Towards a Green Steel Ecosystem in the East African Community

The Commonwealth

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Acronyms and abbreviations

AfCFTA	Africa Continental Free Trade Agreement
BF	blast furnace
bbl/d	barrels per day
BOF	blast oxygen furnace
Bt	billion tonnes
CBAM	EU Carbon Border Adjustment Mechanism
CCUS	carbon capture, utilisation and storage (or CUS)
CET	common external tariff
CO_2	carbon dioxide
COP	Conference of the Parties
COS	cost of service
DIRCO	Department of International Relations & Cooperation (South Africa)
DRC	Democratic Republic of Congo
DRI	direct reduced iron (sponge iron)
EAC	East African Community
EAF	electric arc furnace
EASSI	Eastern African Sub-Regional Support Initiative for the Advancement of Women
ESG	environmental, social and governance
EU	European Union
EV	electric vehicle
FDI	foreign direct investment
Fe	iron (chemical symbol)
GDP	gross domestic product
GHG	Greenhouse Gas
GJ	gigajoule
GSCF	Green Strategic Considerations Framework
GW	gigawatt

GWh	gigawatt hour
HBI	hot briquetted iron
HS	Harmonised Standard tariff code/category
	HS 72: 'Iron and steel'
	HS 73: 'Articles of iron and steel'
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRR	internal rate of return
JORC	Joint Ore Reserves Committee
KfW	Kreditanstalt für Wiederaufbau (German investment and development bank)
kt	thousand tonnes
ktpa	thousand tonnes per annum
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt hour
LAPSSET Corridor	Lamu Port, South Sudan, Ethiopia Transport Corridor
LCC	life cycle cost
LNG	liquefied natural gas
mcf	thousand cubic feet
NPA	National Planning Authority (Uganda)
Mt	million tonnes
Mtpa	million tonnes per annum
MVA	Mineral Value Added
MW	megawatt (1,000 kW)
NDC	Nationally Determined Contribution
NI	National Instrument
NPV	net present value
NTB	non-tariff barrier
OECD	Organisation for Economic Co-operation and Development
PPRA	Public Procurement Regulatory Authority (Tanzania)
PS	EAC Partner State
SDG	Sustainable Development Goal
SGR	Standard Gauge Railway

SNIM	Société Nationale Industrielle et Minière (National Industrial and Mining Company) (Mauritania)
TFTA	Tripartite Free Trade Agreement
tpa	tonnes per annum
TPDC	Tanzania Petroleum Development Corporation
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organization

Executive summary

Steel remains globally foundational for economic and human development. It underpins all sectors of any growing economy, including infrastructure, energy, construction and both capital and consumer goods manufacturing. Steel is also a critical component in green technology, with recycled scrap steel already an integral component of modern steel, which helps close the loop for proactive circular economy transitioning towards decarbonisation. There is no substitute for steel in the foreseeable future.

Steelmaking remains, however, an energy- and greenhouse gas (GHG)-intensive industry, one currently experiencing technological changes and pressures to reduce both. Traditional blast furnace smelting uses thermal coal for energy and metallurgical coal for the coke (which 'reduces' iron ore and adds carbon to steel), emitting high levels of carbon dioxide. The alternative, producing sponge iron via the direct reduction process using thermal coal or, usually, natural gas, emits less, and this could be further reduced by using carbon capture and storage. Ultimately, natural gas can be replaced by green hydrogen (produced from water not natural gas). Sponge iron is then added to scrap steel in electric arc furnaces that require high levels of electricity, but hydroelectric and other renewables can further reduce energy emissions. Policies and technology are driving rapid change within the global steel industry.

Although steel demand across the continent was stagnant in the late 2010s, it has risen sharply across the East African Community (EAC). Kenya and Tanzania together used over 4 million tonnes of steel in 2019, with Ugandan demand pushing towards 1 million tonnes/year. Prior to a COVID-19-induced decline in 2020, net imports of iron and steel (by volume, not price) by EAC countries increased by 11.4 per cent annually between 2010 and 2019. This does not include local production from scrap or nascent primary production using iron ore.

EAC Partner States have prioritised the development of the steel industry given:

- availability of regional raw materials (i.e., iron ore, thermal coal, limestone, natural gas, etc.);
- the economic and employment benefits of value-added industrialisation;
- the potential positive effects on trade balances and current accounts; and
- the risk of global supply disruptions that may arise from logistical issues, pandemics or policy-induced barriers to trade.

Continental and regional trade liberalisation creates further opportunities for steel industry development, and infrastructure expansion (including energy, rail and ports) increases the viability of local steel production and distribution while also driving local demand. Population growth and urbanisation are two of many important drivers of steel demand in the region.

EAC policy-makers and private sector stakeholders will need to work closely to capitalise on investment and market opportunities presented by a world that needs to decarbonise while steel demand *increases*, not decreases, across both traditional and new economy sectors. Scrap steel is a major input into new steel output but there is no possibility of scrap steel completely replacing iron ore. This is because of both limitations in the supply of scrap and the chemical and physical requirements for different types of steel.

A major finding of this study is that the volatile strategic environment for global iron ore and steel production creates both paradoxical trends and opportunities for the EAC. While the lack of major progress in developing large-scale iron ore mining and steel projects over the past decade – in, for instance, Tanzania and Uganda, under a conventional steelmaking framework – could be seen as a missed opportunity, there are now many new risks, obstacles and disincentives with regard to committing to high carbon-emitting integrated steel industries. Given some existing comparative advantages and some potential policy adjustments, the EAC could find that apparent the 'missed opportunity' creates improved prospects for regional economic development while meeting global and regional decarbonisation goals. Ultimately, given available information about EAC iron ore deposits and projects in the pipeline elsewhere, large-scale seaborne iron ore exports are not likely to be economic. Leveraging iron ore and other resources within a regional mineral value added strategy does, however, align with both national and regional development priorities and a growing steel demand appetite.

The EAC thus has an opportunity to position itself as a 'green steel ecosystem.' a commitment to becoming a green steel ecosystem will meet national and regional economic development objectives, the United Nations Sustainable Development Goals and Nationally Determined Contributions under the 2015 Paris Agreement. Identified comparative advantages include a strong and growing regional market for steel products; indications of high-quality iron ore (and related inputs); private sector companies with some steelmaking capability; existing and planned hydro, geothermal and other renewable electricity production; expanding transportation infrastructure; and lack of significant fixed assets tied to conventional, high GHG-intensity iron and steel plants.

Current technology does not require the massive upfront capital investments for conventional integrated steel plants that were previously needed to produce steel. Small-scale mining that can utilise renewable energy and best practices, direct reduction iron technology, and electric arc furnaces can be combined in a cost-effective, incremental manner to produce steel in closer proximity to existing steel fabrication facilities and/or end users. And, as technology is rapidly changing to reduce GHG intensity, new processes and fuels, including green hydrogen, can be added as they became commercially viable, given the lack of large-scale commitment to conventional technology. Greener steel can be cost-competitive at home and enjoy premium pricing abroad.

There is legitimate concern across the continent that extra effort towards 'greening steel' and related climate change policies represent a form of 'carbon colonialism.' Why should African countries with extremely low historical and current carbon footprints be restricted from pursuing every industrialisation pathway available? While it is true that African economies can make a case for leeway in terms of decarbonisation transitions, the reality is that national policy commitments, external market access (e.g., the European Union's Carbon Border Adjustment Mechanism, or CBAM) and inward investment attraction all require the integration of decarbonisation into future development planning. Regionally co-ordinated encouragement of a green steel ecosystem aligns with these parameters and ensures the long-term possibility of expanding steel production of the EAC to meet its growing demands and drive economic transformation.

EAC green steel ecosystem: comparative advantages & incremental adjustments to magnetize regional investment

Energy policy priorities: Keep expanding reliable, cost-competitive, non-fossil fuel electricity generation & access (with natural gas as transitional fuel to replace coal/diesel)

Cleaner sources of base energy (Scope 2): **Hydro, Geothermal** in place & expanding; **Solar/Wind/Ocean** options Increasing; **natural gas** as transitional fuel to replace biomass and diesel; short-term potential for **blue** (derived from methane in natural gas alongside CCUS) and ultimately **green** (derived from clean power electrolysis of water) **hydrogen** (at least for Industrial uses Incl. steelmaking).

Upstream mining: Highlight exploration and development potential of highest quality Iron ore (and nickel-dominant) deposits; highlight regional limestone and graphite resources; leverage most efficient transportation options (rail, road, water) as available; focus on mine and process design to reduce emissions.

Upstream mining policy priorities: prove up highest quality iron ore resources and allow regional exports; coordinate EAC "greener mining" guidelines, training, certification, and tax incentives to promote scope 1 & 3 emission reductions on an ongoing basis (R&D, technology upgrades, process or energy changes, road maintenance, etc.).

Downstream steelmaking: Existing steel Industrial base can be expanded in terms of increasing DRI (perhaps HBI) and EAF Incrementally (no massive projects or Investments required); distributed steelmaking across region, reducing Scope 3 emissions from Imported crude steel including seaborne transportation. Incremental shift from coal In current DRI facility to natural gas and hydrogen, while other iron reduction and steel making processes become financially viable.

Downstream steelmaking policy priorities: promote DRI/HBI & EAF over BF/BOF; move from coal-based DRI to natgas/syngas/hydrogen as feasible; promote R&D partnerships to investigate newest processes in greening steel.

Scope 1 Emission: Direct carbon emission from owned or controlled sources.
Scope 2 Emission: Indirect carbon emission from generation of purchased energy.
Scope 3 Emission: Indirect emission (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions

Background to this study

This report builds on the findings and recommendations of a broader report on mineral value added (MVA) potential across the East African Community (EAC) completed in 2013. In that report, we concluded that, 'The EAC does not have any distinctive global comparative advantage in its specific mineral inheritance,' but the 'EAC's comparative advantage lies in its rich mineral diversity, nascent regional common market, industrial capability and potential, and current policy emphasis on infrastructure and hydrocarbon development' (Precht et al., 2013). The 2013 recommendations remain valid as the EAC seeks to leverage its mineral resources for economic transformation, but global (Paris Agreement, Sustainable Development Goals), regional and technological developments call for some policy adjustments. One of those recommendations suggested that, given a group of 'regional value-added minerals' (termed 'Group A'), the EAC held the potential to scale up a steel industry beyond scrap recycling and fabrication. Group A included iron ore, coal and limestone, and the subgroup nickel, copper and cobalt.

Certain mineral resources were thus targeted for MVA strategies – mostly related to steel – while others were classified as best pursued under a high value mining strategy where the focus would be on promoting upstream exploration and mostly export-oriented monetisation. This owed to either limited downstream and sidestream MVA benefits (e.g., gold) or the difficulties (technological, environmental, etc.) related to downstream processing and beneficiation (e.g., some heavy mineral sands and most rare earth elements).

This study revisits the analysis and recommendations around Group A minerals to focus on key issues surrounding the development of a regional steel industry and makes recommendations to underpin a regional approach.

This follow-up study is concerned with three main areas:

1. strategic issues for the EAC to consider in the development of a regional steel industry, including transitioning to a low-carbon economy and circular economy sustainability. This includes long-term demand/supply considerations (e.g., to 2050) and the risks that the EAC should consider in adopting a regional steel strategy;
2. requirements needed for a sustainable regional steel industry and a framework for the phased approach across the steel value chain. This includes potential comparative advantages for the EAC as well as areas of weakness;
3. for each of the four minerals in Group A (iron ore, coal, limestone and nickel-copper-cobalt), the opportunities and challenges, areas of comparative advantage and recommendations for developing, as per the framework above.

During the process of researching developments in the EAC since 2013, changes in the regional and global context for iron and steel production, technological and capital market shifts in the energy, mining, and processing industries, it became clear that following a conventional pathway to iron and steel development in the EAC was neither desirable nor tenable.

Given existing comparative advantages in the EAC and the market, decarbonisation and political realities facing the global steel industry, EAC Partner States would benefit from promoting the emergence of a regional 'green steel ecosystem.' This report provides the context and initial recommendations to assist EAC policy-makers and private sector decision-makers to see the benefits and begin the shift towards such an ecosystem.

1. Steel after the Sustainable Development Goals, Paris and the Africa Continental Free Trade Agreement

1.1 Introduction

As the world economy slowly emerges from the COVID-19 pandemic with a renewed imperative to decarbonise energy and economic production in line with circular economy rethinking,[1] the East African Community (EAC) faces a critical question: Is there a window of opportunity remaining for its Partner States (PS) to take greater advantage of their abundant mineral resource inheritance as a catalyst to expand regional steel production? Pre-pandemic steel demand in the EAC increased by over 10 per cent per year from 2010 to 2019. Growing regional steel demand, the opportunities that could arise as the Africa Continental Free Trade Agreement (AfCFTA) is implemented and existing East African steel companies that have shown a willingness to take risks provide a basis to assess more deeply the opportunities for expanding East Africa's steelmaking capacity.

The global transition towards renewable energy sources as a result of the climate change crisis means that fossil fuels – particularly coal and crude oil but also natural gas – are facing growing headwinds in terms of attracting investments for both new and mature projects. The energy transition also has implications for upstream mineral exploitation and downstream mineral value added (MVA) industries such as steel, cement and other industrialisation priorities, as these activities are all 'energy-intensive' and all produce considerable CO_2 and other greenhouse gases (GHGs). Cement and concrete production alone accounts for 6 per cent of global CO_2 emissions (Bataille, 2019) while steel production accounts for another 6–7 per cent (equivalent to half of all emissions from passenger vehicles) (IEA, 2020a).

In China – the world's largest steel producer – steel accounts for 15 per cent of national CO_2 emissions (Liu et al., 2021). The Chinese government is already putting pressure on the industry to reduce emissions, given President Xi Jinping's announced intention to peak China's CO_2 by 2030 and achieve carbon neutrality by 2060 (You, 2021). While China begins to open the door to pig iron and steel imports (Bloomberg, 2021a), President Xi has made it clear that 'China will step up support for other developing countries in developing green and low-carbon energy, and will not build new coal-fired power projects abroad' (Xi, 2021). China joins Japan, South Korea and most international financial institutions in turning away from financing or building coal-fired electricity.

However, some East African governments still include new coal-fired plants in their overall electricity growth plans, including for steel and other heavy industry applications. While there is broad consensus that low- and middle-income countries cannot forgo attempts to better the lives of their people after the industrialised world, now including China and India, has benefited from near-unrestricted natural resource exploitation that has driven hundreds of millions out of poverty, the reality of the fast rise in GHGs since the middle of the 20th century will limit some development options today. However, although the lowest-emitting low- and middle-income countries face the hurdle of growing impacts from climate change while being required to recognise decarbonisation in their economic growth and transformation strategies, this apparent hurdle also creates opportunities.

1 For a good overview of circular economy revisioning of economic activity and production, see https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail

This study recognises major changes to the regional and global context of steel production and seeks to outline how this changed environment affects the feasibility and desirability of an expansionary steel industry in East Africa. Broadly, the project team addressed the potential for an expanded EAC steel industry given five strategic shifts since the early 2010s:

1. EAC visions to drive economic transformation by 2032, including to increase gross domestic product (GDP) derived from manufacturing from below 10 per cent to 25 per cent and to raise the local value added content of resource-based exports to at least 40 per cent, with 'iron-ore and other mineral processing' targeted as one of six priority sectors[2];
2. development in the context of the UN's 2015–2030 Sustainable Development Goals (SDGs);
3. economic opportunity in the context of changes in global market dynamics as well as the AfCFTA;
4. 'greening' of extractive and material processing industries in the context of the Paris Agreement, net-zero, circular economy and decarbonisation objectives;
5. demand growth and investment appetite for various minerals and manufactured products (including steel) required for a lower-carbon yet growing electricity demand world.

Ultimately, as hinted at above, **the major finding of the study is that the volatile strategic environment for global iron ore and steel production creates paradoxical trends, and opportunities for the EAC within those trends**. From one perspective, the lack of major progress in developing large-scale iron ore mining and steel industry projects in, for instance, Tanzania and Uganda under a conventional steelmaking framework over the past decade could be seen as a missed opportunity. There are now many obstacles and disincentives to build new, high carbon-emitting integrated steel industries (i.e., use of thermal coal for electricity and heat, and coking coal in blast furnaces (BFs)). But with existing comparative advantages and some potential policy adjustments, the EAC may find the apparent 'missed opportunity' improves its prospects for regional economic development while meeting global and regional decarbonisation goals. EAC members could position themselves as a future 'green steel ecosystem', as steel is one of the most recyclable materials, suitable for the circular economy.

In turning this vision into reality, many political, policy, geological and investment questions remain to be answered. This preliminary analysis provides a starting point for these further investigations. By understanding the broader strategic environment facing global steel through various national and global milestone years (2030, 2032, 2035, 2040, 2050, 2063, etc.), EAC policy-makers and private sector stakeholders will need to work closely to capitalise on investment and market opportunities presented by a world that needs to decarbonise while steel demand increases, not decreases, across both traditional and new economy sectors.

The remainder of Part 1 highlights some key trends and changes since the early 2010s and the 2013 EAC MVA report described in the 'Background' section. This sets the stage for Part 2, which describes the four major strategic issues facing the development and expansion of EAC steel industries.

With these strategic issues in mind, Part 3 then revisits four MVA mineral complexes identified in the 2013 MVA report, with particular emphasis on iron ore, the foundation for any steel industry. It provides additional iron ore case study analysis of conventional CO_2 emission impacts of mining and processing compared with greener approaches. It also provides some preliminary economic analysis of a proposed Tanzania-to-Uganda natural gas pipeline that has been discussed in large part to support iron and steel development in Uganda.

Part 4 then summarises some of those parameters and requirements for an expanding, sustainable, green regional steel industry in the EAC. It also highlights challenges and opportunities related to global trends and the need to attract significant international debt and equity investment for large-scale upstream, downstream and sidestream infrastructure projects. Within the constraints of a high-level study, Part 4 provides a basic framework for a phased approach across the iron-to-steel value chain, pointing out where further work needs to be done.

2 See www.eac.int/industry/eac-and-industrialisation and www.eac.int/industry/eac-and-industrialisation/priority-sectors

The 2013 MVA report concluded that, 'The EAC does not have any distinctive global comparative advantage in its specific mineral inheritance'; however, its 'comparative advantage lies in its rich mineral diversity, nascent regional common market, industrial capability and potential, and current policy emphasis on infrastructure and hydrocarbon development' (Precht et al., 2013: 49). Since 2013, major changes to the global and regional environment for sustainable development, mining, fossil fuels and steel production have necessitated a recalibration of strategies for expanding the EAC steel sector.

The remainder of this part of the report highlights some of the changes and trends that provide the background context for the four strategic issues identified in Part 2:

- EAC mining and steel industry developments (including the EAC steel market);
- international iron ore and steel markets;
- regional (EAC and AfCFTA) trade liberalisation;
- regional infrastructure (energy and transportation);
- green steel: the SDGs and the net-zero revolution.

1.2 Methodology

With COVID-19 restrictions precluding travel, the project team set out to identify relevant changes in the global and regional environment for four MVA mineral complexes identified in the 2013 MVA report most relevant to the steel and metals industry. The team then assessed how these changes might affect previous recommendations, any new challenges and opportunities that had emerged, and what this meant for the development of an EAC steel industry with more regional upstream–downstream linkages. To craft this study, the project team relied on:

- primary documents from governments, companies and international organisations;
- media reports from industry and trade press outlets;
- scientific peer-reviewed articles in academic and industry research journals;
- some outreach to other experts; and
- our own analytical skills, tools and experience.

It should be noted that examples and case studies provided here are not meant to be definitive or exhaustive, and there may be errors of fact about the status of specific plans and projects within the EAC. Any such errors do not affect the overall aim of the study: **to identify, from an independent perspective, strategic issues and challenges facing the expansion of the steel industry in EAC and to provide guidance based on current realities, comparative advantages and potential policy adjustments.**

Since the 2015 Paris Agreement, and particularly over the past year leading up to the 26th Conference of the Parties (COP26) in Scotland (November 2021), the volume of policy reports and scientific studies around green steel, decarbonising energy and heavy industry, and financing energy and industrial transitions has become heavy. It has been impossible to review every relevant study but it is important to note that these represent more than just hopes and aspirations. Steel technology process companies have invested in research and implemented new equipment and configurations to drastically reduce CO_2 emissions and to prepare for the eventual availability of mass quantities of green hydrogen. As this study illustrates, there are many GHG-limiting or GHG-eliminating options already available both for the mining of iron ore and for the steelmaking process. These cases and discussions are designed to stimulate thinking around how the EAC might position itself as a green steel producer of the near future.

1.3 EAC mining and steel industry developments (including the steel market)

Given the momentum and excitement around various mining, energy and industrial projects at the time of the original 2013 MVA report, eight years later there may be some frustration within government and private sector circles that many projects remain unimplemented. This should not be a surprise, however. Mining, oil and gas, and metals have faced a difficult risk capital market since the 2014 price declines. Without upstream mining, energy and infrastructure projects, downstream steelmakers cannot realise their capital investments along the MVA pathway.[3]

3 An interview with the executive director of Roofing Rolling Mills in January 2018 provided a business perspective on MVA challenges amid strong and growing regional demand for steel products (Khisa, 2018).

Steel production in the EAC remains dominated by scrap and mostly imported finished steel that is then fabricated in the region. Based on available evidence, only one company – Tembo Steel in Inanga, Uganda – is using East African iron ore to produce sponge iron for electric arc furnace (EAF) applications. Overall, it is difficult to get precise figures for EAC steel demand from a single source. However, examining various sources, it is clear over the 2010s that regional steel demand increased by over 10 per cent per year.

Table 1.1 shows steel consumption for African countries. Kenya and Tanzania are the only EAC countries that appear in these statistics, as consumption in other EAC countries is too small. The total market for finished steel products in Africa is very small, at around 2-3 per cent of global consumption, and the EAC market generally represents less than 10 per cent of continental consumption. The 2015–2019 annual growth rate for world steel consumption was 4 per cent, while steel use in African countries was lower in 2019 than in 2015. However, steel use in the only EAC countries covered in the World Steel Association statistics, Kenya and Tanzania (in bold in Table 1.2), grew annually by 15 per cent and 9 per cent, respectively, from 2015 to 2019. This aligns with industry and media accounts from East Africa that steel demand remains strong, including in Rwanda and Uganda. To confirm this demand trend, various statistical indicators are examined below.

Table 1.2 shows Kenya as the sole producer of steel among EAC countries and the smallest African producer, though we know these World Steel Association statistics do not capture the reality of Tanzanian and Ugandan crude steel production from scrap as well. Still, the EAC remains a significant importer of crude steel for fabricators as well as steel products, so we shift from trying to measure demand or production directly and instead use net import change over time as a better indicator of regional steel demand, assuming there is also some domestic production in Kenya, Tanzania and Uganda.

Table 1.1 Apparent steel use, finished steel products (thousand tonnes)

Country	2015	2016	2017	2018	2019
Algeria	5,990.0	5,688.0	5,813.0	5,427.5	5,582.3
Angola	779.0	297.2	208.6	214.2	262.7
Cameroon	268.8	241.6	192.3	217.6	202.4
Côte d'Ivoire	344.8	396.1	412.0	399.4	371.4
Egypt	10,862.0	11,683.0	10,178.0	11,067.0	10,354.0
Ethiopia	1,038.2	1,018.6	707.3	669.8	925.2
Ghana	911.0	858.8	725.3	774.8	966.7
Libya	1,385.0	1,385.0	951.0	1,014.9	1,121.4
Morocco	2,700.0	2,859.0	3,030.7	2,976.7	3,036.2
Nigeria	1,760.3	1,298.2	1,103.6	1,585.4	1,596.1
Senegal	418.9	516.8	476.3	592.6	579.7
South Africa	5,294.0	4,970.1	4,739.3	4,663.0	4,470.0
Sudan	320.0	322.0	303.6	314.6	325.9
Tunisia	800.0	809.0	829.0	853.9	864.1
Kenya	**1,713.8**	**1,501.6**	**1,368.4**	**1,419.7**	**3,024.2**
Tanzania	**665.2**	**548.2**	**533.9**	**728.8**	**938.2**
Africa total	35,251.0	34,393.4	31,572.2	32,919.8	34,620.4
World total	1,508,950.6	1,522,490.1	1,635,915.1	1,711,095.2	1,766,739.1
EAC as % of Africa	**6.7%**	**6.0%**	**6.0%**	**6.5%**	**11.4%**
Africa as % of world	2.3%	2.3%	1.9%	1.9%	2.0%

Source: Adapted from World Steel Association

Table 1.2 Production of crude steel (thousand tonnes)

Country	2015	2016	2017	2018	2019
Algeria	650.0	650.0	415.0	2,300.0	2,400.0
Egypt	5,506.0	5,035.7	6,870.1	7,806.8	7,257.0
Ghana	25.0	25.0	25.0	25.0	25.0
Nigeria	100.0	100.0	100.0	100.0	100.0
South Africa	6,417.1	6,141.3	6,301.2	6,327.3	6,151.7
Tunisia	50.0	50.0	50.0	50.0	50.0
Kenya	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**
Africa total	14,763.1	14,018.0	15,778.3	18,627.1	18,002.7
World total	1,625,141.5	1,632,780.4	1,735,874.6	1,825,485.7	1,875,155.4
EAC as % of Africa	0.1%	0.1%	0.1%	0.1%	0.1%
Africa as % of world	0.9%	0.9%	0.9%	1.0%	1.0%

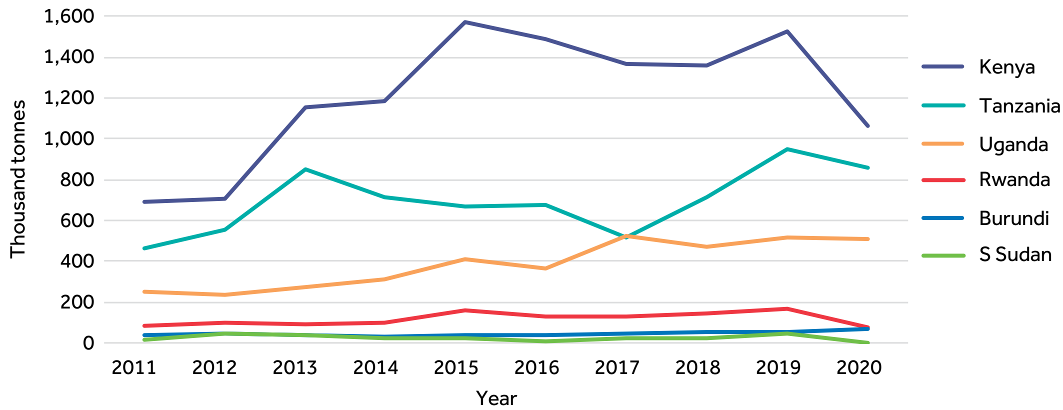
Source: World Steel Association

A more complete picture of demand trends can be generated by adding imports of HS two-digit categories – in this case HS 72 'Iron and steel' and HS 73 'Articles of iron and steel' – as per Figures 1.1 and 1.2. While there is variation year to year, demand in Kenya, Tanzania and Uganda in the second half of the 2010s was stronger than in the first half, leaving aside 2020 as an outlier owing to the impact of the pandemic on global economies. Figure 1.2 illustrates the cumulative EAC total, whereby regional net imports surpassed 3.2 million tonnes in 2019. Again, that total would not include any locally produced crude steel (from iron ore but mostly scrap) used domestically.

The net importer status of the EAC countries is even clearer from Tables 1.3 and 1.4, where all EAC countries have negative trade balances (absence of data for Tanzania in 2019 is unlikely to differ from established trade deficits). 'Iron and steel' negative balances are about 70 per cent higher than those for 'Articles of iron or steel,' and Kenya clearly has the highest negative balances for both commodity groups. We saw earlier that Kenya consumes much more steel than it produces. However, these figures provide less clarity about actual volumes given that they are in US dollar prices, which can vary in terms of underlying global prices year to year and local currency fluctuations.

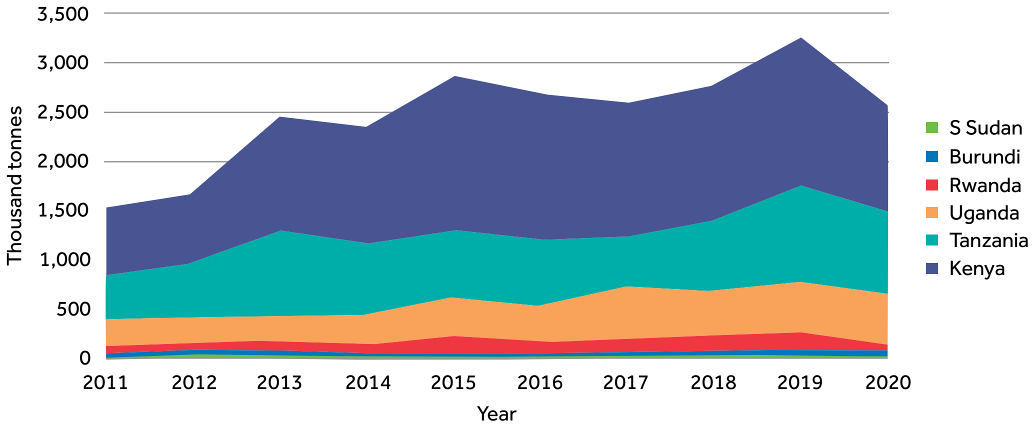
A series of tables in Appendix A show exports and imports of 'Iron and steel' for each EAC country. Additional tables show exports and imports of 'Articles of iron or steel.' These tables also show the

Figure 1.1 EAC net imports of iron and steel (HS 72 and 73) by country



Source: International Trade Centre, Trade Map

Figure 1.2 Cumulative EAC net imports of iron and steel (HS 72 and 73)



Source: International Trade Centre, Trade Map

portion of exports and imports with other African countries and with EAC countries, respectively. Tables 1.5 and 1.6 below summarise EAC country exports and imports of 'Iron and steel' and 'Articles of iron or steel,' respectively. It can be seen that exports of these commodities are overwhelmingly to other African countries, and within this are predominantly to other EAC countries (averaging about 60 per cent for HS 72 and 43 per cent for HS 73). This is especially true for exports of 'Iron and steel.' Other African countries and EAC countries provide a much smaller portion of total imports of these commodities.

EAC iron and steel processing/ manufacturing

The steel manufacturing sector in East Africa has traditionally been dominated by product fabrication from imported hot rolled coil and billets to produce rolled, wire and tube products primarily for the construction sector (see Nasman, 2013; Johnson, 2021) Kenya, Tanzania and Uganda have the largest manufacturing bases (see Table 1.7), while Rwanda has increased its steel fabrication over the past few years.

Overall, most EAC steel plants do not run anywhere near full capacity, for various reasons related to lack of inputs, power shortages, prices, competition, etc., even as EAC steel demand has shown healthy growth over most of the 2010s. EAFs are widely used, with mostly steel scrap, given the lack of high-quality coking coal in the region to use in BF. Processing draws 350–700 kWh per short ton (2,000 lb) of steel produced, with an average of 475 kWh/ton (1.7 GJ/ton of energy equating to 70 per cent efficiency). EAFs equipped with graphite electrodes (with high-quality mined graphite available from Tanzanian sources) draw via 800 kVA transformers, which require direct connection to national grid and a reliable source of power generation (and reasonable pricing to be economically viable). If this electricity comes from a renewable source, a scrap steel EAF mill is already far along the steel decarbonisation and circular economy pathway.

As scrap alone cannot fulfil EAC steel needs, primary steel produced from direct reduced iron (DRI) (or sponge iron) is being undertaken on a small scale by Tembo Steel in Uganda using coal as the reductant. To increase the scale of DRI to significantly replace imported coil and billets, natural gas would be preferred to coal as long as prices were competitive. This has led to high-level discussions between Tanzania and Uganda about a possible natural gas pipeline. Some preliminary analysis of pipeline economics is offered in Part 3 of this report. Ultimately, green hydrogen (produced via electrolysis using renewable sources of electricity) (Mikulka, 2021) could replace coal or natural gas for DRI reduction; other emerging technologies, still far off commercial viability, are also on the horizon. Even before the deployment of green hydrogen or other technologies, given the use of scrap and some DRI produced from regional iron ore, and using significant renewable energy sources to drive DRI, EAF and metal fabrication processes, EAC steelmaking could produce much

Table 1.3 Trade balances – HS 72 'Iron and steel' (US$ thousands)

Country	2014	2015	2016	2017	2018	2019	Annual average
Burundi	($23,346)	($13,928)	($24,489)	($36,101)	($52,571)	($52,191)	($33,771)
Kenya	($614,331)	($599,713)	($488,230)	($627,368)	($747,585)	($781,772)	($643,166)
Rwanda	($62,666)	(97,851.00)	($74,125)	($73,741)	($96,262)	($96,713)	($83,559)
South Sudan	($19,788)	(5,169.00)	($9,233)	($2,794)	($8,499)	($11,729)	($9,535)
Tanzania	($359,479)	(221,849.00)	($268,842)	($244,973)	($385,324)	N.A.	($296,093)
Uganda	($157,924)	(192,960.00)	($138,813)	($217,611)	($284,053)	($296,823)	($214,697)
Total	**($1,237,534)**	**($1,131,470)**	**($1,003,732)**	**($1,202,588)**	**($1,574,294)**	**($1,239,228)**	**($1,231,474)**

Source: International Trade Centre, Trade Map

Table 1.4 Trade balances – HS 73 'Articles of iron and steel' (US$ thousands)

Country	2014	2015	2016	2017	2018	2019	Annual average
Burundi	($12,562)	($8,901)	($12,312)	($9,819)	($9,905)	($15,860)	($11,560)
Kenya	($308,682)	($450,054)	($409,638)	($273,430)	($353,221)	($262,273)	($342,883)
Rwanda	($73,862)	($92,965)	($58,748)	($75,168)	($71,520)	($110,051)	($80,386)
South Sudan	($26,470)	($23,277)	($21,200)	($6,319)	($17,822)	($19,464)	($19,092)
Tanzania	($428,338)	($260,660)	($178,192)	($170,449)	($276,965)	N.A.	($262,921)
Uganda	($66,303)	($29,035)	($46,501)	($24,536)	($39,026)	($42,206)	($41,268)
Total	**($916,217)**	**($864,892)**	**($726,591)**	**($559,721)**	**($768,459)**	**($449,854)**	**($714,289)**

Source: International Trade Centre, Trade Map

Table 1.5 Total EAC trade – HS 72 'Iron and steel' (US$ thousands)

Exports	2015	2016	2017	2018	2019	Average
Burundi	$12,308	$1,664	$1,093	$886	$3,455	$3,881
Kenya	$111,164	$116,188	$107,114	$112,736	$134,919	$116,424
Rwanda	$1,913	$2,613	$6,970	$9,570	$9,121	$6,037
South Sudan	$0	$1,873	$46	$27	$3	$390
Tanzania	$24,991	$76,069	$9,864	$24,463	$40,576	$35,193
Uganda	$86,597	$70,840	$65,954	$85,331	$65,819	$74,908
Total	**$238,988**	**$271,263**	**$193,058**	**$235,031**	**$255,912**	**$238,850**
% to Africa	95.8%	75.9%	97.1%	97.5%	96.5%	92.5%
% to EAC	**56.0%**	**51.9%**	**58.7%**	**67.1%**	**68.1%**	**60.4%**
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Average**
Burundi	$26,236	$26,153	$37,194	$53,457	$55,646	$39,737
Kenya	$710,877	$604,418	$734,482	$860,321	$916,691	$765,358
Rwanda	$99,764	$76,738	$80,711	$105,832	$105,834	$93,776
South Sudan	$5,169	$11,106	$2,840	$8,526	$11,732	$7,875
Tanzania	$384,470	$297,918	$278,706	$269,436	$425,900	$331,286
Uganda	$279,556	$209,653	$283,565	$369,384	$362,642	$300,960
Total	**$1,506,072**	**$1,225,986**	**$1,417,498**	**$1,666,956**	**$1,878,445**	**$1,538,991**
% from Africa	26.2%	28.0%	27.9%	30.4%	37.5%	30.0%
% from EAC	**12.3%**	**14.9%**	**16.2%**	**17.3%**	**18.0%**	**15.7%**

Source: International Trade Centre, Trade Map

Table 1.6 Total EAC trade – HS 73 'Articles of iron or steel' (US$ thousands)

Exports	2015	2016	2017	2018	2019	Average
Burundi	$1,902	$290	$266	$197	$175	$566
Kenya	$58,290	$55,452	$44,524	$45,446	$46,427	$50,028
Rwanda	$517	$1,007	$632	$2,267	$3,278	$1,540
South Sudan	$50	$145	$8	$11	$20	$47
Tanzania	$7,425	$21,004	$33,341	$7,795	$22,361	$18,385
Uganda	$24,936	$27,640	$36,209	$32,093	$31,074	$30,390
Total	$95,135	$107,554	$116,997	$89,827	$105,354	$102,973
% to Africa	87.5%	72.8%	66.3%	79.5%	73.4%	75.9%
% to EAC	**57.7%**	**41.5%**	**31.8%**	**37.2%**	**47.5%**	**43.2%**
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Average**
Burundi	$10,803	$12,602	$10,085	$10,102	$16,035	$11,925
Kenya	$381,592	$508,344	$465,090	$317,954	$398,667	$414,329
Rwanda	$517	$1,007	$632	$2,267	$3,278	$1,540
South Sudan	$23,327	$21,345	$6,327	$17,833	$19,484	$17,663
Tanzania	$439,081	$282,537	$211,738	$183,895	$303,427	$284,136
Uganda	$57,106	$71,437	$52,176	$75,235	$74,299	$66,051
Total	$912,426	$897,272	$746,048	$607,286	$815,190	$795,644
% from Africa	12.2%	10.2%	12.3%	13.7%	10.7%	11.8%
% from EAC	**5.2%**	**5.0%**	**5.4%**	**6.3%**	**5.3%**	**5.4%**

Source: International Trade Centre, Trade Map

Table 1.7 EAC Steel Industry Survey (selected examples of past, current, planned)

Kenya	Uganda	Tanzania
Historical producer Corrugated Sheets & Safal Group (Est. 1962) ***Major companies*** Devki Steel Mills largest steelmaker in Kenya (55MW) Mabati Mills and Insteel (both Safal Group) Corrugated Sheets (Mombasa) Tononoka Rolling Mills Abyssinia Group (incl. some iron ore mining at Homa Bay) Tuffsteel (tubes/ sections distributor) Apex Steel (fabricator/distributor)	Sukulu steel mill Undefined: 71 ktpa (Yager, 2016) Roofings Rolling Mills 20 MW power draw Rolled steel: 200 ktpa (Khisha, 2018) Roofings Rolling Mills (Namanve) steel plant drawing 43 MW power Tube steel: 480 ktpa (Expogroup, 2014)	ALAF (Aluminium Africa, part of Safal Group) (2016) rolled steel: 70 ktpa MM integrated steel mills (2016) rolled steel: 36 ktpa Steel Masters (2016) undefined: 22 ktpa Other steelmakers/ fabricators include Sita Steel, Sayona Steel, Nyakato Steel
USGS Yearbook estimates: **Crude steel total:** 390 ktpa **Semi-manuf**: 590 ktpa **Galvanised:** 257 ktpa *Overall annual demand 600 ktpa domestic + 240 ktpa imported (Barnes, 2015)* **Crude Steel producers (est.):** Devki 250 ktpa Athi 120 ktpa Kenya United 20 ktpa Numerical Machining 20 ktpa **Rolled Steel producers (est.):** Devki 250 ktpa Mbati 200 ktpa Athi 120 ktpa Numerical 100 ktpa Tarmal Steel 100 ktpa (2021) Smaller fabricators 194 ktpa	**Tembo Steels: First DRI plant** in EAC (2019) using rotary coal kiln from India, can produce various grades of stainless steels: 200 ktpa structure mill, 300 ktpa wire rod mill, 300 ktpa bar mill (Aiming for 1.2 mtpa capacity) Pramukh Steel Ltd, Madhvani Steel, and Kabale Steel considering smelting capacity (Atwine, 2022)	***Planned NDC & Sichuan Hongda Liganga iron and coal mine plus integrated steel plant re-announced in 2021:** 600 MW coal power plant (250 MW for integrated steel using BF/BOF, 350 MW for grid) Crude steel: 200 ktpa Rolled steel: 143 ktpa *Not clear in 2022 if this project can still attract the level of capital investment required given focus on coal-fired electricity and conventional BF/BOF technology

greener crude steel and finished products than most Chinese, Indian or Vietnamese producers. This starting point, plus rising regional demand, provides a foundation to investigate global and continental trends to determine whether major iron ore and/or steel exports beyond the EAC are also economically feasible.

With regional steel demand increasing over time, and given existing capabilities and various planned projects, driven by both governments and established private sector firms, significant opportunities remain for steel production to expand across the region. This would reduce imports, smooth out price and currency fluctuations, and create opportunities for increased MVA using local inputs. Despite setbacks that have prevented the development of giant integrated iron and steel projects, greater steelmaking capacity exists today, including the important introduction of DRI in the region. Much of this industrial capacity is not fully utilised, as a result of limited scrap and reliance on imported steel for fabrication. However, this review recognises that the EAC is positioned to benefit from the latest policy and technological trends in the industry, shifting toward decarbonisation and green steel production, particularly if those trends are capitalised on and coordinated regionally to create a magnet for investment in an emerging green steel ecosystem.

In 2018, a Ugandan steel executive said that 'Consumption of steel per capita currently stands at around 15 kg/capita per annum in Uganda whereas it is around 45 kg in Kenya. The world average consumption is close to 250 kg which shows that our industry is still at its infancy stage in comparison with developed countries' (Khisa, 2018). While we can try to figure out past and current steel demand consumption across the EAC, every indication is that demand consumption has the potential to skyrocket given the underlying unmet needs of populations that live in low- and lower-middle-income, largely rural and under-industrialised, economies.

1.4 International iron ore and steel markets

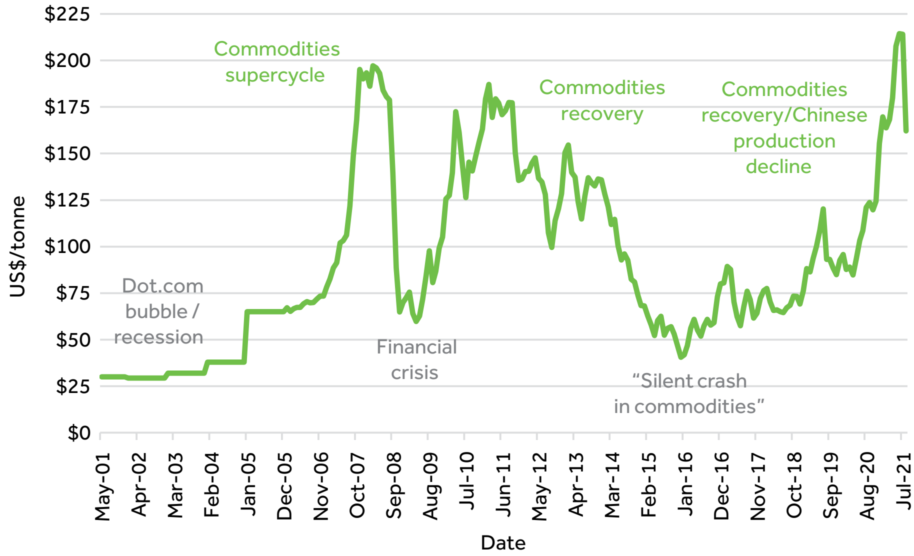
It is impossible to look at the EAC iron and steel sector without considering the international mining and trade context within which it operates, including mineral pricing. It is always risky to attempt to predict any mineral or commodity price too narrowly and too far into the future and then base significant policy and investment decisions on these predictions. Thus, it is important to see through current COVID-19 price volatility and examine deeper trends in both the global iron ore trade and steel production that began a few years before the pandemic. Capital-intensive mining, energy and industrial processing industries require long time horizons, given upfront capital investments and extended payback periods prior to profitability.

The focus is less on price forecasts – though a realistic, average floor price estimate is critical, and long-term offtake agreements can lock in price stability – than on an understanding of supply–demand dynamics based on expectations of future scarcity (e.g., extracted resources and reserves not being replaced by new discoveries and projects), the relative elasticity of demand (e.g., possible technological changes or substitutability) and changing investment appetites and the cost of capital (e.g., decline in risk capital available for mining or fossil fuel projects from 2014 as a result of low commodity prices and increasing portfolio divestment from carbon-intensive industries).

Unexpected shocks, such as the COVID-19 pandemic, can disrupt demand and supply chains and have a material but short-term impact on prices. But that volatility can also have long-term consequences as a result of delayed investment decisions, redirection of limited public and private expenditures, and shifts in trade patterns (e.g., less confidence in global supply chains and just-in-time inventory management). And the increasing global focus on 'decarbonising heavy industry,' primarily cement, steel and chemicals (Bataille, 2019; IEA; 2020; Gross, 2021), creates new incentives (e.g., green steel premiums) and potential costs (e.g., the EU Carbon Border Adjustment Mechanism (CBAM)) that need consideration. Between the upsurge in 'pandemic nationalism' (Mylonas and Whalley, 2022) and ongoing geopolitical tensions between important trading partners such as the US and China, Australia and China, and the UK and the EU, plus decarbonisation trends, trust in long-term stability of existing trading rules and relationships has declined. All these factors create uncertainty but also opportunity for policy-makers and business leaders who can identify the major trends through short-term volatility. Regional MVA can become one strategy to limit some of these global risks.

The goal here is not to estimate future iron ore or steel prices but to look at recent price and market trends as a starting point for the feasibility of expanding EAC steelmaking. Even if the EAC *doubled* its steel demand over a one-year period, this would not have any material effect on global iron ore or steel prices, given a jump from 4 to 8 million tonnes/year when global steel production is nearly 1.9 billion tonnes. First, recent global price volatility trends for iron ore and steel, shifts in major players and changes in overall market dynamics will be assessed. Second, for comparative purposes, upstream (new iron ore projects) and downstream (investments in steel production) trends in Africa are looked at. As the AfCFTA begins to affect trade and investment decisions, mining and steel industries within the continent could become direct competitors in terms of both intra-African and overseas trade but also foreign direct investment (FDI). There are also lessons to be learnt from other jurisdictions about the difficulty in bringing highly prospective projects into production, or how some countries are already integrating decarbonisation into their overall iron and steel policy frameworks.

Figure 1.3 Global iron ore prices, Fe 62% fines



Note: Fe 62% fines = 'iron ore fine china import 62 per cent grade,' a standard, mid-range crushed ore containing at least 62 per cent iron content.
Source: https://www.indexmundi.com/commodities/?commodity=iron-ore&months=240

Iron ore market trends

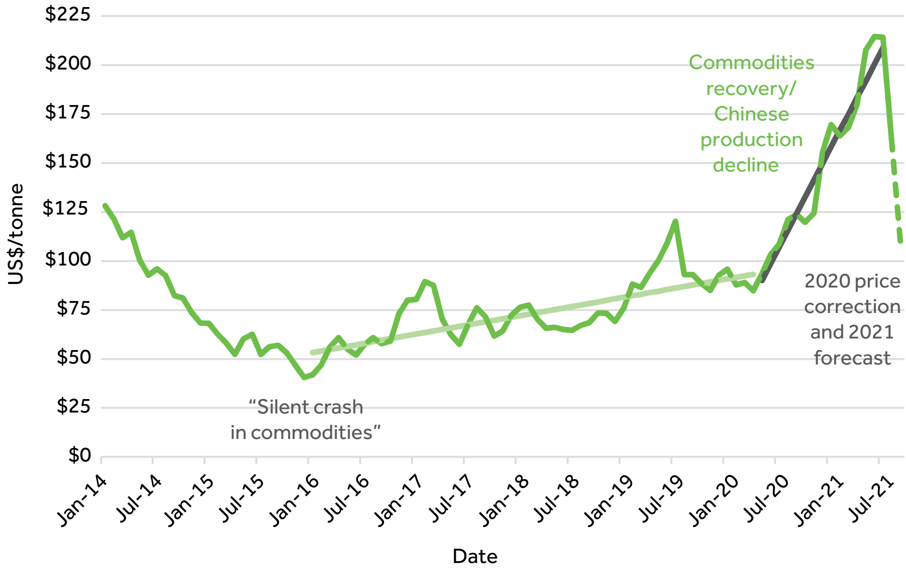
Iron ore, like other globally traded commodities, has experienced wide price variation over the past 20 years (see Figure 1.3). Iron ore prices generally reflect broader economic trends given that iron is the raw material for steel, the backbone of the construction, industrial and consumer goods sectors. Shortly after the 2013 MVA report, both iron ore and oil prices started a long decline. Low prices affect economic feasibility studies for planned projects while capital looks elsewhere for better returns. Global iron ore production declined during the period 2015–2019 as low prices made some mining operations unprofitable and lack of investor interest slowed exploration and development. During the second half of the decade, China's domestic production of iron ore declined rapidly, leading to growing Chinese imports of ores from Australia and Brazil as well as low-quality (two-thirds, <58 per cent, Fe)[4] Indian ores (Zhang and Arora, 2021). While lower-quality ores are cheaper, the energy required and the GHG emissions from their processing (e.g., sintering) are greater. As China reduced steelmaker quotas in 2021 to bring down air pollution and GHG emissions, the price spread between higher-quality ores and mid- and low-grade ores widened (Theo, 2021a).

An examination of more recent iron ore price trends since the low point of 2015 illustrates a gradual shift upwards in the average price prior to the spike in 2020. Iron ore prices did not experience any setback because of the onset of the global pandemic in the first quarter of 2020, and instead spiked as supply disruptions hit various major producers and exporters at different times. But the upward average pricing already reflected tightening supply, given lack of investment and lower production when prices declined and fell below US$50/tonne. From January 2016 to January 2020, the average price (the yellow line in Figure 1.4) went from just over $50/tonne to $90–95/tonne. COVID-19 disruptions plus macroeconomic stimulus pushed prices towards $200/tonne from the middle of 2020 as any existing production slack was quickly taken out of the system. This was despite overall lower production and consumption of steel in 2020 compared with 2019.

But there were three deeper factors driving prices upwards (along the average, not the $200/tonne temporary spike price level). First, the rapid decline in Chinese domestic production of iron ore has increased its import appetite, especially for higher-quality ores, in part to reduce emissions. As Figure 1.5 illustrates, China went from the largest global producer of iron ore in 2010 to third place by 2019. That is still significant domestic production but falls far short of domestic steelmaker demands. Metals analysis provider MetalMiner recently reported that, 'Iron is experiencing a perfect storm at the moment, Beijing's environmental constraints are having a two-pronged impact on prices' (Saefong, 2021).

4 Premium = 65 per cent/low-grade=<60 per cent.

Figure 1.4 Global iron ore prices, Fe 62% fines



Source: https://www.indexmundi.com/commodities/?commodity=iron-ore&months=240

China remains the largest steel producer, producing over 50 per cent of global steel despite recent capacity closures of older plants (Deloitte, 2020a). The first of the giant Guinea Simandou deposits (more below), long dormant as prices languished, is now moving towards production with Chinese and Singaporean firms as majority shareholders, but this production will not reach China until 2025 at the earliest (Le Bec, 2021).

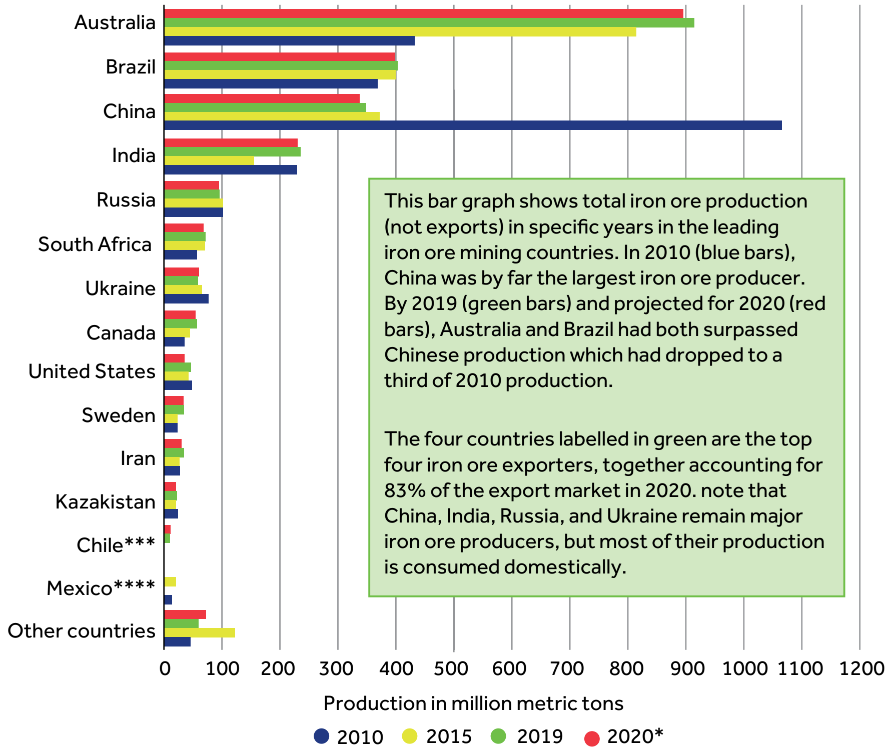
Second, given changes in the iron and steel process industry related to the increasing use of scrap as feedstock in EAFs and, more recently, concerns about CO_2 and other GHG emissions, the quality of ore grades matter more at the same time as better-quality, easily mined deposits are being depleted. Specifically, growing production of DRI (or sponge iron) and hot briquetted iron (HBI) (a compacted, easily transported form of DRI) increases preferences for higher grades of iron ore. Part of China's drastic reduction in iron ore mining owes to more limited supplies of high-grade iron ore while closing down lower-grade production.

Third, investment in new steel production has shifted decisively from conventional, large-scale integrated steel facilities relying on blast/blast oxygen furnaces (BFs/BOFs) towards EAFs and other technologies, which can be built economically at much smaller scales ('mini-mills') and closer to inputs and/or markets (see steel analysis below). And both the DRI process and EAF steelmaking can be incrementally decarbonised using renewable sources of electricity and, eventually, green hydrogen as the reducing agent. These intermediate steps to substantially reduce GHGs in both DRI and EAF processes are mostly unavailable to conventional integrated steel mills producing pig iron.

> This bar graph shows total iron ore production (not exports) in specific years in the leading iron ore mining countries. In 2010 (blue bars), China was by far the largest iron ore producer. By 2019 (grey bars) and projected for 2020 (red bars), Australia and Brazil had both surpassed Chinese production, which had dropped to a third of 2010 production. The four countries labelled in green are the top four iron ore exporters, together accounting for 83 per cent of the export market in 2020. Note that China, India, Russia and Ukraine remain major iron ore producers but most of their production is consumed domestically.

A quick analysis of shifts in global iron ore production since 2010 (see Figure 1.5) further illustrates the case for a secular trend towards higher iron ore prices. Chinese production, while still high, collapsed between 2010 and 2020. China and India utilise most of their domestic Fe production plus imports, although Indian exports to China (mostly low Fe <58 per cent) have grown as prices have increased and as China has reduced its own low-quality production. The overall quality of Chinese and Indian domestic Fe mine production does not match that of Australia or, particularly, Brazil. Australia dominates seaborne

Figure 1.5 Shifts in global iron ore production between 2010 and 2020



Source: US Energy Information Administration. https://www.statista.com/statistics/267380/iron-ore-mine-production-by-country

(mostly 62 per cent) Fe exports, with about 51–53 per cent of the total export market. Brazil is the largest exporter of high quality (Fe >64 per cent) iron ores, with demand growing for better-quality ores leading to forecasts for Brazilian production growth of 5 per cent/year if prices remain elevated (Dyer, 2021; mining.com, 2021a).

In Africa, South Africa remains the leading producer, with about 80 Mtpa, while Guinea's extensive, high-quality iron ore projects could surpass South African production by 2025–2026. Even Mauritania, currently the second largest African exporter, producing around 12 Mtpa (Mining Technology, 2021), aspires to reach 40 Mtpa later this decade, about half of South Africa's current output.

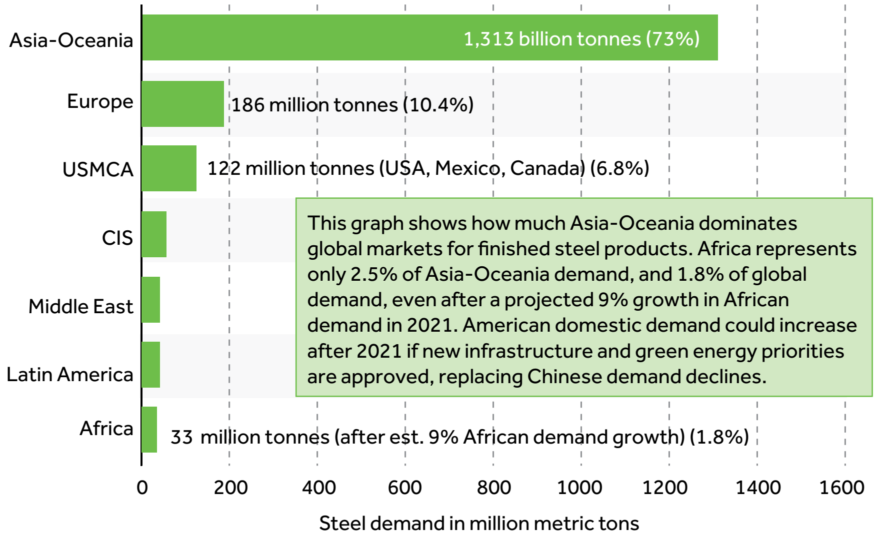
Overall, there are only a handful of significant iron ore exporters, as many countries consume most of their domestic production. The top four exporters in 2020 (Australia, Brazil, South Africa and Canada) accounted for 83 per cent of the global iron ore export market.[5] Australia has the potential to shift from an ore exporter (about 900 Mtpa) up the decarbonised, green steel value chain, given its relatively good-quality ore and tremendous potential for low-cost, renewable electricity that could drive large scale DRI/HBI exports to various Asian steel producers (Gielen et al., 2020; The Conversation, 2021). More recent analysis by Fitch Solutions see the biggest benefits of shifts to low carbon emission green steel accruing to Australia, Canada and perhaps Brazil based on quality of ore produced and possibilities of producing green hydrogen economically (Iannucci, 2021). The demand pull for green steel from more manufacturers and environmental policy changes that will affect tariff and non-tariff trade barriers are the key trends shaping the global iron and steel industry for the foreseeable future.

Steel demand growth

A return to healthy global demand (and thus prices) for steel, after a sluggish second half of the 2010s, is being driven by economies that are emerging from pandemic recessions and disruptions, boosted in part by stimulus spending and pent-up demand for both industrial and consumer goods. In China, price pressure is also a response to government efforts to reduce production in order to reduce urban air pollution and GHG emissions. In the first half of 2021, some steel prices in the USA and other markets tripled, with 'the ripple effects … being felt by everyone from home builders to appliance

5 https://www.statista.com/statistics/300328/top-exporting-countries-of-iron-ore/

Figure 1.6 Projected regional demand for finished steel products in 2021



Source: https://www.statista.com/statistics/246397/estimated-demand-for-steel-worldwide-by-region/

makers' (Deaux, 2021). Total steel output fell slightly in 2020 to about 1.8 Bt (Deloitte, 2020a), while demand forecasts for 2021 were up to 1.9 Bt and perhaps 1.93 Bt in 2022 (Kinch, 2021). Prices are not expected to stay this elevated but supply chain disruptions continue to affect the sector. Figure 1.6 highlights 2021 steel demand across different regions, where Asia-Oceania dominates but Africa shows the most demand growth.

Between price volatility and supply disruptions, there is some concern about demand destruction in the short run: delayed orders owing to high prices or uncertainty of order fulfilment could curtail overall demand or affect the economic viability of specific firms. But the secular trends for rising steel demand, including the Biden Administration's impetus to reinvest in the US infrastructure base from railways and bridges to zero-emission transportation and clean energy transmission (The White House, 2021), look steady even if China eases its once insatiable appetite for steel.[6]

Forecasters predicting global steel demand out to 2025, 2035 or even 2050 consider various factors. First, China's strong demand growth over the past 30 years is expected to wane, declining from nearly 500 kg/per capita in 2015 to a range of 365-388 kg/per capita by 2035 (Accenture, 2017). This owes largely to countries with higher levels of GDP per capita passing their peak steel consumption, as urbanisation slows and economic sectors diversify (see Figure 1.7). Most African countries, and all East African countries (currently 10–50 kg/per capita), are still far from their expected peak steel consumption per capita.

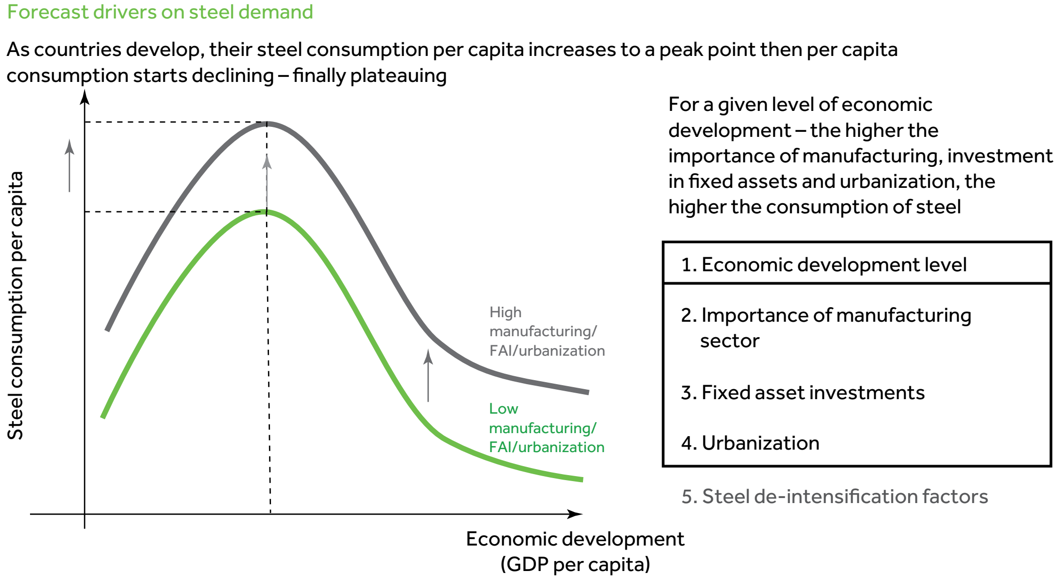
Second, over time there is a de-intensification of steel even at similar levels of economic development, owing to technology changes, material substitution and product demand decline. For East Africa this could mean per capita consumption of steel never peaks at European, North American or even Chinese levels, but the gap was still so large in 2021 that de-intensification would not significantly curtail rising demand across the EAC for the next two decades.

Third, consumption of steel across key sectors will vary by country. Seven steel consumption sectors are rank ordered by global end usage and shown in Figure 1.8:

1. building and infrastructure (including public, commercial and residential construction);
2. mechanical equipment (including capital goods);
3. automotive;
4. metal products;
5. other transport;
6. electrical equipment (likely to increase with renewables generation/transmission);
7. consumer/domestic appliances.

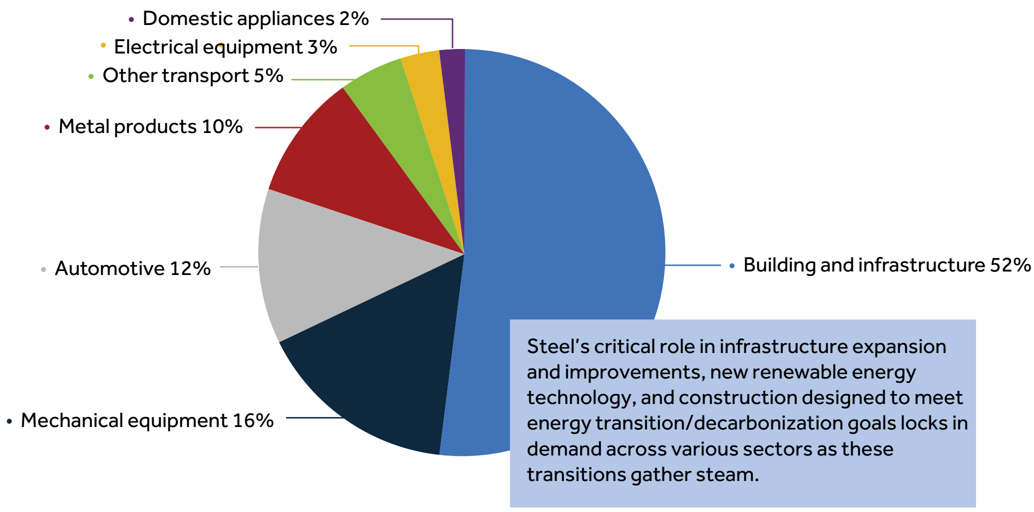
6 Forecasted Chinese production declines to 2050 (Marcus and Vila, 2021).

Figure 1.7 Country steel consumption drivers at different economic development levels



Source: Accenture (2017)

Figure 1.8 Distribution of steel end usage worldwide in 2019, by sector



Source: https://www.statista.com/statistics/1107721/steel-usage-global-segment/

'Building and infrastructure' comprises 52 per cent of global steel usage, and this proportion is higher in those emerging (low- and lower-middle-income) countries where urbanisation shifts are rapid and basic public infrastructure, including roads and energy access, is prioritised. Within this mix of sector consumption, future demand for greener steel is currently unknown. But even at premium prices the expected global demand for lower-GHG steel across Scope 1–3 emission categories will be high, with supply unable to keep up with demand.

European automakers are driving this initial sectoral demand, but the EU's CBAM will have broader sectoral impacts for steel and steel product imports to the EU.[7] Simply put, 'Green steel is a multi-billion dollar opportunity' (Koch Blank, 2020).

7 'The CBAM foresees in an import levy on EU imports of electricity, cement, aluminium, fertiliser and **iron and steel products**, depending on the emission content of production and the difference between the EU ETS [emissions trading system] price and any carbon price paid in the production country' (Dumitru et al., 2021).

Steel's critical role in infrastructure expansion and improvements, new renewable energy technology and construction designed to meet energy transition/decarbonisation goals locks in demand across various sectors as these transitions gather steam.

Fourth, steel is also fundamental to both traditional and green economy applications, so overall demand is not tied to either the old or the new economies. Steel accounts for 71-79 per cent of the material used to build wind turbines (iron and cast iron is an additional 5-17 per cent),[8] while electric vehicles (EVs) remain dependent on high-strength steels to accommodate the extra weight of their battery packs (Steiniger, 2019). Structural steel used in the US Leadership in Energy and Environmental Design Green Building Rating System 'receives maximum credit for its contribution to the overall rating for a structure, due in large part to its recycled content, recycling rate, and transparency.'[9] Demand for steel, and thus its pricing, will continue to be driven by both overall levels of economic activity and regional, sectoral and greener demand trends. And, even as the growth in EAF steel mills accommodates increasing demand for and use of steel scrap, it is estimated that demand for iron ore will only peak between 2025 and 2030 at 2.23–2.34 Bt. Even by 2050 there will be minimum 'annual residual demand of 550-750 Mt of primary steel' (Koch Blank, 2019).

There are significant differences in total steel demand forecasts out to 2035 or 2050. Some forecasters see Chinese declines replaced by India and other emerging regions such as Africa, with minimal overall change from current levels of around 1.8–1.9 Bt out to 2035. Other scenarios forecast up to one-third greater steel demand by 2050, pushing that to 2.4–2.5 Bt (IEA, 2020a). Based on various forecasts, global demand is best described as steady and unlikely to surpass 2.0–2.1 Bt by 2035–2040, but the share of steel produced via EAF processes (utilising scrap and DRI) could comprise half of all steel production outside China by 2035.

Global steel production remains dominated by China, which accounted for 54 per cent of 1.85 Bt in 2020, and also for 49 per cent of steel consumption (Deloitte, 2020a). India, Japan, the USA, Russia and South Korea round out the top producers, each with over 70 Mt in 2019. Egypt (20th place, at 10.3 Mt) and South Africa (32nd place, at 5.0 Mt) were the only African producers in the global top 32 in 2021.[10] However, in the ranking of *net exporters* (exports minus imports), Russia, Japan and South Korea are the top three, with Egypt ranked ninth.[11] It is important to note that, alongside India, Egypt and South Africa represent the geographically closest major steel exporters to the EAC.

Latest African iron ore developments

Other African countries are moving ahead in their efforts to become iron ore exporters or to increase their exports. Below is a quick review of some established and emerging plays (involving six countries) that could shift global and regional iron ore markets, but this is not an exhaustive list. South Africa is not included as it has a mature iron ore industry and is the top African exporter, though that position could be challenged once Guinea's large ore reserves reach the global market beginning in 2025.

Known as one of the leading exporters of high-quality bauxite, the ore used to make aluminium, **Guinea** also has significant reserves of high-quality iron ore that have long been identified but not developed. The two Simandou deposits are estimated to contain over 2 Bt of high-grade ore each (66–68 per cent Fe, mostly friable hematite).[12] While the ore is easily mineable, the infrastructure challenge involved in moving iron ore to tidewater for export has faced major financial, engineering and political hurdles that are just recently being overcome. Simandou and most other iron ore deposits are in the far southeast of the country, making a railway through Liberia the closest route to the Atlantic Ocean (see Figure 1.9). But the Government of Guinea mandated that any rail line must stay within the country to create growth corridors, also increasing length, costs and engineering complexity.

Only in March 2021 was the railway construction project to unlock Simandou iron ore officially

8 https://www.usgs.gov/faqs/what-materials-are-used-make-wind-turbines?qt-news_science_products=0#qt-news_science_products

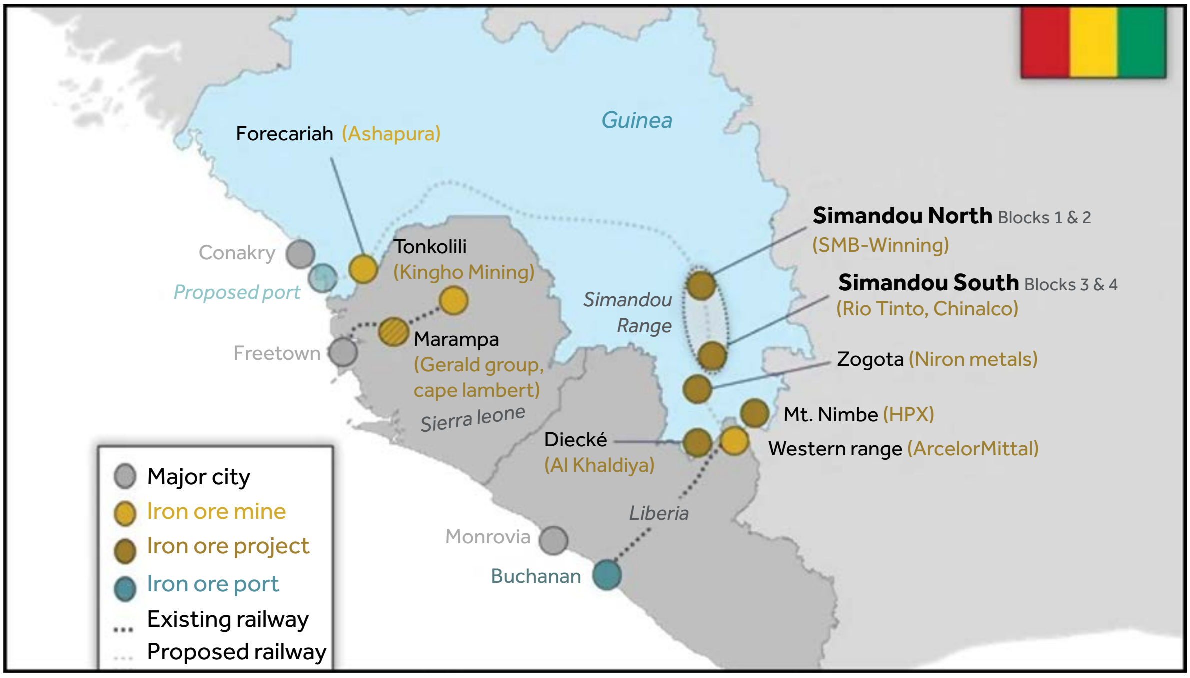
9 https://www.aisc.org/why-steel/sustainability/

10 https://worldsteel.org/steel-topics/statistics/world-steel-in-figures-2022

11 https://worldsteel.org/wp-content/uploads/2021-World-Steel-in-Figures.pdf

12 https://www.nsenergybusiness.com/projects/simandou-iron-ore-deposit/; also see Government of Guinea maps for investment corridors, iron ore mining permits, etc., at https://mines.gov.gn/media/cartographies/

Figure 1.9 Guinea's Simandou iron ore deposits and proposed infrastructure



Source: Nyabiage (2021)

launched. This massive project will require 650 km of new rail line, development of a new deep-water port at Matakong (south of Conakry) and at least two mountain tunnels totalling nearly 20 km (Ajdin, 2021). The new port will be designed to carry the largest dry bulk cargo vessels (Capesize vessels, too large to use the Suez or Panama Canals), with between 60 and 70 Capesize shipments per year. Overall expected investment is over US$15 billion.

The first exports from Simandou are expected in 2025, with production from the first phase ramping up to 60 Mtpa in 2026. With the second phase, production could eventually reach 110 Mtpa. China is expected to be the main export destination, loosening Chinese dependence on Australian imports. Many other global and smaller players have iron ore licences in Guinea that could eventually be developed once the infrastructure for the first big mine is completed.

To date, there has not been much discussion of MVA options for Guinea. Given the location and the investments required for exploitation, in addition to the small size of national and regional markets, only large-scale, export-oriented projects would be economically feasible. However, FDI for export-led iron ore could foster economic diversification, according to the International Finance Corporation (World Bank, 2020). A military coup in September 2021 drove bauxite prices higher but it is not clear if the unconstitutional change of government will affect the timeline for Simandou infrastructure development, first exports to China and other mining-related FDI (Sambhi, 2021). In July 2022, a final agreement between the government and private sector partners seemed to get the project back on track (Biesheuvel and Cang, 2022).

As mentioned previously, **Mauritania** is currently Africa's second largest iron ore exporter, currently at 12 Mtpa, with the state-owned SNIM (the National Industrial and Mining Company) aiming for 40 Mtpa by the middle of the decade. High-quality reserves allow SNIM to export naturally rich fines (65 per cent Fe), very rich concentrates (66 per cent Fe) and siliceous calibres (52 per cent Fe) to China and Europe.[13] SNIM operates its own 700 km railway to take ore to tidewater for export.

Like Simandou and other inland deposits in Guinea, the prospective Mbalam–Nabeba iron ore project (estimated 755 Mt) that straddles the **Cameroon–Republic of Congo** border will require an extensive new (510 km) railroad corridor, in this case from the existing, modern port of Kribi in Cameroon directly east to the border area. A new ore export terminal will have to be built at Kribi. An additional 70 km rail

13 https://www.snim.com/index.php/produits/marches.html

leg will then be constructed into Congo (Kouagheu and Prentice, 2021). Years of drilling and resource estimation work by Australian company Sundance Resources were sidelined first by the low-price environment of the mid-2010s and again when the project was transferred to a new Chinese-Australian consortium (International Mining, 2014).[14] Sundance has filed for international arbitration (mining.com, 2021b).

A major crude oil exporter and a member of the Organization of the Petroleum Exporting Countries, **Angola** also has extensive mineral resources, which were important for its economy while under Portuguese rule. The country is also among the top five or six global diamond producers. Under the economic and privatisation reforms of President João Lourenço, parts of the economy outside the dominant oil sector have been rejuvenated. The country has restarted iron ore production and in the second quarter of 2021 exported for the first time since 1975. That first 60,000-tonne shipment of 60-62 per cent Fe Cutato lump marks the first step towards the target of 1.5 Mtpa by 2022 (Theo, 2021b). Eventual mine capacity could reach 3 Mtpa.

Lastly, **Botswana** is known for its diamonds, copper and other minerals but is not an iron ore producer. However, Tsodilo Resources has been developing the Xaudum Iron Project for nearly a decade, preparing for eventual production of 67 per cent iron magnetite pellets.[15] While infrastructure hurdles, as elsewhere, remain the biggest obstacle to large-scale investment and mine development, Canadian-listed Tsodilo Resources has already identified 'low-carbon steelmaking' as a potential advantage for its high-quality ore project. It recently announced research partnerships with the Department of Chemical, Materials and Metallurgical Engineering at the Botswana International University of Science and Technology and Morupule Coal Mine to undertake metallurgical studies with respect to the potential for generating a pellet feed and DRI product from the Xaudum Iron Formation using its magnetite and Morupule Coal Mine's coal as a reductant (Liedtke, 2021). The Botswana example is of particular interest to the EAC: private–public collaboration to advance the prospects of mine development by incorporating the latest technology and decarbonisation concerns. What Botswana lacks, however, is an alternative to coal as a reducing agent and for power generation.

African steel trends

Africa consumes a tiny fraction of global steel (up to 3 per cent) but produces even less (1 per cent). That means that Africa is a net importer of steel despite its vast reserves of iron ore plus established steel industries in Egypt and South Africa (and those growing in Algeria and elsewhere). Demand for steel across Africa can only grow in response to population growth, urbanisation, infrastructure demands and industrial expansion. More generally, efforts to meet certain SDGs that will improve human development indicators for low- and middle-income populations will also drive steel demand.

Table 1.8, taken from two Organisation for Economic Co-operation and Development (OECD) reports (2019, 2020a), lists new and planned investments in steel production in Africa covering the years 2018–2022. Note that some projects are listed in both reports with slightly different details. But the most important commonality is that the core steelmaking technology is EAF. For most of the world, EAF dominates the type of new capacity coming on stream over the past few years. Notable exceptions are China, India and Vietnam, where many new projects have still been using BOF. But with a growing global focus on reducing GHG emissions and, at least, *greener* steel, EAF is dominating most new investments in steelmaking in Africa and elsewhere.

Within these two most recent OECD reports, no EAC partner state PS is mentioned in the list of new investments. What the OECD does not capture is changes to upstream processing, for example Uganda's Tembo Steel's addition of DRI capability to its Iganga plant during this time. As it already had EAF to utilise scrap, Tembo's important MVA investments to mine and *reduce* Uganda iron ore to produce DRI for its existing facilities to mix with scrap does not appear as a new investment. Thus, the OECD reports may not capture similar investments in other jurisdictions, missing critical information for tracking MVA trends.

14 Also https://www.sundanceresources.com.au/irm/content/the-mbalam-nabeba-project.aspx?RID=217
15 http://www.tsodiloresources.com/s/Metals.asp

Table 1.8 Investments in new steelmaking capacity, 2019 and 2020 reports, Africa only

Region	Economies	Location	Company	Owner (Economies)	Eouipment	Capacity (thousand metric tonnes)	Status	Start
Africa	Algeria	Bethioua	Tosyali	Tosyali Holding (Turkey)	EAF	2 300	operating	2018
Africa	Algeria	Bellara, Jijel	Algerian Qatari Steel	I METAL (Algeria), Qatar Steel (Qatar)	EAF	2 000	underway	2019
Africa	Algeria	Berrahal	ETRHB	The ETRHB HADDAD Group (Algeria)	EAF	800	plan	2020
Africa	Egypt	Sokhna, Suez	Ezz Rolling Mills (ERM)	Ezz Steel (Egypt)	EAF	850	underway	2019
Africa	Namibia	Oshikango, Ohangwena region	Groot Group	Groot Group (Namibia)	Steelmkg	1000	plan	2020
Africa	Nigeria	Lagos	Standard Metallurgical Company	Standard Metallurgical Company (Nigeria)	EAF	250	operating	2018

Region	Economies	Location	Company	Owner (Economies)	Equipment	Capacity	Status	Start	Sources
Africa	Algeria	Bellara, Jijel	Algerian Qatari Steel	IMETAL (Algeria), Qatar Steel (Qatar)	EAF	2 200	operating	2019	Company HP, Plats
Africa	Algeria	Berrahal	ETRHB	The ETRHB HADDAD Group (Algeria)	EAF	1 150	plan	n/a	Company HP, Metal Expert
Africa	Morocco	Jorf Lasfar	Riva Industries	Meski Holding (Morocco)	EAF	800	plan	2020	Metal Expert
Africa	Namibia	Oshikango, Ohangwena region	Groot Group	Groot Group (Namibia)	EAF	1 000	underway	2022	Company HP, Metal Expert
Africa	Egypt	Sokhna, Suez	Ezz Rolling Mills (ERM)	Ezz Steel (Egypt)	EAF	850	underway	2020	Platts, Metal Expert, World Steel Capacities
Africa	Egypt	Qalyubia	Delta Steel Mill	Delta Steel Mill (Egypt)	EAF	250	operating	2019	Metal Expert
Africa	Egypt	Ain Sokhna	Arabian Steel Industries	Arabian Steel Industries (Egypt)	EAF	500	underway	n/a	World Steel Capacities

Sources: top – OECD (2019: Annex A); bottom – OECD (2020a: Annex A)

Global iron and steel trends summary

- **Global steel consumption is currently around 1.8–1.9 Bt and not likely to exceed 2.1 Bt by 2040,** though consumption growth will remain high in India and other emerging economies with low per capita steel consumption, including across African economies that are still undergoing rapid population growth and urbanisation.
- **Scrap alone cannot fulfil global steel production requirements.** Iron ore will remain a requirement for primary steel production in every market segment, and particularly in those markets that do not already generate large volumes of scrap steel, including the EAC. Increasing use of and demand for scrap steel for EAF steelmaking processes, heightening global competition for scrap supplies, outstrips the global supply of scrap. Many countries have banned the export of scrap steel permanently or at times restrict its export.
- **Peak iron ore demand is not expected until 2025–2030.** While overall production of iron ore dipped in the late 2010s, forecasts now point to at least 2 per cent annual iron ore production growth through to 2025, with potentially more production coming on stream after 2025.
- **China's domestic production of iron ore has dropped considerably since 2010**, necessitating more imports and loosening of import restrictions on scrap steel and pig iron. China's domestic steel industry is also under pressure to shut down some of the worst polluting facilities and reduce emissions overall.
- **A handful of emerging or expanding African iron ore projects will enter the seaborne export market by the middle of the 2020s,** with limited MVA forecast.
- **'Green steel' incentives and risks are entering the global marketplace rapidly,** and those jurisdictions that build decarbonisation into their mining and MVA industrial strategies will limit risks and enhance access to capital and markets.

1.5 Regional trade liberalisation: the EAC, TFTA and AfCFTA

Has regional (EAC) and continental (AfCFTA) trade liberalisation increased since the original 2013 MVA report in ways that support the expansion of a regional steel industry? One of the potential comparative advantages of the EAC is that its customs union and common market integration pillars should ease cross-border trade, labour and investment flows, and make the region a more attractive location for investment to take advantage of this larger market of over 170 million. Broadening intra-African trade via the AfCFTA should do likewise on a continental scale. An analysis of the overall effects of the AfCFTA on the EAC has concluded that, as with all trade liberalisation agreements, the overall economic benefits are positive but there will be an uneven distribution of winners and losers and governments have to be ready to adjust (Shinyekwa et al, 2021). Even before the COVID-19 pandemic disrupted trade flows in 2020, however, intra-EAC trade had decreased by US$400 million between 2014 and 2017 (WTO, 2019). And bilateral tensions can have an impact on regional trade, with, for instance, Rwanda closing some of its border crossings with Uganda in 2019 (Blanshe, 2021; The Independent, 2021).

Given incomplete implementation and regular (often annual) exemptions, stays and renegotiations of EAC common external tariffs (CETs) (Deloitte, 2020b; Frazer and Rauschendorfer, 2019) and use of non-tariff barriers (NTBs) as a result of national policy priorities – exacerbated during the COVID-19 pandemic[16] – the impact of trade *liberalisation* measures in the short run on both upstream mining and particularly industrial MVA activities is minimal. There is more emphasis on selective protections of specific products, industries or gazetted firms, which is also applied to some imported steel products (under HS codes 72 and 73). Increasing instability in both steel and cement tariff lines over time, as well as in some other key products, hampers predictability, which, both private sector and government officials admit, affects longer-term business and investment decisions in these and related sectors (Bünder, 2018). But beyond the need for less policy instability, the much more detailed

16 An example of the impact of COVID-19 NTBs on women cross-border traders illustrates the disruptions and unintended impacts these can have (EASSI, 2020).

study of the actual versus potential impacts of tax, tariff and trade policy interactions that needs to be conducted is beyond the scope of this report.

There is broad recognition, however, that increasing intra-African trade will benefit the continent in the long run, and so initiatives such as the AfCFTA and the interim Tripartite Free Trade Agreement (TFTA) among the EAC, the Common Market for Eastern and Southern Africa and the Southern African Development Community will lower trade transaction costs across African borders while increasing attractiveness for capital investment. By mid-2021, 22 members of the three regional economic communities had signed TFTA, while 10 had ratified it (Nyawira, 2021). Similar to the EAC model of CETs (or that of the EU), the long-term vision is that lower tariffs and more standardised NTBs among all African countries, combined with common extra-continental trade relationships, will drive up investment in MVA and trade velocity across the continent.

This is going to take time, however, as the EAC experience over nearly 20 years illustrates, and the timeline for full AfCFTA implementation of a liberalised trade regime from 2021 will only 'gradually lead to an integrated continental market with tariffs phased out on 97% of tariff lines within 10 to 13 years' (Baker McKenzie, 2021). The AfCFTA rules of origin to determine if exports are 'sufficiently worked or processed' should incentivise expansion of steel industries that can claim that most of the raw inputs and MVA, from iron ore to locally sourced (not recently imported from overseas) scrap metal and fabrication, originate or occur within Africa, not just within a single country or region.

There is healthy intra-regional trade of steel products in the EAC already (see Appendix A). EAC PS banned most scrap metal exports back in 2010 to ensure regional firms retained access to raw materials (Recycling International, 2010).[17] Uganda banned iron ore exports in 2011 to ensure MVA benefits accrued in Uganda and not other EAC countries or elsewhere, with apparently one minor exception (The East African, 2017). Unfortunately, this likely delayed necessary investment in proving up, to global mineral reporting standards such as the Joint Ore Reserves Committee (JORC) Code[18] or 43-101,[19] detailed resource estimates that could lead to more upstream investment and eventual MVA (Muwanguzi et al., 2020). As detailed below, to date there is only minimal use of Ugandan iron ore in primary steelmaking in Uganda (and perhaps some in Kenya via a small export exemption); most fabricated products in the region are still produced from imported steel, with some EAF mills using scrap. Use of tariffs and NTBs to promote MVA is common global practice but EAC PS will have to take a more co-ordinated regional approach to build the foundations for a larger and more competitive steel sector to take advantage of growing regional demand and liberalising African markets.

Finally, the United Nations Economic Commission for Africa (UNECA) recently (April 2021) launched a Strategic Environmental Assessment to 'identify how to include environmental considerations into the implementation of the AfCFTA and into the so-called phase II negotiations on investment, competition policy and intellectual property rights, and phase III negotiations on e-commerce due to start soon' (UNECA, 2021a). This builds on the work UNECA has spearheaded to integrate green economy, blue economy and circular economy considerations into strategies for Africa's recovery after the pandemic, in line with the SDGs and Paris Agreement priorities (UNECA, 2021b). While this report does not mention 'steel', UNECA recognises that the green economy will create more demand for many African minerals including iron, and so 'African countries need to make vital policy decisions to leverage those dynamics. They also must seek to promote 'climate-smart' mining technologies that use renewable energy, minimise waste generation and restore degraded land' (ibid.: 52). As UNECA completes its environmental assessment of the AfCFTA, there is a strong likelihood that more environmental parameters will be built into its implementation over the next decade. The institutions and agreements governing global and regional trade are increasingly adding rules that reward greener production along the entire value chain. This will also include those trade preferences that some EAC members benefit from that increase zero- or low-tariff export opportunities to the USA, EU and elsewhere. All countries need to prepare for *green and circular economy* trade liberalisation.

17 The exact ferrous and non-ferrous metals covered by the ban differed slightly in different countries.

18 The JORC Code – the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves – is a professional code of practice that sets minimum standards for public reporting of minerals exploration results, mineral resources and ore reserves.

19 National Instrument 43-101 is a codified set of rules and guidelines for reporting and displaying information related to mineral properties owned, or explored, by companies that report these results on stock exchanges within Canada, a national instrument for the Standards of Disclosure for Mineral Projects.

Table 1.9 EAC countries – socioeconomic data

	2019 population	Surface area	Population density	2018 GDP	2018 GDP/ capita	UN Human Development Index	
	millions	'000 km^2	pop./km^2	US$ millions	US$	Rank	Value
Burundi	11.53	27.8	414.3	3,027	294	185	0.433
Kenya	52.57	592.0	88.8	75,557	1,710	143	0.601
Rwanda	12.63	26.3	479.4	10,111	773	160	0.543
South Sudan	11.06	658.8	16.8	13,616	748	185	0.433
Tanzania	58.01	947.3	61.2	57,819	1,044	163	0.529
Uganda	44.27	241.6	183.3	29,393	704	159	0.544

Source: https://unstats.un.org/home/

1.6 Regional infrastructure (energy and transportation)

In 2013, EAC members had significant energy (natural gas, coal, hydroelectric, geothermal and wind/solar) and transportation projects planned or being built. As per Tables 1.9 and 1.10, PS (now including South Sudan) are all low- or lower-middle-income countries with underserviced populations in terms of energy access and transportation options. South Sudan has the lowest population but the second largest area, and thus very low population density. Burundi and Rwanda have the smallest areas and relatively small populations but very high population densities. All rank very low on the UN's Human Development Index. As described below, the majority (over 100 million people) of the EAC's population live within 500 km of Lake Victoria. Building out energy and transportation networks, far from and also to the Indian Ocean, thus remains a high priority. While along the coast and inland to Nairobi the commercial power and transportation sectors are comparatively well developed, there is still much work to be done to service the bulk of the EAC population and to unlock the mineral riches and MVA opportunities that are concentrated in the Great Lakes region.

Overall, PS rank low in terms of many SDG indicators, with high proportions of the population below the poverty line of US$1,500 annual per capita income and low access to electricity. The high proportion of renewable energy is perhaps misleading, as most of these countries are highly dependent on biomass for cooking. Biomass for cooking is generally consumed inefficiently and often leads to deforestation. As this dependence declines as poverty levels decline, if renewable electricity replaces biomass, this will reduce energy intensity without reducing renewable energy's share. Country carbon footprints are low by international

Table 1.10 EAC countries – selected Sustainable Development Goal indicators

	SDG 1	SDG 7.1	SDG 7.2	Carbon footprint
	Pop. below poverty line (%)	Access to electricity (%)	% renewable energy	CO_2 emissions per capita (tonnes)
Burundi	72	11	85.5	0.100
Kenya	37	70	72.3	0.327
Rwanda	56	38	85.7	0.120
South Sudan	43	7	33.2	0.123
Tanzania	49	38	83.7	0.177
Uganda	42	41	90.3	0.130

Source: Kenya, South Sudan and Tanzania from https://unstats.un.org/home/; Burundi, Rwanda and Uganda from https://www.worldometers.info/co2-emissions/co2-emissions-by-country/

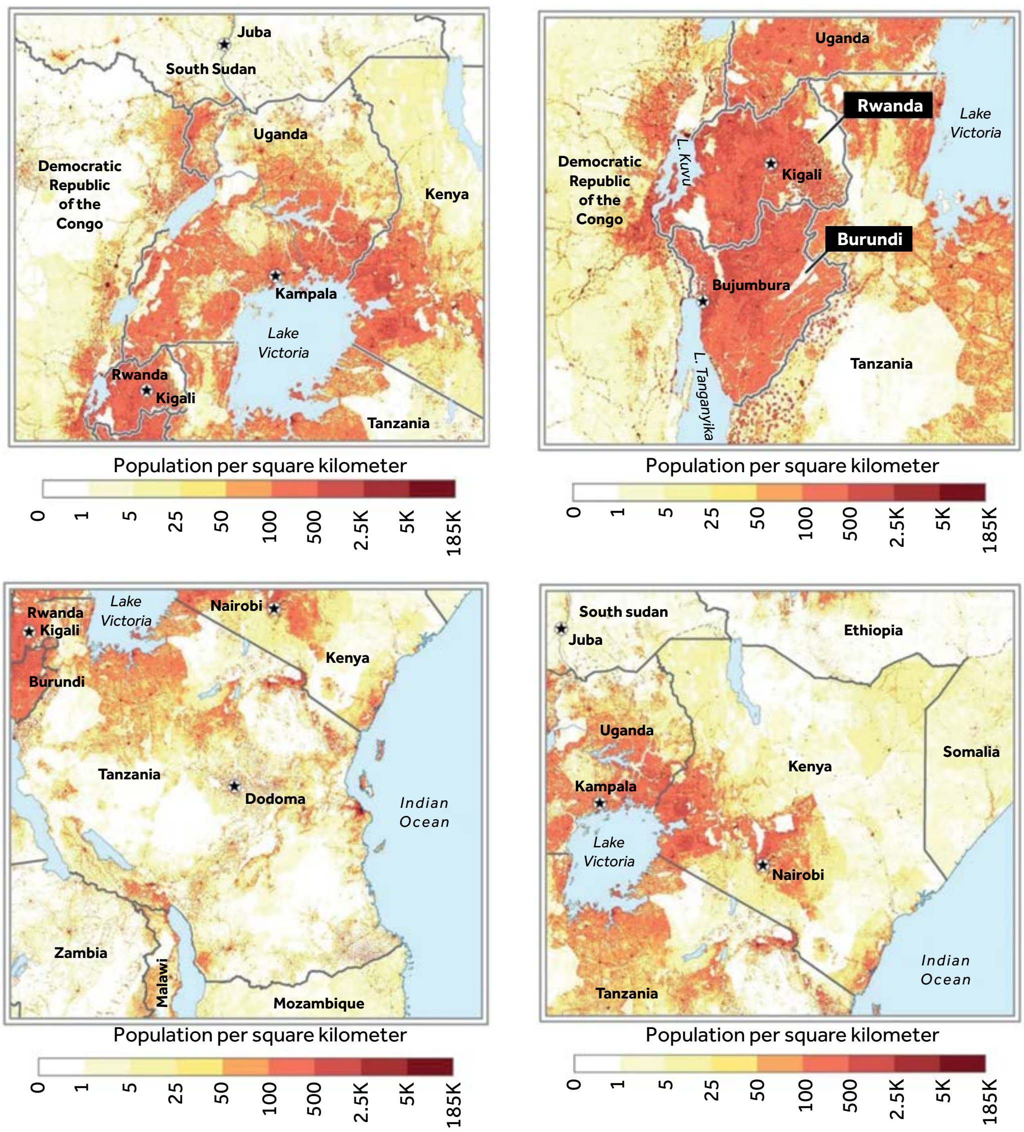
standards, reflecting low energy production and high reliance on renewable energies. Potential for renewables, including imported hydroelectricity, remains promising for the entire region.

Great Lakes population density as a comparative advantage

The majority of the EAC population resides inland, without easy access to ports and seaborne trade. An examination of the population density maps in Figure 1.10 shows that over half of the population is within a 500 km radius of Lake Victoria. This includes the heavily populated eastern borderlands of Democratic Republic of Congo (DRC), a prospective EAC member and current export destination. This inland Great Lakes market of well over 100 million can provide a catchment area for incrementally growing MVA steel output (from DRI/sponge iron through to construction materials and consumer projects) developed using local iron ore plus scrap.

A major structural constraint that limits the option for large-scale, overseas iron ore exports from Uganda (in addition to its current export ban and lack of a global standard resource estimate) is the distance of the most prospective iron ore resources in Uganda (primarily the hematite deposits in the southwest but secondarily the magnetite deposits along the border with Kenya) to tidewater. Even if the planned Standard Gauge Railway (SGR) networks were completed, it is nearly 1,000 km to the Kenya–Uganda border, over 1,500 km from

Figure 1.10 Population density maps for EAC partner countries



Source: https://www.cia.gov

Mombasa to southwest Uganda and over 1,700 km from Dar es Salaam to southwest Uganda via Kigali. While Guinea, Mauritania and Cameroon–Congo contain iron ore reserves that can theoretically support the level of investment to build or maintain 500–700 km rail and port networks, Uganda already has a distance disadvantage that would add additional cost per tonne of ore shipped. Higher value-added manufactured products can, however, be transported longer distances as price per km shipping costs (as a ratio of sales price) drops significantly, and road versus rail options remain viable. Even the massive Carajás Railroad in Brazil that Vale uses to export from the largest open pit iron ore mine in the world is only 892 km.[20]

More realistically, Tanzania's main iron ore reserve, located at Liganga, is about 900 km southwest of Dar es Salaam, and only 600 km west of the southern port of Mtwara. But this integrated iron and coal project, stalled since 2011, would still require a new 600–1,000 km railway to be built to Mtwara to export coal, iron ore and/or steel (Xinhua, 2020; PPRA, n.d.). And, as the project developers admit, the Liganga deposit is primarily vanadium-titanium magnetite, which adds to the 'complexity of the mineralogical constitution – when it comes to separation of titanium from iron ore,' adding risks and costs to mineral processing and suitability for large, carbon-intensive BF/BOF operations not EAF (Mirondo, 2022).

EAC energy overview: deepening comparative advantages

In 2013, the project team concluded, 'The existence of surplus energy resources within the EAC will provide valuable impetus to mining activities in these countries, as well as the mining industry providing an impetus to the development of these energy resources' Precht et al., 2013: 35). While all PS remain energy-deficient in terms of access, some improvements have been made and significant potential for expansion remains. Rapid population growth also continues to drive electricity demand and thus mounting pressure to complete grid interconnections within the Eastern African Power Pool and to the Southern African Power Pool (Olingo, 2019). Country development plans include significant commitments to boost access to electricity over the next decade or two.

Given existing regional energy infrastructure, there is little energy traded among the EAC countries. Uganda and Kenya have oil reserves and require oil export pipelines to tidewater before major production can ramp up. Uganda remains committed to building a 60,000 bbl/d oil refinery at Kabaale, near Lake Albert (Reed, 2021), but the project financing environment remains difficult in 2022 (Barigaba, 2022). Kenya had the only oil refinery in East Africa, which refined crude oil primarily for domestic consumption, but this has not been operational since 2013. All EAC countries rely on imports of refined petroleum products, with modest amounts of re-exports shown, mostly with other EAC countries. The high hopes for Kenyan crude after major discoveries in 2012 had nearly collapsed by 2020 owing to low prices and development challenges (Herbling, 2020; Reed, 2020). Tanzania produces and uses natural gas for electricity generation but there are no export pipelines to date – though there are initial plans to use the planned 1,445 km East Africa Crude Oil Pipeline corridor from Lake Albert, Uganda, to the Tanzanian port of Tanga (Biryabarema, 2021). In May 2021, Tanzania and Kenya signed an accord to study the feasibility of a 600 km gas pipeline between Dar and Mombasa (Esau, 2021). Tanzania's new president is also pushing to resurrect the stalled Mchuchuma thermal power project, with 600 MW of coal-fired power roughly split between the national grid and the integrated steel mill that will utilise Liganga iron (Ng'Wanakilala, 2021). Burundi, South Sudan and Tanzania are largely self-sufficient in electricity generation and consumption, with little trade. Uganda exports about 10 per cent of its electricity generation, mostly to Kenya, with smaller amounts to Rwanda.

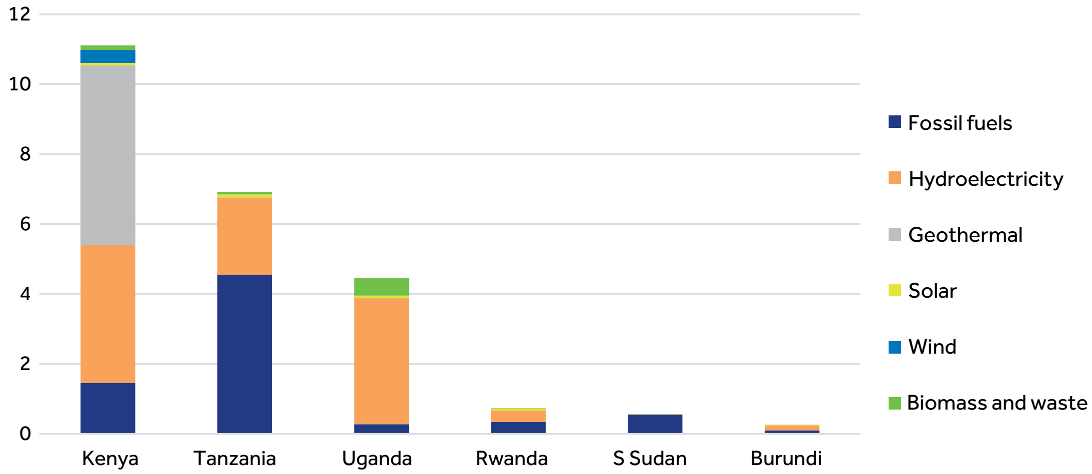
While energy excitement over the past decade has focused on new hydrocarbon discoveries, this has tended to overlook the renewable energy resources that continue to be developed and attract financing, from hydropower projects such as the 600 MW Karuma Dam in Uganda[21] to geothermal projects such as the 86 MW Olkaria VI expansion in Kenya (Kushner, 2021).

Figure 1.11 shows electricity generation by source, the heights of the bars largely reflecting the size of the country's population, and also influenced

20 http://www.vale.com/EN/initiatives/innovation/carajas-railway/Pages/default.aspx

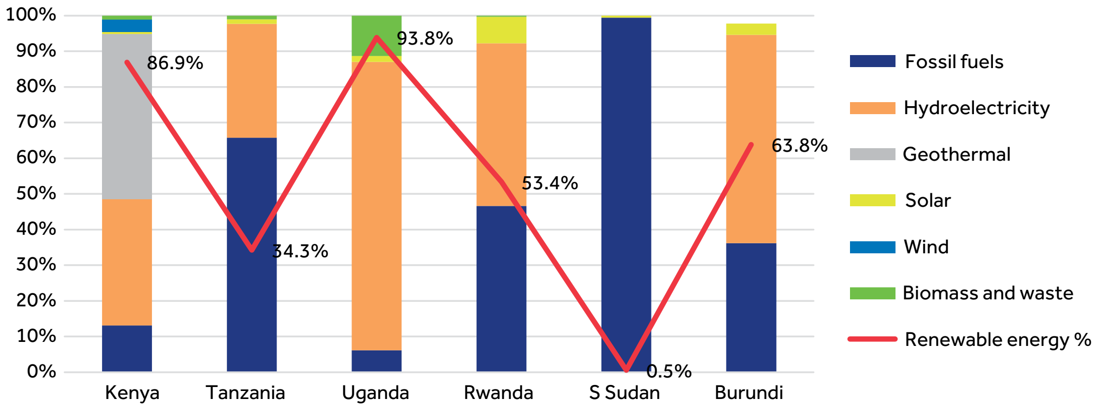
21 https://www.nsenergybusiness.com/projects/karuma-hydropower-project-uganda/#. There have been delays but the project is nearly fully operational (Kiyonga, 2021).

Figure 1.11 Electricity generation by source, 2018 (GWh)



Source: US Energy Information Agency. https://www.statista.com/statistics/267380/iron-ore-mine-production-by-country

Figure 1.12 Electricity share by source, 2018



Source: US Energy Information Agency. https://www.eia.gov/international/data/world/electricity/electricity-generation?

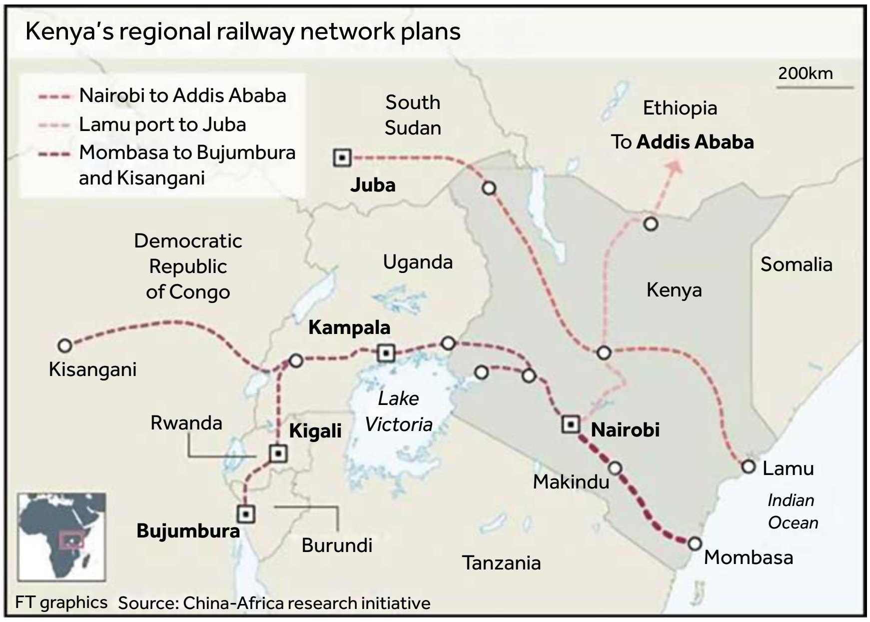
by per capita incomes. Figure 1.12 highlights that East Africa is far ahead of the curve on current (and potential) green energy production, a necessary element in any proposed green steel industrial development. For comparison, China generates about 60 per cent of its electrical energy using fossil fuels, India nearly 70 per cent and South Africa nearly 90 per cent. The EAC potential for expanded hydro, wind, solar, ocean, hydrogen and geothermal renewable sources that can build on the existing electrical generation mix is a comparative advantage (Scope 2 emissions) for greener mining and greener steel that most other jurisdictions cannot match.

EAC transportation infrastructure developments since 2013

As noted previously, transportation infrastructure is the critical piece of the puzzle to advance large-scale iron ore export projects. In many of these cases (Guinea, Mauritania, Cameroon–Congo, Botswana), relatively long rail lines of 500 km or more are required to move ore to ports for export. Only Mauritania has the infrastructure already in place. The three most prospective, potentially large-scale, deposits of iron ore in the EAC are at Kabale/Muko Hills in southwest Uganda, near the border with Kenya in eastern Uganda and at Liganga in southern Tanzania.[22] All three are far from tidewater and currently without rail networks

22 One section of the Liganga iron ore project was set aside to make DRI/sponge iron but technological and financial challenges ended that project in 2017 (The Guardian, 2017). In 2020, the Tanzanian government was still seeking an investor to resurrect that project: see https://zabuni.co.tz/storage/tenders/1591172530.pdf

Figure 1.13 Kenya's original regional SGR network and LAPSSET Corridor plans



Reproduced from Olander (2021)

to connect them to potential export ports. As both governments are focused on domestic and regional MVA strategies for iron ore, the missing option of seaborne export is not immediately problematic. But to create commercial options that reduce risks and costs while increasing market access – for iron ore or steel products – an efficient SGR network will be important. This is even more the case for potential large-scale nickel developments at Kabanga, Tanzania, or Musongati, Burundi, as some MVA requirements for nickel will still entail considerable attention to export markets beyond the EAC. While road development is important, particularly for intraregional trade, large-scale mining development and MVA will become more viable as modern SGR networks connect EAC PS, neighbouring markets and efficient ports.

SGR network expansion: aspirations and realities

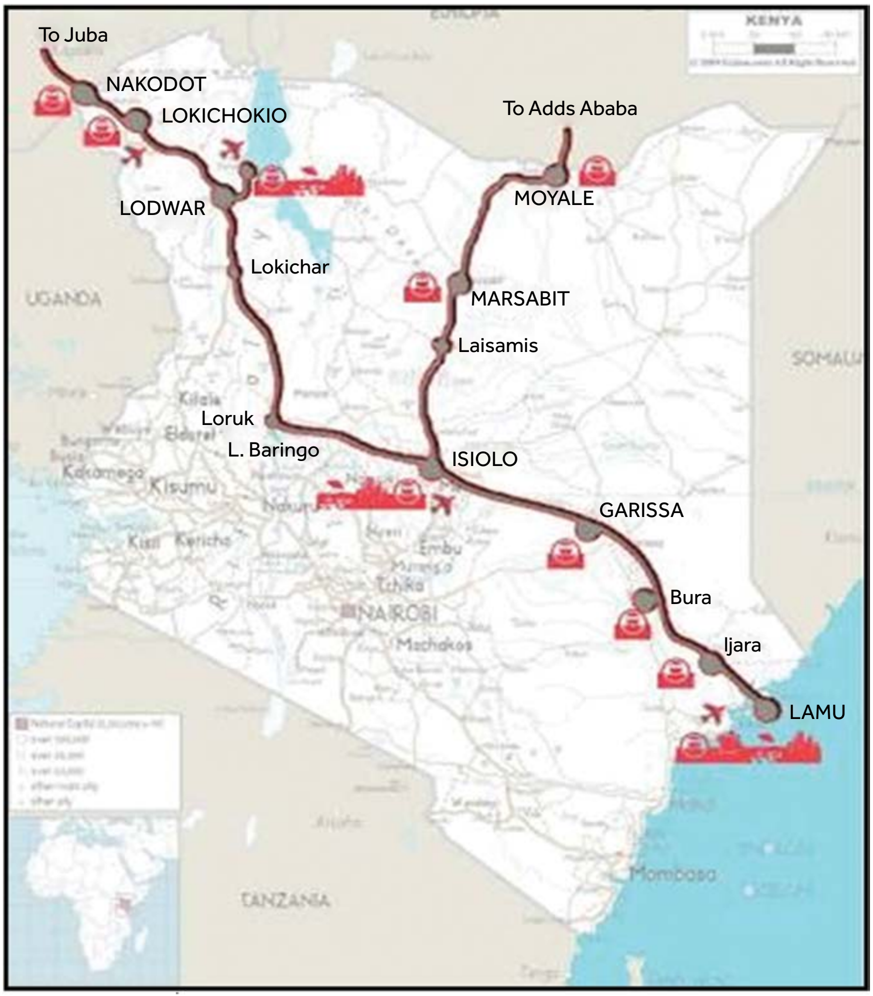
Since 2013, while some impressive road and rail projects have been completed, the planned extension of SGR from tidewater to the Lake Victoria region has not been finished and there are doubts, owing to rising debt loads from previous projects, whether this will occur in the short to medium term (Kiruga, 2020). Even without reaching the Indian Ocean, a modern rail network that links South Sudan to eastern DRC, Rwanda and Burundi would provide a backbone for more extensive regional MVA as well as more efficient trade across all goods and sectors. But the overall objective of tying inland rail networks to coastal connections means that it is difficult to finance sections, for example in Uganda, if Kenya's planned SGR legs are stalled hundreds of miles from the border (ibid.). The 500 m wide Lamu Port, South Sudan, Ethiopia Transport (LAPSSET) Corridor will link a new port at Lamu, Kenya, with roads, rail and pipeline connections to Ethiopia and South Sudan (see Figures 1.13 and 1.14), though progress is well behind original planning.[23]

While Kenya is currently finding it difficult to finance more of its SGR beyond Naivasha (just 120 km northwest of Nairobi, opened in 2019; Miriri, 2019), Tanzania's SGR has been making steadier progress.[24] Earlier in 2021, Burundi and Tanzania announced they were jointly seeking to raise nearly US$2 billion to build a 190 km leg of the Musongati to Isaka connection (Nimubona, 2021). If and when started, this should reawaken interest in both the Musongati and the nearby Kabanga nickel projects. Still, there are financial, engineering and political hurdles to linking Uganda, Rwanda and Burundi via

23 https://www.lapsset.go.ke/#1461328856794-2dee9bba-e774

24 https://constructionreviewonline.com/project-timelines/tanzania-sgr-project-timeline-and-all-you-need-to-know/. Tanzania's SGR will be electrically powered (not diesel), beneficial for addressing Scope 3 value chain emissions IF fossil fuel energy (particularly coal) is not expanded to power the train system.

Figure 1.14 Planned LAPSSET Corridor



Source: Reproduced from https://twitter.com/lapsset/status/951718103246950400

SGR to the Indian Ocean, and even achieving that goal for one or two of the landlocked countries could take years. Political competition between Kenya and Tanzania has sometimes overwhelmed economic and regional efficiency considerations (Cooksey, 2016). This competition has extended from rail to ports, as Kenya pushes the development of Lamu via LAPSSET and Tanzania attempts to rekindle interest in a new port and special economic zone at Bagamoyo, 75 km north of Dar (Reuters, 2021; see Figure 1.15).

Overall, strides have been made across the region, though no planned rail system is complete. Ultimately, given available information about EAC iron ore deposits, large-scale seaborne iron ore exports are not likely to be economic. But growing exports and trade within the EAC and neighbouring states of iron ore, DRI/HBI, steel billets and steel products will still require more efficient road, rail and ferry services.

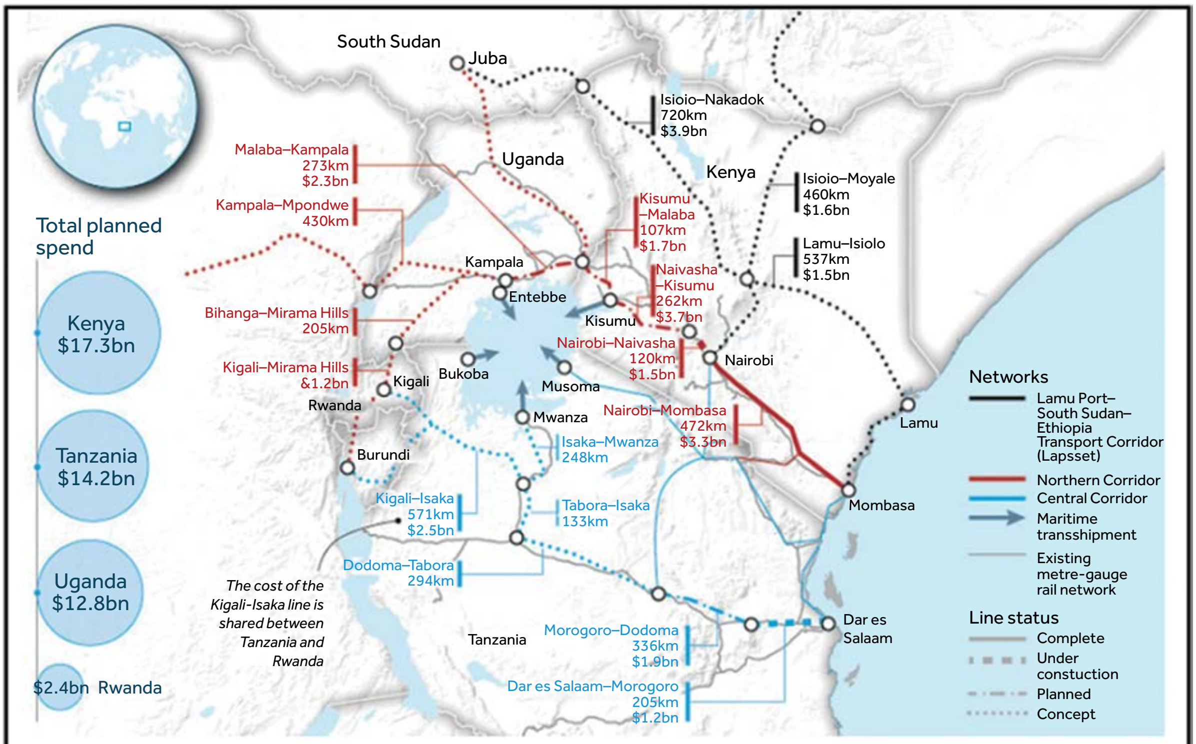
1.7 The SDGs and the net-zero revolution

In 2015, three global initiatives quickened trends affecting the future trajectory of mining and steel industries.

First, the 17 SDGs were agreed to by the majority of UN members, designed to follow from the Millennium Development Goals (2000–2015) but this time to apply to all countries not just developing ones. The SDGs identified various *development* objectives and indicators that would point towards increased need for steel in low- and middle-income countries, and at the same time identified other *sustainability* objectives and indicators that could be negatively affected by traditional energy, mining and industrial practices.[25]

25 https://sdgs.un.org/goals.

Figure 1.15 Detailed overview of planned and completed EAC rail networks, late 2019



Source: Kenya Railways Corporation; Tanzania Railways Corporation; Uganda Railways Corporation; East African Community; media reports

Source: Reproduced from Oxford Analytica (2019)

Second, the Paris Agreement set the stage for all countries to create national plans to reduce GHG emissions. While most of the focus on reducing GHG emissions – from the Kyoto Protocol (1997) to the Paris Agreement (2015) – is related to energy and fossil fuels, two of the biggest emitting industries on the planet are cement and steel.

Third, the International Energy Agency (IEA), set up in the early 1970s to address energy security during the first oil crisis, launched a new modernisation strategy. This included 'strengthening and broadening the IEA's commitment to energy security beyond oil, to natural gas and electricity … and providing a greater focus on clean energy technology, including energy efficiency.'[26] Recently, the IEA has published a series of reports that directly or indirectly build on these new priorities, including the *Iron and Steel Technology Roadmap* (October 2020) and *Financing Clean Energy Transitions in Emerging and Developing Economies* (June 2021).

26 https://www.iea.org/about/history

Taken together, these three global initiatives have firmly placed energy transitions, decarbonisation and green steel onto the agenda of policy-makers and business leaders – but they also do not displace concerns over development and poverty alleviation.

The 2021 UNECA Report *Building Forward for an African Green Recovery* highlights the conundrum of balancing the imperative to leverage Africa's extensive extractive resources to drive poverty reduction and industrialisation with concerns regarding sustainability and climate change:

> *African major fossil fuel producers must counter their vulnerabilities by adding value to the commodities they extract and by diversifying their energy sources and export base. This will help them promote resource-based industrialization as a strategy for creating jobs, inclusive growth and the sustainable use of natural resources. Countries should promote green industrialization and divest away from fossil fuels and move towards an economy that thrives on value addition (p.51).*

This is a tall order but the EAC already has some of the foundations in place to do just this, particularly with its current relatively heavy reliance on renewable energy. While some fossil fuels are currently exploited (i.e., For natural gas today, minimal coal and some crude oil in the near future), the level of dependence on fossil fuels as an export revenue generator is currently negligible. The EAC has instead considerable potential to contribute minerals and metals central to the green energy economy (iron/steel, nickel, copper, cobalt, graphite, etc.) and should be moving quickly towards integrating green energy and 'green mining' along the MVA value chain.

Key climate change terms

Carbon emissions: The CO_2 equivalent of the six major GHGs. As defined by the 1997 Kyoto Protocol, these are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Scope 1 emissions: Direct carbon emissions from owned or controlled sources.

Scope 2 emissions: Indirect carbon emissions from the generation of purchased energy.

Scope 3 emissions: Indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.

Decarbonisation: A systematic effort of companies and governments to align with a low-carbon economy by reducing carbon emissions.

Net zero (emissions): A state in which any carbon emissions produced are offset by removing carbon from the atmosphere. Reaching net-zero emissions by 2050 is critical to limiting average global temperature rise to less than 1.5˚C above preindustrial levels.

Nationally Determined Contributions (NDCs): The 2015 Paris Agreement requests each of the 191 parties to outline and communicate their post-2020 climate actions. NDCs are submitted every five years to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat (2020, 2025, etc.). Successive NDCs should represent a progression compared with previous NDCs.

In 2009, the African Committee of African Heads of State and Government on Climate Change was established. In June 2021, a summit of this Committee, chaired by South African President Cyril Ramaphosa, outlined Africa's position going into the UNFCCC COP26 in Glasgow, UK, in November 2021. President Ramaphosa captured the challenge climate change amelioration has for the African continent, which still includes many low- and middle-income countries (DIRCO, 2021):

> 7.2 The Summit reaffirmed that the international community needs to significantly scale up its efforts, raise the level of ambition and support developing countries with the means to implement climate actions in view of our differentiated responsibilities. All African countries require support from international partners and our development space should be respected to achieve our climate goals and ambitions, while contributing our fair share to the global effort.
>
> 7.3 The meeting affirmed the need for the recognition of our different national circumstances and capacities as it is not realistic to expect Africa to meet the same timelines as developed countries to transition our economies and to disinvest from fossil fuels. This is important, especially given the high levels of inequality, unemployment and developmental needs across our Continent, particularly among women and the youth. Furthermore, we need to send a clear signal that implementation and ambition apply equally to mitigation, adaptation and support.

In a similar vein, there is recognition outside the continent that leveraging natural gas, for instance, as a transition fuel in Africa may replace far worse GHG sources such as solid biomass for cooking (unless the biomass is sourced from a sustainably managed forest), diesel generators and coal-fired power plants. Additionally, a narrow focus on small-scale, off-grid residential renewable projects does not provide the scale of electricity necessary to support rapid urbanisation, industrial projects or the digital economy, thus jobs (Thurber, 2018). Achievement of this balance between the imperative to reduce GHGs and enhancing human development is key: MVA policies that integrate sustainability and decarbonisation concerns can play a critical role in meeting these apparently divergent objectives.

2. Strategic Issues Facing the Development of EAC Steel

Given the changes since the early 2010s outlined in Chapter 1, four significant strategic considerations emerge that EAC policy-makers and corporate leaders need to consider as an addendum to the earlier report. It remains true there are important employment, political, developmental, fiscal, monetary and even environmental reasons to take advantage of geological inheritances from a value added perspective. These considerations are part of general developmental pressures that the EAC PS face alongside specific objectives expressed in national and regional economic transformation and industrialisation plans. These imperatives need to be met taking into account both economic feasibility/efficiency and environmental, social and governance (ESG)/decarbonisation considerations, with the understanding that there are always policy trade-offs at play. Those trade-offs will look different for low- and lower-middle-income countries compared with middle- and high-income countries that contribute substantially more GHG emissions.

EAC governments are prioritising domestic development and poverty alleviation alongside concerns and commitments around decarbonisation. For instance, over 600 million Africans still lack regular access to electricity. In 2020, the entire continent generated less than 4 per cent of global GHG emissions, less than China, the USA, Russia or India (bp, 2021). African states, some leading business leaders argue, cannot ignore or set aside their domestic natural resources (including natural gas) when income and energy poverty remain acute, as other countries continue to utilise theirs for the foreseeable future. Changes in the global public development and commercial financing ecosystems will constrain freedom of action for governments around the world (e.g., President Xi's announcement at the UN General Assembly in September 2021 that China would no longer build coal-fired plants abroad) but concurrently open the door to alternative strategies and funding sources.

Exploration of the three strategic issues points out both the challenges and the opportunities offered by changing policy and competitive dynamics in the iron and steel sector, which EAC PS can leverage using existing energy and iron ore inheritances combined with timely policy adjustments.

2.1 Minerals, steel and the SDGs: paradoxes of prosperity

Since the previous MVA report was completed in 2013, both the SDGs and the Paris Agreement have deeply embedded environmental and climate change priorities into global trade and development policy-making and investments at both national and international levels. Steel remains a fundamental building block for human and economic development, beginning with SDG 1: End poverty in all its forms everywhere. Steel is critical to traditional and new (digital, green, blue, circular) economy infrastructure, housing and commercial construction, capital and consumer goods, transportation, healthcare, agri-food production and storage, etc. Low- and middle-income countries will only increase their demand for steel as per capita incomes rise. It is important to work through how this paradox of complementarity and tension between development and climate initiatives changes the short- and long-term context for an expanding East African steel industry and related upstream and downstream economic linkages.

International consulting group McKinsey & Company pointed out in 2020, 'Currently the steel industry is among the three biggest producers of carbon dioxide, with emissions being produced by a limited number of locations; steel plants are therefore a good candidate for decarbonization. While the industry must adapt to these new circumstances, it can also use them as a chance to safeguard its license to continue operating in the long term' (Hoffman et al., 2020). On average, 'every ton of steel produced in 2018 emitted on average 1.85 tons of carbon dioxide emissions' (ibid.: data from the World Steel Association). For integrated steel mills using thermal coal for energy and conventional BF/BOF processes, steel production can result in over 2 tons of CO_2 emissions per ton of steel produced. All countries, including the largest steel producers China and India, admit that this is unsustainable, and both countries have cracked down on some of their oldest, worst-emitting, plants. China is even opening its market to pig iron and scrap steel imports to try and reduce primary steel production.

While EAC PS have promoted large-scale, integrated steel industries using conventional, high-carbon processes as part of their development and MVA strategies,[27] no PS has implemented this. Attention has turned towards DRI for EAFs.[28] EAFs are already used in the region, so replacing scarce scrap with locally sourced DRI is a natural next step (already initiated by Tembo Steels). This leaves the door open for less carbon-intensive primary steel production as the focus of the future. The EAC could incrementally replace high carbon-intensive steel imports from China and India, among other sources, with domestically produced, lower carbon-intensity steel. Attention to emission reductions across the value chain (Scope 1 through Scope 3), leveraging current and future renewable energy sources, and adopting new technologies as they become financially viable (e.g., shifting from coal to natural gas in DRI processes; using carbon capture, utilisation and storage (CCUS); and ultimately green hydrogen) could put the EAC on track not only to replace foreign imports but also to become an exporter of regular-grade and premium-priced green steel within Africa and to overseas markets.

Steel and the SDGs: key strategic considerations

- Steel demand will continue to be driven by both the development and the sustainability objectives of the SDGs.
- Steel use per capita will increase across the EAC if incomes and various SDG and human development indicators are to improve meaningfully.
- Given the high level of GHG emissions from steel production, this industrial sector faces continuous pressure to decarbonise, with various regulatory, trade and finance instruments deployed across national and regional (e.g., EU) jurisdictions.

2.2 Global competition dynamics (upstream, downstream, automation, etc.)

How do global trends in iron ore and steel production affect the potential for an expanded steel industry within the EAC? First, global steel demand – barring a global recession or at least a drastic demand decline in a major economy such as China – is expected to stay strong into the foreseeable future. Second, a growing proportion of that demand will be met by capturing scrap steel streams, though the competition for scrap will drive up prices, potentially leading to more export bans, and thus reduce the predictability of scrap metal supply, particularly in those regions (such as the EAC) that do not generate sufficient scrap streams.

Third, the overall shift towards EAF from BF/BOF as well as for DRI/HBI underpins a growing demand for scrap rather than pig iron. Fourth, higher demand for steel will continue to lift iron ore prices from the doldrums of the mid-2010s, with average prices likely remaining over US$80/ton rather than $50/ton. China's declining production of iron ore makes it more dependent on exports from Australia, Brazil and, later this decade, emerging producers such as Guinea and Mauritania, and thus more sensitive to global prices and competition.

Fifth, China may also continue to reduce its steelmaking capacity at home while supporting, through investment and imports, emerging producers abroad. Driven by demands to curb toxic air pollution as well as pressures to meet broader GHG reductions, Chinese firms – following in the footsteps of some Indian firms – may take a more active role as investors and partners (not just as engineering contractors) in steelmaking operations in emerging regions, with examples currently being pursued in Tanzania and Uganda. While new investment and technology partners for EAC are desirable, the onus will be on policy-makers to ensure new capacity is not simply an 'emissions

27 The Tanzanian Mchuchuma coal and Liganga iron integrated steel project is a case in point, stalled for a decade but with renewed focus since 2020.

28 See, for example, NPA (2018) and http://www.fonerwa.org/backend/content/green-steel-production-rwanda (unfortunately, details were unavailable).

export' strategy, but instead significantly drives down emissions per ton of steel produced. Sixth, current large-scale iron ore exporters and new projects in development have economies of scale that any potential large-scale, EAC export-driven iron ore project could not meet. That recognition aligns with and may necessitate the mostly inward, import substitution or continentally focused MVA strategies the EAC PS are pursuing today.

Global competition for iron and steel: key strategic considerations

- Global and regional (EAC) steel demand will continue to be driven upwards by both traditional and new economy requirements; global demand will likely stay slightly above 2 billion tons/year in the 2020s and 2030s.
- As more steel producers invest in EAF (versus BF/BOF) plants, increased demand for scrap steel will push scrap prices up and availability down. Primary steel production from iron ore will remain a large part (50 per cent +) of overall steel production into the 2050s.
- While global trade in iron ore shifts in response to lower Chinese production and new or expanding exporters, the EAC's inland population density near renewable power, iron ore and existing steelmaking and fabrication capacity still supports an inward or continentally focused MVA strategy.

2.3 Transition to low carbon, a circular economy and 'green steel'

The speed of change in terms of market premiums, availability of finance, carbon pricing and border adjustment mechanisms (i.e., EU CBAM, tariffs) and regulatory or NTB restrictions targeting high-carbon steel makes it difficult to keep up – but it is imperative to do so. While demand for steel goes up, and over 90 per cent of steel is ultimately recycled, demand for greener or cleaner steelmaking processes (and upstream mining practices) goes up as well. Technology is trying to keep pace but the earlier global trend away from large-scale integrated steel mills using thermal and coking coal in BF/BOF processes towards EAFs that use scrap and DRI/HBI is already laying a foundation for partial decarbonisation. EAF plants are smaller and less expensive to build than integrated steelmaking plants, which, in addition to BOFs, contain blast furnaces, sinter plants and coke batteries for the making of iron.[29] (There is no significant source of metallurgical coal in the EAC, so this would necessitate expensive imports and logistics.) EAFs are also cost-efficient at low production rates – for example 150,000 tonnes per year – while BFs/BOFs are viable only if they produce more than 2 Mt of liquid steel per year. Moreover, EAFs can be operated intermittently, while a BF is best operated at highly constant rates. The electric power used in EAF operation, however, is high, at 360–600 kWh/ton of steel, and the necessary installed power system is substantial. A 100 ton EAF often has a 70 megavolt-ampere transformer. In a jurisdiction where grid power is largely from renewable sources, reliable and reasonably priced, EAF using scrap becomes a natural first step in driving down the Scope 1 and Scope 2 emissions from steelmaking.

As the charge (input) for EAF has historically been scrap steel, the energy and carbon footprint savings of recycled EAF output versus primary steel are significant: they can range from 1.5 tonnes/CO_2 for regular carbon steel to over 4 tonnes/CO_2 for stainless steel. Each recycled tonne of scrap steel saves more than 1,400 kg of iron ore, 740 kg of coking coal and 120 kg of limestone.[30] But the green steel revolution increasingly examines all aspects of the mining, processing and steelmaking stages. This extends to imports of steel billets, coils and finished products: what carbon footprint they make and how many emissions they create during shipping. Otherwise, 'carbon leakage' can occur, whereby producers in one jurisdiction who face carbon prices or other costs and regulations cannot compete with jurisdictions without decarbonisation policies. Better-quality ore bodies

29 According to ArcelorMittal, 'Making one tonne of crude primary steel with the typical blast furnace/basic oxygen method takes 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of recycled steel': https://corporate.arcelormittal.com/sustainability/by-products-scrap-and-the-circular-economy

30 https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/iron-ore-facts/20517

require less energy to crush and screen, with less energy used and lower CO_2 emissions produced in DRI processes. DRI processes do not require coking coal but use cheaper thermal coal as the reducing agent. This coal, however, can be replaced by natural gas and ultimately 'green hydrogen' (Robbins, 2020), and each step away from coal reduces CO_2 emissions substantially. Direct discussions between President Hassan of Tanzania and President Museveni of Uganda in May 2021 regarding a natural gas pipeline demonstrated that President Museveni was keenly aware of the benefits that would bring to the Uganda steel industry, 'to remove oxygen from iron ore' (Domasa, 2021).

More quickly than expected (Mikulka, 2021), however, green hydrogen could be made in the EAC using electrolysis powered by renewable forms of electricity. In the case of Uganda, this is likely from its substantial freshwater resources. Once the costs of green hydrogen can be pushed down close to US$2/kg, it becomes possible to see widescale adoption of hydrogen as a fuel for heavy industry (including steel), aviation, long-distance trucking and shipping, and as a replacement for natural gas in power generation (using green ammonia) (Scott, 2020). At the moment green hydrogen used in DRI and steelmaking is still in the pilot stages: for example, the HYBRIT pilot plant in Sweden was the first to use green hydrogen to produce DRI in June 2021 (see Figure 2.1) (Villa, 2022). Large-scale production will not commence until 2026, but part of the problem for Europe is that much of the installed capacity is not geared towards DRI but rather to traditional pig iron.

The EAC does not have the heavy burden of high-carbon legacy technology in the steel industry. Early concerted public and private co-operation could ensure that the entire region begins to build a 'green mining and steel ecosystem' that meets three important objectives beyond the direct benefit of lowering GHGs while increasing steel production: (1) continuing to drive MVA with all the related economic and developmental benefits; (2) continuing to increase steel production to meet regional and continental demand in an environment where smaller players can be economically viable; and (3) creating an internationally attractive location for green, ESG-friendly and 'impact' investing from public and private sources. This focus could be extended to other critical ingredients needed for a green energy transition, including nickel, cobalt, graphite, etc., as well as downstream products such as EVs. Germany is leading the charge to find international partners, including in Africa, to research and develop economically viable green hydrogen (see below).

Transition to green steel: key strategic considerations

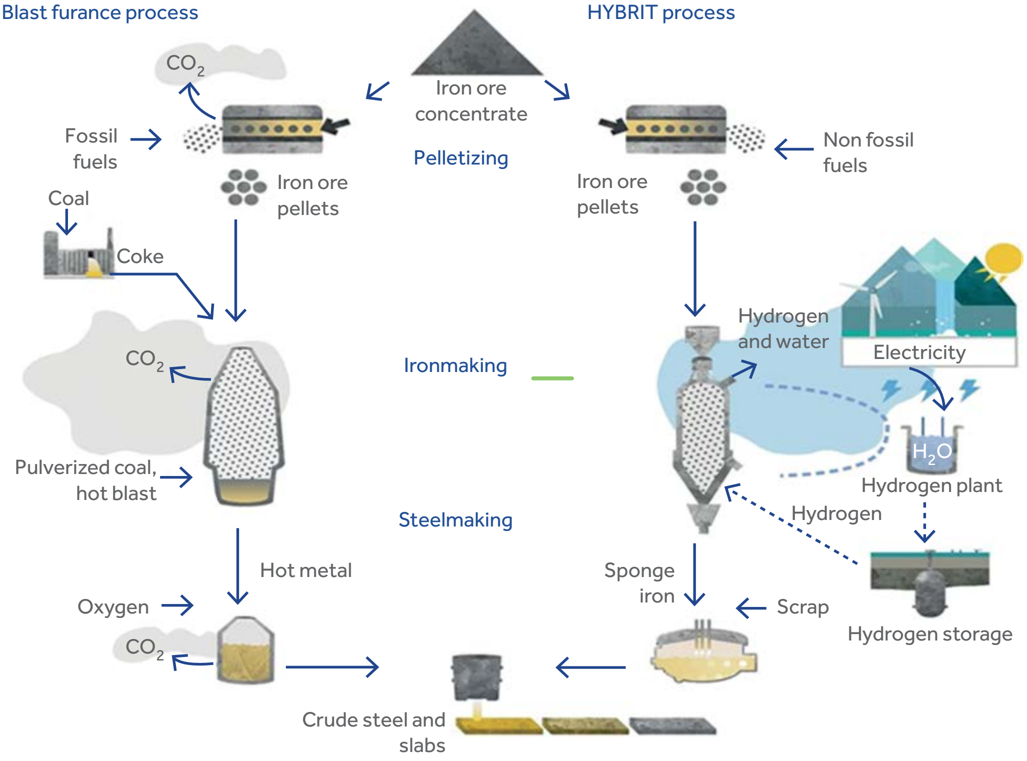
- Existing technological and investment shifts towards DRI and EAF (away from BF/BOF) can lock in decarbonisation pathways that can be improved later on. Some current EAC steelmakers are already on this pathway but lack of non-coal reducing agent is a challenge in decreasing carbon emissions from the DRI process.
- A green mining and steel policy approach targets every element of the value chain, from ore quality and energy used at the mine site, to energy and reductants used to make sponge iron and then steel. Ultimately, green hydrogen will drive the greatest decarbonisation gains.
- A green steel MVA ecosystem creates opportunities for smaller-scale mining, DRI production and steelmaking projects to be economically viable, and becomes more attractive to climate and ESG finance.

2.4 Project financing in a net-zero world

This last strategic consideration follows directly from the above. For international financial and developmental institutions such as the World Bank and the African Development Bank (AfDB), bilateral development and export credit agencies including China, large commercial banks and portfolio investment managers, smaller impact investing or green funds, and even individual companies seeking business opportunities, risks of carbon exposure have rapidly entered the calculations of development and corporate finance.

This is a double-edged sword. On one edge, coal and crude oil projects (from exploration to pipelines and refineries) face an uphill struggle in attracting international financing. Natural gas including 'LNG'

Figure 2.1 Conventional blast furnace compared with Swedish HYBRIT green steel process



Source: Reproduced from https://www.hybritdevelopment.se/en/a-fossil-free-future/a-value-chain-for-fossil-free-steel/

(liquified natural gas) projects are facing headwinds too, though with more countervailing pressure to consider national gas as a lower-carbon, transitional fuel critical for Africa's electrification (Thurber and Moss, 2020).[31]

This financial community reticence could affect the East Africa Crude Oil Pipeline; attempts to resurrect Tanzania's Mchuchuma coal and Liganga iron integrated steel project; and whether the proposed refinery near Lake Albert can attract investment interest. Chinese banks were already backing away from funding coal projects in Africa (e.g., Kenya and Zimbabwe) (Ndlovu, 2021), and President Xi announced a formal end to Chinese assistance to overseas coal-fired electricity projects in September 2021. Even prior to that, Bangladesh slashed up to 10 planned coal-fired power generation projects, partly in response to financing challenges because of their carbon footprint but also because of overcapacity (Gerretsen, 2021).

31 There is, however, pushback from the IEA (Timmermans and Birol, 2021).

In early June 2021, shockwaves followed the statement to governments signed by 457 global investors – collectively managing over US$40 trillion in assets – to speed up climate policy and to commit to earlier, more concrete, net-zero targets. The letter included a call for 'clear decarbonization roadmaps for each carbon-intensive sector,' incentives 'for private investments in zero-emission solutions,' an end to new coal power plants, the phase-out of existing coal power and the removal of fossil fuel subsidies by set deadlines (UNFCCC, 2021).

The other edge of the sword is more promising. Public and private sector financing across a diverse range of green, climate, ESG, impact, gender and development windows has flourished over the past decade, to supplement the Green Climate Fund. Since the Paris Agreement in 2015, increasingly creative funding windows for climate adaptation, mitigation, resilience, capacity-building, public education, research, technology, etc. have emerged. A regionally co-ordinated 'green mining and steel ecosystem' for the EAC could attract financial mechanisms early on, for areas stretching from capacity-building to research. For instance, Germany's state-owned investment and development bank, KfW, has a particular interest in green hydrogen and is already working in South Africa, investing €200 million in a green hydrogen roadmap driven by government and industry (Creamer, T., 2021). The EAC's renewable energy profile, combined with a comprehensive green mining and steel strategy, could leverage funding sources such as KfW for hydrogen and the new U.S. International Development Finance Corporation, which has begun to take equity positions in mining firms active in energy transition metals (Jamasmie, 2020a), and increase EAC utilisation of green bonds (Holtz and Heitzig, 2021).

These examples just scratch the surface regarding the changes that have occurred in climate- and ESG-focused finance. There has been a fundamental shift in both developmental and profit-oriented financing since 2015 to take carbon risks into account, and jurisdictions – whether governments or private sector actors – that ignore these constraints and these opportunities will be left behind. While commitments by high-income countries (that have also been high emitters) towards the US$100 billion climate facility to help lower-income states transition away from fossil fuels have been sluggish to arrive, Canada and other countries worked to get such commitments in place leading up to COP26 in Glasgow (November 2021) (Brown, 2021).

Decarbonised project finance: key strategic considerations

- There is a global shift away from funding new coal-fired power plants, but also growing reticence about natural gas projects.
- Exposure to carbon risks has been added to international investor and development finance risk criteria.
- There is increasing availability of various creative green and climate financing mechanisms around the world that an EAC green mining and steel ecosystem strategy could leverage. South Africa is an example of a country leveraging various international financing mechanisms to reduce its dependence on coal and to move towards green hydrogen.

3. Green Strategic Considerations Framework

This chapter revisits four 'Group A' mineral complexes identified in 2013 as the most promising from an MVA perspective given availability/resource status at that time plus best potential for downstream and sidestream linkages. All four included elements relevant to an emerging EAC steel industry that went beyond using scrap and mostly imported steel for fabrication. (Alternative strategies were suggested for other categories.) This section reassesses the four mineral complexes of iron ore, coal, nickel-*copper-cobalt* (with a focus on nickel in the context of steelmaking here) and limestone to take into account (1) upstream and infrastructure developments since 2013 and (2) the key strategic considerations outlined in Chapter 2.

These considerations highlight the importance of preparing for decarbonisation and the green streel transition that have already begun to influence the regulatory, market, trade, technology and investment environment for mining, energy and heavy industry. As the original analysis from 2013 shows (Figure 3.1), outside of gold and its limited

Figure 3.1 EAC minerals (coal and metals) availability from 2013 MVA report

Modified NAICS	Description	Burundi	Kenya	Rwanda	Tanzania	Uganda	EAC Trend	Scale	Processing complextity	Market
2121	Coal mining									
212111	Bituminous coal & lignite surface mining		4		4		8	LSM	Low	Regional
	Metal mining									
212210	Iron ore mining (Fe)		3	2	4	3	12	LSM	Moderate	National
212221	Gold ore mining (Au)	3	3	2	5	2	15	ASM-MSM-LSM	Moderate	Global
212222	Silver ore mining (Ag)				4		4	MSM	Moderate	Global
212223	Platinum group metals	1			2		3	MSM	High	Global
212231	Lead & Zinc ore mining (Pb, Zn)		2				2	MSM	Moderate-high	National
212234	Copper & Nickel ore mining (Cu, Ni)	3	3		4	2	12	LSM	Moderate	Global
212235	Cobalt (Co)	2			3	3	8	MSM	Moderate	Regional
212236	Bauxite				2	1	2	LSM	Moderate	Global
212291	Uranium-Radium-Vanadium (U, Ra, V)	1			3	1	5	MSM	High	National-Global
212292	Tin (Sn) (Cassiterite)	2		3		2	7	ASM-MSM	Moderate	Regional
212293	Tungsten (W), Wolfram	2		3		2	7	ASM-MSM	Moderate	National-Global
212294	Ilmenite, Rutile (Ti group), Zircon (HMS)		4		1		5	LSM	High	Regional
212295	"Coltan" - columbium (niobium)-tantalum	2	1	3	1	2	9	ASM-MSM	Extreme	Global
212296	Rare Earths/Lanthanides (REE)	2	3	1	2	1	9	MSM	Extreme	Global
212297	Chromite		1		1		2	ASM-MSM	Moderate	Regional

Note: NAICS codes in blue denote proposed EAC specific revisions or additions to the original NAICS mineral codes

Source: Precht et al. (2013)

MVA potential,[32] iron ore and nickel are the two most promising metals for MVA, with iron ore standing out. Given trends in the international iron ore trade already outlined that limit East Africa's export competitiveness as an ore exporter, and the inland characteristics of both the location of the most prospective iron ore in East Africa and regional markets for steel products, the MVA potential of an enhanced steel industry remains promising. Iron ore is the focus of this report and receives the bulk of the analysis at the end of this part, after a more limited review of coal, limestone and nickel-copper-cobalt, which have experienced limited developments since 2013. Within the context of the iron ore review, this part outlines aspects of green mining practices and analyses feasibility to move natural gas to support primary steel production and other facets of importance for a phased approach to green steel production. Where the 2013 report used a 'Systematic Mineral Review Framework' to provide guidance across four analytical categories (regional production and availability; scale; market considerations; and MVA linkages), this part applies a Green Strategic Considerations Framework (GSCF). This builds on those earlier findings by applying the four strategic considerations discussed in Chapter 2.

3.1 GSCF: coal

Coal development across the EAC seemed to have significant momentum at the beginning of the 2010s – for thermal energy generation, industrial uses and exports – but this initial promise faltered. There is also still no indication of metallurgical coal (met coal) resources in the region. If built, any conventional integrated steel mills using BF/BOF would have to import met coal from South Africa or elsewhere, with transportation costs driving up what are already premium prices.

Even those thermal coal projects that were launched in the early part of the decade have either closed or faced significant headwinds in increasing production and becoming profitable. Kiwira Coal Mine in southwest Tanzania closed operations in 2012 and the government has struggled to find a new investor. Tanzania's Rukwa Mine is producing at a low level for industrial clients, awaiting approval from the government for a 120 MW coal-fired plant (TanzaniaInvest, 2021). Tancoal's Ngaka Coal Mine, also in the southwest of Tanzania (650 km west of Mtwara) and the largest coal mine in East Africa (see Figure 3.2), was hard hit by COVID-19. But the larger issues around taxation levels, cost structures, market outlets and whether a 200 MW coal-fired power plant will be constructed nearby have still not been answered. Even before the pandemic – when sales dropped by nearly half – production was less than 1 Mtpa, far below the projected 2-4 Mtpa (Club of Mozambique, 2021).[33] In early 2021, Dangote Cement Factory in Mtwara doubled its production and lowered its costs after switching from diesel and coal to natural gas power, illustrating the uphill struggle for expanding regional-industrial coal markets on competitive and substitutability grounds.

New coal projects in development in Tanzania and Kenya have either stalled or been cancelled outright. For instance, the proposed giant thermal plant at Lamu that would have generated over 1 GW at full capacity was halted when Kenya's National Environmental Tribunal cancelled an environmental licence in 2019; the last funding partners abandoned the project in 2020 (BBC News, 2019; Kamau and Sunday, 2019).[34] The initial coal was to be imported from South Africa; only later was coal to come from a new inland mine in Kitui county.[35] Even the early inclusion of GE Power as technology partner with its 'Ultra Super Critical' clean coal components did not dissuade civil society mobilisation against the project under the banner of 'Save Lamu.'

Meanwhile, despite the reticence of Chinese financiers to invest in new coal projects globally, this has not ended the hopes of President Hassan in terms of relaunching the stalled Mchuchuma coal and Liganga iron ore project – originally announced with great fanfare in 2011 – that would include a 600 MW coal-fired power plant and a conventional integrated steel mill (Shagata, 2021). Recent approval of a detailed feasibility study for a railway

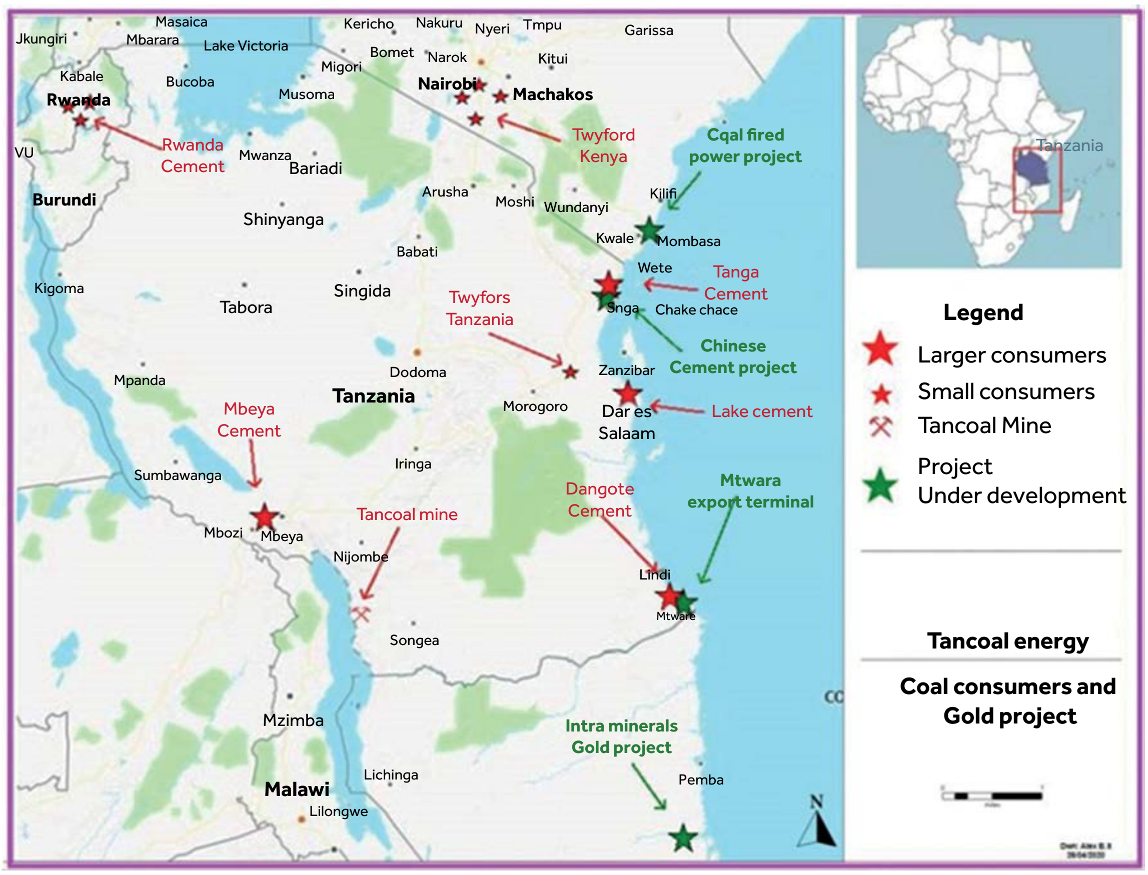
32 A new gold refinery was officially launched in Tanzania in June 2021 (25 per cent owned by the State Mining Corporation) that can process 480 kg of gold a day, with plans to double capacity within a year (Bloomberg, 2021b).

33 See also https://www.tanzaniainvest.com/coal. Tancoal points out that its production output can be matched to market needs.

34 The last large funder of note was China's ICBC Bank, as the Standard Bank of South Africa walked away from coal projects in 2017 and the African Development Bank in 2019.

35 There has been significant pushback to coal mining in the Mui Basin region of Kitui county, requiring a parliamentary investigation in response to a public petition in 2019. See Republic of Kenya (2019).

Figure 3.2 Tancoal Energy's large and small customers across the EAC.



Note: Does not include exports to Uganda that have been reported.
Source: Reproduced from http://intraenergycorp.com.au/coal

from Mtwara to Lake Malawi is one necessary infrastructure link to create export opportunities for the coal and iron projects[36] but the economic and technical feasibility and sustainability profile for this project is less appealing in 2021 than it was in 2011.

Domestic coal resources in Tanzania and to a lesser extent in Kenya appear a latent asset to policy-makers, with late President Magufuli banning coal imports to boost the prospects of Tanzanian coal miners big and small (The Citizen, 2019). But the obstacles faced over the past decade and the difficult future for coal project finance suggest a need to reconsider the planned scaling-up for coal development in the region. From a post-Paris 2015 and SDGs standpoint, adding 900+ MW of coal-fired electricity, even with expensive CCUS, when natural gas and renewable options are available and cost-competitive, will face numerous challenges.[37] Tanzania's SGR is rolling out as the first electrified rail line in East Africa, and it would be a step back to have an electrical rail system powered by coal (Muchira, 2021).[38]

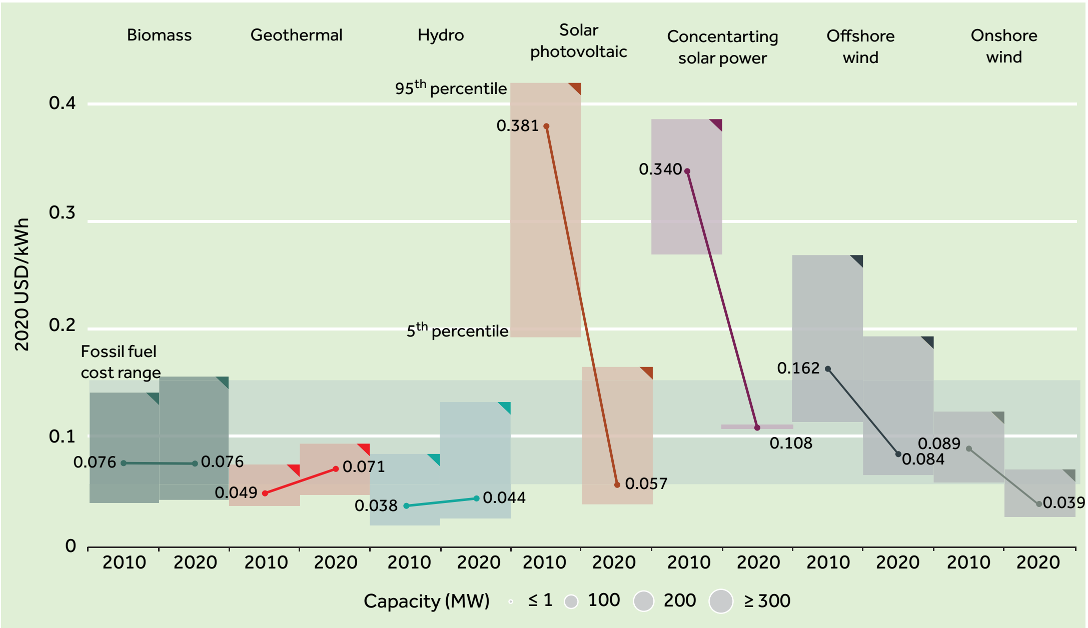
Conversely, Tanzania has already invested heavily in the Julius Nyerere Hydropower Station on the Rufiji River, a project that is about half complete and that will generate 2,115 MW once commissioned in 2022 (Joseph, 2021).

36 Some feasibility and engineering studies were prepared by late 2020 (Xinhua, 2020) but new money (US$6 million) for a detailed feasibility study was announced in July 2021 (Mwangonde, 2021). Estimated capex of the rail project was US$5.5 billion in 2016, with other objectives for building it beyond just the coal and iron projects (https://pp2.au-pida.org/approved-project/?entry=bquvz).

37 Analysis of residential and industrial power needs in rural areas either off grid and/or not economically serviceable by new transmission lines may point to coal-fired plants to meet specific requirements, but even then comparisons should be made on the long-term cost-competitiveness of alternatives as well as GHG impacts. See regional analyses by the International Renewable Energy Agency (IRENA) in April 2021.

38 The first electric trains will arrive from Korea in November (The Citizen, 2021).

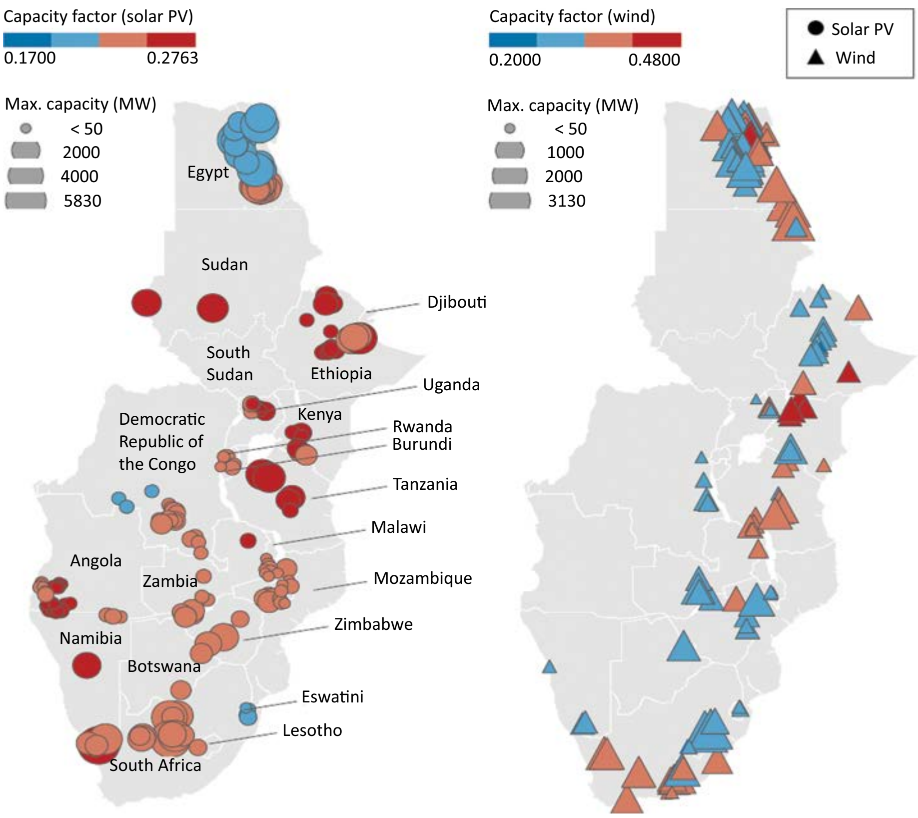
Figure 3.3 Levelised cost of electricity – rapid declines for green fuels



Note: This data Is for the year of commissioning. The thick lines are the global weighted-average LCOE value derived from the Individual plants commissioned in each year. The project-level LCOE Is calculated with a real weighted average cost of capital (WACC) of 7.5% for OECD countries and China In 2010, declining to 5% In 2020; and 10% In 2010 for the rest of the world, declining to 7.5% In 2020. The single band represents the fossil fuel-fired power generation cost range, while the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.

Source: IEA (2021b: 15)

Figure 3.4 Identified solar photovoltaic and wind zones in EAC and region



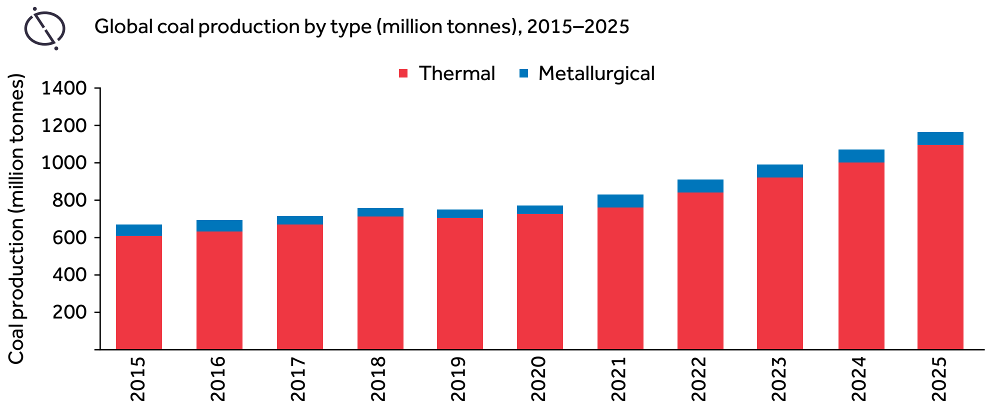
Source: IRENA (2021: 43)

In the medium term, the Grand Ethiopian Renaissance Dam will eventually export power to some East African Power Pool members, and in the long term (post-2030), planned massive additions to the INGA hydroelectric project in DRC could initially add 4,500 MW, some of which may be available to both the East and Southern Africa Power Pools (Holland and Burton, 2021).[39] In July 2021, the European Investment Bank opened a funding window (€80 million) expressly aimed at supporting more private sector geothermal power production across East Africa (Alushula, 2021). This is just one example of multilateral, bilateral and private finance with high investment appetite for all types of energy alternatives. This brings down the cost of capital for energy projects with high upfront construction costs but extremely low operating costs, enhancing the cost-competitiveness of alternatives to coal and natural gas (see Figures 3.3 and 3.4).

Any hopes for potentially exporting large quantities of thermal coal to Asian markets face significant hurdles: strong domestic production in China and India even as carbon emission policies take hold (mining.com, 2021c), the massive scale of Australian and Indonesian coal exports closer to key markets and a medium-term global demand decline as Europe and North America greatly reduce their thermal coal use. It is difficult to see the economic feasibility of large-scale coal exports from southwest Tanzania (whether Ngaka, Mchuchuma or Kiwira) even once planned SGR rail networks reach any of those locations – still a few years away. While global coal production may continue to rise in the short term (see Figure 3.5), coal trade was only 19 per cent of global demand in 2019 (pre-pandemic), showing how much coal is supplied by domestic sources (IEA, 2020b).

The GSCF box summarises multiple strategic considerations regarding EAC coal.

Figure 3.5 Global coal production forecast to 2025 (Mt)



Source: mining.com (2021c)

Green Strategic Considerations Framework: coal

Sustainability and development:

- Potential for local coal as (1) partial solution for electricity generation (SDG 7), (2) driver of industrialisation [steel, cement and other industries (SDG 9)] and (3) potential export commodity (SDG 8). In specific cases, coal-fired electricity may replace higher-polluting energy sources (e.g., diesel generators, firewood).
- Over the past decade, the cost of alternative sources of energy has dropped to the point where they are competitive with coal over time (SDGs 7 and 13).

39 The economic feasibility of transmission of INGA 3 power over long distances is, however, called into question by this report, which argues against South African (ESKOM) long-term commitment to the project given ongoing delays and high costs compared with other renewables (TMP Systems, 2021).

- Thermal coal's role in steel and cement production is declining as a result of process changes, costs and environmental concerns. (The EAC does not have met coal resources.)
- EAC PS NDCs: How would increasing use of coal affect national GHG emission commitments?

Global competition:

- Tanzania, the largest producer, has banned cheaper coal imports, which has increased local and regional markets for Tanzanian producers.
- Difficulty and cost of transportation from inland sources create competitive challenge for potential large-scale seaborne exports.
- While global production and consumption will still edge higher in the near term, both China and India are gradually reducing their reliance on thermal coal (Southeast Asia, however, is increasing coal demand). Oversupply, not scarcity, will weigh on thermal seaborne coal trade into the 2020s.

Green mining transition:

- Expanding coal production for exports, new power production and heavy industry (steel, cement) work against attempts to develop a green mining ecosystem in the EAC. Already, domestic resistance exists against some new coal projects in the region on ESG grounds.
- Coal will still be required for various industrial uses, including some DRI/steelmaking in the near term, and Tanzania's existing coal production can meet EAC requirements into the foreseeable future. But for both cement and steel coal's role is in secular decline.

Decarbonised project finance:

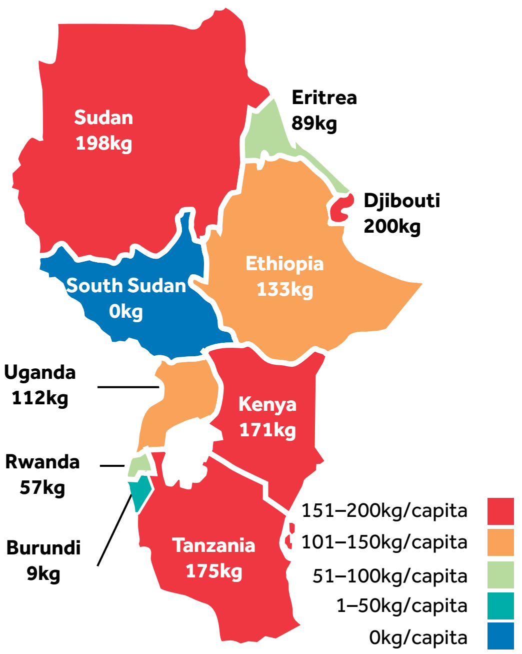
- An already very difficult project finance environment for new coal projects (mining, exports or power generation) should be an important signal for policy-makers.
- Even if new coal projects can be financed, they may be affected by market access, alternative investments and/or climate-related financing of greater net benefit than the coal projects.

3.2 GSCF: limestone

Limestone is found throughout the region, with cement companies the largest producers. Limestone also has a role to play in steelmaking, but a lesser role in DRI/EAF processes compared with conventional BF/BOF. An increasingly competitive cement market has lowered consumer prices despite growing demand [except during supply shortages caused by maintenance or electricity issues (Cemnet, 2020)]. Profit margins are down while demand is up for limestone and potentially coal in the cement sector. International players from Nigeria (Dangote) and China (Huaxin and soon Sinoma), among others, have squeezed once dominant players (ARM Cement in Kenya) to the point of liquidation (Global Cement, 2021a). Sinoma's planned cement plant at Tanga would be the largest in East Africa, with capacity to produce 7 Mt per year, mostly for regional export markets. But the proposed energy source for that plant is new coal-fired electricity generation of up to 1,200 MW and major redevelopment of the Tanga port.

In a post-pandemic marketplace, just Kenya and Tanzania could see their combined cement demand rise to 15 Mt by 2025. Rwanda has built up its capacity to the point where it is a major exporter to Burundi and DRC (Perilli, 2020). Concurrently, there is an ongoing struggle in various countries: end users who prefer low prices and grinders who import clinker versus those integrated cement companies that want imported clinker tariff rates increased to cover their higher production costs as they expand local capacity (Muchira, 2020). There are already moves towards greening cement products in the region: Uganda's Hima Cement launched a new niche product in early 2021 it claims is the 'greenest cement on the Ugandan market.... produced with a reduced carbon footprint, with 54% lower CO_2

Figure 3.6 East African cement production capacity per capita

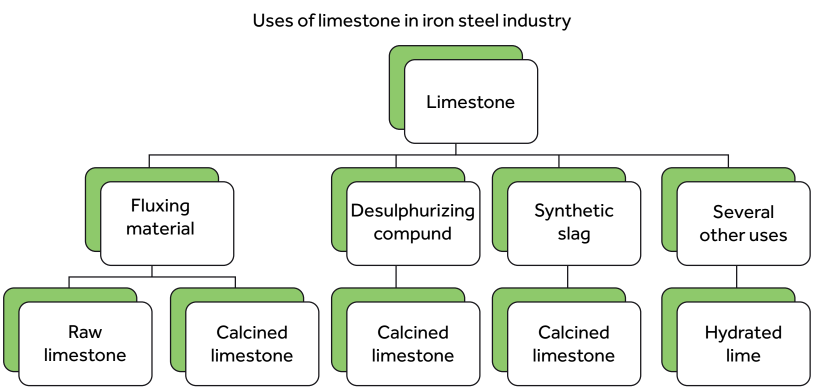


Source: Perilli, 2020. https://www.globalcement.com/news/item/11117-update-on-rwanda

emissions in comparison' to ordinary Portland cement (Global Cement, 2021b). As mentioned previously, Dangote's recent shift away from coal and diesel to natural gas at Mtwara also reduces the GHG footprint of its cement production. Cement producers are looking for ways to save money, increase output and, to some extent, reduce CO_2 emissions as they see decarbonisation concerns penetrating the cement industry.

Overall, continued urbanisation and major infrastructure projects from dams to railways will keep cement and thus limestone and related product demand growing. As cement production is a leading industrial emitter globally (up to 6 per cent of all GHG emissions), there is considerable room to decarbonise. In traditional operations, about 40 per cent of CO_2 emissions come from energy requirements, with 60 per cent coming from the high heat sintering process that produces clinker from crushed limestone, clays and marl, releasing considerable CO_2 in the process. Coal has traditionally been the main energy source for cement production, taking 200-450 kg of coal to produce 1 tonne of cement. However, 'alternative fuels, an ever-reducing clinker factor and more thermally efficient cement production technologies will all each take a bite out of the amount of coal used' (Global Cement, 2016). We can see some of that happening already within the EAC. As for limestone's relevance for steel, we have noted that every recycled tonne through an EAF saves 120 kg of limestone. Even making primary steel through DRI/EAF uses less lime/limestone (up to 50 kg per tonne) than BF/BOF, but it remains an essential input (see also Figure 3.7).[40] Given widespread limestone production throughout the region, increased use for expanding DRI/EAF primary steel production would not impose any major obstacles except for transportation. And slag produced during the EAF process (up to 120–180 kg per tonne of steel produced) can become an input to concrete as an aggregate replacement that can enhance some of its characteristics.

Figure 3.7 Various uses for limestone in iron and steel industry



Source: Ispat Guru (2013)

40 https://www.lime.org/lime-basics/uses-of-lime/metallurgical-uses-of-lime/iron-and-steel.

Green Strategic Considerations Framework: limestone

Sustainability and development:

- Cement is a critical building block for economic growth in general (SDG 8), and for residential/commercial construction (SDGs 1, 6 and 11) and infrastructure/industry (SDG 9) in particular. Limestone and related mined products are main inputs for cement-making, and an important element in steelmaking.
- Globally, the cement industry is a major industrial emitter (6–7 per cent of all GHGs), so SDG 13 and Paris Agreement NDCs will continue to put pressure on to decarbonise.
- Old concrete can be crushed and reused for various applications, replacing new materials, while steel slag can be used as partial aggregate replacement in concrete.

Global competition:

- The EAC has substantial and growing clinker and grinding cement production capacity, with new investments still coming on stream (behind some EAC tariff protections). Cement is a low margin, high volume business where production is best situated close to inputs (limestone, energy) and market access (including good road networks, railways and ports).

Green mining transition:

- Cleaner energy at every phase (mining, crushing, transportation, clinker production, grinding, mixing, packaging, distribution) can substantially reduce the high emission profile of cement. Partial replacement of limestone also reduces CO_2 emissions during sintering and using DRI/EAF for virgin steelmaking reduces overall limestone-related CO_2 emissions.
- Large-scale cement manufacturers in the EAC may find CCUS options economical in future given changing government policies, carbon pricing and market access incentives/tariffs.
- Iron ore mining waste streams, specifically carbonates and silica-based crushed materials have the potential to supplement concrete fabrication input in the generation of higher-strength (reinforced) concrete in infrastructure raw material regional assurance.

Decarbonised project finance:

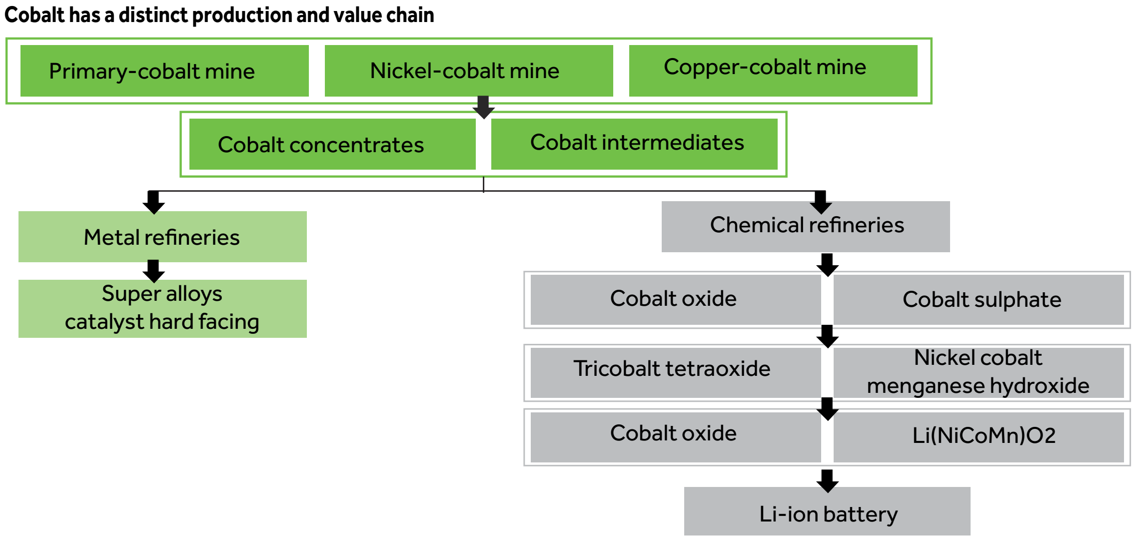
- Most cement industry investment is driven by established regional or global players, but multilateral financiers (e.g., the International Finance Corporation, the African Development Bank) and climate funds concerned about GHGs are relevant to greenfield and brownfield cement FDI in Africa. Cost of capital for changing energy sources or processes (including CCUS) can be attractive for ESG-oriented producers looking for GHG mitigation/transition options.

3.3 GSCF: nickel-copper-cobalt

Where only two EAC PS have substantial coal resources, four of six possess potentially economical nickel, copper and/or cobalt (Ni-Cu-Co) deposits, though no large-scale primary production has commenced. The original 2013 MVA report included this complex of minerals because significant production of one (e.g., nickel) may produce economically viable secondary streams of one or both of the others, and as such all have significant MVA potential. Since 2013, the emergence of all three as central to the global electricity energy transition (e.g., renewables, EVs and batteries) has refocused attention on potentially rising long-term demand.

Debates about the extent of cobalt in batteries have led to price volatility over the last few years: EV market leaders Tesla (USA) and BYD (China) are pushing ahead with non-cobalt containing batteries. But even if cobalt use is restricted as a result of its high price, cobalt demand is still likely to outstrip supply (Leighton, 2021). This is especially true as ESG concerns about sourcing cobalt from DRC may affect supply chains. While giant nickel or copper primary production is common around the world, cobalt is almost always a secondary

Figure 3.8 Cobalt sources and value chains



Source: Leighton (2021)

stream (mostly from gold or copper mines, but also from some nickel mines) (Slack et al., 2017). In the world's largest cobalt producer, DRC, the largest production is associated with copper mines, but there are medium primary producers and many artisanal producers (Reid, 2021). Uganda's Kasese Cobalt wound up operations in 2013, and in 2021 Australia's Jervois halted its gold-copper-cobalt exploration programme in Uganda.[41] Cobalt has two distinct value chains (see below), and the EAC could eventually utilise cobalt in one or both if other MVA industrial developments occur over time. EAC exports of cobalt, even modest quantities, would find a ready market if ESG/green mining ecosystem foundations were in place. Today, however, cobalt is only a minor by-product in regional mining. In Tanzania, Harmony Minerals has resurrected the Dutwa project, given higher nickel and cobalt prices. Though still in feasibility analysis, production could be 26 ktpa nickel and 530 tpa cobalt for over 15 years.[42]

Copper is currently produced as a by-product of gold mining in Tanzania, and also at artisanal and medium scales with volumes dependent on copper prices (Schoneveld et al., 2018). Uganda, Kenya and Burundi also have copper prospects. Even with relatively low production, Tanzania banned export of ores and concentrates of copper, among other minerals, in March 2017 (van Wyngaardt, 2017). The ban was only lifted in 2020 as other structural changes to the mining industry were finalised, including the emergence of Twiga Minerals Corporation (Barrick 84 per cent and Tanzania government 16 per cent) (Jamasmie, 2020b). Tanzania is also an outlet for copper exports from the Copperbelt (Zambia, DRC) when South African export routes become congested or unavailable (Ignacio, 2020), and more regular exports that way could increase if the SGR gets built to the Lake Malawi region.

Copper prices languished in the mid-2010s (see Figure 3.9) but forecasts now reflect energy transition demand and lack of big supply projects coming on. In June 2021, Fitch Solutions Country Risk and Industry 'revised its [global] copper demand forecast to 31.7-million tonnes in 2030, up from the 29.8-million tonnes previously forecast,' with much of that increase driven by demand for 'green copper' (Bulbulia, 2021). A model for green copper production will be the Ivanhoe Mines-Zijin project in DRC, powered by modernised hydroelectricity (Creamer, M., 2021). An independent audit of the planned operation 'confirmed that the project will be among the world's lowest greenhouse gas emitters per unit of copper produced.'[43]

41 https://jervoisglobal.com/projects/non-core-assets/
42 https://www.harmony-minerals.com/dutwa/
43 https://www.ivanhoemines.com/projects/kamoa-kakula-project

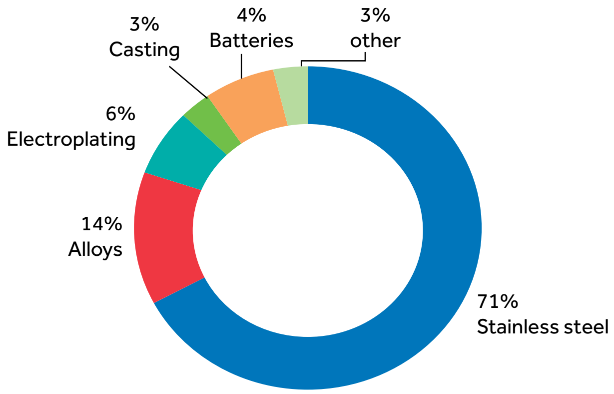
Figure 3.9 Copper prices

Source: Daily Metal Price: https://www.dailymetalprice.com/metalpricecharts.php?c=cu&u=lb&d=20

As the 20-year review of copper prices illustrates, it was trading in a range just below US$3/lb prior to the pandemic and fell sharply as the global economy slumped in early 2020 (green line in Figure 3.9) but increased to record highs by late 2020 and early 2021 (slope B). While these price increases were unsustainable, a higher trading range of $3–4+/lb given secular demand trends is most likely. Even the lowest price is not likely to reach the lows of 2016 (slope A). This will stimulate more project development in a sector that has been starved of investment interest for nearly a decade. To maintain long-term comparative and competitive advantage, any new projects should integrate 'green copper' from the outset with close co-operation of governments, mining companies, suppliers and energy providers. This kind of approach is at an incipient stage in the long-delayed hopes for the Kabanga Nickel deposit in Tanzania.

Since the 2013 MVA report, nickel prices have followed other mineral commodities on a long price decline. From a trading range of US$6-9/lb at that time, prices traded at $3.50–6.50/lb from 2015 to late 2019. Nickel's fortunes were tied mostly to stainless steel demand (see Figure 3.10),

Figure 3.10 Global uses of nickel (2019)



Source: https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/nickel-facts/20519

Figure 3.11 Nickel prices

Source: Daily Metal Price: https://www.dailymetalprice.com/metalpricecharts.php?c=ni&u=lb&d=240

but as the proportion of nickel-containing Li-ion batteries in use increases, it is batteries that will drive demand upwards. Two of the most commonly used batteries, Nickel Cobalt Aluminium and Nickel Cobalt Manganese use 80 and 33 per cent nickel, respectively.[44]

Two large nickel projects in the EAC have been slowly advancing along the project feasibility pathway for well over a decade: Kabanga in Tanzania (previous owners include Sutton, Barrick and Glencore) and Musongati[45] in Burundi. Alongside low prices in the mid-2010s (Figure 3.11). Lack of infrastructure, including railways and inexpensive power, has held back development of both projects. But better nickel prices and projected long-term demand over supply (especially from 2027) have reinvigorated interest in these projects plus Dutwa (mentioned above), among others. In January 2021, Tembo Nickel Corporation was formed between UK privately held company Kabanga Nickel (84 per cent) and the Tanzanian government (16 per cent) (Dausen, 2021). Besides the primary focus on nickel mining operations, Tembo Nickel is charged to 'process and refine Class 1 nickel with copper and cobalt co-products,' currently planned to use hydromet technology, skipping traditional pyrometallurgical processes.[46] From the outset, the UK private firm Kabanga Nickel has integrated ESG and low carbon economy objectives into its development plans, promoting the project as 'a unique, environmental, social and governance (ESG) compliant, responsible mine of the future' (Bhadare, 2021). There is still a long road for Kabanga to finalise its mineral resource model, engineering and processing plans (to escape the production and ESG problems that have plagued Madagascar's Ambatovy high-cost nickel-cobalt project since inception).[47] But the current Tembo Nickel plan for Kabanga, at least on paper, meets ESG, MVA and possible 'green mining ecosystem' objectives that could cement the EAC as a next generation nickel producer capable of meeting stringent value chain requirements.

44 https://nickelinstitute.org/about-nickel/nickel-in-batteries
45 A 2011 bankable feasibility study done on Musongati is available for review (BMM International Ltd, 2011).
46 Similar to processes currently used by Vale: Hydromet technology, www.vale.com/canada/EN/business/mining/nickel/vale-canada/long-harbour/Pages/Hydromet-Technology.aspx
47 https://roskill.com/news/nickel-cobalt-sumitomo-reports-a-further-us289m-impairment-on-ambatovy

Green Strategic Considerations Framework: nickel-copper-cobalt

Sustainability and development:

- Ni-Cu-Co are all seen as critical metals to the global energy transition in power generation, transportation and storage (renewable electricity, EVs, batteries, etc.), particularly relevant for SDGs 7, 8, 9, 11, 12 and 13. Renewable energy systems can use up to 12 times more copper than conventional power systems.
- Historically, however, mining and processing of all three have significant ESG challenges given scale, energy and processes involved – a challenge to SDGs 6, 12, 13, 15 and 16.
- Copper is infinitely recyclable; this uses 85 per cent less energy than primary production. Stainless steel is also regularly recycled, and often produced from recycled materials. Efficient, ESG-friendly battery recycling to recapture nickel and cobalt remains a work in progress and will require co-operation between EV/battery manufacturers and recyclers.

Global competition:

- None of the 10 largest nickel mines in the world are found in Africa. Currently, there is no large-scale nickel production in the EAC. South Africa, Côte d'Ivoire, Zimbabwe and Madagascar are the largest nickel producers on the continent; DRC and Zambia dominate copper and cobalt production.
- Given forecasts of Ni-Cu demand for energy transition (Co to a lesser degree), demand could outstrip supply by the mid-2020s making some EAC projects more attractive especially if renewable energy and rail infrastructure is available. More opportunities for MVA, including links to steelmaking (e.g., stainless), then become possible.

Green mining transition:

- Nickel project promoters (Kabanga, Musongati, Dutwa) including governments stress the role of nickel as a key battery component, as well as ESG and green mining approaches. Integrating ESG/green mining and circular economy frameworks early will allow the energy transition benefits (batteries) while avoiding the potential environmental/GHG harm from traditional mining practices.
- Lessons can be learnt from 'green copper' projects in DRC and elsewhere.

Decarbonised project finance:

- There is significant investment appetite for economically attractive and ESG/green-oriented mining projects that can fulfil 'green', 'climate' and/or 'circular economy' objectives.
- Renewable energy financing that unlocks ESG/green-oriented Ni-Cu-Co projects is increasingly available from multilateral and private sources.

3.4 GSCF: iron and steel

This section is the most technically detailed and, though it focuses on iron mining and steelmaking as MVA, it draws on general lessons about 'green mining' that emerge from the review of coal, limestone and nickel-copper-cobalt above. It also fleshes out in more detail the concepts behind a sequential 'EAC green mining and steel ecosystem' strategy. The 'green mining' components can be applied in various ways to other minerals beyond iron ore – and, to be effective, must be. To date, there still are no large-scale iron ore mines in the EAC despite significant deposits in several countries and various planned projects. Iron ore is currently mined in small-scale operations. Given technology changes, the idea that large-scale mining tied to integrated steel mills is the only route to economic viability is no longer true. EAF use by steel fabricators opens the door to increasing primary steel production using DRI processes combined with scrap metal, limestone, graphite and other materials available in the region. From one perspective it might be beneficial that there are no large-scale, met coal-dependent BF/BOF integrated steel mills in East Africa. The EAC can pursue a different model that meets all sorts of political, economic and environmental objectives, and is tied to regional and continental market dynamics.

The most critical component for moving towards a green mining ecosystem is energy source. DRI/EAF processes do not require imported met coal and can be weaned off thermal coal for electricity and heat/kiln uses. Natural gas can replace most of the coal required, and, eventually, hydrogen can replace natural gas (Homman, 2019). If renewable energy (hydro, solar, wind, geothermal and eventually hydrogen), rather than coal, is producing base electrical power for mining and processing, this is another big step towards a green mining ecosystem that will attract investment, premium prices and market access opportunities. As laid out below, many steps can be taken across the entire mining to MVA spectrum to enhance green mining practices – steps that do not penalise the EAC but in fact build on some of the region's existing comparative advantages in terms of current and future extent of greener energy sources and lack of legacy steelmaking infrastructure.

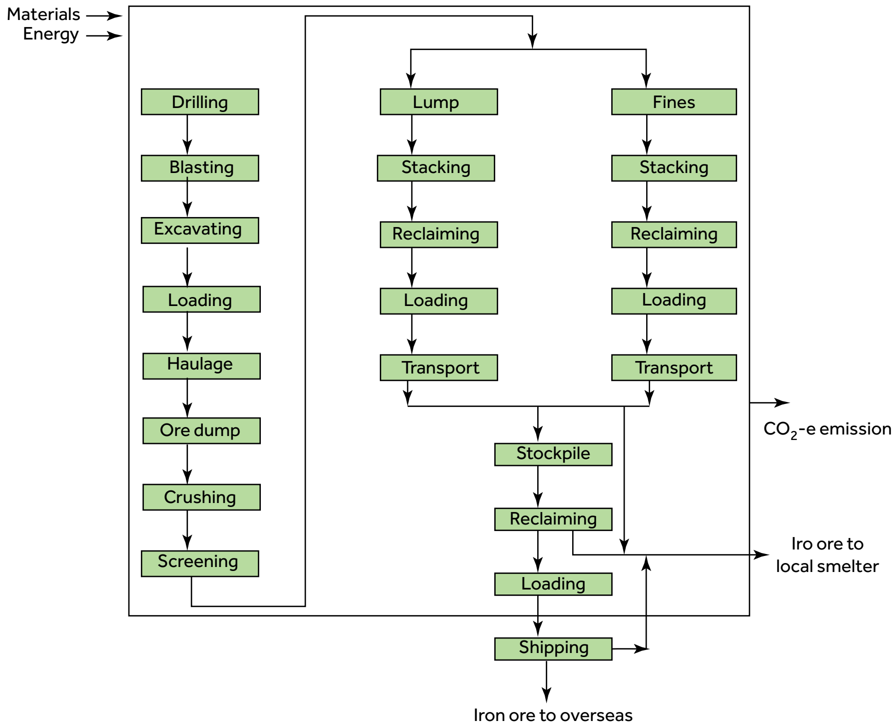
This section breaks down various aspects of iron mining and steel production using some scenario analyses, including ways to reduce GHG during mining and milling operations (upstream) and of the feasibility of replacing thermal coal for electricity and especially DRI kilns in Uganda with natural gas from Tanzania (downstream MVA), as well as a short discussion about CCUS. It does not reiterate the key strategic considerations outlined in Part 2 within a GSCF for iron ore and steel as that would be repetitive. Instead, it discusses these practical considerations on the possible pathway of a green mining ecosystem in some depth. The project team did not have the time or the mandate to investigate individual PS and EAC climate change commitments leading up to COP26 in Glasgow, UK, later in 2021. The recommendation to promote a green mining ecosystem might be enhanced within the context of each PS' NDC towards the Paris objectives.

Upstream green mining considerations

Mining and milling (processing) are not quite as simplistic as indicated by Haque and Northgate (2015) (Figure 3.12), with more detailed considerations of iron ore separation from gangue using magnetic separation after progressive finer crushing and grinding milling operations followed by drying before shipping. With all of these steps contributing CO_2 emissions, the link between input energy (power) for mechanical processes and the output of CO_2 emissions is self-evident. The higher the value of the product produced from the mine site, the greater the energy input and the higher the CO_2 output consequence. As such, there is a value proposition inclusive of emissions considerations proportionate to financial and tangible product gain and worth assessment in developing the value of a regional steel strategy.

The core to a viable regional steel industry is the 'next stage' proving of resources, beyond that established through historical, documented mineral exploration activity. This would permit establishment of an economic reserve under investment-acceptable reserve definition standards. A recent review by Muwanguzi et al. (2020) indicates known Ugandan hematite (Fe_2O_3) and magnetite (Fe_3O_4) iron ore mineral resources in the southwest and southeast regions of Uganda immediately adjacent to the Rwandan and Kenyan borders, respectively. Muwanguzi et al. (2020) indicate that the southwest region's hematite resource is prospectively 497 Mt with an average ore grade of 67.7 per cent Fe content; and the southeast region's magnetite 86 Mt is at 55.2 per cent Fe content. Within the southwest region, two prospective hematite deposits indicate resources of 205 Mt at Buhara and 155 Mt at Muko, both with 68 per cent Fe content. While it should be borne in mind that an indicated resource does not represent economically proven or probable certainty as required within the 43-101 or JORC reserve definitions, the size and grade of both the Buhara and Muko deposits suggest further exploration and proving are likely warranted. Some limited production is already occurring near Muko for Tembo Steel's DRI/EAF production at Iganga, a sign of the high quality of ore there. Higher-quality ores require less energy for milling to prepare for a direct reduction furnace. While iron ore deposits of a much smaller

Figure 3.12 Life cycle assessment of iron ore mining and milling



Source: Haque and Norgate (2015)

scale have been previously mined for local use, including in Kenya at 705 ktpa until 2012 (Yager, 2015), the much larger potential proven resource of 126 Mt at Liganga in Tanzania is still targeted by the government for an integrated steel plant, with a suggestion of a much larger deposit of 1.5 Bt (though with no discernible declared ore grades) (Yager, 2018). After a decade, no development has occurred beyond tentative assurances of investment and government desires to cut any red tape (Shagata, 2021).

The mining and mineral processing (milling) scenario suggested here compares 'conventional' surface mining methods with a 'greener' approach. Targeting the reduction of diesel-sourced energy, particularly for haulage operations from the mine to mill, provides a pathway with a 64 per cent + reduction in CO_2 emissions through the replacement of diesel with battery-powered haulers (trucks) at a scale already proven and in mine application that would be suitable for use in the EAC. The scenario has been assembled as a user-controlled spreadsheet that would be useful in considering the life cycle costs (LCC) associated with prospective surface mining activity at Buhara or Muko over a 25-year period for the resource as indicated by Muwanguzi et al. (2020).

In considering milling operations for mineral processing at an iron ore mine, the authors evaluated CO_2 emissions in processing 2.56 Mtpa ore, at a rate of 3.37 kg CO_2 per tonne ore processed (coal-fired electricity generation referenced). The big CO_2 components of an electricity-powered milling operation are a function of the source of power. In the case of hydroelectric power sources, as indicative of Uganda, the CO_2 emissions are essentially zero, but would likely be priced at a premium to electricity sourced from coal or diesel generators – the latter being the case for remote mining operations with no direct power infrastructure.

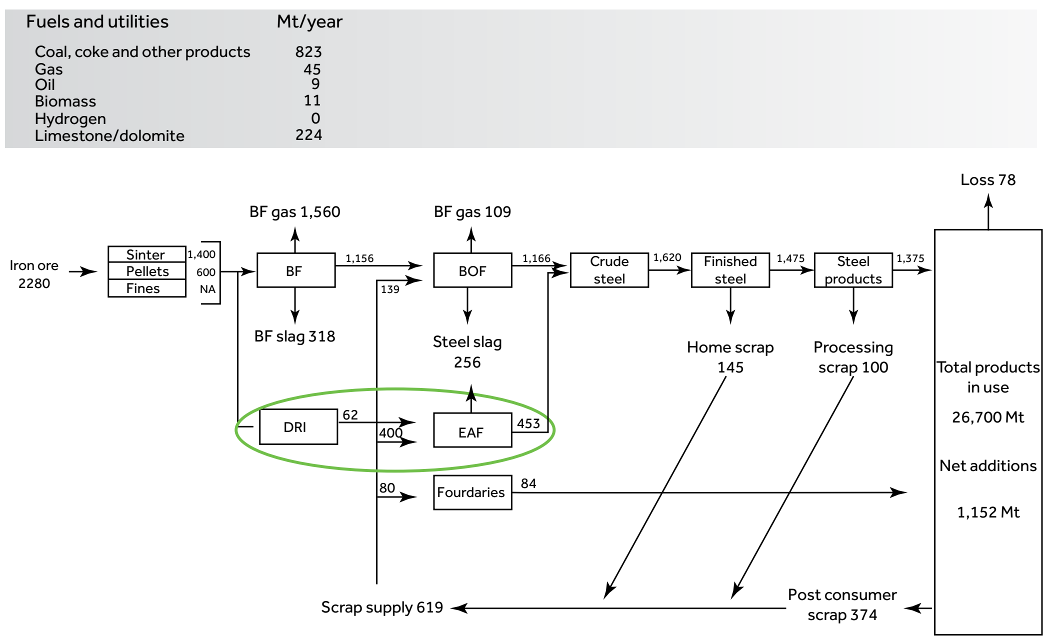
In comparing a diesel haulage and loading mining operation to an electric equivalent for all mobile mining assets, except dozer and graders, an equivalent electric-powered shovel compared with a diesel-powered excavator actually requires more power, so effectively emits more CO_2 if the power is sourced from diesel or coal. In the example scenario that follows here, a hauler fleet of seven trucks would yield a 64 per cent reduction in CO_2 by wholly opting for battery-powered 45-ton electric haulers over the conventional 45-ton capacity diesel equivalent. Overall, this would reduce mining CO_2 emissions by 28 per cent, inclusive of excavation equipment operations. An additional strategy in the absence of electric haulers would be to lower the road hauler interacting rolling resistance through active operational road and hauler performance-based strategies, increasing CO_2 reductions. Regulatory and technical assistance can ensure mine operators take advantage of CO_2 reduction strategies (that usually also save on operating costs) such as active road and right-of-way maintenance on mine sites.

While economic proven reserves are invariably substantially less in both size and grade relative to indicated resources, the analysis undertaken here considers a 'hypothetical model' reserve of 60 per cent by weight of the 155 Mt indicated resource, for a 'theoretical reserve' of 93 Mt, at a lower reserve grade of 60 per cent Fe. The choice of 60 per cent relative to size and grade is arbitrary and should not be taken as any reflection of expected proven, probable or possible reserve at the Muko location. Within the scope of the authors' knowledge and experience, the analysis model also assumes that a surface operation should be able to recover 85 per cent of the reserve through good mine planning and operational execution, essentially sending 79 Mt of raw ore to the mill. Again, through the authors' knowledge and experience, it is assumed that the mill would be able to concentrate the ore, bringing the grade up from 60 to 68 per cent, per international high grade fines' grades, at a 55 per cent by weight feed to product recovery yield, generating 26 Mt of 68 per cent grade iron concentrate for steelmaking over a 25-year period, essentially delivering over 1.0 Mtpa iron concentrate downstream for DRI/EAF steel fabrication. At a targeted 50 per cent DRI to 50 per cent scrap input for EAF, 2.0 Mtpa of steel could be produced.

Gielen et al. (2020) indicate that, although DRI sponge iron addition to EAF steel production in 2015 was 13.4 per cent plus 86.6 per cent scrap steel feed, their projections to 2050 suggest DRI sponge iron addition increasing to 43.6 per cent plus 56.4 per cent scrap steel (see Figures 3.13 and 3.14). This makes the future of mined iron ore for DRI/sponge iron streams for EAF processing viable in the face of a limited future supply of scrap steel. While scrap steel may appear plentiful, there is a finite limit to scrap availability, with the generation of new scrap on a 20-to-40-year cycle, depending on the societal, infrastructure and industrial replacement frequency of steel-related products. Prices for global scrap are already rising, with China now importing scrap as well as pig iron. Many countries, including the EAC, ban the export of scrap to maintain local supplies for EAF steelmakers. Too much reliance on scrap, however, can lead to illegal 'recycling' of steel-in-use, a problem faced in every jurisdiction when steel or copper scrap prices rise too high.

The mine and mineral processing plant LCC were analysed as a hypothetical application to the Muko resource scenario. A conventional diesel-powered haulage fleet of 45-ton class haulage trucks

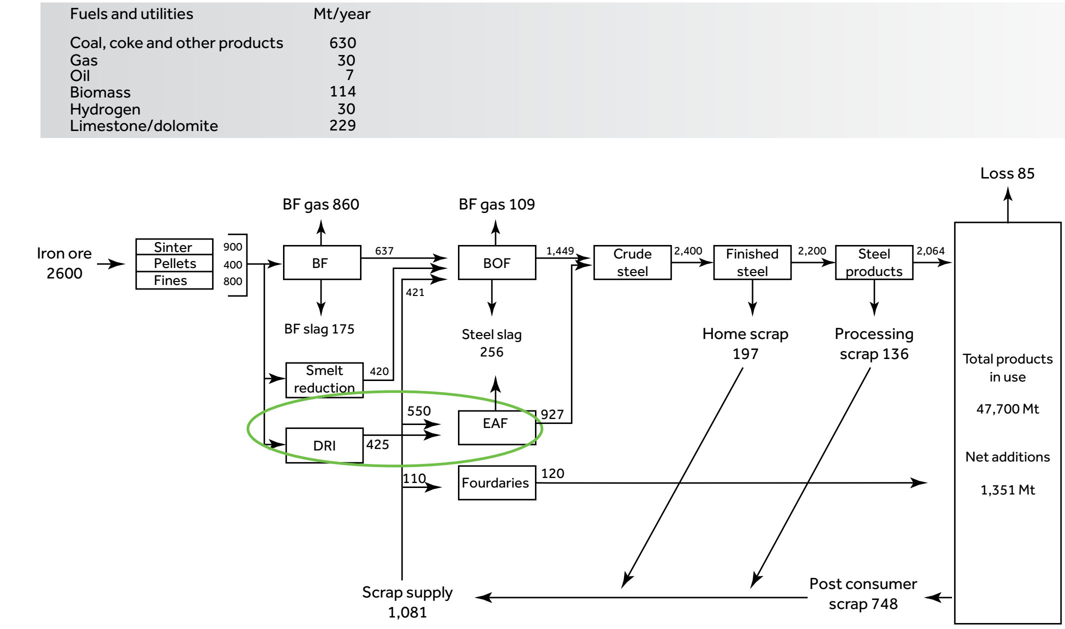
Figure 3.13 2015 comparison of ratio of scrap steel to DRI in EAF



BF, blast furnace; BOF, basic oxygen furnace; DRI, direct reduced iron; EAF, electric arc furnace.

Source: Gielen et al. (2020)

Figure 3.14 2050 comparison of ratio of scrap steel to DRI in EAF



BF, blast furnace; BOF, basic oxygen furnace; DRI, direct reduced iron; EAF, electric arc furnace.

Source: Gielen et al. (2020)

was recently (2017–2019) compared with wholly battery-operated electric 45-ton scale class mine haulage fleet, loaded by either diesel hydraulic excavator versus electric shovel; or diesel versus electric continuous surface miner.

All mining equipment used in the exercise is well known and used in the heavy equipment industry in both mining and construction applications. Selection of the size of the haulage and loading fleets used in the comparison was governed by the simple criteria that the mine should be worked for a minimum of 25 years to be a viable feed source to a potential locally focused steel fabrication industry in the EAC, generating infrastructure-related steel products for regional construction purposes.

In parallel with the case study presented, mining and milling of iron ore generates a substantial proportion of mine waste and tailings, comparable to sand and containing residual iron ore. West African industry has documented the use of such mine waste to replace sands when mixed with cement to create stronger 'reinforced' concrete for the construction

User guide to Appendix B spreadsheet: mine and mill iron ore mine case study

The spreadsheet tool (Appendix B), highlighted in Table 3.1 below, is appended for (1) reference in relation to this report and (2) use in considering the emissions impact of diesel versus electric asset technology for mining at the scale indicated. Overall, the tool provides a means of evaluating both the level of CO_2 emissions for each combination modeled, the outcomes of which are reflected in Table 3.2, and the corresponding cost per tonne mined.

In lieu of an instruction manual, the 'mine and mill' iron ore mine scenario-based analysis spreadsheet appended and illustrated below in Table 3.1 provides a mining engineer/technologist nomenclature savvy user the ability to vary key parameters highlighted in 'green' cells, including:

- expanding production capacity and mine life and extending the start year date;
- selecting diesel or electric mine equipment;
- local inflation rate;
- fleet availability and utilisation;

- hauler payload class, per load cycle time and local diesel fuel cost;
- rock density, blasting cost and swell factor;
- rolling resistance with and without grading;
- UGX to US$ exchange rate;
- dozer and grader size classes; and
- iron ore market price, plant feed grade and plant recovery.

All other spreadsheet cells (not green) should not be varied as they interact to perform the analysis.

industry. While not addressed directly in the LCC analysis modelled here, the benefit of assigning a use for mine solid rock-based wastes has both a 'secondary industry' and an environmental benefit to the EAC region and likely enhances the economic viability of both industries.

In the case of the excavator/shovel/hauler analysis, required fragmentation of rock by blasting essentially doubles the operating cost. If the surface miner does not require blasting and provides highly fragmented mined ore feed to the plant, this reduces the need for large rock crushing and the need for a primary jaw crusher. However, it should be noted that surface miner operations rather than excavator/shovel operations are predicated on the ore deposit geometry in the ground being essentially flat and of a substantial areal extent. Deposits typical of deeper open pit geometry, mined through successive benches to several hundred metre depths, are unsuitable for surface miner operations to navigate. While included in the hypothetical analysis here, it is unlikely that the Muko deposit is in fact a planar style deposit.

Table 3.1 indicates the mining/milling equipment combinations for the LCC analysis model for a prospective 25-year mine and mill life. Depending on proximity to the next iron ore resource, mill life could easily be doubled to 50 years with retrofitting at lower than initial plant capital cost. The major difference between excavator and surface miner-focused operations is the cost of rock breakage through blasting, as mentioned previously. While the summary in Table 3.2 makes it clear that the surface miner/hauler electric-powered operations provide the lowest cost per tonne mined and the highest return on any investment, it is likely the Muko ore deposit is more amenable to excavator/hauler operations, such that the electric-powered shovel and hauler option may in fact be the most viable for the least CO_2 emissions. The operational CO_2 reduction indicated is achievable with greater attention to the running surface conditions for a diesel hauler fleet, through the grading reduction of rolling resistance that affects hauler fuel use and emissions. This is put as an additional case for consideration, should battery-powered electric haulers (Evarts, 2019) prove to have a shorter lifespan than initially indicated in comparison to the long-proven diesel engine hauler in wide use.

Gas pipeline from Dar es Salaam to Uganda

An important consideration in contemplating green, or greener, steel is the source of fuel for a very energy- and heat-intensive process and the reducing agent required to turn ore into DRI or sponge iron (Hoffman et al., 2020). As discussed elsewhere in this report, we believe it may be challenging, if not impossible, to find funding sources for projects based on conventional steel manufacturing processes because of their carbon intensity (i.e., reliance on met/coking coal and large GHG emissions per tonne of steel produced). An option to be considered is to rely on natural gas both for energy (electricity and heat) and to produce the reducing agent. Not only does gas have much lower carbon intensity than coking coal, but also, if combined with CCUS (carbon capture and sequestration), if can be relatively green. While carbon emissions from coking coal can also be combined with CCUS, we note that there is no source of coking coal in the EAC countries, so the coal will need to be imported, possibly from South Africa or outside the continent, and transported overland to landlocked Uganda. There is an abundant underused natural gas resource in Tanzania.

Tanzania's gas is currently transported by pipeline to Dar es Salaam, where it is used as a fuel for power generation and in other industrial processes. There have been discussions regarding extending that pipeline to other EAC countries but nothing

Table 3.1 Mine and mill LCC analysis example (see Appendix B)

INSTRUCTIONS	ONLY VARY GREEN CELLS with RED TEXT, ALL OTHER CELLS ARE SET CALCULATIONS STEPS								
Mining Considerations - Truck/Shovel Operations									
Production capacity multiplier(any Integer)	**1**	**Mine life (years x) multiplier: relative to base case of 25 years per "1"**					1		
Year	0	1	2	3	4	5	6	25	Total
If Excavator & Haulers are "Diesel engine" then "1" or if "Electric drive" then "2"	**1**								
US$2020 Fleet Cap Cost (incl. 1 dozer/excav)	$ 7,270,816								$ 14,950,868
Disposal(15% capital at year 10)								**–$1,152,008**	**–$2,242,630**
Inflation rate (%)	**2%**								
(1+1)^n		1.00	1.02	1.04	1.06	1.08	1.10	1.61	
Year 1 Fleet availability, A% (not in maintenance)	–0.5%/year	**85.00**	84.50	84.00	83.50	83.00	82.50	78.00	
Year 1 Fleet utilization, U % (operational hours % per shift)		**81.0**	81.0	81.0	81.0	81.0	81.0	81.0	
Operating hours / Year		6,031	5,996	5,960	5,925	5,889	5,854	5,535	145,460
Operating hours / day		16.5	16.4	16.3	16.2	16.1	16.0	15.2	
Excavator spot /load time hauler per hauler (s) AND hauler loads per day	270	220	219	218	216	215	214	202	
Hauler rated payload (short tons)	**45**								
Rock density (t/m³) AND Blasting/Loading swell factor, SF and loose density(t/lcm)	**3.00**	**1.30**	2.31						
4-pass loading Excavator roted size (lcm)	4.88	per $RR_{initial}$	per $RR_{improved}$						
Hauler tire size (m) & operational tire life(hrs) & RR adj impact	1.81	3,789	5,519						
Progressive accumulated tire hours at year end		6,031	8,238	6,619	8,755	7,066	9,130	9,045	
Tire hours carried forward to next year per $RR_{initial}$		2,242	659	2,830	1,176	3,276	1,552	1,467	
Tire set replacements per year per hauler	*6 tires per hauler*	1	2	1	2	1	2	2	
Hauler fleet Tire Initial sets and replacement costs $US	$ 171,804	$ 172,846	$ 347,696	$ 174,813	$ 351,486	$ 176,641	$ 355,020	$ 380,482	*$7,107,905*
Hauler cycle time, mins (single complete round trip to excavator) & # haulers	**30**	7	7	7	7	7	7	7	
Productivity (tph)		544	544	544	544	544	544	544	
Production (tpy)		**3,282,914**	**3,263,603**	**3,244,291**	**3,224,980**	**3,205,669**	**3,186,356**	**3,012,556**	**79,176,159**

Table 3.1 Mine and mill LCC analysis example (see Appendix B) (*Continued*)

Productivity, Q(m^3/hr)		236	236	236	236	236	236	236	
Specialist contractor' **drilling** *inclusive of prorated Capcost* + **Blasting Op. costs $/t &($)**	**1.38**	$ 4,586,904	$ 4,586,349	$ 4,584,505	$ 4,581,466	$ 4,577,310	$ 4,572,113	$ 4,632,750	$ 116,697,162
Dozer class size by blade width (ft) and number of dozer units	**7.20**	**1**							
Operating & Maintenance costs (excavator, haulers, dozer, grader)		$ 2,476,437	$ 2,487,819	$ 2,475,280	$ 2,485,448	$ 2,471,536	$ 2,480,659	$ 2,514,944	$ 63,173,565
Local Operator labour rate, (UGX/mo) & UGX/US$	**UGX 1,300,000**	**UGX 3,555**							
Local Operator labour rate (*excavator, haulers, dozer, grader*), (US$/hr)	$ 4.48	$ 327,710	$ 327,670	$ 327,538	$ 327,321	$ 327,024	$ 326,653	$ 330,985	$ 8,337,394
Diesel powered Surface Miner Co2 emissions (tpy)		1,303	1,296	1,288	1,280	1,273	1,265	1,196	31,436
$RR_{initial}$ % and Hauler fleet Litres fuel per year	**8.0**	1,598,300	1,588,898	1,579,497	1,570,095	1,560,693	1,551,291	1,466,676	38,547,241
CO2 emissions (tpy) per $RR_{initial}$ case		4,379	4,353	4,327	4,302	4,276	4,250	4,018	105,609
Hauler fuel cost ($/L) and $/yr	**$ 1.07**	$ 1,726,648	$ 1,726,439	$ 1,725,745	$ 1,724,601	$ 1,723,037	$ 1,721,080	$ 1,743,906	$ 43,928,311
Operating & Maintenance Expenses Total (*excluding drill &blast*)	$ 171,804	$ 4,703,641	$ 4,889,624	$ 4,703,376	$ 4,888,856	$ 4,698,238	$ 4,883,412	$ 4,970,317	$ 122,547,170
Overall Mining Operations' CapEx+OpEx	**$ 7,270,816**	**$ 8,806,464**	**$ 8,818,103**	**$ 8,804,054**	**$ 8,811,071**	**$ 8,792,480**	**$ 8,795,495**	**$ 7,771,899**	**$ 237,273,920**
Grader Impact considerations on diesel fuel, emissions and tire costs									
Year	0	1	2	3	4	5	6	25	Total
Grader class size per blade (moldboard) width (ft)	**14**								
Number of graders	1								
Targeted Improved rolling resistance($RR_{improved}$) & improved fuel usage (L/yr)	**5.0**	1,150,203	1,143,437	1,136,671	1,129,905	1,123,139	1,116,373	1,055,480	27,740,182
CO2 emissions (tpy) per $RR_{improved}$ case		3,151	3,133	3,144	3,096	3,077	3,059	2,892	76,000
Fuel cost savings due to decreasing hauler rolling resistance, RRimproved , $		−$ 484,081	−$ 484,022	−$ 483,828	−$ 483,507	−$ 483,069	−$ 482,520	−$ 488,919	−$ 12,315,689
Co2 reduction (tpy)		**−1,228**	**−1,220**	**−1,213**	**−1,206**	**−1,199**	**−1,192**	**−1,127**	**−29,608**
Next accumulated tire hours at year end		6,031	6,508	6,950	7,355	7,726	8,061	7,487	
Tire hours carried forward to next year		512	989	1,431	1,836	2,207	2,542	1,968	
Tire set replacements	6×hauler	1	1	1	1	1	1	1	
Hauler fleet Tire replacement costs $US	$ 171,804	$ 172,846	$ 173,848	$ 174,813	$ 175,743	$ 176,641	$ 177,510	$ 190,241	$ 4,916,748
Tire cost savings, Rrimproved, $		$ –	−$ 173,848	$ –	−$ 175,743	$ –	−$ 177,510	−$ 190,241	−$ 2,191,157
Overall Summary									

(*Continued*)

Table 3.1 Mine and mill LCC analysis example (see Appendix B) (*Continued*)

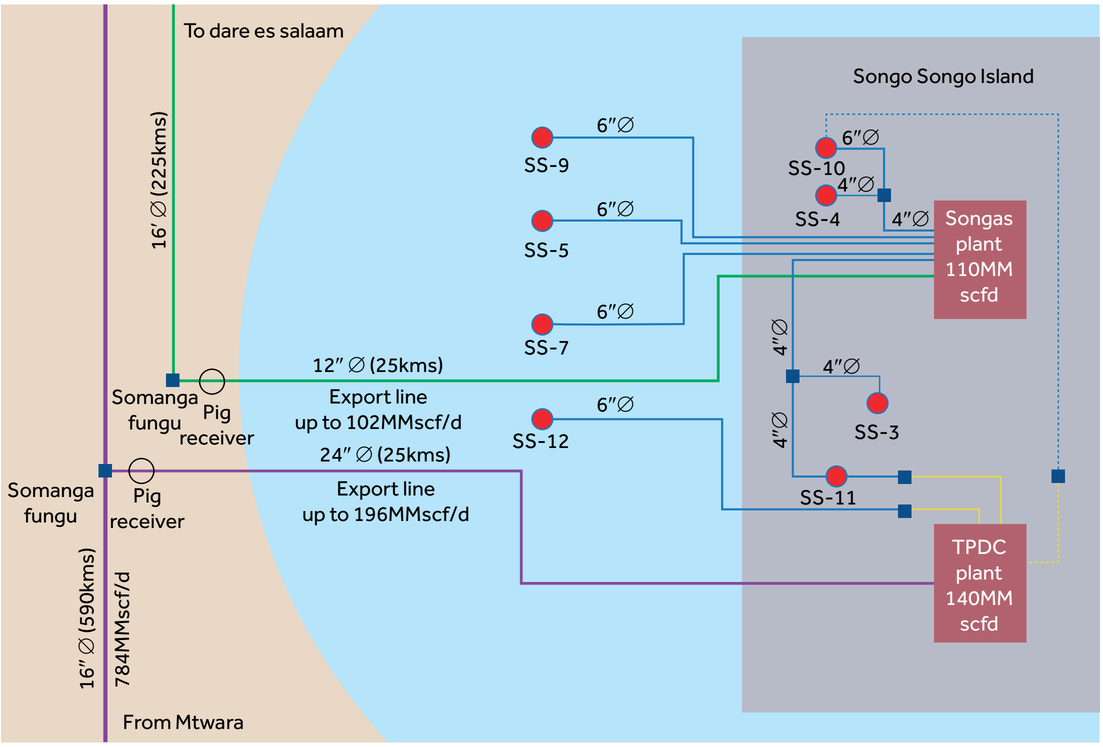
Additional grading effort HAULER FLEET TIRE+FUEL cost savings		–$ 484,081	–$ 657,870	–$ 483,828	–$ 659,250	–$ 483,069	–$ 660,030	–$ 679,160	–$ 14,506,846	
Mining only LCC/t	**$ 3.00**	$ /t								
Mineral Processing Considerations										
Iron Ore Product to Market (tpy)		**1,083,362**	**1,076,989**	**1,070,616**	**1,064,243**	**1,057,871**	**1,051,498**	**994,144**	**26,128,132**	
Concentrate average market bearing price(low margin base)	$ 105.00	$ /t	**Feed Grade**	**60**	%	**Recovery**	**55**	%		
Revenue ($)		**$ 113,752,967**	**$ 113,083,832**	**$ 112,414,697**	**$ 111,745,562**	**$ 111,076,426**	**$ 110,407,291**	**$ 104,385,075**	**$ 2,743,453,907**	
$^{6}/_{10}$ rule TOTAL Capital Cost for Mine + Mill	$ 452,159,900	*over all*								
Pre year 0, Infrastructure (power /roads/ Infrastructure) Capcosts	**$ 437,530,285**	*less mining and proces Pant equipment Capcosts*								
Process Plant Key Equipment Capcoast ($)	$ 7,358,799	*from Plant sheet*								
Processing Operating Cost, at $/hr ($/yr)	$ 2,045,.77	$ 12,338,560	$ 12,265,981	$ 12,193,401	$ 12,120,821	$ 12,048,241	$ 11,975,662	$ 11,322,444	$ 297,577,047	
Processing only LCC/t	**$ 3.85**								**$ 304,935,846**	
Overall Captial(B65) and Operating (C65-L65) Expenditures	$ 452,159,900	$ 21,145,024	$ 21,084,083	$ 20,997,455	$ 20,931,893	$ 20,840,721	$ 20,771,157	$ 19,094,343	**$ 979,740,051**	
Overall Mine + Mill $/t & Mine + Mill Operating Cash flow $/yr	**$ 6.85**	$ 92,607,942	$ 91,999,748	$ 91,417,242	$ 90,813,669	$ 90,235,705	$ 89,636,135	$ 85,290,733	**$ 1,763,713,856**	
NCF	–$ 452,159,900	$ 92,607,942	$ 91,999,748	$ 91,417,242	$ 90,813,669	$ 90,235,705	$ 89,636,135	$ 85,290,733	NPV10	$329,432,864
									IRR	19.8%

Table 3.2 Mining/milling equipment combinations for 25-year LCC model

Mine and mill analysis LCC analysis example: 45-ton haulers, 5 m^3 excavator operations at LCC = US$3.00/t mined + 3.85/t milled, generating internal rate of return (IRR) 19.8 per cent, net present value (NPV) $329 million.				
Parameter	Excavator/hauler mine operations		Surface miner/hauler mine operations	
	Diesel power	Electric power	Diesel power	Electric power
Mining LCC	$3.00/t	$2.51/t	$1.20/t	$0.64/t
Milling LCC	$3.85/t	$3.85/t	$3.64/t	$3.64/t
NPV10	$329 million	$342 million	$374 million	$389 million
IRR	19.8%	20.1%	21.1%	21.5%
Excavating CO_2	1,245 tpa	–	1,530 tpa	–
Hauling CO_2	3,640 tpa	–	3,000 tpa	–
Operations CO_2 reduction	−32.5%	–	−39.0%	

has materialised to date. We have made some preliminary high-level calculations of the potential cost of building a gas pipeline from Dar es Salaam to southern Uganda to provide natural gas for use in steel manufacturing facilities in that region. We do not have a precise estimate of the amount of gas potentially required for steel processing in that region, but we believe other potential gas consumers would take advantage of this pipeline to access natural gas, and we have based our cost estimate on a pipeline with the same diameter and capacity as the pipeline from the Tanzania Petroleum Development Corporation (TPDC) processing plant on Songo Songo Island to Somanga Fungu power plant on mainland Tanzania, shown in Figure 3.15.

Figure 3.15 Tanzania existing gas pipeline diameters and capacities



Source: https://orcaenergygroup.com/operations/tanzania/production-infrastructure/

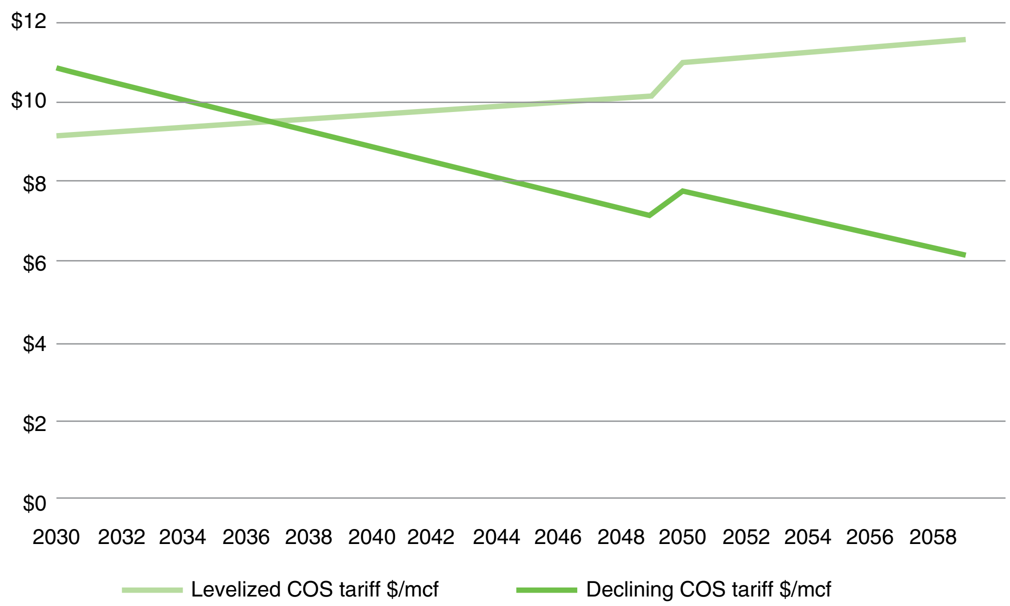
Our 'back of the envelope' analysis of the economics of a gas pipeline to the vicinity of the Uganda iron ore deposits is based on the following essential parameters:

- diameter: 24" – based on export line from TPDC plant on Songo Songo Island to Somanga Fungu;
- capacity: 196 million cubic feet per day – based on export line from TPDC plant on Songo Songo Island to Somanga Fungu;
- length: 1,100 miles (1,760 km) – based on following the Uganda-Tanzania oil pipeline right of way to Tanga, then to Dar es Salaam;
- capex: US$100,000 per diameter inch mile – based on pipeline cost rule of thumb, obtained from an engineer colleague who specialises in project cost estimation;
- opex: 5 per cent annually of total capital costs, higher than traditional rule of thumb to account for non-carbon fuels for compression;
- construction: five years, commencing in 2025;
- operations: 2029 start-up, with 30-year life;
- amortisation: 30 years – estimate;
- debt/equity: 70/30 – estimate;
- debt cost: 12 per cent – estimate;
- equity cost: 18 per cent – estimate;
- tax rate: 30 per cent – Tanzania Income Tax Act;
- tax write-off rate: 5 per cent straight line – Tanzania Class 6 rate.

Using a standard cost of service (COS) calculation model, we estimated a toll averaging US$8.39/mcf over the 30-year operational life of the pipeline. This was compared with a levelised COS calculation yielding an average toll of $10.23/mcf over the same period. These tolls over the 30-year life of the pipeline are shown in Figure 3.16. The toll declines under a standard COS calculation, as the constant rate of depreciation results in lower rate base and lower returns on rate base to owners and lenders. The levelised toll is flatter over its life, only rising because of inflation of operating costs. The average levelised toll is higher because it treats the capital portion of the COS, which is the majority of it, like a mortgage payment with flat annual costs, with a higher portion going to interest in the earlier years so the rate base remains higher for longer.

We note that both these estimated Tanzania–Uganda pipeline tolls are higher than the US$7.30/mcf estimated by the World Bank for a Dar es Salaam to Kigoma pipeline (Santley et al., 2014: Table 4.1, p.36), a slightly smaller and shorter pipeline, at 16" diameter and 1,200 km. Although the World Bank did not provide throughput estimates, it observed that the tariff was very high, and it would be more efficient to provide energy to these areas via power transmission lines. We

Figure 3.16 Estimated tolls for Tanzania-Uganda gas pipeline



suspect the toll on a Tanzania-Uganda gas pipeline would perhaps be prohibitively high and adding a 2020 natural gas price of $4.32/mcf (Orca Energy Group, 2020) would bring the delivered cost of gas to the region of Uganda's iron ore deposits to roughly $13–15/mcf.

There may be other potential consumers of natural gas in this region, in Uganda, Rwanda and Tanzania, which may lead to further economies of scale that can significantly leverage pipeline economics. While we have not done the analysis to identify a sequestration site for CCUS, we note that following the route of the Tanzania–Uganda oil pipeline further upstream may make it possible to use the captured CO_2 for enhanced oil recovery in those fields.

Normally, a portion of the gas transported on a gas pipeline is used as fuel for compression. To avoid additional emissions, our model does not include fuel usage, which is offset by higher operating costs to compensate for renewable fuels (these costs may actually be lower). We note that the Tanzania–Uganda oil pipeline is to be a heated pipeline, to avoid the build-up of wax in the pipeline from Uganda's paraffinic crude oil. There may be potential for economies between these adjacent pipelines' energy facilities for heating and pumping on the oil line and for compression on the gas line.

Using natural gas to develop the iron ore deposits in southern Tanzania would avoid much of these high pipeline tolls. It would entail a much shorter pipeline and would have a natural gas price at source about US$1/mcf lower than the Dar es Salaam price, as it would be priced near the upstream source of gas, another option to consider in a more comprehensive analysis.

Carbon capture, utilisation and storage

CCUS (or CUS) prevents CO_2 from being released into the atmosphere. It involves capturing CO_2 from large single point emitters (e.g., power plants and integrated steel facilities), compressing it for transportation by pipeline and then injecting it into an underground geological formation at a carefully selected site for permanent storage. CCUS can reduce CO_2 emissions from these plants by 80–90 per cent.

CCUS is not an energy technology; it is an energy transition technology and is green in the sense that it allows continued combustion of carbon fuels without adding to GHG accumulations in the atmosphere. The IEA includes CCUS as a necessary component of heavy industry strategy to reach the Paris Agreement goal (IEA, 2019; OECD, 2020b). Its development and growth are dependent on the presence of a commercial incentive to engage in CCUS. In the absence of a subsidy or a sufficiently high carbon price to make CCUS viable, a commercially viable market for CCUS cannot exist.

CCUS is potentially valuable in places without good renewable energy alternatives or where it would be too costly to retire and replace existing plants combusting carbon fuels. CCUS could include turning CO_2 into a product to enhance, for instance, oil production from Ugandan oil fields once well pressures begin to decline.[48] The IEA believes CCUS must play an important role in achieving net-zero emissions. Wood Mackenzie, a leader in energy policy and energy technology analyses, points out that current installed CCUS capacity is capable of capturing just 1 per cent of annual global emissions, and current policy frameworks and technologies are not adequate to allow CCUS to contribute significantly to meeting the targets of SDG 7 and the Paris Agreement (Wood Mackenzie, 2020).

We have considered the potential for a gas pipeline from Tanzania to Uganda to serve the iron ore mining, DRI and steelmaking sectors. Both mining and processing are energy-intensive, and we have looked at ways in which they can be greener and that would require even more electricity. For the overall complex to be greener, the use of gas to generate electricity and potentially to produce hydrogen would need to be complemented with CCUS. Ultimately, green hydrogen produced via renewable electricity and abundant water sources in parts of the EAC would be the long-term goal, utilising existing natural gas transportation networks (if necessary) while eliminating the need for CCUS.

48 https://www.energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery

4. Conclusions

4.1 Requirements for an emergent green regional steel industry

There are some important realities facing EAC countries in their aspiration to see an EAC steel industry develop. The iron ore reserves in the EAC, to the extent they have been explored and are known, appear to be small to moderate by global standards, in both magnitude and quality. Whatever their status, more definitive exploration is required to determine if they can support commercial development. More investor-friendly policies will be required to support this exploration, including policies that allow export of iron ore if it cannot be beneficiated domestically (particularly within the EAC).

Traditionally, a steel industry has required coking coal as a source of carbon for making carbon steel and as a fuel for a very high temperature and energy-intensive process. There is no coking coal in the EAC, so it would have to be imported. As discussed, green steel would not use coking coal or coal, and would rely on natural gas, or hydrogen, which can be produced from natural gas (blue hydrogen with CCUS) or by water electrolysis (green hydrogen if powered by renewable energy). Tanzania has natural gas and would welcome the opportunity to provide gas to iron and steel projects. Our high-level estimate of transporting the gas by pipeline from Dar es Salaam to the southern Uganda region of the iron ore suggests this may not be economically viable. The viability of the pipeline would likely depend on other users of natural gas in that region of the EAC. The availability of natural gas in that region could be especially attractive to Rwanda, which does not have Uganda's options for clean energy from hydro or Kenya's from geothermal, for example.

Green steel using conventional or coal/gas processes would require the capturing and sequestering of CO_2 emissions, using CCUS, with geologically appropriate sites required for sequestration. The coal resources in Uganda could provide a good site for CCUS, and the Ugandan oil fields may also present the opportunity for CCUS, with the CO_2 being used for enhanced oil recovery. Both these possibilities would require a CO_2 pipeline from the steel plant and/or hydrogen plant, which would entail additional cost for an already expensive energy source.

The steel market in the EAC is growing rapidly and should attract more investment, though currently many steel firms in the region do not operate at full capacity for a number of reasons: unreliable or high costs of energy, high prices for imported steel coil or billets, lack of scrap for EAF, etc. EAC countries are significant importers of raw and processed steel. The potential for economic growth in the EAC is high, and its population is also growing quickly, so the local market can be expected to increasingly grow and expand even beyond the 11 per cent annual average growth in the 2010–2019 period. The Ugandan iron ore reserves are well located in terms of providing apparently high-quality ore to steelmakers, more of whom could introduce DRI processes to then feed into existing (and expanded) EAF facilities.

4.2 Framework for a phased approach across value chain

In a world that must rapidly decarbonise its industries and economies to meet the Paris Agreement target of net-zero carbon emissions by 2050, the energy and economic transitions necessitated by developing a green steel industry could provide an opportune economic and environmental catalyst for the EAC. This would stimulate urgently needed economic growth in an industry that produces a product that is itself a necessity for further and continued economic growth but that also fits circular economy considerations. While the energy systems of some EAC countries are already largely green, it would stimulate further greening of the energy systems of other EAC countries. Producing green energy and green steel is likely the only way to finance investment of this nature. Not only may green MVA projects be the only projects that can obtain financing from international sources, whether public or private sector investors and lenders, but also the potential for using green bonds or other creative mechanisms may provide lower-cost access to capital sources that are actively seeking projects of this nature to invest in.

Box 4.1 Sequential steps towards an EAC green mining ecosystem (especially green steel)

Establishing clearer iron ore resource estimates

- Better resource size and ore quality estimates are necessary to attract high-quality, green-oriented mining and MVA investment.
- Additional exploration and analysis is required to confirm indications of high-quality deposits conducive to DRI/HBI and green steel.
- Policy changes to encourage investment by regional and international mining and/or steel companies will likely be required.

Green mining and milling of iron ore

- It will be necessary to identify best practices, processes and energy source options and integrate those into regulatory requirements, taxation incentives and trade promotion efforts across the EAC (including human resource development).
- There is potential for electric trucks, haulage road design and maintenance to reduce Scope 1 emissions (more details in Chapter 3, Section 3.4 above).
- Renewable energy sources in the EAC (to reduce Scope 2 emissions) need to be promoted and developed.

Green steelmaking processes

- Focus on DRI and EAF processes (scrap plus sponge iron) and adopt new technology and processes incrementally that reduce GHGs.
- Investigate the most efficient ways to get natural gas and/or hydrogen to plant sites as coal replacement.
- ***Alternative: one centralised HBI plant that would distribute to regional EAF operators.*** This would require an additional feasibility study to establish economically viable size and to illustrate all the regional benefits both upstream and downstream.
- Find ways to sequester CO_2 to make natural gas use and hydrogen production greener prior to full (decarbonised) green hydrogen production.

Transporting steel to market

- Focus initially on construction and infrastructure market demand growth in EAC and other African countries (with regional and continental common market advantages), but with an eye to selective, premium green steel markets overseas, including automotive markets.
- SGR will improve competitiveness and emissions of transporting steel products to most markets (Scope 3 emissions).

Financing a green steel industry

- Financing investments in traditional steel may no longer be possible.
- New green funding sources are increasingly available, but financing green steel in EAC may still be challenging without strong leadership from government and the private sector, integrating transparently with NDCs.

Further exploration and development work is necessary before it will be realistically possible to contemplate more DRI or HBI projects. This may allow time for some of the green steel technologies currently in their pilot phase to approach commerciality. It would also allow planning regarding expanding energy sources and iron-reductant options, which we expect might be natural gas but, sooner than later, green hydrogen.

EAC green steel ecosystem: comparative advantages & incremental adjustments to magnetize regional investment

Energy policy priorities: Keep expanding reliable, cost-competitive, non-fossil fuel electricity generation & access (with natural gas as transitional fuel to replace coal/diesel)

Cleaner sources of base energy (Scope 2): **Hydro, Geothermal** in place & expanding; **Solar/Wind/Ocean** options Increasing; **natural gas** as transitional fuel to replace biomass and diesel; short-term potential for **blue** (derived from methane in natural gas alongside CCUS) and ultimately **green** (derived from clean power electrolysis of water) **hydrogen** (at least for Industrial uses Incl. steelmaking).

Upstream mining: Highlight exploration and development potential of highest quality Iron ore (and nickel-dominant) deposits; highlight regional limestone and graphite resources; leverage most efficient transportation options (rail, road, water) as available; focus on mine and process design to reduce emissions.

Upstream mining policy priorities: establish highest quality iron ore resources and allow regional exports; coordinate EAC "greener mining" guidelines, training, certification, and tax incentives to promote scope 1 & 3 emission reductions on an ongoing basis (R&D, technology upgrades, process or energy changes, road maintenance, etc.).

Downstream steelmaking: Existing steel Industrial base can be expanded in terms of increasing DRI (perhaps HBI) and EAF Incrementally (no massive projects or Investments required); distributed steelmaking across region, reducing Scope 3 emissions from Imported crude steel including seaborne transportation. Incremental shift from coal In current DRI facility to natural gas and hydrogen, while other iron reduction and steel making processes become financially viable.

Downstream steelmaking policy priorities: promote DRI/HBI & EAF over BF/BOF; move from coal-based DRI to natgas/syngas/hydrogen as feasible; promote R&D partnerships to investigate newest processes in greening steel.

Scope 1 Emission: Direct carbon emission from owned or controlled sources.
Scope 2 Emission: Indirect carbon emission from generation of purchased energy.
Scope 3 Emission: Indirect emission (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions

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Appendix A: Details of iron and steel trade by EAC country (Section 1.4)

Tables A1–A6 show exports and imports of 'Iron and steel' for each EAC country. Tables A7–A12 show exports and imports of 'Articles of iron or steel.' These tables also show the portion of exports and imports with other African countries and with EAC countries, respectively.

Table A1 Burundi trade – Iron and steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$9,539	$1,663	$1,093	$886	$3,455	$1,838
EAC	$ –	$846	$174	$561	$162	$349
Total	$12,308	$1,664	$1,093	$886	$3,455	$3,881
% with Africa	78%	100%	100%	100%	100%	74.2%
% with EAC	0%	51%	16%	63%	5%	14.1%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$6,024	$20,024	$21,080	$24,738	$29,472	$20,268
EAC	$ –	$19,394	$20,590	$19,209	$16,165	$15,072
Total	$26,236	$26,153	$37,194	$53,457	$55,646	$39,737
% with Africa	23.0%	76.6%	56.7%	46.3%	53.0%	51.0%
% with EAC	0.0%	74.2%	55.4%	35.9%	29.0%	37.9%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A2 Kenya trade – Iron and steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$110,759	$116,186	$107,108	$112,653	$133,395	$116,020
EAC	$78,978	$74,084	$67,750	$85,860	$114,503	$84,235
Total	$111,164	$116,188	$107,114	$112,736	$134,919	$116,424
% with Africa	99.6%	100.0%	100.0%	99.9%	98.9%	99.7%
% with EAC	71.0%	63.8%	63.3%	76.2%	84.9%	72.4%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$180,589	$128,603	$181,989	$275,261	$378,917	$229,072
EAC	$1,963	$3,158	$7,285	$11,728	$28,628	$10,552
Total	$710,877	$604,418	$734,482	$860,321	$916,691	$765,358
% with Africa	25.4%	21.3%	24.8%	32.0%	41.3%	29.9%
% with EAC	0.3%	0.5%	1.0%	1.4%	3.1%	1.4%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A3 Rwanda trade – Iron and steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$1,304	$2,183	$6,673	$9,143	$9,011	$5,663
EAC	$587	$620	$2,122	$1,289	$791	$1,082
Total	$1,913	$2,613	$6,970	$9,570	$9,121	$6,037
% with Africa	68.2%	83.5%	95.7%	95.5%	98.8%	93.8%
% with EAC	30.7%	23.7%	30.4%	13.5%	8.7%	17.9%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$44,187	$42,646	$46,506	$59,581	$50,864	$48,757
EAC	$34,298	$29,887	$30,461	$38,116	$31,612	$32,875
Total	$99,764	$76,738	$80,711	$105,832	$105,834	$93,776
% with Africa	44.3%	55.6%	57.6%	56.3%	48.1%	52.0%
% with EAC	34.4%	38.9%	37.7%	36.0%	29.9%	35.1%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A4 South Sudan trade – Iron and steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$ –	$1,873	$ –	$27	$ –	$380
EAC	$ –	$1,873	$ –	$ –	$ –	$375
Total	$ –	$1,873	$46	$27	$3	$390
% with Africa		100.0%		100.0%		97.5%
% with EAC		100.0%		0.0%		96.1%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$4,047	$10,444	$932	$6,663	$10,446	$6,506
EAC	$3,836	$10,443	$932	$6,663	$10,446	$6,464
Total	$5,169	$11,106	$2,840	$8,526	$11,732	$7,875
% with Africa	78.3%	94.0%	32.8%	78.1%	89.0%	82.6%
% with EAC	74.2%	94.0%	32.8%	78.1%	89.0%	81.1%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A5 Tanzania trade – Iron and steel (US$ thousands)

Exports	2014	2015	2016	2017	2018	Avg.
Africa	$22,983	$13,141	$6,551	$21,134	$35,409	$9,844
EAC	$6,784	$5,956	$1,761	$9,625	$25,091	$9,843
Total	$24,991	$76,069	$9,864	$24,463	$40,576	$35,193
% with Africa	92.0%	17.3%	66.4%	86.4%	87.3%	69.9%
% with EAC	27.1%	7.8%	17.9%	39.3%	61.8%	30.8%
Imports	**2014**	**2015**	**2016**	**2017**	**2018**	**Avg.**
Africa	$97,721	$86,823	$84,167	$81,513	$168,122	$103,669
EAC	$10,193	$4,310	$9,234	$9,254	$44,702	$15,539
Total	$384,470	$297,918	$278,706	$269,436	$425,900	$331,286
% with Africa	25.4%	29.1%	30.2%	30.3%	39.5%	30.9%
% with EAC	2.7%	1.4%	3.3%	3.4%	10.5%	4.3%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A6 Uganda trade – Iron and steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$84,251	$70,822	$65,943	$85,295	$65,582	$68,443
EAC	$47,602	$57,537	$41,438	$60,427	$33,737	$53,718
Total	$85,597	$70,840	$65,954	$85,331	$65,819	$74,908
% with Africa	97.3%	100.0%	100.0%	100.0%	99.6%	99.3%
% with EAC	55.0%	81.2%	62.8%	70.8%	51.3%	64.3%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$135,403	$115,807	$160,544	$202,796	$206,799	$164,270
EAC	$61,784	$55,300	$60,845	$59,647	$66,511	$60,817
Total	$279,556	$209,653	$283,565	$369,384	$362,642	$300,960
% with Africa	48.4%	55.2%	56.6%	54.9%	57.0%	54.6%
% with EAC	22.1%	26.4%	21.5%	16.1%	18.3%	20.2%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A7 Burundi trade: Articles of iron or steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$1,131	$289	$251	$197	$174	$408
EAC	$ –	$180	$234	$176	$155	$149
Total	$1,902	$290	$266	$197	$175	$566
% with Africa	59.5%	99.7%	94.4%	100.0%	99.4%	72.2%
% with EAC	0.0%	62.1%	88.0%	89.3%	88.6%	26.3%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$851	$6,443	$6,009	$6,352	$6,059	$5,143
EAC	$1	$6,322	$5,854	$6,130	$5,437	$4,749
Total	$10,803	$12,602	$10,085	$10,102	$16,035	$11,925
% with Africa	7.9%	51.1%	59.6%	62.9%	37.8%	43.1%
% with EAC	0.0%	50.2%	58.0%	60.7%	33.9%	39.8%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A8 Kenya trade – Articles of iron or steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$57,503	$49,540	$43,942	$39,370	$43,750	$46,821
EAC	$36,690	$31,278	$24,760	$26,731	$33,195	$30,531
Total	$58,290	$55,452	$44,524	$45,446	$46,427	$50,028
% with Africa	98.6%	89.3%	98.7%	86.6%	94.2%	93.6 %
% with EAC	62.9%	56.4%	55.6%	58.8%	71.5%	61.0%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$18,819	$9,973	$14,374	$18,754	$17,745	$15,933
EAC	$3,826	$2,889	$2,802	$3,278	$3,136	$3,186
Total	$381,592	$508,344	$465,090	$317,954	$398,667	$399,751
% with Africa	3.7%	2.1%	4.5%	4.7%	5.7%	4.0%
% with EAC	0.8%	0.6%	0.9%	0.8%	1.0%	0.8%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A9 Rwanda trade – Articles of iron or steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$494	$929	$566	$2,192	$3,236	$1,483
EAC	$275	$203	$70	$192	$488	$246
Total	$517	$1,007	$632	$2,267	$3,278	$1,540
% with Africa	95.6%	92.3%	89.6%	96.7%	98.7%	96.3%
% with EAC	53.2%	20.2%	11.1%	8.5%	14.9%	15.9%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$20,765	$15,700	$19,915	$19,267	$27,077	$20,545
EAC	$12,587	$12,656	$15,967	$16,001	$18,987	$15,240
Total	$93,482	$59,755	$75,800	$73,787	$113,329	$83,231
% with Africa	22.2%	26.3%	26.3%	26.1%	23.9%	24.7%
% with EAC	13.5%	21.2%	21.1%	21.7%	16.8%	18.3%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A10 South Sudan trade – Articles of iron or steel (US$ thousands)

Exports	2016	2017	2018	2019	2020	Avg.
Africa	$46	$144	$1	$ –	$18	$42
EAC	$ –	$23	$ –	$ –	$ –	$5
Total	$50	$145	$8	$11	$20	$47
% with Africa	92.0%	99.3%	12.5%	0.0%	90.0%	89.3%
% with EAC	0.0%	15.9%	0.0%	0.0%	0.0%	9.8%
Imports	**2016**	**2017**	**2018**	**2019**	**2020**	**Avg.**
Africa	$9,793	$9,793	$1,859	$1,136	$1,696	$5,137
EAC	$9,772	$9,772	$1,839	$1,136	$1,696	$5,128
Total	$21,345	$21,345	$6,327	$17,833	$19,484	$17,249
% with Africa	45.9%	45.9%	29.4%	6.4%	8.7%	82.6%
% with EAC	45.8%	45.8%	29.1%	6.4%	8.7%	82.1%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A11 Tanzania trade – Articles of iron or steel (US$ thousands)

Exports	2014	2015	2016	2017	2018	Avg.
Africa	$7,425	$21,004	$33,341	$7,795	$22,361	$18,385
EAC	$3,073	$2,711	$3,314	$4,767	$7,983	$4,370
Total	$10,743	$21,877	$33,546	$13,446	$26,462	$21,215
% with Africa	69.1%	96.0%	99.4%	58.0%	84.5%	86.7%
% with EAC	28.6%	12.4%	9.9%	35.5%	30.2%	20.6%
Imports	**2014**	**2015**	**2016**	**2017**	**2018**	**Avg.**
Africa	$51,255	$38,973	$39,215	$27,603	$22,803	$35,970
EAC	$14,899	$5,230	$4,863	$3,391	$3,794	$6,435
Total	$439,081	$282,537	$211,738	$183,895	$303,427	$284,136
% with Africa	11.7%	13.8%	18.5%	15.0%	7.5%	12.7%
% with EAC	3.4%	1.9%	2.3%	1.8%	1.3%	2.3%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

Table A12 Uganda trade – Articles of iron or steel (US$ thousands)

Exports	2015	2016	2017	2018	2019	Avg.
Africa	$27,707	$24,078	$27,437	$32,830	$29,642	$28,830
EAC	$17,972	$17,972	$12,980	$12,185	$6,306	$13,136
Total`	$24,936	$24,936	$27,640	$36,209	$32,093	$30,390
% with Africa	96.6%	96.6%	99.3%	90.7%	92.4%	95.2%
% with EAC	72.1%	72.1%	47.0%	33.7%	19.6%	44.9%
Imports	**2015**	**2016**	**2017**	**2018**	**2019**	**Avg.**
Africa	$10,663	$10,663	$10,721	$10,184	$11,940	$11,085
EAC	$8,392	$8,392	$8,910	$8,247	$10,098	$9,089
Total	$71,437	$71,437	$52,176	$75,235	$74,299	$70,487
% with Africa	14.9%	14.9%	20.5%	13.5%	16.1%	16.0%
% with EAC	11.7%	11.7%	17.1%	11.0%	13.6%	13.1%

Source: International Trade Centre, Trade Map. https://www.trademap.org/Country_SelProduct_TS.aspx

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