Transforming Energy Access in Africa through Circular Economy Approaches: Materials for Perovskite Solar Module Manufacturing

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In 2024, around 737 million people lacked electricity[1], most of them in rural Sub-Saharan Africa[2]. Grid extension is often impractical and unreliable, making decentralised systems more suitable for electrification. Between 2020 and 2022, decentralised solutions, led by solar, provided 55% of new electricity connections in the region[3]. Mesoporous carbon perovskite solar cells (MCPSCs) offer a low-cost, efficient option for rural electrification with straightforward manufacturing[4]. However, research on African supply chains and local production remains limited. This study aims to develop a sustainable, locally sourced supply chain for MCPSC manufacturing, reducing reliance on imports and promoting ethical practices. Strengthening local production can expand access to solar energy, support economic development and increase global availability of affordable, high-performance solar modules.

Introduction

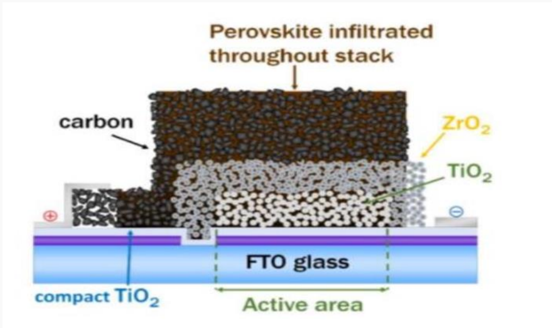


Fig 1: Triple mesoscopic carbon perovskite solar cell (MCPSC)[5]

Advantages [5]

- Screen printing: Low CAPEX technology known for large scale production suitable for local manufacturing
- Uses low cost, widely available material and avoids expensive noble metals like gold and organics like spiro-OMeTAD
- They use low temperature, solution-based fabrication, making layer separation and recycling more feasible
- Low production and energy cost compared to Si-PV.

Methods

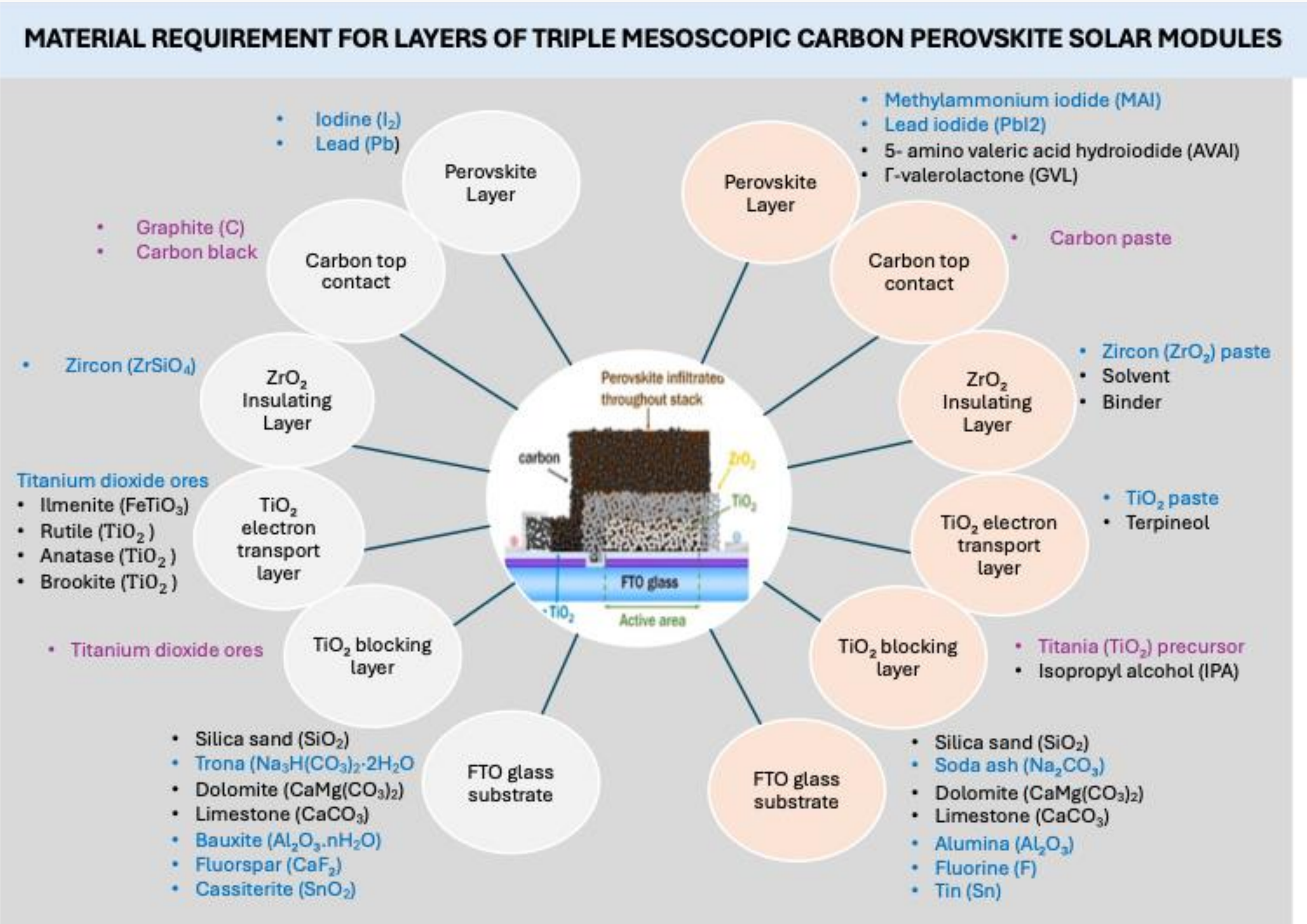
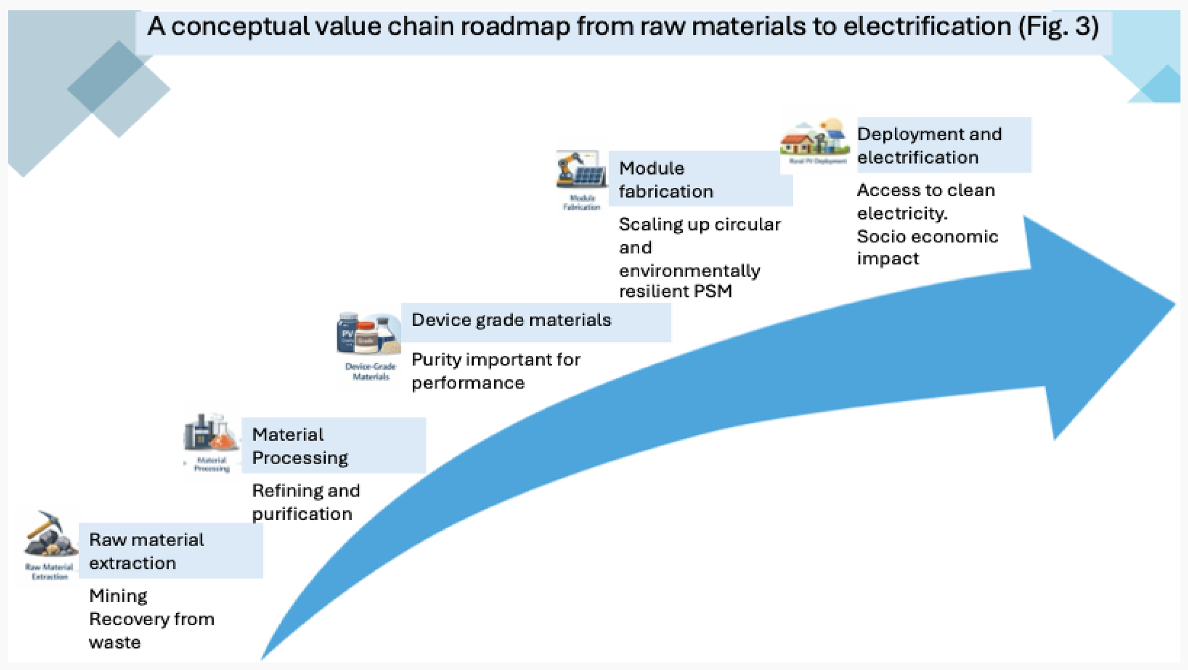


Fig:2 Raw minerals used in constructing the triple MCPSC[5] (left), device grade materials and other necessary chemicals (right)

A conceptual value chain roadmap from raw materials to electrification (Fig. 3)



Summary of methods, 1 and 2 fully completed

1. Material identification: For selected MCPSM device
2. Supply chain mapping: Mapping reserves across Africa and Nigeria
3. Techno-economic analysis and life cycle assessment (LCA)
4. Quantification: Estimate material quantity to meet demands in Nigeria
5. Circular economy assessment: Estimate losses, quantify recovery, assess reuse.

Results

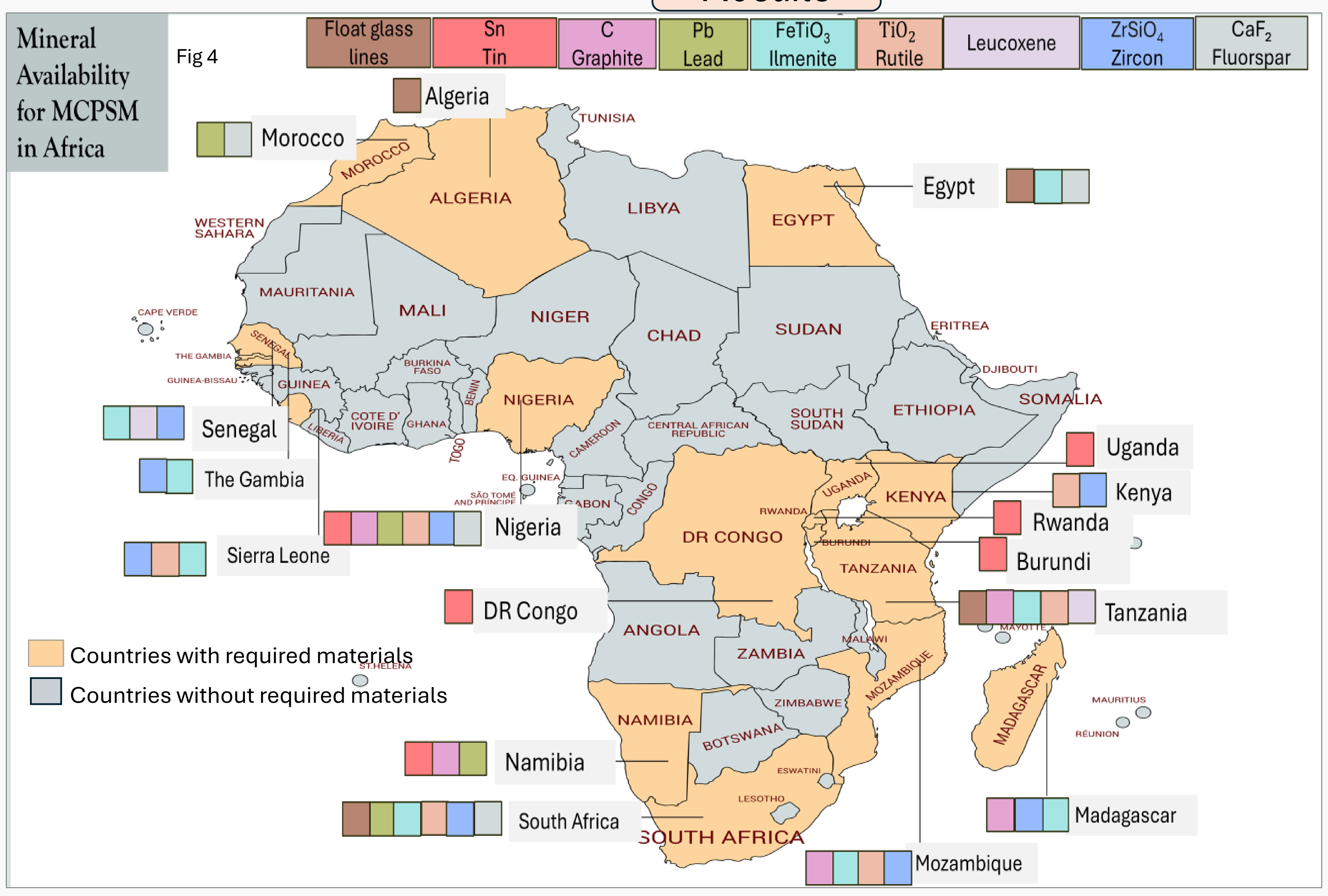


Fig 4 (Map): Overview of African mineral availability relevant to MCPSM manufacturing, illustrating the geographic spread of raw materials and existing float glass production infrastructure across the continent [6,7].

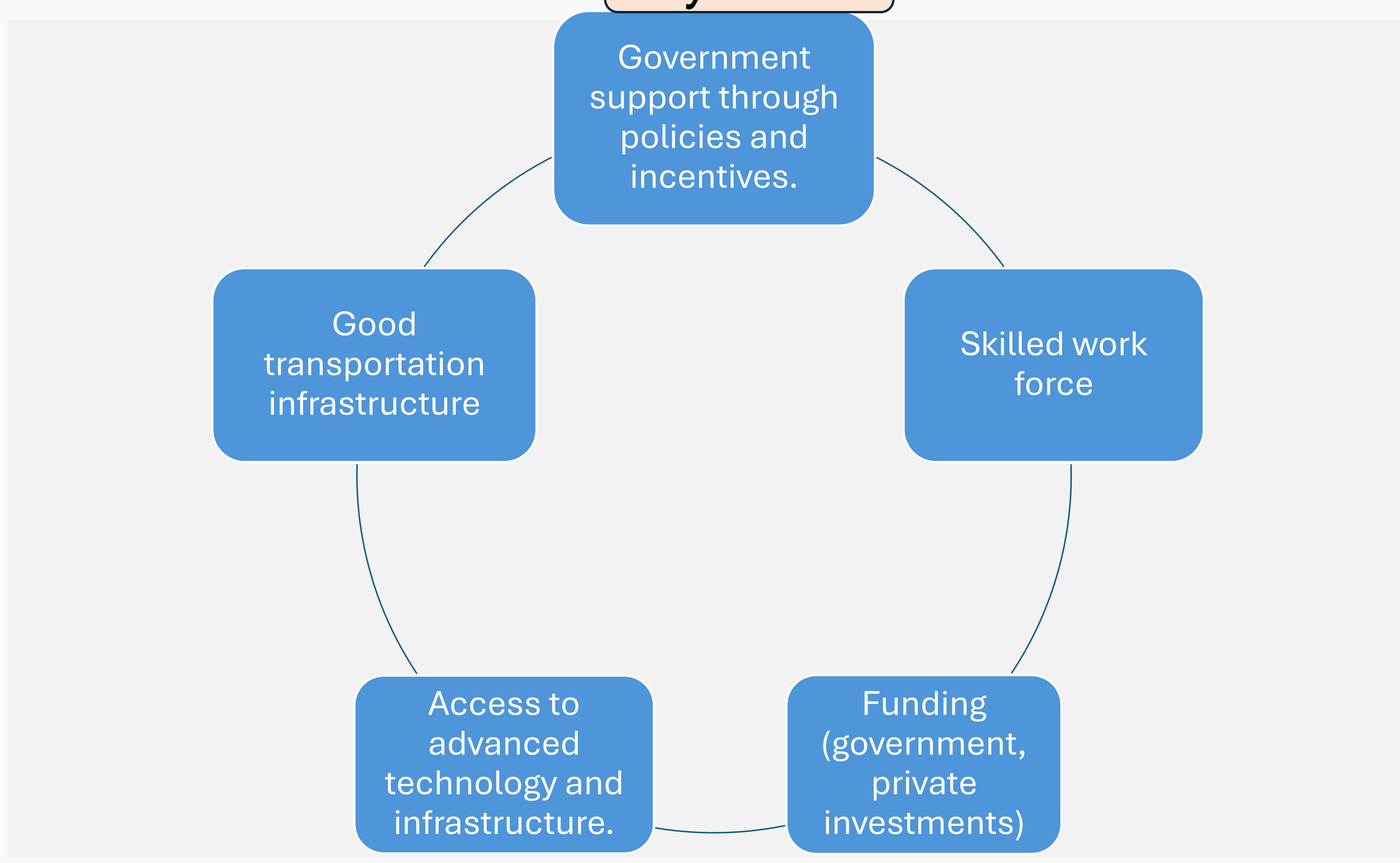
Fig 5

PSM device grade materials	Supply chain strength(raw material)	Existing Manufacturing Base (Also Considering related material)	Local Technology Maturity Level
Lead iodide	3	3	2
Methylammonium iodide	3	3	2
C-TiO_2 precursor ($TiCl_4$)	5	2	2
TiO_2 paste	5	3	4
ZrO_2 paste	5	3	4
Graphite flakes	4	5	5
Carbon black	5	5	4
Eco-friendly carbon black	5	3	2
Float glass	4	4	5
FTO glass	3	2	1

Score	
5	High
4	Strong
3	Medium
2	Low
1	Minimal

Fig 5: Scoring based evaluation of Africa's local supply chain strength, existing manufacturing base, and technology maturity for MCPSM device grade materials, showing strong raw material availability but limited technology readiness.

Key drivers



Powering communities through PSMs

Summary

MCPSMs show strong potential for local manufacturing in Africa due to low production costs, simple fabrication, and high availability of raw material. All required materials are locally available except iodine, which can be sourced from seawater and seaweed. Some device grade materials, such as carbon black and graphite flakes, are already produced in Africa, while TiO_2 and ZrO_2 nanoparticles are manufactured at limited scale. With appropriate funding and infrastructure, the remaining materials can also be locally produced. A baseline LCA is currently at the inventory phase, quantifying the energy use, emissions, and waste for each layer of the device. Next steps includes life cycle impact assessment using SimaPro, sensitivity analysis, comparative LCA of Nigeria and UK, and techno economic evaluation.

Challenges

Key challenges include limited mineral processing facilities in Africa and low investment in value addition. Fragmented supply chains for materials such as PbI_2, MAI, and FTO glass create local supply uncertainty. Addressing these issues requires innovation and investment in local infrastructure to improve supply security and reduce the carbon footprint. Additionally, gaps in life cycle inventory data, particularly for commercial paste and solder compositions, necessitated informed assumptions in emissions estimation.

Acknowledgement

This work was funded by the UK Government's Ayrton Challenge through the International Science Partnerships Fund (ISPF) as part of the REACH-PSM project. We sincerely thank Prof. Matthew Davies for his invaluable guidance and insights. We also acknowledge the Swansea Photochemistry and Circular Economy Group for their support.

REFERENCES

1. International Energy Agency (IEA) . Population without electricity access, 2010-2024 – Charts – Data & Statistics.
2. H. Ritchie, P. Rosado and M. Roser, *Access to Energy*, Our World in Data (online), accessed 1 December 2025.
3. United Nations Statistics Division, *SDG 7 Energy Statistics: Global and regional data tables for Sustainable Development Goal 7.*
4. Xiang J, Han C, Cheng Y, Gao Q, Hu W, Zhou Y, et al. Recent Progress and Advances of Perovskite Crystallization in Carbon-Based Printable Mesoscopic Solar Cells. Adv Mater. 2025 Jan 15;2415405.
5. Meroni SMP, Worsley C, Raptis D, Watson TM. Triple-Mesoscopic Carbon Perovskite Solar Cells: Materials, Processing and Applications. Energies. 2021 Jan 12;14(2):386.
6. British Geological Survey (BGS). World Mineral Production 2018 - 2022. 2024.
7. U.S Geological Survey. Mineral Commodity Summaries 2025. 2025.

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