

Materials Science and Socioeconomic challenges in Africa

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Thierry d'Almeida

Higher Education and Research Expert

EXPERTISE FRANCE/ CEA/LINAC

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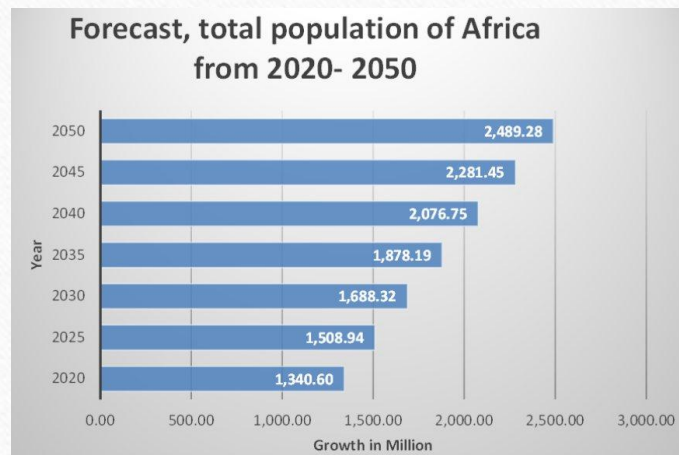
SECTION I



Context

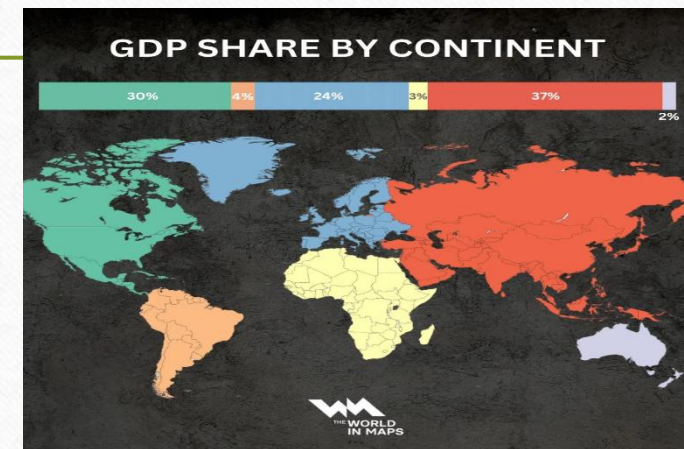
Challenges

Context 1/2



Africa population trends

- 2025: 1.52 billion, 18% of world population
- 2050: ~2.5 billion, 25% of world population
- 2100: ~4 billion, 40% of world population



Africa GDP and share of world economy

- 2025: \$ 2.83 trillion, 2.5% of global nominal GDP of \$114 trillion
- 2050 projection: ~16 trillion nominal GDP, 7% of world GDP \$228 trillion

Context 2/2

Tremendous natural assets

Key natural resources

- Minerals: 40% world's reserves including those required for energy transition
- Oil, Gas and Coal: 12% and 8% of world's oil reserves, *resp.*
- Agricultural potential: 70 % of world's arable land
- Renewable : 10% of internal fresh water sources,
- Forest and Timber: 25% of world's remaining forests
- Wildlife, fisheries, etc.

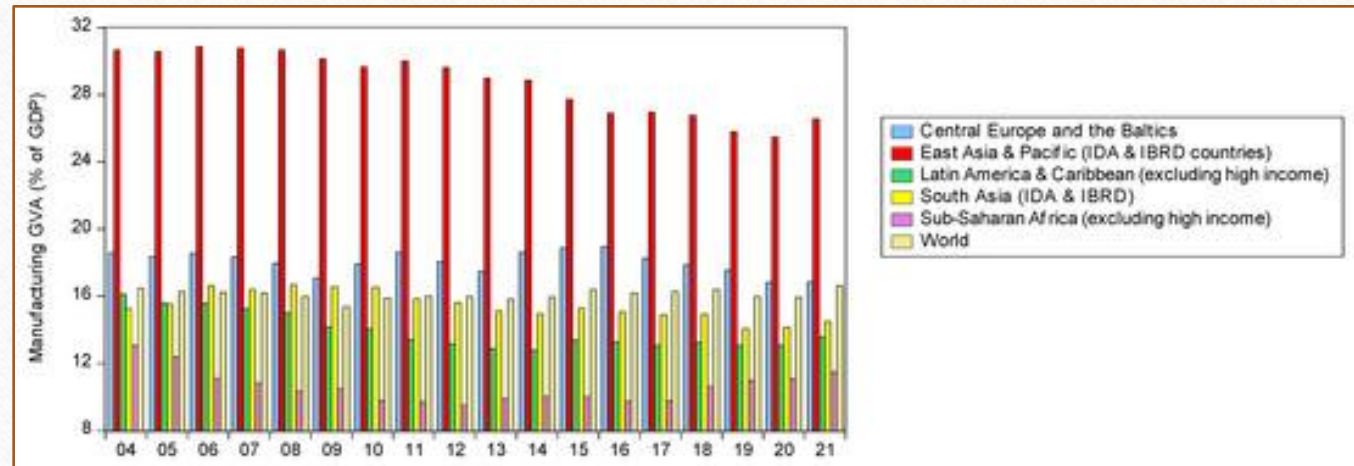


Challenges 1/2

Secondary sector: bulk of value addition to raw materials

Current states and challenges in Africa

- ~13% to GDP
- Low industrial base: many root causes (credit availability, access to energy, etc)
- Poor human resource qualification
- Crucial need: Transition from resource-based to capabilities-based economy



Challenges 2/2

Added value of processing raw materials

Key benefits

- Human capacity building
- Increased research capabilities and output: significant rise of market value
- Industrialization
- Increased economic value
- Job creation and community empowerment
- Market diversification and stability
- Meeting consumer demand

SECTION II

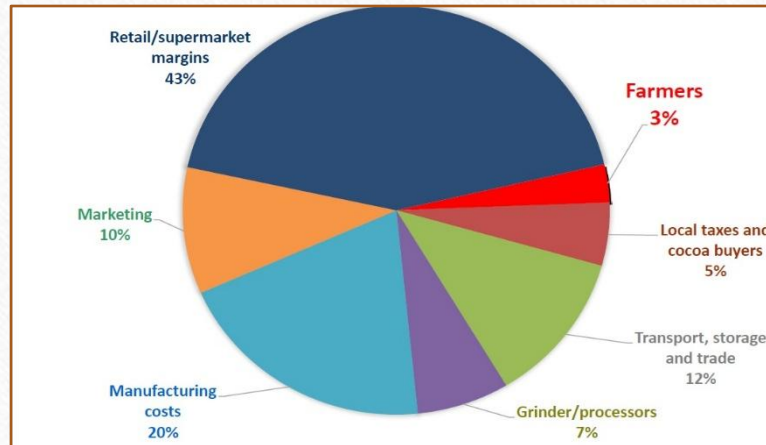
Opportunities

Needs:
Human Resources and
infrastructures

Strategies

Opportunities and avenues 1/3

Cocoa beans to chocolate processing

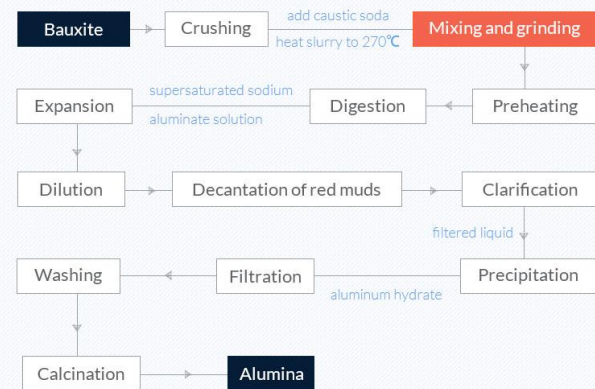


- Global chocolate market: ~\$130.72 billion in 2024, ~ 172.89 billion by 2030
- Where is the economic value created in cocoa-to-chocolate?
 - From cultivating to bean export: ~ 18%
 - Downstream (processing, branding, marketing, retailing): ~82%

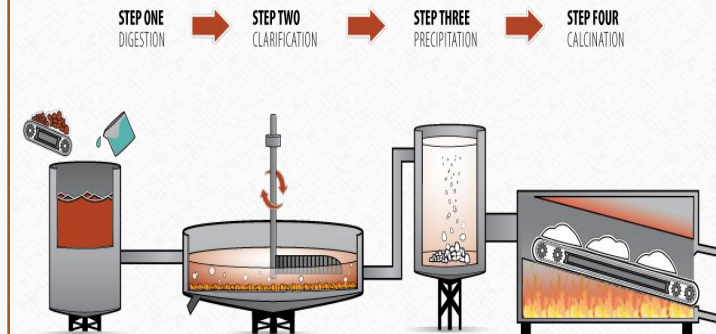
Opportunities and avenues 2/3

Bauxite to aluminum

Bayer process steps for alumina production



ALUMINA REFINING



- Global annual value of bauxite production: 16. 4 billion USD (2024)
- Global value of primary aluminum metal: 206.95 billion USD (2023)
- Forecast: 315.21 billion USD (2031) [*]

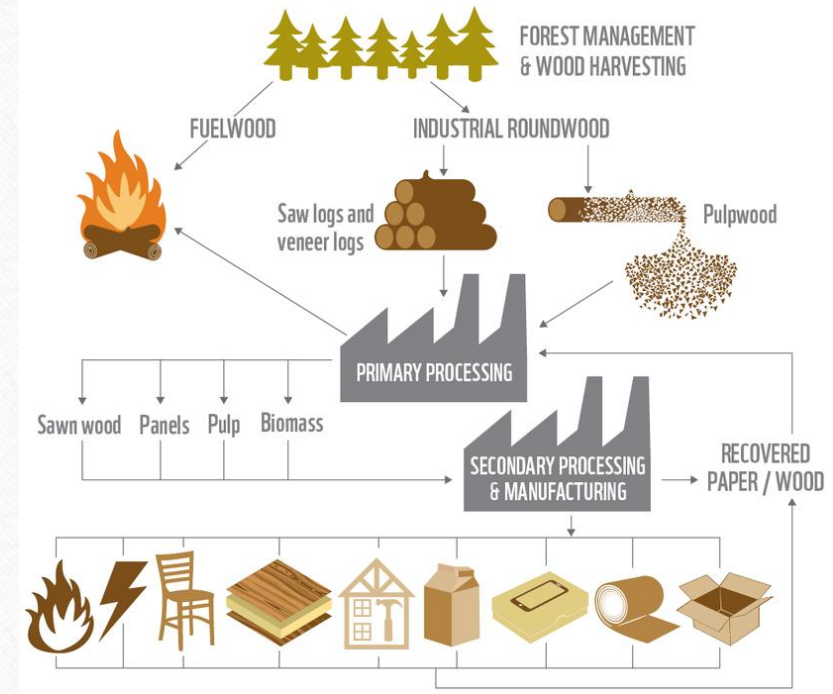
*Primary Aluminum Market Size And Forecast, Verified Market Research, Nov 24, p202

- Where is the economic value created in bauxite to primary aluminum metal?
 - From bauxite to alumina (Bayer process): adds 10 to 20 times the value of raw bauxite
 - From alumina to primary aluminum (Hall-Heroult process): 6 to 20 times the value of alumina
 - Downstream:

Opportunities and avenues 3/3

The timber and logs sector

- Lack of transformation capabilities results in over \$50 billion losses (ADB, 2022):
 - Large trade deficits
 - Missed opportunities for job creation
 - Lack of wealth generation
 - No industrial development
 - Formal timber export ~17 billion
 - Illegal timber export ranges from \$50 to \$150 billion annually



Needs : human resources and infrastructures 1/4

Sub-Saharan Africa Shortage of Engineers

Key Estimates in all sectors*

- Current engineers' shortage: 2.5 millions
- Per capita comparison: less than 1 per 100K people (GA 1 per 770 people!)
- Sectoral demand: Strongly impacts at least 9 of 17 SDGs

Key drivers of demand**

- Infrastructure: urbanization, building and maintenance (roads, bridges, power plant), telecoms
- **Industrial growth and natural resource management: processing, refining (mining, oil, gas, food, etc.)**
- Energy and utilities: power generation, grid expansion

*World Bank, **Empowering Africa's future: Prioritizing STEM skills for youth and economic prosperity**, Sept 2023

** World Bank, **Improving the quality of engineering education and training in Africa**, March 2014

Needs: human resources and infrastructures 2/4

Potential impact on economic growth

- 1.1% increase of overall population of engineers increases GDP/worker ~3000 USD (Arkansas and New Zealand)
- WB and ADB benchmark: 2.5 millions increase adds 2000 USDGDP /worker over time
- If scaled to the materials processing sector, 400 000 engineers are needed annually to achieve additional 2% growth

Royal Academy of Engineering,, Engineers for Africa 2025

Scientific African, Volume 6, November 2019, e00200

World Bank, Improving the quality of engineering education and training in Africa, March 2014

Needs: human resources and infrastructures 3/4

Techniques involved in raw material processing

- Compacting and binding
- Tableting and briquetting: compresses powders to tablets and briquettes to allow transport or storage
- Packaging: adds ergonomics and protection to improve perception and marketability
- Chemical processing: refining and chemical extraction techniques for metals, polymerization for plastics
- Selective sorting and hydrothermal techniques: separate materials by chemical or physical properties to recover valuable constituents and reduce impurities
- Fractionation and biomass processing:



Needs: human resources and infrastructures 4/4

Skilled jobs associated

- Chemical engineers
- Process engineers (Mining and Metals)
- Production engineers
- Environmental engineers: develop sustainable practice
- Process engineers: manufacturing processes and quality standards
- Material scientists: structure and anatomy analysis, processing technologies

Strategies

Capacity building in engineering education

- Strengthen engineering education
- Enhance collaboration and partnerships
- Improve quality assurance
- Links with industry
- Develop regional academic networks
- Invest in modern equipment and innovation
- Encourage public-private partnerships



SECTION III

Virtuous
initiatives

Predictable
impacts

Prospects

Virtuous initiatives and their impact 1/12



Virtuous initiatives and their impact 2/12

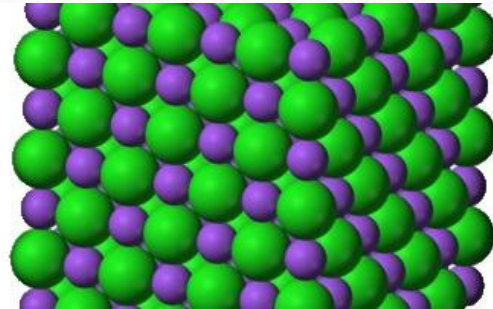
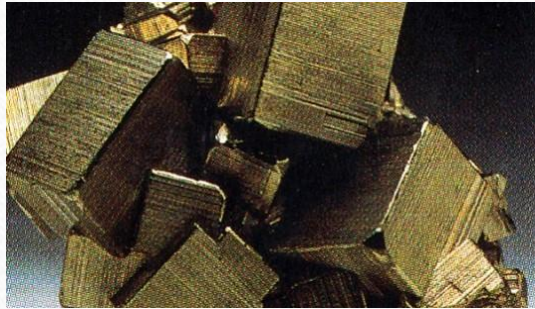
X-TechLab training and research platform

Develop a new model for a collaborative training and research platform focused on solving critical problems in Africa



Virtuous initiatives and their impact 3/12

The X-TechLab materials science program



The abundance of natural resources is a tremendous opportunity:

- High-quality training, particularly in engineering and professional areas
- High-impact, interdisciplinary research, with numerous virtually unexplored themes
- High-impact applications in key sectors: urban planning, industry, agri-food, etc.

Virtuous initiatives and their impact 4/12

X-TechLab's focus on sustainable building materials

Motivation

- Economic: construction market value: \$210 billion in 2023, \$270 billion in 2027*
- Environmental, social and economic impact of inadequate models**
- Opportunity for capacity building

*iCrowdNewswire 11630 SW 97 Street, Miami, Florida 33176, US

*Globaldata.com, September 01, 2023 Report Code: GRCREG000014CN-BB

**[Renewable and Sustainable Energy Reviews](#)

[Volume 184](#), September 2023, 113593



Virtuous initiatives and their impact 5/12

X-TechLab's focus on sustainable building materials

Objectives

- Overall objective: Revisit local materials in the light of the most advanced scientific tools and methods in order to improve their properties and extend their use in modern building



Virtuous initiatives and their impact 6/12

X-TechLab's focus on sustainable building materials

Methodology

- Develop innovative and sustainable materials based on a rigorous experimental and digital validation process.
- Methods combine physics, math-engineering and numerical simulation
 - X-ray imaging and 3D reconstruction (tomography)
 - Morphology extraction (mathematical tools)
 - Numerical calculations: mechanical and thermal moduli at the macroscopic scale (essential for civil engineering assessments)
 - In situ measurements: mechanical and thermal loads during image acquisition

Virtuous initiatives and their impact 7/12

X-TechLab's focus on sustainable building materials

Techniques

- Physical properties
- Chemical composition
- Microstructure
- Thermo-Mechanical behavior



- Behavior
- Design
- Applications

X-TechLab achievements

08

Training sessions
organized during the
period 2019 - 2024

≈200

Learners
(Graduate & PhD students,
Postdoc, Engineers) trained

16

African countries
have been represented
during the training sessions

+100 samples
characterized

+30

Lecturers
from Europe, USA, Asia and
Africa are involved

+1 000

Undergraduate students
initiated to Crystallography
& Symmetry

Virtuous initiatives and their impact 8/12

Timber sector

- \$ 1.2 billion worth of raw timber exported by 4 African countries in 2019
- Global illegal timber market is worth USD 51 to 152 billion per year (Interpol).
- Over \$50 billion annual loss of earning due to lack processing capacity to semi-finished products



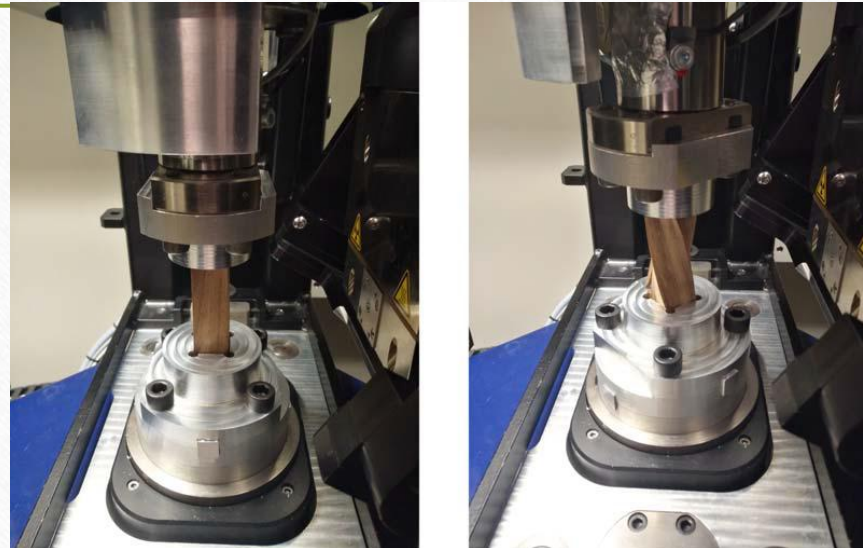
Virtuous initiatives and their impact 9/12

Studies of local wood species

- Microstructure of teak wood to optimize rotation cycles and increase value of local production
- Design innovative wood-based materials for various applications
- Develop R&D collaborations with leading institutions such as NUMATS (UFRJ)

Virtuous initiatives and their impact 10/12

Microtomography and in situ torsion tests of teak wood



Valmalle et al., Comptes Rendus Mécanique 2022, 350, p. 85-98

Virtuous initiatives and their impact 11/12

Innovative wood-based materials at NUMATS



Wood waste



Cement Paste



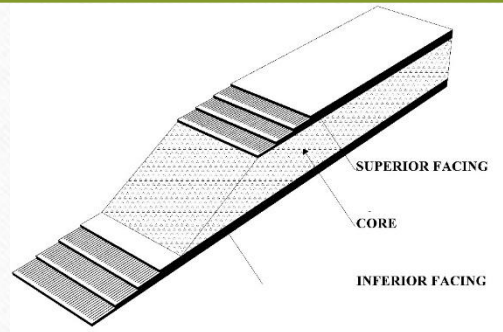
Wood Bio-concretes

Wood-based composites or wood bio-concretes

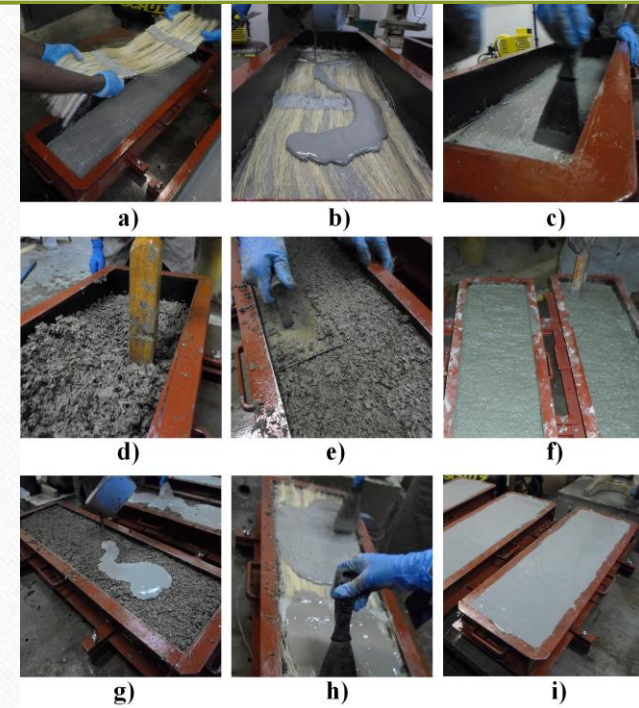
Virtuous initiatives and their impact 12/12

Innovative wood-based materials at NUMATS

Wood-based sandwich panels



Panel Manufacturing Steps: a) Laying of the fibers; b) spreading of the mortar over the fibers; c) Surface adjustment of the mortar; d) hand compacting of the WBC; e) surface adjustment of the WBC 0.5; f) WBC 2.5; g) Spreading of the first mortar layer over the core; h) Spreading of the mortar layer on the fibers; i) end of the molding.



Conclusion & Prospects

- Materials science and engineering can significantly impact economic growth in Africa by driving innovation, industrialization, job creation, and improved productivity across multiple sectors;
- Engineering education fosters critical skills that support Africa's economic growth and innovation;
- Materials science and engineering underpin the development of manufacturing industries, which are essential for shifting African economies from raw materials export to value-added production;
- Materials science and engineering serve as pillars for economic transformation in Africa by enabling industrial diversification, fostering innovation, improving productivity, creating skilled jobs, and building foundational infrastructure critical for sustained economic growth