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Climate Action Platform Africa

Towards sustainable global prosperity – Climate Positive Growth

Climate change fundamentally threatens the future of humanity. Africa suffers greatly from it – yet it can also be a big part of the solution. Africa has all the fundamental to be a cost-competitive green industrial hub for the world, greening what we all consume, and removing carbon at scale.

And whilst African production can help shift global consumption patterns to a sustainable future, climate action can lift Africa to middle income status and beyond. With economic growth driven by climate action, African countries will be able to address energy poverty, strengthen stability, reduce conflict and migration, and secure dignified livelihoods and a viable future for all Africans.

Climate Positive green Growth represents a true global win-win. And it is not rocket science to get it right if the world creates fair and equitable mechanisms to focus our resources where they will yield the highest return. In this, key priorities need to be (1) proper pricing for (climate) externalities, (2) equitable market access to deliver low-embedded emission products and services, (3) industrial policy geared towards maximising climate benefits, (4) high-integrity carbon markets with equal access terms, and (5) measures to increase and optimise global capital allocation to the most viable economic and climate returns.

Development and climate change – a Catch 22?

To date, global emphasis in dealing with climate change has been on decarbonising high-income, high-emission countries and on middle-income countries with rapidly growing emissions that need support to transition into a more sustainable, greener growth path, for which the JET-P has been developed (Just Energy Transition Partnership). Lower-income countries with low current emissions (typically linked to low levels of industrialisation) are generally seen and approached as climate victims: they did little to cause climate change, are often bearing the brunt of the burden, and have limited buffers to deal with that burden, leading to individual and collective economic disruption. For these countries, the global focus so far has been on both adaptation and discussions on loss-and-damage.

Painfully, economic growth, so badly needed for these countries to achieve stable and dignified livelihoods for all, is often seen as being at odds with living within planetary boundaries. Historically, economic growth has always been achieved by growing emissions and only very few countries have been able to curb their per capita emissions downwards as they increase wealth further (part of which is not a real curbing of emissions but rather a function of offshoring manufacturing and its associated emissions). Such a growth path is not available to these lower-income, low-emission countries – or at least not within global planetary boundaries: the global carbon budget simply does not allow for it. If Africa were to grow to upper-middle-income status with the same carbon intensity as current countries in that income bracket, it would add 12 GT[1] of CO2e emissions annually by 2050, putting global net zero by that time well outside of reach.

[1] *Estimates of additional emissions when growing to upper middle income status* are based on current per capita CO_2 emissions, consumption-based, from CAIT (2019) for both Africa and upper-middle income countries, using the World Bank classification for country income status. 2050 baseline is current per capita emission and population growing to projected 2.5 bln. Additional emissions from income growth estimated as per capita difference between current African emissions and current upper middle income countries emissions, multiplied by 2.5 bln population (i.e., sheer impact of population growth to 2.5 bln is excluded in the calculation – 12 GT are the additional emissions if the future population of 2.5 bln goes from current emission level to UMIC emission level). Note that this is a proxy – it excludes other GHGs (which could make the differential greater) yet also uses 2019 emissions as the starting point and thus leaves out innovation that reduces per capita emissions for a given consumption pattern. Lastly, we opted to use CO_2 data as total GHG emissions data is not available for Africa in a consistent way.

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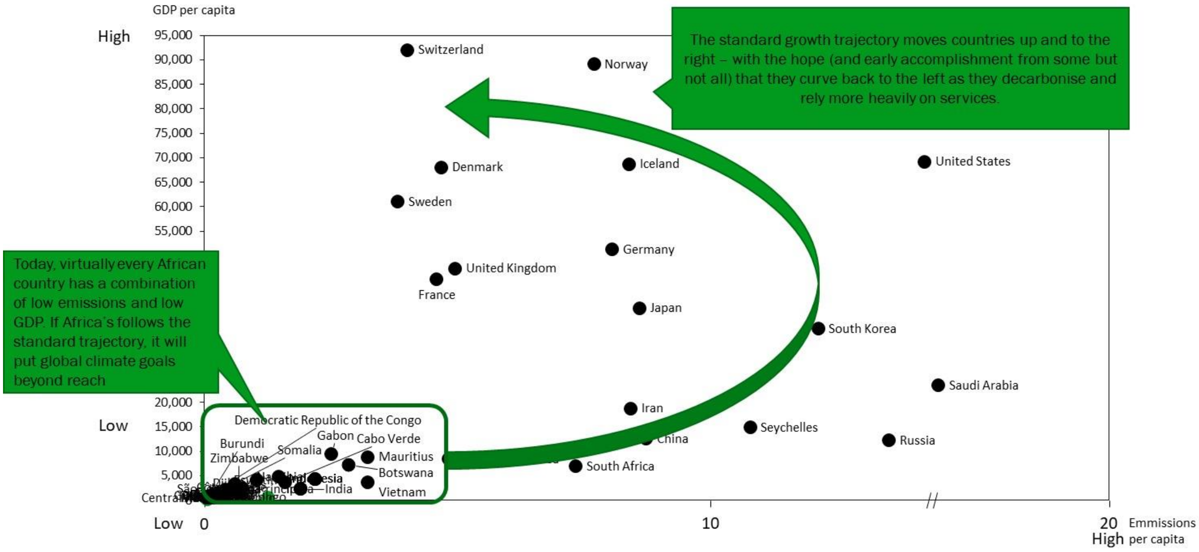
Figure 1: Selection of countries plotted by Emissions[2] per capita (tonnes CO_2/ year per capita) and GDP per capita (USD per year per capita)



Many global actors skirt around this difficult reality. Implicitly, they tell these lower-income, low-emissions countries that the best thing they can do, is to stay poor. If there is time, money, and attention left once the 'polluters' have dealt with climate change, they may help these countries survive – yet there is no answer in the cards for how they can thrive.

Entirely predictably, this framing is problematic. Not only is it morally reprehensible, but it is simply practically not tenable: nobody can stop countries from pursuing their growth – and if the world cannot provide a credible alternative for these countries, they may not only present a threat to achieving global climate goals, but also a source of instability, conflict, and unwanted migration; a humanitarian disaster and a geopolitical powder keg in the making.

Climate Positive Growth – the mutually beneficial answer

Thankfully, stagnating human and economic development, entrenched inequality, a global climate catastrophe, or all of the above combined, is not the only potential outlook. In fact, lower-income, low-emission countries can be a massive and crucial part of the global action that helps avoid a climate catastrophe – and this very role can be the path for them to middle-income status and beyond.

These countries are well-positioned to green global manufacturing and supply chains, and to remove carbon at scale – the very things the world needs to limit global warming to sustainable levels, and to, over time, begin to undo the damage done.

[2] Emissions data sourced from the Global Carbon Project, population and GDP data from the World Bank

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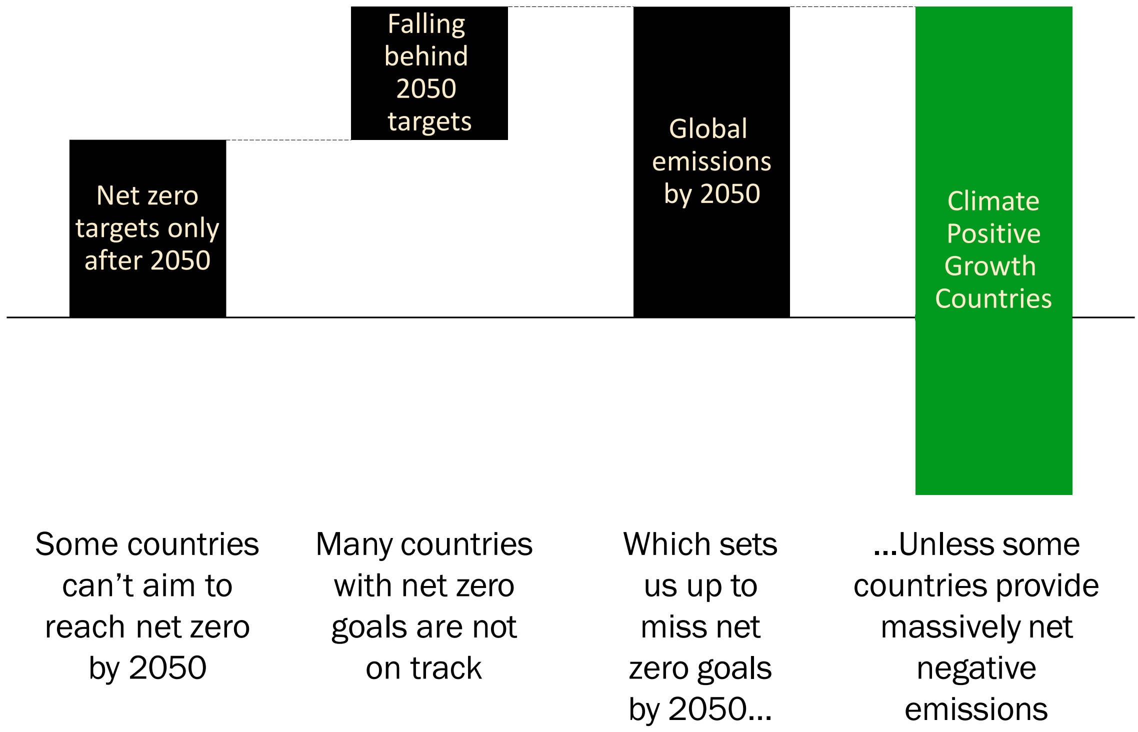
Figure 2: Global greenhouse gas emission levels by 2050, conceptually represented



The math is simple: to reach net zero globally by 2050, broadly accepted to be a necessary requirement to preserving human civilisation as we know it, a number of countries need to contribute massively negative emissions.

And this is even assuming that ambitious plans to green global manufacturing and supply chains and the global food system, succeed in a sufficiently financially viable way.

Countries with low existing emissions are well-positioned to deliver massively net negative emissions. The factors driving the technical feasibility and economic viability of climate-smart solutions to green manufacturing and carbon removal, tend to be low-cost availability of (1) renewable energy, (2) labour force, and (3) relevant natural assets and resources. Crucially, the renewable energy needs to have limited competing use to be directly deployable to providing a part of the solution. In countries with high emission levels, often linked to their electricity production, new renewable generation capacity is needed to achieve the crucial retirement of high-emitting infrastructure. In many developed countries, the construction of a new massive datacentre on the back of a new renewable energy development, is protested against as a climate travesty. For many lower-income, low-emissions countries, such a concurrent development of renewable energy supply and industrial scale anchor demand for its deployment, is exactly the bankable investment needed to tap untapped renewable energy resources.

These assets – untapped renewable energy, labour force, and relevant natural assets and resources – are abundantly available, at low cost, in much of sub-Sahara Africa.[3]

[3] Many sub-Saharan African countries are exactly the lower-income, low-emission countries with abundance of affordable relevant assets that we describe in this paper – and SSA is probably the global region with the greatest proportion of these countries, and is likely to contribute the largest number of these countries in the global 'opportunity pool'. That said, various Latin American and South-east Asian countries also fit this profile and have similar economic opportunities.

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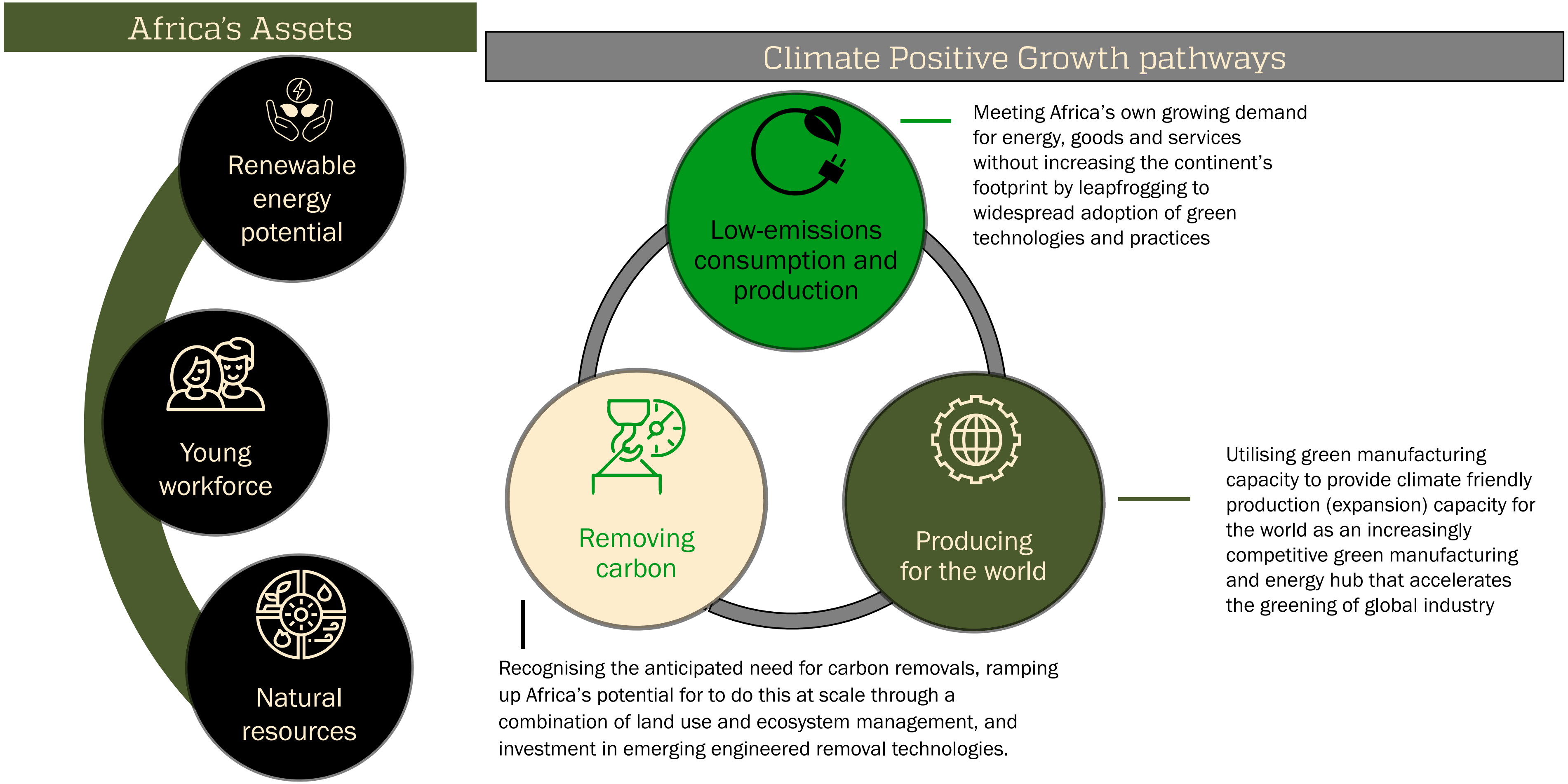
Figure 3: Overview of Africa's assets and Climate Positive Growth economic pathways



We propose the term **Climate Positive Growth** for this economic growth path: inclusive economic growth and job creation, achieved through the climate action that results in net negative emissions at globally relevant scale. The three Climate Positive Growth pathways drive that outcome.

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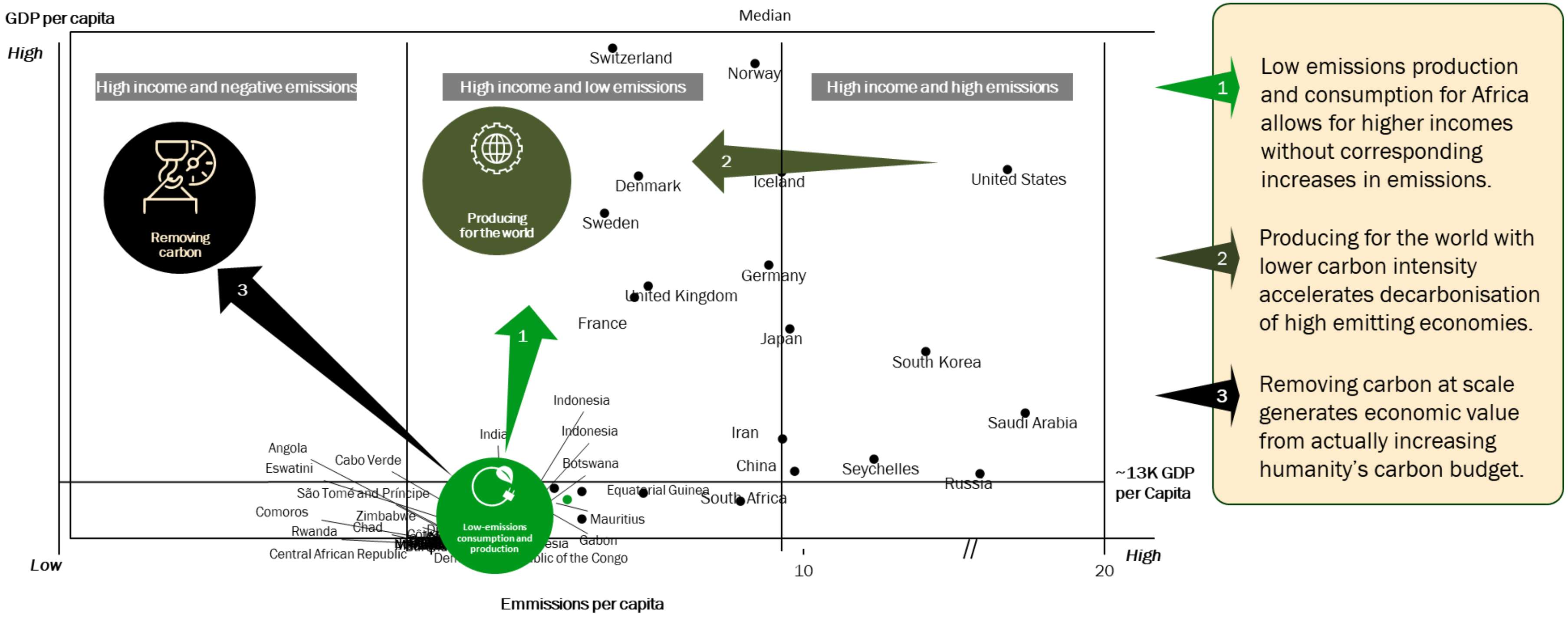
Figure 4: Countries plotted by emissions per capita and GDP per capita, conceptually showing potential growth path for low-emission, low-income countries



The next section covers a specific example in CPG – processing Africa-mined iron ore and bauxite with renewable energy in Africa, and exporting a higher-value add product rather than just ores. This is just one of many examples. Fully deploying Climate Positive Growth will enable meaningful global climate impacts and set in motion a growth trajectory to achieve stable middle income status *(please contact CAP-A for detailed sources and assumptions):*

a. **Africa growing to Upper Middle Income Country status, with GDP growth** (in current $) of **$ 24 trillion – or a 10-fold growth**
b. **Avoidance of additional emissions of over 15% of current global emissions:** Africa can grow to upper middle income status for all its 2.5 bln people by 2050, without the additional **9.4 Gigatonnes of CO_2e per year** that would be associated with this growth in prosperity without focus on green solutions
c. **Emission reduction of over 20% of global emissions (11.2 GT CO_2e)**
    i. Africa's role as a green manufacturing hub allows the continent to reduce global emissions associated with current global consumption by **9.8 Gigatonnes of CO_2e per year**
    ii. Improvement of agricultural and livestock rearing practices reduce diet related current African emissions by **1.4 Gigatonnes of CO_2e per year**
d. **Carbon removal, expanding the residual global carbon budget by 40%,** with Africa driving 50% of all removals activity necessary between now and 2050

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In practice and in numbers – what does Climate Positive Growth in manufacturing look like?

In discussions on climate change, industry tends to be seen as something guilty, dirty – and most of all to be avoided by countries with lower development levels. Yet we need manufacturing – as we need to consume. In fact, global consumption is set to *increase*, not *decrease*, both because the global population has not yet reached its peak and because hundreds of millions of people living in (extreme) poverty aspire to a more secure financial future – and to the elevated consumption that enables. And we should all aspire to that, for all of mankind.

That does not need to spell disaster for climate. In fact, for the first time in history, the technical innovations exist to structurally decarbonise industrial production at massive scale – and equally for the first time in history, building and operating climate-smart industrial capacity is close to, or already at a price level where it is the economically competitive choice.

We need to embrace that innovation, and scale it as rapidly as possible. And when doing so, we need to think about production locations relative to (1) necessary productive resources (notably untapped renewable energy potential and to a lesser degree land and labour), (2) supply of raw materials, and (3) the market for consumption. A future-proof global industrial landscape does not double down on current locations: future markets are not the same as those of the past, and the productive resources needed for climate-smart production are different from those that drove the technical viability and cost prices for and thus decisions about current production locations.

The potential for Africa is huge. **The first step would be primary processing of raw materials mined in Africa. Let's take 2 tangible examples: making steel out of iron ore, and aluminium out of bauxite.** Almost 40% of new city dwellers between now and 2050 will be living in African cities[4], which will drive a huge demand for urban construction, yet Africa produces less than 1% of the global steel production[5] – and not for lack of iron ore. African countries export over 77 million tonnes of iron ore[6] every year (majority to Asia ~54mln and to Europe ~16 mln) – and import nearly 6 million tonnes of steel from these regions. If the first processing step is done in Africa, near the mine, 2/3 of all transport-related emissions (of ore and steel combined) can be avoided, avoiding the emission of over 5 million tonnes[6] of CO_2e per year. **And new green steel factories in Africa, using abundant renewable energy to produce green hydrogen as feedstock and fuel, can cut the total emissions of processing this ore by an astounding 95%. The combined impact of transport and local processing can reduce emissions by over 110 million tonnes of CO_2e per year. This can generate $ 20 bln of additional revenue and drive ~ 24,000 new direct jobs, and ~215,000 jobs (direct + indirect combined).**[6] The **44 GW** of additional renewable electrical capacity this requires, is suitable anchor demand for investment in renewable energy. In addition, this will reduce African trade deficits, strengthen fiscal stability, and reduce strain on African currencies, whilst offering opportunities for global supply chain diversification for European countries. And yes, this does require the deployment of new industrial technology – but it is not a pie in the sky. The first fully green steel has been produced industrially in Sweden – and demand-building initiatives such as SteelZero and individual commitments from steel-heavy industries such as car manufacturers to net zero steel transition, signal the rapidly growing demand for green steel.

And whereas green steel has innovation challenges and the entire potential can only be reached by applying the latest industrial innovations, aluminium is an even more clear-cut case. Its production process runs entirely on electricity – and is a massive consumer thereof. **Processing the 83 million tonnes of bauxite exported annually from Africa to aluminium near the mine using renewable energy, can reduce emissions by 335 million tonnes of CO_2e every year - or close to 1% of all global greenhouse gas emissions. This can generate $ 37 bln of additional revenue, will drive over 60,000 direct jobs and over 280,000 total new jobs (direct and indirect combined), and provide an anchor energy demand of 20 GW.**[6]

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[4] UN Department of Economic and Social Affairs, World Urbanization Prospects, 2018 revision estimates 941 mln growth in urban population in Africa between 2018 and 2050, out of a 2.46 bln global urban population growth in that same period – i.e., 38%. Report accessed on https://population.un.org/wup/publications/Files/WUP2018-Report.pdf

[5] Most recent steel production data sourced from sector association information World Steel Association, as published on www.wordsteel.org - which puts global crude steel production for Q1 2023 at 623 Mt, and Africa's crude steel production in that same period at 5 Mt

[6] Detailed sources and assumptions are available for all trade data and analyses of savings potential; based upon globally recognised data sources, sector information, and scientific articles. See annex for further details.

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What is needed to enable Climate Positive Growth in Africa?

To deliver on its potential for Climate Positive Growth, Africa is not looking for hand-outs. Yes, it is undoubtedly a victim of climate change. Yet it can also be a sizeable and essential part of the global solution, allowing the world to decarbonise its production and consumption system by developing and deploying a global low-emission manufacturing hub. Africa is also not looking for exemptions or special conditions. To make this work, Africa need not be excluded from carbon border adjustment mechanisms or carbon taxation schemes – rather, such measures should be data-driven, truly measure and tax embedded carbon, and be diligently enforced.

Of course there is no silver bullet that will unlock these Climate Positive Growth opportunities – but below are some that are particularly pertinent.

First and foremost, **Countries aspiring to deploy green climate positive growth, need equitable access to markets**: a lot of the lobal opportunity for solution would be missed if these countries produced low-embedded emissions products and services or carbon credits, only not to be able to sell them

- Carbon border taxes may not be designed to generate equitable access. The EU is still designing the technical implementation measures of its Carbon Border Adjustment Mechanism (CBAM) – early indications point towards a potential outcome that makes it very hard for products from emerging and frontier economies to be recognised as low-embedded emissions (if nothing else because these countries and manufacturers are not at the table in the technical discussions), potentially imposing punitively high reference values on these products. This may be a result of the focus of the CBAM, which arises from ensuring low-embedded emission European industrial products do not face unfair competition from higher-embedded emission products from abroad (with a key focus on China). In its conceptualisation, CBAM may not have taken into account that other regions could deliver structurally lower embedded emissions and should be recognised as such. The most powerful interventions here, would be:
    - **Governance of and inputs into design:** Involve emerging and frontier economies in discussion on the definition of metrics and processes to determine embedded carbon
    - **Global best-in-class standard setting:** As the first carbon border tax, CBAM is looked at keenly globally – and has an opportunity to set a global standard to define, measure, track, and price embedded carbon. Involvement of actors such as WTO and ISO can help set these global standards and focus on a true level playing field without undue regional bias.
    - **Global knowledge sharing to advance the pricing of externalities:** As the first and most advanced mechanism in this space, CBAM can help accelerate and improve the development of similar instruments, such as the proposed US PROVE IT Act (Providing Reliable, Objective, Verifiable Emissions Intensity and Transparency). In parallel, rapidly expanding the scope of carbon pricing (such as through proposed shipping and aviation levies) will create both more demand for low-emission products and services and generate resources to finance transition, as well as adaptation and Loss & Damage. As we collectively learn more about the effects of pricing carbon, these lessons should be taken forward to accelerate the pricing of other currently unpriced externalities, such as the negative externality of biodiversity loss, and positive externalities of ecosystem service provision, and socio-economic co-benefits of climate action.
    - **Revenue deployment towards transition support:** Though demand for low-embedded emission products and services can be a powerful 'pull' for products from Africa, pricing on embedded carbon will initially hit current, high-emission, exports from Africa (such as aluminium from Mozambique), as ACF/ LSE showed in their recent analysis. As part of Africa – EU collaboration, the EU could look at deploying (some of) the CBAM revenue

collected, towards supporting rapid transition in priority countries, softening the blow for small current export activity, and reducing resistance to and complexity of transition.

- Currently, access to global (carbon) markets, in particular compliance markets, is both very limited, decreasing and highly complex. The much-needed focus on increasing quality and integrity of carbon credits risks stifling necessary innovation. Many compliance markets are closed to foreign credits – in an effort to limit greenwashing. Yet this leads to an inefficient global capital allocation (with actors forced to fully exhaust their options within their own control and jurisdiction, before being allowed to finance activities elsewhere) – which can lead to drastically reduced climate impact for a given amount of capital

Support to develop nascent global industries ideally takes into account the effect it may have on allocation choices – and optimises for globally efficient capital allocation. A truly nascent industry like Direct Air Capture is currently seeing a massive concentration of new activity in the US, thanks to strong fiscal support (45Q, IRA, and DAC hub support). Early deployment matters in such novel industries, as this will become a magnet for further growth, skills development, supporting industrial activity, and funding. Where Climate Positive Growth countries hold inherent global competitiveness, it is in the interest of the world for such support incentives to be designed to grow industries in these countries as well. Measures such as extending (some of) the fiscal support from IRA or the Green Deal to US resp. EU companies when they deploy eligible technologies in global south Climate Positive Growth countries, could be a win-win: it can support (1) the funder's regional industrial policy and its desire to be a global industrial leader, (2) global climate objectives by accelerating deploying in Africa, and (3) African industrial growth.

Many potential Climate Positive Growth Countries, and in particular African countries, face very **high costs of capital,** driven by real and perceived risk factors, and by underlying sovereign financial situations. Various levers can and should be deployed concurrently:

- Immediate innovations focused on **debt pause and debt restructuring** will directly create fiscal space for investment – and can be linked to investment in climate action. For those concerned about debt sustainability, Climate Positive Growth as a truly sustainable growth path, may provide the much-needed answer to the question how countries can avoid a vicious debt cycle.
- Forward-looking approaches to reassess the Common Framework and the Debt Sustainability Assessment to align these more with future-proof investment can create long-term incentives for countries to align their investments, fiscal, and financial policies to future-proof climate-aligned economic activities. The **expert review initiative by Colombia, Kenya, and France** can set this in motion.
- The **Bridgetown agenda's focus** on (1) increasing concessional capital, (2) allocating a greater proportion of global concessional funding to emerging and frontier economies and (3) making more of it linked to viable climate action, will help avail more suitable funding for these investments.
- The **partial FX guarantee proposal**[7] put forward by Barbados at the Paris Summit in June deserves serious and immediate attention as an elegant mechanism to efficiently overcome a structural market failure.

Low-income, low-emissions countries, notably many in the African continent, can be a key part of the solution to global climate change. They can help the world decarbonise by becoming a green manufacturing hub, and are well positioned to remove carbon at scale. To allow this Climate Positive Growth potential to be realised, the world needs to wake up to the potential of these countries, and take it seriously.

[7] See https://www.climatepolicyinitiative.org/wp-content/uploads/2023/06/An-FX-Guarantee-Mechanism-for-the-Green-Transformation-in-Developing-Countries.pdf for the details of the proposal

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Annex 1: Sources and rationale for current emissions in mining and primary processing of iron ore and bauxite

Overall sources for trade volumes and for emissions associated with transport and with electricity use in the current processing locations

- All trade data sourced from both the ITC Trade map and the World Bank WITS database – both sets are not entirely comprehensive in data for Africa for some routes, commodities, or units (e.g., value data available but not volume/ weight or vice versa), forcing authors to combine, triangulate and cross-reference data. Export from Africa in weight is found directly in ITC trade data yet import back into Africa needs to combine both ITC data (value) and WITS (unit price)
- All analyses of savings potential are based on
    - Trade data from ITC and World Bank WITS database for volumes of ore and product being traded (which indicates processing location)
    - Cargocare carbon emission calculator for transport-related emissions,
    - Emission-intensity of electricity from IFI TWG (international financial institutions technical working group) harmonisation of GHG emissions emissions - as published on UNFCCC website - https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting and https://unfccc.int/sites/default/files/resource/Harmonized_Grid_Emission_factor_data_set.xlsx .
- Emissions linked to exports to other regions than Europe and Asia (9% for iron ore and 1% for bauxite exports respectively) are assumed to be equal to the weighted average of those of exports to Europe and Asia, extrapolating linearly from detailed Europe/ Asia related calculations.
- Job creation opportunities follow from Wood, T., Dundas, G., and Ha, J. (2020). Start with steel. Grattan Institute. ISBN: 978-0-6487380-6-0, table A.2 for labour intensity estimates for both green steel and green aluminium.
- Additional revenue is based on the difference between current export value for iron ore and bauxite (from ITC data) and global commodity unit price findings for steel and aluminium - http://steelbenchmarker.com/history.pdf, and https://markets.businessinsider.com/commodities/aluminum-price for steel resp aluminium price

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Detailed assumptions and sources for process parameters

Metric	***Value***	***Source***	***Comments***
Total emissions from extraction of 1 tonne of bauxite (mt)	0.005	Hitch, Michael & Tost, Michael & Bayer, Benjamin & Lutter, F. Stephan & Moser, Peter & Feiel, Susanne. (2018). Metal Mining's Environmental Pressures: A Review and Updated Estimates on CO2 Emissions, Water Use, and Land Requirements. Sustainability. 10. 10.3390/su10082881 – Table 4. As sourced from: https://www.researchgate.net/figure/Global-CO-2-emissions-of-bauxite-copper-gold-and-iron-ore-mining-in-2016_tbl4_327033995	
Electricity need for production/ processing of aluminium (kWh/ kg)	21 (17 for Hall-Heroult process and electrode production, on average 4 for the Bayer process)	**For the parts of the process:** Andrew R. Hind, Suresh K. Bhargava, Stephen C. Grocott, The surface chemistry of Bayer process solids: a review, Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 146, Issues 1–3,1999, Pages 359-374, ISSN 0927-7757, https://doi.org/10.1016/S0927-7757(98)00798-5 http://wordpress.mrreid.org/2011/07/15/electricity-consumption-in-the-production-of-aluminium/ **Cross-checking the entire process (non-scientific sources)** University of Cambridge, teaching package on aluminium production, as sourced from: https://www.doitpoms.ac.uk/tlplib/recycling-metals/aluminium_production.php https://energyeducation.ca/encyclopedia/Aluminum https://www.lowtechmagazine.com/what-is-the-embodied-energy-of-materials.html	Various sources used: **For the different parts of the process:** 17 kWh for the Hall-Heroult process including the electrode production; 7 - 21 MJ/ kg for the Bayer process (2-6 kWh/ kg, https://doi.org/10.1016/S0927-7757(98)00798-5) 15 kWh/kg (http://wordpress.mrreid.org/2011/07/15/electricity-consumption-in-the-production-of-aluminium/) for the Hall-Heroult process only **Cross-checking estimates for the entire process:** Energy required for the Bayer process and for the Hall-Heroult process together is 225MJ/ kg or 62.5 kWh/ kg whereby authors include the inefficiency of power plants assuming direct fossil fuel combustion (https://www.doitpoms.ac.uk/tlplib/recycling-metals/aluminium_production.php) - assuming energy for producing the anode and the electrolyte are chemical energies. As the emission intensity of power grids is measured in g/ kWh in which inefficiency of power plant ALSO is included, that would doublecount. So the 62.5 kWh/ kg reverts back to 62.5*35% (power plant ineffiency) = net 21.9 kWh (out-of-socket). 190 - 230 MJ/ kg (https://energyeducation.ca/encyclopedia/Aluminum) of primary energy – or 53 – 64 kWh/kg, which converts to 35% in out-of-socket power (19 – 22 kWh) 227 - 342 MJ/ kg (https://www.lowtechmagazine.com/what-is-the-embodied-energy-of-materials.html) of primary energy – which converts to 22 – 33 kWh
Manufactured to raw ratio (%) for Aluminium	22%	https://thanosparaschos.eu/wp-content/uploads/2013/11/Production-of-aluminum-emphasis-on-energy-and-materials-requirements.pdf ***and*** https://natural-resources.canada.ca/our-natural-resources/minerals-mining/minerals-metals-facts/aluminum-facts/20510	The first source mentions 210 million tonnes of bauxite for 41.4 mln tonnes of aluminium (2010 global average), getting to 20% aluminium content. The second source mentions 4 – 5 tonnes of bauxite for 1 tonne of aluminium Recognising this may vary across countries but in absence of reliable country data, use this number throughout as an assumption
Extraction footprint of 1 mt of iron ore	0.026	https://www.sciencedirect.com/science/article/abs/pii/S030142071730512 for the China data and	For China, the ore only related emissions are at 0.27 t CO2/ ton iron ore, whereas an Australian source (https://publications.csiro.au/rpr/pub?pid=csiro:EP1311257) puts Australia at just 11.9 kg CO2e. Digging into it, that probably comes from the low iron content (the figure shows mining alone is ~40 kg but then ore processing and subsequent agglomeration are the rest, and that links to low iron content). That also explains the difference with the Australian source as Australian ores have higher iron content and are less deep (so simpler mining). Given the higher iron content in Guinea (65%), I assume an average between the Chinese mining and the Australian one to account for differences in depth

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Metric	***Value***	***Source***	***Comments***
		https://publications.csiro.au/rpr/pub?pid=csiro:EP1311257 for the Australian data[8]	
Processing footprint in kg CO2e per kg of steel - China (as proxy for Asia)	2.15	Ali Hasanbeigi, Marlene Arens, Jose Carlos Rojas Cardenas, Lynn Price, Ryan Triolo, *Comparison of carbon dioxide emissions intensity of steel production in China, Germany, Mexico, and the United States,* Resources, Conservation and Recycling, Volume 113,2016, Pages 127-139, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2016.06.008	Started with this interesting LCA analysis: https://d-nb.info/1233481819/34 which landed on 2.1 tonnes of CO2e per tonne of hot-rolled coil, which has the right system boundaries including the cokes plant. But this has a global average across locations and technologies which is not sufficient specific. The source to the left compared China, Mexico, Germany and US and has country-specific data on fuel use, efficiency etc. It also splits between BF/ BOF and EAF. Strictly speaking, EAF can be used for ores but when looking at ore processing, we will assume BF/ BOF. For 2 reasons: 1. EAF typically has high recycled content (and globally is not yet used for ore at scale - see https://materialspalette.org/steel/) and 2. In reality, at least in China (according to http://www.sxcoal.com/news/4635483/info/en) the majority of steel production (90%) in that source is the BOF/ OF route, even if EAF is on the rise.
Processing footprint in kg CO2e per kg of steel - Germany (as proxy for Europe)	2.15		
Electricity need per tonne of steel for DRI based EAF processes (based on 16 international comparisons) - kWh per tonne of steel	570	Same as above (Table B2 in appendix B)	
Residual emissions of green hydrogen-based steel manufacturing - tonnes of CO2 per tonne of steel	0.2	McKinsey documents: https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel and https://www.mckinsey.com/capabilities/sustainability/our-insights/net-zero-steel-in-building-and-construction-the-way-forward - based on the LNG needed to make DR pellets	
Manufactured to raw ratio (%) for Iron	65%	Various source - see comments to the right; landed on using number for Guinea as biggest deposit	Range of values available, with 50-60% being the “norm” - https://www.britannica.com/technology/iron-processing/Ores and some industry players estimating 1.6 ton of ore per ton of steel – so a 62.5% content https://www.bhp.com/what-we-do/products/iron-ore) but another player suggesting you use as much as 4 ton of ore (i.e., a 25% weight content which seems to be in line with what the Chinese LCA article has as well). The Guinea ore (biggest deposit) which is processed in China, has 65% content (https://asia.nikkei.com/Spotlight/Caixin/Guinea-agrees-to-resume-Simandou-iron-ore-project#:~:text=The%20region%20holds%20more%20than,7%25%20of%20the%20global%20total.)

[8] Since these were sourced, both articles have been moved from this original location – full citation no longer available. Issue with incomplete citation will be limited as mining related emissions are a small proportion of total emissions – and an emission that is not assumed to change in the innovation assumption

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Annex 2: Assumptions made on innovation for the purposes of calculating savings from local processing of iron ore and bauxite

Category	Assumptions	Comments
Transport	None for ore	No changes made to modality of transport – local processing will just impact volumes transported of ore vs product
Transport	None for product used in Africa	Product will still need to be transported from primary processing location to use location
Transport	Proportional to original export for production that exceeds use in Africa	Ore/bauxite linked to product not used in Africa, is assumed no longer to be transported as ore, but as product
Mining	No change	
Processing - power grid	Fully renewable	
Processing - overall emission reduction lower band aluminium	90%	If e.g., using geothermal without full CCS
processing - overall emissions reduction higher band aluminium	99%	virtually 100% - given that all energy needs are electricity, fully renewable would remove all those emissions in full
Processing - residual emission levels with reduction lower band (in residual tonnes CO2/ tonne of steel)	0.20	Based on assumed residual emissions for a fully green hydrogen driven process (McK documentation - see sources)
Processing, % reduction of emissions on lower band for steel - of emissions that can be avoided (not counting the residual level)	90%	If e.g., using geothermal without full CCS
Processing - % reduction of emissions on max band for steel	99%	Assuming all emissions can be avoided - e.g., incl. CCS for the residual gas use for ore pelletisation