (<https://www.unn.edu.ng/4th>



Credit: Nupo Deyon Daniel, Unsplash

african-nano-conference), which focused on the application of nanotechnology in energy, environment, agriculture, and health. The conference theme was "Nanotechnology: A Springboard for National Development."

Federal University of Technology, Akure

Website: <https://www.futa.edu.ng>

The School of Engineering and Engineering Technology encompasses departments of agricultural and environmental, civil and environmental, electrical/electronics, industrial and production, mechanical, and metallurgical and materials engineering. The metallurgical and materials engineering curriculum covers mineral processing, extractive metallurgy, physical and mechanical metallurgy, production metallurgy, alloy development, corrosion engineering, polymeric materials, glass and ceramic materials, refractory materials, composite materials, nanotechnology, and process and plant design.

SOUTH AFRICA

Central University of Technology

Website: <https://www.cut.ac.za>

Contact page: <https://www.cut.ac.za/contact-us>

The University has programs designed to facilitate the transfer of technology to industry and notes: "The ideal would be for completed research by CUT researchers to be commercialized in the form of new inventions. Hence, the Technology and Innovation unit is supporting staff and students with the protection of intellectual property and by providing incubation facilities and commercialization support." Its Centre for Rapid Prototyping and Manufacturing specialized in additive manufacturing, while its Product Development Technology Station works in product design, prototyping, and short-run production.

Consol

Website: <https://www.consol.co.za>

Contact page: <https://www.consol.co.za/contact>

The company manufactures glass packaging for the food, beverage, pharmaceutical, and cosmetics industries and serves a mix of local and global customers.

University of Cape Town

Website: <http://www.uct.ac.za>

Centre for Materials Engineering Website: <http://www.mateng.uct.ac.za>

Email: robert.knutsen@uct.ac.za

"The research activities of the Centre are aimed at addressing national needs in terms of both the provision of technological solutions and the development of skilled graduates... Current research interests at the Centre for Materials Engineering at UCT are aimed at addressing the need to develop competitive niche areas in the production and application of light metal alloy products for the

transport, medical and chemical industries... The Centre is involved in the development of new metal alloys, polymers, ceramics, and hard materials in cooperation with the materials manufacturing industries, and the optimum choice of these materials for the mining, marine, agricultural, processing, and energy-producing sectors of South Africa."

Thermomechanical processing is a key area of research focus, as is "optimization of titanium alloy properties through the process of tailoring the metal's composition and microstructure." Further details about these projects are available on the Department's research page (<http://www.mateng.uct.ac.za/mateng/research>).

University of Johannesburg

Website: <https://www.uj.ac.za>

The Department of Chemical Sciences houses the Centre for Nanomaterials Science Research, whose focus is on the synthesis, functionalization, characterization, and applications of carbon-based nanomaterials such as carbon nanotubes and strong composites. Its research priorities include bionanomaterials as well as nanomaterials for water treatment, catalysis applications, and sensors and photovoltaic applications. Further details about this work are available at <https://bit.ly/3B9n5p0>.

South African Department of Mineral Resources and Energy

Website: <https://www.dmr.gov.za>

Contact: <https://www.dmr.gov.za/contact>

This government agency has the mission to "regulate, transform, and promote the minerals and energy sectors, providing sustainable and affordable energy for growth and development, and ensuring that all South Africans derive sustainable benefit from the country's mineral wealth." Resources on the site cover mineral regulation and policy as well as a 21-page report on 53 minerals that are indigenous to South Africa (<https://bit.ly/3Bj2lqz>).

South African Institute of Mining and Metallurgy (SAIMM)

Website: <https://www.saimm.co.za>

Contact page: <https://www.saimm.co.za/about-saimm/saimm-contacts>

"The SAIMM is a professional institute with local and international links aimed at assisting members source information about technological developments in the mining, metallurgical and related sectors." Its website provides directories of journal and conference papers that are accessible at no cost. ¹⁰⁰

Africa—A wealth of resources and aspirations

Directory of African refractories

EGYPT

Alexandria Co. for Refractories

Website: <https://mih.eg/myservice/alexandria-co-for-refractories>

Contact form: <https://mih.eg/contact>

The company operates factories in Alexandria (for refractories) and Sornaga (for ceramics). Its primary products include aluminosilicate; high alumina; insulating, chemically bonded, and castable refractories; as well as mortars. Metallurgical Industries Holding, the parent company, provides its full list of subsidiaries in iron, steel, aluminum, copper, glass and crystal, porcelain ceramics, and more at <https://mih.eg/subsidiaries>.

Asfour for Mining & Refractories

Website: <https://asfourmr.com>

Email: info@asfourmr.com

Dolomita Industrial Solutions

Website: <https://dolomita.com.eg/refractories>

Email: info@dolomita.com.eg

The company provides high-performing refractory solutions to customers worldwide and in multiple industries. The raw materials it works with include calcined dolomite, flint pebbles, calcium carbonate, talc powder, iron oxide, and chamotte.

Korra Tradi

Website: <http://korra-holding.com/refractories-profile>

Contact form: <http://korra-holding.com/contact>

The company installs, repairs, maintains, and dismantles production linings. Products for the cement and foundries sectors include all types of refractory bricks, monolithics, all types of ferro alloys, pig iron, recarburizers, cored wires, nickel, inoculants, steel shots, cobalt, metallurgical coke, and magnesium metal.

Nile Co. for Refractories

Website: <https://refnile.com/about-refractories-refractory>

Email: info@refnile.com

The company's brick products include fire clay, high alumina, chemically bonded high-alumina, insulation, silica, expansion joint, anchor, ISO-shape, key, magnesite, magnesia carbon, spinel, dolomite, magnesia dolomite, magnesia chrome, zirconia, and anti-acid (blue bricks). In addition, it offers refractory, low cement and insulation castables, heat set and air wet mortars, kaolin, silica, ball clay, talc, feldspar, folorspar, quartz, dolomite, ferro alloys, coke, kiln furniture, pig iron, steel shoot, steel grit, grinding balls, and steel scrap.

Thermal for Ceramic Refractory & Metallurgical Products

Website: <http://www.thermal-refractory.com>

Email: Thermal_2000@hotmail.com or m.amer@thermal-refractories.com

Products include high- and low-alumina, insulating and anti-acid bricks; mortars; castables for a variety of applications; and ceramic insulators, tiles, and shisha stone. The company also offers inspection and consulting services.

Wataneyia for Refractories SAE

Website: <https://www.w4r-eg.com>

Contact page: <https://www.w4r-eg.com/contact-us>

The company's monolithic refractories serve cement plants, steel mills, and most high-temperature industrial uses. It also offers intumescent and cementitious fireproofing materials for the protection of steel.

KENYA

Citizen Cooling Solutions

Website: <http://citizencoolingsolutions.co.ke/refractory-materials>

Contact page: <http://citizencoolingsolutions.co.ke/contacts>

The company's products include high-temperature refractory materials such as castable cement, fire bricks, insulating cement, refractory mortar, binder cement, fondu cement, chrome magnesite bricks and cement, silicon manganese 60/14, taper bricks, hearth blocks and acid resistant bricks, tiles, cement, and mortar. It supplies and installs thermal insulation and acoustic insulation materials such as ceramic fiber products, rockwool (mineral wool) blankets, fiber glasswool blankets, and polyethelane foam.

Kingsman Engineering & Industrial Insulation

Website: <https://kingsmanengineering.co.ke/refractory-materials>

Email: info@kingsmanengineering.co.ke

Firebricks, refractory castable cements, conventional dense refractories, insulating, and low cement are among the company's products. In addition, it provides CAD and fabrication solutions.

NIGERIA

Eunaco Refractories Limited

Website: <https://eunacorefractories.com.ng>

Email: info@eunacorefractories.com.ng

The company provides iron, steel aluminum, lead, zinc, copper, cement, and lime refractories services.

SOUTH AFRICA

Delta Refractories

Website: <http://www.deltaref.com/company-profile>

Contact page: <http://www.deltaref.com/contact-details>

The company's offerings include dense and lightweight castables and special monolithics as well as production of acid and basic monolithic refractories, design and development of custom mixes, and design and estimation (including CAD drawing). It maintains an independent testing laboratory and can provide turnkey project management and refractory consultation and arbitration. See its brochures page (http://www.deltaref.com/product_brochures) for information about its RH-degasser, casting and transfer ladles, cement industry, Delta Fiber Crete composite castables, wear resistant, pumpable, and grouting products.

Durocast

Website: <https://www.durocast.co.za/refractory-products/home>

Contact page: <https://www.durocast.co.za/refractory-products/contact-durocast>

The company lists the following in its description of its product range: aluminosilicate, basic, silicon carbide, fused silica, insulation, preformed shapes, refractory materials, insulating materials, corrosion / chemical resistant material,



South Africa

Credit: Dan Ginnis, Unsplash

casting, gunning, ramming, mortars, pumping, refractory anchors, chemical resistant products, bricks, castables, guniting, concrete products, fire protection, abrasion resistant flooring, grouts, testing and consulting, tiles, mortars, and monolithic refractory products.

National Refractory Industries

Website: <https://www.caperf.co.za>

Contact page: <https://www.caperf.co.za/index.php/contact-us>

The company describes itself as a "net importer of a wide range of refractory brick, specialized refractories and insulation materials." Its ceramic fiber line encompasses blankets, boards, paper, vacuum-formed shapes, ropes, braids, textiles, and modules. Its product list also includes basic brick, aluminosilicate firebrick, insulation brick, refractory castables, guniting materials, insulation castables, refractory mortars, rammables, precast and fired refractory shapes, foundry products, crucibles, crucible furnaces, mineral wool insulation mat and pipe sections, cold insulation, silicon carbide shapes, fondu cement, refractory metallic anchors and studs and shear studs.

Refraline

Website: <https://refraline.com>

Contact page: <https://refraline.com/contact-us>

The company's areas of specialization include material development, manufacture, supply, demolition, installations, and maintenance of refractory and corrosion solutions for such industries as iron and steel, ferro-alloys, nonferrous metals, platinum group metals, aluminum, chemical and petrochemical, cement and lime, power generation, mining, paper and pulp, clay brick, glass, and ceramics. It also employs specialists in lagging and cladding.

Tecera Africa

Website: <https://www.tecera.co.za>

Email: <https://www.tecera.co.za/contact-us.html>

The company notes that it supplies alumina ceramics with 92% alumina content and high-quality wear resistance, mechanical, electrical, thermal, and chemical properties. Frequently manufactured items include plait flat tiles, weld-on tiles, pre-engineered pipe tiles, impact blocks, pulley lagging tiles, and cylinders. Its product lines also include silicon carbide and basalt linings, ultrahigh molecular weight polyethylene sheets and epoxy wearing compounds, as well as a wide range of ceramic and silicon carbide lined dense medium cyclones and classifying cyclones. 100